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A small brachiopod–gastropod fauna from a core close to the base of the Calytrix Formation within the Grant Group includes the brachiopods *Altiplecus decipiens* (Hosking), *Myodelthyrium dickinsi* (Thomas), *Brachythyrinella narsarhensis* (Reed), *Neochonetes (Sommeriella) obrieni* Archbold, *Tivertonia barbwirensis* sp. nov. and the gastropod *Peruvispira canningensis* sp. nov. The fauna has affinities with that of the late Sakmarian–early Artinskian Nura Nura Member directly overlying the Grant Group in other parts of the basin but, as with all lower Cisuralian (and Pennsylvanian) glacial strata in Western Australia, its precise age remains poorly constrained, especially in terms of correlation to international stages. Although the Calytrix fauna lies within the *Pseudoreticulatispora confluens* Palynozone, the only real constraint on its age (and that of the associated glacially influenced strata) is from Sakmarian (Sterlitamakian) and stratigraphically younger faunas. A brief review of radiometric ages from correlative strata elsewhere in Gondwana shows that those ages need to be updated. The presence of Asselian strata and the position of the Carboniferous–Permian boundary remain unclear in Western Australia.

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WHEREAS late Sakmarian–early Artinskian carbonate–shale facies containing diverse marine faunas are widely distributed in a broad belt, informally designated the East Gondwana interior rift system (Veevers 1988, Harrowfield *et al*. 2005) along the western margin of Australia and extending as far north as Timor-Leste (Haig *et al*. 2014), the distribution of older Permian marine faunas is more erratic, as they were strongly influenced by glacial conditions and local fluvio-deltaic input (Gorter *et al*. 2005, 2008, Mory *et al*. 2005, Mory 2010). In addition, these faunas are not as well documented as their late Sakmarian–early Artinskian successors, especially in the northern Australian basins where few fossil localities are known, and correlations are highly dependent on palynology (Gorter *et al*. 2008, Mory 2010).

Although petroleum exploration has greatly expanded knowledge of Permian strata in Western Australia, there is still a significant dichotomy between outcrop and subsurface studies in terms of both stratigraphic nomenclature and biostratigraphic resolution. In particular, correlation of subsurface sections relies predominantly on microfossil studies, particularly palynomorphs, which can only be recovered under exceptional circumstances from the usually deeply weathered and strongly oxidized outcrops in the west of Australia. Conversely, macrofauna from the subsurface are limited by the availability of core from marine facies. Reconciling these differences will be greatly helped by the recovery of palynomorphs from outcrops (or shallow bores next to outcrop) and, as in this case, macrofauna from cored sections.

The material described in this paper comes from 1–2.5 m above the base of the Calytrix Formation (the middle unit of the Grant Group) in Pasminco BW 9 (74–181.3 m) drilled at 19°27′33″S, 125°7′29″E (Geocentric Datum of Australia 1994) during a 1992 mineral exploration program on the Barbwire Terrace of the Canning Basin (Figs 1, 2; Roberts 1993). Coring in BW 9 commenced at 161 m within the Grant Group (*ca* 10–312 m)

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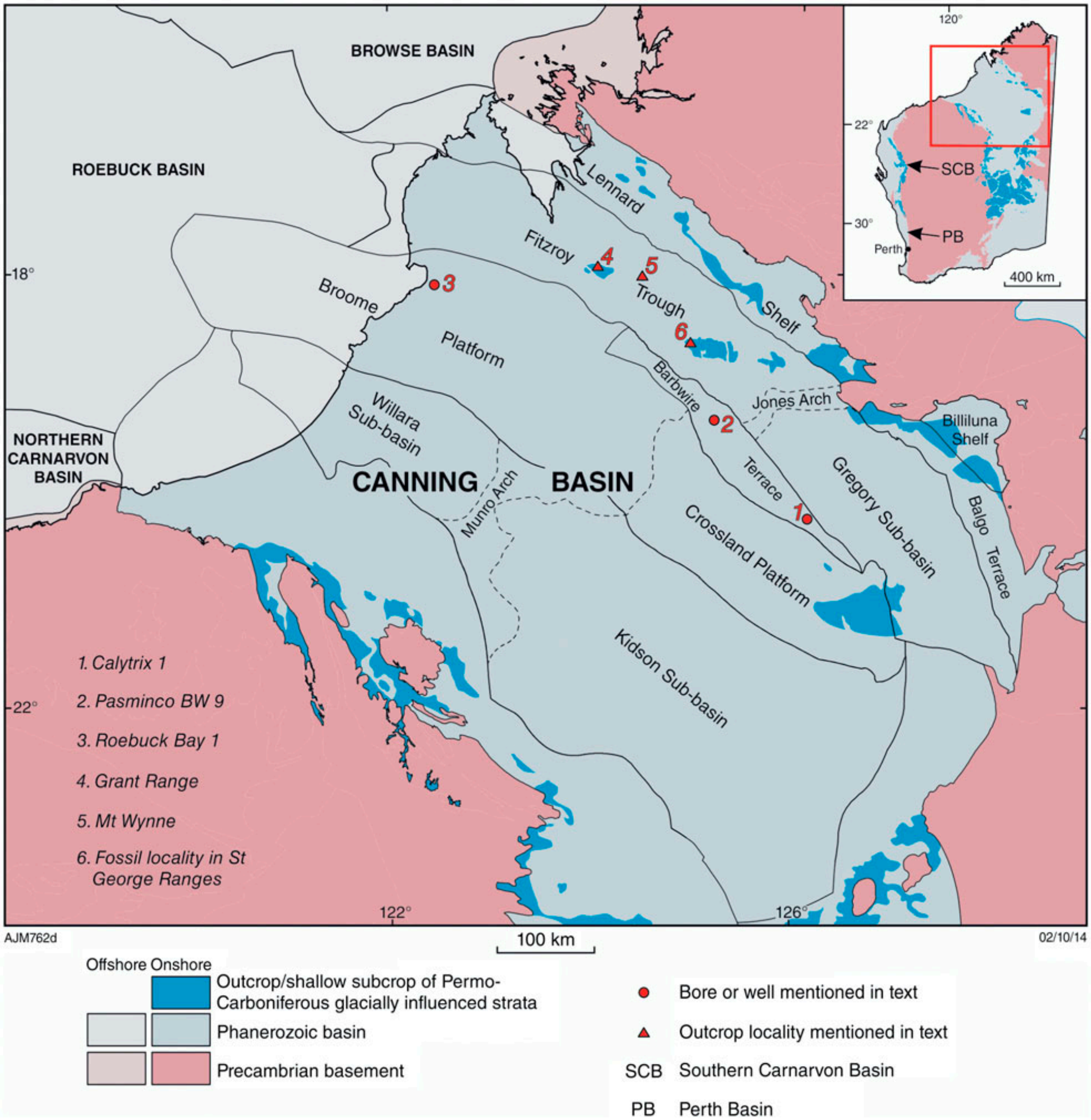

Fig. 1. Location of Pasminco BW 9, Canning Basin, Western Australia.

and continued into the Upper Devonian to a total depth of 700 m. Besides brachiopods and gastropods (described herein), bryozoans, crinoidal debris, foraminifera (organic cemented agglutinated and less common calcareous types) and rare ostracods (Table 1) are also present. Bivalves are noticeably absent.

