SOME PERMIAN BRACHIOPODS AND MOLLUSCS FROM NEW ZEALAND

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Contents

PREFACE

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Although the bulk of macro-faunas have been described, at least as a first approximation, from the Permian of New Zealand, scattered faunas still have not received attention, not to mention additional collections from some levels, notably the Wairaki Breccia of Southland, as well as the bulk of Bryozoa and some corals. In this study, a small fauna is recorded in Article 1 from the Dunton Range of west Otago, which is significant as involving the oldest Permian brachiopods in the country, of mid-Sakmarian age as discussed in Waterhouse (2021). There are older Permian faunas, mostly involving molluscs such as atomodesmids, and the gastropod *Mourlonia*? *impressa* Waterhouse, 1966, as summarized in Waterhouse (2002, p. 120ff; 2021), found in ocean floor and spreading ridge rocks of the Croisilles Volcanics in east Nelson, whereas the fossils described in these reports come from the Brook Street volcanic arc, extending through western and northern Otago, Southland and Nelson.

Grebneffia divaricata n. gen. n. sp. is described in the second article as a new genus and species from the upper Takitimu Group in the Takitimu Mountains of Southland. It is a dielasmid, like many genera and species world-wide, and differs from other dielasmid allies in New Zealand through lacking a high dorsal septum and in being strongly sulcate and plicate, externally resembling Jurassic terebratulids assigned to Loboidothyrioidea.

Fossils from a block in the Queens Beach beds at Stephens Island were reported by Campbell et al. (1984), and two significant species described by Briggs & Campbell (1993).

Series	**Stage**	**East Australasian Biozone**
Lopingian	Changhsingian	(*Wairakiella rostrata*)
		(*Marginalosia planata*)
		Spinomartina spinosa
		Echinalosia denmeadi
	Wuchiapingian	(*Martiniopsis woodi*)
		………..??………..
Guadalupian	Capitanian	*Ingelarella costata* **(4)**
		Ingelarella havilensis FAD
		Marginalosia minima
		Pseudostrophalosia clarkei
		Echinalosia ovalis & subzones
	Wordian	*Pseudostrophalosia blakei* & subzones
	Roadian	*Echinalosia maxwelli*
Cisuralian	Kungurian	*Echinalosia discinia* **(3)**
		Wyndhamia typica
		Glendella dickinsi
		(*Attenuocurvus beds*)
	Artinskian	(*Echinalosia conata*) **(2)**
		(*Spinomartinia adentata*)
		Ingelarella plica
		Notostrophia zealandicus
	Sakmarian	*Taeniothaerus subquadratus*
		Magniplicatina undulata **(1)**
		Notostrophia bifurcata
		Echinalosia curtosa
	Asselian	*Bandoproductus macrospina*
		Unicostatina crassa subzone
		Crassispinosella subcircularis
		Strophalosiaria concentrica

Table. The succession of macro-faunal biozones in east Australia and New Zealand, including marine zones as bracketted in New Zealand, represented by coal measures in east Australia, showing purported international correlations, and the age of faunas described in articles 1-4 herein. The nature of the Ingelarella havilensis band (Havilah fauana of Dear Dear 1972) is yet to be established.

These are re-examined with additional assessments in Article 3, and a Kungurian age reaffirmed. The Queens Beach beds and Stephens Formation in Waterhouse (1964) appear to have slid on to the Maitai sediments from the Brook Street volcanic arc.

Two new species are described in Article 4 from the uppermost Mangarewa Formation at Wairaki Downs, Southland. They belong to a faunal assemblage that is also represented in the youngest marine deposits of the Bowen Basin in Queensland.

This study has been prepared in conjunction with the description of various faunas and a summary of macrofossil zones for the Permian of east Australia, published as Earthwise 19. This facilitates cross-reference between the two volumes, even though this volume appeared first.

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Earthwise 18: 5-64. October 2021.

EARLY PERMIAN BRACHIOPODS AND MOLLUSCS FROM THE DUNTON RANGE, WEST OTAGO

by

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Abstract

Brachiopods and molluscs from the Eglinton Subgroup of the Brook Street assemblage are described from the Dunton Range of western Otago. They are of mid-Sakmarian age, sharing several critical species with faunas of east Australia, and include spiriferoid genera that are exceptional for the region.

New taxa: *Gypospirifer? inexpectans* n. sp., *Alispiriferella turnbulli* n. sp.

New morphological term: (p. 8) cardinal collar, a ridge traversing the external base of the cardinal process in a streptorhynchin genus.

DUNTON RANGE GEOLOGY

The Dunton Range is a N-S oriented mountain range rising to 1,490 metres above sea level, in west Otago some 15 kilometres east of Lake Te Anau. The range lies south of the Countess Range and is separated from the Livingstone Mountains to the east by the Upukerora River valley. The fossils described herein were first discovered in early 1980 by Nick Lindsay during the course of fieldwork for a B. Sc. (Hons) project at the University of Otago, Dunedin. Later that year, fossil collections were made by one of the present authors (HJC) who visited the area with Nick Lindsay, Chuck Landis and Ian Turnbull. Several other fossil localities in the Dunton Range have also provided a few Permian fossils of the same Sakmarian age, mistakenly recorded in Turnbull (1986) as mid-Permian.

The fossil-bearing rocks are part of the Eglinton Subgroup within the Brook Street Volcanics Group (Turnbull 2000), and were classed as part of the basement Brook Street Terrane of the Eastern Province, in the Austral Superprovince by Mortimer et al. (2014). The fossil-bearing lithology is green-grey bioclastic sandstone within a sequence of well-bedded red, gree and-grey volcaniclastic breccias, sandstone, mudstone and minor bioclastic limestone, the limestone comprised of comminuted prismatic atomodesmid shell. These strata were part of a substantial pile of volcaniclastic sedimentary rocks that accumulated in a marine environment on the flanks of a subduction-related volcanic island arc complex. Later, the rocks were subjected to lower greenschist burial metamorphism of the prehnite-pumpellyite to pumpellyite-actinolite facies (Turnbull 1986, 2000). Conspicuous igneous dikes in the Dunton Range belong to the McKay Intrusives of Grindley (1958).

FOSSIL LOCALITIES

GS 12633 = D42/f054. Bed of first major tributary on true right of Upukerora River upstream of Snowdon slip at downstream end of Long Beach Stream ca. 250m upstream from forks of stream in main branch, at 072° from Dunton Peak. See NZMS 1 S141, grid ref 2120100 5540899. Only a few specimens come from this locality, involving a specimen of coral *Euryphyllum*, and a few brachiopods, *Notostrophia, Echinalosia*, *Gypospirifer* and ?*Cyrtella*.

GS 12669 = J42/f070. Found in the bed of the first major tributary on the true right of Upukerora River upstream of Snowdon slip ca 300-400m upstream of fork in stream in main branch, ca 100m upstream of D42/f0054. NZMS 1 S141, grid ref. 2120100 5540800. Specimens are jumbled together, found mostly as single valves, apart from some *Echinalosia* and rarely Spiriferida. A few corals and stenoporiid and fenestellid bryozoans are not examined.

All specimens are kept at the Institute for Geological and Nuclear Sciences (GNS) at Lower Hutt, New Zealand. Significant Brachiopoda are registered serially by number with the prefix BR and important Mollusca are registered serially by number with the prefix TM.

SYSTEMATIC DESCRIPTIONS

Phylum BRACHIOPODA Duméril, 1806

Classification: The *Revised Treatise of Invertebrate Paleontology* of six volumes has established a detailed and comprehensive classification of the Phylum Brachiopoda that offered an ambitious higher-level classification, and just as occurred soon after the appearance of the first *Brachiopod Treatise*, substantial changes have ensued since publication, partly as the result of more detailed analyses, partly from the realization that overall classification was too simplistic and needed to be adjusted, to approach the complexity expressed by the much more realistic *Revised Treatise* classification for the Bivalvia.

Subphylum RHYNCHONELLIFORMEA Williams et al., 1996

Class STROPHOMENATA Williams et al., 1996

Superorder STROPHOMENIFORMII Őpik, 1934

This superorder (nom. transl. Waterhouse 2010, p. 8 ex suborder Strophomenoidea Őpik, 1934, p. 75) includes Strophomenida, Triplesiida and Clitambonitida, for which nomenclatural background and critical aspects of morphology were discussed in the *Revised Brachiopod Treatise* by Cocks & Rong (2000, p. 216 ff) and Williams & Brunton (2000, p. 644 ff). In spite of differences in shell structure, association between the orders is strongly suggested by many aspects of shape, ornament and internal structures (Muir-Wood & Williams 1965). Cocks & Rong (2000) considered that the Plectambonitoidea probably evolved from the Billingselloidea, and gave rise to Strophomenoidea. The Billingselloidea were classed as a distinct Order Billingsellida “Schuchert”, by Williams & Harper (2000), which helps justify amalgamation of these orders in one superorder. Williams & Harper claimed that Schuchert (1893, p. 152) had recognized an ordinal category for *Billingsella* and ally, and so granted the taxon as having priority over Öpik’s ordinal proposal of Clitambonitida. But in fact Schuchert had only recognized a family category “Billingsellida” within Superfamily Orthacea Walcott & Schuchert, so that Őpik’s name has priority as far as orders are concerned. It is surely desirable to unravel various manoeuvres in the *Revised Brachiopod Treatise* (parts 2 & 3) that fictitiously credited various authors with ordinal group proposals.

Order TRIPLESIIDA Moore, 1952

This order was treated as a suborder of Orthotetida “Waagen, 1884” by Wright (2000), but Waagen never proposed any such ordinal group, and the constituent first recognized as having ordinal ranking was Triplesiida Moore (1952, p. 221), as clarified in Waterhouse

(2010, p. 9).

Suborder ORTHOTETIDINA Cooper & Grant, 1974

Williams & Brunton (2000, p. 644) referred to Order Orthotetida Waagen, 1884, but Waagen never proposed such an order or suborder, referring instead to a subfamily. Cooper & Grant (1974, p. 276) were first to promote a Suborder Orthotetidina from Subfamily Orthotetinae Waagen, 1884, p. 576, and as it was they who first interpreted the group as meriting subordinal status, they were credited with the proposal in Waterhouse (2010, 2015a, 2015b). The change of rank from Suborder to Order was promulgated by Williams & Brunton (2000), based on their assessment of the significance of shell structure.

Superfamily **ORTHOTETOIDEA** Waagen, 1884

Family **SCHUCHERTELLIDAE** Williams, 1953

Subfamily **STREPTORHYNCHINAE** Stehli, 1954

Diagnosis: Generally medium-sized with fine branching ribs, high ventral interarea with convex pseudodeltidium and as a rule a perideltidium, linear dorsal interarea with chilidium. No ventral median septum, high cardinal shaft, long lobes leading to erismata in a number of genera, low dorsal septum. Shell extropunctate.

Genus ***Notostrophia*** Waterhouse, 1973

Diagnosis: Non-plicate non-auriculate shells with ventral costae finer as a rule than those of dorsal valve, ventral valve may be reflexed anteriorly. Node each side of cardinal process formed by low ridge continuing as a cardinal collar (new term) across outer face of process. No monticule or perideltidium, no erismata, no dental plates.

Type species*: Notostrophia homeri* Waterhouse, 1973, p. 36 from Brunel Formation, Takitimu Group (Artinskian), New Zealand, OD.

Notostrophia**.** sp.

Fig. 1

Material: Three ventral valves, four dorsal valves, and additional fragments, some from locality GS 12633, others from locality GS 12699.

Description: Ventral valves with irregular umbo, long posterior walls diverging at angles varying from 50^{o} to 105^{o}, and wide convex anterior margin. Inflation is low. The largest specimen BR 2429 is estimated to beene 56mm wide, 40mm long and approximately 12mm high, and BR 2428 is 39mm wide, more than 32mm long and 10mm high, but both valves are incomplete. The dorsal valve is more inflated and transverse, with wide hinge and obtuse cardinal extremities, BR 2432 measuring 40mm in width, 38mm in height and 23mm in height, with hinge at maximum width. Almost nothing can be seen of the interareas for

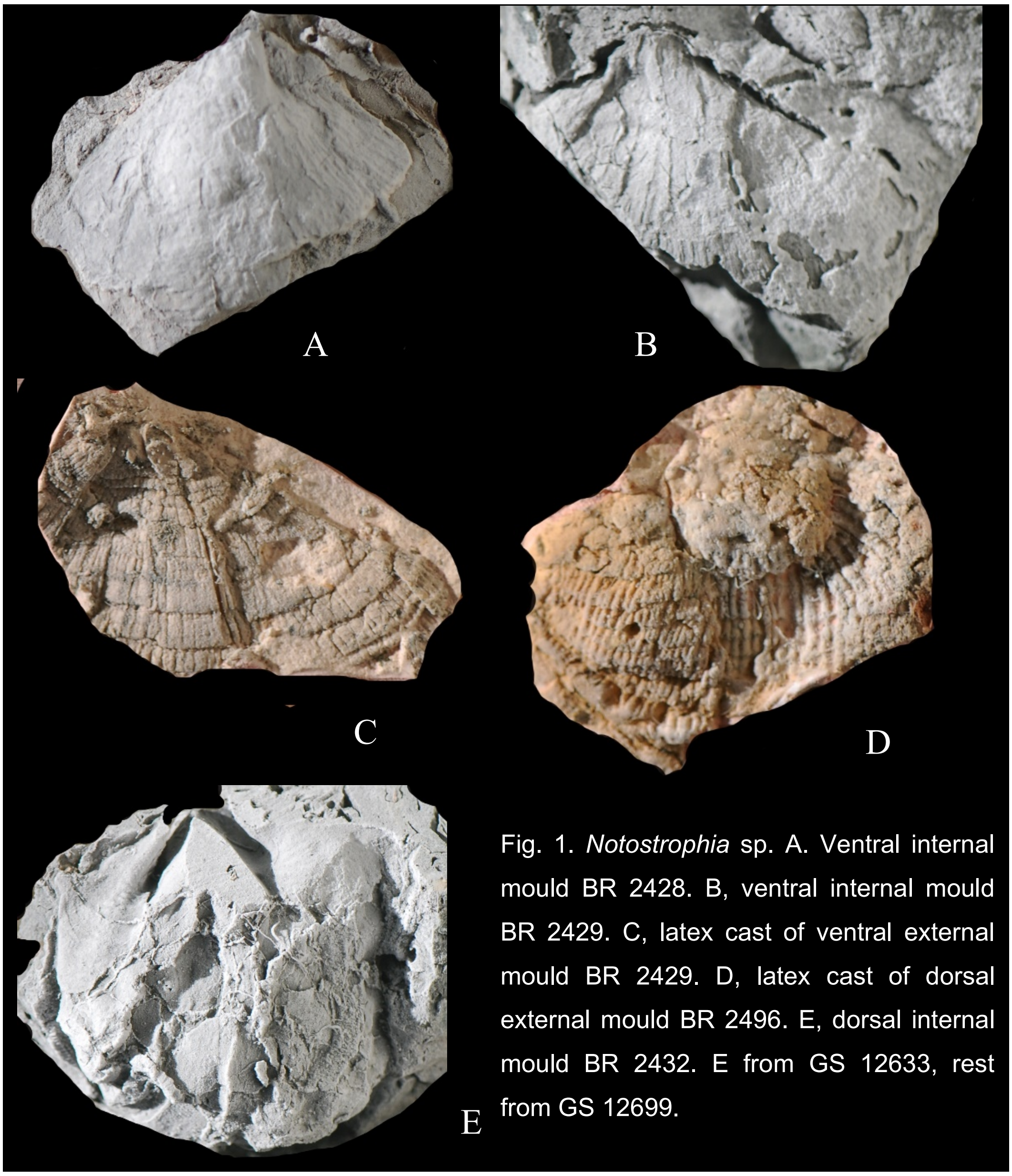


Fig. 1. *Notostrophia* sp. A. Ventral internal mould BR 2428. B, ventral internal mould BR 2429. C, latex cast of ventral external mould BR 2429. D, latex cast of dorsal external mould BR 2496. E, dorsal internal mould BR 2432. E from GS 12633, rest from GS 12699.

either valve. Ventral costae number six in 5mm near mid-line anteriorly, with broad crests and narrow interspaces, and number thirteen to fifteen in 5mm laterally in BR 2429. Dorsal costae stronger, five in 5mm medianly, the number of costae increasing anteriorly, with subdivision of some costa by median slit. The ventral valve has several commarginal growth steps.

No dental supports for the teeth. In the dorsal valve the high and curved cardinal process is supported by sturdy socket ridges, but further detail is not clear. The dorsal shell is at least 1.5mm thick, compared with ventral shell 0.5mm thick, apart from the ventral interarea, which is over 1mm thick.

Resemblances: These specimens are characterized by long and varyingly divergent posterior walls for the ventral valve, with fine ventral costae and slightly broader higher dorsal costae. *Notostrophia zealandicus* Waterhouse (1982a, p. 24, pl. 1d-l, 2a-f, Fig. 17B, C, 18) from the Brunel Formation, Takitimu Group, of south New Zealand, is the closest of known species in terms of ornament and has a reflexed ventral anterior shell, but present material is too incompletely known to allow full comparison. The slightly younger species *N. homeri* Waterhouse (1973, 1982a, p. 26, pl. 3a-h, 4a-d, 5a, Fig. 17D) from overlying beds in the Takitimu Range and also recorded from the Mantle Volcanics of the Skippers Range in northwest Otago by Begg & Ballard (1991) has a less inflated dorsal valve, with strong but narrow costae. The two New Zealand species are younger than the present form (Waterhouse 2002, p. 193; 2021c, pp. 216-218). *N. laticostata* Waterhouse (2015a, p. 57, Fig. 7-9) from the *Taeniothaerus subquadratus* Zone in the Tiverton Formation of the Bowen Basin, Queensland, has broad dorsal ribs that may be clustered into mutiples and lacks a reflexed ventral anterior. *N. bifurcata* Waterhouse (1986a, p. 20, pl. 2, fig. 9-19) from the Fairyland and Dresden Formations of Sakmarian age in the southeast Bowen Basin is a smaller more elongate species with very fine ventral ribs and dorsal ribs that are broad-crested. From the Roses Pride Formation of the southeast Bowen Basin, *N. alta* Waterhouse (1986a, p. 20, pl. 2, fig. 20-24) is a very elongate shell with high ventral interarea, very fine ventral ribs and strong dorsal ribs, broader than those of the Dunton species, and likely to have been a contemporary of the New Zealand species *N. homeri*.

The Tasmanian species *N. costellata* (Clarke, 1992) from the Early Permian basal

Bundella Mudstone and Tasmanites Shale of early Asselian age shows diversified ribbing and more widely divergent cardinal supports.

Superorder PRODUCTIFORMII Waagen, 1883

Order PRODUCTIDA Waagen, 1883

Suborder STROPHALOSIIDINA Waterhouse, 1975

Superfamily **STROPHALOSIOIDEA** Schuchert, 1913

Family **DASYALOSIIDAE** Brunton, 1966

Subfamily **ECHINALOSIINAE** Waterhouse, 2001

Diagnosis: Genera distinguished by having spines of one series on dorsal valve. Ventral valve usually has spines of two series, generally one stout and erect to semirecumbent, and the other fine and recumbent. Fine commarginal lamellae developed on dorsal valve. Radial capillae faint, absent as a rule. Ventral attachment scar, teeth and sockets, interareas, dorsal median septum and muscle scars as in the family.

Tribe **ECHINALOSIINI** Waterhouse, 2001

Diagnosis: Ventral spines of two series. Dorsal valve not thickened anteriorly.

Genus ***Echinalosia*** Waterhouse, 1967

Diagnosis: Spines of two series interspersed over ventral valve, simple, not normally sinuous or arranged in special rows or aggregated to form lateral brush, may be few or missing over ventral ears but usually present, spine cores over middle valve may extend well forward from spine base through the shell. Dorsal spines fine and erect. Capillae present or absent, commarginal ornament limited to growth increments.

Type species: *Strophalosia maxwelli* Waterhouse, 1964, p. 32 from Letham Burn Formation (Roadian), New Zealand, OD.

Discussion: *Echinalosia* is one of the more important genera used to arrange the Permian faunas of east Australia and New Zealand into a succession of biozones, a concept initiated through a pioneering study by Maxwell (1954), and first enunciated in a table by Runnegar & McClung (1975).

Echinalosia curvata Waterhouse, 1986a

Fig. 2 - 4

1986a *Echinalosia preovalis curvata* Waterhouse, p. 26, pl. 3, fig. 25-29, pl. 4, fig. 1-5.

1998 *E. preovalis* [not Maxwell] – Briggs, p. 76 (part).

2015a *E. curvata* – Waterhouse, p. 82, Fig. 30-33.

2021b *E. curvata* – Waterhouse, p. 98, Fig. 2-4.

Diagnosis: Shells usually transverse, moderately concavo-convex and moderately large for the genus. Numerous spines on both valves, many ventral spines sturdy.

Holotype: UQF 73959, Elvinia Formation, southeast Bowen Basin, Queensland, figured in Waterhouse (1986a, pl. 4, fig. 2, 5), OD.

Material: Approximately 100 specimens are available, involving ventral and dorsal valves and specimens with valves conjoined, at varying stages of maturity, from GS 12699. A few ventral valves from GS 12633.

Description: Shells concavo-convex, the largest but distorted ventral valve BR 2457 measuring 29mm wide, 30mm long, and 14.5mm high. The ventral valve is convex, with steep lateral walls and reduced convexity medianly, the umbo often irregular in shape and inconspicuous, and maximum width generally placed near mid-length. Dorsal valve shows slightly reduced concavity medianly. The interareas are almost as wide as maximum shell width, and are of moderate height. The pseudodeltidium is narrow and of variable height, and the notothyrium is narrow and low. Cardinal extremities are as a rule obtuse, at 100° to 110°, with weakly discriminated and small ears. The ventral and lower dorsal interareas bear growth lineations parallel to the commissure, and some weak vertical striae. One small dorsal valve 12mm wide has a concave nepionic area which bears scattered very fine erect spines. In mature specimens the nepionic shell, some 3mm wide, lacks spines, presumably because they have been lost during growth. The trail curves evenly on from the disc, without geniculation visible externally. Ventral spines are dense and mostly erect, up to 0.8mm in diameter, and spaced up to 2mm apart, but may occur in clusters of two or three only 0.5mm apart; weak banding is suggested on some specimens. In some specimens the

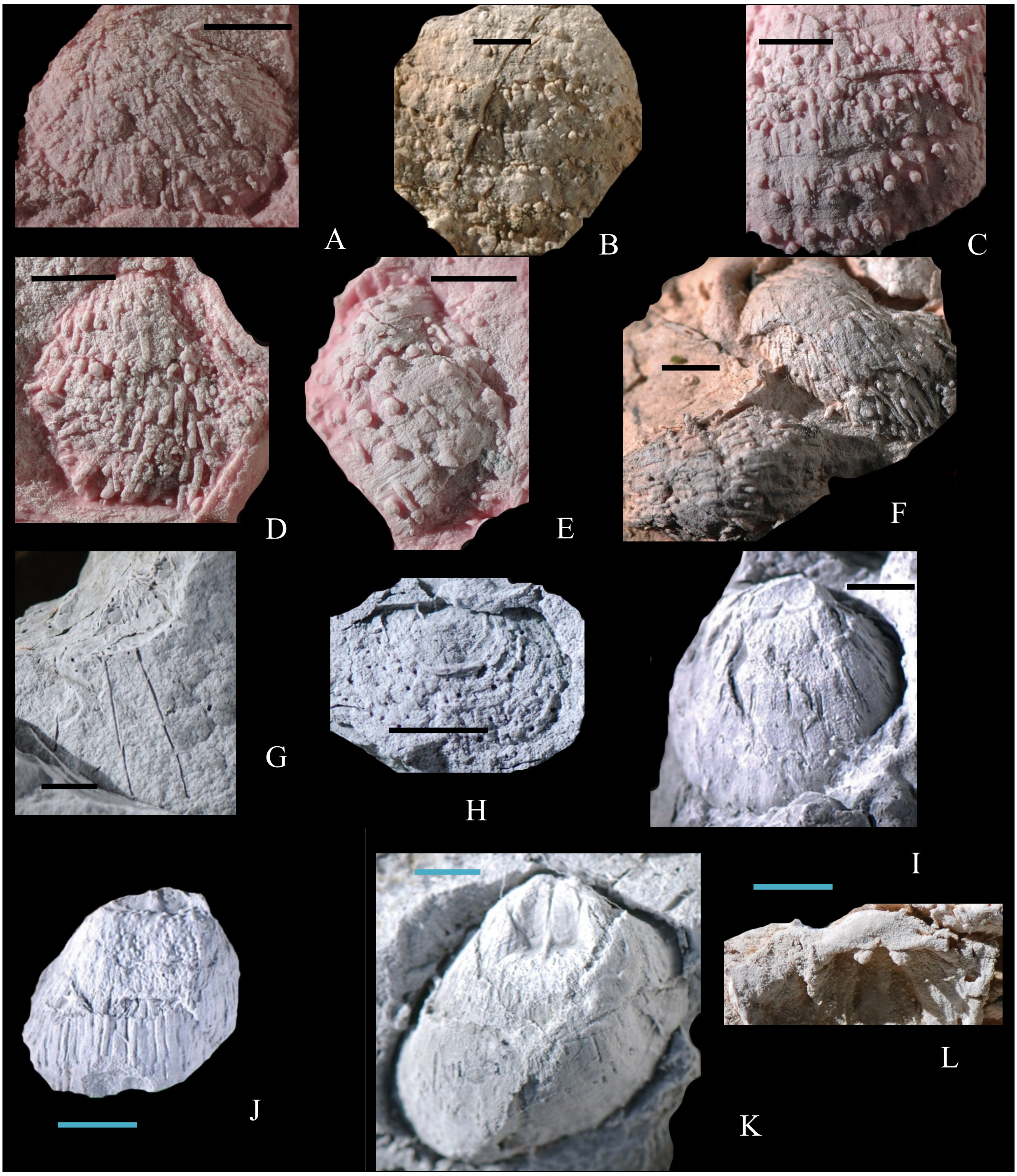


Fig. 2. *Echinalosia curvata* Waterhouse. A, latex cast of ventral external mould, BR 2495. B, latex cast of ventral valve BR 2484. C, latex cast of ventral anterior external mould, BR 2413. D, part of latex cast of small ventral mould BR 2417. E, part of latex cast of ventral external mould, BR 2416. F, latex casts of exterior of two ventral valves with long semicumbent spines, BR 2414 and 2415. G, external mould of small ventral valve showing long spines, BR 2426. H, external mould of dorsal valve BR 2487. I, internal mould of mature ventral valve BR 2457. J, ventral internal mould BR 2492. K, ventral internal mould, BR 2420. L, posterior part of small ventral valve showing teeth; latex cast, BR 2425. All specimens from GS loc. 12699. Space bar 5mm long.

coarse spines are erect, and in others subprostrate, tapering forward and with slightly swollen bases. There is no visible development of coarser spines near the hinge, and spines are up to 17mm long. Finer recumbent spines measure 0.3-0.4mm in diameter. No capillae are visible. Weak growth rugae present but growth increments are obscure, up to five in 1mm anteriorly, and slightly differentiated, and anteriorly growth pauses are developed, separated by gently convex interspaces which bear two to four rows of the thick spines, as well as finer recumbent spines. Dorsal spines are dense and erect, 0.1 to 0.2mm in diameter as a rule, spaced subevenly in quincunx, with prominent commarginal laminae at intervals. Conspicuous dimples are developed between spines anteriorly.

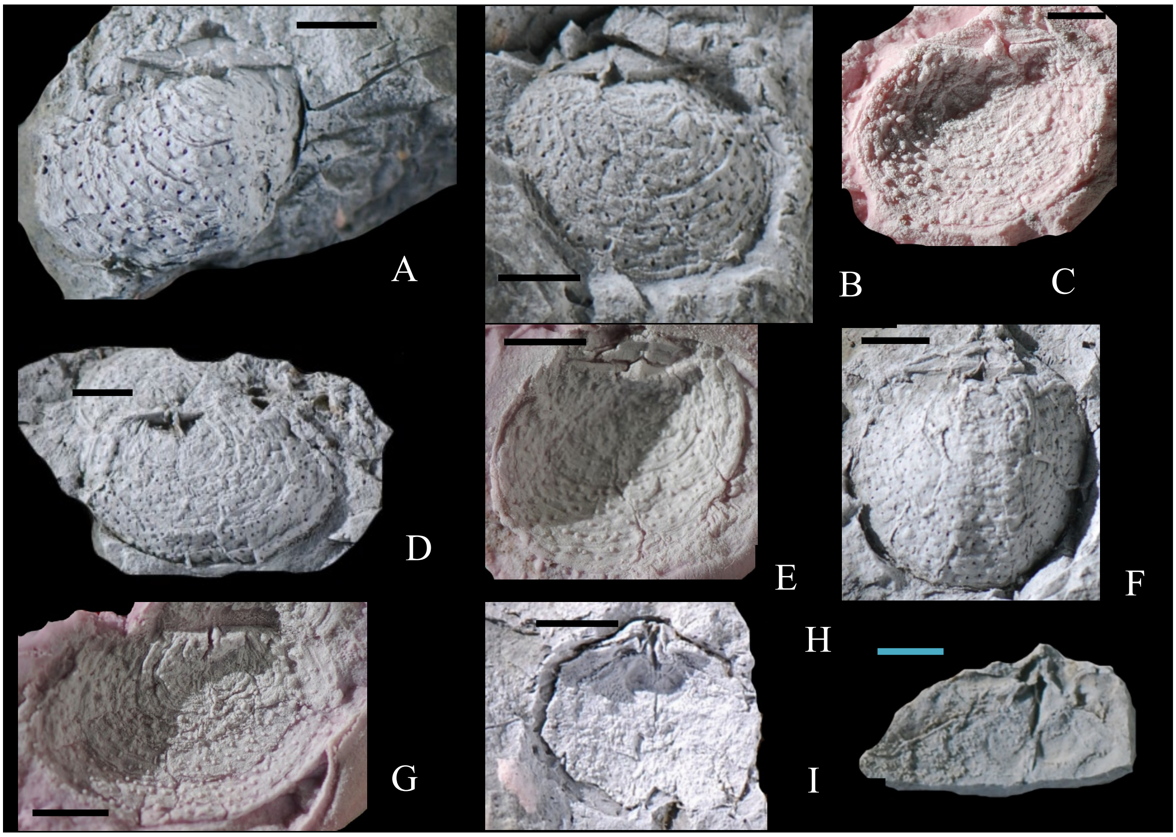


Fig. 3. *Echinalosia curvata* Waterhouse. A, dorsal aspect of external mould, BR 2427. B, E, dorsal aspect of external mould, and latex cast of BR 2491. C, dorsal aspect, latex cast of specimen with valves conjoined, BR 2422. D, G, dorsal aspect of external mould and latex cast of BR 2424. F, dorsal aspect of external mould, BR 2419. H, dorsal aspect of internal mould, BR 2430. I, internal mould of both valves, BR 2422, from dorsal aspect. All specimens from GS loc. 12699. Space bar 5mm long.

Small teeth are developed in the ventral valve, one each side of the pseudodeltidium, without buttresses. The ventral adductor platform is well developed in mature specimens, usually elongate, with smooth surface, raised anteriorly, surrounded by secondary thickening posteriorly, divided by a low posterior myophragm, and bearing anterior growth rugae. Diductor impressions are small, overlapping the anterior third of the adductors. Shallow pits are present over the floor posteriorly, and dense pustules cover much of the ventral interior, including the muscle scars. Some specimens show a few internal spine tunnels, and anterior spines open into the interior.

The cardinal process is slender and lies in the plane of the disc, and the medium septum extends for less than half the length of the valve in small specimens, becoming longer in larger specimens. Teeth are enclosed by small sockets, and anterior adductor scars are large, smooth and raised, but posterior lateral scars are comparatively obscure, though they appear to be small. Brachial impressions are not clear. The valve floor in front of the adductors bears small pustules, and the start of the trail is marked by a few low growth rugae, and is subgeniculate.

Resemblances: These specimens appear to be identical with *Echinalosia curvata* from the *Magniplicatina undulata* Zone in the Elvinia Formation of the southeast Bowen Basin in Queensland, also reported as a few and not completely identical specimens from the middle Tiverton Formation in the *Taeniothaerus subquadratus* Zone (Waterhouse 2015a). The species also occurs in the Macleay "Series" of northern New South Wales and in the Lakes Creek Formation near Rockhampton in Queensland (Waterhouse 2021b).

Fig. 4. *Echinalosia curvata* Waterhouse, external mould of dorsal anterior, BR 2493, showing numerous spine bases. Space bar 10mm long. From GS 12699.

Echinalosia preovalis (Maxwell, 1954) is close in shape and in musculature. Its spines differ significantly, the ventral valve erect series no more than 0.5mm in diameter and often less. Briggs (1998, p. 76) claimed that *curvata* was synonymous with *preovalis*, but *curvata* is an older species with larger size, lower convexity and coarser spines (Waterhouse 2015a, pp. 84, 85).

The present species is readily distinguished from *Echinalosia conata* Waterhouse (2001, p. 58, pl. 3, fig. 12-22, fig. 5e), also figured by Waterhouse (1982a, pl. 23, fig i, text-fig. 19A, B) from the McLean Peaks Formation and at Mt Wilanda in the upper Takitimu Group. The species has coarser spines on both valves, up to 1.5mm in diameter on the ventral valve, and longer better defined ventral adductor scars, with further differences.

Echinalosia maxwelli (Waterhouse) from the Letham Burn Formation of Roadian age (Waterhouse 2021c) tends to be more transverse and has finer and slightly better spaced ventral spines that are more erect and regularly arranged, interspersed with fine recumbent spines.

Suborder LINOPRODUCTIDINA Waterhouse, 2013

Superfamily **PAUCISPINIFEROIDEA** Muir-Wood & Cooper, 1960

This superfamily embraces three families called Paucispiniferidae Muir-Wood & Cooper, Anidanthidae Waterhouse and Yakovleviidae Waterhouse, each of which arose from Devonoproductinae Muir-Wood & Cooper.

Family **ANIDANTHIDAE** Waterhouse, 1968b

Subfamily **LIRARIINAE** Waterhouse 2013

Diagnosis: Both valves costellate, spines inconspicuous, limited to ventral valve, forming row along or close to hinge, may be scattered and erect over ventral valve. Dorsal valve not lamellate. Ventral adductors smooth or deeply scored by longtudinal grooves.

Name genus: *Liraria* Cooper & Grant, 1975, p. 1156 from Bone Spring Formation (Artinskian), Texas, United States, OD.

Discussion: *Liraria* Cooper & Grant, 1975 has fine ribs over both valves, a row of ventral hinge spines, and small erect spines over the ventral disc, much like those of *Anidanthus*. Unlike *Anidanthus* and related genera, the dorsal valve lacks commarginal laminae. No member of Lirariinae displays very large dorsal ears or wedge-like dorsal valve, unlike some genera within Anidanthinae. *Protanidanthus* Liao, 1979, although referred to Anidanthinae by Brunton et al. (2000, p. 533), lacks dorsal laminae, and is judged to belong to Lirariinae.

Genus ***Calandisa*** Waterhouse & Campbell *in* Waterhouse, 2013

Diagnosis: Small highly arched shells with costellae over both valves, spines in hinge row, rare body spines, and one to five strong spines on each outer ear, additional to hinge row spines like those found in related genera.

Type species: *Calandisa solitarius* Waterhouse & Campbell *in* Waterhouse, 2013, p. 333 from Eglinton Volcanic Subgroup, Dunton Range, New Zealand, OD.

Discussion: This genus displays the shape and ribbed ornament characteristic of Lirariinae, and has a row of spines in front of the ventral hinge, and few spines over the disc or trail. The ventral adductor scars are comparatively smooth. What distinguishes the genus is the presence of a few large spines on the outer ventral ear, about midway between the hinge and anterior edge of the ear, whereas ear spines on most of lirariin genera are restricted to a row along along the hinge.

Calandisa solitarius Waterhouse & Campbell *in* Waterhouse, 2013

Fig. 5

2013 *Calandisa solitarius* Waterhouse & Campbell in Waterhouse , p. 333, Fig. 15.25.

Holotype: BR 2400 from GS 12669, Eglinton Volcanic Group, Dunton Range, New Zealand, figured as Fig. 15.25B in Waterhouse (2013) and herein as Fig. 5B, OD.

Diagnosis: Transverse to highly elongate shells with rare ventral spines, and large spine on outer ventral ear.

