

Proceedings of the Linnean Society of New South Wales

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Natural History in all its Branches

Langford, H.E., Lee, S. and
Zhen, Y.Y. (2026). Early
Devonian (Lochkovian) Rugose
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*Proceedings of the Linnean
Society of New South Wales*
148, 1-17.

Published on 23 March 2026 at
<https://openjournals.library.sydney.edu.au/index.php/LIN/index>

Manuscript accepted for publication
25 February 2026

Keywords: Lochkovian, Early
Devonian, Cobar Basin, rugose
corals, Rugosa, taxonomy,
palaeobiogeography

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ISSN 1839-7263

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ABSTRACT

Based on recent collections by the Geological Survey of NSW, this study describes rugose corals from the Beloura Tank Limestone Member of the Baledmund Formation within the Kopyje Group in central New South Wales. Identified species include *Neomphyma karpinskiense* Shurygina, 1968, *Xystriphyllum* cf. *parvum* Yü and Jell, 1990, *Carlinastraea?* cf. *acanthus* Yü and Jell, 1990, and *Battersbyia* cf. *simplex* Vaganova in Shurygina, 1968, together with an indeterminate ptenophylline species. These taxa indicate an early Lochkovian age for the Beloura Tank Limestone Member, suggesting correlation with the Elura Limestone Member of the Brookong Formation in the Cobar Basin and the Shield Creek Formation of Queensland, among those with the earliest Devonian rugose coral assemblages in eastern Australia. Similar rugose coral assemblages have also been documented from the Ural Mountains of Russia, the Great Basin region of North America, and the Altai-Sayan and Tian-Shan Fold Belts of central Asia, implying close biogeographic linkages between Australia and these regions during the Early Devonian.

INTRODUCTION

The Lachlan Orogen of eastern Australia hosts a range of Lower Devonian (Lochkovian to basal Emsian) carbonate rocks, comprising deposits of shallow water shelf, debris flow, deep water carbonate fan, and isolated allochthonous mega-clast facies (Mawson and Talent, 1994; Zhen, 1998). Although widespread throughout eastern Australia, occurrences of Lochkovian-Pragian rugose corals are sporadic, as summarised in Zhen (1998) and Zhen et al. (2001). Earliest Devonian rugose coral assemblages in New South Wales are relatively rare and only known from the Elmside Formation of the Yass district, Camelford Limestone south of Wellington, Cookeys Plains Formation between Bogan Gate and Trundle, Elura Limestone Member of the Brookong Formation north of Cobar, Beloura Tank Limestone Member of the Baledmund Formation southeast of Nymagee, and

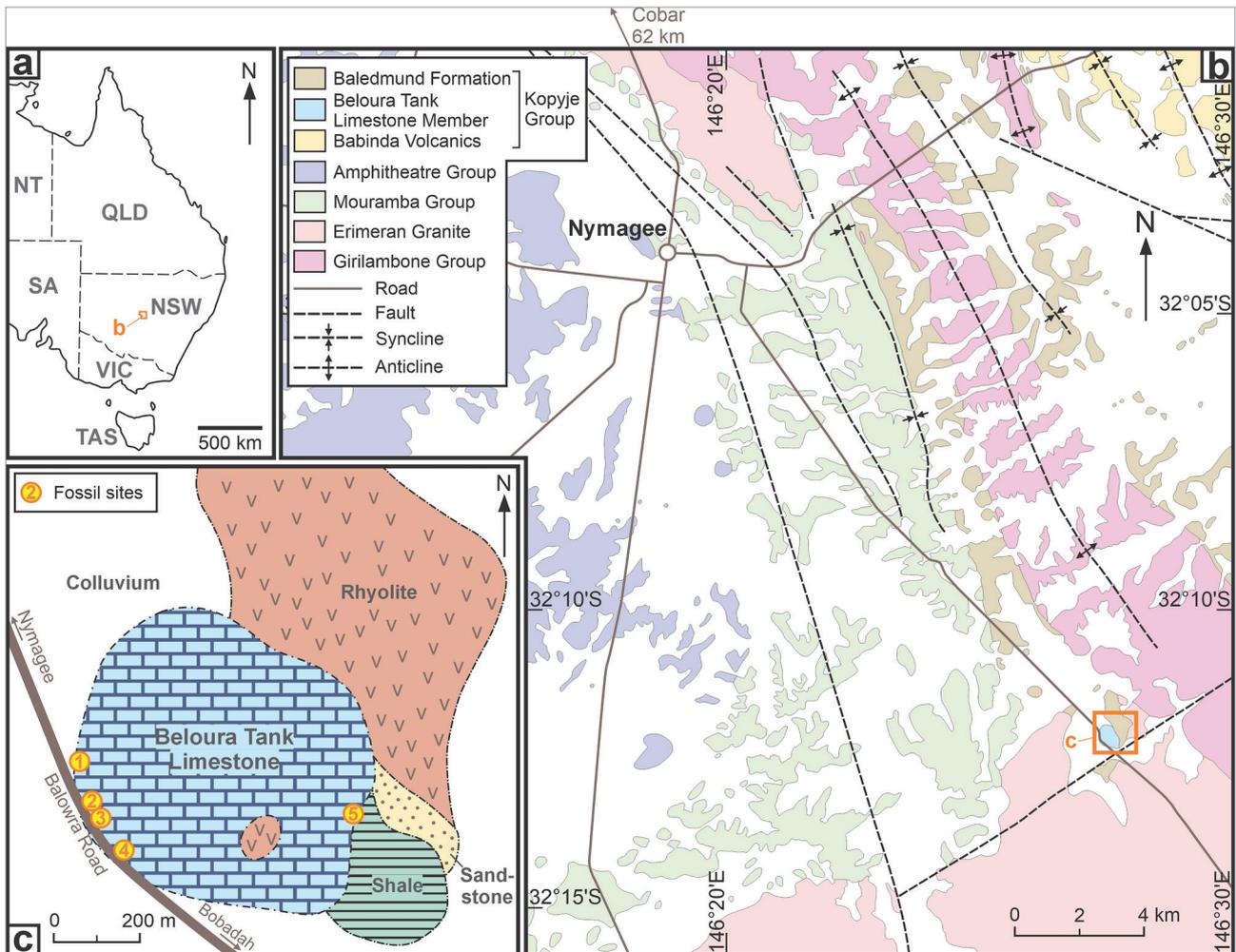


Figure 1. a, location of the study area in central NSW. b, c, simplified geological maps around Nymagee (modified from MacRae, 1987) and five fossil sites in the limestone exposure (Site 1: 32°12'6.01"S, 146°27'25.58"E; Site 2: 32°12'9.37"S, 146°27'26.90"E; Site 3: 32°12'9.55"S, 146°27'27.04"E; Site 4: 32°12'9.73"S, 146°27'27.14"E; Site 5: 32°12'5.71"S, 146°27'47.84"E).

possibly from the Garra Formation near Wellington and the Clandulla Limestone in the Mudgee region (e.g., Zhen, 1998; Talent et al., 2000; Zhen et al., 2001, 2023; Zhen and Fitzherbert, 2021). However, most of these rugose coral assemblages have not been taxonomically described in detail. This study provides detailed descriptions of rugose corals from the Beloura Tank Limestone Member, and discusses the probable age of this unit and its palaeobiogeographical affinities.

GEOLOGICAL SETTING

The Beloura Tank Limestone Member of the Baledmund Formation is part of the Kopyje Group, deposited in the transtensional Cobar Basin located in central NSW (Fig. 1). The Cobar Basin was infilled during the latest Silurian to Early Devonian, with shallow marine shelf deposition (e.g., Mouramba and Kopyje groups) flanked by deep-water turbidite sequences (e.g., Mount Hope and Amphitheatre groups), interspersed with several members of submarine to subaerial volcanic origins (MacRae, 1987; Mathieson et al., 2016; David, 2018), all comprising the Cobar Supergroup (Fig. 2).

Deformation, both thick and thin-skinned, during the Middle Devonian (Tabberabberan Orogeny) and mid-Carboniferous (Kanimblan Orogeny) inverted the basin (Glen, 1990, 1991; Gilligan and Byrnes, 1995; Glen et al., 1996; David, 2006, 2018).

The Kopyje Group comprises upper Silurian to Pragian strata, unconformably overlying the Girilambone Group of largely Ordovician turbidites and cherts (Figs 1b, 2). The Baledmund Formation, a stratigraphically and spatially dominant formation of the Kopyje Group (Fig. 2), consists primarily of laminated siltstones and fine sandstones overlying alluvial conglomerates and medium to coarse sandstones in the basal part, with an overall total thickness of ~1–1.5 km (MacRae, 1987). This formation is interpreted to have been deposited on a shallow shelf during a marine transgression (MacRae, 1987; Glen, 1990; Downes et al., 2016; Mathieson et al., 2016; Zhen and Fitzherbert, 2021; Zhen et al., 2023). The Beloura Tank Limestone Member lies close to the base of the sequence, directly above conglomerates interpreted as alluvial fan debris (MacRae, 1987). Several minor

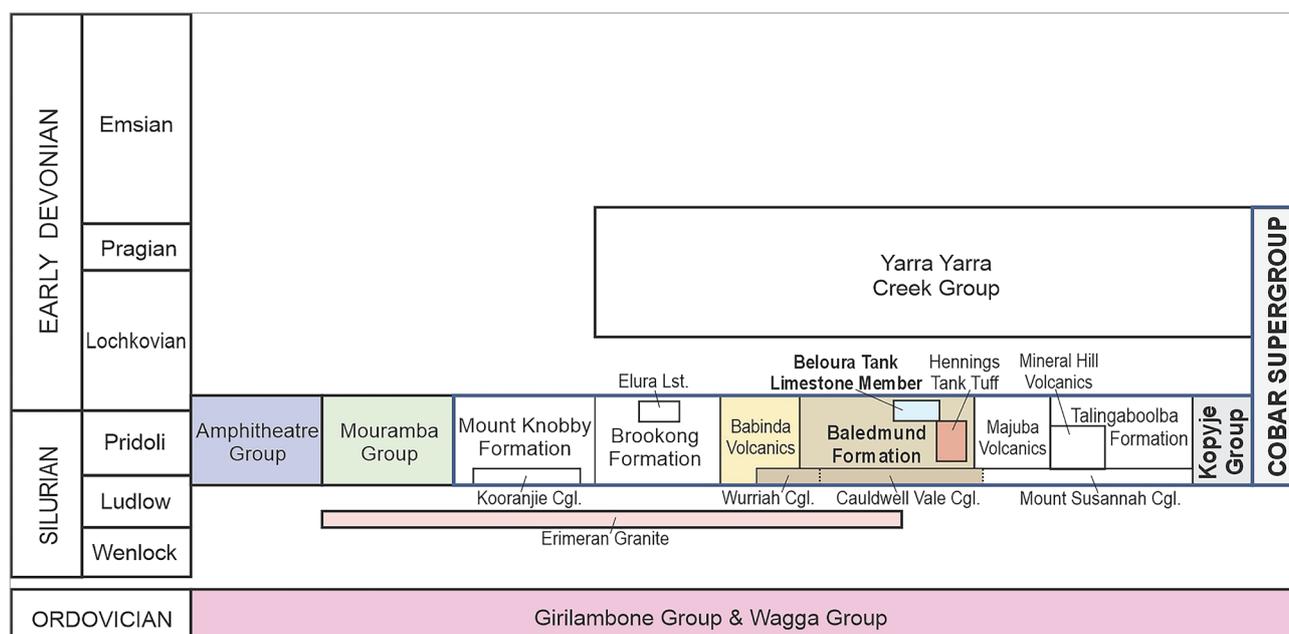


Figure 2. Summary of the stratigraphy of the Cobar Basin, showing stratigraphic subdivisions of the Kopyje Group (modified from Fitzherbert et al., 2016; Zhen and Fitzherbert, 2021). The Beloura Tank Limestone Member, together with other associated lithologies (shale, sandstone, rhyolite), belongs to the Baledmund Formation of the Kopyje Group within the Cobar Supergroup. Colours of lithologic units are matched with those in the geologic map of Fig. 1.

members with volcanic origins are interspersed within the formation, ranging from vitric submarine ash-flow tuffs (e.g., Hennings Tank Tuff Member) to rhyolitic lavas (e.g., Yalgo Rhyolite Member), alongside volcanic agglomerates (e.g., Pangee Road Agglomerate Member).