The drill hole site lies on the northwestern end of the Barbwire Terrace 90 km SSE of the fossiliferous outcrop in the Wye Worry Member (Carolyn Formation) described by Dickins *et al*. (1977) within the Fitzroy Trough, and 140 km northwest of Calytrix 1 from which Foster & Waterhouse (1988) described a fossil assemblage at the southeastern end of the Barbwire Terrace, also from the Calytrix Formation (Fig. 1). Other macrofaunal assemblages in the formation have a patchy distribution and have not been studied in detail. They are absent from nearby petroleum exploration core holes. Macrofossil outcrop localities, apart from that of Dickins *et al*. (1977) and Archbold (1995), have proven remarkably elusive, especially considering there are over 70 such localities in the coeval Lyons Group of the Southern Carnarvon Basin (e.g., Dickins 1957, Dickins & Thomas 1959, Thomas 1969, 1971) although many of these have proven to be sparse and/or difficult to relocate. Only two other invertebrate macrofossil localities are known from outcrop of the Grant Group, and were found in 1956 and 1973 during mapping of the Mount Ramsey and Helena 1:250 000 map sheets,

GSWA sample no. Metres below surface	185871 178.8–179.2	185872 179.3–179.8	185873 179.9–180.3
Organic-cemented agglutinated species			
Glomospirella nyei Crespin	X	X	X
Hyperammina coleyi Parr	X	X	X
Kechenotiske hadzeli (Crespin)	X		
Hyperammina fusta Crespin	X	X	X
Lagenammina sp.		X	
Reophax fittsi (Warthin)	X		
Sansabaina elegantissima (Plummer)	X	X	X
Thuramminoides sphaeroidalis Plummer	X	X	
Tolypammina sp. 1	X	X	
Trochammina sp. 1	X		
Hyaline calcareous species (Order Lagenida)			
Vervilleina sp. 1	X	X	X
Vervilleina sp. 2	X	X	X
Protonodosaria tereta Crespin	X	X	?
Other biogenic particles			
Ostracods	X	X	
Crinoidal debris	X		
Gastropods	X		
Bryozoan debris	X		

Table 1. Distribution of foraminifera associated with the macrofauna in Pasminco BW 9. References to taxon authors are published by Crespin (1958), Haig (2003) and Dixon & Haig (2004).

respectively (Roberts *et al*. 1968, Yeates & Walton 1974). The former is approximately 159 km north-northeast of Calytrix 1 and contains unidentifiable shell fragments (Dickins 1964), whereas the latter is 120 km southeast of Calytrix 1, near the Forebank Hills. Although Yeates & Walton (1974) provided no details of their fauna, Yeates *et al*. (1975, p. 18) mentioned rare pectinids (*Etheripecten* sp.) from the eastern end of the basin but provided no locality details—it is surmised that the pectinids are from near the Forebank Hills. Neither of these very remote sites appears to have been revisited.

The first indication of marine beds in the Grant Group within the Canning Basin was based on foraminifera recovered from cores 31 and 33 (775.1–778.15 m and 807.1–808.65 m) of Roebuck Bay 1, 164 m below the basal Nura Nura Member of the overlying Poole Sandstone (Crespin & Condon 1956). One of us (DWH) found foraminifera similar to those from the Calytrix Formation in cores 30–34 (between 745.55 and 837.6 m) from that well. To date, foraminifera have not been recovered from outcrop of the Grant Group.

Regional geology and structure

All the Permian basins in the west of Australia were intracratonic during the Permian when they lay along the East Gondwana interior rift between present-day India and Antarctica in the south and Greater India and the Australian craton to the north (Harrowfield *et al*. 2005, Haig *et al*. 2014). Lowermost Permian deposits across Australia are usually characterized by glacial features especially diamictite, dropstones and rare varves. In Western Australia, these deposits are assigned to different units according to the basin in which they lie (Nangetty Formation, Perth Basin; Lyons Group, Southern Carnarvon Basin; Grant Group, northern–central Canning Basin; Patterson Formation, southern Canning Basin; Kulshill Group, Bonaparte Basin; Fig. 2) even though there may be little difference in facies or age, especially for the upper parts of these units (Mory *et al*. 2008).

The Canning Basin onlaps (and is surrounded by) mainly Paleoproterozoic–Neoproterozoic terranes. Offshore, the basin probably continues below the thick Mesozoic section of the North West Shelf. The basin is subdivided into structural elements (Fig. 1) that include: 1, an elongate NE-trending depocentre (comprising the Fitzroy Trough and its southeastern extension, the Gregory Sub-basin) containing thick Devonian–Permian and likely older strata; 2, a mid-basin platform (comprising the Broome and Crossland platforms) in which basement is relatively shallow; and 3, southern depocentres (including the Willara and Kidson sub-basins) dominated by a thick Ordovician–Lower Devonian section. The periphery of the basin is flanked by a contiguous series of shelves, including the Lennard Shelf to the north, all of which onlap relatively shallow basement (after Hocking 1994). Note that the use of physiographic terms to classify structural elements does not necessarily have a palaeobathymetric connotation.

Our material is from the Barbwire Terrace that represents a faulted terrace, approximately 350 km long and up to 50 km across, forming a transitional basin sub-division between the Fitzroy Trough to the north and the Broome Platform to the south (Fig. 1). Across the terrace, the Grant Group thickens slightly northwards from *ca* 367 to 400 m. Further northwest, the group reaches over 1000 m thick in the central part of the Fitzroy Trough (Mory 2010). Dips within the terrace (and much of the rest of the basin) rarely exceed 10°, except adjacent to major faults.

Canning Basin stratigraphy

In the Canning Basin, two threefold divisions of the glaciogene Grant Group have been proposed: the Betty, Winifred and Carolyn formations (in ascending order) based on outcrop and some widely spaced wells (Crowe & Towner 1976) and the Hoya, Calytrix and Clianthus formations (Redfern 1991, Redfern & Millward 1994) based on cored sections from the Barbwire Terrace at the southern margin of the Fitzroy Trough (Figs 1, 2). Although Redfern (1991) claimed that the two divisions are approximately equivalent, Apak & Backhouse (1999, p. 7) indicated that within the Fitzroy Trough and some adjacent areas, the group 'is rarely easily divisible on purely lithostratigraphic criteria', a point implicit in Mory's (2010) criticisms of the scheme erected by Crowe & Towner (1976) even though it has been applied widely across the basin.

A major difficulty hindering correlation within the group is that the relative stratigraphic position of glacial characters appears to change across the basin: there are none in the Calytrix and higher units from the Barbwire Terrace; dropstones up to 2 m in diameter are present in outcrop of the Wye Worry Member of the Carolyn Formation (the member is a possible lateral equivalent of the Calytrix Formation) in the Fitzroy Trough; and diamictites are present in the upper part of the group across the Lennard Shelf north of the trough. Whether this is due to profound diachroneity, localized coastal, deltaic and fluvial facies variations, or discrete glacial/interglacial phases is uncertain.

Owing to its northern position compared with the Perth and Southern Carnarvon basins, and significant fluvio-deltaic input possibly owing to its intracratonic position, the Canning Basin appears to have diminished glacial influence that may account for the variation in glacial influences within the Grant Group. Another difficulty is that the group encompasses all of the Lower Permian below upper Sakmarian–lower Artinskian carbonate facies, including fluvial facies that can be difficult to differentiate from the overlying Poole Sandstone or underlying Carboniferous Reeves Formation. Thus, on the Barbwire Terrace, where the Poole Sandstone appears to be missing in most wells, there is a possibility that the uppermost part of the group (the fluvio-deltaic Clianthus Formation) is a lateral equivalent of the Poole Sandstone to the north. Whereas such a correlation equates the upper *Pseudoreticulatispora confluens* Zone with the succeeding *P. pseudoreticulata* Zone, such an equivalence can not be discounted completely even though elsewhere in Western Australia that boundary appears to be one of the most robust Permian palynological datums.

P.E. O'Brien (pers. comm., 2010, in Mory 2010) indicated that the brachiopods he collected (described by Archbold 1995), are from the same Wye Worry Member section as in Dickins *et al*. (1977; 10.3 km at 63° from Mount Tuckfield at 18°39′36″S 124°58′36″E, but now measured at 10.5 km at 58° suggesting a shift owing to a datum mismatch) rather than 9 km away 'east of Mount Tuckfield and Carolyn Bore' at 18°42′48″S 124°54′48″E (as cited by Archbold 1995). One of us (AJM) went to those coordinates in 2010 but found no fossils there. The faunal lists provided by Dickins *et al*. (1977) and Archbold (1995) have only one element in common (*Deltopecten*), but Archbold (1995) conceded that some of his undescribed material is fragmentary and, therefore, not possible to assign to species. Furthermore, *Deltopecten* is also recorded in higher stratigraphic units. Dickins *et al*. (1977) assigned his material to the 'middle part' of the Wye Worry Member, and indicated close faunal links to assemblages from the Carrandibby Formation and the upper Lyons Group of the Southern Carnarvon Basin. By comparison, the fauna described by Archbold (1995) more closely resembles the Calytrix 1 fauna from 220 km to the southeast in the southeastern Barbwire Terrace (Foster & Waterhouse 1988). The relative position of Archbold's (1995) material compared with that described by Dickins *et al*. (1977) remains unclear, as correlation of the Wye Worry Member with the Calytrix Formation is entirely lithostratigraphic. Accordingly, it appears that the collections of Archbold (1995) and Dickins *et al*. (1977) come from different beds in the same section. Whereas the stratigraphic sketch provided by O'Brien (in Archbold 1995, fig. 1) shows the base of the Poole Sandstone 37 m above the fossiliferous bed, that sandstone is more likely to be the Millajiddee Member of the Carolyn Formation, the uppermost unit in the Grant Group, based on the 1:250 000 geological map (Crowe & Towner 1981) and thereby indicates the upper part of the Wye Worry Member, a level Archbold (1995) and Mory (2010) correlated with the Calytrix Formation.

