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DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

BULLETIN No. 39.

THE PERMIAN ORTHOTETACEA OF WESTERN AUSTRALIA

BY

G. A. THOMAS.

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Minister : SENATOR THE HON. W. H. SPOONER, M.M.
Secretary : H. G. RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

Director : P. B. NYE, O.B.E.
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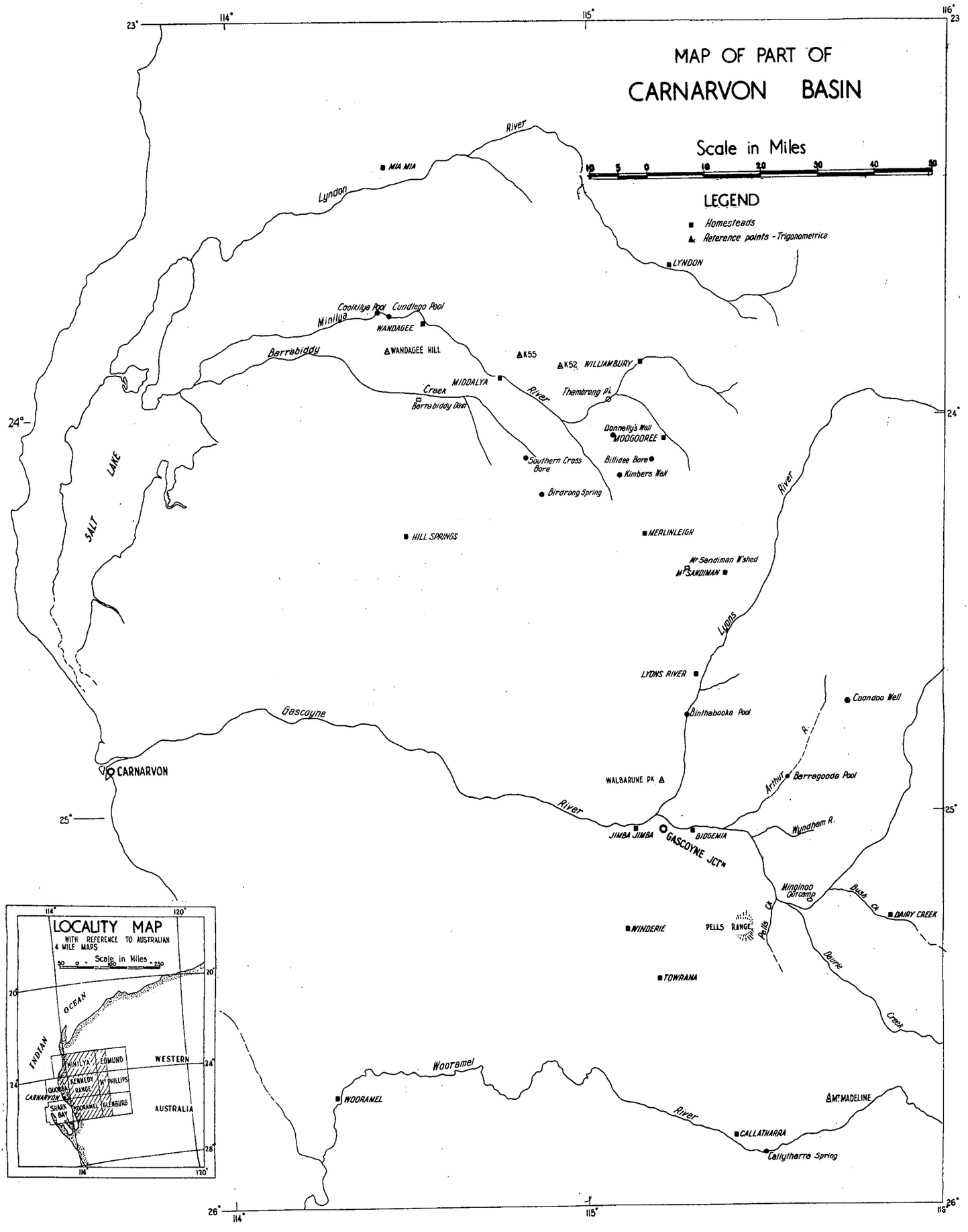
MAP OF PART OF
CARNARVON BASIN
Scale in Miles
10 5 0 10 20 30 40 50
LEGEND
Homesteads
Reference points - Trigonometrica
River
Lyndon
MIA MIA
LYNDON
Cooklilye Pool
Cundlego Pool
Minilya
WANDAGEE
WANDAGEE HILL
K55
K52
WILLIAMBURY
Barrabiddy
Creek
MIDDALYA
River
Thamarang Pl.
Barrabiddy Well
Donnelly's Well
MOOGOOREE
Southern Cross Bore
Billidee Bore
Kimbers Well
Birdrong Spring
SALT
LAKE
HILL SPRINGS
MERLINLEIGH
Mt Sandiman W'shed
MT SANDIMAN
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Lyons
LYONS RIVER
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TOWRANA
Doure Creek
Wooramel
WOORAMEL
River
Mt MADELINE
CALLATHARRA
Lallytharra Spring
24°
25°
26°
114°
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LOCALITY MAP
WITH REFERENCE TO AUSTRALIAN 4 MILE MAPS
Scale in Miles
OCEAN
INDIAN
WESTERN
AUSTRALIA
MINILYA
EDMUND
KENNEDY RANGE
Mt PHILLIPS
CARNARVON
GLENBURGH
SHARK BAY
WOORAMEL
114°
120°
20°
24°
28°

SUMMARY.

Species belonging to the superfamily Orthotetacea Williams form an important part of the Permian marine faunas of Western Australia. Four genera—*Streptorhynchus* King, *Kiangsiella* Chao, *Derbyia* Waagen, and *Permorthotetes* gen. nov.—are represented. Twenty-one species are described and at least two others are indicated by incomplete collections. Many species appear to be restricted in range and are useful in stratigraphical correlation.

Orthotetaceans occur in both the Carnarvon and Fitzroy Basins; the two basins contain related species, but each has a majority of endemic forms. In the Fitzroy Basin, orthotetacean species occur in fossiliferous marine rocks ranging in age from early Artinskian to late Upper Permian, which are widespread and reach a thickness of about 8,000 feet. The rocks of probable Sakmarian age are unfossiliferous. In the Carnarvon Basin, the orthotetaceans occur in a sequence about 15,000 feet thick and ranging in age from Sakmarian to Kungurian.

The Western Australian species are related to faunas from the Salt Range of India, the Himalayas, and Timor, and to a lesser degree to other Asian faunas, e.g. from China. Several species appear to have more or less cosmopolitan affinities.

All the species belong to the family Schuchertellidae Stehli, i.e. the forms lacking dental plates. Both septate and non-septate genera are present. The non-septate and non-plicated genus *Streptorhynchus* displays a rich and diversified development. All the species of this genus possess non-recurved socket plates and most have perforate canals in the "pseudopunctae". (The pseudopunctae in all the Western Australian orthotetaceans are represented by small flexures in the shell walls, and spicules appear to be lacking.)

Four existing and six new species of *Streptorhynchus* are described.

The plicated streptorhynchinid *Kiangsiella* is represented by three new species, all related to the Salt Range species *K. pectiniformis* (Davidson).

Two subfamilies of schuchertellids with median septa are discussed. These are represented in Western Australia by *Derbyia* Waagen, with non-recurved socket plates, and *Permorthotetes* gen. nov. with recurved socket plates.

Permorthotetes has a secondary spondylium formed from the initially discrete dental ridges and septum. This genus is richly developed in Western Australia with six named species and two species of doubtful affinities.

Other genera of the superfamily and the family and subfamily classification are discussed. The evidence for the environments of the Western Australian Permian faunas is reviewed.

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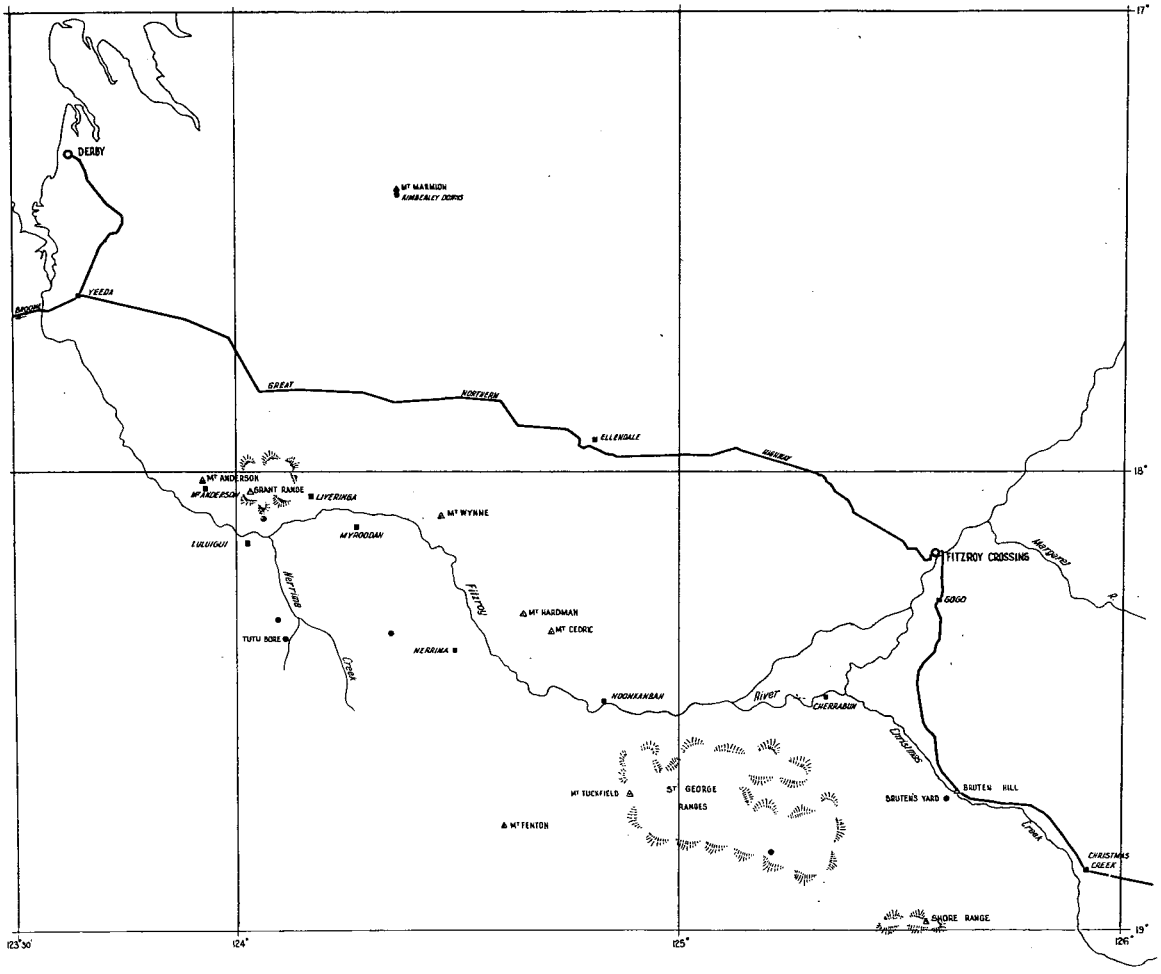
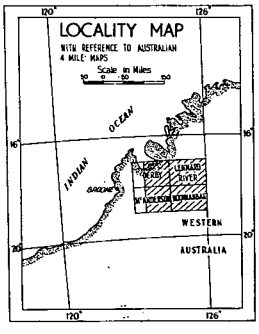




LEGEND

- Homesteads
- Reference points – Trigonometrical
- Fossil Localities (Selected)

MAP OF PART OF
FITZROY BASIN

Scale in Miles

60 5 0 10 20 30 40 50

INTRODUCTION.

The group of strophomenoid brachiopods now known as the superfamily *Orthotetacea* Williams 1953 has been for many years of interest to brachiopod students. Representative species are widely distributed throughout the world. The group attains its acme in the Upper Palaeozoic, particularly in Upper Carboniferous and Permian time.

Six species only have hitherto been recorded in the Permian of Australia. One species has been described from the Permian of Eastern Australia—*Streptorhynchus pelicanensis* Fletcher, originally described by Etheridge in 1892 as *Orthotetes senilis*, from Queensland. *Streptorhynchus perfidiabadensis* (Etheridge) occurs at Treachery Bay, Northern Territory. Two species of *Streptorhynchus* and a *Derbyia*-like form were described from the Permian of Western Australia by Hosking (1932).

In recent years extensive field work by geologists of the Bureau of Mineral Resources and of the University of Western Australia has added greatly to knowledge of the Western Australian Palaeozoic rocks and has augmented collections considerably. The Orthotetacea are now seen to be abundantly represented in Western Australia and are of considerable stratigraphical value. Four genera with at least 23 species can be distinguished in the Permian. The genus *Schuchertella* is known in the Devonian of the Fitzroy Basin and in the Lower Carboniferous Laurel Beds of the Fitzroy Basin. *Schellwienella* has lately been recognized in the Lower Carboniferous Septimus Limestone of the Bonaparte Gulf Basin and in the Lower Carboniferous Moogooree Limestone of the Carnarvon Basin. *Schellwienella* and an unidentified genus are present in the Carboniferous Weaber Group of the Bonaparte Gulf Basin of the Northern Territory.

Source of Western Australian Collections.

The two main collections used belong to the University of Western Australia and to the Commonwealth Bureau of Mineral Resources.

The University of Western Australia collections were largely made by the staff and students of the Geology School under the direction of Dr. C. Teichert. Some other material was collected by T. Blatchford and H. W. B. Talbot, A. Wade, and E. K. Sturmfels.

The Commonwealth Collections have been made in the course of field investigations. Much of the material was collected by J. M. Dickins and the author. Some material was presented by West Australian Petroleum Pty. Ltd. and earlier collections were made by L. Waterford of Freney Kimberley Oil Company.

MORPHOLOGY AND TERMINOLOGY.

The terminology used in this study generally follows that outlined in Cooper (1944). Several terms are introduced or used in a special sense. These are defined in the following review of morphological features found in the late Palaeozoic Orthotetacea.

Structures of the pedicle (ventral) valve.

Palintrope: a shelf-like part of the pedicle valve at the umbonal end, which grows forward from the back on the dorsal side of the valve. The palintrope and the ventral surface of the shell form an irregular cone.

Interarea: the outer surface of the palintrope.

Delthyrium: a triangular notch on the middle of the palintrope.

Pseudodeltidium: a single plate covering the delthyrium, usually convex outwardly.

Perideltidium: (*see* Plate 1, Fig. 2, Plate 2, Fig. 1a): A triangular-shaped portion of the interarea, lying lateral to the pseudodeltidium; distinguished from the rest of the interarea by possession of growth-lines parallel to the hinge-line and longitudinal striations more or less at right angles to the growth-lines (Dunbar and Condra, 1932; Williams, 1953).

Perideltidial Lines: lines marking the outer boundaries of the perideltidium.

Dental Plates: internal plates at the margin of the pseudoldeltidium and palintrope and descending to the floor of the valve.

Dental Ridges: low plates or ridges at the margin of the pseudodeltidium and palintrope, never reaching the floor of the valve.

Teeth: pointed extensions of the dental plates or dental ridges which articulate in sockets of the brachial valve.

Septum: a median internal longitudinal plate on the floor of the valve.

Uniseptum (see text-Fig. 4c): a simple septum formed by up-growth from the floor of valve.

Biseptum (see text-Fig. 4b): a septum formed by fusion of the dental plates (Licharew, 1930).

Spondylium: a spoon-shaped structure in the umbonal region resting on a septum, text Fig. 4b.

Primary spondylium: a spondylium formed by convergence of the dental plates to form a biseptum, leaving a cavity below the pseudodeltidium, text-Fig. 4b.

Secondary spondylium (text-Fig. 4a, Plate 20, Fig. 1 a-k, Fig. 2 a-d) : a spondylium formed from the initially discrete dental ridges and uniseptum which are joined together by secondary shelly material as the shell grows.

Hinge-line: the front margin of the palintrope.

Auriculation: refers to the presence of lateral ear-like extensions of the interarea at the hinge-line.

Structures of the brachial (dorsal) valve.

Palintrope: the brachial palintrope corresponds in position to that of the pedicle valve; in the Orthotetacea it is only a low ridge.

Area (text-Fig. 5a, c, e, g) : the outer surface of the brachial palintrope.

Notothyrium (text-Fig. 5a, c, e, g) : a triangular notch in the middle of the brachial palintrope.

Chilidium (text-Fig. 5c, g) : a plate more or less covering the notothyrium—in the Permian Orthotetacea, this plate is commonly reduced in size and can be divided, e.g., in *Streptorhynchus* and *Derbyia* (text-Fig. 6a, d). In *Derbyoides* the chilidium is quite large, in contact with the dorsal area by part of its sides, and extends on to the socket plates at the sides of the cardinal process. In *Permorthotetes,* a similar chilidium appears to be present though usually not well preserved (text-Fig. 5a). Some specimens show the more or less divided median part (Plate 2, Fig. 1a). Other specimens show the lateral extensions with the median part broken away.

Cardinal Process: the cardinal process is bilobed, with longitudinal diductor muscle grooves on the posterior surface of the lobes (text-Figs. 5a, b, 6a, b, c, d). The process varies in length, size of the lobes, and orientation. Posterior and anterior median ridges are present in some specimens (text-Fig. 5a-g).

Socket Plates: plates supporting the cardinal process at its sides and resting on the floor of the valve. In some genera these plates *recurve,* or grow back towards the hinge-line (text-Fig. 5e, f, g). In other genera they grow forward on the floor of the valve (text-Fig. 6b, c). The name *socket plate* is used in place of *crural* plates (many authors), as there is no evidence that the plates supported the lophophore in the Orthotetacea (Williams, 1953, p. 4).

Socket Ridges (text-Fig. 6a, d) : outwardly directed ridges on the socket plates. These sometimes have extensions. This term is used by Williams (1953, p. 4) in place of crura (of some authors). Dunbar and Condra (1932) used the term " crural buttress " for the socket ridges in species of Derbyia,

Plication (text-Fig. 13) : major radial fold of the shell, involving a number of costellae.

Costellae: fine radial ribs, numbering from 5 to 16 in 5 mm. They commonly multiply by intercalation and only rarely by division. Each new intercalation or division is called a generation.

Lamellae: step-like concentric layers of the shell surface; they mark the stages of growth of the shell.

Growth-lines: fine concentric lines on the outer surface of the shell.

Rugae or Wrinkles: coarse concentric folds in the shell.

Callus: a thickening of the shell wall by growth of secondary or adventitious shelly material. In some species callus is well developed below the palintrope and the muscle scars.

Inclination of the interarea: in most orthotetacean species, the interarea is *apsacline,* i.e., at less than 90° to the posterior extension of the "plane" of commissure of the valves; in a few it is *catacline,* i.e., at 90° or more to the "plane" of the commissure. The surface bounded by the line of commissure of the two valves is very rarely a plane, in most brachiopods. It would therefore be more accurate to record the inclination of the interarea to a line forming the centre of the hinge-line and the middle of the front commissure. (Terminology after Schuchert and Cooper, 1931.)

Muscle Scars: muscle scars are developed in both valves. The amount of impression is variable both specifically and individually.

Convexity: the brachial valves are convex in all the species described. The pedicle valve varies from convex to concave. The following terminology is adapted from McEwan, 1939.

Biconvex: both valves convex.

Dorsiconvex: pedicle valve flat, brachial valve convex.

Resupinate: pedicle valve convex in early growth stages, concave in later stages.

Dimensions: the dimensions of length, breadth, and depth or thickness are recorded in the conventional manner. The longitudinal dimension of the interarea and dorsal area is the height; both vary from low to high. The width of the interarea is the width of the hinge-line; the width of the delthyrium or pseudodeltidium is its dimension at the hinge-line.

Apical Angle: the angle formed at the umbo by the posterior lateral slopes of the pedicle valve. This angle in most specimens is the same as that included by the outer sides of the interarea.

CLASSIFICATION OF THE ORTHOTETACEA.

W. Waagen in 1884 was the first author to set up a higher category for genera now included in the superfamily Orthotetacea. Waagen proposed the subfamily Orthotetinae to include the genera *Triplesia* Hall, *Streptorhynchus* King, *Derbyia* Waagen, *Meekella* White and St. John, and *Orthotetes* Fischer. He included the subfamily in the family Strophomenidae King.

The superfamily *Orthotetacea* was set up by A. Williams in 1953. Williams outlined a new classification of the group which he included in the suborder *Strophomenoidea* Öpik 1934, amended Williams 1953. The suborder and its more primitive members will not be discussed here, except to mention that all the genera included are stated to have a pseudopunctate shell, a character they share with the Productacea. The shell structure of the Western Australian species will be described later.

Orthotetacea Williams 1953 are defined as: " Strophomenoids without a functional pedicle; pedicle valve usually greatly modified and cemented by the umbo or a greater part of the shell surface to a foreign body; brachial valve convex throughout ontogeny; cardinal process bilobed, often greatly extended into the pedicle valve, sometimes highly modified; lophophore probably spirolophous in all stocks, exceptionally impressed and supported by spirally coiled calcareous ribbons. Upper Ordovician to Triassic ".

Williams recognized four families: *Orthotetidae* McEwan 1939 amended Williams 1953, *Gemellaroiidae* Williams 1953, *Schacchinellidae* Williams 1953 and *Thecospiridae* Bittner 1893. Of the above only the *Orthotetidae* are known in the Permian of Australia.

The *Orthotetidae* are defined as: " Orthotetaceids with a variable but well developed hinge-line and interarea in the pedicle valve; pedicle valve consisting of one continuous chamber, pseudodeltidium of earlier stocks apical and chilidium correspondingly massive, in later stocks pseudodeltidium completely covering delthyrium, chilidium vestigial, perideltidium always present; shell surface usually finely costellate with additional radial plicae in many stocks. Upper Ordovician to Permian ".

Williams separated three subfamilies: *Orthotetinae* Waagen 1884 emend. Williams 1953, *Schuchertellinae* Williams 1953, and *Davidsoniinae* King 1850. The Orthotetinae are " Orthotetids equipped with a pair of dental lamellae, often extravagantly developed and in various stages of convergence and coalescence. Upper Ordovician to Permian. Type genus *Orthotetes* Fischer ". The Schuchertellinae are " Orthotetids which have lost the dental lamellae through obsolescence. Devonian to Permian. Type genus *Schuchertella* Girty ".

More recently Stehli (1954) has amended the superfamily. He refers the Schacchinellidae to the Productacea and questions the inclusion of the Gemellaroiidae. He erects a new family, the *Schuchertellidae* Stehli 1954, which contains three subfamilies: *Schuchertellinae* Williams emend. Stehli, *Derbyiinae* Stehli 1954 and *Streptorhynchinae* Stehli 1954. The Orthotetidae is likewise emended and contains two subfamilies.

The Western Australian Permian species can all be included in the family Schuchertellidae Stehli.

The classifications of Stehli and Williams both use for their fundamental divisions of the superfamily Orthotetacea the features of the pedicle (ventral) valves; in particular they stress the presence or absence of strong dental plates. In this they follow Licharew (1930). Earlier classifications also based on the pedicle valve, e.g., those of Girty and I. Thomas, had stressed the presence or absence of a septum. The presence or absence of dental plates seems to be more useful for classification because, as will be discussed later, the septum can rise in various ways and independently in various stocks. The dental plates have long been regarded as significant in generic definitions, but the significance to the living animal is obscure; although they no doubt strengthened the shell in various ways, they are not indispensable. The presence or absence of plication has also been used in generic definition. Plication arises independently in various stocks and appears to be a late development in each line.

The cardinal apparatus of the brachial (dorsal) valve, which is recognized to be of great value in other groups, e.g., by Öpik (1932, 1934) and Sutton (1938), has been less used in generic definitions and in phylogenetic classifications in this superfamily. A notable exception is the genus *Derbyoides* Dunbar and Condra, which was separated from *Derbyia* Waagen because of the nature of the socket plates. Unfortunately, the cardinal apparatus is inadequately known in many genera, especially in the Orthotetidae McEwan emend. Stehli. An attempt is made in this paper to use the structures of the brachial valve in discussing the West Australian species of the Schuchertellidae Stehli.

The Orthotetidae as emended by Stehli comprise "Orthotetacea in which a simple median septum is lacking in the pedicle valve and in which the dental plates are strong and may or may not join to form a spondylium before reaching the floor of the valve". As defined above, this family is not represented in Western Australia. Stehli includes two subfamilies: *Meekellinae* Stehli and *Orthotetinae* Waagen emend. Stehli, which are characterized by the presence or absence of plication respectively. Plication undoubtedly arises in various stocks of the Orthotetacea, usually as a late development. Plicated forms are present in two stocks of the *Schuchertellidae,* and in that family Stehli rightly does not attempt to separate the plicated genera as a subfamily. A more natural

basis for the erection of subfamilies would probably be the degree of coalescence of the dental plates, or might be found in the brachial cardinalia if these were better known.

ORTHOTETIDAE Williams emend. Stehli.

Below is a brief summary of the various Upper Palaeozoic genera which are known to me from the literature and which seem to belong to the Orthotetidae of Stehli. They are grouped in his subfamilies.

a. Orthotetinae Waagen emend. Stehli 1954.

Orthotetes Fischer de Waldheim 1850, Girty 1909, Sokolskaia 1952, 1954. This genus, as reinterpreted by Girty in 1909 from Fischer's original illustrations and descriptions, has been since understood as an orthotetacean with septum and spondylium in the pedicle valve. Girty recognized that Fischer's illustrations of *Orthotetes radiata* depicted the internal features of the ventral valve and that these were similar to the features described by Waagen (1884) as characteristic of the "camerate" group of his genus *Derbyia*. Fischer's specimens from the Moscovian of Russia have been lost for many years. In 1932, Licharew proposed the suppression of the name *Orthotetes* in favour of *Ombonia* Caneva, which he thought had the same features. Recently Williams has held the view that *Ombonia* is synonymous with *Orthotetes* (personal communication, 1955).

Sarycheva and Sokolskaia (1952) and Sokolskaia (1954) have lately reviewed the strophomenoid brachiopods of the Moscow Basin, and Sokolskaia has redescribed *Orthotetes radiata* Fischer, the type species, from new collections. In addition to *O. radiata* she distinguishes four species in the Moscow Basin. In her generic diagnosis, she records that the spondylium (a term not used by her) is small and present only in young forms.

A translation of part of her description reads: "Small teeth are inset at the edges of the delthyrium and joined to dental plates which are developed only within the area on both sides of the delthyrium; they do not extend forward from the teeth along the floor of the valve (Fig. 53). Sometimes, almost exclusively in young specimens and within the limits of the area, dental plates form opposite the middle of the delthyrium and continue into the middle septum which extends towards along the floor of the shell (Fig. 54). In such cases, a small triangular chamber is formed between the dental plates. This chamber is usually absent in adult specimens because the dental plates as well as the septum have become enlarged and thickened; the chamber fills up with shell material and the median septum arises immediately from the middle part of the delthyrium. Plate XV., Fig. 3, illustrates both cases in a small and large specimen". (Sokolskaia, 1954, p. 137.)

Sokolskaia's figures, including those of the cardinal process, are reproduced in text-Fig. 3. The cardinal process is shown to be short with recurved socket plates.

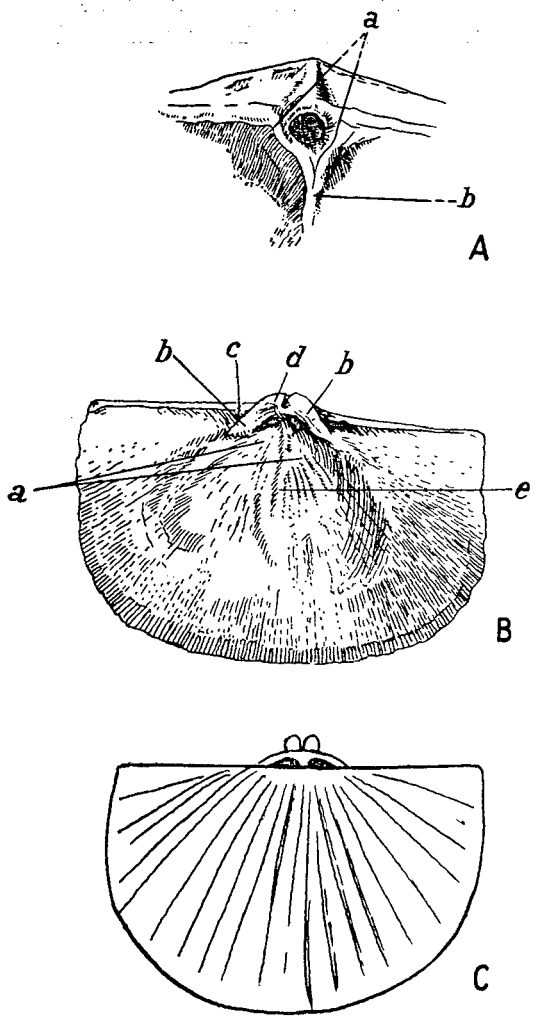


FIGURE 3.

Orthotetes **(after Sokolskaia, 1954).**

A. (After fig. 54.) Internal structure of pedicle valve of young specimen of *Orthotetes*; a, dental plates; b, median septum.

B. (Fig. 55.) Internal structure of brachial valve of *Orthotetes* shell; a, muscle scar; b, crural plates; c, teeth recesses; d, cardinal process; e, septum.

C. (After fig. 56.) External view of cardinal process in *Orthotetes*.

Unfortunately, Sokolskaia does not figure or describe any sections through the umbonal region, and consequently the mode of formation of the plates and septum is still not clear. Her Figure 54 seems to indicate that the spondylium is homologous with that of *Ombonia* (text-Fig. 4b). However, the fact that it

is small and variable and may be absent suggests that it may be a secondary spondylium formed similarly to that of *Permorthortetes* gen. nov., described below (text-Fig. 4a).

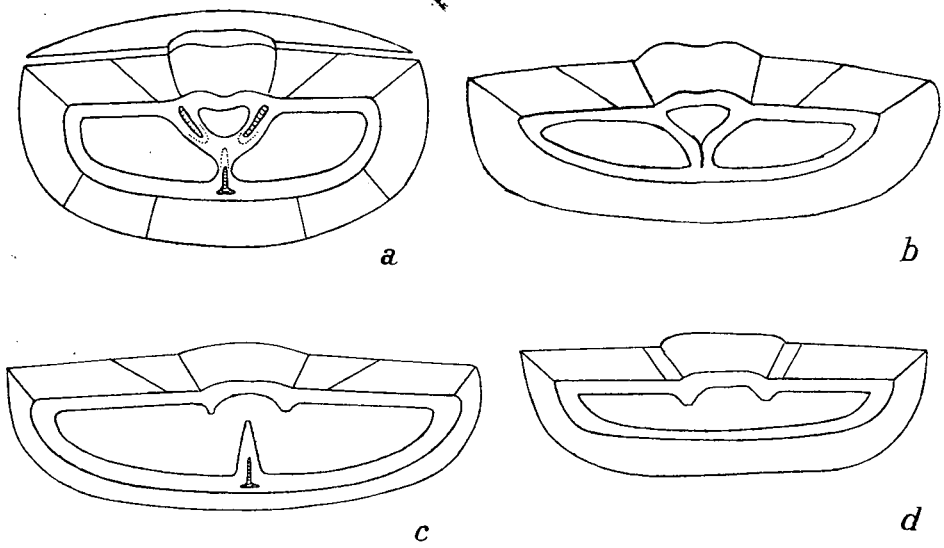


FIGURE 4.

Diagrammatic transverse sections through pedicle valves of orthotetacean genera, in umbonal region.

a. ***Permorthotetes*** **gen nov, showing secondary spondylium with discrete dental ridges and septum, all fused by secondary shell growth. The perideltidial lines on the interarea on either side of the pseudodeltidium are also shown.**

b. ***Ombonia*** **Caneva, showing primary spondylium with long dental plates which fuse to form the biseptum.**

c. ***Derbyia*** **Waagen, showing discrete septum and low dental ridges. Near the umbo, the septum may reach the pseudodeltidium.**

d. ***Streptorhynchus*** **King, showing low dental ridges and absence of septum.**

Sokolskaia has described five species from the Carboniferous of the Moscow Basin, ranging in age from the Visean to the Gschelian. One of these is identified as *Orthotetes regularis* Waagen, the designated type species of *Derbyia*. This identification is discussed below under the genus *Derbyia*.

If further studies of the Russian material should reveal that the spondylium of *Orthotetes radiata* is not like that of *Ombonia*, i.e. with dental plates fusing to form a biseptum, the genus will not display the diagnostic features of the subfamily *Orthotetinae* Waagen emend. Williams and of *Orthotetidae* McEwan as amended by Stehli. In this text it is assumed that the septum and dental plates of *Orthotetes* are homologous with those of *Ombonia*.

Licharew (1930, 1931, 1932), writing on the general relationships of this group, proposed the suppression of the name *Orthotetes* in favour of *Ombonia*,

on the grounds that the types of *Orthotetes* were lost and that the exhaustive studies of Ivanov had failed to find topotypes from the type locality near Podolsk.

Ombonia (Caneva, 1906; Merla, 1931) was a name given to unnamed species from the late Permian "Bellerophon" Limestone of the Carnic Alps of Italy in 1906. The pedicle valves had a long spondylium and septum formed from the dental plates. The species was first named by Merla (1931) as *Ombonia canevai,* and this species and others later described, e.g. *Ombonia girtyana* Merla from the Upper Permian of the Karakoram Range and *Ombonia dieneri* Licharew from the Permian of the Caucasus, are stated to have the septum formed by the coalescing of the long and thin dental plates. Text Fig. 4b is an interpretation of the structure as described by Caneva, Merla, and Licharew. None of these authors figure sections in sufficient detail to show the precise nature of the median septal fusion. This is the type of septal structure named a biseptum by Licharew (1930). Merla (1931) figured the cardinal process of *Ombonia canevai* Merla. It is long and bilobed and supported by strong long diverging socket plates which do not recurve. A median ridge is present also on the floor of the valve. He does not describe the posterior aspect of the process. A process of similar type appears to be present in *Ombonia dieneri* Licharew (Licharew, 1932, Pl. 6, Fig. 2), and *Ombonia transversalis* Licharew. The latter appears to have socket ridges similar to those in *Derbyia,* e.g. *Derbyia hardmani* sp. nov., but the illustrations are not very clear (Licharew, 1931, Pl. LV, Fig. 5).

The redescription of *Orthotetes* by Sokolskaia indicates that *Ombonia* with its distinctive cardinalia cannot be put in synonymy with *Orthotetes. Ombonia* is known from the Upper Permian Bellerophon Limestone of the Carnic Alps (Merla, 1931; Caneva, 1906), from the north Caucasus region of Russia (Licharew, 1932), from the Upper Permian of the Karakoram Range, and from the Sosio beds of Sicily (Greco, 1938). The Sosio beds have a well-known rich Permian fauna probably of the same age as the Word of Texas (Miller and Furnish, 1941).

As will be described below in the new Western Australian genus *Permorthotetes,* a spondylium can be formed in a quite different way from that of *Ombonia* Caneva, so that records of *Orthotetes* in the literature need to be re-appraised. Some of these records will be mentioned in discussing Permorthotetes.

Other orthotetinid genera from the Carboniferous and Permian are:

Orthotetella King 1930 emend. Stehli 1954. Type *O. wolfcampensis* King. This genus has a large primary spondylium and small median septum. Lower Permian.

Perigeyerella Wang 1955. Type *P. costellata* Wang 1955. Dental plates as in *Orthotetina* with a small spondylium like *Ombonia.* Upper Permian of China.

Orthotetina Schellwien (1900). Type *O. persica* (Schellwien). This genus has long, well-developed, and parallel but not coalescing dental plates, reaching the floor of the valve. Permian.

Schellwienella Thomas (1910). Type *S. crenistria* (Phillips). Dental plates are short and divergent but reach floor of valve. Lower Carboniferous.

Hamletella Hayasaka (1953). Type *H. alta* (Hamlet). Long parallel dental plates and a high interarea. The arrangement of the dental plates seems to be essentially that of *Orthotetina* Schellwien. Permian.

Sicelia Merla (1934). Type *S. acropedion* Merla. Spondylium reaches floor of valve: no septum, apparently close to *Orthotetella* King. Permian.

Pseudoderbyia Licharew (1934). This appears to be a *nomen nudum,* as the designated type species *P. netschajewi* is not described and figured. It is stated to have a spondylium and septum. Permian.

Pulsia Ivanov (1926). Type *P. mosquensis* Ivanov (1926) and Sokolskaia (1952). Dental plates, short like *Schellwienella,* but more convergent. Moscovian.

b. The plicated genera included in the Meekellinae Stehli are listed below—

Meekella White and St. John (1867). Type *Meekella striatocostata* (Cox). The dental plates are similar to those of *Orthotetina.* Carboniferous to Permian.

Geyerella Schellwien (1900). Type *G. alpina* Schellwien. The dental plates are long and coalesce to form a medium biseptum. The spondylium is like that of *Ombonia.* Permian.

SCHUCHERTELLIDAE Stehli.

The family Schuchertellidae is defined by Stehli (1954) as "Orthotetacea without dental plates". He includes three subfamilies: *Schuchertellinae* Williams emend. Stehli, *Derbyiinae* Stehli and *Streptorhynchinae* Stehli. The Western Australian faunas contain species of a new genus, *Permorthotetes,* which does not fit readily in his subfamilies, though otherwise belonging to the family.

Schuchertellinae Stehli are "Schuchertellids in which pedicle valve is a low cone and in which the shell is biconvex; brachial valve with a low cardinal process, crural plates recurved and joined to the posterior margin of the shell". This is essentially a definition of the genus *Schuchertella* Girty, type species *S. lens* White of Mississippian age. The type species shows a well-developed chilidium and narrow area in the brachial valve—text Fig. 5a. The length of the cardinal process is probably not a feature of subfamily diagnostic significance. The genus is reported from beds of Devonian to Permian age, but is

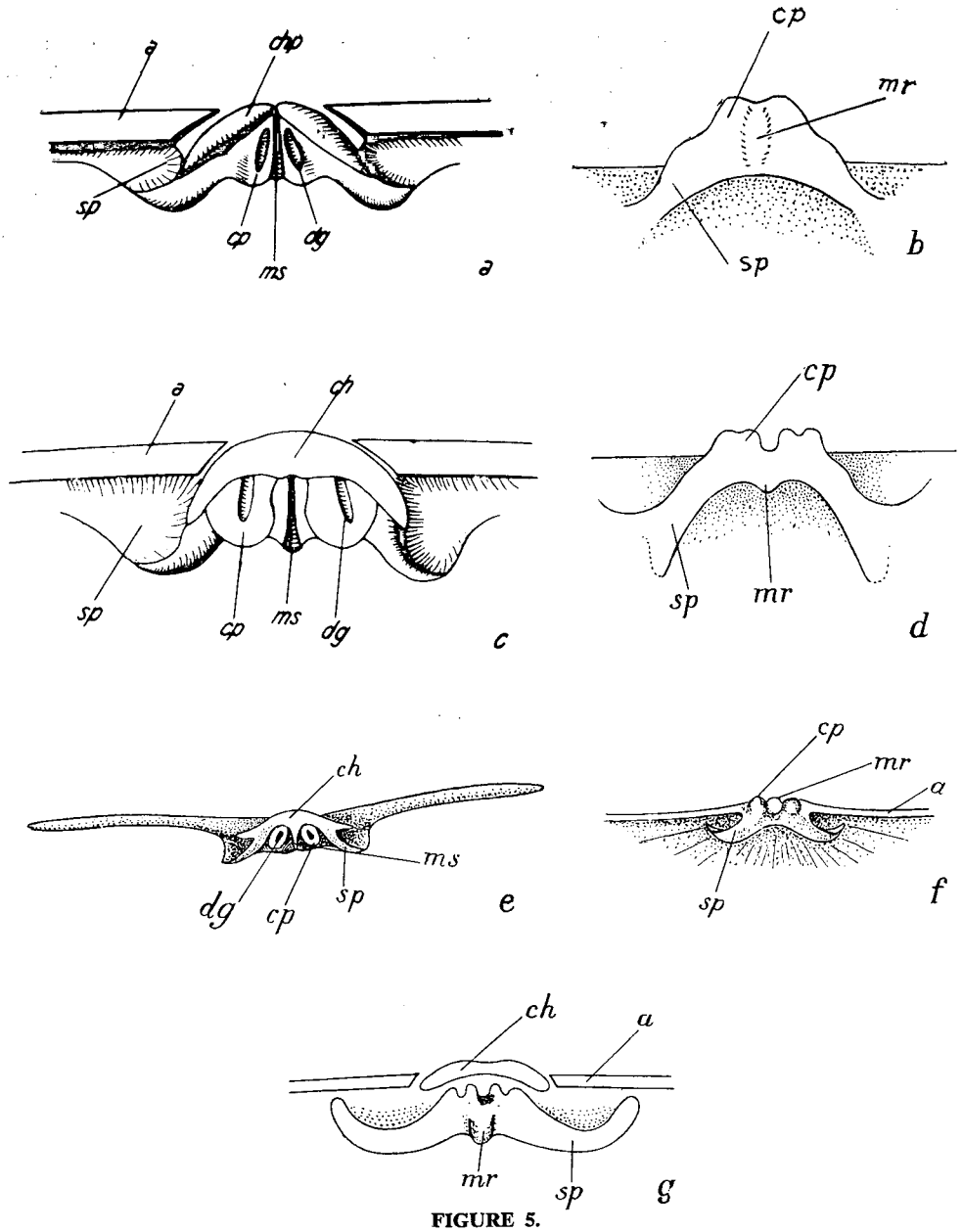


FIGURE 5.

Diagrammatic sketches of cardinal processes of some genera of the family Schurchertellidae Stehli.

a. *Permorthotetes* **gen. nov., posterior to ventral view.**
b. *Permorthotetes* **gen. nov., anterior view.**
c. *Derbyoides* **Dunbar and Condra, posterior to ventral view.**
d. *Derbyoides* **Dunbar and Condra, anterior view.**
e. *Tapajotia* **Dresser, posterior to ventral aspect (after Dresser, 1954).**
f. *Tapajotia* **Dresser, anterior aspect (after Dresser, 1954).**
g. *Schuchertella* **Girty, generalized view of components.**

a = dorsal area; ch = chilidium; chp = chilidial plate; dg = grooves for diductor muscles on posterior surface of lobes of cardinal process; ms = median septum or ridge between lobes of cardinal process on posterior side; cp = cardinal process; sp = socket plate; mr = median ridge or swelling on anterior surface of cardinal process.

rare above the Mississippian. Stehli (1954) describes a new species from the Leonardian of Texas. Other Permian references do not illustrate the internal characters of the brachial valve, which alone would identify the genus with certainty. The genus is not known in the Permian rocks of Western Australia, but is present in the Upper Devonian rocks of the Fitzroy Basin and in the Lower Carboniferous Laurel Beds of the Fitzroy Basin.

Streptorhynchinae Stehli are defined as "Schuchertellidae in which the pedicle valve is a deep cone; brachial valve convex, cardinal process high, crural plates recurved". This definition needs to be revised, since in the type species of *Streptorhynchus*—*S. pelargonatus* (Schlotheim)—the socket plates (crural plates) do not recurve but are divergent and extend forward on to the floor of the valve. All the Western Australian species have this type of socket plate, as do *Kiangsiella pectiniformis* Davidson and the new species *Kiangsiella condoni* (text-Fig. 6a, b). Stehli included three genera in the subfamily: *Streptorhynchus* King, *Kiangsiella* Chao, and *Diplanus* Stehli. The first two genera are well represented in Western Australia; the recurved socket plates of the latter suggest an affinity with *Schuchertella*.

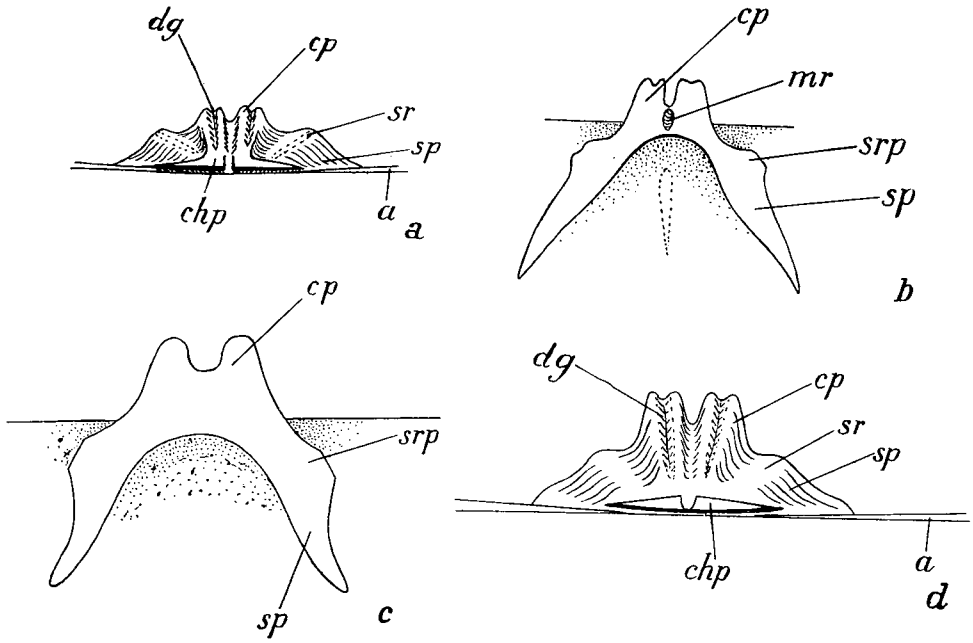


FIGURE 6.

Diagrammatic sketches of cardinal processes of *Streptorhynchus* King and *Derbyia* Waagen.

a. *Streptorhynchus* King, posterior view.

b. *Streptorhynchus* King, anterior view.

c. *Derbyia* Waagen, anterior view.

d. *Derbyia* Waagen, posterior view.

cp = cardinal process; dg = diductor muscle grooves on each lobe of cardinal process; sp = socket plate; sr = socket ridge; srp = socket ridge projection; chp = chilidial plate; mr = anterior median ridge (variably present); a = very narrow dorsal area.

Derbyiinae Stehli are defined as "Schuchertellidae in which there is a well-developed median septum in the pedicle valve; brachial valve with the crural plates not recurved". Stehli includes *Derbyia* Waagen, *Plicatoderbyia* Thomas, *Derbyaeconcha* Licharew, and *Grabauellina* Licharew. These genera, including *Derbyia* Waagen as restricted by Girty (1909), form a convenient and apparently related group with a wide distribution. All except *Grabauellina*, which is poorly known, appear to have a common pattern of cardinal process, which is generally long and supported by strong diverging, non-recurving socket plates. Socket ridges which diverge from near the base of the process on the posterior side are present. The chilidium is small and the dorsal area is narrow or obsolescent (text Fig. 6c, d, and Plate 16, Figs. 7a, b). The septum is a simple structure, not formed from the dental ridges, and it meets them, if at all, only at the apex (text Fig. 4c). *Derbyaeconcha* Licharew 1934, type *D. anomala* (Licharew) 1932, is essentially similar to *Derbyia*, but with a strongly convex pedicle valve. It is recorded from the Permian rocks of the Caucasus. *Plicatoderbyia* Thomas 1937, type *P. magna* (Branson) is a plicated genus with the internal characters of *Derbyia*. It is known in the late Permian.

In the Permian rocks of the Fitzroy and Carnarvon Basins are numerous specimens of a septate schuchertellid genus *Permorthotetes* gen. nov.* which has a number of peculiar features. The pedicle valve has a well-developed median septum; the dental plates are generally low, but near the umbo form with the septum a distinct spondylium which may be very small or comparatively large. Serial sections reveal that the spondylium is a secondary feature (text Fig. 4a). Initially, the septum and short dental plates or ridges are simple and discrete, but as the shell in the apical region increases in thickness by formation of new layers, the three elements become joined to form a secondary spondylium: examples are shown in plates (Plate 20, Figs. 1, 2; Plate 21, Figs. 1, 2, 3; Plate 22, Figs. 1, 2, 3, 4). The secondary spondylium may be unevenly or asymmetrically developed. Such a spondylium is quite different in structure from that of *Ombonia* or *Geyerella*. The cardinal process is of different pattern from that of the *Derbyiinae*. In the type species *Permorthotetes callytharrensis* (Plate 4, Figs. 6, 7, and text Figs. 5a, b), it is short, supported by stout diverging socket plates which recurve on their posterior surface and form open cones with apices directed towards the base of the cardinal process. A dorsal area and divided chilidium are present. This type of cardinal apparatus is closer to that of *Derbyoides* Dunbar and Condra, *Tapajotia*, and *Schuchertella*, than to that of the Derbyiinae.

The low dental ridges of *Permorthotetes* establish that it is a schuchertellid, but the distinctive type of cardinal process shows that it is not a genus of the Derbyiinae. The lineage suggested below appears to be the line of descent of

* *Werriea* Campbell 1957 was published after this bulletin had gone to press. This Lower Carboniferous genus has a secondary spondylium. *Permorthotetes* may possibly be a synonym but appears to differ in the details of the brachial cardinalia: both genera may possibly be synonyms of *Orthotetes* (see pages 13, 83).
[Campbell, K.S.W., 1957—A Lower Carboniferous brachiopod—coral fauna from New South Wales. *J. Paleont.*, 31, 34–98.]

a fourth subfamily, the *Derbyoidinae* subfam. nov., distinguished from the Derbyiinae by the possession of recurved socket plates.

