

PALAEOTAXODONT BIVALVES FROM THE PERMIAN OF NEW ZEALAND

by J. B. WATERHOUSE

ABSTRACT. Fifteen species of palaeotaxodont bivalves are described from the upper Artinskian and Kungurian marine deposits of New Zealand. New species are *Nuculopsis imperta*, *N. oviformis*, *Quadratonucula asymmetrica*, *Polidevcia antequadrata*, *Glyptoleda intricata*, *G. flexuosa*, and *G. simplicata*. One new genus *Nucundata* is proposed, with new species *N. undata*, *N. truncata*, *N. obliqua*, and *N. prolonga*. An Australian species *Nuculana concinna* of Fletcher *non* Dana is renamed *Polidevcia nodulosa* sp. nov. The genera *Phestia*, *Polidevcia*, *Glyptoleda*, and *Nucundata* are referred to the subfamily Polidevciinae within the Nuculanidae.

IN the Permian of New Zealand, palaeotaxodont bivalves are restricted to the middle Permian. Two species are found in the Letham Formation, and thirteen in the overlying Mangarewa Formation. The Letham Formation is probably upper Artinskian in age and the Mangarewa Formation is probably Kungurian (Waterhouse 1963b, 1964).

Classification. In a recent symposium, Cox (1959), Yonge (1959), Owen (1959), and Purchon (1959) have shown that the protobranch bivalves with primary taxodont dentition cannot be grouped with the filibranch Arcacea with their secondarily derived taxodont dentition. As a result, these two groups should not be united under the order Taxodonta Neumayr as in Thiele (1935). The first of these groups has recently been named the Palaeotaxodonta by Korobkov (1954), and this appears to be the most useful taxon for the protobranchs with taxodont dentition. Ctenodonta of Douvillé is unsuitable, being also the name of a genus.

The upper Palaeozoic representatives of the Nuculanidae H. and A. Adams are referred to the Polidevciinae Kumpera, Prantl, and Růžička. These genera, namely *Phestia* Chernyshev 1951, *Polidevcia* Chernyshev 1951, *Glyptoleda* Fletcher 1945, and *Nucundata* gen. nov., are rostrate like the Nuculanidae, and have a chondrophore, but unlike the living forms lack a pallial sinus, and have umbonal pedal retractor scars on an internal rib below the umbones.

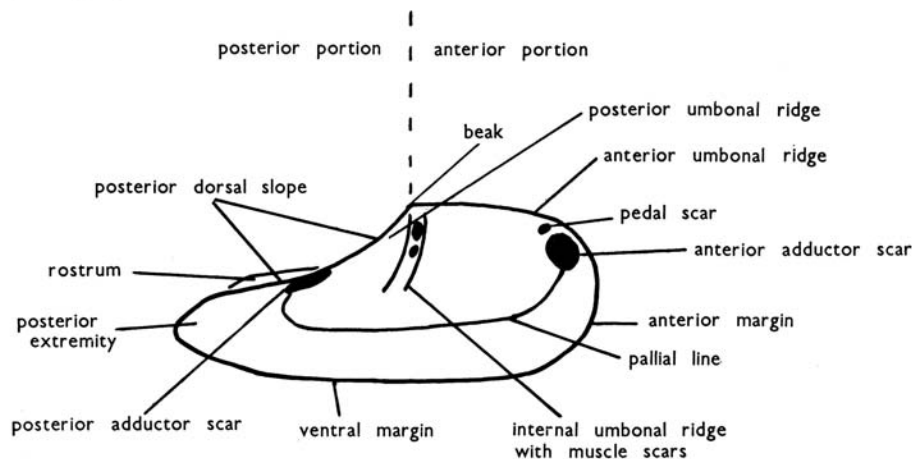
Orientation of specimens. Girty (1910), H. Chronic (1952), J. Chronic (1953), and Elias (1957) orient the shell of the Palaeozoic Nuculidae so that the beaks are prosogyrous and the posterior shell longer than the anterior part, in contrast to living Nuculidae in which the reverse is true. The writer prefers to follow Schenck (1934), Wilson (1960), and Dickins (1963) in considering that the Palaeozoic forms are oriented like the living forms. The groove that Girty and Elias considered to be an inner escutcheon is similar to the groove seen in front of the beaks in living and Recent Nuculids and Nuculanids. Campbell and Engel (1963, p. 100) have also pointed out that the position of the pedal muscle scars in some Palaeozoic species confirms that they are oriented like the living Nuculidae.

Measurements. Because the shells are equivalve the right valves are not measured separately from the left valves. The dimension at right angles to the length and height is termed 'width' rather than 'thickness', following Waterhouse (1960, p. 425). The position of the umbo is important in the recognition of species, and this is indicated in

[*Palaeontology*, Vol. 7, Part 4, 1964, pp. 630-55, pls. 96-98.]

tables of dimensions as 'umbo from anterior'. It refers to the distance between the tip of the umbo and the anterior end of the shell.

Terminology and morphology. For convenience of description the shell may be divided into an anterior portion, in front of the beaks, and a posterior portion behind the beaks (text-fig. 1). The outline of the shell is described in terms of the length and shape of the



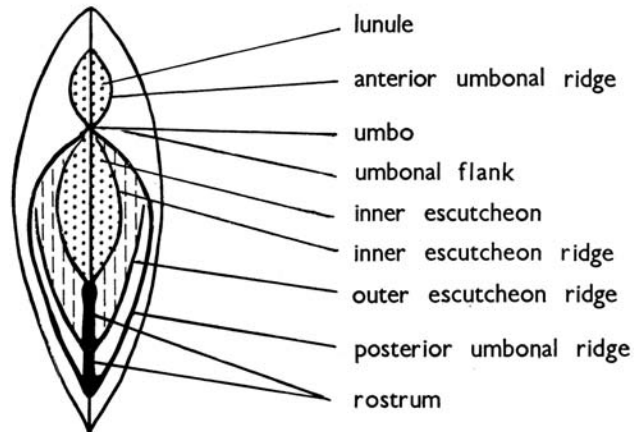
TEXT-FIG. 1. Diagram of internal mould of right valve of typical Phestiinae—showing internal umbonal ridge, muscle scars, and entire pallial line, and terms used in the description of the shell.

anterior and the posterior portions. Close to the dorsal margin of the posterior portion in the Nuculanidae is the 'posterior dorsal slope', which varies considerably in outline and length. It corresponds virtually with the crest of the posterior umbonal ridge seen in lateral aspect. A high median ridge is usually developed along the posterior commissure above the posterior umbonal ridge. Its profile is not considered to be part of the posterior dorsal slope, but it does outline part of the posterior dorsal margin.

In Permian palaeotaxodont genera the external ligament varies considerably. The anterior umbonal ridges generally surround a shallow lunular depression along the hinge, and the lunule may be further enclosed by a second pair of low ridges which lie within the umbonal ridges, and can be loosely termed the 'lunular ridges'. The escutcheon is better defined. It is wide and deeply concave, enclosed by the posterior umbonal ridges and commonly raised along the mid-line in the Nuculanidae. In some genera the escutcheon is subdivided into an inner and outer escutcheon by a pair of ridges, which I term the 'inner escutcheon ridges' (text-fig. 2). These arise from the anterior end of the raised part of the mid-line, and curve forward to unite under the beak with the pair of lunular ridges that surround the lunule. In *Glyptoleda* Fletcher, 'outer escutcheon ridges' are also developed. These lie outside the inner escutcheon ridges, just within the posterior umbonal ridges (text-fig. 2).

In addition to the anterior and posterior adductor and anterior pedal muscle scars, the upper Palaeozoic genus *Phestia* and its allies have one to three umbonal pedal

retractor scars, placed on an internal rib that slopes towards the ventral margin from the umbo. The presence of these muscles and the absence of a pallial sinus distinguish the group from the living members of the Nuculanidae. Dentition consists of numerous taxodont teeth in front of and behind the umbo. A chondrophore lies below the umbonal teeth.



TEXT-FIG. 2. Dorsal view of *Glyptoleda*, showing lunule and escutcheon and ridges.

Preservation. One curious feature in the preservation of the New Zealand Permian Palaeotaxodonta is that the shell material is generally replaced by chlorite. As a result the original shell structure is no longer available for study. The specimens are now composed of almost pure yellow-green or reddish-brown chlorite in tiny interlayered flakelets. Minor zeolite (probably stilbite) is seen in one thin section of *Nucundata obliqua* sp. nov. Chloritic material has also replaced the shell in some New Zealand Permian gastropods (Waterhouse 1963a, p. 90) and some bivalve species, but does not affect all genera—for instance, valves of *Atomodesma* are still composed of calcite (Waterhouse 1963c). One possible explanation is that the original shell substance was dissolved in certain groups of fossils—those with more original aragonite in the shell, perhaps, and that fine chlorite from the surrounding volcanic greywacke detritus was then transported mechanically into the ensuing space. Why the chlorite should be so pure remains a mystery.

Registration of specimens and fossil localities. Each specimen of significance is registered serially by number with the prefix TM. The specimens are all stored at the N.Z. Geological Survey, Lower Hutt. The localities from which the specimens came are serially numbered with the prefix GS. Details of the fossil localities are given in the appendix.

SYSTEMATIC DESCRIPTIONS

Family NUCULIDAE D'Orbigny

Genus NUCULOPSIS Girty 1911

Type species. *Nucula (Nuculopsis) girtyi* Schenck 1934 (new name for *Nucula ventricosa* Hall 1858, originally designated by Girty).

Diagnosis. Beak strongly opisthogyrous, chondrophore ventral to the teeth, ventral margin smooth, lunular depression narrow, weakly delimited by a ridge within the umbonal ridge.

Nuculopsis imperta sp. nov.

Plate 96, figs. 1-2; text-fig. 3

Material. Two specimens with valves conjoined from GS 6323, and a right and left valve from GS 6070. Decorticated, and chondrophore obscured.

Horizon. Letham Formation, GS 6070, 6323.

Holotype. TM 3519, GS 6323, Pl. 96, fig. 2.

Paratypes. TM 3520, GS 6323; TM 2941, 3362, GS 6070.

Diagnosis. Shell with opisthogyrous posterior beak, concave dorsal posterior margin, and low widely spaced costae.

Dimensions in mm.		GS 6323 (both valves)				
Specimen (TM)	Valve	Length	Height	Width	Umbonal angle	Umbo from anterior
3519	both	9.5	7.5	24.5	85°	6.8
GS 6070 (single valves)						
3362	right	9.5	8	3.5	75°	7.2
2941	left	7.5	5.2	2.9	85°	5.7

Description. External. The shells are small, moderately inflated from GS 6323, and more inflated from GS 6070, with an opisthogyrous prominent beak and the posterior dorsal margin very concave in outline. The shell is weakly depressed along the hinge to form a shallow narrow lunule which is defined by a weak ridge within the umbonal ridge in TM 3362. The ventral margin of the shell is smooth, without gape or crenulations. Ornament is composed of low irregular costae, three in 1 mm. at the ventral margin.