Age

The fauna from the base of the Calytrix Formation in Pasminco BW 9 contains *Altiplecus decipiens* (Hosking), *Myodelthyrium dickinsi* (Thomas), *Brachythyrinella narsarhensis* (Reed), *Neochonetes (Sommeriella) obrieni* Archbold, *Tivertonia barbwirensis* sp. nov. and *Peruvispira canningensis* sp. nov., together with several unidentified brachiopods (including possibly *Spirelytha* Fredericks) and bryozoan genera, among others, which collectively comprise a moderately diverse cool- to temperate-water fauna. The association of *Altiplecus decipiens*, *Neochonetes (Sommeriella) obrieni* and *Myodelthyrium dickinsi* (and possible *Spirelytha*) indicates a link with faunas from the base of the

Callytharra Formation (Southern Carnarvon Basin) and an age in the Sterlitamakian, although a slightly older age (latest Tastubian) can not be excluded. The affinities and stratigraphic distribution of *Brachythyrinella narsarhensis*, *Tivertonia barbwirensis* sp. nov. and *Peruvispira canningensis* sp. nov. in other regions, are consistent with this age assignment.

Palynomorphs of the *Pseudoreticulatispora confluens* Zone (the nominal taxon is assigned to *Converrucosisporites* in most other parts of Gondwana; Stephenson 2009) range throughout the Grant Group and are present in Abutilon 1 (over 153–303.9 m; summarized by Mory 2010), about 1 km to the northwest of BW 9. However, the zone does not provide independent evidence of age except by stratigraphic association and position—in Western Australia it is known only from the glacial succession that underlies late Sakmarian–early Artinskian warmer water faunas (summarized by Haig *et al*. 2014). To date, all associated faunal elements known in Australia are endemic, although the ammonoid species *Juresanites jacksoni* (Etheridge) and *Uraloceras irwinense* Teichert & Glenister from the Holmwood Shale belong to widespread genera whose co-occurrence indicates a Sakmarian age (Leonova 1999, 2011). These ammonoids lie within the upper stratigraphic range of *P. confluens* and so provide only a partial control for the age of the eponymous zone. The lower age limit of this zone is virtually unconstrained in Western Australia with the next known ammonoid and conodont faunas below that level lying within Lower Carboniferous strata, thereby leaving the age of intermediate palynofloras, especially the index *Microbaculispora tentula* (the apparent progenitor of *P. confluens*), uncertain. This uncertainty is represented in Fig. 2 by the inclined boundaries between palynozones and also applies to the associated brachiopod faunas, about which Archbold (1999) stated 'The ages of the *Lyonia lyoni* Archbold and *Neilotreta occidentalis* (Thomas) zones, the oldest two brachiopod zones, are constrained by superpositional positions below Sterlitamakian ammonoid occurrences', implying some difficulty in establishing their lower age limit. An alternative correlation, based more on climatic events, shown by Haig *et al*. (2014, fig. 2) is not inconsistent with our correlation given the levels of uncertainty with all the fossil evidence.

Zircons from volcanics that lie within the *P. confluens* Zone in eastern Australia (Roberts *et al*. 1996), Namibia (Bangert *et al*. 1999, Stephenson 2009), Brazil (Santos *et al*. 2006, Simas *et al*. 2012) and Argentina (Césari 2007) have been dated with SHRIMP U–Pb. Even though many of the ages yielded are close to the Carboniferous–Permian boundary (e.g., Césari 2007, Stephenson 2009) to Sakmarian (Roberts *et al*. 1996, Simas *et al*. 2012) these analyses have relatively large associated errors, mostly provide weighted means of the zircon grains analyzed and so require re-evaluation with information provided on individual grains, preferably using ID-TIMS. In addition, estimates of the relative stratigraphic position of the tuffs within the palynological zone are also required. In the case of the Paganzo Group, northwestern Argentina, there is no palynology available from the Las Colinas Formation from which Gulbranson *et al*. (2010) obtained a TIMS age of 296 Ma. More recent work by Di Pasquo *et al*. (2013, 2014) suggests that the *Vittatina costabilis* Zone in Bolivia (approximately equivalent to the *M. tentula*–*P. pseudoreticulata* zones in Western Australia; Stephenson 2008) extends into the Asselian.

At present, the ages of all Permian palynozones are poorly constrained, at least in Western Australia, and there is little independent data to verify the synchroneity of such zones. Tuffs in eastern Australia are relatively common allowing some calibration to international stages (e.g., Metcalfe *et al*. 2011, Smith & Mantle 2013) but none has yet been found in the Lower Permian (R.S. Nicoll pers. comm. 2014).

Although foraminifera have been reported from the Grant Group, all descriptions (Crespin 1958) predate drilling of fully cored sections on the Barbwire Terrace and, as with the concurrent *P. confluens* Palynozone, rely heavily on the Sakmarian ammonoid ages from the overlying Nura Nura Member of the Poole Sandstone (reviewed most recently by Leonova 2011) to constrain the age of the group. The only subsequent published work by Palmieri (1990) mentions the *Tezaquina clivuli* and overlying *Ammodiscus oonahedensis* zones from the Grant Group. Whereas *T. clivuli* has a zone named after it in Afghanistan that Leven (1997) suggested may extend down into the Asselian, the lack of taxonomic descriptions of the west Australian material by Palmieri (1990, 1994) does not permit confidence in accepting his ages. The species from the Grant Group listed by Palmieri (1994) follow those of Crespin (1958), and the inferred Sakmarian age appears to be based on stratigraphic position. Unpublished work by Palmieri on core samples from Western Mining Corporation petroleum wells drilled on the Barbwire Terrace during the 1980s lists mainly agglutinated forms in addition to those mentioned above, together with three species of *Tetrataxis* (*T. conica*, *T. corona* and *T. lata*; C. Foster, pers. comm., 2014) indicative of temperate conditions similar to those inferred for the Nura Nura Member and Callytharra Formation (Haig *et al*. 2014). The foraminifera from the Calytrix Formation (Table 1) show a marked affinity with those from the Nura Nura Member and, although requiring further work, mirror the palaeoclimatic affinities of the brachiopods. Whereas organic-cemented siliceous agglutinated forms are dominant within the Calytrix Formation (Table 1), there are significant variations in the foraminifera (including absences) in other sections suggestive of marked variations in marine influence.

Correlation

The presence of *Altiplecus decipiens*, *Myodelthyrium dickinsi* and possible *Spirelytha* indicates a slightly younger age than the Calytrix 1 and Wye Worry Member faunas described by Foster & Waterhouse (1988) and Archbold (1995), respectively. The stratigraphic interval bearing the Pasminco BW 9 fauna is possibly absent in both the St George Ranges and Grant Range anticlines, implying that the disconformity between the Wye Worry and the Millajiddee members (Mory 2010, fig. 6c) represents a local unconformity (likely entirely within the *P. confluens* Zone), also limiting equivalence between units of the Barbwire Terrace and the Fitzroy Trough.

Archbold (1995) correlated the Wye Worry Member (Fitzroy Trough), Calytrix Formation (Barbwire Terrace) and Carrandibby Formation (Southern Carnarvon Basin) on the common presence of *Neochonetes (Sommeriella) obrieni*. The species has also been identified from the Carrandibby Formation (Southern Carnarvon Basin) based on one decorticated ventral valve (CPC 33512, illustrated by Archbold 1995, fig. 8b) from BMR 8 Glenburgh (also referred to as Mount Madeline) core 18 (507.5–509.5 m). The poor preservation of the specimen does not allow the species to be identified with confidence. The synonymy of this species also includes unillustrated specimens from a conglomerate at the base of the Callytharra Formation (Archbold 1993, 1995). Following Archbold (1995), the stratigraphic range of *Neochonetes (Sommeriella) obrieni* encompasses the Carrandibby Formation plus the basal Callytharra Formation, in other words from cold-water faunas dominated by genera such as *Eurydesma* and *Neilotreta*, to more diverse cool–temperate faunas of the lower Callytharra Formation and its correlatives. Therefore, the Carrandibby Formation and upper Lyons Group could be slightly older, perhaps early Tastubian extending down into the Asselian. A minor complication is that the limestone in BMR 8 Glenburgh that yielded the specimen in question (CPC33212 in Archbold 1995) was originally placed near the base of the Carrandibby Formation (Mercer 1967) but has since been assigned to undifferentiated Lyons Group (Mory & Backhouse 1997, Archbold & Hogeboom 2000), thereby clouding the relative position of the Carrandibby Formation. Nevertheless, the core above (#17, 481.4–482.1 m) yielded palynomorphs of the *P. confluens* Zone (Mory & Backhouse 1997).

