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Wenlock and Ludlow (Silurian) rugose corals from the type section of the Jack Formation, Broken River Province, northeast Queensland

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ABSTRACT

The Jack Formation forms part of the Silurian Graveyard Creek Group within the Graveyard Creek Subprovince in northeast Queensland. The formation comprises alternating intervals of carbonate and siliciclastic rocks deposited in a shallow-marine setting. It is very fossiliferous at a number of levels, and contains numerous species of conodonts, rugose and tabulate corals, stromatoporoids, trilobites, brachiopods, crinoids, low-spired gastropods, molluscs, other invertebrates, microvertebrates, and algae. Conodont data indicate that the succession is Wenlock to Ludlow in age at the type section along the Broken River in the Jack Hills Gorge area. Fourteen rugose coral species and one subspecies, referable to eleven genera, are described from the type section of the Jack Formation. New taxa described are *Aphyllum pachystele* sp. nov., *Pycnostylus polyphyllodus* sp. nov., *Multicarinophyllum vepreculatum* sp. nov., *Dokophyllum hillae* sp. nov., *Vesicospina julli* gen. et sp. nov. and *Ptychophyllum variatum* sp. nov. The rugose coral fauna shows a high degree of endemism with only four species recorded outside the Broken River Province. Within eastern Australia, it is comparable with a Gorstian to early Ludfordian fauna of the Yass district, New South Wales (3 species in common), and 1–2 species are also shared with coral faunas from other Silurian localities in New South Wales, Victoria and Tasmania. At the species level, there is very little in common with overseas faunas. □ *Broken River Province, Jack Formation, north Queensland, Silurian, Wenlock, Ludlow, Rugosa, taxonomy, Tryplasmataceae, Cystiphyllidae, Pycnostylidae, Mucophyllidae, Amsdenoididae, Entelophyllidae, Ketophyllidae, Kyphophyllidae, Ptychophyllidae.*

The Broken River Province (Arnold & Henderson 1976) is a southwest-trending wedge of Cambrian–Ordovician to Permian rocks, located to the west of Townsville in northeastern Queensland. It can be divided into two subprovinces, each with a different history of sedimentation, igneous activity, and deformation, which are separated by a major dislocation, the Gray Creek Fault (Arnold & Henderson 1976;

Arnold & Fawckner 1980; Withnall & Lang 1993). Recognition of the two subprovinces is based on the distinct sedimentary and structural histories of the Silurian and Devonian successions, which occupy the greater part of the province. In the more westerly Graveyard Creek Subprovince (Fig. 1), these rocks form a generally shallow-marine sedimentary succession that contains richly fossiliferous intervals and

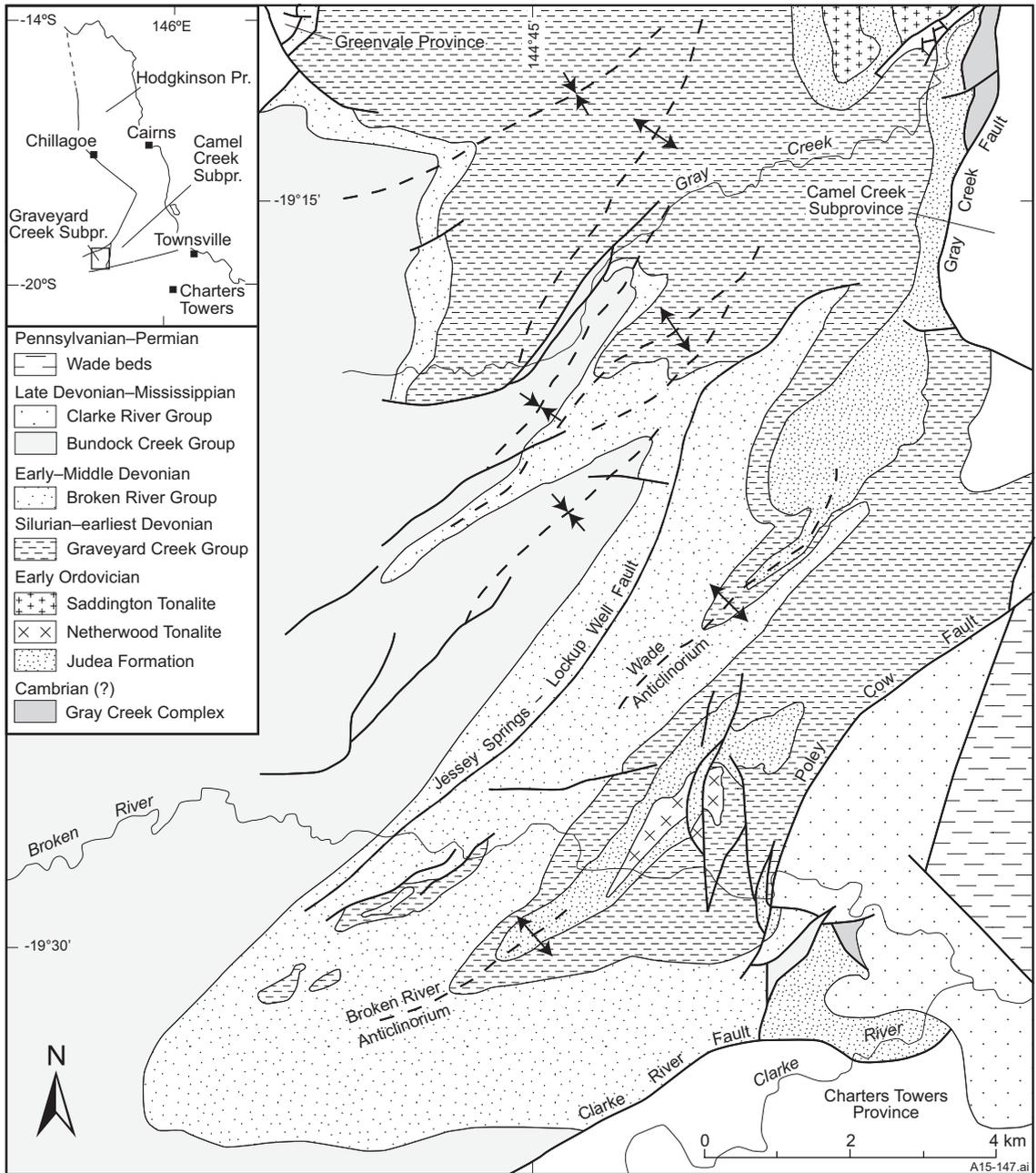


FIG. 1. Simplified solid geology map showing the distribution of the Graveyard Creek Group and the main structural features southwest of the Gray Creek Complex. Cenozoic volcanic and sedimentary covering rocks not shown (redrawn and slightly modified from Henderson & Withnall 2013).

has been deformed by a single phase of upright folding. In the Camel Creek Subprovince to the east, they form a generally deep-marine, turbiditic succession, which is very sparsely fossiliferous and multiply deformed. The Silurian–Devonian successions of the Broken River Province constitute the southern part of the Mossman Orogen (Henderson *et al.* 2013), which also incorporates successions of similar age in the Hodgkinson Province to the north. They unconformably overlie Neoproterozoic–Ordovician rocks assigned to the Thompson Orogen and are unconformably overlain by Upper Devonian–Mississippian rocks of the Bundock and Clarke River basins. A recent summary of the geology of the Broken River Province is in Henderson & Withnall (2013), and the following description is largely derived from this source, except where indicated.

Silurian strata in the Graveyard Creek Subprovince are included within the upper Lower Silurian–middle Lower Devonian Graveyard Creek Group (White 1959a; Withnall *et al.* 1988; Henderson & Withnall 2013). This group is exposed in two main outcrop tracts separated by younger Paleozoic sedimentary rocks and Cenozoic basalt. It unconformably overlies the Lower Ordovician Judea Formation, and is paraconformably overlain by the uppermost Lower to lowermost Upper Devonian Broken River Group (Fig. 1). The Graveyard Creek Group contains siliciclastic and carbonate sedimentary rocks that form a complex facies mosaic ranging in thickness from as little as 150 m to greater than 5000 m. The group has been subdivided into a number of formations; in ascending stratigraphic order, these are the Crooked Creek Conglomerate, Quinton Formation and laterally equivalent Poley Cow Formation, Jack Formation, Ralph Flint Formation and Shield Creek Formation. The geology of these formations was summarised by Henderson & Withnall (2013), who referenced more detailed previous studies. Mapping coordinates use the Universal Transverse Mercator (UTM) grid system.

In the Broken River area, in the south of the Graveyard Creek Subprovince, the Graveyard Creek Group outcrops on both limbs of a large

southwesterly plunging anticline (Fig. 2). It is well exposed along the banks of the Broken River on the western limb of the anticline, where it reaches a maximum thickness of about 1300 m. A thin (30 m) interval of Crooked Creek Conglomerate forms the base of the succession in this area. This is overlain by a 750 m-thick succession of conglomerate, siltstone, and greywacke (Poley Cow Formation), followed by the mixed carbonate–siliciclastic Jack Formation, with a thin interval of Shield Creek Formation on top. North of the Broken River, the Ralph Flint Formation occurs between the Jack and Shield Creek formations, but lenses out just to the north of the river section (Talent *et al.* 2002).

The Jack Formation is richly fossiliferous at various stratigraphic levels, and Munson (1979) provided descriptions of the rugose coral fauna from the type section that are formally described herein.

JACK FORMATION

The Jack Formation (Withnall & Lang 1993) is restricted to the southern outcrop area of the Graveyard Creek Group. It was originally defined by White (1959a) as the Jack Limestone Member of the Graveyard Creek Formation and was given formation status by Withnall *et al.* (1988). Limestones within the formation outcrop on the limbs and noses of a number of anticlines, including the type area near Jack Hills Gorge and a relatively well studied area to the southeast, near the road crossing of the Broken River (Fig. 2). Further to the southwest of these areas, in the vicinity of the Broken River Anticlinorium, limestones are absent and the formation becomes entirely siliciclastic (Talent *et al.* 2002); the succession in this area is not well studied. The formation overlies the siliciclastic Poley Cow Formation with apparent conformity, but the contact possibly interfingers. It is overlain by thinly bedded shale and fine-grained sandstone with thin interbedded calcarenite of the middle Lochkovian Ralph Flint Formation along a disconformable erosive contact (Talent *et al.* 2002), or where the Ralph Flint Formation is

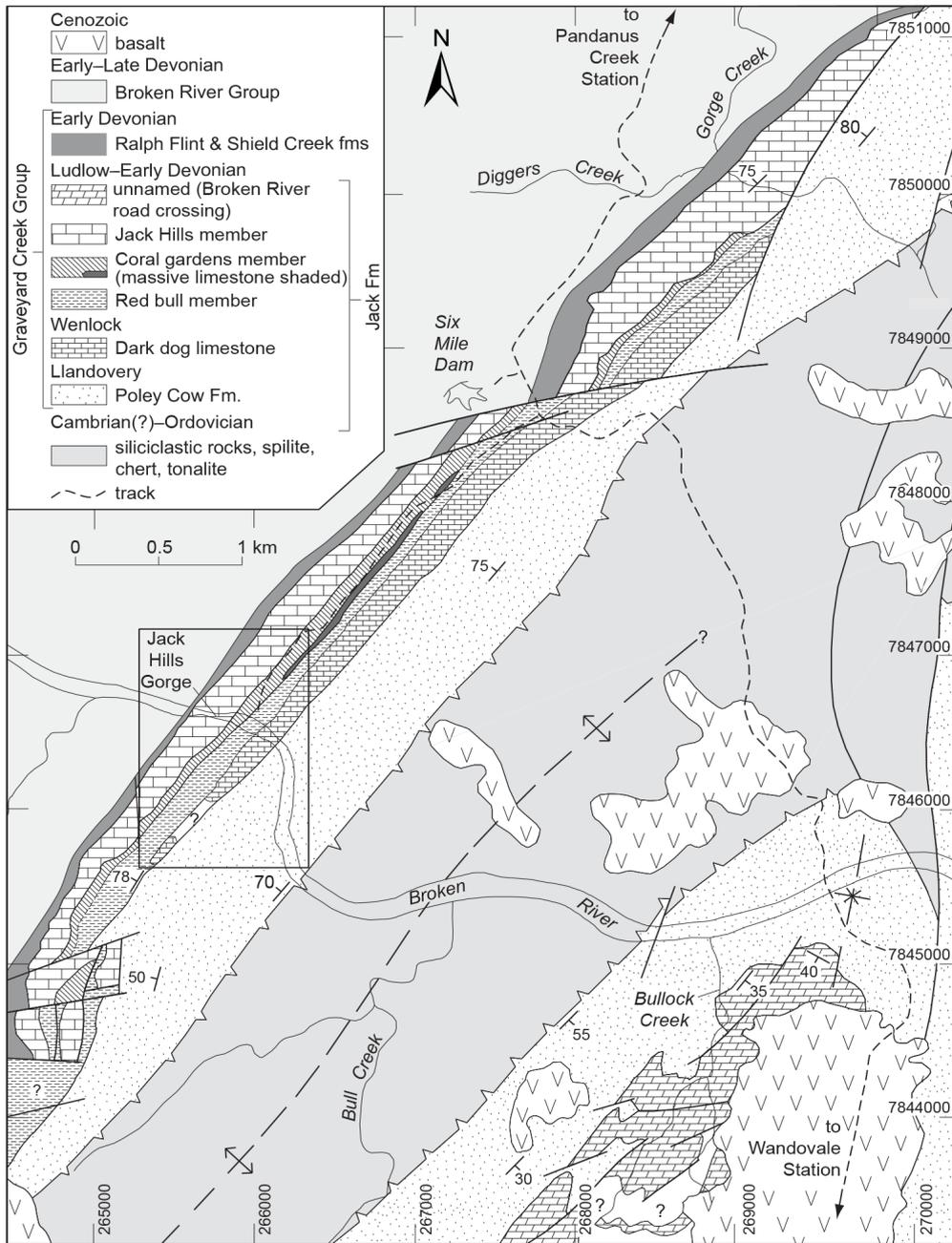


FIG. 2. Solid geology map of the Jack Formation in vicinity of the Broken River, showing the distribution of informal members. Box shows location of Fig. 5.

absent, by the disconformable Lower Devonian Shield Creek Formation. In the north of the Graveyard Creek Subprovince, it is possible that the Ralph Flint Formation might be at least in part a facies equivalent of the Jack Formation, at the level of the Magpie Creek Limestone Member.

Fossil Assemblages. The Jack Formation is very fossiliferous and conodonts, rugose and tabulate corals, stromatoporoids, trilobites, brachiopods, crinoids, low-spined gastropods, molluscs, other invertebrates, microvertebrates, and algae are locally abundant and many have been listed or described in previous studies. General summaries of the fossil assemblages with references to previous work and their biostratigraphic and palaeogeographic significance were reported by Jell *et al.* (1993), Talent *et al.* (2002) and Caldon (2003). The Coral gardens member passes through a significant mid-Ludlow global extinction event (Lau Event), the significance of which was discussed in detail by Caldon (2003), Talent *et al.* (2002) and Jeppsson *et al.* (2007, 2012).

Systematic descriptions and biostratigraphic summaries of the conodont faunas include Telford (1972), Simpson (1983 1995a, b, 1998a, 2000), Sloan *et al.* (1995) and Jeppsson *et al.* (2007, 2012). Other microfossils recovered from the formation include foraminifera, algae, sponge spicules, byroniids, and acanthodian and phyllocarid remains (Simpson 1994; Burrow & Simpson 1995).

The macrofossils have been listed in numerous studies, but only a few have been described. Several species of stromatoporoids were described by Webby & Zhen (1997) and a number of species of trilobites from the Coral gardens beds were identified by PA Jell and listed in Savory (1987). Lists of the coral species were included in White & Wyatt (1960), Hill (1965), Arnold & Henderson (1976) and Jell *et al.* (1993). Hill *et al.* (1969) illustrated and tentatively identified corals and other fossils from the type section.

Succession in Type Section. The type section is located in the Jack Hills Gorge on the Broken River, from ca. 266160mE 7845450mN (base) to ca. 265560mE 7845680mN (top) within the Clarke

River 1:250 000 (SE55-13) and Burges 1:100 000 (7859) mapsheets. In this area (Fig. 2), the formation forms part of the northwesterly limb of a large, southwesterly plunging anticline. The succession within the type section comprises about 580 m of limestone, sandstone and shale (Withnall 1989; Withnall *et al.* 1993). Thicker limestone lenses tend to be bluff-forming, resulting in a karst topography, whereas siliciclastic intervals and thinner carbonate intervals are more recessive. The succession can be subdivided into four conformable carbonate and siliciclastic intervals that can be mapped for several kilometres along strike on both sides of the river until they are truncated by faults at both ends of the outcrop tract (Munson 1979; Jeppsson *et al.* 2007; Fig. 2).

Jeppsson *et al.* (2007) raised the Jack Formation to group status (and by necessity, Graveyard Creek Group to a supergroup) and considered the four stratigraphic intervals in the type section to be formations within this group; in ascending stratigraphic order, the 'Dark Dog Limestone', 'Red Bull Formation', 'Coral Gardens Formation' and 'Jack Hills Formation'. The 'Coral Gardens Formation' was further subdivided into informal numbered members 1–4, based on data from a detailed traverse along the type section. Jeppsson *et al.*'s nomenclature has not been adopted generally, as the formation names were not formally defined, the 'formations' be recognised only within the vicinity of the Jack Hills, and, with the exception of the 'Jack Hills Formation', recognised geographic names were not used. A broadly defined Jack Formation has therefore been retained in subsequent studies (e.g. see Henderson & Withnall 2013), with its constituent 'formations' being regarded as informal members. This schema is followed herein. A formal revision of the nomenclature, as proposed by Jeppsson *et al.* is beyond the scope of the present study.

Dark dog limestone. The Dark dog limestone is ca 100 m thick where it is cut by the river, thickens to a maximum of 120 m further to the northeast, and decreases to 50 m at its southern extremity. This unit consists of generally massive or thickly bedded, partly dolomitised lime mudstone and minor lime wackestone, and extends for about



FIG. 3. Jack Formation limestones. **A**, View northwest (down-dip) of massive to thickly bedded Dark dog limestone exposures in the Broken River, with the Jack Hills Gorge in background. Apparent thin bedding in the image is a solution weathering effect (266100mE 784543mN); **B**, Thinly bedded fossiliferous limestone at the top of Dark dog limestone on the south bank of Broken River (266010mE 7845460mN); **C**, Interbedded nodular limestone and shale of the Coral gardens member, showing coral heads in growth position. Corallum of *Entelophyllum patulum yassense* to the right of the hammer; a tabulate coral corallum in the lower right of image (UQL4009); **D**, Jack Hills Gorge, showing massive bluff-forming limestone of the Jack Hills member. View east from 265520mE 784571mN.

5 km along strike as low-relief strike ridges and rocky pavements, mostly to the northeast of the Broken River (Fig. 3A). Although the bedding in the unit is poorly defined, it is evident through layers rich in skeletal debris, by the orientation parallel to the bedding of elongate fossils, particularly of the rugose coral *Pycnostylus*, and by stromatoporoids in growth position. Thin lenticular interbeds of calcareous siltstone occur at the base and top of the unit and the uppermost 15 m in the Broken River section is well bedded and relatively fossil-rich (Fig. 3B). The member is stylolitic, and towards the top of the unit, microstylolites are common,

forming an irregular network through the limestone; this indicates post-consolidation loss of an unknown thickness of rock.

The lower 50–60 m of the Dark dog limestone is characterised by large bivalve molluscs that reach 20 cm in length and are commonly in growth position. These are observed only in section, and are not readily identifiable; they were referred to the Megalomoidea by Jeppsson *et al.* (2007). Small solitary rugose corals, tabulate corals, small stromatoporoids, pentamerid brachiopods, bryozoans, crinoids, pelecypods, ostracodes and gastropods occur throughout the unit, but are most common in

the upper, more thinly bedded limestones. Withnall *et al.* (1993) also reported the alga *Wetheredella* as oncolites from these beds. Several species of tabulate corals, illustrated by Hill *et al.* (1969), include *Barrandeolites* sp. cf. *bowerbanki* Milne-Edwards & Haime 1851, and species of *Favosites*, *Multisolenia* and *Diploepora*. An unidentified multiserial halysitid is also present at the top of the unit. Stromatoporoids, illustrated by Hill *et al.* (1969) and described by Webby & Zhen (1997) include *Ecclimadictyon* cf. *magnum* Nestor 1976 and an undescribed species of *Simplexodictyon*.

The hard, light to dark grey limestone consists dominantly of micrite, pelmicrite and biomicrite that has been finely recrystallised by aggrading neomorphism. At the top of the unit, the limestone is commonly impure, containing detrital and secondary grains of quartz, and rare feldspar and muscovite. Biogenic allochems within the limestone include corals, disarticulated crinoid ossicles, medium-spined gastropods, brachiopods, and bryozoans.

