EARLY CAMBRIAN CORALS FROM THE MOOROWIE FORMATION, EASTERN FLINDERS RANGES, SOUTH AUSTRALIA

BY

MARGARET FULLER

B. SC. (Hons)

Thesis submitted as a fulfilment of the
Master of Science Degree
Department of Geology and Geophysics
The University of Adelaide
September 1999

ABSTRACT

The Early Cambrian tabulate-like corals, *Flindersipora bowmani* Lafuste 1991, *Moorowipora chamberensis* Fuller & Jenkins 1994, *Arrowipora fromensis* Fuller & Jenkins 1995, *Adelaideipora cancelli* gen. et sp. nov and *Adelaideipora lafustei* sp. nov, *Flindersipora uldanami* sp. nov and *Blinmanipora hawkerensis* gen. et sp. nov, occur in the Moorowie Formation of the eastern Flinders Ranges, South Australia. They are found in a reefal environment in association with archaeocyaths and calcimicrobial accretions which give indications of a crowded high energy habitat. Although recrystallization has occurred, the original skeletal architecture of the corals is well preserved.

The genera *Flindersipora, Moorowipora, Arrowipora* and *Adelaideipora*, the latter three particularly, have tabulate-like characteristics, including the cerioid, sometimes fasciculate form of the corallum, wedge-shaped to spine-like septa and strongly developed tabulae or dissepiment-like tabulae.

Moorowipora chamberensis has some skeletal structures in common with *Tabulaconus kordeae* Handfield, while *Arrowipora fromensis* is similar in form to some members of the family Micheliniidae (Waagen & Wentzel, 1886), which have a time range from the Late Silurian to the Late Permian. Similarities in skeletal structure exist between the genus *Adelaideipora* and *Nyctopora* Nicholson, 1879, while *Blinmanipora hawkerensis* resembles several Ordovician lichenariid corals.

Statistical analysis of corallite diameter in *Flindersipora bowmani, Moorowipora chamberensis* and the two species of *Adelaideipora,* indicate significant differences substantiating their taxonomic separation. However, the statistical difference in the corallite diameters of *Flindersipora uldanami*, *Moorowipora* and *Adelaideipora* is not clearly evident and is not of value in the differentiation of these species.

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

1.2 SOUTH AUSTRALIA

CHAPTER 2 FLINDERS RANGES

CHAPTER 3 THE MOOROWIE FORMATION

CHAPTER 4 THE CORALS

4.2 SYSTEMATIC PALAEONTOLOGY

CHAPTER 5 STATISTICAL ANALYSIS

CHAPTER 6 DISCUSSION THE MOOROWIE CORALS

LIST OF FIGURES

FIGURE 12B. *Adelaideipora cancelli,* paratype, (P34170), rock slab in longitudinal section.

FIGURE 12C. *Adelaideipora cancelli,* paratype, (P34171), rock slab in longitudinal section.

FIGURE 12D. *Adelaideipora cancelli,* transverse thin section.

FIGURE 13A. *Adelaideipora cancelli,* holotype, transverse thin section.

FIGURE 13B. *Adelaideipora cancelli,* holotype, longitudinal thin section.

FIGURE 13C. *Adelaideipora cancelli,* paratype, (P34170), longitudinal thin section.

FIGURE 13D. *Adelaideipora cancelli,* holotype, longitudinal thin section.

FIGURE 14A. *Adelaideipora lafustei,* holotype, transverse thin section.

FIGURE 14B. *Adelaideipora lafustei,* holotype, transverse thin section.

FIGURE 14C. *Adelaideipora lafustei,* holotype, longitudinal thin section.

FIGURE 14D. *Adelaideipora lafustei,* paratype, transverse thin section.

FIGURE 15A. *Adelaideipora lafustei,* paratype, longitudinal thin section.

FIGURE 15B. *Adelaideipora lafustei,* paratype, longitudinal thin section.

FIGURE 15C. *Flindersipora uldanami,* paratype, transverse thin section.

FIGURE 15D. *Flindersipora uldanami,* paratype, longitudinal thin section.

