Early Middle Cambrian trilobites from the Jigaimara Formation, Arafura Basin, Northern Territory

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Early Middle Cambrian trilobites from the Jigaimara Formation from Elcho, Howard and Banyan Islands in the Arafura Basin, Northern Territory include the species: *Pagetia hainesi* sp. nov., *P.* aff. *edura* Jell, P. sp. indet., *Xystridura templetonensis* (Chapman), *X. altera* Öpik, *X. ?filifera* Öpik, *X.* sp. indet., ptychoparioid sp. 1, ptychoparioid sp. 2, *Oryctocephalites ?reynoldsi* (Reed), *Arthricocephalus* sp. nov. and *?Itagnostus* sp.. All indicate an age of early Templetonian (i.e. predating *T. gibbus*), and indicate a close similarity with the fauna of the Beetle Creek Formation of western Queensland.

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THE ARAFURA BASIN is a mainly offshore Neoproterozoic to Permian sedimentary basin which underlies much of the Arafura Sea to the north of Arnhem Land, Northern Territory. However, the southern margin of the basin does extend onshore up to 80 km inland from the north coast (Fig. 1). The age of these rocks was initially problematic, with suggestions ranging from 'Permo-Carboniferous' (Brown 1908) to Lower Cambrian or Precambrian (Wade 1924; Dunnet 1965). Plumb (1963, p. 6) considered the rocks of the Wessel Group, to which all outcropping units were assigned, to be Cambrian in age because of the presence of the trace fossil *Skolithos* in the Buckingham Bay Sandstone, the basal formation of the Group. Subsequently, McDougall *et al.* (1965) radiometrically dated glaucony from low in the Elcho Island Formation as being late Proterozoic, producing ages of about 770 Ma using the Potassium-Argon system and 790 Ma using the Rubidium-Strontium system. Later, Plumb *et al.* (1976) reported on trilobites discovered by Mr E.W. Parr of Elcho Island Mission. These fossils were stated to have come from the Elcho Island Formation near Warnga Point on Elcho Island and therefore cast doubt on the ages postulated by McDougall *et al.* (1965). Indeed, Plumb *et al.* (1976) stated that the fossils were early Middle Cambrian in age and belonged to the "pre-*Ptychagnostus gibbus* portion of the Templetonian Stage as conceived by Öpik" (1968).

Regional mapping by the Northern Territory Geological Survey and the Australian Geological Survey Organisation (Rawlings *et al.* 1997) has refined the stratigraphy of the onshore part of the Arafura Basin, such that the fossiliferous early Middle Cambrian is separated from the Elcho Island Formation and now referred to as the Jigaimara Formation (Fig. 2). It is assigned not to the Wessel Group, but to the Goulburn Group (Rawlings *et al.* 1997, p. 78). The Elcho Island Formation and the other units of the Wessel Group are now thought to be Neoproterozoic in age. This is because the supposed trace fossils referred to *Skolithos* and found in the Buckingham Bay Sandstone are now considered to be abiogenic and to be probable dewatering structures (Rawlings *et al.* 1997, p. 76). Furthermore, *Chuaria*, a widespread Neoproterozoic alga, has been recorded from the Raiwalla Shale (Rawlings *et al.* 1997, p. 76; Haines 1998). Thus there is no conflict between the Neoproterozoic radiometric ages obtained by McDougall *et al.* (1965) and the Middle Cambrian palaeontological age determination as suggested by Plumb *et al.* (1976). This apparent conflict was caused by imperfect understanding of the stratigraphy.

This paper documents the fauna studied by Plumb *et al.* (1976), as well as others from a similar stratigraphic level from nearby islands.

Outcrop of the Jigaimara Formation is poor and brecciated to varying degrees. The rocks are always silicified and mostly comprise white to grey-brown chert and cherty siltstone (presumably after limestone and calcareous

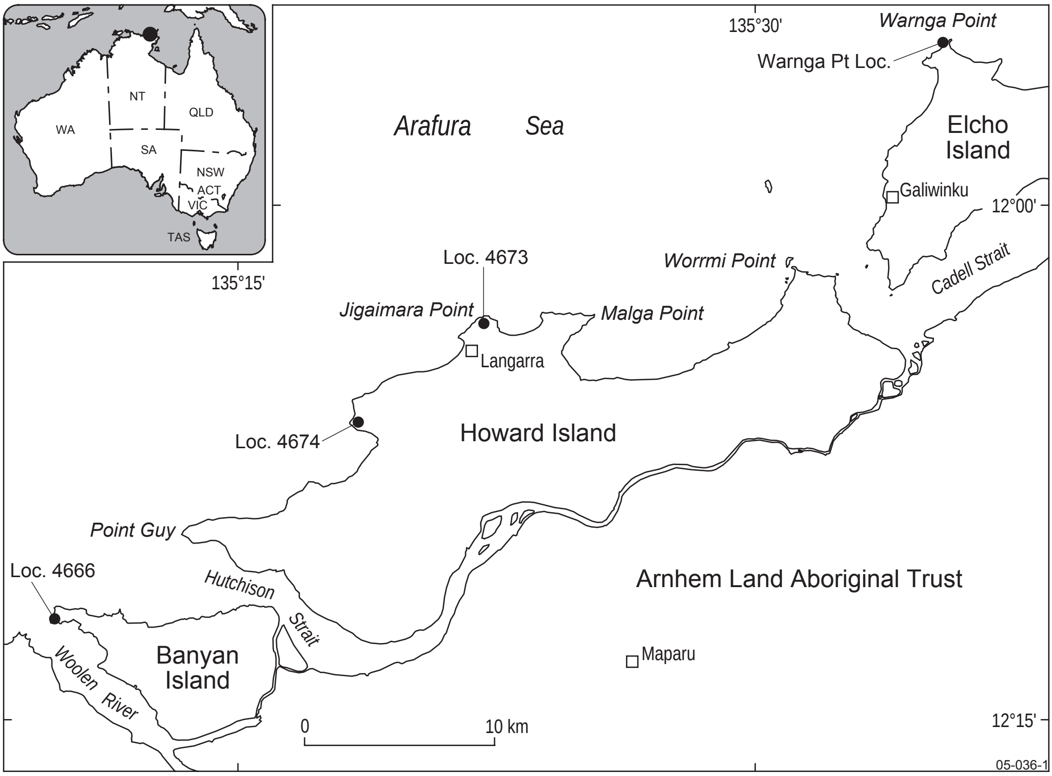


Fig. 1. Source of samples on Elcho, Howard and Banyan Island, northern Arnhem Land, Northern Territory.

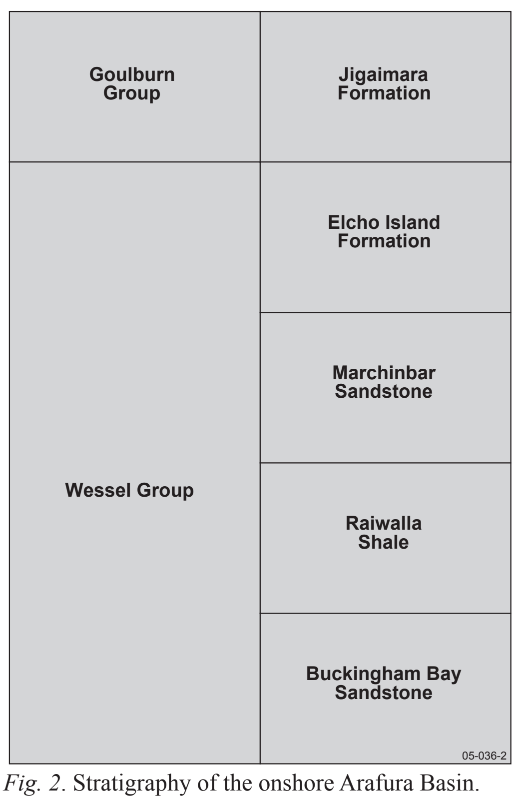


Fig. 2. Stratigraphy of the onshore Arafura Basin.

siltstone) (Rawlings *et al.* 1997, p. 78).

LOCALITY AND SAMPLES

The Jigaimara Formation crops out along the shores of the mainland from the settlement of Dhipirrinjura, east to the mouth of the Woolen River, as well as on the northwestern extremities of Banyan, Howard and Elcho Islands (see Fig. 1), and to the west on islands near the settlement of Milingimbi. The formation is named after Jigaimara Point on Howard Island, but its type locality is on the western tip of Banyan Island (Rawlings *et al.* 1997, p. 109). The samples available here comprise those from Elcho Island examined by Shergold (in Plumb *et al.* 1976) and include the samples collected by M.Z. Stefanski, M.J. Wiltshire and S.K. Skwarko. All these collections are held by Geoscience Australia. Three other collections made by P. Haines (formerly Northern Territory Geological Survey, NTGS), one from Banyan Island and two from Howard Island, were made available to the author by Dr P.D. Kruse (NTGS).

The samples from Elcho Island are from the beaches adjacent to Warnga Point on the southwestern portion of the island (see Plumb *et al.* 1976, fig. 1). The samples from Locality 4666 on Banyan Island are from AMG Grid

Reference NG172478 and are from the western tip of the island. The samples from Localities 4673 and 4674 on Howard Island are from AMG Grid Reference NG398640 and NG329582, respectively. Locality 4673 is from Jigaimara Point, while Locality 4674 is from an unnamed point 9 km southwest of Jigaimara Point. All samples examined herein comprise cream, pink, yellow, orange to pale brown silicified siltstone.

EARLY MIDDLE CAMBRIAN OF AUSTRALIA

The early Middle Cambrian of northern Australia was originally separated into an earlier Ordian and a later Templetonian Stage by Öpik (1968, 1970, 1975, 1979). Neither stage was clearly defined and subsequently they have been shown to be in part contemporaneous by Shergold *et al*. (1989) and Southgate & Shergold (1991). Thus, Shergold *et al.* (1989) and Shergold (1996) concluded that the Ordian *Redlichia chinensis* assemblage of Öpik (1970) and the Templetonian *Xystridura templetonensis* assemblage were temporally equivalent biofacies, together constituting a combined Ordian/early Templetonian Stage. Concomitantly, the uppermost Templetonian (i.e. *Triplagnostus gibbus* Zone) was grouped with the subsequent Floran as the combined Late Templetonian/Floran Stage (Fig. 3).

MIDDLE CAMBRIAN	Mindyallan	*Lejopyge laevigata*
	Boomerangian	
	Undillan	*Goniagnostus nathorsti*
		Doryagnostus deltoides
		Ptychagnostus punctuosus
	Late Templetonian-Floran	*Euagnostus opimus*
		Acidusus atavus
		Triplagnostus gibbus
	Ordian-Early Templetonian	*Xystridura templetonensis-Redlichia chinensis*

05-036-3

Fig. 3. Middle Cambrian biostratigraphy of Australia.

FAUNA AND AGE

Shergold (in Plumb *et al.* 1976, p. 51) listed the following trilobites from the Elcho Island collections: *Lyriaspis* cf. *sigillum* Whitehouse, 1939; *Oryctocephalites runcinatus* Shergold, 1969; *Pagetia* cf. *significans* (Etheridge, 1902); *Pagetia* aff. *significans* (Etheridge, 1902); *Pagetia* sp. nov.; *Peronopsis* cf. *normata* (Whitehouse, 1936); *Xystridura* cf. *templetonensis* (Chapman, 1929); and xystridurid undet. They also listed aff. *Indota* sp. undet. (bradoriid), *Hyolithes*? sp. undet. (hyolith) as well as undetermined 'inarticulate' brachiopods and sponge spicules. Plumb *et al.* (1976) stated that the "fauna has a Middle Cambrian age and belongs to the pre-*Ptychagnostus gibbus* portion of the Templetonian Stage as conceived by Öpik (1968, p. 136)" and was most similar to the association found in the Beetle Creek Formation in western Queensland.

The analysis presented here allows a more detailed list of species from Elcho Island and also allows the addition of data from Banyan and Howard Islands.