Climatic indicators

Although the Grant Group in the Canning Basin, together with correlative units in other Western Australian basins, are generally ascribed a glacial origin based on their contained sedimentary structures (Mory *et al*. 2008), the fossiliferous basal beds of the Calytrix Formation indicate an influx of temperate marine waters. Curiously, the distribution of this fossiliferous facies is patchy in the Canning Basin, and is absent in Abutilon 1 (1 km to the northwest of Pasminco BW 9). Whether this indicates variable water conditions or onlap of the Calytrix Formation onto the underlying Hoya Formation is unclear. In other cored sections, the fauna is restricted to siliceous agglutinated foraminifera that, higher in the Calytrix Formation, rapidly diminish in abundance and diversity indicating a regressive marine phase prior to deposition of overlying fluvio-deltaic facies (Clianthus Formation of Redfern 1991, Redfern & Millward 1994). Based on latest Carboniferous (latest Gzhelian) warm-water foraminifera from Timor-Leste, Davydov *et al*. (2013) proposed a global warm spike during that time was responsible for rapid melting of ice sheets in the Canning, Southern Carnarvon and northern Perth basins and initiation of rapid glacially influenced sedimentation.

Striae of supposed glacial origin illustrated by Mory (2010, fig. 7d) within sandstone of the lower part of the Wye Worry Member at Mount Wynne are similar to striae in Patagonia (Taboada & Pagani 2010, fig. 10), Brazil (Bigarella *et al*. 1967, fig. 2) and north Africa (Le Heron & Craig 2008). Alternate explanations, such as intraformational sliding (John Isbell pers comm. 2013, Huuse *et al*. 2012, p. 9), are not entirely satisfactory, at least for some of the Western Australian examples, in that they do not account for the smooth, commonly crescentic, slip faces akin to current crescents between some striated layers (e.g., Mory *et al*. 2008, fig. 3B; Mory 2010, fig. 7d; O'Brien & Christie-Blick 1992, fig. 6), or within sandstone supposedly at the base of the glacially influenced Lyons Group in the Southern Carnarvon Basin (Hocking *et al*. 1987, fig. 49). Similar striae have also been found in the Nangetty Formation, Perth Basin (Mory *et al*. 2005, fig. 22) and in the Ordovician of north Africa (Le Heron & Craig 2008, fig. 3B). We favour a genesis akin to that for groove casts and fluid drag casts (Ricci Lucchi 1995, plates 98, 99) and, although not a uniquely glacial feature, they are not entirely incompatible with deposition associated with such conditions, especially fluvio-glacial outwash.

Summary

There are few constraints on the lower age range of known macrofaunas associated with the *P. confluens* Zone within the Grant Group, but a Sakmarian age is most likely, although the *P. confluens* Zone may have initiated earlier. Similarly, there are no macrofaunal or other constraints for the older *M. tentula* and *Deusilites tenuistriatus* palynozones but which, on stratigraphic grounds, probably extend into the Pennsylvanian. Whether Asselian strata are present or not, and hence the position of the Carboniferous–Permian boundary, remain unclear in Western Australia.

Systematic palaeontology

All described specimens come from Pasminco BW 9 borehole on the Barbwire Terrace, Canning Basin, Western Australia, and are housed in the Invertebrate fossil collection of the Geological Survey of Western Australia Perth, Western Australia, with the prefix GSWA. Classification largely follows Carter *et al*. (2006) for Spiriferida, Carter & Johnson (2006) for Spiriferinida, Racheboeuf (2000) for Chonetidina, and Bouchet & Rocroi (2005) for Gastropoda.

Phylum BRACHIOPODA Duméril, 1806
Order SPIRIFERINIDA Cooper & Grant, 1976

Carter & Johnson (2006; see also Carter *et al*. 1994) referred the authorship of Spiriferinida to Ivanova (1972) who first proposed the Suborder Spiriferinidina, although Cooper & Grant (1976) had independently proposed the Order Spiriferinida. However, as pointed out by Waterhouse (2001), suprafamilial classifications are not required to follow the law of priority in zoological nomenclature and, consequently, we also attribute Spiriferinida to Cooper & Grant (1976), following Waterhouse (2001).

Suborder SPIRIFERINIDINA Ivanova, 1972
Superfamily PENNOSPIRIFERINOIDEA Dagys, 1972
Family RETICULARIINIDAE Waterhouse, 1975

Altiplecus Stehli, 1954

Type species. Altiplecus cooperi Stehli, 1954, from locality 625, Bone Spring Formation, Leonardian (roughly Kungurian) of the Sierra Diablo, Texas, USA.

Altiplecus decipiens (Hosking, 1933) comb. nov. (Fig. 3A–D)

1933 *Spiriferina cristata* var. *decipiens* Hosking, p. 53, pl. 4, figs 6, 7.
1936 *Spiriferina cristata* var. *decipiens* Hosking; Condit *et al*., p. 1041.
1993 *Gjelispinifera decipiens* (Hosking); Archbold *et al*. (in Skwarko, 1993), p. 259, pl. 44, only figs 1, 3, microfiche sheet 5, D7, D8 (copy Hosking 1933, figs 6, 7)

Material. One articulate and mostly decorticated specimen. GSWA 51501.

Geographic and stratigraphic distribution. In addition to the present material, the only other occurrence is from a creek 0.8 km west of Callytharra Springs on the Wooramel River, Callytharra Formation (late Sakmarian–early Artinskian), Southern Carnarvon Basin (Hosking 1933, Condit *et al*. 1936, Archbold *et al*. 1993).

Description. Medium-size *Altiplecus* (Fig. 3A–D), ventribiconvex, outline transversely subrhombic, width/length ratio 1.3, maximum width (23 mm) at hinge line. Ventral interarea incurved towards dorsal valve, marked by horizontal lines: delthyrium wide, open. Three plications on each flank of ventral valve and two on each flank of dorsal valve; plicae flanking sinus strong, 2–3 times coarser than the next and the third plicae on each ventral flank; plicae on dorsal valve more uniform in size when compared with plicae of ventral valve, but generally decreasing laterally from being moderately strong to weak. Cardinal angles rounded and commissure multiplicate with subangular fastigium. Shell surface ornamentation of strong irregularly spaced growth lamellae. Shell punctate, punctae density 3–4 per mm.

Discussion. The specimen described here closely resembles *Spiriferina cristata* Schlotheim var. *decipiens* Hosking (1933), from the Callytharra Formation, Southern Carnarvon Basin, Western Australia. This species had been referred to both *Altiplecus* sp. and *Gjelispinifera* sp. by Thomas (1969, 1981). In a further revision, Archbold *et al*. (1993) recognized this species as *Gjelispinifera decipiens* (Hosking). However, an examination of the specimens figured by Hosking (1933) and Archbold *et al*. (1993, pl. 44, only figs 1, 3) strongly indicates that they show diagnostic features of *Altiplecus* Stehli, 1954, such as a subrhombic outline, a deep sulcus, strong irregular concentric growth lamellae, a strong median fold and extended fastigium, with fewer plicae decreasing noticeably in size towards the flanks. The spine pattern in *Altiplecus* is usually represented by one or two concentric rows of a few thick long hollow spines on the growth lamellae, becoming thicker and more numerous anteriorly (Stehli, 1954). However, spines could also be rare or absent as noted in some type material of *Altiplecus cooperi* Stehli, 1954, and other congeneric species figured by Cooper & Grant (1976).

One of the specimens figured as *Gjelispinifera decipiens* (Hosking) by Archbold *et al*. (1993, pl. 44, fig. 2) has widely spaced hollow spines arranged radially on crests and flanks of plications, a characteristic that would strongly suggest attribution to *Gjelispinifera* Ivanova, 1975, although the species itself appears to be very distinctive from Hosking's (1933) species (this latter view agrees with Dr V. Poletaev's opinion, 2013, pers. comm.).