FIGURE 16A. *Flindersipora uldanami,* holotype, transverse thin section.

FIGURE 16B. *Flindersipora uldanami,* paratype, transverse thin section.

FIGURE 16C. *Flindersipora uldanami,* holotype, longitudinal thin section.

FIGURE 16D. *Flindersipora uldanami,* holotype, longitudinal thin section.

FIGURE 17A. *Flindersipora bowmani,* holotype, transverse thin section.

FIGURE 17B. *Flindersipora bowmani,* holotype, longitudinal thin section.

FIGURE 17C. *Flindersipora bowmani,* (P34174), transverse thin section.

FIGURE 17D. *Flindersipora bowmani,* (P34174), longitudinal thin section.

FIGURE 17E *Flindersipora bowmani,* (P34174), longitudinal thin section.

FIGURE 18A. *Blinmanipora hawkerensis,* holotype, transverse thin section.

FIGURE 18B. *Blinmanipora hawkerensis,* holotype, transverse thin section.

FIGURE 18C. *Blinmanipora hawkerensis,* holotype, longitudinal thin section.

FIGURE 18D. *Blinmanipora hawkerensis,* holotype, longitudinal thin section.

FIGURE 18E. *Blinmanipora hawkerensis,* holotype, transverse thin section.

FIGURE 19A. Histogram of results, *A. lafustei* (holotype).

FIGURE 19B. Histogram of results *A. lafustei* (paratype).

LIST OF TABLES

GLOSSARY OF TERMS

A. CORAL COLONY

CORALLUM. The complete compound skeleton.

MASSIVE corallum. Corallites not separated by space.

CERIOID corallum. Massive corallum where corallites are contiguous or prismatic.

FASCICULATE corallum. Straight or curved corallites that are not laterally contiguous.

CORALLITE. Exoskeleton, built by individual polyps.

MID-LINE, MEDIAL-LINE OR SUTURE. The junction of two adjoining corallites, which in life comprised epitheca, recrystallized carbonates appear as either light or dark lines.

INCREASE. Addition of corallites to a compound corallum.

PARRICIDAL. A term applied to the type of increase in which tabularium of parent corallite ceases to grow distally.

OFFSETS. New corallites formed in a compound corallum.

B. CORALLITE

CALICE. Distal space of each corallite formally occupied by a polyp.

SEPTAL ELEMENTS. Radially and longitudinally arranged in outer parts of the tabularium.

TABULAE. Horizontal skeletal elements which extend across the corallite.

TABELLAE. Small convex plates which do not extend across the tabularium, and the edges of which may lie on a wall, one another or tabulae.

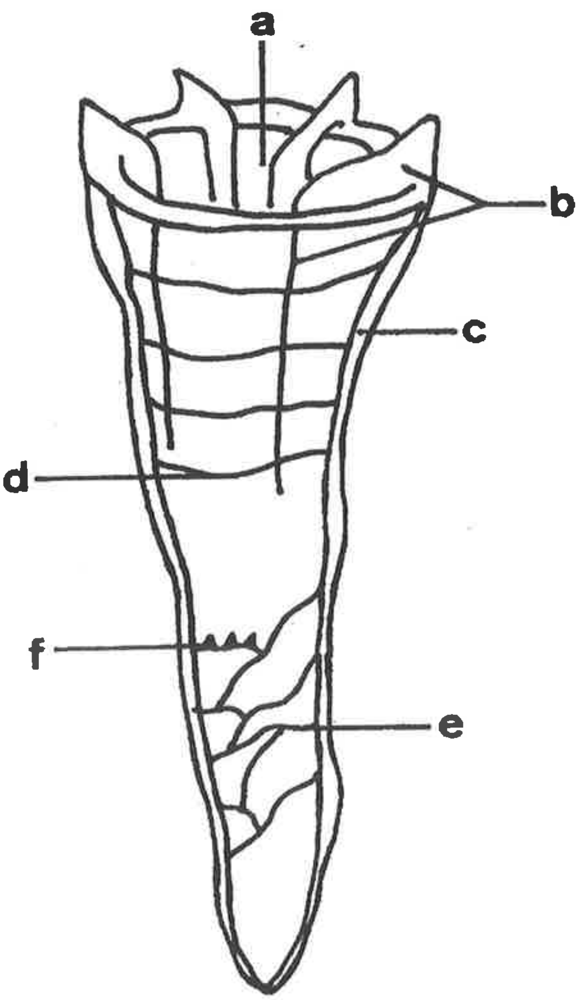
DISSEPIMENTS. Small domed plates forming cyst-like enclosure in marginarium (peripheral part of interior of corallite).