Internal. At least three posterior taxodont teeth and about ten anterior teeth occur in the holotype, and six posterior teeth are visible in TM 2941. The anterior adductor muscle scar lies in front of the hinge close to the ventral margin. It is rounded and slightly impressed. The pedal and posterior scars are not visible.

Resemblances. *Nucula glendonensis* Dana from Maitland beds at Glendon, New South Wales, is somewhat similar in shape but its beak is lower and more posteriorly placed.

Nuculopsis glendonensis (Dana 1849)

Plate 96, figs. 3-5; text-fig. 3

Nucula glendonensis Dana 1849, p. 699, pl. 7, fig. 5.

New Zealand material. Three right and three left valves from GS 6071 and two right valves from GS 6072.

Horizons. Mangarewa Formation, GS 6071, 6072. Muree Formation, Maitland Group, at Glendon, New South Wales.

Holotype. Specimen figured by Dana 1849, pl. 7, fig. 5.

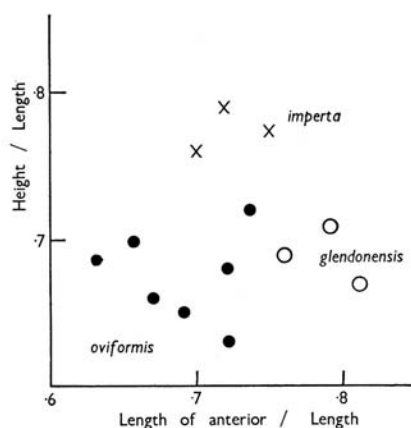
Diagnosis. Oval specimens with low very posterior beaks, and short posterior dorsal margin.

Dimensions in mm.

Specimen (TM)	Length	GS 6071 (left valves)		Umbonal angle	Umbo from anterior
		Height	Width		
3615	5	3.5	1.8	90°	3.8
2359	13.5	9	4.5	95°	11
		GS 6072 (right valves)			
3616	8.8	6.3	2.6	95°	7

(TM 3615 and 3616 are internal moulds)

Description and resemblances. The New Zealand specimens match well in external appearance with Dana's type, except that the measured valve from GS 6072 is slightly more elongated with a height/length ratio of 0.71, compared with 0.69 for Dana's



TEXT-FIG. 3. Graph of dimensions expressed in ratios for New Zealand Permian species of *Nuculopsis*. The 'length of anterior' refers to the distance between the anterior end of the shell and the tip of the umbo.

specimen. The low posteriorly placed beak is particularly diagnostic. A narrow lunular depression, defined by a low ridge within the umbonal ridge, is present in TM 3614, 2446, and perhaps in 3615. Taxodont dentition is seen in TM 3620 and in a poorly preserved specimen TM 3621.

Nuculopsis girtyi Schenck 1934 from the upper Carboniferous of the United States is moderately close, especially in its early growth stages, but the posterior dorsal margin is higher and a little more concave in outline. *Nucula poposiensis* Branson 1930, pl. 10, figs. 1-6, from the Lower and Middle Phosphoria of Wyoming has a posteriorly placed but more prominent beak.

Nuculopsis oviformis sp. nov.

Plate 96, figs. 6-8; text-fig. 3

Material. A left valve from GS 7811, two left valves from GS 3616, two left and four right valves from GS 6071, and three specimens with valves conjoined from GS 6072.

Horizon. Mangarewa Formation, GS 3616, 6071, 6072, 7811.

Holotype. TM 2447, GS 6072, Pl. 96, figs. 6, 7.

Paratypes. TM 2338-40, GS 6071; TM 2341, 2342, GS 6072; TM 2940, GS 7811.

Diagnosis. Suboval inflated shell with low beak placed near posterior third, dorsal posterior margin of moderate height and concavity. Costae fine.

Dimensions in mm.

<i>Specimen (TM)</i>	<i>Valve</i>	<i>Length</i>	<i>Height</i>	<i>Width</i>	<i>Umbonal angle</i>	<i>Umbo from anterior</i>
3613	left	9.5	GS 3616	2.3	85°	7
			6.8			
2338	left	12.2	GS 6071	2.9	?85°	8.8
			8.1			
2340	right	12.2	GS 6072	3.7	90°	8.8
			7.7			
2447	both	12.5	GS 6072	9.0	100°	8.7
			9.2			
2341	left	12.6	GS 6072	4.6	90°	8.7
			8.2			
2342	right	13.4	GS 6072	4	100°	9
			8.8			
2940	left	9.5	GS 7811	2.0	100°	6
			6.7			

Description. External. The specimens are oval in outline, with moderately opisthogyrous beaks situated just behind the posterior third of the shell length. The dorsal posterior margin is only moderately concave in outline. Inflation and shape vary. The specimens from GS 6072 are well inflated, and the holotype and TM 2341 are subglobular. Specimens from GS 6071 vary from highly inflated to little inflated forms. The lunule is narrow and short, and bounded by a low ridge within the umbonal ridge (TM 2447). The escutcheon is broad, without well-defined umbonal ridges. Costae are low and concentric, five occurring in 1 mm.

Internal. At least sixteen anterior teeth are present in TM 3613. The adductor scars are subrounded and little impressed. Other details are unknown.

Resemblances. This species is distinguished from *N. imperta* of the underlying Letham Formation by its less opisthogyrous beak, shorter, less concave posterior dorsal margin, and more numerous costae. The outline of *N. glendonensis* Dana is more oval and the beak more posteriorly placed (text-fig. 3).

Closest species is *N. darlingtonensis* Dickins 1963, pl. 1, figs. 1-6 from the Fossil Cliff Formation, Nura Nura Member, and Cuncudgerie Sandstone of Western Australia. The Australian specimens agree well in outline and inflation with the more inflated specimens from GS 6071 and 6072, and have similar fine costae (six in 1 mm.). But they are only half the size of this species, and the umbonal angle is wider than that of most of the New Zealand specimens.

Genus QUADRATONUCULA Dickins 1963

Type species. *Quadratonucula australiensis* Dickins 1963, by original designation.

Diagnosis. Shell subquadrate in outline, with subangular posterior dorsal extremity, beak low, weakly opisthogyrous, lunular depression narrow and defined by weak ridges.

Discussion. A feeble lunular ridge in paratype B of the type species has been observed by the writer at the Bureau of Mineral Resources, Canberra.

Quadratonucula asymmetrica sp. nov.

Plate 96, fig. 9

Material. Three valves from GS 6071, and single valves from GS 6074 and 7813, showing the hinge but not the chondrophore.

Horizon. Mangarewa Formation, GS 6071, 6074, 7813.

Holotype. TM 3618, GS 6071, Pl. 96, fig. 9.

Paratype. TM 3619, GS 6071.

Dimensions in mm.

Specimen (TM)	Length	GS 6071 (right valves)		Umbonal angle	Umbo from anterior
		Height	Width		
3619	3.2	2.5	0.5	95°	2.8
3618	12.2	11.4	3.7	92°	9.5
		GS 6074 (right valve)			
2343	7.1	6.5	3.0	100°	5

(TM 3618 is an internal mould)

Description. External. The shells are high, with prominent, weakly opisthogyrous, posteriorly placed beaks, the posterior dorsal margin weakly concave in outline, and the ventral margin well rounded in outline. The anterior dorsal margin is poorly known but seems to be excavate and bounded by anterior umbonal ridges. Ornament consists of about three growth-lines in 1 mm., with traces of radial striae.

Internal. The hinge is almost as long as the shell, and has numerous taxodont teeth each side of the beak. A chondrophore might be present below the teeth but is not exposed. Faint oval adductor impressions lie just below the anterior and posterior extremities of the hinge at mid-height, and are joined by an entire pallial line.

Resemblances. The New Zealand species is smaller than *Q. australiensis* Dickins 1963, pl. 1, figs. 16–24 from the Fossil Cliff Formation of Western Australia, and the beak is more posteriorly placed.

EXPLANATION OF PLATE 96

Figs. 1–2. *Nuculopsis imperta* sp. nov., ×4. 1, Left valve TM 2941, GS 6070. 2, Holotype, TM 3519, GS 6323.

Figs. 3–5. *Nuculopsis glendonensis* (Dana). 3, Right valve TM 2942, GS 6071, ×4 approx. 4, Right valve TM 3616, GS 6072, broken posteriorly, ×4. 5, Left valve TM 3615, GS 6071, ×4.5.

Figs. 6–8. *Nuculopsis oviformis* sp. nov., ×2.6. 7, Dorsal view (posterior pointing to top of plate) and right valve of holotype, TM 2447, GS 6072. 8, Left valve of TM 2342, GS 6072.

Fig. 9. *Quadratonucula asymmetrica* n. sp., ×2. Holotype, right valve, TM 3618, GS 6071.

Figs. 10–12. *Polidevecia ovata* (Laseron) ×2. 10, Internal mould of left valve, TM 3483, GS 6071. 11, Left valve TM 3499, GS 6071. 12, Right valve TM 3500, GS 6071.

Figs. 13–15. *Polidevecia antequadrata* sp. nov., ×2. 13, Holotype, TM 3441, GS 6071. 14, Internal mould TM 3433, GS 6071. 15, Internal mould, TM 3435, GS 6071.

Fig. 16. *Polidevecia* aff. *nodulosa* sp. nov., ×2. TM 3471, GS 6072.

Nucula montpelierensis Girty 1909, pl. 4, figs. 1–3 from the Phosphoria beds of Idaho is moderately close, but is distinguished by its slightly more triangular outline and the posterior position of its beak. No lunular ridge is present inside the anterior umbonal ridge in this form.

Family NUCULANIDAE H. and A. Adams

Subfamily POLIDEVCIINAE Kumpera, Prantl and Růžička

Type genus. *Polidevcia* Chernyshev 1951, emend. Kumpera et al. 1960.

Diagnosis. The Upper Palaeozoic genera *Phestia* Chernyshev 1951, *Polidevcia* Chernyshev 1951, *Glyptoleda* Fletcher 1945, and *Nucundata* gen. nov. agree in dentition and shape with the Tertiary and living members of the subfamily Nuculaninae but lack a pallial sinus and possess umbonal pedal retractor scars on an internal rib below the umbones.

Remarks. The genus *Phestia* is better known than the type genus *Polidevcia*. The two other genera based on bizarre ornamentation are of minor importance, having been short-lived and restricted in geographic distribution. It would appear that the Cretaceous Nuculanidae belong to the Nuculaninae, but the affinities of the lower Mesozoic Nuculanidae, particularly from the Triassic, are more obscure.

Genus POLIDEVCIA Chernyshev 1951

Type species. *Polidevcia karagandensis* Chernyshev 1951, by original designation.