Spiriferina cristata var. *decipiens* listed by Condit *et al*. (1936) from a fossil assemblage of the Callytharra Formation at its type locality (Callytharra Springs on the Wooramel River), probably also belongs to *Altiplecus decipiens* (Hosking). Hosking (1933, pp. 52–53, pl. 4, fig. 5) figured one ventral valve as *Spiriferina cristata* (Schlotheim). This valve was later assigned to *Gjelispinifera decipiens* (Hosking) by Archbold *et al*. (1993), even though it has one more plica on each flank of the ventral valve compared with the type specimens of *Altiplecus decipiens* as figured by Hosking (1933). With

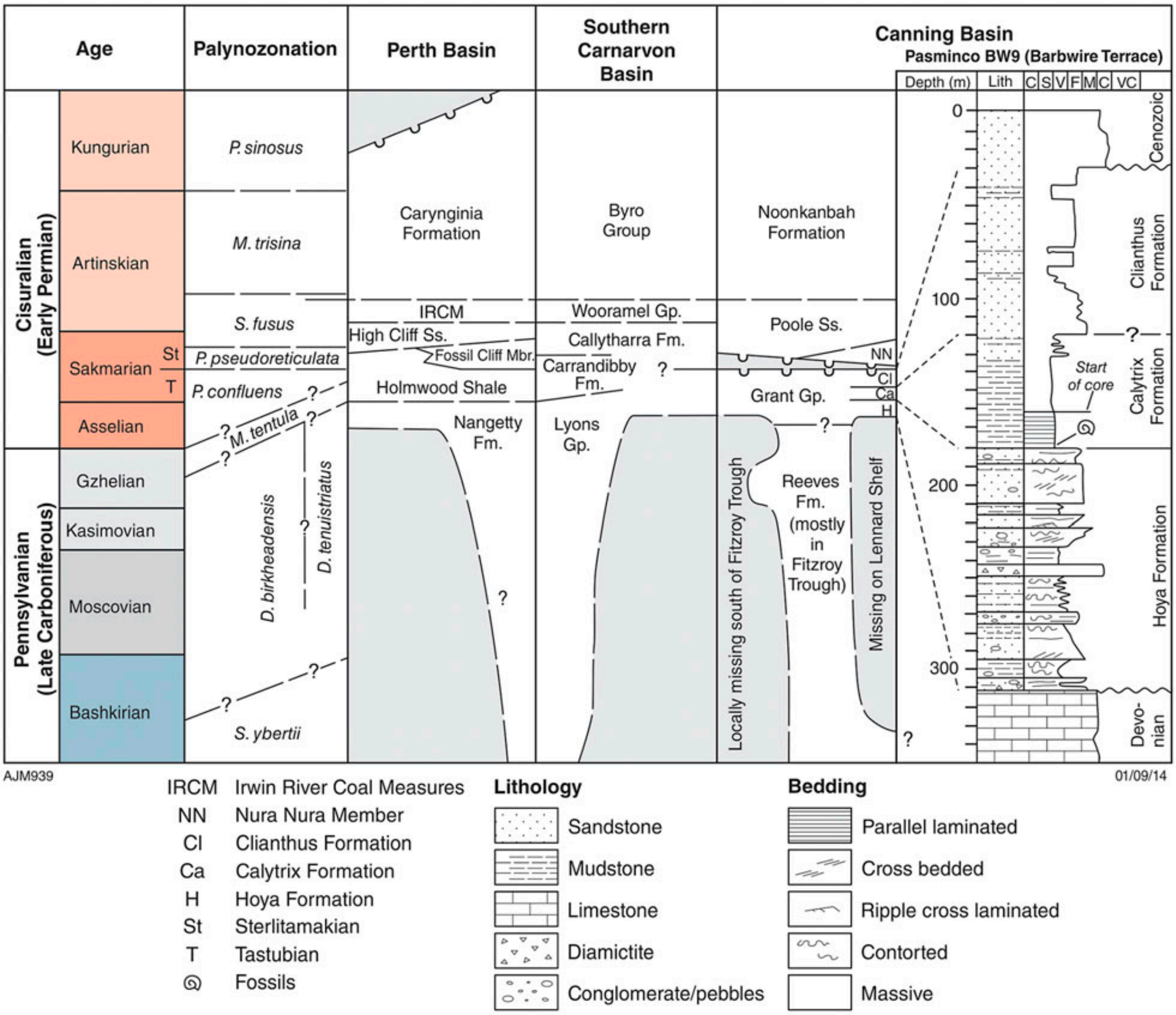

Fig. 2. Generalized Lower Permian stratigraphic correlation in Western Australia, including a lithological log of Pasminco BW 9. Note that the sloping lines between the palynozones are meant as an indication of uncertainty rather than diachroneity, although such a possibility can not be completely discounted.

only one ventral valve and limited information, it is unclear whether this ventral valve should be assigned to *Altiplecus* or *Gjelispinifera*.

Another species similar to *Altiplecus decipiens* (Hosking) is *Altiplecus mongolica* (Grabau, 1931) from the Jisu Honguer Formation (Middle Permian) of Inner Mongolia in northeast China. However, the former exhibits a stronger biconvexity of the shell, more transverse outline, more rounded plicae and a more strongly deflected fold and sinus when compared with *Altiplecus decipiens* (Hosking).

Superfamily SYRINGOTHYRIDOIDEA Fredericks, 1926
Family SYRINGOTHYRIDIDAE Fredericks, 1926
Subfamily PERMASYRINXINAE Waterhouse, 1986

Myodelthyrium Thomas, 1985

Type species. Pseudosyringothyris dickinsi Thomas, 1971, about 1.3 km at 270º from Callytharra Springs, Callytharra Formation (late Sakmarian–early Artinskian), Southern Carnarvon Basin, Western Australia.

Myodelthyrium dickinsi (Thomas, 1971) (Fig. 3J)

1897 *Syringothyris exsuperans* (de Koninck), Etheridge, pp. 46–47, only text-fig. B.
1971 *Pseudosyringothyris dickinsi* Thomas, pp. 140–148, figs 10 (1–5), 11 (1, 2), 12 (1–4), 13 (3a, 3b), 29 (7), text-figs 53–56.
1993 *Myodelthyrium dickinsi* (Thomas, 1971), Archbold *et al*. (in Skwarko 1993), figs 36 (3, 8–10), microfiche sheet 4, G11 [copy of Thomas 1971, figs 10 (3a), 11 (1a–c)].
2000 *Myodelthyrium dickinsi* (Thomas, 1971), Archbold & Hogeboom, fig. 12J.