Red bull member. Overlying the basal Dark dog limestone is a 165 m thick, red to purple, deeply weathered recessive succession, consisting of soft, friable conglomerate, fine to coarse micaceous quartz sandstone and siltstone. Exposures are poor and generally confined to gullies and washouts. Coarser lithologies are found towards the base of the unit, which has an overall fining-upward trend. Beds are 15 cm–2 m thick and are commonly normally graded. At the top of the Red bull member (at locality UQL4329; Fig. 4) is an interval of very weathered siltstone and rarer fine sandstone that contains thin fossil-rich layers with fragmented, iron-stained casts and moulds of decalcified brachiopods and trilobites including an ecrinurine (Munson 1979). Concretions and ferruginous staining along joints are common in these beds.

Coral gardens member. This is a heterolithic unit consisting of siltstone, thinly interbedded siltstone and limestone, lesser thickly bedded to massive limestone, and minor oolitic and oncolitic limestone. It is ca 80 m thick in the type section of the formation along the Broken River (Jeppsson *et al.* 2007) and has a strike

length of ca 6.5 km (Fig. 2). Exposures are generally recessive and form low pavements of steeply dipping beds, commonly covered by soil or scree, except for a more thickly bedded to massive lime mudstone lens at the base of the unit to the northeast of the type section that tends to be bluff-forming; this lens is about 1700 m in length and reaches a maximum thickness of about 35 m (Fig. 2).

Jeppsson *et al.* (2007) measured a section through this unit along the type section of the Jack Formation, on the banks of the Broken River, which was sampled for conodonts and C, O and Sr isotopes. They recognised and numbered 4 informal ‘members’.

The Coral gardens member commences with a few metres of dark grey to grey-brown, calcareous quartz siltstone and fine micaceous sandstone, succeeded by a thick interval of thinly interbedded siltstone and limestone. The contact is transitional, marked by the appearance of infrequent thin lenses of light to dark grey limestone that become more closely spaced over a distance of a few metres up-section. This interval is equivalent to members 1 and 2 of Jeppsson *et al.* (2007).

The thin, lenticular or nodular limestone layers of ‘Member 2’ of Jeppsson *et al.* (2007) average 4–7 cm, rarely 10 cm or more, in thickness, and are separated by 1–10 cm of siltstone (Fig. 3C). Much of this succession is very fossiliferous, and is characterised by abundant coral heads (Munson 1979; Caldon 2003) and stromatoporoids (Webby & Zhen 1997) in growth position, hence known colloquially as the ‘coral gardens’. Commonly, tabulate corals in growth position pass through and interfinger laterally with several layers of siltstone. The siltstones appear to have, partially smothered the corals, which expanded again once they had grown above the sediment–water interface. A similar relationship is found with stromatoporoids, and to a lesser extent with colonial rugosans. Thinning and upturning of sediments against, and depression of sediments beneath coral heads and stromatoporoids were probably caused by post-depositional compaction. The limestone comprises recrystallised impure

micrite and biomicrite, with abundant fine grains of quartz and less common muscovite. Allochems comprise 5–40% of the limestone and in some cases have syntaxial replacement rims; the majority consist of skeletal fragments, mostly less than 5 mm in diameter.

Towards the top of the nodular limestone sequence, siltstone layers become thinner and less abundant, eventually giving way to a more prominently exposed interval of micritic limestone, 8 m thick on the north bank of the river, with 5–10 cm-thick beds that are crudely defined by stylobedding and layers of skeletal debris. This limestone is broadly equivalent to 'Member 3' of Jeppsson *et al.* (2007). It differs petrographically from the underlying unit in having larger more abundant skeletal allochems and fewer siliciclastic grains. Brachiopods, gastropods, crinoids and ostracodes are common, but corals are rare, except as abraded fragments. Jeppsson *et al.* reported abundant cyanobacteria, microproblematica, *Girvanella*, *Sphaerocodium* and *Wetheredella* from this interval.

Above these limestone beds is a ca 30 m-thick succession, equivalent to 'Member 4' of Jeppsson *et al.* (2007), of siltstone and fine sandstone overlain by interbedded limestone and siltstone. The lower interval of grey-brown to red-brown calcareous quartz-mica siltstone and lesser interbedded fine sandstone is 17 m thick on the south bank. It contains abundant fragments of brachiopods, trilobites, crinoids and bryozoans (Caldon 2003) that commonly form nuclei for irregularly shaped macro- and pisoncolites. Rare, abraded, coral debris is also present. Elongate grains and micas are commonly aligned with the bedding. This siltstone contains thin layers rich in trilobites, brachiopods and bivalves (Talent *et al.* 2002). The upper interval comprises thinly interbedded light to dark grey limestone and siltstone, which is 15 m thick on the south bank of the river. Beds are up to and sometimes exceed 20 cm, and the limestone beds become thicker and more evident towards the top. The limestone contains recrystallised ooids, with subordinate micro- and pisoncolites, skeletal fragments, pellets, minor detrital and secondary quartz, and minor detrital muscovite. These are

set in a granular neomorphic spar, which has corroded some ooids. Skeletal allochems include brachiopod, crinoid, bryozoan, and, more rarely, coral debris. Withnall *et al.* (1993) reported the presence of channeling and long-wavelength low-angle cross-beds from this interval.

Solitary and colonial rugose corals are abundant within the Coral gardens member, particularly within the interbedded limestones and siltstones that comprise a large proportion of the unit. Tabulate corals, illustrated by Hill *et al.* (1969), include *Favosites richardsi*? Jones 1937, *Pseudoplasmodium* sp. cf. *heliolitoides* (Lindström 1899), *Heliolites daintreei* Nicholson & Etheridge 1879, (group 4 of Jones & Hill 1940) and species of *Mesofavosites* and *Barrandeolites*?. Stromatoporoids, described by Webby & Zhen (1997), include common occurrences of *Schistodictyon jackense* and *Ecclimadictyon microvesiculosum* (Riabinin 1951). Other invertebrates include small brachiopods, medium- and high-spined gastropods, several species of trilobites (including an ecrinurine), bryozoans, crinoids, and rare tentaculitids. The crinoids are typically represented by disarticulated columnals with round or pentapetaloid lumens; several species are present.

Jack Hills member. The Jack Hills member is the uppermost carbonate interval of the Jack Formation, and has previously been mapped as the top of the Graveyard Creek Group (White 1965; Arnold & Henderson 1976). It is a thick and extensive, predominantly massive, light to dark grey micritic limestone, with high topographic relief, through which the Broken River has cut a narrow gorge (Fig. 3D). This limestone can be traced along strike for ca 8.5 km (Fig. 2). It is ca 215 m thick on the north bank of the river and reaches a maximum of ca 400 m in thickness in the vicinity of Gorge Creek, northeast of the type section.

Bedding is crudely defined by layers of skeletal material, stromatoporoids in growth position, rare thick pisoncolitic layers, and irregular layers of hard nodular chert and dolomite that are particularly prominent in the top 100 m of the unit. Scattered zones occur where microstylolites are so common that

they form an irregular network through the limestone, similar to those found within the Dark dog limestone.

The basal 20 m of the limestone shows signs of bioturbation and is rich in skeletal debris, particularly brachiopods, corals, bryozoans, medium-spined gastropods and ostracodes. Crinoid stem plates with round lumens are characteristic; small, flat or slightly domed stromatoporoids in growth position and reaching 20–25 cm in length also occur. The succeeding 70–80 m is relatively poor in skeletal fragments, although small crinoid ossicles are relatively common throughout and there are scattered favositids, small stromatoporoids, some thin layers of solitary rugose corals (mainly *Tryplasma*) and pentamerid brachiopods. Stromatoporoids are more common and larger up-section. The limestone is mostly composed of fine, recrystallised micrite, biomicrite, and pelmicrite, except for the topmost 10 m, which is a recrystallised biomicrudite, rich in crinoid ossicles, brachiopod valves, tentaculitids, bryozoans, high- and medium-spined gastropods, and rare corals. This increase in fossil content of the limestone is accompanied by a considerable increase in the size and numbers of stromatoporoids. These are usually strongly domical, rarely laminar or weakly domical, and reach widths greater than 2 m and thicknesses of 50–60 cm.

The top 4–5 m of the biomicrudite are interbedded with a very fine-grained quartz-bearing, micaceous limestone, which continues for another 10 m up-section before the outcrop is concealed by alluvium. Fresh surfaces of the limestone are light grey to grey-green in colour, but weathered surfaces are brown or red-brown. The limestone consists of 10–40% biotite and muscovite in varying proportions, with a large amount of anhedral calcite grains, and minor quartz, set in a fine granular calcite cement. The limestone is poor in fossils, but contains echinoid and brachiopod fragments.

The thickly bedded to massive limestones of the Jack Hills member, are impoverished in rugose corals. Colonial rugosans, other than rare subcompound *Stylopleura liliiforme*

are absent, but uncommon solitary species occur. Tabulates recorded by Hill *et al.* (1969) include *Favosites allani* Jones 1937 and *Heliolites daintreei* Nicholson & Etheridge 1879. There are several species of stromatoporoids, including *Plexodictyon* sp. (Webby & Zhen 1997).

Environment of deposition. Fleming in Withnall *et al.* (1988) considered the depositional environment of the Jack Formation in the Broken River area to have been a nearshore shallow-water complex of fans, bars, restricted lagoons, and marine tongues or bays, and this interpretation is generally followed here. Although the environment was conducive to carbonate sedimentation, the presence of interlensed and interbedded siliciclastic intervals within the succession indicates the close proximity of land.

The massive or thickly bedded, bluff-forming limestone intervals within the succession (Dark dog and Jack Hills members, basal Coral gardens member) are carbonate mudbank deposits indicative of generally low-energy, marine conditions. Thin layers of bioclastic debris at various levels within the limestones suggest periodic storm events. Corals, stromatoporoids and algae that occur throughout the succession indicate relatively shallow water depths. This lithofacies probably accumulated in a restricted lagoonal environment. Darker limestones with sparse faunas are probably indicative of relatively anaerobic conditions, whereas lighter-coloured limestones with more abundant faunas and debris layers resulted from more oxygenated and agitated conditions.

Fleming in Withnall *et al.* (1988) interpreted the thick siliciclastic Red bull member as possibly fluvial, at least towards the base, emphasising the presence of red-brown, poorly sorted sandstone, pebbly trough cross-bedded brown sandstone and purplish red beds, and the absence of fossils. The overall fining-upward succession suggests a general deepening of the environment, but the evidence for early fluvial deposition is not conclusive, as the sedimentary structures are also typical of shallow-marine environments, and the red-brown colour is almost certainly

the result of more recent weathering. Sparse brachiopod and trilobite fossils near the top of this unit indicate a marine setting. It is therefore possible that the coarser lower part of the succession was deposited in a relatively high-energy shallow-marine environment, perhaps a nearshore, proximal fan or shoal setting.

Most of the overlying Coral gardens member consists of relatively fine lithologies that were deposited under low to moderate energy conditions, but higher-energy conditions are suggested for the uppermost beds of oolitic limestone and cross-bedded calcarenite. Fleming interpreted the environment of deposition for this heterolithic unit as a shallow to extremely shallow marine bay, bounded by bars and shoreline. The diverse and abundant fauna indicates shallow, clear and warm conditions. The thinly interbedded limestones and siltstones that constitute much of the succession accumulated under fluctuating depositional conditions. Limestone beds were deposited during periods of minimal clastic influx, whereas dilution of carbonates during periods of increased runoff from siliciclastic source areas resulted in the deposition of siltstone and fine sandstone. The nodular structure of many limestone beds is probably the result of differential compaction between the limestone and siltstone so as to form sedimentary boudinage structures. During unconfined compaction, the incompetent siltstone layers move laterally, and pull apart the less competent limestone. Oolitic and oncolitic limestones near the top of the Coral gardens member indicate shallow more energetic conditions. Fleming in Withnall *et al.* (1988) considered these to be marine bar sediments. The cross-bedded calcarenites at the top of the unit were interpreted as carbonate fan or tidal channel deposits in a shoaling environment by Withnall *et al.* (1993) and Talent *et al.* (2002).

Although the shallow marine succession of the Jack Formation was deposited at various water depths, Fleming noted that apparent transgressive–regressive events may not necessarily represent regional relative changes in sea level; for example, the distribution of

facies may have been effected by local patterns of deposition, such as the movement of bars or damming by fans.

Age of Jack Formation. Conodonts and macrofossils (Talent *et al.* 2002) indicate that the type section of the Jack Formation in the Jack Hills Gorge area is early Wenlock (Sheinwoodian) to late Ludlow (Ludfordian) in age (Fig. 4), with some intervals more securely dated than others.

A sparse conodont fauna of broad Wenlock age was recovered from the base of the Dark dog limestone near Six-Mile Dam, 3 km northeast of, and along strike from the type section (Simpson 1998a, Fig. 2). The underlying, dominantly siliciclastic succession (Poley Cow Formation and its equivalent, the Quinton Formation) yielded late Llandovery (Telychian) graptolites (*turriculatus* to *greistonensis* zones; Jell *et al.* 1993; Rickards & Jell 2002) and conodonts (Simpson 1999). Jeppsson *et al.* (2007) considered it likely that there was little or no time break between the Poley Cow Formation and the Dark dog limestone, and inferred that the base of the limestone is most probably of early Wenlock age (lower *Kockelella ranuliformis* Zone). They concluded that the base of the Ludlow in the type section is near the base of the Red bull member and that the Dark dog limestone might therefore represent the whole of Wenlock time.

The Coral gardens member includes the *Ancoradella ploeckensis*, *Polygnathoides siluricus*, *Icriodontid* (a portion of which corresponds, at least partly, with the *Icriodus latialata* Zone of Walliser 1964) and *Ozarkodina snajdri* zones (Simpson 1998a; Jeppsson *et al.* 2007). Four new subzones discriminated by Jeppsson *et al.* (2007) are not used herein.

The type section of the Jack Hills member is entirely late Ludlow (*Ozarkodina crispa* Zone) in age (Simpson 1998a, 2000; Talent *et al.* 2002). However, to the southeast of the type area, near the road crossing of the Broken River (Fig. 2), conodonts of the Early Devonian (early Lochkovian) *Icriodus woschmidti* Zone (equivalent to the *Caudicriodus hesperius* Zone) were recovered (Simpson 1995b, 1998b, 2000), with no obvious break in succession. In

that area, the Jack Formation extends through a generalised Přídolí interval into the Early Devonian. In all other areas, the Jack Formation is no younger than Ludlow, owing to significant erosion of the Jack Formation in those areas prior to deposition of the Ralph Flint Formation (Simpson 1995a, 2000; Talent *et al.* 2002). It is notable that in the vicinity of the road crossing, there is no equivalent of the Dark dog limestone, and the Coral gardens member directly overlies siliciclastic rocks of the Quinton Formation (Simpson 2000). Both the base and top of the formation are therefore demonstrably diachronous between these two areas.

Rugose Coral Fauna. Jell (1967) named the rugose coral fauna of the Jack Limestone the *Entelophyllum* fauna as this genus occurs throughout the succession. Fourteen rugose coral species are recognised, but only four have been recorded outside the Broken River Province: *Tryplasma derrengullenense* Etheridge 1907, *Stylopleura liliiforme* (Etheridge 1907), *Entelophyllum patulum yassense* (Etheridge 1892a) and *E. latum* Hill 1940. The fauna includes a new genus, *Vesicospina*, and new species of *Aphyllum*, *Pycnostylus*, *Ptychophyllum*, *Dokophyllum* and *Multicarinophyllum*. This last genus has not previously been recognised from Australia. Other genera present include *Amplexoides*, *Cystiphyllum?* (*Cystiphyllum*) and *Cystiphyllum* (*Hedstroemophyllum*).

The biostratigraphic distribution of rugose coral species from the type section of the formation is shown in Fig. 4. Fossil localities from which the rugose coral fauna was collected are shown in Fig. 5 and listed in Appendix 1. Note that identifications of species from the Dark dog limestone and Jack Hills member are based largely on field observations and are therefore more tentative; specimens from the massive or thickly bedded limestones of these units are difficult to collect without the use of power tools (eg rock saws), which were not available at the time of the original fieldwork in the late 1970s.

There is a weakly defined rugose coral biozonation within the Jack Formation that is likely to have been influenced by facies type

as well as time. Massive to thickly bedded lime mudstones of the basal Dark dog limestone and upper Jack Hills member have relatively low coral diversity (5 and 6 species, respectively) and abundance. This is interpreted as being due to the low-energy deeper water conditions, relatively high turbidity, and mudbank substrates that were less suitable for coral growth. The greatest species diversity (13 rugose species) is in the interbedded limestones and siltstones of the Coral gardens member, where environmental conditions were generally more favourable.

The only species unique to the Dark dog limestone are the relatively common *Pycnostylus polyphyllodus* and a rare unnamed species of *Tryplasma*. Other species from this unit are relatively long-ranging and occur in overlying strata. *Pycnostylus polyphyllodus*, *Tryplasma derrengullenense* and *Entelophyllum latum* occur throughout the unit. In the more thinly bedded limestones at its top in the river section, the fauna includes *Multicarinophyllum vepreculatum* and *Tryplasma pachystele*. However, neither species has been recorded from this unit along strike to the north and south of the Broken River.

Thinly interbedded limestones and siltstones of the Coral gardens member contain the most diverse rugose coral assemblage. Common are *Entelophyllum patulum yassense*, *E. latum*, *Ptychophyllum variatum*, *T. derrengullenense*, and towards the top of the nodular beds, *Dokophyllum hilliae* and *Vesicospina julli*. Other species recorded include *Stylopleura liliiforme*, *Cystiphyllum?* (*Cystiphyllum*), *C. (Hedstroemophyllum)* and *Amplexoides*. *M. vepreculatum* and *A. pachystele*, common at the top of the Dark dog limestone, persist into the base of the Coral gardens member, but are rare.

Oncolitic and oolitic limestones at the top of the Coral gardens member have fewer corals and these are generally abraded, reflecting the energetic shifting substrates these probable marine bar sediments. These facies, at the top of the interbedded limestone and siltstone succession, also correspond to the globally recognised Lau extinction event, which is reflected in the conodont assemblages and other faunas (Caldon 2003; Jeppsson *et al.* 2007).

Silurian rugose corals Jack Formation

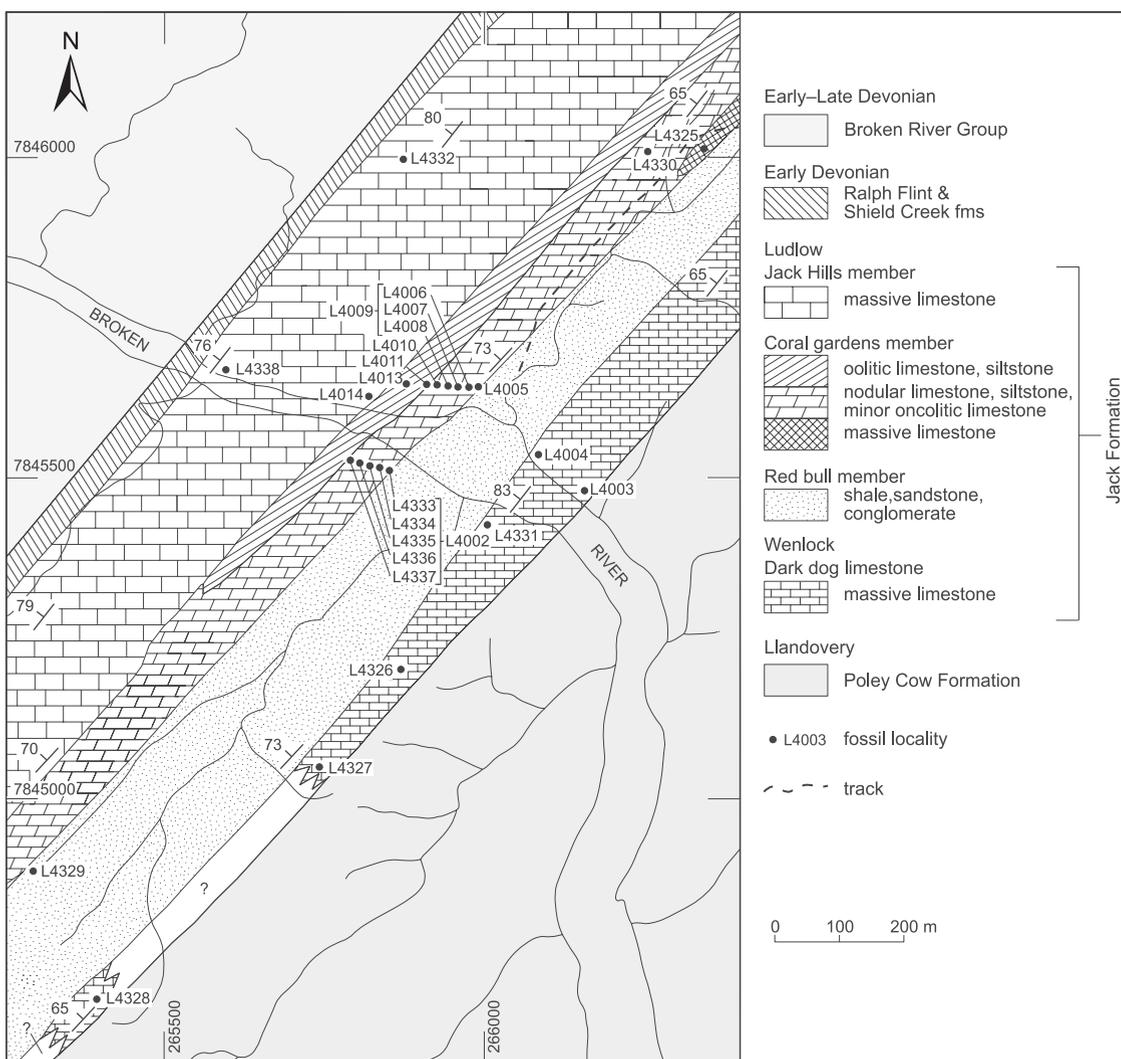


FIG. 5. Solid geology map of the Jack Formation in the vicinity of the type section, showing fossil localities referred to in the text. Localities are listed in Appendix 1.