Diagnosis. Shell prolonged behind the beaks, beaks opisthogyrous, lunule and escutcheon present, escutcheon divided by an 'inner escutcheon ridge'. Ornament of concentric costae. Numerous taxodont teeth, subequal in number in front of and behind the chondrophore; faint adductor and pedal scars, and up to three umbonal scars on a short internal umbonal ridge; pallial line entire.

Discussion. In 1951 Chernyshev erected two genera *Phestia* and *Polidevcia* for upper Palaeozoic species previously assigned to *Leda* or *Nuculana*. *Phestia* is typically short, often with a posterior ventral sinus (though not in the type species), and is said to lack a lunule (Chernyshev 1951, p. 9). It has a long rib internally on the umbonal slope, marked by a single muscle scar. The posterior teeth are one and a half times more numerous than the anterior teeth, from which they are separated by a chondrophore. The type of *Polidevcia* is more elongated, with a lunule according to the definition, and without a posterior ventral sinus. The escutcheon is divided by an escutcheon ridge. No such ridge is mentioned in the description of *Phestia*, nor is one visible in the illustrations (i.e. Chernyshev 1951, pl. 1, figs. 1*b*, 5*b*, 6*b*, 15*b*). Teeth are subequal in number in front of and behind the beak. According to Chernyshev a chondrophore is absent from *Polidevcia*, but the writer agrees with Elias (1957, p. 750), Wilson (1960, p. 119), Dickins (1963), and Campbell and Engel (1963) that one is probably present. Chernyshev referred several species to *Polidevcia*, *N. attenuata* Fleming, *N. bellistriata* Stevens, *N. prolongata* Morningstar, and *N. meekana* Mark, and all of these species have a chondrophore. Lintz (1958, p. 106) proposed a new genus *Culunana* for *N. bellistriata* and similar forms, to be used should *Polidevcia* prove to lack a chondrophore.

Specimens of *N. bellistriata* at the N.Z. Geological Survey have a long inner umbonal ridge, not a short one, and the posterior teeth above the chondrophore are very dense and tiny (as described for *Phestia* by Chernyshev). An inner escutcheon ridge is present as in *Polidevcia*, though it is weakly defined.

Dickins (1963) has recently suggested that the genus *Polidevcia* be abandoned in favour of *Phestia*, because a chondrophore is probably present in *Polidevcia*. He also recorded variation in the number of scars on the umbonal slopes. Wilson (1960) noted that posterior teeth are twice as numerous as anterior teeth in *N. attenuata* Fleming, one of the species referred to *Polidevcia* by Chernyshev. Yet *Polidevcia* is supposedly characterized by teeth of subequal number in front of and behind the umbones. No generic importance can be attached to the relative length of the shell, because related genera characterized by bizarre ornament vary considerably in length from species to species. Unless a host of new genera is to be erected to cover these different variations, it appears that the distinctions between *Phestia* and *Polidevcia* lie in the nature of the external hinge. *Polidevcia* has a lunule and an inner escutcheon ridge, *Phestia* lacks these features. These differences, if real, are likely to be of considerable taxonomic significance. Thus, pending a re-examination of the Russian types, I propose to adopt Chernyshev's distinctions and try to apply them to the allied New Zealand species. The New Zealand forms here described have a lunule and inner escutcheon ridge, and are therefore provisionally referred to *Polidevcia*.

Polidevcia ovata (Laseron 1910)

Plate 96, figs. 10–12

Nuculana ovata Laseron 1910, p. 219, pl. 15, figs. 5, 6, 7.

Nuculana ovata Fletcher 1945, p. 304, pl. 20, figs. 4–8; pl. 21, fig. 3.

New Zealand material. Three right valves and eight left valves are available from GS 6071, most broken, hinge poorly known, and shell replaced by chlorite. A fragmentary left valve from GS 3616, and a crushed specimen with valves conjoined from GS 6072.

Horizons. Mangarewa Formation, GS 3616, 6071, 6072. Burrier, Wandrawandian beds, South Coast; lower Branxton beds, Cessnock, New South Wales.

Lectotype. Specimen figured by Laseron 1910, pl. 15, figs. 5, 6, 7; designated and refigured by Fletcher 1945, pl. 20, figs. 4, 5.

Diagnosis. High shell with well-rounded anterior and ventral margins, beak low, situated close to mid-length, costae of moderate strength, parallel to ventral margin.

Dimensions in mm.

Specimen (TM)	Valve	Length (L)	Height (H)	Width (W)	Umbonal angle	Umbo from anterior (U)	H/L	U/L
GS 6071								
3500	right	14.8	11.5	2.8	120°	7	0.78	0.47
3501	right	17.5	14	4	112°	9	0.80	0.51
3492	left	20.5?	13	3.6		9.7	0.63	0.47
3499	left	21.5?	14.7	4	115°	?10	0.69	0.47
GS 6072								
3450	left	19?	11.5	3.1		9.5	0.60	0.50

Description. External. The shell is of moderate size, and slightly elongated, with low

opisthogyrous beaks placed usually just in front of mid-length and occasionally at mid-length. In outline the anterior part of the shell is high and well rounded, the posterior extremity is high, and obtuse, and the posterior dorsal slope moderately concave, sloping at 120° from the anterior dorsal margin. The lunule is not visible. The escutcheon is gently concave, bounded by strong umbonal ridges, and raised posteriorly along the mid-line. Preservation is too poor to show whether an inner escutcheon ridge is present or not.

More than forty costae occur on the larger shells, but the poor preservation does not allow the fine costae over the umbo to be counted. They lie parallel to the ventral margin. Crests are sharp, and lie about 0.75 mm. apart near the ventral margin, separated by wide flatly concave interspaces. The costae are crossed by fine oblique lirae passing postero-ventrally from the dorsal margin.

Internal. The number of teeth is uncertain. The anterior adductor muscle impression is rounded in outline and lies close to the anterior end of the hinge. The posterior scar is elongately oval, and is placed on the umbonal ridge, next to the escutcheon. Muscle scars below the umbones are obscure. A low internal umbonal ridge is present in TM 3500 and 3501, with a rounded scar in TM 3445.

Resemblances. The New Zealand specimens agree well in shape, size, and ornament with the distinctive species described as *Nuculana ovata* by Laseron. The types have been examined at the Australian Museum, Sydney. The chief differences are that the Australian specimens are slightly more inflated, and the beak more posteriorly placed than in some but not all of the New Zealand specimens. The costae appear to be weaker on the New Zealand specimens than in the Australian types, but this is probably because the New Zealand specimens are decorticated. The spacing of the costae is the same in both series of specimens.

P. ovata is short and high like *Phestia inflatiformis* Chernyshev 1951, pl. 1, figs. 9–11, but has a faint lunular depression and broad inner escutcheon ridges enclosing an unusually wide and long inner escutcheon. Specimen F 41408 at the Australian Museum has two umbonal muscle scars.

Nuculana thomasi Dickins 1956, pl. 1, figs. 1, 2, 10 from the upper Artinskian Norton Greywacke and Kungurian Coolkilya Greywacke of Western Australia is less inflated than the types of *ovata*, and is distinguished from the New Zealand specimens by the higher beak, a low depression near the posterior extremity, and finer costae. No inner escutcheon ridge is recorded by Dickins in this species, which therefore might belong to *Phestia*.

Leda obesa peruviana Thomas 1928, pl. 6, fig. 5; pl. 7, figs. 3, 3a from Peru is close, but has a more opisthogyrous beak and more concave posterior dorsal margin.

Polidevcia antequadrata sp. nov.

Plate 96, figs. 13–15

Material. A left valve and six right valves from GS 6071, partly decorticated, and the shell replaced by chlorite. Two right valves from GS 6072 and an entire specimen and a left valve from GS 7347 might be conspecific.

Horizon. Mangarewa Formation, GS 6071, 6072, ? 7347.

Holotype. TM 3441, GS 6071, Pl. 96, fig. 13.

Paratypes. TM 3433, 3435, 3454, 3484, 3487, 3481, GS 6071; TM 3460, GS 6072.

Diagnosis. Beaks posteriorly placed, broad, anterior portion large and subquadrate, posterior portion narrow and long. Costae concentric.

Dimensions in mm.

<i>Specimen (TM)</i>	<i>Valve</i>	<i>Length (L)</i>	<i>Height (H)</i>	<i>Width</i>	<i>Umbonal angle</i>	<i>Umbo from anterior (U)</i>	<i>H/L</i>	<i>U/L</i>
GS 6071								
3433	right	22?	10.3	4	90°	11.2	0.46	0.5
3481	left	23.5	10.5	3	95°	12.8	0.44	0.54
3435	right	25.5	13	4.5	80°	14.5	0.54	0.56
3441	right	27.3	11.5	4.7	100°	15.1	0.42	0.55
GS 6072								
3482	right	8.8	4.7	1.8	85°	6	0.53	0.68
GS 7347								
3461	left	14	8	2	100°	8	0.57	0.57
3507	left	19	10.3	3.4	90°	12	0.54	0.63

(TM 3433 and 3435 are internal moulds)

Description. External. The shells are elongated in outline with a large subquadrate anterior portion, and low weakly opisthogyrous beaks. The posterior dorsal slope forms an angle of 100° with the anterior margin and is highly concave in outline. The posterior portion is attenuated, with a moderately low, but not pointed, extremity. The anterior umbonal ridge encloses a poorly defined lunular depression, and the posterior umbonal ridge encloses a narrow concave escutcheon, which is subdivided by a low inner escutcheon ridge passing back from each umbo. A low ridge is formed along the posterior part of the mid-line within the escutcheon.

Ornament is composed of low costae parallel to the ventral margin, two to three occurring in 2 mm. They are crossed by striae which pass obliquely back to the ventral margin.

Internal. There are at least eight posterior teeth and five anterior chevron teeth in TM 3435, but the full number is unknown. The chondrophore is well seen in TM 3487.

The anterior adductor impression is shallow, and oval in some specimens, rounded in others. The posterior scar is more deeply impressed and elongate. A shallow internal ridge is seen on the umbonal flanks of TM 3433 and 3435, and possibly has a muscle scar in TM 3435.

Variation. The specimens from GS 7347 agree moderately in shape with those from GS 6071, but the beaks are very posteriorly placed. Ornament is not preserved.

Resemblances. This species is similar in ornament to *Polidevcia ovata* (Laseron) but the anterior part of the new species is longer, and more subquadrate in shape, the beak is more acute, and more posteriorly placed, the posterior dorsal slope more concave in outline, and the posterior part of the shell narrower and the ventral margin less rounded. Also the anterior adductor scar seems to be less impressed than in *ovata*.

No known overseas species appears to be very close.

Polidevcia nodulosa sp. nov.

Nuculana concinna, Fletcher non Dana 1945, p. 305, pl. 22, figs. 3–5.

Horizon. Branxton subgroup, New South Wales.

Holotype. Specimen figured by Fletcher (1945, pl. 22, figs. 4, 5), F 39313, Australian Museum.