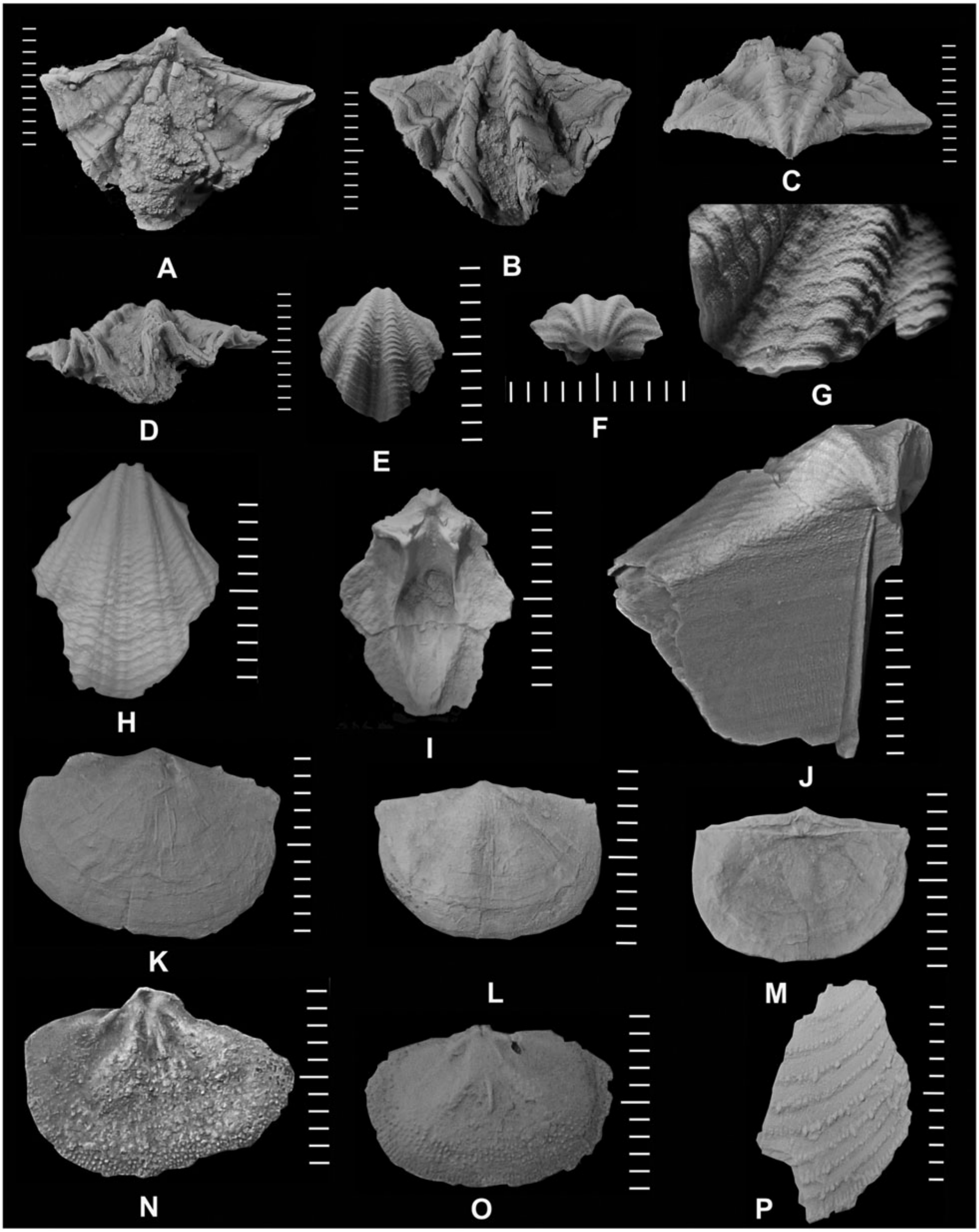

Fig. 3. Altiplecus decipiens (Hosking), **A**–**D**, GSWA 51501, articulate specimen in dorsal, ventral, postero-ventral and anterior views. *Brachythyrinella narsarhensis* (Reed), **E**–**G**, GSWA 51515, ventral valve exterior in ventral and posterior views and detail of micro-ornamentation. **H**, **I**, GSWA 51519, ventral valve exterior and ventral valve interior. *Myodelthyrium dickinsi* (Thomas), **J**, GSWA 51513, ventral valve in posterior view. *Neochonetes (Sommeriella) obrieni* Archbold, 1995, **K**, GSWA 51504, ventral valve exterior; **L**–**M**, GSWA 51506, ventral valve exterior and dorsal valve exterior; **N**, GSWA 51525, dorsal valve interior; **O**, GSWA 51536, dorsal valve interior. *Spirelytha?* sp., **P**, GSWA 51540, ventral valve? fragment. Scale-bar increments are in millimetres.

2006a *Myodelthyrium dickinsi* (Thomas, 1971), Carter, p. 1900, figs 1265 (1a–e) [copy of Thomas 1971, figs 10 (3a), 11 (1a–c, 2b)].

Material. One fragmentary ventral valve. GSWA 51513 (Fig. 3J).

Geographic and stratigraphic distribution. The species has been recorded elsewhere in Western Australia from the lower beds of the Poole Sandstone in St. George Ranges, the equivalent 'Cuncudgerie Sandstone' at Well 27 on the Canning Stock Route, Canning Basin; and the Callytharra Formation (late Sakmarian–early Artinskian), at Callytharra Springs, Towrana Station, Williambury Station, Lyons River Station, Gascoyne River 4 km SSW of Trig. Station K39 (previously referred to the Jimba Jimba Calcarenite), and Bidgemia 1, Southern Carnarvon Basin (Thomas 1971, Archbold & Hogeboom 2000).

Description. Fragmentary ventral valve with rounded sulcus and 11 rounded simple costae on right flank, which decrease slightly in size towards outer margin. Micro-ornament of fine short radial striae interspersed with densely grouped suboval pustules extending to interarea outside perideltidium. Umbo incurved over hinge line. Interarea high, wide, slightly concave. Delthyrium long and narrow with apical angle near 20°. Delthyrium flanked by a dental ridge bearing a rounded tooth in its anterior end and a longitudinal groove in its internal side. Deltidium relatively short, extending one-quarter of delthyrial length and indented a few millimetres at anterior margin, flat to slightly concave, marked with fine concave growth lines parallel to anterior margin of deltidium; perideltidium marked with bifurcating longitudinal grooves crossed at right angles by growth lines.

Discussion. Macro- and micro-ornamentation and general characteristics of the interarea in the described specimen are typical of *Myodelthyrium dickinsi* (Thomas, 1971), although its small size suggests a juvenile form of this species in the Canning Basin, as previously recognized in the Fitzroy Trough (northern Canning Basin) by Thomas (1971).

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883
Superfamily SPIRIFEROIDEA King, 1846
Family TRIGONOTRETIDAE Schuchert, 1893
Subfamily TRIGONOTRETINAE Schuchert, 1893
Tribe TRIGONOTRETINI Schuchert, 1893

Brachythyrinella Waterhouse & Gupta, 1978

Type species. Spirifer narsarhensis Reed, 1928, from Narsarha railway cutting, two miles west of Umaria railway station, Kaharbari and basal Barakar formations (Sakmarian–Artinskian), Rewa Basin, Umaria district in the state of Madhya Pradesh, India.

Discussion. After being accepted by Archbold (1982a), *Brachythyrinella* was suppressed by the same author (Archbold 1991), whereas Cisterna *et al*. (2002) considered it to be useful as a subgenus of *Trigonotreta* Koenig, 1825. In this regard, Waterhouse (2004) refined the discrimination of *Brachythyrinella* by characters such as its smaller size, thinner shell and lack of posterior sulcal plicae, presence of a grooved or flat-crested fold, short hinge and rounded cardinal extremities and well-developed regularly spaced concentric laminae; it also appears to lack a bulbous apical callosity and a true delthyrial plate (see also Thomas 1971, Archbold & Thomas 1984, Cisterna & Archbold 2007). *Trigonotreta narsarhensis occidentalis* Thomas, 1971, currently the type species of *Neilotreta* Waterhouse, 2008, matches in form and type of costation with *Brachythyrinella narsarhensis* (Reed), but is smaller and more delicate when compared with *Neilotreta occidentalis*. The main differences between *Brachythyrinella* and *Neilotreta* are the sulcal and fold ornamentation patterns. *Brachythyrinella* has no posterior sulcal plicae but a median sinus ridge is present, together with a simple fold commonly with a median channel (Reed 1928, Waterhouse 2004, 2008). *Neilotreta* has 5–7 costae on the sulcus with a low median costa originating near the umbo, and a fold usually carrying 4–5 costae (Thomas 1971, figs 38 m–o). Clarke (1990) indicated that *Neilotreta occidentalis* (Thomas) is identical to small, less thickened growth stages of Tasmanian populations of *Trigonotreta stokesi* Koenig, 1825, so the name may serve to distinguish small populations of possible immature individuals. On the other hand, *Neilotreta* represents a genus originated by paedomorphy from *Trigonotreta stokesi* (Waterhouse, 2008); both are probably derived from *Pericospira*-like ancestors. Cisterna & Archbold (2007) recognized their *Pericospira* as the most similar genus to *Brachythyrinella* by sharing the 5–7 pairs of narrow plicae on each flank and a grooved fastigium, as was also noted by Waterhouse (2004). The type species *Pericospira pericoensis* (Leanza, 1945) has a costate sulcus (Leanza 1945, text-fig. 1, fig. V, 5), although allied species, such as *Pericospira riojanensis* (Lech & Aceñolaza, 1987) and *Pericospira sanjuanensis* (Lech & Aceñolaza, 1990), lack posterior sulcal plicae (Cisterna & Archbold 2007). In summary, *Brachythyrinella* is small with minor shell thickening, a dorsal fastigium with a gentle median groove or flat crest, rounded cardinal extremities, costae in fascicles of three with the middle costa of each fascicle being coarser and a median sinus ridge (Reed 1928, Thomas 1971, Waterhouse 2004, 2008, Cisterna & Archbold 2007).

Brachythyrinella narsarhensis (Reed, 1928) (Fig. 3E–I)

1928 *Spirifer narsarhensis* Reed, pp. 379–382, figs 33 (7, 7a, 7b, 8–10), 36 (1–5).

1928 *Spirifer narsarhensis* var. *pauciplicatus* Reed, pp. 382–383, figs 33 (11), 36 (6, 7).

1971 *Trigonotreta narsarhensis narsarhensis* (Reed), Thomas, fig. 19 (7, 8).

2004 *Brachythyrinella narsarhensis* (Reed), Waterhouse, text-fig. 29, 1, 3 [copy of Reed 1928, fig. 36 (2, 6).

