Silurian Brachiopods from the Historic Woolshed Creek Area, Canberra, Australia

Desmond L. Strusz

Department of Earth and Marine Sciences, Research School of Earth Sciences, Australian National University, Canberra ACT 0200 (desmond-strusz@homemail.com.au)

Published on 21 November 2011 at http://escholarship.library.usyd.edu.au/journals/index.php/LIN

Strusz, D.L. (2011). Silurian brachiopods from the historic Woolshed Creek Area, Canberra, Australia. *Proceedings of the Linnean Society of New South Wales* **133**, 33-51.

The brachiopod fauna of seven species from the Canberra Formation at Woolshed Creek near Duntroon, Canberra, is revised. Four species were collected by W.B. Clarke in 1844 and represent the first formal recognition of Silurian rocks in Australia. Referred to European species and genera by de Koninck in 1876, these are now recognised as *Mesoleptostrophia (Mesoleptostrophia) oepiki*, *Morinorhynchus oepiki*, *Apopentamerus clarkei* n.sp. and *Atrypa (Atrypa) duntroonensis*. The last dominates the fauna, and was first described by Mitchell and Dun in 1920; a Canberra atrypid compared by Strusz in 1985 to the Victorian Early Devonian species *Spinatrypa perflabellata* is now known to be *A. (A.) duntroonensis*. *Salopina mediocostata*, *Hedeina oepiki*, and *Spirinella caecistriata* are also present, together with uncommon trilobites (mostly *Batocara mitchelli*), corals, gastropods and bryozoans, some of which are illustrated. The fossils occur in repeated crowded layers which probably represent storm deposits. The age is most likely to be Homerian (latest Early Silurian).

Manuscript received 10 June 2011, accepted for publication 15 November 2011.

Key words: *Apopentamerus*, *Atrypa*, brachiopods, Canberra, corals, *Hedeina*, Homerian, *Mesoleptostrophia*, *Morinorhynchus*, *Salopina*, Silurian, *Spirinella*, trilobites.

INTRODUCTION

Woolshed Creek runs south to join the Molonglo River a little to the east of Royal Military College, Duntroon (eastern Canberra), where it is crossed by Fairbairn Avenue. Duntroon was the family home of Robert Campbell, a wealthy merchant and grazier who first took up land along the Molonglo River in 1825. The property was managed by James Ainslie; Campbell only lived at Duntroon after his wife's death in 1833, and died there in 1846. In 1844, Rev. W.B. Clarke, pastor and geologist, visited the area during his travels in southern New South Wales on behalf of the colonial government, and undoubtedly stayed with Campbell (whom he would have known from his period as headmaster of the Kings School from 1839 to 1841, a school established partly at Campbell's instigation). While at Duntroon, Clarke collected fossils from the vicinity, and from Yarralumla a few kilometres to the west. He recognised that these fossils were of undoubted Silurian age, a conclusion he published in 1848. This was the first published identification of Silurian fossils in Australia, and much later led to an area along Woolshed Creek, including the original outcrop, being registered as a Geological Heritage Site. Clarke's fossil collections were subsequently examined by L.G. de Koninck of Leuven University (Belgium), and published by him in 1876-7. The collections were destroyed in the Garden Palace fire of 1882 in Sydney. Mitchell and Dun recollected Clarke's site, and in 1920 described *Atrypa duntroonensis* based on three rather poor specimens. Öpik (1958, figs 19, 20), published photos of the outcrop north of Fairbairn Avenue, at which time layers crowded with brachiopods could be seen. Unfortunately since then there has been much deterioration, so that the site is no longer as spectacular.

New material

At the beginning of the 21st Century traffic along Fairbairn Avenue became sufficiently heavy that the ACT government proposed duplicating the existing bridge across Woolshed Creek. This was to be sited just downstream of the existing bridge, in a part of the heritage site lacking outcrops - hence not disturbing the existing exposure. Excavations for the bridge

abutments were carried out in 2008, and yielded large quantities of fossiliferous material. Opportunity was taken to collect specimens, and these form the basis of the present paper.

The fauna is dominated by *A. duntroonensis*. The fossils occur in repeated layers crowded with shells, with mostly dissociated but unbroken or only slightly damaged convex upwards valves indicating that most layers are probably storm deposits from below normal wave base (Fig. 1). Occasional layers contain syringoporoid corals which appear to be in growth position, and are less crowded with shells, suggesting these were subject to less disturbance before being buried by silt. Seven species of brachiopod have been identified in the collections. Of these, only one - a very rare smooth pentameride - is new, and overall the fauna is typical of the Canberra Formation, as described by Strusz (1985a). Interestingly, four of the brachiopods (including the rare pentameride) were collected by Clarke and identified reasonably accurately as European Silurian species by de Koninck (1876-7), who consequently (but unfortunately) neither described nor illustrated them.

All the material is distorted, partly by compaction and partly due to tectonic forces. The degree of distortion is variable, probably because of different amounts of compaction depending on the amount and nature of the silt enclosing the fossils. Shells are randomly oriented on the bedding planes, so that analysis of size and proportions is feasible but can only be approximate (see remarks in Strusz 1985a:112-114).

Stratigraphy and age

The Woolshed Creek locality was included by Öpik (1958) in his Riverside Formation, which is now regarded as part of the lithologically variable Canberra Formation. Unfortunately there is no reliable evidence from conodonts or graptolites for the age of this unit, which must therefore be argued on the basis of stratigraphic correlation with the succession at Yass, north of Canberra; for a fuller discussion see Strusz (2010b). The most likely age for the Canberra Formation has been deduced to be late Sheinwoodian to early Homerian. From mapping by the Engineering Geology section of the former Australian Bureau of Mineral Resources (now Geoscience Australia), it is likely that the Woolshed Creek locality is high in the

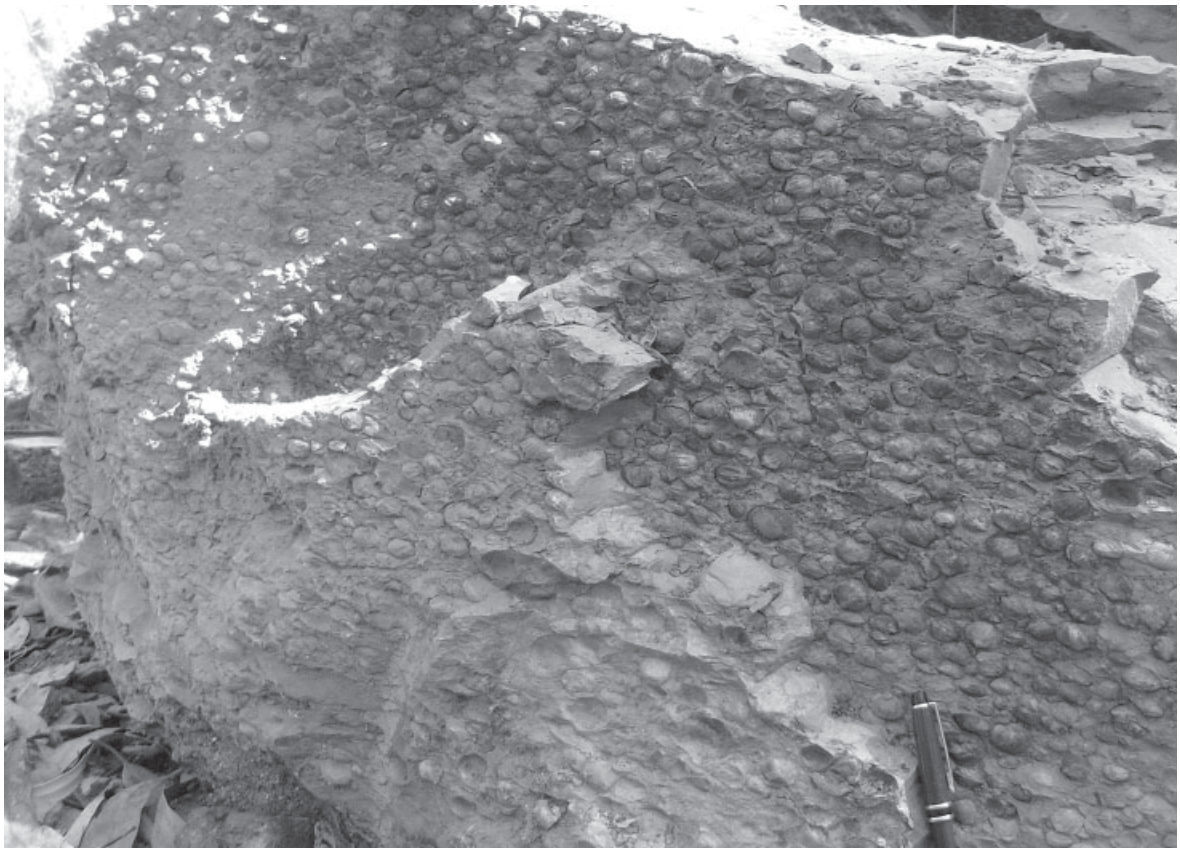

Figure 1. Large excavated slab of siltstone from Woolshed Creek, showing successive layers crowded with *Atrypa* valves and shells, mostly moulds and convex-upwards.

formation, which would indicate an early Homerian age (see Strusz and Henderson 1971, Henderson and Matveev 1980).

SYSTEMATIC PALAEONTOLOGY

Specimens registered with the Australian Museum, Sydney, have numbers prefixed AM F, those with the Department of Earth and Marine Sciences, Research School of Earth Sciences, Australian National University are prefixed ANU, and those in the Commonwealth Palaeontological Collection, Geoscience Australia, Canberra, are prefixed CPC. Geoscience Australia and the Research School of Earth Sciences, Australian National University, also hold unregistered bulk material.

Classification follows that in the Treatise on Invertebrate Paleontology, part H (Revised). References to supra-generic taxa can be found in the relevant parts of the Treatise. Only *Atrypa duntroonensis* and the new pentameride are fully described.

Class STROPHOMENATA Williams et al. 1996
Order STROPHOMENIDA Öpik, 1934
Superfamily STROPHOMENOIDEA King, 1846
Family LEPTOSTROPHIIDAE Caster, 1939
Genus MESOLEPTOSTROPHIA Harper and Boucot, 1978
Subgenus MESOLEPTOSTROPHIA Harper and Boucot, 1978

Type species

Mesoleptostrophia kartalensis Harper and Boucot, 1978, p. 68 [= *Strophodonta (Leptostrophia) explanata* Paeckelmann and Sieverts, 1932, non Sowerby, 1842]. Early Devonian, Turkey.

Mesoleptostrophia (Mesoleptostrophia) oepiki (Strusz, 1985)
Fig. 2

Synonymy

Leptaena compressa, J. de C. Sowerby; de Koninck 1876:27; non *Orthis compressa* J. de C. Sowerby, 1839, which is *Mesoleptostrophia (Mesoleptostrophia) compressa* - see Cocks 2008:70; de Koninck (transl. Dun in David, David and Dun) 1898:22.

Leptostrophia (Leptostrophiella) oepiki Strusz, 1985a:110-111, Figs 4-5.

Pholidostrophiidae? gen. et sp. indet. Strusz, 1985a:111, Fig. 6.

M. (Mesoleptostrophia) oepiki (Strusz); Strusz 2010b, Figs 2, 3K-M.

Type material

Holotype CPC24751, paratypes CPC24744-24750, 24752-24783, 24877, 24880-24883, 24903-24905, 24917-24922. Canberra Formation, Fyshwick, ACT. Wenlock.