Material: Some ten ventral valves and scarce dorsal valves from GS 12699.

Description: Shells weakly transverse, the ventral valve highly convex, umbo incurved with angle of 95^o to 100^o, moderately large convex ears and obtuse cardinal extremities. Transverse convexity is reduced medianly, but there is no sulcus, and the anterior commissure varies from slightly receeded or produced. The dorsal valve is concave over the disc, and the large ears are concave, and the trail subgeniculate and moderately long. Both valves are crossed by fine radial ribs, eight in 5mm at mid-length on the ventral valve, and covering the ears. The ventral valve is also covered over the disc and trail by low to very low rugae, at least thirteen on the largest specimen, and marking the ears of some specimens, and there are fine closely spaced growth increments which arch hingewards over the ribs. The dorsal valve bears very low growth rugae and pauses, but no laminae. A single row of spines lies along the ventral hinge, the outermost spine 1mm wide, and strong erect spines varying between one and five lie on each outer ear in front of the hinge. Erect spines lie over the anterior disc and start of trail, each with a diameter between 0.2 and 0.3mm, arising from the crest of a costa, which passes throughotherwise undisturbed. There are no dorsal spines.

Dimensions in mm: ventral valves

BR	Width	Length	Height
3091	26	14	
3065	22	17	8
2400	22+	24	12 latex cast
2402	21.5	25	9.5
2407	24	19	10.5
2484	16	12.5	5

Ventral adductor scars short and wide, smooth and raised; diductor scars oval, more anteriorly positioned and scarcely impressed, floor in front bearing large pits, remainder of floor finely pustuled. In another specimen the adductors are more elongate. No dorsal interiors are available.

Resemblances: The distinctive feature of this species, as for the genus, lies in the presence of the large erect spine or spines on each ventral ear. Otherwise the genus and species is moderately close to species of *Liraria* Cooper & Grant, 1975 and *Cimmeriella* Archbold *in* Archbold & Hogeboom, 2000. In *Liraria*, thecardinal process is low with median shaft deeply divided in two, with a zygidium. Ventral adductor scars were described as small and located within a pit, and dorsal adductor scars are not strongly impressed, and neither smooth nor clearly dendritic. Cooper & Grant (1975, p. 1157, pl. 434, fig. 28, 30) drew attention to the presence in *Liraria* of two dorsal ridges, one each side of

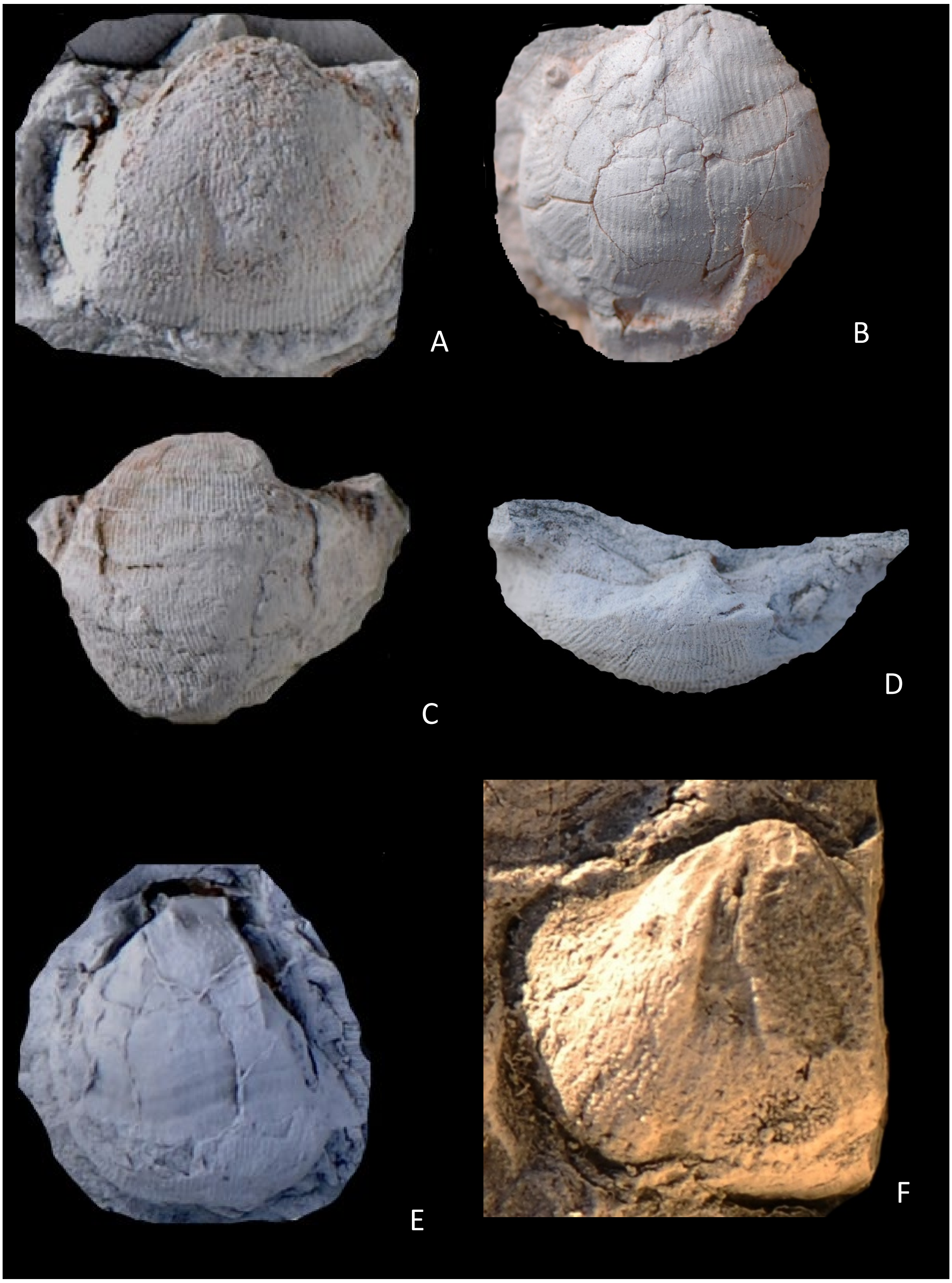


Fig. 5. *Calandisa solitarius* Waterhouse & Campbell. A, ventral internal mould BR 3065, x3. B, latex cast of ventral valve holotype, BR 2400, x3. C, D, ventral and posterior aspects of ventral valve BR 3091, x2. E, internal mould, ventral valve BR 2486, x2.5. F, internal mould of ventral valve BR 2402, x3.5. From GS 12699. (Waterhouse & Campbell 2013).

the median septum, between the adductor scars. They erred in stating (1975, p. 1156) that spines lay only on the dorsal valve, because type *Liraria* has ventral spines and no dorsal spines. Ear spines are fine and lie in a row close to the hinge, placed well in front of the hinge laterally.

Cimmeriella Archbold in Archbold & Hogeboom, 2000, p. 101, based on *Productus foordi* Etheridge, 1903, and best figured in Archbold (1983), is characterized by strong ribs. Ear spines lie in a row close to the hinge and the outer spines are strong. This genus would appear to be close amongst known genera to the present form, but is even closer to *Liraria* and invites closer inspection to determine if it should be synonymized with that genus, which it resembles in many respects apart from its coarser ribbing. It has rather smooth ventral and dorsal adductor scars, and the adductor scars are bisected by a ridge (Archbold 1983, p. 250, Fig. 5S, T).

Calandisa is distinguished from *Bookeria*, as described below, by the lack of numerous spines over the venter and fewer ear spines, and lack of ventral spine tunnels.

Superfamily **PROBOSCIDELLOIDEA** Muir-Wood & Cooper, 1960

Family **PAUCISPINAURIIDAE** Waterhouse, 1986

Diagnosis: Ventral spines with elongate bases arranged in regular quincunx over disc, erect and crowded or rare over ears and in row or rows along hinge, dorsal spines crowded as a rule, erect, may be large. Radial ribs and weak to strong commarginal rugae. Body corpus moderately thick, ventral adductor scars dendritic. Cardinal process trilobed. Trail well developed and not multiple or elongated into a proboscidellid tube.

Discussion: Members of the Family Auriculispinidae Waterhouse are distinguished by thin body corpus, less regular and generally fewer and often thinner ventral spines, and more slender spine bases. Its dorsal spines are much less commonly developed than in Paucispinauriidae. The ventral adductor impressions of *Auriculispina* tend to be striate rather than dendritic until late in ontogeny. The group was treated as a subfamily in Brunton et al. (2000) in the *Revised Brachiopod Treatise*, but their classification incorporated various unrelated genera, and other genera showing close morphological similarities to Auriculispinidae were scattered amongst various family groups (Waterhouse 2013). Both Paucispinauriidae and Auriculispinidae are largely of Permian age, whereas Proboscidellidae is of Lower Carboniferous age. Its constituent genera lack dorsal spines and display a bilobed cardinal process, and often a long proboscidellid trail.

Subfamily **PAUCISPINAURIINAE** Waterhouse, 1986

Diagnosis: Ventral spines with elongate bases arranged in regular quincunx over disc, crowded or rare over ears and in row or rows along hinge, tend to be large over inner ears, dorsal spines crowded, may be of varied diameter. Radial ribs present as a rule, and commarginal rugae are weak or absent. Body corpus moderately thick.

Tribe **PAUCISPINAURIINI** Waterhouse, 1986

Diagnosis: Weakly transverse shells with thick visceral corpus. Ventral spines uniform over disc, ribbing present.

Discussion: Holotricharinini Waterhouse is an exceptional tribe which has lost the ribbing and developed thin as well as thick ventral disc spines, and low regular rugae over both valves.

Genus ***Bookeria*** Waterhouse, 2015a

Diagnosis: Shells with variable number of moderately large spines along ventral inner ears and as a rule over the lower and anterior umbonal slopes, other ventral disc and trail spines of modest to low diameter. Dorsal spines numerous but slender on the whole, lacking strong anterior spines.

Type species*: Bookeria sparsispinosa* Waterhouse, 2015a, p. 120 from middle Tiverton Formation (Sakmarian), Queensland OD.

Discussion: Members of this genus are very close to other genera found in east Australia and New Zealand, called *Paucispinauria* Waterhouse and *Terrakea* Booker. *Paucispinauria* Waterhouse, 1983, type species *Terrakea concava* Waterhouse, 1964, p. 67 from Letham Burn Formation (Roadian) in New Zealand is characterized by having few ventral ear spines, and dorsal anterior spines tend to be large. Genus *Terrakea* Booker, 1930, type species *Productus brachythaerus* Morris, 1845, p. 284, from the Broughton Formation (Capitanian), south Sydney Basin of New South Wales, is distinguished by having a brush of sturdy spines over the ventral ears and lateral posterior slopes, and dorsal anterior spines also tend to be thick. *Bookeria* is interpreted as progenital to both *Paucispinauria* and *Terrakea*. Two species, *sparsispinosa* and *geniculata*, have few ventral ear spines, and are believed to have developed into *Paucispinauria*, whereas *B. pollex* (Hill, 1950) has numerous ventral ear spines, as in *Terrakea*, and both of these genera have coarse anterior dorsal spines, unlike *Bookeria*. *Bookeria* is of lower and upper Sakmarian age, *Terrakea* commenced in

Aktastinian time, and the oldest known species of *Paucispinauria* known so far is *Paucispinauria concava wardenensis* from the Wandrawandian Formation (Roadian) at Warden Head, south Sydney Basin, and in the lower Letham Formation, of Irenian (upper mid-Kungurian) age in New Zealand (Waterhouse 2001, p. 35).

Bookeria drysdalei Waterhouse, 2015a

Fig. 6

1964 *Terrakea pollex* [not Hill] – Hill & Woods, pl. P5, fig. ?8 (part, not fig. 7 = *pollex*).
1972 *T. pollex* [not Hill] – Hill, Playford & Woods, pl. P5, fig. ?8 (part, not fig. 7 = *pollex*).
1986 *Terrakea pollex* [not Hill] – Waterhouse, p. 49, pl. 11, fig. 20, 24 (part, not fig. 19, 21-23, 25-27 = *pollex*).
1998 *T. pollex* [not Hill] – Briggs, p. 163, Fig. 81A-C, E, G (part, not Fig. 81 D, F = *pollex*).
2015a *Bookeria drysdalei* Waterhouse, p. 126, Fig. 78-83.

Diagnosis: Small subequilateral shells with weakly to moderately convex transverse venter, moderately large ears clearly separated from umbonal walls, few spines on outer ears but a cluster lies over the posterior lateral walls that border the ears, ventral spines emerge at high angle with broad comparatively short bases, dorsal spines fine and erect.

Holotype: Specimen UQF 81242 from Tiverton Formation, Queensland, figured in Waterhouse (2015a, Fig. 80C, 83A), OD.

Material: Three specimens with valves conjoined, eighteen ventral valves and two dorsal valves, with other fragments from GS 12669.

Description: Specimens vary from transverse to elongate, specimen BR 2404 measuring approximately 32mm wide, 20mm long and nearly 10mm high, compared with another more elongate specimen BR 2411 measuring 21mm wide, 25mm long and 13mm high, both specimens incomplete and slightly distorted. The ventral umbo is incurved, and posterior walls are moderately steep and diverge at 90° to 110°. The hinge is slightly shorter than maximum width, which lies close to anterior third of shell length. Ventral ears are comparatively small but well defined, gently convex and with subalate cardinal extremities. Ventral valve highly convex, with median reduction in curvature but no sulcus. Dorsal valve concave, following curvature of ventral valve and anteriorly may have weak narrow and low fold, trail subgeniculate. Both valves bear faint and apparently discontinuous radial over the mid-ventral valve, and up to twenty three in 5mm over the anterior dorsal valve near the trail. Spines over the ventral disc are more or less in quincunx, up to 0.6mm in diameter anteriorly, with very short slightly swollen bases up to 1.5mm in length, reaching up to 2.5mm in length at the start of trail. More sturdy and erect spines are arranged along the inner ears and low umbonal slopes, usually 0.75mm up to 1mm in diameter. There are two rows of spines along the ventral hinge in BR 2404, and a short third row. Erect spines pass in rows from the lower umbonal slopes on to the anterior inner ears anteriorly. Another fragmentary specimen shows the band of strong erect spines along the lower

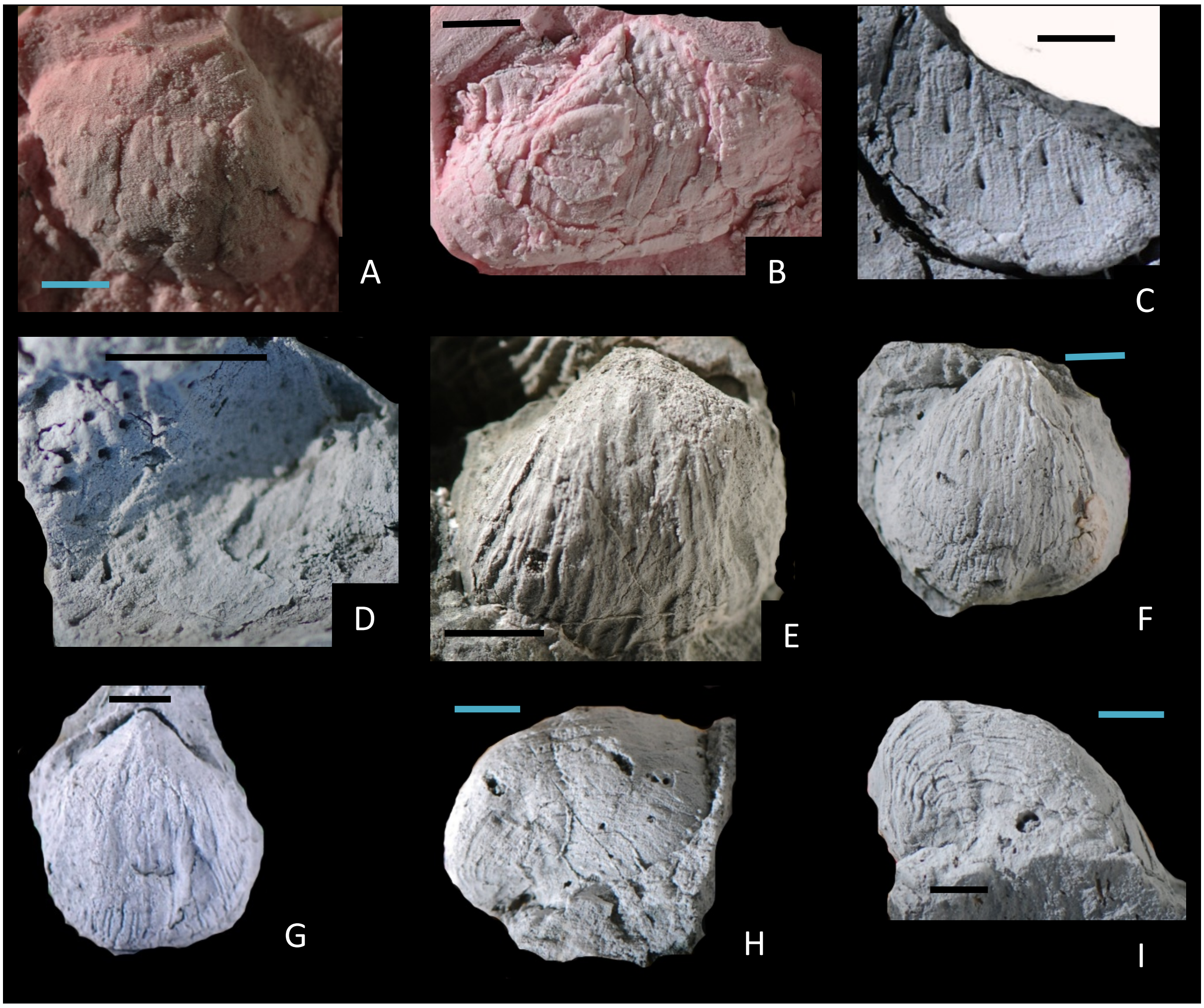


Fig.6. *Bookeria drysdalei* Waterhouse.A, latex cast of ventral valve BR 2405. B, latex cast of ventral valve BR 2404. C, external mould showing ventral ornament, BR 2406. D, external mould of ventral valve showing erect spine bases over ears, BR 2407. E, ventral internal mould BR 2403. F, H, ventral internal mould BR 3555, ventral and lateral aspects. Fig. 6H is oriented for comparison with Fig. 6I, but shows a different commissure. G, I, internal mould, ventral and lateral aspects of ventral valve, BR 2410. Space bar 5mm long. From GS 12669.

umbonal slopes. Dorsal spines are numerous, erect and fine, measuring 0.2-0.4mm in diameter. As well, shallow slightly elongated pits lie in quincunx over the anterior disc, and there are a few low commarginal rugae, and very fine and closely spaced growth increments.

Ventral adductors lie on broad posterior ridges, with a weakly discriminated diductor scar each side, marked by linear grooves and ridges. Much of the valve floor is marked by long spine tunnels. Little of the dorsal interior is displayed, apart from a bifid small cardinal process and long narrow median septum in front, and slight thickening along the hinge.

Resemblances: These specimens are not well preserved, but the ornament and size point to *Bookeria*, because the dorsal anterior spines are comparatively slender. Specimens indicate that several erect spines lie along the inner ear and base of the umbonal slopes, suggesting identification with *Bookeria drysdalei* Waterhouse from the middle Tiverton Formation of the north Bowen Basin in Queensland. Other species of *Bookeria* involve *sparsispinosa*, which has only two to four ear spines, distinctly less than in the present specimens, and *geniculata* Waterhouse, 1986a, which also has few ear spines, and is close in many respects to *sparsispinosa*. *B. pollex* (Hill, 1950) includes thumb-like ventral valves like some of those present in the Dunton Range, with slightly thicker and more numerous ear spines, and more strongly impressed ventral adductor scars. *Terrakea dickinsi* Dear, 1971 is found in the overlying *Ingelarella plica* Zoneof the Bowen Basin, and together with the very closely allied (and probably indistinguishable) ally *dickinsi aurispina* Waterhouse (1982a, p. 47) from the same zone in the Takitimu Mountains of New Zealand is much larger in size, with strong ventral ear spines and large spines over the dorsal trail.

Class RHYNCHONELLATA Williams et al., 1996

Order RHYNCHONELLIDA Kuhn, 1949

Suborder RHYNCHONELLIDINA Kuhn, 1949

Superfamily **WELLERELLOIDEA** Licharew, 1956

Family **WELLERELLIDAE** LIcharew, 1956

Subfamily **PLEKONELLINAE** Waterhouse, 2010

Diagnosis: Both valves mostly covered by angular-crested costae and fine radial lirae, deltidial plates well developed, hinge plate (septalium) entire with sturdy median ridge, supported by short median septum. Socket plates smooth or crenulate. Crura oval in section, curve towards ventral valve.

Discussion: This subfamily differs from Wellerellinae through having an entire hinge plate which shows no median trough or median slit, but instead bears a well developed median ridge.

Genus ***Plekonella*** Campbell, 1953

Diagnosis: Strongly plicate with sulcus and fold, dental plates present, dorsal septalium bearing median ridge, dental sockets crenulate.

Type species: *Plekonella acuta* Campbell, 1953 from Ingelara Formation, Queensland, OD.

Plekonella n. sp.

Fig. 7

Material, Description: Several fragmentary ventral valves are available from GS 12669. Two show an only moderately well-defined ventral sulcus which bears two costae, and five costae on the lateral flanks of the shell, of which some costae show anterior arching at the commissure (Fig. 7B). Another specimen is similar, except for the failure of further costae to appear by intercalation anteriorly. Well developed dental plates are preserved in a fragment BR 2473. An internal mould of a specimen BR 2437 has valves conjoined, and strong ribs which number three each side of the dorsal valve. There are dental plates, and small umbonal foramen. The dorsal septum extends over the posterior third of the valve, supporting a septalium which bears a swollen median ridge. A fragmentary dorsal valve is

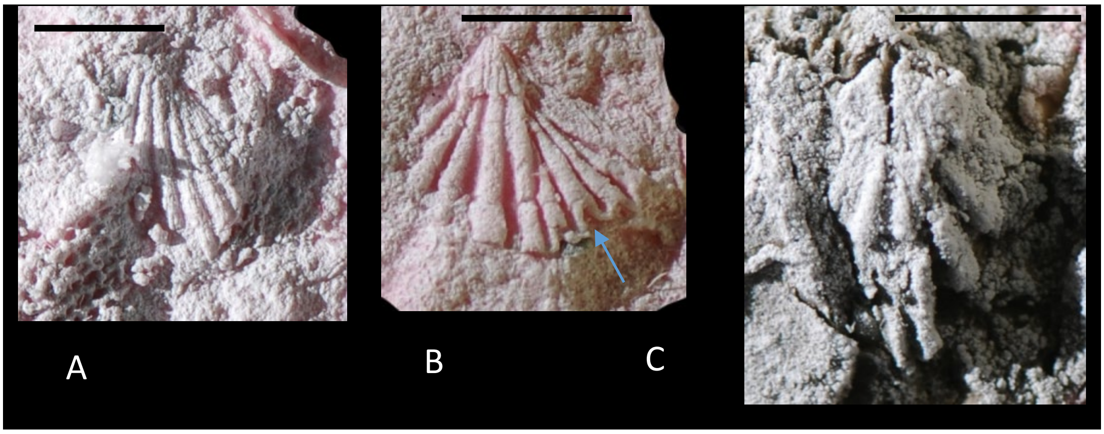


Fig. 7. *Plekonella* sp. A, part of ventral valve, BR 2444. B, part of ventral exterior, cast, BR 2443, showing anterior arching of lateral ribs, as arrowed. C, dorsal aspect of internal mould BR 2437. Space bar 5mm. From GS 12669.

somewhat similar in costation, and the anterior dorsal fold has two median costae, one each side of a moderately defined median channel, and two costae diverge further back from the fold (Fig. 7C).

Resemblances: *Plekonella whitehousei* Waterhouse, 2015a is close to this material in age, coming from the *Taeniothaerus subquadratus* Zone and including the *Svalbardia armstrongi* band in the Tiverton Formation of the northern Bowen Basin, but is more transverse and has a different fold, with a median costa rather than groove, and two or three lateral costae each side.

Rhynchonellida gen. & sp. indet.

Fig. 13D

A small specimen BR 2500 5mm wide and 3mm high from GS 12669 has five costae in the sulcus and some ten fine costae on each side. With no dorsal valve and no internal detail, the generic position and classification are not known.

Superorder SPIRIFERIFORMII Waagen, 1883

Order SPIRIFERIDA Waagen, 1883

Discussion: Overall classification is close to that offered by Carter & Gouvennec (2006a) and is updated according to more recent studies by Waterhouse (2010, 2016).

Suborder MARTINIIDINA Waterhouse, 2010

Diagnosis: Shells planoconvex to biconvex, smooth or coarsely plicate, some members broadly plicate, with varied micro-ornament of tiny spinules or pustules or grooves and pits. Characterized by development of tabellae in many genera; dental plates and adminicula highly varied.

Discussion: Martiniidina is very diverse, and is subdivided into three major infrasuborders, united by the sharing of tabellae in at least early members**.** A feature of the suborder is the variation in internal plates, proceeding within a slender morphological range, consonant with external features of shape and micro-ornament, and consistent to a degree with the variation displayed with sister-group Delthyridina.

Infrasuborder MARTINIIMORPHII Waterhouse, 2010

Diagnosis: Genera with smooth or openly plicate shells, may be sulcate, micro-ornament varied, early genera with adminicula and short tabellae, which were lost in the course of evolution.

Superfamily **MARTINIOIDEA** Waagen, 1883

Diagnosis: Suboval biconvex shells, smooth, sulcate and or plicate, micro-ornament of fine pits or spines. Dental plates may be reduced or absent, no adminicula; crural plates not supported by tabellae.

Family **MARTINIIDAE** Waagen, 1883

Diagnosis: As for superfamily. Dental plates present or absent, lateral slopes may be smooth, weakly ribbed, or plicate.

Discussion: For Martiniinae, plates and septa were said to be absent from both valves (Carter *in* Carter & Gourvennec 2006b, p. 1747), but the statement ignored the presence of dental plates, crural plates and socket plates in many genera.

Subfamily **SPINOMARTINIINAE** Waterhouse, 2016

Diagnosis: Micro-ornament of small spines or pustules.

Genus ***Duntonia*** Waterhouse & Campbell *in* Waterhouse, 2016

Diagnosis: Micro-ornament of tiny pustules. Hinge narrow or wide .Well defined radiating vascular canals linked by transverse canals to form a network.

Type species: *Duntonia duntonensis* Waterhouse & Campbell *in* Waterhouse, 2016, p. 99 from the Eglinton Volcanic Subgroup, Dunton Range, New Zealand, OD.

Discussion: This genus shares well defined and net-like vascular impressions with *Chapursania* Angiolini, 1995, but unlike the type species of that genus often has a short hinge, and has a micro-ornament of pustules. The type species of *Chapursania* is *C. tatianae* Angiolini, 1995, p. 210 from the Panjshah Formation of the central Karakorum, and was further described by Angiolini (2001). The genus was said to be characterized by its thick shell, wide hinge (though the hinge is not significantly broader than in several other martiniiform genera), large muscle field, and coarse sinuous branching vascular imprints connected by cross-bars, in a pattern more net-like than in other martiniid genera. The micro-ornament has been described as consisting of growth lamellae becoming sinuous anteriorly. No data has been provided on the internal plates. Efforts by Dr. Angiolini (pers. comm.) to clarify the interior have not proved successful, so we are forced to identify the taxon mainly from.the micro-ornament and the pattern of vascular imprints, shown for one of the original type specimens.

Globosospiniger Waterhouse, 2010 from the Rat Buri Limestone of south Thailand, of Roadian age, is highly globose, with anterior plicae and micro-ornament of pustules. The mantle canal system is dominated by a radial mantle canal system rather than a network. *Spinomartinia* Waterhouse, 1968b is allied, displaying a mantle canal system also dominated by radials, but has better formed and well-spaced spinules.

Duntonia duntonensis Waterhouse & Campbell *in* Waterhouse, 2016

Fig. 8

2016 *Duntonia duntonensis* Waterhouse & Campbell *in* Waterhouse, p. 99, Fig. 102.

Diagnosis: Variably transverse to elongate ,with narrow or wide hinge, narrow ventral furrow at least posteriorly, no dental plates, distinctive network of vascular impressions, small socket plates, micro-ornament of fine spinules.

Holotype: BR 2447, figured by Waterhouse & Campbell *in* Waterhouse, 2016, Fig. 102A-C and herein as Fig. 8D-F, OD, from the Eglinton Volcanic Subgroup, Dunton Range.

Material: Two specimens with valves conjoined, three ventral valves and four dorsal valves, as well as several fragments, all from GS 12669.

Description: Shells small to medium in size. A juvenile specimen, BR 2438, the holotype, preserved as a complete internal and much of the external mould, is transverse, 13.5mm wide, 10mm long and 6.5mm high, the dorsal valve less than a third of the height of the ventral valve. The hinge is only 4mm wide and bears a high narrow ventral interarea, and the delthyrium is obscure, with angle of 40-50°. A dental flange lies along each side of the delthyrium, but the dorsal interarea is not known. The ventral umbo is weakly incurved with angle close to 90°, and the dorsal umbo is small, extended, and pointed with an apparent angle of 75°. A slender groove extends for the length of the ventral valve, and there are no plicae and no dorsal fold. The cardinal extremities are obtuse in all specimens. A larger more elongate ventral valve BR 2442(Fig. 8A) that is 23mm wide, 27mm long and 8mm high with similar umbo has a median sulcal channel which extends over the posterior third of the shell

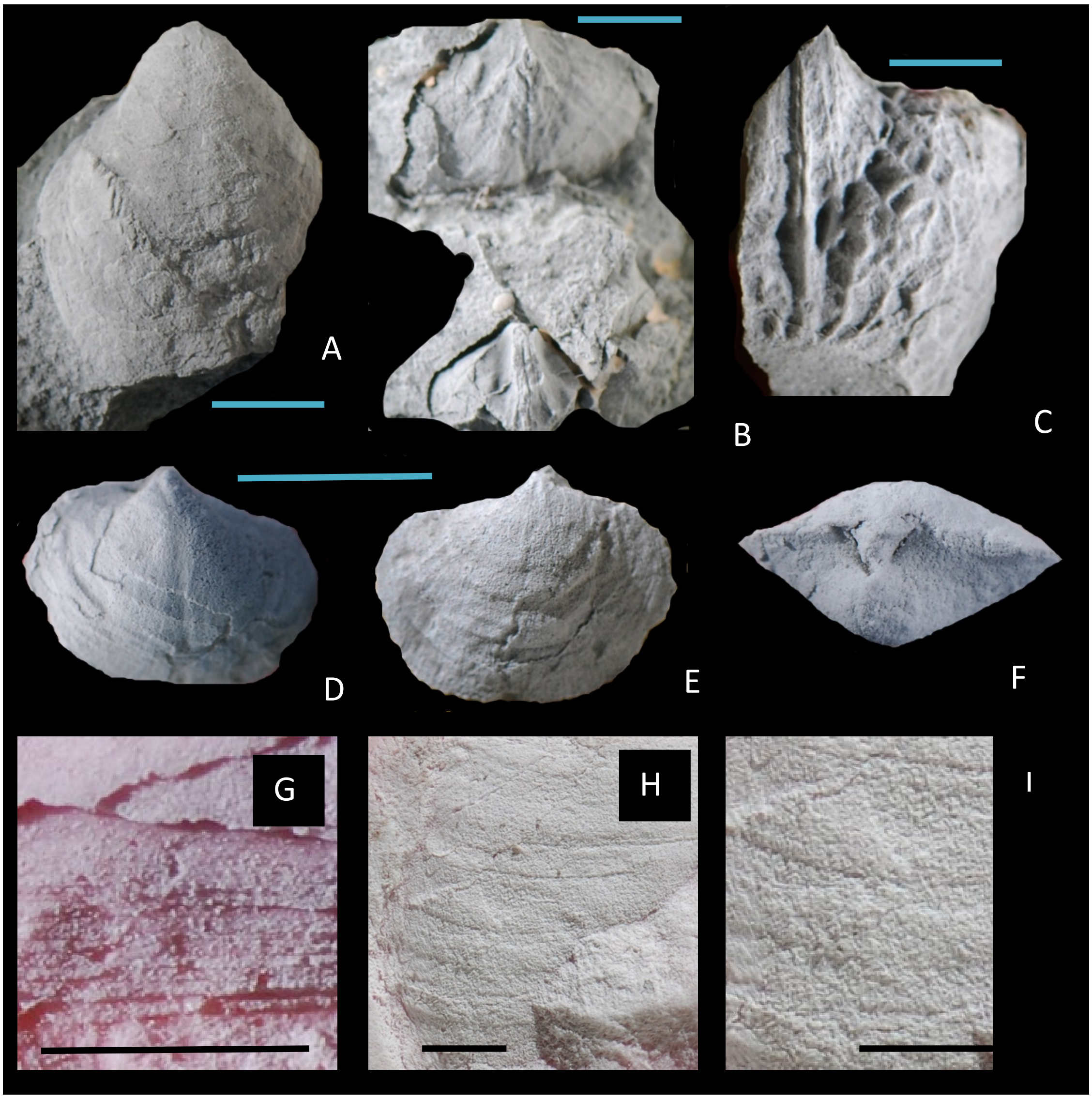


Fig. 8. *Duntonia duntonensis* Waterhouse & Campbell. A, ventral valve BR 2442. B, block with two ventral internal moulds BR 2439 and 2440. C, internal mould of mature ventral valve, showing reticulate vascular network, BR 2447. D-F, holotype, ventral, dorsal and posterior aspects of small internal mould with both valves present, BR 2438, sharing a space bar. G, fine spinules over anterior margin of ventral valve BR 2446. Valve 35mm long. H, spinules on the same specimen nearer the umbo. I, surface detail on same specimen. Space bar 10mm long in Fig. 8A-F, 2mm long in Fig. 8G-I. From GS 12699. (Part Waterhouse 2016).

length, and resumes close to the anterior margin. The hinge is narrow at 12mm, as in the small specimen.

Other specimens have a wide hinge. In one of the wide-hinged specimens, BR 2407, the ventral muscle is posteriorly placed, with two narrow adductor ridges divided by a median groove, and much broader diductor scars with two or three irregular longitudinal ridges and grooves. The vascular impressions form an elaborate network of radiating grooves linked by cross–grooves. Two other internal moulds of the ventral valve are less mature, with weak vascular impressions, and both lack dental supports. The muscle field is divided by a low median ridge in the larger specimen BR 3439 (Fig. 8B), with long adductor impressions and broader diductor scars, bearing faint longitudinal grooves and weak oblique grooves parallel to the anterior margin. The other specimen BR 2440 in Fig. 8B has more compact and slightly impressed adductor scars. The hinge is wide in both of these specimens. Another specimen that has a wide hinge consists of a ventral valve collapsed into the dorsal valve, and the dorsal valve shows a broad laminate ctenophoridium, well formed dental sockets comprised of subhorizontal socket plates and low inner plates. The crural bases lie each side of the ctenophoridium. Adductor scars are shallow, narrow and subrectangular, divided by low median ridge. Vascular grooves are shallow and not branching, the pattern typical of the genus not becoming evident until maturity.

External moulds from several specimens suggest that the shell surface is marked by a shagreen structure of small pits, suggesting the ends of prisms in the shell. The anterior margin of one large fragment, BR 2446 (Fig. 8G), has growth laminae, and fine growth increments which bear tiny pustules, four to five in 1mm. There are six to eight growth increments per mm, with low growth laminae and steps, and other fragments show a similar density of pustules.

Resemblances: *Chapursania* Angiolini, 1995, based on *C. tatianae* Angiolini from the Karakorum Range, has a consistently wide hinge, more swollen ventral valve, broad anterior sulcal tongue, and slightly different pattern of vascular impressions. It comes from the Panshah Formation, Member 2, of Wordian age. Internal structures are virtually unknown for type *Chapursania*, and its micro-ornament according to Angiolini consists of growth lines.

Superfamily **INGELARELLOIDEA** Campbell, 1959

Diagnosis: Shells usually with sulcus and fold, simple or no plicae, variably developed micro-ornament, involving small spines, grooves, or/and exopunctae. Ventral interior with well developed dental plates and adminicula as a rule, dorsal valve with socket and crural plates and varied development of tabellae.