The Beloura Tank Limestone Member has previously been referred to as the ‘Balowra Limestone’ (Curran, 1888), the ‘Beloura Tank Limestone’ (Lloyd, 1936; Rayner, 1969), and ‘Balowra Tank Limestone’ (Pickett, 1977) – see Zhen et al. (2023) – and was subsequently formalised as the Beloura Tank Limestone Member within the Baledmund Formation by Pogson and Felton (1978). The member is partially underlain by the Hennings Tank Tuff Member and is commonly enclosed in or interfingering with siltstones and sandstones of the Baledmund Formation; it also may lie nonconformably on the Erimeran Granite (MacRae, 1987; Mathieson et al., 2016; Zhen et al., 2023; see Figs 1, 2). The Beloura Tank Limestone Member is approximately 300 metres thick according to Zhen et al. (2023), although it is difficult to determine an accurate thickness due to the massive nature of the limestone unit. A variety of fossils such as conodonts, crinoids, corals, brachiopods, bryozoans, gastropods and trilobites, have been documented from the unit (Fletcher, 1975; MacRae, 1987; Mathieson et al., 2016; Zhen et al., 2023).

STUDY AREA AND MATERIALS

The Beloura Tank Limestone Member is exposed on the east side of the Balowa Road connecting Nymagee and Bobadah, approximately 20 km southeast of Nymagee in central NSW (Fig. 1). Geological fieldwork

led by a team from the Geological Survey of NSW was conducted at the locality in 2023 and 2024, with extensive sampling of fossils from five sites (Fig. 1c), including solitary and cerioid rugose corals, tabulate corals, stromatoporoids, and crinoids (Fig. 3). The fossiliferous part of the member is mainly composed of packstone and grainstone. According to previous studies (MacRae, 1987; Mathieson et al., 2016; Zhen et al., 2023), the limestone blocks dip shallowly towards the southwest. However, our field observations in this study found no traces of bedding layers in the exposures and demonstrated the massive nature of the unit. Vitric rhyolite present as scree on the northeastern side of the limestone locality was previously interpreted as corresponding to the Hillcrest Tuff Member of the Babinda Volcanics by MacRae (1987), but is more likely attributable to the Hennings Tank Tuff Member as mapped by Mathieson et al. (2016).

Thin sections of corals (both transverse and longitudinal sections) were prepared from the limestone samples, and each thin section was then digitally imaged with a backlit film scanner and polarising filter. Utilising the imaged thin sections, morphological features (e.g., corallite diameter, number of major septa, thickness of peripheral stereozones, and number of dissepiment rows to the axis in longitudinal sections) were measured for each corallite and summarised in Table 1. The studied thin sections and limestone samples are registered with prefix ‘MMF’ and are housed in the Palaeontological collections of the Geological Survey of NSW, at the WB Clarke Geoscience Centre, Londonderry in western Sydney.

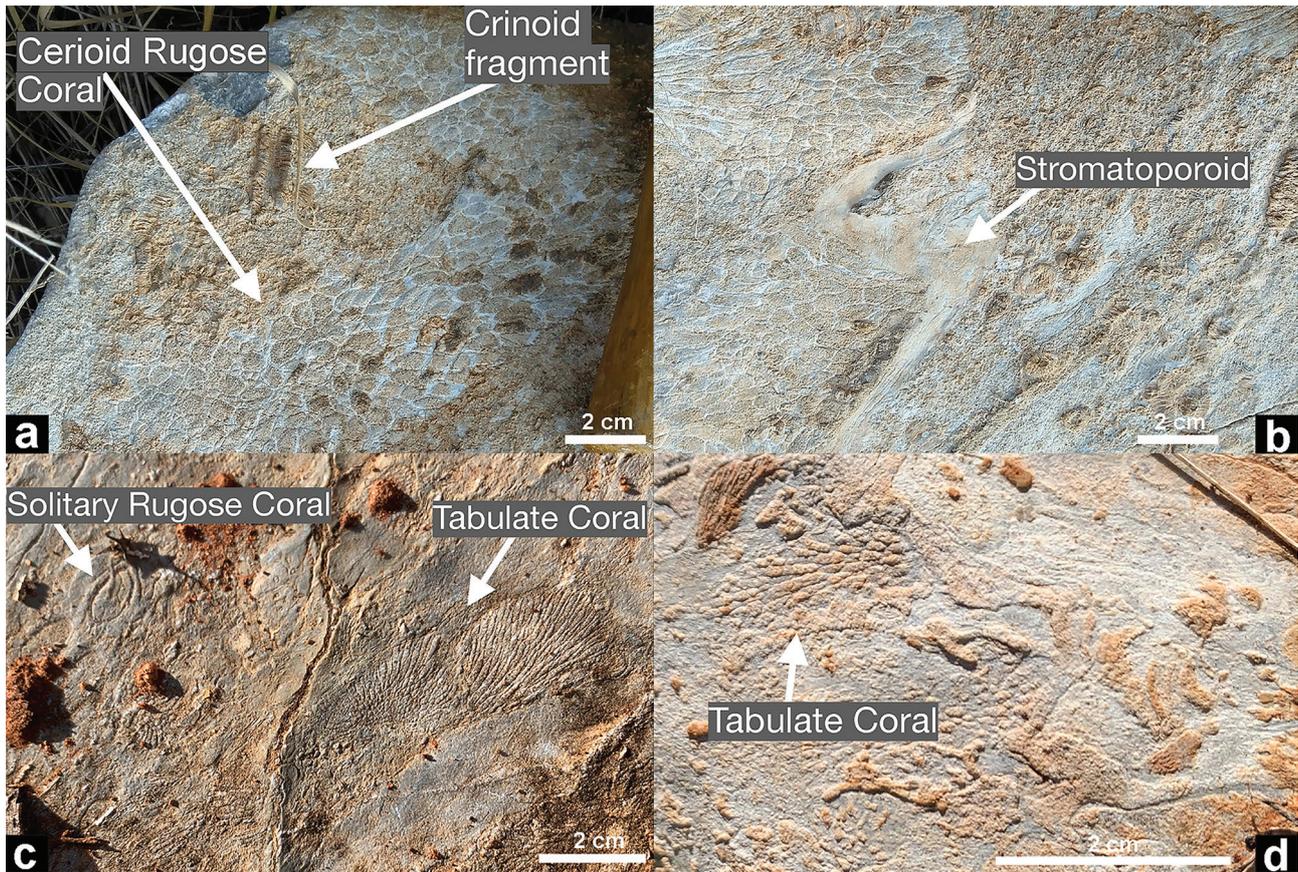


Figure 3. Field photographs of the Beloura Tank Limestone Member illustrating typical fossil preservation. a, b, outcrop area near Site 2 containing cerioid rugose corals, crinoid fragments, and stromatoporoids; c, outcrop block at Site 5 showing solitary rugose corals and tabulate corals; d, fragmented and syn-vivo intergrowth of tabulate corals and stromatoporoids alongside other biological debris, from near the northwestern side of the study area.

Rugose coral taxa (measured corallite numbers in TS & LS)	Corallite diameter	Number of major septa	Thickness of peripheral stereozone	Number of dissepiment rows	Growth form	Occurrences
<i>Neomphyma karpinskiense</i> Shurygina, 1968 (27, 10)	2.50–8.25 mm (5.84 mm)	4–22 (16.9)	0.13–0.75 mm (0.35 mm)	2–4 (2.6)	fasciculate	Sites 1, 2, 3
<i>Carlinastraea?</i> cf. <i>acanthus</i> Yü and Jell, 1990 (9, 6)	4.00–9.50 mm (6.36 mm)	4–21 (10.6)	0.13–0.38 mm (0.24 mm)		cerioid	Site 1
<i>Xystriphylum</i> cf. <i>parvum</i> Yü and Jell, 1990 (26, 8)	3.25–8.25 mm (5.47 mm)	13–21 (17.5)	0.20–1.00 mm (0.36 mm)	2–3 (2.5)	cerioid	Site 2
Ptenophyllinae gen. et sp. indet. (1, 0)	14.75 mm	20	0.625 mm		fasciculate	Site 4
<i>Battersbyia</i> cf. <i>simplex</i> Vaganova in Shurygina, 1968 (47, 9)	2.25–5.50 mm (4.14 mm)	13–18 (15.9)	0.05–0.50 mm (0.26 mm)	2–3 (2.1)	fasciculate	Sites 2, 3, 5

Table 1. Measurements of rugose corals from the Beloura Tank Limestone Member. Numbers in parentheses indicate the mean values. TS, transverse section; LS, longitudinal section.

SYSTEMATIC PALAEOLOGY

The terminology used to describe the features of the corals discussed herein mainly follows Hill (1935, 1956, 1981). In addition, some terms of Pedder and Murphy (1997) are adopted, specifically ‘presepiment’ (e.g., ‘presepimentarium’, ‘presepimented’) to refer to peripheral vesicles formed before septa; this feature was previously referred to as lonsdaleoid dissepiments, for example, by Hill (1935).

- Class ANTHOZOA Ehrenberg, 1834
- Subclass RUGOSA Milne-Edwards and Haime, 1850
- Order STAUROIDA Verrill, 1865
- Suborder PTENOPHYLLINA Wedekind, 1927
- Family SPONGOPHYLLIDAE Dybowski, 1873
- Subfamily PTENOPHYLLINAE Wedekind, 1923

Remarks

Many studies have noted morphologically gradational similarities, especially in the nature of tabulae and microstructure, between taxa of the Ptenophyllidae Wedekind, 1923 and Spongophyllidae Dybowski, 1873. Specifically, the similarities of *Carlinastraea* Merriam in Merriam and McKee, 1976 with *Australophyllum* Stumm, 1949, *Spongophyllum* Milne-Edwards and Haime, 1851 with *Xystriphylum* Hill, 1939, and *Neomphyma* Soshkina, 1937 with *Lyriellasma* Hill, 1939 put into question the distinction between the two families. As the Family Ptenophyllidae was erected later, both Pedder (1964) and Strusz (1966) placed it into the Spongophyllidae as a subfamily, a decision adopted in subsequent studies (e.g.,

Birenheide, 1978; Pedder and Murphy, 1997; Zhen and Fitzherbert, 2021), and followed in this study.

Genus *Neomphyma* Soshkina, 1937

Type species

Neomphyma originatum Soshkina, 1937, from the Lower Devonian of the Severouralsk region in the northern Ural Mountains, Russia.

Remarks

Disagreement on the concept of *Neomphyma* revolves around whether the genus includes solitary or fasciculate forms or covers both of these. Lin et al. (1995, p. 280) regarded *Neomphyma* as strictly solitary, while Pedder and Murphy (1997, p. 362) and Zhen and Fitzherbert (2021, p. 18) saw it as strictly fasciculate. A middle ground was taken by Merriam (1973a, p. 51) and Hill (1981, p. F240) who argued that the genus encompasses both forms. This study follows the fasciculate definition. Zhen and Fitzherbert (2021) also highlighted key differences between fasciculate *Neomphyma* and the closely related cerioid genus *Spongophyllum*, being a trabeculate stereozone and the presence of variably developed presepiments in *Neomphyma*. Based on the refined diagnosis, Zhen and Fitzherbert (2021) reassigned species without these features previously suggested to be *Neomphyma* to *Spongophyllum*. *Neomphyma* is also similar in the morphology of septal apparatus and dissepiments to *Grypophyllum* Wedekind, 1922, (of which many species have been assigned to *Embolophyllum* Pedder, 1967). However, *Grypophyllum* is represented solely by solitary forms (see Oliver, 1960), and *Embolophyllum* is further distinguished in having flanged septa. *Carlinastraea* also resembles *Neomphyma* in longitudinal section and septal arrangement, but is differentiated by its cerioid corallum as noted by Pedder and Murphy (1997, p. 360), and commonly a more presepimented marginarium, for example in the species *Carlinastraea halysitoides* Etheridge, 1918. *Battersbyia* Milne-Edwards and Haime, 1851 is another genus resembling *Neomphyma*, although generally differentiated by fewer dissepiment rows and the lack of presepiments. Therefore, species with far fewer presepiments, such as *Neomphyma karpinskiense* Shurygina, 1968, approach *Battersbyia*, as outlined in McLean (2018).

There are currently 17 known species of *Neomphyma*, the majority being recorded from the Lochkovian rocks of the Ural Mountains in Russia (Artyushkova and Maslov, 2008; Mavrinskaya and Slavik, 2013), the Altai-Sayan Fold Belt and southern Tien-Shan Fold Belt in central Asia and the Great Basin in North America (Merriam and McKee, 1976; Oliver and Johnson, 1977; Pedder and Murphy, 1997). Other occurrences are in the Eifelian and Givetian of Belgium and Germany (Coen-Aubert, 1990), and the Lochkovian to Givetian of eastern Australia (Hill, 1950, 1954; Zhen, 1991; Zhen et al., 2001; Zhen and Jell, 1996; Zhen and Fitzherbert, 2021; Zhen et al., 2023; this study).

Neomphyma karpinskiense Shurygina, 1968

Fig. 4

Material

Eight thin sections of five specimens (MMF47538, MMF47541, MMF47543, MMF48577, MMF48578).