Woolshed Creek material. AM F.110137-110141, 110193-110196, 110212-110214, 110225-110226, 110253-110254, 110259, 110263, 110268, 110276-110280, 110316-110318, 110350, 110368, 110413-110418, 110423-110424.

Diagnosis (new)

Moderately concavo-convex *Mesoleptostrophia* of medium to large size, uniformly costellate, with long narrow alae, denticulation to 1/3 width of corpus; low ridges posterolaterally bounding subtriangular, posteriorly strongly impressed ventral muscle field, lateral to which valve floor is coarsely tuberculate; fine ventral myophragm; prominent notothyrial platform continuous with dorsal myophragm and pair of often prominent curved muscle-bounding ridges.

Discussion

The description given by Strusz (1985a) is generally adequate, except that the outline is erroneously described there as elongate (instead of transversely) semi-elliptical. Ls/Ws (excluding alae) varies in the Fyshwick material between 2/3 and 3/4. The material from Woolshed Creek agrees well with that from Fyshwick, although in some bands the distortion is greater.

Two species of *M. (Mesoleptostrophia)* are now known from the Silurian of the Yass-Canberra region (see Strusz, 2010b). *M. (M.) oepiki* differs from the somewhat younger *M. (M.) quadrata* (Mitchell, 1923) in its long, slender alae separated from the less quadrate corpus by weaker reentrants, coarser ribs, no anterior sulcus in gerontic shells, a fine ventral myophragm, and curved dorsal muscle-bounding ridges. *M. (M.) oepiki* is readily distinguished from the similarly alate *Mesopholidostrophia bendeninensis* (Mitchell, 1923) by its stronger ornament, weaker convexity, stronger ventral and dorsal muscle-bounding ridges, and stronger notothyrial platform.

The large dorsal valve (CPC24884) considered by Strusz (1985a) to be a probable pholidostrophiid is distinctive in that its strong muscle-bounding ridges and myophragm are supplemented by two distinct

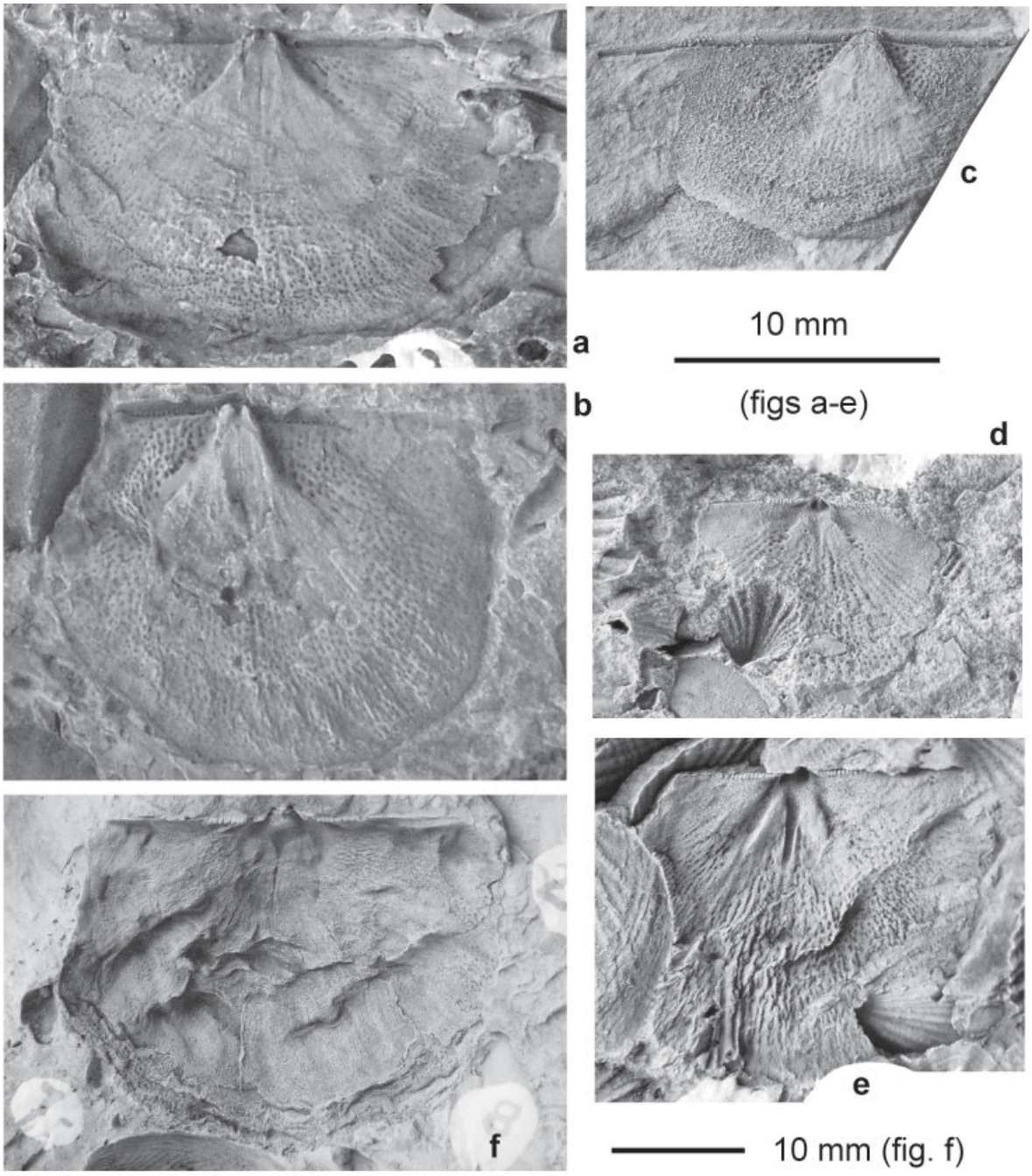

Figure 2. ***Mesoleptostrophia*** **(*Mesoleptostrophia*)** ***oepiki*** **(Strusz, 1985); a, AM F.110193, ventral internal mould; b, AM F.110194, ventral internal mould; c, AM F.110141, incomplete ventral internal mould showing long narrow ala and concave lateral margin; d, AM F.110413, incomplete dorsal internal mould clearly showing bifid cardinal process, denticulate cardinal margin; e, AM F.110415, incomplete dorsal internal mould showing relatively robust myophragm and muscle-bounding ridges; f, AM F.110317, crushed gerontic dorsal internal mould showing more complex muscle field, including curved bounding ridges and short anderidia - compare CPC24884 (Strusz 1985a, fig. 6).**

ridges within the adductor muscle field. One large dorsal internal mould from Woolshed Creek (AM F.110317, Fig. 2f) has a similar complex of structures, and I now think it is most likely that the Fyshwick specimen is a gerontic *M.(M.) oepiki*.

The specimens collected by Clarke from "Duntroon" and reported (but not figured) by de Koninck (1876) can confidently be referred to *M. (M.) oepiki*.

Order ORTHOTETIDA Waagen, 1884
Suborder ORTHOTETIDINA Waagen, 1884
Superfamily CHILIDIOPSOIDEA Boucot, 1959
Family CHILIDIOPSIDAE Boucot, 1959
Subfamily CHILIDIOPSINAE Boucot, 1959
Genus MORINORHYNCHUS Havlíček, 1965

Type species

Morinorhynchus dalmanelliformis Havlíček, 1965, p. 291. Ludlow, Bohemia.

Morinorhynchus oepiki Strusz, 1982
Fig. 3

Synonymy

Strophomenes pecten, Linnaeus; de Koninck 1876:28; non *Anomia pecten* Linnaeus, 1767, which is *Coolinia pecten* - see Cocks, 2008:99; de Koninck (transl. Dun in David, David and Dun) 1898:22.

Morinorhynchus oepiki Strusz, 1982:119-122, Figs. 14-15; Strusz, 1985a:111-112, Fig. 7; Strusz, 1985b:681-682, Figs 3.1-9; Strusz 2003:31-32, Fig. 20; Strusz, 2010b, Figs 2, 3 K'-M'.

Morinorhynchus oepiki?; Strusz, 1985b:681-682, Fig. 3.10.

Type material

Holotype CPC20987, paratypes CPC20415-20419, 20988-20994. Walker Volcanics, Canberra. Late Wenlock.

Woolshed Creek material

AM F.110165, 110297, 110335, 110346, 110369-110370

Diagnosis

Thin, nearly planoconvex to slightly resupinate *Morinorhynchus* with fine unequally parvicostellate ornament (Strusz 2003).

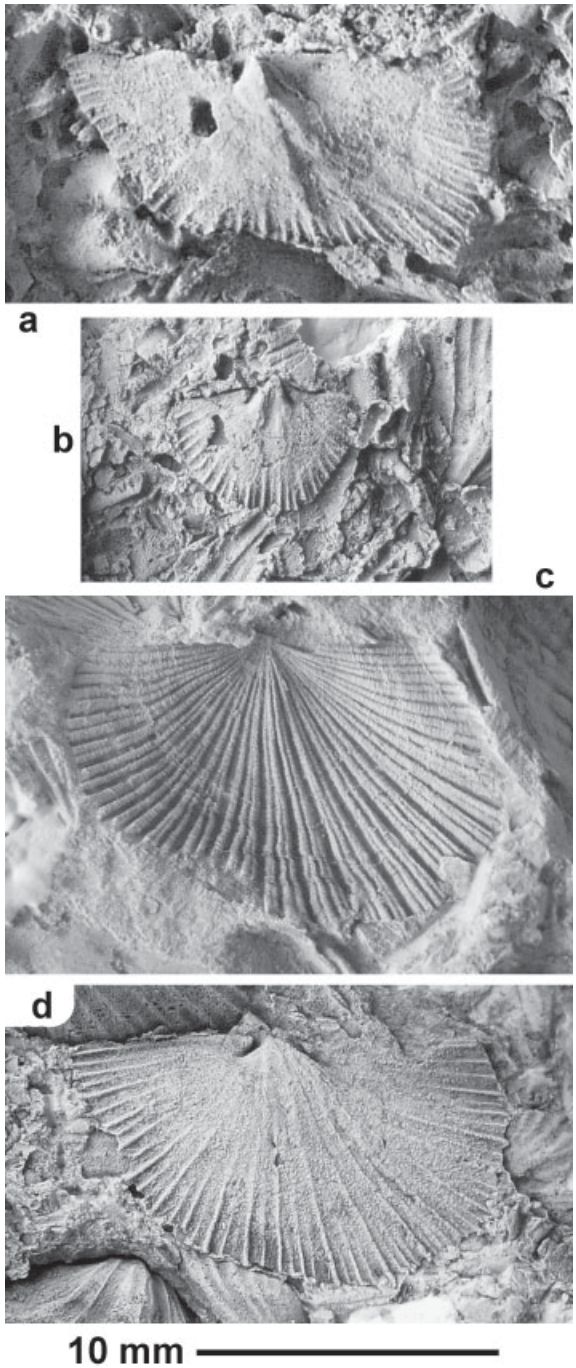

Figure 3. *Morinorhynchus oepiki* Strusz, 1982; a, AM F.110297, incomplete and rather strongly distorted ventral internal mould; b, AM F.110346, small ventral internal mould; c, AM F.110335, dorsal external mould; d, AM F.110370, dorsal internal mould.

Remarks

The few small specimens from the Woolshed Creek excavations are very similar to those described

by Strusz (1985a) from the Canberra Formation in Fyshwick, and the remarks made therein still apply. It is an uncommon species at all known localities.