Other genera which it seems reasonable to associate with *Permorthotetes* are *Tapajotia* Dresser and *Derbyoides* Dunbar and Condra. These three genera can be arranged in what seems to be a progressive series. The cardinal apparatus appears to be a conservative feature, being essentially similar to that of *Schuchertella lens* White, but modified in *Permorthotetes* by the reduction of and division of the chilidium.

The postulated lineage *Schuchertella—Tapajotia—Derbyoides—Permorthotetes* shows a progressive development of the septum. Some Lower Carboniferous species of *Schuchertella* show a very rudimentary ventral septum, which I. Thomas (1910) called a "median pseudo-septum", instancing one of Davidson's figures (Plate 26, Figure 5, Davidson 1860-61) of a *Schuchertella* from the Carboniferous Limestone of Hook Point, County Wexford, Ireland. This is merely a slight median shell-thickening in the muscle area.

Tapajotia Dresser, from the Upper Carboniferous (Middle Pennsylvanian) Epoch of Brazil, shows a slightly further stage with a more pronounced but still low septum (Dresser, 1954, Plate 4, Fig. 4). Dresser's figures of the cardinal apparatus are reproduced in text Figure 5e, f.

Derbyoides Dunbar and Condra (1932) possesses a strong median septum. Stehli (1954) is mistaken in suggesting that it had not a septum; it is clearly illustrated for the type species *Derbyoides nebrascensis* Dunbar and Condra (1932, Plate 9, Fig. 3). This species is described from the Upper Pennsylvanian Iatan Limestone of Nebraska. The genus is evidently present also in the Lower Permian of North America. Specimens of silicified shells in the University of Melbourne Collection, from the Fort Riley member of the Barnston Formation, from south end of Cedar Point, Chase County, Texas, of Wolfcampian age, have the characters of this genus. The septum is strong and rather broad and thickens markedly at its posterior end. The low dental ridges join this thickened septum near the umbo. A strong chilidium is present and also a dorsal area. The apical structures of these shells could not be sectioned, but they are reminiscent of some specimens of *Permorthotetes guppyi* sp. nov. in which the secondary spondylium is obliterated by shell thickening.

Permorthotetes has low dental ridges, a strong septum and a variable secondary spondylium. The chilidium is divided and reduced in size. *Permorthotetes* is of late Sakmarian (Wolfcampian) to Artinskian age. The series is outlined in text Figure 7.

Within the family Schuchertellidae Stehli, two basic patterns of brachial cardinal apparatus become evident. The more primitive is that represented by *Schuchertella lens* (White) (see Weller, 1914, Plate 3, Figs. 1-8; Hall and Clarke 1892, Plate 11A, Figs. 16-22; and text Figure 5g of this Bulletin). It is present in the Devonian. It is retained in later species of *Schuchertella*, in *Tapajotia*,

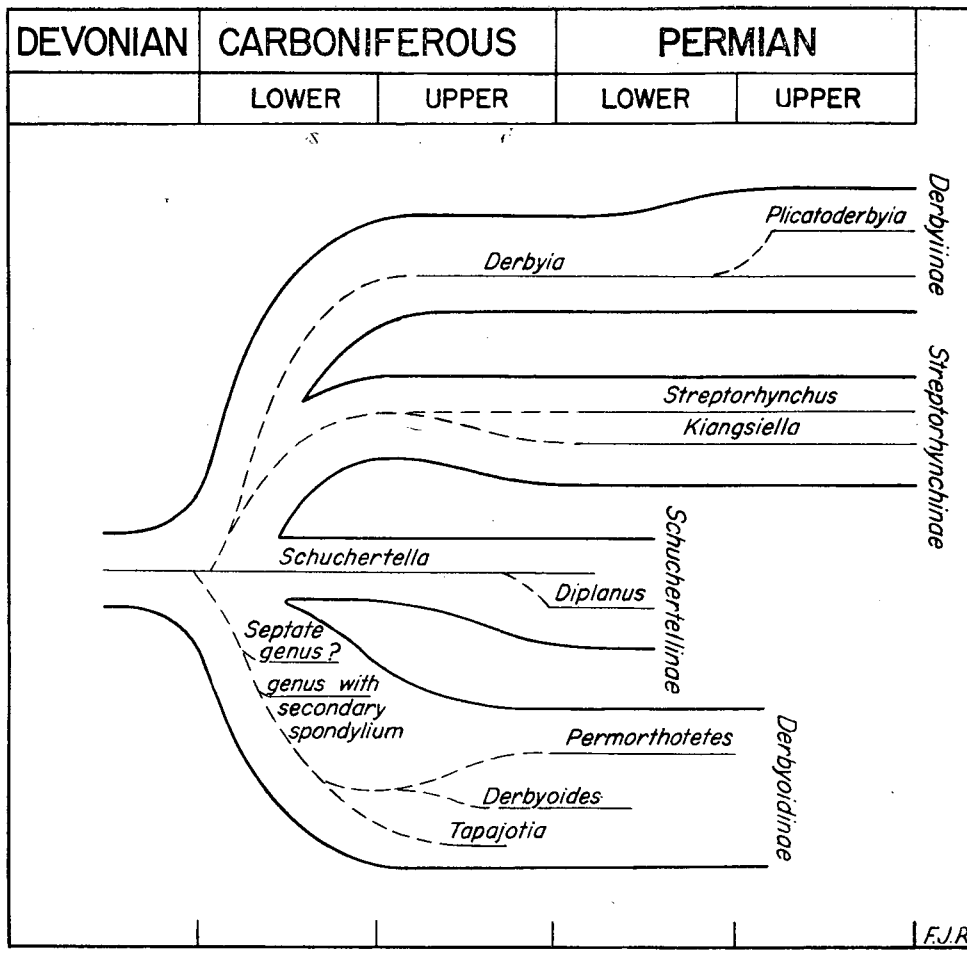
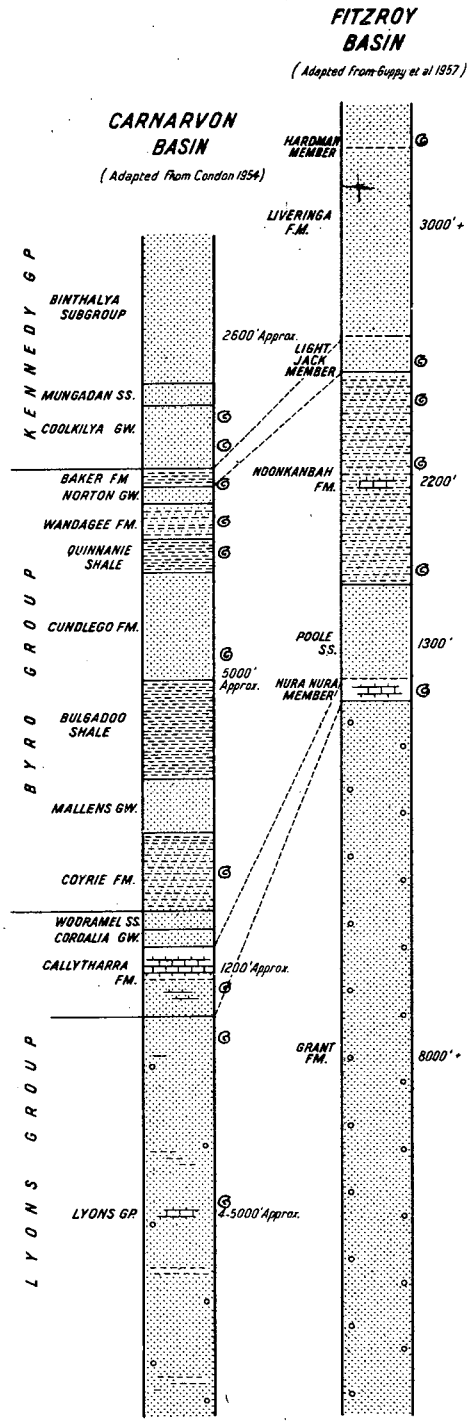


FIGURE 7.

Outline of the suggested relationships of genera belonging to family *Schuchertellidae* Stehli.

in *Derbyoides* and with modifications in *Permorthotetes*. The other pattern is that of the Derbyiinae and Streptorhynchinae (see text Figures 6a-d; and Plate 5, Fig. 9a, b; Plate 14, Fig. 4; Plate 16, Fig. 8a, b). This type is presumably derived from the Schuchertellid stock and probably arose in the Lower Carboniferous; it is particularly well developed in the Upper Carboniferous and Permian (text Fig. 7).

If the genus *Orthotetes* possessed a secondary spondylium essentially similar to *Permorthotetes*, it would fit fairly well into this grouping. The socket plates are recurved and Sokolskaia's figures appear to indicate two small reduced chilidial plates (text Fig. 3). *Permorthotetes* in that event would probably be regarded as a sub-genus of *Orthotetes* or even possibly be referred to synonymy.


FITZROY BASIN
(Adapted from Guppy et al 1957)
CARNARVON BASIN
(Adapted from Condon 1954)
KENNEDY GP
BYRO GROUP
LYONS GROUP
BINTHALYA SUBGROUP
MUNGADAN SS.
COOLKILYA GW.
BAKER FM
NORTON GW.
WANDAGEE FM.
QUINNANIE SHALE
CUNDLEGO FM.
BULGADOO SHALE
MALLENS GW.
COYRIE FM.
WOORAMEL SS.
CORDALIA GW.
CALLYTHARRA FM.
LYONS GP.
2600' Approx.
5000' Approx.
1200' Approx.
2-5000' Approx.
HAROMAN MEMBER
LIVERINGA F.M.
3000'+
LIGHT JACK MEMBER
NOONKANBAH FM.
2200'
POOLE SS.
1300'
NURA NURA MEMBER
GRANT FM.
8000'+
REFERENCE
SS. Sandstone
GW Greywacke
FM Formation
GP Group
Approximate stratigraphical positions of the described specimens.

STRATIGRAPHIC RANGE AND REGIONAL DISTRIBUTION OF THE WEST AUSTRALIAN PERMIAN ORTHOTETACEA.

The species described in this Bulletin occur in the Carnarvon and Fitzroy Basins. The Carnarvon Basin is a basin of Palaeozoic to Recent sediments from Onslow in the north to the Murchison River in the south and up to 130 miles inland. The most recent published account is found in Condon (1954). Earlier important references are Raggatt (1938) and Teichert (1947 and 1952). The maximum thickness of Permian deposits is attained in the Minilya River-Kennedy Range area. The generalized stratigraphical column showing these maxima is shown in text Figure 8. South of the Gascoyne River the Permian section is much thinner, the higher formations are not present and different formations are now recognized for some parts of the sequence. This work is not yet published. The localities are indicated in text Figure 1. The vertical ranges of the species are shown in text Figure 10.

The Fitzroy Basin is defined by Guppy et al. (1958) as the part of the Canning Basin that lies north of the Fenton Fault. The Canning Basin is the area of Palaeozoic and Mesozoic rocks bounded by the Precambrian of the Kimberley Plateau in the north and of the Pilbara area in the south and extending westward on to the continental shelf. The vertical ranges of the orthotetacean species from the Fitzroy Basin are shown in text Figure 9. The localities are indicated in text Figure 2. Permian outcrops cover great areas in the Fitzroy Basin, indicated by the distribution of localities in text Figure 2. Permian outcrops are known also from the southern margin of the Canning Basin (Traves, Casey, and Wells, 1956).

The correlations indicated in text Figure 8 are derived from Thomas and Dickins, 1954.

As indicated on Text-Figures 9 and 10, many of the species appear to have restricted vertical ranges. Further collections may extend some of these. A number of species appear to be very useful in local correlation. *Streptorhynchus plicatilis* is a useful index fossil for the Callytharra Formation and *S. luluigui* is restricted to the Hardman Member of the Liveringa Formation. *S. crassimurus, S. costatus* and *S. variabilis* have so far been found only at different levels in the Noonkanbah Formation. *S. johnstonei* is a good index fossil for the Coolkilya Formation.

Kiangsiella condoni appears to occur only in the lower part of the Byro Group. The species of *Permorthotetes* have also some value in correlation, though they are difficult to identify specifically from fragmentary collections. Thus *P. callytharrensis* and the allied species *P. lindneri* occur in the early Artinskian deposits in Western Australia. *Derbyia hardmani* has so far been found only in the Hardman Member.

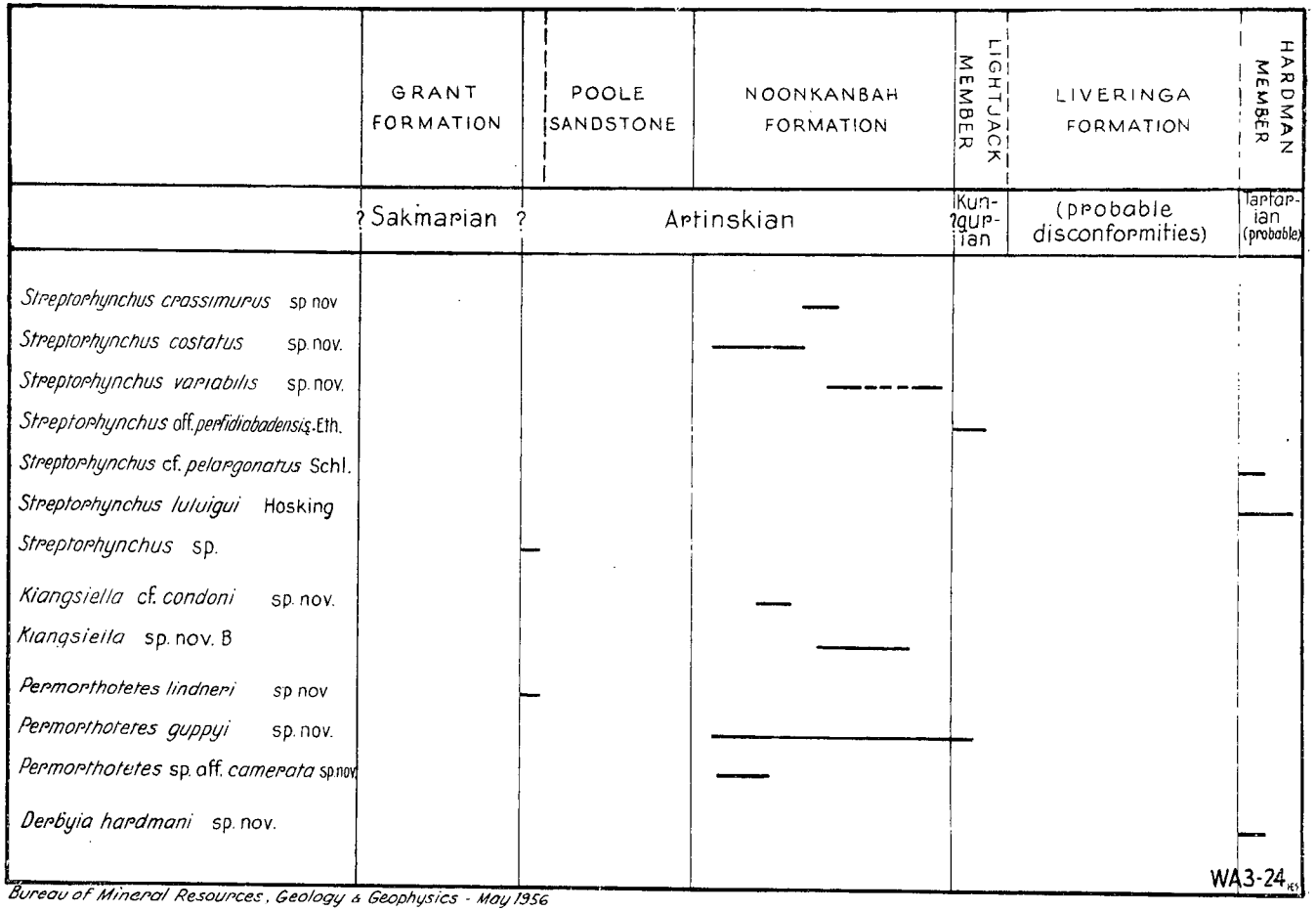
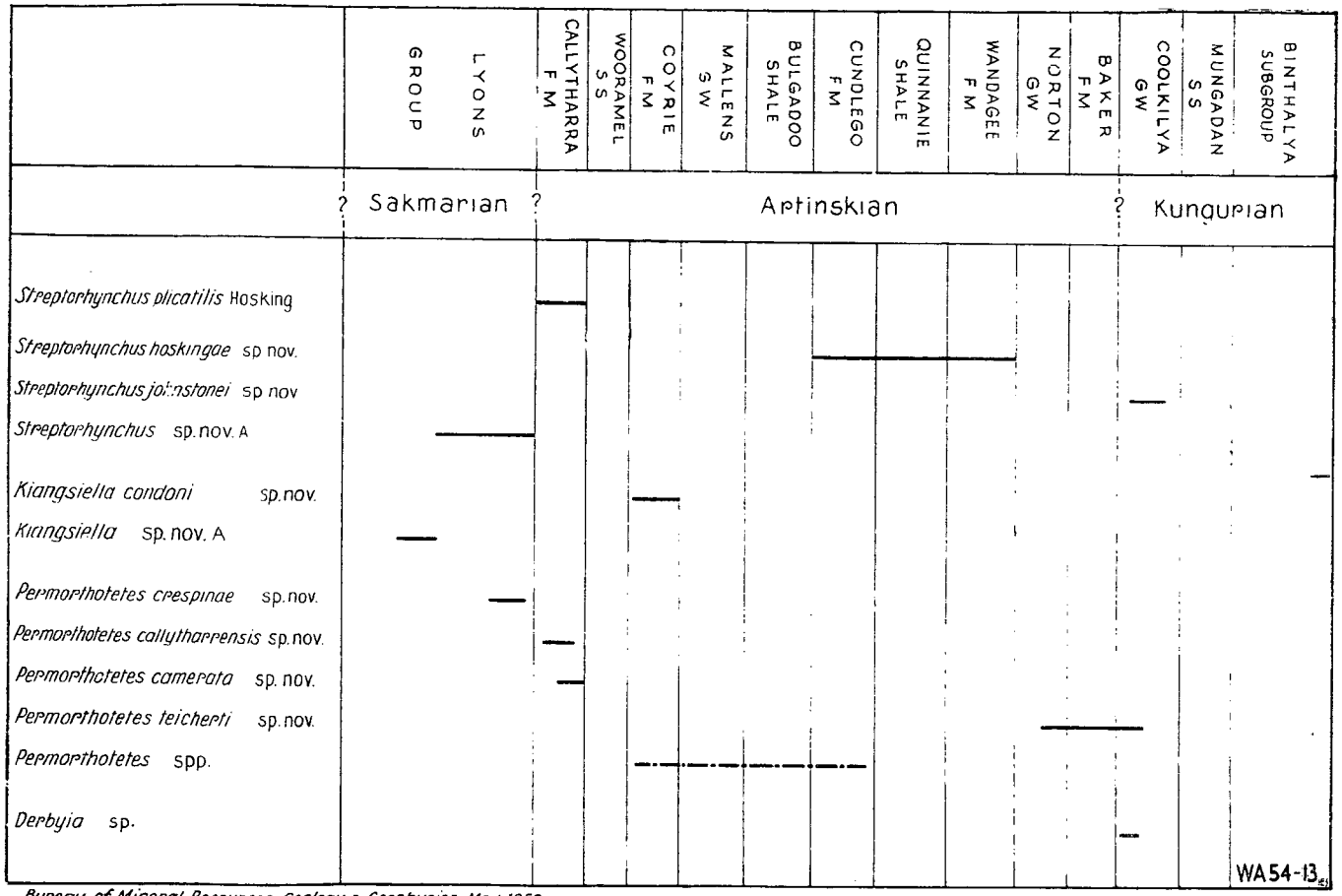


FIGURE 9.

Stratigraphic range of species in Fitzroy Basin.



Bureau of Mineral Resources, Geology & Geophysics May 1956

FIGURE 10.

Stratigraphic range of species in Carnarvon Basin.

ENVIRONMENT OF THE WESTERN AUSTRALIAN ORTHOTETACEA.

The Permian sediments in the Carnarvon Basin are marine and the lithologies indicate that they were deposited on a shelf area which varied from very stable to moderately unstable (Condon, 1954). The lithology of the Permian rocks in the Fitzroy Basin is similar and is mainly marine, but includes some terrestrial beds.

Most of the Permian sediments in the two basins are clastics ranging from quartz sandstone to greywacke, with siltstone and subordinate shale and limestone. Very coarse sediments are rare except in the Grant Formation and the Lyons Group, which both contain evidence of glacial conditions. Permian reefs have not so far been found.

Both areas are rich in fossils, many of them well preserved and unabraded; they give the impression of being not far from their original environment. In a general way the various formations contain characteristic fossil assemblages which are related broadly to the depth of sea bottom at the time of deposition. Orthotetacean species are found in many of the formations.

For the purpose of a review of the general associations of the Orthotetacea, the views of Elias (1937) are provisionally adopted. Elias claimed in his study of the Lower Permian Big Blue Series of Kansas that various assemblages of fossils could be associated with depth of the sea bottom at the time of deposition (the Big Blue Series is a sequence of largely marine cyclic sediments). Elias recognized seven cyclically recurring fossil assemblages which he believed to be related to the bathymetric depths at the time of deposition. By analogy with modern bathymetric distribution of related marine organisms he estimated the depths of deposition of the Big Blue Series. The precise depths suggested by Elias are not necessarily applicable to the Western Australian deposits, but in a broad way the fossil associations seem to give an indication of the depths of the sea bottom. The fossil assemblage in any particular bed is not, of course, necessarily in the position of growth: some or all fossils may have been transported. The fossils themselves will provide some evidence of this. Also depth of sea bottom is not the sole factor in determining assemblages. The observations are general, and are based on field assessments of faunal content for particular formations and refer only to outcropping beds. In any future detailed analysis, the effect of factors other than depth will have to be considered.

The Western Australian Permian fossil assemblages can be grouped mainly in three of Elias's associations, arranged here in order of depth of sea bottom.

1. "Molluscan": largely pelecypods, very subordinate calcareous brachiopods and bryozoa, crinoids;
2. "Mixed": pelecypods, calcareous brachiopods and bryozoa, and crinoids;
3. "Brachiopod": predominantly calcareous brachiopods, with bryozoa, subordinate corals and crinoids; mollusca are rare.

Benthonic forms only are included in the associations. Elias estimated a depth of 60 to 90 feet for the "molluscan" association, 90 to 110 feet for the "mixed" association, and 110 to 180 feet for the "brachiopod" association. His deepest association, not represented in the Western Australian collections, is the "fusulinid" at 160 to 180 feet. Climate may be one of the causes of the absence of fusulinids in the Permian of Western Australia.

More recently Sloan (1955) has attempted a statistical analysis of faunas in Pennsylvanian marine shales in Palo-Pinto County, Texas. He used an index of brachiopod and benthonic mollusc frequencies as an indicator of relative depth where the lithologies were constant. He considered that benthonic animals are dependent principally upon depth and the condition of the substratum. It is hoped to make a detailed analysis on similar lines on Western Australian faunas in the future.

Stehli (1954) considers that the Leonardian (Lower Permian) brachiopods of the Sierra Diablo, Texas, preferred near-shore shallow off-reef waters and that the molluscs preferred slightly deeper waters. The brachiopods are the dominant element in the Sierra Diablo fauna and many of them are somewhat specialized attached forms. The evidence in Western Australia, where Permian reef conditions are unknown, is that the "molluscan" assemblage seems to occur in shallower-water deposits than the "brachiopodal". All Elias's assemblages are in comparatively shallow water.

The Permian sequence of the Carnarvon Basin, as exposed in the Minilya River-Kennedy Range region, is shown in Figure 8. The lowest Permian formation, the Lyons Group, is believed to be mainly marine and contains evidence of glacial conditions, including boulder beds (Condon, 1954). At least eight marine fossiliferous, usually calcareous, beds are present in the sequence. Many of the fossiliferous calcareous sandstones are coarse-grained. The faunal associations range from "molluscan" to "mixed", commonly with large accumulations of one or two species. The Lyons faunas are reviewed elsewhere (Dickins and Thomas, 1958). The Orthotetacea are not abundant and mostly are not well preserved. They include species of *Kiangsiella, Permorthotetes,* and *Streptorhynchus.*

The Callytharra Formation has somewhat deeper faunas of the "mixed" to "brachiopod" associations. Well-preserved large and small calcareous brachiopods, bryozoa of many types, crinoids, solitary corals and mollusca are present in this mainly calcareous formation. The Orthotetacea include abundant *Permorthotetes,* including numerous large specimens, and a small species of *Streptorhynchus.*

The Wooramel Sandstone in the area north of the Gascoyne is very poorly fossiliferous, and contains no Orthotetacea. It was laid down in shallow water. In the Wooramel River area it is more fossiliferous and contains poorly preserved *Permorthotetes* and other fossils.

The Byro Group varies from very-fine-grained to medium-grained clastic rocks which are often calcareous. The faunas also range from "molluscan" to "mixed" and "brachiopod" associations. Some formations are poorly fossiliferous, notably the Quinnanie Shale and Mallens Greywacke. Euxinic conditions appear to have existed in some areas during deposition of parts of the Bulgadoo and Quinnanie Shales. *Lingula* is found locally in abundance in the latter formation. The Wandagee Formation is the richest in fossils, which include many large calcareous brachiopods, numerous bryozoa, crinoids and some molluscs. *Streptorhynchus* is common in the Wandagee Formation and is more sparsely present in the lower formations. *Kiangsiella* is abundant at one or two levels low in the Byro Group; it has not been observed in higher formations. *Permorthotetes* is sparsely present in the top beds.

The Kennedy Group shows evidence of mainly shallow-water deposition, which persisted until the end of Permian sedimentation in the Carnarvon Basin. Some fluctuations occurred during deposition of the Coolkilya Greywacke, which has "molluscan" and "mixed" faunas. *Streptorhynchus* and *Chonetes* flourished at several levels. *Permorthotetes* is present but is rare. The higher formations are poorly fossiliferous and were evidently deposited in shallow water.

The Fitzroy Basin deposits indicate similar environments to the Carnarvon Basin, but with a different history. The Grant Formation, which contains some tillite and boulder beds, is almost unfossiliferous.

The Poole Sandstone contains terrestrial plants, but in a number of areas marine fossils occur near the base, notably in the Nura Nura limestone Member near Mount Wynne and the fossiliferous sandy beds in the south part of the St. George Range. The fauna of the latter areas is of the "mixed" to "brachiopod" association with abundant specimens of *Permorthotetes,* associated with other large brachiopods, some bryozoa and pelecypods. At Mount Wynne ammonoids are also found.

The Noonkanbah Formation is largely shaly, with thin calcareous beds and thicker sandy sequences. Most of the faunas are rich in calcareous brachiopods, with less abundant bryozoa, crinoids, and in places some molluscs. The fossils are richest in the more calcareous beds. Extremely well preserved delicate brachiopods and bryozoa have been collected from several beds. Local shallowings are suggested by the presence of current bedding. Phosphatic nodules are also known. Species of *Permorthotetes, Streptorhynchus,* and *Kiangsiella* are abundant.

The Noonkanbah Formation is overlain, usually with transitional beds, by the Lightjack Member of the Liveringa Formation (Guppy et al., 1958). This member, which locally contains ferruginous oolites, has a predominantly "molluscan" fauna with very few brachiopods. Locally, however, notably in the Shore Range, a deeper environment of deposition is indicated by the presence, in the lower part of the member, of a "brachiopod" association which includes species of *Streptorhynchus* and *Permorthotetes* otherwise not known in the Lightjack Member.

The major part of the Liveringa Formation contains only terrestrial plants above the Lightjack Member and at higher levels. Deposition was probably shallow or even terrestrial. Thin coal seams have been recorded locally. At the top of the Formation deeper-water deposition is again indicated by the faunas of the Hardman Member, which contains a rich "brachiopod" to "mixed" association, including well preserved delicate spinose and other brachiopods, branching bryozoa and pelecypods. The fossils are mostly ferruginized and ferruginous oolites are present in places. Mollusca appear to be more dominant in the oolitic beds. Orthotetaceans are richly represented by two species of *Streptorhynchus* and one of *Derbyia.*

Most Western Australian Orthotetaceans were probably unattached, at least in their adult stages, and are more or less symmetrical. The asymmetric species such as *Streptorhynchus variabilis, Streptorhynchus hoskingae, Streptorhynchus* cf. *pelargonatus, Kiangsiella condoni,* and *Permorthotetes guppyi,* were probably attached by the ventral umbonal region to the substratum; but no specimens showing attachment were observed. The majority of the shells were perforated by boring organisms, during or after the life of the brachiopod. The perforations are concentrated on the ventral valves in the umbonal region, i.e. parts of the shell which may have been partially buried in mud or sand during life. These perforations are described on page 37.

RELATIONSHIP WITH OTHER ORTHOTETACEAN FAUNAS.

The fauna described in this bulletin shows considerable affinity with that of the Permian of the Salt Range of India, though the two are far from identical. The most striking resemblance is the presence, in both regions, of species of *Kiangsiella.* The Western Australian species *K. condoni* evidently belongs to the group of *K. pectiniformis* (Davidson) as described by Waagen (1884). *K. pectiniformis* and its varieties are known from the Middle and Upper Productus Limestones of India, whereas *K. condoni* occurs in older beds, of Artinskian age. New varieties of *K. pectiniformis* and a new species were described from India by Reed (1944). *K. condoni* is not closely allied to the type species *K. tingi* (Grabau) from China. The genus is represented also by an unnamed species in the Lyons Group, of Sakmarian age.

The Western Australian species of *Streptorhynchus* also show Salt Range affinities. *S. hoskingae* somewhat resembles *S. praeceps* Reed and *S. mistus* Reed from the Salt Range; the coarsely costellated form *S. costatus* has some resemblance to *S. memor* Reed. *S. pelargonatus* (Schl.), or a form close to it, is present in the Middle Productus Limestone and in the Upper Permian of the Fitzroy Basin.

The Salt Range faunas are rich in species of *Derbyia.* One species only has so far been recognized in Australia—*D. hardmani;* it shows affinities with *D. grandis* Waagen and *D. regularis* Waagen of the Salt Range.

The new Western Australian genus *Permorthotetes* has not been recognized among the species so far described from India; but some of these, notably *D. vercherei* Waagen and *D. altestriata* and some of Reed's species (Reed, 1944), are inadequately known. Re-examination of Indian material referred to some species of *Derbyia* by earlier workers may perhaps reveal the presence of *Permorthotetes.*

The Western Australian Permian faunas are notable for the absence of members of the family Orthotetidae McEwan emend. Stehli; i.e., forms possessing dental plates. The Orthotetidae are sparsely if at all present in the Indian Permian. *Meekella* was recorded by Reed (1944), but the identification is uncertain as dental plates were not observed.

The relationships are less obvious with faunas elsewhere in India and nearby Asia. The few orthotetacean species in the Himalayan Permian faunas show little affinity with the Western Australian. A Kashmir species, "*Derbyia*" *dorsiplana* Diener from the Lower Permian Fenestella Shales, is described as possessing a small irregular spondylium. It may possibly be a representative of *Permorthotetes.* The Permian fauna from the Karakoram Range appears to be largely distinct from the Western Australian. It is distinguished by the presence of *Ombonia,* which links it with the western Tethys (Merla, G., 1934).

The Shan States of Burma yield a Lower Permian species, *Streptorhynchus shanensis* Diener, which shows some resemblance to *S. costatus.*

Indo-China has a scant representation of Orthotetaceans in the Permian System. *Meekella* and *Streptorhynchus* are both doubtfully present (Mansuy, 1912, 1913). The internal shell structure of the species referred to *Meekella* is unknown and the species may belong to *Kiangsiella.*

There appear to be some links with the faunas of China and Mongolia. *Kiangsiella* is well known in the Lower Permian of China; otherwise the Chinese species do not appear to be allied to the Australian. The Mongolian species *Streptorhynchus broilii* Grabau shows some resemblance to *S. costatus* (Grabau, 1931).

Timor has the geographically closest Permian fauna to Western Australia and some affinities are evident. However, the Timor Orthotetacea are inadequately known and the stratigraphy is uncertain. *S. variabilis* may be allied to the Timor form *S. beyrichi* Rothpletz. *K. pectiniformis* (Davidson) was recorded by Hamlet (1928) from Timor but not figured. At the same time Hamlet recorded a form with a spondylium, "*Orthotetes crenistria* var. *senilis*". This may possibly be a representative of *Permorthotetes. Meekella* and *Hamletella* (Hayasaka), both described from Timor, are unknown in Western Australia.

Sumatra has a small Permian fauna, which includes an inadequately described species of *Streptorhynchus* and a species of *Orthotetina* with curiously sinuous parallel dental plates (Fliegel, 1902; Meyer, 1922). This fauna is distinct from the Australian.

Resemblances to more distant faunas are mostly general. However, the resemblance of *S. plicatilis* and *S. crassimurus* to *S. kempei* Anderson from Spitzbergen and Greenland may be noted (Wiman, 1914; Dunbar, 1955). In Dunbar's view, *S. kempei* occurs in Upper Permian beds in Greenland. The Australian species *S. plicatilis* and *S. crassimurus* are Artinskian.

Streptorhynchus pelargonatus (Schlotheim) appears to be a cosmopolitan Upper Permian species. *Derbyia* is represented by numerous species in many Upper Carboniferous and Permian sequences throughout the world.

In eastern Australia, the only Permian form so far described is *S. pelicanensis* Fletcher from the Middle Bowen of Queensland. It appears to show some affinities with *S. variabilis,* but is readily distinguished. Fletcher (1952) records this species also from Southland, New Zealand.

To summarize, the Western Australian Permian deposits are rich in species belonging to the family Schuchertellidae Stehli. These species are Permian in aspect and are fairly closely related to those of the Permian of the Salt Range of India. The Western Australian Permian Period is characterized by unusual proliferation of species of *Streptorhynchus,* which is also well represented in India, but with fewer species. Species of *Kiangsiella* and *Derbyia* show close affinity with Indian species, but *Permorthotetes* is not yet known outside Australia.

Geographical isolation is probably the main factor in causing the differences between the Indian and Western Australian faunas. However, shallow seaways between the two areas no doubt existed from time to time during the Permian Period. Insufficient data are available to assess the importance of climatic factors. The Timor fauna, which is unfortunately insufficiently known, is related to both the Western Australian and the Indian.

The eastern Australian Permian province was probably more or less isolated from Western Australia in post-Sakmarian time, as indicated by other studies of Dickins and Thomas (1958). Only one species of *Streptorhynchus* is known in the Permian of Queensland and none are known from New South Wales. An undescribed species of *Schuchertella* is present in the Permian of Tasmania.

THE AGE OF THE WESTERN AUSTRALIAN PERMIAN ROCKS.

The age of the Western Australian Permian rocks has been discussed by Teichert (1941, 1947, 1952). The fossil evidence has been reviewed by Thomas and Dickins (1954), and in Hill (1955), Coleman (1957), and Crockford (1957). Dickins (1956) also discussed the age of the faunas, and Dickins and Thomas (1958) and Dickins (1957) discuss the age of the Lyons Group. Crockford (1951) outlined the evidence of the bryozoal collections available at that time. Reference to earlier writers can be found in the above papers. The ages and correlations outlined in Thomas and Dickins (1954) are followed in this study.

The Lyons Group is considered to be mainly of Sakmarian age, the succession from Callytharra Formation to Norton Greywacke is Artinskian and the Baker Formation to Coolkilya Greywacke range from late Artinskian to early Kungurian. The topmost beds of the Carnarvon Basin lack fossils, but they are probably not younger than Kungurian.

The Grant Formation of the Fitzroy Basin is correlated with the Lyons Group and regarded as Sakmarian. The Poole Sandstone and Noonkanbah Formation are Artinskian, and the Lightjack Member of the Liveringa Formation is of late Artinskian to Kungurian age. The Hardman member is considered by Thomas and Dickins to be correlated with the Upper Productus Limestone of the Salt Range and is therefore probably late Upper Permian.

In this study the Lower Permian is understood as including Sakmarian, Artinskian and Kungurian ages (following Nalivkin, 1938). The Upper Permian includes the Kazanian and Tartarian. Moore, Lalicker, and Fischer (1954) have used the name Chideruan for the youngest Permian age, probably intending this to replace Tartarian. On the evidence so far available, the Chideru beds, i.e., Upper Productus Limestones, cannot be precisely correlated with the Tartarian beds of Russia. The Chideru beds are the topmost marine Permian beds in the Salt Range and contain ammonoids of the *Cyclolobus* Zone, which Miller and Furnish (1940) and Ruzencev (1956) state to be the youngest Permian ammonoid zone. Gerth (1950) has also used the name Chideru Stage, apparently as corresponding in age to the *Cyclolobus* Zone. In this report the age name Tartarian will be used to imply late Upper Permian.

MICROSCOPIC STRUCTURES.

Pseudopunctae.

The shells of species now referred to the Strophomenoidea, as well as Productacea and certain other brachiopod groups, are stated by many recent workers to be pseudopunctate. The distinctive character of the pseudopunctae was first recognized by Kozlowski (1929) and they have been further recognized and described by Öpik (1932, 1934), Cooper (1944), H. Schmidt (1931), Williams (1953). Kozlowski (1929) demonstrated that the so-called punctae of the Strophomenoids were not perforate structures as has been believed by Carpenter (in Davidson, 1853). The microscopic structures simulating pores are superimposed interlocking cones in the thin laminae of the shells. Kozlowski described in the axis of the little conical structures a core of homogeneous calcite; Carpenter had observed these structures, but regarded them as infilled canals. Öpik (1932, 1934) described similar structures in the plectambonitids and certain clitambonoid species, e.g. *Estlandia margareta* (Pahlen) (Öpik, 1932, text Figure 55, and 1934, plate 2, Figures 1-3). Kozlowski and Öpik both show the pseudopunctae as extending into small spines or papillae on the internal surface of the shell.

However, Herta Schmidt (1951), in discussing the stropheodontids, states that the pseudopunctae do not possess a central core of homogeneous calcite

but that the laminae extend across the axes of the cones. She considers that the core is an optical illusion or may perhaps in some cases be simulated by alteration of the shell. Thus the pseudopunctae described by her are merely the superimposed interlocking conical bends or flexures of the laminae. In Schmidt's view the pseudopunctae serve primarily as a means of strengthening the shell and perhaps assist to provide a greater area of contact between shells and animal. She suggested that small round shells would possess more numerous pseudopunctae than large flat shells such as *Orthotetina*, which, she states, lacks pseudopunctae.

Williams (1953), writing on strophomenoids in general, states that the pseudopunctae "represent long unbranched arcuate calcareous rods embedded within the fibrous layer of the shell. They do not penetrate the lamellar layer and it is supposed that they were laid down by the outer epithelial layer of the mantle immediately behind the outer lobe. It is probable that the deposition and growth of these spicules were limited mainly to the mantle proper, for in the postero-median portion of the adult shell, an area presumed to have been occupied by the viscera, an inner impunctate fibrous layer generally extends over a pseudopunctate zone laid down in the early stages of shell growth. In addition, the structure grouped around the notothyrium—the cardinal process, socket ridges and notothyrial platform are impunctate". The "spicules" are presumably the axial cores described by Kozlowski.*

As far as I know, little appears to have been written about the "pseudopunctae" of orthotetacean species. Kozlowski (1929, p. 89) states that the structures described by him are not present in the "Orthotetinae". Dunbar and Condra (1932, p. 67) state of the shell structure of the Pennsylvanian orthotetacean species: "The shell substance is imperforate but is thickly studded with rod-like structures of compact calcite which appear as papillae on the interior of the shell". They do not describe the shell of any species in detail nor do they figure any sections.

Demanet (1934) records that the internal surface in Dinantian species of *Schellwienella* and *Schuchertella* is largely covered with "granules spiniformes", but does not figure any thin sections. Paeckelmann (1930) figured "poren" in species of *Schuchertella*, and H. Schmidt (1951) suggests that certain large orthotetaceans, e.g. *Orthotetina*, lack pseudopunctae.

Several dozen thin sections, both tangential and transverse, have been prepared from various Western Australian Permian species. All possess structures that are similar to pseudopunctae, regarding the latter as superimposed interlocking conical flexures of the shell laminae. The species of *Streptorhynchus* present some differences, described later. Some of the slides are illustrated in Plates 18 and 19. In these two plates, all the figures except Plate 19, Figures 1, 3 and 5, are oriented with the inner surface of the shell wall towards the bottom of the page.

* A. Williams (1956) has renamed the spicules as talcolae in his paper "The calcareous shell of the brachiopods and its importance to their classification" (*Biol. Rev.* 31, 243–287). The paper was not available when this Bulletin went to press.

Permorthotetes: Transverse sections of species of this genus show laminae with numerous close inwardly-directed superimposed cones. No spicules were detected; the appearance of spicules is sometimes simulated in the axes of the cones, but no distinct boundaries can be detected and the laminae extend across the axis. In a shell of *P. guppyi* the cones are very close and numerous (Plate 18, Figure 2). The inner and outer layers of this shell are exfoliated. A transverse section from the front of a shell of *Permorthotetes callytharrensis* (Plate 18, Figure 4), shows rather fewer cones. The axes of the cones tend to show a radial disposition with respect to the axial planes of the costellae. The outer layers of this specimen are partly exfoliated.

Well-preserved specimens of the various species of *Permorthotetes* show numerous fine papillae or spinules on the inner surface of the shell. Many of these papillae are more or less oblique to the surface of the shells.

Derbyia: Sections of shells of *Derbyia hardmani* display cones similar to those of *Permorthotetes* but much less numerous. In some parts of the shell they seem to be absent. Plate 18, Figure 6, is a transverse section from the front of a shell of this species. The inner surface is exfoliated. The outer layers of the shell show few or no cones, but the inner layers display a number of superimposed inwardly directed cones more or less at right angles to the laminae, which are themselves roughly parallel to the costellae of the outer surface. The very fine dark irregular threads seen in this section are probably parasitic. Another section from the front of a specimen of this species shows no conical flexures on the inner or outer parts of the shell. The inner laminae in this shell have flattened out (Plate 19, Figure 2). No distinct spicules were detected in this species.

Streptorhynchus: All the species of *Streptorhynchus* from Western Australia when partly exfoliated and slightly eroded show pits on the surface, which are concentrated near the axes of the costellae, though a few extend on to the troughs between the costellae. Many of these "pseudopunctae" in eroded specimens are enlarged into definite pits in the outer surface. The surfaces of well preserved internal moulds display a linear arrangement of fine pustules which correspond to hollows on the internal surface of the shells.

In transverse section no conical flexures of the laminae are directed inwards; they are directed towards the outer surface and concentrated near the axes of the costellae. Various species are illustrated in Plate 19, Figures 1, 3-6. In many slides there seems to be an opaque fine core in the axes of the cones. These fine cores appear to be of the same material as the matrix infilling the shells, e.g. Plate 19, Figures 1, 4. Tangential sections display the same fine cores. It is suggested that these are fine infilled canals occupying the axes of the outwardly directed cones but probably not of all of them. Some of the canals branch toward the outer surface (Plate 19, Figure 1). In Plate 19, Figure 3, the section is slightly oblique to the axes of the canals, which thus appear to extend across only a few laminae.

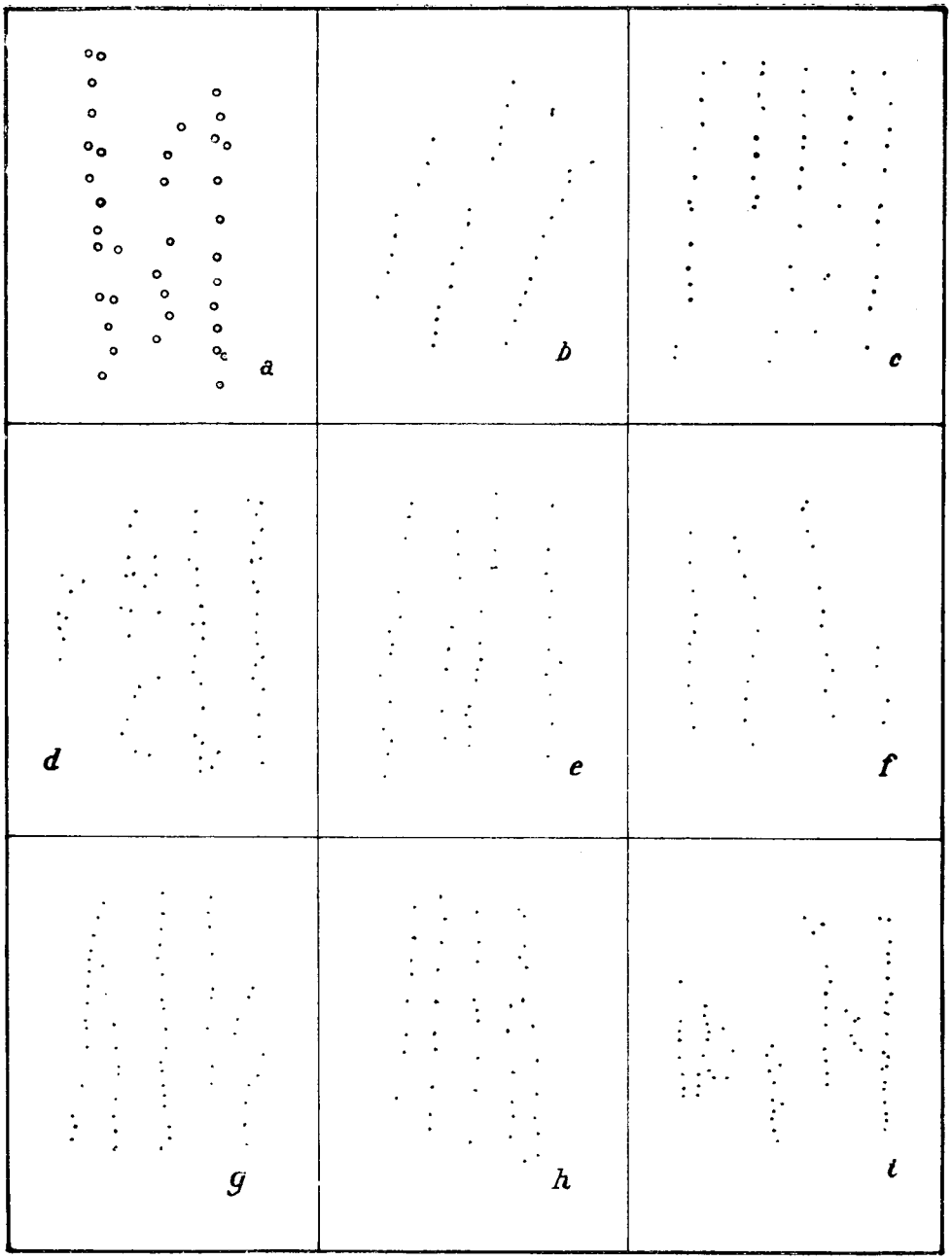


FIGURE 11.

Plans of arrangement of "pseudopunctae", from camera lucida drawings, at 19 times magnification.

a. *Streptorhynchus hoskingae* **sp. nov., UWA 33360/2, pits enlarged by erosion, pedicle valve.**

b. *S. hoskingae*, **from Minilya syncline, pedicle valve.**

c. *S. luluigui*, **paratype UWA 3040, pedicle valve at mid-length.**

d. *S. variabilis* **sp. nov., holotype CPC 1413, pedicle valve at mid-length.**

e. *S. variabilis*, **pedicle valve at mid-length.**

f. *S. plicatilis* **Hosking, pedicle valve, anterior end.**

g. *S.* **sp. aff.** *S. perfidiabadensis* **Etheridge, F 17505, brachial valve, posterior part near lateral margin.**

h. *S.* **cf.** *pelargonatus* **Schlotheim, F 17510, pedicle valve, about mid-length.**

i. *S. crassimurus* **sp. nov., CPC 1412, paratype, pedicle valve.**

Where the matrix is pale the canals do not show up boldly but can still be detected. All of them appear to extend nearly to the surface of the shell, but none were observed to pierce the outermost layers. Very probably not all the " pseudopunctae " possess these infilled canals, but they appear to be present in the majority.

The " pseudopunctae " of *Streptorhynchus* are concentrated near the axial planes of the costellae, i.e., of the troughs as seen from the inside of the valve. (They are generally not common on the palintrope and pseudodeltidium. Plate 19, Figure 1, is rather exceptional in this respect.) The " pseudopunctae " of *Streptorhynchus* therefore are not identical with those of the other genera described in this paper. In fact they seem to some extent to resemble the punctae of such dalmanellid genera as *Pionodema*, which is figured with a linear arrangement of the punctae (Cooper, 1944, Plate 105, Figure 18).