The uppermost Jack Hills member has an impoverished fauna containing mainly solitary forms, all of which are present in the underlying Coral gardens member. Rare specimens of *V. julli* and *D. hillae* are found at the base of the unit, whereas *Ptychophyllum variatum*, *T. derrengullenense*, *E. latum*, *Amplexoides*, *C.?* (*Cystiphyllum*) and the sub-compound *S. liliiforme* occur sparsely throughout. It is unclear whether the reduction in rugose coral

diversity and numbers is related to the change in facies from the interbedded limestones and siltstones of the Coral gardens member to the lime mudstones of the Jack Hills member, to the Lau extinction event, or to a combination of these factors.

Correlation of Entelophyllum Fauna. Rugose corals from other localities within the Jack Formation are yet to be studied in detail, but

were listed by Arnold & Henderson (1976) from a large exposure of this formation, south of the Broken River, where it is crossed by the Pandanus Creek to Wando Vale homesteads road (Fig. 2). The section in that area is equivalent to just the Coral gardens and Jack Hills members, but as noted above, conodont data indicate that the top of the formation is younger than in the Jack Hills Gorge area, extending into the earliest Devonian (early Lochkovian; Simpson 1995b, 2000). Rugose coral taxa listed by Arnold & Henderson are equivalent to those from the type section and include *Tryplasma*, *Ketophyllum* [= *Dokophyllum hillae*], *Entelophyllum* cf. *yassense*, [= *E. patulum yassense*], ?*Phaulactis* (= *Ptychophyllum variatum*) and ?*Cystiphyllum*. Also listed were the tabulate corals *Heliolites daintreei*, *Favosites* of the *gothlandicus* group and *Pseudoplasmopora*.

Within eastern Australia, the *Entelophyllum* fauna is most comparable with a coral fauna from the Yass-Bowning district of New South Wales (see Hill 1940; Link & Druce 1972; McLean 1976). The Jack Formation species, *T. derrengullenense*, *S. liliiforme*, and *E. patulum yassense* have all been recorded from the Gorstian to earliest Ludfordian Bowspring Limestone and Hume Limestone members (Silverdale Formation) in the Yass Basin (Thomas & Pogson 2011), and *E. latum* is found in older Wenlock strata at Glenbower to the west (Hill 1940). The genera *Pycnostylus*, *Cystiphyllum* and *Tryplasma* are also common to both the Jack Formation and Yass Basin.

In the Wellington district (central New South Wales) *E. latum* and *T. derrengullenense*? were recorded in probable Ludlow sediments of the Mumbil Group (see Strusz 1961; McLean 1975a; Vandyke & Burnes 1976), and *T. derrengullenense*? ranges into overlying Early Devonian strata, but at that level has probably been reworked from underlying Silurian limestone (D.L. Strusz pers. comm. 2015).

Stylopleura liliiforme is known from the Ludlow of Victoria (Chapman 1920), and *E. latum* also occurs in the Wenlock?–Ludlow of Tasmania (Hill 1942a).

Of the other genera of the *Entelophyllum* fauna, *Ptychophyllum* and *C. (Hedstroemophyllum)* occur in the upper Llandovery Quarry Creek and Rosyth Limestones (New South Wales), and *Dokophyllum* is known from the Rosyth Limestone (as *Ketophyllum*: McLean 1974a, 1975b). Species of *Amplexoides* are until now known only from Llandovery strata in Australia; two species are present within the late Llandovery Quinton Formation in the northern Graveyard Creek Subprovince (Munson & Jell 1999) and a single species was recorded from the Panuara area of central NSW (McLean 1985).

Only a few elements of the *Entelophyllum* fauna are sufficiently similar to overseas forms to be of value for international correlation. Faunas from Asia, Europe and North America contain several genera in common with those of the Jack Formation, but the species are generally dissimilar.

Entelophyllum, *Tryplasma*, *Ketophyllum* and *C. (Hedstroemophyllum)* are common in Silurian deposits of Asia, and *Stylopleura* is known from the middle Ludlow of the Urals and the Eifelian of Salair (see Pedder 1985). *Ptychophyllum* occurs in the Wenlock of China as *P. "Nanshanophyllum"* (Yu 1956) and *C.?* (*Cystiphyllum*) might be present in Llandovery deposits of Dolgiy Island and the Siberian Platform as *Cystilasma Zaprudskaya & Ivanovskiy* 1962. *Multicarinophyllum* has been previously recorded from Lower Devonian to Givetian strata of central Asia (Ivanovskiy 1970). Species of *Entelophyllum*, *Dokophyllum*, *Tryplasma*, *Cystiphyllum* (*Cystiphyllum*), and *C. (Hedstroemophyllum)* have all been recorded in the Silurian of Europe, and species of *Pycnostylus*, *Ptychophyllum*, *Tryplasma*, *Entelophyllum*, *Dokophyllum* and *C. (Cystiphyllum)* have been found in the Silurian of North America (see Systematic Palaeontology for more details and references).

At the species level, *Entelophyllum patulum yassense* probably occurs in the Late Silurian of Inner Mongolia (Guo 1978), and *Stylopleura liliiforme* possibly occurs in the Ludlow of Germany as *Amplexus (Coelophyllum) eurycalix* Weissermel 1894.

SYSTEMATIC PALAEOLOGY

All fossil specimens are part of the Queensland Museum collection (ex University of Queensland, Department of Earth Sciences), and are prefixed with their original UQF numbers; UQL numbers refer to fossil localities in the Department of Earth Sciences locality catalogue. UQL numbers are listed in Appendix 1, and are shown on Fig. 5. Systematic descriptions are arranged following the suprageneric classification of Hill (1981).

Class Anthozoa Ehrenberg 1834

Subclass Rugosa Milne-Edwards & Haime 1850

Order Cystiphyllida Nicholson in Nicholson & Lydekker 1889

Family Tryplasmatae Etheridge 1907

Subfamily Tryplasmatinae Etheridge 1907

Genus *Tryplasma* Lonsdale 1845.

Type Species. *Tryplasma aequabile* Lonsdale 1845: 613–614, 633, pl. A, figs 7, 7a (see Ivanovskiy & Shurygina 1975: 15). Early Devonian or Eifelian, east slope of Ural Mountains, Kavka R. (subsequent designation, Etheridge 1907: 42).

Diagnosis. Corallum solitary or with one or more parricidal offsets from calice, but not forming fasciculate coralla; may have epithecal scales; with narrow peripheral stereozone of contiguous laminar bases of commonly short rhabdacanthine, holacanthine, or dimorphacanthine septa, trabeculae free distally; tabulae complete, commonly subhorizontal, some with median notch; dissepiments absent (Hill 1981: F98).

***Tryplasma derrengullenense* Etheridge 1907**

Fig. 6

Tryplasma derrengullenense Etheridge 1907: 88, pl. 22, figs 5–8; Hill 1940: 407, pl. 12, fig. 16.

Tryplasma derrengullenense?; Strusz 1961: 345–346, pl. 42, fig. 14, pl. 43, fig. 12.

Tryplasma sp. cf. *derrengullenense*; Hill *et al.* 1969: s.12, pl. S VI, figs 2–3.

Lectotype (designated Hill 1940: 407). F9789, Australian Museum, Ludlow, Limestone Creek, near Bowning, Yass Basin, New South Wales. Figured in Etheridge (1907: pl. 22, fig. 8).

Material. UQF72681–72683, 72685–72686, 72694 from UQL4002; UQF72684 from UQL4009; UQF72687, 72691–72692 from UQL4336; UQF72688 from UQL4004; UQF72689 from UQL4003; UQF72690, 72693 from UQL4335.

Diagnosis (modified from Hill 1940). Small, solitary, trochoid or ceratoid *Tryplasma* with irregular rejuvenescence; calice very deep. Small, fine trabeculae on distal surfaces of tabulae.

Description. Solitary, trochoid or ceratoid, with frequent rejuvenescence, succeeding calices not being greater in diameter than the original; resulting in an irregular corallum shape. Epitheca longitudinally ridged. Maximum observed diameter 18 mm, maximum length more than 4.5 cm. Calice very deep, flat-floored, bears numerous spines in vertical series, each series representing a septum. Thin-walled rootlets, 1–2 mm in diameter and lacking transverse partitions, may be developed.

Two orders of septa numbering between 78 and 86 in largest specimens. Septa composed of rhabdacanthine trabeculae directed upwards and inwards at 30–50° from the horizontal, sometimes piercing several tabulae. Major septa up to 3 mm long, minor septa slightly shorter. Small trabeculae, representing axial continuations of septa, borne on distal surfaces of tabulae. Tabulae complete or in some cases incomplete, spaced at 8–12 per cm, flat, rarely flexuous or gently sagging, commonly slightly upturned at periphery of corallite. Peripheral stereozone 1–2 mm-wide, showing indistinct lamination parallel to epitheca.

Remarks. Specimens vary in width from 5 to 18 mm, but as septal numbers can be correlated with corallum diameter, they are likely to be conspecific (Fig. 7). Tabulae completeness also varies; UQF72684 has sagging, dominantly incomplete tabulae (Fig. 6B), whereas UQF72686 has complete, planar or slightly flexuous plates (Fig. 6E). Complete and incomplete tabulae may be developed in one corallum, indicating that this variation is intraspecific.

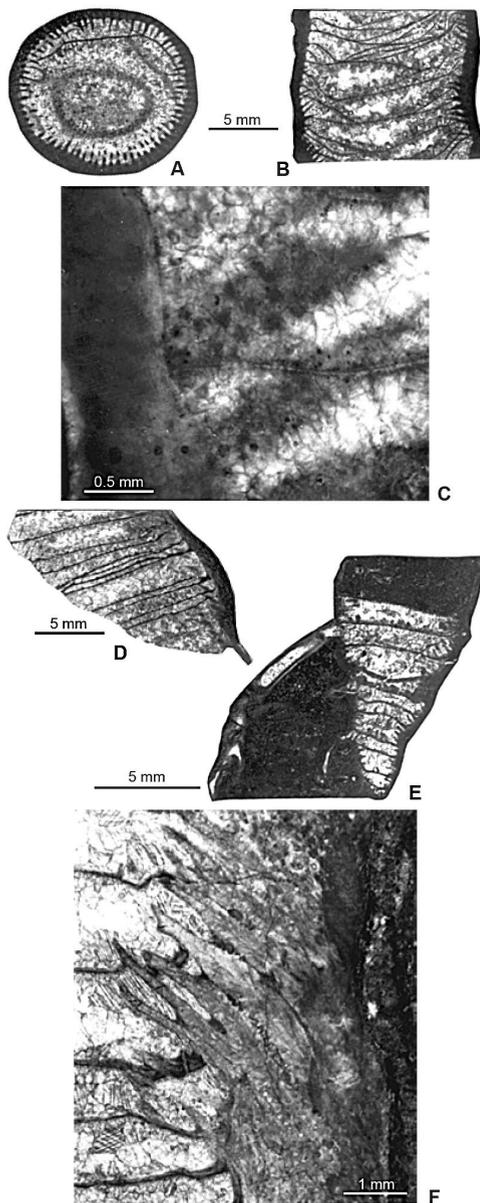


FIG. 6. *Tryplasma derrengullenense* Etheridge 1907. A-C, UQF72684 from UQL4009; A, B, transverse and longitudinal sections; C, portion of B, showing rhabdacanthine septal spines; D, UQF72687 from UQL4336, longitudinal section; E, UQF72686 from UQL4002, longitudinal section, showing rootlets; F, UQF72681 from UQL4002, portion of longitudinal section, showing piercing of tabulae by septal trabeculae.

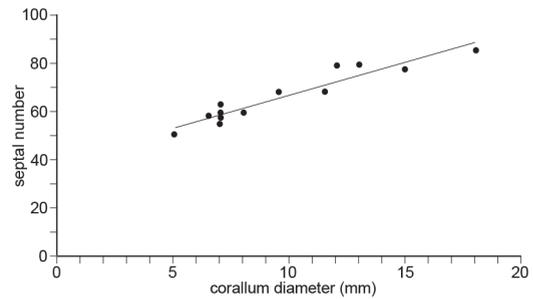


FIG. 7. Linear least squares plot of corallite diameter against septal number (correlation coefficient 0.91) for Jack Formation specimens of *Tryplasma derrengullenense* Etheridge 1907.

Tryplasma derrengullenense is distinguished from other species of *Tryplasma* by its size and septal number, and by its tabular trabeculae. Of other Australian species, it most closely resembles *T. columnare* Etheridge 1907, from the Wenlock to Early Devonian of NSW, which has a larger, more regular corallum but fewer septa (60–80 at a diameter of 25 mm).

Strusz (1961) described poorly preserved internal moulds of a solitary coral from the Wellington district (New South Wales) as *T. derrengullenense*?. The specimens were collected from a breccia in the early Lochkovian Cuga Burga Volcanics, and have probably been reworked from underlying Silurian limestone. Minor septa in that species tend to be expressed as rows of holes, whereas the bases of the major septa are continuous, so forming distinct grooves (D.L. Strusz, pers. comm. 2003, 2015). The species was tentatively identified from the size of the corallum, the septal number and by “the depth of the grooves left by the weathering of the septa”. It reaches a larger diameter, and has more septa than other specimens of *T. derrengullenense* (100–120 at the largest diameter of about 25 mm), and is therefore only tentatively included in the synonymy.

Distribution and Range. Wenlock and Ludlow of Broken River Province (north Queensland; Fig. 4); Gorstian and earliest Ludfordian of Yass Basin (New South Wales); early Lochkovian (probably reworked Silurian) of Wellington district? (New South Wales).

Tryplasma sp.

Fig. 8

Material. UQF72702 from UQL4004; the specimen is badly worn.

Description. Corallum probably cylindrical, external and calical features unknown. Specimen is 19 mm in diameter and has 58 major and minor septa over an arc of 250°, giving an estimated total of 84. Major septa about 2 mm long, slightly longer than minor septa. Septa embedded in narrow peripheral stereozone (<1 mm wide). Septal trabeculae usually directed upwards and inwards at very low angle (0–10°). Microstructures generally obscured by recrystallisation. Tabulae complete, evenly spaced (5–6 per cm), horizontal or slightly sagging, typically upturned peripherally.

Remarks. This species is very similar to Broken River specimens of *T. derrengullenense* Etheridge 1907, but has a slightly larger corallum; slightly smaller, more shallowly inclined septal spines, and lacks tabular trabeculae. Fragments of a coral from the Early? Devonian of the Tamworth district (New South Wales), referred to as *Tryplasma* sp. by Hill (1942b), closely resemble this form, differing only in having slightly more distant tabulae.

Genus *Aphyllum* Soshkina 1937

Type Species. *Aphyllum sociale* Soshkina 1937: 45–46, pl. 7, figs 1–4. Late Wenlock, west slopes of the Ural Mountains, right bank of Tury River, near Yelkino (by original designation).

Diagnosis. Fasciculate, increase lateral or peripheral and pseudoaxial; may have epithelial scales; corallites with acanthine septa and narrow peripheral stereozone of contiguous laminar septal bases from which discrete rhabdacanthine or holacanthine trabeculae are directed inward and commonly upward; tabulae complete, horizontal, in some with median notch, or slightly curved (Hill 1981: F100).

Aphyllum pachysteles sp. nov.

Fig. 9

“*Tryplasma*” sp. Hill *et al.* 1969: s.12, pl. S VI, fig. 1.

Etymology. Greek pachys = thick, stele = pillar, column, referring to the robust corallites of this species.

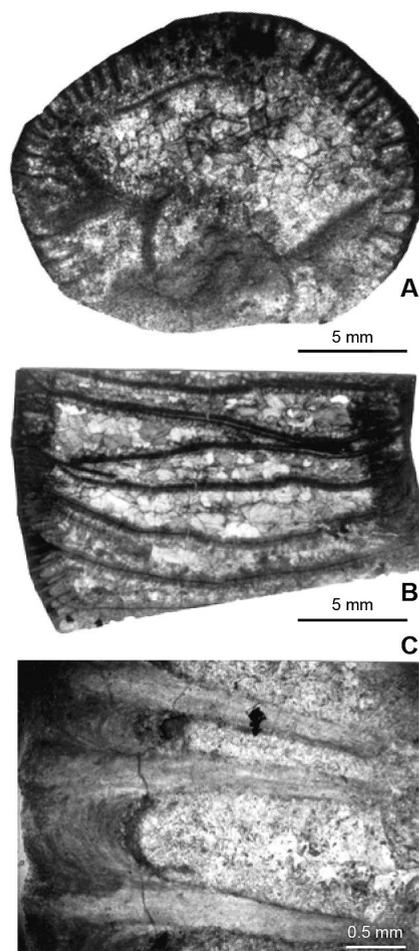


FIG. 8. *Tryplasma* sp., UQF72702 from UQL4004. A, B, transverse and longitudinal sections; C, portion of A, showing microstructures of wall and septa.

Holotype. UQF72695 from UQL4004. Late Wenlock, Jack Formation, Graveyard Creek Group, Jack Hills Gorge area, north Queensland.

Material. UQF72695–72698, 72700, 72699 (27 serial sections) from UQL4004; UQF72701 from UQL4010.

Diagnosis. Large *Aphyllum* with parricidal increase; 110–120 major and minor septa; septal trabeculae rhabdacanthine. Tabulae flat or gently arched. Connecting processes and rootlets common.

Description. Corallum large, fasciculate. Corallites cylindrical, straight or slightly curved, separated by up to 2–3 cm. Maximum diameter 25–30 mm,

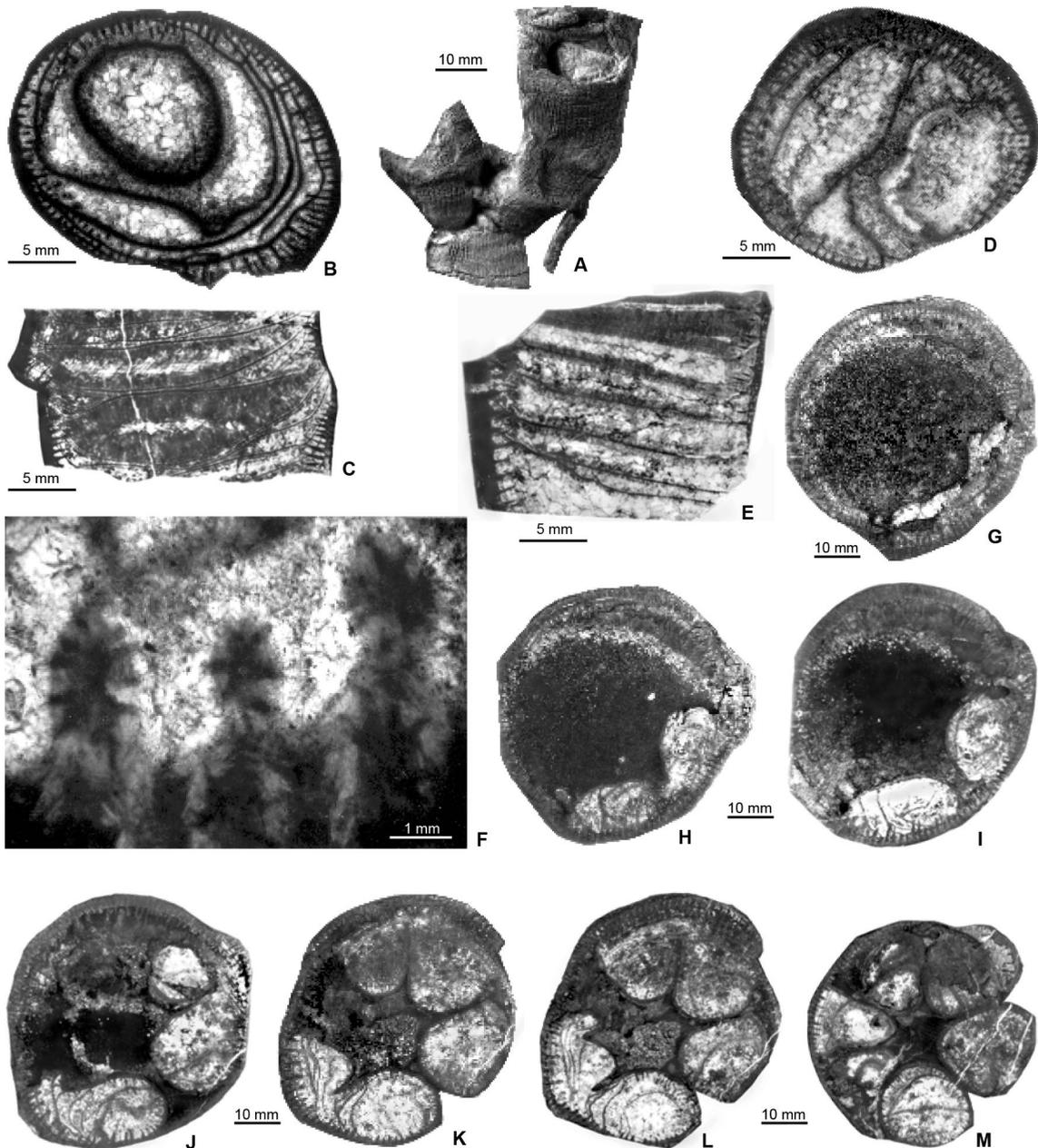


FIG. 9. *Aphyllum pachystele* sp. nov. A–B, UQF72698 from sUQL4004; A, exterior of corallum, showing rootlet and connecting processes; B, transverse section; C, UQF72697 from UQL4004, longitudinal section. D–F, UQF72695, HOLOTYPE from UQL4004; D, E, transverse and longitudinal sections; F, portion of D, showing rhabdacanthine trabeculae; G–M, UQF72699 from UQL4004, selected serial transverse sections showing peripheral increase; distances show cumulative distal growth from first section; G, 0 mm; H, 1 mm; I, 2 mm; J, 3.5 mm; K, 5.5 mm; L, 6.5 mm; M, 10.5 mm.

maximum observed height 8–10 cm. Connecting tubules and small rootlets common, 1–2 mm in diameter, with thin, irregular, transverse partitions. Epitheca longitudinally ridged with faint growth striations.