The fauna from Warnga Point, on Elcho Island, comprises the species: *Pagetia hainesi* sp. nov., *Pagetia* sp. indet., *Xystridura templetonensis* (Chapman, 1929), ptychoparioid sp. 2, *Oryctocephalites ?reynoldsi* (Reed, 1899) and *Itagnostus* sp. The presence of *X. templetonensis* indicates a correlation with the Beetle Creek Formation, in which this species is the predominant fossil. From one of the main localities in the Beetle Creek Formation (i.e. M434 of Öpik 1975, 1979), '*Peronopsis*' *normata* (Whitehouse 1936) (Öpik 1979, p. 55) is also recorded. This species is very similar to the agnostids from the Jigaimara Formation, which are illustrated herein. Examination of the several pieces of shale used by Öpik to construct his line drawing of '*Peronopsis*' *normata* shows that it also contains many, mostly small specimens of *X. templetonensis*, and two species of *Pagetia*, one of which is very similar to *P. hainesi* described below. It therefore seems that a correlation with the Beetle Creek Formation can be clearly established. The Beetle Creek Formation was determined to be Templetonian in age, but older than *Triplagnostus gibbus* age, by Öpik (1979, p. 56).

The fauna from Locality 4666 on Banyan Island contains *Pagetia* aff. *edura* Jell, *Xystridura ?filifera* Öpik and *Itagnostus* sp.. As noted above, the *Itagnostus* sp. is similar to the early Templetonian '*P.*' *normata*. *Xystridura filifera* is known from the Sandover River area in the western Georgina Basin and Öpik (1975) considered it to be early Templetonian in age, i.e. predating *Triplagnostus gibbus*.

The fauna from Locality 4673 on Howard Island contains *Pagetia* aff. *edura* Jell, *Xystridura altera* Öpik, ptychoparioid sp. 1, *Arthricocephalus* sp. nov. and *Itagnostus* sp.. The species listed here as *Itagnostus* sp. is similar to '*P.*' *normata* from the early Templetonian Beetle Creek Formation. *Xystridura altera* Öpik is found in the Sandover Beds of the western Georgina Basin and was considered to be early Templetonian in age (Öpik, 1975, p. 70).

The fauna from Locality 4674 on Howard Island contains *Pagetia* aff. *edura* Jell and *Xystridura* sp.. Little can be done with such limited material, but the presence of *P*. aff. *edura* Jell, which is also found at the other locality on Howard Island and also on Banyan Island, indicates that the fauna is of similar age to that found at those localities, i.e. early Templetonian.

Analysis of the above faunas indicates that, despite the variation in specific composition, all localities are of early Templetonian age. This confirms the assessment originally made on the fauna from Elcho Island by Shergold (in Plumb *et al.* 1976, p. 51).

SYSTEMATIC PALAEONTOLOGY

All specimens are held in the Commonwealth Palaeontological Collection (prefix CPC) at Geoscience Australia, Canberra.

Class TRILOBITA Walch, 1771
Suborder EODISCINA Kobayashi, 1939
Superfamily EODISCOIDEA Raymond, 1913
Family EODISCIDAE Raymond, 1913

Pagetia Walcott, 1916

Type species. *Pagetia bootes* Walcott, 1916.

Remarks. Measurements of cranidial length in the species of *Pagetia* described below are taken from the posterior margin of the cranidium and do not include the glabellar spine. Similarly measurements of pygidial length are taken from the posterior margin of the pygidium and do not include the axial spine.

Pagetia hainesi sp. nov. (Figs 4, 5)

Etymology. After Peter Haines, for his work in elucidating the stratigraphy of the Arafura Basin.

Material. Holotype cranidium CPC38886; Paratype cranidia CPC38874-CPC38885, CPC38887-CPC38892; Paratype pygidia CPC38893-CPC38899; all from Warnga Point, Elcho Island, Northern Territory.

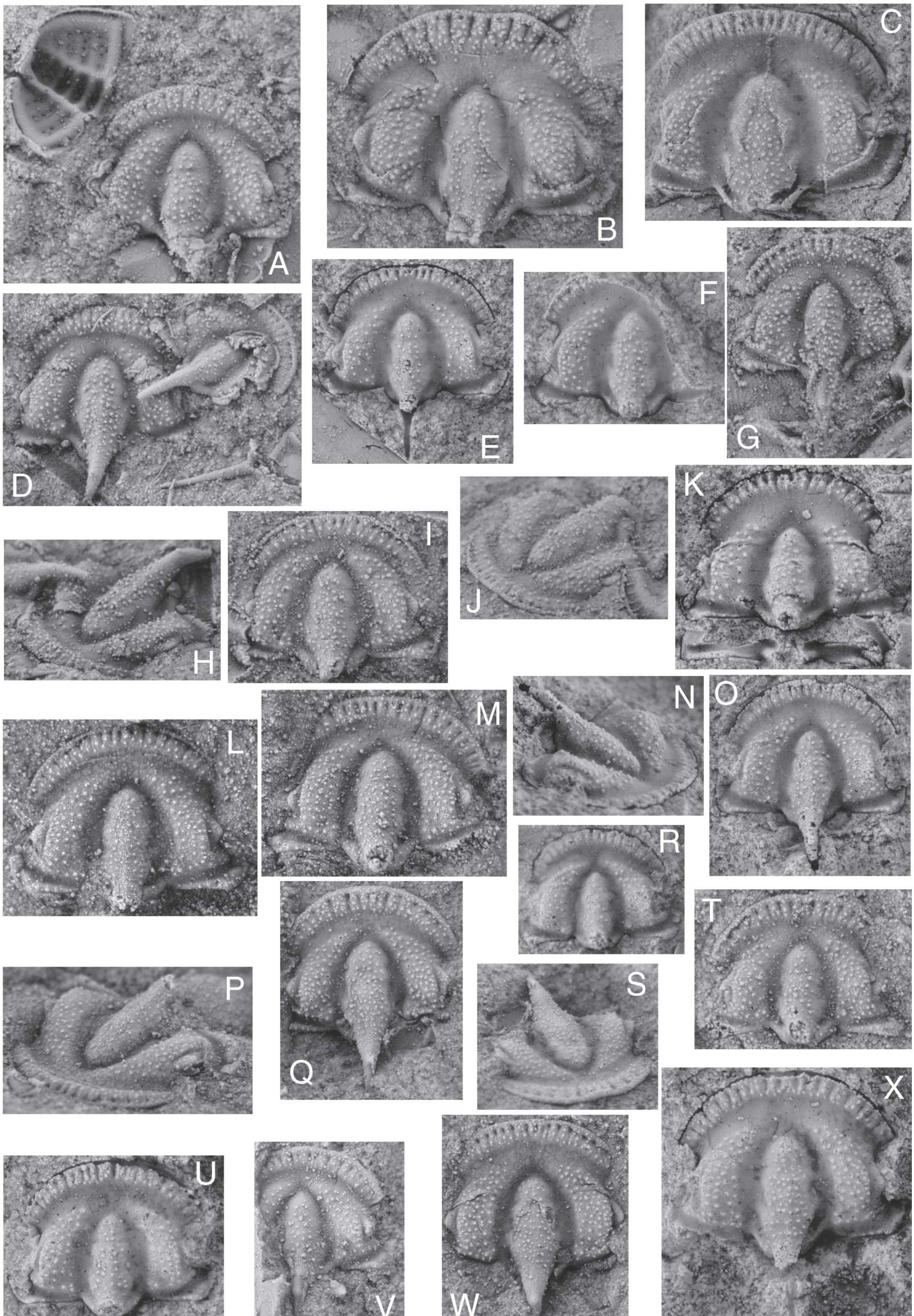
Diagnosis. Moderately large, with pustulose prosopon, very well defined palpebral lobes, five axial pygidial rings and with pleural ribs weakly developed to absent.

Description. Moderately large, with largest cranidium being just over 3 mm long (excluding glabellar spine). The largest pygidium is 2.4 mm long (excluding axial spine). Prosopon comprises pustules on glabella, genal fields, palpebral lobes and borders of cranidium and on axial rings, pleural fields and border of pygidia. Pustules are absent in furrows and seem to be less prominent or absent on glabellar spine and absent on pygidial axial spine. Cranidium from 63% to 77% (mean 69%) as long as wide, with maximum width across posterior limbs of fixigena.

Glabella elongate, semiovate, from 55% to 69% (mean 59%) as wide (across L1) as long, strongly convex, separated from genal fields by very deep, broad furrows, and occupying between 60% and 68% (mean 63%) of cranidial length. LO narrow (exsag.), bent strongly backwards, with lateral portions separated from L1 by deep, narrow SO, which is directed strongly backwards from axial furrow and effaced across middle third of glabella. S1 short and weakly developed, directed strongly backwards from axial furrow. S2 usually only developed as weak indentations in sides of glabella, occasionally developed as a weak transverse depression across glabella. Anterior margin of glabella rounded to obtusely angular. Posterior extremity of glabella produced into long, broadly based spine which may extend as much as 1.3 mm beyond posterior cranidial border in larger specimens.

Genal fields strongly convex, with maximum height attained posterolaterally. Eye ridges generally absent to very weakly developed on external moulds, weakly to well developed on internal moulds, extending laterally from

Fig. 4. *Pagetia hainesi* sp. nov.: All x10. All paratypes except where noted. All from Warnga Point, Elcho Island. A; latex replica of external mould of cranidium with associated external mould of pygidium, CPC38874. B; latex replica of external mould of large cranidium, CPC38875. C; latex replica of external mould of large cranidium, CPC38876. D, H; latex replica of external mould of cranidium in part overlain by smaller cranidium; D, dorsal view; H, anterolateral oblique view, CPC38877. E; internal mould of cranidium, CPC38878. F; internal mould of partial cranidium, CPC38879. G; Latex replica of external mould of cranidium, CPC38880. I, J; latex replica of external mould of cranidium; I, dorsal view; J, anterolateral oblique view, CPC38881. K; internal mould of cranidium showing well developed eye ridges, with associated thoracic segment, CPC38882. L, P; latex replica of external mould of cranidium; L, dorsal view; P, anterolateral oblique view, CPC38883. M; latex replica of external mould of cranidium, CPC38884. N, O; internal mould of cranidium; N, anterolateral oblique view; O, dorsal view, CPC38885. Q, S; latex replica of external mould of holotype cranidium; Q, dorsal view; S, anterolateral oblique view, CPC38886. R; internal mould of small cranidium, CPC38887. (*continued opposite*)



T; latex replica of external mould of cranidium, CPC38888. U; internal mould of cranidium, CPC38889. V; latex replica of external mould of partial cranidium, CPC38890. W; latex replica of external mould of cranidium, CPC38891. X; internal mould of cranidium, CPC38892.

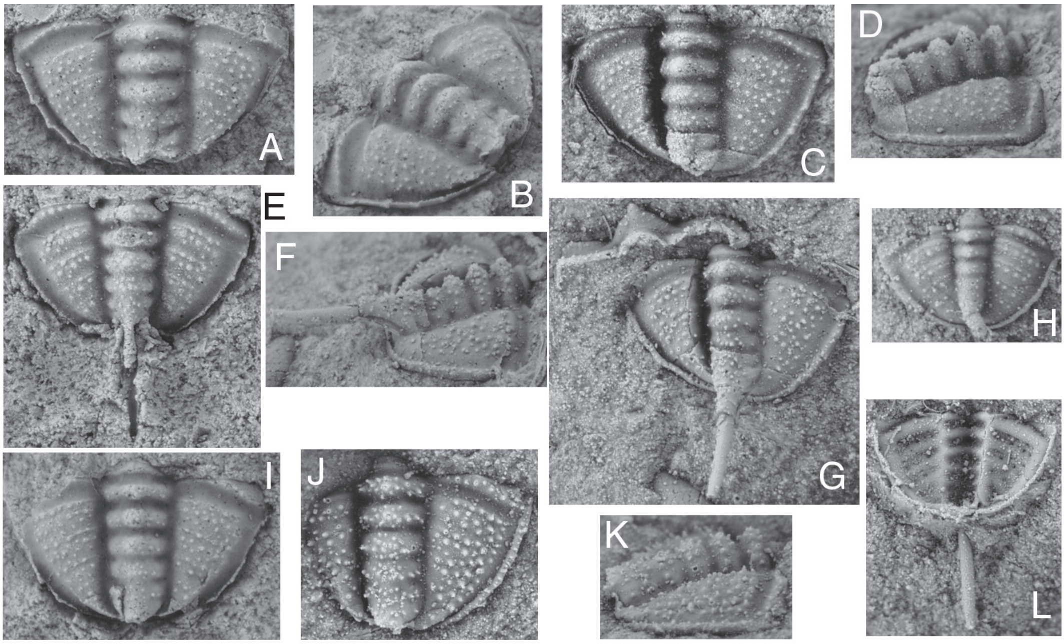


Fig. 5. Pagetia hainesi sp. nov.: All x10. All from Warnga Point, Elcho Island. A, B; internal mould of slightly flattened pygidium; A, dorsal view; B, posterolateral oblique view; CPC38893. C, D, F, G; slightly distorted pygidium; C, dorsal view of internal mould; D, lateral oblique view of internal mould; F, lateral oblique view of latex replica of external mould; G, dorsal view of latex replica of external mould; CPC38894. E; internal mould of pygidium, CPC38895. H, latex replica of external mould of small pygidium, CPC38896. I, internal mould of pygidium, CPC38897. J, K; latex replica of external mould of partial pygidium; J, dorsal view; K, slightly oblique lateral view; CPC38898. L; latex replica of external mould of small pygidium, ventral view, CPC38899.

axial furrow about level with midlength of L3, curving rearward distally to anterior extremities of palpebral lobes. Palpebral furrows very deep, narrow, slightly convex laterally. Palpebral lobes depressed well below level of genal field, flattened, semiovate to subtriangular in shape.