This is almost certainly the species from "Duntroon" referred by de Koninck (1876) to *Anomia pecten* Linnaeus, 1767, a species which has since been referred to the related and quite similar genus *Coolinia* Bancroft, 1949.

Class RHYNCHONELLATA Williams et al., 1996
Order ORTHIDA Schuchert and Cooper, 1932
Suborder ORTHIDINA Schuchert and Cooper, 1932
Superfamily ENTELETOIDEA Waagen, 1884
Family DRABOVIIDAE Havlíček, 1950
Subfamily DRABOVIINAE Havlíček, 1950
Genus SALOPINA Boucot in Boucot et al., 1960

Type species

Orthis lunata J. de C. Sowerby, 1839. Ludlow, Shropshire.

Salopina mediocostata Strusz, 1982
Fig. 4

Synonymy

Salopina mediocostata Strusz,1982:111-114, Figs 5-7; Strusz 1984:125-126, Figs 2-3; Strusz, 1985a:108, Fig. 3; Strusz 2002:67-70, Figs 11-13; Strusz, 2010b: Figs 4, 5 M-P.

Type material

Holotype CPC20337, paratypes CPC20253-20336, 20338-20344, 20932-20942. Walker Volcanics, Wenlock, Canberra.

Woolshed Creek material

AM F.110127-110132, 110227, 110255, 110371-110374, 110396-110397.

Remarks

This species is not common at Woolshed Creek, and nearly all of the specimens are quite small - the largest measured is AM F.110227 with a width of 7.2 mm, but most are less than 4 mm across. However, they are closely comparable with previously published specimens, especially the similarly distorted Fyshwick material (Strusz 1985a) e.g. compare the ventral internal mould of AM F.110130 (Fig. 4a) with CPC24731 (1985a, fig. 3C), and the dorsal internal mould AM F.110227 (Fig. 4c) with CPC24913 (1985a, fig. 3G). Unfortunately all available external moulds are incomplete and not well preserved, so the presence of the enlarged median costella on the dorsal valve, characteristic of the Walker Volcanics specimens, cannot be confirmed.

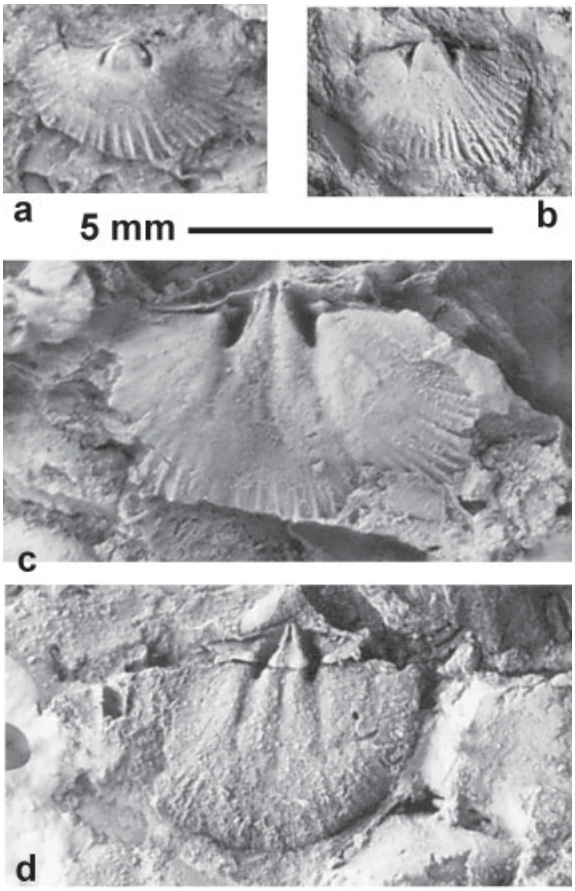

Figure 4. ***Salopina mediocostata*** **Strusz, 1982; a, AM F.110130, small ventral internal mould - compare Strusz, 1985a, fig. 3C; b, AM F.110372, small ventral internal mould; c, AM F.110227, incomplete dorsal internal mould - compare Strusz, 1985a, fig. 3G; d, AM F.110374, dorsal internal mould.**

Order PENTAMERIDA Schuchert and Cooper, 1931
Suborder PENTAMERIDINA Schuchert and Cooper, 1931
Superfamily PENTAMEROIDEA M'Coy, 1844
Family PENTAMERIDAE M'Coy, 1844
Genus APOPENTAMERUS Boucot and Johnson, 1979

Type species

Apopentamerus racinensis Boucot and Johnson, 1979. Wenlock, Wisconsin, USA.

Diagnosis (new)

Smooth non-lobate pentamerine, moderately to strongly biconvex with ventral valve usually deeper than dorsal valve; outline transversely oval to pyriform; ventral median septum long, supporting narrow spondylium; inner hinge plates subparallel, long, their junction with outer hinge plates smooth, without flanges.

Discussion

The diagnosis is based on the original diagnosis of Boucot and Johnson, plus the discussion of pentamerine relationships by Rong, Jin and Zhan (2007) analysed below.

Boucot and Johnson erected *Apopentamerus* for a Wisconsin pentameride species differing from *Isovella* Breivel and Breivel in Antsigin et al., 1970, in the presence of a spondylium, and from *Harpidium* Kirk, 1925, in its significantly longer ventral median septum. The dorsal interior is as in *Pentamerus* J. Sowerby, 1813. Sapel'nikov (1985) considered *Isovella* and *Apopentamerus* to be synonyms of *Harpidium*.

Boucot, Rong and Blodgett (in Kaesler, 2002), treated *Isovella* as a subgenus of *Harpidium*, characterised by a moderately long ventral median septum and substantial thickening in the ventral umbo. They considered *Apopentamerus* to be a synonym of *H. (Isovella)*, and *Sulcipentamerus* Zeng, 1987, to be a third subgenus of *Harpidium* characterised by its elongate and markedly ventribiconvex shell, and a short ventral median septum.

Sulcipentamerus has been extensively revised on the basis of large collections by Rong, Jin and Zhan (2007) and Jin, Harper and Rasmussen (2009). In their discussion of generic relationships, they noted that *Isovella* has laterally projecting crural bases (the flanges of Boucot et al. in Kaesler 2002) at the junction of inner and outer hinge plates - flanges not seen in *Harpidium*, *Apopentamerus*, and *Pentamerus* itself. As this is a feature previously recognised as taxonomically useful, Rong et al. (2007: 248) noted 'This implies that *Apopentamerus* is either a valid genus or a subgenus of *Harpidium* and that *Isovella* is most likely to be a genus independent of *Harpidium*.'. These authors also pointed out that Boucot et al. (in Kaesler 2002) regarded *Sulcipentamerus* as a subgenus of *Harpidium* on the assumption that it lacked trilobation. However, the strong variability shown by the large Chinese collections (including species with a weak tendency in large shells to trilobation), and also by collections of *Pentamerus oblongus* J. de C. Sowerby, 1839, from Estonia and Norway (ranging from non-lobate to markedly trilobate), '..suggests that *Sulcipentamerus* is more closely related to *Pentamerus* than to *Harpidium*.' (Rong et al. 2007:249). It seems to me, from the above, that *Apopentamerus* is best treated as a valid genus distinct from both *Pentamerus* and *Harpidium*.

Apopentamerus clarkei n.sp.
Fig. 5

Synonymy

Pentamerus oblongus, J. Sowerby; de Koninck 1876:31; Jenkins 1879:26, 30, pl. 6, fig. 3; Mitchell 1887:1198; de Koninck (transl. Dun in David, David and Dun) 1898:24-25.

Pentamerus australis M'Coy; Etheridge 1892:51-52, non M'Coy 1877 (which is *Meristella* - Gill 1951:32).

Etymology

In honour of the Rev. W.B. Clarke, who first collected this species from Woolshed Creek.

Type Material

Holotype AM F.110260, Paratypes AM F.110168, 110298-110299, 110314-110315, 110343-110345, 110358, 110398-110399.

Other Material

ANU46537, from Yass locality KC48 (see Strusz 2002), is tentatively identified as *A. clarkei*.

Distribution

Canberra Formation, Canberra; basal Bowspring Limestone and probably Yarwood Siltstone Member, Yass. Early Homerian to early Ludfordian.

Diagnosis

Large strongly pyriform ventribiconvex *Apopentamerus* with prominent ventral beak, long ventral median septum, narrow spondylium, very long subparallel inner hinge plates.

Description

Moderately sized, smooth, ventribiconvex shell of pyriform to subtriangular outline with prominent postero-dorsally directed ventral beak, low dorsal beak. Ventral area small, triangular, gently concave, sharp-edged; delthyrium partly closed by concave crescentic pseudodeltidium. Anterior commissure (where preserved) appears to be broadly and very gently sulcate, and in one dorsal valve there is a possible faint sulcus. The largest, rather strongly distorted, specimen is 25.4 mm long and about 44 mm wide.