Discussion: Several groups included by Carter & Gourvennec (2006b) in Martinioidea have been segregated as Ingelarelloidea (see Waterhouse 2015a, p. 149), including Ingelarellidae Campbell, 1959, Notospiriferidae Archbold & Thomas, 1986, Gerkispiridae Carter, 1985 and Rorespiriferidae Waterhouse, 2001, the latter family senior to Crassumbidae Carter *in* Carter & Gourvennec 2006b, which should be downgraded to subfamily standing. Genera within these families and subfamilies have well formed dental plates and adminicula in the ventral valve and crural plates supported by varyingly developed and often sturdy tabellae in the dorsal valve. By contrast, tabellae are completely missing from Martinioidea.

Family **INGELARELLIDAE** Campbell, 1959

Diagnosis: Smooth or plicate shells, fold crest round or channeled, sulcus with subplicae, costa, or smooth, fine surface ornament of dense grooves, rarely with c-shaped sliver-spines, internal plates include dental plates, adminicula, socket plates and as a rule well developed tabellae, ventral myophragm low or absent.

Genus ***Tigillumia*** Waterhouse, 1998

Diagnosis: Sulcus may be very shallow, especially in older species, fold varies from low to high, with rounded crest, micro-ornament of shallow elongate grooves arranged in quincunx. Adminicula and tabellae long and close-set, tigillum or median thickening generally present along anterior mid-line of ventral valve.

Type species: *Martiniopsis biparallela* Waterhouse, 1987 from the Brae Formation (Kungurian), southeast Bowen Basin, Queensland, OD.

Tigillumia adminiculata Waterhouse, 1982a?

Fig. 9

?1964 *Martiniopsis* n. sp. Waterhouse, p. 147, pl. 30, fig. 1, 2, text-fig. 70.

?1982a *M. adminiculata* n. sp. Waterhouse, p. 56.

?1998 *Tigullumia adminiculata* – Waterhouse, p. 27.

2021b *T. adminiculata* – Waterhouse, p. 125, Fig. 18.

Diagnosis: Subglobular broadly sinuate shell with well inflated dorsal valve, no plicae, low fold, adminicula long and close-set, tabellae long and well spaced.

Holotype: BR 603 from Brunel Formation, Takitimu Group, figured in Waterhouse (1964), OD.

Material: A ventral internal mould BR 2445, and fragments of external moulds from GS 12669.

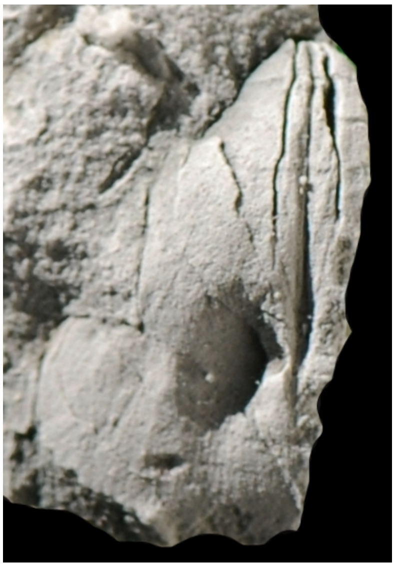


Fig. 9. *Tigillumia adminiculata* (Waterhouse)?, ventral internal mould BR 2445, x6, from GS 12669.

Description: A small internal mould 21mm long and 23mm wide has narrow umbo close to angle of 80°, long posterior walls that are gently concave in outline, and apparently no sulcus, and no plicae. The hinge is only 10mm wide, and cardinal extremities are obtuse, and shell widest towards anterior third of length. External fragments show a dense array of exopunctae in quincunx, some nine per mm along rows, and each close to 0.2mm long. Adminicula are long and subparallel, diverging forwards very slightly. The adductors lie on a slender median ridge, and are placed between much broader but still narrow diductor scars marked by faint traces of longitudinal striae and oblique growth ridges parallel to the anterior margin. A tigillum or bar of shell thickening extends in front for 3mm, without reaching the anterior margin.

Resemblances: This specimen is close to *Tigillumia adminiculata* (Waterhouse, 1982a) from the Takitimu Group, apart from being narrower, and the specimen is assigned to that species, with a query because the dorsal valve is not known. The type species of the genus, *T. biparallela* (Waterhouse) from the Brae Formation (Kungurian) of the Bowen Basin in Queensland is also moderately close, and its dorsal valve has long tabellae, diverging in a similar manner. The younger species *T. parallela* (Waterhouse, 1968a) from New Zealand and southeast Queensland is more plicate, and has longer and more closely spaced tabellae than in type *T. adminiculata*. *T. mintyi* Waterhouse, 1999, p. 22, text-fig. 1a-d; 1968a, p. 73, pl. 14, fig. 8, not pl. 13, fig. 3, 5, 6, pl. 14, fig. 7 = *parallela*) from the Hilton Limestone at Wairaki Downs, New Zealand, also has long adminicula, and shows heavy shell thickening, prominent ventral umbo, shallow or no sulcus and prominent adductor ridge in the posterior ventral muscle field. This species is also found in the upper South Curra Limestone of Changhsingian age in Queensland (Waterhouse 2015b, p. 114, Fig. 41A-C).

Family **NOTOSPIRIFERIDAE** Archbold & Thomas, 1986

Notospiriferid sp.

Fig. 10D

Material: Six ventral valves from GS 12699.

Description: Largest specimen over 14mm wide and 13mm long, transverse with broad ventral umbo and four pairs of low rounded plicae, sulcus with angle close to 20^{o}, bearing two obscure subplicae anteriorly. Dorsal valve with four pairs of plicae and a fold which is anteriorly sulcate. Micro-ornament obscure, with signs of small spines and possibly elongate surface grooves. Interior not preserved.

Discussion: The micro-ornament is obscure in this specimen and the generic position not secure. The genus *Notospirifer* Harrington, 1955 is characterized in part by having sulcal subplicae and low flattening or groove along the dorsal fold. Its micro-ornament is not fully known, but involves large swollen exopunctae, which are not clearly developed on present material. The closest species in shape and number of plicae with non-costate sulcus to the present form was described as *Notospirifer paraextensus* Waterhouse (1987a, p. 38, pl. 9, fig. 2, pl. 10, fig. 15, pl. 11, fig. 4) from the Fairyland Formation of early Sakmarian age in the southeast Bowen Basin of Queensland.

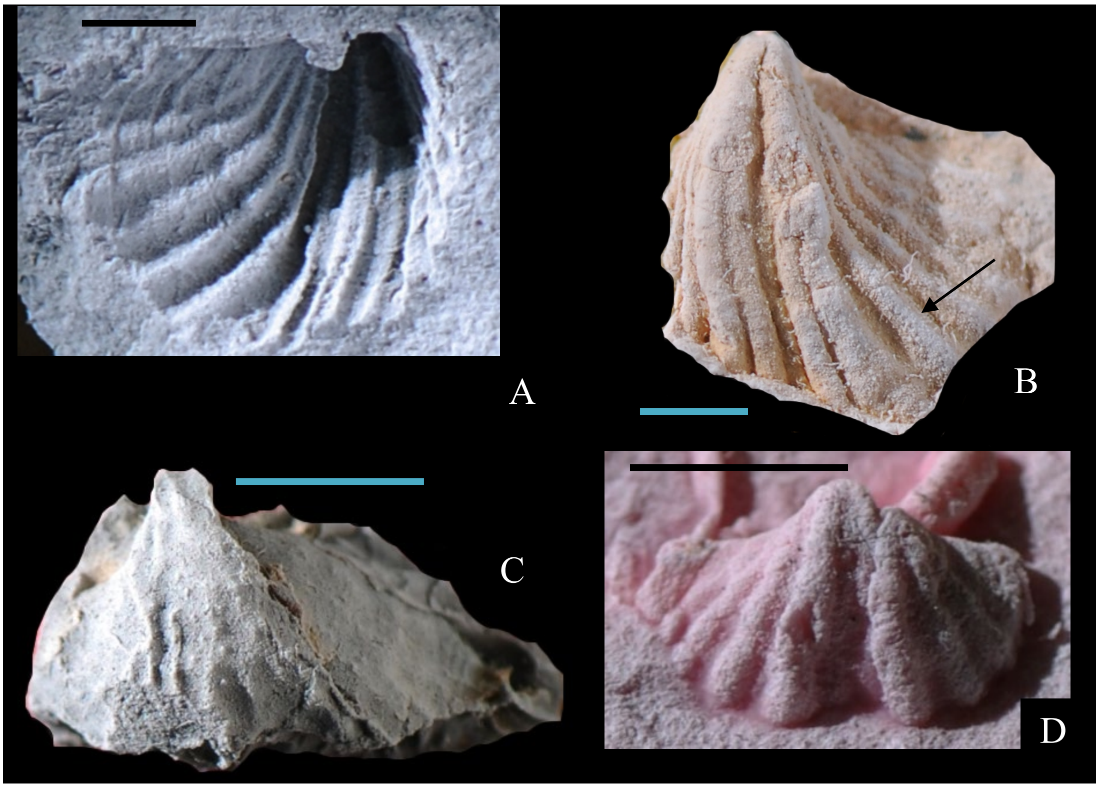


Fig. 10. A-C, *Pustuloplica* sp. A, B, external mould and latex cast of ventral valve, BR 2477. Fine pustules visible in Fig. 10B, as arrowed. C, internal mould of posterior ventral valve BR 2478. D, Notospiriferid sp., external cast of ventral valve BR 2497. Specimens from GS 12669. Space bar 5mm long.

Family **BRACHYTHYRIDAE** Fredericks, 1924

Subfamily **PUSTULOPLICINAE** Waterhouse, 2004

Diagnosis: Shells characterized by nodose micro-ornament. No form of deltidial plate, umbonal callosity present.

Genus ***Pustuloplica*** Waterhouse, 1968a

Diagnosis: Small, fold and sulcus and simple plicae, with discontinuous capillae and numerous pustules. No dental plates, adminicula, crural plates or tabellae.

Type species: *Pustuloplica baccata* Waterhouse, 1968a, p. 45 from Brunel Formation, Takitimu Mountains, OD.

Discussion: Pustuloplicinae differs from Brachythyrinae in the presence of pustules, and further differs in the lack of any form of deltidial plate and presence of umbonal callosity.

Pustuloplica sp.

Fig. 10A-C

Material, Description: A ventral valve BR 2477 from GS 12669 is 15mm wide and has six pairs of narrow round-crested high plicae, the innermost pair bordering a narrow sulcus, which bears three costae commencing up to 2mm in front of the beak. The hinge is narrow, cardinal extremities obtuse, and delthyrium narrow. Micro-ornament is worn, but suggests fine commarginal growth increments, and shows numerous tiny pustules, and fine radial capillae, ten to twelve in 1mm. Fine capillae and small pustules are visible on a plicate external fragment.

A ventral internal mould BR 2478 with attenuated umbo shows narrow and elongate adductor impressions, and there are no internal plates.

Suborder SPIRIFERIDINA Waagen, 1883

Diagnosis: Highly diverse group characterized as a rule by transverse outline, ornament of costae and plicae, micro-ornament typically cancellate, may be capillate or pustulose. Interareas well developed, hinge often denticulate, delthyrium variously open or variably closed by deltidium or stegidia, notothyrium present. Myophragm or septum may be present in ventral valve and low median septum in dorsal valve. Dental plates and short adminicula in ventral valve, ctenophoridium, socket and crural plates, no tabellae in dorsal valve, spiralia transverse as a rule, postero-laterally oriented in some groups.

Superfamily **SPIRIFERELLOIDEA** Waterhouse, 1968a

Discussion: Spiriferelloidea constitute a highly distinctive group, and its longevity depends on a possible link to Spinellinae Johnson, 1970 of Devonian age. Relationships are yet to be firmly established, but both groups share plates and pustules and open plication. The special attributes of a number of Spiriferelloidea include the narrow interspaces between plicae in many members, cancellate micro-ornament, and thick ventral shell of *Spiriferella* itself, features which are not displayed in Spinellinae. The superfamily does not fit within Trigonotretoidea, which lacks any form of subdelthyrial plate, and often lacks a deltidial cover. Spiriferelloidea shows persistent differences from Spiriferoidea, especially in the surface micro-ornament, plicae and ribs, thick shell and stubby adminicula, but does share a subdelthyrial connnector plate. Constituent genera in the superfamily vary in development of deltidial or stegidial plates.

Family **SPIRIFERELLIDAE** Waterhouse, 1968a

Diagnosis: Externally distinctive shells with rounded plicae and narrow interspaces, may be smooth or costate, micro-ornament cancellate with pustules in many forms. Interior as in suborder, posterior ventral valve heavily thickened as a rule.

Discussion: This is a highly distinctive family, and shows more variation than in Spiriferidae, Neospiriferidae and Trigonotretidae. For example the micro-ornament may be pustulose, cancellate or limited to growth increments, the plicae may be costate or smooth, the fold varies considerably in prominence and crest profile, and the delthyrium may be open with umbonal callus developed from the subdelthyrial connector plate, or closed by a deltidial cover. Secondary thickening may be great or slight.

Subfamily **SPIRIFERELLINAE** Waterhouse, 1968a

Genus ***Alispiriferella*** Waterhouse & Waddington, 1982

Diagnosis: Medium to large, transverse with alate cardinal extremities and wide median channel along dorsal fold.

Type species: *Spirifer* (*Spiriferella*) *keilhavii ordinaria* Einor, 1939, p. 140 from Novaya Zemlya (Sakmarian), OD.

Alispiriferella turnbulli n. sp.

Fig. 11, 12

Derivation: Named for I. M. Turnbull.

Diagnosis: Shell of medium size, weakly subalate cardinal extremities, three to four pair of plicae with a few anterior costae, postero-lateral shell costate.

Holotype: BR 2468, Fig. 11A, D-F, here designated.

Material: Three specimens with valves conjoined, five ventral valves and three dorsal valves, as well as fragments from GS 12669.

Dimensions in mm:

	Width	Length	Height ventral	Height dorsal
BR 2471 dorsal valve	38	26		9
BR 2468, internal mould	34	23	7	8

Description: Ventral valve bears a slightly incurved umbo with umbonal angle varying from 65° up to almost 90°, dorsal umbo lower and broader, extended only slightly over hinge, maximum width of shell placed near mid-length, ventral valve nearly three times higher than dorsal valve. Ventral sulcal angle measures 15° over umbonal region, widens to nearly 20° in larger specimens, dorsal fold low with angle of 22°, bearing well formed median channel. Hinge wide, delthyrium open with angle close to 50°, and bordered by dental tracks, notothyrium wide with angle of 100°. Ventral interarea high, concave under the tip of the beak, marked by weak horizontal striae and discontinuous vertical striae that form fine denticulations along hinge, cardinal extremities weakly alate. Dorsal interarea low. Sulcus bearing two costae near the umbo, fading anteriorly, and no median costa, fold with complex of costae, three each side of median channel. Three pairs of ventral plicae in the holotype, with rounded crests and narrow interspaces, costae absent from posterior 7mm of plicae. The innermost plicae pair and intervening sulcus bear ten fine costae anteriorly, and the next pair has three costae. A costa extends along the next interspace, and seven or eight costae lie on the outer slopes, arising close to the hinge. In another specimen BR 2469 (Fig. 11C), costae are few, and there are four pairs of ventral plicae, and only two costae on the posterior lateral shell. Dorsal valve BR 2449 displays three pairs of plicae, innermost plication bears three costae commencing 18mm from the umbo and three broad costae lie laterally. The fold has three pairs of costae, and posterior lateral margins are non-costate. Specimen BR 2472 is much the same, and three costae lie each side on the anterior median fold. In the holotype, BR 2468 (Fig. 11A, D-F), there are

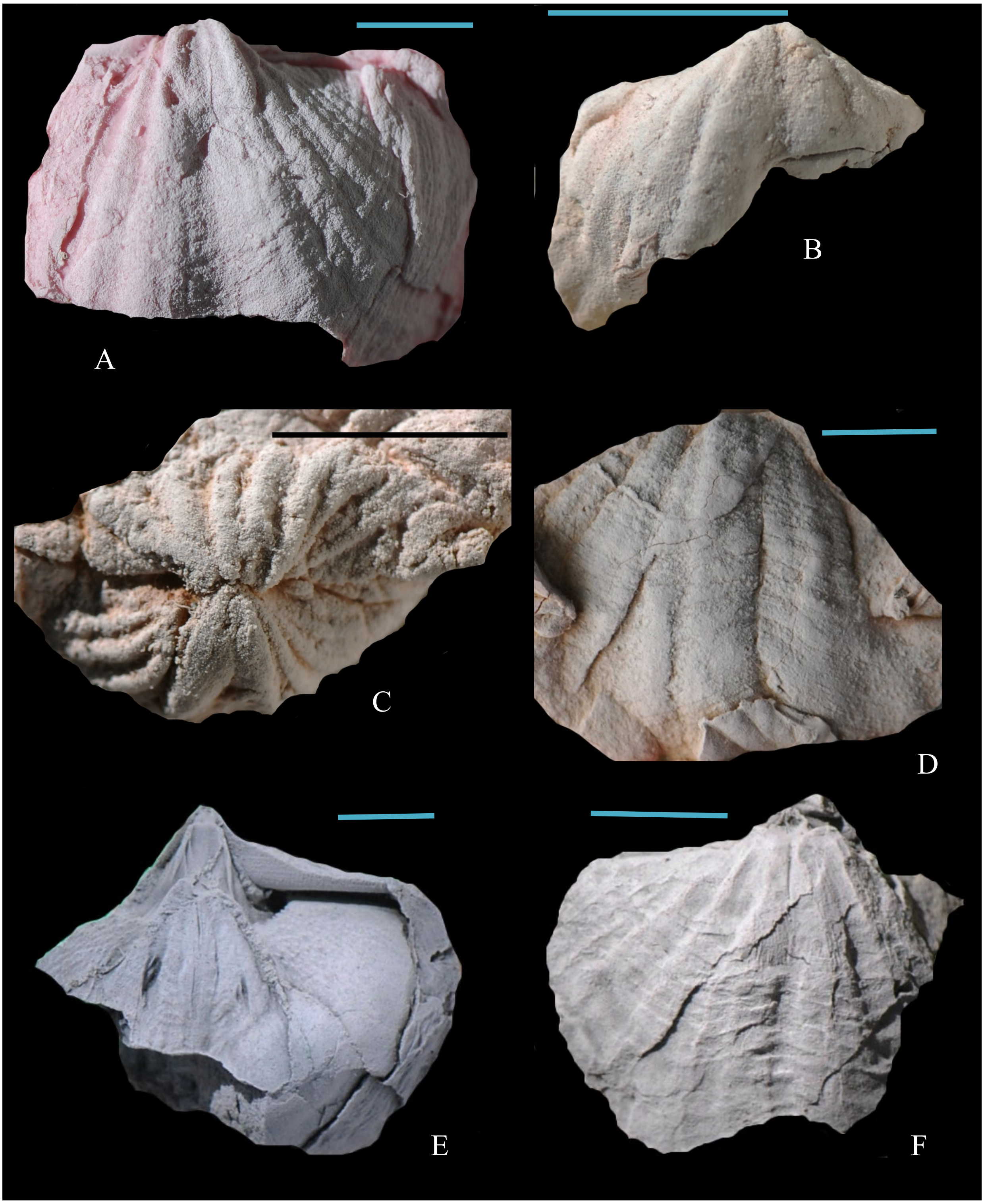


Fig. 11. *Alispiriferella turnbulli* n. sp. A, D-F, holotype, BR 2468. A, latex cast, showing much of ventral valve. D, latex cast of dorsal external mould of the same specimen. E, F, ventral and dorsal aspects of internal mould. B, latex cast of small ventral valve, ventral exterior, BR 2480. C, latex cast of specimen with valves conjoined, BR 2469, dorsal valve on top, fold with median channel. Space bar 10mm long. From GS 12669.

three simple non-costate plicae pairs posteriorly each side of the fold, and four subdued costae laterally. As well as fine radial capillae, the surface of both valves is crossed by sublaminate growth increments, eight to ten in 1mm, some of which bear three to four tiny spinules per mm; rarely a spinule extends over two growth increments. The spinules may be c-shaped, and open anteriorly in fragment BR 2454, but as a rule they are subrounded in outline.

Well developed teeth lie each side of the delthyrium, which is open, and bordered by dental tracks. Adminicula are short and buried in secondary shell, and a low callosity lies under the delthyrium and covers the inconspicuous connnector plate. The adductor scars are elongate, divided posteriorly by a slender ridge, which broadens and becomes lower in front. The diductor scars are broader than the adductors and widen forward.

The ctenophoridium is small and laminate, and a slender median septum extends over the posterior third of the shell length. Ventral teeth are enclosed by subhorizontal socket plates and subvertical crural plates, and crural bases lie each side of the base of the ctenophoridium. Adductor scars are weakly impressed and subrectangular in shape. Unlike the ventral valve, there is little secondary thickening.

Resemblances: Compared with the type species *Alispiriferella ordinaria* (Einor, 1939), which is also of Sakmarian age, the present species is slightly more transverse with more incurved ventral interarea, and has more costae postero-laterally and anteriorly, and tends to have one fewer pair of plicae. Canadian specimens of *A. ordinaria* described from the lower Jungle Creek Formation by Waterhouse & Waddington (1982) and Shi & Waterhouse (1996) include some more transverse and subalate specimens, but none show the posterior lateral costae of the present species. *A. gydanensis* (Zavodowsky, 1968) from the Omolon Horizon of northeast Russia and Spitsbergen (Miloradovich 1936) and Assistance Formation of the Canadian Arctic Archipelago (Waterhouse & Waddington 1982; Waterhouse 2020) also lacks posterior costae, and *Canalisella leviplica* (Waterhouse & Waddington, 1982; Waterhouse 2020) from the Degerböls Formation of the Canadian Arctic Archipelago has five pairs of plicae and no costae and narrower channel over the dorsal fold. These latter two species are of Middle Permian age.

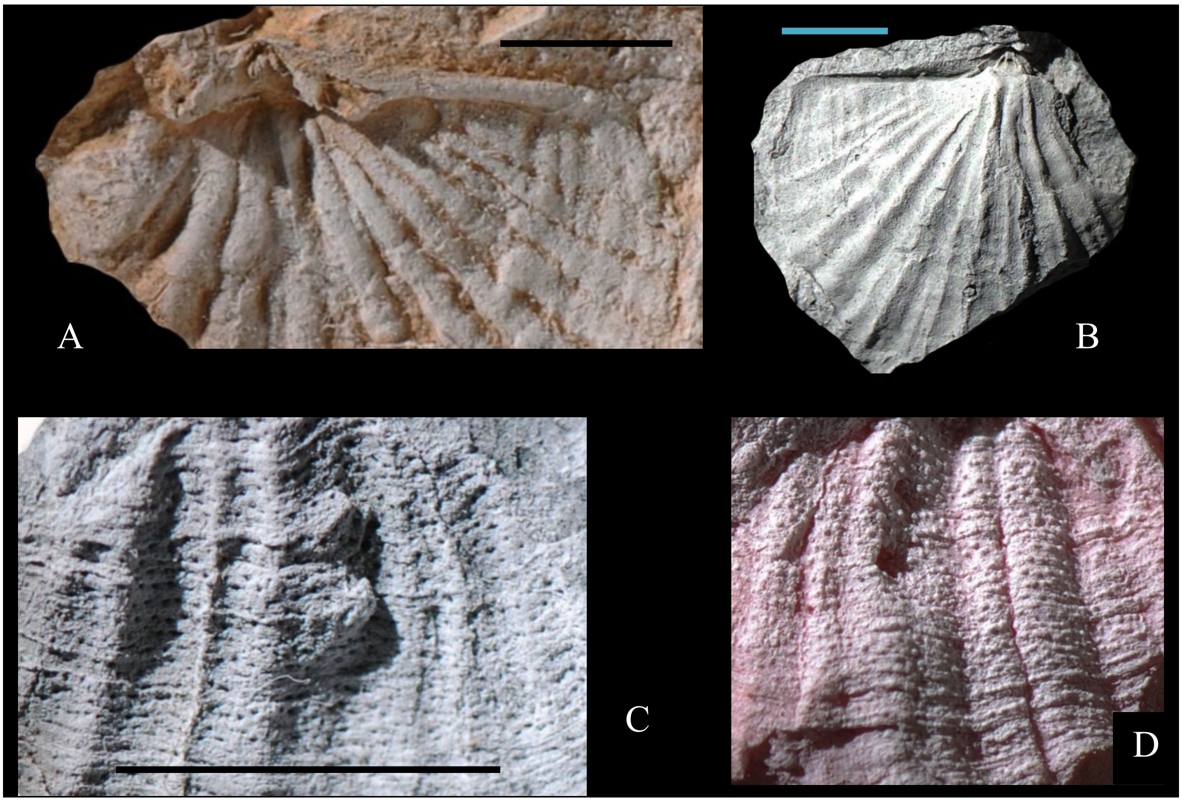


Fig. 12. *Alispiriferella turnbulli* n. sp. A, B, latex cast and internal mould of dorsal valve BR 2449. C, D, external mould and latex cast of dorsal exterior near fold, BR 2455, showing minute spinules, sharing space bar. Space bar 10mm long. From GS 12669.

Alispiriferella sp. described by Waterhouse (2001, pl. 7, fig. 1-3) from the *Echinalosia denmeadi* Zone of the lower Glendale Formation, Wairaki Downs, Southland, is represented by a few specimens which show substantial secondary thickening in the ventral valve and have five pairs of narrow dorsal plicae succeeded laterally by strong costae, unlike the arrangement in the present form, which has three or less commonly four pairs of plicae followed laterally by fine costae.

Superfamily **TRIGONOTRETOIDEA** Schuchert, 1893?

Diagnosis: Transverse with plicae and often costae, hinge line denticulate as a rule, delthyrial cover may be developed in form of neodeltidium. No subdelthyrial connector plate.

Family **NEOSPIRIFERIDAE** Waterhouse, 1968a?

Diagnosis: Usually large transverse shells with strong plicae, costate, with deltidial or stegidial cover plate over delthyrium in many genera, subdued or no umbonal callosity.

Subfamily **NEOSPIRIFERINAE** Waterhouse, 1968a?

Diagnosis: Plicate and costate shells with sulcus that generally expands to incorporate innermost pair of plicae in many genera. Delthyrium covered by neodeltidium, no subdelthyrial connector plate. Dental plates, short adminicula, socket and crural plates are all present, no tabellae, no high median septum. Branching vascular impressions known in a few genera. Spiralia laterally directed in *Neospirifer* and allied genera.

Discussion: The classification of *Gypospirifer* Cooper & Grant in Neospiriferinae can only be considered as provisional. Its ribs differ somewhat from those of *Neospirifer* and allies, and at least one species, *G. condor* (d'Orbigny), has postero-laterally directed spiralia. The delthyrium may be closed by deltidial plates rather than a neodeltidium, or single plate. These unknown or uncertain aspects mean that the classification of *Gypospirifer* has significant uncertainities.

Genus ***Gypospirifer*** Cooper & Grant, 1976

Diagnosis: Medium to large shells, cardinal extremities may be alate in juveniles, rounded to subangular in adults, fold and sulcus well developed, costae coarse and conspicuously branched, weakly fasciculate posteriorly. Exceptionally, stegidia are preserved.

Type species: *Gypospirifer nelsoni* Cooper & Grant, 1976, p. 2209 from Wolfcampian beds of Texas (Asselian), OD.

Discussion: Cooper & Grant (1976, p. 2210) reported that the ventral muscle area was divided by a low median ridge, relying on excellent figures of *Gypospirifer condor* from Bolivia in Kozlowski (1914, fig. 16, pl. 1, fig. 1). This ventral muscle ridge is slender but well developed in New Zealand specimens, which are preserved as external and internal moulds, to show some of the internal features better than in the silicified material from Texas. In other specimens of *G. condor* figured from Bolivia by Samtleben (1971, pl. 11, fig. 1a, b, 2, 3), the spires are postero-laterally inclined, but no other specimens, including those from Texas, are known that indicate the course of the spiralia. This orientation may well prove significant, because it is shown that critical members of Trigonotretidae have postero-laterally oriented spiralia, in contrast to laterally oriented spiralia in most known menbers of Neospiriferidae (Waterhouse 2021a). The New Zealand material from the Dunton Range shows spiralia which seem to be laterally rather then posterolaterally oriented, placing a question against its generic position.

***Gypospirifer*? *inexpectans* n. sp.**

Fig. 13, 14

Derivation: in – not; exspecto – await, look out for, Lat.

Diagnosis: Moderately large with strong costae, wide hinge and alate cardinal extremities, plicae weak and fade anteriorly.

Holotype: BR 2458 figured herein as Fig. 13A, here designated.

Material: Five ventral valves, four dorsal valves and other fragments from GS 12669. One ventral valve BR 2431 from GS locality 12633.

Description: Shells moderately large, ventral umbo broad, little incurved, umbonal angle 140° (BR 2454) to 110° (BR 2450). The hinge is placed close to the maximum width of the shell, which lies near mid-length. The ventral interarea is very high, concave under the umbo, and planar for most of its height, and is traversed by fine striae parallel to the hinge, and crossed by very subdued and faint vertical striae. Whether the hinge is denticulate is not shown. The delthyrium is open, and there is only subdued callus, with no conspicuous umbonal callosity. The delthyrial angle is 35° in BR 2450, and close to 45° in BR 2451. Little of the dorsal interarea can be seen. The ventral sulcus commences at the umbonal tip, widening at an angle of 24° in BR 2450, and at an estimated in 35° in the large specimen BR 2458, in which the middle of the sulcus is subangular in profile rather than evenly curved. The sulcal angle measures 25° in BR 2451, with a channel developed along the centre of the sulcus. The dorsal fold is narrow posteriorly, and remains high and well defined to the anterior margin, the crest well rounded and flanks steep. On BR 2450 three broad-crested plicae arise close to the umbonal tip, with

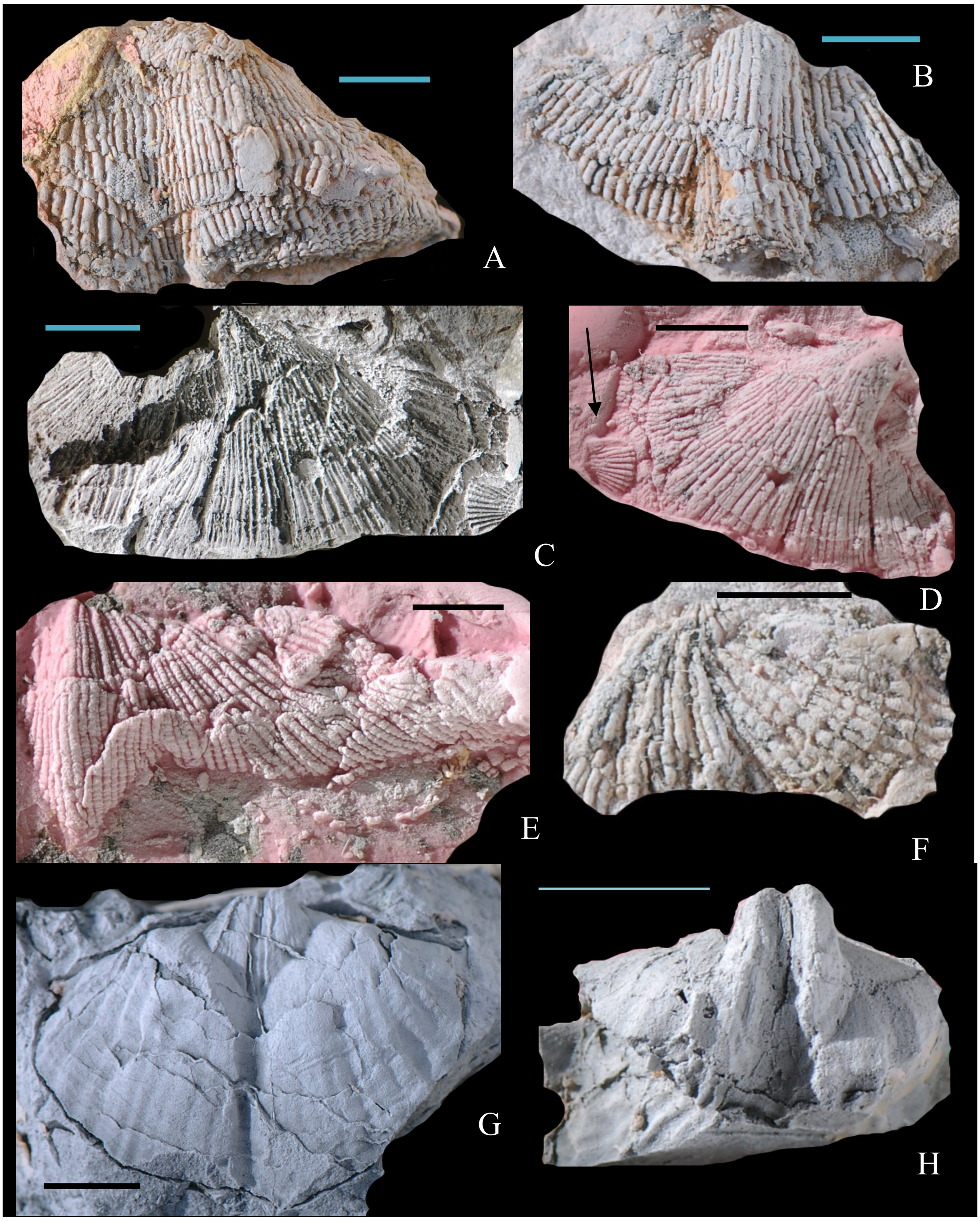


Fig. 13. *Gypospirifer*? *inexpectans* n. sp. A, latex cast of ventral exterior, BR 2458, holotype. B, latex cast of dorsal exterior, BR 2462. C, D, external mould and latex cast of broken ventral valve BR 2431, with rhynchonellid external mould, as arrowed. E, latex cast of dorsal exterior, BR 2463. F, latex cast of ventral exterior of small ventral valve, BR 2451. G, internal mould of immature ventral valve, BR 2434. H, internal mould of ventral valve, BR 2471, showing myophragm. Specimens from GS loc. 12669, except Fig. 13C, D, from GS 12633. Space bar 5mm.

outer shell smooth, and these plicae split into two or three low costae with low rounded crests, the inner costa appearing before the outer costa, and three narrower and finely costate plicae appear laterally. The plicae persist for 20 to 25mm, remaining low and disappearing anteriorly, whereas the costae increase in strength to three or four in 5mm and persist to the anterior margin. Crests are rounded, and flanks steep. Anteriorly, a fine costa commences by splitting on the flank of a strong costa, either on the inner or outer side, and it becomes just as strong. Two costae arise close to the umbo within the ventral sulcus, and an outer pair develops close to 10mm from the umbonal tip. The inner four ribs become fasciculate, each branching into three costae and plicae become faint at some 15-20mm from the hinge, and more costae appear laterally.

A ventral internal mould BR 2478 with attenuated umbo shows narrow and elongate adductor impressions. The teeth leave a well defined dental track or flange along each side of the ventral delthyrium, and are supported by steeply inclined high dental plates, and short adminicula largely buried in secondary shell. The muscle field is broad, with narrow adductor scars on two ridges, divided posteriorly by a well defined myophragm and divided anteriorly by a shallow groove. The diductor impressions are much broader than the adductors and bear radial grooves. The posterior floor of the valve is thickened and marked by vascular impressions, and the rest of the valve finely pitted.

The dorsal interior is not well preserved, but BR 2465 shows that tabellae are not developed, and that a low median ridge lies over the posterior shell. The spire is revealed on BR 2450; it seems to be laterally directed and has twenty turns in the spire (Fig. 14).