Posterior border furrow, deep, wide, curving forward so that border widens laterally. Genal angle obtusely angled to narrowly rounded. Anterior border furrow very wide, deep, widest and commonly shallower medially, coalescing with the anterior extremities of the axial furrow. Anterior cranidial border wide, flattened to slightly convex, with inner margin clearly defined. Radial scrobicules variably developed, from deeply incised to fairly shallow, usually deepest distally, occasionally coalescing into an epiborder furrow which separates the scrobiculate part of the border from a narrow (sag., exsag.) roll-like, convex outer portion.

Librigenae, rostral plate and hypostome unknown. Thorax known only from isolated partial segments. Posterior segment has small axial spine (see Fig. 5G).

Pygidium semiovate, with lateral and posterior margins broadly rounded, between 59% and 70% (mean 65%) as long as wide (excluding pygidial axial spine), with a long, weakly tapering axis. Axis defined by a deep, fairly broad axial furrow. Anteriorly (across anterior axial ring), the axis occupies from 24% to 28% (mean 26%) the maximum width of the pygidium, and tapers to between 71% and 87% (mean 81%) of the anterior width. Axis comprises a narrow (sag.), convex, articulating half-ring, five axial rings and a terminal piece which extends into a long, narrow spine. Axial rings are separated from one another by transverse ring furrows which become progressively less well developed posteriorly. Anterior ring furrow is wide and deep, while the ring furrow which separates the fifth axial ring from the terminal piece is developed as weak, narrow furrows visible only on lateral portions of the axis. Similarly, the axial rings are surmounted by small nodes which become progressively weaker posteriorly such that on the fourth and fifth axial rings the nodes are very poorly developed or absent. Pleural field convex, with pleural ribs weakly developed to absent; where present, a maximum of four backwardly directed ribs can be seen. On some specimens a very narrow interpleural furrow can be seen separated from the pleural furrow in front by a narrow posterior band surmounted by a single row of pustules, and from the pleural furrow behind by an anterior band with a single or double row of pustules. Furrow separating anterior pleural rib from articulating half-rib is deep and fairly wide. Articulating half-rib narrow with a single row of pustules, and laterally has a well developed articulating facet. Border furrow deep, narrows posteriorly, clearly delimiting narrow roll-like border, which has prominent pustules opposite the distal ends of the pleural furrows, such that the border has the appearance of having widely separated serrations.

Remarks. A coarse pustulose prosopon is rare in species assigned to *Pagetia*. In this regard, P. hainesi is most like the rather poorly known *P. walcotti* Rasetti, 1966, which has a similar prosopon. However, *P. walcotti* differs in having better developed pleural furrows and in lacking the well defined palpebral lobes. *Pagetia rasettii* Young & Ludvigsen, 1989, also has a pustulose prosopon, but it is more sparsely distributed than in *P. hainesi*. Furthermore, *P. rasettii* has very much longer, more clearly defined curved palpebral lobes. *Pagetia bigranulosa* Rasetti, 1967, has similarly arranged and defined palpebral lobes and it also has a pustulose prosopon, but this is more subdued than in *P. hainesi*. The pygidium differs in being much more strongly convex and less transverse, and in having much more strongly developed pleural furrows.

Pagetia aff. edura Jell, 1975 (Fig. 6)

Material. Complete carapace, CPC38900; cranidia, CPC38901, CPC38903-CPC 38904; enrolled specimen and associated small pygidium CPC 38905; pygidia, CPC 38906-CPC38908, CPC38910 from Locality 4666, Banyan Island and cranidia CPC38902, CPC38909 from Locality 4673, Howard Island, Northern Territory.

Description. Moderately large, with largest cranidium being just over 3 mm long (excluding glabellar spine). The largest pygidium is 2.5 mm long (excluding axial spine). Single complete specimen is approximately 6.2 mm long (excluding pygidial axial spine). Prosopon smooth. Cranidium from 73% to 80% (mean 76%) as long as wide, with maximum width across posterior limbs of fixigena. Glabella elongate, semiovate, from 53% to 62% (mean 56%) as wide (across L1) as long, strongly convex, separated from genal fields by very deep, broad, furrows, and occupying between 56% to 62% (mean 59%) of cranidial length. LO narrow (exsag.), bent strongly backwards, with lateral portions separated from L1 by deep, narrow SO which is directed strongly backwards from axial furrow, and is effaced across middle two thirds of glabella. S1 very weakly developed as slight indentation in side of glabella. S2 usually developed only as weak indentation in side of glabella, occasionally extending across glabella as vague, transverse depression separating off a broad, rounded-triangular anterior lobe. Anterior margin of glabella narrowly rounded. Posterior extremity of glabella produced into stout, broadly based spine which extends up to 1.0 mm beyond posterior margin of cranidium in larger specimens.

Genal fields strongly convex, with maximum height located posterolaterally. Eye ridges usually visible as faint, narrow ridges extending laterally from just in front of S2 furrows, only curving rearward distally to anterior extremities of palpebral lobes. Palpebral lobes very poorly defined; palpebral furrows absent or very faint.

Posterior border furrow broad, deep, curving gently forward from lateral extremities of occipital ring; border very narrow (exsag.) proximally, widening gradually to about genal angle and then narrowing as it bends forward. Genal angle narrowly rounded or obtusely angled. Anterior border furrow very wide and poorly defined medially, becoming narrower and deeper laterally. Anterior cranidial border wide, flattened to weakly convex, usually not clearly defined, and with usually weakly developed radial scrobicules.

Librigenae, rostral plate and hypostome unknown.

Thorax of two segments in single complete specimen (Fig. 6A). Anterior segment very slightly narrower (tr.) and slightly longer (sag., exsag.) than posterior segment. Only posterior part of axis is visible and anterior is covered by occipital ring and glabellar spine; postannulus narrow (sag.), lenticular, separated from pleural region of segment by narrow furrow. Pleural furrow weakly defined adaxially; deepening abaxially such that level with fulcral point it is at its deepest, then abruptly shallowing before disappearing near distal extremity of segment. Posterior thoracic segment with much wider (sag.) postannulus, separated from pleural region of segment by narrow furrow. Pleural furrow developed as in anterior segment.

Pygidium semiovate, of low to moderate convexity, with lateral margins broadly rounded and posterior margin more narrowly rounded, such that some specimens have a parabolic shape; between 73% and 78% (mean 76%) as long as wide (excluding pygidial axial spine), with a long, narrow, weakly tapering axis. Axial furrow deep, narrow. Anteriorly (across the anterior axial ring) the axis occupies from 25% to 27% (mean 26%)

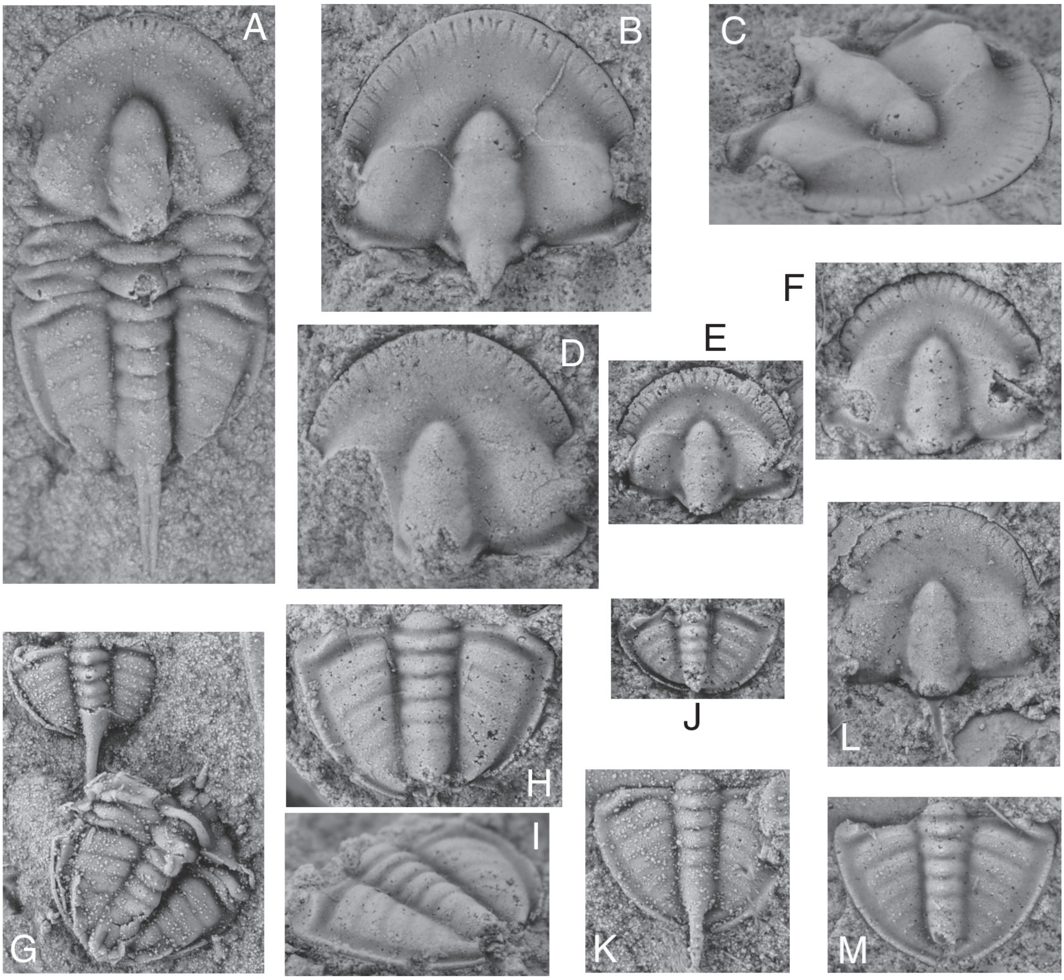


Fig. 6. *Pagetia* aff. *edura* Jell, 1975, all x10, All from Locality 4666, except where noted. A; Latex replica of external mould of complete carapace CPC38900. B, C; Internal mould of large cranidium; B, dorsal view; C, anterolateral oblique view CPC38901. D; Internal mould of partial large cranidium, Loc 4673, CPC38902. E; Internal mould of small cranidium, CPC38903. F; Internal mould of cranidium, CPC38904. G; Latex replica of external mould of enrolled specimen and associated small pygidium, the former showing the tip of the glabellar spine off to the top left of the specimen, CPC38905. H, I; Internal mould of large pygidium; H, dorsal view; I, posterolateral oblique view, CPC38906. J; Internal mould of small pygidium, CPC38907. K; Latex replica of external mould of pygidium, CPC38908. L; Internal mould of cranidium, Loc 4673, CPC38909. M; Internal mould of pygidium, CPC38910.

the maximum width of the pygidium and tapers to between 63% and 73% (mean 69%) of the anterior width. Axis comprises a broad (sag.), convex articulating half-ring, four or five axial rings and a long terminal piece which extends into a long, narrow spine which extends up to 2.9 mm beyond the posterior pygidial border in larger specimens. Anterior axial ring surmounted by a low, poorly defined node. Axial rings are separated from one another by narrow, transverse, ring furrows which become progressively narrower and shallower posteriorly such that the furrow separating the last ring from the terminal piece is barely visible. Pleural field convex with pleural furrows weakly to moderately well developed, five or six in number, with anteriormost being the best developed and the others being progressively less well developed such that posteriorly they are poorly developed or absent. Furrow separating anterior pleural rib from articulating half-rib is deep and relatively narrow. Articulating half-rib very narrow (exsag.) adaxially, widening dramatically near fulcral point, at which point it bends abruptly rearward to accommodate the short (tr.), concave articulating facet. Border furrow deep and wide anteriorly; narrows posteriorly and vaguely defines narrow, roll-like border.