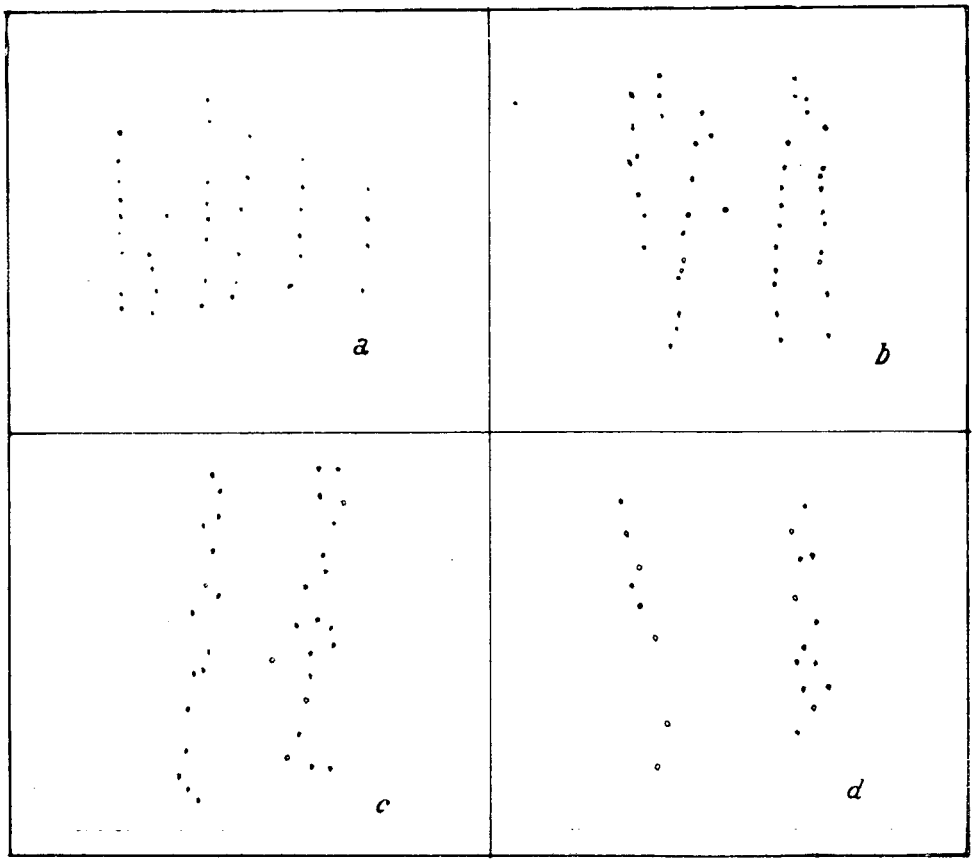


FIGURE 12.

Plans of arrangement of " pseudopunctae ", camera-lucida drawings, all at magnification of 19 times.

a. *Streptorhynchus johnstonei* **sp. nov. pedicle valve at mid-length.**
b. *Kiangsiella condoni* **sp. nov. CPC 1450, holotype, pedicle valve about mid-length.**
c. *Streptorhynchus costatus* **sp. nov. CPC 1523, pedicle valve, anterior end.**
d. *S. costatus* **F. 17485 dorsal valve, large shell towards anterior end.**

Kiangsiella: Sections of shells of *Kiangsiella condoni* resemble those of species of *Streptorhynchus* except that the shells are plicated and the inner laminae tend to flatten out. Plate 18, Figure 1, is a transverse section of the somewhat crushed front portion of a shell showing the two valves pressed into contact. The "pseudopunctae", as in *Streptorhynchus,* are outwardly directed conical flexures, but the axial canals appear to be less numerous.

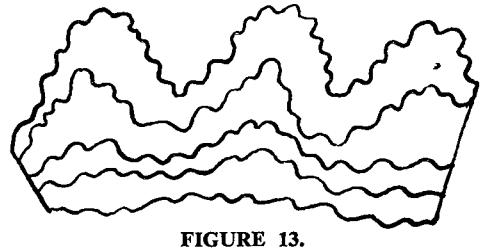


FIGURE 13.

Transverse Section through shell of *Kiangsiella condoni* sp. nov. X5.

Many of the Western Australian shells possess coarse perforations or holes. These holes are concentrated near the umbonal part of the shell and are found in all the genera. Perforations in Orthotetacean shells have been reported by a number of authors, e.g., Yakovlew, 1907; Licharew, 1932; Douvillé, 1909; and W. King, 1850. Douvillé, who recorded such holes in a specimen of *Derbyia* attached to a larger shell, claimed that they correspond to the bases of hollow spines. Yakovlew suggested that the holes in specimens of *Meekella eximia* Eichwald were formed by the extrusion of living material to assist in attachment.

Sections of a number of Western Australian shells indicate that the holes in them are cylindrical perforations probably of parasitic origin. Typical examples are seen in a shell of *Permorthotetes callytharrensis* (Plate 19, Figures 3, 4). These perforations are somewhat irregularly oriented and transect the growth laminae. In some specimens they can be seen to communicate with fine irregular threads such as those in Plate 19, Figure 6. In Plate 19, Figure 4, similar perforations are oriented more or less parallel to the surface of the shell. Their diameters range from 0.8 to 1.1 mm., but they may be enlarged by weathering. These perforations appear to be rather smaller than the borings formed by the parasitic worm *Conchotrema* described by Teichert (1944). They distinctly resemble some of the figures of ctenostomatous bryozoans described by Condra and Elias (1944) from the Pennsylvanian and Permian of North America. The Western Australian specimens, however, do not display the perforations over the entire surface of the valves. In the serial sections of Plates 20, 21 and 22, their disposition is diagrammatically shown.

SYSTEMATIC DESCRIPTIONS.

Family SCHUCHERTELLIDAE Stehli 1954.

Diagnosis: Orthotetaceae without dental plates.

Discussion: Three subfamilies are included by Stehli (1954) : the Schuchertellinae, the Streptorhynchinae and the Derbyiinae. A fourth subfamily can also be distinguished; it is represented in Western Australia by *Permorthotetes*

gen. nov. It is proposed to name this subfamily the Derbyoidinae subfam. nov. The subfamilies of the Schuchertellidae are reviewed on pages 17 to 22.

The Western Australian fauna contains representatives of the Streptorhynchinae, with eleven species of *Streptorhynchus* King, and four species of *Kiangsiella* Chao. The Derbyiinae are represented by two species of *Derbyia* Waagen. The Derbyoidinae are represented by eight species of *Permorthotetes* gen. nov.

Subfamily STREPTORHYNCHINAE Stehli 1954, emend. nov.

Diagnosis: Schuchertellidae without septum in pedicle valve; socket plates not recurved, but divergent on floor of valve.

Discussion: Stehli's diagnosis stated that the crural plates are recurved and joined to the posterior margin of the shell. This is incorrect because stout divergent socket plates are present in *Streptorhynchus* King and *Kiangsiella* Chao. *Diplanus* Stehli, which possesses recurved socket plates, should not be included in the subfamily. Socket ridges (text Figure 6a) are present in many species and the cardinal process is commonly long.

The pedicle valve may form a deep cone as stated by Stehli, but although the interarea is high in many species, it is low in others. Even within a species the height of the interarea is variable. Many species have distorted interareas. The dental ridges are invariably low in species belonging to this sub-family. The pseudodeltidium and palintrope show continuous growth laminae in transverse section, with a flexure at the position of the socket ridge (Plate 22, Figure 5).

The brachial valve is invariably convex, but in some species may be only slightly so; the dorsal area is low or missing in most species and the chilidium is small and divided.

Both non-plicate and plicate genera are included in the subfamily; *Streptorhynchus* King is non-plicate and *Kiangsiella* Chao plicate. Both are well represented in Western Australia.

Genus STREPTORHYNCHUS King 1850.

Type species: Terebratulites pelargonatus Schlotheim 1816.

Diagnosis: Non-plicate schuchertellinids; maximum width greater than hinge-line; dental ridges low; brachial valve convex, brachial area low or absent, chilidium small and divided.

Discussion: The pedicle interarea in *Streptorhynchus* is very variable in height and inclination and is distorted in many species, including the type species. The majority of sufficiently well described species possess socket ridges like those in text Figure 6a, b.

Most species are not large; the type species *S. pelargonatus* is not generally more than 2.5 cm. long and 2 cm. wide. The Western Australian faunas contain two species much larger than is usual in this genus; a brachial valve of *Streptorhynchus costatus* sp. nov. is 5.1 cm. long and 7.5 cm. wide; the maximum shell length must be greater. The other large species, *Streptorhynchus luluigui* Hosking, reaches 5.5 cm. long and 5.5 cm. wide.

The type species *S. pelargonatus* (Schlotheim) is a well-known species from the Zechstein beds of Germany and equivalent beds of England. This Upper Permian species, well described by Davidson, King, Geinitz, Hall and Clarke, and more recently by Malzahn, is small and variable in shape. The smallness and irregularity may well result from the peculiar saline character of the Zechstein seas, although the species appears to be present in normal environments elsewhere. The brachial cardinalia are not very well illustrated by the various authors, but the socket plates evidently diverge at about 90° on the floor of the valve, where they flank the dorsal muscles. The posterior aspect does not appear to have been described and it is not clear whether socket ridges are present. Davidson and King mention a variable narrow brachial area, but Malzahn's specimens apparently lacked this. Specimens in the collection of the University of Melbourne and National Museum of Victoria from Germany and England show that the costellation is fine, about 14-15 in 5 mm., and that the shell is thin. Each costella is lined with "pseudopunctae" along the crest, an arrangement also noted in Western Australian species. Many records of *S. pelargonatus* in the literature are probably erroneous because the illustrations show that no internal details were available and the identification was made because the specimens were small.

In text-Figure 6a, b, the brachial cardinalia of the Western Australian species have been generalized. The cardinal process is variable in length and in its attitude. The socket plates are never recurved and mostly show well-developed socket ridges. The cardinal process has at its base on the posterior side a narrow and divided chilidium which is separated from the external surface of the valve by a narrow groove. The resemblance of this type of cardinal process to that of many species of *Derbyia* is striking. On the internal surface of the process in some specimens a narrow median ridge is developed; but this may be present or absent even within a single species.

The genus is widely distributed, especially in the Permian. *Streptorhynchus* has been recorded from the Lower Carboniferous of Germany, Russia, Belgium and North America. Most of those records may be doubted. Where the cardinalia are known they suggest different affinities, possibly closer to *Schuchertella,* which is usually stated to be relatively wide at the hinge-line and to possess a low interarea; the brachial valve is in some species only slightly convex. Some species of *Streptorhynchus* approach this outline, though the brachial valve is invariably convex. The most valuable distinguishing characters appear to be the cardinalia, especially the socket plates, but these are not always described.

For the Mississippian species referred to *Streptorhynchus*, Weller (1914) has not figured the cardinalia. These species are moderately large forms, as are those from the Lower Carboniferous of Belgium which are similarly uncertain. *Streptorhynchus subpelargonatus* Demanet (1934, *non* Fliegel, 1901) has an irregular outline similar to some Permian species. The genus is described from Argentina in beds reputed to be Lower Carboniferous (Leanza, 1945) and is also recorded from the Lower Carboniferous of Nova Scotia (Bell, 1929).

Upper Carboniferous references are comparatively few. One Pennsylvanian species from North America, *Streptorhynchus affinis* Girty (1929, *non* Gemellaro, 1892) has recurved socket plates, though the process is relatively long and hence this species probably does not belong to the genus. *S. suspectus* Girty (1929) is inadequately known. *S. mjatschkowensis* Sokolskaia (1952, 1954) from the Moscovian of Russia resembles Permian species, but displays recurved socket plates and may not belong to this genus. *"Streptorhynchus" hallianus* (Derby) from the Middle Pennsylvanian of Brazil (Dresser, 1954) should probably be referred to *Kiangsiella*. *Streptorhynchus* is recorded also from the Upper Carboniferous of Persia by Douglas (1950) but not described. It is also recorded from the Upper Carboniferous of Nabeyama, Japan (Hayasaka, 1933), and very doubtfully from the Upper Carboniferous of North China (Ozaki, 1931).

Permian references are numerous, although the descriptions are often inadequate. The genus is widely, but not ubiquitously, distributed in Permian deposits. The major occurrences include the Salt Range of India (Waagen, 1884; Reed, 1944), where species range in age from Artinskian to late Permian, and also the Shan States (Diener, 1911) and Kashmir (Bion, 1928; Reed, 1932), the Karakoram Range (Merla, 1934), Timor and Rotti (Broili, 1915, 1916; Hamlet, 1928), Malaya (Meyer, 1922; Fliegel, 1901), the Lower and Upper Permian of China (Grabau, 1924; Chao, 1927; Huang, 1932, 1933), the Upper Permian of Mongolia (Grabau, 1933), Cape Kalouzin, Ussuriland in Eastern Russia (Fredericks, 1924), the North Caucasus (Licharew, 1932), and the Kolwa River in the Urals. The Russian references also include the Artinskian of the East Urals and the Kazanian (Netschajew, 1894, 1911), and the Permian of Novaya Zemlya (Licharew and Einor, 1939). The genus is known from the Lower and Upper Permian of Greenland (Dunbar, 1955) and the Lower Permian of Spitzbergen (Wiman, 1914). Other records are from the Zechstein of Germany (Geinitz, 1861, Malzahn, 1937) and equivalent beds in England (King, W., 1850); and the Sosio beds of Sicily (Greco, 1938) and the Lower Permian and possibly the Upper Permian of the Carnic Alps (Schellwien, 1892; Metz, 1936; Gortani, 1906; Merla, 1931). North American occurrences are the Upper Permian of British Columbia (Crockford and Warren, 1935), and the Permian of Texas, New Mexico, and Mexico (Girty, 1909; King, R. E., 1930; Cooper, 1953; Stehli, 1954). These references are not of equal value, the description in some being very inadequate.

A feature of the Western Australian species is the ill-defined character of the perideltidial lines which mostly, if present, appear to be near the lateral margins of the interarea. The figures of the genotype and most other species referable to the genus appear to be similarly ill-defined in this respect.

Eleven Western Australian species are described in this study. They can be separated into four groups—

(*a*) the thick shelled forms—*S. plicatilis* and *S. crassimurus*

(*b*) the forms with widely spaced costellae—*S. costatus*

(*c*) the species with costellae of two orders of size—*S. variabilis*

(*d*) the group of finely costellated and thin shelled species—*S. hoskingae, S. johnstonei, S.* aff. *perfidiabadensis, S.* cf. *pelargonatus, S. luluigui,* and two unnamed species.

The species of the last group are distinguished by differences in proportions, size, convexity, amount of distortion, presence or absence of auriculation and size of costellation. The species are all separated stratigraphically and geographically. As the characters are all variable it is sometimes difficult to identify individual specimens (especially youthful ones) with certainty. The diagnosis in most species includes a combination of characters.

STREPTORHYNCHUS PLICATILIS Hosking.

(Plate 11, Figures 1, 2, 3, 4, 5, 6; Plate 18, Figure 7; Table 1; text Figure 11 f.)

Streptorhynchus plicatilis Hosking, 1932, 48-49, Plate 5.

Diagnosis: Small more or less symmetrical species, maximum size 2.2 cm. long and 2.1 cm. wide; thick-walled, both valves gently convex; length about equal to width; hinge-line auriculate; brachial valve with short cardinal process, no area and no socket ridges; costellae vary in size and number (7-15 in 5 mm.); costellae flat and uneven and widening to the front, and multiplying by division and by intercalation; shell with thick deposits of callus in maturity and old age.

Differential diagnosis: This species is smaller than, but resembles, *S. crassimurus.* It is distinguished from *S. crassimurus* in that the costellae are more uneven and flat, a dorsal area and socket ridges are absent and it is commonly auriculate.

Material: About 24 shells or isolated valves from various localities in the Callytharra Formation.

**Description:* This species was described by Miss L. F. V. Hosking from one specimen, a pedicle valve (Geological Survey W.A. 1/4972) from creek, half-mile west of Callytharra Spring, Wooramel River, Western Australia. The type specimen was not available for examination. A considerable number of specimens now available from the Callytharra Springs area and elsewhere belong to this species. CPC 1400 (Plate 11, Figures 1a-d) is a small pedicle valve, gently convex in transverse section and slightly convex longitudinally; irregularly conical; the maximum width nearer the front margin. The lateral and anterior margins are roughly circular in outline. The interarea is apsacline, flat, slightly winged at the lateral margins and slightly concave at the pointed umbonal tip. The umbo is slightly asymmetrical. The pseudodeltidium is wide.

* Specimen numbers prefixed with "CPC" belong to the Commonwealth Palaeontological (type) Collection, and those with "F" to the Bureau's museum collection, both housed in the Bureau of Mineral Resources, Canberra. "UWA" refers to the collection of the University of Western Australia.

The perideltidial lines are very faint but appear to be present near the lateral margins. The dental ridges are broad and low and extend into strong, more or less flat, pointed teeth. The surface is covered by fine, rather uneven, costellae, which widen to the front, and are flat to gently rounded in cross section. They multiply by intercalation and by division. The intertroughs are much narrower. The surface is covered with numerous fine concentric growth-lamellae and also by coarser more pronounced concentric growth interruptions. The costellae number about 15 in 5 mm. at the margin, i.e. 1.5 cm. from the umbo. Internally there is no sign of a septum; the dental ridges are low and broad. The shell is smooth and thick, over 1.5 mm. on the margins, and the costellae are not discernible on the inside. An oval muscle hollow extends about $\frac{3}{4}$ of the length. It is deeper at the umbonal end; the diductor impressions appear to be median and posterior. CPC 1401 (Plate 11, Figure 5a, b) is a small shell rather crushed but retaining convexity near the umbo. The outline is similar to CPC 1400 but the interarea is lower and catacline; the brachial valve is similar in shape, and also crushed; the surface is similarly ornamented but numbers 11 costellae in 5 mm. on the front pedicle margin and 9 in 5 mm. on the front brachial margin. The costellae expand anteriorly and increase by irregular division. CPC 1402 (Plate 11, Figure 2a, b) is a slightly larger, probably gerontic, pedicle valve with very considerable callosity in the muscle field, which nearly reaches the front margin. The shell is about 2 mm. thick at the edges. CPC 1403 (Plate 11, Figure 3a, b) is a crushed shell with a small interarea. The surface is ornamented like the others and has 12 costellae in 5 mm. at 2 cm. from the umbo on the pedicle side and 8 at the same distance on the brachial. This shell shows very slight plications on the lateral margins, reminiscent of *Kiangsiella*. It is the only shell showing this tendency in the collection from the Callytharra Formation. The lateral margins of the hinge-line show slight wings. This shell was collected with a number of shells, CPC 1404, 1405, F.17450, 17451, 17461-3, which display less or no indication of plications. Two specimens of the group, F.17451 and F.17463, have larger interareas and show that the broad pseudodeltidium has a narrow median convex part flanked by flatter edges which correspond to the bases of the dental ridges. Continuous parallel growth-lines extend across the pseudodeltidium and interarea. CPC 1405 (Plate 11, Figure 11a, b) is a symmetrically convex small brachial valve with 9 costellae in 5 mm. at the anterior margin. CPC 1404 is a small symmetrical shell illustrated in Plate 11, Figure 6. F.17452 is an isolated brachial valve with a narrow hinge-line, rounded margins, and a slight median sulcus. The costellae are 7 to 8 in 5 mm. at 1.4 cm. from the umbo. This shell shows short socket plates diverging at about 90° on the floor of the valve. Unfortunately the cardinal process is broken. There is no area. A young specimen F.17491 is similar and lacks socket ridges. CPC 1406 (Plate 11, Figure 4) has a relatively large interarea and slight wings at the cardinal extremities. The brachial valve is crushed but is evidently convex except at the posterior lateral slopes, which are concave. The perideltidial lines cannot be discerned. The pseudodeltidium is broad and similar to that in specimens F.17451 and F.17463. From another locality come two slightly larger specimens, F.17459, 17460. F.17460 is a gently convex sulcate brachial valve with 7 costellae per 5

mm. at the front margin. The pseudopunctae are seen, in exfoliated specimens, to be arranged linearly, and are largely confined to the axes of the costellae (text Figure 11f). In transverse section the inner shell laminae tend to flatten out the costellae and intertroughs. The pseudopunctae are essentially outwardly directed conical flexures in section (Plate 18, Figure 7). The specimen, C.P.C. 1535, is a portion of the transverse section of a pedicle valve near the lateral edge and towards the front of the shell. The thickening is towards the shell margin.

Dimensions are as shown in Table 1.

TABLE 1.—STREPTORHYNCHUS PLICATILIS HOSKING.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L	W / Lb.	Height of Area.	Width of Hinge-line.	Width of Deltyrium.
CPC 1400 ..	1.5	..	1.5	1.0	..	0.55	1.1	0.5
CPC 1401 ..	1.46	1.46	1.7	1.16	1.16	0.35	..	..
CPC 1402 ..	2.2	..	2.1est.	0.9	..	0.80	1.5	..
CPC 1403 ..	2.2	1.85	2.3	1.04	1.24	0.45	1.0	0.5
CPC 1404 ..	1.5	..	1.4	0.93	..	0.50	0.9	0.2
F.17450 ..	..	..	..	..	..	0.6	1.4	0.3
CPC 1405 ..	..	1.3	1.5	..	1.15	..	..	..
F.17452 ..	..	1.50	1.70	..	1.13	..	..	..
F.17453 ..	1.9	..	1.9	1.0	..	..	..	..
F.17459 ..	2.4	..	2.4	1.0	..	..	..	..
F.17460 ..	..	2.6	2.9	..	1.16	..	..	..
F.17464 ..	0.70	..	0.75	1.07	..	0.15	0.55	..

Occurrences: Many of the specimens come from the Wooramel River area, from a section 600 yards west of Callytharra Springs, in the Callytharra Formation—

F.17452, F.17491, 0-10 feet above base of formation.

CPC 1403, 1404, 1405, 1535; F.17450-17454, 17461-17463, 10-22 feet above base of formation.

CPC 1402, 22-35 feet above base of formation.

F.17464, 35-57 feet above base of formation.

CPC 1400-1401, 73-90 feet above base of formation.

F.17455-8, 90-102 feet above base of formation.

F.17459, 17460, locality ML33, approximately 5½ miles bearing 116° from Donnelly's Well, Williambury Station, 340-346 feet above base of Callytharra Formation.

Other localities are—

GW131, 3 miles 620 yards bearing 79° from Dairy Creek Homestead, at 65′-85′ above base of Callytharra Formation. GW124, 15 miles, bearing 55° from Towrana Homestead, 58′ to 78′ above base of formation. UWA 33385, near south bank of Gascoyne River, 2½ miles S.S.W. of Trig. station K39, Callytharra Formation.

Geological Age: Early Artinskian.

Observations: S. plicatilis is so far known only in the Callytharra Formation, which is richly fossiliferous and largely calcareous. The fossils are, however, mainly weathered from the less calcareous beds; they are associated with numerous other brachiopods, solitary corals, bryozoa, and some large pelecypods.

S. plicatilis appears to have some affinities with *S. crassimurus* from the Noonkanbah Formation. The latter species has a roughly similar outline and external ornament and is thick-shelled, but it is invariably larger and has a dorsal area. Of overseas species, the nearest morphologically appear to be *S. kempei* Anderson and allied species from the "Spirifer limestone" of Spitzbergen. These species are most fully described by Wiman (1914). *S. kempei* is a much larger shell and displays a cardinal process of the type illustrated in text Figure 6a, b. The "Spirifer limestone" is stated to be of Sakmarian to Early Artinskian age (Gee et al., 1952). *S. kempei* is also present in the Upper Permian of Greenland (Dunbar, 1955). *Diplanus lamellatum* (King), from the Leonardian of Texas, has some external resemblance, notably in the close lamellae, but it possesses a dorsal area and has recurved socket plates. Some individuals of *S. plicatilis* have a general resemblance to some figures of *S. hallianus* Derby (e.g., Dresser, 1954; Hall and Clarke, 1894). *S. plicatilis* resembles this species in showing signs of plications in one individual. In this it approaches *Kiangsiella.* Another American species with some resemblance is *S. pygmaeum* Girty of the Delaware Formation.

Streptorhynchus crassimurus sp. nov.

(Plate 12, Figures 1, 2, 3, 4, 5, 10; Plate 19, Figure 4; Table 2; text Figure 11i.)

Diagnosis: Small to medium, thick-walled species, maximum size 3.5 cm. wide and 3.3 cm. long, most specimens wider than long; both valves gently convex, not auriculate; brachial valve with long cardinal process and stout socket ridges, definite brachial area; costellae fine and rounded (11-12 in 5 mm.); strongly lamellate; thick callus in palintrope.

Differential diagnosis: The species is distinguished from *S. plicatilis* by possession of a dorsal area, rounded and even costellae and socket ridges on socket plates; and in not being auriculate.

Material: Numerous shells in highly fossiliferous biostromal bed, several feet thick, in Noonkanbah Formation type section.

Description: Although numerous shells of this species have been collected many are crushed or difficult to extract from the matrix. The holotype, CPC 1407 (Plate 12, Figure 1), is embedded in tough limestone. It is the largest

pedicle valve in the collection. It is somewhat crushed but originally was gently convex. The lateral and anterior margins are rounded. The apical angle is 123° and the cardinal extremities are rounded. The surface is somewhat abraded; it is covered by fine, radiating, slightly uneven-sized, costellae numbering 11 in 5 mm. at 3 cm. mesially from the umbo. The costellae are rounded in cross section and wider than the troughs between; they multiply by intercalation. Numerous concentric growth lamellae are present. Paratype CPC 1408 is a larger brachial valve (Plate 12, Fig. 4a, b), gently convex, with all margins convexly rounded. It is similarly ornamented, with 11 costellae in 5 mm. at 3 cm. from the umbo. A very slight median sulcus is discernible. Paratype CPC 1409 (Plate 12, Figure 10) is a crushed brachial valve with pronounced concentric growth lamellae which form a step-like arrangement. The shell wall is 2 mm. thick. The cardinal process, though incomplete, is stout, with broad socket plates. A dorsal area, about 2 mm. high, is present. Paratype CPC 1410 is an incomplete pedicle valve (Plate 12, Figure 5). This valve is also thick with convexly rounded lateral and anterior margins. The internal costellation is visible only on the margins. The interarea is moderately high and flat and has a low apsacline angle of inclination. The pseudodeltidium is wide and its lateral margin forms the base of the broad low dental ridge. Paratype CPC 1411 (Plate 12, Figure 3a, b) is a crushed brachial valve, convex in longitudinal and transverse profile. The costellae are slightly uneven, rounded in section and wider than the interspaces. Where well preserved they show numerous close fine concentric lamellae. Coarser growth-lamellae are numerous. The costellae number 12 in 5 mm. at 2.5 cm. from the umbo. Paratype CPC 1412 (Plate 12, Figure 2a, b, c) is a small brachial valve showing some of the internal details. The cardinal process is slightly crushed in the middle. It is bilobed with posterior diductor muscle grooves and no median anterior ridge. It is supported by short socket plates diverging at about 90°. The plates have outwardly directed processes. The socket ridges are very slightly developed in comparison with CPC 1409 (Plate 12, Figure 10). An area, notothyrium, and divided chilidium can be distinguished. The area is about 1 mm. high, tapering off rapidly at the cardinal margins. The costellae are not completely covered over on the internal surface of this shell (Plate 12, Figure 2b).

Other specimens from this bed are recorded in Table 2. They vary in dimensions, but all show the shell thickness and surface features. One pedicle valve, F.17473, a small shell, has a nearly catacline interarea with a ventrally projecting pointed umbo. The pseudopunctae are fine and arranged linearly (text-Figure 11i). Plate 19, Figure 4, illustrates a portion of a pedicle valve in transverse section towards the front. Both external (top of figure) and internal surfaces are somewhat eroded. The inner shell laminae tend to obliterate the folds of the costellae. The "pseudopunctae" are in places occupied by fine opaque cores, but appear to be mainly flexures of the shell. The shell is pierced by irregular cylindrical holes which are probably caused by boring organisms, possibly worms or bryozoa.

TABLE 2.—DIMENSIONS OF S. CRASSIMURUS.

(Dimensions in cm.)

Specimen No	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L.	W / Lb.	Length of Hinge Line.	Height of Area.	Width of Delthyrium.
CPC 1407 ..	3.3	..	3.5	1.06	..	..	..	..
CPC 1408 ..	..	3.1	4.1	..	1.32	2.5	..	..
CPC 1409 ..	..	2.7	3.2	..	1.18	1.6	..	..
CPC 1410 ..	2.7	..	2.6 est.	.96	..	1.6 est.	0.75	0.7 mm. est.
CPC 1411 ..	..	2.9	3.3	..	1.14	..	..	..
CPC 1412 ..	..	1.5	2.1	..	1.40	1.0	..	..
F.17465 ..	..	1.7	2.2	..	1.29	1.5	..	..
F.17466 ..	..	2.4	3.1	..	1.29	2.1	..	..
F.17467 ..	..	1.9	1.9	..	1.0	1.2	..	..
F.17468 ..	..	2.7	3.0	..	1.11	..	..	..
F.17469 ..	..	1.7	2.2	..	1.29	1.6	..	..
F.17470 ..	..	1.3	1.9	..	1.46	..	..	..
F.17471 ..	2.1	..	2.5	1.19	..	1.8	0.5	..
F.17472 ..	1.4	..	1.8	1.28	..	1.1	0.25 mm.	..
F.17473 ..	2.2	..	2.5	1.13	..	..	0.55	..

Occurrence: Holotype CPC 1407 and paratypes CPC 1408-1412, and other specimens, all from KNF 73, $2\frac{1}{5}$ miles, bearing 288° from Bruten's old yard, Cherrabun Station; type section of Noonkanbah Formation at 745 feet above base.

Geological Age: Artinskian.

Observations: S. crassimurus resembles *S. plicatilis,* but is larger in size and has a dorsal area; the costellae are rounded and it is not auriculate. One specimen, associated with the others, showed distinct plication. This has been referred to *Kiangsiella* sp. nov. *B,* but it could be an unusual variant of *S. crassimurus.* The presence of slight plication in some individuals of *S. plicatilis* has also been noted.

In its thick shell and rounded outline this species appears to have some affinities with *Streptorhynchus kempei* Anderson (Wiman, 1914) of the "Spirifer limestone" of Spitzbergen; but *S. kempei* is larger and often has a wide hinge-line. *S. macrocardinalis* Toula from the same beds, as illustrated by Wiman (1914), also appears to have some resemblances. The costellae are apparently finer and more even and concentric lamellae are much less pronounced.

S. crassimurus is known only in one bed, a few feet thick, in the Noonkanbah Formation, where it is associated with a rich fauna of brachiopods, bryozoa, crinoids, and blastoids, many of which are delicate and well preserved. The fauna is probably near its position of growth and is essentially a "mixed" to "brachiopod" assemblage.

STREPTORHYNCHUS VARIABILIS sp. nov.

(Plate 10, Figures 12, 13; Plate 11, Figures 7, 8, 9, 10; Plate 19, Figure 1; text-Figures 11d, e; Table 3.)

Diagnosis: Medium-sized thin-walled species, maximum size 5 cm. long and 4.1 cm. wide; asymmetric, very variable in shape and proportions; pedicle valve gently and unevenly convex, not auriculate; brachial valve sulcate to non-sulcate, costellae fine (11-15 in 5 mm.) with stouter ones at irregular intervals.

Material: Numerous specimens from several beds in Noonkanbah Formations. Usually poorly preserved; most specimens from red calcareous often nodular siltstones.

Description: S. variabilis is difficult to define briefly because of the extreme variability of shape. It has been noted in the Noonkanbah Formation type section over a rather narrow stratigraphical range, and in other Noonkanbah beds in this area of roughly the same level. The holotype and paratypes all come from a calcareous siltstone bed several feet thick at about 550 feet above the base of the type section. The holotype, CPC 1413 (Plate 11, Figure 9a, b), is a rather exfoliated shell, gently convex in profile. The maximum width is near the front margin. The outline is slightly asymmetrical. The interarea is asymmetrical, nearly flat, and has a gently convex pseudodeltidium; the teeth are strong. The surface is largely exfoliated, finely costellate, with 15 in 5 mm. at 4 cm. mesially from the umbo. Single lines of pseudopunctae occupy the crests of the costellae. Paratype CPC 1414 (Plate 10, Figure 13a, b) is a smaller shell with asymmetric outline and convex profile. A ventral mesial depression occurs at about two-thirds of the length from the umbo, which is rounded. Paratype CPC 1415 (Plate 11, Figure 10a, b) is an exfoliated incomplete dorsal valve. It is gently convex in lateral and transverse profile. The maximum width is near the front margin. The surface is finely costellated, numbering 10-11 per 5 mm. at 3.5 cm. mesially from the hinge-line. The costellae are rounded and narrower than the troughs. They increase by intercalation; they are uniformly spaced, but occasionally one is more prominent than the rest. The cardinal process is obscured, but is typically streptorhynchid. CPC 1416 (Plate 11, Figure 7a, b) is another asymmetrical pedicle valve, gently convex except on the left lateral flank, which has a strong convex band. The surface is finely costellate, with more pronounced costellae at uneven intervals of five to seven. The surface is also crossed by many concentric lamellae. There are eleven costellae in 5 mm. at 2.5 cm. mesially from the umbo. CPC 1417 (Plate 11, Figure 8a, b) is a brachial valve, moderately convex in profile and sulcate. The short dental plates diverge at a little over 90°. The surface shows two sizes of costellae. F.17476 is a strongly and asymmetrically convex brachial valve; the maximum convexity is near the umbo. The posterior lateral slopes are slightly concave. The lateral margins are gently convex and the front nearly straight. The sulcus is slight. Paratype CPC 1418 (Plate 10, Figure 12a, b) is a large gently convex pedicle valve, roughly circular in outline.

To generalize, the pedicle valve is convex but may have a rather acute or rounded umbo, and the outline varies from irregularly triangular to rounded. The brachial valve is more uniform in outline but varies in convexity and sulcation. The two orders of costellation are visible only in unexfoliated shells. The cardinal process is short, lacks a median anterior swelling, and has short supporting socket plates with the typical streptorhynchid socket ridges. The dorsal area is very narrow or missing. The shell is thin, usually about 1 to 1.5 mm. near the margin. The costellae are visible on the internal surface.

The pseudopunctae are arranged linearly along the costellae (text-Figure 11d, e). Plate 19, Figure 1, illustrates a transverse section of a pedicle valve near the front. The innermost laminae have been mechanically detached from the rest. The outer surface is partly exfoliated. In the axes of some of the costellae lie opaque rods, which may branch. They occupy the cores of the pseudopunctae and appear to be canals infilled by matrix. They do not appear to cross the outer shell layer.

TABLE 3.—DIMENSIONS OF S. VARIABILIS.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L	W / Lb.	Length of Hinge Line.	Height of Area.	Width of Deltyrium.
CPC 1413 ..	5.0	..	4.2	0.84	..	2.3	1.3	0.9
CPC 1414 ..	2.2	..	2.2	1.0	..	1.5	0.9	0.6
CPC 1415 ..	..	3.7	4.6	..	1.24	0.8	..	..
CPC 1416 ..	3.2	..	3.5	1.1	..	..	..	..
CPC 1417 ..	..	2.7	3.6	..	1.33	..	..	..
F.17476 ..	..	3.3	3.8 est.	..	1.15	2.9 est.	..	..
F.17477 ..	4.0	..	5.0	1.25	..	..	..	..
CPC 1418 ..	3.6	..	4.8	1.33	..	2.5	0.7	0.5
F.17478 ..	3.1+	..	3.2	1.0	..	..	..	..
F.17480 ..	4.8	..	4.5	0.93	..	..	..	..
F.17481 ..	2.3	..	2.5	1.08	..	2.1	0.9	0.5
F.17482 ..	3.2	..	3.1	0.96	..	2.1	1.2	..
F.17483 ..	3.5 est.	..	3.8	1.08	..	..	..	..
F.17484 ..	..	2.8	3.8	..	1.36	..	..	..

Occurrence: The holotype, CPC 1413, paratypes CPC 1414, 5, 8, and other specimens, CPC 1536, F.17477, 8, 17481-3 are from the locality KNF 84, 2 miles at 255° from Bruten's old yard, Cherrabun Station, Fitzroy Basin, 650 feet above base of Noonkanbah Formation type section. F.17480, 17484 and others are from KNF 85, 50 feet above KNF 84 in the same section. The species is also present at 780 feet in the type section. CPC 1416-7, F.17476, 9 are from locality PR 288, in the same area. Another locality is KNC 61, $1\frac{3}{5}$ miles west of Bruten's Yard, at about the same level as KNF 84. The species appears to be present also at localities KPN 197 and KPN 198. These are from a section in the Noonkanbah Formation measured near Christmas Creek Homestead and traversing from south of the homestead to about 4 miles north-east. The localities are at 430 feet and 1,412 feet above the base. The latter position is near the top of the formation.

Geological Age: Artinskian.

Observations: The combination of rounded outline, high variability, and uneven costellation distinguish this from other Western Australian species. The costellation observed on unexfoliated shells with two orders of size resembles that of *Streptorhynchus beyrichi* Rothpletz, which, however, is not very well known. It is not recorded as possessing much variability of shape and is stated to have a low wide area. It is referred by Hamlet (1928) to the genus *Schuchertella.* It is known from the Basleo-Wesleoe beds of Timor.

Streptorhynchus pelicanensis Fletcher from the Middle Bowen beds of Queensland has certain resemblances. It is similarly large and rather variable in shape. The area is often high and rather narrow, tending to be pointed. The pedicle valve appears to be usually more convex in longitudinal profile. The costellae are somewhat coarser, at about 9 in 5 mm., and appear to be all roughly equidimensional. As in the Western Australian species, the pseudopunctae are roughly linear along the axis of the costellae. Finer pseudopunctae are present on the area, a feature not usual in the Western Australian species.

The presence of two orders of costellae is noted by Cowper Reed (1944) in the Salt Range species *S. praeceps,* a smaller symmetrical form which he refers to *Schuchertella.* The internal details are not described. This species is from the Lower Productus Limestone. Costellation apparently of the same type is known also in other species. Examples include *Schuchertella radialis* Phil., described from the Lower Carboniferous of the Moscow Basin (Sokolskaia, 1954, Plate 8, Figure 3); and the German Lower Carboniferous species *Schuchertella portlockiana* Paeckelmann (1930, Plate 10, Figures 5, 6, 8a, 9). The species of *Schuchertella* are otherwise quite different from our forms.

Streptorhynchus inaequiornatus Leanza from Argentina possesses costellae with two orders of size on the brachial valve only. This species, which apparently belongs to *Streptorhynchus,* occurs in beds reputed to be Lower Carboniferous in age (Leanza, 1945).

The specimens referred to *S. variabilis* occur in reddish partly nodular calcareous siltstones. In the same beds are numerous brachiopods—spiriferids, terebratulids, *Camarophoria* sp.—, many specimens of *Ptychomphalina,* and some bryozoa.

STREPTORHYNCHUS COSTATUS sp. nov.

(Plate 15, Figures 1, 2, 3, 4, 5, 6, 7; Plate 19, Figure 5; Plate 22, Figure 5; text-Figure 12, c, d; Table 4.)

Diagnosis: Large thin-walled species, maximum size (a brachial valve) 7.5 cm. wide and 5.1 cm. long; symmetrical, wider than long, pedicle valve variable in convexity, some specimens with median fold, interarea moderately high; dorsal valve moderately and evenly convex, sulcate; costellae rather coarse and widely spaced (5-7 in 5 mm. at 3-4 cm. from the umbo).

Material: Many shells were collected from several beds in the lower part of Noonkanbah Formation, south of Grant Range, Fitzroy Basin.

Description: Although many shells are available, very few are complete and no single specimen shows all the characters of the species.

The holotype (CPC 1419, Plate 15, Figure 1), is an incomplete shell with both valves broken at the sides. The pedicle valve is flat in longitudinal profile; in transverse profile it has a low median fold. The surface is strongly convex at the posterior lateral slope; the change of convexity is angular. The interarea is high and wide, and makes an angle with the ventral surface of 58°; it is rather exfoliated and only transverse lineation can be seen. The pseudodeltidium is narrow in proportion to the hinge-line. It is gently convex, flatter on the sides. The apical angle is about 110°. The brachial valve is strongly convex, slightly asymmetrical in profile with maximum convexity nearer the umbo. The lateral slopes near the hinge-line are flat. The valve is sulcate with sulcus deepening towards the front. The costellae are rather uneven and number 7 to 8 in 5 mm. at 4 cm. from the umbo; they appear to be rounded and as wide as the troughs. Lines of fairly coarse pseudopunctae are present on the axes of the costellae. Paratype CPC 1420, from the same bed, is the somewhat exfoliated internal aspect of the brachial valve and palintrope of another shell. The proportions are similar to the holotype. The dental ridges are low and rounded (Plate 15, Figure 6a, b). Paratype CPC 1421 is an incomplete cardinal process from the same bed. The process is long, supported by short socket plates which continue forward on the valve floor as low ridges. Streptorhynchid socket ridges are present. There is no median anterior swelling on the cardinal process (Plate 15, Figure 7). F.17492 is another cardinal process, smaller and shorter but also with streptorhynchid socket plates. CPC 1422 is another incomplete shell (Plate 15, Figure 4a, b). Like the holotype it is gently convex with a marked change of slope on the posterior lateral flanks. The brachial valve is gently convex and sulcate. F.17485 is the largest brachial valve in the collections; it measures 5.1 cm. long and 7.5 cm. wide. The lateral margins and front are convexly rounded, the front gently. The shell is sulcate, and asymmetrically convex in profile; the maximum is nearer the umbo. The costellae are broad and rounded with about 5 in 5 mm. at 4.5 cm. from the hinge-line in the sulcus. The pseudopunctae are, as usual in this genus, arranged along the crests of the costellae in irregular lines. A few are present on the troughs. As in the other shells of this species the costellae multiply by intercalation (text-Figure 12d). A very low area is present. The short socket-plates diverge at about 120°. The shell is less than 2 mm. thick at the lateral margins. CPC 1423 (Plate 15, Figure 2a, b) is a generally similar shell. There are seven costellae in 5 mm. at 3 cm. from the hinge-line on the brachial valve. This shell is from a lower bed than CPC 1419-22. It has a gently convex median longitudinal ridge or fold. An associated rather crushed shell, CPC 1523, is figured in Plate 15, Figure 5.

The pedicle valve has a gentle median ridge or fold, but is slightly concave in lateral profile. Faint irregular plications are present near the lateral margins. The interarea resembles that of the holotype. The apical angle is about 116°. The costellae are 7 in 5 mm. at 3 cm. from the umbo on the pedicle valve. The

narrow chilidial plates are visible in the figure. CPC 1424 (Plate 15, Figure 3a, b) is a broad pedicle valve, strongly convex in profile near the umbo but flattening to the front. There is no distinct median fold. CPC 1524 is associated with CPC 1423 and 1523. The pedicle valve is irregularly concave. This shell was sectioned (Plate 22, Figure 5a, b). Sections reveal a streptorhynchid condition of the dental ridges and an absence of any septum. As in other examples of this species the shell is comparatively thin. From the same bed another pedicle valve, CPC 1600, has an irregular pedicle surface but with a distinct median longitudinal fold and gentle concavities on either side. The longitudinal profile is gently concave. F.17488, which was found with CPC 1423, has a distinctly sulcate anterior margin.

The pseudopunctae, in this species corresponding to the costellae, are very widely spaced. On exfoliated surfaces they form comparatively large pits. Although mainly on the costellae, a few extend on to the troughs (text-Figure 12c, d). Plate 19, Figure 5, is a transverse section near the front of a ventral valve. The inner layers are accidentally separated. The small specks represent opaque rods oblique to the section. These rods appear to be in the cores of little flexures and are probably infilled canals. They do not appear to reach the outer surface of the costellae in the slide.

TABLE 4.—DIMENSIONS OF S. COSTATUS.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L.	W / Lb.	Length of Hinge Line.	Height of Area.	Width of De.thyrium.
CPC 1419 ..	4.5+	..	..	..	..	4.4 est.	1.5	1.15
CPC 1420 ..	..	..	5.9+	..	..	4.1	1.3	1.1
F.17485 ..	..	5.1	7.5	..	1.47	4.6	..	..
CPC 1422 ..	..	..	4.8	..	..	4.0	1.3	..
CPC 1423 ..	4.0+	..	..	..	..	2.7	1.0	0.9
CPC 1523 ..	3.9+	3-2+	6.0 est.	..	..	4.0	1.2	1.2
CPC 1424 ..	..	..	6.5+	..	..	4.5	..	..
F.17488 ..	4.9+	..	6.5	1.32	..	..	..	..
F.17490 ..	4.1	3.8	5.4	..	..	3.6 est.	..	..

Occurrence: The holotype CPC 1419 and paratypes CPC 1420-2, and specimens F.17485 and 17487, are from locality KNA 28. Specimens CPC 1423, 1523, 1524, 17488-17490 are from locality KNA 23 and CPC 1424 from KNA 24. These localities are all from the Noonkanbah Formation section south of the Grant range and about 8 miles south-west of Mount Anderson Homestead West Kimberley Division. KNA 23 is at 690 feet, KNA 24 at 760 feet and KNA 28 at 905 feet above the base. In addition, some rather fragmentary specimens indicate the presence of this species at KNA 17 at 160 feet above the base, and at KNA 22, 610 feet, and KNA 21, 570-610 feet. The species was not detected in other collections from the Noonkanbah Formation.

Geological Age: Artinskian.

Observations: The large size and widely spaced costellae distinguish this from other Western Australian species. There are few descriptions of streptorhynchid species with coarse costellae in the literature. *Streptorhynchus memor* Reed from the Salt Range of India is a coarsely costellated form with a high area. The shell figured by Reed (1931) is much smaller than and differs in outline from *S. costatus*. *S. broilii* Grabau from the Upper Permian Jisu Honguer beds of Mongolia, has coarse costellae, but is a small form of different outline. This species is also reported from China by Grabau (1936). *S. shanensis* Diener from the Lower Permian "Anthracolithic" of the Shan States, Burma, also has coarse costellae and reaches 6 cm. in width. The ventral valve is, however, resupinate and apparently does not display a fold. Reed (1934) refers *S. shanensis* to *Derbyia* without advancing reasons.

S. costatus is associated with a fauna of brachiopods, including *Permorthotetes, Neospirifer,* and *Dictyoclostus,* and bryozoa and has been found only in calcareous beds in the Noonkanbah Formation.

STREPTORHYNCHUS HOSKINGAE sp. nov.

(Plate 12, Figures 6, 7, 9; Plate 13, Figures 1-6; text Figure 11a, b; Table 5.)

Diagnosis: Medium-sized thin-walled species, maximum size 4.7 cm. wide and 4 cm. long, front margin usually straight or concave; pedicle valve variable in convexity; some specimens show resupination, others gently convex, others have slight median fold, generally somewhat asymmetric, some specimens slightly auriculate; interarea apsacline and in some specimens concave; brachial valve strongly convex, convexity greater near hinge-line, slightly sulcate, low dorsal area; costellae fine (10 per 5 mm.), some specimens rugose.

Differential diagnosis: This species resembles most closely *S. johnstonei* and *S.* aff. *perfidiabadensis.* It is larger and much less symmetrical with a more variably convex pedicle valve than *S. johnstonei* and is larger and has a more apsacline interarea than *S.* aff. *perfidiabadensis,* which is not sulcate. *S. luluigui* is much larger and longer.

Material: Many shells and internal moulds from a number of beds, ranging from Cundlego Formation to Wandagee Formation, in the Carnarvon Basin.

Description: Although many specimens are available, few are complete. The forms included here embrace a somewhat variable group, and better material might enable subspecies to be separated. The holotype is from the Wandagee Formation. This is a pedicle valve of medium size (CPC 1425, Plate 13, Figure 1a, d). The valve is nearly symmetrical; an irregular cone with the interarea as a flattened side. The lateral margins are convexly rounded, the anterior margin very gently so. The surface is gently convex in all profiles, flattened at the posterior lateral flanks. The interarea is apsacline, at about 76°; it is slightly concave and rises to a point apically. Faint lateral wings can be discerned. The pseudodeltidium is convex, slightly flattened on its flanks where the dental ridges are based. The latter are set at an acute angle to the palintrope

and extend into flattened bluntly pointed teeth. Muscle scars are long and oval with a central slight ridge. The surface is finely, slightly irregularly, costellate. The costellae are rounded, close, and number 10 in 5 mm. at 2 cm. from the umbo. They increase by intercalation and rarely by splitting, and are faint internally. Paratype CPC 1426 is an incomplete shell from the same locality (Plate 13, Figure 2a, b). It has an irregularly strongly convex pedicle valve with a pointed umbo. The interarea is low and asymmetrical. It is convex on the left and slightly concave on the right side. The brachial valve is gently convex with a median swelling and slightly concave posterior flanks. The fine costellae are irregularly crowded near the hinge-line, in the middle. A shell fragment found with CPC 1426 shows that a low brachial area is present. CPC 1427 (Plate 13, Figure 3a, b) is an internal mould of a gently convex pedicle valve of similar outline to the holotype. This is nearly flat in lateral profile, gently convex in transverse. The interarea is apsacline. Associated is another pedicle valve, F.17495, relatively broader and with a gentle convex median ridge externally. The muscle scars are round in outline, with front edge at the mid-length of the shell. CPC 1428 a, b, c, are a group of shell impressions (Plate 12, Figure 6a, b, c). The brachial valve is moderately convex and slightly sulcate in transverse profile. Growth lamellae are present near the margins. CPC 1428a has the costellae numbering 10 in 5 mm. at 3 cm. medially from the hinge-line. Several other localities in the Wandagee Formation have forms of this general type. Some are recorded in Table 5.