Resemblances: This is a highly distinctive species, with very strong subeven costae, fading plicae, and wide subalate hinge and prominent dorsal fold. The apparent transverse orientation of the spiralia in one specimen (Fig. 14) must place a question against the generic position, given that specimens ascribed to *Gypospirifer* from Bolivia indicate postero-laterally oriented spiralia, but in shape and ornament the New Zealand form is otherwise very close. *Gypospirifer nelsoni* Cooper & Grant (1976, p. 2214, pl. 591, fig. 6-9) from the Hueco Formation in Texas has more fasciculate costae and lower dorsal fold, though close in many respects. The present material is larger and costal pairs less prominent than in *Gypospirifer anancites* Cooper & Grant (1976, p. 2210, pl. 593, fig. 16-25) from the Hueco Canyon Formation of Texas, and costae are stronger and fold higher than in *G. gryphus* Cooper & Grant (1976, p. 2211, pl. 591, fig. 1-5) from the basal Permian Graham Formation of Texas. *G. condor* (d'Orbigny, 1842, p. 46, pl. 5, fig. 11-14) has also been figured by Kozlowski (1914, p. 67, pl. 1, fig. 1, pl. 7, fig. 10-14, text-fig. 16) and Samtleben (1971, p. 105, pl. 9, fig. 1-8, pl. 10, fig. 1-10, pl. 11, fig. 1-3, text-fig. 25-30) with other references summarized in Samtleben (1971, pp. 105-106). It comes from the Early Permian Copacabana Group of Bolivia, and is a more alate shell with narrow well defined ventral sulcus and low fold. A lamellate deltidial cover plate is clearly figured in Samtleben (1971, pl. 10, fig. 6). Cooper & Grant recorded stegidial plates in some but not all of their species: such plates are readily lost. No such plates are preserved in present specimens.

Fig. 14. *Gypospirifer inexpectans* n. sp., section through specimen with both valves conjoined, showing spiralia that apparently are oriented laterally, BR 2450. Specimen from GS loc. 12669. Space bar 5mm.

The strong costae with their mode of increase, and the fading plicae are also features of *Cartorhium* Cooper & Grant, 1976, a genus especially common in the Guadalupian Series of Texas, United States, and commencing in the Decie Ranch Member of the Skinner Ranch Formation, of upper Cisuralian age. The American species tend to have more rounded cardinal extremities, and less conspicuous dorsal fold, which as a rule broadens anteriorly. *Cartorhium limitaris* (Reed, 1944, pl. 28, fig. 5, 6) from the upper Wargal Formation (Wuchiapingian) in the Salt Range, Pakistan, has a wide hinge and fading plicae, but the fold is low. Angiolini (2001) considered that specimens from the Wordian Panjshah Formation Member 2 of the Karakorum in Pakistan were related, and Termier et al. (1974) recorded the species from the Murgabian of Afghanistan at Wardak. *Purdonella alisangensis* Termier et al. (1974, p. 136, pl. 35, fig. 1-5, text-fig. 24a-e) from the so-called upper Murgabian of Afghanistan has short hinge and well-rounded cardinal extremities, approaching *Ovispirifer* Waterhouse, 2004.

The fragment of a dorsal valve from the Gondor Formation of the Eglinton Valley, west of the Dunton Range is unlikely to be congeneric, as it has slightly better defined fascicles and lower dorsal fold. It was recorded as *Aperispirifer* or *Neospirifer* by Waterhouse, Williams & Campbell (1983, p. 303, Fig. 2).

Order SPIRIFERINIDA Ivanova, 1972

Suborder SYRINGOTHYRIDINA Grunt, 2006

Superfamily **SYRINGOTHYROIDEA** Fredericks, 1926

Family **SYRINGOTHYRIDAE** Fredericks, 1926

Subfamily **PERMOSYRINXINAE** Waterhouse, 1986b

Diagnosis: Normally transverse shells with narrow sulcus, fold and plicae, micro-ornament of radial capillae and transverse growth lamellae. Syrinx absent, short adminicula.

Genus ***Cyrtella*** Fredericks, 1924

Diagnosis: Transverse shells with narrow sulcus and channelled fold, numerous slender plicae, micro-ornament of dense papillae.

Type species: *Cyrtia kulikiana* Fredericks, 1916, p. 43 from Russia, OD.

Cyrtella? sp.

Fig. 14

Material: Three ventral valves, with additional fragments from GS locality 12669, and BR 2460 comes from GS locality 12633.

Description: Small ventral valves little more than 10mm long have sulcus and five pairs of narrow plicae, and two additional pair anteriorly, bearing small crowded spines that number three to four along 1mm, and fine punctae, up to 15 in 1mm. Commarginal laminae cover the surface, three to five in 1mm on some specimens, but spacing more variable in others. Signs of radial capillae are preserved on some specimens. No specimens show the ventral interior.

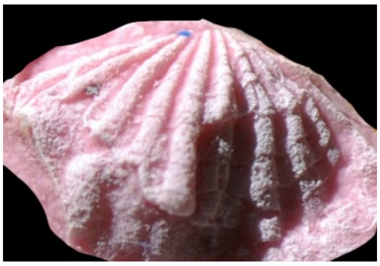


Fig. 14. *Cyrtella*? sp. A, external cast of ventral valve, BR 2459, from GS 12669, x3.

Resemblances: Material is poorly preserved, and the generic position in need of confirmation, especially because the number of plicae are fewer than in the type and other species of *Cyrtella*.

Phylum Mollusca Cuvier, 1797

Class Bivalvia Linnaeus, 1758

Subclass Autobranchiata Grobben, 1894

Infraclass Pteriomorphia Beurlen, 1954

Order PECTENIDA Gray 1854

Suborder ANOMIIDINA Gray, 1854

Hyporder AVICULOPECTENOIDEI Starobogatov 1992

Superfamily **CHAENOCARDIOIDEA** Miller, 1889

Family **STREBLOCHONDRIIDAE** Newell, 1938

Subfamily **ORBICULOPECTENINAE** Waterhouse, 2001

Genus ***Orbiculopecten*** Gonzalez, 1978

Diagnosis: Small upright to weakly opisthocline shells with left valve more inflated, right anterior auricle costate, fine ribs on left anterior wing, both valves ornamented by fine radial filae and commarginal growth threads. Ligament lativincular.

Type species: *Orbiculopecten parma* Gonzalez, 1978 from lower Tepuel Group, Argentina, OD.

Discussion: It is urged that family and ordinal groupings based on genera and named accordingly should preserve the genus name as far as is euphonious, rather than conform with the arcane rules that demand alterations to the generic name. Hence Orbiculopecteninae is preferred, rather than Orbiculopectininae. The name of the genus is *Orbiculopecten*, not *Orbiculopectin*. Classification should surely centre on biological names rather than grammatical rules devised for a language heavily altered by scholars during medieval and modern times.

***Orbiculopecten*? sp.**

An obscure right valve nearly 20mm long and with three or four weak commarginal rugae might belong to this genus. It comes from GS 12669.

Superfamily **HETEROPECTENOIDEA** Beurlen, 1954

Family **HETEROPECTENIDAE** Beurlen, 1954

Subfamily **ETHERIPECTENINAE** Waterhouse, 1982b

Genus ***Etheripecten*** Waterhouse, 1963b

Diagnosis: Left valve bears costae in several orders as a rule, arising by intercalation, primary costae generally remaining prominent. Right valve costae simpler and more uniform. Growth lines arch dorsally in interspaces. Shell aragonitic or calcitic, depending on paleolatitude.

Type species: *Etheripecten striatura* Waterhouse, 1963b, p. 195 from Kildonan Member (Changhsingian), New Zealand, OD.

Discussion: Shell material in specimens from high paleolatitudes lacks the aragonitic component found in shells of allied taxa in lower paleolatitudes (Waterhouse 1982b, 2008b). The stress on shell composition and structure in recent studies seems to take no account of ecological and latitudinal change.

Etheripecten farleyensis (Etheridge & Dun, 1906)

Fig. 15, 16

1906 *Deltopecten farleyensis* Etheridge & Dun, p. 29, pl. 6, fig. 2?, pl. 13, fig. 4, ?5, 6, pl. 16, fig. 4.

1929 *D. farleyensis* – Fletcher, p. 25.

Diagnosis: Slender and fan-shaped with long hinge and fine crowded costae over left valve, weakly differentiated over right valve.

Holotype: Specimen figured by Etheridge & Dun (1906, pl. 13, fig. 6) from Farley Formation, Hunter Valley, New South Wales, kept at Australian Museum, Sydney, here designated.

Material: A well preserved right valve and fragments of left valves from GS 12669.

Description: The right valve is subequidimensional, 46mm long, 45.5mm high, and less than 4mm wide, with gently convex shell, long prominent and gently convex anterior ear that has a deep byssal notch, and incomplete but long and concave posterior wing. The valve is closely and finely costate, with some eight ribs in 10mm, and a few finer intercalated slender ribs. The anterior ear bears a number of fine ribs, and the poorly preserved posterior wing appears to bear fine growth increments, but no ribs.

Fig. 15. *Etheripecten farleyensis* (Etheridge & Dun), cast of right valve TM 9260 from GS 12669, x2.

Two left valve fragments might be conspecific. One is only about 13mm high, gently convex with fine ribs and close-set growth increments; moderately conspicuous primary ribs bearing broad convex crests and wide interspaces, occupied each by a single secondary rib arising by intercalation an estimated 5mm below umbo, followed by a third order of fine ribs. Commarginal growth lines are closely spaced. Another fragment of a more mature specimen but of comparable size shows fine and closely spaced ribs in four orders, increasing by intercalation, and crossed by fine commarginal growth increments.

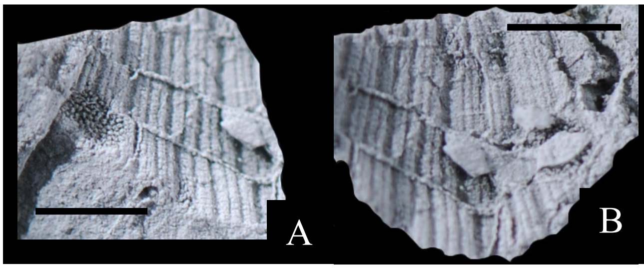


Fig. 16. *Etheripecten farleyensis* (Etheridge & Dun). A, fragment of external mould of left valve, TM 8221. B, fragment of external mould of left valve, TM 8218. Space bar 5mm. From GS 12669.

Resemblances: The species *farleyensis* is not well known, and still requires clarification. It was named by Etheridge & Dun (1906, p. 29, pl. 6, fig. 2?, pl. 13, fig. 4, 5?, 6, pl. 16, fig. 4?), the questioned specimens having been later reassigned to the species *leniusculus* Dana by Fletcher (1929, p. 25). Etheridge & Dun (1906) described the species *farleyensis* as slender and fan-shaped, with chondrophore, characterizing the “Lower Marine” later called Dalwood Group of New South Wales. A right valve from Pokolbin, New South Wales, was included, and it shows ribs less differentiated than those displayed on the present specimen, and slightly longer anterior auricle, much as in their specimen from New England (Etheridge & Dun 1906, pl. 6, fig. 2). Fletcher (1929, p. 25) cast doubt on aspects of their study, claiming that a number of their figured specimens belonged to the species *leniusculus* (Dana), which is a prominent and closely ribbed form now also placed in *Etheripecten.* He claimed to figure three specimens (1929, p. 25, pl. 6, fig. 1-3) but in the caption to the plate, only fig. 1 was regarded as *farleyensis*, and his specimen, from Jamberoo, shows no ornament so its identity is obscure. Two of the figures in Etheridge & Dun, a right and a left valve, were considered to represent typical *farleyensis* in the original description, and these need to be amplified by further material.

The fragments of left valves from GS 12669 (Fig. 16) are presumed to be conspecific with the right valve. They have weaker primary costae than in *Etheripecten tenuicollis* (Dana, 1847, 1849), but their ornament approaches that of *E. subquinquelineatus* (M'Coy, 1847).

Class Gastropoda Cuvier, 1797

Order PROSOBRANCHIATA Milne-Edwards, 1848

Suborder PLEUROTOMARIIDINA Cox & Knight, 1960

Superfamily **PLEUROTOMARIOIDEA** Swainson, 1840

?Family **SINUOPEIDAE** Wenz, 1938

Genus ***Pandospira*** Waterhouse, 1963a

Pandospira nuda Waterhouse, 1963a

1963a *Pandospira nuda* Waterhouse, p. 116, text-fig. 1A, 7, 8.
1991 *P. nuda* – Begg & Ballard, p. 150, text-fig. 9, 10.

Diagnosis: Wide sutural shelf, narrow umbilicus, broad spiral ribs and fine collabral ornament.

Holotype: TM 3198, figured by Waterhouse (1963a, text-fig. 1A, 7) from Brunel Formation, Takitimu Group, OD.

Material: A fragment of part of the base, TM 8220 from GS 12669.

Resemblances: The fragment as far as it is preserved suggests *Pandospira nuda*, in the nature of its lower aperture, base and ornament. The species has been described from the Brunel Formation of the Takitimu Group in western Southland and from the Mantle Volcanics Formation of the Skippers Range in western Otago.

Family **EOTOMARIIDAE** Wenz, 1938

Subfamily **NEILSONIINAE** Knight, 1956

Tribe **NEILSONIINI** Knight, 1956

Genus ***Peruvispira*** Chronic, 1949

Peruvispira robusta Waterhouse, 1963a

Fig. 17, 18

1963a *Peruvispira robusta* Waterhouse, p. 591, text-fig. 1, 10-15.

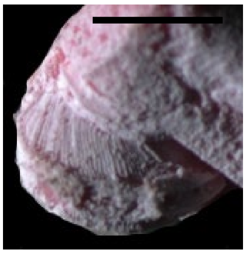
1991 *P. robusta* - Begg & Ballard, p. 150, text-fig. 11.

Diagnosis: Small shell, upper whorl concave, peribasal carina well formed, ribs number seven to nine in 1mm, somewhat subdued.

Holotype: TM 3010 figured by Waterhouse (1963a, text-fig. 10, 12) from Brunel Formation (lower Artinskian), Takitimu Group, OD.

Material: Four specimens from GS 12669.

Fig. 17. *Peruvispira robusta* Waterhouse, latex cast of worn specimen TM 8219, oblique aspect showing body whorl and selenizone. Specimen from GS 12669. Space bar 5mm long.



Description: Small specimens, including one 5mm and the other 7mm high, with slender spire, well formed carinae, selenizone concave with well formed lunulae and slightly lower than the underlying concave band; ornament of low and well formed radial threads, seven to nine in 1 mm on last formed whorl.

Fig. 18. *Peruvispira robusta* Waterhouse. cast of worn specimen TM 8219, from GS 12669. Space bar 5mm long.

Resemblances: The specimens are identified with *Peruvispira robusta*, a species also recorded from the Mantle Volcanic Formation of the Skippers Range by Begg & Ballard (1991). Correlative beds in the north Bowen Basin contain a comparably small and high-spired form, *Pleurocinctosa allandalensis* Fletcher, 1958, distinguished by its convex upper whorl and fine radials at twelve to eighteen in 1mm (Waterhouse 2015a, p. 332).

SUMMARY OF FAUNA

The following species are recorded in this text:

Notostrophia sp.
Echinalosia curvata Waterhouse
Calandisa solitarius Waterhouse & Campbell
Bookeria drysdalei Waterhouse
Tigillumia adminiculata Waterhouse?
Notospirifer? sp.
Duntonia duntoni Waterhouse & Campbell
Alispiriferella turnbulli n. sp.
Gypospirifer? *inexpectans* n. sp.
Cyrtella? sp.
Orbiculopecten? sp.
Etheripecten farleyensis (Etheridge & Dun)
Pandospira nuda Waterhouse
Peruvispira robusta Waterhouse

CORRELATION

Most of the formally recognized macro-faunal biozones found in the New Zealand Permian are also found in east Australa, especially Queensland, so that the biozones as most recently outlined in Waterhouse (2008a, 2021c) are geographically widespread, and the present fauna is no exception, being represented especially in the Bowen Basin of central Queensland, involving the Elvinia Formation of the southeast Bowen Basin and its equivalents in the middle Tiverton Formation of the northern basin, and related to incompletely described brachiopod and molluscan faunas in the Sydney Basin and Tasmania. The Dunton fauna includes *Echinalosia curvata* which helps typify the *Magniplicatina undulata* Zone in the Elvinia Formation of the southeast Bowen Basin (Waterhouse 1987), and is found rarely in the *Taeniothaerus subquadratus* Zone in the Tiverton Formation of the north Bowen Basin (Waterhouse 2008a, 2015a, 2021c) and in the Lakes Creek Formation near Rockhampton in Queensland (Waterhouse 2021b). *Bookeria drysdalei* is found in the *Taeniothaerus subquadratus* Zone and also the top of the underlying *Magniplicatina undulata* Zone in the north Bowen Basin (Waterhouse 2015a). The two critical Productida allow correlation with either the *Magniplicatina undulata* macrofaunal Zone or the *Taeniothaerus subquadratus* Zone, as defined and elaborated in Waterhouse (2021c), and the slightly older match seems more likely, because *Echinalosia curvata* is especially widespread at this level, and there are no specimens of *Taeniothaerus* in the present collections from the Dunton Range, whereas the genus is common and conspicuous in its eponymous zone.

Other species from the Dunton collection are apparently shared with or closely related to faunas from the *Notostrophia zealandicus* and *N. homeri* Zones of Aktastinian (Lower Artinskian) age in the Takitimu and Skippers Ranges of New Zealand, including possible *Tigillumia adminiculata* with *Peruvispira robusta* and *Pandospira nuda*. Some gastropods so far as is known have a limited range, but others range for more than a zone in both New Zealand and east Australia, so that their presence in the *zealandicus* and *homeri* Zones need not indicate an exact correlation, and their value is deemed to be outweighed by the affinities of the Productida.

Three species in the present fauna are of particular interest, because they belong to genera largely unknown in east Australia, and have limited affinities in New Zealand. *Duntonia duntonensis* is a martiniid, allied to but not congeneric with species found in New Zealand in the *Spinomartinia adentata* and *S. spinosa* Zones, and known in eastern Australia in the Brae Formation as *S. queenslandica* in the Bowen Basin as well as *S. spinosa* in the upper South

Curra Limestone and Gigoomgan Limestone in the neighborhood of Gympie, southeast Queensland. In several respects the species is similar to *Chapursania* from the Wordian faunas of Afghanistan. *Gypospirifer*? *inexpectans* is of considerable interest. It possibly belongs to a genus found in the Cisuralian of Texas (Gaptank, Lenox Hills, Hueco Canyon and other faunas), the Middle Carboniferous (Bashkirian) to Lower Permian (Cisuralian) of Russia, and Asselian of Bolivia (Carter 2006, p. 1799). The genus is also apparently represented in New Zealand by a specimen accurately figured as "a brachiopod" by Hada & Landis (1995, Fig. 3, inset) from the north of the Waitaki River near Benmore Dam, in Permian deposits that include the Capitanian fusuline *Yabeina*. (The whereabouts of the brachiopod specimen is now not known). *Alispiriferella turnbulli* belongs to a genus also found in the *Echinalosia denmeadi* Zone of the lower Glendale clastics (Waterhouse 2001, p. 97). The genus is based on a Sakmarian species from Arctic faunas, and is more common in high temperate paleolatitudes of the northern hemisphere and to some extent the Dunton fauna is a southern hemisphere counterpart.

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2. *Grebneffia divaricata*, A NEW DIELASMID GENUS AND SPECIES FROM THE UPPER TAKITIMU GROUP OF SOUTHLAND, NEW ZEALAND

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Abstract

A new genus and species is described from the upper Takitimu Group of Southland, characterized by external shape, with a narrow-crested plication bordering the well defined sulcus on each side in the ventral valve, and a low broad median fold bordered by a well defined groove on each side in the dorsal valve. Both valves are ornamented also by sturdy costae which divaricate forward from the sulcal-bordering plicae and fold-bordering grooves. The internal morphology is like that typical of Dielasmini, with short well-formed dental plates and large brachidium that is not supported by a high medium septum.

New taxon: *Grebneffia divaricata* n. gen., n. sp.

INTRODUCTION

The single fossil BR 3454 described herein was collected by HJC and John Begg during reconnaissance field investigations on 13/1/1988, while exploring rock exposures along the Wairaki River for several kilometres down-stream of the Elbow Creek confluence. The fossil was found on an extensive bedding-plane surface striking at 333° and dipping 72°NE, within a sequence of well-bedded fine to coarse sandstone, breccia and minor siltstone. No other complete fossils were found, but comminuted prismatic atomodesmatinid (bivalve) shell debris and possible brachiopod shell fragments are present throughout these beds. The locality GS 15517 is situated on the true right-hand side of the Wairaki River, 20-25 metres down-stream from the confluence of a south-flowing tributary stream at map reference D44/162779, on the 2005 edition of NZMS260 topographic map Takitimu Sheet D44. The fossil is registered as D44/f0390 at the Institute of Geological and Nucelar Science, Lower Hutt..

The fossil is a dielasmid brachiopod, found in the Takitimu Group of Mutch (1957, 1972) in the McLean Peaks Formation of Houghton (1981) in in western Southland. The specimen is well preserved and highly exceptional in its morphology. Fossils are not common in this formation, so that any discovery has some interest, and in this case the fossil belongs to a very unusual member of the brachiopod family Dielasmidae, unusual for New Zealand Permian fauna, because it lacks the high dorsal median septum found in related genera, which are classed as Fletcherithyrini.

SYSTEMATIC DESCRIPTION

Order TEREBRATULIDA Waagen, 1883

Suborder TEREBRATULIDINA Waagen, 1883

Superfamily **DIELASMOIDEA** Schuchert, 1913

Family **DIELASMIDAE** Schuchert, 1913

Subfamily **DIELASMINAE** Schuchert, 1913

Diagnosis: Dental plates well developed, septalium of inner and outer hinge plates, may be divided, sessile or raised on low to high septum, loop deltiform.

Tribe **DIELASMINI** Schuchert, 1913

Diagnosis: Medium septum low or absent, so that the septalium is sessile or almost so.

Grebneffia n. gen.

Derivation: Named for Andrew Grebneff.

Diagnosis: Biconvex, transverse and subpentagonal in outline with maximum width near mid-length, epithyrid foramen well developed, well defined ventral sulcus bordered each side by narrow-crested plication, dorsal valve of comparable inflation with broad median fold bordered by channel on each side, anterior margin parasulcate. Both valves also ribbed by divaricate costae, lying along longitudinal axis within the sulcus and fold, and diverging forward and outward over the lateral shell from along the sulcal and fold margins. Dental plates short, teeth small. Septalium broad and extending forward for at least a quarter of the length of the dorsal valve, lying close to floor of the valve and bearing an upright crural base on each side. The cardinal process is small and non-laminate, with a low median ridge, between a broad oval depression to each side.

Type species: *Grebneffia divaricata* n. sp., here designated.

Discussion: This genus is distinguished by its distinctive transverse outline, less elongate than most other members of Dielasmidae (Dielasmatidae), with sulcus defined by sharply raised ridges diverging anteriorly, the ridges opposed to grooves along the outer edges of the fold in the dorsal valve, and the shell is parasulcate. The surface of both valves is crossed by divaricate ribs, which branch and diverge from the ridges bordering the ventral sulcus and from the grooves bordering the dorsal fold. No exactly comparable arrangement of sulcus and fold, and divaricate ornament where coupled with internal structures is known to us amongst other Dielasmidae, although several suggest a general approach.

One example is provided by members of the genus *Gilledia* Stehli, 1961, common in Permian faunas of east Australia. *G. homevalensis* Campbell, 1965 from the Early Permian Tiverton Formation of Bowen Basin, Queensland, has ornament of fine furrows, described by Campbell (1965, p. 75) as straight medianly, and outwardly concave laterally (see Campbell 1965, pl. 1, fig. 14, 16, 20). *Gilledia* has different overall shape from *Grebneffia*, and internally, the dorsal margin of the inner hinge plates rest on the floor of the valve. The genus was classed in Gillediinae Campbell, Family Gillediidae Campbell, by Campbell (1965), as followed by Jin et al. (2006), whereas Stehli (1965) classed the genus in Heterelasminidae Likharev, 1956, which it somewhat approaches internally. Waterhouse & Piyasin (1970) placed *Gilledia* in Gillediinae Campbell, Family Heterelasminidae Likharev. The closely allied genus *Paragilledia* Waterhouse in Shi et al. (2020), widespread in the Kungurian and Middle Permian of east Australia, has a ventral sulcus bearing a median fold and lateral fold, and the dorsal valve bears a median fold with one or more pairs of lateral folds, so that there is some degree of similarity of overall shape, but there are no ribs, and the interior is like that of *Gilledia,* as exemplified by the type species *P. ulladullaensis* (Campbell, 1965, pl. 7, fig. 1-23, pl. 15, fig. 8-11, text-fig. 33, 34).

Another externally somewhat similar species from east Australia was described as *Fletcherithyris parkesi* by Campbell (1965, p. 43, pl. 8, fig. 1-23, text-fig. 16). This species has a median ventral fold within a sulcus, and dorsal median sulcus varyingly defined by bordering ridges. There are no ribs, and the interior is typically like that of *Fletcherithyris* Campbell, 1965, with high dorsal median septum.

Superfamily Dielasmoidea Schuchert, 1913
Family Dielasmidae Schuchert, 1913
  Subfamily Dielasminae Schuchert, 1913
    Tribe Dielasmini Schuchert, 1913
    Tribe Plectelasmini Waterhouse, 2010
    Tribe Fletcherithyrini Waterhouse, 2010
    Tribe Hoskingini Waterhouse, 2010
  Subfamily Centronelloideinae Stehli, 1965
  Subfamily Nucleatulinae Muir-Wood, 1965

Table 1. Classification of Dielasmidae (= “Dielasmatidae”) Schuchert, after Waterhouse (2015a, Table 21, p. 220).

Another genus which rarely shows a slight approach to the ornament of this new genus is *Dielasma. D. pictile* Cooper & Grant (1976, pl. 751, fig. 23-46) shows colour bands on the dorsal and ventral valves which are straight medianly, and curve concave outwards to the sides. *Dielasma* King, 1859 has dental plates, pedicle collar in the ventral valve, and well formed septalium in the dorsal valve which is either sessile or supported on a very low median septum, much as in the present form. King (1850, pl. 6, fig. 30-45) illustrated a range of shapes for *Dielasma elongatum* (Schlotheim) that include comparatively transverse individuals. As Cooper & Grant (1976, p. 2861) recorded, the septalium of *Dielasma* varies: generally the inner hinge plates are fused with the floor of the valve anteriorly, and may be divided by a low ridge. *Dielasma* comes close internally to the new form. Other genera have a similar interior. *Amygdalocosta* Waterhouse, 1967 has anterior short plicae, *Dielasmina* Waagen, 1882 has numerous anterior plicae, median dorsal septum, and dorsal valve geniculated near mid-length, *Whitspakia* Stehli, 1964 is sulciplicate and close to *Dielasma*, and *Yochelsonia* Stehli, 1961 is distinguished by its pronounced dorsal sulcus and median fold with sulcus each side in the ventral valve. *Hoskingia* Campbell, 1965 usually displays subtriangular shape and outer hinge plates resting on the floor of the dorsal valve. These genera are all relatively close internally to each other and the new genus, and generally differ from each other in external detail, involving sulcus, plicae and outline. They are comparatively smooth, and none comprehensively approach the new form in overall external shape, sulcation, or ribbing.

In summary, this genus is distinguished by its external appearance, with the sulcus bordered by plicae, and the fold bordered by channels, and both valves also ornamented by well developed divaricate costae. No member of Dielasmidae comes close, though a very few genera have ribs or anterior narrow plicae, such as *Dielasmina* Waagen, 1882 and *Amygdalocosta* Waterhouse, 1967. Internally the structure of the present genus is comparatively normal for the subfamily Dielasminae, with well formed if small dental plates, and a large sessile septalium.

Grebneffia divaricata n. gen., n. sp.

Fig. 1, 2

Derivation: divarico – spread asunder, Lat.

Holotype: BR 3454 from GS 15517, x2.

Diagnosis: As for genus. Only one specimen is so far known for the genus, but it is an outstanding specimen.

Holotype: BR 3454 from McLean Peaks Formation (Baigendzinian), Fig. 1, 2, here designated.

Dimensions in mm:

Width	Length Ventral	Length Dorsal	Height both	Height ventral	Height dorsal
28	27	22	15	9	11

Description: Shells small-medium in size, biconvex, pedicle well developed with collar, epithyrid. Ventral umbonal walls weakly concave in outline and diverge at 90°, continuing into well rounded lateral extremities, with maximum width placed just behind mid-length. The dorsal valve is slightly higher than the ventral valve near mid-length, and anteriorly the dorsal valve curves ventrally to occupy the ventral sulcus, the anterior margin displaying a modified parasulcate commissure, and the lateral commissure is sinoidal. The sulcus is enclosed by an angle of 13-14°, and bordered each side by a strong plication with narrowly rounded crest.

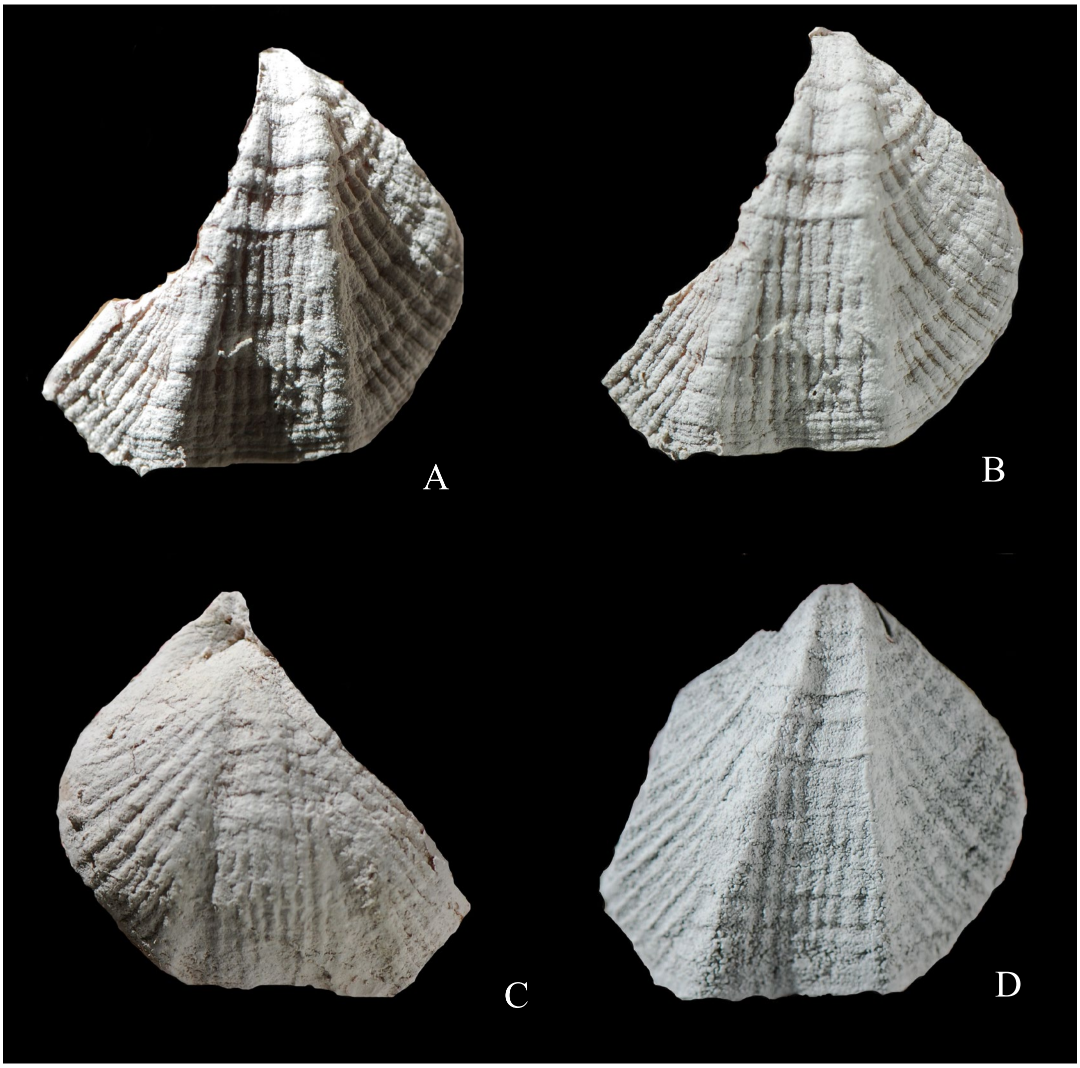

Fig. 1. *Grebneffia divaricata* n. gen., n. sp. A, B, ventral aspects of external cast under different lighting. C, dorsal aspect of external cast. D, ventral aspect of internal mould. BR 3454.

These structures are opposed on the dorsal valve by a broad gently rounded fold commencing at the dorsal umbo, and the fold is bordered each side by a well formed but shallow and narrow channel, the channels commencing a little in front of the umbo, and diverging at 25°. As well, the surface of both valves is diversified by firm ribs with well-rounded crests. The posterior sulcus bears only two ribs, compared with eight near the

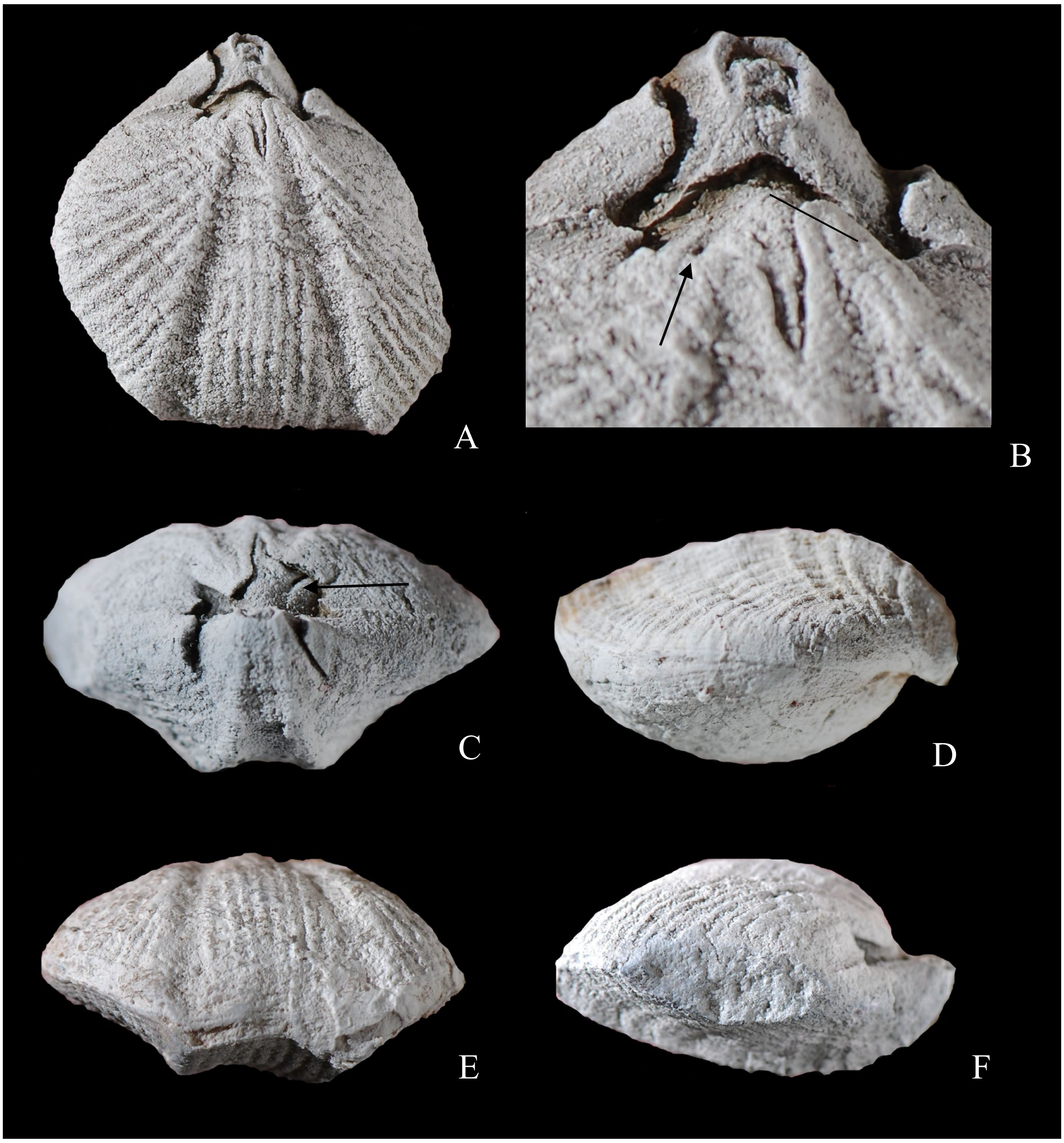

Fig. 2. *Grebneffia divaricata* n. gen., n. sp., internal mould of holotype, BR 3454. A, B, dorsal aspect, B showing posterior detail, x2, x4. Arrow points to crural base. Single line indicates mould of cardinal process. C, posterior aspect, dorsal valve on top, x2. Arrow points to crural base. D, F, lateral aspects, dorsal valve below in D and on top in F, x2. E, anterior aspect, dorsal valve on top, x2.

anterior margin, and the ventral ribs originate from the crest of the plicae bordering the sulcus. The lateral ventral valve is ornamented by similar ribbing, which commences at the crest of the plicae bordering the sulcus. The ribs diverge laterally forward, numbering some four in 5mm, and anteriorly, a few ribs increase by intercalation towards the commissure and fine ribs lie over the surface of some of the larger ribs. Dorsal ornament is similar. Some eight ribs lie anteriorly over the fold, and the number is reduced posteriorly, though the actual number is obscure. Both the ribs over the median fold and over the lateral shell commence within each of the channels that border the fold.