Remarks. This species falls in the group that could be described as the standard or archetypal *Pagetia*, belonging to the huge group of named species which more or less centre around the type species *P. bootes*. This group of species contains a large proportion of the species erected by Jell (1975) and includes *P. edura*, *P. oepiki*, *P. polygnota*, *P. prolata*, *P. silicunda*, *P. sinesulcata* and *P. triaena*. The specimens described above are similar in many respects to every one of these species, but differ in some way from all of them (see below). Many of these differences seem relatively minor and I doubt in many cases that they are of taxonomic significance. Whether they are sufficiently different from one another to be placed in separate species is problematic and probably requires a more detailed analysis of the assorted specimens used by Jell (1975) in addition to many others from the same and other localities. I suspect that Jell (1975) has 'oversplit' *Pagetia* but cannot demonstrate it conclusively for all of his species. My reasons for this assertion are discussed elsewhere (Laurie 2006).

The cranidium of this species is similar to that of *Pagetia edura*, but the pygidium of the latter is slightly longer relative to its width. The Jigaimara Formation specimens are similar to many of Jell's species, as noted above, but they differ from most in some minor way. *Pagetia oepiki* is slightly wider and its cranidium has very prominent genal fields which overhang the librigenae, to such an extent that they, in part, obscure the librigenal border. The cranidium of *P. polygnota* is relatively wider. *Pagetia prolata* has a slightly wider cranidium and pygidium with a relatively narrower pygidial axis. *Pagetia silicunda* has a distinctly wider cranidial border and a more convex pygidium with a slightly wider axis. *Pagetia sinesulcata* has a wider cranidium and a slightly narrower pygidial axis, while *Pagetia triaena* has a wider cranidium and pygidium with a less well developed taper to the axis.

Pagetia sp. indet. (Fig. 7)

Material. Cranidium, CPC38911; thorax and pygidium, CPC38912; and pygidium CPC 38913 all from Warnga Point, Elcho Island, Northern Territory.

Description. Small, with single available cranidium being only 1.7 mm long (excluding glabellar spine). The two available pygidia are 1.5 mm and 1.9 mm long. The largest of these pygidia has a thorax of three segments attached. Prosopon is smooth. The single, poorly preserved cranidium is 66% as long as wide, with maximum width across posterior limbs of fixigenae. Glabella is about 59% as wide as long, narrowly rounded anteriorly and occupying about 64% of the cranidial length. LO narrow (exsag.), bent strongly backwards and separated from L1 by deep narrow SO. Other glabellar furrows are unclear, although the glabella does seem to be fairly strongly constricted just in front of its midlength. Posterior extremity of glabella is produced into a fairly narrow spine.

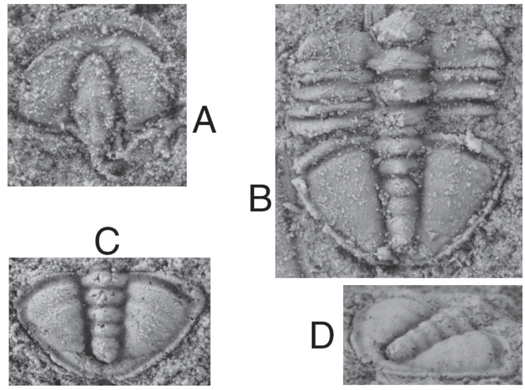


Fig. 7. Pagetia sp. indet. All x10, all from Warnga Point, Elcho Island, Northern Territory. A; latex replica of external mould of cranidium, CPC38911. B; latex replica of external mould of pygidium and three attached thoracic segments, CPC38912. C, D; internal mould of pygidium, CPC38913; A, dorsal view; B, posterolateral oblique view.

Genal fields broad, laterally overhanging border furrow and part of border. Posterior border very narrow where preserved, separated from genal field by very deep, wide, posterior border furrow. Deep, relatively narrow, anterior border furrow sharply defines inner edge of wide, flattened border which only preserves traces of radial scrobicules.

Librigenae, rostral plate and hypostome unknown.

Thorax of three segments in single known specimen (Fig. 7B). Anterior segment comparatively very wide (sag., exsag.), with very broad (sag.), convex lenticular, articulating half-ring and wide (tr.), convex, lunulate postannulus. Pleurae wide (exsag.) and flat adaxially, with broad, shallow, slightly forwardly directed pleural furrow separating very narrow (exsag.) posterior band from very wide (exsag.) anterior band. At about level with the fulcral point, the furrow deepens and continues this way to the pleural extremity. Posterior pair of segments are very similar in appearance in that both have a wide (tr.), convex lunulate postannulus (that on the posteriormost segment is slightly smaller than that on the middle segment). Wide, fairly deep pleural furrow extends from the axial furrow, deepens abaxially and separates a slightly narrower (exsag.), convex, anterior pleural band from the broader (exsag.), convex, posterior pleural band. Pleural furrow reaches its maximum depth about level with the fulcral point and shallows slightly abaxially until it reaches the pleural extremity.

Pygidium semiovate, of low to moderate convexity, with lateral margins broadly rounded and posterior margin more narrowly rounded, giving the pygidium a broadly parabolic outline, between 62% and 67% (mean 65%) as long as wide, with a long, narrow, tapered axis. Axial furrow deep, and anteriorly (i.e. across the anterior axial ring) occupies 23% to 25% (mean 24%) of the maximum width of the pygidium, and tapers to about 61% of the anterior width. Axis comprises a broad (sag.) convex articulating half-ring, four axial rings and a short, semiovate terminal piece. Anterior two axial rings are each surmounted by a low, poorly defined node, and each ring is separated from the adjacent ring by a transverse ring furrow. Anterior two ring furrows are very deep and well defined; the third is narrow and shallow, while the fourth is poorly defined. Pleural field moderately convex with pleural furrows absent or with anterior two weakly defined adaxially. Furrow separating pleural field from articulating half-rib is deep and wide. Articulating half-rib narrow (exsag.) adaxially, widening abaxially. Border furrow fairly deep and narrow around entire margin, clearly defining narrow roll-like border.

Remarks. This species is similar to *Pagetia significans* (Etheridge, 1902) in having a transverse cranidium with the glabella occupying just under two thirds of the cranidial length and a pygidium with a clearly tapered pygidial axis. However, the poor preservation of the cranidium of this species and the limited material preclude confident assignment to a species.

Order REDLICHIIDA Richter, 1932
Superfamily PARADOXIDOIDEA Hawle & Corda, 1847
Family XYSTRIDURIDAE Whitehouse, 1939

Xystridura Whitehouse 1936
[=*Milesia* Chapman, 1929 (non Latreille, 1804); *Inosacotes* Öpik, 1975; *Polydinotes* Öpik, 1975]

Type species. Milesia templetonensis Chapman, 1929.

Remarks. As noted by Laurie (in Kruse *et al.* 2004, p. 28-29), it is probable that *Xystridura* has been 'oversplit' by Öpik (1975). In that work, I also defined four morphological groups based on pygidial characteristics (p. 29), to one or other of which I assigned most of Öpik's (1975) species. I considered it possible that each of these represented a single species, but did not therein formally synonymise any of the assigned Öpik species. To one of these groups (No. 3), I assigned the species *X. altera* Öpik and *X. remorata* Öpik, and by inference *X. altera obtusa* Öpik. I consider these to be conspecific and in the same volume (Laurie 2004, p. 255), synonymised them. This subdivision of the genus into species groups was superficial because far too little is known of the intraspecific variation in *Xystridura*. Furthermore, little is known of the stratigraphic range of the genus because all of Öpik's material came from spot localities which were placed in stratigraphic succession by analysing the associated agnostid faunas and correlating these with the Scandinavian scheme of Westergård (1946).

Discriminating between Öpik's species of *Xystridura* based on cranidial morphology is essentially impossible. This is in part due to his suspected oversplitting, the limited material he illustrated and possibly to the limited differentiation of cranidial morphology between species. That is why the species groups of Laurie (in Kruse *et al.* 2004) were constructed solely based on pygidial morphology. Therefore, the species I discriminate herein from the localities in the Jigaimara Formation are based solely on pygidial morphology; the associated cranidia are then assumed to belong to that species. An attempt was then made to assign these to a species erected by Öpik (1975). This is a very unsatisfactory result, but until the taxonomy of *Xystridura* is properly understood, little else can be done.

Xystridura templetonensis (Chapman, 1929)
(Figs 8, 9)

1929 *Milesia templetonensis*; Chapman, p. 214, pl. 22, fig. 19.
1975 *Xystridura* (*Xystridura*) *templetonensis*; Öpik, p. 43, pl. 13, fig. 5, pl. 15, figs 3, 5, pl. 22, figs 1-5, pl. 26, fig. 2.

Material. Cranidia, CPC38914-CPC38918; cranidia with associated librigenae, CPC 38919-CPC38920; thorax and partial pygidium, CPC 38921; pygidium and partial thorax, CPC38922; hypostomes, CPC38923-CPC38924; pygidia, CPC38925-CPC38931, all from Warnga Point, Elcho Island, Northern Territory.

Emended diagnosis. Pygidium about 42% as long

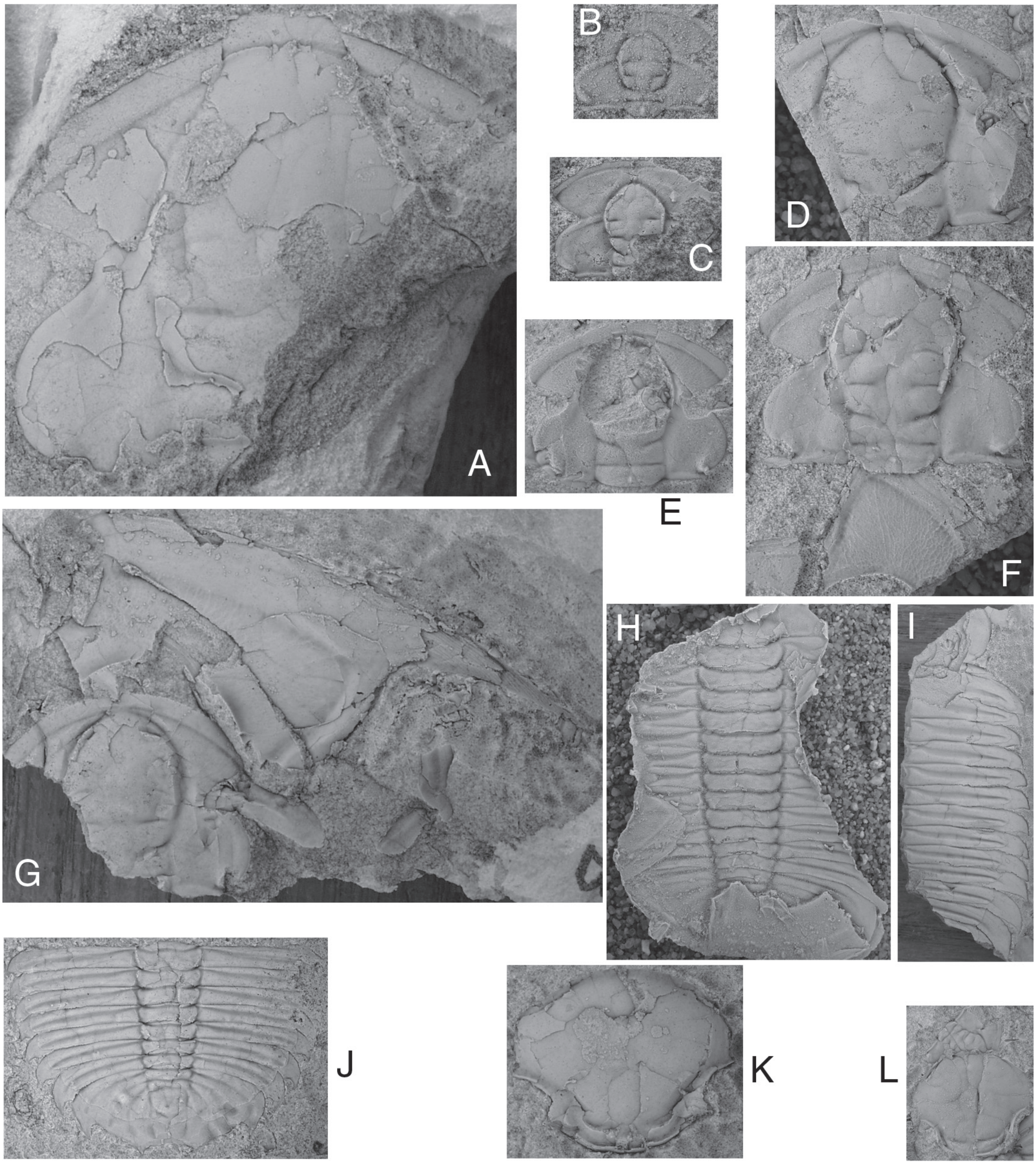


Fig. 8. *Xystridura templetonensis* (Chapman, 1929). All x2 except where noted, all from Warnga Point, Elcho Island, Northern Territory. A; partly exfoliated partial large cranidium, CPC38914. B; partial ?meraspid cranidium, x4, CPC38915. C; partial small ?holaspid cranidium, x3, CPC38916. D; partial cranidium, CPC38917. E; cranidium lacking most of glabella, CPC38918. F; cranidium, with associated partial librigena, CPC38919. G; partial cranidium with associated large librigena, CPC38920. H, I; thorax and partial pygidium, CPC38921; H, latex replica of external mould; I, internal mould. J; pygidium and partial thorax, CPC38922. K; large hypostome, CPC38923. L; hypostome, CPC38924.

as wide; axis broad, about 87% as wide as long, occupying 64% of pygidial length (sag.), with 2-3 axial rings. Pygidial spines all broadly based.