Diagnosis. Moderately elongated, high shells with well-spaced strong costae, lunule and inner escutcheon outlined by low nodules.

Remarks. I am proposing a new species for the well-preserved Branxton specimens described as *Nuculana concinna* (Dana) by Fletcher (1945, pl. 22, figs. 3–5). Fletcher (1945, p. 305) has already recorded his hesitation in referring them to Dana's species. *Nucula concinna* Dana (1847, p. 157; 1849, p. 699, pl. 7, fig. 4) is based on an internal mould with the ornament and escutcheon destroyed. It came from the Allandale Formation, Harper's Hill (Sakmarian). Fletcher's specimens came from the Branxton beds at Abermain No. 3 shaft, near Cessnock (upper Artinskian), and are thus significantly younger than Dana's form. Compared with *N. concinna* they have a lower and possibly more extended posterior portion, with the posterior dorsal slope much more concave in outline. The escutcheon is wider in the younger species, and the umbonal angle lower by 20°. The outstanding characteristic of the new species is the perforated nodules which lie just outside the inner escutcheon ridge, as is well shown in Fletcher 1945, pl. 22, fig. 5. The nodules also outline the lunule, though not shown in the figure. They probably represent an extreme elongation of the dental sockets (Trueman 1952; McAlester 1963).

The new species is close in several respects to the specimens described as *Nuculana darwini* (de Koninck) by Fletcher (1945, pl. 21, figs. 1, 2; pl. 22, figs. 1, 2) from the Abermain No. 3 shaft and the Caledonian shaft near Cessnock, Hunter Valley. Nodules outline the inner escutcheon in these specimens but are not seen around the lunule. Costae are finer than in the new species, the posterior part of the shell is longer, and the posterior dorsal slope slightly less concave in outline.

Possible occurrence in New Zealand. A specimen (Pl. 96, fig. 16) from GS 6072, Mangarewa Formation, New Zealand, might be conspecific with *P. nodulosa*. It compares moderately well in shape and size, but the escutcheon, lunule, and ornament are poorly preserved, so that the identification lacks certainty.

Genus NUCUNDATA gen. nov.

Type species. *Nucundata undata* sp. nov.

Diagnosis. Short or elongate Phestiinae, characterized by costae which are oblique to the ventral margin behind the beaks. Anterior to the beak the costae are concentric, and the two sets in several species meet to form an inverted 'V' under the umbones. Inner escutcheon narrow, anterior, limited by ridges. Teeth taxodont, subequal in number before and behind the beak, especially fine posteriorly above the chondrophore. Short internal ridge on umbonal flank, with at least one muscle scar.

Discussion. A minor change in ornament occurred in a New Zealand stock of Phestiinae, comparable to but less drastic than that shown by the Australasian genus *Glyptoleda*

Fletcher, and probably equally short-lived. The change simply emphasized tangential instead of concentric ornament. A Kaibab species *Nuculana obesa* White from United States seems to have identical ornament (Chronic 1952, pl. 6, figs. 1-3).

Nucundata undata sp. nov.

Plate 97, figs. 1-3; text-fig. 4A

Material. One right and two left valves and other fragments from GS 6071. Two left valves and a right valve from GS 6072; two other left valves and two right valves might be conspecific. A left valve from GS 7811. An external fragment of a left valve from GS 3616. Lunule and escutcheon obscured, and ornament abraded in some specimens.

Horizon. Mangarewa Formation, GS ? 3616, 6071, 6072, 7811.

Holotype. TM 3503, GS 6071, Pl. 97, figs. 1, 2.

Paratypes. TM 3494, 3525, 3834, GS 6072; TM 2333, 3502, 3476, GS 6071.

Diagnosis. Anterior portion prominent, moderately rounded, beak subcentral, posterior portion truncate. An inverted V is formed by the costae, which are concentric near the anterior margin and oblique behind the beak.

Dimensions in mm.

<i>Specimen (TM)</i>	<i>Valve</i>	<i>Length</i>	<i>Height</i>	<i>Width</i>	<i>Umbonal angle</i>	<i>Umbo from anterior</i>
			GS 6071			
3503	left	15	10	3	115°	7.3
3502	left	16	9	3.5	?100°	8
3476	right	19	11	3.4	110°	9.3
			GS 6072			
3494	left	16.5	9	3.3	?90°	9.5
3525	left	19	—	3.4		10.3
3495	left	19.5	11	2.7	90°	6

(TM 3525 is an internal mould)

Description. External. The shell is short and moderately high, with a well-rounded ventral margin, subrounded anterior portion, and tapered posterior portion. The beak lies just in front of mid-length, and the posterior dorsal slope is moderately concave, and forms an angle of 125° with the anterior dorsal margin.

The lunule is very shallow, and the escutcheon more concave, and limited by an

EXPLANATION OF PLATE 97

Figs. 1-3. *Nucundata undata* gen. and sp. nov., ×2. 1, 2, External cast and internal mould of holotype, left valve TM 3503, GS 6071. 3, Left valve TM 3525, GS 6072.

Fig. 4. *Nucundata* aff. *undata* sp. nov., ×2. Right valve TM 3475, GS 6072.

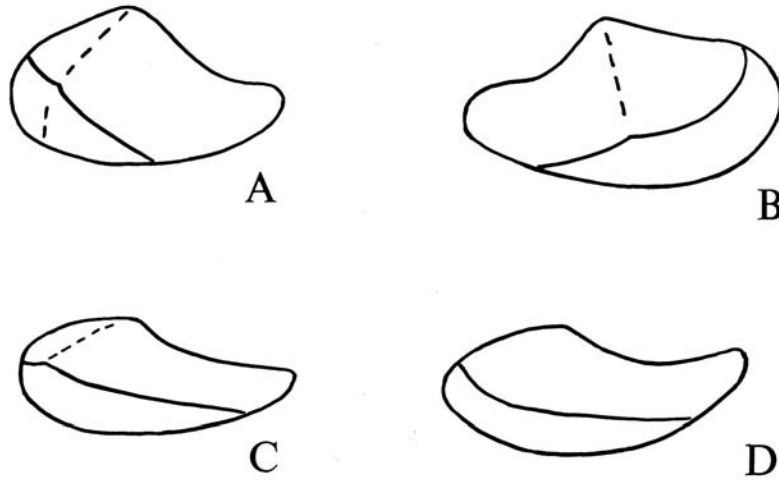
Fig. 5. *Nucundata truncata* sp. nov., ×2. Holotype, TM 3576, GS 6071.

Figs. 6-13. *Nucundata obliqua* sp. nov., ×2. 6, 8, Holotype, external cast, valves slightly displaced in fig. 6, TM 3440, GS 6072. 7, 11, Right and left valves of TM 3442, GS 6072. 9, Left side of TM 3453, GS 6072. 10, Part of right valve TM 3452, GS 6072. 12, Dorsal view of internal mould, TM 3453, GS 6072.

Figs. 14-17. *Nucundata prolonga* sp. nov., ×2. 14, TM 3459, GS 6071. 15, Internal mould, TM 3466, GS 6071. 16, Holotype TM 3470, GS 6071. 17, TM 3468, GS 6071.

umbonal ridge on each side. Both lunule and escutcheon are comparatively obscure. TM 3835 has a low inner escutcheon ridge.

Ornament is comprised of about forty-five fine sharp-crested and closely spaced costae, three occurring in 1 mm. near the ventral margin. They form a shallow inverted V with the axis close to the anterior margin and inclined anteriorly from the umbo at 50° from horizontal. The costae forming the anterior limb of the V are concentric, parallel to the ventral margin; the costae of the posterior limb turn sharply to pass obliquely to the ventral margin, approximately parallel to the posterior dorsal slope. Traces of fine vertical striae are also visible, ten occurring in 1 mm.



TEXT-FIG. 4. Holotypes of New Zealand species of *Nucundata*, showing the course of the costae. A—*N. undata* sp. nov.; B—*N. truncata* sp. nov.; C—*N. obliqua* sp. nov.; D—*N. prolonga* sp. nov.; $\times 2$. The dashed line marks the axis of the inverse V.

Internal. The dentition is taxodont, with at least twelve anterior and ten posterior chevron teeth in the holotype. The chondrophore lies ventral to the umbonal teeth and the posterior teeth below the umbo are particularly small. TM 2333 also has twelve anterior and at least ten posterior teeth, with the chondrophore ventral to the teeth.

The anterior adductor muscle impression is subquadrate in shape, and the posterior scar is better defined, elliptical, and placed behind the last tooth. A narrow internal umbonal ridge is present but a muscle scar cannot be recognized with certainty.

Variation. Specimens TM 3835, 3475, 3490, 3495 from GS 6072 and the one from GS 3616 are tentatively included in the species because they have the same ornament. They differ from the holotype in having a more anterior beak, higher shell, and more rounded anterior and ventral margins.

Resemblances. This species shows some resemblance to *N. obesa* White 1879 from the Kaibab formation. As in the New Zealand form this species has fine close costae, which intersect the ventral margin obliquely, and may even form a very faint inverted V

(Chronic 1952, pl. 6, fig. 1*a*). The American species differs in shape, with a more rounded ventral margin, more concave dorsal slope behind the beak, and more extended posterior extremity.

Tellinomya darwini Koninck 1877, pl. 16, fig. 9; Fletcher 1945, pl. 21, figs. 1–2; pl. 22, figs. 1–2 from the Branxton beds of New South Wales is close in outline. The neotype in particular compares well with the holotype of *undata*, except for a slightly less concave posterior dorsal slope. The ornament differs, for the costae of Koninck's species do not form a V.

Nucundata truncata sp. nov.

Plate 97, fig. 5; text-fig. 4B

Material. Two left valves and eight right valves. Several show parts of the hinge and musculature. Since only two (TM 3575, 3576) have ornament the remainder are tentatively identified by their shape.

Horizon. Mangarewa Formation, GS 6071.

Holotype. TM 3576, Pl. 97, fig. 5.

Paratypes. TM 3575, 3477, 3479–80, 3486, 3488.

Diagnosis. Shell with very large quadrate anterior portion, beak opisthogyrous, narrow, posteriorly placed, posterior portion truncate, short. Costae as in *N. undata*, with the crest of the V more posteriorly placed.

Dimensions in mm.

<i>Specimen</i> (TM)	<i>Valve</i>	<i>Length</i> (L)	<i>Height</i> (H)	<i>Width</i>	<i>Umbonal</i> <i>angle</i>	<i>Umbo from</i> <i>anterior (U)</i>	<i>H/L</i>	<i>U/L</i>
3575	right	23.5	13.5	4.5	78°	15.8	0.57	0.67
3479	left	23.5?	14	4.3	80°	15.4	0.59	0.65
3576	right	26.5?	14.7	4.7	80°	15.2	0.55	0.57
3480	right	28.0	14.5	4.5	75°	16.5	0.55	0.59

(TM 3479 is an internal mould)

Description. External. The anterior part of the shell is large and subrectangular in outline, the beaks are opisthogyrous and narrow, and the posterior extremity sharply tapered. The posterior dorsal slope is highly concave in outline, and the ventral margin little rounded. The escutcheon is deep but poorly known. Ornament comprises fine undulating costae, two in 1 mm. near the ventral margin. Anteriorly the costae lie parallel to the ventral margin, but below the beak they turn sharply to lie parallel to the posterior dorsal margin and intersect the ventral margin obliquely. In TM 3575 the oblique costae intersect a peripheral band of costae which lie parallel to the ventral margin.