There are 110–120 rhabdacanthine major and minor septa. Major septa 20–25 mm long; minor septa 0.5–0.6 length of major septa and buried in, or extending just beyond 1 mm-wide peripheral stereozone. Septal trabeculae form discrete spines, directed upwards and inwards at 5–10° from horizontal, spaced vertically at 8–12 per cm. Rhabdacanthine ‘rods’ closely spaced, diverge steeply from trabecular axis in broad curves, their ends are directed almost normally to that axis. Lateral processes have thick walls showing distinct lamination parallel to their exteriors. Connecting tubules are narrow extensions of wall and lumen of one corallite to another, may have irregularly spaced, thin, flexuous transverse partitions.

Tabulae flat or gently sagging, mostly complete, spaced about 4–5 per cm, commonly with upturned edges. Dissepiments absent.

Increase. Increase is parricidal. In UQF72699, six offsets are formed at different levels around the periphery of the parent calice, and were examined in 27 serial transverse sections (see Fig. 9G–M). The two lowermost offsets appear as a thin, irregular wall, attached to the axial ends of the major septa on one side of the parent calice (Fig. 9G). Once developed, this wall expands axially into the calice and becomes separated from the major septa. Simultaneously, the midpoint of the wall develops an invagination that enlarges until the two developing corallites are defined (Fig. 9H, I).

Septa of the parent calice that are enclosed by the walls of an early offset are incorporated into the offset’s morphology. Other septa develop as the offset takes shape: firstly, a few stubby, major septa appear at points opposite the axial ends of the major septa of the parent; then additional major septa are inserted and

finally minor septa. Septa then lengthen to differing extents, the major septa reach 1 mm in a corallite of 9 mm diameter. Concurrently, the inner walls of the offset are modified until it assumes a sub-circular shape, and grows free of the parent calice. Daughter corallites formed after the first two offsets display slightly different development. Initially, the wall of the earlier corallite bulges laterally near the calical margin of the parent. This ‘bud’ expands along the periphery of, and incorporates septa from the old calice. An invagination forms and deepens between it and the earlier offset, and development then proceeds as described above (Fig. 9J–M).

During increase, a sub-bilateral symmetry is imposed on the parent corallite; the symmetry plane being between the earliest two and the last two offsets. Offsets to either side of this plane do not necessarily develop in pairs or at the same rate. When all are formed, they are fairly evenly arranged around the old calice.

Remarks. A specimen from the “lower part” of the Jack Formation, illustrated by Hill *et al.* (1969) as “*Tryplasma*” sp., has corallites with relatively long major septa (to 3 mm); a wide peripheral stereozone (to nearly 2 mm); and flat or slightly arched tabulae. The specimen otherwise closely resembles the holotype of *A. pachystele*.

The new species is distinguished from other Australian *Aphyllum* by its large robust appearance and numerous septa. *A. lonsdalei* (Etheridge 1890), and *A. delicatula* (Etheridge 1907), both from the early to middle Ludlow of New South Wales, and *A. leptostylum* Munson & Jell 1999 from the late Llandovery of the Quinton Formation, Broken River Province, all have much smaller corallites with maximum diameters of 6–8 mm, 3 mm, and 5 mm, respectively. *A. murrayi* (Etheridge 1907) from the Devonian of Victoria also has smaller corallites (ca 12 mm) and fewer septa (about 50) of one order.

Distribution and Range. Late Wenlock and Ludfordian of Broken River Province, north Queensland (Fig. 4).

Family Cystiphyllidae Milne-Edwards
& Haime 1850

Genus *Cystiphyllum* Lonsdale 1839

Diagnosis. Solitary, turbate to cylindrical; major and minor septa long, each represented by trabeculae typically developed only on upper surfaces of successive globose dissepiments and tabellae; sclerocones not strongly developed, thicker and more continuous peripherally than axially; calicular floors inversely conical, inclination of dissepiments and tabellae commonly similar (Hill 1981: F113).

Cystiphyllum (*Cystiphyllum*) Lonsdale 1839

Type Species. *Cystiphyllum siluriense* Lonsdale 1839: 691, pl. 16, figs 1, 1a, non 2. Middle Silurian, Much Wenlock Limestone Formation, Dudley, Worcestershire, UK.

Diagnosis. Axis of sclerocones centric, thickening weak, commonly absent on tabellae; trabeculae grain-like, to moderately long and contiguous, to separate (Hill 1981: F113).

Cystiphyllum? (*Cystiphyllum*) sp.

Fig. 10A, B

Material. UQF72632 from UQL4002; the specimen occurs within a corallum of *Entelophyllum patulum yassense* (Etheridge 1892a), and is almost completely buried in matrix.

Description. Small cylindrical corallum, 12 mm in diameter, at least 4 cm high. Calice not preserved, exteriors not visible. Septa absent. Dissepiments small, globose, steeply inclined peripherally, may be shallower adaxially. Axial region 7–8 mm wide, composed of larger, more elongate and globose plates that are sub-horizontally or shallowly based. Towards the margins, these “tabellae” are difficult to distinguish from dissepiments.

Remarks. The single specimen was recovered from the Coral gardens member; a number of other specimens probably of this species were identified within the Jack Hills member, but could not be extracted from massive limestones.

Forms that differ from *Cystiphyllum* only in lacking septa have previously been included

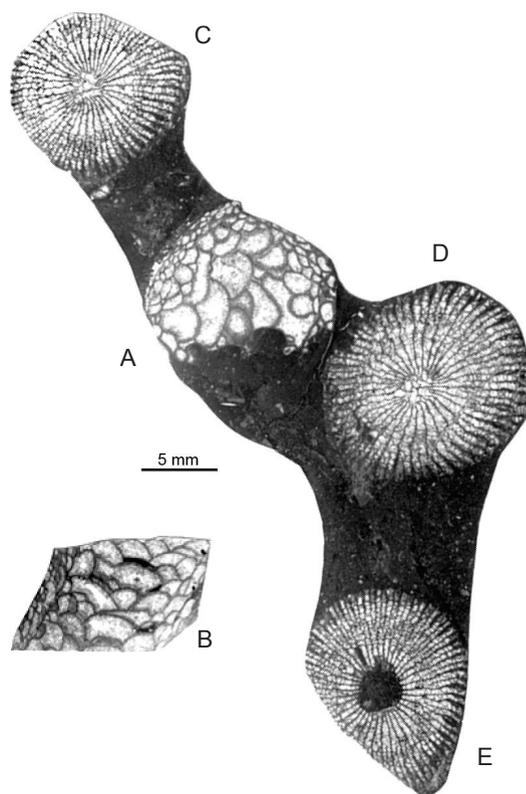


FIG. 10. A–B, *Cystiphyllum?* (*Cystiphyllum*) sp., UQF72632 from UQL4002; A, B, transverse and longitudinal sections; C–E, *Entelophyllum patulum yassense* (Etheridge 1892a), UQF72631 from UQL4002, transverse sections showing thickened septa.

in *Cystilasma* Zaprudskaya & Ivanovskiy 1962, although Hill (1981) tentatively regarded the two genera as synonymous. Species of *Cystilasma* are known from the Llandovery of Dolgiy Island (Arctic USSR) and the late Llandovery of the Siberian Platform. The type species, *C. sibiricum* Zaprudskaya & Ivanovskiy 1962, differs from the Broken River species in having much coarser dissepiments. If the two forms are congeneric, the range of *Cystilasma* would be extended into the Ludlow [i.e. similar to that of *C. (Cystiphyllum)*], and there would be little biostratigraphic value in separating the two genera. Thus, following Hill (1981), the Broken River form is tentatively included in *C. (Cystiphyllum)*.

Cystiphyllum? (*Cystiphyllum*) sp. lacks septal trabeculae, but otherwise closely resembles some New South Wales' specimens of *C. (C.) siluriense cylindricum* Lonsdale 1839, which have small rare septal spines, similar elongated, tabellae-like axial plates and a similar lack of "lamellar sclerenchyme tissue" (McLean 1974b: pl. 1, figs 4, 7). However, other specimens of *C. (C.) s. cylindricum* have numerous long septal spines and greatly thickened horizontal elements (McLean 1974b: text-fig. 3c). There appears to be continuous variation between these two forms.

Distribution and Range. Late Gorstian and Ludfordian of Broken River Province, north Queensland (Fig. 4).

**Genus *Cystiphyllum* (*Hedstroemophyllum*)
Wedekind 1927**

Type species (by original designation) *Hedstroemophyllum articulatum* Wedekind 1927: 65, 67, pl. 21, figs 1, 2, pl. 26, figs 6–12. Silurian, middle part of horizon III of Hedström. Northwest coast of the Isle of Gotland, Sweden.

Diagnosis (after Hill 1981). Trabeculae long?tufted monacanth, continuous through several successive calicular floors, separate except for their bases in wall or on sclerocones, sclerocones commonly thin especially in axial parts.

Remarks. *Cystiphyllum* (*Hedstroemophyllum*) was considered to differ from *Holmophyllum* Wedekind 1927 (type species, *H. holmi* Wedekind 1927, from the Silurian of Gotland) in having monacanthine, as opposed to rhabdacanthine trabeculae; a less sharply marked junction between the tabularium and the dissepimentarium; and inversely concave tabularial floors, with scattered large, convex plates, rather than the flat or concave floors that are common in *Holmophyllum* (Jell & Hill 1970; McLean 1974b). As Jell & Hill pointed out, further study of the Gotland material was needed as Wedekind's original descriptions failed to adequately define (differentiate) the two genera.

Cystiphyllum (*Hedstroemophyllum*) differs from *C. (Cystiphyllum)* Lonsdale 1839, principally in

having longer septal spines that penetrate several dissepiment layers (McLean 1974b; Hill 1981).

Australian species of *C. (Hedstroemophyllum)* were discussed by McLean (1974b).

***Cystiphyllum* (*Hedstroemophyllum*) sp.
Fig. 11**

Material. UQF72633 from UQL4002; the specimen is worn and partially embedded in matrix.

Description. Corallum probably cylindrical or weakly curved, 12 mm in diameter and at least 25 mm high; proximal end and calice missing, exterior not visible.

Septal spines based on wall, dissepiment crests and tabulae. Twenty-one 'rows' of spines over a peripheral arc of 135° give estimated total of 56. Major and minor septa indistinguishable. Septal spines 0.1–0.15 mm thick, directed upwards and inwards at 30–40° from horizontal towards periphery, steep to nearly vertical towards axis; longest spines pierce five tabular plates. In transverse section, they appear as short, radially arranged 'rows' of spines around corallum margin and as small 'dots' in axial region. Partially recrystallised septal spines deeply inset in corallum wall may have dark medial lines, indicating that they were originally monacanthine trabeculae. Corallum wall 0.1–0.2 mm thick, with indistinct lamination parallel to exterior of corallum.

Dissepiments globose or weakly to strongly elongate, steeply inclined inwards at about 60°

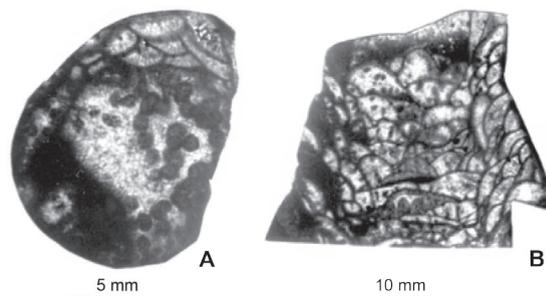


FIG. 11. *Cystiphyllum* (*Hedstroemophyllum*) sp., UQF72633 from UQL4002. **A**, transverse section; **B**, longitudinal section.

from the horizontal at periphery. Large, weakly domed tabulae and smaller globose tabellae developed across 6–7 mm wide axial zone.

Remarks. The only other described Australian species of *C.* (*Hedstroemophyllum*) is *C. (H.) crebrum* (McLean 1974b), from the upper Llandoverly Quarry Creek and Rosyth Limestones of New South Wales. The north Queensland specimen differs in having slimmer, shorter septal spines that are strongly developed over the axial region and less prominent in the dissepimentarium.

Hill *et al.* (1969) illustrated a fasciculate specimen from the “upper part of the Jack Formation” as “*Hedstroemophyllum*” sp., coralla of which differ from the present specimen in being larger, and in having numerous, strongly radially arranged septal spines, a very wide dissepimentarium and an axial region that lacks well developed spines. That species resembles *C. (H.) nikiforovae* Strelnikov 1971 from the Late Silurian of the Subpolar Urals, but is larger, and has more septa and a wider dissepimentarium. All three forms are known only from single specimens and their relationships are unclear. The species described here could be a juvenile of Hill *et al.*'s specimen.

Distribution and Range. Late Gorstian or early Ludfordian of Broken River Province, north Queensland (Fig. 4).

Order Stauriida Verrill 1865

Suborder Stauriina Verrill 1865

Family Pycnostylidae Stumm 1953

Genus *Pycnostylus* Whiteaves 1884

Type Species. *Pycnostylus guelphensis* Whiteaves 1884: 3, pl. i, figs 1–16. Wenlock, Guelph Formation, Ontario, Canada (subsequent designation, Miller 1889: 202).

Diagnosis. Fasciculate, increase peripheral, commonly four offsets simulating axial quadripartite increase; corallites with very narrow peripheral stereozone; septa amplexoid, peripheral continuous part very short; no dissepiments; tabulae complete, horizontal (Hill 1981: F140).

Remarks. The synonymy, distribution and taxonomic relationships of *Pycnostylus* were discussed by Munson & Jell (1999).

Pycnostylus polyphyllodus sp. nov.

Fig. 12

Pycnostylus sp. cf. *guelphensis* Whiteaves 1884; Hill *et al.* 1969: s.12, pl. S VI, fig. 6.

Etymology. Greek polys = many, phyllon = leaf, referring to the numerous septa in this species.

Holotype. UQF72664 from UQL4004. Late Wenlock, Jack Formation, Graveyard Creek Group, Jack Hills Gorge area, north Queensland.

Material. UQF72664–72666, 72668 from UQL4004; UQF72667 from UQL4326.

Diagnosis. *Pycnostylus* with small corallites having 80–90 major and minor septa, and thin peripheral stereozone; septal ridges short. Tabulae flat or gently arched, commonly with upturned edges.

Description. Fasciculate holotype corallum an irregularly shaped weathered fragment, 10–15 cm in diameter 14 cm high. Corallites in contact, or separated by 2–4 cm, slender, cylindrical, subparallel and slightly flexuous, with diameters averaging 6–7 mm, maximum 8 mm. Epitheca longitudinally ridged, with fine transverse growth lines. Calice deep, with flat sides and base.

Two orders of septa radially arranged, number between 80 and 90. Septa thin, amplexoid, extending 1–2 mm towards axis as low ridges on distal surfaces of tabulae. Vertically continuous sections of major septa reach 1 mm in length; minor septa 0.6–0.8 length of major septa. Septal trabeculae fine, closely spaced, directed upwards and inwards at 30–40° from horizontal. Peripheral stereozone up to 0.5 mm thick, axially concave between septa, and indistinctly laminated parallel to corallite exterior.

Tabulae thin, complete, planar or rarely flexuous, slightly arched or horizontal, commonly with upturned edges; spacing 3–6/cm. Increase axial, typically quadripartite.

Remarks. *P. polyphyllodus* is distinguished from other Australian species of *Pycnostylus* by its small corallites, numerous septa and thin peripheral

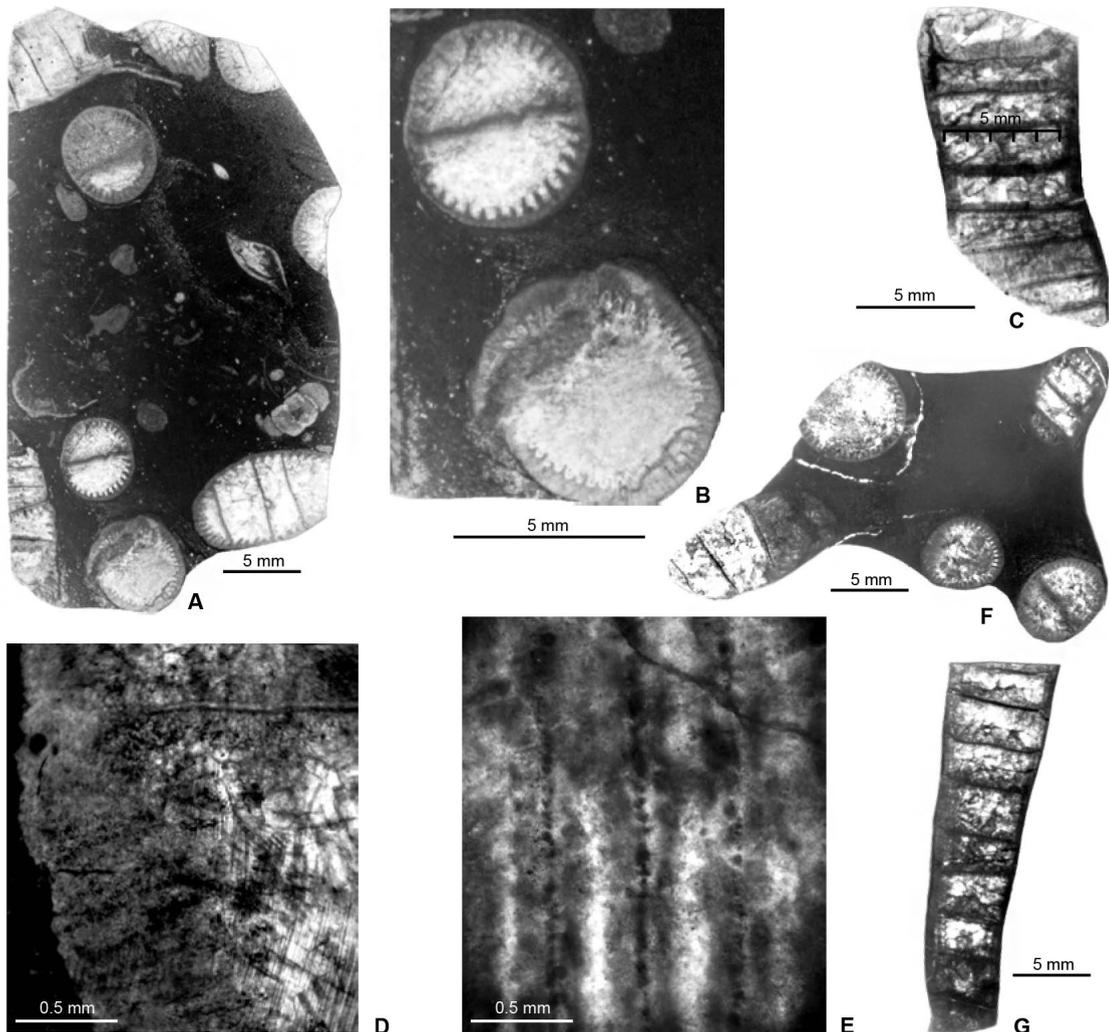


FIG. 12. *Pycnostylus polyphyllodus* sp. nov. A-E, UQF72664, HOLOTYPE, from UQL4004. A, transverse and oblique sections of several corallites; B, enlargement showing two corallites. Note trace of tabula on lower-left corner of lower corallite, showing amplexoid septal ridges; C, longitudinal section; D, portion of C, showing septal trabeculae and thin tabula. E, tangential section through corallite periphery, showing closely spaced trabecular axes. F-G, UQF72665 from UQL4004; F, transverse and oblique sections of several corallites; G, longitudinal section.

stereozone. *P. congregationis* (Etheridge 1907) from the Gorstian to earliest Ludfordian of the Yass Basin has corallites 10–15 mm in diameter with numerous connecting process arranged in tiers. The two orders of septa total between 34 and 36, and extend almost to the axis as low ridges on the distal surfaces of the tabulae (Hill 1940). *P. dendroides* (Etheridge 1907) also from

the early–middle Ludlow of the Yass Basin, has a dendroid corallum, with corallites averaging 12 mm in diameter and expanding to 15 or 20 mm just before increase. Major and minor septa are indistinguishable and number about 55 (Hill 1940). Both of these species are distinct from *P. polyphyllodus*.