TRABECULA. Pillar of radiating calcareous fibres comprising skeletal elements in structure of septum and related components.

TABULARIUM. The axial part of the interior of corallites where horizontal skeletal elements are developed.

MURAL PORES. Circular or oval holes in the wall between adjoining corallites.

WALLS. Peripheral stereozone normally sheathed externally by epitheca.



a. calice
b. septal elements
c. walls
d. tabulae
e. tabellae and dissepiments
f. trabeculae

From Hill (1981).

ACKNOWLEDGEMENTS

I thank my supervisors Dr. Richard Jenkins and Dr. James Gehling for their support and encouragement, and Dr. Richard Jenkins for providing me with the opportunity to work on this exciting project. Thanks must also go to Mr. Gino Snidero and Dr. James Gehling for their much needed assistance and guidance with photography. I wish also to acknowledge Brent Bowman and John Hart who collected the studied material, Dr. David Gravestock for his assistance with assorted queries, and Dr. Andrew Kenner for his ANOVA statistical analysis.

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

SIGNATURE: .... **DATE:** ......24/9/99......

NAME: MARGARET FULLER **COURSE:** MASTER OF SCIENCE

I give consent to this copy of my thesis, when deposited in the University Libraries, being available for photocopying and loan.

SIGNATURE: .... .. **DATE:** ......30/9/99......

CHAPTER 1

1.1 INTRODUCTION

The Early Cambrian corals, *Flindersipora bowmani* Lafuste 1991, *Moorowipora chamberensis* Fuller & Jenkins 1994, *Arrowipora fromensis* Fuller & Jenkins 1995, *Adelaideipora cancelli* gen. et sp. nov, and *Adelaideipora lafustei,* sp. nov., *Flindersipora uldanami, sp. nov. and Blinmanipora hawkerensis* gen. et sp. nov. (the latter four described herein), occur in slumped reefal blocks within a megabreccia, sited close to the disused Moorowie Mine (Fig. 1).

The Moorowie Mine is situated about 1 km. south of the eastern end of Mount Chambers Gorge in the eastern Flinders Ranges, South Australia, about 400 km north of Adelaide. The area comprises sediments of the Early Cambrian Hawker Group and possible Middle Cambrian, Billy Creek Formation, with remnants of the Late Neoproterozoic Umbertana Group present in diapiric intrusives. The area is extensively faulted with the small diapiric intrusions comprising the older Neoproterozoic carbonate breccias and gangue, occurring along fault zones, of which the major ones are the Arrowie Fault just west and the Wertaloona Fault, about 500 metres east of the mine site. Limestones are often dolomitised and silicified (Mount 1970; Hart 1989; Polito 1993).

The corals are preserved as upright coralla relative to bedding, and commonly are in life position within individual slump blocks. These slumped blocks occur in the middle part of the Moorowie Formation and was originally reefal system. The corals occur in association with both fragmental and encrusting remains of the calcimicrobes *Renalcis* Vologdin 1932, *Girvanella* Nicholson & Etheridge 1878 and *Epiphyton* Bornemann 1886, as well as archaeocyaths. The archaeocyaths may also occur in life position or more commonly as current deposited debris.

Archaeocyaths and corals provided a substrate for each other and the calcimicrobes, though overall, coral colonies are rare elements within the biota.