Description. Large, usually smooth or with venulose pattern on fixigenal and librigenal fields. Largest cranidium estimated to be about 33 mm long (sag.), and largest pygidium estimated to be about 13 mm long (sag.). Cranidium of moderate convexity, from 80% to 88% (mean 84%) as long as wide, with maximum width across anterior limb of fixigena (β-β). Narrowest point of cranidium immediately in front of palpebral lobes (γ-γ), where it is between 64% and 70% (mean 67%) of maximum cranidial width.

Glabella moderately convex, with maximum

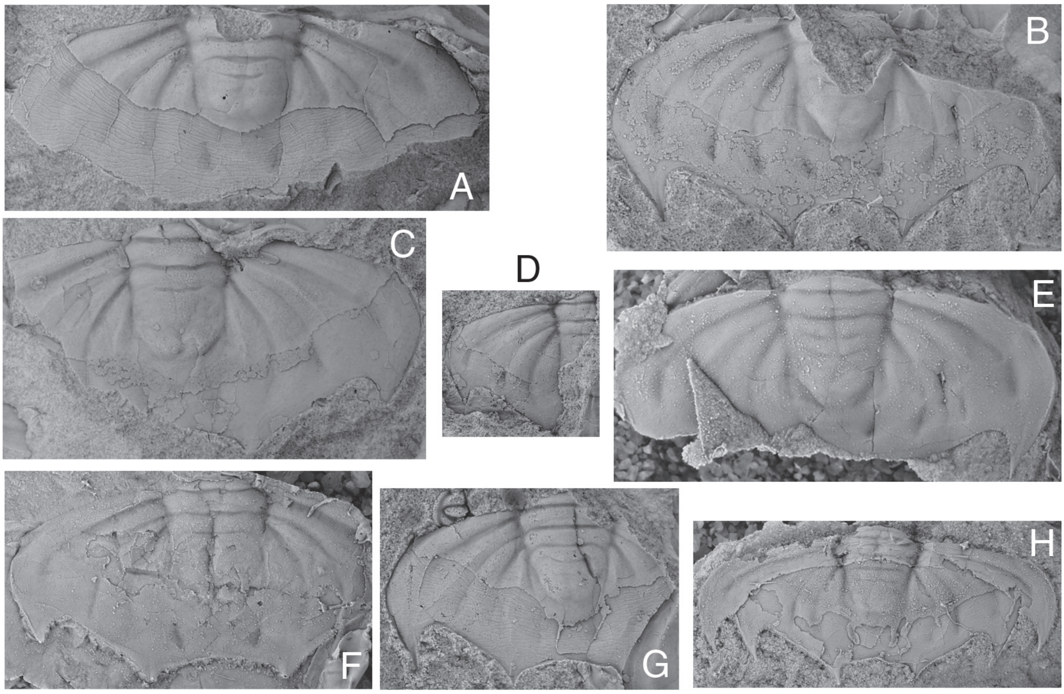


Fig. 9. Xystridura templetonensis (Chapman, 1929). All x2, all from Warnga Point, Elcho Island, Northern Territory. A; Partial pygidium, CPC38925. B, E; Pygidium, CPC38926; B, partial internal mould; E, latex replica of external mould. C; Partial pygidium, CPC38927. D; Partial pygidium, CPC38928. F; Flattened partial pygidium, CPC38929. G; Partial pygidium, CPC38930. H; Flattened pygidium, with posteriormost thoracic segment partly superimposed, CPC38931.

convexity across anterior lobe, from 63% to 66% (mean 64%) as wide as long, occupying from 90% to 92% (mean 91%) of cranidial length and extending to, or very nearly to, anterior border furrow. Anterior margin of glabella broadly parabolic, with maximum width at about where eye ridges intersect axial furrow. Posterior to eye ridges, lateral margins of glabella broadly concave such that the glabella is constricted, with its narrowest point being across S1 or L1. LO clearly defined with a small median node in posterior half. SO deep and narrow laterally, shallower and broader medially. S1 straight, relatively deep, extending posteromedially from axial furrow to about three quarters distance to glabellar midline, at an angle of about 160° to each other. S2 narrow, moderately deep, straight, extending medially from axial furrow to about two thirds distance to glabellar midline. S3 narrow, usually shallow, but commonly clearly developed, not intersecting axial furrow, commonly arched forward.

Border moderately and evenly wide, flat to weakly convex, separated from genal field by narrow, clearly defined border furrow. Palpebral lobe long (exsag.), strongly curved, with curvature increasing posteriorly; inner margins very weakly defined, connected to axial furrow by short, broad, poorly defined eye ridge. Posterior limbs of fixigenae wide (tr.), very short (exsag.), flat to slightly convex (exsag.), comprising only posterior border of cranidium, curving forward distally.

The γ-β segments of cephalic suture anteriorly diverge strongly from one another at an angle of about 100-130°, with γ a short distance from axial furrow just behind lateral extremities of S3. The ε-ω segments of cephalic suture diverge very strongly from each other such that they are adaxially collinear; abaxially they curve forward.

Librigena of fairly low convexity, with well developed, broad, weakly convex lateral border and narrow border furrow. Border extends posteriorly into large genal spine which occupies over one third total length of librigena (exsag.). Posterior border relatively narrow (exsag.), slightly convex, separated from genal field by narrow, shallow, border furrow.

Rostral plate unknown.

Hypostome broad (tr.), with large, transverse middle body and broad (exsag.) anterior wings. Maculae narrow, slit-like, anteriorly bounding a very narrow (sag., exsag.) crescentic posterior lobe. Border furrow deep, well defined, separating narrow posterior and lateral borders from middle body. Posterior margin of hypostome broadly rounded, separated from concave lateral margins by variably developed angular lateral extension.

Thorax of thirteen segments, with the axial lobe of each segment clearly defined, widest (tr.) anteriorly. Anterior three of four axial lobes all of similar width, with each axial lobe behind these becoming progressively narrower (tr.), such that axial lobe of posteriormost segment is only about 60% the width of that of the anteriormost segment. Pleural lobes weakly convex (tr.), with pleural furrow extending from near anterior extremity of axial furrow to a short distance from the lateral extremity of the pleural lobe. Pleural furrow is narrow adaxially, then widens to about one third the width (exsag.) of the pleural lobe, before narrowing abaxially and fading out about level with the inner margin of the pleural doublure. Pleural extremities are pointed and curved backwards, with each being more strongly curved backwards than that of the pleural lobe in front.

Pygidium transverse, subovate in outline, moderately convex, about 39% to 45% (mean 42%) as long (sag.) as wide, with a broad (tr.), strongly convex, tapered axis which is from 67% to 102% (mean 87%) as wide as long and occupies 58% to 69% (mean 64%) of pygidial length (sag.). Pleural field weakly convex, sloping down from axial furrow to poorly defined border. Axis with well defined articulating half-ring, separated from anterior axial ring by deep, narrow, articulating furrow. Anterior axial ring always posteriorly delimited by deep, narrow, transverse interring furrow. Second axial ring variably defined posteriorly, with interring furrow rarely extending to axial furrow and having a slight rearward bend. Third axial ring, either absent or poorly defined by vague interring furrow which never extends to axial furrow and commonly has a slight rearward bend medially. Axial furrow clearly developed adjacent to ring furrows, but weak to effaced around semiovate terminal piece. Pleural furrows usually well developed with anterior furrow deepest, extending from near anterior extremity of axial furrow and only curving posteriorly in its abaxial half. Second pleural furrow arises opposite first interring furrow and is evenly curved backwards along most of its length. Third pleural furrow arises opposite midlength of second axial ring and curves slightly backwards such that distal extremity is parallel to midline of pygidium. Fourth pleural furrow arises opposite midlength of third axial ring and is initially parallel to pygidial midline, but then curves towards midline, such that distal extremities are behind terminal piece of axis. Border flat, poorly defined by gradual break in slope near terminations of pleural furrows. Pygidial margin with four broadly based, posteriorly directed spines; medial pair arise between the terminations of third and fourth pleural furrows; lateral pair arise from lateral extremities of pygidium. Pygidial margin between medial spines evenly concave, that between medial spine and lateral spine mostly straight to slightly concave.

Remarks. These pygidia are of only moderate convexity, have two or three axial rings, fairly large, broadly based, marginal spines and a length to width ratio of about 42%. These features indicate an assignment to *Xystridura templetonensis* (Chapman, 1929) is most appropriate and they are confidently assigned to that species.

Xystridura altera Öpik, 1975 (Fig. 10)

1975 *Xystridura* (*Xystridura*) *altera*; Öpik, p. 65, pl. 5, figs 1-6, pl. 6, figs 1-4, pl. 26, fig. 5.
1975 *Xystridura* (*Xystridura*) *altera obtusa*; Öpik, p. 68, pl. 6, fig. 1, pl. 26, fig. 4.
1975 *Xystridura* (*Xystridura*) *remorata*; Öpik, p. 68, pl. 30, figs 1-7.

Material. Cranidia, CPC38932-CPC38933, CPC38935, CPC38939; Cranidium with associated librigena and thoracic segment, CPC38934; hypostome, CPC38937; rostral plate, CPC38938; thorax and partial pygidium, CPC38936; partial thorax, CPC38940; pygidia, CPC38941-CPC38944; all from Locality 4673, Howard Island, Northern Territory.

Emended diagnosis. Pygidium about 42% as long as wide, axis narrow, about 77% as wide as long, occupying about 74% of pygidial length (sag.), with 3 axial rings. Pygidial spines narrow, with median pair very small.

Description. Of moderate size, smooth, with largest cranidium estimated to be about 22 mm long (sag.) and largest pygidium about 9 mm long (sag.). Cranidium of moderate convexity, from 81% to 86% (mean 84%) as long as wide (the latter is measured across the anterior limbs of the fixigenae, β-β, despite the maximum width most commonly being across the posterior limbs of the fixigenae, ω-ω). Narrowest point of cranidium is immediately in front of palpebral lobes (γ-γ), where it is between 62% to 75% (mean 68%) of the width across β-β.

Glabella moderately convex, with maximum convexity across anterior lobe, from 61% to 63% (mean 62%) as wide as long, occupying from 88% to 94% (mean 92%) of cranidial length and extending to, or nearly to anterior border furrow.