The new species most closely resembles the type species, *P. guelphensis* Whiteaves 1884, from the Wenlock of Canada. From Stearn's (1956) description of this species and from examination of a topotype (UQF3458) it differs from *P. polyphyllodus* in having corallites of slightly smaller diameter (5–6 mm); fewer than one-half the number of septa (30–40); and more closely spaced tabulae (ca 14 per cm).

Distribution and Range. Wenlock of Broken River Province, north Queensland (Fig. 4).

Family Amplexidae Chapman 1893

Genus *Amplexoides* Wang 1947

Type Species. *Amplexoides appendiculatus* Lindström 1883: 63–64, pl. 6, figs 7–8, Wenlock, Chaotien, Sichuan Province, China (by original designation).

Diagnosis. Corallum solitary, trochoid to sub-cylindrical, septa amplexoid, longitudinally continuous only in narrow peripheral stereozone, major septa extending adaxially only as long, low ridges developed on upper surfaces of complete, horizontal tabulae that may have downturned edges; minor septa short; no dissepiments (Hill 1981: F146–147).

Remarks. The synonymy, distribution and taxonomic relationships of *Amplexoides* were discussed by McLean (1977) and Munson & Jell (1999).

Amplexoides sp.

Fig. 13

Material. UQF72602 from UQL4006; UQF72603 from UQL4002; UQF72604 from UQL4008. All specimens badly worn.

Description. Corallum large, probably cylindrical or possibly ceratoid, approaches 3 cm in diameter; most complete specimen (UQF72602) is approximately 8 cm long. Poorly preserved calice of one specimen (UQF72602) appears to be shallow and flat-floored. Neither proximal ends nor epitheca preserved.

Two orders of septa; in UQF72603 105 septa over a peripheral arc of 300° give an estimated total of 126; UQF72602 has 128 septa. Major septa amplexoid, extending at least halfway

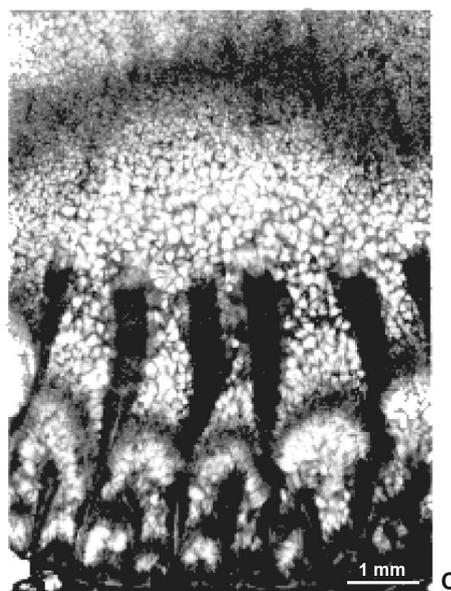
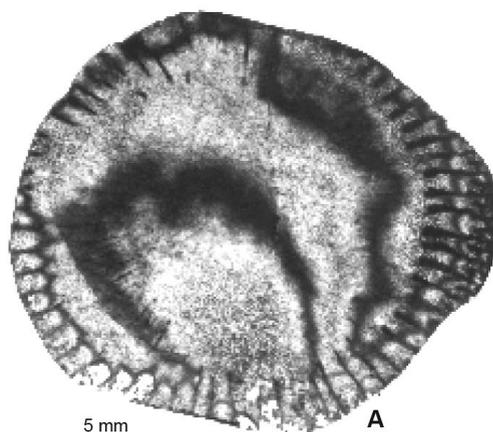


FIG. 13. *Amplexoides* sp., UQF72603 from UQL4002. **A, B**, transverse and longitudinal sections; **C**, portion of **A** showing structure of wall and rhopaloid amplexoid septa.

towards axis as very low ridges over upper surfaces of tabulae. Vertically continuous sections 4–5 mm long, slightly rhopaloid, i.e., axial ends slightly dilated and appear club-shaped in transverse sections. Minor septa 1–1.5 mm long, also slightly rhopaloid, but not amplexoid. Microstructure partly obscured by recrystallisation, particularly in areas of septal dilation. Septal trabeculae, visible only in small region of UQF72602, fine, closely spaced, directed upwards and inwards at low angle (30–40° from the horizontal). Corallite wall is up to 0.5 mm thick, with distinct lamination parallel to exterior of corallum, laminations concave towards interseptal loculi, forming small non-septal bulges similar to those described below in *Multicarinophyllum vepreculatum* sp. nov.

Tabulae mostly complete, flat or slightly domed, with downturned edges; area of downturning appears to be equivalent to zone where major septa are vertically continuous. Tabular spacing unequal; from nearly in contact to 4–5 mm apart. Tabulae finely laminated parallel to their bases.

Remarks. This is a large species with numerous septa, distinctive slightly rhopaloid septa and minor septa that are not amplexoid. Insufficient numbers of specimens and the very weathered coralla preclude a precise determination of the species.

Amplexoides grayense Munson & Jell 1999, from the upper Llandovery Quinton Formation in the north of the Graveyard Creek Subprovince, can be readily distinguished from this species by its very elongate, slightly smaller corallum (diameter to 23 mm), and fewer septa (maximum 76). *Amplexoides* sp. A, also from the Quinton Formation, is known from a single poorly preserved specimen that is slightly smaller (diameter 25 mm) than *Amplexoides* sp., but has a comparable number of septa (about 110). That species also has shorter amplexoid major septa, and major and minor septa are not dilated at their axial ends.

The only other described species of *Amplexoides* from Australia, *A. gephyra* McLean 1985, from the early Llandovery of New South Wales, has a probable trochoid or ceratoid corallum,

with a diameter of 25–36 mm, similar in size to *Amplexoides* sp., but also has proportionally fewer septa (80–90), and a less regular tabularium.

Etheridge, in Jack & Etheridge (1892b), described and illustrated a single coral fragment, from the Broken River area, as *Amplexus* sp. ind. The precise location of the specimen was not given, and it is of uncertain age; thus limiting its stratigraphic value. The specimen differs from those described above in having fewer septa (ca 30) and an apparently well developed aulos (Etheridge 1892b: pl. 37, fig. 16). Etheridge's description and figures are inadequate for precise identification, but the specimen is possibly referable to the late Paleozoic genus *Amplexocarinia* Soshkina 1928.

Distribution and Range. Late Gorstian and Ludfordian of Broken River Province, north Queensland (Fig. 4).

Suborder Streptelasmatina Wedekind 1927

Family Mucophyllidae Hill 1940

Genus *Stylopleura* Merriam 1973

Type Species. *Stylopleura berthiaumi* Merriam 1973: 34–35, pl. 3, figs. 6–20. Late Silurian, Roberts Mountains Formation, Roberts Creek Mountain, Nevada (by original designation).

Diagnosis. Fasciculate to sub-compound, with unequal corallites joined by connecting processes that may be hollow; mature calices flaring and trumpet-shaped; wall a narrow peripheral stereozone from which short laminar septa project adaxially as low ridges with little or no distinction between major and minor; tabulae complete, horizontal; no dissepiments; increase marginal, unequal (slightly modified after Hill 1981: F178).

Remarks. The synonymy, distribution and taxonomic relationships of *Stylopleura* were discussed by Merriam (1973) and Pedder (1985).

Stylopleura liliiforme (Etheridge 1907)

Fig. 14

? *Amplexus* (*Coelophyllum*) *eurycalix* Weissermel 1894: 634, pl. 50, figs 8, 9, pl. 51, fig. 1.

Tryplasma liliiformis Etheridge 1907: 95, pl. 14, figs 2, 3, pl. 15, figs 2, 3, ?4, pl. 17, figs 7, 8, pl. 24, fig. 1, pl. 25, fig. 8, pl. 27, figs 1, 2.

Tryplasma liliiformis Etheridge; Chapman 1920: 184, pl. 17, fig. 3. *Mycophyllum liliiforme* (Etheridge); Hill 1940: 401, pl. 11, figs 18, 19, pl. 12, figs 3–6.

Mucophyllum liliiforme (Etheridge); Hill *et al.* 1969: s.12, pl. S VI, figs 4–5.

Lectotype (selected Hill 1940: 401). F8892, Australian Museum, Silurian, Barber's Creek, off Derrengullen Creek, Bowning district, New South Wales; illustrated Etheridge 1907: pl. 15, fig. 3.

Material. UQF72657, 72662 from UQL4002; UQF72658–72660 from UQL4010; UOF72661 from UQL4332; UQF72663 from UQL4009; UQF60108, replacement slide from specimen illustrated by Hill *et al.* (1969: pl. S VI, figs 4, 5) from the Jack Formation, Jack Hills Gorge.

Diagnosis (modified from Hill 1940). Sub-compound *Stylopleura* with turbinate or trochoid stem, and thin, spreading calical rim; with scattered peripheral increase.

Description. Corallum large, commonly sub-compound; corallites liliaciform, with proximal trochoid or turbinate stems, and expanding bell-shaped but not everted calical rims, which reach maximum thickness of 3 mm. Offsets arise by peripheral increase from calical rim; 6 are present in UQF72657. Calice deep and flat floored, expands to 7.5 cm in diameter in largest specimen (UQF72657). Stem usually between 20 and 25 mm across; largest reaches 3 cm; longest complete stem measures 2 cm.

Corallite exterior marked by prominent radial lines corresponding to joins between dilated septa, and fine concentric growth lines. Edge of calical rim, where preserved, scalloped, the undulations occurring at septal junctions. Small, 1–2 mm wide rootlets may be developed over stem, and are thick-walled and hollow, commonly with irregularly and distantly spaced transverse partitions, flat or convex towards rootlet tip. No evidence found of an operculum, which Hill (1940) suggested might be present.

About 80 septa, major and minor septa indistinguishable, strongly dilated, laterally in contact except at tabularium, where all taper to abrupt, free spinose ends. Septa appear to continue across tabularium as rows of small fine spines completely buried in tabular thickening or occasionally with free distal ends. Septa may reach 2–3 mm wide at calicular edge in larger specimens. Septal trabeculae rhabdacanthine, typically spaced ca 1 mm apart, their axes directed normally to inner and outer surfaces of corallite wall and calical rim. Rhabdacanthine rods widely spaced, diverge from trabecular

axes in very broad arcs at ca 30° from axis. Dilated septa distinctly laminated parallel to their distal surfaces.

Tabulae complete or less commonly incomplete, flat or gently arched, usually spaced about 6–8 per cm but may be very close together; UQF60108 has 12 over vertical distance of 5 mm. Tabulae usually thin, but may be thickened to as much as 0.5 mm. Thickened tabulae laminated, laminae broadly and shallowly concave distally, appearing to 'lap' onto small tabular trabeculae which are fine and rhabdacanthine. Rootlet walls also laminated, reach a maximum thickness of 0.5 mm. Rootlet partitions much thinner, their laminae continuous with those of walls. Dissepiments absent.

Remarks. This species was assigned to *Stylopleura* by Pedder (1985: 588). The Broken River specimens differ from those previously assigned to *S. liliiforme* in possessing tabular trabeculae, and in having undifferentiated major and minor septa; other Australian specimens of the species have major and minor septa that are just distinguishable by length (Etheridge 1907; Hill 1940). All other diagnostic characters of *S. liliiforme* are present in the Broken River specimens.

Variation between specimens is slight, but the calical rim varies from less than 1 mm in UQF72663 to about 3 mm in UQF60108. The wall of the stem is usually thin (>1.5 mm) except in UOF72660, in which it is greatly thickened to 4 mm. However, that specimen, which is partially crushed, has a narrow calical rim (<2 mm) but is otherwise similar to the remaining material. The only other variation of any note between the specimens is in the degree of development of tabular trabeculae; weak in some corallites, relatively strong in others.

Distribution and Range. Late Gorstian and Ludfordian of Broken River Province, north Queensland (Fig. 4); Ludfordian of Yass Basin, New South Wales.

Family Amsdenoididae Hill 1981

Genus *Multicarinoephyllum* Spasskiy 1965

Multicarinoephyllum Spasskiy 1965: 24.

Multicarinoephyllum Spasskiy; Bulvankar *et al.* 1968: 16.

Multicarinoephyllum Spasskiy; Dubatolov & Spasskiy 1971: 107.

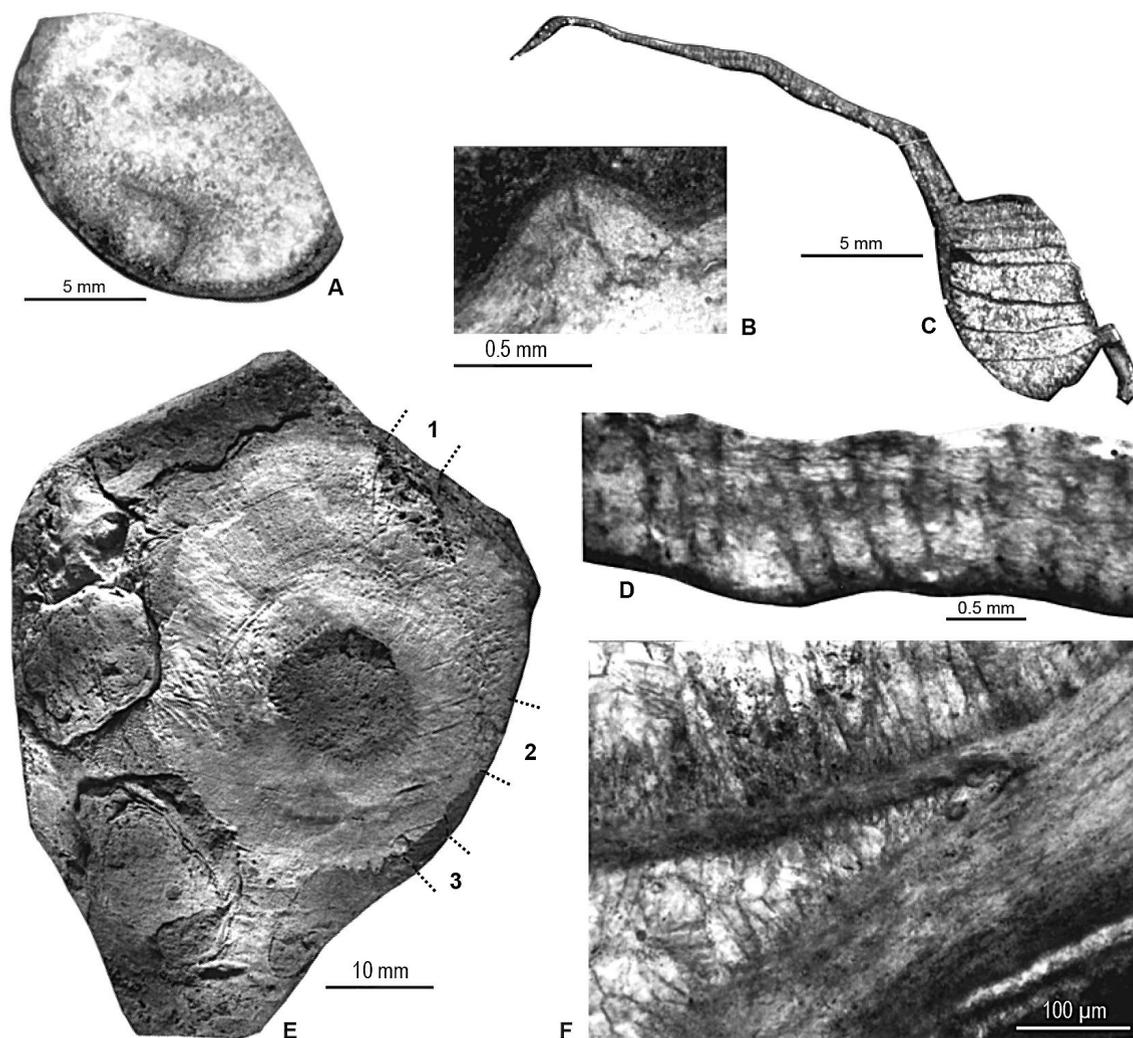


FIG. 14. *Stylopleura liliiforme* (Etheridge 1907). A, UQF72661 from UQL4332, transverse section of stem; B, UQF72658 from UQL4010, portion of transverse section through calice, showing rhabdacanthine septal trabeculae. C–D, UQF72659 from UQL4010; C, longitudinal section, showing stem with rootlet, and wide calice (missing at right); D, portion of C, showing microstructure of calical wall; E, UQF72657 from UQL4002, proximal view (stem missing), showing subcompound corallum; three visible daughter corallites, (left and lower part of figure), and position of three others (not visible in this view) marked 1–3; F, UQF72662 from UQL4002, portion of rootlet showing structure of wall and transverse partition (centre-left).

Type Species (by original designation, p.25). *Multicarinothylacium multicarinatum* Spasskiy 1965: 25, pl. 1, figs 1–2. Eifelian (early Middle Devonian), central Asia.

Diagnosis (modified from Dubatolov & Spasskiy 1971). Large ceratoid solitary coral. Epitheca with longitudinal ridges and transverse growth

annulations. Calice moderately deep with sharp edges. Fine, long major septa convolute axially; axial ends may be united. Minor septa 0.25–0.5 length of major septa. All are strongly vepreculate particularly towards the periphery where a stereozone or rare, large dissepiments may be present. Tabulae closely spaced,

incomplete, and usually domed, with many additional plates axially.

Remarks. *Amsdenoides* Sutherland 1965, was erected the same year as *Multicarinophyllum* and is a very similar genus. The type species of *Amsdenoides*, *A. acutiannulatum* (Amsden 1949) differs from *M. multicarinatum* in being smaller with fewer septa, in having vepreculae that are developed only on the major septa, and a less complex tabularium with only very sparsely developed tabulae. Kato & Minato (1977) suggested that the two genera might be synonymous, but Hill (1981) tentatively regarded them as distinct. *Amsdenoides* occurs in the Early Silurian (Telychian) of Japan (Kido 2009), Ludlow of North America (Sutherland 1965) and possibly the Early Devonian of north Queensland (Yu & Jell 1990).

The occurrence of vepreculae distinguishes *Multicarinophyllum* from several other genera that would otherwise superficially resemble it. These include *Grewingkia* Dybowski 1873, which also differs in having a less complex axial structure; *Tabulophyllum* Fenton & Fenton 1924, in which the major septa are withdrawn from the axis and do not form a vortex; *Dinophyllum* Lindström 1882, which also has shorter, almost rudimentary minor septa; and *Zmeinogorskia* Spasskiy (cited Dubatolov & Spasskiy 1971; original reference not quoted), which also has a less complex convoluted zone.

***Multicarinophyllum vepreculatum* sp. nov.**

Fig. 15

Dinophyllum sp.; Hill *et al.* 1969: p. s.10, pl. S V, fig. 2.

Etymology. Refers to the characteristic vepreculae of this form.

Holotype. UQF72613 from UQL4335. Ludfordian, Jack Formation, Graveyard Creek Group, Jack Hills Gorge area, north Queensland.

Material. UQF72605–72612, 72614–72615, 72617 from UQL4004; UQF72613 from UQL4335; UQF72616, 72618, 72620 from UQL4002; UQF72619 from UQL4334; UQF53982, from which a thin section was illustrated by Hill *et al.* (1969).

Diagnosis. Large, ceratoid or cylindrical *Multicarinophyllum*. Between 47 and 55 weakly or moderately convolute major septa; axial

ends commonly united. All septa vepreculate towards periphery. Cardinal septum short, in open cardinal fossula; alar fossulae weakly developed. Tabulae closely spaced, incomplete, slightly or moderately domed; peripheral plates commonly inclined upwards and outwards. Dissepiments absent.

Description. Corallum ceratoid or cylindrical; largest specimen (UQF53982) reaches maximum diameter of ca 40 mm and height of at least 120 mm. Longitudinal ridges corresponding to interseptal loculi, and transverse growth annulations mark epitheca. Calice wide, moderately deep, with flat sides and distally convex base.