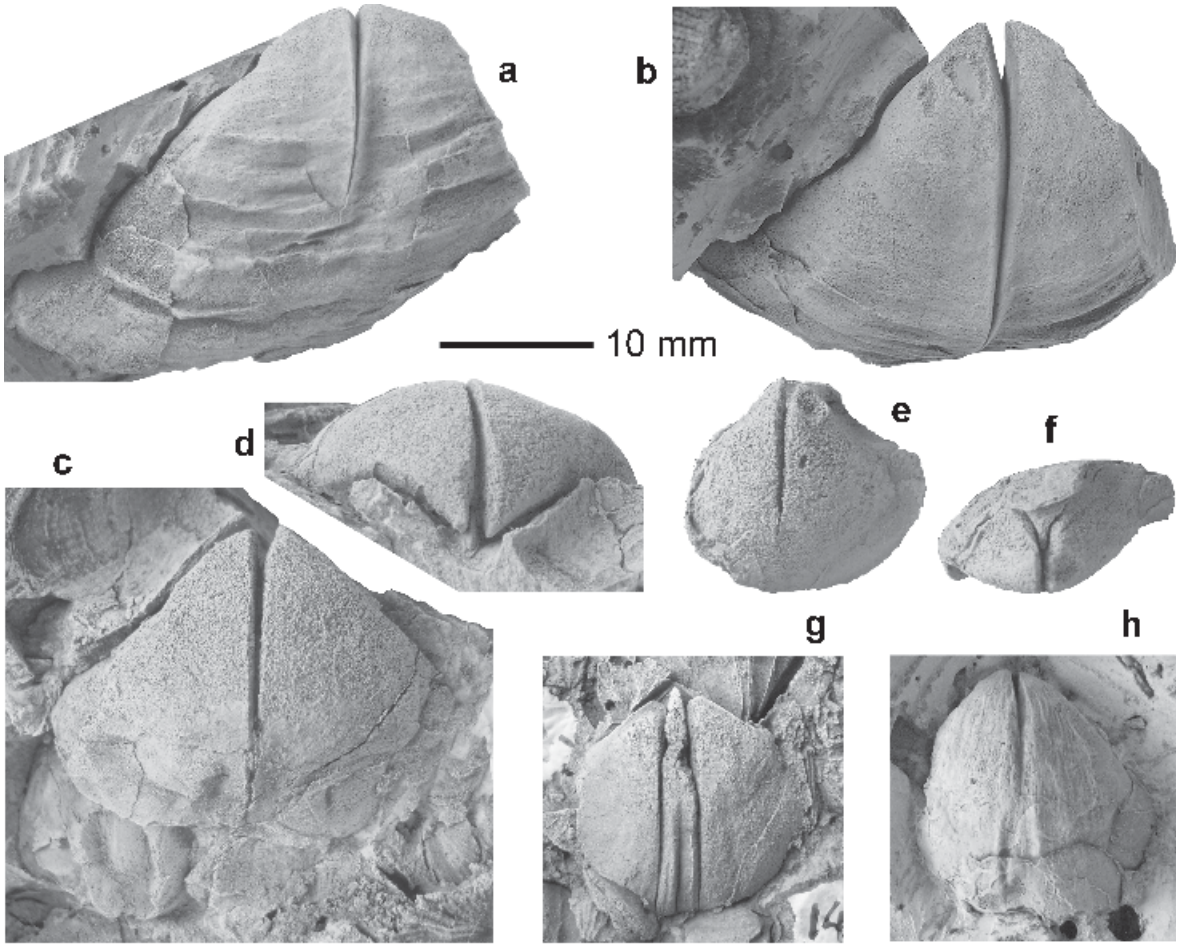

Figure 5. a-g, *Apopentamerus clarkei* n. sp., Canberra Formation, Woolshed Creek, probably early Homerian; a, b, holotype AM F.110260, ventral internal mould in ventral and postero-ventral views, the latter clearly showing the narrow spondylium; c, d, paratype AM F.110345, damaged ventral internal mould in ventral and posterior views, the latter revealing the small pseudodeltidium; e, f, paratype AM F.110344, small ventral internal mould in ventral and posterior views; g, paratype AM F.110168, dorsal internal mould showing the very long subparallel inner hinge plates; the anterior median furrow suggests the possibility of a similar external furrow. h, ?*Apopentamerus clarkei*, ANU46537, Yarwood Siltstone Member, Black Bog Shale, Yass (locality KC48), early Ludfordian; incomplete ventral mould in ventral view, showing the long septum supporting a narrow spondylium.

Ventral median septum high, extending to between 1/3 and 2/3 but generally about half valve length; spondylium narrow, upwardly flaring, of uncertain length but apparently not reaching mid-length. There may be a little thickening umbonally in large specimens. Teeth unknown.

Inner hinge plates subparallel and fairly close, extending along valve floor to near anterior valve margin; posteriorly they are gently medially convex, and merge smoothly with more strongly convex outer hinge plates. Crural bases obscure; no flanges. Dental sockets narrow, diverge at about 90°. Outer socket ridges flat-topped. Low, narrow median ridge between hinge plates anterior to mid-length in some specimens.

Discussion

From the previous discussion of generic relationships, these few specimens are most likely to be either *Sulcipentamerus* or *Apopentamerus*. The former is highly variable externally, with some species being noticeably trilobate while others are non-lobate; the shell is markedly ventribiconvex, the dorsal valve sometimes flat or concave, and more generally bears a gentle sulcus. *Apopentamerus* is much less strongly ventribiconvex, and characteristically has a

faint median furrow on each valve, giving a slightly emarginate outline. Moreover, the general shell shape in *Sulcipentamerus* is elongate, even subcylindroidal, whereas *Apopentamerus* is generally transverse, often subpyriform. Internally, the median septum in *Sulcipentamerus* is shorter than in *Apopentamerus*, while the spondylium is wider and relatively long. On balance, therefore, I consider the Woolshed Creek specimens belong in *Apopentamerus*.

This species is undoubtedly that identified by de Koninck (1876) as *Pentamerus oblongus*, an equally smooth northern hemisphere species from which it clearly differs in its wide pyriform shape. The incomplete dorsal internal mould from near Hattons Corner, Yass, figured by Jenkins (1879, pl. 6, fig. 3) as *Pentamerus oblongus* is almost identical to specimens AM F.110314. 110315 and 110344. Etheridge (1892:1198) thought Jenkins' specimen could be identified with *Pentamerus australis* M'Coy, 1878, but that species, from the Early Devonian of Lilydale, Victoria, was transferred to *Meristella* by Gill (1951:320) and is clearly unrelated. ANU46537, a single incomplete ventral internal mould from Yass locality KC48 and previously thought unidentifiable, is now recognised to be probably *A. clarkei*, and is figured here (Fig. 5h).

Apopentamerus clarkei differs from the type species *A. racinensis* Boucot and Johnson, 1979, in a rather longer ventral median septum, and an upwards-flaring spondylium. From *A. szechuanensis* Rong et al., 2007, it differs in its much greater convexity, gently sulcate anterior commissure, and lack of median furrows on ventral and most dorsal valves. It differs from *A. muchuanensis* Rong et al., 2007, also in its longer ventral median septum and inner hinge plates.

Order ATRYPIDA Rzhonsnitskaya, 1960
Suborder ATRYPIDINA Moore, 1952
Superfamily ATRYPOIDEA Gill, 1871
Family ATRYPIDAE Gill, 1871
Subfamily ATRYPINAE Gill, 1871
Genus ATRYPA Dalman, 1828
Subgenus ATRYPA Dalman, 1828

Type species

Anomia reticularis Linnaeus, 1758; Ludlow, Gotland.

A. (Atrypa) duntroonensis Mitchell and Dun, 1920
Figs 6-9

Synonymy

Atrypa reticularis, Linnaeus; de Koninck 1876:35; de Koninck (transl. Dun in David, David and Dun) 1898:26.

?*Atrypa? hemisphaerica*, J. de C. Sowerby; de Koninck 1876:35; de Koninck(transl. Dun in David, David and Dun) 1898:26-27.

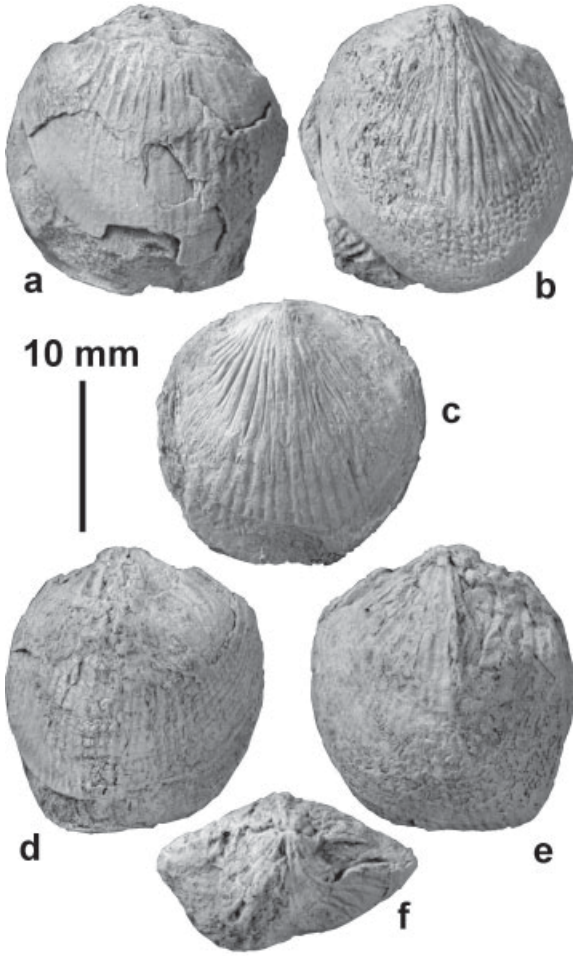

Figure 6. *Atrypa* (*Atrypa*) *duntroonensis* Mitchell and Dun, 1920; a, b, paralectotype AM F29202 in dorsal and ventral views - original of Mitchell and Dun, pl. XVI, figs 9, 12; c, paralectotype AM F29201 in ventral view - original of pl. XVI, fig. 8; d-f, lectotype AM F29203 in dorsal, ventral and posterior views - original of pl. XVI, fig. 10. Note the significant distortion of the ventral valve visible in the posterior view of the lectotype.

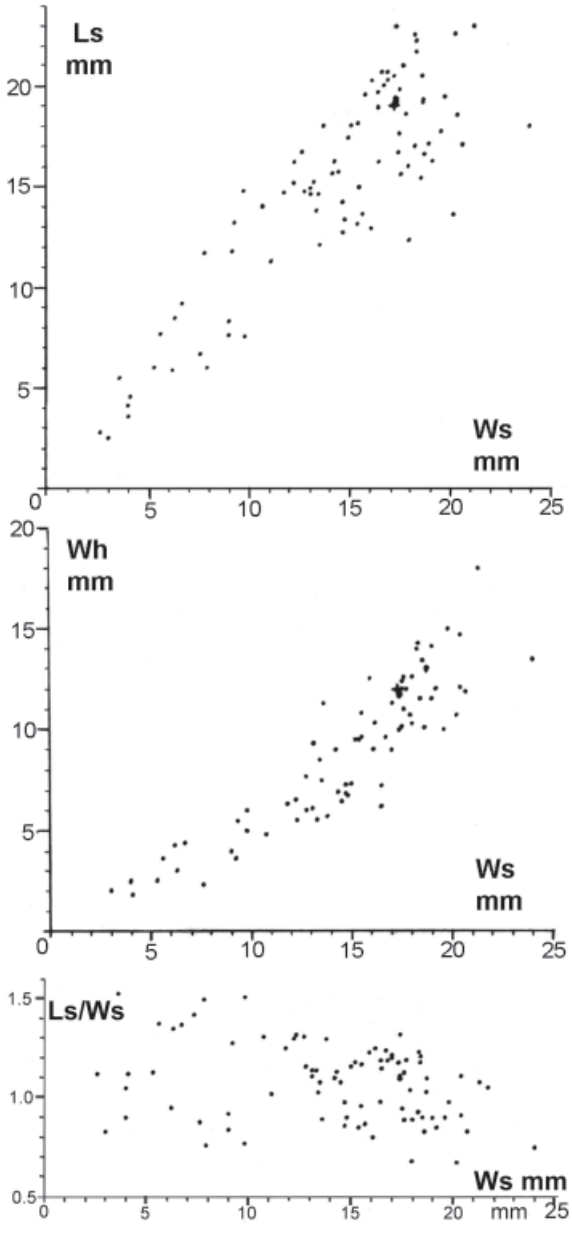

Figure 7. *Atrypa* (*A.*) *duntroonensis*; plots of shell length Ls, hinge width Wh, and the ratio of shell length to width against shell width Ws - the cross in the first two is the lectotype. The significant change in slope in the plot of Wh:Ws suggests that maturity, indicated by an increasingly wide cardinal margin, is reached at a width of about 12-13 mm.

Atrypa duntroonensis; Mitchell and Dun,1920:270-271, pl. XVI, figs 8-12.

Atrypa sp. cf. *perflabellata* (Talent, 1963); Strusz 1985a:112-114, figs 8A-S.

Spinatrypa sp. cf. *perflabellata*; Strusz 2010b, figs 6, 7U-W.

Type material

Mitchell and Dun did not designate a holotype, and figured four specimens, which are thus syntypes. The originals of Plate XVI, figs 8-10 are registered with the Australian Museum as AM F29201-29203; the original of fig. 11 is missing. I here designate F29203, the original of Pl. XVI, fig. 10, as lectotype. The remaining syntypes thus become paralectotypes.

Type locality

Mitchell and Dun described their locality as 'near Duntroon homestead....' The only fossiliferous outcrops in that area are in Woolshed Creek, which flows south into the Molonglo River just east of the Royal Military College, Duntroon. De Koninck reported that the specimens collected by Rev. W.B. Clarke in 1844 and examined by him came from Duntroon, and Mitchell and Dun were quite certain that their species was the same as that collected by Clarke. The outcrop where preservation matches that of the type specimens is just north of Fairbairn Avenue where it crosses Woolshed Creek; this locality is now a designated Geological Heritage Area.