Description

The corallites are generally sub-cylindrical and often tightly crowded, displaying intermural increase in many cases. Corallite diameter ranges from 2.5–8.25 mm (5.84 mm in average), with 17×2 septa ranging up to 22×2 (Fig. 5; Table 1). Major and minor septa are basally thickened, in some cases forming a marginal stereozone up to 0.75 mm in thickness (Table 1). Major septa are sinuous and attenuate in transverse section although curved in younger corallites, and sometimes interrupted by presepiments. Most corallites lack presepiments, but where present 1–3 presepiments are visible in transverse section. Otherwise dissepiments are elongated to globose and concave outwards between septa in transverse sections, forming 2–4 rows in longitudinal sections. Tabulae are incomplete, spaced at 6–10 per 5 mm vertically, flat to concave; tabularium approximately a third of corallite diameter.

Remarks

Neomphyma karpinskiense is differentiated from the type species of the genus, *N. originatum*, by the complete development of septa, a smaller diameter, and a narrower peripheral stereozone. It is comparable with '*Neomphyma simplex*' Vaganova in Shurygina, 1968 reported from the Lower Devonian of the eastern slope of the Ural Mountains (Shurygina, 1968, p. 137, pl. 61, figs 2, 3). However, *N. karpinskiense* is characterised by significantly larger corallites and sinuous septa, whereas '*N. simplex*' has straight, and shorter minor septa. Moreover, '*N. simplex*' essentially lacks presepiments and has a reduced number of dissepiments, leading McLean (2018) to suggest that it may be a species of *Battersbyia*. Specimens of *N. karpinskiense* recently identified from the Elura Limestone Member by Zhen and Fitzherbert (2021) are similar to those from the Beloura Tank localities, but differ in having slightly sharper basal thickening of septa in the stereozone, and slightly increased intercorallite spacing allowing corallites to be generally more cylindrical in shape, although a similar range of corallite morphologies is observed.

Neomphyma karpinskiense was first recorded in Russia, from the Gornovaya River, west of Karpinsk, in the Lochkovian reef facies of the Saraynoy Horizon of the eastern central Ural Mountains (Shurygina, 1968). The endorheic Great Basin in North America also hosts the species in rocks of approximately Lochkovian age, including the Windmill Limestone in the northern Simpson Park Range and the Tor Limestone in the Toquima Range (Merriam and McKee, 1976; Oliver and Johnson, 1977; Pedder and Murphy, 1997). *Neomphyma karpinskiense* is now also known from the Elura Limestone Member (Zhen and Fitzherbert, 2021) and the Beloura Tank Limestone Member (Zhen et al., 2023; this study) within the Kopyje Group in central NSW.

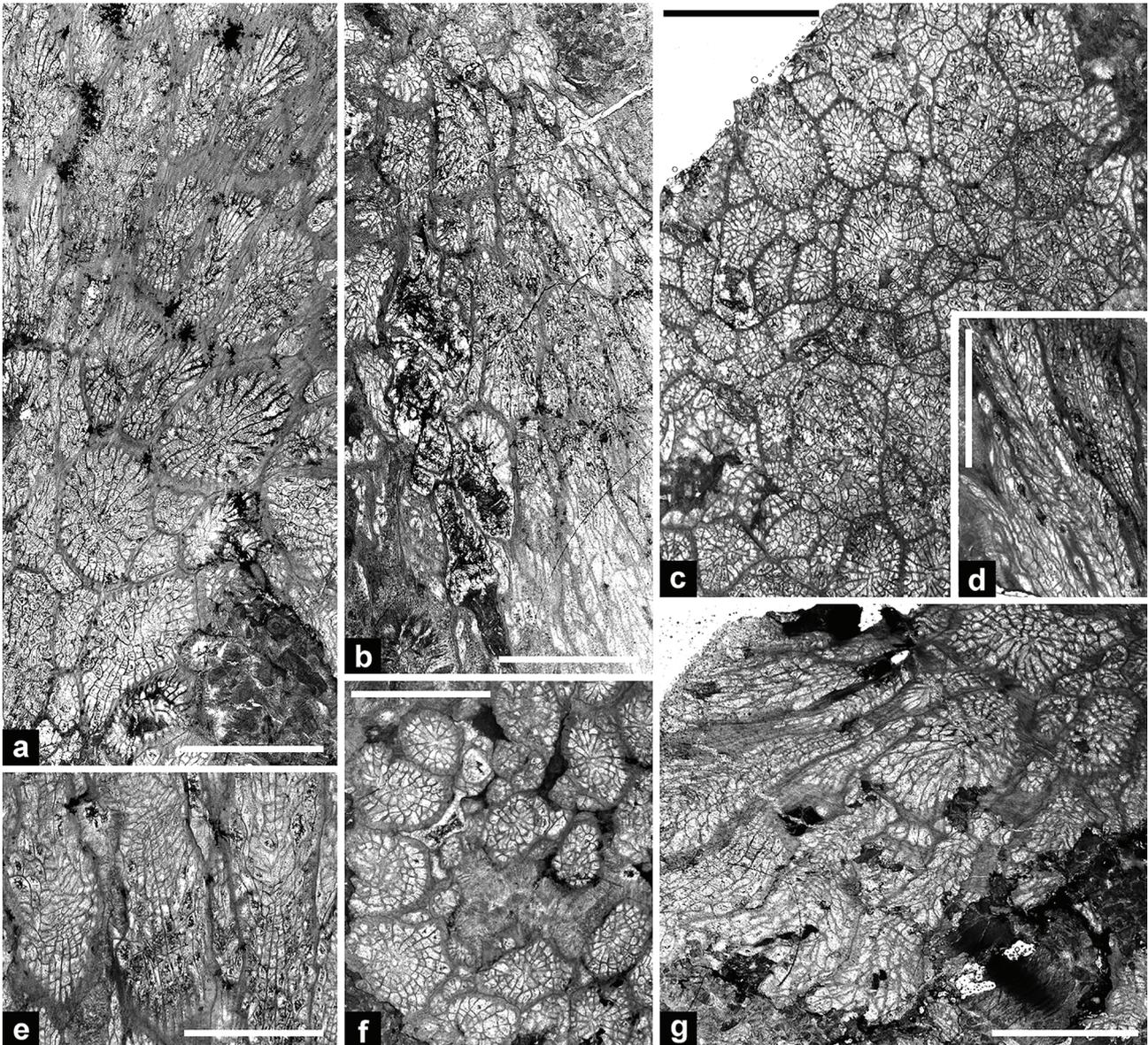


Figure 4. *Neomphyma karpinskiense* Shurygina, 1968 from the Beloura Tank Limestone Member. a, MMF48577, TS; b, MMF48578, TS with OLS; c, d, MMF47538, TS, LS; e, f, MMF47543, TS, LS with OLS; g, MMF47541, LS with TS and OTS. TS, transverse section; LS, longitudinal section; OTS, oblique transverse section; OLS, oblique longitudinal section. Scale bars = 10 mm.

Genus *Carlinastraea* Merriam in Merriam and McKee, 1976

Type species

Carlinastraea tuscaroraensis Merriam in Merriam and McKee, 1976, from the Lochkovian of the Roberts Mountains Formation in Nevada, USA. Its age was revised from late Silurian to Lochkovian by Oliver and Johnson (1977; also see Hill, 1981).

Remarks

Despite the loss of the original type material for *Spongophyllum* (*S. sedgwicki* Milne-Edwards and Haime, 1851), comparison of *Carlinastraea* to this genus reveals a high degree of similarity (see Hill, 1981, p. F231). The original illustrations for *S. sedgwicki* (Milne-Edwards and Haime, 1853, pl. 56, fig. 2, 2a-2e) are believed to show

two different genera (see Merriam and McKee, 1976, p. 32), one without presepiments, and the other with thin walls and peripheral presepiments, which is the type generally referred to as *Spongophyllum*, and to which Merriam and McKee (1976) compared their specimens. Conversely, Hill (1981) figured a neotype without presepiments, demonstrating the ambiguity of the genus definition. Despite this, by comparison, *Carlinastraea* has shorter septa, a much thicker stereozone and peripheral wedge-shaped crests attached to the side of the wall, and a much more presepimented marginarium with larger presepiments than *Spongophyllum*. The ‘peripheral crests’ of *Carlinastraea* are similar to features seen in some other spongophyllids identified in this study (*Neomphyma karpinskiense* Shurygina, 1968 and *Xystriphyllum parvum* Yü and Jell, 1990). However, unlike in those species,

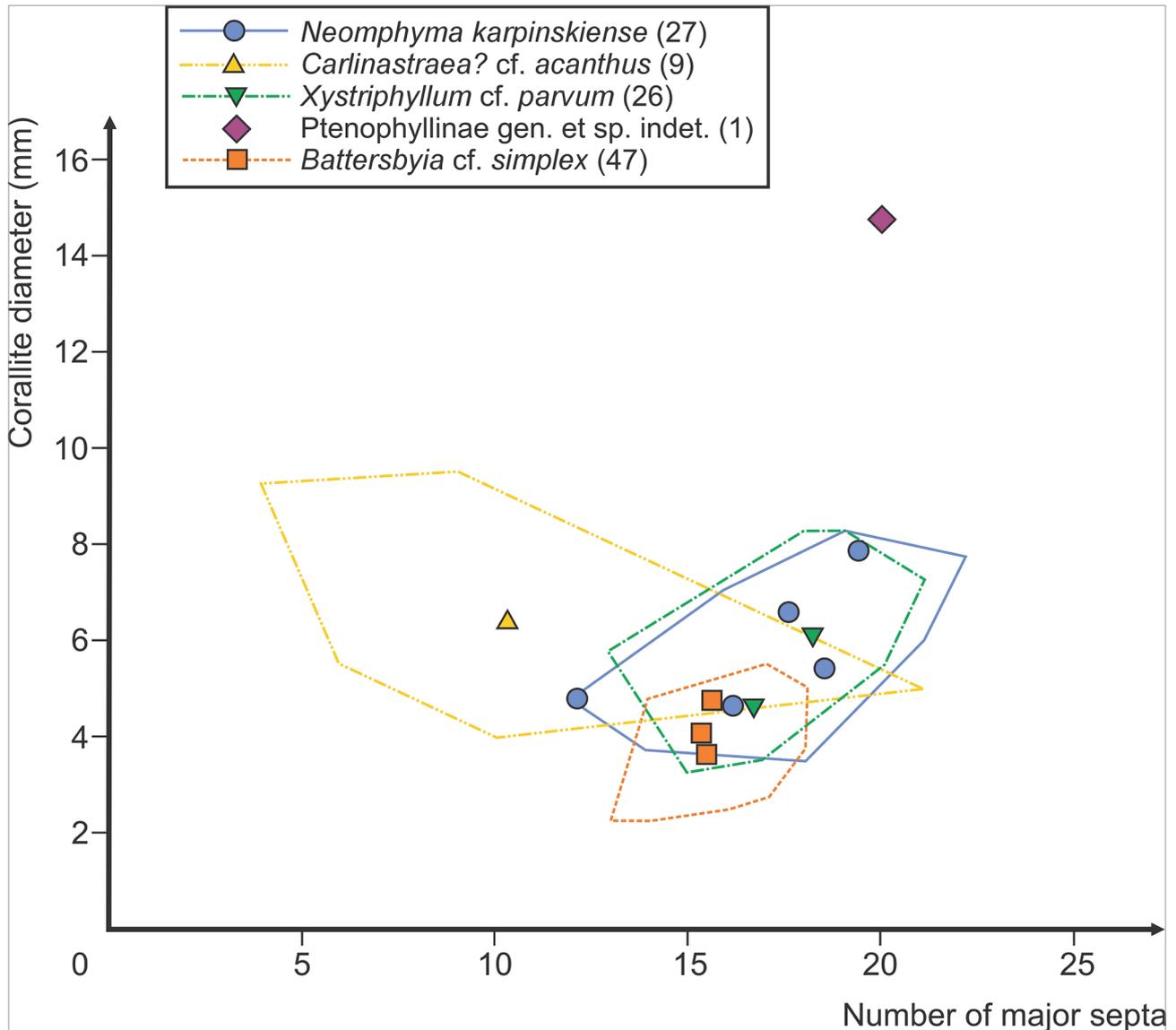


Figure 5. Scatter diagram of the mean intracolony corallite diameter and number of major septa for rugose coral species from the Beloura Tank Limestone Member. Symbols represent intracolony means and polygons represent the field of individual variability for each species. Numbers after the names of the taxa indicate the number of measured corallites.

they are not necessarily in association with septal bases, as septa are commonly aborted. *Carlinastraea* is further differentiated from *Neomphyma* by its cerioid corallum, whereas *Neomphyma* is fasciculate. *Australophyllum* is another cerioid ptenophylline genus morphologically similar to *Carlinastraea* but is differentiated by a larger average diameter corallite, more common presence of septa close to the axis, and elongated, steeply inclined dissepiments in several rows, alongside rarely complete, closely spaced concave tabulae (Zhen, 1994).