Internal. In TM 3478 twelve chevron teeth lie in front of the chondrophore, and about fifteen behind: over the chondrophore the posterior teeth are very fine. The anterior adductor scar is rounded, the posterior impression elliptical. A broad internal ridge passes forward over the umbonal flanks with possibly two shallow depressions at the ventral end.

Resemblances. The species is akin to *Nucundata undata* in its ornament, but the crest of the V formed by the costae lies below the beak, not close to the anterior margin

(text-fig. 4). The shape of the two species differs considerably, *N. truncata* having a much larger anterior portion. It thereby approaches *Polidevcia antequadrata* sp. nov., from which it is distinguished by the higher outline with more posteriorly placed, opisthogyrous, narrow beaks, the short low posterior extremity, and different ornament.

Nucundata obliqua sp. nov.

Plate 97, figs. 6-13; text-fig. 4C

Material. Eighteen specimens with valves conjoined, and three right and two left valves from GS 6072. All are fragmentary, and the hinge not well known. The shell is replaced by chlorite. Fragmentary specimens with similar ornament come from GS 3616 and 7351, and poor specimens from GS 7353. A specimen with valves conjoined from GS 7808.

Horizon. Mangarewa Formation, GS 6071, 7353, ? 3616, ? 7351, 7808.

Holotype. TM 3440, GS 6072, Pl. 97, figs. 6, 8.

Paratypes. TM 3430, 3442, 3446-8, 3451-3, 3455, 3458, GS 6072.

Diagnosis. Moderately elongate species, with subquadrate anterior portion, low umbones just in front of mid-length, and strong costae, oblique to ventral margin, in some specimens forming a V with its limbs diverging widely.

Dimensions in mm.

<i>Specimen</i> (TM)	<i>Length</i> (L)	<i>Height</i> (H)	<i>Width</i>	<i>Umbonal</i> <i>angle</i>	<i>Umbo from</i> <i>anterior (U)</i>	<i>H/L</i>	<i>U/L</i>
GS 6072 (both valves)							
3458	19	9	4.5		8.5	0.47	0.44
3440	22.6	9.7	74.6	120°	9.5	0.43	0.42
3446	22.7	9.8	—	—	10.5	0.44	0.46

Description. External. The shells are elongate, with a large subquadrate anterior portion, low umbones situated just in front of mid-length, and an attenuated posterior portion. The umbones are incurved, contiguous, and opisthogyrous, the anterior margin well rounded, and the posterior dorsal slope moderately concave in outline, inclined from the anterior margin at 135° in the holotype, but at 115° in other specimens. It makes an angle of 30° to 35° with the ventral margin. The posterior extremity is obtusely rounded. The lunule is shallow, narrow, and well defined by low lunular ridges in TM 3455. The shell is raised a little along the commissure in front of the umbones, and is also raised behind the umbones. The escutcheon is enclosed by well-defined narrow posterior umbonal ridges and is divided by inner escutcheon ridges which pass back from the umbones to meet the mid-line ridge less than midway between the umbones and posterior end of the shell.

About thirty-five to forty costae are present, with sharply raised crests, separated by flatly concave interspaces. Over the umbones the costae are fine, sixteen occurring in 3 mm.; near the ventral margin three to four costae occur in 3 mm. In outline the costae are slightly irregular, and on some specimens form a low V below the beak near the anterior margin (text-fig. 4). They are not parallel to the ventral margin, but intersect it at 10° to 15°. Dorsal costae turn abruptly forward across the umbonal ridges and escutcheon to intersect the dorsal commissure. The costae are crossed by very fine capillae or striae, which slant from the anterior dorsal margin to the posterior ventral margin, twelve to fourteen occurring in 1 mm.

Internal. The hinge is not well known. Ten chevron teeth lie in front of the umbones in TM 3452 and about sixteen behind in TM 3453. The chondrophore is not visible.

The anterior adductor scar is impressed, moderately large, and oval or triangular or vertically elongated in shape, and the posterior impression lies close to the posterior extremity and is oval or subrectangular in outline, with the long axis parallel to the length of the shell. The pallial line lacks a sinus (TM 3458). The umbonal ridge is seen faintly in some specimens but the small muscle scars cannot be distinguished.

Variation. Specimens from GS 6072 vary a little in the concavity of the posterior umbonal slope, and in a few specimens the posterior extremity is upturned and is sharply ended in some, but blunt in others. The specimen from GS 7808 has a rounded anterior portion.

Resemblances. *Tellinomya darwini* Koninck 1877, pl. 16, fig. 9, as redescribed by Fletcher (1945) from the Maitland beds of New South Wales, is close in general appearance. Fletcher's specimens have been examined at the Australian Museum, Sydney. They are elongated shells with a low beak in front of mid-length, and differ from the New Zealand species in being higher with a more rounded anterior portion and a more gently concave posterior dorsal slope, which is inclined more from the anterior dorsal margin. The inner escutcheon ridge is nodular and the costae are finer. In most specimens of *darwini* the costae are parallel to the ventral margin, although in the neotype F 41409 (Fletcher 1945, pl. 21, fig. 1) and in F 41411 the costae intersect a band of concentric costae near the ventral margin. A few specimens from the Maitland Colliery shaft at Cessnock are long like the new species. But these are only a few individuals; the collections as a whole differ consistently.

The subquadrate anterior of *Nucundata obliqua* recalls that of *Polidevcia antequadrata* sp. nov., but *N. obliqua* has a more anterior beak, stronger and oblique costae and wider umbones.

Nucundata prolonga sp. nov.

Plate 97, figs. 14-17; text-fig. 4D

Material. Five right valves and four left valves, most fragmented, shell replaced by chlorite.

Horizon. Mangarewa Formation, GS 6071.

Holotype. TM 3470, Pl. 97, fig. 16.

Paratypes. TM 3459, 3462, 3464-6, 3468, 3469, 3489.

Diagnosis. Beak anteriorly placed, low; anterior shell short and rounded, posterior portion extended, upturned, ventral margin well rounded. Costae oblique, not forming an inverted V.

Dimensions in mm.

<i>Specimen (TM)</i>	<i>Valve</i>	<i>Length (L)</i>	<i>Height (H)</i>	<i>Width</i>	<i>Umbonal angle</i>	<i>Umbo from anterior (U)</i>	<i>H/L</i>	<i>U/L</i>
3466	left	20.5	11.5	4.5	?100°	8	0.56	0.39
3470	right	21+	10.7	4		8.3	0.51	0.39
3459	left	24	10.7	+3	?130°	9.7	0.44	0.38
3462	right	25	?12	4		10.3	0.48	0.41

(TM 3466 and 3470 are internal moulds)

Description. External. The shells are elongate, with anteriorly placed, low, opisthogyrous beaks, and a moderately short, well-rounded anterior portion. The ventral margin is rounded, the posterior extremity prolonged and upturned, the posterior dorsal margin gently concave near the beak and inclined from the anterior dorsal margin at 140° . A shallow lunular depression lies in front of the beaks, and a broad, deeply concave escutcheon lies behind the beaks, bordered by umbonal ridges, raised a little along the mid-line, and subdivided on each side by an inner escutcheon ridge.

Costae are fine, sixteen occurring in the lower 6 mm. of TM 3459, and they intersect the ventral margin obliquely. Traces of fine more oblique striae are also seen.

Internal. About fourteen or more posterior teeth are present, but the number of anterior teeth is obscure. A chondrophore is seen in TM 3465. Adductor muscle scars are moderately impressed, the anterior scar being ovoid, the posterior elongate, and placed well behind the beak. An internal umbonal ridge with a possible scar is faintly indicated in TM 3468.

Resemblances. This form comes closest to *N. obliqua* sp. nov., being roughly similar in the position of the beak and in the oblique ornament. Differences are that the anterior part of the shell and the ventral margin are more rounded in *N. prolonga* and the posterior extremity higher. Also the costae are finer. The differences are consistent, with little evidence for convergence between the two forms.

Several Australian forms come close in shape. ? *Polidevcia etheridgei* (Johnston 1888, pl. 13, fig. 12) from Porters Hill, Hobart, has a rounded anterior portion, a well-rounded ventral margin, an upturned posterior extremity and beak placed well forward at 0.36 of the shell length. Differences are that the posterior dorsal slope of *etheridgei* is more gently concave, and the beak more prominent, and the costae lie parallel to the margin.

The shell described as *Nuculana lyonsensis* by Dickins 1956, pl. 1, figs. 7-9 is close in appearance, apart from being larger in size, and having a more pointed posterior extremity, and less rounded posterior ventral margin, and costae parallel to the ventral margin.

A species recorded as *Glyptoleda buarabae* by Campbell 1951, from the Biarville beds of Queensland has a short subrounded anterior portion, but the Queensland shell tapers more posteriorly, and its posterior dorsal margin is usually very gently concave in outline, and the costae are coarser and more wavy than in the New Zealand form.

Polidevcia nodulosa sp. nov. is moderately close in shape, though the beaks are more anteriorly placed than in this species, and the shell is higher, the posterior dorsal slope straight rather than concave, and the ventral margin less rounded in outline. No fine oblique striae are seen in this species.

Genus GLYPTOLEDA Fletcher 1945

Type species. *Glyptoleda reidi* Fletcher 1945, by original designation.

Diagnosis. Shells resembling *Polidevcia* in shape and dentition, distinguished by costae which form a V pointing towards the ventral margin, and presence of outer escutcheon ridges (text-fig. 2).

Glyptoleda glomerata Fletcher 1945

Text-fig. 5

Glyptoleda glomerata Fletcher 1945, p. 300, pl. 20, figs. 1-3.*Glyptoleda glomerata* Campbell 1953, p. 21, pl. 6, figs. 13, 14; pl. 3, figs. 27, 28; pl. 7, fig. 15.*Glyptoleda* Fletcher 1958b, p. 363, fig.*New Zealand material.* A right valve, part of the anterior shell destroyed.*Horizon.* Letham Formation, GS 7344. Ingelara Shale, Queensland.*Holotype.* Specimen figured by Fletcher 1945, pl. 20, figs. 1-3.*Diagnosis.* Beak posteriorly placed, anterior portion large and subquadrate in outline, posterior portion tapering rapidly. Costae form a well-defined V, with its axis behind the beak, and minor zigzags.*Dimensions* in mm.