New material

Large numbers of specimens have been collected from the excavations (see Introduction) about 20 m along strike from the type locality: only those providing useful information for the redescription of this species have been registered. These are AM F.110119-110126, 110145-110150, 110154-110155, 110166-110167, 110173-110192, 110207-110211, 110217, 110228-110231, 110235-110251, 110257-110258, 110264-110265, 110269-110272, 110282-110294, 110300-110310, 110325-110331, 110336-110342, 110347-110349, 110359-110366, 110375-110386, 110400-110409, 110419.

Horizon, age

Canberra Formation, Wenlock. In the absence of conodonts and graptolites, the precise age cannot be determined, but as discussed above the most likely age for the Woolshed Creek locality is early Homerian.

Diagnosis (new)

Small to medium sized biconvex to dorsibiconvex *Atrypa* with short marginal frills, impressed ventral muscle field with raised anterior rim, relatively delicate teeth and crural plates, and dental cavities retained in adult shells.

Description - exterior

Adult shells biconvex to dorsibiconvex, moderately to strongly swollen, with outline varying

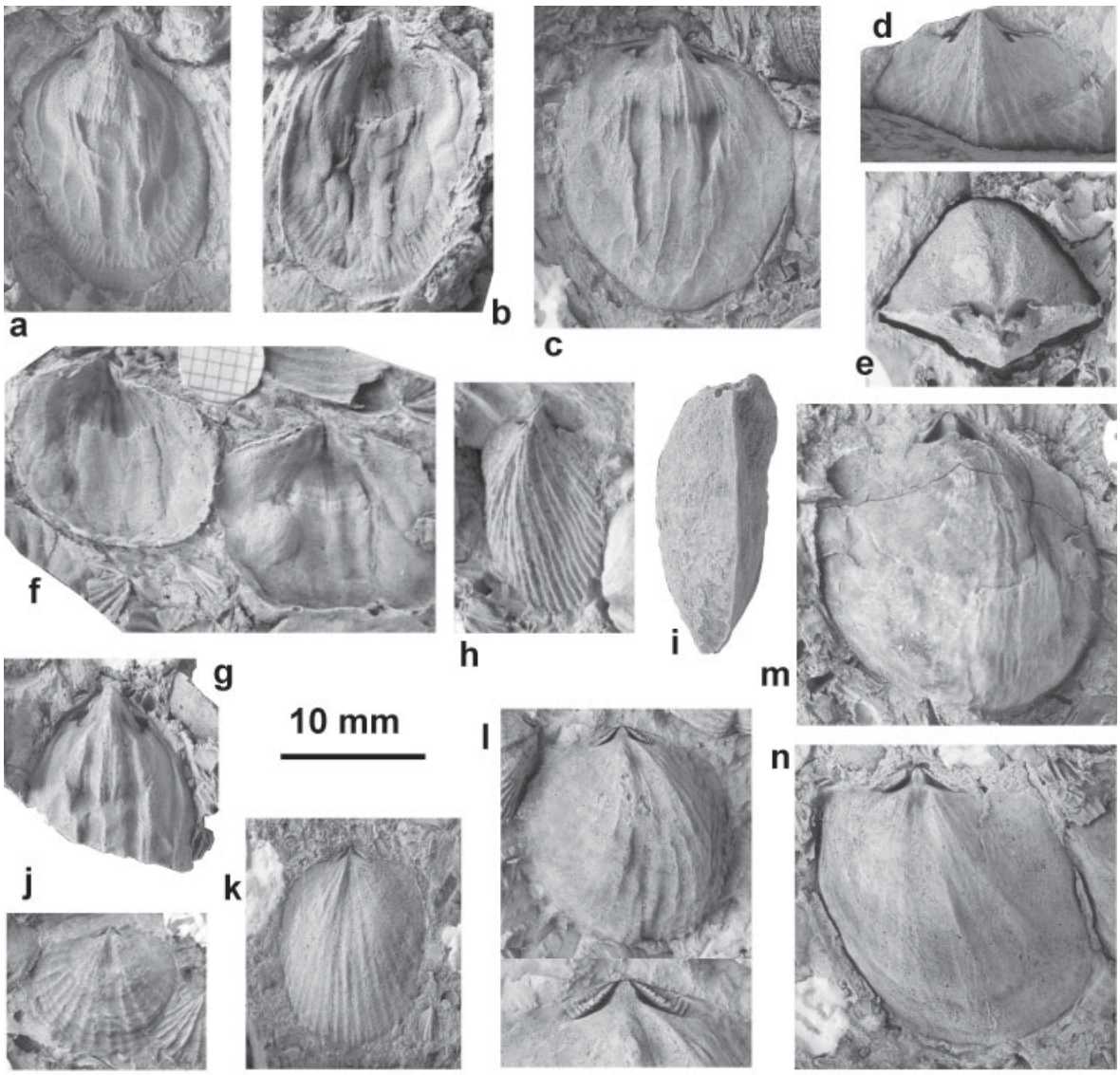

Figure 8. ***Atrypa* (*A.*) *duntroonensis*; a, b, AM F.110210, ventral internal mould and latex replica showing strong vascular impressions; c, AM F.110207, ventral internal mould; d, AM F.110251, incomplete large ventral internal mould with weakly expressed muscle field (see also Fig. 9b); e, AM F.110328, partly exposed steinkern in posterior view with very convex dorsal valve, 3-ridged cardinal process; f, AM F.110419, latex replica of two adjacent ventral valves with deeply impressed anteriorly scalloped and somewhat raised muscle fields (see also Fig. 9c); g, AM F.110269, incomplete laterally compressed ventral internal mould showing impressions of narrow triangular teeth; h, AM F.110383, incomplete strongly laterally compressed juvenile ventral internal mould, showing relatively narrow cardinal margin; i, AM F.110342, moderately convex steinkern in lateral view; j, AM F.110147, longitudinally compressed juvenile dorsal internal mould; k, AM F.110408, laterally compressed juvenile dorsal internal mould; l, AM F.110329, dorsal internal mould - cardinalia enlarged below to show corrugated sockets and outer hinge plates; m, AM F.110124, large dorsal internal mould with robust crural plates; n, AM F.110407, large distorted dorsal internal mould. The infill of dental cavities is clearly visible in Figs 8c, d, g, h.**

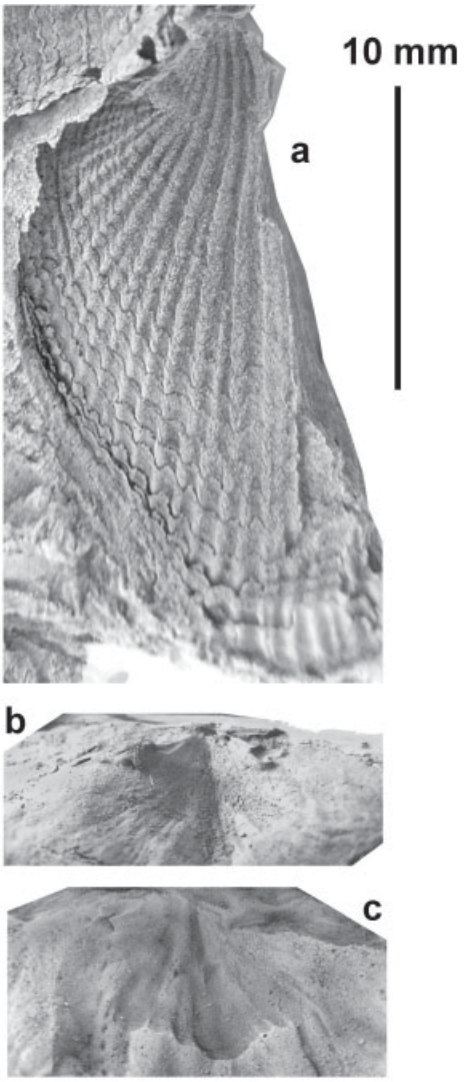

Figure 9. ***Atrypa* (*A.*) *duntroonensis*; detailed views of external and internal structures; a, AM F.110348, incomplete external mould showing short growth lamellae, and short marginal frill; b, AM F.110251, latex replica of large ventral valve in antero-dorsal view, showing dental cavities (that on the right was occupied by a bubble, so clearly shows the significant size); c, AM F.110419, latex replica of large ventral valve in antero-dorsal view, showing slit-like dental cavities, raised anterior margin to muscle field.**

from rounded to shield-shaped or subquadrate. Cardinal margin highly variable in width, and weakly to fairly strongly curved but not incurved. Most adult shells are 15 to 20 mm wide, with mean Ls/Ws 1.05 (overall mean is 1.066); a plot of Ls/Ws against Ws suggests a trend to less elongate shells with growth, but variability is high. The two largest specimens are ventral valves with Ls 18.0 mm, Ws 24.0 mm, and Ls 23.0 mm, Ws 21.3 mm. Four steinkerns and two whole shells including the lectotype are between 15.0 and 22.0 mm wide, and their Ts/Ws varies between 0.46 and about 0.7. The least swollen specimens tend to be nearly equibiconvex, whereas in large swollen shells the dorsal valve can be twice the thickness of the ventral valve. In transverse profile ventral valve is medially rounded, may be weakly carinate posteriorly, and has almost planar flanks, while dorsal valve is evenly rounded. Anterior commissure gently to fairly strongly uniplicate. In longitudinal profile ventral valve is most convex posteriorly, flattening anteriorly, frequently forming very shallow sulcus which can extend dorsally as a tongue. Marginally, where growth lamellae are very crowded, valve surface often turned strongly dorsally. Dorsal valve evenly convex, frequently with flattened to upturned margins. Dorsal umbonal region with median depression which dies out anteriorly. Ventral beak low, wide, suberect to gently incurved, generally closely adpressed over extremely low dorsal beak. Large parabolic delthyrium occupies most of small apsacline ventral area, and mostly truncates beak.

Ribs low, 5-12 but mostly 6-8 in an arc of 5 mm at 5 mm radius, slightly coarser medially than laterally. Ventral valve has two raised ribs postero-medially, from length of about 6 mm separated by very fine single mid-rib. Increase is usually by splitting, always at growth lamellae, and most often episodic at radii of about 6-7 and 12-13 mm; there may be some intercalated ribs towards adult shell margins. Growth lamellae faint umbonally, then low, about 1 mm apart, becoming very crowded in narrow marginal zone, where they may form short oblique frills up to 1 mm long. The lamellae curve forward in inter-rib troughs, but do not form spinose outgrowths. A narrow skirt (about 2-3 mm) extending dorsally from ventral valve margin is occasionally preserved.

Interior

Teeth transversely elongate, of moderate size, separated by narrow transverse grooves from cardinal margin; well-preserved moulds show weak corrugations. Dental cavities slit-like cones, widely divergent, reduced but always present even in large shells. Muscle field medium to large, flabellate to subtriangular, variably but often strongly impressed, longitudinally furrowed with anteriorly raised rim which may be finely grooved. Adductor scars small, slightly raised either side of median depression posteriorly placed within muscle field. Pedicle callist weak, separated anteriorly from muscle field by fine

concentric ridge; a few specimens show what appears to be a small pedicle collar at apex of delthyrium. Mantle canal system saccate, variably but sometimes strongly impressed on valve floor.