A small group of specimens from this formation, but collected south of the others, near Lyons River Homestead, shows a somewhat different pedicle lateral profile, though similar marginal outline. These are UWA 33360/2, 33360 and 33359/2 and other fragments. Specimen 33360/2 (Plate 12, Figure 7a, b) is a fairly large pedicle valve which is convex near the umbo but concave towards the front and anterior lateral margin. The area is wide, but the external height is unknown. The figure shows the inner surface, which is partly exfoliated. Specimen UWA 33360 is similarly slightly resupinate in longitudinal profile (Plate 13, Figure 5a, b). The brachial valve is moderately convex. This shell has a wide low area. A brachial valve, UWA 33359/1 (Plate 13, Figure 6a, b), is strongly and symmetrically convex in lateral profile. It is very faintly sulcate. The costellae are 10 in 5 mm. at 3.2 cm. from the umbo. They are fairly even, rounded, and with deep rounded narrower troughs. Seven growth lamellae are present. The cardinal process of this specimen, though distorted, conforms to the *Streptorhynchus* pattern, illustrated in text-Figure 6a, b. The two lobes are asymmetric; no median anterior ridge is present. The socket plates diverge at about 90° and possess strong socket ridges radiating from near the base of the cardinal process. The divided chilidial plates are comparatively large. A low area is present which slightly overhangs the internal surface of the shell.

Also included in the species are a few specimens from the Quinnanie Shale (F.20930 and F.20941) and a small group from the Cundlego Formation. These include UWA 28185 (Plate 13, Figure 4a, b, c), a partly exfoliated shell.

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This is a little broader than the stratigraphically higher forms. The interarea is narrower. The pedicle valve is convex with a distinct median fold and a concentric wrinkle. The brachial valve is entirely and strongly convex with a gentle median sulcus. It has a maximum convexity near the umbo. The costellae number 10 in 5 mm. at 3 cm. from the umbo. The anterior margin of this shell is slightly concave in outline; it is also slightly sulcate. A brachial valve impression, CPC 1429 (Plate 12, Figure 9a, b), is broader than the rest and very slightly sulcate. A number of incomplete shells from the base of the Cundlego show that the shapes are rather variable. The pedicle valve in most is gently convex as in the holotype. One brachial valve, F.17498, is about as broad as the Wandagee forms and is strongly convex like UWA 28185 (Plate 13, Figure 4). A broken cardinal process on F.17498 is longer than those of the later forms but apparently otherwise similar.

All the specimens referred to this species have moderately thin shells, about 1.0-1.5 mm. thick except near the margins, where they are considerably thicker, as in the holotype. On the internal surface the costellae may be nearly obliterated by shell growth. The fairly fine pseudopunctae, as usual, are concentrated linearly along the crests of the costellae (text-Figure 11a, b). Two small irregular specimens with similar costellae were collected in the Wandagee Formation. One of these, UWA 27330, is 2.5 mm. long and 2.3 mm. wide. The pedicle valve is flat in lateral profile, very convex in transverse profile. It has a nearly catacline area and a strongly convex brachial valve. The other shell, UWA 27271, is more like the usual forms, but with a high distorted area. The length of the shell is 1.9 cm. Both are probably unusual variants of the species.

TABLE 5.—DIMENSIONS OF S. HOSKINGAE.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L	W / Lb.	Length of Hinge Line.	Height of Area.	Width of De thyrium.
CPC 1425 ..	2.35	..	2.75	1.17	..	1.9	0.8	0.5 mm.
CPC 1426 ..	..	..	..	..	..	2.0	0.65	0.4 mm.
CPC 1427 ..	3.6	..	4.1	1.14	..	2.7	..	..
F.17495 ..	3.6+	..	4.5	1.25	..	..	..	..
CPC 1428a ..	3.2	..	3.5	1.09	..	..	..	..
CPC 1428b ..	..	2.7	3.6	..	1.33	..	..	..
UWA 33360/2	4.0+	..	4.7+	1.18	..	3.1	..	..
UWA 33359/1	..	3.1	4.0	..	1.29	2.6	..	..
UWA 33360..	3.9	..	4.9 est.	1.26	..	4.0	0.7	0.9
UWA 28185..	3.6	3.2	4.5	1.25	1.4	2.2	0.9	..
CPC 1429 ..	..	2.2	3.4	..	1.55	..	..	..
F.20930 ..	..	2.7	3.8	..	1.41	..	..	..
F.17498 ..	..	3.3	4.4	..	1.33	..	..	..

Occurrence: CPC 1425-6 and F.17493 from west limb of Minilya syncline, north of Minilya River, about 1½ miles south-west of Coolkilya Pool; lower part of Wandagee Formation. F.17494, locality ML 58, Minilya syncline, north bank of Minilya River, about 1½ miles south-west of Coolkilya Pool; from 130-139 feet above base of type section of Wandagee Formation. CPC 1427,

1428, F.17495, locality MG 207A, 9¾ miles bearing 220° from Moogooree Homestead, or 2¼ miles bearing 142° from Kimber's Well, Williambury; lower part of Wandagee Formation. F.17496, locality ML 82, north bank of Minilya River, about 1½ miles south-west of Coolkilya Pool; at 190 feet above base of Wandagee Formation. F.17497, locality ML 44, Minilya River, south bank, 9 miles west of Wandagee homestead, 1⅜ miles south-west of Coolkilya Pool; lower part of Wandagee Formation. CPC 1429, locality MG 170, about 2½ miles, bearing 282° from Barrabiddy Dam, Wandagee Station; base of Cundlego Formation. CPC 17498, locality ML 54, north bank of Minilya River, 1 mile south-west of Coolkilya Pool, Wandagee Station; base of Cundlego Formation. F.20930, locality MG 32, 1¾ miles bearing 10° from Paddy's Well, Middalya Station, Quinnanie Shale. F.20941, locality MG 252, 300 yards north-west of Coolkilya Pool, Wandagee Station; type section of Quinnanie Shale. F.20911, locality MG 177, 1¼ miles east of Trig. Point, Wandagee Hill, Wandagee; Wandagee Formation.

University of Western Australia Collections: UWA 28185, recorded as "Horizon 37, locality 1, Field No. C37, 14"; Cundlego Formation. UWA 33359/1, 33360/2, about 3½ miles west of Binthabooka Creek, about 5½ miles west of Lyons River homestead; low in Wandagee Formation. UWA 27271, "WC (29-32)3, *Calceolispongia* horizon south of shed gate, Mungadan Paddock, Wandagee."; Wandagee Formation. UWA 27330, recorded as "WC (27-28)3, N.E. of flag 12, to 1850 E. of Mungadan, east fence S. of flag 11, Wandagee Station", Wandagee Formation.

Geological Age: Artinskian.

Observations: S. hoskingae, though somewhat variable, is not as much so as *S. variabilis,* and the costellation is both coarser and more uniform than in the latter species. *S. johnstonei* sp. nov. appears to be a fairly closely related form, though it is invariably smaller and much less variable, and is symmetrical and never auriculate. The Lower Productus Limestone species *S. mistus* Reed and *S. praeceps* Reed have a certain general resemblance, but are insufficiently described to compare them in detail. *S. hoskingae* is rather common in the richly fossiliferous "mixed to brachiopod" assemblage of the Wandagee Formation, and is apparently rarer in the poorer Cundlego Formation and Quinnanie Shale.

The species has been named in honour of L. F. V. Hosking (Mrs. Hanrahan) who first described the genus *Streptorhynchus* in Western Australia.

Streptorhynchus johnstonei sp. nov.

(Plate 14, Figures 1-6; text-Figure 12a; Table 6.)

Diagnosis: Small thin-walled species, maximum size 2.8 cm. wide, 2.3 cm. long, symmetrical, wider than long; pedicle valve flat to gently concave, not auriculate; interarea flat at a variable apsacline angle; brachial valve strongly and unevenly convex with maximum nearer hinge-line, sulcate, no area; costellae fine (12-15 in 5 mm.).

Differential diagnosis: *S. johnstonei* most closely resembles *S. hoskingae* and *S.* aff. *perfidiabadensis.* It is smaller and more symmetrical, with a flatter pedicle valve, than *S. hoskingae,* and lacks a dorsal area and is not auriculate. It differs from *S.* aff. *perfidiabadensis* in that the interarea has in most specimens a low apsacline angle and the brachial valve is sulcate.

Material: Numerous internal and external moulds from Coolkilya Greywacke, Carnarvon Basin. A few incomplete shells are also available.

Description: The holotype, CPC 1430 (Plate 14, Figure 1a-c), displays the characteristic features of the species. It is an internal mould with which is an external impression of the brachial valve and interarea (Plate 14, Figure 2). The pedicle valve is nearly flat in lateral profile, and gently convex in transverse profile near the hinge-line. The umbo is pointed; the apical angle is about 115°. The lateral margins are convexly rounded and the front is straight. The brachial valve is asymmetrically convex and sulcate. It is slightly concave on the lateral flank near the hinge-line. The interarea is flat and apsacline at a low angle; the delthyrium is comparatively narrow; the teeth are prominent, and the pseudodeltidium is convex, slightly flattened near the lateral margins. The brachial surface is finely and evenly costellated; the costellae number 15 in 5 mm. at 1.5 cm. from the hinge-line. The cardinal process is typically streptorhynchid (Plate 14, Figure 3a, b). The short socket plates diverging at about 90° have outward extensions of the socket ridges which radiate from near the base of the process. Paratype CPC 1432 (Plate 14, Figure 4) is a cardinal process and internal view of the palintrope of an associated specimen. The process is relatively long, bilobed near the end, and fits close to the inside of the pseudodeltidium. A low median ridge is present on the floor of the brachial valve. The dental ridges are low and extend into teeth which articulate anterior to the socket ridges. Paratype CPC 1431 is another mould (Plate 14, Figure 5b), similar to the holotype but distinctly concave in lateral profile of the pedicle valve. The external impression of this valve (Plate 14, Figure 5a) shows fine even costellae, 12 in 5 mm. at 2 cm. from the umbo. The costellae are rounded, with deep narrow troughs, and are crossed by very fine concentric lamellae and some coarser ones near the margins. Increase is by intercalation in two generations. The brachial valve is asymmetrically convex with maximum convexity near the umbo; it is sulcate. The interarea of this specimen and also F.17499 are at a nearly catacline angle to the commissural plane. The umbonal slope is rather steeply inclined to the longitudinal profile in F.17499. F.17500 is a mould very similar to the holotype. It comes from Wandagee Hill. The pedicle lateral profile is nearly flat.

Specimens of similar type are F.17501, F.17502, F.1652. Another specimen from Wandagee Hill (UWA WH7) is a rounded brachial valve without a sulcus and evenly convex in profile. It has a short cardinal process, and short socket plates diverging at about 90°. It is figured in Plate 14, Figure 6a, b.

The only available shells (F.17503) are rather fragmentary. They show fine pseudopunctae arranged linearly along the crests of the costellae; the shell is thin (text-Figure 12a). The shells of this species do not vary much in size and shape though collected over a considerable area.

TABLE 6.—DIMENSIONS OF S. JOHNSTONEI.
(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L.	W / Lb.	Length of Hinge Line.	Height of Area.	Width of Delthyrium.
CPC 1430 ..	2.3	1.9	2.8	1.22	1.47	1.7	0.65	0.5+
CPC 1431 ..	2.1	1.8	2.6	1.24	1.45	..	..	..
F.17499 ..	1.8	1.7	2.2	1.22	1.30	1.4	0.5	0.5
F.17500 ..	2.3	..	2.7	1.17	..	1.6	0.75	..
F.17501 ..	2.0	..	2.3	1.15	..	..	..	..
F.17502 ..	2.0	..	2.3	1.15	..	..	..	..
UWA WH 7..	..	2.1	2.25	..	1.07	..	..	..
F.1652 ..	1.85	..	2.2	1.18	..	..	..	..

Occurrence: CPC 1430, 1431, 1432 and F.17499 are from locality TJ198, Kennedy Range, ¾ mile south of Southern Cross Bore, Middalya Station; Coolkilya Greywacke, amended type section, about 549 feet above the base. F.17500, locality ML75, east side of Wandagee Hill, Wandagee Station; Coolkilya Greywacke, original type locality, about 200 feet below the top. F.17501, locality ML121A, about ¾ mile south of Southern Cross Bore, about 485 feet above the base of Coolkilya Greywacke type section. F.17502, locality ML75, east side of Wandagee Hill; Coolkilya Greywacke, original type locality, 100 feet below top. F.17503, locality ML117, about ¾ mile south of Southern Cross Bore, Middalya Station; Coolkilya Greywacke type section at about 345 feet above the base of Formation. F.1652, locality 32, Waterford Collection, about 2 miles west of K40, Walberune Peak, Jimba Jimba Station, Carnarvon Basin; Coolkilya Greywacke. UWA WH7, Wandagee Hill, recorded as "just N. of Cairn C, *Chonetes—Streptorhynchus* band, Cairn A to Flag 6; Wandagee Hill Series" of Teichert; Coolkilya Greywacke.

Geological Age: Late Artinskian to Early Kungurian.

Observations: S. johnstonei has certain resemblances to *S. hoskingae* as noted under that species. It is, however, invariably smaller, more symmetrical and much less variable. In size and costellation it somewhat resembles *S.* sp. aff. *perfidiabadensis* (Etheridge) from the Liveringa Formation. The latter form has a more catacline and convex area. The species is common in several beds of the Coolkilya Greywacke, which is not otherwise rich in fossils except near the base, which is calcareous and contains a largely molluscan fauna with some brachiopods and crinoids.

S. johnstonei is usually associated with *Chonetes* sp. in thin rich bands from which the original calcareous material has been generally leached. Specimens are often ferruginized. The species is named in honour of Mr. Daryl Johnstone, who collected with the author the holotype and paratype from the Kennedy Range.

STREPTORHYNCHUS sp. aff. S. PERFIDIABADENSIS (Eth. fil.).

(Plate 15, Figures 8a, b, 9a, b, 10a, b; Table 7; text-Figure 11g.)

Orthotetes perfidiabadensis, Etheridge 1906, p. 6, Plate 2, Figures 1-9, Plate 5, Figures 3-4.

Diagnosis: Small to medium thin-walled species (typical size 3.2 cm. wide and 2.7 cm. long); wider than long, somewhat asymmetric, pedicle valve unevenly convex, low pointed interarea with high apsacline inclination tending to be catacline; brachial valve strongly and evenly convex without sulcation; costellae fine, 11 in 5 mm.

Differential diagnosis: This form most nearly resembles *S. hoskingae* and *S. johnstonei.* It differs from the former in being smaller and in having a non-auriculate nearly catacline interarea and non-sulcate brachial valve. *S. johnstonei* is smaller, more symmetrical, with flat pedicle valve and sulcate brachial valve.

Material: Twelve rather corroded and incomplete valves. All from beds at base of Liveringa Formation, Shore Range, Fitzroy Basin.

Description: The specimens are rather variable in shape, but appear to resemble the forms described by Etheridge as *Orthotetes perfidiabadensis* from Fossil Head near Treachery Bay, Victoria River Estuary, Northern Territory, in beds now referred to the Port Keats Group, and low in the Group. This species should be referred to as *Streptorhynchus,* not *Orthotetes.* The internal details of this pedicle valve are not exposed in the type material; the type specimens are all ferruginous replacements of shells. However, the form of the pedicle valve, including the interarea, corresponds well with some of the smaller Western Australian Permian *Streptorhynchus.** Moreover the cardinal process is very similar to the type common in species of *Streptorhynchus.* All the nine figured specimens of *O. perfidiabadensis* are small shells. They are finely costellate. The pedicle interarea is moderately high, 6 mm. in one specimen. The dimensions roughly correspond to those of most specimens from the Shore Range. The outlines are similarly variable. The brachial valves are convex and slightly sulcate. The figured cardinal process (Etheridge, 1907, Plate 2, Figures 3, 4, 5,) shows a well developed divergently bilobed process with short strong socket plates which have the socket ridge extensions like the Western Australian species of *Streptorhynchus.* The process is nearly at right angles to the plane of commissure. The socket plates diverge on the floor of the valve at about 90°.

The Shore Range specimens are with one exception small. CPC 1433 (Plate 15, Figure 8a, b) is a pedicle valve, irregularly convex. It has a small depression in front of the outwardly projecting umbo. The lateral posterior flanks are strongly convex. The interarea is convex, nearly catacline at the apex. The teeth are prominent. The surface is finely costellate, with eleven costellae in 5 mm. at 2.2 cm. mesially from the umbo. The pseudopunctae are linear on the

* Some recently collected topotype material from Fossil Head, including pedicle valves showing internal details, confirms that this species belongs to *Streptorhynchus.*

axes of the costellae. Several small brachial valves are also available. CPC 1434 (Plate 15, Figure 10a, b) is strongly convex and lamellate like Etheridge's Plate 2, Figure 2. CPC 1435 (Plate 15, Figure 9a, b) is another small non-sulcate brachial valve. In this specimen the hinge-line appears to be rather wider than in *S. perfidiabadensis*. The cardinal process (Plate 15, Figure 9b) is about the same length as in *S. perfidiabadensis,* but the socket plates are more divergent and the area was evidently very narrow, though now largely eroded away. One rather large specimen was also collected, F.17504. This has a similar cardinal process to CPC 1434. The valve is only slightly convex and non-sulcate. The shells are moderately thin, about 1.5 mm. The Shore Range specimens differ from the Treachery Bay specimens in that the brachial valves are not sulcate, and some are larger. The plan view of the disposition of the pseudopunctae is illustrated in text-Figure 11g.

TABLE 7.—DIMENSIONS OF S. sp. aff. S. PERFIDIABADENSIS.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L	W / Lb.	Length of Hinge Line.	Height of Area.	Width of Delthyrium.
CPC 1433 ..	2.7	..	3.2 est.	1.18	..	1.6	0.8	0.4
CPC 1434 ..	..	2.2	2.9	..	1.32	..	..	..
CPC 1435 ..	..	2.6	3.1	..	1.19	..	..	..
F.17504 ..	..	4.1	4.5+	..	1.09+	..	..	..
F.17506 ..	..	2.5	3.1	..	1.24	..	..	..
F.17507 ..	..	2.0	2.3	..	1.15	..	..	..

Occurrence: CPC 1433-1435, F.17504-7, locality KLD 64, about 2.6 miles at 70° bearing from Shore Range Trig. Point, Shore Range, Fitzroy Basin. From beds low in Liveringa Formation, Lightjack Member; similar forms are found in a higher bed, KLD 65, about 30 feet above LKD 64.

Geological Age: Late Artinskian to early Kungurian.

Observations: Streptorhynchus perfidiabadensis (Eth.) was found at Treachery Bay, Northern Territory, in beds probably low in the Port Keats Group (Traves, 1955). The associated pelecypod fauna also has affinities with the fossils from the lower beds of the Liveringa Formation (J. M. Dickins, personal communication). Hence this part of the Port Keats Group is probably to be correlated with the Lightjack Member of the Liveringa Formation. The other major known fossiliferous sequence in the Port Keats Group—the beds at Port Keats Mission—contains a different and younger brachiopodal fauna showing strong affinities with the top marine Hardman Member of the Liveringa Formation. These forms have not been described. The Shore Range locality is rather rich in brachiopods, including spiriferids. In this it differs from the usual character of the Lightjack Member, which is predominantly a " molluscan " (pelecypod) fauna. The Shore Range sequence was probably deposited in rather deeper water than the other exposed sequences of the Member. The brachiopod fauna has several species not known elsewhere in the Fitzroy Basin.

STREPTORHYNCHUS sp. cf. S. PELARGONATUS (Schlotheim).

(Plate 16, Figures 1-9; text-Figure 11h; Table 8.)

Diagnosis: Small to medium thin-walled species, maximum size 3.5 cm. wide and 3.1 cm. long, majority rather less, many specimens longer than wide, highly asymmetric with high pointed twisted interarea, not auriculate; brachial valve gently and unevenly convex, maximum near hinge-line, low area, some specimens sulcate; costellae fine—13 in 5 mm.; some pedicle valves rugose.

Differential diagnosis: The high twisted interarea and small size distinguish this species from *S. luluigui,* which it resembles in proportions. Also the dorsal valve is much less convex.

Material: Fifteen valves and incomplete shells, numerous fragments, all from upper part of Liveringa Formation at Mt. Hardman.

Description: A characteristic specimen of the species, CPC 1436 (Plate 16, Figures 1a, b, c), is a small, incomplete irregularly convex pedicle valve with a few strong concentric step-like wrinkles. The area is gently concave and is high, apsacline and asymmetrical. Its angle with the " plane " of commissure is about 45°. The costellae are fine, 13 in 5 mm. near the front. The pseudodeltidium is rather narrow and strongly convex; the teeth are prominent. Concentric growth lines are numerous. CPC 1437, 1438 (Plate 16, Figure 4a, b; 2, 3a, b), are other smaller pedicle valves with similar features. The dental ridges are rounded and extend up to the umbo. Both pedicle valves are strongly and irregularly convex in the umbonal region. CPC 1439 (Plate 15, Figure 5), is a smaller and slightly more symmetrical pedicle valve, otherwise similar. Somewhat larger and more symmetrical pedicle valves are present, e.g. F.17510 and F.17513. The former is nearer to a youthful *S. luluigui* in outline than the other shells and the interarea has an apsacline angle of inclination of about 70°. The costellae number 13 in 5 mm. at the front; they are rounded in section and fairly even.

Six brachial valves are available. They include CPC 1440-1443 (Plate 16, Figures 7a, b; 9a-c; 8a, b; 6a, b, c). The smaller specimens are gently convex in lateral and transverse profile, flattening on the posterior lateral slopes. A narrow area is usually present, and two small chilidial plates. The cardinal process is variable in length. Its base is set at right angles to the floor of the valve, but the distal end of the process may turn back towards the umbonal apex.

The process is bilobed, often with the lobes divided at the ends by the diductor grooves. A median anterior ridge or swelling may be present. The socket plates are strong with socket ridges extending outward into projections. The socket ridges are nearly parallel to the diductor lobes, converging towards the base of the cardinal process.

A few brachial valves are more convex and asymmetrical in lateral profile with a maximum convexity near the umbo, e.g., F.17514. A slight sulcus is present in this specimen, which is a nearly complete shell. The pedicle interarea is asymmetrically twisted.

The dorsal muscles of the brachial valves are very faintly impressed, but some specimens possess a faint median ridge on the floor of the valves. F.17869, a pedicle valve, was collected from the lowest fossiliferous bed at Mount Hardman. It is small and symmetrical. The interarea is at about 80° to the "plane" of commissure. The distribution of the pseudopunctae is seen in plan view in text Figure 11h.

TABLE 8.—DIMENSIONS OF S. sp. cf. S. PELARGONATUS.
(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width W.	W / L.	W / Lb.	Length of Hinge Line.	Height of Area.	Width of Deltyrium.
CPC 1436 ..	2.9 est.	..	2.5 est.	0.8	..	1.7	1.1	0.45
CPC 1437 ..	..	..	..	..	..	0.75	0.75	0.30
CPC 1438 ..	..	..	1.7 est.	..	..	1.3	0.80	0.40
CPC 1439 ..	1.45	..	1.4 est.	0.96	..	1.0	0.35	..
CPC 1440 ..	..	..	2.1	..	..	..	..	..
F.17509 ..	..	1.2	1.5	..	1.35	1.1	..	..
CPC 1443 ..	..	1.3	1.7	..	1.3	1.3	..	..
F.17511 ..	..	2.7	3.3	..	1.21	..	..	..
F.17510 ..	3.1	..	3.5	1.12	..	1.8	0.80	..
F.17513 ..	3.2	..	3.2+	1.0+	..	2.4	1.0	..
F.17514 ..	3.0	2.80	3.1	1.03	1.11	1.8	0.7	..
F.17869 ..	1.6	..	2.0	1.24	..	1.35	0.6	..

Occurrence: All but one of the specimens described, CPC 1436-43 and F.17509-14, came from the locality KLB 11, Mount Hardman, from beds about 4 feet thick at about 130 feet below the top of the hill: the highest fossiliferous beds in the Hardman Member in this area. The species is also present at KLB 10—F.17869—about 60 feet lower.

Geological Age: Upper Permian—probably Tartarian.

Observations: In the upper Liveringa Formation beds at Mount Hardman, many small streptorhynchid shells were collected. No large specimens referable to *S. luluigui* Hosking were observed. Noteworthy characters of many of the shells are the high twisted interarea of the pedicle valve and the gentle symmetrical convexity of the brachial valves.

The collection may perhaps represent an association of small distorted specimens of *S. luluigui* or an extreme variant of that species. The Mount Hardman beds contain a rich assortment of well-developed brachiopods (including the large *Derbyia hardmani* sp. nov.), bryozoa and pelecypods. Hence the environment was very favorable for most brachiopods. The productids retain long delicate spines; and as many intact shells are found this association is at its position of growth. *S. luluigui* is commonly much larger and symmetrical. It seems best therefore to regard *S.* cf. *pelargonatus* as a distinct species.

The high twisted interarea suggests that this was an attached species. Many specimens are incomplete at the umbo and possibly the breaks correspond to the cicatrices of attachment. Many shells display fine perforations in the umbonal region in the ventral surface and on the area, e.g., Plate 16, Figure 1.

These holes are probably parasitic borings. Umbonal perforations were reported by W. King in the English members of *S. pelargonatus*. In its variable shape, small size and gently convex brachial valve this species strongly resembles *S. pelargonatus* (Schlotheim) as figured by King (1850), Davidson (1858), Geinitz (1861), Malzahn (1937), from the Zechstein of Germany and Upper Permian Magnesian Limestone of England, and the costellae are of about the same size. Some Western Australian specimens are rather larger than the English and German representatives of the species. The cardinal process is incompletely figured by Geinitz, King, and Davidson, and hence a complete affinity of the Mount Hardman form with *S. pelargonatus* is not certain. Waagen (1884) and Cowper Reed (1944) record the species from the Middle Productus Limestone of the Salt Range. *S. pelargonatus* has a long list of records, but many of these may be doubted as the specimens are inadequately described and figured. The species is discussed above in the definition of the genus.

STREPTORHYNCHUS LULUIGUI Hosking.

(Plate 8, Figures 9, 10; Plate 17, Figures 1-5; Plate 19, Figures 3 and 6; text-Figure 11c; Table 9.)

Streptorhynchus luluigui Hosking 1932, p. 45-48, Plate 4, 5.

Diagnosis: Large thin-walled species, maximum 5.5 cm. long and 5.5 cm. wide, symmetrical, many specimens as wide as long; pedicle valve usually flat to very gently convex, very rarely auriculate; brachial valve strongly and unevenly convex with maximum nearer hinge-line, no area; costellae fine and even (13 in 5 mm.); surface commonly with numerous lamellae which are closer near the front.

Differential diagnosis: This species is distinguished from *S. hoskingae* by its large size, equality of length and width and general symmetry. It also has a flatter pedicle valve. The costellation is very fine. It differs from *S.* cf. *pelargonatus* in being much larger and symmetrical and has a strongly convex brachial valve.

Material: Numerous shells, many internal moulds in ferruginized sandstone, from many localities—all in the Hardman Member of the Liveringa Formation Fitzroy Basin.

Description: This species has been well described by L. F. V. Hosking. She did not specify a holotype and I designate the specimen 3040L, UWA collection (Hosking, 1932, Plate IV., Figures 1a-c), as the lectotype. She described and figured several other specimens, all from near Luluigui Homestead, Fitzroy Basin. Much more material, now available from many other localities, illustrates some of the variations in this species (Table 9).

Plate 17, Figures 1, 2, an internal mould and ventral external impression (CPC 1444), illustrates the features of a large symmetrical individual. The shell is as broad as long, pedicle valve nearly flat, convex on the umbonal lateral

flanks. The prominent circular muscle field, reaching the mid-length and with two narrow median posterior diductor impressions, is well shown. The maximum width is near the mid-length. The costellae are fine and even and number 13 in 5 mm. at 4 cm. mesially from the umbo; they multiply by intercalation. The growth lamellae of this and many other specimens are well defined, becoming more numerous towards the front. They are often gently step-like.

The areas of the lectotype and associated material varied in convexity, width and height. Further variation is shown in specimens from beds of approximately the same stratigraphical level at locality FL 220, two miles east of Luluigui Homestead. These specimens (F.17515-9 and others) show that the interarea may be higher and narrower than in the lectotype and syntypes (Table 9). In F.17516, the interarea is high and asymmetrically gently concave. In F.17515, the delthyrium is asymmetrically disposed to the right. The pedicle valve may be rather convex in lateral profile near the umbo.

A more distant locality, KNB 53, near the St. George Range, where the fossils are also present as shells, provided more specimens with high narrow areas, e.g. F.17520. Other specimens are more like the holotype, e.g. F.17521, 17522.

Many ferruginous moulds from other localities are also available. Most come from the large Dry Corner Syncline, north-west of Nerrima Dome. CPC 1446 (Plate 17, Figures 3a-d) is a symmetrical form close in outline and proportions to the type material. The strongly and asymmetrically convex brachial valve is very slightly sulcate on the maximum convexity, where a low median internal ridge is present. The cardinal process is set nearly at right angles to the commissural plane. The socket plates extend into low ridges which flank the roughly circular muscle area. The rather high and flat interarea is set at about 30° to the plane of commissure. The pseudodeltidium is gently convex, flat in the middle. The surface of the pedicle valve is sharply overturned on the posterior lateral flanks. The pedicle musculature may be very deeply impressed, in some specimens, e.g. 1447 and 1448 (Plate 8, Figures 9, 10). Specimens at about the same horizon as CPC 1446, on the eastern flanks of the Dry Corner syncline, tend to be rather distorted. They also show some signs of being relatively wider than the average. These specimens, F.17527-35, probably are only a variant of the species, as some individuals are close to the holotype.

Young forms are sometimes relatively wide, and some have a pronounced brachial sulcus. In one youthful specimen F.17537 the sulcal region is distorted, with the costellae converging irregularly towards the middle of the sulcus. The very youthful specimen (F.17538) has a very slightly convex brachial valve.

The cardinal process of mature individuals is very stout and long. The base is nearly at right angles to the plane of commissure, but the outer part may be turned posteriorly. The process is bilobed and may be further subdivided at the ends of the lobes by the diductor muscle grooves. No anterior

ridges or swellings were observed. Plate 17, Figure 4, is an illustration of UWA 2772/0, figured by Hosking (1932, Plate IV, Figure 4a, b). The outward projections of the socket plates are extensions of the socket ridges.

Plate 17, Figure 5a, b, shows a very similar specimen (CPC 1445). This is a latex rubber impression from an internal mould. The rather short socket plates diverge at about 115° on the floor of the valve. The socket plate projections mark the position of the socket ridges which radiate out from near the base of the cardinal process. The socket plates extend forward on the floor of the valve as low ridges which flank and surround the oval adductor muscle scars, which are divided by a low median ridge. The posterior surface of this cardinal process is not available but some of the shells show the presence of narrow divided chilidial plates. The socket ridges are usually roughly parallel to the process. The brachial area is very narrow or absent. The pseudopunctae in this species show, as usual, in plan view in exfoliated specimens a linear arrangement along the axes of the costellae (text-Figure 11c). In section many if not all of the pseudopunctae are seen to be flexures of the shell lamellae with narrow opaque rods occupying the cores. Plate 19, Figure 3, is a transverse section of a pedicle valve, CPC 1538, at the junction of the pseudodeltidium with the rest of the shell. The external surface is at the top. The numerous short lines cutting the lamellae are the opaque cores of the pseudopunctae. They give a strong impression of being infilled tubules. They are present on the pseudodeltidium but not on the teeth. The outer surface is exfoliated. Figure 6 is the same specimen sectioned at the front.

TABLE 9.—STREPTORHYNCHUS LULUIGUI Hosking.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width W.	W / L.	W / Lb.	Length of Hinge Line.	Height of Area.	Width of Delthyrium.	Thickness, Maximum.	Thickness. Brachial Valve only.
UWA. 3040 L ..	4.1	3.4	4.1	1.0	1.20	2.4	1.1	0.8	1.9	..
CPC 1444 ..	5.5	..	5.5	1.0	..	..	..	..	..	..
CPC 1445 ..	..	4.7	5.5	..	1.17	4.4	..	..	..	2.1
CPC 1446 ..	5.2	4.1	5.5	1.06	1.34	4.4	1.4	1.0	2.9	..
F.17516 ..	..	..	5.5	..	..	2.9	1.6	0.8	..	..
F.17517 ..	..	..	..	..	..	3.1	1.7	0.8	..	..
F.17515 ..	..	..	..	..	..	3.6	2.2	1.0	..	..
F.17518 ..	3.5	..	4.0	1.14	..	2.6	1.0	..	..	..
F.17519 ..	4.9	..	5.1	1.04	..	3.2	..	..	..	..
F.17520 ..	4.1	..	..	..	..	3.2	1.8	..	..	..
F.17521 ..	4.5	..	4.7	1.04	..	..	..	..	..	..
F.17522 ..	..	..	..	..	..	2.3	0.9	..	..	..
F.17523 ..	5.1+	4.1	5.1	1.0	1.24	3.3	1.6	..	2.5	..
F.17525 ..	4.1	3.2	4.1	1.0	1.28	2.2	1.2	..	..	..
F.17526 ..	3.2	..	4.0	1.25	..	..	..	..	..	2.0
F.17527 ..	..	4.0	5.0	..	1.25	..	..	..	2.2	..
F.17529 ..	3.3	3.3	4.0	1.21	1.21	1.9	1.0	0.8	2.3	2.3
F.17530 ..	3.1	2.9	3.6	1.16	1.24	..	..	..	3.0	..
F.17533 ..	5.2	..	5.4	1.02	..	..	..	..	..	..
F.17535 ..	4.1	3.7	4.8	1.17	1.30	3.0	1.2	0.9	2.6	..
F.17534 ..	..	5.3	6.3	..	1.18	..	..	..	..	..
F.17536 ..	..	3.2	4.4	..	1.38	2.6	..	..	..	..
F.17537 ..	..	2.3	3.3	..	1.44	1.8	..	..	..	0.8
F.17538 ..	1.3	1.0	1.4	1.08	1.4	0.8	0.3	..	..	..
F.17539 ..	2.5	..	3.7	1.48	..	..	..	..	..	..

Occurrence: The lectotype and associated specimens were all from near Luluigui Homestead, Fitzroy Basin, from several adjacent beds high in the Liveringa Formation, probably topmost fossiliferous beds. CPC 1444-6, F.17523-6, F.17536-8 are from locality KLC 42, near Tutu Bore, Nerrima Station, on southern flank of Dry Corner Syncline, north-west of Nerrima dome; Hardman Member of Liveringa Formation about 300 feet below top. CPC 1447-8, locality KLC 14, about ¼ mile bearing 120° from Mount Cedric, Fitzroy Basin; Hardman Member of the Liveringa Formation. F.17520-2, locality KNB 53, near Andy's Well, Noonkanbah Station, about 8.1 miles at bearing 47° from Mount Fenton; Hardman Member of Liveringa Formation. F.17515-17519, locality FL 220, 2½ miles at 95° bearing from Luluigui Homestead, from several adjacent beds very high in Hardman Member, probably about same horizons as at Luluigui Homestead. The Liveringa Formation in this area, south of Grant Range, is over 3,000 feet thick. F.17527-35, locality KLC 40, 4⅝ miles at 339° from Moffatt's Bore, Nerrima Station, on eastern flank of the great syncline about same horizon as KLC 42 (Tutu Bore); about 300 feet below top of Liveringa Formation. F.17539, locality KLC 43, ⅞ mile, at 228° from Dry Corner Well, Myroodah Station on south-western flank of the syncline, near the top of Liveringa Formation, estimated about 100-150 feet below top. UWA 29249, 1 mile south of north-west corner of Calwynyardah Station—Wade's Field No. B142; Hardman Member of Liveringa Formation.

The species is also present in the upper Liveringa Formation beds of the Millyit Range (W.A. Petroleum Ltd. collections).

Geological Age: Upper Permian (probably Tartarian).

Observations: This large and distinctive species is characteristic of the Hardman Member of the Liveringa Formation. It is distinguished by its fine costellation and shape from the other large Western Australian species *S. costatus,* which attains a greater size. In its costellae it resembles *S. hoskingae,* which is, however, smaller and wider, and more variable in the convexity of the pedicle valve. Smaller individuals of *S. luluigui* and also earlier growth stages of such specimens as CPC 1444 (Plate 17, Figure 1) have about the same ratio of width to length as specimens of *S. hoskingae.*

The possible affinity with *S.* cf. *pelargonatus* (Schl.) has been commented on. However, that species is evidently different in habit, with a twisted form, the result of attachment at the umbo, and is much smaller in its maximum growth. *S. mistus* Reed of the Lower and Middle Productus Limestone of the Salt Range has some resemblance, but is not as large as *S. luluigui* and is auriculate. Cardinal ears appear only occasionally in *S. luluigui. S. mistus* appears to be known only from two specimens. Few other described species show much resemblance. In size and shape *S. luluigui* resembles the Upper Productus Limestone species *Derbyia hemisphaerica* Waagen; but *D. hemisphaerica* is a septate form.

Streptorhynchus luluigui Hosking is an index fossil for the Hardman Member of the Liveringa Formation. It is associated with a rich variety of brachiopods, rarer pelecypods, bryozoa and crinoids.

STREPTORHYNCHUS sp. nov. A.

(Plate 12, Figure 8.)

Diagnosis: Shell large for genus, shape uncertain, finely costellate.

Material: A few incomplete specimens from two localities in the Lyons Group, Carnarvon Basin.

Description: A rather large *Streptorhynchus* is present in the Lyons Group, but insufficient material is available to determine its form or affinities. The shells are finely costellated, with pseudopunctae arranged along the costellae, giving a beaded effect in some exfoliated specimens.

One collection of specimens (CPC 1449, F.17542, F.17543) comes from near the top of the Group. The dimensions of CPC 1449 are: width about 4.5 cm. and length 3.8 cm.; and F.17542 is about 5.2 cm. in length and width. The pedicle valve appears to be flat. The costellae are about 10 in 5 cm. CPC 1449 is illustrated in Plate 12, Figure 8.

The other collection is very fragmentary and from lower in the Lyons Group. The specimens are of about the same dimensions as the others and similarly costellated. One irregularly convex pedicle valve F.17544 is 4 cm. wide and 3.5 cm. long.

Occurrence: CPC 1449 and F.17542-3 are from locality TP 79, about 1⅝ miles west of Cooracootharra Well, Williambury Station; Lyons Group, about 300 feet below top. F.17544-5 are from locality CC 125, 9,500 feet north-west of Coyango Well, Williambury; Lyons Group, about 1,750 feet below top of group.

Geological Age: Sakmarian.

Observations: Adequate knowledge of this species will have to await further collections. It is not possible to discuss its relationships with the succeeding species. No large *Streptorhynchus* is so far known from the Callytharra Formation, which lies above the Lyons Group.

STREPTORHYNCHUS sp. indet.

Included under this heading are two small brachial valves (ferruginized internal moulds) from the Nura-Nura Member of the Poole Sandstone of the Fitzroy Basin. Both are incomplete, but serve to indicate the presence of a species of *Streptorhynchus*. One specimen is 1.4 cm. long and 1.8 cm. wide, the other is slightly larger. Both are finely costellated.

Geological Age: Early Artinskian.

Observations: These two specimens are insufficient for discussion of their affinities.

Occurrence: F.17546, locality KNuA 1, about 4½ miles west of Mount Wynn Trig. Point, Fitzroy Basin; Nura-Nura Member of Poole Sandstone.

Genus KIANGSIELLA Chao (1927).

Type Species: Kiangsiella tingi (Grabau) 1924, Chao 1927.

Diagnosis: Plicate streptorhynchinids.

Discussion: Kiangsiella closely resembles *Streptorhynchus* in the internal structure of the pedicle and brachial valve. It is distinguished by the development of plication. The most important group of species, that including *Kiangsiella pectiniformis* (Davidson) and the new Western Australian species *K. condoni,* has a number of persistent features, which are, however, not generically diagnostic. The pedicle valve commonly displays an irregular lateral profile (*see* Plate 9, Figure 1b). The hinge-line is commonly auriculate; as in *Streptorhynchus,* the perideltidial lines are obscure; the interarea is variable in height and can be distorted. The maximum width is considerably greater than the hinge-line. The brachial valve is always strongly convex and can be sulcate; a pronounced median ridge is commonly present in the dorsal muscle field; the cardinal process is long and prominent; socket ridges are usually present; the dorsal area is narrow.

Kiangsiella condoni sp. nov. seems to be a large representative of the genus, attaining a width of 5.6 cm. and a length of 4.3 cm. The other species of *Kiangsiella* are somewhat smaller than this.

The plicated streptorhynchinids which are now referred to this genus may well be polyphyletic. Plication seems to be a late development in many orthotetacean stocks, and *Kiangsiella* has been recognized in Upper Carboniferous and Permian deposits in Asia, South America, and Europe.

The type species *Kiangsiella tingi* occurs in the Lower Permian Hsiaokiang Limestone of China. It is a finely costellated form with numerous pronounced rounded plications which begin about 14 mm. from the umbo on the ventral valve. The lateral ventral profile is fairly gently and evenly convex and the interarea low; the holotype of the species does not display ears, though Chao's figures suggest that abrasion is possible. Chao did not observe the brachial cardinalia. However, he claimed as a representative of his genus the plicated form *Streptorhynchus pectiniformis* Davidson, well represented in the Upper and Middle Productus Limestone of the Salt Range. Waagen's figures of *K. pectiniformis* show strongly plicated shells with streptorhynchinid internal features. The plications may be somewhat angular in section, commonly with a stronger costella occupying the troughs. The plications are usually somewhat less numerous than in the Chinese form. The cardinal process is strongly developed with the lobes deeply divided. The chilidium is reduced and divided; the dorsal area is narrow. The diverging socket plates extend on to the floor of the valve and the socket ridges are well developed. The cardinal apparatus is identical with that of *Streptorhynchus* (text-Figure 6a, b). Reed (1944) has recognized four varieties of *Kiangsiella pectiniformis* (Davidson) and a new species *K. compressa* in the Salt Range faunas. The genus is strongly represented in the Middle and Upper Productus Limestone beds, which are of Upper Permian (Kazanian-Tartarian) age. It would seem to have early

representatives in the Upper Carboniferous, notably *K. halliana* (Derby) of Middle Pennsylvanian age from Brazil. Individual shells of this species show a tendency to plication. *Kiangsiella pinguis* Chronic (1953) from the Lower Permian (Wolfcampian) of Peru has the diagnostic characters of the genus well developed.

Asian records of the genus include the Lower Permian Hsiaokiang Limestone and the Chihsia Limestone (Chao, 1927; Huang, 1933; Grabau, 1924). It is recorded in the mainly Upper Permian deposits of the Karakoram Range (Merla, 1934). A species from Indo-China referred to *Meekella* by Mansuy (1913) may belong to the genus (Reed, 1931). A plicated streptorhynchinid allied to *K. halliana* has been recorded from Lower Permian deposits of the Urals (Tschernyschew, 1902) and a species allied to *K. tingi* from the Permian of the North Caucasus of Russia (Licharew, 1932). In Western Europe the genus appears to be present in the Upper Permian Bellerophon Limestone of the Carnic Alps (Merla, 1931) and it is also recorded from Serbia. Nearer to Australia, Hamlet (1928) records *Kiangsiella pectiniformis* from the Permian deposits of Timor. She does not figure her examples.

Perideltidial lines could not be discerned with certainty in the Western Australian forms; they are not shown in figures published for other species. *Kiangsiella condoni* sp. nov. and the other species from Western Australia all seem allied to the Salt Range forms, but are older, being known mainly in beds of Artinskian age, with one inadequately known species in the Sakmarian. Three species are distinguished in the Western Australian faunas, but the collections are insufficient adequately to describe two of them.

KIANGSIELLA CONDONI sp. nov.

(Plate 9, Figures 1-7; Plate 10, Figures 1, 5, 6, 8, 9; Plate 18, Figure 1; text-Figures 12b, 13; Table 10.)

Diagnosis: Large species, maximum size 5.6 cm. wide and 4.3 cm. long, wider than long; pedicle valve unevenly convex and concentrically rugose, maximum convexity near the umbo, auriculate, pseudodeltidium wide and displaying a small anterior convexity in middle of front margin and growth lines; brachial valve strongly and unevenly convex, maximum nearer the hinge-line, sulcate, plication well developed, but tending to be obliterated on inner layers of the shell; muscle scars strongly impressed in both valves.

Material: Numerous weathered-out shells from the Coyrie Formation on Lyndon River, Carnarvon Basin. Many of the shells are crushed, but enough are uncrushed to enable the shape to be determined. The uncrushed specimens mainly occur in nodules, possibly phosphatic. Numerous internal moulds occur low in the Byro Group, south of the Gascoyne River.

Description: The holotype (CPC 1450) is figured in Plate 9, Figures 1a-d. This is a large uncrushed shell, largely exfoliated, and hence is partly an internal mould. The pedicle valve is strongly convex longitudinally and transversely and is wrinkled for about a third of the length from the umbo. Farther

forward the valve is transversely gently convex and nearly flat in longitudinal profile. The interarea is relatively narrow, apsacline and concave. The pseudodeltidium is exfoliated, but is curved to the left (in brachial aspect) and is flanked by two closely placed grooves on both sides, which correspond to the sides of the dental ridges. The cardinal angles are abraded, but probably originally had wing-like extremities. The brachial valve is strongly and irregularly convex in lateral profile with the maximum convexity nearer the hinge-line. It is less strongly convex transversely, with a gentle but distinct sulcus. The anterior margin is slightly sulcate. The posterior lateral flanks are slightly concave.

The surface of the shell is covered by somewhat irregularly spaced costellae which number about 7 in 5 mm. near the anterior margins. They are closer near the umbo. Superimposed on the costellae are gentle radiating plications, more pronounced on the lateral margins, where they involve about ten costellae. The largely exfoliated nature of this shell shows that each costella has along its axis a row of fine pseudopunctae, which appear to be very rare on the troughs. The pseudopunctae appear as tiny bosses on the surface of the mould (text-Figure 12b). Paratype CPC 1452 (Plate 9, Figure 2; Plate 10, Figures 6a, b, 1) is an incomplete brachial valve and portion of a pedicle valve. This shell is also uncrushed and displays the nature of the fasciculate plications very well. The plications are strongly pronounced on the outermost shell layers, with about nine to ten costellae in each at the front margin. They are rather angular in section. There is a stouter costella between each pair of adjacent plications and occupying the troughs. The shell-wall is thick, about 3 mm. maximum. The plications become less pronounced on the inner shell layers and are quite gentle on the internal surface. Furthermore, the external surface displays numerous pronounced crenulated growth lamellae. In longitudinal profile the brachial valve is strongly convex near the hinge-line and is slightly sulcate. The length is close to that of the holotype. Each plication expands to the front by intercalation of costellae.

The cardinal process of CPC 1452 is strong and long. It projects nearly at right angles to the commissural "plane". The specimen is somewhat exfoliated. At the hinge-line the structure is narrow, with a median groove which disappears further out. This portion is probably the remnant of the divided chilidium. About one-third of the length away from the hinge-line the diductor grooves appear, very faint at first, becoming pronounced towards the edge, where the structure becomes bilobed with small secondary lobes at the extremities. The diductor grooves are situated obliquely to the length of the process. There appears to be no median anterior ridge or swelling on the process. Laterally, the process is supported by socket plates which are not widely divergent but extend anteriorly out into the floor of the valve. The surface is somewhat damaged, but there is evidently a strong broad socket ridge which originates a little to the side of the cardinal process and extends radially out to form an extension of the free margin of the plate. A narrow area is

present, and a widely divergent notothyrium. Paratype CPC 1451 (Plate 9, Figure 5) is a complete shell rather foreshortened by crushing. The surface is strongly plicate, not as regularly as in CPC 1452. Each plication has about five costellae near the anterior margin and the single inter-plication costellae are not pronounced. This specimen displays small but distinct ears at the cardinal extremities of each valve. The interarea is flat to concave near the umbonal tip. The pseudodeltidium is convex in the middle, flatter on the sides. The lamellate growth-lines extend across the interarea and pseudodeltidium, arching towards the front in the median convex part of the latter. The flat lateral faces of the pseudodeltidium probably correspond to the bases of the broad but low dental ridges. No perideltidial lines could be detected. Paratype CPC 1453 (Plate 9, Figure 6) is a similarly crushed shell showing marginal wings at the hinge-line. The interarea lacks perideltidial lines, but longitudinal striation extends to the margin, possibly excepting an irregular strip near the lateral edge. The median convex part of the pseudodeltidium is somewhat flattened and the growth-lines bend towards the front. The divided chilidial plates of the brachial valve juxtapose with the curved front margin of the pseudodeltidium. Paratype CPC 1454 (Plate 10, Figure 9) is a shell with the slightly concave interarea at a higher apsacline angle than the other forms: it is nearly at a right angle with the commissural plane. The pedicle valve is not as strongly convex as in the holotype. A median fold is more evident in transverse section. The brachial valve has a strong median sulcus. Paratype CPC 1455 (Plate 9, Figure 4) illustrates a specimen with a high twisted area. The plicated surface is similar to the other crushed forms. The shape of the area appears to be original and not the result of crushing. Paratypes CPC 1456 and 1457 (Plate 9, Figures 3, 7) are other crushed shells. CPC 1457, crushed longitudinally, displays the cardinal wings.