Specimen (TM)	Length (L)	Height (H)	Width	Umbonal angle	Umbo from anterior (U)	H/L	U/L
3437	12	6.8	2.6	80°	7.5	0.57	0.62

Description and resemblances. The New Zealand specimen has the shape and ornament characteristic of *G. glomerata*. In the holotype examined at the Australian Museum, Sydney, the posterior dorsal slope is less steeply inclined by 20° from the anterior dorsal margin, but specimens figured by Campbell have the same concave posterior dorsal slope as in the Letham specimen. Costae are twice as coarse in the Ingelara specimens, suggesting that the New Zealand specimen is mature in spite of its small size, as if dwarfed by an unfavourable environment.*Glyptoleda intricata* sp. nov.

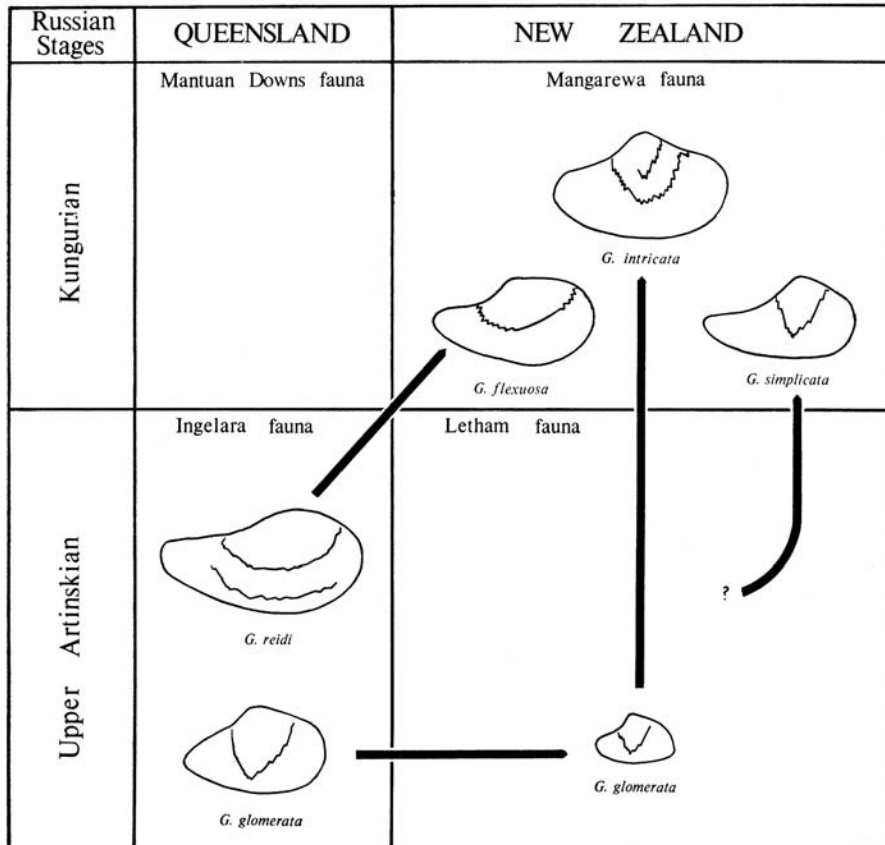
Plate 98, figs. 1-5

Material. Four specimens with valves conjoined and other fragments, all partly decorticated and broken. Shell replaced by chlorite.*Horizon.* Mangarewa Formation, GS 6072.*Holotype.* TM 3508, Pl. 98, figs. 1-3.*Paratypes.* TM 3517, 3509, 3524.*Diagnosis.* Close to *G. glomerata*, distinguished by more erect umbones and higher posterior portion, costae form a V with its axis placed well forward and highly complicated by minor zigzags.*Dimensions* in mm.

Specimen (TM)	Length (L)	Height (H)	Both valves, partly decorticated			
			Width	Umbo from anterior (U)	H/L	U/L
3517	18.5	10	6.5	11.5	0.53	0.62
3524	24	?15.5	8	13.5	0.64	0.56

Description. External. The specimens are subrectangular in outline, with a prominent anterior portion subquadrate in outline, moderately rounded ventral margin, and high

posterior extremity. The umbones are placed just behind mid-length and are suberect and opisthogyrous. The umbonal angle in TM 3518 is only 60°, and the posterior dorsal slope is highly concave in outline, and makes an angle of 100° with the anterior dorsal margin.



TEXT-FIG. 5. Distribution and relationships of *Glyptoleda* in Queensland and New Zealand. The sketch of the New Zealand *Glyptoleda glomerata* is from the actual specimen, the others are based largely on holotypes, and all are approximately natural size.

The lunule is shallow and concave, weakly defined by an umbonal ridge on each side and raised along the mid-line. Posteriorly the mid-line is raised into a high ridge. The escutcheon is delimited by narrow outer escutcheon ridges which lie within the umbonal ridges, and is subdivided by the inner escutcheon ridges which converge from the umbones at 40°, to meet the mid-line ridge half way between the umbones and posterior extremity.

The costae are about 0.75 mm. apart, with rounded symmetrical crests, and form a complex V, with the axis inclined forward from the beak, except in TM 3518, in which it is inclined posteriorly. The base of the V is clearly defined for 4 or 5 mm. from the beak, and then becomes obscured by ten to twelve intricate small v's, and the limbs of the large V also become complex. Behind the beaks the costae turn posteriorly across the posterior umbonal ridge, and within the outer escutcheon form a small v with base towards the beak: they are obscured on the inner escutcheon, but seem to turn back into the mid-line.

Internal. Several taxodont teeth lie in front of and behind the umbones in TM 3509, but the full number is not known. The anterior adductor impression is oval with the long axis vertical, and lies close to the anterior cardinal extremity. The posterior scar is more faintly impressed, and is elongated along the posterior umbonal ridge on which it lies. Umbonal scars and the pallial line are uncertain.

Resemblances. The new species comes close to *G. glomerata* Fletcher from the Ingelara Shale of Queensland, and the Letham Formation, New Zealand, and may have descended from this species. The two have the same basic pattern of ornament, and a large sub-quadrate anterior portion and the escutcheon set within the outer escutcheon ridges. Unlike *G. glomerata* the new species has a more erect beak and a high posterior extremity, whereas that of *glomerata* tapers rapidly. In *G. glomerata* the axis of the V is usually inclined posteriorly from the beak. In the new species it is inclined forwards and is far more intricately zigzagged (text-fig. 5).

Glyptoleda flexuosa sp. nov.

Plate 98, figs. 6-12

Material. Two left valves, a right valve, and other fragments with shell only partly replaced by chlorite from GS 7811. A left and right valve from GS 7812, and two specimens with valves conjoined, two left valves and three right valves from GS 6072, and one left valve and three right valves from GS 6071, all somewhat fragmentary and decorticated, with the shell replaced by chlorite.

Horizon. Mangarewa Formation, GS 6071, 6072, 7811, 7812.

Holotype. TM 3511, GS 6072, Pl. 98, figs. 7-9.

Paratypes. TM 3444, 3456, 3485, 3526, GS 6072; TM 3434, 3516, GS 6071; TM 3531, 3625, 3626, GS 7811.

Diagnosis. Moderately elongate shells with subrounded anterior portion, beaks placed just in front of mid-length. V formed by costae highly opisthocline, and not well defined.

EXPLANATION OF PLATE 98

Figs. 1-5. *Glyptoleda intricata* sp. nov., $\times 2$. 1-3, Left, right, and dorsal aspects of holotype, TM 3508, GS 6072. 4, Left aspect of internal mould TM 3524, posterior beak destroyed, GS 6072. 5, Right valve of TM 3509, GS 6072.

Figs. 6-12. *Glyptoleda flexuosa* sp. nov., $\times 2$. 6, External cast of TM 3626, GS 7811. 7, 8, 9, Holotype TM 3511, GS 6072. 10, Internal mould, TM 3434, GS 6071. 11, TM 3526, GS 6072. 12, Internal cast of TM 3531, GS 7811.

Figs. 13-15. *Glyptoleda simplicata* sp. nov., $\times 2$. Holotype, dorsal, left and right aspects, TM 3529, GS 6072.

Dimensions in mm.

Specimen (TM)	Valve	Length (L)	Height (H)	Width	Umbonal angle	Umbo from anterior (U)	H/L	U/L
GS 6072								
3526	left	+19	10.8	3	95°	8		
3511	right	23	12.4	3.7		11.9	0.53	0.51
GS 6071								
3434	right	21.5	12.3	3.7		10	0.57	0.47
GS 7811								
3625	left	14.4	7.7	2.5		6.8	0.52	0.47
3626	left	21?	11.6	3.1		12.5?	0.55	0.59
3531	right	25	11.9	3.2	95°	11.8	0.44	0.44

(TM 3434 is an internal mould)

Description. External. The anterior part of the shell is relatively large and moderately subquadrate in outline, the anterior and ventral margins are well rounded, and the posterior part is moderately high and obtusely terminated. The beaks are low, opisthogyrous and incurved, and placed usually in front of mid-length. The posterior dorsal slope is inclined at 135° from the anterior dorsal margin near the beak, and is concave but not upturned posteriorly. The lunule is shallow, the escutcheon well defined, raised along the mid-line, and limited by an umbonal ridge that is particularly low in the specimens from GS 7811 and 7812. There does not seem to be any outer escutcheon ridge in specimens from GS 7811. The escutcheon is divided by short inner escutcheon ridges passing back from the umbo. Costae are fine, two occurring in 1 mm. The axis of the V formed by the costae is posteriorly inclined and lies roughly parallel to the posterior umbonal slope. Anteriorly the costae are concentric, parallel to the ventral margin. They then pass into a wide band of small v's below the umbo, before turning vertically to pass forward to the edge of the escutcheon. Within the escutcheon they turn even more sharply forward toward the hinge.

Internal. The hinge is well exposed in TM 3531 from GS 7811. Fifteen or more teeth lie in front of the beak and eighteen lower less chevron-shaped teeth behind (Pl. 98, fig. 12). The chondrophore is exposed in TM 3456 from GS 6072. The anterior adductor scar is large and subrectangular with the long axis vertical. The posterior adductor scar is placed well back from the beak and is small, and elongated along the posterior umbonal ridge on which it rests. Umbonal muscle scars and pallial line are not known for certain.

Variation. Most of the shells from GS 6072 have a slightly more prolonged and upturned rostrum than those from other localities.

Resemblances. These specimens differ from *G. intricata* from the same horizon in both shape and ornament. The anterior part of the shell is more rounded, the beaks are less erect and more anteriorly placed, the posterior part of the shell is lower and more prolonged, and the ventral margin more rounded than in *G. intricata*. The costae are finer, and the axis of the V more posteriorly inclined.