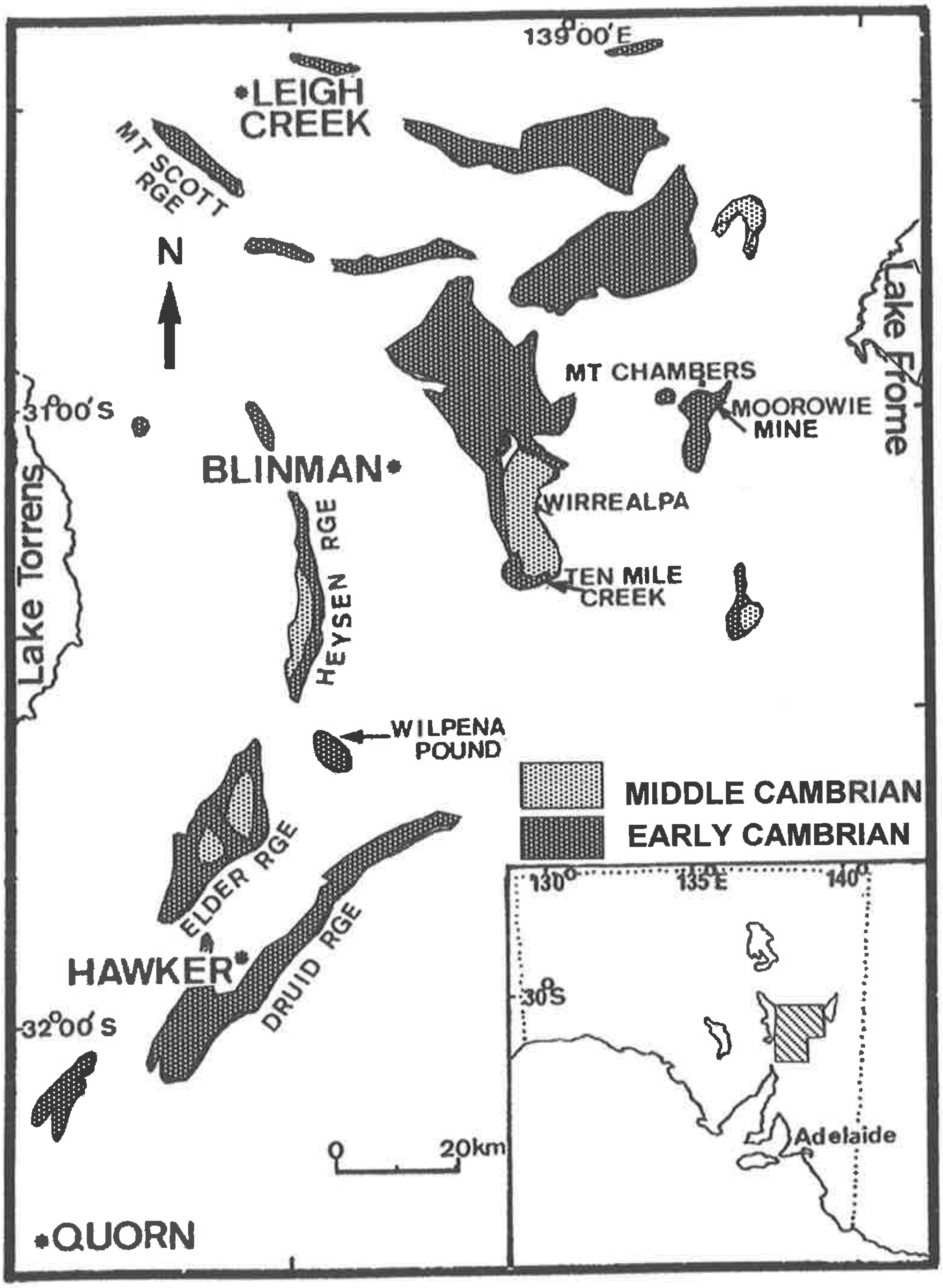


Figure 1. Location map showing fossil occurrence near the Moorowie Mine, Ten Mile Creek and the distribution of Early and Middle Cambrian outcrops in the Flinders Ranges South Australia.

The three previously described genera, *Flindersipora, Moorowipora* and *Arrowipora,* bare little resemblance to each other or to *Blinmanipora hawkerensis,* but the genus *Adelaideipora* has some morphological characteristics in common with both *Flindersipora* and *Moorowipora*.