Carlinastraea has commonly been found in Lochkovian and Pragian rocks in eastern Australia (Struz, 1966; Yü and Jell, 1990; Zhen, 1998; Zhen et al., 2001; Zhen and Fitzherbert, 2021), having a wide geographical but relatively short stratigraphic range (Pedder, 1985, p. 592). It has also been reported from rocks of Přídolí (late Silurian) to early Emsian ages in

Tajikistan of central Asia, in inner Mongolia, Tibet and western Yunnan of China, in the Gornyy, Altai, and Ural Mountains of Russia, in Alaska and Nevada of northern America, and in the Czech Republic and Austria of Europe (see Shurygina, 1968; Merriam and McKee, 1976; Pedder, 1985; Liao, 1990; Schröder, 2007).

Carlinastraea? cf. acanthus Yü and Jell, 1990

Fig. 6

Material

Two thin sections of one specimen (MMF47539).

Description

Cerioid corallum of polygonal (3-7 sided) to subcylindrical corallites ranging between 4 mm and 9.5 mm in diameter, with an average diameter of 6.36 mm (Fig. 6, Table 1). A variably thickened stereozone is formed

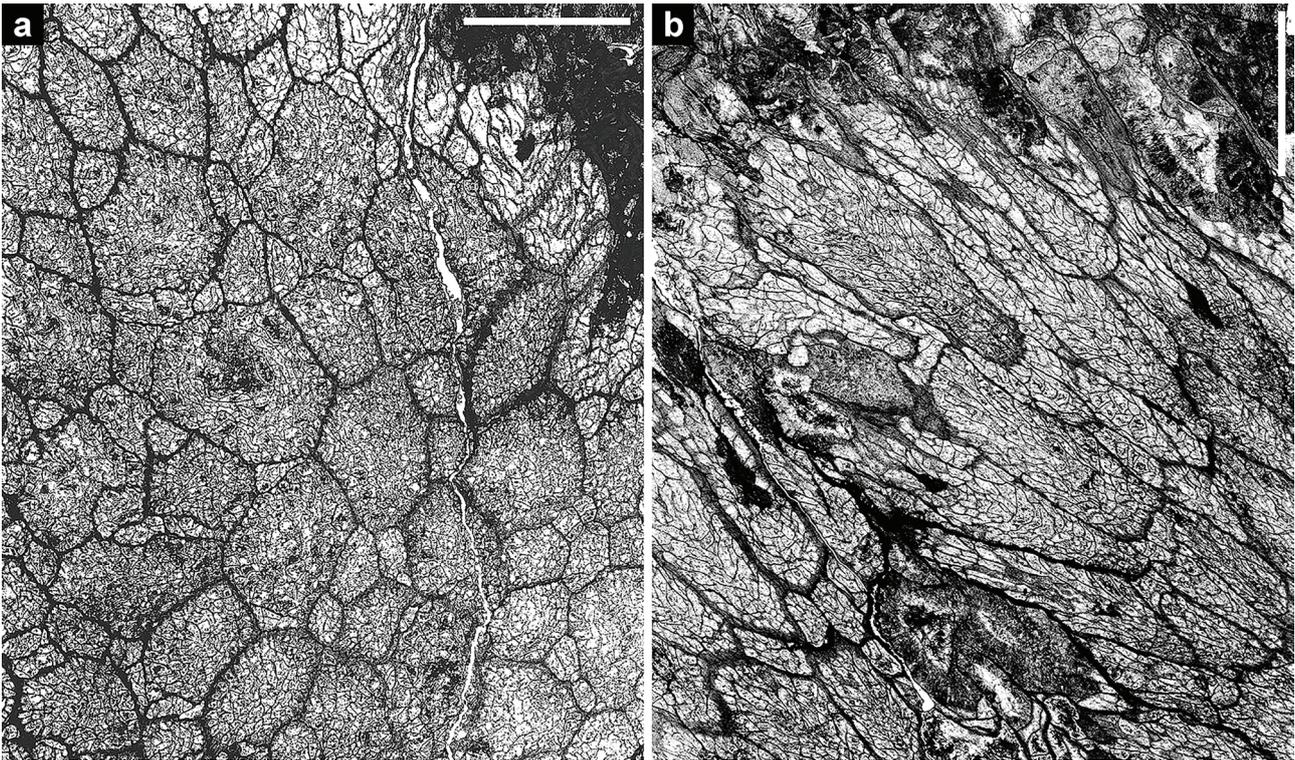


Figure 6. *Carlinastraea?* cf. *acanthus* Yü and Jell, 1990 from the Beloura Tank Limestone Member, MMF47539, TS (a), LS (b). Scale bars = 10 mm.

by peripheral crests variably attached to the base of septa, 0.13–0.38 mm thick with an average of 0.24 mm (Table 1). Septa are variably present and mostly interrupted by a wide presepimentarium of 3–7 rows of unevenly sized and shaped (rounded to pointed and steeply inclined) presepiments. Septa are rarely preserved, but when present numbering 4–21, with an average of 11. Septa are straight or zigzag and vepreculate, with major septa extending from a third of corallite radius almost to the axis, and minor septa mostly short. The peripheral stereozone crests range in number from 11–22, with an average of 19. The tabularium is one-quarter to one-third of the corallite width, with flat to sagging tabulae.

Remarks

Due to the poor preservation of the single available specimen, identification of the species is difficult. Some features, such as the thin septa and some aspects of the presepiments/dissepiments, are also difficult to confirm as its diagnostic characteristics. Despite the morphological ambiguity, the specimen seems to be comparable to *Carlinastraea acanthus* described from the Shield Creek Formation (late Lochkovian to early Pragian) of northern Queensland by Yü and Jell (1990, p. 184, fig. 8c–f). Their similarities include the even distribution of presepiment size throughout the marginarium in approximately 3–6 rows (see Yü and Jell, 1990, fig. 8e), numbers of peripheral crests [19–25 in *C. acanthus* described by Yü and Jell (1990), and 11–22 in the present species], and flat to concave tabulae. However, the species herein described has a larger corallite diameter ranging up to

9.5 mm, whereas *C. acanthus* ranges from 2.6–3.5 mm. The Beloura Tank Limestone Member species also has a more irregular corallite size distribution throughout the corallum, and more irregularly shaped presepiments. Yü and Jell (1990) diagnosed their specimens as having a wide presepimentarium of rounded presepiments, and with vepreculate (thorn-like) or zig-zag septa sometimes continuous from wall to axis although commonly withdrawn. When *C. acanthus* was erected by Yü and Jell (1990), it was compared with *Carlinastraea tuscaroraensis*, as the closest analogue. However, it was also noted that *C. acanthus* had thinner corallite walls and a narrower dissepimentarium than *C. tuscaroraensis*. *Carlinastraea halysitoides* Etheridge, 1918 resembles the Beloura Tank Limestone Member specimen in having a large number of septal crests and 2–4 rows of presepiments, yet the corallite of *C. halysitoides* is generally smaller in diameter (2.9–6.0 mm). Also, the presepiments of *C. halysitoides* decrease in size towards the axis, with individual peripheral vesicles sometimes up to a third of corallite circumference (see Schröder, 2007, fig. 5). Further, *C. halysitoides* is also distinguished in variably possessing one to two rows of small dissepiments and developed septa at the axis in transverse section, and has presepiments less elongated and less inclined in longitudinal section as compared to the Beloura Tank Limestone Member specimen.

Another comparable species *Carlinastraea originale* Zhmaev in Kraevskaya, 1955, shares with the present specimen a similar development of weak presepimented marginarium, yet its small size, with corallites 2.5–3 mm

in diameter, and 20–24 septa indicate a much closer affinity to *C. acanthus*. In addition, differences surrounding the increased abundance of continuous septa in the transverse section alongside larger-sized corallites lead the authors to question its placement in *Carlinastraea*, instead suggesting its possible affinity to *Australophyllum*, in combination with a longitudinal section typical of *Carlinastraea*.

Genus *Xystriphyllum* Hill, 1939

Type species

Cyathophyllum dunstani Etheridge, 1911, p. 3, pl. A, figs 1, 2 (OD), from the Emsian Douglas Creek Limestone of Clermont, central Queensland.

Remarks

A close morphological relationship has been observed between *Xystriphyllum* and *Australophyllum*, yet *Australophyllum* can be differentiated from *Xystriphyllum* mainly through the presence of 1–2 rows of peripherally well-developed presepiments. This generic division has been debated however, where Fontaine (1961) considered *Australophyllum* a junior synonym of *Xystriphyllum*, and conversely some species referred to as *Xystriphyllum* by Birenheide (1979) were thought by Zhen (1994, p. 22) to be *Australophyllum*. *Spongophyllum* is also similar to *Xystriphyllum*, differing through the presence of presepiments, although they are generally more globose

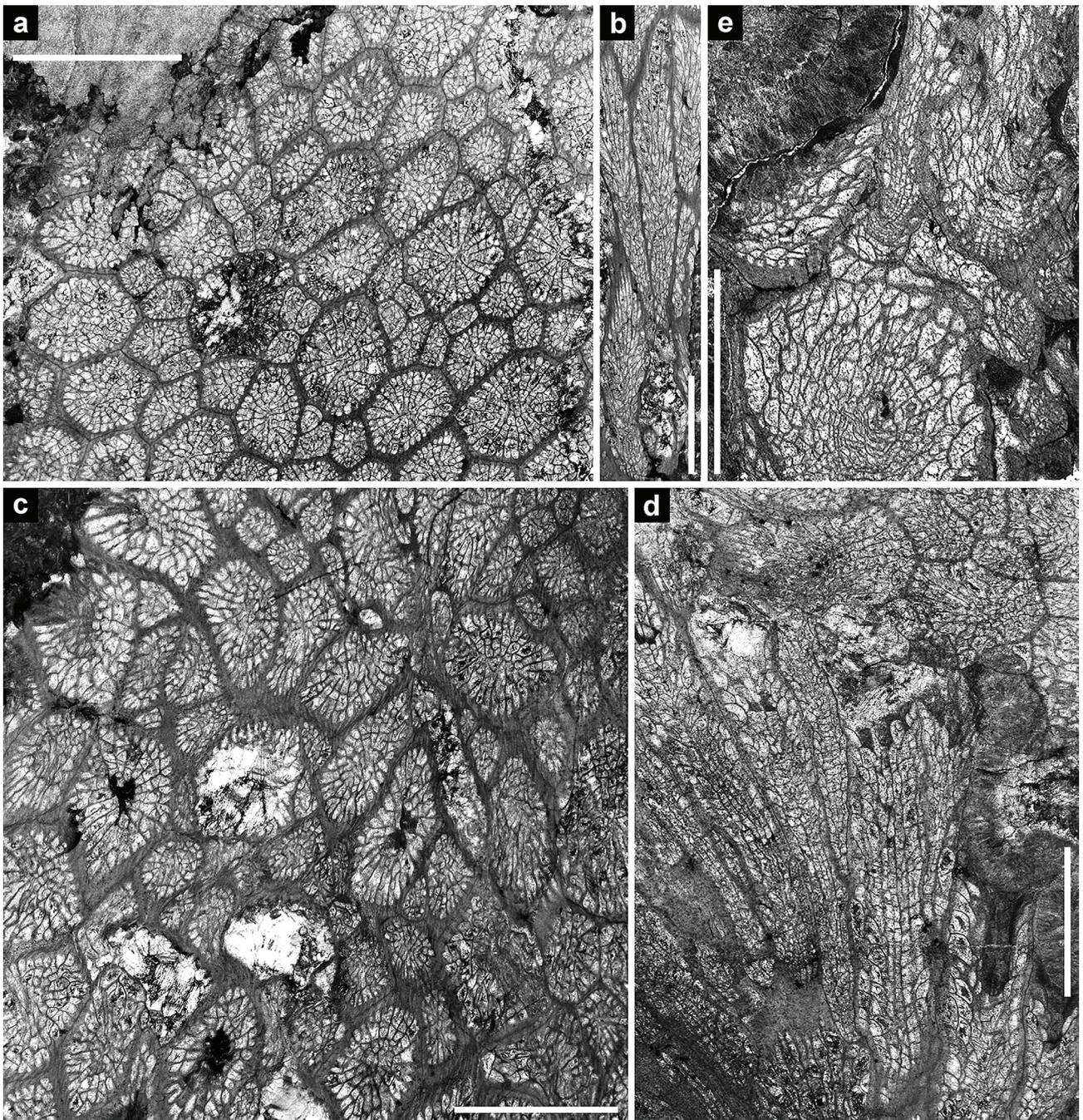


Figure 7. a-d, *Xystriphyllum* cf. *parvum* Yü and Jell, 1990 from the Beloura Tank Limestone Member. a, b, MMF47540, TS, LS; c, d, MMF47544, TS, LS with TS. e, *Ptenophyllinae* gen. et sp. indet., MMF47547, TS with OTS. Scale bars = 10 mm.

than those of *Australophyllum*; i.e., *Spongophyllum sedgwicki*. Another similar genus, as noted by Zhen (1994, 1995), is *Gaynaphyllum* Pedder, 1980, which, although similar in general structural form, has domed tabular floors and dissepiments close to the tabularium which are poorly differentiated from the outer tabellae, features not seen in *Xystriphyllum*. Additionally, interdigitation of the major septa is not observed in *Gaynaphyllum*, but can be noted as a common feature of *Xystriphyllum*, as seen in *X. dunstani* and *X. magnum* Hill, 1942, however less so in *X. mitchelli* Etheridge, 1892. *Xystriphyllum* species in eastern Australia range in age from Early Devonian to early Middle Devonian (Yü and Jell, 1990; Zhen, 1998).