Between 47 and 55 major septa usually reach axis where they tend to coalesce, though not all at same point, and are weakly or moderately convolute. Short cardinal septum about twice length of minor septa, and lies in open cardinal fossula that may be slightly expanded axially. Alar fossulae not prominent, usually recognisable by presence of contratingent septa on their counter sides. Minor septa 4–5 mm in length. Both orders of septa thin, with deep keels and slightly dilated peripheral ends. Vepreculae developed on all septa, more numerous towards periphery. Microstructures obscured in most specimens by recrystallisation, but rarely, in longitudinal section, axes of trabeculae appear as dark lines spaced ca 150 µm apart, and directed upwards and inwards at between 30° and 40° from the horizontal.

Marginal stereozone variable in thickness, reaches maximum of 3.5 mm across in holotype, and shows distinct lamination roughly parallel to epitheca. In interseptal loculi, laminae bulge axially to form stubby, non-septal projections with irregular medial dark lines; these may be weakly developed or 1–2 mm long. Incomplete tabulae fine, regular, close (as many as 15 per cm in holotype), slightly to moderately domed. Peripheral plates commonly inclined upwards and outwards at low angle. Dissepiments absent.

Remarks. Some variation is shown by this species: the marginal stereozone varies in thickness from less than 1 mm to 3.5 mm; the degree of axial convolution of the major septa

Silurian rugose corals Jack Formation

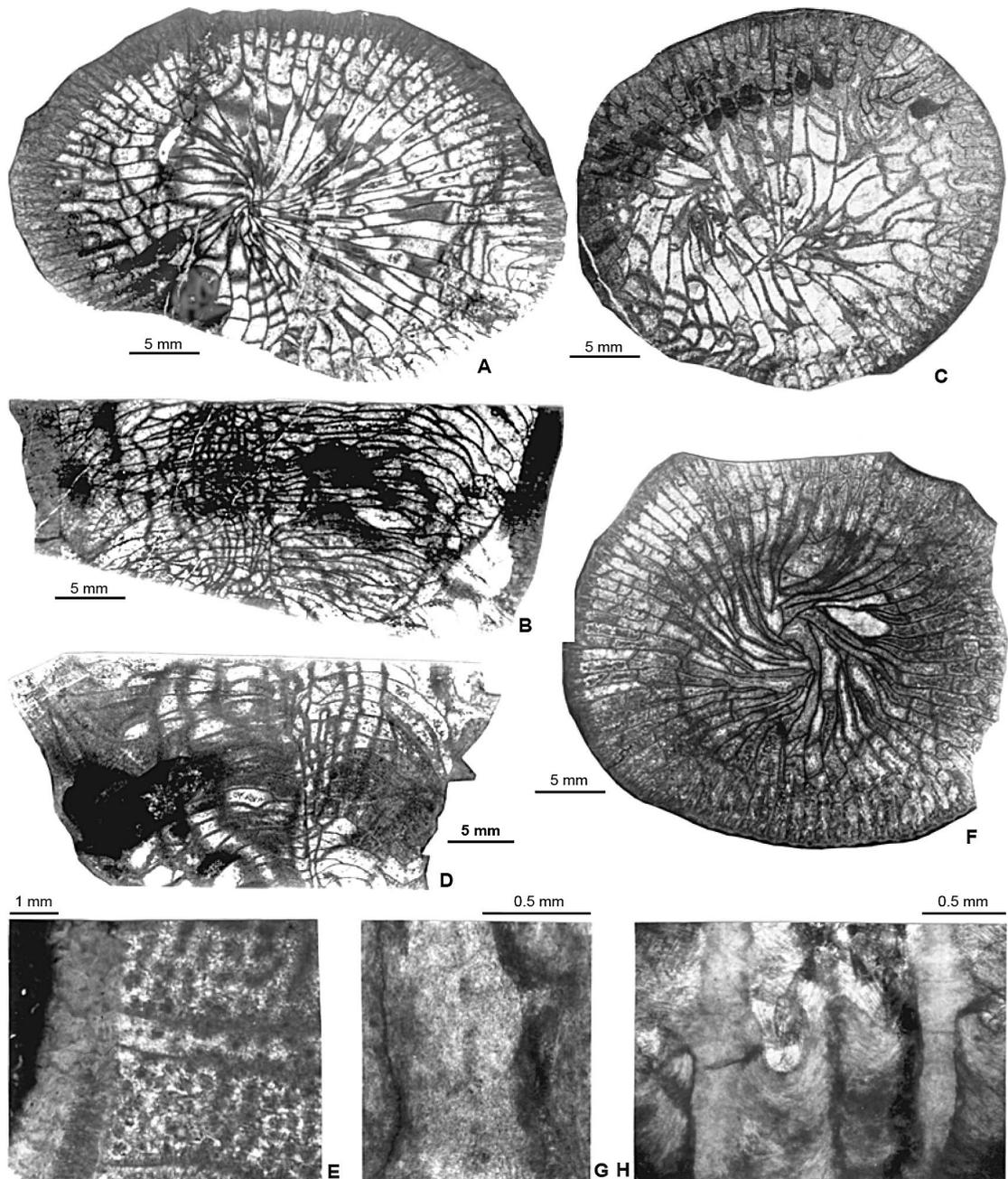


FIG. 15. *Multicarinophyllum vepreculatum* sp. nov. **A, B**, UQF72613 from UQL4335, HOLOTYPE, transverse and longitudinal sections; **C**, UQF72606 from UQL4004, transverse section; **D**, UQF72607 from UQL4004, longitudinal section; **E**, UQF72615 from UQL4004, portion of longitudinal section showing vepreculae; **F-H**, UQF72619 from UQL4334; **F**, transverse section; **G**, tangential section through periphery of corallum showing axes of septal trabeculae and longitudinal section of veprecula (right); note dark medial line (arrow); **H**, portion of **F** showing structure of wall.

may be weak or moderate; vepreculae are more numerous in some specimens than others; the non-septal bulges of the stereozone in the interseptal loculi may be weakly developed or 1–2 mm long. As the variation among specimens appears to be continuous, further subdivision of the taxon is of little value.

All three other recorded species of *Multicarinophyllum* are from central Asia. *M. multicarinatum* Spasskiy 1965, the type species, is closest to *M. vepreculatum*, but can be distinguished by the shape and structure of its tabulae; these are wavy and more complete, and the peripheral plates are inclined upwards and inwards rather than upwards and outwards as in the new species.

Multicarinophyllum cinctum Dubatolov & Spasskiy 1971 differs in possessing tabulae with a pronounced medial sag and septa that are dilated towards the periphery, coalescing into a thin stereozone. *M. concauum* Dubatolov & Spasskiy 1971, differs in having large, lonsdaleoid dissepiments which are absent in *M. vepreculatum*. *M. cinctum* and *M. concauum* are also distinguished by having major septa that may be withdrawn from the axis, and are much less convolute.

A poorly preserved species, *Amsdenoides? dubius* Yu & Jell 1990, from the overlying Early Devonian (Lochkovian–Pragian) Shield Creek Formation, is very similar to *M. vepreculatum*, but there are a number of significant differences. *Amsdenoides? dubius* is about one-half the diameter of *M. vepreculatum*, but has a similar number of septa (about 50). All specimens are abraded, so details of the corallum wall and the peripheral ends of septa are poorly known. Septa are dilated peripherally and gradually attenuate towards the axis, whereas those of *M. vepreculatum* are generally thin and are dilated only at their peripheral ends. The major septa in the younger species are commonly slightly withdrawn from the axis, whereas those of *M. vepreculatum* reach the axis and are usually conjoined. The tabulae of *A.? dubius* are sparsely developed, as is typical of *Amsdenoides*,

whereas those of *M. vepreculatum* are regular and close. Although these species are clearly related, these differences are sufficient to distinguish the two forms.

The vepreculae in *M. vepreculatum* appear to be prolongations of lateral, secondary trabeculae given off from the larger primary trabeculae. This is suggested by the presence of rare medial dark lines within vepreculae in tangential section (Fig. 15G) that are interpreted as probable remnant trabecular axes. The vepreculae are thicker than the rods of rhabdacanths, such as those of *Aphyllum pachystele* sp. nov. (Fig. 9F) and are longer and more prominent. They invariably project at right angles to the plane of the septum rather than radially as do the rods of rhabdacanths, and the rhabdacanths also differ in that they are formed entirely of rods; no distinct axial pillar occurs. Spacing is also important. The rods of the rhabdacanth are usually closely and uniformly spaced along its length, whereas the vepreculae in *M. vepreculatum* are more widely and irregularly spaced. Rhipidacanths, described by Jell (1969), more closely resemble vepreculae and are compound, consisting of a central primary trabecula from which short secondary trabeculae are given off at regular intervals. They are distinguished from the vepreculae in *M. vepreculatum* by the closer, more regular spacing of the non-spinose secondary trabeculae; these are similar in size to the primary trabecula, whereas vepreculae are smaller.

Distribution and Range. Late Wenlock and early Ludfordian of Broken River Province, north Queensland (Fig. 4).

Suborder Arachnophyllina Zavoronkova 1972

Family Entelophyllidae Hill 1940

Genus *Entelophyllum* Wedekind 1927

Type Species (designated Lang *et al.* 1940). *Madreporites articulatus* (Wahlenberg 1821). "Upper Silurian", Gotland.

Diagnosis (slightly modified after Jell & Sutherland (1990). Solitary, phaceloid or dendroid

rugosans; septa long, generally radially arranged, counter-cardinal septa rarely distinguishable, smooth or asymmetrically carinate; major septa slightly withdrawn from axis; minor septa contraclined or contratigent in some; tabularium wide, broadly domed commonly with depressed axial area and marginal periaxial trough formed by small subhorizontal or concave tabellae; dissepiments numerous, small, globose with lonsdaleoid dissepiments in some.

Remarks. The synonymy, distribution and taxonomic relationships of *Entelophyllum* were fully discussed by Jell & Sutherland (1990). They considered that solitary forms with thickened and carinate septa could possibly be included in *Nanshanophyllum* Yu (1956; type *N. typicum* Yu, Middle Silurian, China) as a subgenus of *Entelophyllum*. However, there does not seem to be any biogeographic or stratigraphic significance for such a division and Jell & Sutherland did not take that step. Solitary forms such as *E. latum* are thus retained within a broader generic concept.

***Entelophyllum patulum*
(Foerste 1888) comb. nov.**

- Cyathophyllum patula* Foerste 1888: 129, pl. 13, figs 9–11.
Heliophyllum yassense Etheridge 1892a: 170, pl. 11, fig. 8, pl. 12, figs 1–3.
Xylodes yassense (Etheridge); Jones 1936: 56, pl. 7, figs 3, 4 (non fig. 5).
Entelophyllum yassense (Etheridge); Hill 1940: 412, pl. 13, figs 11, 12.
Entelophyllum yassense var. *patulum* (Foerste); Hill 1940: 413, pl. 13, figs 13 a, b.
Entelophyllum sp. cf. *yassense* (Etheridge); Hill *et al.* 1969: s.10, pl. S V, figs 6, 7.
Entelophyllum yassense yassense (Etheridge 1892a); McLean 1976: 185–186, pl. 18, figs 8–10, pl. 19, fig. 1, text-fig. 3.
Entelophyllum yassense patulum (Foerste); McLean 1976: 186–187, pl. 19, figs 2–6, pl. 20, figs 1–3.

Diagnosis. Patellate or fasciculate *Entelophyllum*. Septa carinate and thin, minor septa 0.3–0.5 length of major. Tabularium divided into arched axial series and periaxial concave series; tabulae very closely spaced.

Remarks. The species epithet *patulum* predates *yassense* and takes precedence as the specific name (cf. McLean 1976: 185–187). Includes *E. patulum yassense* (*sensu* Etheridge 1892a) as well as the nominate subspecies.

Distribution and Range. Ludlow of New South Wales; late Gorstian to early Ludfordian of Broken River Province, north Queensland; Late Silurian (undifferentiated) of Inner Mongolia.

***Entelophyllum patulum yassense*
(Etheridge 1892a)
Figs 10 C–E, 16**

- Heliophyllum yassense* Etheridge 1892a: 170, pl. 11, fig. 8, pl. 12, figs 1–3.
Xylodes yassense (Etheridge); Jones 1936: 56, pl. 7, figs 3, 4 (non fig. 5).
Entelophyllum yassense (Etheridge); Hill 1940: 412, pl. 13, figs 11, 12.
Entelophyllum sp. cf. *yassense* (Etheridge); Hill *et al.* 1969: s.10, pl. S V, figs 6, 7.
Entelophyllum yassense yassense (Etheridge); McLean 1976: 185–156, pl. 18, figs 8–10, pl. 19, fig. 1, text-fig. 3.

Lectotype (here designated). F4015, Australian Museum, from the Ludlow of the Yass district, New South Wales, figured by Etheridge (1892a: pl. 12, fig. 3). Jones (1936) indicated that the specimens described by Etheridge were missing, but one slide of the type material had subsequently been found.

Material. UQF72621, 72623–72631 from UQL4002; UQF72622, 72634 from UQL4010.

Diagnosis. Fasciculate *Entelophyllum patulum*; corallites may be united by lateral expansions; increase non-parricidal. Septa may be dilated in dissepimentarium. Tabularium narrow. Dissepimentarium in two zones; outer of 1–2 series of large rhomboid dissepiments; inner of small globose dissepiments; dissepiments horizontal or shallowly inclined inwards at periphery, more steeply inclined at junction with tabularium.

Description. Corallum fasciculate, corallites irregularly spaced; some in contact, others separated by as much as 5 cm (average spacing just less than 1 cm). Corallum expands very rapidly, is usually far wider than high at maturity; largest recorded specimen (*in situ*) had a diameter of 36 cm and a height of 14 cm. Corallites cylindrical or slowly expanding, 8–17 mm in diameter, up to 9 cm high. Calice broad and flat with small axial boss, epitheca shows longitudinal double ridges. Increase peripheral and unequal, larger part of parent corallite being unaffected with continuing growth of parental tabularium.

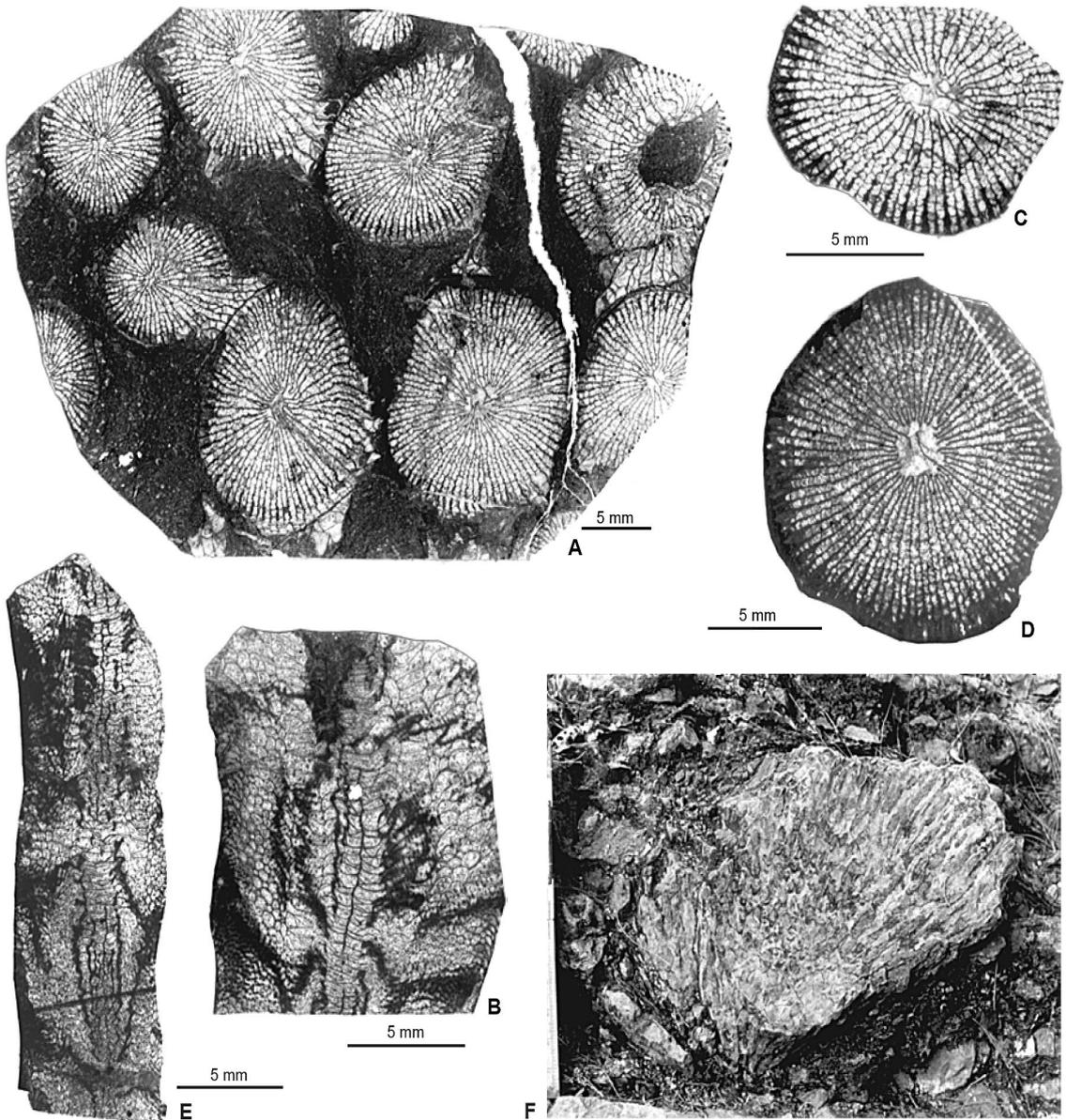


FIG. 16. *Entelophyllum patulum yassense* (Etheridge 1892a). A–B, UQF72624 from UQL4002. A, transverse section showing thin septa and lateral extensions between corallites; B, longitudinal section; C, UQF72629 from UQL4002, transverse section showing dilated carinate septa; D, UQF72622 from UQL4010, transverse section showing dilated carinate septa; E, UQF72625 from UQL4002, longitudinal section; F, exterior of *in-situ* corallum at UQL4009, about 14 cm high.

Two orders of septa number between 70 and 80 in largest corallites. Septa usually attenuate but may be dilated towards corallite periphery. Both orders possess xyloid carinae most prominent in dissepimentarium. Major septa usually slightly withdrawn from axis, leaving small axial space, typically less than 1 mm in diameter, into which longer cardinal and counter septa project. Major septa adjoining cardinal septum may be shortened, or may be slightly curved to outline small fossula. Minor septa usually between 0.3 and 0.5 length of major septa. Septal trabeculae thin, contiguous, and directed normally to upper surfaces of dissepiments. Carinae are lateral outgrowths from trabeculae, are parallel to them, and are irregularly arranged on either side of each septum. Corallite wall very thin, dilated only in vicinity of lateral extensions where it may be as thick as 0.5 mm. Dilated septa show distinct lamination parallel to septa and reach maximum thickness of nearly 0.5 mm.

Lateral extensions may be present between any two corallites. These are irregular prolongations of wall and lumen of one corallite to another and may join corallites for much of their lengths. Only one corallite forms the extension, and its septa and dissepimentarium extend into the process as far as the wall of second corallite, which is greatly dilated in area of contact. Septa within extension usually non-carinate.

Tabularium 0.4–0.5 diameter of corallite, consists of two series of incomplete tabellae: axial series forms loose axial structure with outermost plates globose, innermost flat or sagging; periaxial series of small, slightly sagging plates.

Dissepiments also in two zones: outer of 1–2 series of large rhomboid dissepiments, horizontally based or slightly inclined inwards; inner of smaller globose and more steeply inclined dissepiments. In some cases, a single long, shallow, more gently curved plate may replace several. Dissepiments may be weakly geniculate.

Remarks. Variation occurs in respect to corallite size and the amount of dilation of the septa. Corallites with dilated septa tend to have

smaller diameters than those with unthickened septa, but septal numbers correlate well with corallum diameter (Fig. 17), which indicates that this represents intraspecific variation.

The Broken River material differs from previously described specimens of *E. patulum yassense* in possessing septal dilation in some specimens, and in being smaller overall. These differences are considered to be insufficient to recognise at specific rank (see above).

Entelophyllum patulum patulum (Foerste 1888) can be distinguished from *E. patulum yassense* by its patellate growth form and more numerous septa.

Guo (1978) illustrated a transverse section of a specimen from the Late Silurian of Inner Mongolia as *Entelophyllum* aff. *yassense* (Etheridge). That specimen closely resembles *E. patulum yassense*, but is not described and is insufficiently illustrated for precise specific identification.