The dental plates are only 5mm long, diverge forward, and are bow-shaped in section, diverging more widely in front. Teeth are short, and dental sockets small. The cardinal process is small, with a low median ridge and subrounded depression each side. There is a large and broad septalium, resting on the floor of the dorsal valve as far as can be seen: if there was a median septum it must have been very low, and no trace is preserved. Narrow high crural supports lie moderately close to the lateral margins of the septalium, and signify that the loop is likely to be intact. The inner and outer surface of both valves show fine dense punctae, whereas the septalium has a smooth surface.

Resemblances: This taxon is readily distinguished by the external features, with unusual ventral sulcus bordered by narrow plicae, and median fold bordered by grooves, as well as well-formed ribs. No upper Paleozoic genus is known to be comparable. Internally, the species is close in structure to that of members of Dielasmini, in having dental plates and a broad well-formed and sessile septalium. No other genus within Dielasminae from the Permian faunas of New Zealand or east Australia is similar, because these genera and species have a high and well-formed medium septum, typical of Fletcherithyrini. The present species and genus is highly distinctive, but the lack of information about the loop means that family relationships needs consolidation.

The closest genus externally is *Tegulithyris* Buckman, 1918, a Middle Jurassic genus based on *Terebratula bentleyi* Davidson (1851, p. 58, pl. 13, fig. 9, 10) from Callovian deposits of Northamptonshire, England (see Fig. 3 herein). *T. bentleyi* has a sulcus that is angular in profile, with bordering plicae, and the narrow dorsal fold is bordered by two broad sulci. There are no ribs. Internally the cardinal process is bilobed. Davidson (1851, pl. 13, fig. 12-15) also figured a lightly ribbed terebratulid as *Terebratula coarctata* Phillips from the Great Oolite of Bath, England, that is particularly close in external appearance (Fig. 4), displaying for one specimen a ventral sulcus bordered by plicae, and a dorsal fold bordered by a channel on each side. Surface ornament also involves fine costellae. The interior as figured by Davidson (1851, pl. 13, fig. 13) shows the dorsal interior typical of *Tegulithyris*. The type species of *Tegulithyris* was examined by Cooper (1983, p. 159, pl. 30, fig. 1-9, pl. 69, fig. 10, 11), and several figures provided of the dorsal interior (Fig. 5). It is clear that the interior of the present genus differs considerably, with much larger septalium extending laterally and forward, and in possessing dental plates that are not developed in *Tegulithyris*. *Tegulithyris* is classed as Tegulithyridae Muir-Wood, 1965, placed in turn in Loboidothyroidea (Loboidothyrididoidea) Makridin, 1964, as reviewed by Lee, Smirnova & Dagys (2006). Members of Loboidothyroidea lack dental plates and have well developed crural plates but inner hinge plates are rarely developed, and the loop is deltiform and usually long flanged. The superfamily ranges from Triassic into the Lower Cretaceous. So the present genus is

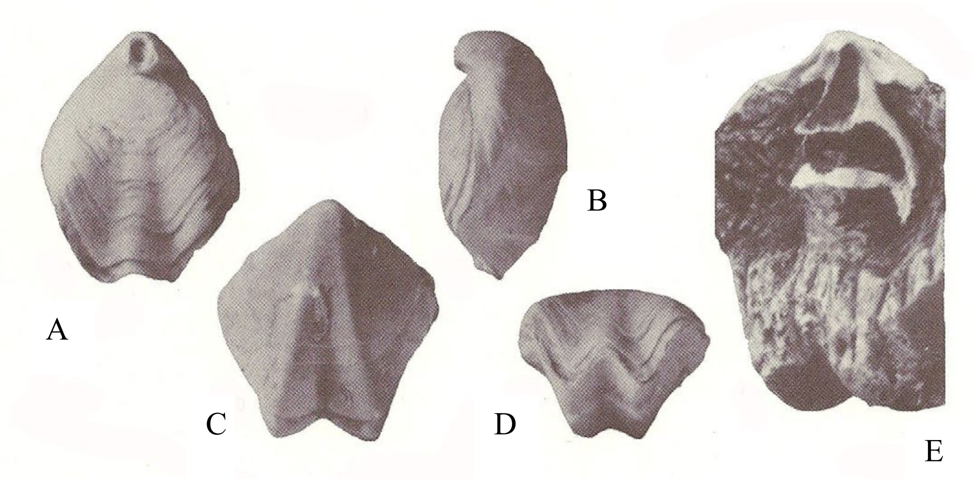

Fig. 3. *Tegulithyris bentleyi* (Davidson). A-D , dorsal, lateral, ventral and anterior aspects (dorsal valve on top in D), x1. E, dorsal interior, x2. As presented in Lee et al. (2006), from Cooper (1983).

externally similar to a considerable degree, but differs markedly in its internal structures, having dental plates and very well developed inner hinge plates.

The nature of the brachial loop is not known for the present form. It is apparently preserved in the present specimen, but we are reluctant to section the specimen, believing that procedures are now available to determine the internal features by x-ray, as was demonstrated by Lee et al. (2016), so that it is feasible to hope that the loop can be determined in future, whilst leaving the specimen intact. Whatever the nature of the loop, the present form is internally readily distinguished from *Tegulithyris* and its ally *Prototegulithyris* Almeras, Elmi & Benshill, 1988.

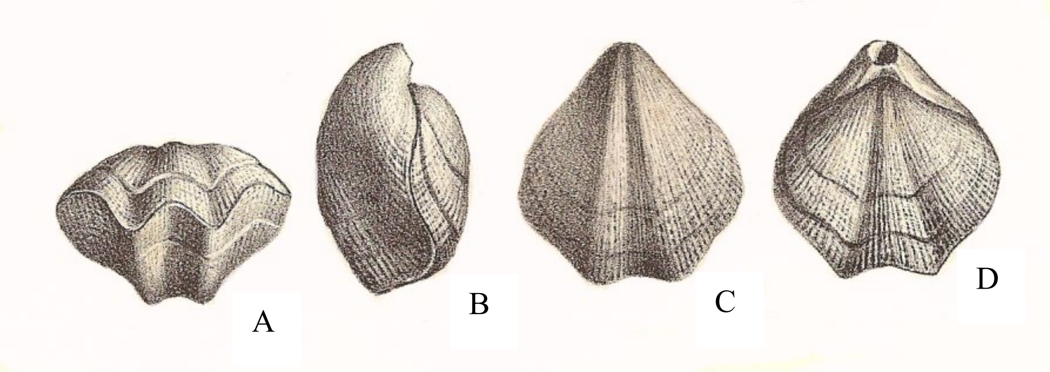

Fig. 4. *Terebratula coarctata* Parkinson, as figured by Davidson (1851, pl. 13, fig. 12). A-D, anterior (dorsal view on top), lateral, ventral and dorsal aspects, from Great Oolite of Bath, England.

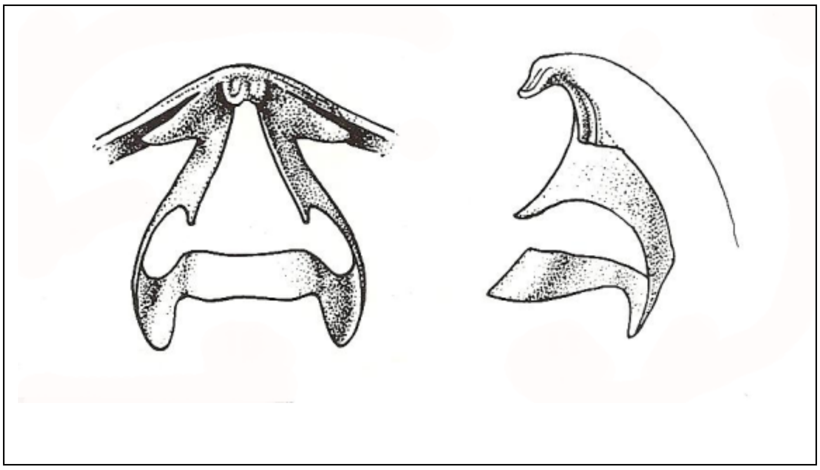

Fig. 5. *Tegulithyris* loop drawing provided by Cooper (1983, pl. 69, fig. 10, 11), x2.

AGE

The McLean Peaks Formation has yielded scattered faunas from throughout the Takitimu Range, assembled as the *Echinalosia conata* Zone (Waterhouse 2001, 2002, 2008, 2021). Prominent species include brachiopods *Echinalosia conata* Waterhouse, *Attenuatella altilis* Waterhouse, *Arcullina humilis* Waterhouse, and the gastropod *Spirovallum fasciatum* Waterhouse. The faunal assemblage is not that typical for most of the New Zealand biozones, because *Arcullina* is otherwise not known in New Zealand, and *Spirovallum* is rare: the present taxon helps to reinforce the unusual nature of the faunal assemblage.

The age of the *Echinalosia conata* Zone is discussed by Waterhouse (2002, 2008, 2021c), and shown as upper Baigendzinian (= upper Artinskian) of the Early Permian Cisuralian Series. The new genus adds nothing to age parameters.

ACKNOWLEDGMENTS

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Earthwise 18: 79-122. October 2021.

3. A FOSSILIFEROUS PERMIAN BOULDER FROM STEPHENS ISLAND, NEW ZEALAND

J. B. Waterhouse

Abstract

The brachiopod faunule recorded from a boulder on Stephens Island by Campbell et al. (1984) is reassessed from published figures. It is confirmed that the species *solitus* is present, and is to be classed as *Anidanthus*. Reassessments of other brachiopod identifications help to confirm a Kungurian or late Early Permian age, close to the age forwarded by Briggs in Briggs & Campbell (1993) rather than the Late Permian age preferred in Campbell et al. (1984). The boulder was sourced from the Queens Beach Member, which with other members is upgraded to formational status. The stratigraphy is discussed for the rocks described and mapped as Stephens Formation in Waterhouse (1964a), with support provided for stratigraphic subdivision. Following these assessments, the Stephens Group from which the boulder came is firmly recognized as being of Triassic age, and this group is placed above the Goat Hill Group of east Nelson, Permian in age, upgraded from a subgroup of Waterhouse (1987b). Both groups were, it is suggested, emplaced by sliding from the nearby Brook Street volcanic arc onto the Ladinian and Anisian-Scythian (Middle and Lower Triassic) Waiua and Greville Formations of the Maitai Supergroup, which accumulated in a trough seawards of the arc. The Brook Street volcanic arc was always close to the Maitai depocentre, and never separated by any great distance.

INTRODUCTION

This article looks at the brachiopod fauna reported at Stephens Island in the Queensland Beach Member of Campbell et al. (1984), within what was called the Stephens Formation by Waterhouse (1964a), the spelling of the name corrected from Wellman (1957). Thanks to illustrations of two Productida provided by Briggs & Campbell (1993), it is possible to add information on the affinities of those two taxa, and the identity for some of the remaining taxa may be at least partly circumscribed, to reinforce the analysis that the fauna was derived from a source close in age to that of the Wandrawandian Formation in New South Wales, of likely Kungurian age. Assessment of the article by Briggs & Campbell (1993) and its claims is not a simple matter, because the Stephens Island material used by Briggs & Campbell has never been returned to New Zealand, and may well prove to have been "lost" or "misplaced" (pers. comm., M. Terezow, collection manager and principal technician, GNS).

The stratigraphic unit originally named Stevens (now Stephens) Formation is divided, following and emending Waterhouse (1987b), into two subgroups, upgraded herein to groups, the older one Permian, the younger Triassic, and both are deemed to have been emplaced through mass sliding or nappe-movement from the Brook Street volcanic arc on to the adjoining sediments of the Maitai Supergroup during the Cretaceous Rangitata Orogeny. This understanding is based on the nature and relationships of the sediments, and the fact that at their base the sediments are much older than the Waiua and Greville Formations on which they lie. The interpreted implication for "terrane histories" is also elaborated, with the suggestion that major facies or domains are involved for the Permian rocks of east Nelson, rather than terranes composed of rocks that originally accumulated far from each other. The claim that terranes were involved circumvents the original definition of terranes, and is rejected.

SYSTEMATIC DESCRIPTIONS

Suborder LINOPRODUCTIDINA Waterhouse, 2013

Superfamily **PAUCISPINIFEROIDEA** Muir-Wood & Cooper, 1960

Family **ANIDANTHIDAE** Waterhouse, 1968b

Subfamily **ANIDANTHINAE** Waterhouse, 1968b

Fig. 1. *Anidanthus springsurensis* (Booker). A, decorticated interior of topotype dorsal valve figured by Booker (1932, pl. 4, fig. 4). B, decorticated dorsal interior of paratopotype. From Cattle Creek, Springsure, Bowen Basin. Specimens x2. (Waterhouse 1968a).

Diagnosis: Prominent radial ornament, spines limited to ventral valve, forming well defined hinge row and scattered or rare over disc and trail. Dorsal valve bearing prominent commarginal laminae, thickened into a wedge or slender with long trail, ears laterally extended, may be twisted and/or bifid. Dorsal trail short, geniculate.

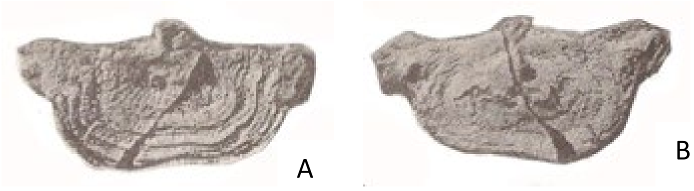

Fig. 2. *Anidanthus springsurensis* (Booker), external and internal latex casts, originally described as *Nothokuvelousia aurifera* Waterhouse, showing dorsal laminae and wedge-shape and short trail, x1. From Roses Pride Formation, Queensland. (Waterhouse 1986a).

***Anidanthus* Booker**

Discussion: Several genera are relevant to deciphering the systematic position of the material from Stephens Island. *Anidanthus* Whitehouse, 1928 is a very distinctive form, characterized by laterally extended dorsal ears, and by an anteriorly thickened dorsal valve in which mutiple trails are fused into a wedge (Fig. 1, 2). The wedge-shaped dorsal valve is clearly figured in the illustrations in Booker (1932, pl. 4, fig. 1, 2, 3) and Waterhouse (1968a, pl. 1, fig. 2, 3). The type species is *Linoproductus* [now *Anidanthus*] *springsurensis* Booker, 1932 as clarified by Hill (1950) from the upper Cattle Creek Formation of lower Artinskian age in the Bowen Basin in Queensland, and this species is also abundant, and with a similar wedge-shaped dorsal valve, in the Roses Pride Formation of the southeast Bowen Basin (Waterhouse 1986a, pl. 14, fig. 13, 16-18) where it was described, wrongly, as a separate species and genus. A further species of Kungurian age, *Anidanthus solitus* (Waterhouse, 1968a) with a wedge-like dorsal valve, is represented in the Branxton Subgroup of the north Sydney Basin (Briggs 1998, Fig. 98; Waterhouse 2013, Fig. 15.20). Specimens from the Belford Dome clearly have a wedge-shaped dorsal valve. But the specimens figured by Briggs (1998) were never deposited in the Australian Museum as claimed in his Association of Australasian Palaeontologists publication, nor returned to the Queensland Museum where they belonged. They have disappeared, and their whereabouts not known. Briggs has abandoned geology and as far as is known, has never provided any information on their location.

Anidanthia Waterhouse

Another genus *Anidanthia* Waterhouse 2013, is based on *Anidanthus paucicostatus* Waterhouse, 1986a from the Elvinia Formation (Sakmarian) of the southeast Bowen Basin in Queensland. This species and genus consistently lacks the wedge-shaped dorsal valve of *Anidanthus*, and has a long slim trail (Fig. 3) instead of a short thick trail. It is not always easy to interpret figures of the two genera, because both have a similar dorsal disc that is encircled by a sturdy marginal ridge, and because the external disc is ornamented as a rule by well developed laminae. It is the length of the trail that is judged to provide the crucial difference between the two, consistently long and slender in well-preserved *Anidanthia*, very short and thick in *Anidanthus*. The dorsal ears of some *Anidanthia* bear moderately well defined ribs, whereas those of at least some mature *Anidanthus* are smooth, though that aspect appears to have been variable and the ears extend laterally, and are never twisted in either genus. The species *Anidanthus cessnockensis* Briggs, 1998 from the Farley Formation of the north Sydney Basin, New South Wales, seems likely to be a junior synonym of *Anidanthia paucicostatus*, as analyzed in Waterhouse (2013, p. 331), and also lacks the wedge-shaped dorsal valve. A few specimens from higher beds of the Wandrawandian Formation were described as *Megousia crenulata* Briggs, 1998. No specimens have a wedge-

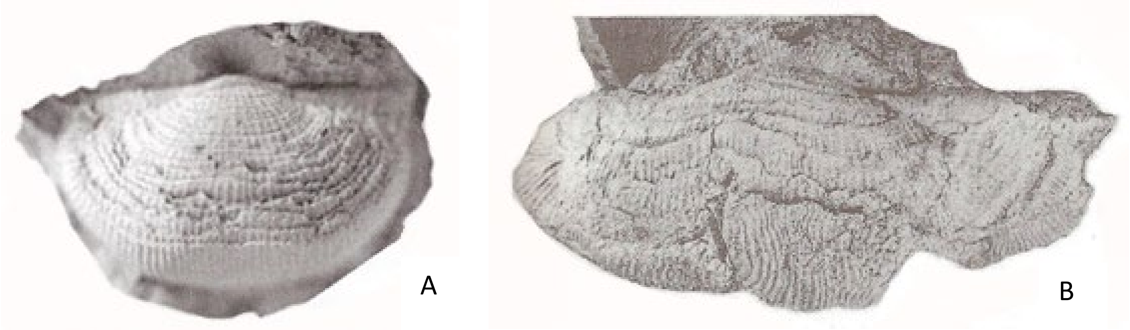

Fig. 3. A, *Anidanthia paucicostata* (Waterhouse), dorsal external mould from lower Tiverton Formation, Queensland, x2. (Waterhouse 2015a). B, *A. cessnockensis* (Briggs), dorsal external mould x2. (Briggs 1998). This species appears to the same as *paucicostata*. Both figured dorsal valves show long trails and the dorsal valve is not thickened and wedge-shaped.

shaped dorsal valve, and the concavity of the dorsal valve and the slender anterior trail suggests *Anidanthia*. The form has feebly costate non-bifid and laterally extended untwisted dorsal ears. This is one of the many species named by Briggs (1998) that is based on specimens which have now disappeared, so that its viability is under a cloud, and the occurrences need verification. The younger species *Anidanthia aplini* Waterhouse & Balfe occurs in the South Curra Limestone at Gympie (Waterhouse 2015b) and lacks the wedge-shaped dorsal valve and the dorsal ears carry ribs. The non-Briggs material is safely ensconsed at the Queensland Museum in Brisbane.

Megousia Muir-Wood & Cooper

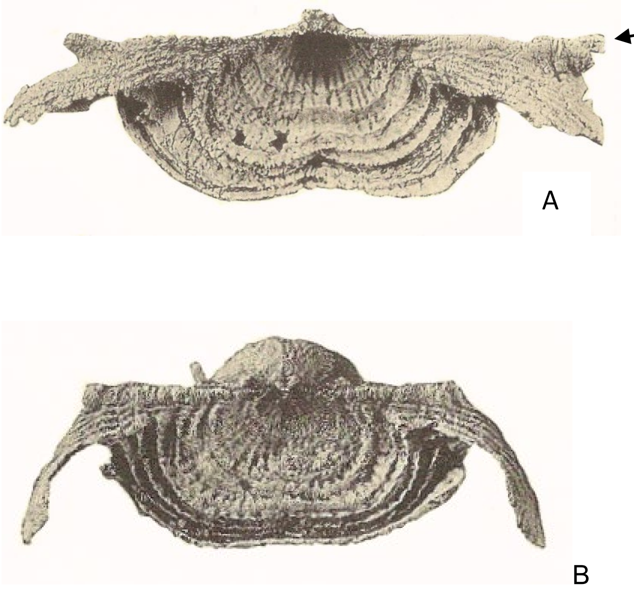

Fig. 4. *Megousia auriculata* Muir-Wood & Cooper. A, dorsal aspect of small paratype, x3, with arrow pointing to small posterior ear, giving a bifid appearance. B, dorsal aspect of mature specimen, holotype, showing slender trail, x3. Wordian of Texas. (Muir-Wood & Cooper 1960).

Anidanthia is like *Megousia* Muir-Wood & Cooper, 1960 in having laterally extended dorsal ears and a moderately long slender trail. The dorsal ears in *Anidanthia* extend laterally, and rarely forwards. In *Megousia*, the large dorsal ears in many specimens show a forward twist, as displayed in the Glass Mountains species described by Cooper & Grant (1975) as *auriculata, definita, flexuosa*, and *mucronata.* In addition, the dorsal ears are normally bifid, with a small posterior protuberance (Fig. 4) and the dorsal valve is never thickened into a wedge shape. The generic position of species *girtyi* (King) is uncertain due to incomplete preservation, and could even belong to *Protoanidanthus* Waterhouse, 1986a, and *waagenianus* Girty from the Capitanian Stage looks close to *Fusiproductus*

Waterhouse, 1966, named for extremely transverse shells with tapered cardinal extremities. An additional distinction for *Megousia*, noted by Brunton et al. (2000, p. 531), is that the dorsal ears bear ribs which curve anterodorsally, whereas the external dorsal ears in *Anidanthus* tend to be smooth.

***Kuvelousia* Waterhouse**

Kuvelousia Waterhouse, 1968a is the northern hemisphere equivalent of *Anidanthus* in that the dorsal valve is wedge-shaped and the dorsal ears laterally extended and are not bifid. Unlike Australian species, the hinge is denticulate. The Canadian species assigned to *Kuvelousia* include the type species *K. sphiva* (Fig. 5) of Middle Permian age and other species, including a number from northeast Russia.

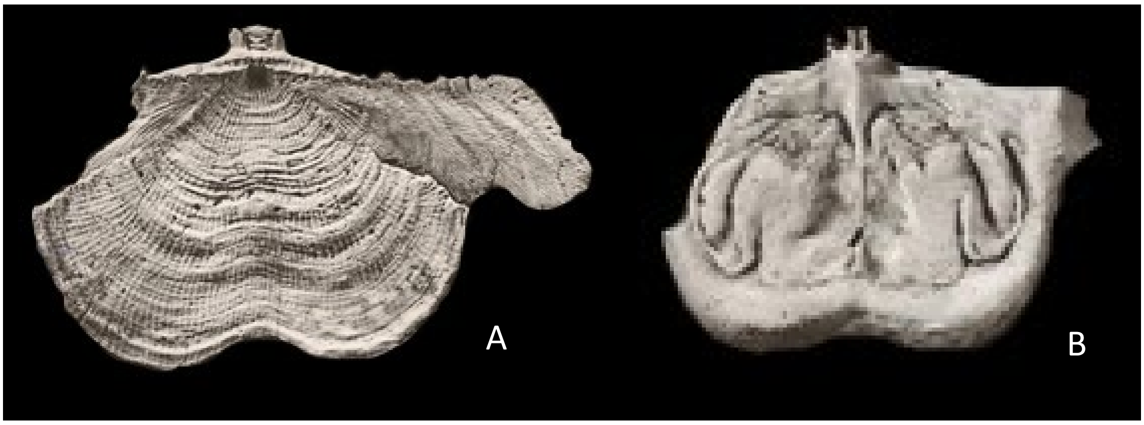

Fig. 5. *Kuvelousia sphiva* Waterhouse. A, dorsal exterior showing denticulate hinge and laterally extended auricle. B, dorsal interior with broken ear, showing wedge-shape. Specimens x2, from Trold Fiord Formation, Canadian Arctic. (Waterhouse 2013).

***"Kuvelousia" leptosa* Waterhouse (= n. gen.)**

A separate stream involves the Oregon species *leptosa* Waterhouse (Fig. 6), assigned to *Kuvelousia* by Waterhouse (1968b), but distinguished from that genus by its bifid though untwisted dorsal ears, which suggests that the species is more closely related to *Megousia*, and distinguished from *Megousia* by its wedge-shaped dorsal valve with short trail and strongly denticulate hinge.

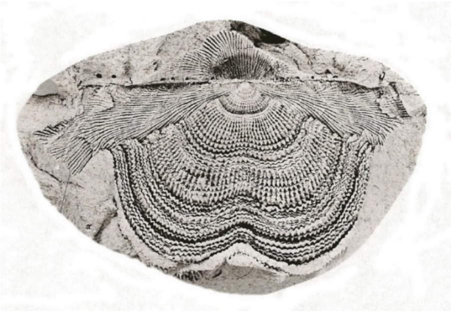

Fig. 6. "*Kuvelousia*" *leptosa* Waterhouse, dorsal external mould and posterior part of ventral valve with row of hinge spines, left as holes. USNM 151591j, holotype, x1. From Canyon Butte Formation (Sakmarian), Oregon, United States. (Waterhouse 1968b).

Which genus at Stephens Island?

So which genus is represented at Stephens Island? Surely not *Megousia* nor *Bifidauria*, because the dorsal ears are not bifid, and do not twist forwards as in *Megousia*. Some of the original figures are unquestionably *Anidanthus,* because the dorsal valve is wedge-shaped, and there appear to be no ribs over the ears. Other figures provided for so-called *Megousia solita* are a little ambiguous, conceivably suggesting *Anidanthia* (Briggs & Campbell 1993, Fig. 2.1-3, 8), although this is far from established, and none of the specimens definitely indicates a long trail. Nor do they have a denticulate hinge.

Anidanthus solitus (Waterhouse, 1968a)

Fig. 7 - 10

1968b *Megousia solita* Waterhouse, p. 1172, pl. 154, fig. 1-6, 8-10.

1984 *Anidanthus* sp. Campbell et al., Fig. 6.11-13.

1987b *Anidanthus* Waterhouse, p. 533.

1993 *Megousia solita* – Briggs & Campbell, p. 326, Fig. 3.1-10.

1998 *M. solita* – Briggs, p. 207, Fig. 98A-I.

2013 *Anidanthus perdosus* Waterhouse, p. 328, Fig. 15.10A-C.

Diagnosis: Transverse shells with large dorsal ears at maturity that extend forward close to the visceral disc, dorsal valve wedge-shaped without extended trail.

Holotype: ANU 17752 figured by Waterhouse (1968a, pl. 154, fig. 1, 9) and herein as Fig. 10A, B from lower Wandrawandian Formation, south Sydney Basin. For *perdosus*, UQF75365 figured by Briggs (1998, Fig. F-H) and repeated by Waterhouse (2013, Fig. 15.20A-C), and herein (Fig. 7), OD.

Resemblances: The shells described as *Megousia solita* Waterhouse (1968a, p. 1172, pl. 154, fig. 1-

6, 8-10) from the Wandrawandian Formation of the south Sydney Basin are close to the dorsal external moulds from Stephens Island in the development of moderately prominent commarginal laminae and in the presence of a low fold. Ribbing is possibly coarser than in specimens from Stephens Island, at eight or nine in 5mm, but costal counts were not provided by Briggs & Campbell. Dorsal ears in the Australian specimens are much larger, and tend to be sharply distinguished from the inner shell, being more dorsally placed (Fig. 10), but this may be explained by the differences in size and probably maturity of the specimens concerned. There is a closer approach to what was called *Anidanthus perdosus* Waterhouse 2013, p. 328, Fig. 15.20; Briggs 1998, p. 207, Fig. 98F-I from the Belford Dome band of the Branxton Subgroup in the north Sydney Basin. Specimens so named are clearly *Anidanthus*, and so approach the dorsal valve of *Anidanthus* figured from Stephens Island by Briggs & Campbell (1993, Fig. 3. 9, 10). That is why the Stephens Island specimens were referred to *A. perdosus* by Waterhouse (2013). But there must be reservations over the validity of any separation from *solitus*, given the ambiguity over the wedge-shape or otherwise of the dorsal valve and the length of its trail in the types. What is clear is that the generic assignment of the specimens from Stephens Island in Briggs & Campbell (1993) with *Megousia* may be firmly set aside, given the different orientation of the dorsal ears and their non-bifid nature.

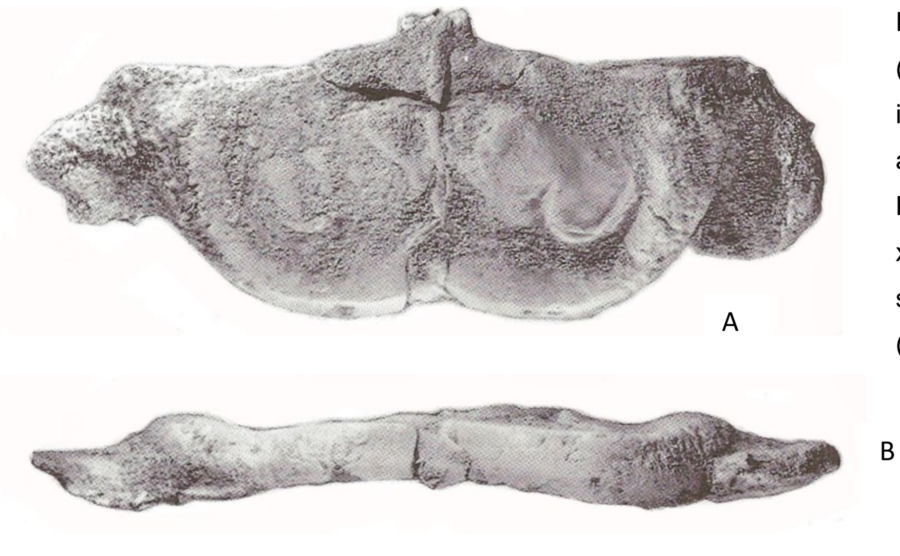

Fig. 7. *Anidanthus solitus* (Waterhouse), dorsal internal and anterior aspects, from Belford Dome, New South Wales, x2. Note the short trail shown in Fig. 8 herein. (Briggs 1998),

The figures in Waterhouse (1986a, p. 63, pl. 14, fig. 3,10-19) described as "*Nothokuvelousia aurifera*" from the Roses Pride Formation and now synonymized with *Anidanthus springsurensis* make it clear that although external moulds of dorsal moulds bear laminae, like those of the specimens from Queens Beach and Belford Dome specimens assigned to "*Megousia solita*", shells or latex casts rather than moulds are preferable for demonstrating whether the dorsal valve is wedge-shaped, with a thickened short dorsal trail as in *Anidanthus*, or a slender longer trail, as in *Anidanthia*. That means that their relationship to the poorly known and now lost "*Megousia*" *crenulata* from the upper Wandrawandian Formation remains uncertain. The dorsal valves assigned to *crenulata* by Briggs are transverse and strongly laminate, rather like the external moulds of Queens Beach specimens figured in Briggs & Campbell (1993, Fig. 3.1-3), and the Briggs material has apparently vanished, so there can be no adequate comparison, unless replaced by further topotypes.

Fig. 8. *Anidanthus solitus* (Waterhouse), latex cast of dorsal valve BR 2325 from Stephens Island, x1.5. (Briggs & Campbell 1993). This specimen does not tally with the description of the dorsal interior provided by their text.

The interior of the dorsal valve for the Queens Beach material was described in detail (Briggs & Campbell 1993, p. 327), yet no BR specimen was quoted, and no figures provided, and the published figures do nothing to verify the observations, because the one figured dorsal interior in Briggs & Campbell as reproduced in Fig. 8 shows almost no detail whatsoever. The applicability of the description of the dorsal interior in Briggs & Campbell (1993) to the Queens Beach material therefore seems questionable.

Briggs & Campbell (1993, Fig. 3, fig. 11, 12) compared a specimen from the Caravan Formation at Wairaki Downs, Southland, with *Megousia solita*, and this appears to belong to *Anidanthus*. But the specimen is now lost, a troubling way to treat the material, because fossils in this formation are sparse, and difficult to find.

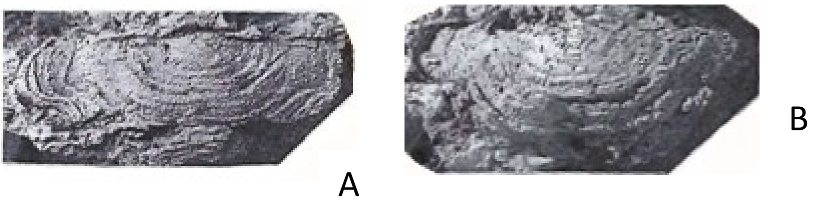

Fig. 9. *Anidanthus solitus* (Waterhouse). A, dorsal external mould, BR 2316. B, dorsal external mould BR 2315. Both from Stephens Island, x1.5. (Briggs & Campbell 1993).

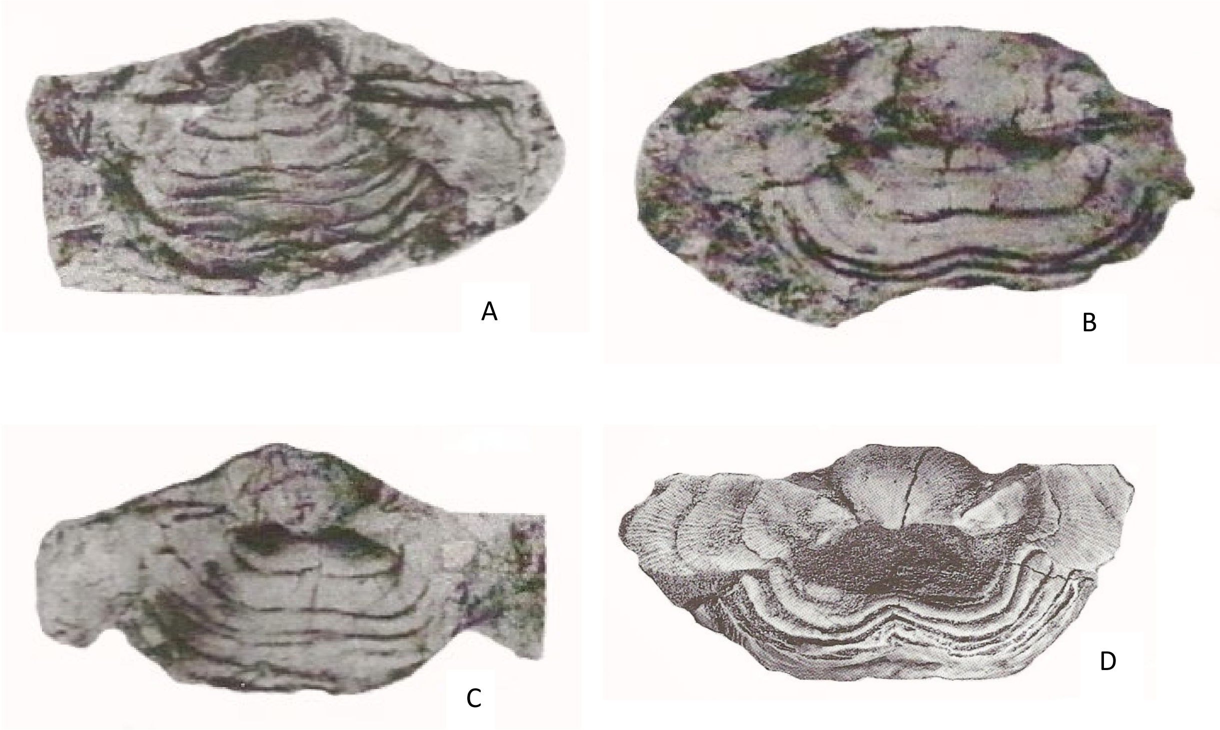

Fig. 10. *Anidanthus solitus* (Waterhouse). A, B, dorsal aspect of external mould and latex cast, holotype ANU 17752, x 1.5. C, dorsal aspect AMF 23986, latex cast of external cast. Specimens from Berrara, New South Wales. (Waterhouse 1968b). D, latex cast of specimen from Belford Dome, x 1.5. (Briggs 1998). The quality of these figures A – C reproduced from the Journal of Paleontology reflects my somewhat flawed copying process, so that reference to the original publication is recommended.