The type species *Xystriphyllum dunstani* (Etheridge, 1911) was originally reported from the Emsian Douglas Creek Limestone in Queensland. Other species of *Xystriphyllum* have also been reported from various localities with Pragian to Givetian strata in eastern Australia, New Zealand, eastern Eurasia (e.g., Laos and Eastern Russia), central Asia (the Zeravshan Range, Tajikistan), Europe (the Ural Mountains in Russia, Czech Republic, Slovakia and Minorca), and North America (Yukon Territory and Alaska) (see Hill, 1941, 1956, 1981; Merriam, 1973b; Yü and Jell, 1990; Zhen, 1995, 1998; Pedder and Murphy, 1997; Zhen et al., 2001; Schröder, 2007).

Xystriphyllum cf. *parvum* Yü and Jell, 1990

Fig. 7a-d

Material

Four thin sections of two specimens (MMF47540, MMF47544).

Description

Ceroid corallum with mostly polygonal corallites of 4–8 sides, although a minor portion, mostly of younger corallites, is subangular. Corallite diameter is as low as 3.25 mm and ranges up to 8.25 mm, with an average of 5.47 mm (Fig. 5), and the stereozone is usually somewhat thickened between 0.2 mm and 1 mm with an average of 0.36 mm (Table 1). An average of 18 slightly carinate major septa are observed, ranging between 13 and 21 (Fig. 5), with minor septa mostly short reaching only one-fifth of corallite radius, and major septa in most cases reaching the axis. All septa are basally thickened and weakly pinnate. Up to three rows of dissepiments observed, in most cases flat or slightly concave towards the wall in transverse section. Although poorly represented in the sections, tabulae appear to be incomplete, likely irregularly sagging and axially compressed in longitudinal section (6–11 per 5 mm vertically), with dissepiments becoming larger and more globose toward the wall.

Remarks

Xystriphyllum parvum Yü and Jell, 1990 (p. 196, fig. 12), originally reported from the Lochkovian to Pragian intervals of the Shield Creek Formation in northern Queensland, is generally smaller than the type species *Xystriphyllum dunstani* with corallites being usually less than 5.5 mm in diameter, whereas in *X. dunstani* corallites are mostly around 6–8 mm in diameter, and show a higher degree of axial interdigitation

of the septa, as discussed by Yü and Jell (1990). A specimen previously designated as *Xystriphyllum* cf. *parvum* from a previous survey of the Beloura Tank Limestone Member by Zhen et al. (2023) is similar to the holotype of *X. parvum* described by Yü and Jell (1990), although the Beloura Tank Limestone Member specimen has more septa, a smaller dissepimentarium with larger dissepiments, and thicker peripheral stereozone. The specimen discussed in Zhen et al. (2023) is similar to those identified in this study, sharing differences from the holotype and paratypes of Yü and Jell (1990). These include having generally thicker stereozones, an average of 18×2 septa (whereas the Queensland species has $12\text{--}15 \times 2$) and an upper range of 5 dissepiment rows and average of 3, compared with specimens from the Shield Creek Formation, which have between 4 and 7. However, differences in stereozone thickness may be due to recrystallisation, as Yü and Jell (1990) cited local thickening of 0.35 mm - 0.55 mm, potentially due to this effect, whereas the average thickness in this study is 0.36 mm. Additionally, the typical specimens of *X. parvum* from the Shield Creek Formation have incomplete, thin, and typically sagging tabulae, all of which are observed in the specimens from the Beloura Tank Limestone Member, implying a close relationship.

The specimens here compared with *X. parvum* are also comparable with *Xystriphyllum insigne* Hill, 1940 in small corallite diameter (generally 2–3 mm in *X. insigne*, but rarely up to 7 mm according to Strusz, 1966, fig. 16) and a lower degree of axial septa interdigitation as compared to other species. However, it is worth noting that *X. insigne* is still poorly defined due to the limited preservation and lack of longitudinal section in the holotype specimen (Hill, 1940, pl. 3, fig. 5a, b), leading to difficulties in more detailed comparison. Yü and Jell (1990) noted differences between the two species (*X. parvum* and *X. insigne*), citing thicker and straighter septa and formation of a stereozone by basally thickened septa in *X. insigne*, not seen in *X. parvum*. Zhen et al. (2023, p. 32) compared their specimen of *Xystriphyllum* cf. *parvum* to *X. insigne* from the Emsian age Craigilee Beds in Queensland (Blake, 2010, fig. 57a, b) and noted a thinner stereozone developed in the *X. insigne* specimen from Queensland.

Ptenophyllinae gen. et sp. indet.

Fig. 7e

Material

One thin-sectioned specimen (MMF47547).

Description

Fasciculate, subcylindrical corallite bearing large globose presepiments with septa warped around a cardinal fossula, extending to the centre of the corallite, where dissepiments become highly compressed. Rare septa are visible in the dissepimentarium, with bases commonly absent at the periphery in transverse section. The longitudinal section is poorly preserved but still reveals dissepiments becoming more elongated toward the wall, with sagging tabulae spaced at ~ 13 per 5 mm. Corallite diameter is 14.75 mm, and stereozone is 0.625 mm thick in the single measurable corallite (Table 1). Major septa are estimated at 20, judging from the spacing of visible septa.

Remarks

Because of the incomplete preservation of the single specimen, it cannot be confidently described at the genus- or species-level. Nevertheless, its general morphology appears to be comparable with two different family groups, Ptenophyllinae and Cystiphyllidae Milne-Edwards and Haime, 1850 (the latter falls under Cystiphyllida Nicholson in Nicholson and Lydekker, 1889). ?*Cystolyrielasma* sp. reported from the Booth Limestone Member (Lochkovian to early Pragian) of the Winduck Group also in the Cobar Basin by Zhen et al. (2023, fig. 37g, h), shares a similar compression of dissepiments around a cardinal axis with the Beloura Tank Limestone Member specimen, but the former seems to have a solitary form. Additionally, Zhen et al. (2001) reported the presence of *Cystolyrielasma* in the Shield Creek Formation (Yü and Jell, 1990).

Family FASCIPHYLLIDAE Soshkina, 1954

Remarks

Fasciphyllidae and Spongophyllidae, both in the Suborder Ptenophyllina, differ by a commonly incomplete single dissepiment series and common vepreculate septa in the Fasciphyllidae (Hill, 1981, p. F246). The Fasciphyllidae differs from the Stauriidae Milne-Edwards and Haime, 1850 (Suborder Stauriina Verrill, 1865) in wider peripheral stereozone and flat to concave tabulae, whereas the Stauriidae has flat to arched tabulae (McLean, 2018).

Genus *Battersbyia* Milne-Edwards and Haime, 1851

Type species

Battersbyia inaequalis Milne-Edwards and Haime, 1851, p. 227, from the Permian Teignmouth Breccia in Devon (UK), as limestone clasts of likely Devonian age (Hill, 1981; Coen-Aubert, 1992; McLean, 2018).

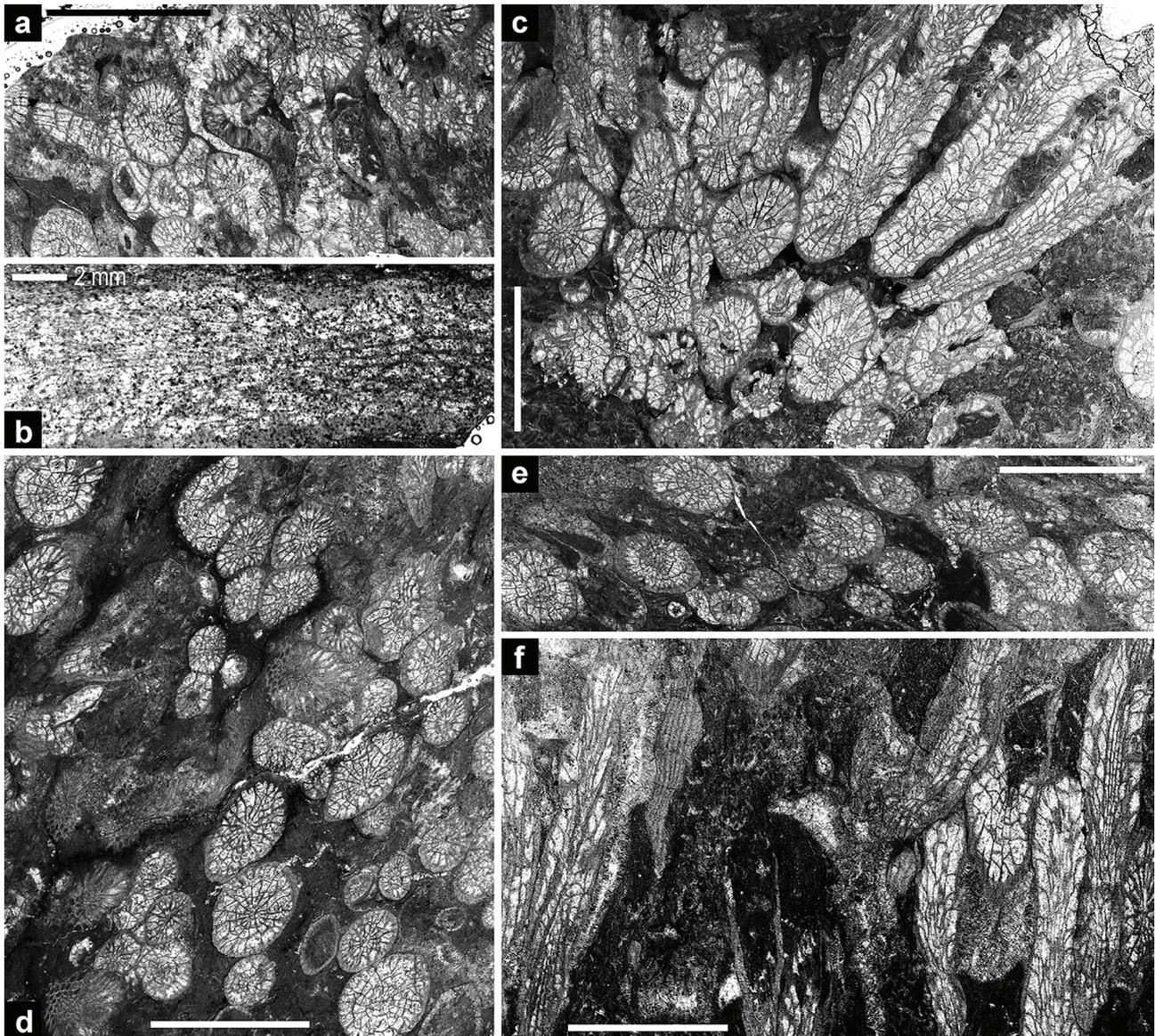


Figure 8. *Battersbyia* cf. *simplex* Vaganova in Shurygina, 1968 from the Beloura Tank Limestone Member. a, b, MMF47533, TS, LS; c, MMF47537, LS with TS; d-f, MMF47545, TS, TS, LS. Scale bars = 10 mm except for Fig 8b.