Cardinal pit deep, triangular in juveniles but slot-like in adults, with fine ridges at apex forming cardinal process, and floor raised a little above general valve floor. Crural plates robust in large shells, fine in small shells, forming deep triangular impressions in internal moulds. Sockets narrow, widely divergent, somewhat arcuate in all but smallest valves, corrugated; inner socket ridges flat-topped, often also corrugated; outer socket ridges fine, overhang sockets. Fairly prominent forward-expanding myophragm in juveniles, usually with fine median ridge, frequently becomes subdued or obscure in large shells. Mantle canal system obscure. Two medium-sized worn steinkerns show dorso-medially directed spiralia of 9-10 whorls; no further details are visible.

Ontogeny

Juvenile shells lenticular, rounded to elongate, with sharp nearly straight ventral beak, narrow curved cardinal margin, biconvex to somewhat dorsibiconvex profile. Ventral umbonal region generally moderately to fairly strongly carinate posteriorly, dorsal umbo with narrow sulcus. Margins without crowded frills or skirt. External sculpture strongly imprinted on valve floors in thin-shelled juveniles, generally lost in thicker-shelled adults. Dental cavities well developed, diverging at 90-120°, ventral muscle field generally not noticeably impressed. Sockets prominently corrugated. The size at which shell morphology changes from juvenile to adult appearance is highly variable, with some relatively large shells retaining an almost juvenile appearance apart from greater convexity and more deeply impressed ventral muscle field. Particularly for ventral valves, however, the change from juvenile to adult morphology is usually very marked.

Discussion

Morphological variation is considerable and, while overlain by post-burial distortion, it is apparent that in common with many species of *Atrypa* much of this is inherent variability. With the material now available it is quite clear that *A. (Atrypa) duntroonensis* is conspecific with the material from the Canberra Formation of Fyshwick compared by Strusz (1985a) with *Spinatrypa perflabellata* Talent, 1963, from the Pragian of Victoria. In my discussion in 1985 I considered Talent's species to be *Atrypa* rather than *Spinatrypa*, while in my recent biostratigraphic summary (Strusz 2010b) I chose to follow Talent, Gratsianova and Yolkin (2001) in reverting to the original assignment, pending the results of the present study. The relationship between the Silurian and Pragian taxa is not clear, although on the basis of internal structures one could speculate that the latter could have been derived from the former.

A. (A.) duntroonensis is clearly the species identified by de Koninck (1876-7) as *A. reticularis*. While the destruction of Clarke's collections precludes absolute certainty, I am confident in the light of the variability shown by the current collections from Woolshed Creek that the specimens identified by de Koninck as *A. hemisphaerica* were juvenile *A. (A.) duntroonensis*.

As noted by many authors up to and including Copper (2004:35), distinguishing between species and even genera of Silurian atrypids can be difficult, and there has been considerable disagreement in deciding the boundaries between, and content of, the various genera and subgenera that have been erected. In general, I follow Copper (in Kaesler 2002; 2004). Doing so, however, leads me to recognise in the present species characters used to distinguish several Silurian genera: *Atrypa* itself, *Protatrypa* Boucot, Johnson and Staton, 1964, *Gotatrypa* Struve, 1966, *Rugosatrypa* Rzhonsnitskaya, 1975, and *Oglupes* Havlíček, 1987.

The dorsibiconvex shape of most larger *A. (A.) duntroonensis*, in which the anterior part of the ventral valve is flattened and even gently sulcate, is very typical of *A. (Atrypa)* but can also be seen in some *Oglupes* - e.g. *O. visbyensis* Copper, 2004 (see Copper's Pl. 12, figs a-e). Generally, though, *Oglupes* is a very globose form with a more even longitudinal convexity to the ventral valve, and more prominent ribs.

The Llandovery *Protatrypa* is small and lenticular, with a carinate ventral valve, very subdued growth lamellae, and dental cavities in adult shells - the last not generally known in *Atrypa*. Juvenile *A. duntroonensis* thus resemble adult *Protatrypa*, but adults can be readily distinguished by greater convexity, more prominent growth lamellae, and the presence of short marginal frills.

Gotatrypa is fairly small, biconvex to dorsibiconvex (Copper 2004, Pl. 10, fig. Bb), with short frills as in *A. duntroonensis*, but dental nuclei rather than dental cavities, and deltidial plates in juveniles. Moreover the ventral valve does not become flat or gently sulcate anteriorly, and the growth lamellae are projected as short spines in the inter-rib troughs.

Rugosatrypa is not well illustrated and the original description is brief, but it would appear to

differ from *Atrypa* in smaller size, a lenticular profile, regular rather widely spaced concentric growth rugae but low growth lamellae not forming frills or a skirt, the presence of deltidial plates in adults, a weak pedicle callist, and prominent dental cavities. *A. (A.) duntroonensis* differs from it in a more swollen profile, no concentric rugae or deltidial plates, and reduced dental cavities in large shells.

On balance, therefore, I think the present species is best retained in *Atrypa (Atrypa)*, differing from other species by consistently retaining distinct dental cavities in adult shells.

Order SPIRIFERIDA Waagen, 1883
Superfamily CYRTIOIDEA Frederiks, 1924
Family CYRTIIDAE Frederiks, 1924
Subfamily EOSPIRIFERINAE Schuchert, 1929
Genus HEDEINA Boucot, 1957

Type species

Anomia crispa Linnaeus, 1758. Ludlow, Gotland.

Hedeina oepiki Strusz, 2010
(Figs 10-11)

Synonymy

Howellella sp. aff. *elegans* (Muir-Wood, 1925); Strusz 1982 partim (Fig. 27B only).
Cyrtiidae gen.? et sp. nov.; Strusz 1985a:115-117, Figs 11-12.
Hedeina oepiki Strusz, 2010a:103-104, fig. 13; Strusz, 2010b: Figs 6, 8 I-K.

Type material

Holotype CPC24671, paratypes CPC24831-24870. Canberra Formation, Fyshwick ACT; Wenlock.

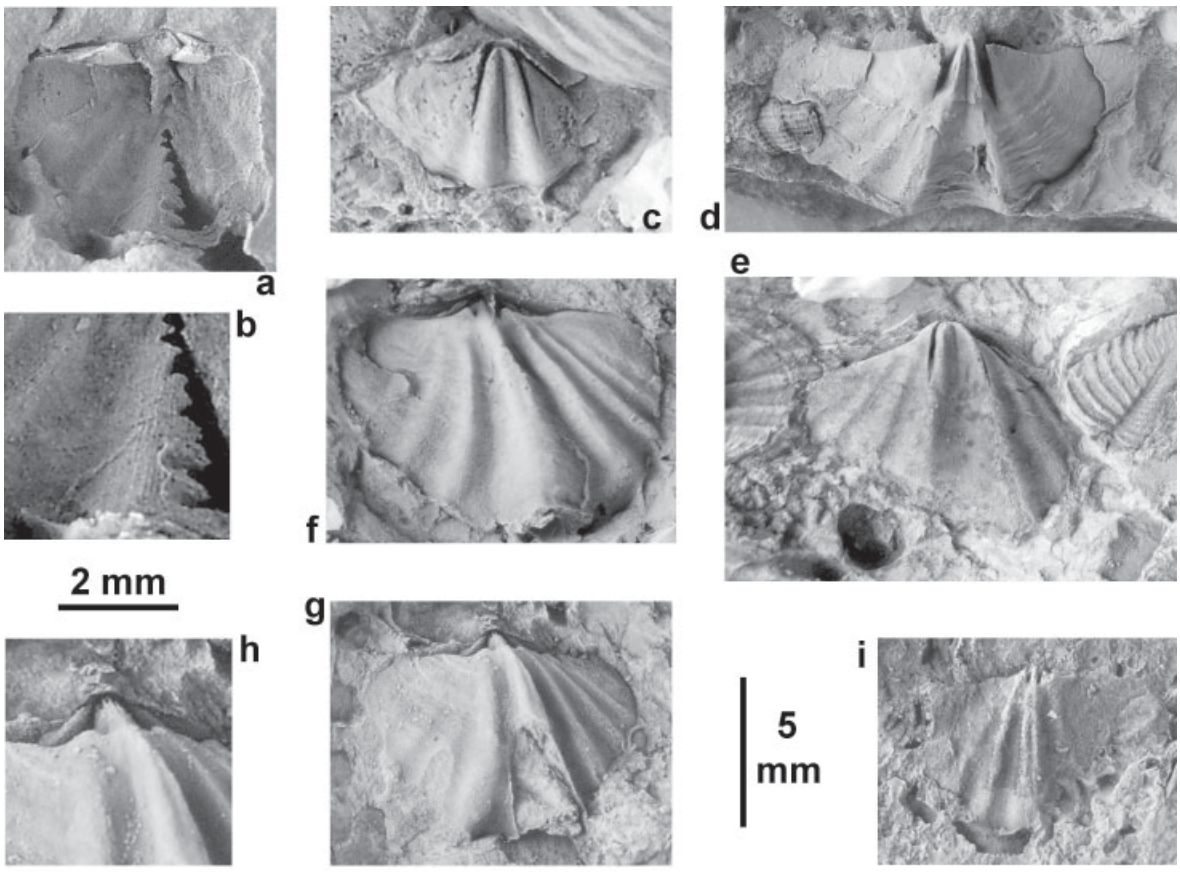

Figure 10. *Hedeina oepiki* Strusz, 2010; a, b, AM F.110252, ventral external mould with shape of dental lamellae shown by infill of the delthyrial cavity, and enlargement showing capillae preserved in the sulcus; c, AM F.110390, longitudinally compressed ventral internal mould with weak ribs on flanks; d, AM F.110355, ventral internal mould; e, AM F.110160, ventral internal mould; f, AM F.110135, distorted dorsal internal fold; g, h, AM F.110262, dorsal internal mould and enlargement showing ctenophoridium; i, AM F.110133, incomplete dorsal internal mould with well developed myophragm. 2 mm scale bar applies to Figs 10b, h.

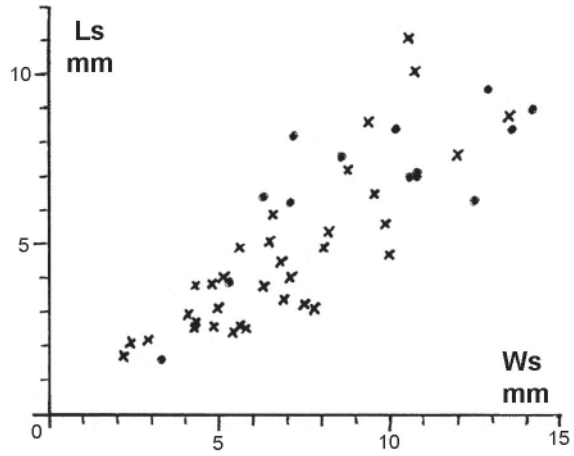

Figure 11. ***Hedeina oepiki*** **Strusz, 2010; plot of shell length Ls against width Ws for specimens from the Canberra Formation at Woolshed Creek (●) and Fyshwick (x).**

Woolshed Creek material

AM F.110133-110135, 110142-110144, 110151-110152, 110156-110162, 110169-110171, 110197-110206, 110219-110224, 110252, 110262, 110267, 110273-110274, 110295-110296, 110319-110324, 110354-110357, 110387-110395, 110420-110421.

Distribution, age

Canberra Formation and Walker Volcanics, Canberra; Wenlock (late Sheinwoodian? to Homerian).