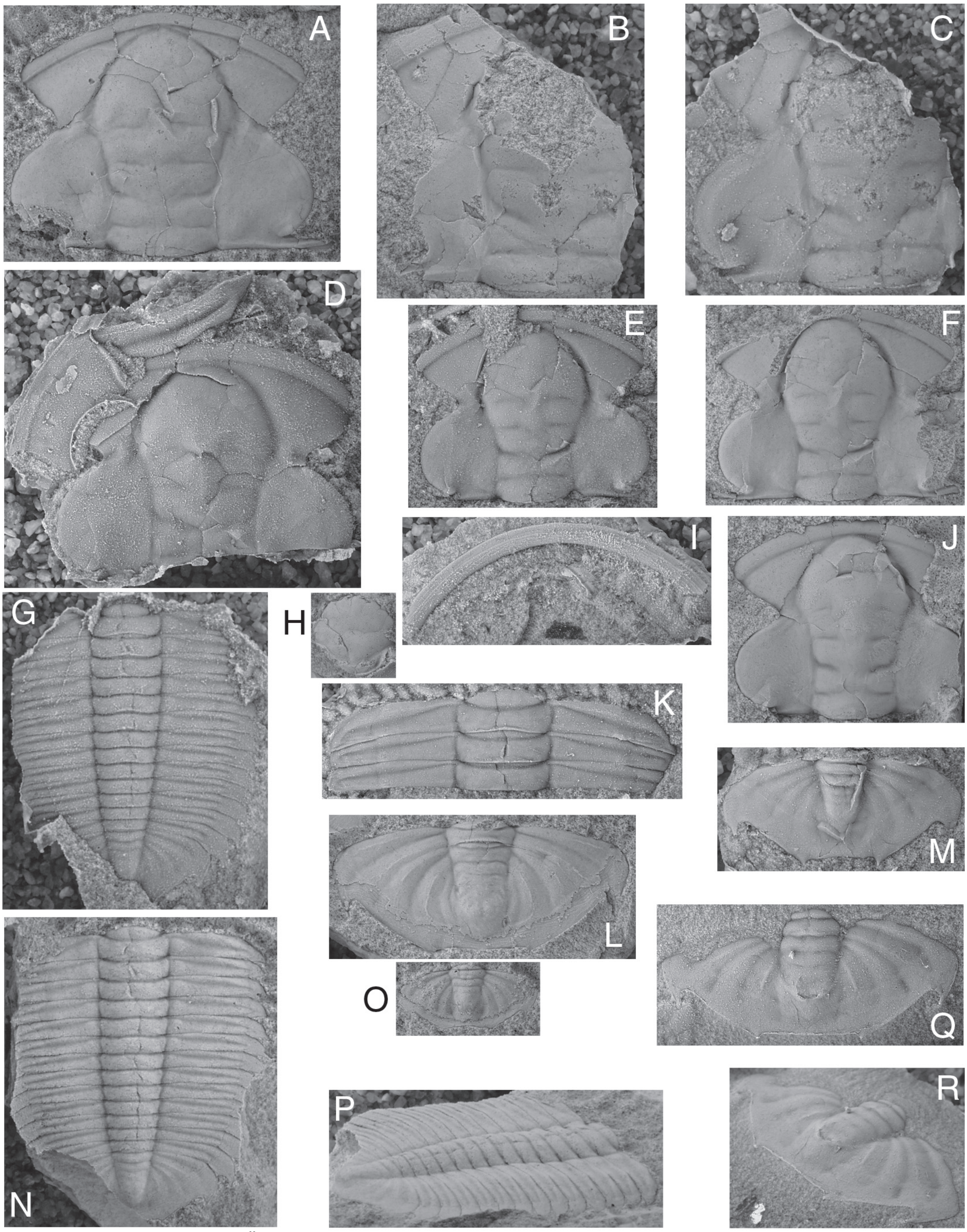


Fig. 10. Xystridura altera Öpik, 1975. All x2, all from Locality 4673, Howard Island, Northern Territory. A; Cranidium, CPC38932. B, C; Large partial cranidium, CPC38933; B, internal mould; C, latex replica of external mould. D; partial cranidium with associated partial librigena and partial thoracic segment, CPC38934. E, F; Cranidium, CPC38935; E, latex replica of external mould; F, internal mould. G, N, P; Thorax and partial pygidium, CPC38936; G, latex replica of external mould, dorsal view; N, dorsal view or internal mould; P, posterolateral oblique view of internal mould. H; Small hypostome, CPC38937. I; Large rostral plate, CPC38938. J; Cranidium, CPC38939. K; Three conjoined thoracic segments, CPC38940. L; Pygidium, CPC38941. M; Small pygidium, CPC38942. O; Small pygidium, CPC38943. Q, R; Latex replica of external mould of pygidium, CPC38944; Q, Dorsal view; R, posterolateral oblique view.

Anterior margin of glabella broadly parabolic, with maximum width at about where eye ridges intersect axial furrow. Posterior to eye ridges, lateral margins of glabella broadly concave such that the glabella is constricted, with its narrowest point being across S1. LO clearly defined, with a very small, poorly defined median node in its posterior half. SO well defined, narrow laterally, broader and less clearly defined medially, commonly with a slight forward bend. S1 straight, relatively deep, extending posteromedially from axial furrow to about two thirds distance to glabellar midline, at an angle of about 155° to 170° to each other. S2 narrow, moderately deep, straight, collinear, commonly not intersecting axial furrow, extending adaxially to about two thirds distance to glabellar midline. S3 weakly developed, not intersecting axial furrow, commonly arched forward.

Border moderately and evenly wide, flat to weakly convex, separated from genal field by narrow, clearly defined border furrow. Palpebral lobe long (exsag.), strongly and fairly evenly curved; inner margins weakly defined, connected to axial furrow by short, broad, poorly defined eye ridge. Posterior limbs of fixigena very wide (tr.), very short (exsag.), flat, curving slightly forward distally.

The γ-β segments of cephalic suture anteriorly diverge strongly from one another at an angle of about 90-110°, with γ a short distance from axial furrow about level with S3. The ε-ω segments of cephalic suture diverge very strongly from each other such that they are adaxially collinear; abaxially they curve slightly forward.

Librigena of fairly low convexity, with well developed, broad, weakly convex to flat lateral border furrow and narrow border furrow. Border extends posteriorly into genal spine of unknown extent. Posterior border very narrow (exsag.), slightly convex, separated from genal field by narrow border furrow.

Rostral plate broad (tr.), arcuate, slightly to moderately convex, with well developed terrace lines.

Hypostome broad (tr.), with large transverse middle body and probably with broad anterior wings. Maculae narrow, slit like, anteriorly bounding a narrow (sag., exsag.), crescentic posterior lobe. Border furrow well defined, separating narrow posterior and lateral borders from middle body. Posterior margin of hypostome broadly rounded.

Thorax of at least thirteen segments, with axial lobe of each segment clearly defined, widest (tr.) anteriorly. Anterior few axial lobes are all of similar width, with each axial lobe behind these becoming progressively narrower (tr.), such that axial lobe of posteriormost segment is only about 60% the width of that of the anteriormost segment. Pleural lobes weakly convex (tr.), with pleural furrow extending from near anterior extremity of axial furrow to a short distance from the lateral extremity of the pleural lobe. Pleural furrow is narrow adaxially, then widens to about one third the width (exsag.) of the pleural lobe, before narrowing abaxially and fading slightly beyond the inner margin of the pleural doublure. Pleural extremities are pointed and curved backwards, with each being more strongly curved backwards than that of the segment in front.

Pygidium transverse, subovate in outline, moderately convex, about 39% to 44% (mean 42%) as long (sag.) as wide, with a long narrow, tapered axis which is from 73% to 84% (mean 77%) as wide as long, and occupies 67% to 80% (mean 74%) of sagittal pygidial length. Pleural field weakly convex, sloping down from axial furrow to poorly defined border. Axis with three rings and well defined articulating half-ring, separated from anterior axial ring by deep, narrow, articulating furrow. Anterior axial ring posteriorly delimited by deep, transverse or slightly backwardly bowed interring furrow, or in one specimen by a pseudo-articulating half ring (Fig. 10L). Second axial ring always clearly defined posteriorly, with interring furrow weakly sinusoidal, with narrow forward arch near lateral extremities separated by broad backward arch over axial midwidth. Third axial ring defined posteriorly by weakly developed interring furrow, which is narrow, shallow and commonly does not extend to axial furrow. Axial furrow clearly developed adjacent to ring furrows, but weak to effaced around semiovate terminal piece. Pleural furrows variably developed, with anterior furrow commonly deepest and curving posteriorly only slightly. Second pleural furrow arises opposite first interring furrow and is evenly curved backwards along most of its length. Third pleural furrow arises opposite midlength of second axial ring and curves backwards such that the distal extremity is parallel to the pygidial midline. Fourth pleural furrow arises about opposite midlength of third axial ring and curves towards pygidial midline such that its distal extremity is behind the lateral extremity of the terminal piece. Pleural ribs are commonly capped by a low, narrow ridge. Border flat, poorly defined by gradual break in slope near terminations of pleural furrows. Pygidial margin with four narrow, posteriorly directed spines; medial pair are very small and arise between the termination of the third and fourth pleural furrows; larger lateral pair arise from lateral extremities of pygidium. Pygidial margin between medial spines straight to very slightly

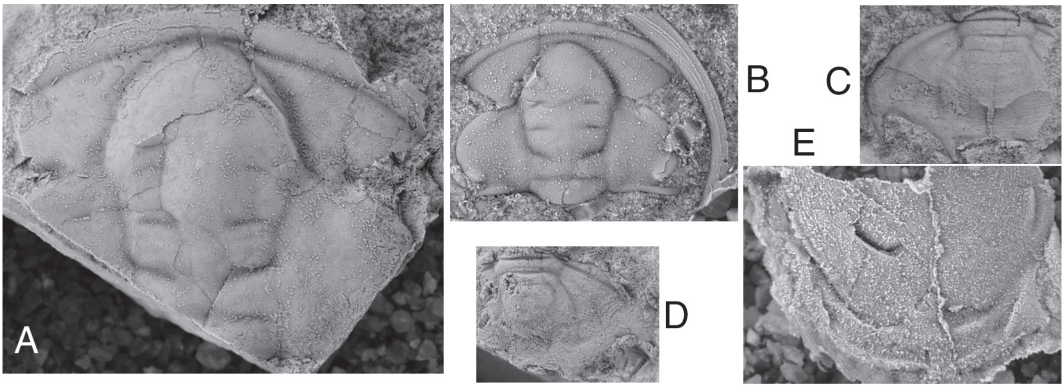


Fig. 11. *Xystridura ?filifera* Öpik, 1975. All x3, all from Locality 4666, Banyan Island, Northern Territory. A; Partial crandium, CPC38945. B; Cranidium with associated rostral plate, CPC38946. C; Small partial pygidium, CPC38947. D; Small partial pygidium, CPC38948. E; Large partial hypostome, CPC38949.

concave, that between medial spine and lateral spine straight to very slightly convex.

Remarks. These pygidia seem to be of the same species and are of only moderate convexity, have three axial rings, fairly small, narrow marginal spines and a length to width ratio of about 42%. These features indicate an assignment to *Xystridura altera* Öpik, 1975 is most appropriate and these specimens are confidently assigned to that species.

Xystridura ?filifera Öpik, 1975 (Fig. 11)

Material. Cranidium, CPC38945; cranidium with associated rostral plate, CPC38946; hypostome, CPC38949, pygidia CPC38947-CPC38948, all from Locality 4666, Banyan Island, Northern Territory.

Description. Of moderate size, smooth, with largest cranidium estimated to be about 16 mm long (sag.) and largest pygidium about 6 mm long (sag.). Cranidium of moderate convexity, about 80% as long as wide (the latter is measured across the anterior limbs of the fixigenae, β-β, despite the maximum width most commonly being across the posterior limbs of the fixigenae, ω-ω). Narrowest point of cranidium is immediately in front of palpebral lobes (γ-γ), where it is between 63% to 64% (mean 64%) of the width across β-β.

Glabella moderately convex, with maximum convexity across anterior lobe, about 60% as wide as long, occupying about 90% of cranidial length and extending to or nearly to anterior border furrow. Anterior margin of glabella parabolic, with maximum width about where the eye ridges intersect the axial furrow. Posterior to eye ridges, lateral margins of glabella are broadly concave such that glabella is constricted with its narrowest point being across S1. LO clearly defined, with posterior margin arched strongly backward and with a small axial node at about its midlength. SO transverse, straight, clearly defined, slightly wider across middle third of glabella. S1 straight or slightly curved, relatively deep, extending posteromedially from axial furrow to about two thirds distance to glabella midline, at an angle of about 140° to 150° to each other. S2 narrow, moderately deep, transverse, straight or slightly curved, commonly not intersecting axial furrow, extending adaxially to about two thirds distance to glabellar midline. S3 weakly to moderately well developed, transverse, straight to slightly curved, not intersecting axial furrow.

Border moderately and evenly wide, slightly convex, separated from genal field by narrow, clearly defined border furrow. Palpebral lobe long (exsag.), strongly and fairly evenly curved; inner margins weakly defined, connected to axial furrow by short, poorly defined eye ridge. Posterior limbs of fixigena very wide (tr.), very short (exsag.), slightly convex, curving slightly forward distally, comprising only border.