Remarks

Battersbyia has been regarded as synonymous with the genus *Fasciophyllum* by many recent workers, but not used by most due to the lack of certainty on the original type specimen (Hill, 1981; Coen-Aubert, 1992; Wrzolek, 1993; Zhen and Jell, 1996). The type material was first illustrated as drawings from polished transverse sections of beach pebbles from the Permian Teignmouth Breccia in Devon (UK), considered to be limestone clasts of likely Devonian age (Hill, 1981; Coen-Aubert, 1992; McLean, 2018), figured in Milne-Edwards and Haime (1853, pl. 47, fig. 2a, b). A lectotype of the type species *Battersbyia inaequalis* was designated by Hill (1981, p. F246), and was subsequently discussed by Coen-Aubert (1992), who figured thin sections from the lectotype. More recently, McLean (2018) re-examined these sections, confirming the validity of Hill (1981)'s designation and the congeneric relationship between the two genera. McLean (2018) conceded that the specimen would not be an ideal type, but argued its adequacy as such, drawing an analogy to *Spongophyllum*, whose type specimen is plagued by similar issues (more discussion of this can be found under the section for *Carlinastreaea* in this study). McLean (2018), following Birenheide (1978), discussed a synonymization of *Battersbyia* with *Nadotia* Tsyganko, 1974, which sought to include *Battersbyia* species where dilated septa formed a columella. The type specimen of *Nadotia stilifera* does show this pattern, but not in all corallites, leading both Birenheide (1978) and McLean (2018) to regard it as a junior synonym of *Battersbyia*.

Loyolophyllum (*Fasciloyolophyllum*) proposed by Zhen (2007) is differentiated from *Fasciophyllum*, here referred to as *Battersbyia* following Mclean (2018), by the rarity of dissepiments. Mclean (2018) synonymised this genus with *Battersbyia* due to the wider range of dissepiment development in his accepted definition, which encompasses corallites without necessarily continuous rows following Hill (1981, p. F246), and this view is accepted herein. The genus *Pseudogrypophyllum* Cherepnina, 1968 has an overall similarity with *Battersbyia*, but was defined with reference to microstructural features, specifically peripherally spinose and axially acicular trabeculae. However, the published images of its type specimens (Cherepnina, 1968, pl. 1, figs 1–3; Cherepnina, 1971, pl. 23, figs 1–4) do not clearly show these microstructural characteristics. Without access to the holotype specimens (likely lost, although possibly transferred to the collections at the Siberian Research Institute of Geology, Geophysics and Mineral Resources, in Novosibirsk, Russia), these distinguishing factors cannot be confirmed, bringing into question the validity of the genus as separate from other fasciculate forms of Ptenophyllina (e.g., *Lyrielasma* Hill, 1939, *Neomphyma*, *Battersbyia*). Hill (1981, p. F240) suggested that the type species of *Pseudogrypophyllum* might even be a stringophyllid, although due to the lack of presepiments this is unlikely. Lacking better images of the original specimens, and due to the inaccessibility of other literature regarding the genus, this study cannot establish the relationship of *Pseudogrypophyllum* to *Battersbyia*.

The genus *Vepresisociophyllum* Kong, 1981 is similar to *Pseudogrypophyllum* and to *Battersbyia*, yet differs from *Pseudogrypophyllum* in thicker stereozone, and from both by the presence of flanged septa in the tabularium. While Zhen and Jell (1996) suggested a possible synonymy of *Vepresisociophyllum* with *Battersbyia*, Zhen and Fitzherbert (2021) treated it as a *nomen dubium*, or possibly as a junior synonym of *Lyrielasma*, on the basis that *Vepresisociophyllum* was defined by the presence of a presepimentarium which was found to be lacking in its type species, *Vepresisociophyllum gaofengense* Kong, 1981 from the Eifelian Gaofengjie Formation of the Guangxi Province, South China.

Similarities can be drawn between *Battersbyia* and fasciculate spongophyllid genera, such as *Neomphyma* and *Lyrielasma*, the latter of which though characteristically possessing flanged septa in the tabularium and in most cases more rows of dissepiments, shares features with *Battersbyia* such as a peripheral stereozone, concave tabulae, and a common lack of presepiments. McLean (2018) discussed the morphological scope of *Battersbyia* in respect to presepimentation, limiting it to specimens with minimal to no occurrence. This is an important distinction from species of *Neomphyma*, which, although it has a type species with developed presepiments (*N. originata* Soshkina, 1937), these are much less developed in species such as *N. karpinskiense* (see Fig. 4), which are otherwise similar in morphology to *Battersbyia*. The species *N. simplex* Vaganova and *N. planevesiculosum* Shurygina, originally described from the Urals in Shurygina (1968), were since considered to belong to *Battersbyia* due to their lack of presepiments, demonstrating the similarity between the two genera (McLean, 2018).

Pedder (1967) erected *Embolophyllum* for Australian fasciculate species, previously placed in *Acanthophyllum*, that did not fit well into either *Lyrielasma* or *Grypophyllum*. Both *Embolophyllum* and *Lyrielasma* have a fasciculate, dendroid to phaceloid corallum, commonly with wedge shaped septa bases, but *Embolophyllum* differs in lacking peripheral lamellar sclerenchyme, and has a narrower septal stereozone, well-developed carinae and more numerous dissepiments, mostly vesicular rather than elongate as in *Lyrielasma*. Both genera are distinguished from *Battersbyia* by the presence of flanged septa, and a wider dissepimentarium (Pedder, 1967; McLean, 2018). More similarities can be observed between *Battersbyia* and *Grypophyllum* Wedekind, 1922, in interdigitating septa and sparse presepiments, yet *Grypophyllum* differs by closely spaced narrow tabulae, carinate septa (though sometimes vepreculate in *Battersbyia*) and solitary form (Brownlaw and Jell, 2008).

Battersbyia (often referred to as *Fasciophyllum*) has a temporal range of Lochkovian to Givetian, being reported from Russia and Tajikistan in central Eurasia, Austria, Czech Republic, Belgium and Poland in Europe, Alaska and Canada in North America, and many locations in eastern Australia (e.g., Jell and Hill, 1970; Lavrushevich, 1971; Chudinova et al., 1974; Tyazheva et al., 1976; VandenBerg et al., 1976; Wrzolek, 1993; Zhen, 1996; McLean, 1997).

Battersbyia cf. *simplex* Vaganova in Shurygina, 1968
Fig. 8

Material

Five thin sections of three specimens (MMF47533, MMF47537, MMF47545).

Description

Dendroid corallum with an average corallite diameter of 4.14 mm, ranging between 2.25 mm and 5.5 mm. Peripheral stereozone thickness averages 0.26 mm, ranging from 0.05–0.5 mm (Table 1), partially formed by basal thickening of smooth septa into crest-like formations. Corallites have 16×2 septa on average, ranging between 13 and 18 (Table 1). Major septa are sometimes axially flanged, reaching the centre of the corallite, and minor septa are short or sometimes reaching a third of the corallite radius. No presepiments can be seen in the sample set, with 2 or 3 rows of generally elongate dissepiments, becoming smaller inwards. In longitudinal section, tabulae are incomplete to complete and flat to sagging, with around 8 per 5 mm vertically. The tabularium is a third of the corallite diameter, surrounded by inclined elongated dissepiments in larger individuals with smaller more globose dissepiments in smaller ones. The corallum shows a non-paricidal peripheral branching pattern (Fig. 8f).

Remarks

The new specimens are very similar in morphology to some specimens of *B. simplex* (see Shurygina, 1968, p. 137, pl. 61, figs 2, 3). Similarities include corallite size, elongated dissepiments in only a few rows, inclined and inflated dissepiments in longitudinal section, similarly spaced flat to concave tabulae and a lack of presepiments. Basal thickening of septa and their count of $16\text{--}17 \times 2$ is also common between the species. However, the Beloura Tank Limestone Member specimens differ somewhat in having slightly more sinuous septa and a thinner peripheral stereozone; the width of the peripheral stereozone in *B. simplex* seems consistent at 0.5 mm, whereas in the present specimens it ranges from 0.05–0.5 mm (average 0.26 mm) (Table 1). These are relatively minor differences which may be explained as intraspecific variation, indicating potential synonymy. *Battersbyia simplex* was first recorded in the Early Devonian Petropavlovsk Suite of the northeastern slope of the Ural Mountains, in the Lochkovian accompanied by *Neomphyma karpinskiense* (see Shurygina, 1968, table. 3). *Embolophyllum aggregatum cracente* Pedder, 1967 shares similarities with the Beloura specimens, from thin peripherally dilated septa ranging in number between 17 and 21×2 (similar to the $13\text{--}18 \times 2$ in the Beloura Tank Limestone Member specimens), to 2 to 4 rows of steeply inclined and globose dissepiments in longitudinal section (2–3 in the Beloura Tank Limestone Member specimens). Differences include the corallite size of *E. aggregatum cracente*, which ranges from 7.5–14.5 mm, usually sitting within a range of 8 mm to 11 mm, whereas this study's specimens average between 2.25 mm and 5.5 mm. Additionally, in line with the genus,

E. aggregatum cracente has smaller vesicular dissepiments as compared to the elongated dissepiments evident in the present specimens.

The specimens from the Beloura Tank Limestone Member are comparable with *Lyrielsma? micrum* Strusz, 1966 from the Garra Formation in NSW. They share an almost identical corallite size range of $\sim 4\text{--}6$ mm and $16\text{--}19 \times 2$ septa alongside a lack of presepiments. However, adequate comparison is difficult due to the inadequate material figured in Strusz (1966, pl. 89), lacking a clear longitudinal section. '*Fasciphyllum*' *miakottaense* (see Schröder, 2007, p. 132, fig. 4g, h), herein assigned to the genus *Battersbyia*, resembles the Beloura Tank Limestone Member species in having only a few rows of inclined inflated dissepiments, concave tabulae, and similar tabularium width, but *B. miakottaense* has a much thinner peripheral stereozone, commonly a row of smaller aligned dissepiments near the periphery (Fig. 8c). The Beloura Tank specimens are similar to the type species of *Pseudogrypophyllum*, *Pseudogrypophyllum limatum* Cherepnina, 1968 (p. 159, pl. 1) from the Lower Devonian Remnev Beds in the Altai Mountains, Russia. That species is characterised by a fasciculate corallum with weakly branching, slender and cylindrical corallites. Similar to the Beloura Tank Limestone Member specimens, the major septa commonly reach the axis, and tabulae are concave, with large dissepiments forming 1–3 rows. Their similarities are especially evident in a longitudinal section of the paratype illustrated by Cherepnina (1971, pl. 24, fig. 3) which shows the inflated dissepiments and concave tabularium; these features are similar to those shown in the longitudinal section of *Battersbyia* cf. *simplex* in Fig. 8c. Despite this, the larger corallite size of *Pseudogrypophyllum limatum* (6–11 mm), compared to the Beloura Tank Limestone Member specimens (2.25–5.5 mm; see Table 1), and variably lengthened minor septa, alongside in many cases double the number of septa (Table 1; see also Cherepnina, 1968), can differentiate them. More adequate comparison is difficult, because of the obscure microstructure in the specimens from the Beloura Tank Limestone Member, probably caused by the later deformation and heating of the Cobar Supergroup (e.g., Glen, 1990, 1991).

AGE AND BIOSTRATIGRAPHIC CORRELATION

As rugose coral species generally have long stratigraphic ranges, precise age determination based on the taxonomic composition of rugose coral assemblages is usually limited. However, they can still act as supplementary evidence and provide critical age control when no other biostratigraphic data are available.