1.2 SOUTH AUSTRALIA

1.2.1 Regional geology and geological history

The Flinders Ranges overlap the Early Cambrian Arrowie Basin, and form part of the Adelaide Geosyncline (Gravestock and Hibburt, 1991). During the Early Cambrian, the saddle-shaped Arrowie Basin extended from the Stuart Shelf in the west, to the Barrier Ranges in the east, opening into the Officer Basin and Warburton Basins to the north and the Stansbury Basin to the south (Fig. 2). The latter basin has Cambrian sediments of generally deeper water aspect, while in the Officer Basin sediments accumulated in a shallow sea (Gravestock and Hibburt, 1991). A broad central shelf was situated between the Stuart Shelf and the Willyama Block. This configuration was probably inherited from the late Proterozoic, with the two distinct depocentres of the Officer and Stansbury Basins accumulating marine sediments during most of the Early Cambrian.

Within the Adelaide Geosyncline, the Cambrian depositional sequences were terminated by the Late Cambrian-Early Ordovician Delarmerian Orogeny, which extensively deformed and metamorphosed sediments in the southern region of Kangaroo Island and the Fleurieu Peninsula (Jenkins 1990; Mancktelow 1990; Toteff 1990; Preiss 1990). Less deformed Cambrian sediments in the Flinders Ranges, on Yorke Peninsula, the north east coast of Kangaroo Island and near Sellick Hill on the Fleurieu Peninsula, preserve broad overall Cambrian faunal assemblages.

Within this region, many normal and reverse faults truncate and rarely repeat sedimentary sequences. These faults may be associated with early basin subsidence, and probably were reactivated during later deformation events, such as the Tertiary separation of Australia from the Antarctic, which initiated last-stage uplift of the Adelaide Geosyncline (Wellman & Greenhalgh 1988). Faulting, uplift and subsequent erosion has removed direct connection between