Suborder LINOPRODUCTIDIINA Waterhouse, 2013

.Superfamily **PROBOSCIDELLOIDEA**Muir-Wood & Cooper, 1960

Family **PAUCISPINAURIIDAE** Waterhouse, 1986a

Subfamily **PAUCISPINAURIINAE** Waterhouse, 1986a

Tribe **PAUCISPINAURIINI** Waterhouse, 1986a

Genus ***Terrakea*** Booker, 1930

Diagnosis: Ventral valve with incurved umbo, visceral disc thick, capillae over both valves, ornament distinguished by a cluster of thick erect spines over ventral umbonal slopes and ears, dorsal anterior disc and trail spines also thick. Ventral disc spines with cores prolonged anteriorly into the shell.

Type species: *Productus brachythaerum* Morris (1845, p. 284, pl. 2, fig. 4c) from Gerringong Volcanics, south Sydney Basin (Int. Comm. Zool. Nomen. 486, 1957).

Terrakea exmoorensis Dear, 1971

Fig. 11 - 13

1964 *Terrakea* cf. *fragilis* [not Dana] – Hill & Woods, pl. P5, fig. 9-10.

1971 *Terrakea elongata exmoorensis* Dear, p. 18, pl. 5, fig. 3-5.

1972 *T. elongata exmoorensis* – Hill et al., pl. P5, fig. 9, 10.

?1982a *Terrakea* sp. Waterhouse, p. 48, pl. 10h, j.

1983 *T. elongata exmoorensis* – Waterhouse & Jell, p. 242, pl. 1, fig. 10.

1983 *T. brachythaera* [not Morris] – Waterhouse & Jell, p. 242, pl. 1, fig. 9, 11-18, pl. 2, fig. 1.

1984 *Terrakea* sp. Campbell et al., Fig. 6.3, 4.

1993 *Terrakea* sp. Briggs & Campbell, p. 328, Fig. 3.13-19.

?1993 ?*Terrakea* sp. Briggs & Campbell, Fig. 3.11, 12.

?1998 *T. rhylstonensis* Briggs, p. 168, Fig. 83A-H.

1998 *T. exmoorensis* – Briggs, p. 179.

2001 *T. exmoorensis* – Waterhouse, p. 42, pl. 1, fig. 16, 17, text-fig. 5c.

Diagnosis: Subelongate, subquadrate or slightly elongate shells with numerous erect spines over ventral ears and adjoining umbonal and posterior lateral slopes, body spines of moderate strength and number, closely spaced, spine bases short, dorsal valve may be dimpled, dorsal spines fine and erect, moderately coarse and well spaced over trail.

Holotype: GSQF 5537 figured by Dear (1971, pl. 5, fig. 3), Hill & Woods (1964, pl. P5, fig. 9, 10) and Hill et al. (1972) from lower Blenheim beds, north Bowen Basin, Queensland, OD. Holotype for *rhylstonensis*, AMF 45480, figured by Briggs (1998, Fig. 83C) from Snapper Point Formation, OD.

Discussion: As noted in Waterhouse (2001, p. 42), *Terrakea rhylstonensis* Briggs (1998, p. 168, Fig. 83) from the Snapper Point Formation of the south Sydney Basin is very difficult to distinguish from *exmoorensis.* It was described in an inadequate diagnosis merged with description by Briggs (1998) that failed to distinguish the species clearly from *exmoorensis.* It would be an advantage to separate the two, because *rhylstonensis* comes from distinctly though only slightly older beds (Waterhouse

2001, p. 44; 2021c). The dorsal trail spines are possibly slightly weaker and the ventral ears possibly slightly larger in *rhylstonensis*, to judge from figures provided by Briggs (1998), but Waterhouse (2001, p. 43) cautioned that the variation and morphological range for many specimens found at the level of *rhylstonensis* had been ignored in the Briggs account.

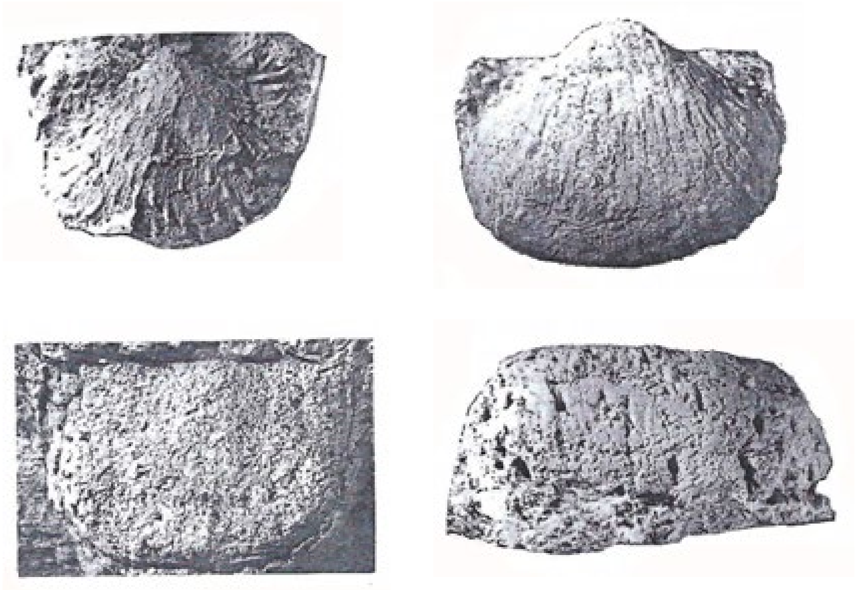

Fig. 11. *Terrakea exmoorensis* Dear. A, latex cast of ventral valve. B, internal mould of ventral valve. C, D, dorsal and anterior aspects of dorsal valve, Specimens x1.5, from Queens Beach Formation. BR numbers were applied, but specimens have now disappeared. (Briggs & Campbell 1993).

General shape, moderately stout and numerous erect spines over the ventral ears (see especially Briggs & Campbell 1993, Fig. 3.14) and strong spines over the dorsal trail suggest that the Queens Beach material should be referred to *Terrakea exmoorensis* Dear. This species comes from the lower Blenheim Formation of the north Bowen Basin (Dear 1971, Waterhouse & Jell 1983) and possibly occurs also in the lower Wandrawandian Formation of the south Sydney Basin (Waterhouse 2002a, p. 178). In New Zealand, similar shells have been reported from the upper Letham Formation (*Echinalosia discinia* Zone) and lower Mangarewa Formation – unit 5 - in the *Pseudostrophalosia blakei* Zone (Waterhouse 2001, p. 43). Related material was figured in Waterhouse (1982a, pl. 10, fig. h, j) from Wairaki Downs in the Caravan Formation, a unit proposed by Landis (1987) and consolidated by Waterhouse (1998b). Waterhouse (2001, pl. 1, fig. 14) showed a moderately

Fig. 12. *Terrakea exmoorensis* Dear, dorsal aspect of internal mould with both valves preserved, UQF 73210 x1.5, from lower Blenheim Formation. (Waterhouse & Jell 1983).

similar specimen. Regrettably, it appears that the 1982 figured material was passed to Briggs, who has failed to return them, whereas plaster moulds expertly prepared by the New Zealand Geological Survey technician Ian Keyes would have sufficed. The need to protect and care for figured material was either not understood, or disregarded. The specimens could well be referable to *exmoorensis*, but also come close to Snapper Point specimens described as *rhylstonensis* Briggs, a taxon in need of clarification. One Caravan specimen examined and figured as ?*Terrakea* sp. in Briggs & Campbell (1993, Fig. 3.11, 12) is less well preserved, and has a very wide hinge. These specimens have since

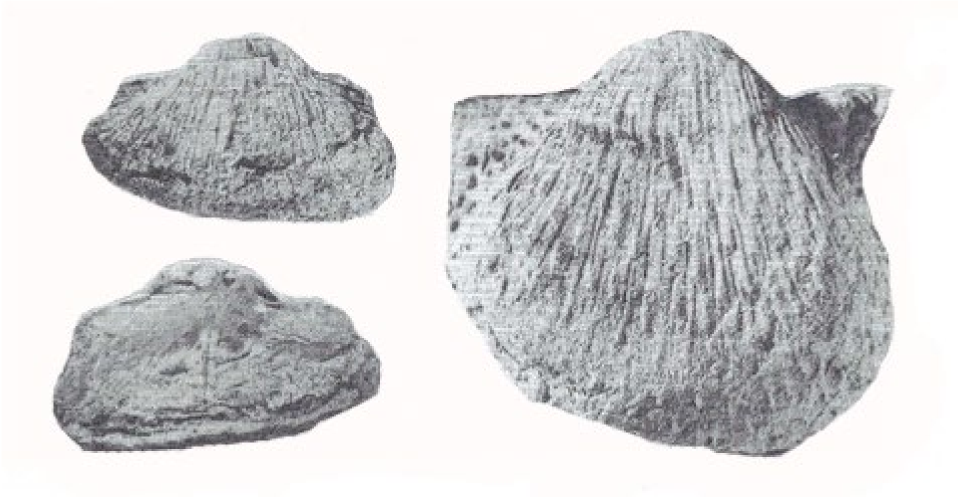

Fig. 12. *Terrakea exmoorensis* Dear. A, B, ventral and dorsal aspects of internal mould, UQF 73207, x1. C, ventral internal mould, UQF 73208, x2. From lower Blenheim Formation. (Waterhouse & Jell 1983).

“disappeared”. Briggs in Briggs & Campbell (1993, p. 329) stated that the Caravan material resembled specimens from the Elderslie Formation of the north Sydney Basin at the University of New England locality L990 and undertook to describe this material elsewhere, but I have not found the description of such material in his 1998 memoir.

FURTHER QUEENS BEACH FOSSILS

The following identifications are based solely on scrutiny of the figures provided in Campbell et al. (1984, Fig. 6), and are no more than provisional. The synonymies are limited for the most part to the reference in Campbell et al. (1984) and a possibly related or identical taxon.

Capillonia aff. ***semicircularis*** (Campbell, 1953

aff. 1953 *Lissochonetes semicircularis* Campbell, p. 6, pl. 1, fig. 10-13.

1984 Chonetidae genus indet. Campbell et al., Fig. 6.5.

aff. 1986a ?*Capillonia semicircularis* – Waterhouse, p. 22, pl. 2, fig. 34, pl. 15, fig. 2, 4.

aff. 1988 *Capillonia semicircularis* – Parfrey, p. 12, pl. 12, fig. 11-13.

Discussion: The shape of an internal mould of a ventral valve figured from the Queens Beach locality resembles that of *Lissochonetes semicircularis* Campbell, 1953, widely reported in the Bowen Basin of Queensland from the lower Peawaddy Formation as well as Barfield Formation (Dear 1971, Waterhouse 1986a, Parfrey 1988) and even lower Flat Top Formation. With only an internal mould of one ventral valve figured, the identification is somewhat conjectural.

Cleiothyridina sp.

1984 *Cleiothyridina* sp. Campbell et al., Fig. 6.9.

Discussion: A dorsal valve from Stephens Island is moderately close to *Cleiothyridina anabathra* Waterhouse, 1968b from the upper Letham Formation of Waitaki Downs, but also comes close in displaying what appears to be a dorsal anterior fold to a species yet to be described from the *Pseudostrophalosia clarkei* and *Marginalosia minima* Zones in the northern Bowen Basin.

Ingelarella ingelarensis Campbell, 1960?

?1960 *Ingelarella ingelarensis* Campbell, p. 1115, pl. 135, fig. 1-3, pl. 138, fig. 4.

?1978 *I. ingelarensis* – McClung, p. 51, pl. 1, fig. 1-3, 5, 12, 17, 24, 26-28, ?10; pl. 2, fig. 16, 17; pl.

10, fig. 16, 17; pl. 11, fig. 1-5.

1984 *Ambikella* aff. *furca* [not Waterhouse] – Campbell et al. Fig. 6.8.

Discussion: An internal mould of the ventral valve shows well-formed moderately spaced adminicula, but few other details. There is considerable similarity within those very narrow limits to *Ingelarella ingelarensis*, a well-known species described widely from east Australia, mostly from the Ingelara Formation and lower Blenheim Formation and Barfield Formation (Waterhouse 1987a) in the Bowen Basin, as well as the Fenestella Shale and Wandrawandian Formation of the south Sydney Basin (McClung 1978) and in Tasmania (Clarke & Banks 1975). In New Zealand the species is restricted to the middle and upper Letham Formation at Wairaki Downs (Waterhouse 1998a). The species has been widely reported from other formations, but reliability is low: however that caution must also be attached to the present suggestion. The lack of the dorsal valve and the small size and incomplete nature of the figured ventral valve means that the specimen cannot be securely distinguished from *Ingelarella subplicata* Waterhouse, 1968b, a species of more restricted range and typical of the upper Letham Formation and middle and upper *Echinalosia discinia* Zone, and also present in the Fenestella Shale of the north Sydney Basin (Waterhouse 2001). The assignment of the Queens Beach specimen to the species *furca* in Campbell et al. (1984) seems speculative: *furca* differs from *ingelarensis* by belonging to a different genus, *Ambikella* Sahni & Svrivatsava, 1956, with rounded dorsal fold, and with strong sulcal subplicae. As is well known, relying on an immature internal mould is never satisfactory, and the exterior and of course the dorsal valve would have been much more informative about the relationships to named species.

Aperispirifer cf. ***lethamensis*** Waterhouse, 1968b

cf. 1968b *Aperispirifer lethamensis* Waterhouse, p. 38, pl. 3, fig. 13, pl. 4, fig. 1-7, pl. 5, fig. 2-4, pl. 6, fig. 3, text-fig. 11-13, 14A-C (part, not pl. 3, fig. 15, pl. 5, fig. 1, 5, 6, pl. 6, fig. 2, text-fig. 11-13, 14D, 15 = *A. parfreyi* Waterhouse).

cf. 1978 *A. lethamensis* – Suggate et al. pl. 4.6, fig. 10-12.

cf. 1981 *A. lethamensis* – Speden, pl. 6, fig. 10-12.

cf. 1982a *A. lethamensis* – Waterhouse, p. 91, text-fig. 29c.

1984 *Aperispirifer* cf. *nelsonensis* [not Waterhouse] – Campbell et al., Fig. 6.1, 2.

cf. 1999b *A. lethamensis* – Waterhouse, p. 13.

cf. 2001 *A. lethamensis* – Waterhouse, p. 93.

Discussion: The likely presence of this species at Stephens Island is supported by two figures in Campbell et al. (1984). One shows a small, probably immature ventral valve with at least three pairs of well-formed plicae and moderately strong costae. The ventral valve and its plicae and costae are moderately similar to specimens of *Aperispirifer lethamensis*, within the limits constrained by preservation. The other figure shows a larger though broken dorsal valve with firm though not outstandingly strong or broad costae and a number of ill-defined plicae. This shows some similarity in the strength of its costae and numerous somewhat persistent plicae with ribs tending to be paired and fasciculate anteriorly to the dorsal valve of *lethamensis* figured by Waterhouse (1968b, pl. 3, fig. 13). The similarities are not conclusive, and a younger species *A. parfreyi* also shows some degree of similarity. The species *lethamensis* is particularly characteristic of the upper Letham Formation and *Echinalosia discinia* Zone in New Zealand, and the species is present in the Fenestella Shale of the north Sydney Basin. The specimens from Stephens Island were compared to *Aperispirifer nelsonensis* by Campbell in Campbell et al. (1984), but this species is more transverse as a rule with better defined sulcus and somewhat stronger more angular-crested costae and stronger plicae. There is little similarity between *nelsonensis* and the material from Stephens Island.

Sulciplica sp.

1984 ?*Notospirifer* sp. Campbell et al., Fig. 6.7.
1987b *Sulciplica* sp. Waterhouse, p. 533.

Discussion: This specimen is small and presumably immature. It is not at all like *Notospirifer*, which belongs to Ingelarelloidea, but may be placed within Trigonotretoidea (see Waterhouse 2021a, p. 31 a).

Further species

Several other taxa are indeterminable even to genus level without more information. The internal dorsal mould of an aulostegid (Campbell et al. 1984, Fig. 6.14) is likely from the regional context to belong to *Megasteges* Waterhouse or some such genus (Waterhouse 1987b, p. 533), and examination of the dorsal external mould, which should have been collected, and hopefully was not passed on to Briggs, will help narrow down the options.

The *Notospirifer* sp. of Campbell et al. (1984, Fig. 6.6) and *N.* aff. *macropustulosus* (Fig. 6.10) need clarification of micro-ornament.

The large external mould assigned to “Terebratulacea” by Campbell et al. (1984, Fig. 6.15) requires more information, though the large size suggests possible *Maorielasma* or *Marinurnula* as named and described in Waterhouse (1964b).

AGE OF THE FAUNULE

Anidanthus solitus indicates placement in or close to the *Echinalosia discinia* macrofaunal Zone of east Australia, and other species as evaluated herein would permit such a correlation with the zone in both New Zealand and east Australia, whilst some of the potential similarities do range higher. The *Echinalosia discinia* Zone is considered to be of Kungurian age (Waterhouse 2021b, p. 229), much the same as the age allocated by Briggs & Campbell (1993), as shown in Table 1.

GEOLOGICAL SETTING

Campbell et al. (1984) concluded that the block from which the collection was sourced was older than the enclosing sediments of the Queens Beach Member, which lay at the base of what they called the Stephens Formation on Stephens Island. They were unsure whether the Stephens Formation was of Permian or Triassic age. It was concluded that the fauna and its boulder were to be correlated with the *Aperispirifer nelsonensis* Zone (now named *Marginalosia planata* Zone), and tentatively matched with the upper Hawtel Formation or Wairaki Breccia at the top of the Permian sequence at Wairaki Downs, Southland. But in their view, that did not establish a late Permian age for the Queens Beach Member, because the source block had been redeposited “perhaps by slumping of a beach or shelf” (Campbell et al. 1984).

Briggs in Briggs & Campbell (1993) drastically lowered the Late Permian age assigned in Campbell et al. (1984), to match the Elderslie and Wandrawandian Formations of the Sydney Basin, which equates to the upper Letham Formation at Wairaki Downs, of Kungurian age, and the present reassessment confirms this assessment and regards the block and its fauna as likely to be of Kungurian age, as shown in Table 1, p. 96. Given that the fossiliferous boulder has been reworked, there is no fossil evidence to indicate the age of the enclosing sediment, but it is deemed likely to be Triassic, through assessment of the regional geology.

Series	Stage	Age of Queens Beach Boulder
Lopingian	Changhsingian	← Campbell et al. 1984
	Wuchiapingian	
Guadalupian	Capitanian	
	Wordian	
	Roadian	
Cisuralian	Kungurian	← Briggs & Campbell 1993
	Baigendzinian	
	Aktastinian	
	Sakmarian	
	Asselian	

Table 1. Showing the revision to the age proposed by Campbell et al. (1984) for the fossils from a boulder in the Queens Beach Member, Stephens Island.

STRATIGRAPHY

The Stephens Formation was briefly proposed – indeed just tabulated – as Stevens Formation by Wellman (1957), without type section or description, and the proposal was elaborated with detail on measured sections, illustrations and summary of fossil content by Waterhouse (1964a), followed by description of the brachiopods in 1964b and 1967. The type section was cited as being at Cape Stephens, D'Urville Island. Even then, the view was expressed that the unit was diverse and variable, and merited upgrading to the level of subgroup.

In 1984 Campbell et al. subdivided the sequence exposed on Stephens Island into four members:

(top) Titapu (or Titapua) Member, 230m thick, well bedded grey sandstone, minor conglomerate and green sandstone.

Takapourewa Member: 430m thick of sandstone, minor conglomerate, including volcanic material.

Incline Member: 300m well bedded grey sandstone and mudstone, some more massive beds.

Queens Beach Member: 35m thick, conglomerate and massive and well-bedded volcanogenic sandstone.

In my view the members should be upgraded to formational status, which would match the treatment of corresponding units described from south of the Alpine Fault by Landis (1974) and Aitchison et al. (1988). They were retained as members by Johnston (1996) but were not even shown in his map, and were nowhere shown anywhere to the south in his other 1:50 000 maps. These maps, as far as the Stephens Formation is concerned, seem more suitable for publishing at a scale of 1:250 000, given the lack of detail and the predominance of contours and other topographic information over geological information, so that it is hardly surprizing that members or constituent major lithological divisions were not or could not be mapped. That may well have reflected on the time made available for the task at hand, and the instructions under which which Dr Johnston was working, not that I know, but it does seem possible that the limitations of his mapping were a reflection of imposed institutional limits, reflective in turn of financial constraints imposed by government.

The type and measured section for the members on Stephens Island passed along tracks near the middle of the rugged island, which meant that rocks were somewhat weathered, and coloration unreliable. Far superior outcrops are available along the waters' edge, but the island is surrounded by high cliffs and stormy waters (see Johnston 1996, Fig. 13), not ideal for close study unless the geologists are patient and skilled rock climbers. The same is true of nearby Cape Stephens at the northeast tip of D'Urville Island, which has even more formidable cliffs, so that the persistence of the rock units into the nearby cape is insecure. Islands west of D'Urville Island such as Victory Island (Waterhouse 1964a, Fig. 34) show massive sandstone yet to be firmly correlated:

World Stage Age	Fauna	New Zealand		
		Supergroup	Group	Formation and Fossils
Middle Triassic		Te Mokai	Stephens (emend)	Big Creek
	Paranorites			Mead Bridge
Smithian, Dienerian (Early Triassic) Scythian				Shaggery
Upper Changhsingian (Permian)				faunal gap
	Marginalosia planata Z		Goat Hill	Pig Valley
				Holland Farm
Ladinian		Port Hardy		Waiua
Anisian (mid Triassic) (Early Triassic) Scythian	*Durvilleoceras wordmani* *Stenopopanoceras*		Greville	South Arm
				Washley
				Wells Arm
Changhsingian (Late Permian)	*Spinomartinia spinosa*	Boundary Creek		Little Ben
	Echinalosia denmeadi			Tramway
Wuchiapingian (Late Permiam)		Wooded Peak		Malita
				Roding
				Sclanders

Table 2. The stratigraphic sequence from east (at base) to west (at top) of formations, subgroups and groups within east Nelson, extending to D'Urville Island, and their faunas and international correlations. The upper Greville and Waiua rocks are Middle Triassic, younger than the overlying Goat Hill Group.

Takapourewa Member or Incline Member on Stephens Island may be suggested. Johnston (1996) pointed out that neither the base nor top of the sedimentary pile had been ascertained, but what appears to be a basal conglomerate for the Queens Beach unit is exposed on the west side of Cape Stephens above the Waiua Formation (Waterhouse 1964a, p. 47, text-fig. 35; Johnston 1996, text-fig. 14, 15; Begg & Johnston 2000, text-fig. 13). This deposit was named the Cape Stephens Conglomerate Member in the Queens Beach Formation by Waterhouse (2002a, p. 139), and its significance is further discussed below on p. 111: it is interpreted as having been tectonically generated.

Further south, in the neighborhood of Lee River south of Nelson City, Waterhouse (1987b) named two formations within the younger rocks previously referred to the Stephens Formation. The Mead Bridge Formation (Table 2), commences with conglomerate up to 75m thick. A section was measured along the north side of the Lee River, through mostly conglomerates and sandstone, followed by thin argillite and sandstone. The section appears to match that of the Queens Beach Formation, but though far more accessible, the named stratigraphic unit does not have seniority. Devitrifed ignimbrite shards were found by Waterhouse & Flood (1981) in the volcaniclastic matrix around the boulders and cobbles. Overlying beds 800m thick were assigned to a Big Creek Formation, with shales and siltstones, as well as thin sandstones, and including white tuffs and red argillite and green sandstone in the upper part of the formation. Distribution details were provided in Waterhouse (1987b, 2002a, p. 140). This formation can be matched to some extent with the Incline and Takapourewa Formations on Stephens Island. Again the Lee River area is far more accessible. Probably its upper outcrops involve sediments younger than those of Stephens Island, given the presence of red beds, which suggest a lateral facies of the Waiua Formation of the upper Port Hardy Group above the Greville Subgroup (Table 2). Arguably these beds deserve recognition as a separate stratigraphic unit, perhaps matching the Snowdon Formation of Landis (1974), as outlined below.

At the base of the Triassic part of the former Stephens Formation in the region of the Lee River and Wairoa River catchments in east Nelson lies the Shaggery Formation (formerly member) of Waterhouse (1987b). This is up to 200m thick, of fine fissile shale and laminites and scattered limestone pebbles and boulders (Waterhouse 2002a, p. 138). The assignment of a Triassic age is based on the very important discovery of early Triassic ammonoids by Owen (1991, 1992, 1995). Although it was stated by Owen that the ammonoids came from the upper part of the large limestone lenses with Permian fossils, examination of several of the recorded ammonoid localities by the writer showed lithologies differing from those of the Permian lenses and lying distinctly above them. They come from carbonate boulders, stained with iron unlike any of the Permian boulders, lenses and olistoliths. The most accessible of localities is well exposed where a farm and quarry road is crossed by the Wairoa River. The age adduced by Owen needs adjustment, because whereas he thought that the ammonoids belonged to the Smithian Stage of the world Triassic, some specimens are assignable to *Paranorites*, of the underlying Dienerian Stage (Waterhouse 2002b), and some suggest a later Scythian age, pointing to the development of a sparsely occupied cementery of ammonoid remains. The fossils were examined at the Department of Geology, University of Otago, Dunedin, and were considered by Waterhouse (2002a, p. 143) to indicate a range of ages and affinities, through first-hand comparison with ammonoids from the Himalaya, Salt Range and Timor. Ammonoids from these regions and faunas which were extensively monographed by Waagen (eg. 1895) and Diener (eg. 1897) should have been carefully assessed by Owen: instead he compared the Stephens specimens with the meagre but geopolitically enforced world standard collections found in Arctic Canada. The Himalayan faunas are far more relevant to the Permian and Triassic faunas of New Zealand, given that they are found along the same megacomplex of sediments and volcanic arcs then in the same hemisphere, and given that the Himalayan ammonoids are much more diverse and more clearly in sequence than those of Arctic Canada. It is a pity that I did not write more on the New Zealand ammonoids, but that was deferred in the understanding that Campbell, Owen & Landis (1995) had promised forthcoming articles on stratigraphy and ammonoids by Owen “in press”. No such article has ever appeared on the ammonoids, so I should have proceeded at the time, regardless. Campbell & Owen (2003) did publish an interpretation of the ammonoid *Durvilleoceras woodmani* Waterhouse, in proposing a new and local Nelsonian Stage for the New Zealand Triassic, which they evaluated as being of Scythian age, when the age is likely to be upper Anisian, judged from faunal and extensive stratigraphic evidence, and based on direct comparison with Himalayan, Timor and Canadian evidence (Waterhouse 1999a, 2002a, 2002b).

In the Countess Range of western Southland, separated from the rocks of D’Urville Island and Nelson Province by displacement along the Alpine Fault, Aitchison et al. (1988) subdivided the Countess Formation of Grindley (1958) into the Kiwi Burn Formation (which is like the Holland Farm Formation of Waterhouse 1987b – see below), the Acheron Lakes Formation (like Queens Beach Member), followed by the Cerebus Formation (approaching Incline unit), then Eldon Formation (approaching the Titapu unit), capped by the Snowdon Formation of Landis (1974). There is no sign of the Early Triassic Shaggery Formation exposed in east Nelson. The basal Snowdon Formation contains red beds like those of the upper Big Creek Formation, and so is reminiscent of the Waiua Formation and to limited extent the upper Big Creek Formation of east Nelson. Highly provisional matches were suggested with the Stephens Island subdivisions by Waterhouse (2002a, p. 141), as repeated here, but the rocks do differ from area to area, suggesting deposition from a variety of sources in different settings, which would warrant the recognition of all the units, subject to closer scrutiny. The one geologist who has mapped the rocks throughout east Nelson Province is M. R. Johnston (eg. 1981, 1990, 1993, 1996, Begg & Johnston 2000) with further references. Johnston was content to map all units as belonging to one Stephens Formation, following Waterhouse (1964a). He did record various lithologies and differences, but did not show any detail in his maps, even for the named Stephens Island units.

Should it be determined that recognition is possible of a consistent succession of formations throughout the entire region, it is important that the rules of priority prevail, unless overruled by strong counter arguements. It seems likely that some formations were more persistent than others, and that intervening sediments varied. But for the most part, the names proposed by Landis (1974) and Campbell et al. (1984) should receive priority, followed by Waterhouse (1987b) and Aitchison et al. (1988).

Reappraisal of group allegiances

Regardless of whether local units can be discriminated, the assemblage initially classed as Stephens Formation needs to be divided: because the rocks mostly belong to the Triassic Period, and some to the Permian Period. Waterhouse (1987b) proposed replacing the original Stephens, as described and mapped by Waterhouse (1964a) with the newly proposed Te Mokai Group, but this would be better regarded as a supergroup, and its usefulness is open to debate, though features in common include probable origin over the volcanic arc and subsequent sliding into the Maitai trough, so that it is a natural stratigraphic megaunit that developed in one geographic area with a common tectonic history. Adjusting the proposals in Waterhouse (1987b), the Stephens Group, upgraded from Wellman 1957, and based on D’Urville Island outcrops at Cape Stephens and Stephens Island, incorporates the Triassic deposits. But the deposits at Cape Stephens and Stephens Island are less complete that those at Lee River and nearby in east Nelson. These involve, apparently, rocks as young as the Waiua Formation (?Ladinian – upper mid-Triassic) in the upper Mead Bridge Formation, and older rocks of Scythian (Early Triasssic) age, named the Shaggery Formation in Lee and Wairoa river valleys.

Goat Hill Group

Wellman in concept, and Waterhouse (1964a) in writing up the Stephens rocks, included the underlying Permian rocks exposed south of D'Urville Island. Waterhouse (1987b, 2002a, p. 141), proposed to partially segregate the Permian rocks. In east Nelson, sedimentary rocks between the Waiua Formation to the east and Queens Beach – Mead Bridge and correlative formations to the west of the restricted Stephens Group are placed in the Goat Hill Group [formerly Subgroup] of Waterhouse (1987b). The basal unit is the Holland Farm Formation, of chiefly dark argillite, up to 125m thick, with rare fine sandstone and thin white tuffs, but no known fossils. The rocks are very like those of the Kiwi Burn Formation recognized by Aitchison et al. (1988) in the Countess Range, which though arguably a junior synonym, has more tuff and more sandstone, to doubtfully justify separate recognition. The upper part of the Goat Hill Group is changed from Waterhouse (1987b) to accommodate further field work and especially the significant discoveries of Early Triassic ammonoids by S. R. Owen, so the proposed Waiiti Formation, designed to incorporate two units each with a component of limestone is abandoned. The Pig Valley Formation (initially proposed as a member) contains limestone olistostromes, boulder beds and volcanogenic sandstones and tuffs (Waterhouse 1964a, Waterhouse & Flood 1981), 75m to 95m thick. The most conspicuous of the varied lithologies is provided by large lenses, some more than a kilometre in length, of dense grey-black limestone as shown in Waterhouse (1964a, Fig. 4, 36, 42; 1982, Frontispiece). These lenses and enclosing clastics belong to the *Marginalosia planata* Zone, discovered during pioneering days by A. McKay in the nineteenth century, with fossils first described by Trechman (1917). Early geological work during the nineteenth century focused on these deposits, whereas the rocks of D'Urville Island were largely unknown, until the studies by Wellman and Waterhouse.

MAJOR FACIES, TERRANE ALLEGIANCES

From its inception, the Stephens Formation was conceived by Wellman (1957) and Waterhouse (1964a) as the uppermost part of the Maitai Group, as in the early studies by the New Zealand Geological Survey, and this understanding has endured, conveyed for example in the mapping studies by Johnston (eg. 1996) and Begg & Johnson (2000). It was realized that most of the formations in the Lee River Group and overlying Maitai Group each progressively showed younging upwards towards the overlying formation, from Wooded Peak, to Tramway, to Little Ben, to Greville, to Waiua, and it was thought, into Stephens, so that even though beds were steeply dipping, and even overturned, there appeared to be no reason to doubt the overall succession and relationships from formation to formation. Most of the known fossils came from what was then called lower

Stephens Formation, and these were understood to be of Late Paleozoic age (Hector 1878, Trechman 1917), refined to Late Permian by Waterhouse (1964b), to imply that all the underlying formations were also of Permian age. This interpretation of overall and consistent westward younging was first challenged by Johnston (1970), who relied on Dr. I. G. Speden, Mesozoic field expert and publisher on a few New Zealand Mesozoic bivalves and some Cretaceous bivalves of United States, to identify *Atomodesma* aff. *trechmanni* (Marwick) in the Rai Sandstone of the Lee River Group, and on that basis to propose that the formation was younger than the apparently overlying Wooded Peak limestones, and belonged to the so-called Puruhauan Stage, more or less equivalent to the Tramway Sandstone or perhaps Little Ben Sandstone in the lower Maitai Group. The identification of Speden's "*Atomodesma*" [ie. *Maitaia*] aff. *trechmanni* has been reassessed in Waterhouse (1982b) to establish that the fossils are much closer to *Aphanaia otamaensis* (Waterhouse 1979, p. 6, pl. 2, fig. 4-8). This species belongs to a different genus, and has a more quadrate shape, longer posterior hinge, and wider umbonal septum than displayed by *M. trechmanni*. It was initially described from the Waipahi Group of Southland, and upper Brunel or Chimney Peaks Formation of the *Spinomartinia adentata* Zone in the younger Takitimu Group, of Early Permian age (see Waterhouse 2002a, p. 196; 2021b, pp. 222-3, 2021b), much older than the Puruhauan Stage. Johnston has continued to dispute this, and never acknowledged that the assessment by Dr Speden with its cautious "aff." might have not been infallible. So much for fossils – if you cannot identify them with what you wish them to be, then they have no merit. The fact is that fossil identifications and age assignments for the Permian System in New Zealand, as shown by the much needed revision of the Campbell et al. report led by D. J. C. Briggs on the fossils from Stephens Island, have not fared well in the hands of certain local geologists. An identification by Johnston & Stevens (1985) of *Maitaia obliquatum* (Waterhouse) in the Kaka Formation of east Nelson also has had to be challenged. The Kaka specimens were named *Aphanaia glabra* Waterhouse, 2001, and most closely approach specimens found in the *Spinomartinia adentata* Zone of the Takitimu Mountains, based on material reported in Waterhouse (1980) as further assessed in Waterhouse (2001, p. 110). The species *obliquatum* has lower anterior walls, heavier commarginal rugae, a narrower umbonal septum, and overall different shape, compared with *glabra*, and the posterior wing is not defined. The fossil indicates that the Kaka volcanics are much older than type *obliquatum*. Johnston & Stevens (1986) sought to excuse their assessment by pointing out that that many fossils were not well preserved and that extensive parts of New Zealand geology were still poorly dated and poorly known. No wonder, when ages are arbitrarily imposed and fossils misrepresented. It has been clearly shown by Biakov et al. (2021) that atomodesmid taxa are time-limited, and they together with allies have been extensively used as zonal indices for the Permian of northeast Russia.