Hill (1940) noted that the overseas species that most closely resemble '*E. yassense*' are possibly the Wenlock and Ludlow *E. articulatum* and *E. pseudoianthum* from England and the Baltic. These species differ in having parricidal increase, and in lacking an outermost series of rhombic dissepiments. Hill also indicated that the Wenlock, North American *E. rugosum* Smith

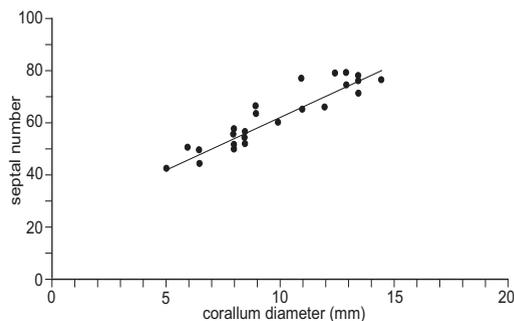


FIG. 17. Linear least squares plot of corallite diameter against septal number (correlation coefficient 0.92) for Jack Formation specimens of *Entelophyllum patulum yassense* (Etheridge 1892a).

1933, had similarities with '*E. yassense*'. McLean (1976), however, suggested that Smith's species was closer to the Soviet genus *Strephophyllum* Lavrusevich 1971, because of its similar flat or sagging tabulae and narrow dissepimentarium. He suggested it may be intermediate between the two genera.

Distribution and Range. Late Gorstian to early Ludfordian of Broken River Province, north Queensland (Fig. 4); Ludfordian of New South Wales; Late Silurian (undifferentiated) of Inner Mongolia?

Entelophyllum latum Hill 1940

Fig. 18

Entelophyllum latum Hill 1940: 413–414, pl. 13, figs 8–10; Strusz 1961: 338–339, pl. 42, figs 3–5.

Entelophyllum sp. Hill 1942a: 4, pl. 2, figs 1 a, b.

Holotype. F8973, Australian Museum (collected by AJ Shearsby 1903), from the Wenlock anticline at Glenbower, between Yass and Canberra, near the Boambolo crossing of the Murrumbidgee River, New South Wales.

Material. UQF72635–72639, all from UQL4002.

Diagnosis (after Hill 1940). *Entelophyllum* with numerous thin septa, and with axial structure so wide as almost to fill the tabularium.

Description. Corallum solitary, cylindrical or broadly trochoid. External characters not observed. Specimens vary from 13 to 22 mm in diameter, with 42 major, and 42 minor septa at a diameter of 17 mm. Septa are attenuate, smooth, or with weakly developed xyloid carinae in dissepimentarium. Major septa generally of unequal length, may unite at their axial ends, but more usually slightly withdrawn from axis leaving axial space 1–2 mm in diameter. A small, weakly developed fossula may be outlined by slightly curved major septa next to cardinal septum. Minor septa 0.3 to 0.5 length of major septa, not quite reaching width of dissepimentarium. Septal trabeculae fine, closely spaced, directed upwards and inwards normally to dissepiments. Carinae unclear in longitudinal section. Apart from no secondary thickening of septa or walls in any observed specimens, microstructure resembles that of *E. patulum yassense* (Etheridge 1892a).

Tabularium of numerous incomplete tabellae forming a wide axial structure separated from

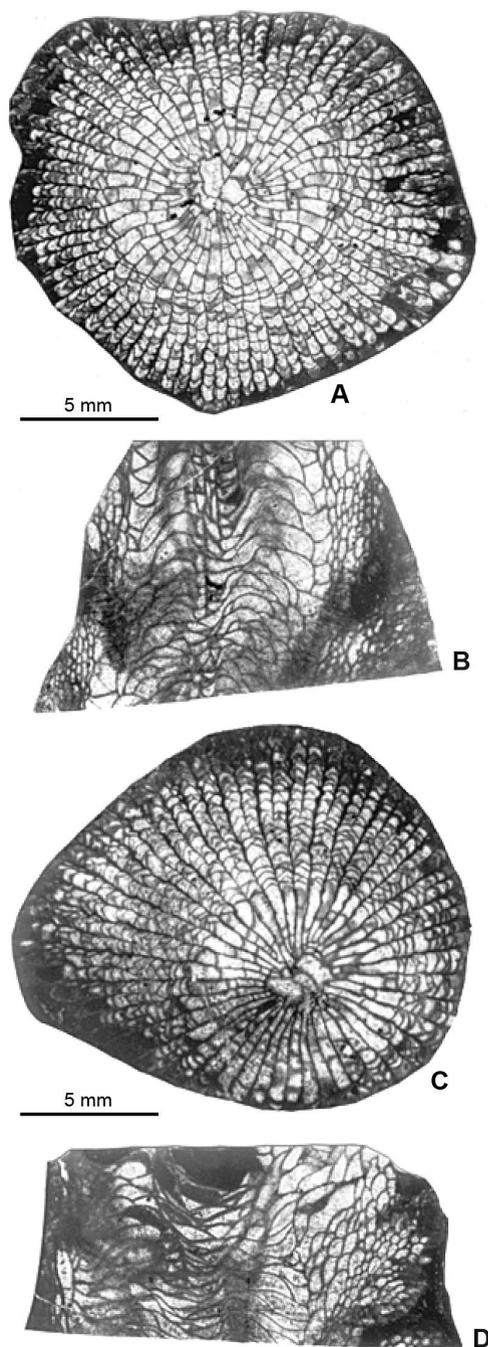


FIG. 18. *Entelophyllum latum* Hill 1940. A, UQF72637 from UQL4002, transverse section; B, UQF72636 from UQL4002, longitudinal section; C, D, UQF72635 from UQL4002, transverse and longitudinal sections.

dissepimentarium by periaxial series of small, flat or slightly sagging tabellae inclined upwards and outwards. Axial structure of central flat or shallowly concave tabellae surrounded by circumferential series of domed, horizontally based tabellae. Dissepiments generally small globose, inclined steeply inwards towards axis. In some cases several may be replaced by a single long shallow tabella.

Remarks. Hill (1940) described considerable variation in the development of septal carinae in *E. latum*. The holotype lacks carinae, while three paratypes are carinate, but Hill regarded them all as conspecific. Strusz (1961) described a large specimen of *E. latum*, with carinate septa from the Wellington district, New South Wales, and the Broken River specimens are all weakly carinate, otherwise closely resembling the holotype. They are smaller than Strusz's specimen, which is 40 mm in diameter, but are very close to a Tasmanian specimen described by Hill (1942a) as *Entelophyllum* sp. That specimen was reinterpreted by Strusz as *E. latum*.

Of overseas species, *E. latum* most closely resembles *E. articulatum* Wahlenberg 1821, from the Wenlock and Ludlow of Europe, but differs in having more septa and a wider axial structure (Hill 1940).

Distribution and Range. ?Wenlock or Ludlow of Tasmania; Wenlock and Ludfordian of Yass Basin, New South Wales; Wenlock and Ludlow of Broken River Province, north Queensland (Fig. 4); Ludlow (undifferentiated) of Wellington district, New South Wales.

Suborder Ketophyllina Zavoronkova 1972

Family Ketophyllidae Lecompte 1952

Genus *Dokophyllum* Wedekind 1927

Type Species (by original designation). *Dokophyllum annulatum* Wedekind 1927. Ludlow, Klinteberg Beds, Gotland.

Diagnosis (slightly modified after Hill 1981). Solitary, large corallum, septa long, radial, slightly dilated wedgewise in marginarium that is in late stages a lonsdaleoid dissepimentarium with some small concentric or angulate interseptal plates; major septa continue into

tabularium as thin, low ridges on upper surfaces of tabulae; tabulae flat with edges turned down or up, grouped; prominent cardinal tabular fossula, and in some alar fossulae also.

Remarks. Discussed (as *Ketophyllum*) in McLean (1974a: 657–659) and in Hill 1981: F219). *Dokophyllum* has page priority over *Ketophyllum* Wedekind 1927.

Dokophyllum hillae sp. nov.

Fig. 19

Ketophyllum sp. cf. *crassiseptatum* Wedekind 1927; Hill *et al.* 1969: s.12, pl. S VI, fig. 8a, b.

Etymology. After the Late Professor Dorothy Hill.

Holotype. UQF72672 from UQL4010. Ludfordian, Jack Formation, Graveyard Creek Group, Jack Hills Gorge area, north Queensland.

Material. UQF72669, 72678 from UQL4334; UQF72670, 72675 from UQL4335; UQF72671, 72674, 72680 from UQL4002; UQF72672–72673, 72676–72677 from UQL4010; UQF72679 from UQL4337.

Description. Corallum large, solitary, up to 6.5 cm in diameter and 12 cm in height. Over neanic, turbinate or broadly trochoid stages, epitheca shows longitudinal double ridges, over ephebic, cylindrical stage, septal grooves are weakly developed, and strong transverse wrinkling reflects lonsdaleoid dissepiments. Calice shallow, with flat or gently domed floor. Corallum may show scattered rejuvenescence and rare budding.

Septa amplexoid, extending to axis as low, thin ridges on upper surfaces of tabulae, but otherwise leave axial space up to 1.5 cm across. Major and minor septa not well defined, just distinguishable by length in some specimens (e.g. UQF72677). All are vertically discontinuous, forming septal crests separated by rows of dissepiments, particularly towards periphery where septa may be slightly dilated. Accurate determination of septal number difficult due to irregular septal development; typically 120–135 septa in specimens ca 4 cm in diameter, UQF72672 has 144 septa at diameter of 6.5 cm. Irregular stereozone may be developed in places over dissepimentarium; this is most strongly developed in UQF72672. Septal trabeculae thin, contiguous, directed normal to plates on which

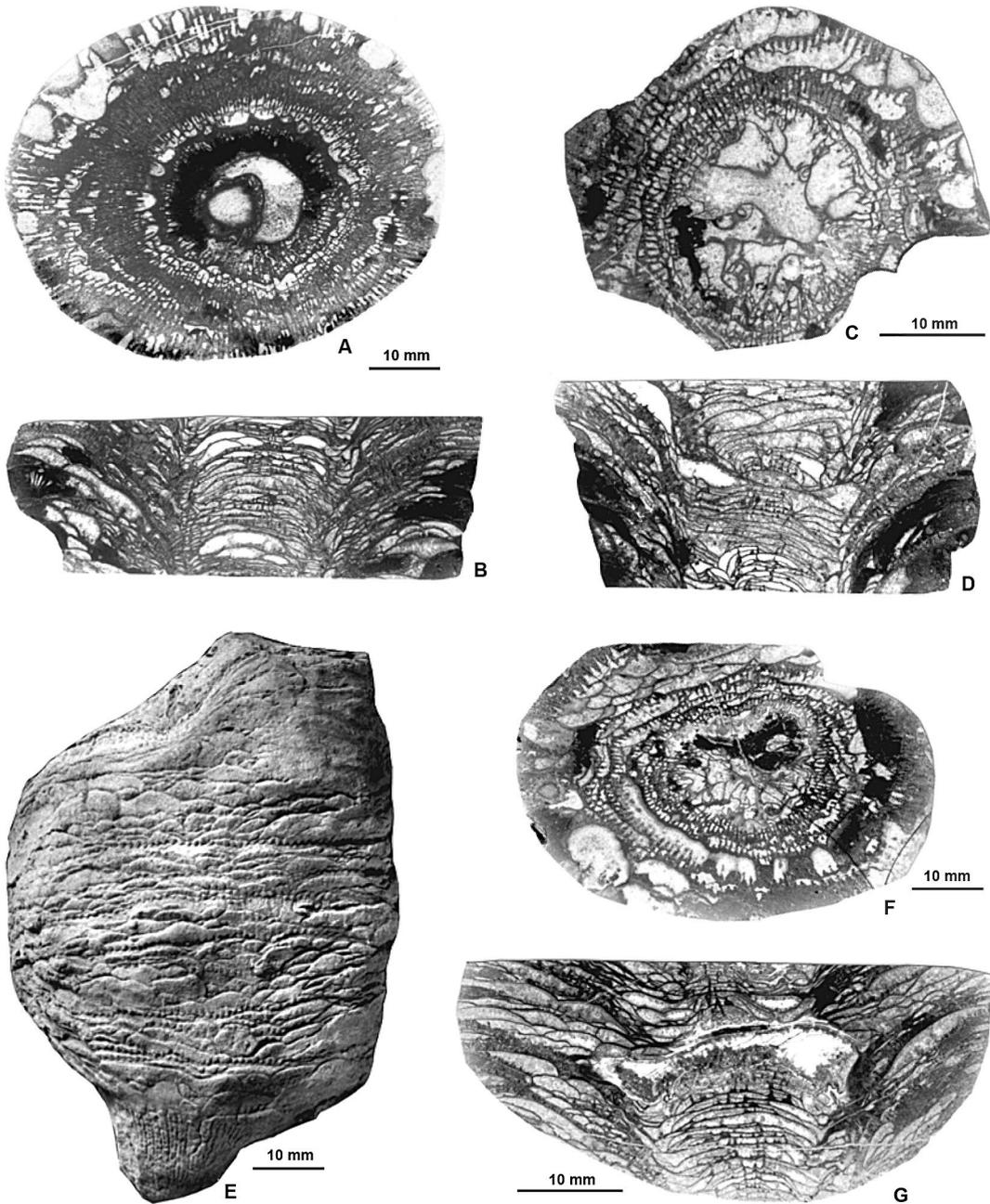


FIG. 19. *Dokophyllum hillae* sp. nov. **A, B**, UQF72672, HOLOTYPE, from UQL4010, transverse and longitudinal sections; **C, D**, UQF72677 from UQL4010, transverse and longitudinal sections; **E**, UQF72679 from UQL4337, exterior; **F, G**, UQF72673 from UQL4010, transverse and longitudinal sections.

they are based. Peripherally, they may pierce several layers of dissepiments. Between septa, and over dissepimentarium, discontinuous indistinctly laminated stereozone may be developed; these laminae usually concave towards axis in interseptal loculi.

Tabularium generally 0.3–0.5 corallite diameter. Tabulae complete or in some cases incomplete, flat or gently arched, some with upturned edges, commonly occur in groups of 2–6 tabulae. Spacing varies from 10–26 per cm. Slightly thickened tabulae may be developed that show an indistinct lamination parallel to their basal layers. Small shallow tabular fossula may be developed.

Lonsdaleoid dissepiments large (in UQF72673, one intersected 35 septa) very elongate, shallowly inclined inwards, or horizontally based at corallite periphery, but may steepen inwards to about 45° at junction with tabularium. Dissepiments present at all stages of growth, but less common in proximal portions.

Remarks. The specimens show substantial variation in septal discontinuity. For example, the transverse section of UQF72672 has relatively few lonsdaleoid dissepiments and septa that are nearly continuous, whereas UQF72673 has numerous dissepiments, and considerably interrupted septa. Longitudinal sections indicate that this variation occurs even within a single corallum; in several specimens (e.g. UQF72672) the number and size of lonsdaleoid dissepiments varies with the particular growth stage of the corallum. The variation is therefore interpreted as intraspecific, rather than reflecting the presence of several coexisting species.

McLean (1974a: 658) remarked that many of the twenty species and varieties of *Dokophyllum* and *Ketophyllum* erected by Wedekind (1927) are synonyms, and that a revision of the genus was needed. However, as a revision of the Gotland species is still pending and as the north Queensland material represents a morphologically distinct taxon that can be largely distinguished from congeneric forms in Gotland, it is appropriate to name the species. *Dokophyllum hillae* shows some resemblance to three of Wedekind's species

from the Wenlock of Gotland. In common with *K. crassiseptatum*, UQF72677 has comparatively short septa that are interrupted close to the periphery (Fig. 19D). However, it lacks the greatly thickened septa of that Gotland species, and the horizontal elements cannot be compared, as Wedekind did not describe or illustrate those of *K. crassiseptatum*. UQF72672 (Fig. 19A) and UQF72676 are closer to *K. bulbosum* Wedekind which has similar long, more complete septa, but these specimens lack the well grouped, commonly sagging tabulae of that form. Wedekind's third species, *K. elegantulum*, closely resembles UQF72673 (Fig. 19F), in its similar strongly discontinuous septa, showing slight wedgewise dilation towards the periphery. *K. elegantulum* also has flatter tabulae showing more clearly defined grouping, and both it and *K. bulbosum* have a much more clearly defined tabular fossula than in the Broken River material.

Distribution and Range. Late Gorstian to Ludfordian of Broken River Province, north Queensland (Fig. 4).

Family Kyphophyllidae Wedekind 1927

Genus *Vesicospina* gen. nov.

Etymology. Latin vesica = blister, spina = thorn, referring to the small trabeculae on the dissepiments.

Type Species. *Vesicospina julli* sp. nov. Ludfordian, Jack Formation, Graveyard Creek Group; Jack Hills Gorge area, Broken River Province, north Queensland.

Diagnosis. Corallum large, solitary, initially turbinate or broadly trochoid, becoming cylindrical. Calice very deep with axial boss. Septa thin, weakly carinate, interrupted late in ontogeny by peripheral zone of large, lonsdaleoid dissepiments; major septa strongly swirled at axis; minor septa short. Tabularium of complete domed tabulae with axial sag and deep, asymmetric peripheral troughs; peripheral troughs periodically filled by close-set periaxial tabellae. Dissepiments geniculate, shallowly based at periphery but vertical at junction with tabularium; lonsdaleoid dissepiments dominate over small globose interseptal dissepiments; lonsdaleoid dissepiments with small, widely spaced, fine trabeculae directed normal to upper surfaces.

Remarks. *Vesicospina* has some characters intermediate to all three subfamilies of the Arachnophyllidae, but has most in common with the Kyphophyllinae and the Ptychophyllinae, each of which contains one genus, *Kyphophyllum* Wedekind 1927, and *Ptychophyllum* Milne-Edwards & Haime 1850, respectively.

The type species of *Ptychophyllum*, *P. stokesi* Milne-Edwards & Haime 1850, from the upper Wenlock–lower Ludlow of Michigan, differs from *Vesicospina* in being patellate with common rejuvenescence; in having major septa that are less convolute axially; a long, narrow cardinal fossula; a less complex tabularium, and septa that may be cavernous over the dissepimentarium. *P. stokesi* also lacks the fine trabeculae over the outer dissepiments which are characteristic of *Vesicospina*, and lacks septal carinae.

Kyphophyllum lindstromi Wedekind 1927, from the Silurian of Gotland, the type species of *Kyphophyllum*, differs from *Vesicospina* in having non-convolute, slightly withdrawn major septa, slight peripheral septal dilation, non-carinate septa, no periaxial tabellae in the peripheral troughs of the tabulae, and trabeculae over the outer dissepiments that are aligned with the septa and are in vertical series. The trabeculae of the new genus are widely and more irregularly spaced.

Kyphophyllum appears to be closer to *Vesicospina* than does *Ptychophyllum* but it is not congeneric; hence, the new genus is placed in the Kyphophyllinae.

A Western Australian taxon, *Tabulophyllum? lowryi* Hill & Jell 1970, from the Upper Devonian Napier Formation of the Canning Basin shows some resemblance to *Vesicospina*, but differs in having more irregular, less geniculate dissepiments, less prominent minor septa, thicker major septa buttressed by shard-like plates in the dissepimentarium, non-carinate septa, and a less complex tabularium. McLean (1975a: 190) suggested that the Broken River and Western Australian forms might be congeneric, but *T? lowryi* was described from only one specimen, and without further material

its taxonomic position remains unclear. Hill and Jell regarded it as a possible new genus.

A transverse section of a specimen from the Silurian of Gotland, illustrated by Wedekind (1927: pl. 27, fig. 13) as *Kyphophyllum* sp. has strongly swirled major septa, and resembles neanic specimens of *Vesicospina*. It was not described, and is insufficiently illustrated to allow its precise identification.

Distribution and Range. Late Gorstian to Ludfordian of north Queensland; Silurian (undifferentiated) of Gotland?; Late Devonian of Western Australia?

Vesicospina julli sp. nov.

Fig. 20

Pilophyllum sp.; Hill *et al.* 1969: s.12, pl. S VI, figs 9a, b.

Etymology. After the Late Dr. R.K. Jull.

Holotype. UOF72642 from UQL4335. Ludfordian Jack Formation, Graveyard Creek Group, Jack Hills Gorge area, north Queensland.

Material. UQF72640, 72643 from UQL4002; UQF72641–72642 from UQL4335; UQF72644–72645 from UQL4010; UQF72646 from UQL4008; UQF72647 from UQL4336.

Diagnosis. *Vesicospina* with diameter of 35 mm, height of at least 45 mm and up to 80 septa.

Description. Corallum solitary, large; holotype has diameter of 35 mm and height of at least 45 mm. Epitheca over neanic, turbinate or broadly trochoid stage has longitudinal double ridges; over cylindrical stage epitheca has less well developed septal grooves and strong transverse wrinkles reflecting lonsdaleoid dissepiments. Calice very deep with steep walls, prominent axial boss.