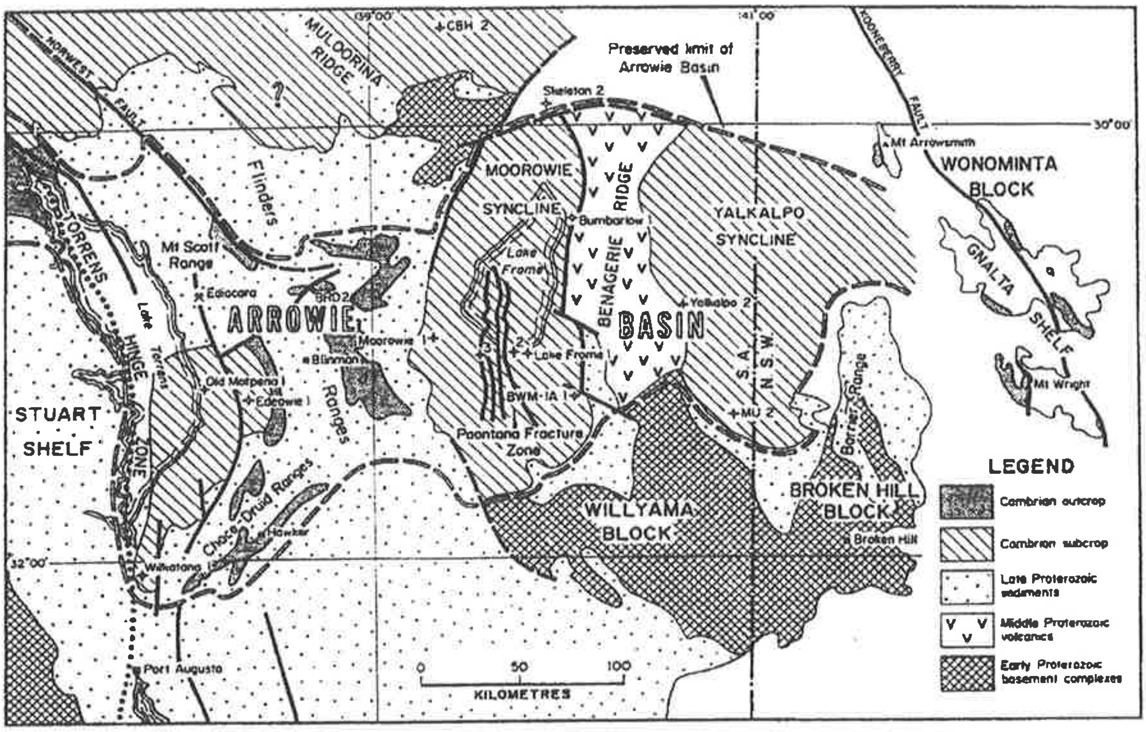


Figure 2. Arrowie Basin, showing Proterozoic and Cambrian outcrops and simplified structures. (from Gravestock & Hibburt 1991).

the Cambrian sequences of major regions. However, correlations are possible based on fossil faunas.

1.2 SOUTH AUSTRALIA

1.2.2 History of Early Cambrian fossil discoveries

Early Cambrian fossils from South Australia were first described in the mid-late nineteenth century. Early researchers include Tepper (1879;1881) who described the first archaeocyaths from near Ardrossan on Yorke Peninsula, mistaking them for Silurian tabulate corals (Zhuravelev & Gravestock 1994). Tate (1892), described trilobite moults and Hyoliths in the same region. Etheridge (1889;1890;1905;1919) described archaeocyaths; Howchin's work (1897;1907;1922), was more generalized.

In the early part of this century, reef associated organisms, predominantly archaeocyaths, were investigated by researchers including Taylor (1910), Bedford R. & Bedford W. R. (1934;1936) and Bedford, R. & Bedford, J. (1936;1937;1939), and while Chapman (1940) described one of the first known Early Cambrian sponges. From about the middle of this century numerous researches have added to the knowledge of Early Cambrian fossils in South Australia, with Daily (1956;1963;1969;1972;1976b;1976c;1990) and Debrenne (1969;1970;1973;1974a;1974b) being two of the principal workers.

Daily's (1956) recognition of the sequential occurrence of ten faunal assemblages, was probably the first attempt at biostratigraphic correlation in South Australia. Walter (1967), and more recently Gravestock (1984), have studied archaeocyaths in stratigraphic order. Bengtson *et al.* (1990), concentrated on describing Early Cambrian trilobites and shelly fossils from the various regions in South Australia, subsequently erecting zones based predominantly on trilobite species.

The Early Cambrian corals from the Moorowie Mine area were first collected in the mid to late 1980's by the Late Brian Daily and Brent Bowman.

Additions to the collection were made in 1989 by John Hart. No information was published until 1991, when Lafuste *et. al* described the first taxon *Flindersipora bowmani.*

CHAPTER 2
FLINDERS RANGES

2.1 Depositional environments and stratigraphy

The Moorowie Formation and its lateral equivalents, the upper part of the Wilkawillina Limestone, Mernmerna Formation [= Parara Limestone, Dalgarno & Johnson (1962)] and Oraparinna Shale, form part of the Early Cambrian Hawker Group of Dalgarno (1964).

The lower part of the Hawker Group consists of lowstand and strandline shallow marine sediments of the Uratanna and Parachilna Formations, interpreted as being the beginning of sequence C1.1 of Gravestock & Hibburt (1991), (Fig. 3). The sandstones and carbonates of the above formations are followed stratigraphically by stromatolitic mudflats and ooid shoals of the Woodendinna Dolomite (Haslett 1975; Gravestock & Hibburt 1991). Together with the lower Wilkawillina Limestone they are represented throughout the Flinders Ranges, being deposited when shallow seas covered most of the Arrowie Basin.

The lower Wilkawillina Limestone generally consists of platform derived archaeocyathan-calcimicrobe limestone with a predominance of rubbly and argillaceous limestone. A distinctive thin red-stained band or `horizon' considered to terminate this succession is widely recognized through the Flinders Ranges and on Yorke Peninsula. (James & Gravestock 1990). At most localities this boundary is an erosional horizon, but at some sites constitutes a condensed section. This `Flinders Unconformity' (James & Gravestock 1990), represents a hiatus resulting from a fall in sea level, with characteristics such as surface karst and large open fractures.