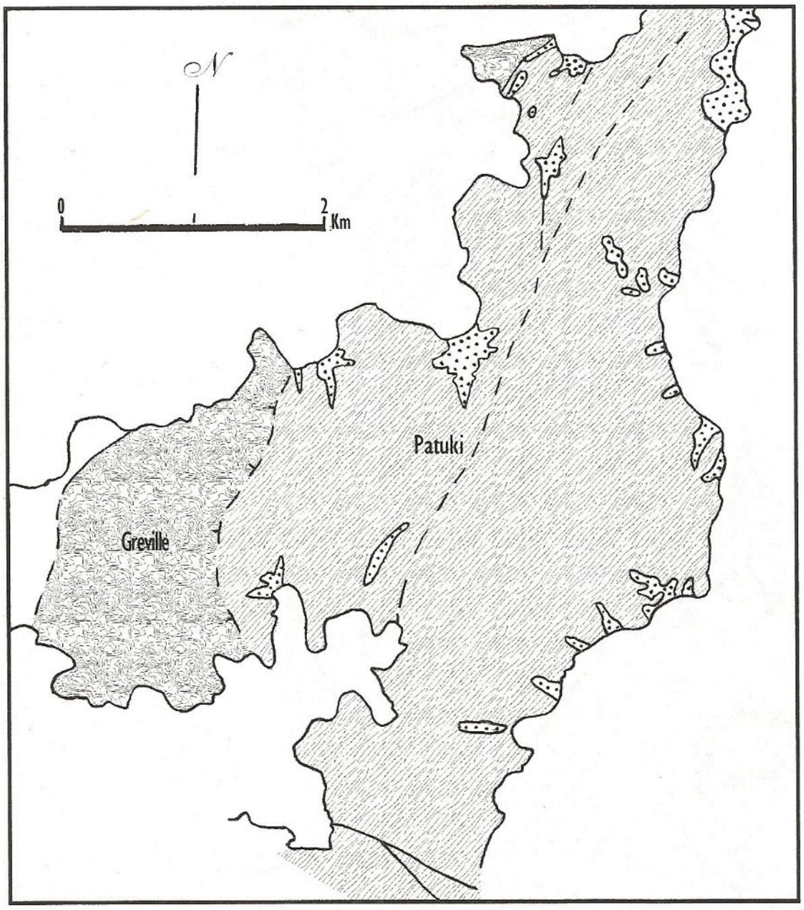

Fig. 13. Northeast D'Urville Island, as mapped by Johnston (1996). Detail of rock distributions is not provided, even though the scale differed little from that employed by Sivell & Rankin (1982) or Waterhouse (1975). Not even the extensive outcrops of volcanics were mapped, and the rocks of the Greville Formation, with thick laminites divided by a massive sandstone formation, were not discriminated. (Waterhouse 2002a). Pleistocene outcrops shown as dots are less than accurate.

Perhaps the saddest aspect stems from the claim that the Nelson Permian was being mapped by Johnston at 1:50 000. Not by modern standards. In the northern part of D'Urville

Island, Johnston (1996) showed most of the rocks as a blank so-called melange, meaning that in his opinion, it was too complicated to be mapped, allegedly because the rocks had been disaggregated into impersistent blocks (Fig. 13). That assertion was wrong, as he would have discovered had he tried to map the rocks, instead of listening to so-called experts from academia, or it must be acknowledged, been allowed sufficient time and expense to unravel the geology and be fully supported with expert geochemical and faunal analyses.

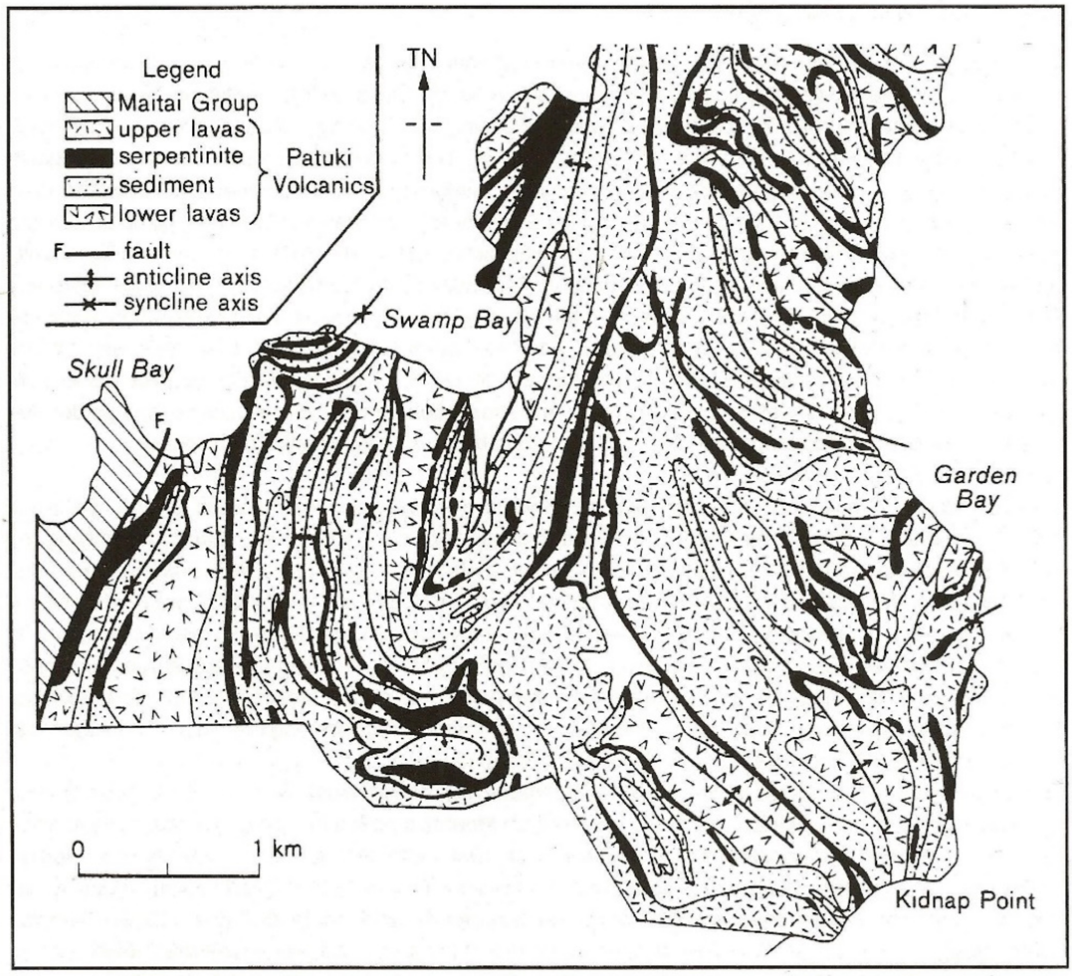

Fig. 14. A map of part of northeast D'Urville Island by Sivell & Rankin (1982). The map improved on that offered by Waterhouse (1975), by discriminating lower and upper suites of volcanics with the differences reinforced chiefly through light rare earths. But the map published for the same area by Johnston (1996) woefully oversimplified the outcrops (Fig. 13). The Sivell & Rankin map required sophisticated geochemistry coupled with patient and time-consuming geological mapping, coupled with a prime focus on the actual rocks, perhaps beyond the sources of local geologists

The same so-called “unmappable melange” had already been mapped as a number of stratigraphic and igneous units by both Waterhouse (1975) and independently by Sivell in Sivell & Rankin (1982). The same practise of “unmappable – too broken” has been applied elsewhere in New Zealand, but such statements are never verified by detailed maps,

FORMATION	**FOSSIL ZONE**	**AGE**
uppermost Big. Creek Ftm =Snowdon Ftm		Ladinian?
Big Creek, Mead Bridge, (Stephens Is. rocks)		Anisian
Shaggery Formation	*Paranorites, Meekoceras* etc	Scythian **B**
Pig Valley	*Marginalosia planata*	late Changhsingian
Holland Farm	no fossils	probably Changhsingian **B**
Waiua	(miospores)	?Ladinian
South Arm	*Durvilleoceras woodmani*	upper Anisian
Washley	no fossils	Anisian
Wells Arm	*Stenopopanoceras*	Scythian, upper part = lower Anisian **M**
Little Ben	*Trabeculatia trabeculum*	middle Changhsingian
Tramway	*Maitaia trechmanni*	lower Changhsingian
Wooded Peak	scattered fossils	Wuchiapingian **M**

Table 3. Sequence of formations from east at the base of the table at the top of the table to west for the Permian-Triassic proceeding through the rocks in east Nelson, showing an apparent stratigraphic succession that is complex, and telescoped through nappe movement, as proven by faunal analysis. Wuchiapingian and Changhsingian are Upper Permian; Scythian is Early Triassic and Anisian and Ladinian are Middle Triassic. B – slices from Brook Street arc, M from Maitai Basin and trough. For Greville ammonoids, see Waterhouse (2002a, p. 134).

STRATIGRAPHIC UNIT	**FAUNAL ZONE**	**AGE**
Murihiku		Triassic-Jurassic **MU**
Wairaki Breccia	*Wairakiella rostrata*	Late Changhsingian
Hilton Limestone in Coral Bluff tectonic assemblage	*Spinomartinia spinosa*	Middle Changhsingian with older sediments **B**
Hawtel		Jurassic **B**
Glendale		Wuchiapingian?
Glendale	*Echinalosia denmeadi*	lower Changhsingian? **M**
Hawtel		Jurassic **B**
Mangarewa	four biozones	Capitanian, Wordian
Letham Burn	*Echinalosia maxwelli*	Roadian
Letham	*E. discinia* *Wyndhamia typica*	Irenian, Elkin
Caravan	?*Anidanthus solita*	Filippovian
Elbow Creek	*Attenuocurvus altilis*	Saraninian **B**
Old Wairaki Hut	*Pseudoflemingites*	Scythian **B**
McLean Peaks	*Echinalosia conata*	Upper Baigendzinian **B**

Table 4. Stratigraphic and faunal units at Wairaki Downs, Southland, from east at the base of the table to west at the top of the table, in schuppen or thin nappe-like slices, B affinities with Brook Street volcanic arc, M Maitai, and Mu Murihiku. The slices cannot be unravelled without the use of refined age-dating, presently dependent on up-to-date fossil analysis, beyond the expertise of most geologists. Saraninian, Filippovian, Irenian and Elkin are stratigraphic and less, biological Russian divisions for the Kungurian Stage, Capitanian Wordian and Roadian are stages of the Guadalupian (Middle Prmian) Series.

or even by accurately interpreted photographs: it seems to have been the default reaction to any rocks that were complexly folded, or even just poorly exposed, and whatever the cause, requiring considerable time to unravel. But merit still adheres to Johnston's recognition that the succession may not be entirely uniform in its direction of younging. His thesis that there was not uniform westward younging is supported by the evidence from fossils for the age of each formation classed as Maitai. The base of what used to be called the Stephens Formation and emended to Goat Hill Group in the east Nelson Province is Late Permian, with fossil links especially to the well dated sequences of the Himalaya and northeast Russia (see Waterhouse 2021b). The age of the underlying Waiua Formation is Middle Triassic, upper Anisian or Ladinian (de Jersey & Raine 1990; Waterhouse 2002a, p. 100), based on miospores. The underlying Greville Subgroup has yielded scattered ammonoids of mostly Anisian age, including upper Anisian (Waterhouse 1993, 1996a, b, 1999a, 2002a), with a few ammonoids from the lower Greville deemed indicative of a basal Triassic (Scythian) age. The facies for these ammonoids is very different from those with Scythian ammonoids in the rocks of east Nelson and also the shelf-rocks of Wairaki Downs, coming from a trough facies as compared with an island arc facies. Such ages suggest a natural stratigraphic succession, younging upwards from the Late Permian Wooded Peak, Tramway and Little Ben Formations into Triassic. Then the Goat Hill Group exposed at Lee and Wairoa rivers and elsewhere in east Nelson disrupts this upward progression, and is mostly upper Permian, instead of being late Middle or Upper Triassic. Yet the beds are conformable and young in the same direction. Normally, in most parts of the world, this would be deemed to indicate low angle thrusting, or massive slumping, forming the kind of disruption typical of nappes. One would-be authority has pronounced that in the New Zealand Permian-Triassic, nappes are impossible, because no heaped-up deposits that have accumulated at the front of a nappe have ever been found. Such frontal deposits are found at one locality, in western Europe, where nappes developed, but they are absent from New Zealand. Therefore, he concluded, there are no nappes in New Zealand. Yet there are no such frontal deposits in the Himalayas, or Rocky Mountains, or Appalachians. Geologists, notwithstanding the opinion of that would-be expert, agree that nappes are well developed in those regions, despite the lack of frontal

EAST NELSON, LEE RIVER **(western rocks at top)**	**SOUTH OTAGO, WAIPAHI** **(southern rocks at top)**	**AGE** **(from fossils)**
Murihiku Nappe	Murihiku Nappe	Triassic-Jurassic **MU**
Big Creek, Snowdon		late middle , ?upper Triassic
Mead Bridge	?Leicester Fields	Middle Triassic Anisian
Shaggery		Scythian **B** (Early Triassic)
Pig Valley		late Changhsingian
Holland Farm		**B**
Waiua	Popotunoa	?Ladinian
Greville	Popotunoa	Anisian - Scythian **M**
Little Ben	Trig DD	mid-Changhsingian
Tramway	Kildonan Mbr	mid-Changhsingian
	minor units	? and without fossils
Wooded Peak	Otaria Limestone	Wuchiapingian
Patuki	Waipahi Group	Guadalupian Cisuralian **M**

Table 5. Match between successive east Nelson rocks of the Maitai trough with slide deposits from the volcanic arc and overthrust Murihiku nappe and rocks of the (present east) – and north flank of the Maitai trough at Waipahi and Arthurton in south Otago, beyond the slide deposits from the volcanic arc, and so shown as blank. M, B and Mu as in Tables 3 and 4.

Changhsingian and Wuchiapingian are Late Permian, Guadalupian is Middle Permian and Cisuralian Early Permian.

heaps. He was wrong to insist that frontal deposits are a prerequisite for establishing the presence of nappes. Detailed mapping and accurate age dating are necessary, without which no pronouncements are justified. To explain the contact between Goat Hill and upper Maitai deposits by other geological means, such as tilting and subvertical faults, is possible, but requires elaborate mechanisms much less simple than massive sliding. Moreover the contact has brought into juxtaposition two different megafacies, or domains, the domain of the Brook Street volcanic arc, which was source area for the Stephens in the Wellman sense, into contact with sediments of the Maitai trough domain. The unusual nature of this arrangement is sustained south of the Alpine Fault in the Countess and Snowdon Ranges. Here the Greville Subgroup of Scythian followed Anisian (Early and Middle Triassic) ages and locally Waiua Formation (?Ladinian, Middle Triassic) are overlain by the Kiwi Burn Formation, like the Holland Farm Formation of Permian age in the Nelson Province, and a succession of formations likely to be of Triassic age. And “above” or west of these formations come the older rocks of Murihiku Group, again of Middle Triassic age, and of an entirely different facies (Frost & Coombs 1989; Aslund 1989; Paull et al. 1996; Waterhouse 1993), though this assessment is conveniently left out of many regional assessments on New Zealand geology. There are three repetitions of mostly Anisian rocks derived from different megafacies, and the simplest explanation is accumulation and convergence through major tectonic sliding.

At Wairaki Downs of Southland, the Takitimu Group of the Brook Street volcanic arc is overlain to the north and east by a complicated – but mappable —- sequence of fault-bounded and highly fossiliferous rocks, mostly of Middle and Upper Permian age, largely confirmed in their sequence and ages by comparison with similar successions in east Australia. In this area the youngest stratigraphic unit of the Takitimu Group is the Elbow Creek Formation, embracing the upper middle of Houghton’s (1981) Elbow Formation and lower part of the Caravan Formation of Landis (1968) and Landis et al. (1999), with well bedded fine clastics containing the brachiopod *Attenuocurvus altilis* (misidentified in Landis et al. as *Biconvexiella*) and flows of ankaramite (Waterhouse 1998b, 2002a, p. 23). To the east in faulted contact lies the Old Wairaki Hut Formation of Waterhouse (1998a, b; 2002a, p. 78), made up of red and green sandstones containing late Scythian ammonoids, discovered separately by C. A. Landis and J. D. Campbell, and identified in Waterhouse (2002a, p. 81) with *Pseudoflemingites* (middle and late Scythian) and *Eophyllites* (Late Scythian, early Anisian), near the eastern Tin Hut fault. These ammonoids are close in age to the ammonoids discovered in east Nelson by S. R. Owen. To the east lies a comparatively full succession of formations with Middle and Late Permian fossil zones, including a Coral Bluff Tectonic Assemblage, which involves components of Takitimu Group (Early Permian), mixed with tectonic slices of Elbow Creek (Jurassic) and Old Wairaki Hut (Late Permian) formations, and substantial sheets of limestone referred to the Hilton Limestone of Mutch (1972). These beds have clearly slid from the Brook Street volcanic arc to form schuppen-style slices (Waterhouse 2002a, p. 66 ff). North of Wairaki Downs in the neighborhood of Pleasant Creek, the same Hilton limestone is present *in situ*, resting on Takitimu Group rocks. The Hilton Limestone has yielded diverse faunas of the *Spinomartinia spinosa* Zone, and is widely developed in the region (Waterhouse 2002a). The *Spinomartinia spinosa* Zone is best known in south Otago near Clinton as the Trig DD Formation, and shares the key species *Trabeculatia trabeculum* with the Little Ben Sandstone of Nelson and D'Urville Island.

The source for the Stephens rocks as understood by H. W. Wellman, and published in Waterhouse (1964a) was surely from the Brook Street terrane, involving the nearby volcanic arc, because the sediments are volcanogenic, and include numerous tuffs. Radiometric ages have been determined in the Countess Range by Harper & Landis (1987) and these are likely to date the time of substantial tectonic displacement, according to Johnston (1996). The radiometric ages indicate major Cretaceous disturbance, which would accord with displacement of sediments during the opening of the Tasman Sea. At the same time, the nature of the Stephens sediments indicate shared commonalities with the nearby Maitai Group, as stressed in accounts by Johnston (1990, 1993, 1996) who drew attention to sediments like Greville laminites, and the appearance of red claystones like those of the Waiua Formation in the upper Stephens. Such a thesis also allows the presence of the Stephens Island boulder with Kungurian brachiopods, and assumes the presence of fossiliferous deposits in the volcanic arc that were later destroyed by erosion, or removed by massive sliding. There is one major challenge to this overall thesis, and that is posed by the Cape Stephens Conglomerate Member of Waterhouse (2002a), at the base of Stephens deposits on D'Urville Island. This member contains boulders of Waiua rock, derived from the underlying Waiua Formation. Given the overall setting, nature of the sediments, and fossil evidence which suggests that the Cape Stephens Member was largely sourced from rocks older than the underlying Waiua, it appears most likely that the boulders were picked up by the overmass as it slid away from the volcanic arc and came to rest on Maitai sediments.

Northern limb, Southland Synclinorium

The geology of the region of Waipahi, Arthurton and Clinton in south Otago has long caused confusion to geologists, representations of the geology by Ongley (1939) and Cawood (1987) corresponding poorly with the actual rocks, whereas Wood (1956) and Bishop (1965) achieved much more realistic and complex approximations, beyond the experience of Ongley working in pre-war days, and beyond Cawood's experience largely limited to well-exposed and tectonically simple outcrops in Australia. The Permian and Triassic sequences in the Waipahi-Clinton area approach those of the Nelson-D'Urville Island sequence, but lack any strong suggestion of thick and coarse clastics emplaced over Waiua-Greville. This is just what would be expected, because the area lies far from the Brook Street volcanic arc, beyond the reach of sediments sliding off the arc into a deep off-shore trough. The youngest Permian sediments, placed in the Trig DD Formation and with a rich fauna belonging to the *Spinomartinia spinosa* Zone, including the species *Trabeculatia trabeculum* (found also in the Little Ben Sandstone of Nelson), is overlain by the Popotunoa Group of Bishop (1965), as elaborated in Waterhouse (2002a, p. 100). Outcrops are less than ideal, but are revealed by drainage ditches and along the Awakia Stream, and palynomorph evidence for age is summarized in Waterhouse (2002a, p. 100). Equivalents of the Waiua Formation are followed by greywackes, argillite, conglomerate and crystal and vitric tuffs, coarse sandstone and shales as described by Wood (1956) and Bishop (1965), and segregated as the Leicester Fields Formation in Waterhouse (2002a, p. 100). There are no known fossils, and whether the beds represent distant outwash from the Stephens Subgroup, or simply a coarse and diverse clastic assemblage deposited in sequence above the Waiua Formation, is yet to be clarified.

From further south come outcrops of the Wairuna Peak beds, of lower Middle Triassic age, and older than the Waiua Formation. They belong to the Murihiku nappe or terrane.

Overall, this reconstruction shows that the Maitai Group accumulated seaward of the

Brook Street volcanic arc, and that both formed in juxtaposition from inception, as affirmed by observations in various reports by Johnston, such as 1996, which compared upper Stephens Group lithologies with those of the Waiua and Greville rocks. They never were separate terranes, though the claim that there was a Brook Street and separate Dun Mountain-Maitai terrane has been urged in some quarters for decades (eg. Mortimer et al. 2014). Turnbull & Allibone (2003) proposed a more realistic segregation of the Brook Street-Maitai terrane, from the Murihiku terrane. The Brook Street and Maitai entities were natural and very different megafacies or domains, and now separated from similar component parts exposed in southeast Queensland and New Caledonia. They indeed do not complete the full picture, because a third major component named after Dun Mountain and sometimes called the Dun Mountain ophiolites underlies the Maitai as a spreading ridge, to be coupled with the Brook Street volcanic arc (Waterhouse & Sivell 1987). The three different entities constitute three major facies associations, as domains or geotectonic developments, each distinct, but formed close to each other, and never having converged over major distances to now lie in juxtaposition: they always were in juxtaposition, and are now squeezed into a smaller area through sea-floor spreading.

Souheast Queensland

In the Gympie district of southeast Queensland, the Brook Street volcanic arc as represented by the Highbury Volcanics is closely associated with Maitai sediments, in the form of the South Curra Limestone (which broadly is of Late Permian age like the Wooded Peak limestones) and overlying Tamaree Formation, both with Changhsingian (Late Permian) fossils. The age of the Tamaree Formation needs more study. It has yielded a gastopod *Ananias campbelli* Waterhouse that is found also in the *Spinomartinia spinosa* Zone of New Zealand, to suggest that it lay within this zone, but that may be deemed open to caution, given the paucity of fossils. But there is no indication that the beds are as young as those of the *Marginalosia planata* Zone that had developed over the volcanic arc. The Tamaree beds are followed by the Keefton clastics, judged to be of lower Scythian age, and with early Triassic plant remains in the Gigoomgan area (Runnegar & Fergusson 1969, p. 258). Overlying shales with some lithic sandstone of the Traveston Formation contain Smithian ammonoids which are found in a Maitai facies equivalent in general age to the sediments of the volcanic arc, as represented by the Shaggery Member of east Nelson and the Old Wairaki Hut beds of Wairaki Downs. Above comes the Kin Kin “phyllite” (Runnegar & Ferguson 1969; Runnegar 1969; Jell & Cranfield 2013), equivalent to and very close in appearance to the Greville laminites There are complexities and uncertainities, because exposures are not ideal, and structural complications are present, leading to the suggestion that Kin Kin phyllites were duplicated in Runnegar & Fergusson (1969), but overall the sequence is close to that of the New Zealand succession, without any equivalents of the slide depositis from the Brook Street volcanic arc.

Stratigraphic unit	**Faunal zone or fauna**	**Age**
Kin Kin		Middle Triassic
Traveston	*Meekoceras gracilitatus*	Scythian
Keefton		
Kin Kin		Middle Triassic
Tamaree	*Ananias campbelli*	mid-Changhsingian
South Curra	*Spinomartinia spinosa*	mid-Changhsingian
South Curra	*Echinalosia denmeadi*	mid-Changhsingian

Table 6. The younger Permian and Triassic succession at Gympie, southeast Queensland, equivalent to Maitai of New Zealand, and summarized from Runnegar & Ferguson (1969) and Waterhouse (2015b). The older Permian in this region involves the Rammutt Formation, with Asselian (basal Permian fossils) and radiometric age indicating late Early Permian, placed in turn above the Highbury Volcanic Arc, which seems likely to be of Carboniferous age. That suggests the volcanic arc was older than in New Zealand, where it is called the Brook Street Volcanic arc, with age changing along strike, unless the Longwood complex in Southland includes Carboniferous rock.

REPOSITORIES

AMF: Australian Museum, Sydney; **BR**: Brachiopod Registry, GNS, Lower Hutt; **GSQ**: Geological Survey of Queensland (now kept at Queensland Museum Bulk Storage, Hendra, Brisbane; **UQ**: University of Queensland, now kept at Bulk Storage, Hendra, Brisbane.

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4. NEW SPECIES OF *Pseudostrophalosia* AND *Terrakea* FROM THE UPPER MANGAREWA FORMATION, WAIRAKI DOWNS, NEW ZEALAND

J. B. Waterhouse

Abstract

Two new species belonging to *Pseudostrophalosia* and *Terrakea* are described from the topmost Mangarewa Formation of late Capitanian age at Wairaki Downs, southern New Zealand.

New taxa: *Pseudostrophalosia routi* n. sp., *Terrakea densispinosa* n. sp.

SYSTEMATIC DESCRIPTIONS

Phylum Brachiopoda Duméril, 1806

Order PRODUCTIDA Waagen, 1883

Suborder STROPHALOSIIDINA Waterhouse, 1975

Infrasuborder STROPHALOSIIMORPHII Waterhouse, 1975

Superfamily **STROPHALOSIOIDEA** Schuchert, 1913

Family **DASYALOSIIDAE** Brunton, 1966

Subfamily **ECHINALOSIINAE** Waterhouse, 2001

Tribe **WYNDHAMIINI** Waterhouse, 2010

Genus ***Pseudostrophalosia*** Clarke, 1970

Diagnosis: Large suboval shells, the ventral valve moderately to well inflated with small umbonal cicatrix and dense recumbent varying through semirecumbent to erect spines generally arranged in commarginal rows, in more or less two series over disc and trail, and, as prime characteristic, close-set coarse spines clustered over the ventral ears. Dorsal valve as a rule heavily thickened or wedge-shaped, bearing numerous erect spines.

Type species: *Strophalosia brittoni* Maxwell, 1954, p. 543 from Tiverton Formation (Sakmarian), Bowen Basin, OD.

Pseudostrophalosia routi n. sp.

Fig. 1-5

1964 *Wyndhamia clarkei* [not Etheridge] – Waterhouse, p. 51, pl. 8, fig. 5-9, pl. 37, fig. 5, Fig. 7I, J, 8C, 15A-C, 18, 19.

1982 *Wyndhamia* sp. aff. *clarkei* – Waterhouse, p. 39, pl. 7h, j.

Derivation: Named for M. V. Rout.

Diagnosis: Shells characterized by wide hinge, mature shells considerably inflated with steep lateral walls, dorsal valve flatly concave and wedge-shaped with coarse erect spines, high marginal ridge at maturity. Ventral valve without strong spine tunnels, raised muscle platform with elongate ventral adductors, dental buttresses low or not developed.

Holotype: BR 221, figured by Waterhouse (1964, pl. 8, fig. 6, 7) and herein as Fig. 1B, C from GS 6071 (D44, f9622), upper Mangarewa Formation, here designated.

Material: Specimens are recorded at a number of localities including GS 6071 and 7811 (see p. 137) from the uppermost Mangarewa Formation, tabulated as *Pseudostrophalosia clarkei* [not Etheridge] in Waterhouse (2002, Table 18, pp. 56, 57). Further specimens have been listed in this study from D44/f132, 338, 335 and 361, but fossils from D44/f 339, south of Productus Creek, need further examination to verify their identity, because they come from slightly older beds.

Description: This species has been described by Waterhouse (1964, 1982), and is characterized by its wide hinge, and spine tunnels that are not particularly numerous or prominent in the ventral valve. The mature ventral valve is swollen with high lateral walls, whereas the dorsal valve is almost flat externally, and shows comparatively few and coarse erect spines. Internally the teeth are subelongate and dental buttresses poorly developed (Waterhouse 1964, fig. 7I, J), unlike those of *Pseudostrophalosia brittoni* (Waterhouse 1964, Fig. 7F, G, H; 2015a, Fig. 34-40). The ventral adductor platform is particularly high and

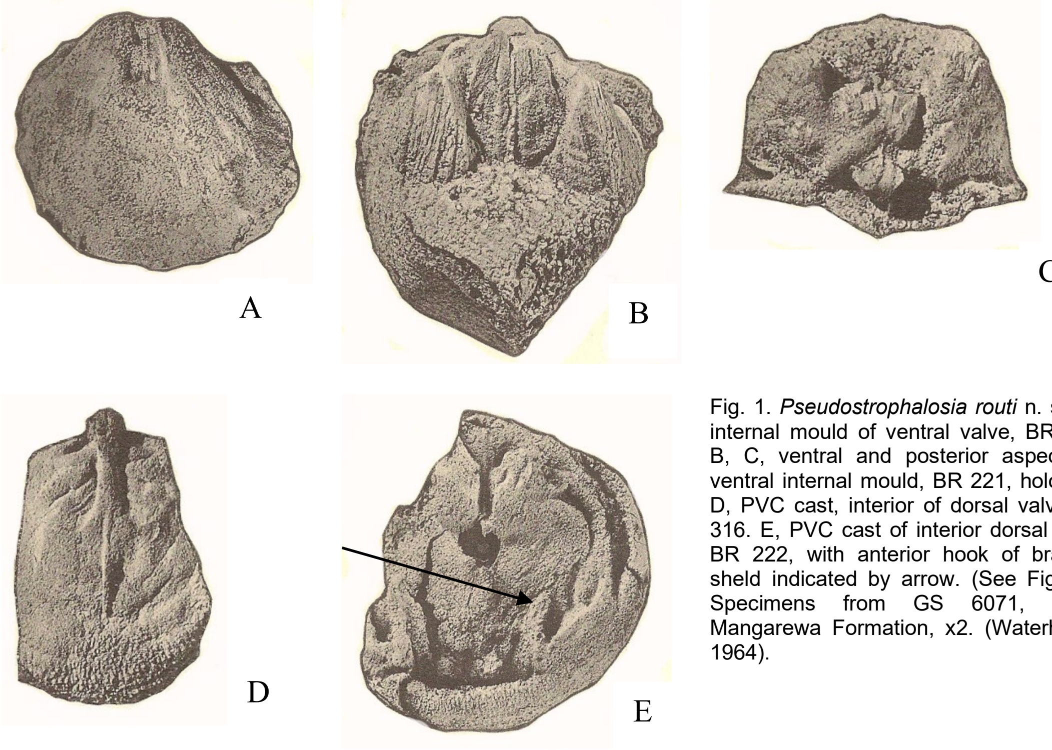

Fig. 1. *Pseudostrophalosia routi* n. sp. A, internal mould of ventral valve, BR 219. B, C, ventral and posterior aspects of ventral internal mould, BR 221, holotype. D, PVC cast, interior of dorsal valve BR 316. E, PVC cast of interior dorsal valve BR 222, with anterior hook of brachial sheld indicated by arrow. (See Fig. 4A) Specimens from GS 6071, upper Mangarewa Formation, x2. (Waterhouse 1964).

elongate. In the mature dorsal valve, the cardinal process (Fig. 3) bears prominent muscle apophyses. The marginal ridge is high laterally and in front in mature specimens, and the brachial ridges describe an anterior hook (Fig. 1E, 4A, 5B) which is anteriorly placed and tightly recurved compared with the corresponding feature in *Echinalosia* (Fig. 5A). The dorsal valve is thickened and wedge-shaped.

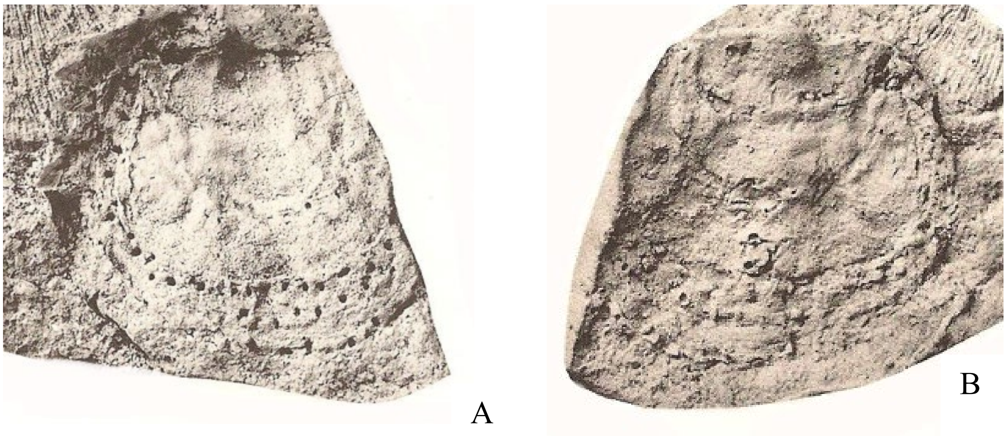

Fig. 2. *Pseudostrophalosia routi* n. sp. A, B, external mould and latex cast of dorsal valve BR 1177 from GS 7812, x2. (Waterhouse 1982).

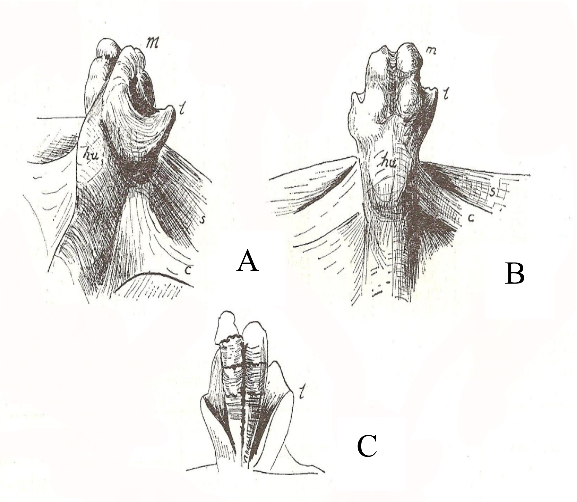

Fig. 3. *Pseudostrophalosia routi* n. sp. , cardinal process in BR 316 from GS 6071. A, anterior oblique view, B, anterior aspect and C, posterior aspect, x9. (Waterhouse 1964). c = supporting ridge for cardinal process, hu = anterior hump, l = lateral lobe, m = muscle apophyses, s = dental socket.

A critical facet concerns the nature of the ventral ornament. None of the ventral valves display any spines, and this is believed to be connected with the advanced maturity of shells, which may lead to decortication. Specimens have been recorded from a number of additional localities, and it seems highly probable that these will afford the necessary information. Furthermore, allied material is found in the Bowen Basin of Queensland (Waterhouse in prep.), where *Pseudostrophalosia* in beds of comparable age and sharing a number of critical morphological features display coarse posterior lateral

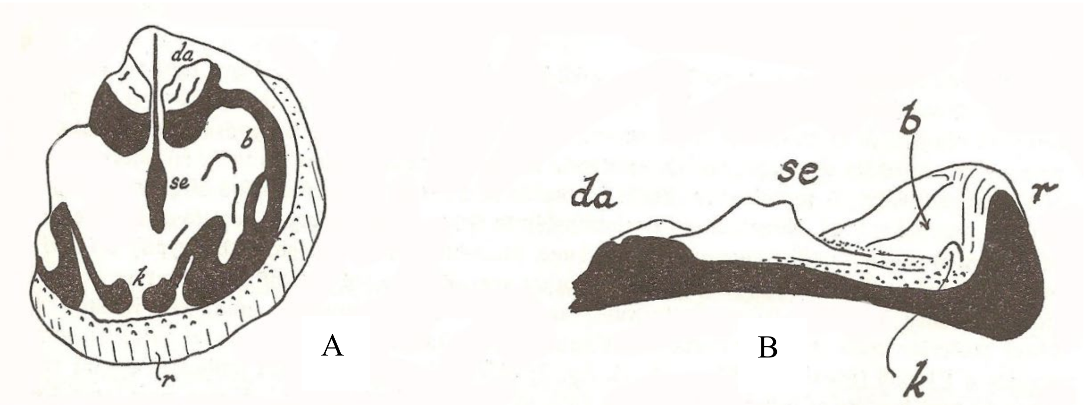

Fig. 4. *Pseudostrophalosia routi* n. sp. A, dorsal interior. B, transverse section through dorsal valve, both showing BR 222 from GS 6071, x2, x3. b = brachial ridge, da = dorsal adductor platform, k = knob at which brachial ridges appear to terminate, r = marginal ridge and trail, se = median septum. (Waterhouse 1964).

ventral spines, indicating *Pseudostrophalosia*, and fine spines over the rest of the ventral valve, including the disc and trail. Dickins (1989; p. 79, pl. 3, fig. 3-6, 11) recorded these specimens as *Echinalosia* cf. *minima* [not Maxwell] (part, not fig. 1 = *Terrakea densispinosa*?, not fig. 10, 12-21 = *Maxwellosia* n. sp.?). These allied shells from Queensland are distinguished from *densispinosa* by their much smaller size, and are possibly a subspecies of *Ps. routi*.