Other specimens, not figured, associated with the holotype display the same general characters. F.17547 is a large crushed shell similar in size to the holotype. The fasciculated plications are rather narrower and more numerous. F.17548 includes a number of shell fragments which show that the pedicle muscle area is very strongly calloused with a strong marginal flange. Other fragments (F.17797) show that the fasciculate plications, even where very pronounced externally, tend to be less pronounced on the inner surfaces (text-Figure 13). In consequence adult shells do not show a zig-zag line of junction of the valves at their front margins. One shell fragment, however, does retain plication on the inner surface. F.17549 is a crushed shell with more pronounced cardinal wings than the other figured specimens. Many other specimens are available, some showing asymmetry of the cardinal wings.

A number of internal moulds are referred to the species. These are all from localities south of the Gascoyne River. Two of these are figured. CPC 1459 is figured in Plate 10, Figure 5a, b. This is a strongly convex and sulcate brachial valve. The brachial muscle scars in front of the socket plates are strongly developed and have a distinct median ridge. The plications are slight except near the shell margins.

Another, unfigured, specimen, F.17800, is a youthful brachial valve with long cardinal process and socket plates similar to paratype CPC 1452. It also has deep muscle scars and a median ridge in front of the socket plates. CPC 1458 (Plate 10, Figure 8a, b) is a pedicle valve internal mould. The plication and strongly developed muscle scar are well shown. A number of other moulds are also available.

Plate 18, Figure 1, illustrates a transverse section through the crushed and partly abraded shell of a specimen from the type locality. The part sectioned is towards the front. The internal obliteration of the plications is clearly shown. The pseudopunctae appear to be essentially outwardly directed conical flexures; no tubular or rodlike cores were observed in the sections examined. In plan view the pseudopunctae resemble those of *Streptorhynchus*; they are arranged linearly and are largely confined to the costellae (text Figure 12b).

TABLE 10.—DIMENSIONS OF K. CONDONI.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width W.	$\frac{W}{L}$	$\frac{W}{Lb.}$	Length of Hinge Line.	Height of Area.	Width of Delthyrium.
CPC 1450 ..	4.3	3.9	5.6	1.3	1.43	2.9+	1.0+	1.0
CPC 1451 ..	..	..	..	..	..	2.3	0.8	0.6
CPC 1453 ..	..	..	..	..	..	2.8	1.0	0.8
CPC 1454 ..	3.0	..	4.4 est.	1.46	..	2.4	0.8	..
CPC 1455 ..	..	..	..	..	..	2.1	1.4	0.6
F.17547 ..	4.3	..	5.6	1.3	..	..	..	..
F.17796 ..	2.5	..	2 3 (crushed)	..	..	..	..	..
CPC 1459 ..	..	3 3	4.3	..	1.33	..	..	..
F.17801 ..	..	4.2	6.0	..	1.43	..	..	..
CPC 1458 ..	3.5	..	4.1	1.16	..	..	..	..
F.17802 ..	..	3.2	3.9	..	1.22	..	..	..

Occurrence: CPC 1450, 1457, F.17547-8; locality ML 87—about 8½ miles bearing 82° from Mia Mia homestead, on north bank of the Lyndon River, between Burdghinmurrow and Salt Pools, Carnarvon Basin; lowest fossiliferous bed in Coyrie Formation in this area. CPC 1451-6, F.17549, 17796-8; locality ML 87, 20 feet stratigraphically above the holotype. CPC 1459, F.17799, F.17800, locality GW95, 10½ miles bearing 83° from Bidgemia Homestead (between M 25 and Wyndham Wells), Carnarvon Basin; red-brown calcareous siltstone mapped as Coyrie Formation. CPC 1458, F.6618 "Permian, east of Talbot's Cairn, Wooramel River"; this locality is low in the Byro Group. F.17802, 3, locality GW 54, 4¾ miles bearing 115° from Dairy Creek homestead, on south branch of Bush Creek; mapped as Coyrie Formation. F.17801,* locality WB 169, about 4¼ miles bearing 200° from Mount Madeline trig. point, Carnarvon Basin; this locality is in the upper part of the "Madeline Formation" (unpublished name) a formation at base of Byro Group in the Wooramel River area. Other localities near the Wooramel River are WB 179 and WB 51. Both these localities are low in the "Madeline Formation".

* J. M. Dickins (pers. comm.) states that F.17801 probably came from WB 179, and that *K. condoni* is restricted to the lower beds of the Madeline Formation.

Geological Age: Artinskian.

Observations: K. condoni is evidently related to the Salt Range group of species of the genus, described by Waagen (1884) and F. R. C. Reed (1944). Some specimens bear a considerable resemblance to some of Waagen's figures of *Kiangsiella pectiniformis* (Davidson), originally referred to *Streptorhynchus.*

The cardinal process is quite similar, though the Australian specimens are not as well preserved. The socket ridges of the Australian form are not as pronounced as in Waagen's Plate IV., Figure 10a, b, c. The grouping of the costellae of *K. condoni* is in some individuals like Plate IV., Figure 4b, with the stouter costella between adjacent groups of seven forming the plications. Also the longitudinal profile of the holotype of *K. condoni* resembles in its variable convexity Waagen's Plate IV., Figure 4c. Both species show distinct cardinal ears. Differences however are recognizable: *K. condoni* appears to be larger than most of Waagen's forms; the uneven convexity of the ventral valve holotype is greater; the obliteration internally of the plications by shell thickening appears to be a peculiarity of the Australian forms; as a result the front margin is not plicate, though the outer layers are; the area is higher and more irregular. However, the affinity with the Indian forms is evidently close and *K. condoni* might perhaps be regarded as a sub-species of *K. pectiniformis.* Reed (1944) recognized four new varieties of *K. pectiniformis* and if these are accepted, some of Waagen's specimens might be included under one or another of them. Two of the varieties, *pauciplicata* and *fissicostata,* are evidently distinct with their coarse deep plications. His varieties *fasciculata* and *latesinuata* do not appear to be very distinctive. He recognized also a new species *K. compressa,* which again is not very distinctive. All Reed's forms are from the Middle Productus Limestone: Waagen states that *S. pectiniformis* is common in the Upper Productus and more rare in the Middle Productus Limestone. The little known species *K. deltoidens* (Waagen) does not appear to be closely related.

The Australian form bears less resemblance to the type species *K. tingi.* That species lacks ears and has rounded plications, not displaying costellae of two orders of size. Most other Asian, Russian and European species that can be referred to the genus are inadequately described and figured for detailed comparison. *Kiangsiella hallianus* (Derby) (Dresser, 1954), of the Middle Pennsylvanian of Brazil, shows an incomplete development of plications and is not closely related. *Kiangsiella pinguis* Chronic (1953), of the Lower Permian (Wolfcampian) of Peru, has resemblance to both *K. pectiniformis* and *K. condoni.* It has ears and costellae of two orders of size, but is smaller and relatively longer than the Australian form. The plications tend to include more costellae. The cardinal process appears to be of the same general pattern with four lobes at its end.

None of the Western Australian specimens, nor apparently, where illustrated, the other species referred to this genus, shows well defined perideltidial lines. *K. condoni* displays a wide pseudodeltidium, flattened on either side.

This flat area probably corresponds to the base of the dental ridges as it probably does in Reed's species *K. pectiniformis* var. *fissicostata* (Reed, 1944, Plate V., Figure 11). The sinuous character of the front margin of the pseudodeltidium appears to be a peculiarity of *K. condoni*.

The holotype and paratype specimens of *K. condoni* described here were collected from silty beds formerly regarded as low in the Bulgadoo Formation (Condon, 1954) but now placed in the Coyrie Formation (Condon, personal communication). Most of the shells are crushed. The irregular interareas suggest that the species was an attached form, but no specimens actually showing attachment are available and the holotype is more or less symmetrical. Associated is a rich variety of brachiopods, and rare bryozoa and crinoids. The specimens collected from south of the Wooramel River are all from beds low in the Byro Group, i.e., from the Coyrie Formation or the Madeline Formation, which are of approximately the same age (fide J. M. Dickins).

The species is named in honour of Mr. M. A. Condon, who collected some of the specimens described in this report.

KIANGSIELLA sp. cf. K. CONDONI.

Material: Shell fragments in tough fossiliferous limestone in Noonkanbah Formation.

Description: From locality KNA 28, several pieces of shell indicate the presence of a large plicated streptorhynchid. The size of costellation and of the plication is similar to specimens of *Kiangsiella condoni* from the Carnarvon Basin. The largest of these specimens (F.17806) indicates that the shell was considerably more than 4 cm. long.

Occurrence: F.17804-6, locality KNA 28, from a section in Noonkanbah Formation, south of Grant Range, beginning at 8 miles, bearing 120° from Mount Anderson Station, Fitzroy Basin, 905 feet above base of section.

Geological Age: Artinskian.

Observations: This identification is tentative as the material is fragmentary.

KIANGSIELLA sp. A.

(Plate 10, Figures 2a, b; 3a, b; 4.)

Material: Several incomplete valves, embedded in tough gritty calcareous greywacke rich in fragments of brachiopods and bryozoa (fenestellids); Lyons Group, Carnarvon Basin.

Description: The presence of *Kiangsiella* in the Lyons Group is indicated by a few rather inadequate incomplete valves. One specimen CPC 1460, a sulcate brachial valve, is figured in Plate 10, Figures 3a, b. Part of the ornament is preserved. The valve appears to be relatively long, length 2.2 mm., estimated width 3.2 mm., with a nearly straight lateral margin which makes an angular junction with the front margin. The surface is finely costellate, with costellae in fasciculate arrangement into gentle plications. At the margin

there are up to five costellae in each plication with a stouter costella between plications. Sinuate growth lamellae are present. The surface resembles some specimens of *Kiangsiella condoni,* e.g., Plate 10, Figures 1, 6a, but the plications are less pronounced and have fewer costellae. The costellae number about 12 in 5 mm. at the anterior margin. CPC 1461 is figured in Plate 10, Figures 2a, b. This is the external surface of a sulcate brachial valve showing little sign of plications; it is 2.9 mm. in width. CPC 1462 (Plate 10, Figure 4) is part of the inside of a pedicle valve. The plications are gentle, but can be clearly seen to be diagonal to the costellae near the anterior margin. The costellae number about 14 in 5 mm. at the anterior margin. F.17807 is an exfoliated brachial valve, 2.1 mm. wide at the hinge-line. Another dorsal valve, F.17808, is 4.2 cm. wide, 3.1 cm. long and has strong short divergent socket plates.

Occurrence: All specimens from locality GW 62, 3½ miles bearing 65° from Coondoo Well, Arthur River Station, Carnarvon Basin; Lyons Group, above a boulder bed, from fairly low in the Lyons Group in this area, within lower third of the Group.

Geological Age: Sakmarian.

Observations: This species seems to be distinct from *K. condoni,* but insufficient material is available to describe it adequately. It is from one of the characteristic calcareous fossiliferous beds of the Lyons Group. Associated with this species are other incomplete brachiopods and bryozoa.

KIANGSIELLA sp. B.

(Plate 10, Figure 7, 10, 11; Plate 9, Figure 8.)

Material: Numerous incomplete valves and impressions from calcareous beds in upper half of Noonkanbah Formation, Fitzroy Basin.

Description: In a number of collections from beds in the upper half of the Noonkanbah Formation are indications of the presence of a small to moderately sized plicate streptorhynchid. Most of this material is incomplete or fragmentary. It is hardly sufficient to diagnose the characters of the species or to ascertain if more than one form is present. Several specimens are figured and the occurrence of the others is listed below. One group of specimens occurs in a thin bed very high in the type section of the Noonkanbah Formation, west of Bruten's Yard. This group comprises specimens CPC 1463, 1464, and F.17809-12 and several fragments. CPC 1463 (Plate 10, Figure 11) is a pedicle valve of average size for the specimens from the bed. The valve is flat to slightly concave with numerous small plications each including four or five costellae, which are angular in section and number 19 to 20 in 5 mm. near the anterior margin. The lateral plications include six or seven costellae. The several strong lamellate growth lines show a median concavity in outline towards the front margin. The shell is thick. Internally, it has the streptorhynchid lack of strong dental lamellae and septum. CPC 1464 (Plate 10, Figure 10a, b) is a smaller brachial valve. It is very gently convex and slightly sulcate. The surface is exfoliated; plications are present only on the lateral margin. Costellae

number 7 to 8 in 5 mm. in the lateral plications, 3 to 4 in the middle of the shell; a more pronounced costella flanks each plication. This detail is reminiscent of *Kiangsiella condoni.* Each costella has a single row of small pseudopunctae which form a beaded appearance. F.17810 is a similarly sized, more convex, sulcate brachial valve. F.17811 shows a much corroded long cardinal process at right angles to the commissural "plane".

Dimensions:

Specimen No.	Width of Shell.	Length of Pedicle Valve.	Length of Brachial Valve.
	Cm.	Cm.	Cm.
1463	3.4	2.4	..
1464	2.5 est.	..	1.5
17809	3.1	2.5	..
17810	2.5	..	1.7
17811	..	..	2.5

These specimens are associated with a rich fauna of brachiopods and some bryozoa, crinoids (*Calceolispongia*), and a trilobite. A lower bed in this section contains an internal mould F.17813. This form is a little larger than the above; it is 3 cm. long and 3.9 cm. wide. Its profile is very similar to the holotype of *K. condoni,* though the brachial valve is much less convex. The palintrope is concave with a broad pseudodeltidium. CPC 1465 (Plate 9, Figure 8) is an incomplete flat pedicle valve from 745 feet above the base in the Bruten's Yard Section. This specimen was collected with numerous specimens referred to *Streptorhynchus crassimurus* and may possibly be an unusual variant of that species. The plications are present on the anterior part of the valve. Fragments of a *Kiangsiella,* smaller than those above, also occur at 1,760 feet from the base of the Noonkanbah section, south of Grant Range, e.g. F.17814.

Other examples are known from isolated localities, e.g. CPC 1466 (Plate 10, Figure 7). This is a small slightly convex pedicle valve with irregularly sized plications. Slightly larger specimens showing strong, irregular plications are also known from the Noonkanbah Formation, of uncertain level, in the Bruten's Yard area.

Occurrence: CPC 1463, 1464 and F.17809-12, locality KNF 88, 2.6 miles at 310° from Bruten's Old Yard, Cherrabun Station; 1,230 feet above base, about 57 feet below top of Noonkanbah Formation type section. CPC 1465, from 745 feet above the base in the same section. F.17813 from locality KNF 86, in the same section at about 650 feet above the base. F.17814, locality KNA 35, Noonkanbah Formation section, 8½ miles south-west of Mount Anderson Homestead, 1,760 feet above base of formation. CPC 1466, locality GG 2, 8 miles at 188° from "Gogo" Homestead. Noonkanbah Formation, horizon uncertain.

Geological Age: Artinskian.

Observations: The forms included here are evidently distinct from *K. condoni* but are insufficient in number to be certain whether only one species is present and if so, how much it varies; for the same reason they cannot be compared with other species.

Subfamily DERBYIINAE Stehli (1954).

Diagnosis: Schuchtertellidae in which there is a well developed median septum in the pedicle valve, no spondylium, brachial valve with the socket (crural) plates not recurved.

Discussion: The subfamily is discussed in pages 17 and 20. Four genera have been referred to it by Stehli (1954):—*Derbyia* Waagen, *Plicatoderbyia* Thomas, *Derbyaeconcha* Licharew, and *Grabauellina* Licharew. Only *Derbyia* and *Plicatoderbyia* are adequately known. Both possess a simple uniseptum and lack any form of spondylium. The cardinal process and supporting plates of the brachial valves are of similar type to that of *Streptorhynchus* (text-Figure 6c, d). *Plicatoderbyia* Thomas, 1937, type species *P. magna* (Branson) appears to have internal features like *Derbyia,* but is plicated. It is a rather rare Upper Permian genus known from the Upper Phosphoria of Wyoming (Branson, 1930), from the Middle and Upper Productus Limestone of the Salt Range (Reed, 1944), and possibly from Japan (Hayasaka, I. & S., 1953) though the Japanese species might be better referred to *Meekella. Plicatoderbyia* is probably polyphyletic. *Derbyaeconcha* Licharew 1934, type species *D. anomala* (Licharew) is less well known. Licharew (1934) separated it from *Derbyia* apparently on the criterion that the pedicle valve is more convex than the brachial. It has been identified only in the Permian deposits of the North Caucasus.

Grabauellina Licharew, 1934, type *G. mongolica* (Grabau) 1931, from the Jisu Honguer beds of Mongolia, is inadequately known. The genus was named *Derbyina* by Grabau 1931; this name was a synonym. The solitary exfoliated monotypical specimen appears to be uniseptate, without spondylium. It may not be an orthotetacean at all; the area appears to be high and the pseudodeltidium very wide.

The subfamily is represented by a single determinable species in Western Australia.

Genus DERBYIA Waagen (1884).

Type Species: Derbyia regularis Waagen (1884).

Diagnosis: Non-plicate Derbyiinae, pedicle valve with well developed uniseptum in contact with pseudodeltidium near umbo; dental ridges either flank septum or meet it at posterior end; socket plates extend forward on to floor of valve and possess well developed socket ridges.

Discussion: The type species was formally designated by Girty in 1909. The genus *Derbyia* has subsequently been widely used to include species showing the above group of characters. Waagen in his original descriptions had intended

the genus to embrace septate orthotetaceae either with or without a spondylium. The former he designated the "camerate" division and the latter the "septate". However, he referred all his Indian species to the septate division. Girty (1909) referred the "camerate" to the genus *Orthotetes*, the description of which, by Fischer in 1850, Waagen had misinterpreted.

Since Girty's excellent analysis *Derbyia* has been used to designate many species from the Upper Carboniferous and Permian. The Pennsylvanian species described by Dunbar and Condra (1932), for example, clearly display the above group of features; they are also found in such Permian species as *Derbyia grandis* Waagen and *D. cymbula* Hall and Clarke. Recently Sokolskaia (1952, 1954) has redescribed *Orthotetes* Fischer. She shows this genus to have a small cardinal process with recurved socket plates. The spondylium may be quite small and obliterated in the adult stage. She refers *Derbyia regularis* to *Orthotetes* and thus makes *Derbyia* a synonym. It does not appear that Sokolskaia re-examined the types of *D. regularis* but identified one of her Moscow forms as this species.

It seems quite evident that such species as *D. grandis* Waagen or *D. cymbula* Hall and Clarke are quite distinct from *Orthotetes radiata* Fischer. They differ markedly in the cardinal process (text-Figures 6a, b and 3) and lack spondylia. Waagen's figures of the cardinal process of *Derbyia regularis* are not entirely clear and he was not able to observe the umbonal part of the septum and associated structures. Hence *D. regularis* was an unsatisfactory choice for the type species, which Waagen had not named. *D. grandis* Waagen is quite clear and displays the features which Girty and later authors have understood for the genus. Some specimens of *D. cymbula* Hall and Clarke show an additional socket ridge on each socket plate, e.g. silicified specimens from the Speiser Formation of Kansas.

Re-examination of the holotypes of *D. regularis* is needed. If it should prove that the cardinal process differs markedly from *D. grandis*, it would be desirable to apply for a suspension of the Rules of Zoological Nomenclature, in order to retain the name *Derbyia*, which has been widely recognized, used in the sense outlined here, by numerous authors, notably Licharew, Dunbar and Condra, Cloud, Chronic, Koslowski, Reed, Stehli, and Dresser. It may be noted here that Tschernyschew (1902, p. 577-578 and Figure 54) claims that specimens of *D. regularis* from the Lower Productus Limestone showed the septum in contact with the deltidium at the umbo. This would preclude a spondylium. *Derbyia* is recorded many times from the Lower Carboniferous to the Permian. The Lower Carboniferous and some Upper Carboniferous references are unsatisfactory since the cardinalia are not recorded. I. Thomas (1910) has described *D. hindi* and *D. gigantea* from the Millstone Grit of England. The latter is a large septate form but the cardinalia are not recorded. The same is true of *D. subaequalis* Reed, 1954, from Scotland and of *D. ambigua* Muir-Wood (1931) from the Tuedian beds of North Cumberland. Demanet (1934) has described *D. depressa* and *D. gigantea* from the Dinantian of Belgium, again without recording the cardinalia. Demanet (1943) records

D. hindi in the Westphalian of Belgium. Sokolskaia (1954) referred *D. hindi* to *Orthotetes*. The German records from the Lower Carboniferous, by Gallwitz (1932) and Paeckelmann (1930), are insufficiently described and may be of some other genus.

The genus is well developed in the Pennsylvanian of the United States (Dunbar and Condra, 1932) and in the Middle Pennsylvanian of Brazil (Dresser, 1954; Duarte, 1937). It is possibly present in the Upper Carboniferous of North China (Ozaki, 1931). The genus is fairly widely distributed in the Permian of North America, notably in Kansas and Texas, New Mexico, Arizona and Mexico (Girty, 1909; King, R. E., 1937; Cooper, 1953; Stehli, 1954). It is known from the Lower Permian of Peru and Bolivia (Chronic, 1953; Koslowski, 1914; Dunbar and Newell, 1945). Asian Permian references include the Lower to Upper Productus Limestones of the Salt Range (Waagen, 1884; Reed, 1944), Chitral (Reed, 1925) and possibly the Ku-un Lun Range (Renz, 1940), the Upper Permian of the Karakoram Range (Merla, 1934) and the Upper Permian Zewan Beds of Kanaur and Spiti (Diener, 1915), the Upper Permian Jisu Honguer Beds of Mongolia (Grabau, 1931), and the Lower Permian Chihsia beds of China (Chao, 1927), though this form appears to be related to *Ombonia*. Russian localities include Cape Kalouzin (Fredericks, 1924), the North Caucasus (Licharew, 1932) and the Urals and Timan (Tschernyschew, 1902) and probably Novaya Zemlya (Licharew and Einor, 1939). *Derbyia* is present also in the Upper Permian of Greenland (Dunbar, 1955). The genus is not known in the German or English Permian; it is probably present in the Lower Permian of the Carnic Alps (Schellwien, 1892; Metz, 1936) and doubtfully in the Sosio beds of Sicily (Gemmellaro, 1892), and is recorded in Yugoslavia. These records are not all of equal value; in some cases it can only be said that a septate orthotetacean is present.

The pedicle valve in *Derbyia* varies in convexity, and commonly is wrinkled. The interarea in most species is high. The dental ridges in some large species are several millimetres high but never reach the floor of the valve (text-Figure 4c). The brachial valve is always convex, in some species sulcate; the area is always low or missing and the chilidium small and divided (text-Figure 6d).

Some of the Permian species attain large dimensions: *Derbyia grandis* Waagen measures as much as 11.9 cm. wide and 11.6 cm. long.

The genus is represented in Western Australia by one determinable species and some fragments.

DERBYIA HARDMANI sp. nov.

(Plate 5, Figures 5, 6, 7, 8, 9; Plate 18, Figure 6; Plate 19, Figure 2; Table 12.)

Diagnosis: Large shell, maximum 7.8 cm. long, 5.7 cm. wide; pedicle valve flat to gently convex, interarea low to moderate in height, brachial valve gently convex in lateral and transverse profile, non sulcate and oval in outline; surface with fine costellae (12 in 5 mm.) and concentric wrinkles, cardinal process stout and with projecting socket ridge.

Material: All the available material comes from beds at Mount Hardman, Fitzroy Basin, Western Australia, in the topmost beds of the Liveringa Formation. The forms described, except one, were collected from a 4-foot bed. They consist of partly weathered pedicle valves (two specimens), one brachial valve complete, one brachial internal mould with adherent shell, one isolated cardinal process.

Description: D. hardmani is based on a rather small but very distinctive collection. The holotype is a pedicle valve, CPC 1467 (Plate 5, Figures 5a, b, c, d). This valve is incomplete, with strong concentric wrinkles, and was probably convex in complete lateral profile. The surface is marked with fine even costellation. The interarea is rather low—its maximum height is 9 mm.—flat and apsacline at about 50° to the posterior surface of the valve. At the posterior lateral flanks the valve is convex. The pseudodeltidium is slightly convex and about 6 mm. wide at the hinge-line. The perideltidium can be readily discerned.

Removal of matrix near the umbo revealed that the septum is in contact with the pseudodeltidium for 2 to 3 mm. near the apex. The dental ridges are elevated and join the septum slightly asymmetrically close to the apex. There is no sign of a spondylium. The maximum height of the dental ridges is about 2.5 mm. They extend into pointed teeth, continuing about 1.1 mm. beyond the hinge-line. Muscle details are unknown. The septum is at least 1.3 cm. in length. Paratype CPC 1468 (Plate 5, Figure 6) is a larger pedicle valve. It is nearly flat in lateral profile with broad gentle concentric wrinkles. On the posterior lateral flanks, the surface is strongly convex; as a result the median part of the shell is concave in posterior transverse profile. The surface is covered with fine even-sized costellae which multiply by intercalation. They are rounded in cross-section; the troughs are about the same width. The costellae number 11 to 12 in 5 mm. at 5 cm. mesially from the umbo. The lateral and anterior margins are convex. The interarea is flat, apsacline at 55°, and rather low—9 mm. near the middle. The apical angle is very wide. The pseudodeltidium is missing and the perideltidium is obscured. Exfoliated shell layers near the umbo indicate the absence of a spondylium. The septum is at least 2 cm. long. Paratype CPC 1469 is a large brachial valve (Plate 5, Figure 7a, b, X ½). The valve is largely exfoliated with traces of fine costellation. It is entirely and rather gently convex, evenly in transverse profile, and slightly unevenly in lateral profile with maximum curve nearer the umbo. The outline is gently convex at the lateral and anterior margins. The cardinal process is obscured, but is massive and slightly larger than the isolated process (Plate 5, Figure 9a, b). There appears to be a narrow area. Costellae number 11 to 12 in 5 mm. at 5.5 cm. from the umbo. CPC 1470 is a portion of a pedicle valve with strong step-like wrinkles near the anterior margin. The outermost wrinkle has a lamellate edge. A transverse section (Plate 18, Figure 6), was prepared from this specimen. Paratype CPC 1471 (Plate 5, Figure 9a, b) is a stout isolated cardinal process. The two lobes are deeply grooved on the posterior side and lack any median ridge on the anterior side. The

socket plates are strong, with a pronounced radial extension corresponding to and also in front of the well-developed socket ridge. The chilidial plates cannot be clearly made out because of exfoliation. This process evidently comes from an individual smaller than CPC 1469. It bears a striking resemblance to Waagen's figure (Waagen, 1887, Plate LIII, Figure 5a, b, c) of *Derbyia grandis* Waagen from the Upper Productus Limestones of the Salt Range. CPC 1472 (Plate 5, Figures 8a, b) is an incomplete brachial internal mould showing a similar profile to CPC 1469, though smaller. It has four rather pronounced but rounded concentric wrinkles. Part of the shell adheres near the hinge-line. The socket plates are divergent and continue towards the front as ridges flanking the sides of the muscle scars, which are well developed. In the muscle scar a small median ridge is present, which widens towards the front.

Pseudopunctae are not evident in exfoliated specimens in plan view; but in transverse section inwardly directed conical flexures are present, though not invariably, on the inner parts of the shell. Plate 18, Figure 6 (CPC 1470) and Plate 19, Figure 2 (CPC 1537), illustrate these features.

TABLE 11.—DIMENSIONS OF D. HARDMANI.

(Dimensions in cm.)

Specimen No.	Length.	Length of Brachial Valve Lb.	Width W.	W / L.	W / Lb.	Width of Hinge Line.
CPC 1467 ..)	5.7	..	7.8 est.	1.37	..	6.5 est.
Growth .. .. }	2.1	..	3.2 est.	1.53	..	..
Stages .. ..)	3.8	..	6.0 est.	1.58	..	..
CPC 1469	..	7.3	9.2	..	1.26	..

Occurrence: CPC 1467-71, CPC 1537 are from locality KLB 11, Mount Hardman, Fitzroy Basin. CPC 1472 is also from Mount Hardman, but stratigraphically about 60 feet lower. KLB 11 collection was made in 4 feet of beds about 130 feet below the top of the Hardman Member of the Liveringa Formation.

Geological Age: Upper Permian (probably Tartarian).

Observations: This species evidently has affinities with the Salt Range group of species of *Derbyia,* notably *Derbyia grandis* Waagen. The massive cardinal process is very similar to Waagen's figures for *D. grandis.* The species is, however, smaller and less irregular and the ventral valve flatter than in *D. grandis.* The costellae of *D. hardmani* are finer than in any of the Indian species. The species is distinguished from *D. regularis* in having a less convex pedicle valve and in the proportions of the cardinal process. *D. regularis* resembles *D. hardmani* in being rather gently wrinkled and in general proportions. *D. hardmani* has a much wider apical angle than any of the Indian species. The other Indian species, e.g., *D. altestriata* Waagen, *D. hemisphaerica, D. vercherei* Waagen, all differ significantly in form, as do the Indian varieties and species described by F. R. C. Reed (1944 and earlier); *D. buriensis* Reed

has a somewhat similar general form, but has coarser costellae. The internal details, particularly of the brachial valve, of many other species referred to *Derbyia,* are unknown. Exceptions are the American Upper Carboniferous and Permian species described by Dunbar and Condra (1932), King (1930), Dresser (1954), Koslowski (1914), Cooper (1953), Stehli (1954) and others. Some of these have a general resemblance, but the cardinal processes never seem to be as massive and in some are long and delicate.

Derbyia hardmani is known only from the beds at Mount Hardman. It is found with a rich variety of well-preserved brachiopods, bryozoa and some large pelecypods. The bryozoa and fine-spined brachiopods (*Aulosteges* and *Waagenoconcha*) are evidently near their position of growth. The beds consist of silty fine-grained grey-brown sandstone, partly calcareous. Associated with the large form are small *Streptorhynchus* cf. *pelargonatus* (Schl.).

DERBYIA? sp. A.

A cardinal process, F.17816 from the Coolkilya Greywacke in the Kennedy Range, Carnarvon Basin, although incomplete appears to have features like those of *D. hardmani.* It is a stout process without median anterior ridge. The socket ridge resembles *D. hardmani* in that it forms an outwardly directed process on the socket plate, which is not recurved as in *Permorthotetes callytharrensis.*

The valve has a low dorsal area. It is possible that the fine-ribbed specimen F.17859 referred to *Permorthotetes teicherti* sp. nov. from near Birdrong Spring, in the Coolkilya Formation, should be associated with this cardinal process in the genus *Derbyia.* No other specimens are available despite extensive collecting in the formation. At the same locality specimens of *Streptorhynchus johnstonei* were collected.

Occurrence: F.17816, locality ML 117, about ¾ mile south of Southern Cross Bore, Middalya Station; Coolkilya Greywacke, at 345 feet above the base of the formation type section.

Geological Age: Late Artinskian to early Kungurian.

Observations: The presence of this cardinal process in the Coolkilya Greywacke gives *Derbyia* a known range in Western Australia of early Kungurian to late Upper Permian.

It is possible that other specimens of *Derbyia* are available in collections, but without knowledge of the internal details it is not possible to identify them.

Subfamily: DERBYOIDINAE subfam. nov.

Diagnosis: Septate schuchertellidae, with recurved socket plates in the brachial valve.

Discussion: This new subfamily is discussed on pp. 20-22. The new Western Australian genus *Permorthotetes* possesses a secondary spondylium, but this is most probably not a structure of subfamily diagnostic importance.

The other genera which are provisionally included in this subfamily are *Tapajotia* Dresser and *Derbyoides* Dunbar and Condra. Both these genera are septate, with recurved socket plates, and possess well-developed chilidia and dorsal areas. The brachial cardinal apparatus in both resembles that of *Schuchertella* Girty.

The chilidium in *Permorthotetes* is smaller and divided; otherwise the socket plates and dorsal area are similar to those of *Derbyoides* (see text-Figure 5a, b, c, d). A postulated line of descent is shown in text-Figure 7. *Permorthotetes* is common in Western Australia. Six species are described in this bulletin.

Genus PERMORTHOTETES gen. nov.*

Type Species: Permorthotetes callytharrensis sp. nov.

Diagnosis: Non-plicate Derbyoidinae, pedicle valve with uniseptum and low dental ridges forming a secondary spondylium, perideltidial lines well developed; brachial valve with an area, chilidium small and divided, socket plates recurved on the posterior surface.

Discussion: A group of species with the above diagnostic features forms an important element in the Western Australian faunas. The most striking features of these species is the secondary spondylium and septum of the pedicle valve (text-Figure 4a). Serial sections of the umbonal region of the type species (Plate 20, Figures 2a-m, Plate 18, Figure 3) shows three discrete elements, the two dental ridges and the septum. In the early stages these are separate, but as the shell increases in thickness the three plates become joined together by shelly material. In the type species, the secondary spondylium is usually fairly small and may be asymmetrical. In some species, notably *P. camerata* sp. nov., it is large and is as long as the pseudodeltidium (Plate 6, Figure 1a).

The brachial cardinalia are very characteristic (text-Figure 5a, b; Plate 4, Figures 2a, 6a-c, 7a, b; Plate 1, Figures 3, 4). The brachial area and socket plates, recurved on the posterior surface, resemble *Derbyoides* Dunbar and Condra and to some degree *Schuchertella* Girty (text-Figure 5c, d, g). The chilidium is, however, divided and reduced though still usually visible.

The chilidium seems to be somewhat variable in preservation and cannot be recognized clearly in all specimens. An anterior median ridge is in some specimens present on the cardinal process, and some specimens show traces of a narrow median posterior ridge analogous to that of *Derbyoides, Schuchertella,* and *Tapajotia.* Ridges of both these types appear to be quite variably developed in the Orthotetacea within a single species.

Well preserved specimens of *P. callytharrensis* and *P. lindneri* show the chilidial plates extending on to the socket plates at the sides of the cardinal process. A similar development is present in *Derbyoides* (text-Figure 5a, c). The socket plates may extend forward and partially flank the muscle areas.

* See footnote, p. 20.

The combination of secondary spondylium and specialized cardinalia appears to separate the Western Australian species from any described genus, except possibly *Orthotetes* Fischer emend. Sokolskaia. As discussed above, this genus has been interpreted by authors as having a primary spondylium like Ombonia, and unfortunately Sokolskaia (1952, 1954) has not settled this point. She states, however, that the spondylium may be obliterated by growth of shell callus. Her figures of the dorsal cardinalia of *Orthotetes radiata* are reproduced in text-Figure 3. These have some resemblance to *Permorthotetes* though the chilidia appear to be smaller; the posterior aspect is not well illustrated.

The existence of this genus outside Western Australia is not known with certainty. However, re-appraisal of a number of septate species in Permian and Carboniferous rocks may lead to its recognition elsewhere. In many cases where a spondylium is recorded the associated cardinalia are not described. For example Hamlet (1928) mentions that a shell from the Permian of Timor which she refers to "*Orthotetes crenistria* var. *senilis*" has a septum and spondylial structure. This is, however, neither figured nor adequately described and the brachial internal features are unknown.

A number of Carboniferous septate species have been referred to *Orthotetes* primarily on the presence of spondylia. In none of these is the spondylium sufficiently well figured to establish the spondylium as of primary or secondary type. "*Orthotetes*" *keokuk* Hall and "*Orthotetes*" *kaskaskiensis* McChesney, of the Mississippian, possess small variable spondylia which may be of the secondary type. They are described by Weller (1914) and Hall and Clarke (1892). However, the socket plates of *O. keokuk* are very short and therefore of different pattern from *Permorthotetes callytharrensis*. *Orthotetes cantrilli* Thomas (1910) from the early Westphalian (Ammanian) of England is likewise not sufficiently described in the spondylial region and the cardinal process is not known. The details of the spondylium and the cardinal process are not known for the Pennsylvanian species "*Orthotetes*" *mutabilis* Girty from the Wells Formation of Idaho.

Some Permian references may be mentioned also. Licharew's figures of an unnamed species from the Urals (Licharew, 1931, figure 2) show a spondylium of the secondary type. He does not refer to the cardinalia. "*Derbyia*" *dorsiplana* Diener from the (probably) Lower Permian Fenestella Shales of Kashmir is figured by Diener (1915) as possessing a small spondylium in the beak, but its structure is not described in detail. Reed (1934) states that a specimen which he names *Orthotetes* cf. *capuloides* Waagen, from the Anthracolithic Beds of the Shan States, possesses a spondylium, which he does not illustrate. Waagen referred this Salt Range species to *Streptorhynchus*. The possession of a secondary spondylium in a species need not imply close relationship as it seems likely that it could be formed independently in various septate schuchertellid stocks. K. Campbell has recognized an orthotetacean genus possessing such a secondary spondylium in the Lower Carboniferous rocks of

New South Wales (personal communication, 1955).* The pedicle valve in the various species of *Permorthotetes* varies in convexity; some are gently concave to flat, others are gently convex. The brachial valve is always convex and can be sulcate. Some species reach considerable dimensions: *P. callytharrensis* attains a width of 8.6 cm. and a length of 6.1 cm.; *P. camerata* attains a width of 9.0 cm. and a length of 7.8 cm.; and *P. teicherti* attains a width of 9.5 cm. and length of 7.3 cm.

The Western Australian species are evidently all related. *P. camerata* is distinguished by its widely spaced costellation. The others, all with fine costellae, are distinguished by peculiarities in shape, proportions, convexity, size, symmetry, thickness of shell and tendency to formation of callus, length of septum and spondylium, &c. As all these qualities are variable, the species are difficult to define briefly. The species distinguished are from beds well separated, stratigraphically and geographically. Six named species are described. Other species are indicated also by fragmentary collections.

Permorthotetes callytharrensis sp. nov.

(Plate 4, Figures 1-8; Plate 5, Figures 1-4; Plate 6, Figure 6; Plate 18, Figures 3-5; Plate 20, Figure 1a-k, 2a-m; Table 12.)

Diagnosis: Large thin-walled species, maximum size 9 cm. wide and 6.5 cm. long, wider than long with ratio decreasing with growth, maximum width at about half of shell length in most specimens; pedicle valve in most specimens convex, in a few nearly flat; internally with short septum less than one-third of shell length; secondary spondylium short and symmetrical; brachial valve unevenly convex with maximum in most specimens nearer hinge-line, sulcate, cardinal process long in large forms; costellae fine, 9 to 10 in 5 mm., rugae strongly developed in many specimens.

Differential diagnosis: P. callytharrensis is larger, has a straighter front margin and longer cardinal process, and is less symmetrical than *P. lindneri.* The pedicle valve is much more convex and irregular than in *P. teicherti.* The shell is thinner and the secondary spondylium more pronounced than in *P. guppyi.* The apical angle is not as wide as in *P. crespinae* and the valves are not equidimensional.

Material: Numerous moulds and external casts from the type locality G202, Carnarvon Basin, and numerous isolated valves and portions of shells from other localities in the Callytharra Formation.

Description: Although *P. callytharrensis* is abundantly represented in the Callytharra Formation, complete shells are rare in collections. All the features can rarely be seen in a single specimen. The holotype (CPC 1473) illustrates certain features of the species; it is an internal mould of part of a medium-sized pedicle valve (Plate 4, Figure 1a-d). The growth-lines and pronounced concentric wrinkles are well shown. This valve is irregularly convex in lateral profile; the profile from umbo to first wrinkle is slightly concave. The interarea

* See footnote, p. 20.

is apsacline and flat. Plate 4, Figures 1b, c, show the nearly symmetrical secondary spondylium and rather short septum, less than one-third of the reconstructed length of the valve.

Paratype CPC 1475 is a medium-sized incomplete pedicle internal mould, of larger size (Plate 4, Figure 4, a latex impression). This valve is irregularly flat, with a septum and part of the short spondylium preserved. The flat interarea was nearly at right angles to the surface of the valve which was slightly convex near the umbo. The muscle scar is well developed with its posterior margin just anterior to the spondylium. The internal surface of the pseudodeltidium has a slight median ridge. CPC 1485 (Plate 4, Figure 5) is portion of a ventral external impression which has a nearly flat interarea approximately at right angles to the ventral surface. Other broken specimens show that the posterior lateral marginal flanks can be very convex. Another medium-sized pedicle internal mould is CPC 1477 (Plate 4, Figures 3a, b). This valve is irregular, convex in lateral profile and on the left lateral flank but slightly concave on the right flank, viewed from the pedicle side. The septum is 1 cm. long, about a quarter of the shell length. Muscle scars are very faint. The maximum width is just in front of the hinge-line.

A number of moulds illustrate the features of the brachial valve. The lateral profile is unevenly convex, usually not wrinkled; paratype CPC 1474 shows a rather angular change of convexity in lateral profile (Plate 4, Figures 2a, b). There is usually a slight sulcus. The flanks are convex except near the posterior lateral margin where there is a slight concavity. The convexity may be rather gentle, and in a few specimens the maximum convexity is anterior to the midlength, e.g., F.17817, a juvenile specimen. In outline the shells show convex lateral, and gently convex, straight, or concave anterior margins with the maximum width anterior to the hinge-line.

Surface details are available in only a couple of specimens from the type locality; F.17823, an impression of a brachial exterior, shows that the costellae are rounded with wider troughs and number 9 in 5 mm. near the centre line at 4.5 cm. from the dorsal umbo. Their size does not vary over the surface and they increase by intercalation in two or three generations. Faint concentric growth-lines are present. The concentric wrinkles, pronounced on many pedicle valves, are rather gentle on the brachial valves.

The pedicle valve internal mould (CPC 1477, Plate 4, Figure 3a) shows that the costellae (in this case the impressions of the internal ribbing), vary slightly with the convexity of the valve. At about 3 cm. from the umbo they number 8 in 5 mm. on the convex left flank and 6 in 5 mm. on the slightly concave right flank. Latex impressions of cardinal processes were obtained from several of the moulds (Plate 4, Figures 7a, b; 6a, b, c). The processes are short, with two diductor muscle grooves on the posterior side and a very faint median ridge between. No median lobe or ridge is present on the anterior side, in the paratypes. The process is supported by well-developed widely diverging socket plates which have an outwardly

directed extension and upturned marginal lips and continue on the floor of the valve as slight ridges flanking the faint muscle scars which have a faint double median ridge. In posterior aspect the plates recurve towards the hinge-line. A ridge or lip flanks the free edge of the socket plate so that the sockets form asymmetric conical hollows with the apices directed centrally. A low area and divergent notothyrium and small divided chilidium are present. The median part of the chilidium is often broken, but it appears to extend laterally on to the socket plates. The cardinalia are generalized in text-Figures 5a, b, which also illustrate *P. lindneri* and other species.

An unusual small asymmetrical external impression from G 202 (CPC 1484) is doubtfully included here. It is illustrated in Plate 10, Figure 14, which shows the interarea with perideltidial lines and flat brachial valve. The cardinal process is also preserved as a ferruginized replacement. The asymmetric development is reminiscent of I. Thomas' figure (1910, Figure 5—*Schellwienella* sp.).

A considerable number of shells from various localities in the Callytharra Formation are regarded as being conspecific with the specimens from G 202. The collections are mostly small and the specimens mostly incomplete. They agree in outline and size of costellae with the G 202 material. Some reach larger dimensions, and give an indication of the range of variety in the species.

CPC 1478 shows an isolated pedicle valve and CPC 1479 a brachial valve (Plate 5, Figure 1, 2a, b). These specimens are embedded in tough limestone. The interarea of the pedicle valve is covered by matrix but the broken short septum and incomplete secondary spondylium can be seen. The outline is characteristic of the species and the anterior margin is straight in the median part. This valve is nearly flat and convex only on the posterior lateral flanks, and near the umbo. The costellae number about 8 in 5 mm. at 4.5 mm. from the umbo. The floor of the valve is slightly depressed near the umbo. This depression is similar to that in Plate 4, Figure 4. The associated brachial valve, CPC 1479 (Plate 5, Figure 2a, b), is slightly sulcate and is otherwise entirely and gently convex, with the maximum convexity slightly anterior to the mid-length.

The inside of a youthful pedicle valve, CPC 1480, is illustrated in Plate 5, Figure 3. This valve is slightly convex with two well defined wrinkles. The short septum is about a quarter of the valve length. The spondylium is short and slightly asymmetrical. The teeth are well developed. The nearly circular muscle area is more pronounced than in most specimens of this species; it is skirted by a low ridge on the posterior lateral flanks.

An incomplete pedicle valve, F.17826, shows a slightly concave interarea; the umbonal tip is slightly twisted. Another specimen from this locality, CPC 1482, was serially sectioned (Plate 20, Figures 1a-k). This example shows that the spondylium is of the secondary type with the septum and dental ridges originally separate, but as growth of the inner layers continues the elements become fused to form a small chamber ventral to the pseudodeltidium.

Isolated brachial valves are also common. From locality G 192 are two good specimens. The larger, F.17824, has a short cardinal process similar to CPC 1474 and 1476, but with a faint median posterior ridge similar to that in some specimens of *Permothotetes lindneri* sp. nov. The smaller specimen, F.17825, has the same features. Both valves are gently convex and with the slight median sulci. The costellae number in the median position for the small valve 9 to 10 in 5 mm. at 3.5 cm. from the umbo and for the larger valve 8 in 5 mm. at 5.6 cm. from the umbo.

A very large isolated specimen is referred with some doubt to this species. This specimen (CPC 1481), a brachial internal mould, is strongly wrinkled and is strongly asymmetrically convex; in profile the angular change in convexity is nearer the hinge-line (Plate 5, Figures 4a, b). The costellae number 7 in 5 mm. mesially at 8 cm. from the hinge-line.

An unusually large isolated cardinal process (CPC 1483, Plate 4, Figures 8a, 8b) was found at locality ML 32. This specimen is referred to the species with some doubt, but it was collected with a piece of shell with fine costellation. The process is unusually long and has a well developed median anterior ridge. The posterior surface of the well developed socket plate recurves towards the hinge-line. A wide notothyrium and two small rather eroded chilidial plates are present. The dorsal area is 3.4 mm. high. A faint posterior ridge is present between the deep muscle grooves of the diverging lobes near the hinge-line. This specimen could belong to *P. camerata* sp. nov. but no undoubted examples of that species were associated with it.

A further indication that the cardinal process can be longer than in the paratype specimens is seen in F.1701. This is a gently convex brachial mould of medium size with a long process elongated posteriorly, with two long lobes. The socket plates are characteristic of the species. No median posterior ridge is present.

A large specimen, CPC 1532, from an uncertain level of the Callytharra Formation is illustrated in Plate 6, Figure 6a, b, c, and in Plate 18, Figures 3, 4, and 5. It displays the general proportions of the species. The brachial valve is gently sulcate. The umbonal region of this specimen was sectioned (Plate 20, Figures 2a-2m, and Plate 18, Figures 3, 4, and 5). The specimen is fractured along the septum. The secondary spondylium is well illustrated. Plate 20, Figure 2g-m, illustrate the cardinal process and socket plates flanked by the teeth of the ventral valve.

One point worthy of note is that all the shells of this species examined show costellation on the internal surface. They are usually rather thin-shelled away from the hinge-line, even in larger specimens such as F.17824 and CPC 1532. The valves lack thick callus in the umbonal region and muscle fields. The pseudopunctae appear to take the form of close inwardly directed conical flexures. No spicules were detected in the slides examined. Plate 18, Figure 4, is a transverse section of CPC 1532 from near the front of the brachial valve. The outer layers are partly exfoliated. They

appear to be free of pseudopunctae. The pseudopunctae of the inner layers are shown to be closely packed conical flexures of the shell laminae with apices inwardly directed. Exfoliation does not produce perforations and the conical flexures appear to be present over the entire internal surface of the valve.

TABLE 12.—DIMENSIONS OF P. CALLYTHARRENSIS.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Width of Shell W.	Length of Brachial Valve Lb.	W / L.	W / Lb.	Width of Hinge Line.	Height of Area.	Width of Delthyrium.
CPC 1473 ..	..	4.9	..	..	..	..	0.7	0.5
CPC 1473 ..	2.6	3.6	..	1.4	..	..	..	..
Young Stage								
CPC 1474 ..	..	6.6 est.	4.2	..	1.58	..	..	..
CPC 1476 ..	..	6.0 est.	3.8	..	1.58	..	..	..
F.17817 ..	..	6.0	3.9	..	1.54	4.5	..	..
F.17818 ..	..	3.6	2.3	..	1.57	..	..	..
CPC 1485 ..	..	..	..	..	..	3.5	1.0	0.7
CPC 1477 ..	4.2	5.2	..	1.24	..	4.8 est.	..	..
CPC 1478 ..	5.6 est.	6.9	..	1.23	..	..	..	..
F.17824 ..	..	8.6	6.1	..	1.4	7.9	..	..
F.17825 ..	..	6.1	4.2	..	1.45	..	..	..
CPC 1481 ..	..	13.0	8.7	..	1.5	..	..	..
F.17826 ..	..	..	..	..	..	5.2	1.5	1.0+
CPC 1480 ..	3.8	4.8	..	1.26	..	..	..	..
F.1701A ..	..	8.0	5.7	..	1.4	..	..	..
F.1701B ..	..	8.4	5.8	..	1.42	..	..	..
CPC 1532 ..	7.2	9.0	6.5	1.25	1.4	..	1.2	0.9

Occurrences: (All localities are in the Callytharra Formation). CPC 1473-7, 1485-6, F.17817-23, locality G 202, 5⅛ miles bearing 335° from Lyons River Homestead; about middle of formation. CPC 1478, 1479, near Lyons River Homestead; lower part of formation. CPC 1480, locality GW 75, ¾ mile west of Callytharra Springs; 13 feet above base of formation. F.17824, 5, locality G 192, north side of Baracooda Pool, Arthur River; 75-90 feet above base of formation. CPC 1481, ML 32 about 8 miles east of Lyons River Homestead; about middle of formation. CPC 1482, F.17827, locality GW 127 (north of Pell's Range), 15 miles at bearing 54° from Towrana Station; 125 to 140 feet above base of formation. Another specimen from this area occurs at GW 126; 118 feet above base of formation. F.17828, locality ML 93, Lyndon River; 320 feet above base. CPC 1483, locality ML 32, about 5¼ miles bearing 116° from Donnelly's Well, Williambury Station; 310-320 feet above base. Other occurrences in this area are ML 26 at 155-160 feet and ML 24 at 90-120 feet. F.1701 (Waterford's locality 4), about 1 mile north-north-west of Lyons River Homestead; about middle of formation. F.17601, locality TP 294, 100 yards south of Billidee Well, Merlinleigh Station; in upper half of formation. F.17108, locality TJ 388, about ¾ mile north-east of Mount Sandiman Woolshed, Mount Sandiman Station. F.17235, locality TP 78, 3¾ miles bearing 140° from Thambrong Pool, Williambury Station; in upper half of formation. F.16999, locality TJ 12, near Lands Department Trig. Point K 55, Moogooloo Range, 1 mile north of Mongie No. 1 Bore, Middalya Station; 155 feet below top of

formation. UWA T 33a, from near Lands Department Trig. Point K 52, Middalya Station, 424 feet above base of formation. CPC 1532 is from an uncertain level in the formation in the vicinity of K 52.