2006b *Brachythyrinella narsarhensis* (Reed), Carter, pp. 1802, 1805, fig. 1195 (1a–c) [copy of Reed 1928, figs 33 (7, 7a, 7b), 1195 (1d, 1e) and copy of Thomas 1971, fig. 19 (7, 8)].

Material. Three fragmentary ventral valves. GSWA F51515, F51516, F51519.

Geographic and stratigraphic distribution. In addition to the present record, the species is also known in the Karharbari and basal Barakar formations (Sakmarian, Tastubian), Rewa Basin in the Umaria district of India (Reed 1928).

Description. Small, thin-shelled, gentle to moderately convex ventral valves with flattened median sinus bearing a thin median rib. Flanks with three rounded plicae preserved, decreasing in size towards cardinal angles. Each plica splits unequally into three costae, the middle one slightly coarser than the lateral ones; plical splitting is present at one-third to one-half of their length; interspaces between plicae rounded and narrower than plicae. Umbo pointed, incurved with gently concave umbonal shoulders. Shell surface covered with strong sub-equidistant imbricating concentric lamellae and fine reticulate micro-ornamentation made of delicate close radial lines and fine subdued concentric growth lines (Fig. 3G). Interarea narrow, gently concave, apparently smooth. Delthyrium open without apical callus. Ventral interior with adminicula of moderate length and little shell thickening. Elongate suboval muscle field with indistinct subradial muscle scars.

Discussion. Ornamentation pattern, shell size and ventral interior suggest assignment to *Brachythyrinella narsarhensis* (Reed, 1928), for which Reed (1928) noted the presence of concentric lamellae crossed by delicate close radial striae, a feature also present in our specimens. Our exceptionally well-preserved shells also bear subdued fine concentric growth lines. Reed (1928) did not recognize internal structures, such as septa or dental plates, but adminicula illustrated from topotypic material by Thomas (1971) are also present in our material (Fig. 3I).

Material from eastern and Western Australia referred to or considered very similar to *Brachythyrinella narsarhensis* (Reed) are included in *Trigonotreta victoriae* Archbold, 1991, and *Neilotreta occidentalis* (Thomas) (originally *Trigonotreta narsarhensis occidentalis* Thomas, 1971) by Waterhouse (2008). Likewise, *Brachythyrinella* cf. *narsarhensis* (not Reed) Waterhouse & Gupta (1978, see also Clarke, 1990) from the Bijni tectonic unit, Garhwal Himalaya, has been reassigned to *Trigonotreta thomasi* Waterhouse, 2004. Material similar to *Brathythyrinella narsarhensis* (Reed) was also reported from Lower Permian deposits of Tibet (Jin 1979, Sun 1993, Shi *et al*. 1996).

Order CHONETIDA Nalivkin, 1979
Suborder CHONETIDINA Muir-Wood, 1955
Superfamily CHONETOIDEA Bronn, 1862
Family RUGOSOCHONETIDAE Muir-Wood, 1962
Subfamily RUGOSOCHONETINAE Muir-Wood, 1962

Neochonetes Muir-Wood, 1962

Subgenus **Neochonetes (Sommeriella)** Archbold, 1982b

Type species. Chonetes prattii Davidson, 1859, probably from Fossil Cliff on the Irwin River, Fossil Cliff Member of the Holmwood Shale (Archbold 1981), Perth Basin, Western Australia.

Neochonetes (Sommeriella) obrieni Archbold, 1995 (Fig. 3K–O)

1988 *Neochonetes (Sommeriella)* aff. *pratti* Waterhouse (in Foster & Waterhouse, 1988), p. 155, figs 7a, b.

1995 *Neochonetes (Sommeriella) obrieni* Archbold, pp. 98–100, figs 3A–N, 5D–I, 8B.

Material. Twenty-five disarticulated mostly fragmentary ventral and dorsal valves. GSWA 51504, 51506, 51508–51512, 51523–51536, 51544–51547.

Geographic and stratigraphic distribution. This species was also recorded in Western Australia from BMR 8 Glenburgh (formerly Mount Madeline) core, Carrandibby Formation (Southern Carnarvon Basin); the Carolyn Bore, Wye Worry Member of the Carolyn Formation; and in Western Mining Corporation (WMC) Calytrix 1, Calytrix Formation, Grant Group (Canning Basin; Archbold 1995, Foster & Waterhouse 1988). Archbold (1993, 1995) reported the species in the Woolaga Limestone Member of the Holmwood Shale (Perth Basin) and the conglomerate at the base of the Callytharra Formation (Southern Carnarvon Basin).

Description. Small transverse *Neochonetes* of 1.4–1.6 width/length ratio and maximum width (15.2 mm) at mid-length of valve. Ventral valve gently convex with median portion flattened but lacking a sulcus. Dorsal valve moderately concave without median fold. Shell ornamentation of fine concentric growth lines, in some

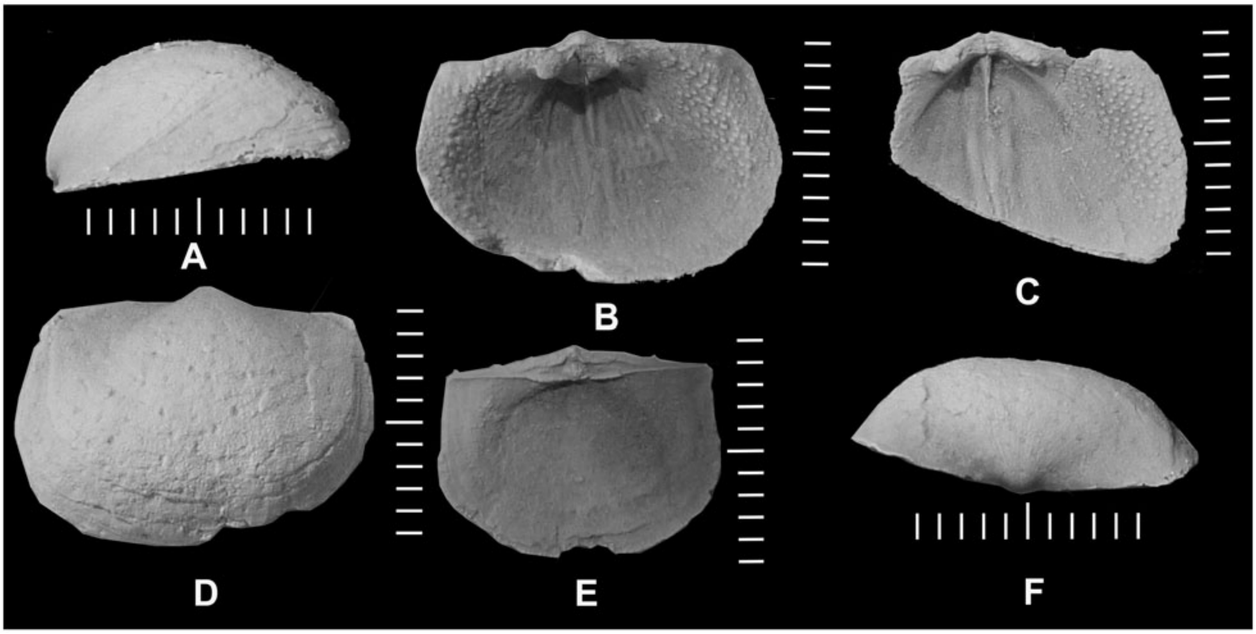

Fig. 4. Tivertonia barbwirensis sp. nov., **A**–**B**, **D**, Holotype GSWA 51502, ventral valve in lateral view, ventral valve interior and ventral valve exterior in ventral view; **C**, GSWA 51522, ventral valve interior; **E**, Paratype GSWA 51503, dorsal valve exterior; **F**, GSWA 51502, ventral valve in posterior view. Scale-bar increments are in millimetres.

cases stronger anteriorly, and fine capillae (4–5 per mm at anterior margin) increasing in number by bifurcation. Ventral and dorsal interarea low. Three to four orthomorph oblique cardinal spines on each side, projecting posterolaterally at 35–45° from hinge line. Interior of dorsal valve with median septum of half valve length, distinct alveolus, subelliptical anterior adductor scars and moderately impressed brachial ridges.

Discussion. The shell size, outline, convexity, median flattening of its ventral valve, lack of sulcus, its dense and bifurcating capillae, and dorsal external and internal features are all strongly indicative of *Neochonetes (Sommeriella) obrieni* Archbold, 1995, originally described from the Calytrix and Carolyn formations of the Canning Basin and the Carrandibby Formation of the Southern Carnarvon Basin, Western Australia (Waterhouse in Foster & Waterhouse 1988, Archbold 1995).