Two orders of attenuate septa number 72–80 in adult specimens. Septa axially smooth, but may possess weak xyloid carinae in dissepimentarium. Peripheral zone of large lonsdaleoid dissepiments interrupts both orders late in ontogeny, but septa may continue over their crests as discontinuous low ridges. Major septa thin, most extend to axis where they are strongly swirled, commonly around small axial space less than 1 mm across. Because of severe crowding in axial vortex some major septa do not extend far into convolute zone and are occasionally even curled back on themselves. Cardinal and counter septa cannot be recognised. Minor septa short, extending just

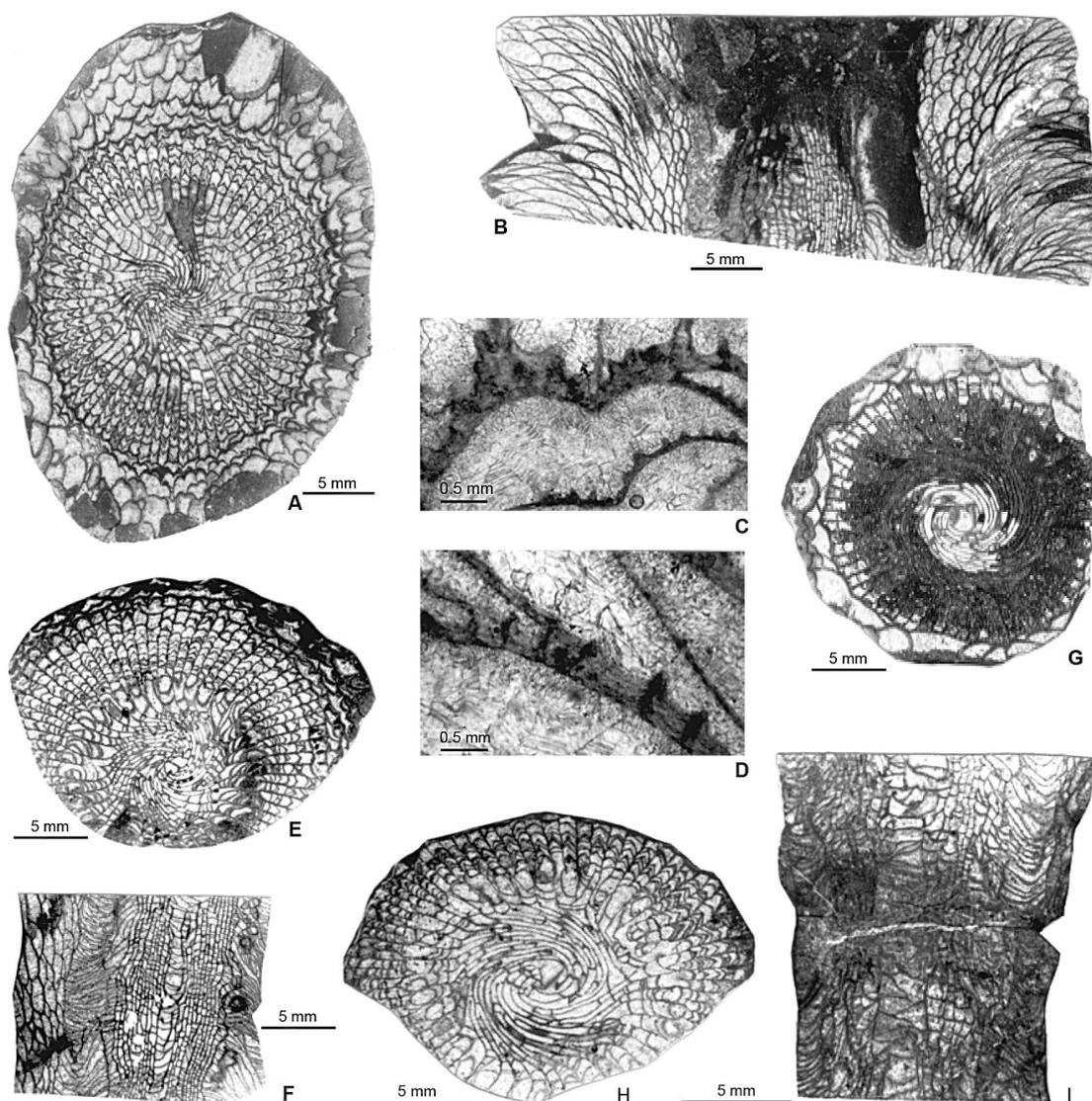


FIG. 20. *Vesicospina julli* gen. et sp. nov. A–D, UQF72642, HOLOTYPE, from UQL4335; A, transverse section; B, longitudinal section through calice showing dissepimentarium; C, portion of A showing small trabeculae on upper surfaces of dissepiments; D, portion of B showing small trabeculae directed normally to dissepiment surfaces; E, F, UQF72644 from UQL4010, transverse and longitudinal sections; G, UQF72643 from UQL4002, transverse section showing weakly carinate septa; H, I, UQF72645 from UQL4010, transverse section of youthful stage, and longitudinal section.

beyond zone of interseptal dissepiments, and not involved in axial convolution. Septal trabeculae thin, contiguous, and directed normally to upper surfaces of dissepiments. Trabecular structure generally masked by recrystallisation.

Large, complete, strongly domed tabulae have axial sag and outer edges upturned to form deep, asymmetric peripheral troughs. Tabulae spaced 20–25 per cm at axis, closer towards the margins. At intervals in corallite growth,

peripheral troughs infilled by small, close-set, slightly sagging tabellae.

Dissepiments geniculate, horizontally based or adaxially inclined to ca 45° at periphery, but steepen inwards to be vertical at junction with tabularium. Large, flatly curved, very elongate lonsdaleoid dissepiments predominate over small, globose interseptal plates. Small, fine, widely spaced trabeculae scattered on, and directed normally to upper surfaces of many lonsdaleoid dissepiments, but very rare on interseptal dissepiments. Peripheral stereozone absent.

Remarks. Little intraspecific variation is present. UQF72643 varies from the holotype in having far more septal carinae, and a narrow interseptal dissepimentarium that is only a few series wide; in the holotype it stretches for 0.25 the diameter of the corallum. The holotype varies from the rest of the material in lacking an axial space, although the major septa are strongly swirled and their axial ends are not conjoined.

Hill *et al.* (1969) illustrated a specimen of *V. julli* from the type area, as *Pilophyllum* sp., but that genus possesses a well developed marginal stereozone and a weaker axial vortex (McLean 1975a), and is easily distinguished from *Vesicospina*. In addition to these differences, *Pilophyllum keyserlingi* Wedekind 1927, the type species of *Pilophyllum* from the Ludlow of Gotland, differs from *V. julli* in having slightly withdrawn major septa, a minor septal stereozone developed at the edge of the tabularium, non-geniculate dissepiments, and incomplete domed tabulae that lack peripheral troughs and do not sag axially.

Ptychophyllum variatum sp. nov. can be distinguished from neanic specimens of *V. julli* by its weaker axial vortex, more strongly carinate septa, and incomplete, domed tabulae. Mature specimens of *V. julli* are readily distinguished by their peripheral zone of lonsdaleoid dissepiments.

A distinctive feature of this species is the presence of short fine trabeculae on the upper surfaces of many of the plates of the dissepimentarium. They do not appear to be continuations of the existing septa as they are not in vertical series nor are they aligned with the septa. It is possible they are a relict feature inherited from some ancestral species that had

greatly dilated septa, but *V. julli* lacks thickened septa in both the neanic and ephebic stages and the affinities of these tabular trabeculae therefore remain unclear.

Distribution and Range. Late Gorstian to Ludfordian of Broken River Province, north Queensland (Fig. 4).

Suborder Cyathophyllina Nicholson in Nicholson & Lydekker 1889

Family Ptychophyllidae Dybowski 1873

Genus *Ptychophyllum* Milne-Edwards & Haime 1850.

Type Species (by original designation). *Ptychophyllum stokesi* Milne-Edwards & Haime 1850. Upper Wenlock-lower Ludlow, "Lockport Dolomite", Drummond Island, Lake Huron, Michigan.

Diagnosis (slightly modified from Hill 1981). Solitary, ceratoid, turbinate, or patellate; calice with wide, commonly everted platform and broad axial boss in tabularial pit; septa numerous, long, may bear lateral dissepiments; tabularial parts of major septa convolute, unequal, longer reaching axis and shorter confluent with longer; tabular floors domes with edges turned out or up; tabulae incomplete; dissepiments numerous, small, subglobose, interseptal; cardinal fossula long, narrow, inconspicuous, invading tabularium.

Remarks. Australian species of *Ptychophyllum* are discussed in McLean (1975b). Smith (1945) added to the original diagnosis of *Ptychophyllum* that the major septa "break up peripherally in such a way that in transverse section they appear to split into component strands." McLean (1975b) described similar cavernous septa in New South Wales specimens of *Ptychophyllum*, and they are also found in the Broken River material. However, cavernous septa may be present or lacking in *Ptychophyllum* even within species, and McLean (1975b) therefore excluded this feature from the generic diagnosis.

Ptychophyllum variatum sp. nov.

Fig. 21

Phaulactis sp. cf. *shearsbyi* Sussmilch 1914; Hill *et al.* 1969: s.10, pl. SV, figs 1a, b.

Etymology. Latin varius = different, variable, referring to the septal variation.

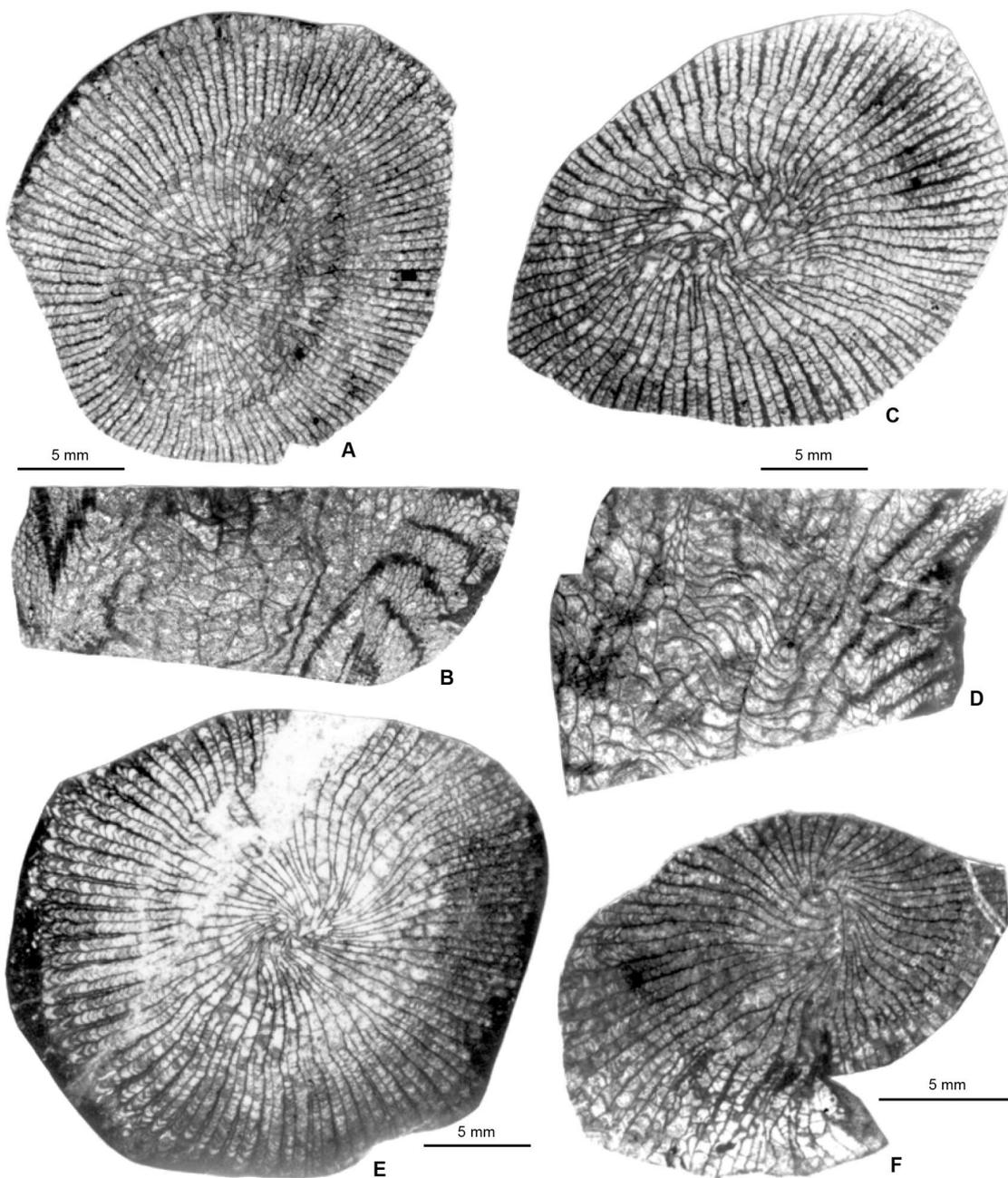


FIG. 21. *Ptychophyllum variatum* sp. nov. **A, B**, UQF72654, HOLOTYPE, from UQL4002, transverse and longitudinal sections respectively; **C-D**, UQF72652 from UQL4335. **C**, transverse section of youthful stage showing fusiform major septa of uneven length; **D**, longitudinal section; **E**, UQF72650 from UQL4337, transverse section showing cavernous septa; **F**, UQF72653 from UQL4336, transverse section showing rejuvenescence.

Holotype. UQF72654 from UQL4002. Late Gorstian to Ludfordian, Jack Formation, Graveyard Creek Group, Jack Hills Gorge area, north Queensland.

Material. UQF72648 from UQL4010; UQF72649, 72654 from UQL4002; UQF72650, 72656 from UQL4337; UQF72651–72652, 72655 from UQL4335; UQF72653 from UQL4336; UQF60102 from which two thin sections were figured by Hill *et al.* (1969).

Diagnosis. Ceratoid *Ptychophyllum* with weak axial vortex and numerous, weakly carinate septa; major septa thickened at periphery and sometimes at axial ends, majority slightly withdrawn from axis in younger stages; minor septa thin. Tabulae domed, but flat or sagging across axial region.

Description. Corallum solitary, ceratoid, with infrequent rejuvenescence, reaching diameter of 32 mm and height of 10 cm. Longitudinal ridges and widely spaced growth annulations mark epitheca. Calice wide and deep, small axial boss.

Two orders of weakly carinate xyloid septa number 124 in specimen 29 mm in diameter. Major septa of irregular length in young stages, mostly reach axis in mature stages, gently curved in tabularium. Septa generally thin, may be slightly dilated peripherally and axially. Peripheral thickening fusiform or wedge-shaped. Rarely, septa may be cavernous in dissepimentarium, component strands either reuniting, or turn outwards to become contiguous with dissepiments. Thin minor septa extend to edge of dissepimentarium, and are 0.5–0.6 length of major. Cardinal septum generally slightly elongated, in narrow fossula defined by shorter, slightly curved adjacent major septa. Septal trabeculae directed upwards and inwards normally to upper surfaces of dissepiments. Carinae infrequent, arranged parallel to septal trabeculae. Dilated septa show distinct lamination parallel to septa. Marginal stereozone absent.

Tabularium of small, mainly elongate, incomplete plates forming wide zone 0.4–0.5 corallite diameter. Tabulae domed, but flat or sagging across axial region. Dissepimentarium wide, dissepiments small, globose or slightly elongated, shallowly inclined near corallite

periphery, but steepen axially to almost vertical at junction with tabularium.

Remarks. *Ptychophyllum variatum* closely resembles the Middle Silurian, Chinese *Ptychophyllum* (“*Nanshanophyllum*”) *typicum* Yu 1956, but the two forms are not easily compared as *P.* (“*N.*”) *typicum* was originally described from only one specimen. *P. variatum* differs in having more numerous septa, thinner minor septa, and in lacking two series of plates in the tabularium.

Of the Australian species of *Ptychophyllum*, *P. variatum* most closely resembles *P. auctum* McLean 1975b, from the Llandoverly of central New South Wales. This species differs in being turbinate or patellate, in having a more prominent axial vortex, fewer septa (60–70 at an average diameter of 20–25 mm), and short, often lonsdaleoid minor septa.

Considerable variation occurs in the character of the septa within this species. The axial vortex may be nearly absent or weak, and is less prominent than those of other Australian species of *Ptychophyllum* (cf. *P. auctum* McLean 1975b). Septal dilation is absent or weak at the axial ends of the major septa, and weak or moderate towards the periphery. Over the dissepimentarium, it may be accompanied by strong zigzagging of the septa, not necessarily accompanied by carinae. Cavernous septa are developed only in some septa of UQF72650 (Fig. 21E), the remaining septa being simple in structure.

Specimens of *Entelophyllum latum* Hill 1940, from the Jack Formation, bear a superficial resemblance to *P. variatum*, but differ in lacking an axial vortex, in having major septa withdrawn from the axis at maturity, shorter minor septa, and less peripheral septal dilation.

Distribution and Range. Late Gorstian to Ludfordian of Broken River Province, north Queensland (Fig. 4).

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Silurian rugose corals Jack Formation

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APPENDIX 1: FOSSIL LOCALITIES

All localities are from the vicinity of the type section of the Jack Formation in the Jack Hills Gorge area, Broken River Province, north Queensland and are within the Clarke River 1:250,000 (SE55-13) and Burges 1:100,000 (7859) mapsheets. They are listed in numeric order and are mapped in Fig. 5. Grid references refer to the MGA94 datum; bearings refer to true north.

- UQL4002: South bank of Broken River, composite collection from section between UQL4333 and UQL4337. Coral gardens member (ca 265820mE 7845510mN).
- UQL4003: North bank of Broken River, 350 m east of east end of Jack Hills Gorge (UQL4014). Base of Dark dog limestone (266160mE 7845480mN).
- UQL4004: North bank of Broken River, 100 m up-section from UQL4003. Top of Dark dog limestone (266080mE 7845530mN).
- UQL4005: North bank of Broken River, 150 m east of east end of gorge (UQL4014). Base of Coral gardens member (265990mE 7845640mN).
- UQL4006: North bank of Broken River, 16 m up-section from UQL4005. Coral gardens member (265980mE 7845640mN).
- UQL4007: North bank of Broken River, 11 m up-section from UQL4006. Coral gardens member (265960mE 7845640mN).
- UQL4008: North bank of Broken River, 16 m up-section from UQL4007. Coral gardens member (265940mE 7845640mN).
- UQL4009: North bank of Broken River, composite collection from section between UQL4006 and UQL4008. Coral gardens member (ca. 265960mE 7845640mN).
- UQL4010: North bank of Broken River, 13 m up-section from UQL4008. Top of Coral gardens member (265930mE 7845650mN).
- UQL4011: North bank of Broken River, 8 m up-section from UQL4010. Oncolitic limestone at top of Coral gardens member (265910mE 7845650mN).
- UQL4013: North bank of Broken River, 35 m up-section from UQL4011. Micritic limestone at top of Coral gardens member (265880mE 7845650mN).
- UQL4014: North bank of Broken River, at east end of Jack Hills Gorge. Base of Jack Hills member (265820mE 7845630mN).
- UQL4325: Bluff-forming limestone lens at base of Coral gardens member, 500 m bearing 025° from point on north bank of Broken River, 350 m downstream from western end of Jack Hills Gorge (266340mE 7846010mN).
- UQL4326: Bluff-forming limestone lens of Dark dog limestone, 270 m bearing 205° from point on south bank of Broken River, 550 m downstream from west end of Jack Hills Gorge (265870mE 7845200mN).
- UQL4327: Bluff-forming limestone lens of Dark dog limestone, 550 m bearing 205° from point on south bank of Broken River, 550 m downstream from west end of Jack Hills Gorge (265740mE 7845050mN).
- UQL4328: Isolated bluff-forming limestone lens of Dark dog limestone, 1,000 m bearing 205° from point on south bank of Broken River, 550 m downstream from west end of Jack Hills Gorge (265390mE 7844690mN).
- UQL4329: Gully, 900 m bearing 205° from point on south bank of Broken River 350 m downstream from west end of Jack Hills Gorge. Decalcified siltstone in Red bull member (265290mE 7844890mN).
- UQL4330: Hill slope, 500 m bearing 025° from point on north bank of Broken River 300 m downstream from west end of Jack Hills Gorge. Coral gardens member (266260mE 7846010mN).
- UQL4331: Hill slope, 30 m from point on south bank of Broken River 500 m downstream from west end of Jack Hills Gorge. Top of Dark dog limestone (266000mE 7845430mN).
- UQL4332: Hill slope, 450 m bearing 025° from west end of Jack Hills Gorge. Top of Jack Hills member (265870mE 7846000mN).
- UQL4333: South bank of Broken River, 350 m from west end of Jack Hills Gorge. Base of Coral gardens member (265850mE 7845510mN).
- UQL4334: South bank of Broken River, 16 m up-section from UQL4333. Coral gardens member (265840mE 7845520mN).
- UQL4335: South bank of Broken River, 12 m up-section from UQL4334. Coral gardens member (265820mE 7845520mN).
- UQL4336: South bank of Broken River, 17 m up-section from UQL4335. Coral gardens member (265810mE 7845520mN).
- UQL4337: South bank of Broken River, 15 m up-section from UQL4336. Top of Coral gardens member (265790mE 7845530mN).
- UQL4338: North bank of Broken River, at west end of Jack Hills Gorge, Top of Jack Hills member (265600mE 7845670mN).