Geological Age: Early Artinskian.

Observations: P. callytharrensis is evidently closely related to *P. lindneri* sp. nov. but reaches a larger size, has a more convex pedicle valve, has usually a straight front margin, tends to be more asymmetric, and has a shorter septum than *P. lindneri*. The cardinal process is also longer in mature specimens. It differs from the associated *P. camerata* sp. nov. in the size of the costellae and in the size of the spondylium. *P. crespinae* sp. nov., another related form, differs in that the apical angle is very wide and the area is catacline. In consequence, the two valves are nearly equidimensional. *P. guppyi* sp. nov. differs in that it tends to be less wide in mature specimens, is thick shelled, has a short hinge-line, heavily calloused, and is without internal costellae. It tends to be concave in the pedicle valve and appears to show a reduction of the secondary spondylium in some specimens. Some specimens are strongly distorted. *P. teicherti* sp. nov. differs in that it is a very large, relatively wide form and it has a non-wrinkled very flat pedicle valve. *P. callytharrensis* is a very common species in the limestones of the Callytharra Formation. It is associated with a rich fauna of brachiopods, bryozoa, solitary corals, mollusca and crinoids.

Permorthotetes crespinae sp. nov.

(Plate 1, Figure 5, 6; Plate 2, Figures 4, 5, 6, 7, 8; Table 13.)

Diagnosis: Medium to large thin-walled species, maximum 8 cm. wide and 6.8 cm. long, most specimens nearly symmetrical, wider than long, front margin straight, pedicle and brachial valves nearly equal in size; pedicle valve flat to gently convex, apical angle very wide, interarea nearly catacline in most specimens, brachial valve gently convex, slightly or not sulcate; costellae number 7 to 9 in 5 mm., rugae gentle and uneven.

Differential diagnosis: This species most closely resembles *P. callytharrensis*. The apical angle is much wider and the valves are nearly equal in size. The brachial valve is consistently less convex and less sulcate. The secondary spondylium is longer and the costellae coarser than in *P. callytharrensis*. The species is smaller and with less widely spaced costellae than *P. camerata*.

Material: Twelve more or less complete isolated valves, mostly internal moulds in fine white to brown sandstone, numerous incomplete shell impressions, all from one locality in the Lyons Group.

Description: The holotype, CPC 1487 (Plate 1, Figures 5a, b, 6a, b, c), is an internal mould of a brachial valve, which illustrates some of the distinguishing features of this species. The valve, which is abraded, is gently and irregularly convex, with maximum convexity nearer the hinge-line. The lateral margins are rounded; the anterior margin is incomplete. A faint sulcus and

broad wrinkles are present. The ratio of width to length of 1.20 is lower than that for the brachial valves of other species at similar growth size. The cardinal process (Plate 1, Figures 6a, b, c,) is known from latex rubber moulds. The process is short and nearly at right angles to the floor of the valve. It has a pronounced anterior median ridge. The diductor muscle grooves are faint and the chilidial plates are not distinguishable. The socket plates are short but continue as a ridge anteriorly on the flanks of the faint muscular area. The left socket plate (viewing from the pedicle side) is recurved on its posterior side and lacks the marginal lip noted in *P. lindneri* and *P. callytharrensis*. On the right side, the socket ridge is flanked by a mould of the ventral tooth which continues beyond the margin of the socket plate. Other specimens lack the anterior median ridge, but do show slight marginal lips on the socket plates and vestigial chilidia as in text Figure 5a. Paratype CPC 1488 (Plate 2, Figure 5) is a pedicle internal mould. It is irregularly flat and the surface is irregularly and gently wrinkled, and marked with fine concentric growth-lines. The costellae, i.e. the internal impressions, are regular low rounded ridges with wider interspaces and number 7 to 8 in 5 mm. at 4 cm. mesially from the hinge-line. The interarea (here actually the inside of the palintrope) is nearly at 90° to the ventral surface, and is about 1 cm. high. The pseudodeltidium is rounded and wide, although now partly obscured; it is at least 9 mm. wide at the hinge-line. The septum is 1.6 cm. long, about one-third of the valve length, and is flanked by faint muscle scars; it forms a small asymmetric secondary spondylium with the low dental ridges. Paratype CPC 1489 (Plate 2, Figures 6a, b), is another pedicle mould. This is irregularly convex in profile and somewhat irregularly wrinkled. The septum is 1.3 cm. long, about 2/7 of the length of the valve. It is flanked by an ovate rather narrow muscle field. The pseudodeltidium is obscured but is evidently wide (1.2 cm. at least at the hinge-line). The secondary spondylium is short and asymmetric. F.17822 is a gently convex brachial valve. It is relatively wider than the other shells. It is faintly sulcate and has 9 costellae in 5 mm. at 3.5 cm. mesially from the hinge-line. Paratype CPC 1490 (Plate 2, Figure 8), an external impression, shows some features of the pedicle valve surface. The valve is slightly but irregularly convex. The costellae are narrow but rounded with wider interspace; fairly uniform in size and increased by intercalation in two generations. They number 7 in 5 mm. at 3 cm. from the umbo. Paratype CPC 1491 (Plate 2, Figure 4) is a similar pedicle valve external impression. It is nearly flat, with pronounced concentric wrinkles. The costellae number 7 in 5 mm. at 3.5 cm. mesially from the umbo. The anterior margin is nearly straight. Paratype CPC 1492 (Plate 2, Figure 7a, b) is a pedicle internal mould. The valve is incomplete and is distorted by a radial pucker near the septum, probably a feature of the living animal. The surface is approximately flat in the middle and convex on the lateral flanks and posterior left flank. The septum is 1.9 cm. long, nearly 4/9 of the shell length. The figures illustrate a rubber mould of the spondylial and septal region. The septum is bent to one side parallel to the pucker. An asymmetric spondylium is formed by the dental plates and

septum. The spondylium is several millimetres long and is raised above the floor of the valve, resting on the septum. The interarea is at about 78° to the ventral surface, and is flat. The deltidial base appears to be about 8 mm. wide and the teeth are well developed pointed extensions. The septum is flanked by elongate oval muscle scars, 1.3 cm. in greatest width. F.17867 is an incomplete partly obscured pedicle mould of larger size. The septum is 2.7 cm. long and flanked by narrow oval muscle scars. Other details are obscured, but a very elongate spondylium is present, at least 1.4 cm. in length. The palintrope is missing, but apparently was apsacline at a lower angle than other specimens from this locality. F.17839 and F.17840 are brachial valve moulds; F.17840 is more convex than the other brachial valves.

The intimate details of the spondylium are unknown for this species, but it is assumed to be of the same secondary type as the other species of *Permorthotetes*.

TABLE 13.—DIMENSIONS OF P. CRESPINAE.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width of Shell.	W / L.	W / Lb.	Width of Hinge Line.	Height of Area.	Width of Delthyrium.
CPC 1487 ..	..	5.6	6.7	..	1.20	4.5 est.	..	..
CPC 1489 ..	4.7	..	5.8 est.	1.23	..	4.4	0.7	..
CPC 1488 ..	4.5	..	6.2	1.37	..	4.5	1.0	0.9
F.17822 ..	..	5.0	6.7	..	1.34	4.5 est.	..	..
CPC 1490 ..	4.5	..	5.8	1.29	..	4.7	..	..
CPC 1491 ..	4.5	..	5.7	1.26	..	..	..	..
CPC 1492 ..	4.5	..	5.4	1.2	..	3.9	1.1	1.0
F.17839 ..	..	4.5	5.5	..	1.22	..	..	..

Occurrence: CPC 1487-92, F.17822, 17839-17841, 17867, locality 41, Waterford collection, about ¼ mile east of Winderie Station, Carnarvon Basin; about 300 feet below top of Lyons Group.

Geological Age: Sakmarian.

Observations: P. crespinae is somewhat difficult to assess because of the restricted distribution and rather fragmentary nature of the available material. The single collection described here seems to indicate the presence of a distinct species a little older than the type species *P. callytharrensis*. In form it approaches some individuals of *P. callytharrensis* and in costellation it approaches *P. camerata*, and therefore is possibly ancestral to both. The proportions vary, but the majority of shells are fairly long; the pedicle and brachial valves are commonly nearly equal in size. The similarity in size of the two valves is the result of the usually catacline inclination of the interarea. The hinge-line is variable, but is short in most specimens. The length of the septum varies, but averages about one-third of the shell length.

The cardinal process resembles that of *P. callytharrensis*, but as far as can be seen from the few specimens available the socket plates, which recurve on

the posterior side, may lack the upturned marginal ridge or lip and hence the conical hollows pointed towards the cardinal process are not present in all specimens.

Associated with *P. crespinae* are fenestellid bryozoa and numerous specimens of *Linoproductus lyoni* Prendergast, all preserved as moulds in fine sandstone.

The species is named in honour of Miss I. Crespin, who first recognized this species in Waterford's collection. Miss Crespin kindly made her notes available to me.

PERMORTHOTETES LINDNERI sp. nov.

(Plate 1, Figures 1-4; Plate 2, Figures 1-3; Plate 3, Figures 1-6; Table 14.)

Diagnosis: Medium to large thin-walled species, maximum 6.5 cm. long and 5.5 cm. wide, more or less symmetrical, outline rounded including front margin; wider than long, maximum width at about half the length but near hinge-line on some specimens; pedicle valve nearly flat, internally with short septum less than two-fifths of shell length; secondary spondylium in most specimens small; dorsal valve strongly and unevenly convex with maximum nearer hinge-line, gently sulcate or non-sulcate, cardinal process short, costellae fine (7 to 9 in 5 mm.). many specimens with pronounced rugae, step-like lamellae common.

Differential diagnosis: P. lindneri most closely resembles *P. callytharrensis;* it is smaller and more symmetrical, with flatter pedicle valve and more rounded front margin, and tends to have a more quadrate outline, though with rounded angles. It differs similarly from *P. guppyi,* which has a much thicker shell wall and has a longer septum.

Material: Numerous moulds and external impressions from beds about 6 feet thick near the base of the Poole Sandstone, St. George Range, Fitzroy Basin. No shells are preserved, but details can be reconstructed with latex rubber moulds.

Description: The holotype, CPC 1494a and b (Plate 1, Figures 1a-e), is an internal mould and external impression of an immature individual. The shell is dorsi-convex. The maximum thickness is 1.2 cm. The pedicle valve is not perfectly flat, but has a depression on the left lateral posterior slope and a gentle concavity on the right lateral posterior slope; it is slightly concave towards the anterior margin on the right side. The brachial valve is gently and irregularly convex, with maximum convexity nearer the umbo. A faint median sulcus is present; this is more pronounced near the mid-length. The lateral slopes from umbo to cardinal extremities are slightly concave. The interarea (more correctly, in an internal mould, the inside of the palintrope) is fairly low and is asymmetric (Plate 1, Figure 1c). Internally the ventral valve has a well-marked narrow septum 1.3 cm. long, about one-third of the shell length. The ventral muscular impressions are very faint. The pseudodeltidium is nearly flat and

nearly as wide as high. A latex rubber impression (Plate 1, Figure 1e) shows the secondary spondylium formed by the low dental ridges converging with the septum to form a small chamber. The brachial aspect (Plate 1, Figures 1b, c) displays the short, widely diverging socket plates which continue anteriorly as a very faint ridge around the very faint muscular impression which possesses a low median ridge. Plate 1, Figure 2, illustrates the external impression of the same individual. The interarea is flat and more symmetrical than in the internal mould, but is only slightly higher, indicating that the shell was thin. The perideltidial region is clearly marked, subtending an angle of 114° at the umbo. The apical angle of the interarea is about 142°. The pseudodeltidium forms a low flat arch and is marked with concentric growth-lines. The dorsal valve shows a strong step-like wrinkle and a narrow area with small divided chilidial plates, neatly fitting against the pseudodeltidium. The surface is costellate. The costellae are rounded in section, fairly smooth, some very slightly beaded, and uniform in size except near the beginning of each generation, which is formed by intercalation; the troughs are also rounded. The surface has numerous fine concentric growth-lines. Paratype CPC 1495a, b (Plate 3, Figures 1, 2a-c) is an internal mould with external impression showing a marked asymmetry of the septum and pseudodeltidium. The dental ridges extend into long and pointed teeth (Plate 3, Figures 2b, c). The interarea is higher than in the holotype. The spondylium is also asymmetrically developed; the left dental ridge is the longer. The external impression of this shell does not show any marked asymmetry (Plate 3, Figure 1). It has, however, a different outline from most other individuals, being widest at the hinge-line. Two other specimens, F.17843 and F.17819, shows an asymmetry of the septum in the opposite sense, i.e., to the right, viewed from the brachial side. Paratype CPC 1496 (Plate 2, Figures 1a, b) is a nearly complete impression of a brachial valve and interarea of the pedicle valve of a large individual. This is one of the largest specimens seen. The shell is nearly symmetrical. The interarea is slightly convex and moderately high; the perideltidium is well shown. The gently convex pseudodeltidium has a slight median depression. The interarea does not extend to the cardinal extremity, but the pedicle valve surface, which is strongly convex at the anterior lateral margin, arches over and is visible from the brachial side. The apical angle is 140° and the apex of the perideltidium 104°. The cardinal extremities are obtusely angular (about 120°) in outline. The antero-lateral margins are slightly convex and the anterior margin is broadly convex. The brachial valve has a distinct low area and a small divided chilidium, which neatly dovetails into the pseudodeltidial anterior margin. The posterior lateral slopes are slightly concave and there is a broad shallow sulcus which becomes more pronounced anteriorly. The surface is concentrically wrinkled into abrupt steps which presumably mark sharp interruptions of growth. They are more numerous anteriorly, where they are lamellate. Fine concentric growth-lines are also present. The costellae are rounded, smooth, and have slightly wider rounded troughs. They multiply by intercalation in two generations and are fairly uniform in size. They number 9 in 5 mm. in

the median position at 2.5 cm. and also at 3.5 cm. from the hinge-line. Paratype CPC 1499, a ventral internal mould, has a similar outline (Plate 3, Figure 4). The septum is 2.2 cm. long, about two-fifths of the length of the valve. The ventral muscle field is well developed in this valve; it lies distinctly anterior to the umbo and has a slight ridge round the posterior margin. CPC 1498 (Plate 2, Figure 2) is a good example of a pedicle valve external impression. The valve is nearly flat, slightly convex at the cardinal margins. The step-like lamellae and fine growth-lines are well displayed. The lamellae are closer towards the front. The costellae multiply by intercalation in two generations; they increase slightly in diameter to the front, are generally smooth and rounded, sometimes faintly beaded. At 2.5 cm. from the umbo, they number 9 to 10 in 5 mm., at 3.5 cm. number 8, and at the anterior margin, i.e., 5.6 cm., are 6 to 7 in 5 mm. Another shell with a low interarea and non-sulcate brachial valve is CPC 1521 (Plate 3, Figure 3a, b).

Numerous other specimens have the general outline of CPC 1496, 1498 and 1499. Dimensions of a number are recorded in Table 14. Ratios of width: length for different growth stages were measured on CPC 1498, a ventral valve. They are 3.22: 2.26 mm., 5.2: 4.1 mm., and 7.2: 5.8 mm., giving ratios of 1.41, 1.23 and 1.22. Similar measurements on CPC 1522, a brachial valve (Plate 3, Figure 5a, b), give ratios of 1.60, 1.52, and 1.50. Although in most specimens the greatest width is in front of the cardinal line, at about one-half of the shell length from the umbo, in some it is at the cardinal line, e.g. F.17845 and CPC 1495 (Plate 3, Figure 1).

The cardinal process is distinctive. Plate 2, Figure 3, of paratype CPC 1502, shows the internal aspect of a medium-sized individual. In anterior aspect the process is bilobed, short and broad, with a slight anterior median swelling. The socket plates have pronounced outward extensions, are divergent, and terminate abruptly. The brachial muscular impression is very slight. The teeth fit neatly on to the socket plates. CPC 1500 (Plate 1, Figure 4) is a latex mould of a medium-sized individual. In anterior aspect the process is short, bilobed, without any median swelling. Upturned lips are present on the ventral free margin of the socket plates and tend to form small open cones on each side. The brachial musculature is very slight and a faint median ridge is present. In posterior aspect, the bilobed process has a deep rounded groove along the middle of each lobe, and the socket plates tend to recurve towards the hinge-line. CPC 1501 (Plate 1, Figure 3), another latex mould, shows a slightly older individual in anterior aspect. The median ridge is well defined and the socket plates do not end so abruptly, but partly surround the musculature. They are recurved on the posterior side.

A divided chilidium is present in some well preserved specimens, e.g. Plate 2, Figure 1a. A distinct area is always present in the brachial valve. This is usually less than 2 mm. in maximum width, decreasing laterally. Plate 3, Figure 6, illustrates a specimen showing the dorsal area and partly abraded chilidial plates. Text-Figures 5a, b, illustrate the general features of the

cardinal process of this species and of *P. callytharrensis*. Most of the internal moulds show costellation and the shells were evidently thin, and without callosity in the umbonal region.

TABLE 14.—DIMENSIONS OF P. LINDNERI.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Width of Pedicle Valve W.	Length of Brachial Valve Lb.	W / L.	W / Lb.	Width of Hinge Line.	Height of Area.	Width of Delthyrium.
CPC 1494B ..	4.1	5.6	3.5	1.37	1.6	4.5	1.25	1.1
CPC 1495 ..	5.1	6.1	4.5	1.2	1.36	5.1	1.6 est.	1.1
CPC 1496 ..	5.6 est.	6.9 est.	4.8 est.	1.23	1.4	4.9	1.3	1.1
CPC 1522 ..	..	7.4 est.	4.9	..	1.5	..	..	..
CPC 1521 ..	4.6 est.	6.0	4.2 est.	1.3	1.41	4.3	0.7	0.7
CPC 1498 ..	5.8	7.2	..	1.22	..	5.3	..	..
CPC 1499 ..	5.5	6.5	..	1.18	..	..	..	..
CPC 1501 ..	..	5.2 est.	3.4	..	1.52	..	..	..
F.17843 ..	3.5	4.8	3.2	1.37	1.5	3.8	0.8	..
F.17844 ..	4.1	5.4 est.	3.8	1.32	1.42	..	0.7	0.5
F.17845 ..	5.1	6.5	..	1.28	..	..	..	..

Geological Age: Early Artinskian.

Occurrence: CPC 1494-1502, 1521-2, F.17843-9, F.17819, and other specimens, locality KPA 54, 16 miles at 120° from Mount Tuckfield, in southern part of St. George Range; base of Poole Sandstone.

The collection on which this species was based was made in one locality from the St. George Range, which was originally discovered by Mr. A. W. Lindner. There are two beds about 1 foot thick and about 4 feet apart near the base of the Poole Sandstone, here a ferruginized greywacke-type sandstone. All specimens described come from the lower bed, KPA 54a. The other bed contains similar material.

Observations: The material available gives a clear idea of the distinguishing features of the species. Variable features are the height of the area, presence or absence of a gentle sulcus on the brachial valve, presence or absence of a swelling on the internal face of the cardinal process, and to some degree, the outline. The septum is in most cases fairly symmetrical but may be distorted to right or left. This is not necessarily reflected in the externals.

The spondylium is invariably present but may be asymmetrical even where the septum is symmetrical. One specimen (F.17849), in ventral aspect, shows the dental ridge to be attached to the septum on the left side for a very short distance and on the other side for much longer. The intimate structure of the spondylium cannot be elucidated in this species as no shells are available, but from the evident affinity with *P. callytharrensis* it is most probably secondary.

P. lindneri differs from *P. guppyi* in being strongly lamellate and thin shelled and in having a fairly flat pedicle valve. It is also smaller. The distinction from *P. callytharrensis* is discussed under that species. The

environment of this form was apparently favorable for brachiopod development as the St. George Range beds contain a rich assemblage of brachiopods and a few molluscans.

The species is named in honour of Mr. A. W. Lindner, who discovered the type locality.

PERMORTHOTETES GUPPYI sp. nov.

(Plate 7, Figures 1-3; Plate 8, Figures 1-4; Plate 18, Figure 2; Plate 21, Figures 1a-c, 2a-g, 3a-e; Plate 22, Figures 1a-c, 2a-e, 4; Table 15.)

Derbyia sp., Etheridge, 1914; *Geol. Surv. W. Aust. Bull.* 58, 35, pl. VII, figs. 1, 2.

Derbyia cf. *D. senilis* Philips, Hosking, L. F. V., 1932: *J. Roy. Soc. W. Aust.*, 18, 44, pl. 5, figs. 6, 7.

Diagnosis: Large usually thick-walled species, maximum size 8.0 cm. long and 6.8 cm. wide, most specimens nearly symmetrical, some very distorted; undistorted pedicle valves have wide oval outline, are concave to flat, interarea high, maximum width nearly twice hinge-line, septum long, attaining more than half the shell length, secondary spondylium variable in development, may be obliterated by shell callus; brachial valve gently to moderately convex and most specimens not sulcate, cardinal process with stout lobes and deep wide diductor grooves; costellae fine, 9 to 13 in 5 mm.; rugae slight.

Differential diagnosis: This species is usually much thicker shelled than *P. callytharrensis* and *P. lindneri,* which it resembles. The septum is much longer and the secondary spondylium is commonly less well developed; the brachial valve is less convex. The secondary spondylium tends to be less well developed than in *P. teicherti,* which is less rugose and has a flatter pedicle valve.

Material: Numerous isolated valves from many localities in the Noonkanbah Formation of the Fitzroy Basin and one locality in basal Liveringa Formation. Complete shells are very rare in collections.

Description: P. guppyi is difficult to delimit precisely because of its considerable variability and the rather fragmentary nature of most of the collections. It is possible that more than one species is present in the material described. The forms grouped here range from fairly low in the Noonkanbah Formation to the base of the Lightjack Member of the Liveringa Formation.

The holotype was collected from near the top of the Noonkanbah Formation. CPC 1503 (Plate 7, Figures 1a-d) is a nearly complete pedicle valve of roughly oval outline. The lateral margins are gently convex and the anterior margin slightly convex. The maximum width is 1.9 times the short hinge-line. Part of the ventral posterior lateral surface is sharply bent over and is visible on the brachial side of the shell. In both lateral and transverse profile the shell is strongly concave; the surface is gently wrinkled, lamellose at the front and

with numerous fine growth-lines. The costellae are rather fine and even—9 in 5 mm. at 5.5 cm. mesially from the umbo. The surface is rather corroded, but the costellae appear to be slightly angular in section with rounded troughs between. The interarea is nearly flat, but is weathered; it is fairly high—1.5 cm. maximum. Laterally the interarea extends into the sharp overturned lateral posterior flank of the valve; both lateral flank and interarea would have articulated with the brachial valve. The delthyrium is rather narrow—9 mm. at the front. The interarea makes an angle of about 60° with the proximal part of the outer surface of the valve.

Internally the valve is very thick, with large deposits of callus near the musculature, on the anterior margins, and behind the palintrope. The anterior edge is 7 mm. thick; elsewhere the shell is about 4 mm. The costellation is obliterated by shell growth except at the margins, where, despite the great thickness, it is present on the inner surface. The dental lamellae are strong and extend into stout teeth. The septum is also prominent, bent to one side; it is 4 cm. long, or four-sevenths of the shell length. It is flanked by the strongly calloused broad muscle area which has strong longitudinal ridges and a pronounced flange. The deltidial cavity is almost completely infilled with callus, and consequently the dental plates and septum do not unite to form a spondylium. However, this was no doubt present in the early growth stages, as indicated in the serial sections of an associated specimen of the same size, paratype CPC 1504 (Plate 21, Figures 3a-e). This shell is much corroded inside and out. The sections do not show all the deltidial region because of the corrosion. As in the other species of *Permorthotetes* the septum and dental lamellae are initially discrete. As the shell layers grew, the septum and dental plates were fused into a thick structure behind the pseudodeltidium. The spondylium appears to have been always rather shallow as the growth layers are nearly horizontal in the spondylial region. This is in contrast with specimens CPC 1505, from a little higher stratigraphically, and CPC 1513, from lower in the Noonkanbah Formation, in both of which the spondylium is a longer structure. CPC 1504 is less concave than the holotype. Another associated pedicle valve, F.17850, is slightly convex. No brachial valves are available from KNF 76A.

From Mount Marmion at the top of the Noonkanbah Formation two incomplete shells are available. One specimen, a medium-sized shell, CPC 1505, is illustrated, in part, in Plate 7, Figure 2. This shell is incomplete, and the outline, though similar to CPC 1504, is relatively longer. The ventral valve is gently concave in profile except at the umbo. The apical angle of about 70° is also less than in the holotype. The surface is not strongly wrinkled. The ventral posterior lateral margins are only slightly overturned. The area is about 0.8 mm. high. The costellae are fine, 8-9 in 5 mm. They appear only marginally on the internal surface. They are rather angular in cross section, with wider rounded troughs, and multiply by intercalation. The growth lines are lamellate, particularly near the margins. Serial sections of this specimen indicate the characteristic secondary spondylium of the genus (Plate 22, Figures

1a-c). The brachial valve is also incomplete. It appears to be gently convex. The cardinal process is short and bilobed, with deep broad diductor muscle grooves on each lobe, and a median anterior ridge or swelling. The socket plates are short and recurved on the posterior surface with lips on the free margins as in *P. callytharrensis*. The plates are set at right angles to the floor of the valve. The marginal lips continue outwards as small processes, and the plates continue as low ridges on the floor of the valve, flanking the muscle scars. Another specimen (F.17851) is a portion of a large thick-walled brachial valve with fine even costellae numbering 9 to 10 in 5 mm. at 8 cm. mesially from the umbo. It is strongly convex.

From the basal beds of the Liveringa Formation in the Shore Range come a considerable number of incomplete shells also referred to this species. They are very fragmentary and evidently highly variable in shape. All display a fine even costellation, e.g., CPC 1506, a pedicle valve with 9 to 10 in 5 mm. at 4.5 cm. from the umbo, and CPC 1473, also a pedicle valve with 9 in 5 mm. at about 7 cm. from the umbo. The outline of the pedicle valve is very variable, as illustrated by CPC 1506 and CPC 1507 (Plate 7, Figure 3a-b; and Plate 8, Figure 1). Brachial valves CPC 1508 and 1509 (Plate 8, Figures 4a, b, and 2), are moderately convex, flat near the posterior lateral flanks, and very faintly sulcate. A length of 7 cm. for a brachial valve (F.17853) and a width of over 8 cm. for a pedicle valve (CPC 1510) show that the shells are comparable in size with the other Noonkanbah examples. Serial sections of another Shore Range specimen, CPC 1510 (Plate 22, Figures 2a-e), show that this specimen has the initially discrete septum and dental lamellae and has also the great deltidial thickening of CPC 1505, but the spondylium seems not to have been developed quite in the same way. It is possible that this specimen is nearer to *Derbyia,* but the shell otherwise appears to resemble those from Mount Marmion. However, in a section of the distorted specimen CPC 1506 (Plate 7, Figures 3a, b, and Plate 22, Figure 4) the secondary spondylial development characteristic of *Permorthotetes* is seen. An isolated much corroded cardinal process (F.17854) is broad and stout.

From locality KNA 28 comes CPC 1511 (Plate 8, Figure 3). This is a finely costellate pedicle valve, slightly convex, but comparable in outline with the holotype. The costellae number 10 in 5 mm. at 3.3 cm. mesially and 8 in 5 mm. at 45° radially from the umbo. A broken brachial valve has 13 costellae in 5 mm. at about 5 cm. from the umbo. Two of the shells were sectioned; CPC 1513 has a flat to slightly concave pedicle valve with the interarea 1 cm. high at an angle of about 45° to the external surface. The other, CPC 1512, is an irregular shell with the area 1.2 cm. high at about 70° to the proximal outer surface of the valve. Both display the secondary spondylial details of the genus. CPC 1512 is illustrated in Plate 21, Figures 2a-g, CPC 1513 in Plate 21, Figures 1a-h. These valves are both finely costellated with 8 to 9 in 5 mm. at 3 to 4 cms. from the umbo. Both have pseudodeltidia about 7 to 8 mm. wide at the hinge-line.

Several slides of transverse sections were prepared. One is illustrated in Plate 18, Figure 2. The appearance is of closely spaced, superimposed, inwardly directed conical flexures. Calcareous spicules were not observed. These sections resemble closely those of *P. callytharrensis*. The figured specimen is exfoliated especially on the external surface (top of figure). No pseudopunctae are macroscopically visible in tangential view, but fine papillae are visible on well preserved internal surfaces.

TABLE 15.—DIMENSIONS OF P. GUPPYI AND P. sp. aff. GUPPYI.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Width of Shell W.	W / L.	Width of Hinge Line.	Height of Interarea.	Width of Delthyrium.
CPC 1503	6.8	8.0	1.17	4.2	1.5	0.9
	5.9	7.7	1.30 Growth	..	..	..
	3.3	5.0	1.52 Stages	..	..	..
	1.7	3.0	1.76			
CPC 1511	6.0	7.6	1.26 Growth	..	..	..
	3.3	5.0	1.51 Stages	..	..	..
CPC 1519	5.1	6.0	1.18	3.9	..	..
CPC 1520	2.3	2.8 est.	1.21	..	..	..

Occurrence: Most of the specimens described and some others come from two sections measured in the Noonkanbah Formation. One section, south of the Grant Range, at about 8 miles bearing 120° from Mount Anderson Homestead, totalled 2,436 feet. Representatives of the species were collected from beds at 160 feet to 1,760 feet above the base. They are listed in ascending order: F.17857, locality KNA 19, several broken shells, 160 feet above base of formation; broken shells, at KNA 23, at 670 feet above base; CPC 1511-3, locality KNA 28 at 905 feet above base; also at KNA 29 at 910 feet and at KNA 35 at 1,760 feet above the base.

The other section is the type Noonkanbah Formation section, measuring 1,287 feet, 4.3 miles at 298° from Bruten's Old Yard, Cherrabun Station. Specimens are listed in ascending order: F.17858, locality KNF 87, a fragment at 675 feet from base; CPC 1503-4, F.17850, locality KNA 76A at about 1,190 feet above base of the formation.

Other localities are: CPC 1505, F.17851, Mount Marmion; topmost beds of Noonkanbah Formation near foot of Mount Marmion, about 1 mile at 22° from Kimberley Downs Homestead. CPC 1506-7, locality KLD 64, 2.6 miles bearing 70° from Shore Range Trig. Point; basal beds of Liveringa Formation (Lightjack Member). CPC 1508-10, F.17853-5, locality KLD 65. 2.28 miles at 70° from Shore Range trig. point, about 30 feet above KLD 64.

Incomplete valves are known from many other localities in the Noonkanbah Formation.

Geological Age: Artinskian and possibly early Kungurian.

Observations: The forms here described as *P. guppyi* have a wide geographical distribution in the Fitzroy Basin and a rather long stratigraphical range. It is possible that more than one species is present, but the quality of material from any one bed is usually insufficient to establish any consistently peculiar characteristics.

The specimens from low in the Noonkanbah Formation, at 160 feet and at 670 feet from the base in the Grant Range section, are fragmentary. They may belong to another species. CPC 1511-3 from 905 feet are reasonably good material and appear to be specifically close to the holotype from 1,205 feet, in the Bruten's Yard section. This is near the top of the formation, not far below the Mount Marmion and Shore Range horizons. Only some of the specimens described display the secondary spondylium as distinctly as do specimens of *P. callytharrensis.* This feature may become less pronounced in the later forms of the genus, until the septal condition of *Derbyia* is approached. Only the Mount Marmion specimens provide a good cardinal process: this is of the *P. callytharrensis* type.

P. guppyi evidently has affinities with the other Western Australian species of *Permorthotetes,* notably *P. callytharrensis* and *P. lindneri.* In contrast the available material indicates that the pedicle valve is commonly concave but may be distorted. The spondylium apparently tends to disappear. In this respect it differs from *P. teicherti,* which ranges as high stratigraphically. A noteworthy feature of *P. guppyi* is the very thick shell and lack of costellae on the internal surface, except on the margins of evidently mature specimens. The width/length ratio decreases considerably with increasing age (Table 15).

The incomplete specimens originally described by Etheridge (1914) and redescribed by Hosking (1932) as *Derbyia* cf. *D. senilis* (Philips) were collected from Mount Marmion. These specimens have not been restudied but the publications show that they should probably be referred to *Permorthotetes guppyi.* No specimens certainly referable to *Derbyia* are known from Mount Marmion.

P. guppyi is commonly found in the more calcareous beds of the Noonkanbah sequence and is generally associated with a rich fauna of brachiopods, bryozoa, and in places crinoids, notably *Calceolispongia.*

The species is named in honour of Mr. D. J. Guppy, who has been concerned in the geological investigations of the Fitzroy Basin for some years.

PERMORTHOTETES TEICHERTI sp. nov.

(Plate 8, Figures 6, 7, 8; Plate 22, Figures 3a-d; Table 16.)

Diagnosis: Large symmetrical thin-walled species, maximum size 9.5 cm. wide and 7.3 cm. long; pedicle valve wide, flat to slightly concave, without pronounced rugae; brachial valve gently convex, sulcate; costellae 7 to 12 in 5 mm.

Differential diagnosis: P. teicherti is distinguished from *P. callytharrensis* and *P. lindneri* by its flat non-rugose pedicle valve and gently convex brachial valve; it is thinner shelled and has a longer secondary spondylium than *P. guppyi.*

Material: Three specimens from one locality, Coolkilya Flat, near Coolkilya Pool, Minilya River, one specimen from near Birdrong Spring and another from the Norton Greywacke, near Coolkilya Pool, all in the Carnarvon Basin.

Description: The holotype, UWA 28045A (Plate 8, Figure 7), is a pedicle valve, with internal aspect exposed but with the inner shell layer almost completely exfoliated. The shell is broad, with rounded lateral margins and a fairly straight anterior margin. The maximum width is near the mid-length. Concentric wrinkles are present but are faint. The shell is very slightly concave in lateral profile and in posterior transverse profile, but gently convex near the umbo. The costellation is fairly fine and even, with 7 in 5 mm., at 5 cm. from the umbo and at the middle of the anterior margin. Paratype UWA 28045B (Plate 8, Figure 6) is a very similar valve, slightly different in dimensions. This shell was sectioned serially (Plate 22, Figures 3a-d). Though a little weathered, the shell displays a very well-developed secondary spondylium which evidently extends to the front for the full length of the pseudodeltidium; it is infilled with shelly material near the umbo. The interarea is at least 7.5 mm. high and the delthyrium 7 mm. wide near the hinge-line. The costellae are even and number 8 in 5 mm. at 5.7 cm. mesially from the umbo.

One brachial valve, paratype UWA 28036 (Plate 8, Figures 8a, b) was collected from the same locality. It is gently and evenly convex in lateral profile with a distinct but gentle median sulcus. The posterior lateral slopes are flat and slightly concave at the hinge-line. This shell has finer costellation than the two pedicle valves. The costellae, which are even in size, number 10 in 5 mm. at 3 cm. from the umbo on the median surface flanking the sulcus. They are rather angular in cross section with wider rounded troughs. The concentric wrinkles are very slight.

The fourth specimen, F.17859, is an incomplete brachial valve impression, somewhat larger, slightly more convex and non-sulcate. Concentric wrinkling is more pronounced and the growth-lines are lamellate towards the margins. The growth-lines show an anterior concavity at the sulcus which is more pronounced in front. The anterior margin is also concave. This shell should perhaps be

associated with *Derbyia*? sp. A. F.17860 is a part of a crushed brachial valve. This has rather fine even costellation—12 per 5 mm. at 3 cm. from the middle of the hinge-line.

The cardinal process of this species is unknown.

TABLE 16.—DIMENSIONS OF P. TEICHERTI.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width.	W / L.	W / Lb.	Width of Hinge Line.
UWA 28045 A	7.3	..	9.5 est.	1.3	..	..
Growth stage	4.0	..	6.2	1.55	..	..
UWA 28045 B	7.1	..	9.4 est.	1.32	..	..
Growth stage	4.15	..	5.7	1.4	..	..
UWA 28036	..	3.8	5.6	..	1.48	5.0
Growth stage	..	2.5	3.9	..	1.56	..

Occurrence: UWA 28045A and B and 28036 come from field locality WF 9.6, Wandagee Station, Carnarvon Basin. The precise locality is uncertain, but is recorded as the "*Thamnopora-Aulosteges* bed near the Cretaceous, Coolkilya Flat and in the Linoproductus Stage". This bed is probably in the Baker Siltstone. F.17859, from G 38, 2 miles, 540 yards, bearing 297° from Birdrong Spring, Hill Springs Station, Carnarvon Basin; Coolkilya Formation. F.17860, from ML 52, 1½ miles bearing 250° from Coolkilya Pool, Minilya River, Wandagee Station; Norton Greywacke, top beds.

Geological Age: Late Artinskian to early Kungurian.

Observations: P. teicherti is stratigraphically the highest *Permorthotetes* recorded from the Carnarvon Basin. It is evidently descended from *P. callytharrensis,* differing from that species in its outline, and by the smoothness and flatness of the pedicle valve. It is also slightly broader. It differs from the later examples of *P. guppyi* in its flatness and smoothness and particularly by the strong symmetric development of the spondylium, which tends to be reduced in the later examples of *P. guppyi.*

The species is named in honour of Dr. C. Teichert, to whom the author is indebted for his introduction to the Carnarvon area.

PERMORTHOTETES CAMERATA sp. nov.

(Plate 6, Figures 1-5; Table 17.)

Diagnosis: Large fairly thin-walled species, maximum 9 cm. wide and 7.8 cm. long (isolated brachial valve 12 cm. wide); wider than long, maximum width shifts to front with growth (one specimen only); pedicle valve flat to slightly concave, interarea high and convex in longitudinal profile, secondary spondylium long, septum long nearly half shell length; brachial valve variable in convexity, cardinal process long; costellae widely spaced and coarse, 5 to 7 in 5 mm.; rugae broad and gentle; fine concentric ornament between costellae.

Differential diagnosis: P. camerata is distinguished by its large size and widely spaced costellae and very well-developed secondary spondylium. It differs in these respects from the associated *P. callytharrensis,* which is finely costellated and with a short secondary spondylium.

Material: Not abundant; it comprises incomplete shells embedded in limestone from four localities and several moulds from one locality. All localities are in Callytharra Formation.

Description: The holotype, CPC 1514 (Plate 6, Figure 1a, b), displays the main distinguishing features of the species. The valve is incomplete and the shape cannot be ascertained. The interarea is incomplete, but was evidently fairly high. The part remaining is about 1.5 cm. high near the pseudodeltidium.

It is strongly convex, apsacline at about 45° at the anterior part and 90° at the umbo. The pseudodeltidium is also convex in transverse section; its anterior margin is broken. The internal details are well displayed. A long secondary spondylium extending in front of the broken pseudodeltidium is formed by the junction of the dental ridges and the septum. The dental ridges are slightly asymmetrically developed; that on the left combines with the septum for a slightly longer distance than the other. The secondary spondylium is also slightly asymmetric in transverse aspect. At its front the spondylium stands about 0.5 cm. above the floor of valve, supported by the septum, and extends back to the umbo. The pseudodeltidium is thicker than the dental ridges and can be seen to be in layers, as erosion has formed a cavity between the outer and inner layers, now partly infilled with calcareous matrix. The septum and dental plates are also layered. None of the specimens referred to in this species was sectioned, but the spondylium is probably of the secondary type. The septum, now broken, evidently extended at least to the front of the well-developed muscle scars, which have a low marginal ridge on the posterior lateral flanks and are elevated slightly above the floor of the valve. Adductor and diductor areas cannot be clearly distinguished. The longitudinal ridges of the muscle scars are well developed. The valve floor is not flat, but shows rather broad concentric wrinkles. At the umbo the valve possesses a slight external convexity. The costellation, as reflected on the inside of the valve, is spaced at 5 in 5 mm. at 4 cm. from the umbo at about 45° from the longitudinal midline of the shell. Paratype CPC 1515 (Plate 6, Figures 2a, b) is an incomplete brachial valve embedded in the same piece of rock as the holotype. It is partly an internal mould with portions of shell adhering at the cardinal process. The valve is very gently and irregularly convex, slightly sulcate and with a pronounced concentric wrinkle. The cardinal process, though poorly preserved, is evidently elongated posteriorly and slightly ventrally and has two long lobes. There does not appear to be any median anterior ridge. The socket plates are elongated on the anterior side. This valve has six costellae in 5 mm. near the

mid-line at 4 cm. from the umbo. The troughs are much wider than the costellae. CPC 1516 is an incomplete mould of a pedicle valve in brown sandstone from locality G 348 (Plate 6, Figures 4a, b). It is convex in longitudinal profile though comparatively flat in the septal region. The outline, though broken, reveals that the form changed considerably with growth. In the earlier stages the maximum width was near the hinge-line, but in later growth is nearer the front margin. Concentric rugae or wrinkles and growth-lines are present. The septum is long, about 3.2 cm.—about three-sevenths of the shell length. The muscle scars have a lateral marginal ridge and strong calluses at the anterior end of the septum. The muscle field is elongate and oval in outline. The costellae number 5 in 5 mm. at about 4.5 cm. mesially from the umbo. The interarea is incomplete, but undoubtedly exceeded 1.5 cm. in height. It is convex, but entirely apsacline. A more youthful mould from the same locality (F.17830) displays similar costellation, about 4 to 5 in 5 mm. at 3 cm. centrally from the umbo. Adjacent to this specimen is a smaller brachial mould (F.17831). This is gently but irregularly convex with a slight sulcus. The maximum convexity in side view is near the hinge-line. The costellae number 9 in 5 mm. at 2 cm., mesially from the hinge-line. Another incomplete brachial mould, F.17832 from G 348, of larger size, has about 7 in 5 mm. at about 4 cm. from the hinge-line. The convexity of this valve is very gentle and it is not sulcate.

Another collection is CPC 1517, 1518 and F.17833, all from one slab of limestone. CPC 1517 (Plate 6, Figures 3a, b), displays the convex pseudodeltidium, long septum, and well developed, though crushed, secondary spondylium of this species. The costellae number 6 in 5 mm. at 5 cm. mesially from the umbo. This valve is slightly but unevenly convex. Wider flat troughs which have numerous faint lamellae with an anterior concavity separate the rounded costellae. Other pedicle shell fragments show this detail very distinctly on the external surface, although the outer shell layer is missing.

Brachial valves CPC 1518 (Plate 6, Figure 5a, b), and F.17833 display gently convex lateral profiles with a maximum convexity near the umbo. The shells are otherwise convex with a flattening on the posterior lateral margins. The costellae are more numerous than in the pedicle valves, numbering 8 in 5 mm. at 5 cm. mesially from the hinge-line. Gentle concentric wrinkles are present.

Another incomplete pair of valves, F.1702a, b, are ascribed to this species. These valves are very large. The pedicle valve has the widely spaced costellation and long septum and the brachial valve displays a finer costellation. The septum measures 3.5 cm., nearly half the estimated length of the valve.

A portion of a pedicle valve with wide costellation is placed also in this species (F.17835).

TABLE 17.—DIMENSIONS OF P. CAMERATA.

(Dimensions in cm.)

Specimen No.	Length of Pedicle Valve L.	Length of Brachial Valve Lb.	Width of Shell W.	W / L.	W / Lb.
CPC 1516	7.8	..	9.0	1.15	..
CPC 1516 (Early stage)	4.5	..	6.3	1.4	..
F.17830 (Early stage)	2.7	..	4.4	1.63	..
F.17831	..	2.5	3.9	..	1.56
F.17832	..	4.7	7.4	..	1.57
CPC 1518	..	5.1	8.5	..	1.67
F.17834	..	4.2	6.4	..	1.53
F.1702 A	7.0	..	10.6	..	1.60
F.1702 B	..	..	12.0	..	..

Occurrences: All localities are in the Callytharra Formation, Carnarvon Basin. CPC 1514, 1515—locality GW 32, 4 miles bearing 330° from Minginew Outcamp, Bidgemia Station; near top of formation. CPC 1516, F.17830-2, locality G 348, about 2 miles, 1,000 yards bearing 170° from Mount Sandiman Woolshed; middle to upper part of formation. CPC 1517, 1518, F.17833-4, locality GW 113A, about 14 miles, 1,400 yards, bearing 59° from Towrana Homestead; middle of formation. F.17835, locality ML 33, about 5 miles, 500 yards, bearing 116° from Donnelly's Well, Williambury Station; 340-346 feet above base of formation. F.1702—Waterford's locality 35, Wyndham Gorge, about 5 miles west of Fossil Hill; upper part of formation.

Geological Age: Early Artinskian.

Observations: This large species, though incompletely known, is easily distinguishable. The wide spacing of the costellation and large dimensions, in addition to the strong development of the spondylium, distinguish it from the other species of the genus. The detail of the fine curved lamellae between the costellae was not observed in other species. This lamellation appears to resemble the structure of *Streptorhynchus craticulatus* Reed. In that form, however, as figured by Reed (1944), the lamellae are convex to the front. This or an analogous feature appears to be present in other genera also, e.g. *Schuchertella.*

Most brachial valves have closer costellae and in isolation are difficult to distinguish from *P. callytharrensis.* The large cardinal process described under the latter species (Plate 4, Figures 8a, b), may possibly belong to *P. camerata.*

PERMORTHOTETES sp. aff. P. CAMERATA.

Material: A small number of incomplete shells from tough limestone beds in the lower half of the Noonkanbah Formation, Fitzroy Basin, south of the Grant Range.

Description: The shells noted here are associated with finely costellated forms referred to *P. guppyi.* Insufficient material is available for adequate description, but the coarse costellation appears to distinguish it. One specimen, F.17861, is an incomplete wide pedicle valve measuring 7.8 cm. in width and 5.8

cm. in length—the ratio width/length is 1.35. The surface is slightly concave but with a low median fold, and possesses low wrinkles and growth-lines. The growth-lines and the anterior margin are concave towards the front where they cross the fold. The costellae which are rounded and wider than the intertroughs, number 7 in 5 mm. at 3.5 cm. from the umbo and 5 to 6 at 5 cm. from the umbo near the mid-line. The shell has a well developed secondary spondylium.

An incomplete brachial valve, F.17862, is included in this species. This specimen is deeply sulcate with 8 prominent costellae in 5 mm. at about 4 cm. from the umbo. Other specimens that have been included here are F.17863, a pedicle fragment with 6 costellae per 5 mm. at 4.5 cm. from the umbo, and an incomplete pedicle valve, F.17864, 8 cm. wide. Stratigraphically highest is an incomplete shell with prominent coarse costellae—F.17865.

Occurrence: All specimens are from a measured section of the Noonkanbah Formation, south of Grant Range, about 8 miles west of Mount Anderson Homestead; they are distributed as follows:—F.17861 comes from KNA 19 at 430 feet above base; F.17862 from KNA 20 at 560 feet; F.17863-4 from KNA 23 at 690 feet; and F.17865 from KNA 28 at 905 feet.

Geological Age: Artinskian.

Observations: This species is distinguishable from *Permorthotetes guppyi*, with which it was collected, though the one measurable specimen has comparable dimensions. The deep widely spaced costellae and strongly sulcate brachial valve are distinctive features. The costellae thus resemble those of *P. camerata* but do not appear to be quite as wide. This form may prove to be closely allied to or identical with *P. camerata* when better material is available. The presence of associated coarsely and finely costellated species in both the Callytharra Formation and in the lower Noonkanbah beds near the Grant Range is of interest and may prove to have some stratigraphical significance.

PERMORTHOTETES sp. aff. P. ? GUPPYI.

(Plate 7, Figure 4; Plate 6, Figure 3; Table 15.)

Material: Two pedicle valves, one crushed brachial valve, from a coquinoid calcareous bed in Noonkanbah Formation.