Remarks

The specimens from the Woolshed Creek locality show even greater variation in the degree of distortion than those described from Fyshwick. Allowing for that, and the effects it will have on any statistical comparison, the present material agrees in every important respect with *Hedeina oepiki* from Fyshwick (respective means for specimens from Fyshwick and Woolshed Creek: Ls/Ws 0.64 / 0.74, Wh/Ws 0.71 / 0.80, Wf/Ws 0.31 / 0.27). The ribs vary in form and number, but those flanking the ventral sulcus are always noticeably more prominent than the next lateral pair, and the dorsal fold is strong, its crest somewhat flattened. Internally, the ventral myophragm varies from low to quite strong; the dental plates are robust, clearly extrasinal, and extend to about one-third valve length. In the dorsal valve the crural plates are strongly recessive, and there is a low notothyrial platform supporting an apical ctenophoridium. There can be no doubt that populations of just one species occur at Woolshed Creek and Fyshwick. A comparison with the younger species *H. bruntoni* can be found in Strusz (2010a).

Strongly distorted small specimens with weak lateral ribs can be difficult to distinguish from *Endospirifer anxius* Strusz, 1982, in which one or rarely two faint lateral ribs are sometimes present. That species, however, has a suboval rather than subtriangular outline, less divergent dental plates which are barely extrasinal, and no notothyrial platform.

Superfamily RETICULARIOIDEA Waagen, 1883
Family RETICULARIIDAE Waagen, 1883
Subfamily RHENOTHYRIDINAE Gourvennec, 1994
Genus SPIRINELLA Johnston, 1941

Type species

Spirinella caecistriata Johnston, 1941. Late Wenlock, Yass, NSW.

Spirinella caecistriata Johnston, 1941
Fig. 12

Synonymy

Meristina (?) australis Shearsby 1912:112-113, *non* Dun 1904.
Spirinella caecistriata Johnston, 1941:161-167, Pl. VII, figs 1-11; Johnson, Boucot and Murphy 1976: Pl. 28, figs 17-27;

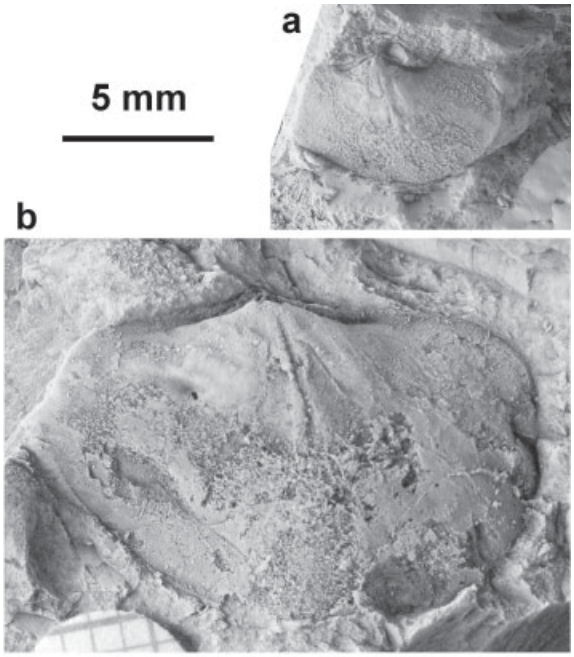

Figure 12. ***Spirinella caecistriata*** **Johnston, 1941; a, AM F.110234, small incomplete dorsal internal mould; b, AM F.110266, large dorsal internal mould - compare Strusz, 1985a, fig. 14C.**

Strusz 1984:144-147, Figs 18-19; Strusz 1985a:117-118, Fig. 14; Strusz 2005:29-30, Fig. 1; Strusz, 2010a:112-117, Figs 18-20; Strusz, 2010b, Figs 6, 8V-X.

Reticulariopsis silurica Strusz, 1982:134-136, Fig. 28.

Type material

Holotype AM F39376. Paratypes AM F39378, 39379 and figured topotype AM F39377 have since been lost - see Strusz (1984, 2005). Yass Formation (Cliftonwood Limestone Member), Yass, NSW; Homerian.

Woolshed Creek material

AM F.110163-110164, 110172, 110215-110216, 110232-110234, 110266, 110311-110313, 110367, 110410.

Diagnosis (Strusz 2010a)

Suboval, moderately ventribiconvex *Spirinella* with prominent ventral umbo, erect to slightly incurved beak; interarea concave, weakly apsacline, not well delineated laterally. Teeth small, triangular; dental plates long, moderately divergent, continued anteriorly by grooves of *vascula media*; ventral muscle field generally somewhat impressed, elongate, longer than dental plates; delthyrial plate or apical thickening small, crescentic; crural plates narrow, triangular, more or less convergent downwards, rest posteriorly on small notothyrial platform; lanceolate dorsal adductor field and myophragm.

Remarks

Spirinella caecistriata is a minor component of the Woolshed Creek fauna. The few specimens are not well preserved, but are clearly conspecific with the similarly distorted specimens from Fyshwick. In particular, compare the dorsal internal mould AM F.110266 (Fig. 12b) with CPC24876, figured Strusz 1985a, Fig. 14C. The largest measurable specimens are over 16 mm wide, with Wh/Ws varying considerably around 0.73 - this compares well with the data from undistorted material in Strusz (2010a, tables 8 and 9).

ASSOCIATED FAUNA

Associated with the brachiopods, but none abundant, are trilobites, particularly the encrinurine trilobite Batocara mitchelli, rugose and tabulate corals of which a tryplasmatid, a columnar halysitid and a heliolitid are most common, gastropods and bivalves, and a strap-shaped bryozoan. The trilobites and some of the corals are shown in Fig. 13.

ACKNOWLEDGEMENTS

I would like to thank Luke Williams (Guideline ACT site engineer for the Woolshed Creek bridge construction) for his willing and interested cooperation during sample collection and subsequent transport of bulk material to ANU at Black Mountain, Canberra. Cooperation by the Office of the Environment and Heritage, ACT Department of Territory and Municipal Services, was also excellent - my thanks for interesting discussions with Euroka Gilbert in particular. Material was collected by John Laurie and Peter Butler of Geoscience Australia, and myself. This paper has benefited greatly from discussion with Paul Copper on Silurian atrypid discrimination. I am also grateful to Ian Percival for reviewing the initial draft of the paper.The work was done in the Department of Earth and Marine Science (ANU) in my capacity as a School Visitor, and also as a Research Associate of the Australian Museum, Sydney.

REFERENCES

Antsigin, N.Y., Breivel, I.A., Breivel, M.G., Varganov, V.G., Nasedkina, V.A. and Yanet, F.E. (1970). Pogranichnye otlozheniya mezhdu ordovikom i silurom na srednem i prilegayushchei chasti severnogo Urala i ikh paleontologicheskaya kharakteristika. *Materialy po paleontologii Urala, Instituta Geologii i Geokhimii, Uralski Filial, Akademiya Nauk SSSR, Sverdlovsk*, 3-12, 52-56, Pls I-III.

Bancroft, B.B. (1949). Welsh Valentian brachiopods. In Welsh Valentian brachiopods and the *Strophomena antiquata* group of fossil brachiopods. (Ed. A. Lamont) pp. 2-10, Pls I-II. Preprint from *The Quarry Managers' Journal*, Times Printing Co. Ltd, Mexborough, Yorkshire.

Boucot, A.J. (1957). Revision of some Silurian and Early Devonian spiriferid genera and erection of Kozlowskiellinae, new subfamily. *Senckenbergiana Lethaea* **38**, 311-334, Pls 1-3.

Boucot, A.J. and Johnson, J.G. (1979). Pentamerinae (Silurian Brachiopoda). *Palaeontographica, Abteilung A* **163**, 87-129.

Boucot, A.J., Johnson, J.G. and Staton, R.D. (1964). On some atrypoid, retzioid, and athyridoid Brachiopoda. *Journal of Paleontology* **38**, 805-822.

Boucot, A.J., Martinsson, A., Thorsteinsson, R., Walliser, O.H., Whittington, H.B. and Yochelson, E. (1960). A Late Silurian fauna from the Sutherland River Formation, Devon Island, Canadian Arctic Archipelago. *Bulletins of the Geological Survey of Canada* **65***, 1-51.*

Chatterton, B.D.E. and Campbell, K.S.W. (1980). Silurian trilobites from near Canberra and some related forms from the Yass Basin. *Palaeontographica, Abteilung A* **167**, 77-119, Pls 1-16.

Clarke, W.B. (1848). On the occurrence of trilobites in New South Wales, with remarks on the probable age of the

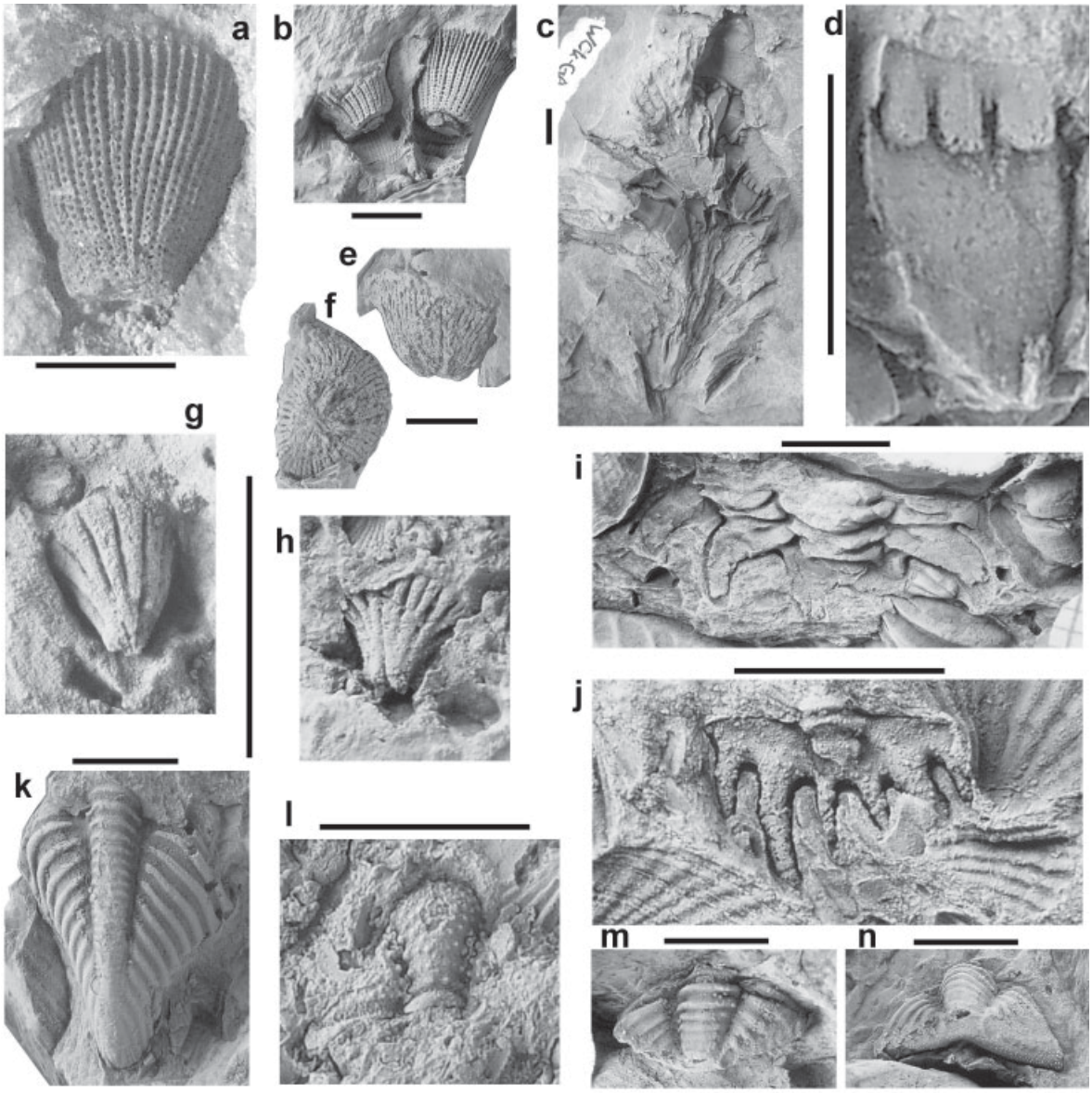

Figure 13. Moulds of corals and trilobites associated with the brachiopod fauna at Woolshed Creek; a-b, *Tryplasma* sp., a, AM F.110218, b, AM F.110256; c-d, *Halysites* sp., AM F.110351, columnar corallum and enlargement of one smooth-sided palisade showing macrocorallites and intervening microcorallites; e-f, *Entelophyllum*? sp., AM F.110261; g-h, undetermined diminutive cyathaxoniid?, g, AM F.110153, h, AM F.110281; i, cheirurine pygidium cf. *Cheirurus* sp. Chatterton and Campbell, 1980, AM F.110422; j, *Uriarra kausi* Chatterton and Campbell, 1980, AM F.110411, pygidium; k-l, *Batocara mitchelli* (Foerste, 1888), k, AM F.110275, pygidium, l, AM F.110136, small incomplete cranidium; m, n, indet. calymenid AM F.110332, small pygidium in dorsal and posterior views. All scale bars 5 mm long.

formation in which they occur. *Quarterly Journal of the Geological Society, London,* **4**, 63-66.