The γ-β segments of cephalic suture anteriorly diverge strongly from one another at an angle of about 115°-135°, with γ a short distance from axial furrow about level with S3. The ε-ω segments of cephalic suture diverge very strongly from each other such that they are adaxially collinear; abaxially they curve slightly forward.

Librigena unknown.

Rostral plate broad (tr.), arcuate, wider laterally, slightly to moderately convex (sag., exsag.), with well developed terrace lines.

Hypostome represented by a single poorly preserved partial specimen which has a large middle body the extent of which is unclear.

Maculae are narrow, slit-like and anteriorly bound a narrow (sag., exsag.) crescentic posterior lobe. Border furrow fairly well defined posteriorly; border narrow posteriorly. Posterior margin rounded.

Thorax unknown.

Pygidium transverse, subovate in outline, moderately convex, about 48% as long (sag.) as wide, with a short, tapered axis, which is about 93% as wide as long and occupies about 65% of sagittal pygidial length. Pleural field moderately convex, sloping down from weak axial furrow to poorly defined border. Axis with very well defined articulating half-ring, separated from anterior axial ring by deep, narrow, straight, articulating furrow. Anterior axial ring posteriorly delimited by well defined, straight interring furrow. Second axial ring posteriorly delimited by weak, narrow, straight, interring furrow. Third axial ring sometimes delimited by very weak interring furrow or fused to semiovate terminal piece. Axial furrow clearly developed only adjacent to anterior pair of axial rings, faint or effaced posteriorly. Pleural furrows variably developed, with anterior furrow deepest and curving backwards only near its distal extremity. Second pleural furrow arises opposite first interring furrow and is very weakly defined, and curves backward over most of its length. Third pleural furrow arises opposite midlength of second axial ring and curves backwards over its entire length such that the distal extremity is subparallel to pygidial midline. Fourth pleural furrow arises about opposite midlength of third axial ring and is initially directed straight backwards; it then curves towards pygidial midline such that its lateral extremity is located behind the lateral margins of the axial terminal piece. Border flattened, poorly defined by a break in slope near terminations of pleural furrows. Pygidial margin with four, relatively long, narrow, posteriorly directed spines; medial pair are almost as large as lateral pair and arise behind the termination of the third pleural furrows; lateral pair arise from lateral extremities of pygidium. Pygidial margin between medial spines slightly concave; that between medial spine and lateral spine straight to slightly concave.

Remarks. These pygidia seem to belong to the one species and are of only moderate convexity, have two or three axial rings, fairly long but narrow marginal spines and a length to width ratio of about 48%. These features indicate an assignment to *Xystridura filifera* Öpik, 1975, but the paucity of material makes certainty impossible. Consequently, the assignment is queried.

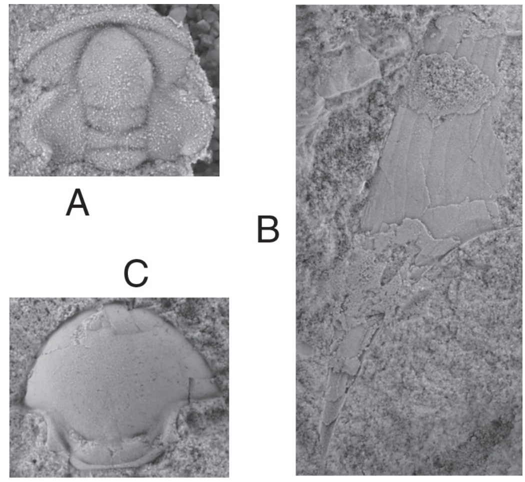


Fig. 12. Xystridura sp. indet. All x 3 except where noted, all from Locality 4674, Howard Island, Northern Territory. A; Small, poorly preserved cranidium, CPC38950. B; Large, partial doublure of librigena, x2, CPC38951. C; Well preserved hypostome, CPC38952.

Xystridura sp. indet. (Fig. 12)

Material. Cranidium, CPC38950; partial librigena, CPC38951; hypostome, CPC38952, all from Locality 4674, Howard Island, Northern Territory.

Description. Large, smooth, with specimens comprising a single cranidium about 7 mm long, a single hypostome of similar length and a posterior portion of a librigena with a large genal spine, totalling about 30 mm in length. The single small cranidium is not very well preserved, but is about 83% as long as wide. The narrowest point of the cranidium is immediately in front of the palpebral lobes (γ-γ), where it is about 64% of the width across β-β.

Glabella moderately convex, with maximum convexity across anterior lobe, about 52% as wide as long, occupying about 89% of cranidial length and extending to border furrow. Anterior margin of glabella narrowly parabolic, with maximum width at about where eye ridges intersect axial furrow. Posterior to eye ridges, lateral margins of glabella are broadly concave such that glabella is constricted, with its narrowest point being across S1. LO clearly defined, with posterior margin arched strongly backwards. SO well defined, arching slightly forward. S1 deep, straight, extending posteromedially from axial furrow to about two thirds distance to glabellar midline, at an angle of about 135° to each other. S2 straight, extending inward and slightly backward from axial furrow. S3 developed as

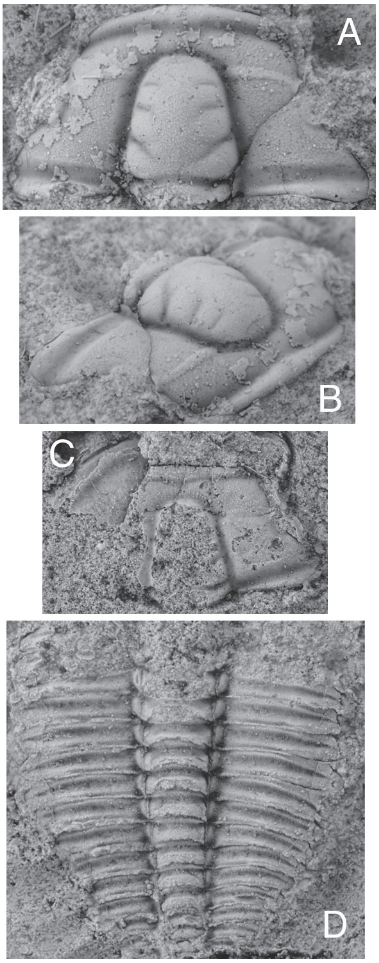


Fig. 13. A, B; Ptychoparioid sp. 1. cranidium, x6, CPC38953 from Locality 4673, Howard Island; A, dorsal view; B, anterolateral oblique view. C, D; Ptychoparioid sp. 2., both x6, both from Warnga Point, Elcho Island; C, poorly preserved cranidium, with associated librigena, CPC38954; D, partial thorax, CPC38955.

weak depressions.

Border moderately and evenly wide, slightly convex, separated from genal field by narrow, clearly defined border furrow. Palpebral lobes long, fairly evenly curved, inner margins fairly clearly defined, connected to axial furrow by short, broad, poorly defined eye ridges.

The γ-β segments of cephalic suture anteriorly diverge strongly from one another at an angle of about 120°, with γ a short distance from axial furrow about level with S3.

Librigena only represented by the ventral impression of a posterolateral portion of a large specimen. The genal spine is long and broadly based, while the doublure is broad (tr.) and covered in evenly spaced terrace lines.

Hypostome represented by a single, very well preserved specimen. Middle body large, broad, moderately convex, with an approximately parabolic anterior. Maculae narrow, slit-like, and anteriorly bound a narrow (sag., exsag.) crescentic posterior lobe. Border furrow very narrow posteriorly, bounding narrow, roll-like posterior border. Furrow deepens behind maculae and then broadens near where the middle furrow intersects the border furrow, at the same time the border becomes less well defined and has a well developed, angular lateral extension. From there the border furrow curves through about 90° such that the lateral extremities of the furrow are approximately collinear. Near the lateral extremities of the hypostome, the border furrow narrows.

Rostral plate, thorax and pygidium unknown.

Remarks. As there is no pygidium known from this locality, it cannot be assigned to a species and is therefore left under open nomenclature.

Order PTYCHOPARIIDA Swinnerton, 1915
?Family PTYCHOPARIIDAE Matthew, 1887

Ptychoparioid sp. 1 (Fig. 13A-B)

Material. A single cranidium, CPC38953 from Locality 4673, Howard Island, Northern Territory.

Remarks. This relatively well preserved cranidium is similar in many respects to the specimens assigned to *Lyriaspis alroiensis* by Whitehouse (1939), particularly in general appearance and proportions. However, it differs from that species in having considerably shorter eyes and consequently a much wider (exsag.) posterior limb to the fixigena. The lack of any other sclerites precludes generic assignment.

Ptychoparioid sp. 2. (Fig. 13C-D)

Material. A single poorly preserved cranidium, with an associated librigena, CPC38954, and a partial thorax, CPC38955, both from Warnga Point, Elcho Island, Northern Territory.

Remarks. This pair of specimens is unable to be assigned to a genus because of the limited material and its poor preservation. The cranidium is similar in proportion to the specimen discussed above (Ptychoparioid sp. 1), but has a straight, rather than curved anterior cranidial margin and a slightly narrower glabella. The thorax has at least 14 segments.

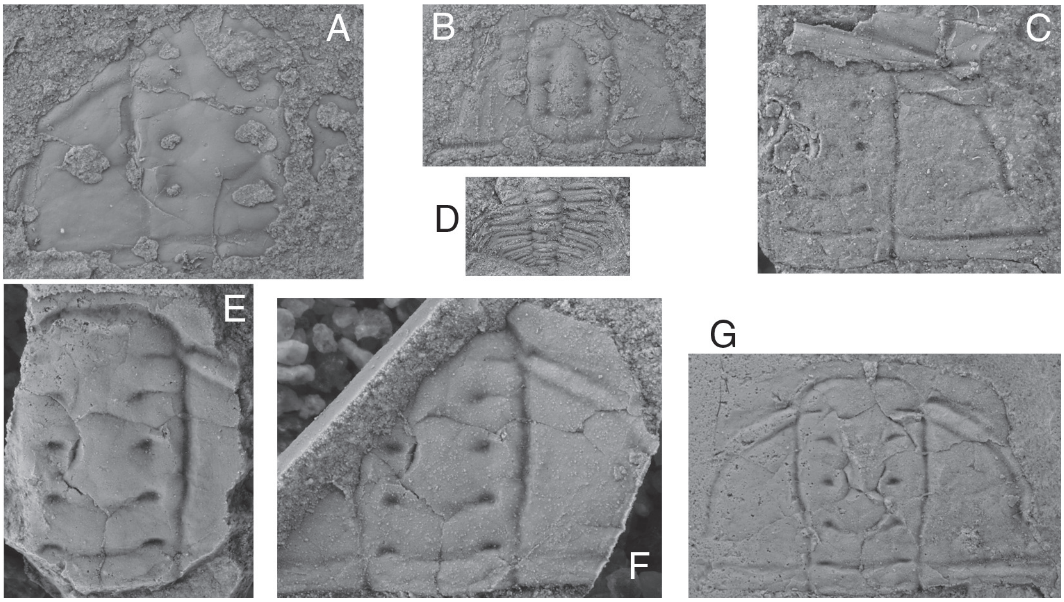


Fig. 14. Oryctocephalites ?reynoldsi (Reed, 1899); all x5, all from Warnga Point, Elcho Island, Northern Territory. A; partial cranidium, CPC38956. B; poorly preserved small cranidium, CPC38957. C; partial cranidium, CPC38958. D; small, partly disarticulated thorax possibly belonging to this species, CPC38959. E, F; partial cranidium, CPC38960; E, dorsal view of internal mould; F, latex replica of external mould. G; poorly preserved cranidium, CPC38961.

Order CORYNEXOCHIDA Kobayashi, 1935
Family ORYCTOCEPHALIDAE Beecher, 1897
Subfamily ORYCTOCEPHALINAE Beecher, 1897

Oryctocephalites Resser, 1939

Type species. Oryctocephalites typicalis Resser, 1939.

Remarks. Shergold (1969) used the number of pairs of spines on the pygidium to separate *Oryctocephalus* from *Oryctocephalites*, the former having six, the latter five. Palmer (in Palmer & Halley 1979) distinguished the genera on the basis of *Oryctocephalus* having at least two transglabellar furrows, while *Oryctocephalites* had only one. Sundberg & McCollum (1997) found neither of these criteria satisfactory in undertaking a cladistic analysis of the Subfamily Oryctocephalinae and determined that *Oryctocephalus* could be distinguished from *Oryctocephalites* in having "parallel-sided or conical glabella, two or more transglabellar furrows, longitudinal glabellar furrows, and 12 or more thoracic segments" (Sundberg & McCollum 1997, p. 1071).