Description: These valves are discussed separately from *P. guppyi* because of their outline and the apparent lack of a spondylium. Examples of *P. guppyi* are found in beds lower and higher stratigraphically. CPC 1519 is a pedicle valve interior (Plate 7, Figure 4). The outline is rounded. The surface is nearly flat but gently wrinkled. The interarea is missing, but was evidently about 3.9 mm. wide. The septum is about 2.4 mm., nearly half the shell length; it is flanked by a broad oval muscle scar with a raised margin. At the umbonal end the septum broadens and the now broken dental ridges were attached on either side; a broad-based cavity behind the deltidium is present, but other shells will need to be sectioned to determine the intimate structure. A smaller

incomplete specimen, CPC 1520, is apparently rounded in outline. The width-length ratio is much less than for the early growth stages of other specimens of *P. guppyi.* This specimen (Plate 8, Figure 5) has a low interarea and wide delthyrium. The narrow septum is in contact with the pseudodeltidium near the apex. The dental ridges are quite distinct from the septum and there is no sign of a spondylium. This specimen may be in a stage of growth comparable with the very early stages of *P. callytharrensis* and *P. guppyi,* before the secondary spondylium was formed.

A brachial valve, F.17836, appears to be sulcate, but is crushed. The cardinal process is obscured by tough matrix. All the valves have fine costellation comparable in size with *P. lindneri* and *P. callytharrensis.*

Geological Age: Artinskian.

Occurrence: CPC 1519, 1520, F.17836, locality KNF 73, $2\frac{1}{5}$ miles, bearing 288° from Bruten's Old Yard, Cherrabun Station, 745 feet above the base, in the Noonkanbah Formation type section.

Observations: The three specimens here discussed were collected with numerous specimens of *S. crassimurus.* The reason for their separation from the somewhat variable *P. guppyi* are noted above. Better collections might indicate that the distinction is not valid.

Permorthotetes spp.

A number of small nondescript collections from various localities in the Carnarvon Basin contain specimens which probably should be referred to *Permorthotetes.*

None of these are sufficient for specific identification, but they serve to indicate the range of the genus. They are listed below in ascending order stratigraphically with brief notes. The stratigraphical range is from Wooramel Sandstone to basal Cundlego Formation.

Occurrences: M 41 (W.A. Petroleum Ltd.), $4\frac{3}{4}$ miles, bearing 66° from Callytharra Spring Wooramel River area, 545 feet above base of Wooramel Sandstone (Siltstone at base of "One Gum Formation"). A few shell fragments of a large *Permorthotetes* are present. F.17837, locality GW 54, $4\frac{3}{4}$ miles, bearing 115° from Dairy Creek Homestead, Carnarvon Basin; from the transitional beds at top of Wooramel Group to lower Byro Group. The collection comprises a brachial internal mould and some fragments. F.17838, locality LM 54, 300 yards west of Cundlego Crossing, south side of Minilya River, 9 miles west of Wandagee Homestead; basal bed of Cundlego Formation. A short incomplete cardinal process was found at this locality. F.17866, locality ML 89, $8\frac{1}{2}$ miles, bearing 82° from Mia Mia Homestead, north bank of Lyndon River between Burdghinmurrow and Salt Pools; Coyrie Formation. This collection comprises incomplete fragments of large thick-shelled specimens with rather coarse costellation like *P. camerata.* F.6618B, "East of Talbot's Cairn, Wooramel River", Byro Group. A brachial internal mould only is available. This was found with a brachial valve of *Kiangsiella condoni.*

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PLATE 1.

1 a, b, c, d, e. *Permorthotetes lindneri* sp. nov. CPC 1494a, holotype. Internal mould in ventral, dorsal, posterior and profile views and latex mould showing secondary spondylium. All x 1.

2. *Permorthotetes lindneri.* CPC 1494b. External impression of same specimen. x 1.

3. *Permorthotetes lindneri.* CPC 1501. Latex mould of cardinal process in anterior view. x 2.

4. *Permorthotetes lindneri.* CPC 1500. Latex mould of cardinal process in anterior view. x 2.

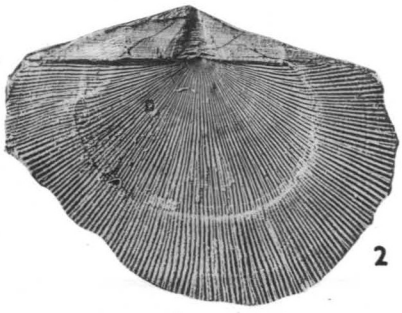
5 a, b. *Permorthotetes crespinae* sp. nov. CPC 1487, holotype. Brachial valve internal mould in dorsal view and profile. x 1.

6 a, b, c. *Permorthotetes crespinae.* CPC 1487. Latex mould of cardinal process of above specimen, in posterior and anterior views. 6 a, b, x 1. 6 c, x 2.

Figures 1-4. Poole Sandstone, Fitzroy Basin.

Figures 5-6. Lyons Group, Carnarvon Basin.

1a



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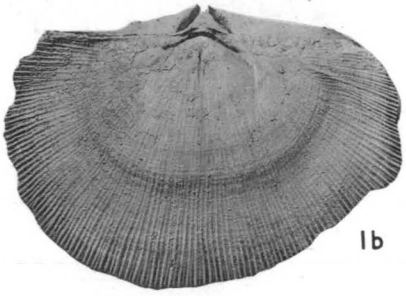
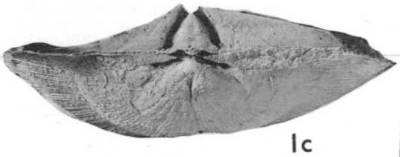


1b

1d

1e

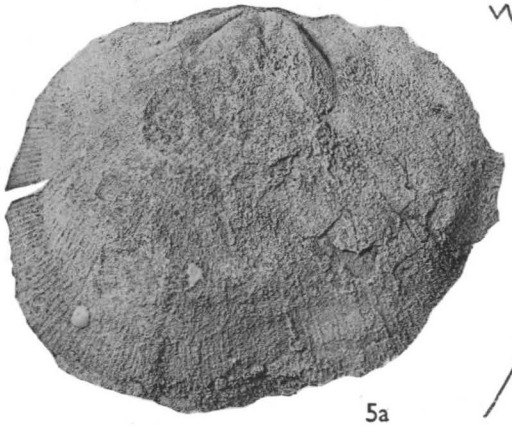
3



1c

4

6a



5a

5b

6b

6c

PLATE 2.

1 a, b. *Permorthotetes lindneri.* CPC 1496, paratype. Latex impression of natural mould of a shell, profile. x 7/8.

2. *Permorthotetes lindneri.* CPC 1498, paratype. External impression of pedicle valve. x 1.

3. *Permorthotetes lindneri.* CPC 1502, paratype. Internal view of part of shell showing cardinal process and socket plates. x 1.

4. *Permorthotetes crespinae.* CPC 1491, paratype. Pedicle valve, external impression.

5. *Permorthotetes crespinae.* CPC 1488, paratype. Pedicle valve, internal mould. x 1.

6 a, b. *Permorthotetes crespinae.* CPC 1489, paratype. Internal mould of pedicle valve, profile. x 1.

7 a, b. *Permorthotetes crespinae.* CPC 1492, paratype. Latex mould, showing the interarea with broken pseudodeltidium and interior view of asymmetric spondylium and septum. x 2.

8. *Permorthotetes crespinae.* CPC 1490, paratype. Pedicle valve, external impression. x 1.

Figures 1-3. Poole Sandstone, Fitzroy Basin.
Figures 4-8. Lyons Group, Carnarvon Basin.

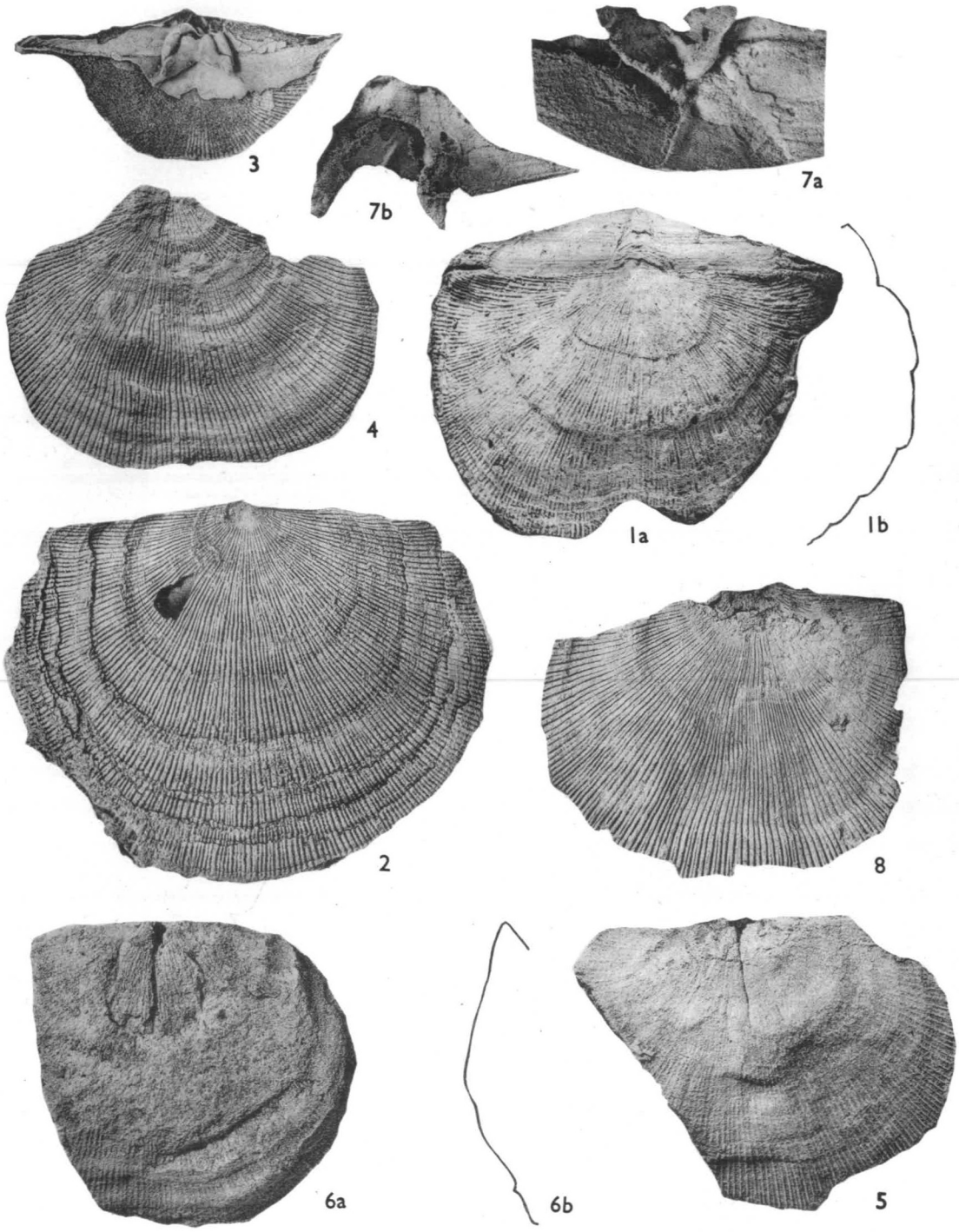

3
7b
7a
4
1a
1b
2
8
6a
6b
5

PLATE 3.

1. *Permorthotetes lindneri.* CPC 1495 b, paratype. External impression of pedicle valve. x 1.

2 a, b, c. *Permorthotetes lindneri.* CPC 1495 a, paratype. Internal mould in ventral and dorsal aspects and latex mould of spondylium and septum. x 1.

3 a, b. *Permorthotetes lindneri.* CPC 1521, paratype. Latex mould of the external impression of a shell in dorsal view, profile. x 1.

4. *Permorthotetes lindneri.* CPC 1499, paratype. Internal mould of pedicle valve. x 1.

5 a, b. *Permorthotetes lindneri.* CPC 1522, paratype. Latex mould of external impression of brachial valve, profile. x 1.

6. *Permorthotetes lindneri.* CPC 1497. Latex mould of external impression of brachial valve in posterior view. x 2.

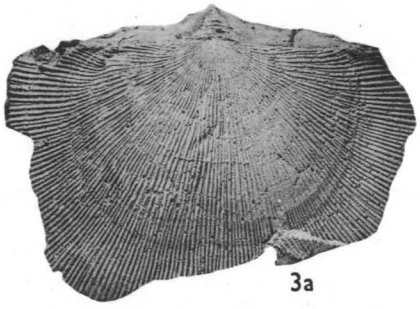
All specimens, Poole Sandstone, Fitzroy Basin.


1

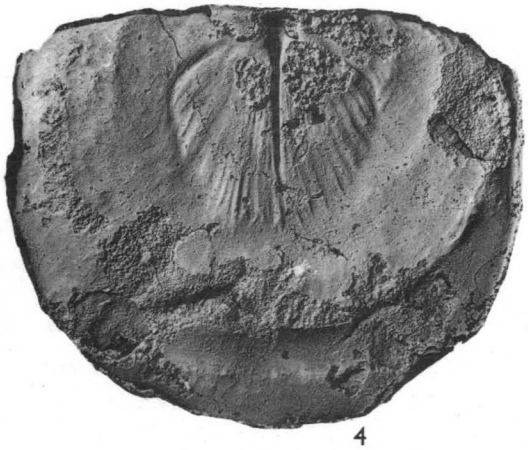

2a


2b

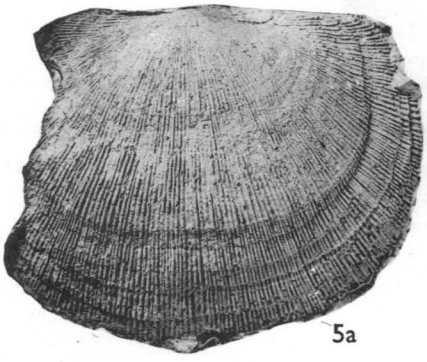

2c


3a


3b


4


5b


5a


6

PLATE 4.

1 a, b, c, d. *Permorthotetes callytharrensis* sp. nov. CPC 1473, holotype. Internal mould of pedicle valve, ventral aspect, palintrope, latex mould of spondylium and profile. x 1.

2 a, b. *Permorthotetes callytharrensis.* CPC 1474, paratype. Internal mould of brachial valve and profile. x 1.

3 a, b. *Permorthotetes callytharrensis.* CPC 1477, paratype. Internal mould of pedicle valve, profile. x 1.

4. *Permorthotetes callytharrensis.* CPC 1475, paratype. Latex mould of internal mould of a pedicle valve. x 1.

5. *Permorthotetes callytharrensis.* CPC 1485, paratype. Latex mould of internal mould of a pedicle valve, showing interarea, with perideltidial lines. x 1.

6 a, b, c. *Permorthotetes callytharrensis.* CPC 1476, paratype. Latex mould from internal mould of a brachial valve, showing cardinal process in posterior (a, b) and anterior views. x 3/2.

7 a, b. *Permorthotetes callytharrensis.* CPC 1474, paratype. Latex mould of internal mould of a brachial valve, showing cardinal process in posterior and anterior views. x 2.

8 a, b. *Permorthotetes callytharrensis*? CPC 1483. Isolated cardinal process in anterior and posterior views and showing area and eroded chilidial plates. x 2.

All specimens from Callytharra Formation, Carnarvon Basin.

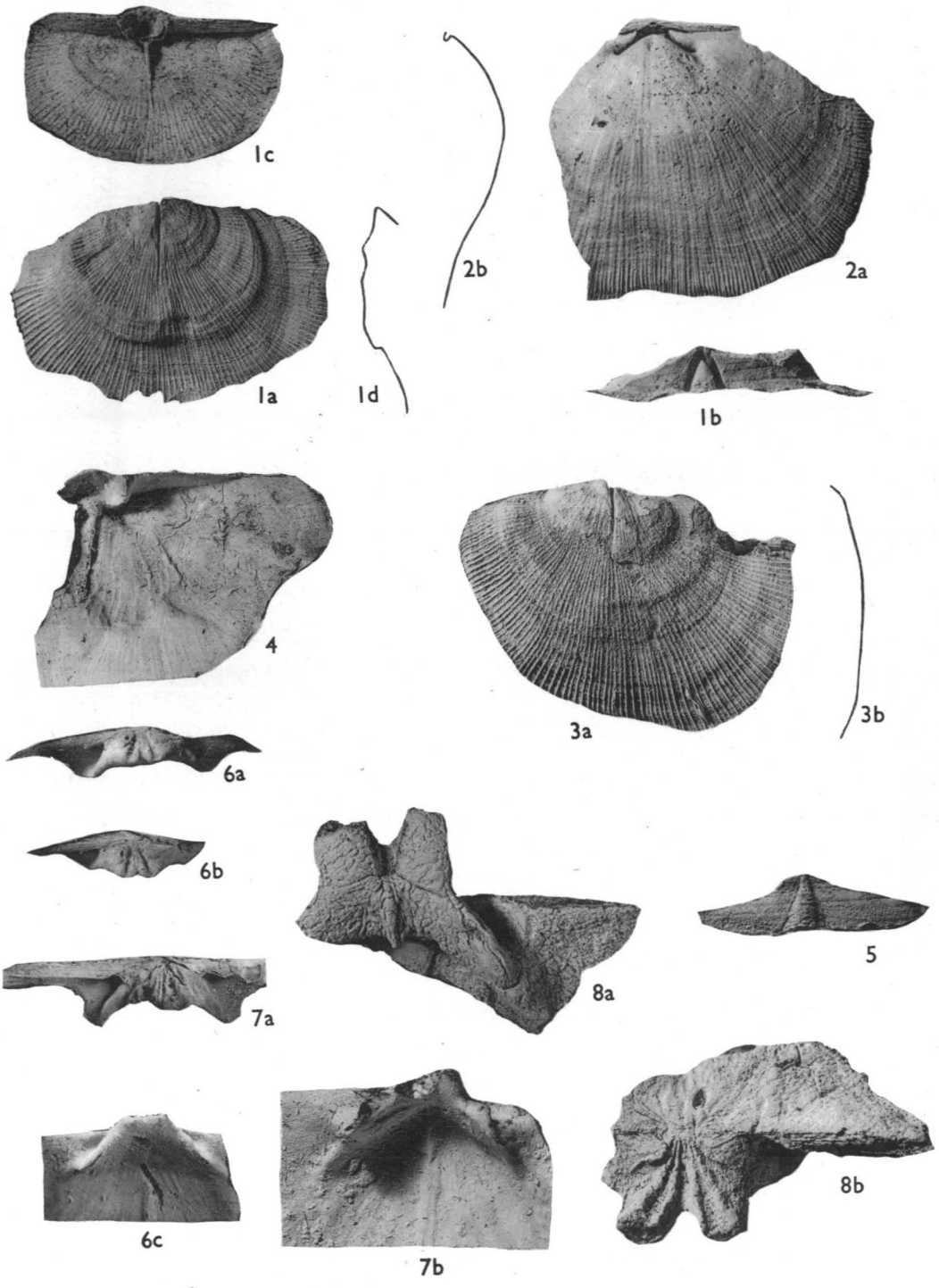

1c
1a
1d
2b
2a
1b
4
3a
3b
6a
6b
8a
5
7a
6c
7b
8b

PLATE 5.

1. *Permorthotetes callytharrensis* sp. nov. CPC 1478. Pedicle valve, internal view. x 1.

2 a, b. *Permorthotetes callytharrensis*. CPC 1479. Brachial valve, internal view and profile. x 1.

3. *Permorthotetes callytharrensis*. CPC 1480. Pedicle valve, internal view. x 1.

4 a, b. *Permorthotetes callytharrensis*. CPC 1481. Internal mould of brachial valve and profile. x 1/2.

5 a, b, c, d. *Derbyia hardmani* sp. nov. CPC 1467, holotype. Pedicle valve showing external view, interarea, septum and dental ridges (pseudodeltidium broken), profile. 5 a, b, d, x 1; 5 c, x 2.

6. *Derbyia hardmani*. CPC 1468, paratype. Pedicle valve, ventral view. x 1.

7 a, b. *Derbyia hardmani*. CPC 1469, paratype. Brachial valve, external view and profile. x 1/2.

8 a, b. *Derbyia hardmani*. CPC 1472. Internal mould of brachial valve, profile. x 1/2.

9 a, b. *Derbyia hardmani*. CPC 1471, paratype. Isolated cardinal process, posterior and anterior views. x 1.

Figures 1-4. Callytharra Formation, Carnarvon Basin.

Figures 5-9. Hardman Member of Liveringa Formation, Fitzroy Basin.

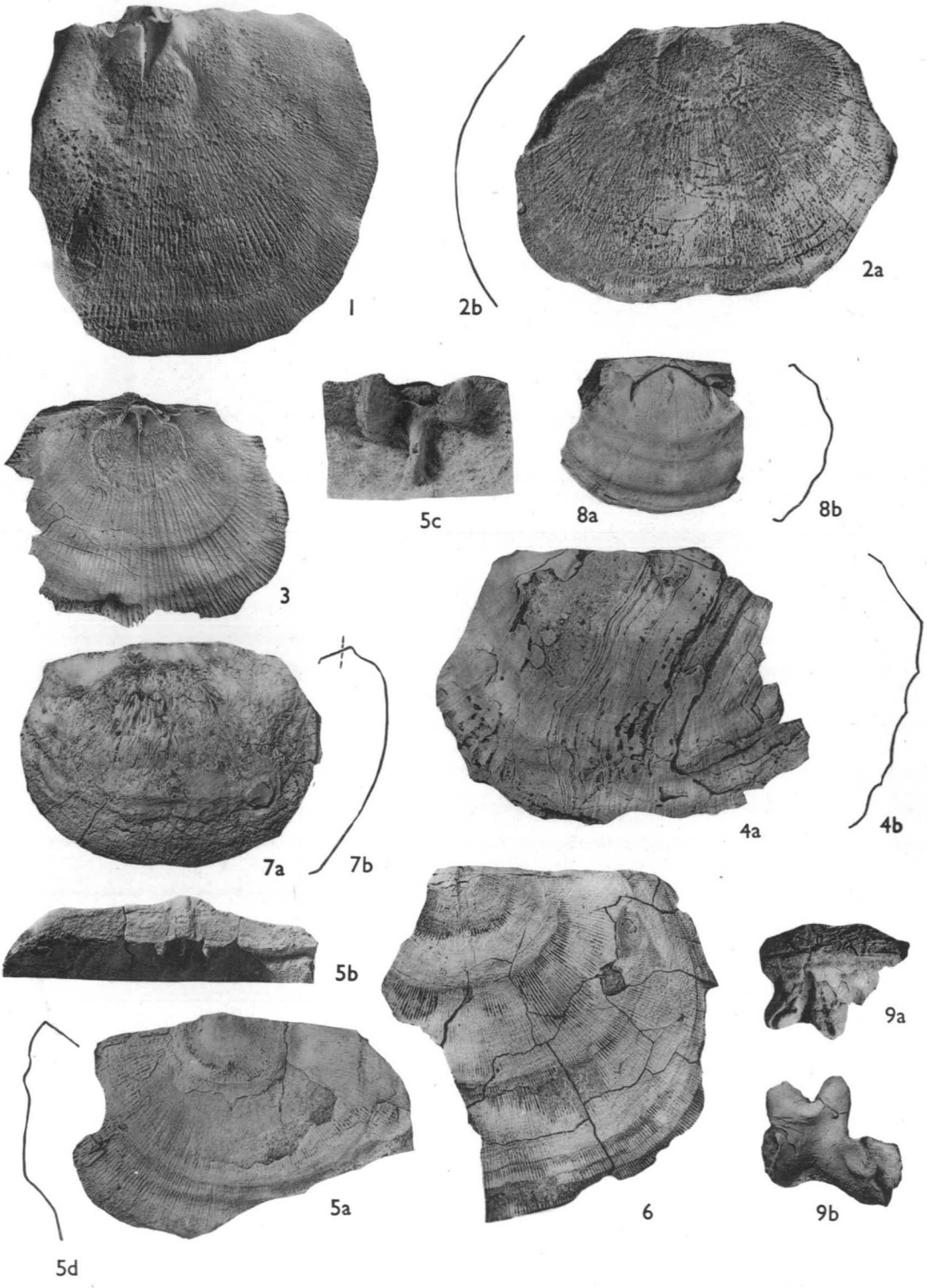

1
2b
2a
5c
8a
8b
3
4b
7a
7b
4a
5b
9a
6
5a
9b
5d

PLATE 6.

1 a, b. *Permorthotetes camerata* sp. nov. CPC 1514, holotype pedicle valve, internal view and profile. x 1.

2 a, b. *Permorthotetes camerata.* CPC 1515, paratype. Internal mould of brachial valve and profile. x 1.

3 a, b. *Permothotetes camerata.* CPC 1517. Pedicle valve, internal view and profile. x 1.

4 a, b. *Permorthotetes camerata.* CPC 1516. Internal mould of pedicle valve and profile. x $\frac{1}{2}$.

5 a, b. *Permorthotetes camerata.* CPC 1518. Brachial valve, external view and profile. x 1.

6 a, b, c. *Permorthotetes callytharrensis.* CPC 1532. Shell in dorsal, profile and posterior-dorsal views. x 1.

All specimens from Callytharra Formation, Carnarvon Basin.

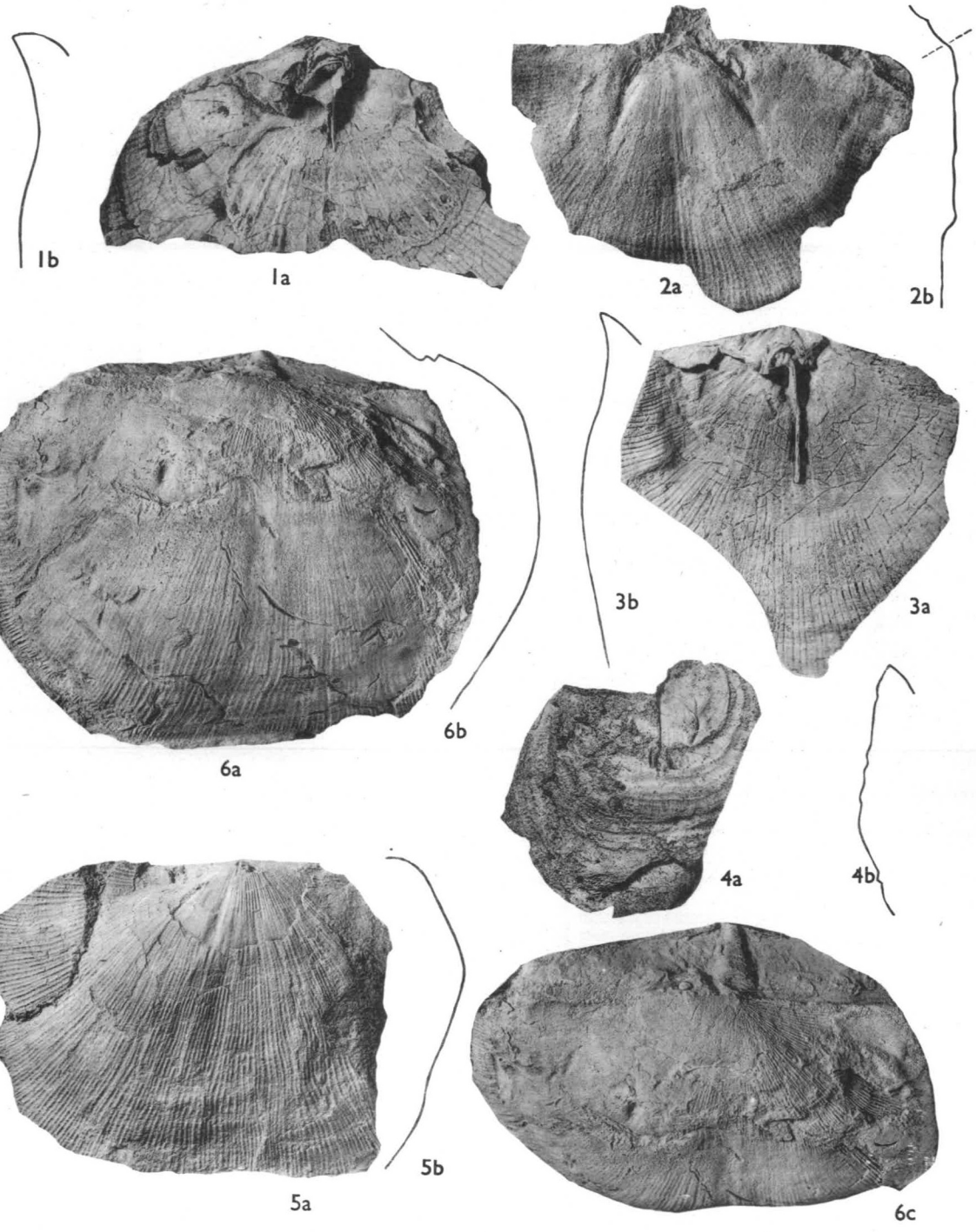

1b
1a
2a
2b
6a
6b
3b
3a
4a
4b
5a
5b
6c

PLATE 7.

1 a, b, c, d. *Permorthotetes guppyi* sp. nov. CPC 1503, holotype. Pedicle valve in ventral, internal, anterior internal and profile views. x 1.

2. *Permorthotetes guppyi.* CPC 1505. Incomplete shell, showing brachial valve interior and part of pedicle valve. x 1.

3 a, b. *Permorthotetes guppyi.* CPC 1506. Pedicle valve, external view with umbo ground away. x 1.

4. *Permorthotetes* sp. aff. *? P. guppyi.* CPC 1519. Incomplete pedicle valve, internal view. x 1.

All specimens from Noonkanbah Formation, Fitzroy Basin.

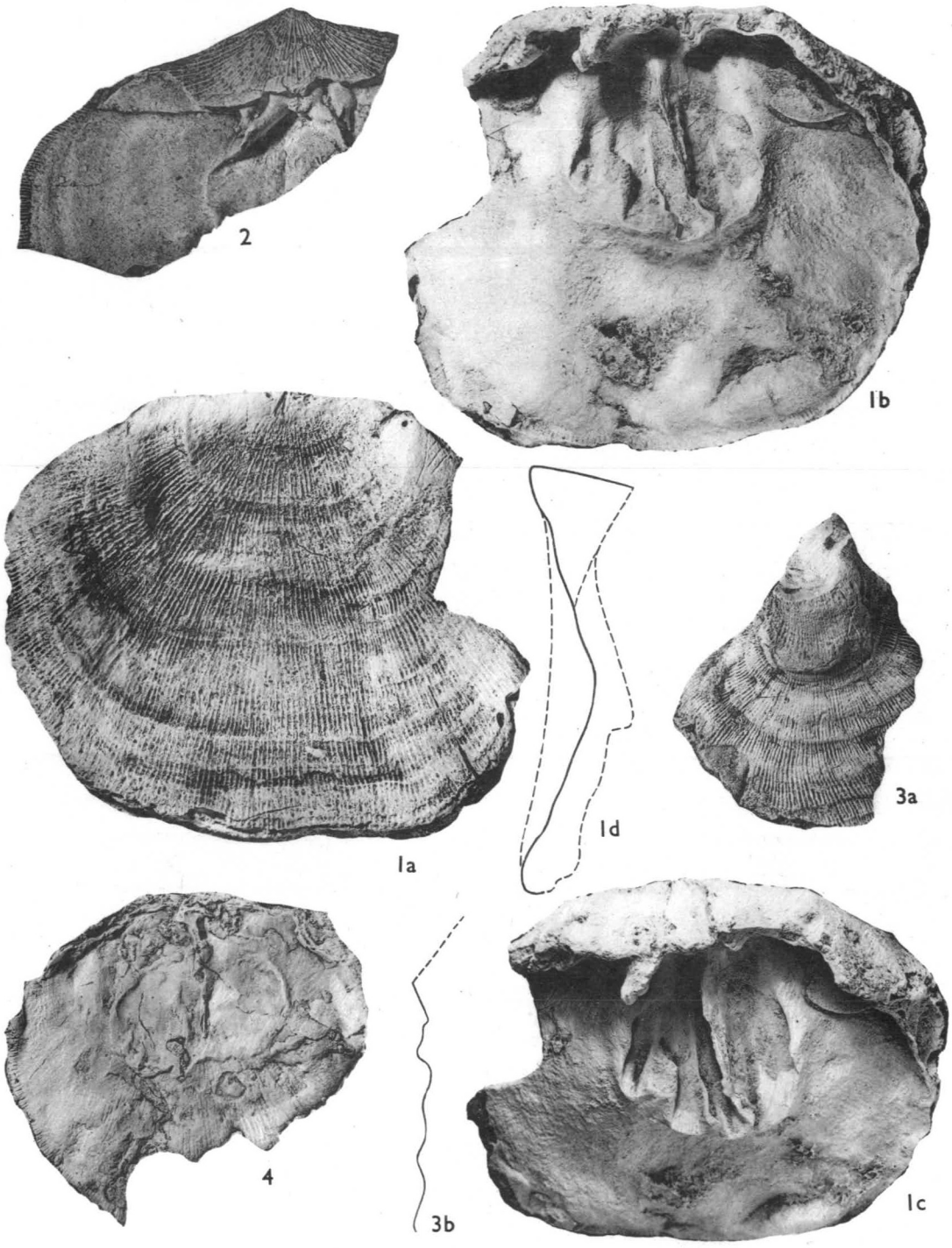

2
1b
1a
1d
3a
4
3b
1c

PLATE 8.

1. *Permorthotetes guppyi.* CPC 1507. Pedicle valve, ventral aspect. x 1. Lightjack Member, Liveringa Formation, Fitzroy Basin.

2. *Permorthotetes guppyi.* CPC 1509. Brachial valve, anterior part. x 1. Lightjack Member, Liveringa Formation, Fitzroy Basin.

3. *Permorthotetes guppyi.* CPC 1511. Pedicle valve, exterior. x 1. Noonkanbah Formation, Fitzroy Basin.

4 a, b. *Permorthotetes guppyi.* CPC 1508. Brachial valve, external view and profile. x 1. Lightjack Member of Liveringa Formation, Fitzroy Basin.

5. *Permorthotetes* sp. aff. *P. guppyi.* CPC 1520. Pedicle valve, internal view. x 1. Noonkanbah Formation, Fitzroy Basin.

6. *Permorthotetes teicherti* sp. nov. UWA 28045 B, paratype. Pedicle valve, external view. x ½. Baker Siltstone, Carnarvon Basin.

7. *Permorthotetes teicherti.* UWA 28045 A, holotype. Pedicle valve, ventral view. x ½. Baker Siltstone, Carnarvon Basin.

8 a, b. *Permorthotetes teicherti.* UWA 28036, paratype. Brachial valve, external view and profile. x 1. Baker Siltstone, Carnarvon Basin.

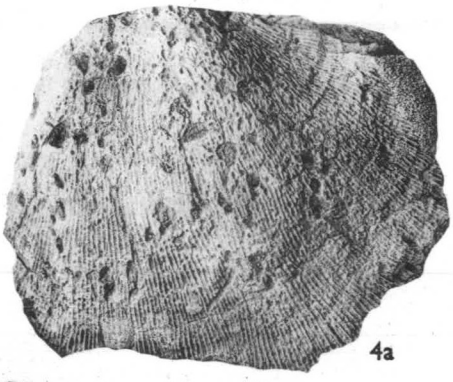
9. *Streptorhynchus luluigui* Hosking. CPC 1448. Pedicle valve, internal mould, ventral view. x 1. Hardman Member, Liveringa Formation, Fitzroy Basin.

10. *Streptorhynchus luluigui.* CPC 1447. Pedicle valve, internal mould, ventral view. Hardman Member, Liveringa Formation, Fitzroy Basin.

1

2

3

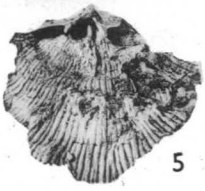


4a

4b

9

6



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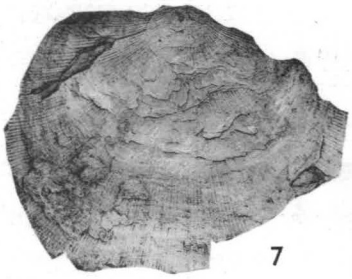

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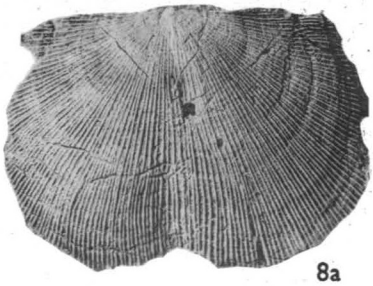
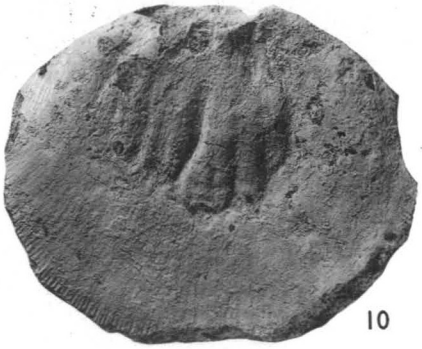


8a

8b



10

PLATE 9.

1 a, b, c, d. *Kiangsiella condoni* sp. nov. CPC 1450, holotype. Partly exfoliated shell in anterior dorsal, lateral, dorsal and ventral views. x 1.

2. *Kiangsiella condoni.* CPC 1452, paratype. Brachial valve, posterior view, showing cardinal process and socket plates. x 2.

3. *Kiangsiella condoni.* CPC 1456, paratype. Crushed shell in ventral view. x 1.

4. *Kiangsiella condoni.* CPC 1455, paratype. Crushed shell in dorsal view. x 1.

5. *Kiangsiella condoni.* CPC 1451, paratype. Crushed shell in dorsal view. x 1.

6. *Kiangsiella condoni.* CPC 1453, paratype. Crushed shell in dorsal view. x 1.

7. *Kiangsiella condoni.* CPC 1457, paratype. Crushed shell in ventral view. x 1.

8. *Kiangsiella* sp. *B.* CPC 1465. Incomplete shell, ventral view. Noonkanbah Formation, Fitzroy Basin.

Figures 1-7, from Coyrie Formation, Carnarvon Basin.

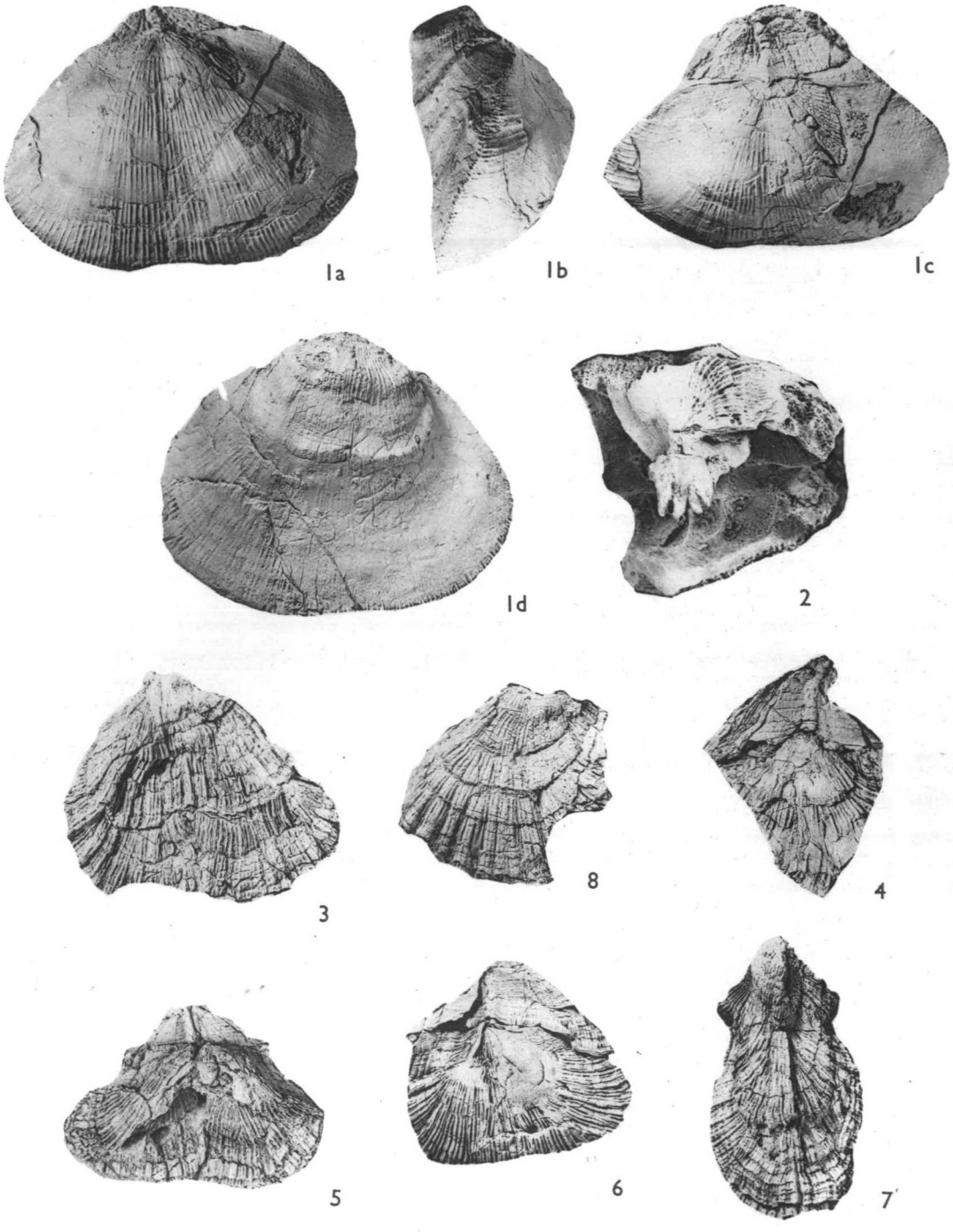

1a
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PLATE 10.

1. *Kiangsiella condoni.* CPC 1452, paratype. Ventral surface at anterior end. x 2. Coyrie Formation, Carnarvon Basin.

2 a, b. *Kiangsiella* sp. A. CPC 1461. Brachial valve, somewhat eroded, and profile. Lyons Group, Carnarvon Basin.

3 a, b. *Kiangsiella* sp. A. CPC 1460. Brachial valve, external view x 2, and profile x 1. Lyons Group, Carnarvon Basin.

4. *Kiangsiella* sp. A. CPC 1462. Pedicle valve, internal view. x 1. Lyons Group, Carnarvon Basin.

5 a, b. *Kiangsiella condoni.* CPC 1459. Internal mould of brachial valve and profile. x 1. Coyrie Formation, Carnarvon Basin.

6 a, b. *Kiangsiella condoni.* CPC 1452. Brachial valve, external view and profile. x 1. Coyrie Formation, Carnarvon Basin.

7. *Kiangsiella* sp. B. CPC 1466. Pedicle valve, external view and profile. x 1. Noonkanbah Formation, Fitzroy Basin.

8 a, b. *Kiangsiella condoni.* CPC 1458. Internal mould of pedicle valve, ventral view and profile. x 1. Byro Group, lower beds, Carnarvon Basin.

9. *Kiangsiella condoni.* CPC 1454. Pedicle valve, external view. x 1. Coyrie Formation, Carnarvon Basin.

10 a, b. *Kiangsiella* sp. B. CPC 1464. Brachial valve, external view and profile. x 1. Noonkanbah Formation, Fitzroy Basin.

11. *Kiangsiella* sp. B. CPC 1463. Pedicle valve, external view. x 1. Noonkanbah Formation, Fitzroy Basin.

12 a, b. *Streptorhynchus variabilis* sp. nov. CPC 1418, paratype. Pedicle valve, external view and profile. x 1. Noonkanbah Formation, Fitzroy Basin.

13 a, b. *Streptorhynchus variabilis.* CPC 1414. Pedicle valve, external view and profile. x 1. Noonkanbah Formation.

14. *Permorthotetes callytharrensis?* CPC 1484. External impression of interarea and brachial valve. x 1. Callytharra Formation, Carnarvon Basin.

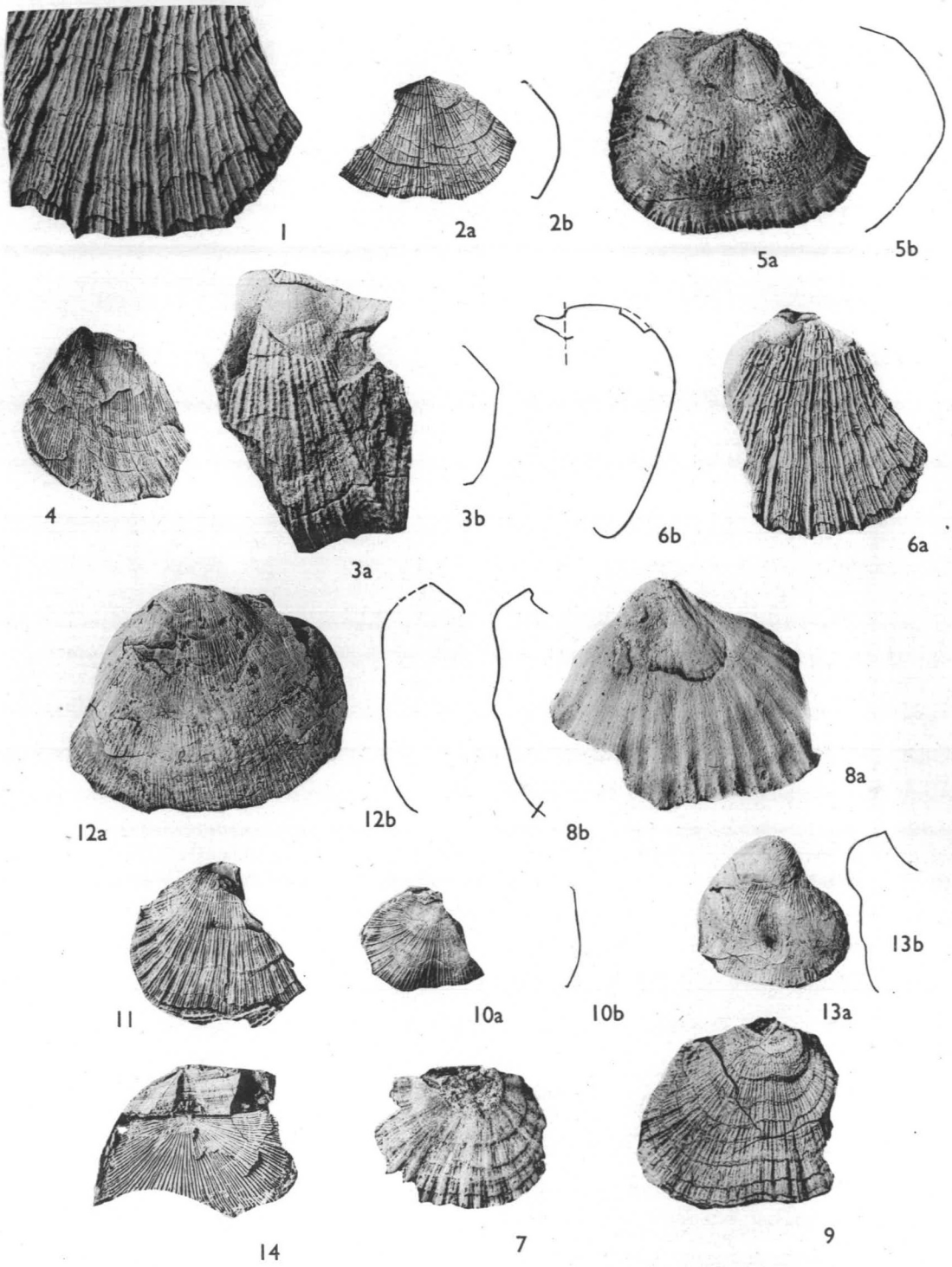

1
2a
2b
5a
5b
4
3a
3b
6b
6a
12a
12b
8b
8a
11
10a
10b
13a
13b
14
7
9

PLATE 11.

1 a, b, c, d. *Streptorhynchus plicatilis* Hosking. CPC 1400. Pedicle valve, showing internal anterior, internal, external and profile views. 1 a-c, x 2. 1 d, x 1.

2 a, b. *Streptorhynchus plicatilis.* CPC 1402. Pedicle valve, internal view x 2, and profile x 1.

3 a, b. *Streptorhynchus plicatilis.* CPC 1403. Shell in ventral and dorsal views. x 2.

4. *Streptorhynchus plicatilis.* CPC 1406. Shell in dorsal view. x 2.

5 a, b. *Streptorhynchus plicatilis.* CPC 1401. Shell in ventral view and profile. 5 a, x 2. 5 b, x 1.

6. *Streptorhynchus plicatilis.* CPC 1404. Shell in dorsal view. x 2.

7 a, b. *Streptorhynchus variabilis.* CPC 1416. Pedicle valve and profile. x 1.