The Ingelara form *G. reidi* Fletcher 1945, pl. 19, figs. 1-3; also figured by Campbell 1953, pl. 7, figs. 6-8 is closely allied. *G. reidi* has a somewhat similar anterior portion, and well-rounded ventral margin, though the beaks are more incurved, and the shell

more prolonged posteriorly. The pattern of ribbing is similar, with a vaguely outlined V and many small v's, but the V is usually less posteriorly inclined in *reidi* (text-fig. 5).

Glyptoleda simplicata sp. nov.

Plate 98, figs. 13-15

Material. A specimen with valves conjoined, and three left valves from GS 6072, and three right valves and four left valves from GS 6071, with other fragments.

Horizon. Mangarewa Formation, GS 6071, 6072.

Holotype. TM 3529, GS 6072, Pl. 98, figs. 13-15.

Paratypes. TM 3467, 3514, 3530, GS 6072; TM 2337, 3510, 3515, 3518, 3521-3, GS 6071.

Diagnosis. Moderately elongate high shell with anterior and ventral margins well rounded, beak well in front of mid-length, costae form a simple V with few zigzags, axis inclined slightly back from beak.

Dimensions in mm.

GS 6072							
<i>Specimen</i> (<i>TM</i>)	<i>Valve</i>	<i>Length</i> (<i>L</i>)	<i>Height</i> (<i>H</i>)	<i>Width</i>	<i>Umbo from</i> <i>anterior (U)</i>	<i>H/L</i>	<i>U/L</i>
3514	left	16.5	8?	3.5	7.5	—	0.45
3467	left	18	10.5	4	7.8	0.58	0.43
3530	left	18.2	10.5	3.6	7.1	0.57	0.39
GS 6071							
3515	right	22.3	13.2	4	9.2	0.59	0.41
3523	left	23?	12?	4.2	9.5?	0.52	0.41

(TM 3515 is an internal mould)

Description. External. The shells are elongate, with prominent incurved slightly opisthogyrous beaks of which the umbonal angle measures 95° to 100°. The dorsal anterior margin is almost straight, the anterior and ventral margins well rounded, the posterior extremity obtuse, and the dorsal posterior slope moderately concave, lying at 120° from the anterior dorsal margin, measured just behind the beak. The lunule is deeply concave in front of the beaks, and slightly raised along the mid-line. The escutcheon is bounded by two outer escutcheon ridges, which, as in *G. glomerata* Fletcher and *G. intricata* sp. nov., lie just within the umbonal ridges. It is divided by a pair of inner escutcheon ridges, and raised along the mid-line, much as in *G. glomerata*.

The costae are sharply defined, two or three occurring in 1 mm., and form a well defined V of which the axis curves posteriorly from the umbones. A few zigzags are present.

Internal. Ten posterior teeth are seen in TM 3523, but otherwise the dentition is obscured. The same specimen shows a large anterior adductor impression and an elongate posterior adductor impression situated under the escutcheon near the posterior extremity. In other specimens the muscle scars are faintly impressed and their outlines vague. One specimen, TM 2337, has a narrow short internal umbonal ridge with a small deep scar.

Variation. TM 3522 and 3523 have an angular anterior portion and straight dorsal posterior margin compared with other specimens. The ornament is like that of the holotype as far as can be seen, but is too obscure to allow certain identification.

Resemblances. In ornament these specimens resemble *G. glomerata* Fletcher but are distinguished by their different shape, having a more rounded anterior and more prolonged posterior portion. Some of the Ingelara specimens figured by Campbell (1953) are moderately close in appearance, but seem to be broken. Even so, they have a less concave posterior dorsal slope, and the beak is less anteriorly placed. Compared to other *Glyptoleda* from the Mangarewa Formation, this form is easily distinguished both by ornament and shape, having an anterior beak and simple V.

Glyptoleda sp. described by Dickins 1956, pl. 1, figs. 3, 4 from the upper Artinskian Wandagee Formation of the Carnarvon Basin, Western Australia, has somewhat similar ornament and an anterior beak. The posterior dorsal slope is a little less concave than in the new species, and the anterior portion more rounded in outline.

Acknowledgements. Dr. J. M. Dickins, Bureau of Mineral Resources, Canberra, kindly sent literature not available to the writer in New Zealand. I am also indebted to Mr. H. O. Fletcher, Australian Museum, for the gift of a duplicate of *Polidevicia ovata* and to Dr. K. S. W. Campbell, Australian National University, for the gift of specimens of *Glyptoleda*. Photographs are by Mr. S. N. Beatus, New Zealand Geological Survey.

Description of fossil localities

<i>GS locality</i>	<i>Description</i>	<i>Collectors</i>
Letham Formation (upper Artinskian)		
6070	Two chains east of Pack-track in small saddle south of second east branch, Letham Burn. NZMS 1 inch to the mile map sheet, S159. Grid reference 988770, 1945 edition.	A. R. Mutch K. N. Phillips J. B. Waterhouse
6323	Small bluff on south edge of first small north tributary up the first east tributary of Letham Burn. S159/991760.	A. R. Mutch J. B. Waterhouse
7344	Small outcrop at south edge of first small north tributary of the first east tributary of Letham Burn, 20 ft. below GS 6323. S159/990759.	A. R. Mutch J. B. Waterhouse
Mangarewa Formation (Kungurian)		
3616	'Productus Creek', 118 chains at 220° from Letham Trig. S159/994748.	M. V. Rout R. W. Willett
6071	Ridge 10 chains north-north-east of junction of east branch and Letham Burn. S159/989763.	A. R. Mutch J. B. Waterhouse
6072	Ten yards south of GS 6071.	A. R. Mutch J. B. Waterhouse
6074	Second east branch (south fork) of Letham Burn by prominent scarp of conglomerate on edge of beech forest. S159/990770.	M. Hall J. B. Waterhouse
7347	First east branch of Letham Burn, 2 chains west of prominent conglomerate scarp on north side. S159/993758.	A. R. Mutch J. B. Waterhouse
7351	Small outcrop high on west side of ridge across stream from prominent conglomerate scarp on north side of first east branch of Letham Burn. S159/992755.	J. B. Waterhouse
7808	Small promontory north of coral bioherm of GS 6068, 2 chains south of tributary of Letham Burn, north of 'Coral Bluff'. S159/994793.	J. B. Waterhouse
7811	Crest of ridge below the limestone scarp and 1 chain south of GS 6072. Small outcrop only 18 in. square. S159/991763.	M. Hall J. B. Waterhouse
7812	Two chains north of GS 6071, across the tiny creek by 7 yards (second east tributary of Letham Burn) in bluffs 6 ft. high. S159/765990.	M. Hall J. B. Waterhouse

GS locality	Description	Collectors
7813	West edge of beech forest 6 chains south of Coral Bluff in loose scree and solid beds to east, on ridge between stream and swampy stream-let. S159/992777.	M. Hall J. B. Waterhouse
7353	Small outcrop on east side and at the top of the second north branch of Productus Creek. S159/994751.	J. B. Waterhouse