Carlinastraea was originally erected from the Roberts Mountains Formation of early Lochkovian age in Nevada, USA, and thus the genus has commonly been regarded as indicating a Lochkovian to Pragian age (Pedder, 1985; Yü and Jell, 1990). Furthermore, the presence of species comparable with *Xystriphyllum parvum* and *Carlinastraea acanthus* indicates a strong correlation with the Lochkovian to Pragian Shield Creek Formation in Queensland (Yü

and Jell, 1990). The presence of *Battersbyia* lends further support to this interpretation, although it has a longer range from the Lochkovian (e.g., the Ural Mountains in Russia, Tyazheva and Zhavoronkova, 1977) to the Givetian (e.g., Zhen, 1996, identified as '*Fasciphyllum*' *immersum* in the Burdekin Formation of Queensland). The occurrence of *Battersbyia* cf. *simplex* in the Beloura Tank Limestone Member also suggests its correlation with Lochkovian strata from the northeastern slope of the Ural type area of *B. simplex* and *Neomphyma karpinskiense* (see Shurygina, 1968). *Battersbyia simplex* was also identified (as *Fasciphyllum simplex*) from the Pragian to Emsian of the Zeravshan-Hissar Range in Tajikistan (Lavrusevich et al., 1973). *Neomphyma karpinskiense* was initially recorded from the Lochkovian reef facies of the Gornovaya River, corresponding to the Saraynoy Horizon of the east-central Ural Mountains (Shurygina, 1968). Merriam and McKee (1976) identified a species of '*Kyphophyllum*' from the lower Tor Limestone (late Lochkovian) of the Toquima Range in North America, later shown by Pedder and Murphy (1997) to be synonymous with *N. karpinskiense*. Those authors also identified it from the upper Windmill Limestone of the Simpson Park Range in USA. *Neomphyma karpinskiense* was recently documented from the Elura Limestone Member of the Brookong Formation (also belonging to Kopyje Group; see Fig. 2). The age of the Elura Limestone Member was refined to early Lochkovian by the discovery of the conodont *Cypriocriodus hesperius* Klapper and Murphy, 1975 (see Zhen and Fitzherbert, 2021; Zhen et al., 2025). In addition, the recent study by Zhen et al. (2025) of fossil faunas recovered from limestones intersected in eight exploration wells in the nearby area between Nyngan, Trundle and Narromine, confirmed ages extending from the latest Silurian to Early Devonian (possibly Pragian) for these limestones. The presence of *C. hesperius* at the top of the sequence intersected by drill hole GND0014, immediately above typical late Silurian faunas, indicates potentially the best example of the Siluro-Devonian boundary in Australia, and provides a strong regional reference point for age determination of the Beloura Tank Limestone Member. The presence of *N. karpinskiense* in that member provides compelling evidence for a generally Lochkovian age for the unit, suggesting correlation with the Elura Limestone Member previously referred to, and possibly also with the upper Windmill Limestone of the Simpson Park Range, and also the Tor Limestone of the Toquima Range in the Central Great Basin of the USA, the Saraynoy Horizon of the east-central Ural Mountains in Russia, and to a lesser extent the Altai-Sayan and southern Tien-Shan fold belts of central Asia. Zhen and Fitzherbert (2021), following Carolan (1999), also indicated a transgressive phase after the Elura Limestone Member during the middle-late Early Devonian. This suggests the probability of a similar history for the contemporary Beloura Tank Limestone Member, constraining its deposition to during the early to middle Lochkovian. Significantly, the confirmation of the Lochkovian age for the Beloura Tank Limestone Member would represent the earliest record of *Xystriphyllum*.

CONCLUSIONS

Taxonomic study of rugose coral specimens from the Beloura Tank Limestone Member identified four species: *Neomphyma karpinskiense*, *Carlinastraea* cf. *acanthus*, *Xystriphyllum* cf. *parvum*, and *Battersbyia* cf. *simplex*, together with an indeterminate ptenophyllinid.

These rugose coral species suggest a Lochkovian age for the Beloura Tank Limestone Member, and show strong links to Lochkovian faunas from the Elura Limestone Member. They also show possible correlation with those from the Shield Creek Formation of northern Queensland, the upper Windmill Limestone of the Simpson Park Range, the Tor Limestone of the Toquima Range of the Great Central Basin, and the Saraynoy Horizon of the east-central Ural Mountains.

ACKNOWLEDGEMENTS

This study is derived from the BEnvSc (Hons) thesis of the first author, completed in 2024. H.E.L. and S.L. would like to express their gratitude to Guang Shi (UOW) for his continued support and expert feedback, to the late Anthony Wright (formerly UOW) for his guidance in coral taxonomic study, to Jose Abrantes (UOW) for his effort in making the thin sections, and to Terry Lachlan (UOW) for generously lending his film scanner during his Honours program. We extend our thanks to Ian Percival (GSNSW) for his helpful and constructive review of an early version of this manuscript, Patrick Smith (formerly Australian Museum) for his expertise during fieldwork and kindness in providing his field photos, and to Patrick Dwyer (GSNSW) for his assistance. Finally, we would like to thank Des Strusz and Doug Benson for their careful reviews and constructive comments, which improved the manuscript. Y.Y.Z. publishes with the permission of the Head of the Geological Survey of NSW.

REFERENCES

- Artyushkova, O.V. and Maslov, V.A. (2008). Detailed correlation of the Devonian deposits in the South Urals and some aspects of their formation. *Bulletin of Geosciences* **83**, 391–399.
- Birenheide, R. (1978). Rugose Korallen des Devon. In: Krömmelbein, K. (ed.) *Leitfossilien begründet von Georg Gürich 2*, Gebrüder Borntraeger, Berlin, 176.
- Birenheide, R. (1979). *Xystriphyllum* und *Sociophyllum* Arten (Rugosa) sue dem Eifelium der Eifel. *Senckenbergiana lethaea* **60**, 189–221.
- Blake, P.R. (2010). Devonian Corals of the Yarrol Province, eastern-central Queensland. *Memoirs of the Association of Australasian Palaeontologists* **38**, 1–191.
- Brownlaw, R.L.S. and Jell, J.S. (2008). Middle and Upper Devonian Rugose Corals from the Canning Basin, Western Australia. *Memoirs of the Association of Australasian Palaeontologists* **35**, 1–126.
- Carolan, P.M. (1999). Geology of Shelf Strata and Carbonate Hosted Mineralisation at the Elura Mine, Cobar, NSW. BSc (Honours) thesis, University of Wollongong, New South Wales, 132 pp.
- Cherepnina, S.K. (1968). Novyy rod Tetrakorallov iz Nizhnego Devona Gornogo Altaya. In: V.V. Kuybysheva (ed.) *Trudy Tomskogo Ordena Trudovogo Krasnogo Znameni 1968 Gosudarstvennogo Universiteta* **202**, 1–4. [in Russian]

- Cherepnina, S.K. (1971). Rugozy zhedinskikh otlozheniy Gornogo Altaya (remnevskiy sloi) in Rugozy i stromatoporoidei paleozoya SSSR. *Materialy Vsesoyuznogo simpoziuma po iskopayemym korallam. Korally SSSR* **2**, 89–91. [in Russian]
- Chudinova, I.I., Churkin, M.Jr. and Eberlein, G. D. (1974). Devonian syringoporoid corals from southeastern Alaska. *Journal of Paleontology* **48**, 124–134.
- Coen-Aubert, M. (1990). Deuxième note sur les Rugueux coloniaux de Eifelien supérieur et de la base du Givetien à Wellin (bord sud du Bassin de Dinant, Belgique). *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* **60**, 5–28.
- Coen-Aubert, M. (1992). Rugueux coloniaux mésodévoïens du Fondry des Chiens à Nismes (Ardenne, Belgique). *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* **62**, 5–21.
- Curran, J.M. (1888). Carboniferous and Silurian fossils from central New South Wales. *Proceedings of the Linnean Society of New South Wales* **13**, 800–804.
- David, V. (2006). Cobar Superbasin Metallogenesis. *Mines and Wines-Mineral Exploration Geosciences in NSW Extended Abstracts* **1**, 39–51.
- David, V. (2018). Cobar Deposits - Structural control. *ASEG Extended Abstracts 2018* **1**, 1–9.
- Downes, P., Tilley, D., Fitzherbert, J. and Clissold, M. (2016). Regional metamorphism and the alteration response of selected Silurian to Devonian mineral systems in the Nymagee area, Central Lachlan Orogen, New South Wales: a HyLogger™ case study. *Australian Journal of Earth Sciences* **63**, 1027–1052.
- Dybowski, N.W. (1873). Monographie der Zoantharia Sclerodermata Rugosa aus der Silurformation Estlands, Nord-Livlands und der Insel Gotland. *Archiv für die Naturkunde Liv, Ehst- und Kurland Dorpat* **1**, 415–532.
- Ehrenberg, C.G. (1834). Beiträge zur physiologischen Kenntniss der Corallenthiere im allgemeinen, und besonders des rothen Meeres, nebst einem Versuche zur physiologischen Systematik derselben. *Abhandlungen der Königlichen Akademie der Wissenschaften, Berlin* **1**, 225–380.
- Etheridge, R.Jr. (1892). In: Jack, R.L. and Etheridge, R. (eds) *Geology and Palaeontology of Queensland and New Guinea*. Geological Survey of Queensland, Publication No. **92**, 1-768, pls. 1-68.
- Etheridge, R.Jr. (1911). The Lower Palaeozoic corals of Chillagoe and Clermont, part 1. *Geological Survey of Queensland* **231**, 1–8.
- Etheridge, R.Jr. (1918). Two remarkable corals from the Devonian of New South Wales. *Records of the Australian Museum* **12**, 49–51.
- Fitzherbert, J., Downes, P.M. and Blevin, P.L. (2016). *Cobar 1:500 000 Special Metallogenic Map*. Geological Survey of New South Wales, Maitland.
- Fletcher, H.O. (1975). Silurian and Lower Devonian fossils from the Cobar Area of New South Wales. *Records of the Australian Museum* **30**, 65–85.
- Fontaine, H. (1961). Les Madréporaires paléozoïques du Vietnam, du Laos et du Cambodge. *Archives C, géologiques du Viet-nam* **5**, 1–276.
- Gilligan, L.B. and Byrnes, J.G. (1995). Cobar 1:250,000 metallogenic map. *Geological Survey of New South Wales metallogenic study and mineral deposit data sheets SH/55-14*, 1–240.
- Glen, R.A. (1990). Formation and inversion of transtensional basins in the western part of the Lachlan Fold Belt, Australia, with emphasis on the Cobar Basin. *Journal of Structural Geology* **12**, 601–620.
- Glen, R.A. (1991). Inverted transtensional basin setting for gold and copper and base metal deposits at Cobar, New South Wales. *BMR Journal of Australian Geology and Geophysics* **12**, 13–24.
- Glen, R.A., Clare, A.P. and Spencer, R. (1996). Extrapolating the Cobar Basin model to the regional scale: Devonian basin formation and inversion in western New South Wales. In: Cook, W.G., Form, A.J.H., McDermott, J.J., Standish, P.N., Stegman, C.L. and Stegman, T.N. (eds) *The Cobar mineral field - a 1996 perspective*, Australasian Institute of Mining and Metallurgy, Carlton, 43–83.
- Hill, D. (1935). British Terminology for Rugose Corals. *Geological Magazine* **72**, 481–519.
- Hill, D. (1939). The Middle Devonian Rugose Corals of Queensland, I. Douglas Creek and Drummond Creek, Clermont District. *Proceedings of the Royal Society of Queensland* **50**, 55–64.
- Hill, D. (1940). The Middle Devonian Rugose Corals of Queensland, II. The Silverwood-Lucky Valley Area. *Proceedings of the Royal Society of Queensland* **51**, 150–168.
- Hill, D. (1941). The Middle Devonian Rugose Corals of Queensland, III. Burdekin downs, Fanning River, and Reid gap, North Queensland. *Proceedings of the Royal Society of Queensland* **53**, 229–268.
- Hill, D. (1942). The Devonian rugose corals of the Tamworth district, NSW. *Journal and Proceedings of the Royal Society of New South Wales* **76**, 142–164.
- Hill, D. (1950). Middle Devonian corals from the Buchan district, Victoria. *Proceedings of the Royal Society of Victoria* **62**, 137–164.
- Hill, D. (1954). Coral faunas from the Silurian of New South Wales and the Devonian of Western Australia. *Bulletin of the Bureau of Mineral Resources, Geology and Geophysics* **23**, 1–51.
- Hill, D. (1956). Rugosa. In: Moore, R.C. (ed.) *Treatise on Invertebrate Paleontology, Part F, Coelenterata*, Geological Society of America, New York and University of Kansas Press, Lawrence, 233–344.
- Hill, D. (1981). Rugosa and Tabulata. In: Teichert, C. (ed.) *Treatise on Invertebrate Paleontology, Part F, Coelenterata Supplement 1*, Geological Society of America, Boulder and University of Kansas Press, Lawrence, 95–298.
- Jell, J.S. and Hill, D. (1970). Revision of the Coral Fauna from the Devonian Douglas Creek Limestone, Clermont, Central Queensland. *Proceedings of the Royal Society of Queensland* **81**, 93–120.
- Klapper, G. and Murphy, M.A. (1975). Silurian–Lower Devonian conodont sequence in the Roberts Mountains Formation of central Nevada. *University of California Publications in Geological Sciences* **111**, 1–62.
- Kong, L. (1981). Middle Devonian rugose corals from Dachang of Nandan district, Guangxi. In: Palaeontological Society of China (ed.) *Selected Papers for 12th Annual Conference of the Palaeontological Society of China*, Science Press, Beijing, 50–60.
- Kraevskaya, L.N. (1955). Tetrakorally nizhnego i srednego Devona. In: Khalin, L.L. (ed.) *Atlas rukovodyaschikh form iskopaemykh fauny i flory zapadnoy Sibiri, I*, Gosgeoltek-hizdat, Moscow, 206–218. [in Russian]
- Lavrusevich, A.I. (1971). Cheshuychatyye rugozy tsentralnogo Tadzhikistana. In: Ivanovskij, A.B. (ed.) *Rugozy i stromatoporoidei paleozoya SSSR, Papers of the All union*