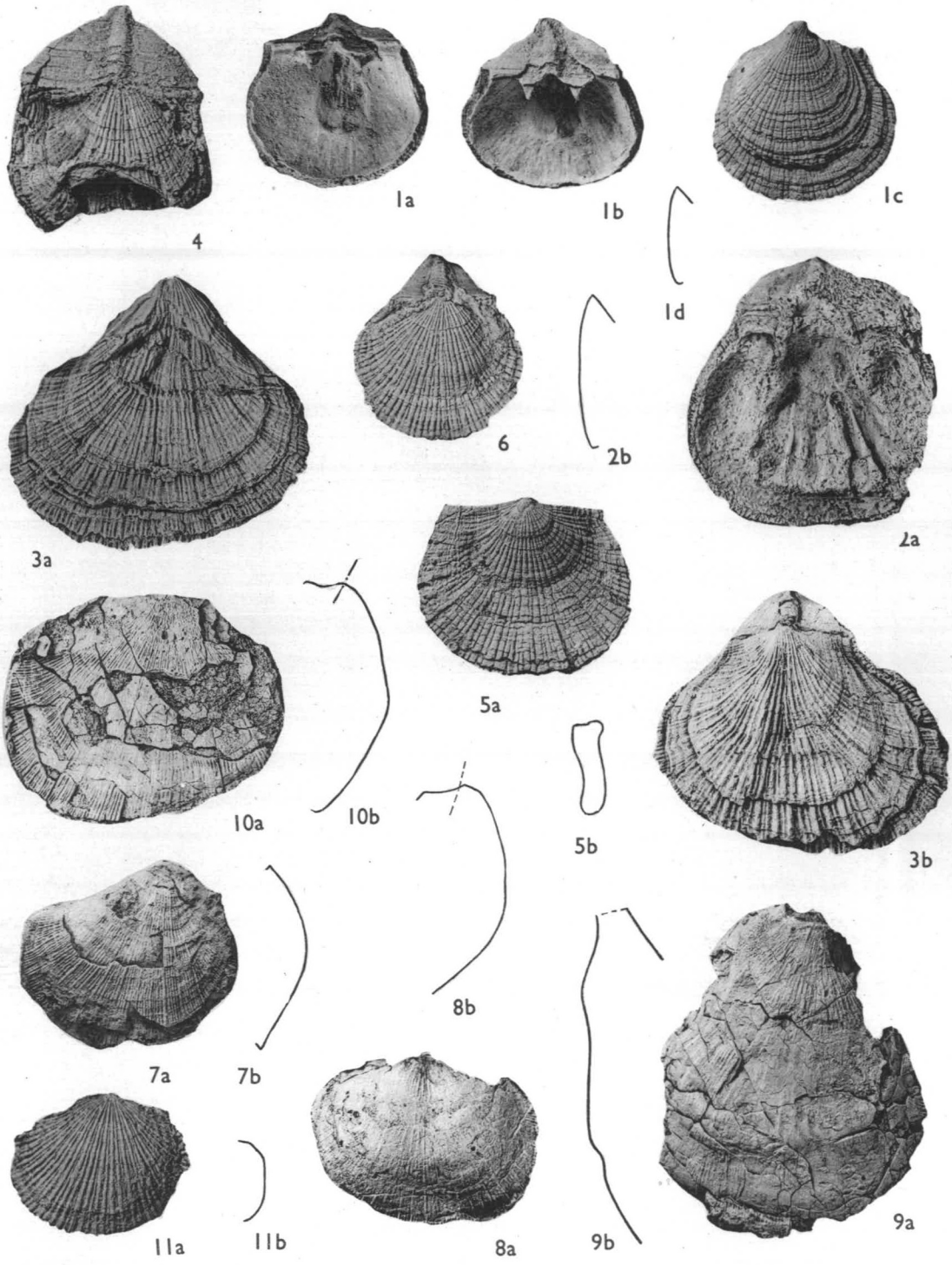
8 a, b. *Streptorhynchus variabilis.* CPC 1417. Brachial valve, external view, somewhat eroded, and profile. x 1. Noonkanbah Formation, Fitzroy Basin.

9 a, b. *Streptorhynchus variabilis.* CPC 1413, holotype. Pedicle valve, external view, somewhat eroded, and profile. x 1. Noonkanbah Formation, Fitzroy Basin.

10 a, b. *Streptorhynchus variabilis.* CPC 1415, paratype. Brachial valve, external view and profile. x 1.

11 a, b. *Streptorhynchus plicatilis.* CPC 1405, paratype. Brachial valve, external view x 2, and profile x 1.

Figures 1-6 and 11, Callytharra Formation, Carnarvon Basin.
Figures 7-10, Noonkanbah Formation, Fitzroy Basin.


4
1a
1b
1c
1d
3a
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2a
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10a
10b
5b
3b
7a
7b
8b
11a
11b
8a
9b
9a

PLATE 12.

1. *Streptorhynchus crassimurus* sp. nov. CPC 1407, holotype. Pedicle valve, somewhat crushed, external view. x 1. Noonkanbah Formation, Fitzroy Basin.

2 a, b, c. *Streptorhynchus crassimurus*. CPC 1412, paratype. Brachial valve, showing the interior, posterior and anterior views of the cardinal process. x 1. Noonkanbah Formation, Fitzroy Basin.

3 a, b. *Streptorhynchus crassimurus*. CPC 1411, paratype. Brachial valve, external view and profile. x 1. Noonkanbah Formation, Fitzroy Basin.

4 a, b. *Streptorhynchus crassimurus*. CPC 1408, paratype. Brachial valve, dorsal view and profile. x 1. Noonkanbah Formation, Fitzroy Basin.

5. *Streptorhynchus crassimurus*. CPC 1410, paratype. Pedicle valve, dorsal view. x 1. Noonkanbah Formation, Fitzroy Basin.

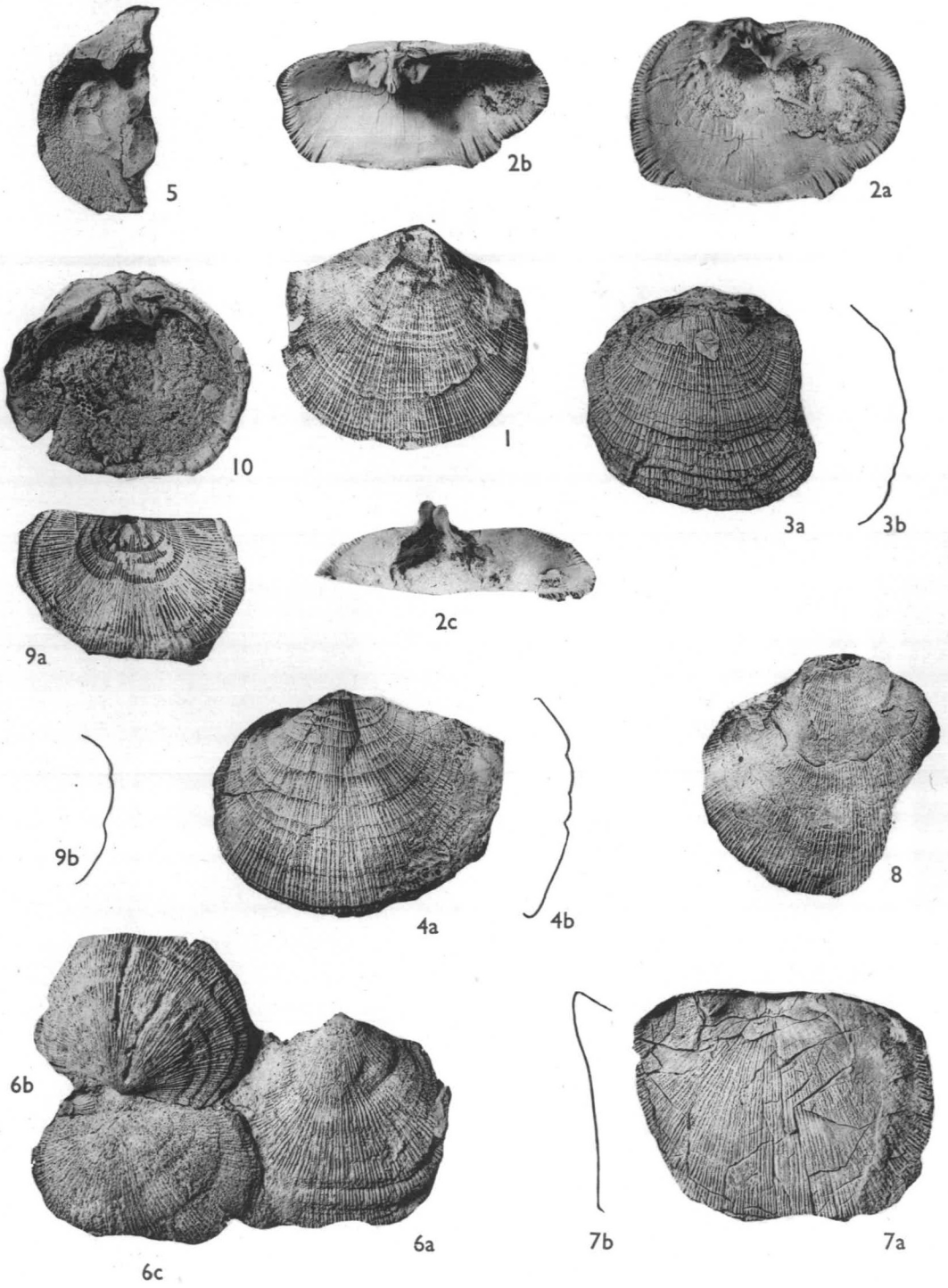
6 a, b, c. *Streptorhynchus hoskingae*. CPC 1428. Latex moulds of natural external impressions, pedicle and two brachial valves. x 1. Wandagee Formation, Carnarvon Basin.

7 a, b. *Streptorhynchus hoskingae*. UWA 33360/2. Pedicle valve, internal view and profile. x 1. Wandagee Formation, Carnarvon Basin.

8. *Streptorhynchus* sp. A. CPC 1449. Pedicle valve, external view. x 1. Lyons Group, Carnarvon Basin.

9 a, b. *Streptorhynchus hoskingae*. CPC 1429. Brachial valve, external impression and profile. x 1. Cundlego Formation, Carnarvon Basin.

10. *Streptorhynchus crassimurus*. CPC 1409, paratype. Brachial valve, ventral view. x 1. Noonkanbah Formation, Fitzroy Basin.


5
2b
2a
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3a
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9a
2c
9b
4a
4b
8
6b
6a
6c
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7a

PLATE 13.

1 a, b, c, d. *Streptorhynchus hoskingae.* CPC 1425, holotype. Pedicle valve showing dorsal, dorsal posterior, dorsal anterior and profile views. 1 a-c x 2, 1 d x 1. Wandagee Formation, Carnarvon Basin.

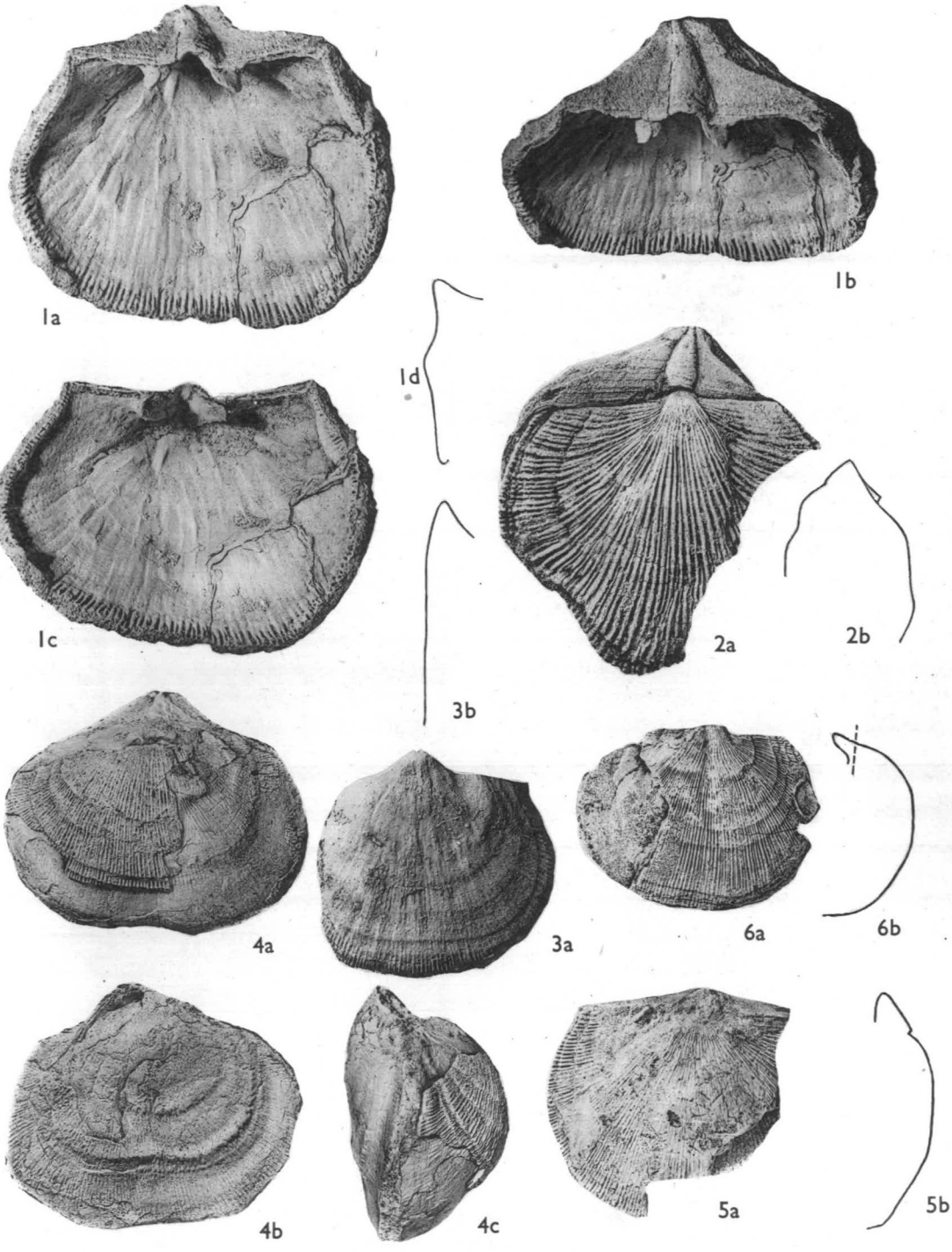
2 a, b. *Streptorhynchus hoskingae.* CPC 1426, paratype. Shell from dorsal side, x 2, profile x 1. Wandagee Formation, Carnarvon Basin.

3 a, b. *Streptorhynchus hoskingae.* CPC 1427. Pedicle valve, natural mould in ventral view and profile. x 1. Wandagee Formation, Carnarvon Basin.

4 a, b, c. *Streptorhynchus hoskingae.* UWA 28185. Shell, partly exfoliated in dorsal, ventral and profile views. x 1. Cundlego Formation, Carnarvon Basin.

5 a, b. *Streptorhynchus hoskingae.* UWA 33360. Shell in dorsal view and profile. x 1. Wandagee Formation, Carnarvon Basin.

6 a, b. *Streptorhynchus hoskingae.* UWA 33359/1. Brachial valve, dorsal view and profile. x 1. Wandagee Formation, Carnarvon Basin.


1a
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1c
1d
2a
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3a
3b
4a
4b
4c
5a
5b
6a
6b

PLATE 14.

1 a-c. *Streptorhynchus johnstonei* sp. nov. CPC 1430 a, holotype. Internal mould in dorsal, lateral and ventral view. x 2.

2. *Streptorhynchus johnstonei.* CPC 1430 b. Latex mould of external impression of same individual. x 2.

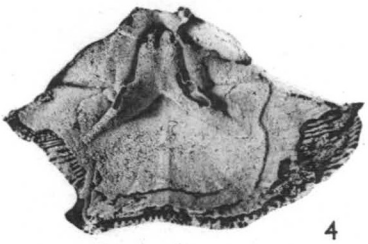
3 a, b. *Streptorhynchus johnstonei.* CPC 1430 a. Latex mould of natural internal mould showing cardinal process in anterior and posterior view. x 1.

4. *Streptorhynchus johnstonei.* CPC 1432, paratype. Ferruginized shell replacement, showing cardinal process and interior of palintrope. x 2.

5 a, b. *Streptorhynchus johnstonei.* CPC 1431, paratype. External impression of pedicle valve and lateral profile. x 2.

6 a, b. *Streptorhynchus johnstonei.* UWA WH7. Ferruginized brachial valve, internal view and profile. x 1.

All specimens from Coolkilya Formation, Carnarvon Basin.



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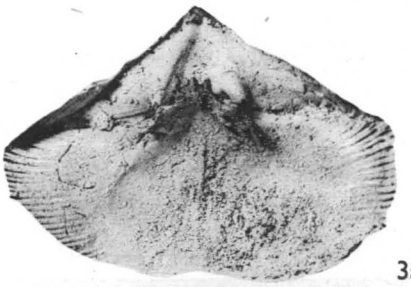

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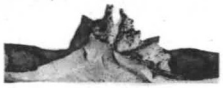

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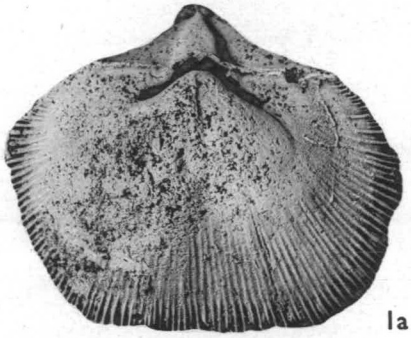

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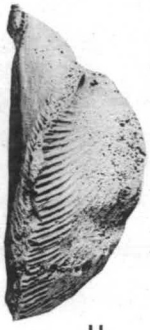
2



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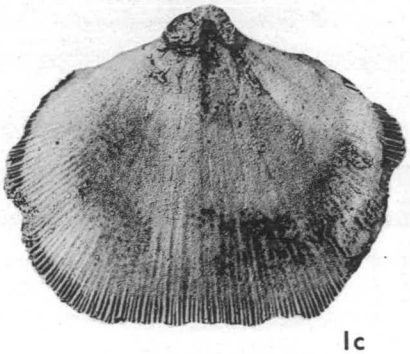


1c

5a

5b

6b

6a

PLATE 15.

1. *Streptorhynchus costatus* sp. nov. CPC 1419, holotype. Shell in dorsal view. x 1.

2 a, b. *Streptorhynchus costatus*. CPC 1423. Shell, dorsal view and profile. x 1.

3 a, b. *Streptorhynchus costatus*. CPC 1424. Pedicle valve, largely exfoliated, ventral view and profile. x 1.

4 a, b. *Streptorhynchus costatus*. CPC 1422. Shell in ventral view and profile. x 1.

5 a, b. *Streptorhynchus costatus*. CPC 1523. Shell in dorsal view and profile. x 1.

6 a, b. *Streptorhynchus costatus*. CPC 1420, paratype. Shell, corroded, showing internal view of palintrope and dorsal valve, and profile. x 1.

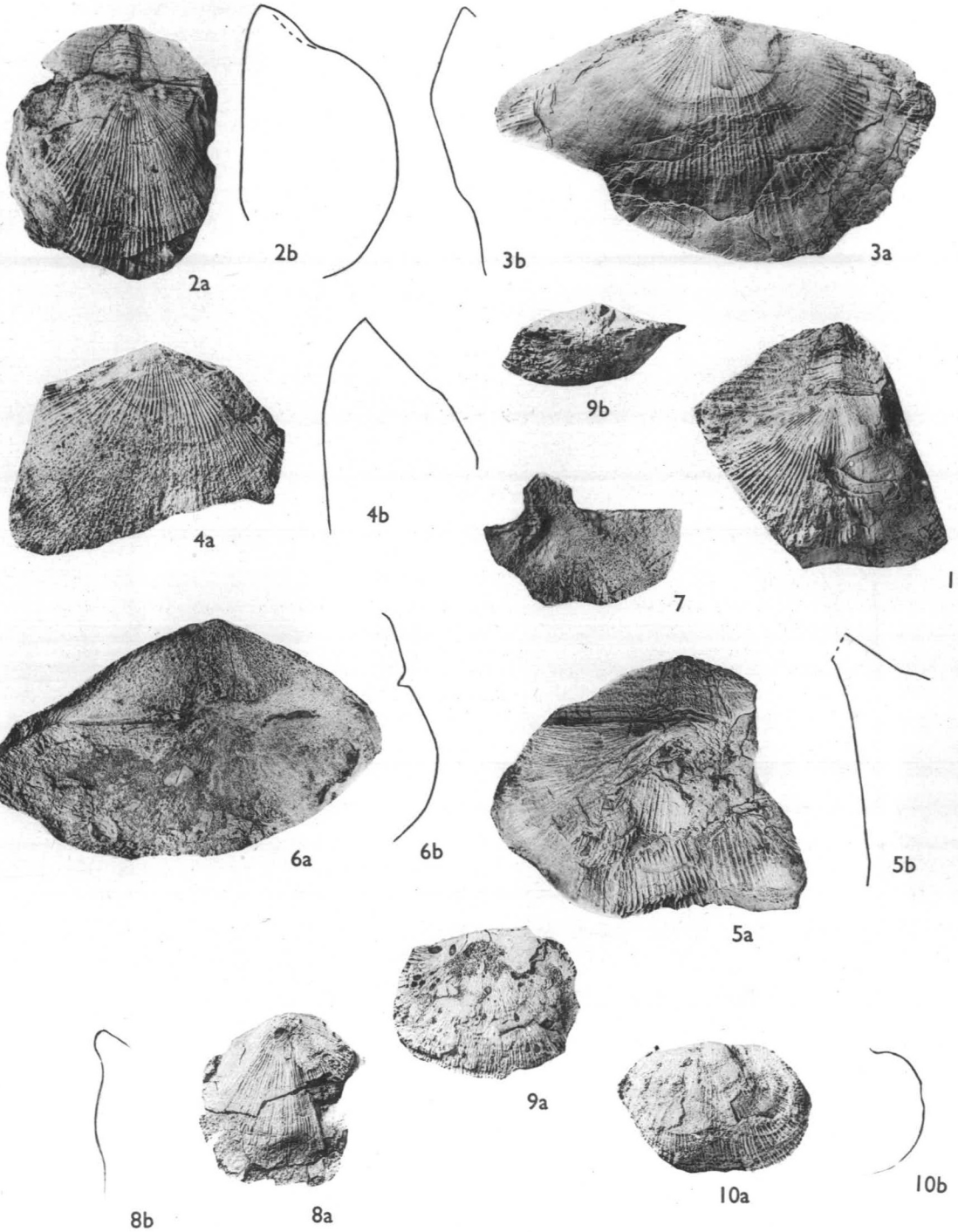
7. *Streptorhynchus costatus*. CPC 1421, paratype. Incomplete cardinal process, anterior view. x 1.

8 a, b. *Streptorhynchus* sp. aff. *S. perfidiabadensis* Etheridge. CPC 1433. Pedicle valve, eroded, external view and profile. x 1.

9 a, b, c. *Streptorhynchus* sp. aff. *S. perfidiabadensis*. CPC 1435. Brachial valve, dorsal posterior view and lateral profile.

10 a, b. *Streptorhynchus* sp. aff. *S. perfidiabadensis*. CPC 1434. Brachial valve, external view and profile. x 1.

Figures 1-7, Noonkanbah Formation, Fitzroy Basin.
Figures 8-10, Lightjack Member, Liveringa Formation, Fitzroy Basin.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10b

PLATE 16.

1 a, b, c. *Streptorhynchus* sp. cf. *S. pelargonatus* (Schlotheim). CPC 1436. Pedicle valve, ventral and dorsal views, x 2, profile x 1.

2. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1438. Pedicle valve, external view. x 2.

3 a, b. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1438. Same shell, showing interarea x 2 and profile x 1.

4. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1437. Pedicle valve, dorsal view showing interarea and profile. x 1.

5. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1439. Pedicle valve, dorsal view. x 2.

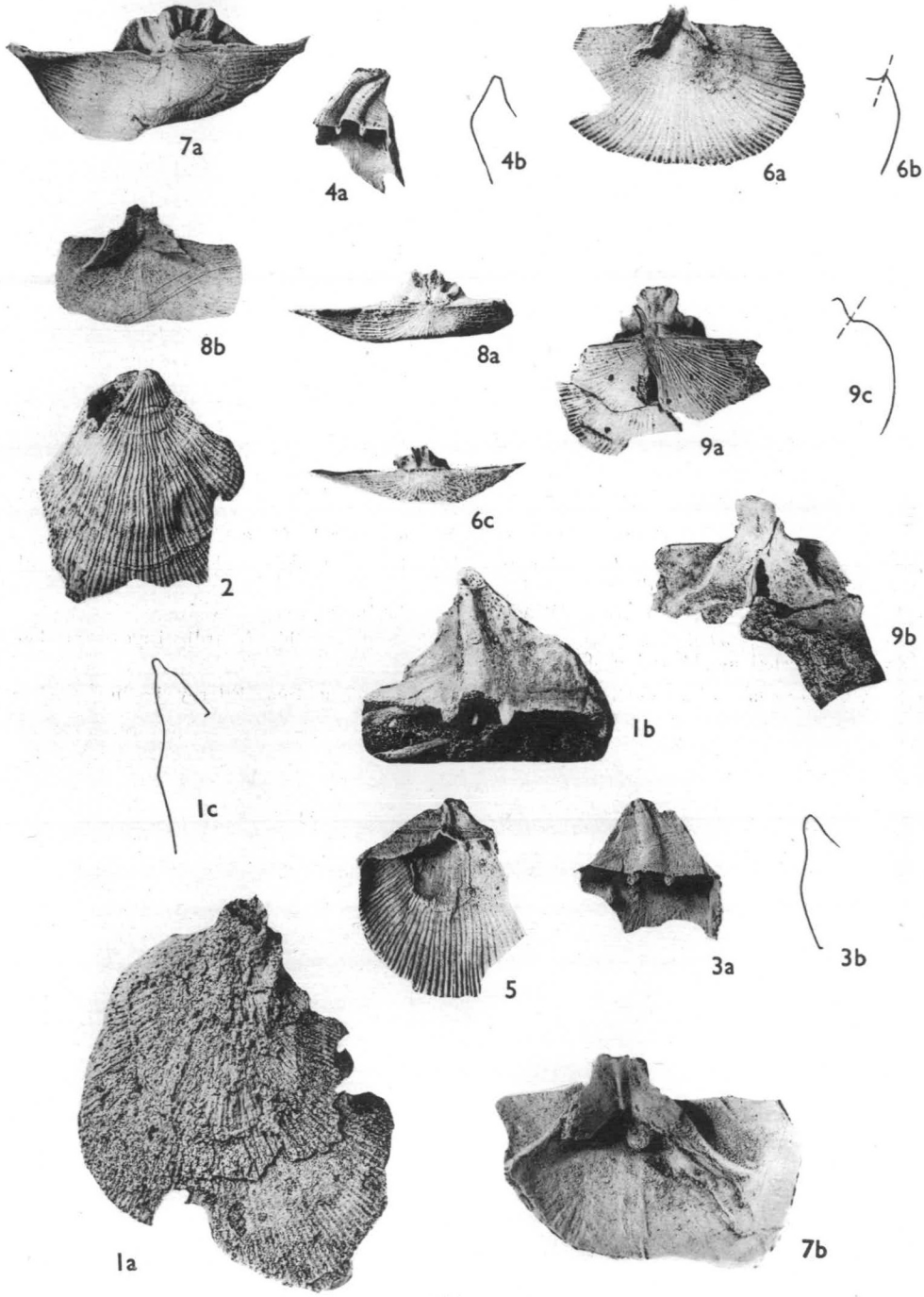
6 a, b, c. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1443. Brachial valve, internal view x 2, profile x 1.

7 a, b. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1440. Brachial valve showing cardinal process in posterior and anterior views. x 2.

8 a, b. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1442. Brachial valve, posterior and anterior views of cardinal process. x 2.

9 a, b, c. *Streptorhynchus* sp. cf. *S. pelargonatus*. CPC 1441. Brachial valve, showing cardinal process in dorsal and ventral views, x 2, profile x 1.

All specimens from Hardman Member, Liveringa Formation, Fitzroy Basin.


7a
4a
4b
6a
6b
8b
8a
9a
9c
6c
2
9b
1b
1c
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3a
3b
1a
7b

PLATE 17.

1. *Streptorhynchus luluigui* Hosking. CPC 1444. Pedicle valve, external impression. x 1.

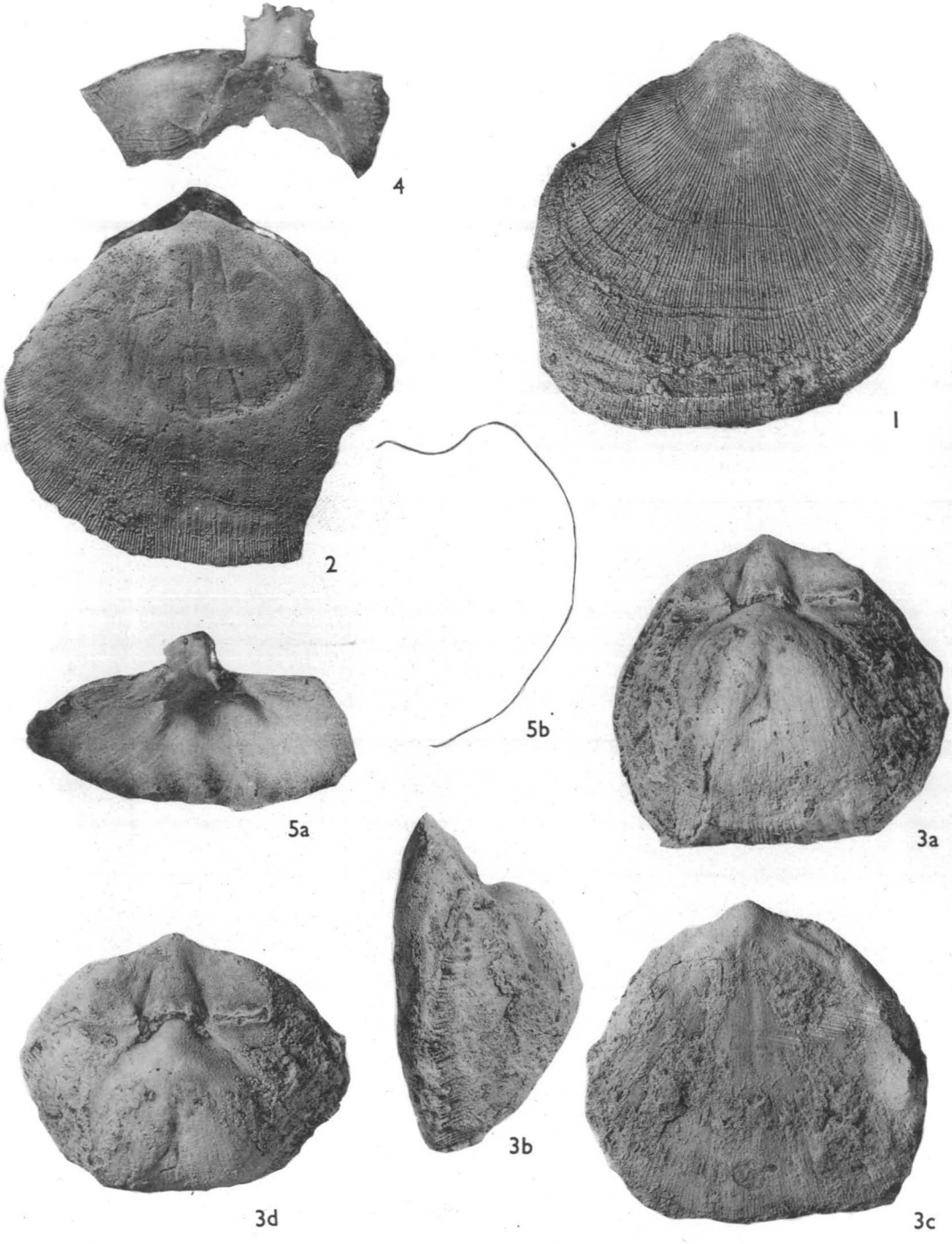
2. *Streptorhynchus luluigui*. CPC 1444. Internal mould of same individual. x 1.

3 a, b, c, d. *Streptorhynchus luluigui*. CPC 1446. Internal mould, in dorsal, lateral, ventral and posterior dorsal views. x 1.

4. *Streptorhynchus luluigui*. UWA 2772/0. Cardinal process. x 1.

5 a, b. *Streptorhynchus luluigui*. CPC 1445. Latex mould of cardinal process taken from an internal mould and profile. x 1.

All specimens from Hardman Member, Liveringa Formation, Fitzroy Basin.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3b
3d
3c

PLATE 18.

1. *Kiangsiella condoni.* CPC 1533. Transverse section of anterior part of crushed shell, locality ML87, Bulgadoo Shale, Carnarvon Basin. x 18.

2. *Permorthotetes guppyi.* CPC 1534. Transverse section of pedicle valve, anterior part, locality KNA28, Noonkanbah Formation, Fitzroy Basin. x 26.

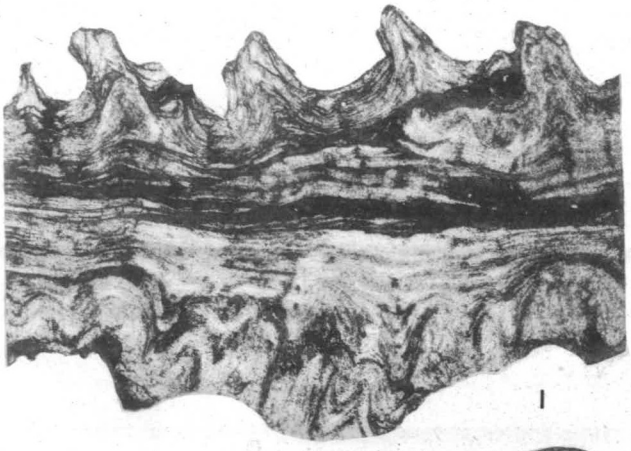
3. *Permorthotetes callytharrensis.* CPC 1532. Transverse section of pedicle valve at about 3 mm. from the umbonal tip, locality K52, Carnarvon Basin. x 4.

4. *Permorthotetes callytharrensis.* Transverse section of anterior part of same shell, locality K52, Carnarvon Basin, external surface partly exfoliated. x 26.

5. *Permorthotetes callytharrensis.* Transverse section, same as fig. 3, showing parasitic perforations. x 22.

6. *Derbyia hardmani.* CPC 1470. Transverse section of anterior part of shell, internal surface partly exfoliated, locality Mount Hardman, Fitzroy Basin. x 27.

7. *Streptorhynchus plicatilis.* CPC 1535. Transverse section of pedicle valve at posterior end, exterior partly exfoliated, locality GW82, Carnarvon Basin. x 22.



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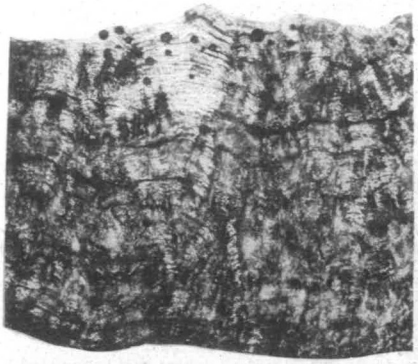

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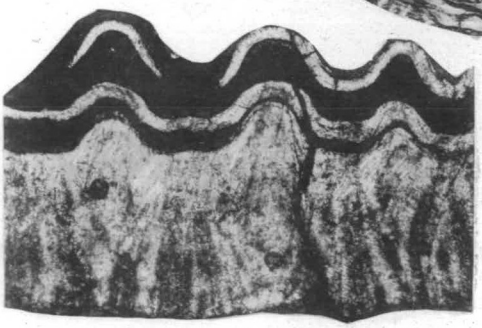

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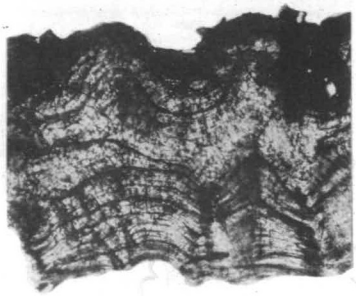

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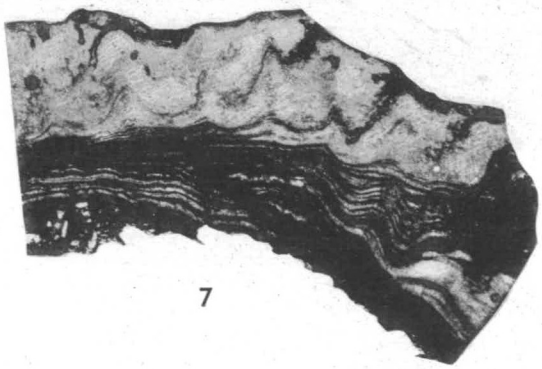

7

PLATE 19.

1. *Streptorhynchus variabilis.* CPC 1536. Transverse section, anterior part of shell, inner layers separated from outer layers, outer layers partly exfoliated, locality KNF84, Fitzroy Basin. x 22.

2. *Derbyia hardmani.* CPC 1537. Transverse section of anterior part of shell, locality Mount Hardman, Fitzroy Basin. x 27.

3. *Streptorhynchus luluigui.* CPC 1538. Transverse section, posterior end, showing dental ridge and part of pseudo-deltidium, external surface exfoliated, locality FL220, Fitzroy Basin. x 30.

4. *Streptorhynchus crassimurus.* CPC 1540. Transverse section, anterior end of shell, external surface exfoliated and inner surface eroded, locality KNF73, Fitzroy Basin. x 18.

5. *Streptorhynchus costatus.* CPC 1539. Transverse section at posterior end of shell, inner layers separated from rest, locality KNA28, Fitzroy Basin. x 18.

6. *Streptorhynchus luluigui.* CPC 1538. Transverse section at anterior end of shell, inner layers exfoliated, outer partly exfoliated, locality FL220, Fitzroy Basin. x 22.

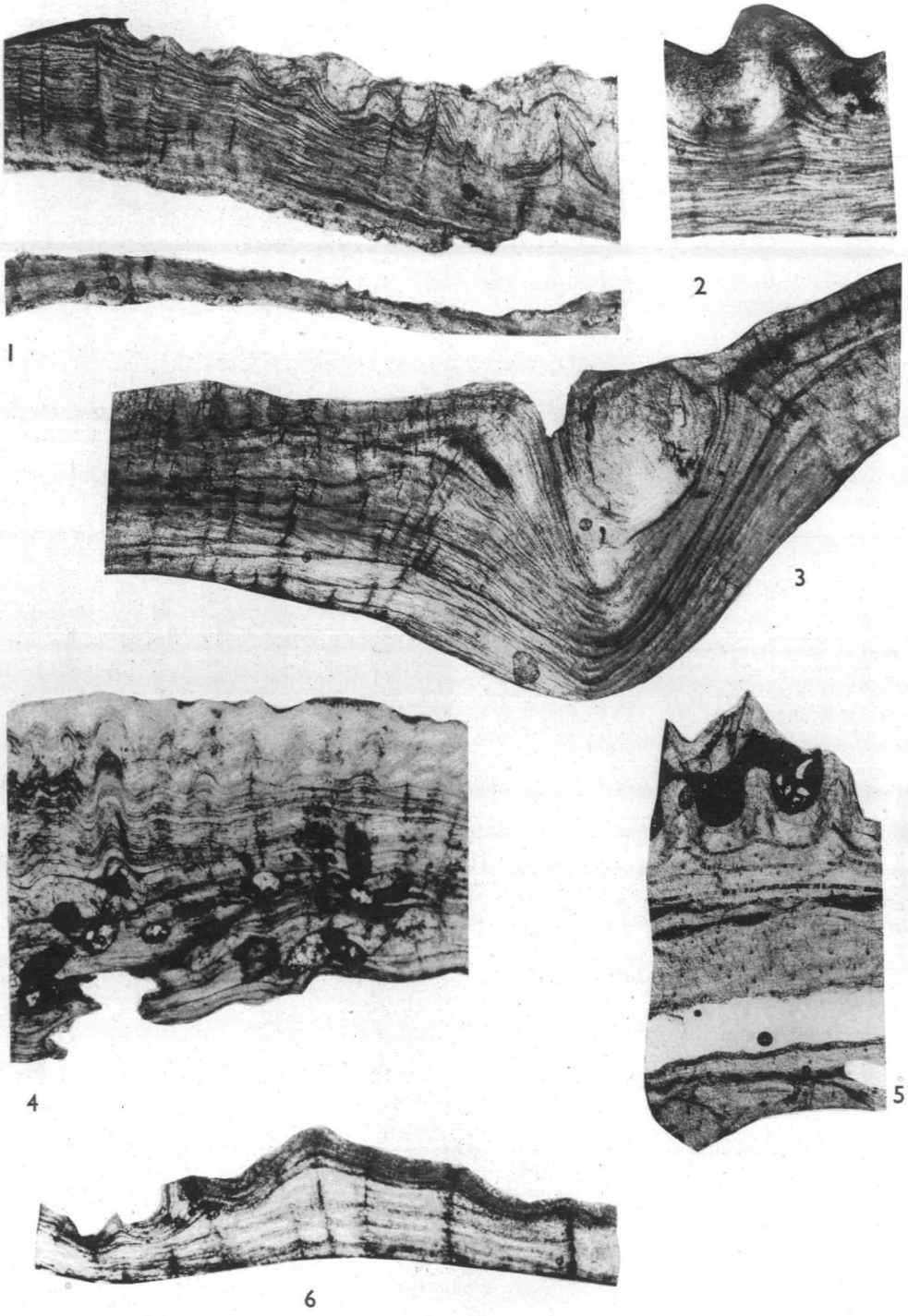

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Plate 20.

1a-k. *Permorthotetes callytharrensis.* Transverse sections of CPC 1482 at the following intervals measured from the tip of the umbo:—a, 0.8 mm., b, 1.6 mm., c, 2.6 mm, d, 3.1 mm., e, 3.6 mm., f, 4.6, mm., g, 5.6 mm., h, 6.6 mm., j, 7.6 mm., and k, 8.6 mm.

2 a-m. *Permorthotetes callytharrensis.* Transverse sections of CPC 1532. This is sectioned at the following intervals measured from the tip of the umbo:—a, 2.0 mm., b, 5.0 mm., c, 7.0 mm., d, 8.0 mm., e, 10.0 mm., f, 12.0 mm., g, 15.6 mm., h, 17.0 mm., j, 18.0 mm., k, 19.0 mm., l, 20.0 mm., m, 20.2 mm.

The figures are all camera lucida drawings from parallel sections at a magnification of about 1¼ times natural size The dorsal or brachial side is uppermost in each section. Figs. 1a-k are of a pedicle valve and 2 a-m of combined pedicle and brachial valves.

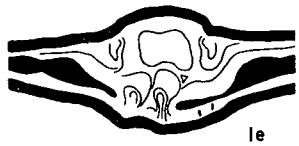
PLATE 20


1a


1b


1c


1d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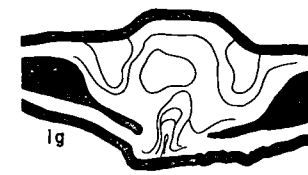
1f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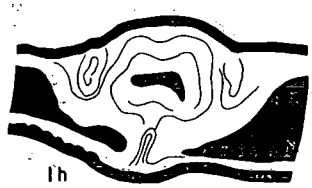
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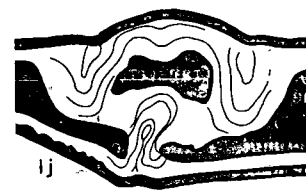
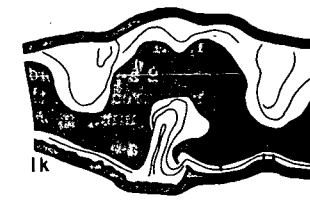
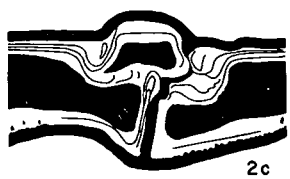
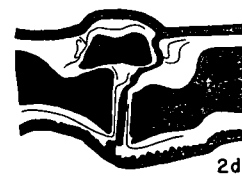

1j

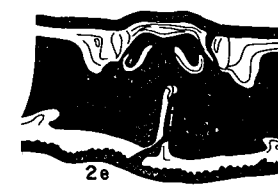

1k


2a


2b


2c


2d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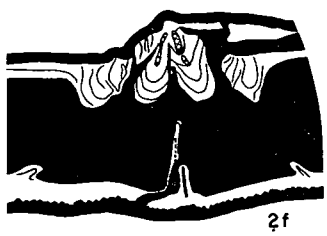
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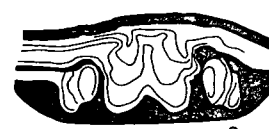
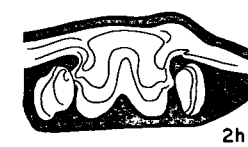
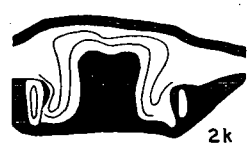

2g


2h


2j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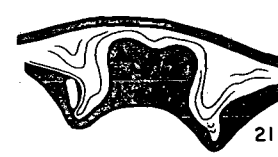

2l

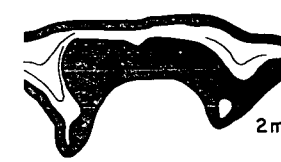

2m

PLATE 21.

1 a-h. *Permorthotes guppyi.* Transverse sections of CPC 1513 at the following intervals measured from the tip of the umbo:—a, 1.0 mm., b, 1.6 mm., c, 2.1 mm., d, 2.6 mm., e, 3.1 mm., f, 4.1 mm., g, 5.1 mm., h, 6.1 mm.

2 a-g. *Permorthotetes guppyi.* Transverse sections of CPC 1512 at the following intervals measured from the tip of the umbo:—a, 0.5 mm., b, 1.0 mm., c, 1.5 mm., d, 2.0 mm., e, 3.0 mm., f, 4.0 mm., g, 5.0 mm.

3 a-e. *Permorthotetes guppyi.* Transverse sections of CPC 1504 at the following intervals measured from the tip of the umbo:—a, 1.99 mm., b, 2.4 mm., c, 4.4 mm., d, 6.8 mm., e, 7.4 mm.

The figures are all camera lucida drawings from parallel sections at a magnification of about $1\frac{1}{4}$ of natural size.

The dorsal or brachial side is uppermost and all the specimens are pedicle valves.

PLATE 21


1a


1b

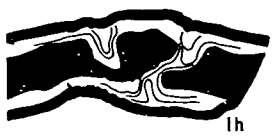

1c


1d


1e


1f

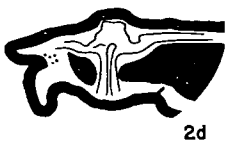

1g

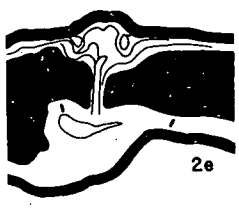

1h

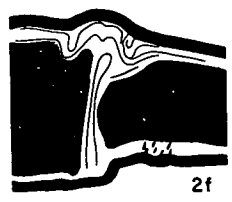

2a

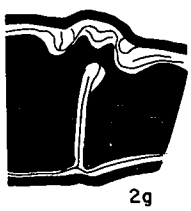

2b


2c


2d


2e

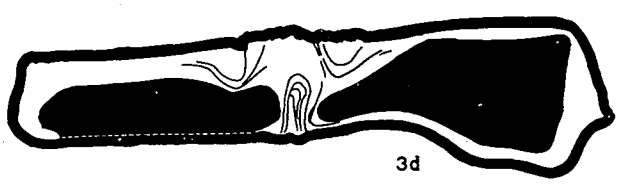

2f


2g


3a


3b


3c


3d


3e

PLATE 22.

1 a-c. *Permorthotetes guppyi.* Transverse sections of CPC 1505, at the following intervals measured from the tip of the umbo:—a, 2.0 mm., b, 4.01 mm., c, 5.01 mm.

2 a-e. *Permorthotetes guppyi.* Transverse sections of CPC 1510, at the following intervals measured from the tip of the umbo:—a, 1.5 mm., b, 2.5 mm., c, 4.5 mm., d, 4.8 mm., e, 5.8 mm.

3 a-d. *Permorthotetes teicherti.* Transverse sections of UWA 28045 B, at the following intervals measured from the tip of the umbo:—a, 2.4 mm., b, 4.9 mm., c, 7.3 mm., d, 7.6 mm.

4. *Permorthotetes guppyi.* Transverse section of CPC 1506, at about 5.0 mm. from the umbonal tip.

5. *Streptorhynchus costatus.* Transverse sections of CPC 1524, at the following intervals measured from the tip of the umbo:—a, 2 mm., b, 6.8 mm.

The figures are all camera lucida drawings from parallel sections at a magnification about 5/4 times natural size. The dorsal or brachial side is uppermost; all sections are of pedicle valves.

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PLATE 22

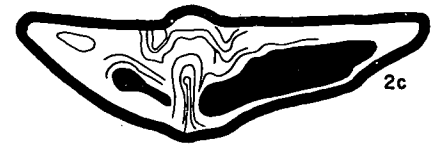

1a


1b

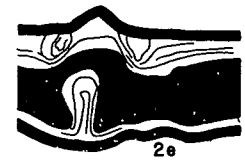

1c


2a

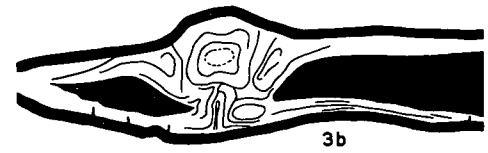

2b

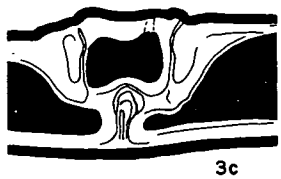

2c

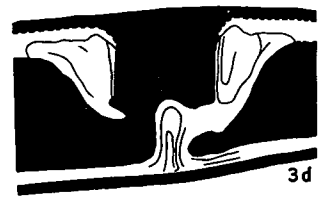

2d


2e


3a


3b


3c


3d


4


5a


5b