Resemblances: Dear (1971) and Briggs (1998) doubted the identity of the New Zealand material with *Pseudostrophalosia clarkei*, and were right to do so, comments by Waterhouse (2001) notwithstanding. The ventral valve of *clarkei* is larger and less swollen, with lower lateral walls. On the other hand the dorsal valve is almost flat and is wedge-shaped, and the anterior brachial ridges suggest the same anteriorly placed hook as featured in the present species, and these features are considered to help demonstrate a relationship to *Pseudostrophalosia*. Dear (1971, p. 12) suggested that the New Zealand specimens “probably represent” *gattoni* Maxwell, 1954, agreeing with this form in its inflation, and it may be added, poor development of spine tunnels. But *gattoni* is based on meagre material, though Dear (1971) did report addditional material from the type locality in the Big Strophalosia Band (now Scottville Member of Runnegar & McClung 1975) and wrote of it having a lower adductor platform, whereas that of the present species is high. Dear also reported the form from the *Streptorhynchus pelicanensis* bed, in the Pelican Creek fauna of Dear (1972). Dorsal valves were recorded as wedge-shaped, as in *Pseudostrophalosia*. Unfortunately the lack of any figures in Dear (1971) or subsequent studies, and the failure to record the nature of the ventral or dorsal ornament means that the taxon remains in limbo, though citation of additional and registered specimens by Dear (1971) should prove useful, provided the specimens have not been taken by Briggs, who managed to take many specimens from the Queensland Museum, and never return them. One further item of significance concerns the dental buttresses, which were described as well developed in *gattoni* by Dear (1971), whereas such features are feeble or absent from the present species.

The present specimens come from high in the Mangarewa Formation at Wairaki Downs, accompanied by distinctive species of bivalves and *Ingelarella costata* Waterhouse.

Several of the same species together with *I. costata* are also found in high marine beds of the Bowen Basin as discussed in part by Dickins (1989). These Bowen Basin specimens of *Pseudostrophalosia* have a wide hinge and are moderately inflated, even though specimens are at no more than early maturity. The ventral valve displays coarse ear spines and fine disc spines more or less in quincunx. The dorsal valve is poorly shown in figures presented by Dickins (1989), due perhaps to the coarse screen used in publication, but does display erect spines, as determined from first hand inspection at Canberra, though the diameter needs to be assessed. The Australian specimens are regarded as constituting a subspecies of the present species.

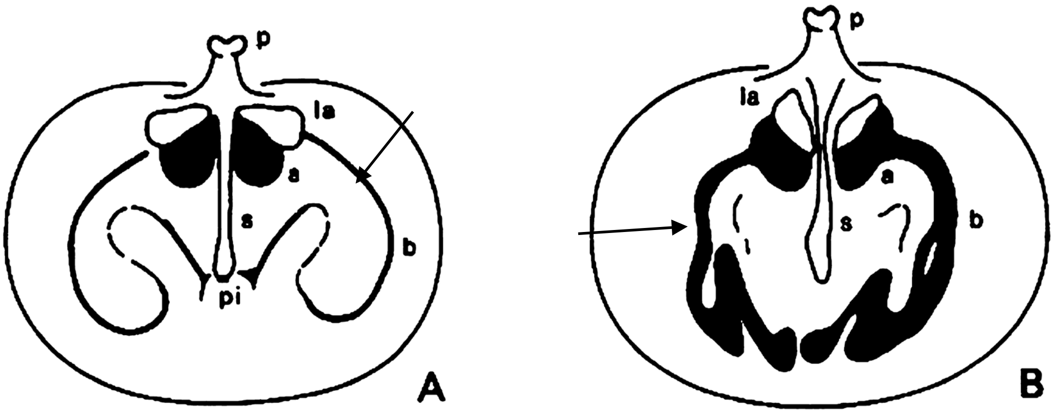

Fig. 5. Comparison between internal features of dorsal valve in A, *Echinalosia maxwelli* (Waterhouse) and B, *Pseudostrophalosia routi* n. sp. *Echinalosia* has a posteriorly extended more open and broadly recurved hook as arrowed in the outline of the brachial ridges, compared with the anterior position for the corresponding feature in *Pseudostrophalosia routi*, as arrowed. a = anterior adductor scars, b = brachial ridge, la = lateral or posterior adductor scar, p = cardinal process, pi = pillar at anterior end of septum, s = septum. (Waterhouse 1982).

Suborder LINOPRODUCTIDIINA Waterhouse, 2013

Superfamily **PROBOSCIDELLOIDEA** Muir-Wood & Cooper, 1960

Family **PAUCISPINAURIIDAE** Waterhouse, 1986

Subfamily **PAUCISPINAURIINAE** Waterhouse, 1986

Tribe **PAUCISPINAURIINI** Waterhouse, 1986

Genus ***Terrakea*** Booker, 1930

Diagnosis: Ventral valve with incurved umbo, visceral disc thick, capillae over both valves, spine ornament distinguished by a cluster of thick erect spines over ventral umbonal slopes and ears, dorsal anterior disc and trail spines may also be thick.

Type species: *Productus brachythaerum* Morris (1845, p. 284, pl. 2, fig. 4c) from Broughton Formation, Gerringong Volcanics, south Sydney Basin, OD.

Discussion: This genus is discussed in post-Treatise (and post-Briggs) terms by Waterhouse (2013, 2015a), in analyzing the distributions of spines and their nature in different species.

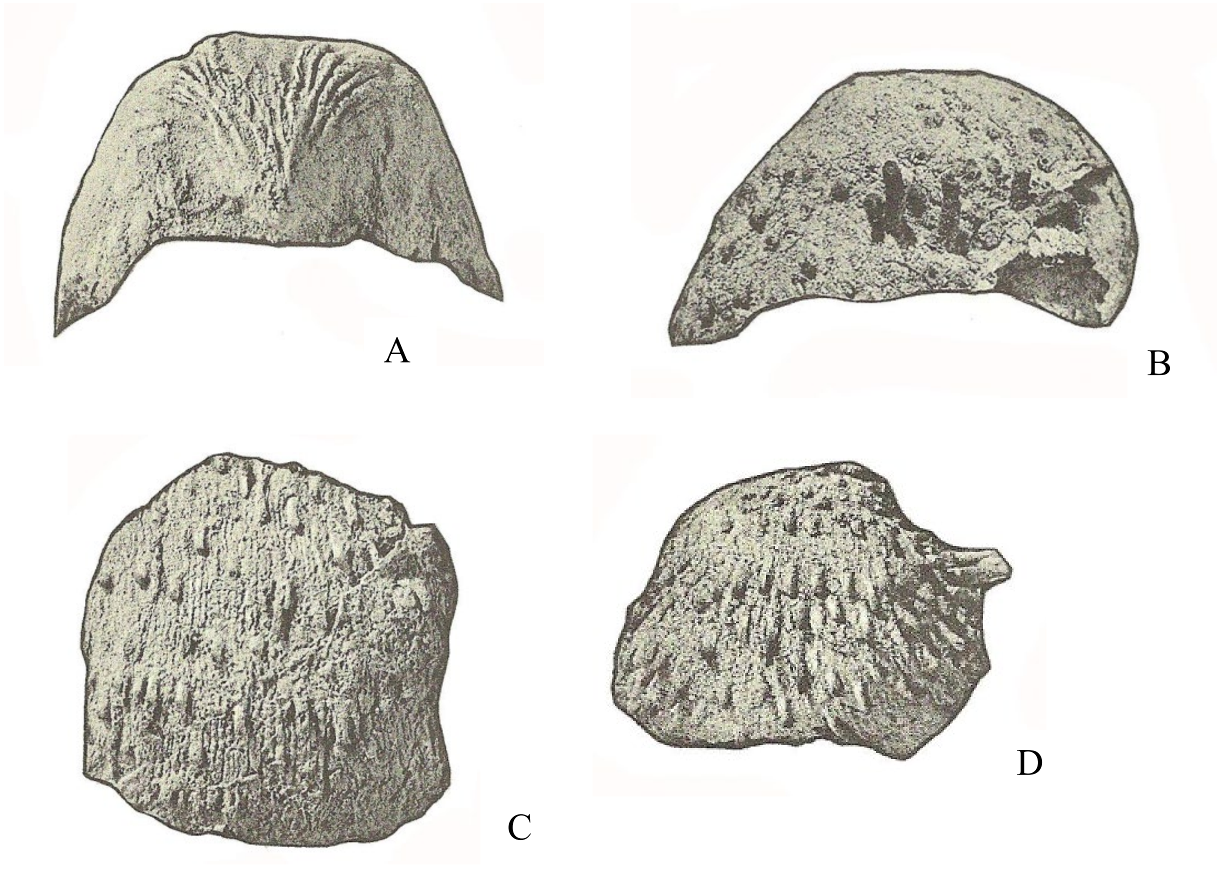

Fig. 6. *Terrakea densispinosa* n. sp. A, posterior aspect of BR 136. B, holotype, lateral aspect of PVC cast of ventral valve, BR 66, showing base of crowded ear spines. C, PVC cast of exterior, BR 932. D, PVC external cast of immature specimen BR 80. Specimens from GS 6071, x2. (Waterhouse 1964).

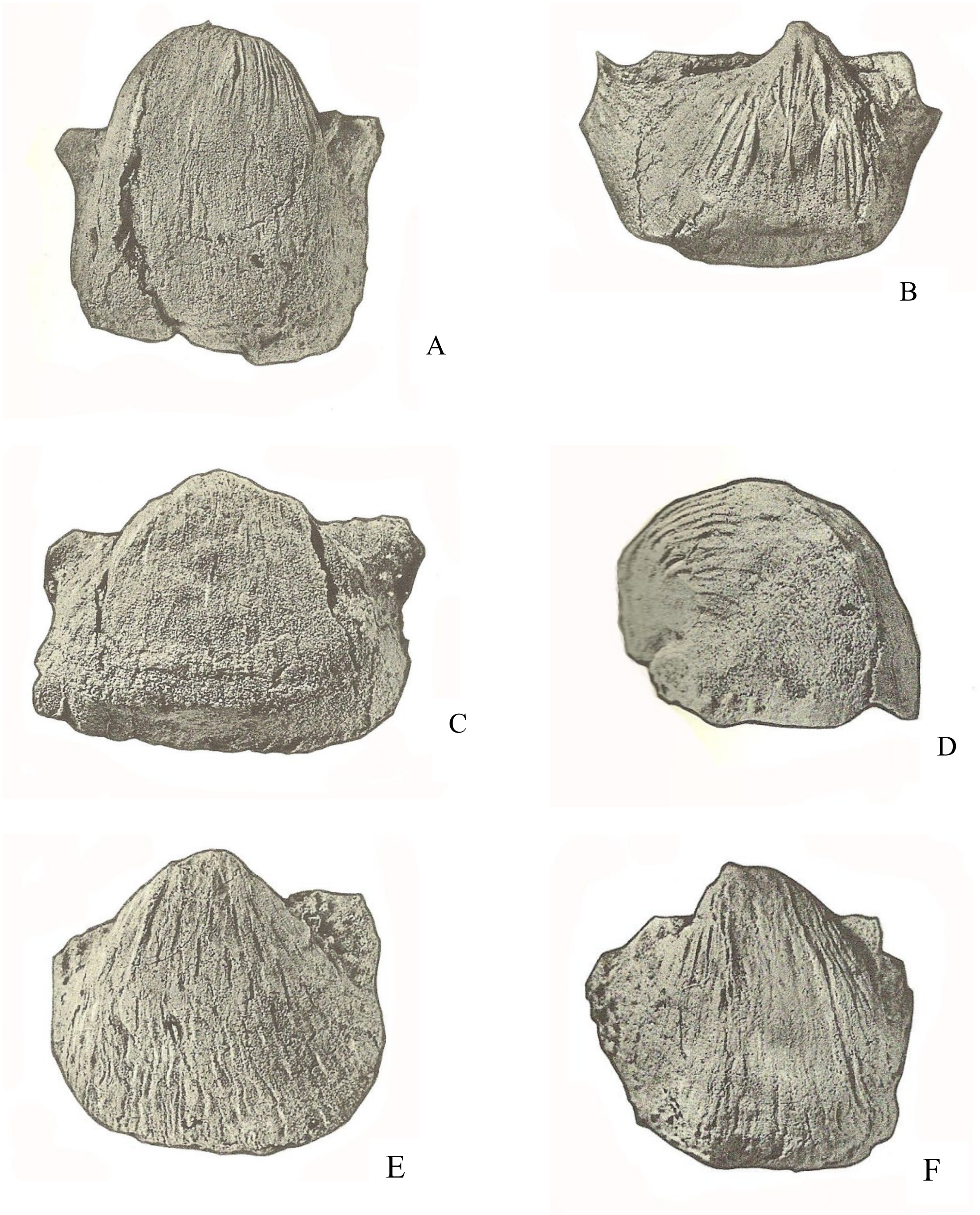

Fig. 7. *Terrakea densispinosa* n. sp. Ventral internal moulds from GS locality 6071, x2. A, B, ventral anterior and ventral posterior aspects of BR 95. C, transverse specimen BR 74. D, F, lateral and ventral aspect of BR 162. E, ventral valve BR 159. (Waterhouse 1964).

Terrakea densispinosa n. sp.

Fig. 6 - 9

1964 *Terrakea brachythaera* [not Morris] – Waterhouse, p. 73, pl. 12, fig. 1-8, pl. 13, fig. 1-12, pl. 14, fig. 1-13, pl. 37, fig. 1. Text-fig. 23c, 24D, E, 26-31.

1978 *T. brachythaera* – Suggate et al., text-fig. 4.5, Fig. 4, 5, 11.

1981 *T. brachythaerum* – Speden, pl. 5, fig. 4, 5, 11.

cf. 1989 *Echinalosia* cf. *minima* [not Maxwell] – Dickins, p. 75, pl. 3, fig. 1, 6 (part, not fig. 2-5, 11 = *Pseudostrophalosia routi* n. subsp. not fig. 10, 12-21 = *Maxwellosia*?.

cf.1989 *Terrakea solida* [not Etheridge & Dun] – Dickins, p. 75, pl. 4, fig. 1-7.

Derivation: densus – close, crowded; spina – thorn, Lat.

Diagnosis: Shells transverse as a rule, but some specimens slender and elongate, disc as a rule gently transverse, lateral walls high, dorsal disc curves sharply into a trail of moderate but not exceptionally great height, radial ornament strongly developed and totalling some 120 ribs across the valve. Spines crowded over both valves, with short elongate bases over ventral disc, strong, erect and crowded over ventral ears; numerous and erect over dorsal valve.

Holotype: BR 66, figured in Waterhouse (1964, pl. 13, fig. 12) and herein as Fig. 6B, from GS 6071 (D44/ f9622), upper Mangarewa Formation, Wairaki Downs, Southland, here designated.

Description: This species is extensively described and illustrated in Waterhouse (1964), with attention drawn to the variation displayed within the species. Many specimens are internal moulds of ventral valves which show external ornament because the shell was thin, but care was taken to prepare casts from external moulds. Dorsal valves are well represented by internal and external moulds, from which casts were prepared.

Resemblances: Present material originally was identified as *Terrakea brachythaera* (Morris), an identification endorsed by Briggs (1998, p. 176). *Terrakea brachythaera* was first described from what is considered to be the Broughton Formation at Gerringong, south Sydney Basin, New South Wales, as indicated by the matrix of the type specimen BB9466

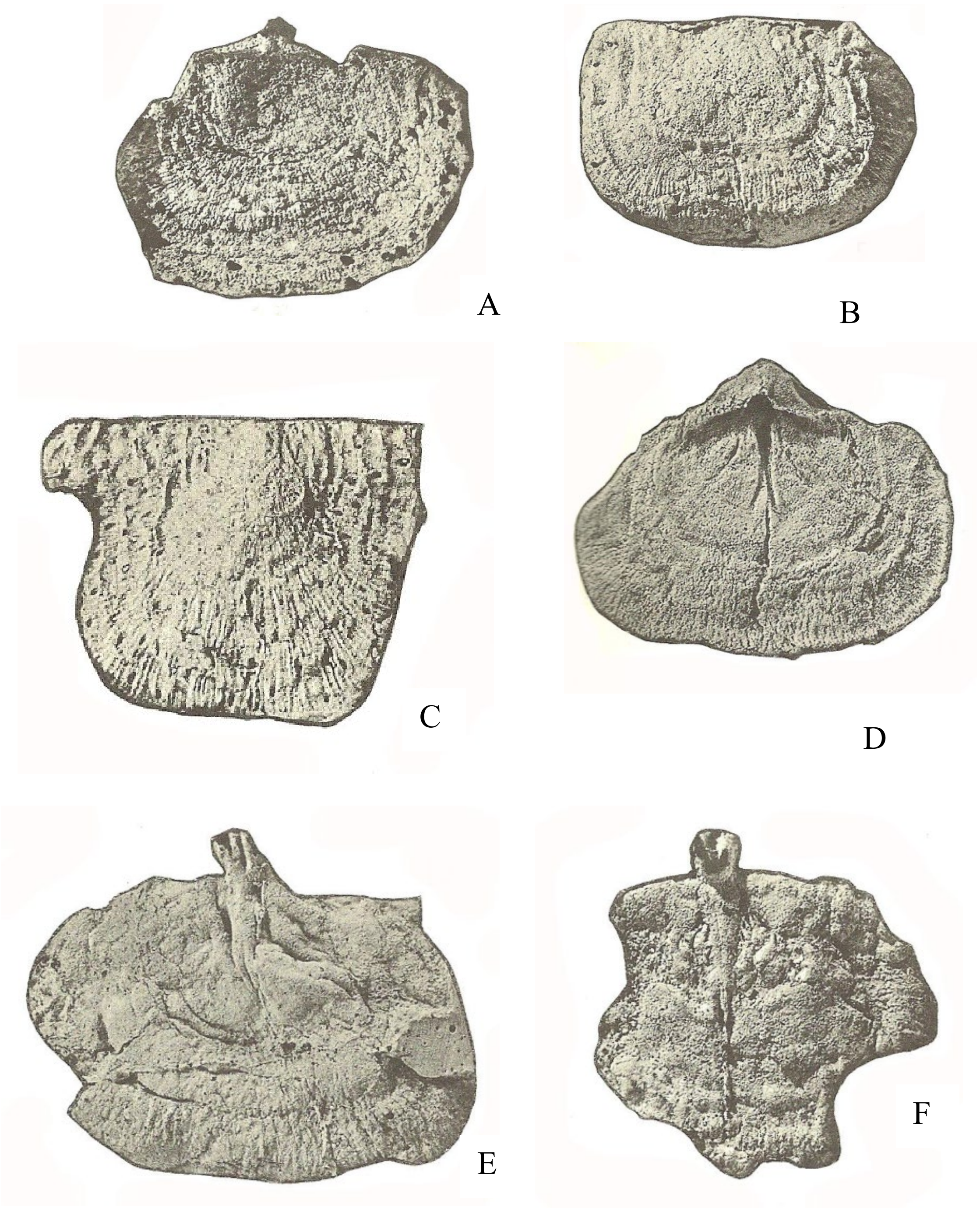

Fig. 8. *Terrakea densispinosa* n.sp. Dorsal valves from GS 6071, x2. A, PVC cast of dorsal external mould BR 146. B, external mould of BR 163. C, external mould of dorsal valve BR 96. D, internal mould, dorsal aspect, BR 163. E, PVC of dorsal interior, BR 65. F, PVC cast of dorsal interior, BR 923. (Waterhouse 1964).

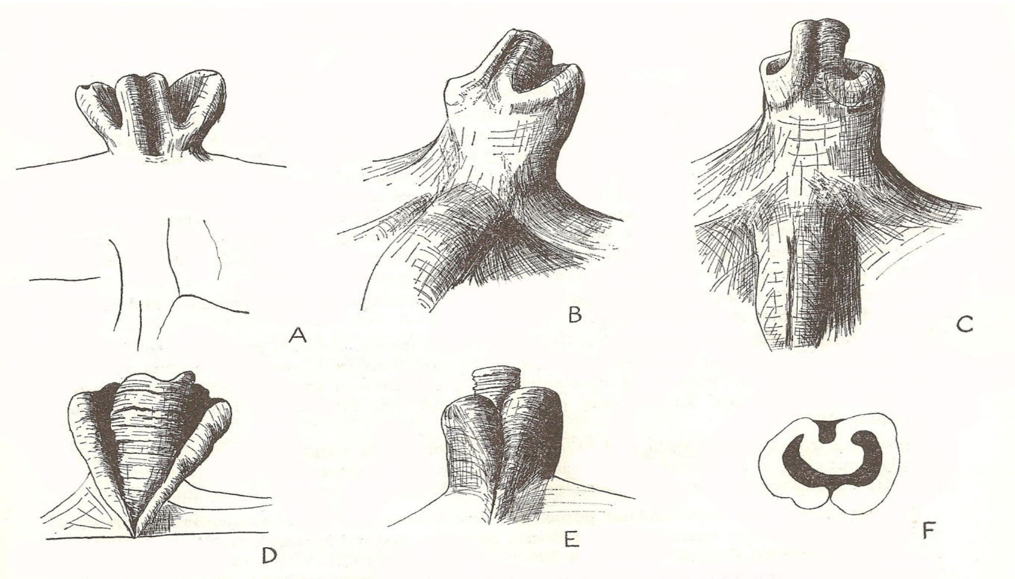

Fig. 9. *Terrakea densispinosa* n. sp. Cardinal processes, from GS 6071, x7.5. A, B, D, ventral, anterior oblique and posterior views of BR 65, with widely splayed lobes. C, ventral, E, posterior and F top views of more usual process, BR 344. (Waterhouse 1964).

(Briggs 1998, p. 178), though other possible sources have been suggested. Hill (1950) and Waterhouse (1964) had pointed out that the material probably came from the Illawarra district of the south Sydney Basin, where the Broughton Formation is exposed, whereas Clarke

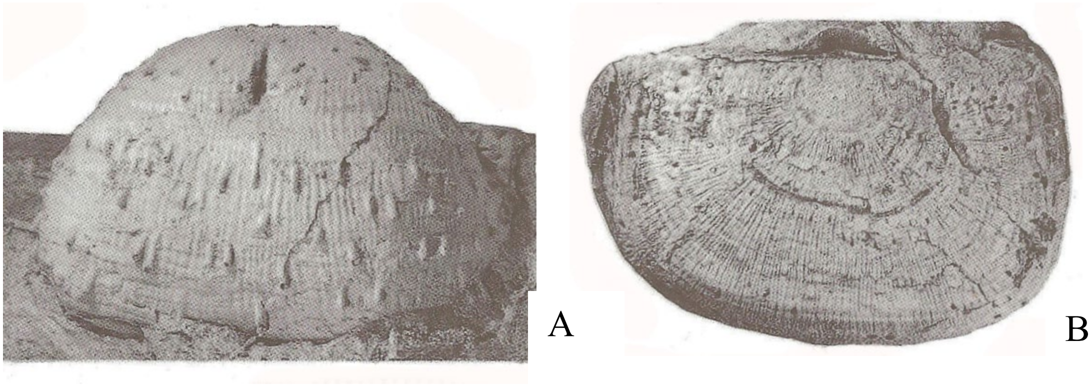

Fig. 10. *Terrakea brachythaera* (Morris). A, latex cast of ventral valve UQF 75339. B, dorsal external mould, UQF 75340. Specimens from Broughton Formation at Gerringong, x1.5. (Briggs 1998).

Fig. 11. *Terrakea elongata* n. subsp. A, latex cast of specimen with valve conjoined, UQF 82670, x1.5. B, anterior view of dorsal external cast UQF 82646 showing long trail, x2. C, anterior aspect of ventral internal mould 82677, showing long trail, x2. D, anterior aspect of ventral internal mould UQF 82676, x2. Specimens from bed UQL 3135 just above the Big. Strophalosia Band, now called the Scottville Member, in the Blenheim Formation, north Bowen Basin. (Waterhouse in prep.).

(1987) forcefully declared that it had come from the Muree Sandstone of the north Sydney Basin, and attacked Waterhouse (but not Hill) for the south Sydney Basin proposal. Clarke was almost certainly wrong. In the original description, Morris (1845, p. 284) had indicated the locality as "Illawara, Raymond Terrace (New South Wales); Eastern Marshes, Mount Wellington, etc. (Van Diemen's Land)".

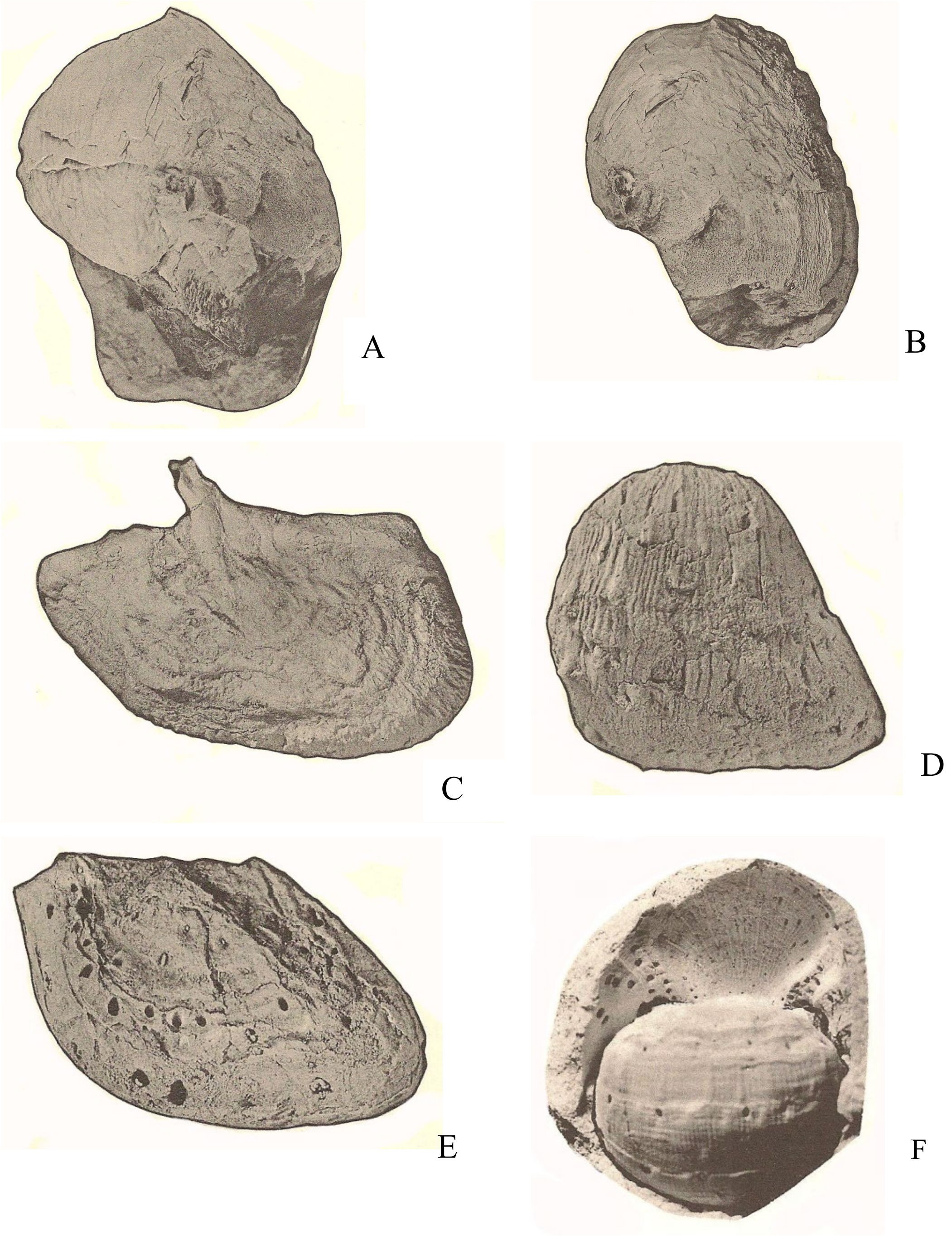

Fig. 12A-E. *Terrakea elongata* n. subsp. A, B, oblique and lateral aspects of BR 183. C, inner view of dorsal valve BR 193. D, ventral valve BR 182. E, dorsal external mould BR 749. Specimens x2 from GS 3616, which includes fossils from two zones, *Echinalosia ovalis - Paucispinauria solida* Zone and *Terrakea elongata* (s. l.) Zone. (Waterhouse 1964). F, *Terrakea elongata elongata* (Etheridge & Dun), anterior view of external mould of both valves, unregistered UQ specimen from the Big Strophalosia Band (Scottville Member), *Pseudostrophalosia clarkei* Zone, Clermont, Bowen Basin. (Waterhouse 1982).

The present species is close to *Terrakea brachythaera*, as figured by Morris (1845), Dana (1849, pl. 2, fig. 7 – as *fragile*), Booker (1930, pl. 1, fig. 2, 5), Hill (1950, pl. 2, fig. 1) and Muir-Wood & Cooper (1960, p. 119, fig. 14-23 – including the junior synonym *fragile*). It is moderately close in shape, with wide disc, similar ears, numerous ventral ear spines, short bases over the ventral disc, short trail and somewhat similar muscle scars and dorsal interior. The ventral valve is less convex and on the whole narrower in type *brachythaera*, whereas the New Zealand form is more highly arched, with higher steeper lateral ventral walls. Radial ornament is very fine over both species, with some 120 capillae, but capillae are finer and lower on the dorsal valve, and low and slightly broader on the ventral valve of *brachythaera*, whereas capillae over *densispinosa* are just as numerous, but more sharply defined and more raised. Ventral spines are more numerous and crowded over the ventral disc of *densispinosa*, and ear spines are particularly strong and crowded, and extend a little in front of the ears along the lateral slopes. Dorsal spines are also prominent, and are more numerous over the trail than in the specimens figured by Briggs (1998, Fig. 87E, F). These differences are not great, and originally were ascribed to differences caused by facies and infrasubspecific differentiation from *brachythaera*.

Northern Bowen Basin, Queensland	**Wairaki Downs, New Zealand**
Ingelarella costata Zone	*Ingelarella costata* Zone
Ingelarella havilensis (FAD) fauna	present in NW Nelson
Marginalosia minima - *Terrakea elongata planidisca* Zone	*Terrakea elongata planidisca* Zone
Pseudostrophalosia clarkei Zone	absent
Echinalosia ovalis Zone (superzone)	*Echinalosia ovalis* Zone

Table 1. Capitanian (Middle Permian) macrofaunal biozones in Queensland and New Zealand.

Waterhouse (2001, p. 57) proposed to shift allegiances of the specimens to *Terrakea elongata* (Etheridge & Dun, 1909) because the present suite is close to *elongata* in the steepness of the lateral walls of the ventral valve, and in having a few coarse and erect ventral spines over the lateral slopes in front of the ventral ears in both suites, unlike those attributes in the species *brachythaera*. However the present ventral valves are not as high as those of *elongata*, and the trail is much lower, and *elongata* has more erect coarse spines laterally than in the present species.

IMPLICATIONS FOR MACROFAUNAL ZONATION

The two Productida recognized in this study as being distinct from species *Pseudostrophalosia clarkei* (Etheridge) and *Terrakea brachythaera* (Morris) or *Terrakea elongata* (Etheridge & Dun) help consolidate the distinction of an *Ingelarella costata* Zone, that lies above a zone with *Terrakea elongata* n. subsp. in the upper beds of the Mangarewa Formation (Waterhouse in prep.) as mapped in Fig. 13. The *Ingelarella costata* Zone at Wairaki Downs also has a number of distinctive bivalves, especially amongst Nuculanidae, that are shared with the *Ingelarella costata* Zone in the Bowen Basin.

The occurrence of one species, *Johndearia pelicanensis* (Campbell) in the New Zealand zone points to a slightly greater age, because this species is reliably found in east Australia only in the Bowen Basin and in the Pelican Creek fauna of Dear (1971), at the top of the *Marginalosia minima* Zone, which underlies and is a little older than the *costata* Zone in the Bowen Basin of Queensland, and lies below what Dear (1972) called the Havilah fauna, with the first entry of *Ingelarella havilensis* Campbell. But shells close to *Johndearia pelicanensis* also were figured by Wass & Gould (1969) at South Marulan in New South Wales, in a fauna still poorly understood, but possibly as young as the Havilah fauna of Dear (1972). It may be suggested that *pelicanensis* persisted beyond the *Marginalosia minima* Zone, because it is likely to have evolved into *Johndearia isbelliformis* (Waterhouse), found in the Nemo and other beds of the *Spinomartinia spinosa* Zone in New Zealand (Waterhouse & Mutch 1978), and in the *Spinomartinia spinosa* Zone of the Gigoomgan Limestone near Gympie as well as in the *Echinalosia denmeadi* Zone of the Gundiah Bridge Greywacke (Waterhouse 2015b) in southeast Queensland.

Fossil localities

GS 6071. Ridge 200m NNE of junction of first east branch and Letham Burn. D44/f622. Upper Mangarewa Formation. Collected by A. R. Mutch and J. B. Waterhouse.

GS 7811. Crest of ridge below the limestone scarp and 20m south of GS 6072. See Waterhouse (1982, Fig. 10). Collected by A. R. Mutch and J. B. Waterhouse.

GS 7812. Forty metres north of GS 6071, six metres across the tiny second east tributary of Letham Burn up from its junction with Wairaki River, in bluffs two metres high. See Waterhouse (1969, Fig. 1). Collected by A. R. Mutch and J. B. Waterhouse.

Fossil localities have been mapped by Mutch (1972) and Waterhouse (2002), with many illustrated in Waterhouse (1982, 2002).

REPOSITORIES

BB: Museum of Natural History, London; **BR**: Brachiopod registry, GNS, Lower Hutt, **GS**: fossil locality for former Geological Survey of New Zealand, now GNS, Lower Hutt; **UQF**: University of Queensland, kept at Bulk Storage for Geological Survey of Queensland, Hendra, Brisbane.

ACKNOWLEDGEMENTS

Tribute may be paid to A. R. Mutch in his fine pioneering mapping of the fossiliferous beds at Wairaki Downs, and his initial discovery of the locality at GS 6071. M. V. Rout was the first to discover Permian fossils at Wairaki Downs.

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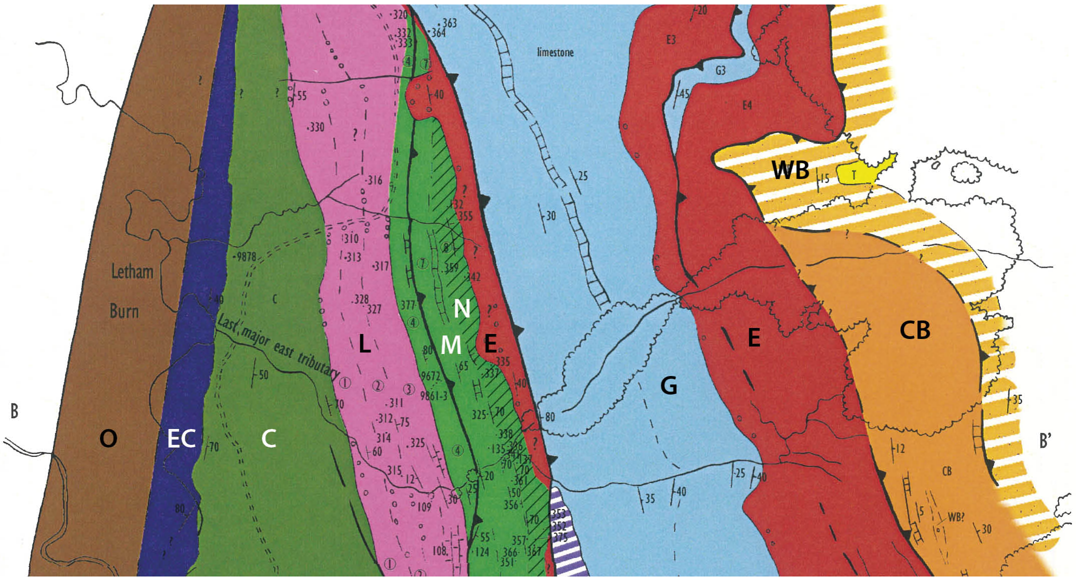

Formation

Cretaceous or Jurassic?
- W Weetwood

Jurassic
- E Hawtel + uncertain conglomerate at ??

Triassic
- T Malakoff Hill
- O Old Wairaki Hut

Triassic - Permian
- CB Coral Bluff Tectonic Association with Permian Hilton Limestone and Old Wairaki Hut Formation

Permian
- WB Wairaki Breccia Conglomerate
- G Glendale with siltstone at ∷
- N Mangarewa with unit ⑧ *Ingelarella costata* zone
- M Mangarewa with units ④ to ⑦
- L Letham with units ① to ③
- C Caravan
- EC Elbow Creek

Fig. 13. Geological map of part of the Wairaki Downs, showing the position occupied by rocks and faunas in the *Ingelarella costata* Zone, source of the species described herein.

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