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- Symposium on fossil corals of the USSR* **2**, 32–41. [in Russian]
- Lavrusevich, A.I., Lavrusevich, V.I., and Saltovskaya, V.D. (1973). Dauntion i nizhniy devon Zeravshano-Gissarskoy gornoy oblasti. *Sovetskaya Geologiya* **12**, 10–25. [in Russian]
- Liao, W.H. (1990). The Biogeographic Affinities of East Asian Corals. *Palaeozoic Palaeogeography and Biogeography, Geological Society Memoir* **12**, 175–179.
- Lin, B.Y., Xü, S.Y., Jia, H.Z., Guo, S.Z., Oyang, X., Wang, Z.J., Ding, W.J., Cao, X.D., Yan, Y.Y. and Chen, H.C. (1995). *Monograph of Palaeozoic corals: Rugosa and Heterocorallia*. Geological Publishing House, Beijing, 778 pp.
- Lloyd, A.C. (1936). Geological survey of the Cobar district. Progress report. *New South Wales Department of Mines Annual Report (for 1935)*, 87–89.
- MacRae, G.P. (1987). *Geology of Nymagee 1:100 000 sheet 8133*. Geological Survey of New South Wales, Sydney.
- Mathieson, D., Mawson, R., Simpson, A.J. and Talent, J.A. (2016). Late Silurian (Ludlow) and Early Devonian (Pragian) conodonts from the Cobar Supergroup, western New South Wales, Australia. *Bulletin of Geosciences* **91**, 583–652.
- Mavrinskaya, T. and Slavík, L. (2013). Correlation of Early Devonian (Lochkovian to early Pragian) conodont faunas of the South Urals (Russia). *Bulletin of Geosciences* **88**, 283–296.
- Mawson, R., and Talent, J.A. (1994). Age of an early Devonian carbonate fan and isolated limestone clasts and megaclasts, east-central Victoria. *Proceedings of the Royal Society of Victoria* **106**, 31–70.
- McLean, R.A. (1997). Middle Devonian rugose coral faunas in northeastern British Columbia and District of Mackenzie, western Canada. *Boletín de la Real Sociedad Espanola de Historia Natural, Seccion Geologica* **92**, 289–300.
- McLean, R.A. (2018). Fasciphyllid and spongophyllid rugose corals from the Middle Devonian of western Canada. *Palaeontographica Canadiana* **37**, 1–117.
- Merriam, C.W. (1973a). Silurian Rugose Corals of the Central and Southwest Great Basin. *United States Geological Survey Professional Paper* **777**, 1–66.
- Merriam, C.W. (1973b). Middle Devonian Rugose Corals of the Central Great Basin. *United States Geological Survey Professional Paper* **799**, 1–53.
- Merriam, C.W. and McKee, E.H. (1976). The Roberts Mountains Formation, a regional stratigraphic study with emphasis on rugose coral distribution. *United States Geological Survey Professional Paper* **973**, 1–51.
- Milne-Edwards, H. and Haime, J. (1850). A monograph of the British fossil corals. First part. Introduction; Corals from the Tertiary and Cretaceous Formations. *Palaeontographical Society Monograph* **3 (issue 7)**, i–71.
- Milne-Edwards, H. and Haime, J. (1851). Monograph des polypiers fossiles des terrains paléozoïques. *Museum of Natural History, Paris, Archives* **5**, 1–502.
- Milne-Edwards, H. and Haime, J. (1853). A monograph of the British fossil corals. Fourth Part. Corals from the Devonian Formation. *Palaeontographical Society Monograph* **7 (issue 20)**, iv–12.
- Nicholson, H.A. and Lydekker, R. (1889). *A Manual of Palaeontology for the use of students* **1**, 276–302. Blackwood and Sons, Edinburgh
- Oliver, W.A. (1960). Middle Devonian Coral Faunules from Illinois and Their Bearing on Biogeography. In: Sando, W.J. (ed.) *Shorter Contributions to Paleontology and Stratigraphy*, United States Geological Survey Bulletin **1690**, Denver, D1–D9.
- Oliver, W.A., and Johnson, J.G. (1977). Notes on Upper Silurian and Devonian coral zones in the Great Basin. In: Murphy, M.A., Berry, W.B.N., and Sandberg, C.A. (eds) *Western North America: Devonian*, University of California Riverside Campus Museum Contribution **4**, 107–111.
- Pedder, A.E.H. (1964). Correlation of the Canadian Middle Devonian Hume and Nahanni Formations by Tetracorals. *Palaeontology* **7**, 430–51.
- Pedder, A.E.H. (1967). *Lyriellasma* and a New Related Genus of Devonian Tetracorals. *Proceedings of the Royal Society of Victoria* **80**, 1–30.
- Pedder, A.E.H. (1980). Devonian corals of late Eifelian age from the Ogilvie Formation of Yukon Territory. *Canadian Journal of Earth Sciences* **7**, 594–616.
- Pedder, A.E.H. (1985). Lower Devonian rugose corals of Lochkovian age from Yukon Territory. *Geological Survey of Canada Paper* **85**, 587–602.
- Pedder, A.E.H. and Murphy, M.A. (1997). Lochkovian Rugosa of Nevada. *Geological Society of America Special Paper* **321**, 341–385.
- Pickett, J.W. (1977). Conodont samples from Balowra, Canbelego and Bungonia, *Geological Survey of New South Wales Report, GS1977*, 157.
- Pogson, D.J. and Felton E.A. (1978). Reappraisal of geology, Cobar-Canbelego-Mineral Hill region, central western New South Wales. *Quarterly Notes of the Geological Survey of New South Wales* **33**, 1–14.
- Rayner E.O. (1969). The copper ores of the Cobar region, New South Wales. *Geological Survey of New South Wales, Memoir (Geology)* **10**, 1–131.
- Schröder, S. (2007). Colonial Rugosa from the Early Devonian (Pragian) of the Zeravshan Range, Tajikistan. *Alcheringa: An Australasian Journal of Palaeontology* **31**, 121–151.
- Shurygina, M.V. (1968). Pozdnesiluriyskie i rannedevonskie ruгоzy vostochnogo sklona Severnogo i Srednego Urala. Pp 117-165 In: Ivanovskiy, A.B. (ed.) *Korally pogranichnykh sloev silura i devona Altae-Sayanskoy gornoy oblasti i Urala Izdatelstvo*, Nauka, Moscow, 1–150. [in Russian]
- Soshkina, E.D. (1937). Korally verkhnego silura i nizhnego devona vostochnogo i zapadnogo sklonov Urala. *Akademiya Nauk SSSR, Trudy Paleozoologicheskoy Institut* **6**, 1–155. [in Russian]
- Soshkina, E.D. (1954). Devonskie chetyrekhluchevye korally Russkoy Platformy. *Akademiya Nauk SSSR, Trudy Paleontologicheskogo Institut* **52**, 1–76. [in Russian]
- Strusz, D.L. (1966). Spongophyllidae from the Devonian Garra Formation, NSW. *Palaeontology* **9**, 544–598.
- Stumm, E.C. (1949). Revision of the families and genera of the Devonian Tetracorals. *Geological Society of America Memoir* **40**, 1–92.
- Talent, J.A., Mawson, R., Aitchison, J.C., Becker, R.T., Bell, K.N., Bradshaw, M.A., Burrow, C.J., Cook, A.G., Dargan, G.M., Douglas, J.G., Edgecombe, G.D., Feist, M., Jones, P.J., Long, J., Phillips-Ross, J.R., Pickett, J.W., Playford, G., Rickards, R.B., Webby, B.D., Winchester-Seeto, T., Wright, A.J., Young, G.C. and Zhen, Y.Y. (2000). Devonian palaeobiogeography of Australia and adjoining regions. *Memoirs of the Association of Australasian Palaeontologists* **23**, 167–257.
- Tsyganko, V.S. (1974). Novy rod devonskikh kolonialnykh chetyrekhluchevykh koralllov. *Akademiya Nauk SSSR*,

- Ezhegodnik Instituta geologii Komi filiala* **1973**, 86–89. [in Russian]
- Tyazheva, A.P., Zhavoronkova, R.A. and Garifullina, A.A. (1976). *Korally i brakhiopody nizhnego devona Yuzhnogo Urala*, Nauka, Moscow, 116–119. [in Russian]
- Tyazheva, A.P. and Zhavoronkova, R.A. (1977). Southern Urals. In: Martinsson, A. (ed.) *The Silurian-Devonian boundary (IUGS, Series A, Number 5)*, Stuttgart, Schweizerbart'sche, 203–210.
- VandenBerg, A.H.M., Garratt, M.J. and Spencer-Jones, D. (1976). Silurian-Middle Devonian. In: Douglas, J.G. and Ferguson, J.A. (eds) *Geology of Victoria*, Geological Society of Australia Special Publication **5**, Melbourne, 45–76.
- Verrill, A.E. (1865). Classification of Polyps (Extract condensed from a synopsis of the Polypi of the North Pacific exploring expedition under Captains Ringgold and Rodgers). *Annals and Magazine of Natural History* **16**, 191–197.
- Wedekind, R. (1922). Zur Kenntnis der Stringophyllen des oberen Mitteldevon. *Sitzungs-Berichte der Gesellschaft zur Beförderung der gesamten Naturwissenschaften zu Marburg* **1921**, 1–16.
- Wedekind, R. (1923). Die Gliederung des Mitteldevons auf Grund von Korallen. *Gesellschaft zur Beförderung der gesamten Naturwissenschaften zu Marburg Sitzungsberichte* **1**, 24–35.
- Wedekind, R. (1927). Die Zoantharia Rugosa von Gotland (bes. Nordgotland). *Sveriges Geologiska Undersökning* **3**, 1–94.
- Wrzosek, T. (1993). Rugose corals from the Devonian Kowala Formation of the Holy Cross Mountains. *Acta Palaeontologica Polonica* **37**, 217–254.
- Yü, C. and Jell, J.S. (1990). Early Devonian rugose coral fauna from the Shield Creek Formation, Broken River Embayment, north Queensland. *Memoirs of the Association of Australasian Palaeontologists* **10**, 169–209.
- Zhen, Y.Y. (1991). Devonian rugose coral faunas and biostratigraphy of the Fanning River Group, north Queensland. Unpublished PhD thesis, University of Queensland, Brisbane, 394 pp.
- Zhen, Y.Y. (1994). Givetian rugose corals from the northern margin of the Burdekin Basin, north Queensland. *Alcheringa: An Australasian Journal of Palaeontology* **18**, 301–343.
- Zhen, Y.Y. (1995). Late Emsian Rugose Corals of the Mount Podge area, Burdekin Basin, North Queensland. *Alcheringa: An Australasian Journal of Palaeontology* **19**, 193–234.
- Zhen, Y.Y. (1996). Succession of coral associations during a Givetian transgressive-regressive cycle in Queensland. *Acta Palaeontologica Polonica* **41**, 59–88.
- Zhen, Y.Y. (1998). Biogeographic and Biostratigraphic Perspectives for Australian Devonian Rugose Corals. *Acta Palaeontologica Sinica* **37**, 359–373.
- Zhen, Y.Y. (2007). Revision of *Microplasma parallelum* Etheridge, 1899 (Cnidaria: Rugosa) from the Middle Devonian Moore Creek Limestone of New South Wales. *Proceedings of the Linnean Society of New South Wales* **128**, 201–208.
- Zhen, Y.Y. and Jell, J.S. (1996). Middle Devonian rugose corals from the Fanning River Group, north Queensland, Australia. *Palaeontographica Abteilung A* **242**, 15–98.
- Zhen, Y.Y., Wright, A.J. and Jell, J.S. (2001). Rugose coral diversifications and migrations in the Devonian of Australasia. *Historical Biology* **15**, 61–76.
- Zhen, Y.Y. and Fitzherbert, J. (2021). Lochkovian (Early Devonian) corals and conodonts from the Elura Limestone Member, north of Cobar in central-western New South Wales. *Quarterly Notes of the Geological Survey of NSW* **154**, 1–27.
- Zhen, Y.Y., Smith, P.M., Zhang, Y.D., Strusz, D.L., Percival, I.G., Burrow, C.J., Rutledge, J.M. and Trigg, S.J. (2023). Field guide and catalogue of Ordovician-Devonian fossils from the Cargelligo and Nymagee 1:250,000 mapping areas, central New South Wales. *Quarterly Notes of the Geological Survey of New South Wales* **157**, 1–83.
- Zhen, Y.Y., Colquhoun, G.P., Burrow, C.J., Smith, P.M., Wells, T.J., Murray, R. and Ogden, T.E. (2025). Late Silurian and Early Devonian fossils from subsurface strata in central NSW: implications for the regional stratigraphy of the northern Junee–Narromine Volcanic Belt. *Quarterly Notes of the Geological Survey of New South Wales* **159**, 1–46.