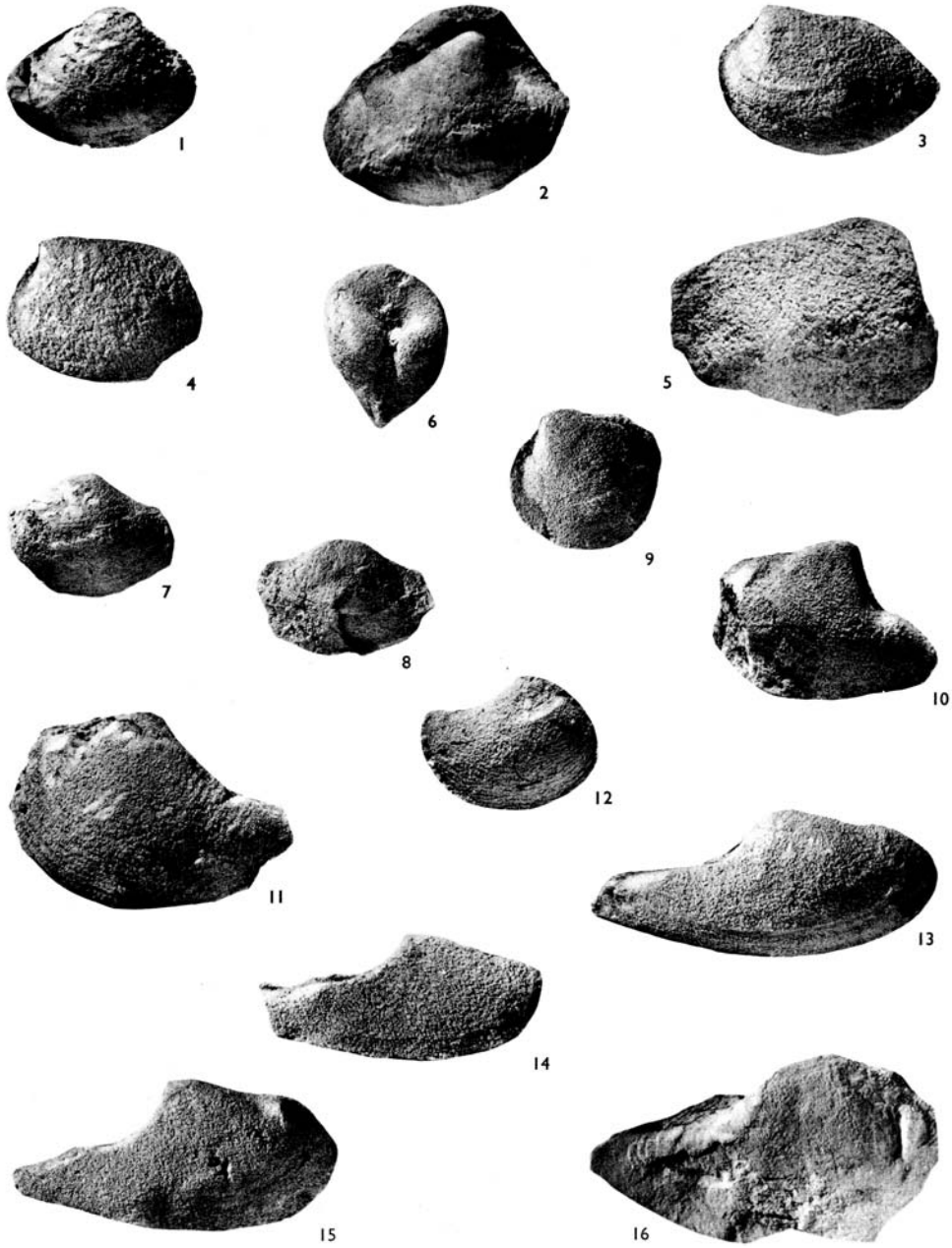
REFERENCES

- BRANSON, C. C. 1930. Paleontology and stratigraphy of the Phosphoria Formation. *Univ. Mo. Stud.* **5** (2).
- CAMPBELL, K. S. W. 1951. The geology of the Cressbrook-Buarabae area. *Univ. Queensland Pap. Dep. Geol.* **3** (17).
- 1953. The fauna of the Permo-Carboniferous Ingelara beds of Queensland. *Ibid.* **4** (3).
- and ENGEL, B. A. 1963. The faunas of the Tournaisian Tulcumba Sandstone and its members in the Werrie and Belvue Synclines, New South Wales. *J. geol. Soc. Aust.* **10** (1), 55–122.
- CHERNYSHEV, V. I. 1951. The family Ledidae from the Coal Measures of the USSR. *Trudy Inst. Geol. Nauk., Strat. and Palaeont., Akad. Nauk. Ukraine SSR.* **2**, 1–20 [in Russian].
- CHRONIC, H. 1952. Molluscan fauna from the Permian Kaibab Formation, Walnut Canyon, Arizona. *Bull. geol. Soc. Amer.* **63**, 95–166.
- CHRONIC, J. 1953. In NEWELL, N. D., CHRONIC, J. and ROBERTS, T. G. Upper Paleozoic of Peru. *Mem. geol. Soc. Amer.* **58**.
- COX, L. R. 1959. The geological history of the Protobranchia and the dual origin of Taxodont Lamellibranchia. *Proc. malac. Soc. London*, **33**, 200–9.
- DANA, J. D. 1847. Descriptions of fossil shells of the collections of the Exploring Expedition under the command of Charles Wilkes, U.S.N., obtained in Australia, from the lower layers of the coal formation in Illawarra. . . . *Amer. J. Sci.* (2) **4**, 151–60.
- 1849. In United States Exploring Expedition during the years 1838, 1839, 1840, 1841 under the command of Charles Wilkes, U.S.N. **10**: Geology, 681–713.
- DICKINS, J. M. 1956. Permian pelecypods from the Carnarvon Basin, Western Australia. *Bur. Min. Resourc. Aust. Bull.* **29**.
- 1963. Permian pelecypods and gastropods from Western Australia. *Bull. Bur. Min. Resourc. Aust.* **63**.
- ELIAS, M. K. 1957. Late Mississippian fauna from the Redoak Hollow Formation of southern Oklahoma. Pt. 3. Pelecypoda. *J. Paleont.* **31**, 737–84.
- FLETCHER, H. O. 1945. A new genus *Glyptoleda* and a revision of the genus *Nuculana* from the Permian of Australia. *Rec. Aust. Mus.* **21**, 293–312.
- 1958. Fossils and their value in Stratigraphy. *Aust. Mus. Mag.* **12**, 361–6.
- GIRTY, G. H. 1909. Paleontology of the Manzamo Group of the Rio Grande Valley, New Mexico. *Bull. U.S. Geol. Surv.* **389**, 41–136.
- 1910. Fauna of the phosphate beds of the Park City Formation in Idaho, Wyoming and Utah. *Ibid.* **436**.
- 1911. On some new genera and species of Pennsylvanian fossils from the Wewoka Formation of Oklahoma. *Ann. N.Y. Acad. Sci.* **21**, 131–4.
- HALL, J. 1858. Palaeontology of Iowa. *Rep. on Geol. Surv. of State of Iowa*, **1** (2), 716–17.
- JOHNSTON, R. M. 1888. *Systematic account of the geology of Tasmania*. Govt. Printer, Hobart.
- KONINCK, L. E. G. DE. 1877. Recherches sur les fossiles paléozoïques de la Nouvelle-Galles du Sud (Australie). *Mém. Soc. Sci. Liège* (2), **6**, 7.
- KOROBKOV, I. A. 1954. Handbook on and systematic guide to the Tertiary Mollusca Lamellibranchia. *State Scient.-Tech. Publishing Agency Oil and Mineral Fuel Lit.* Leningrad, 444 pp., 96 pp. [in Russian].
- KUMPERA, O., PRANTL, F. and RŮŽIČKA, B. 1960. Revision of the Nuculanidae from the Ostrava-Karavíná district (Pelecypoda). *Acta Mus. nat. Prag.* **16B**, 17–123.

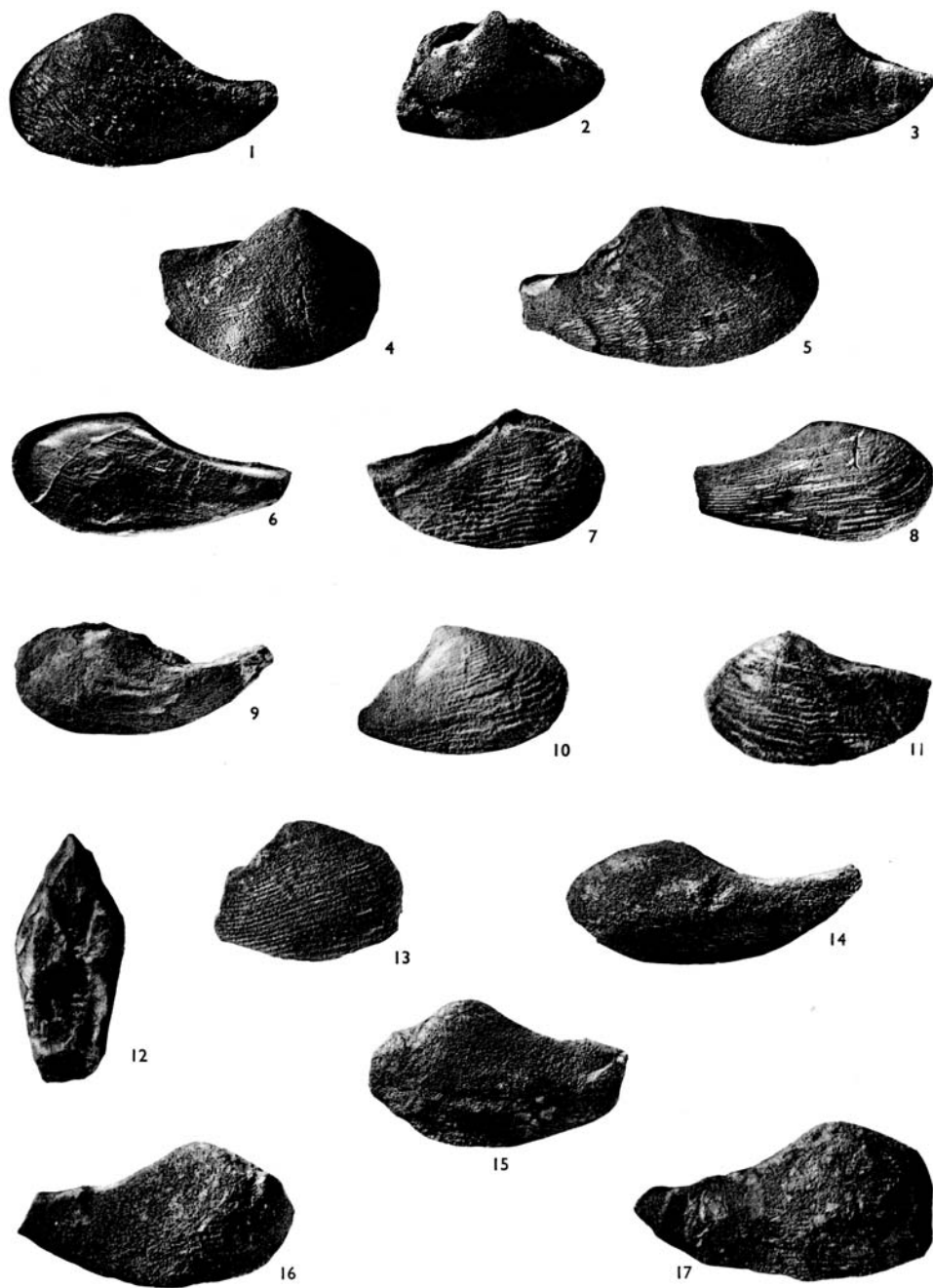
- LASERON, C. F. 1910. Palaeontology of the Lower Shoalhaven River. *J. roy. Soc. N.S.W.* **44**, 190-225.
- LINTZ, J. 1958. The fauna of the Ames and Brush Creek shales of the Conamaugh Formation of Western Maryland. *J. Paleont.* **32**, 97-112.
- MCALESTER, A. L. 1963. Revision of the type species of the Ordovician Nuculoid Pelecypod genus *Tancrediopsis*. *Postilla*, **74**, 1-19.
- OWEN, G. 1959. The ligament and digestive system in the Taxodont bivalves. *Proc. malac. Soc. London*, **33**, 215-23.
- PURCHON, R. D. 1959. Phylogenetic classification of the Lamellibranchia, with special reference to the Protobranchia. *Ibid.* 224-30.
- SCHENCK, H. G. 1934. Classification of Nuculid pelecypods. *Bull. Mus. Hist. nat. Belg.* **10** (20).
- THIELE, J. 1935. *Handbuch der systematischen Weichtierkunde*. Teil 3, Classis Bivalvia. Jena (G. Fischer).
- THOMAS, H. D. 1928. An Upper Carboniferous fauna from the Amotape Mountains, North-western Peru. *Geol. Mag.* **65**, 215-34.
- TRUEMAN, E. R. 1952. Observations on the ligament of *Nucula*. *Proc. malac. Soc. London*, **29**, 201-5.
- WATERHOUSE, J. B. 1960. Some Carnian pelecypods from New Zealand. *Trans. roy. Soc. N.Z.* **88**, 426-42.
- 1963a. Permian gastropods of New Zealand. Pt. 1, Bellerophontacea and Euomphalacea. *N.Z.J. Geol. Geophys.* **6**, 88-112.
- 1963b. The Permian Faunal Succession in New Zealand. *J. geol. Soc. Aust.* **10**, 165-76.
- 1963c. New Zealand species of the Permian bivalve *Atomodesma* Beyrich. *Palaeontology*, **6**, 699-717.
- 1964. Permian stratigraphy and faunas of New Zealand. *Bull. N.Z. geol. Surv.* **72**, 1-101.
- WHITE, C. A. 1879. Palaeontological papers No. 11. Remarks upon certain Carboniferous fossils from Colorado, Arizona, Idaho, Utah and Wyoming, and certain Cretaceous fossils from Colorado, together with descriptions of new forms. *U.S. Geol. Geogr. Survey of the Territories Bull.* **5**, 209-21.
- WILSON, R. B. 1960. A revision of the types of the Carboniferous lamellibranch species erected by J. Fleming. *Bull. Geol. Surv. G.B.* **16**, 110-26.
- YONGE, C. M. 1959. The status of the protobranchia in the bivalve Mollusca. *Proc. malac. Soc. London*, **33**, 210-14.

J. B. WATERHOUSE
 N.Z. Geological Survey,
 P.O. Box 368,
 Lower Hutt, New Zealand

Manuscript received 9 July 1963



WATERHOUSE, Permian Palaeotaxodonta of New Zealand



WATERHOUSE, Permian Palaeotaxodonta of New Zealand



WATERHOUSE, Permian Palaeotaxodonta of New Zealand