Oryctocephalites ?reynoldsi (Reed, 1899) (Fig. 14)

Material. Cranidia, CPC38956-CPC38958, CPC38960-CPC38961; thorax probably of this species, CPC38959, all from Warnga Point, Elcho Island, Northern Territory.

Remarks. These specimens are either poorly preserved or fragmentary and no pygidia have been found. They are most similar to the specimens assigned to *Oryctocephalus reynoldsi* by Shergold (1969), which Sundberg & McCollum (1997) assign to *Oryctocephalites*, and to the single cranidium assigned to *Oryctocephalus ?reynoldsi* by Laurie (2004, p. 252). Like Shergold's specimens, the Elcho Island specimens have a slightly expanded glabella, a wide (exsag.) anterior cranidial border and well developed eye ridges which are separated from the anterior border by a thin (exsag.), subtriangular section of fixigenal field. However, there are some differences. These include the S4 glabellar furrows which, in the Elcho Island specimens and in *O. ?reynoldsi* of Laurie (2004), are transverse, whereas those in Shergold's specimens are directed anteromedially from the axial furrow. Also, the fixigenae in the Elcho Island specimens are slightly wider than in those of Shergold (1969) and Laurie (2004),

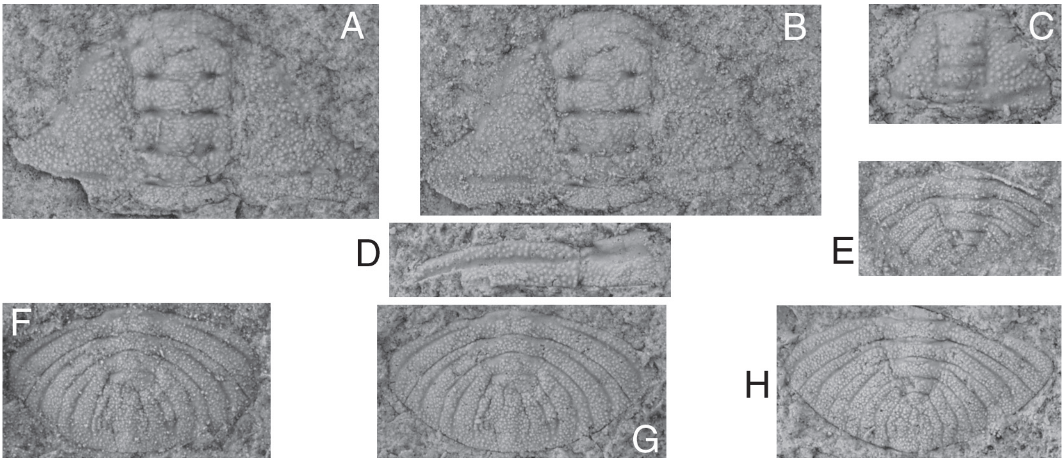


Fig. 15. *Arthricocephalus* sp. nov.; all x10, all from Locality 4673, Howard Island, Northern Territory. A, B; Cranidium, CPC38962; A, internal mould; B, latex replica of external mould. C; small cranidium, CPC38963. D; partial thoracic segment, CPC38964. E, H; pygidium, CPC38965; E, latex replica of part of external mould; H, internal mould. F, G; pygidium, CPC38966; F, latex replica of external mould; G, internal mould.

and the palpebral lobes are slightly shorter. In these features, it is like *Oryctocephalites gelasinus* Shergold, 1969, but that species has a more strongly arched anterior cephalic margin, a narrower anterior cephalic border, the border furrow of which is subparallel to the eye ridges, rather than diverging laterally. As a consequence of these differences, the species is left under open nomenclature.

Subfamily ORYCTOCARINAE Hupé, 1955

Arthricocephalus Bergeron, 1899

Type species. *Arthricocephalus chauveaui* Bergeron, 1899.

Arthricocephalus sp. nov. (Fig. 15)

Material. Cranidia, CPC38962-CPC38963; thoracic segment, CPC38964; pygidia, CPC38965-CPC38966, all from Locality 4673, Howard Island, Northern Territory.

Description. Small, with single large cranidium being about 2.7 mm long and the two pygidia being about 1.9 mm long. The cranidium is approximately 53% as long as wide, with the widest point being across the posterior limbs of the fixigenae. Entire surface, except for furrows, coarsely pustulose.

Glabella long, about 57% as wide as long, nearly parallel-sided for most of its length, but expands anteriorly (in front of S3), so that the width across the occipital ring is about 84% maximum glabellar width, which is across the anterior lobe. Anterior margin of glabella broadly rounded; lateral margins straight to slightly concave; anterolateral corners angular to very narrowly rounded. LO clearly defined, slightly wider medially than laterally, bent slightly backward. SO bent slightly backward, shallow medially, deep laterally. S1 developed as two deep pits connected by a broad, indistinct furrow which is bent slightly backward. S2 developed as two deep pits connected by a broad, indistinct furrow which is bent very slightly backward. S3 developed as two deep pits connected by a very vague transverse depression. S4 developed as small, transverse depressions, with deepest part closer to axial furrow than all other glabellar furrows, adjoining axial furrow adjacent to posterior margins of eye ridges.

Eye ridges unclear on this specimen, but fairly short, trending posterolaterally from axial furrows, such that eye ridges are at about 135° to one another. Palpebral lobe also indistinct on this specimen, short, slightly curved, directed posterolaterally from ends of eye ridges. Fixigenae in front of eye ridges not preserved; posterior to eye ridges, fixigenae are subtriangular and very wide. The ε-ω segments of the cephalic suture diverge very strongly from each other and are probably proparian. Posterior border fairly narrow adjacent to axial furrow, widening laterally, separated from genal field by wide border furrow.

Librigena, rostral plate and hypostome unknown.

A single, partial thoracic segment is known.

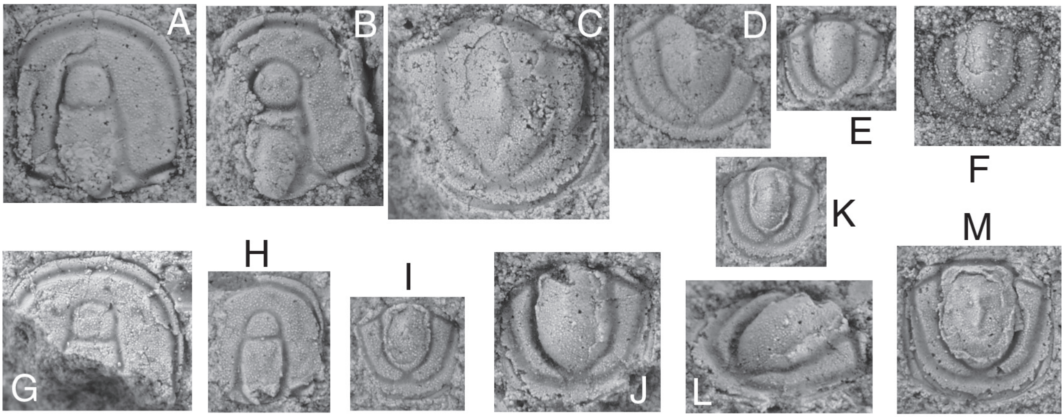


Fig. 16. ?*Itagnostus* sp.; all x10; A, B from Locality 4666, Banyan Island; C-E from Locality 4673, Howard Island; F-M from Warnga Point, Elcho Island. A; cephalon, CPC38967. B; partial cephalon, CPC38968. C; poorly preserved large pygidium, CPC38969. D; partial pygidium, CPC38970. E; small pygidium, CPC38971. F; latex replica of small pygidium, CPC38972. G; partial cephalon, CPC38973. H; small cephalon, CPC38974. I; small pygidium, CPC38975. J, L; pygidium, CPC38976; J, dorsal view; L, posterolateral oblique view. K; small pygidium, CPC38977. M; pygidium, CPC38978.

This has a well developed articulating half-ring separated from the postannulus by a broad articulating furrow. The pleural lobe curves slightly backward beyond the fulcrum and possesses a deep pleural furrow along its entire length (the distal extremity is missing). The anterior band is very narrow adjacent to the vague axial furrow and widens slightly abaxially, while the posterior band is very wide near the axial furrow and narrows slightly abaxially; however, it is always wider than the anterior band.

Pygidium transversely subovate in outline, very weakly convex, with the two specimens being 52% and 53% as long as wide, with a short, strongly tapered axis which is 77% and 83% as wide as long, and occupying 63% and 68% of the pygidial length. Axis poorly defined by very vague axial furrow, with a poorly defined articulating half-ring. Four axial rings are visible and on one specimen a very small triangular terminal piece is evident; on the other specimen this part of the pygidium seems to be either taphonomically or pathologically distorted. Interring furrows are very well defined and continue across pleurae as very narrow interpleural furrows, extending all the way to the arcuate pygidial margin. Pleural furrows are well developed and wider than the interpleural furrows, but they also extend all the way to the pygidial margin. However, near their distal extremities, they have a sharp backward bend unlike the interpleural furrows. As a consequence, at the pygidial margin, the pleural furrows tend to be closer to the posterior of the two adjacent interpleural furrows, despite being closer to the anterior of the two through most of its length.

Remarks. These specimens clearly belong to the Oryctocarinae and most likely belong in *Arthricocephalus* because of the transglabellar furrows and the proparian sutures (Sundberg, pers. comm. September, 2004). They differ from the type species of that genus (*A. chauveaui*) in having more rearwardly angled eye ridges and a wider pygidial axis with only four axial rings. *Arthricocephalus granulus* Qian & Lin (in Zhou *et al.*, 1977) is also similar in some respects, but has a wider (tr.) and longer (exsag) posterior limb to the fixigena and a very much more transverse pygidium. While it is clear this species is new, the material available is not sufficient to name a species, consequently it is left under open nomenclature.

It is worth noting that this species is probably the youngest representative of the genus *Arthricocephalus*, as it is associated with what is probably an early Middle Cambrian fauna. All other species of the genus have been recorded from the Early Cambrian. However, the Early-Middle Cambrian boundary in the central and northern Australian succession is unlikely to be where Öpik (1968, 1970) placed it (i.e. below the Ordian). Indeed, if the first appearance datum of *Oryctocephalus indicus* is selected as the guide fossil for the GSSP, as appears likely, it is perhaps most probable that the Early-Middle Cambrian boundary lies somewhere near the base of the Templetonian (as revised by Laurie 2006) as suggested by Paterson & Brock (in press).

?Class TRILOBITA Walch 1771
Order AGNOSTIDA Salter, 1864
Superfamily AGNOSTOIDEA M'Coy, 1849

Itagnostus Öpik, 1979

Type species. *Agnostus elkedraensis* Etheridge Jr, 1902.

?Itagnostus sp. (Fig. 16)

Material. Cephala, CPC38967-CPC38968 from Locality 4666, Banyan Island; pygidia, CPC38969-CPC38971 from Locality 4673, Howard Island; cephala, CPC38973-CPC38974; and pygidia, CPC38972, CPC38975-CPC38978 from Warnga Point, Elcho Island.

Remarks. All of these specimens are fairly similar in appearance in that the cephala have a well defined glabella with a prominent anterior lobe, very small triangular basal lobes and a posteriorly located glabellar node. The nonspinose pygidia all have a very broad axis which extends to, or nearly to, the border furrow and lacks transverse furrows. Consequently, they are assumed to be conspecific, but this cannot be known with any certainty. The features listed above clearly indicate an assignment to *Itagnostus* Öpik, although this series of specimens is unlike any of the well known species assigned to that genus. Its cephalon and pygidium are narrower (tr.) and its pygidial axis comparatively wider (tr.) than those of *I. elkedraensis* (Etheridge, 1902) (see Laurie, 2004, p. 237), *I. walleyae* Laurie (2004, p. 240) and *I. oepiki* Laurie (2004, p. 239). The proportions of the cephalon and pygidium are quite similar to '*Peronopsis*' *normata*, recorded by Whitehouse (1936) and Öpik (1979, p. 55) from the Beetle Creek Formation, but lack the well developed posterolateral pygidial spines evident on '*P.*' *normata*. The limited amount and poor preservation of the material precludes any more detailed analysis.

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