Cocks, L.R.M. (2008). A revised review of British Lower Palaeozoic brachiopods. *Monograph of the Palaeontographical Society London*, 1-276, Pls 1-10 (Publ. No. 629, part of vol. 161).

Copper, P. (2004). 'Silurian (Late Llandovery- Ludlow) atrypoid brachiopods from Gotland, Sweden, and the Welsh Borderlands, Great Britain'. (National Research Council of Canada: Ottawa); 215 pp, 29 pls.

Dalman, J.W. (1828). Uppställning och Beskrifning af de i Sverige funne Terebratuliter. *Kongliga Svenska Vetenskapsakadamien Handlingar for 1827* **3**, 85-155, Pls 1-6.

De Koninck, L.G. (1876-7). Récherches sur les fossiles paléozoiques de la Nouvelle-Galles du Sud (Australie).

Memoires de la Société royale des Sciences de Liège, série 2, **2**, 1-235 (English translation T.W.E. David, Mrs C. David and W.S. Dun, 1898 - Description of the Palaeozoic fossils of New South Wales. *Memoirs of the Geological Survey of New South Wales, Palaeontology,* **6**; 298 pp.).

Dun, W.S. (1904). Notes on some new species of Palaeozoic Brachiopoda from New South Wales. *Records of the Geological Survey of New South Wales* **7**, 3-8-325, Pls LX-LXI.

Etheridge, R. Jr (1892). The Pentameridae of New South Wales. *Records of the Geological Survey of New South Wales* **3**, 49-60, Pls X-XI.

Foerste, A.F. (1888). Notes on Paleozoic fossils. *Bulletins of the Science Laboratories, Denison University* **3**, 116-137, Pl. XIII.

Gill, E.D. (1951). Revision of McCoy's 'Prodromus' types from the Lilydale and Killara districts of Victoria. *Proceedings of the Royal Society of Victoria* **63**, 31-39.

Harper, C.W. Jr and Boucot, A.J. (1978). The Stropheodontacea, Part 1: Leptostrophiidae, Eostrophodontidae and Strophonellidae. *Palaeontographica, Abteilung A* **161**, 55-118, Pls 1-18.

Havlíček, V. (1965). Superfamily Orthotetacea (Brachiopoda) in the Bohemian and Moravian Palaeozoic. *Věstník Ústředního ústavu geologického* **40**, 291-294, Pls I-II.

Havlíček, V. (1987). New genera of Silurian brachiopods. *Věstník Ústředního ústavu geologického* **62**, 239-244, Pls I-II.

Henderson, G.A.M. and Matveev, G. (1980). 'Geology of Canberra, Queanbeyan, and environs'. (Bureau of Mineral Resources, Geology and Geophysics, Australia, 1:50 000 map: Canberra).

Jenkins, C. (1879). On the geology of Yass Plains. *Proceedings of the Linnean Society of New South Wales* **3**, 21-32, Pl. 6.

Jin, J-S., Harper, D.A.T. and Rasmussen, C.M.Ø. (2009). *Sulcipentamerus* (Pentamerida, Brachiopoda) from the Lower Silurian Washington Land Group, North Greenland. *Palaeontology* **52**, 385-399.

Johnson, J.G., Boucot, A.J. and Murphy, M.A. (1976). Wenlockian and Ludlovian age brachiopods from the Roberts Mountains Formation of central Nevada. *University of California Publications in Geological Sciences* **115**, 102 pp, 55 pls.

Johnston, J. (1941). Studies in Silurian Brachiopods. 1. Description of a new genus and species.*Proceedings of the Linnean Society of New South Wales* **66**, 160-168.

Kaesler, R.L. (ed.) (2002). 'Treatise on Invertebrate Paleontology, Part H, Brachiopoda, revised, volume 4: Rhynchonelliformea (part)'. (Geological Society of America: Boulder, and University of Kansas Press: Lawrence).

Kirk, E. (1925). *Harpidium*, a new pentameroid brachiopod genus from southeastern Alaska. *Proceedings of the United States National Museum* **66**, 1-7, Pls 1-2.

Linnaeus, C. (1758-1767). 'Systema Naturae, sive Regna tria Naturae systematicae proposita per Classes, Ordines, Genera et Species', 10th ed. 1758, 1, 1-823; 12th ed, 1767, 1(2), 533-1327. (Holmiae, Stockholm).

M'Coy, F. (1877). 'Prodromus of the Palaeontology of Victoria, Decade 5.' (Geological Survey of Victoria: Melbourne) (fide Gill, 1951).

Mitchell, J. (1887). Notes on the geology of Bowning, N.S.W. *Proceedings of the Linnean Society of New South Wales* **11** (for 1886), 1193-1204, Pl. XXI.

Mitchell, J. (1923). The Strophomenidae from the fossiliferous beds of Bowning, New South Wales. Part. 1. *Stropheodonta*. *Proceedings of the Linnean Society of New South Wales* **48**, 465-474.

Mitchell, J. and Dun, W.S. (1920). The Atrypidae of New South Wales, with references to those recorded from other States of Australia. *Proceedings of the Linnean Society of New South Wales* **45**, 266-276.

Öpik, A.A. (1958). The geology of the Canberra City district. *Bulletins of the Bureau of Mineral Resources, Geology and Geophysics, Australia* **32**, 99 pp.

Paeckelmann, W. and Sieverts, H. (1932). Neue Beiträge zur Kenntnis der Geologie, Palaeontologie und Petrographie der Umgegend von Konstantinopel. 1.Obersilurische und devonische Faunen der Prinzeninseln, Bithyniens und Thraciens. *Abhandlungen der preussisches geologisches Landesanstalt, N.F.* **142**, 1-79, Pls 1-4.

Rong, J-Y., Jin, J-S. and Zhan, R-B. (2007). Early Silurian *Sulcipentamerus* and related pentamerid brachiopods from South China. *Palaeontology* **50**, 245-266.

Rzhonsnitskaya, M.A. (1975). Biostratigrafiya Devona okrain Kuznetskogo Basseina, Tom 2, Opisanie brakhiopod, Chast' 1, Pentamerida i Atrypida. *Trudy Vsesoyuznyi Ordena Lenina Nauchno-issledovatel'skii Geologicheskii Institut, n.s.* **244**, 1-232, Pls I-XXXIV.

Sapel'nikov, V.P. (1985). 'Sistema i stratigraficheskoye znacheniye brakhiopod podotryada pentameridin'. (Nauka: Moscow); 205 pp, 48 pls.

Shearsby, A.J. (1912). The geology of the Yass District. *Reports of the 13th Meeting of the Australasian Association for the Advancement of Science, Sydney 1911*, 106-119.

Sowerby, J. (1813). 'The Mineral Conchology of Great Britain, vol. 1'. (London; not seen, fide Boucot and Johnson, 1979).

Sowerby, J. de C. (1839). Shells. Pp 579-712, Pls 1-27 in R. I. Murchison, 'The Silurian System, part II. Organic remains'. (John Murray: London; not seen, fide Cocks 2008).

Sowerby, J. de C. (1842). Description of Silurian Fossils from the Rhenish Provinces. *In* Archiac, D' and De Verneuil, M.E. - On the fossils of the older deposits in

the Rhenish Provinces. *Transactions of the Geological Society, London* **6**, 408-410, Pl. 38.

Strusz, D.L. (1982). Wenlock brachiopods from Canberra, Australia. *Alcheringa* **6**, 105-142.

Strusz, D.L., 1984. Brachiopods of the Yarralumla Formation (Ludlovian), Canberra, Australia. *Alcheringa* **8**, 123-150.

Strusz,D.L. (1985a). Brachiopods from the Silurian of Fyshwick, Canberra, Australia. *BMR Journal of Australian Geology and Geophysics* **9**, 107-119.

Strusz, D.L. (1985b). The orthotetacean brachiopod *Morinorhynchus* in the Silurian of Yass, N.S.W. *Journal of Palaeontology* **59**, 677-683.

Strusz, D.L. (2002). Brachiopods of the Orders Protorthida and Orthida from the Silurian of the Yass Syncline, southern New South Wales. *Alcheringa* **26**, 49-86.

Strusz, D.L. (2003). Late Silurian strophomenate brachiopods from Yass, New South Wales. *Alcheringa* **27**, 1-35.

Strusz, D.L. (2005). Type specimens of *Spirinella caecistriata* (Silurian brachiopod) from Yass, New South Wales. *Alcheringa* **29**, 29-30.

Strusz, D.L. (2010a). Silurian spiriferide brachiopods from Yass and Molong, New South Wales. *Memoirs of the Association of Australasian Palaeontologists* **39**, 85-120.

Strusz, D.L. (2010b). Silurian brachiopod distribution in strata of the Canberra-Yass region, southeastern Australia. *Memoirs of the Association of Australasian Palaeontologists* **39**, 147-158.

Strusz, D.L. and Henderson, G.A.M. (1971). 'Canberra City A.C.T. - 1:50,000 geological map and explanatory notes'. (Bureau of Mineral Resources, Geology and Geophysics, Australia: Canberra).

Struve, W. (1966). Einige Atrypinae aus dem Silurium und Devon. *Senckenbergiana Lethaea* **47**, 123-163, Pls 15-16.

Talent, J.A. (1963). The Devonian of the Mitchell and Wentworth Rivers. *Memoirs of the Geological Survey of Victoria* **24**, 118 pp.

Talent, J.A., Gratsianova, R.T. and Yolkin, E.A. (2001). Latest Silurian (Pridoli) to middle Devonian (Givetian) of the Asio-Australia hemisphere: rationalization of brachiopod taxa and faunal lists; stratigraphic correlation chart. *Courier Forschungsinstitut Senckenberg* **236**, 221 pp.

Zeng, Q-I. (1987). Brachiopoda. Pp 209-245, Pls 8-18 in 'Biostratigraphy of the Yangtze Gorge area, vol. 2. Early Palaeozoic Era'. (Geological Publishing House: Beijing). In Chinese.