Subfamily SVALBARDINAE Archbold, 1983

Tivertonia Archbold, 1983

Type species. Lissochonetes yarrolensis Maxwell, 1964, from the Yarrol Formation (Sakmarian), Yarrol Basin, Yarrol Station, Monto District, eastern Australia.

Tivertonia barbwirensis sp. nov. (Fig 4A–F)

Material. Two ventral valves, two articulate specimens and fragments of ventral valves, Holotype GSWA 51502, paratype GSWA 51503. Other material GSWA 51505, 51507, 51520–51522.

Type locality, unit and age. Pasminco BW9 borehole, Barbwire Terrace, Canning Basin; Grant Group; ?Sakmarian.

Etymology. From the Barbwire Terrace.

Description. Of medium size for the genus, subcircular, thin shelled, on average one-third wider than long with strong concave-convex profile (Fig. 4A–F). Maximum width (15.5 mm) at mid-length of valve. Ventral valve smooth with fine concentric growth lines slightly lamellose anteriorly, delicate spinules and three apparently orthomorph oblique hinge spines. Dorsal valve exterior with similar ornamentation to the ventral valve but

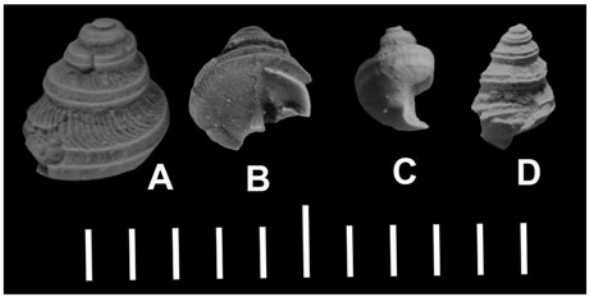

Fig. 5. Peruvispira canningensis sp. nov., **A**, holotype GSWA 51559, oblique view; **B**, paratype GSWA 51558, basal oblique view; **C**, GSWA 51560, lateral view; **D**, GSWA 51557, lateral-basal oblique view. Scale-bar increments are in millimetres.

minute spinules not observed. Interior of ventral valve strongly papillose peripherally with fine median septum reaching one-third of valve length and large striate, well-impressed diductor scars of one-half valve length. Cardinal process quadrifid externally. Interior of dorsal valve unknown.

Discussion. The subcircular outline, ornamentation pattern and the ventral internal features of our specimens strongly favour assignment to *Tivertonia* Archbold, 1983. In particular, the present material is close to the type species *T. yarrolensis* (Maxwell, 1964), widely recorded from the Sakmarian–early Artinskian ages of eastern Australia (Yarrol, Bowen, Gympie and Sydney basins; Maxwell 1964, Runnegar & Ferguson 1969, Archbold 1983, 1986, Waterhouse *et al*. 1983) and New Zealand (Begg & Ballard 1991). However, the much stronger convexity in the lateral profile of our material, which lacks even an incipient sulcus, clearly suggests some potentially significant differences to *T. yarrolensis*. These same features, combined with a moderately concave dorsal valve, would also differentiate *Tivertonia barbwirensis* sp. nov. from the older *Tivertonia tatamariensis* Singh & Archbold, 1993 and *Tivertonia chumikensis* Archbold & Gaetani, 1993, both from the Lower Permian of India. *Tivertonia leanzai* Taboada, 2006, from the Cordón del Jagüel Formation (Sakmarian–early Artinskian?, formerly Agua del Jagüel Formation in part, *emend*. Limarino *et al*. 2012), western Argentina, has a more transverse outline, a more gently concavo-convex profile, and a greater number of cardinal spines compared with *Tivertonia barbwirensis*. *Tivertonia pillahuincensis* (Harrington, 1955) (Pagani 1998) from the Bonete Formation (Sakmarian) of eastern Argentina has a general similarity to the Calytrix material, but some of its essential morphological features, such as ventral and dorsal internal characters and cardinal spines, are unknown (not preserved), thus hampering a precise specific comparison with the current material. Based on these comparisons, it is likely that the present material represents a new species of *Tivertonia*.

Phylum MOLLUSCA Linnaeus, 1758
Class GASTROPODA Cuvier, 1797
Order VETIGASTROPODA Salvini-Plawen, 1980
Superfamily EOTOMARIOIDEA Wenz, 1938
Family EOTOMARIIDAE Wenz, 1938
Subfamily NEILSONIINAE Knight, 1956

Peruvispira Chronic, 1949

Type species. Peruvispira delicata Chronic, 1949 from the Copacabana Formation (Early Permian), Huanta, Perú.

Discussion. Knight *et al*. (1960) and Dickins (1961) synonymized *Pleurocintosa* Fletcher (1958) with *Peruvispira* Chronic because of their equivalent sizes, whorl height and outline, selenizone and the concave revolving area beneath the selenizone (alveozone of Batten 1989), ornamentation pattern and lower apical angles. On the other hand, Waterhouse (1987) distinguished *Pleurocinctosa* as a valid genus, differentiated from *Peruvispira* by its gently convex, rather concave, upper whorl profile and by the weak development of its peribasal carina. Waterhouse (1987) also indicated in the diagnosis of *Pleurocinctosa* the presence of weak spiral filae, an inconspicuous character noted only in *Pleurocinctosa fletcheri* Waterhouse, 1987. On this basis, Waterhouse (1987) also referred *Peruvispira umariensis* (Reed, 1928) (see also Dickins 1957, 1961) to *Pleurocinctosa*. Nevertheless, *Peruvispira umariensis* has a flattish (never markedly convex) upper part of the whorl according to descriptions and illustrations by Reed (1928) and Dickins (1957), who also showed that the development of a third and peribasal carina bounding the alveozone is also a highly variable feature in *Peruvispira umariensis* and other congeneric species. Therefore, a peribasal carina can not be regarded as a valid character for generic distinction.

Peruvispira canningensis sp. nov. (Fig. 5A–D)

Material. Fifteen mostly crushed specimens. Hototype GSWA 51559, paratype GSWA 51558. Other material GSWA 51537–51539, 51551–51557, 51561–51562.

Type locality, unit and age. Pasminco BW9 borehole, Barbwire Terrace, Canning Basin; Grant Group; ?Sakmarian.

Etymology. From the Canning Basin.

Description. Small (maximum height 5 mm, maximum width 3 mm) *Peruvispira* with 4–5 whorls with moderately high spire, apical angle about 40° (Fig. 5A–D). Upper part of the whorl flat, ornamented with opistoclinal colabral lirae (9–10 per mm) and wider interspaces. Lirae start at suture at right angle and then curve to meet the upper peripheral carina of the selenizone at about 45°. Suture located below selenizone at a distance equal to selenizone width. Selenizone concave, bounded by two carinas and ornamented with numerous concave lunulae (18–20 per mm) marking the lower carina the periphery of the shell. Alveozone weak- to moderately concave, limited by a slightly to moderately raised peribasal carina. Basal part of whorl gently convex, anomphalous.

Discussion. The small size, number of whorls, low apical angle, presence of alveozone and high density of lirae, collectively allow us to distinguish *P. canningensis* sp. nov. from other species. The most similar species appears to be *P. fletcheri* (Waterhouse, 1987) from the

Artinskian Dresden Limestone (Buffel Formation) of eastern Australia (Bowen Basin, Queensland). Its dimensions are comparable with *P. canningensis*, but the former has a slightly concave upper part of the whorl and faint traces of fine spiral threads, unlike the new species. *Peruvispira canningensis* has a similar apical angle and ornamentation pattern to *P. umariensis* (Reed, 1928) from the Karharbari and basal Barakar formations (Sakmarian–Artinskian) of peninsular India (Rewa Basin, Umaria district in the state of Madhya Pradesh) and the Tastubian Carrandibby Formation (Southern Carnarvon Basin) of Western Australia (Dickins 1957, 1961), but the former can be easily distinguished by its small size and greater number (9–10) of colabral threads on the upper part of the whorl, compared with only 4–5 colabral threads per mm in the latter species [measured from Dickins 1957, fig. 9 (5); see also Manceñido & Sabattini 1974]. An undescribed species of *Peruvispira* (=*Pleurocinctosa*) was previously reported from the Calytrix 1 fauna assemblage on the Barbwire Terrace (Foster & Waterhouse 1988, table 3).

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