The Flinders Unconformity marks the beginning of sequence C1.2, and is regarded as a transgressive systems tract related to an increase in basin subsidence (Gravestock & Hibburt 1991), linked to lithospheric stretching (Jenkins 1990).

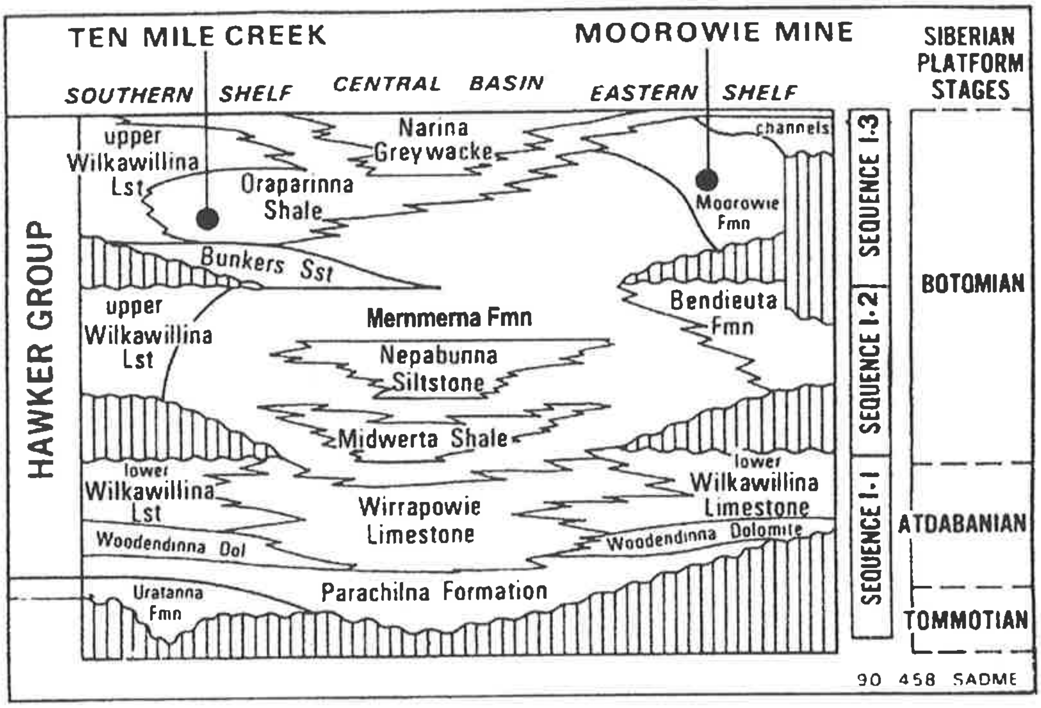


Figure 3. Hawker Group stratigraphy and subdivision into three depostional sequences. Moorowie Mine and Ten Mile Creek are located on the eastern and southern carbonate shelves in Sequence 1.3. (Adapted from Gravestock & Hibburt 1991 pg.181 and Lafuste et al. 1991: pg. 699).

The Mernmerna Formation, Oraparinna Shale, upper Wilkawillina Limestone, Moorowie Formation, Bunkers Sandstone and Narina Greywacke interfinger to form discontinuous sequences governed by depositional environments (Gravestock & Hibburt 1991, Fig 3). The Mernmerna Formation consists of predominantly grey to black, rhythmically bedded or massive calcareous shales, mudstones and limestones. The Oraparinna Shale is characteristically olive-green to brown\khaki green in colour, and composed of micaceous and calcareous shales, mudstones and siltstones. The Mernmerna Formation and Oraparinna Shale are shelf-slope and slope to basin carbonates, which display characteristics of carbonate turbidites, starved basins and both aerobic and dysaerobic environments of a starved basin (James & Gravestock 1990; Gravestock & Hibburt 1991).

The stratigraphically lower part of the Mernmerna Formation correlates with the C1.2 transgressive cycle of Gravestock and Hibburt (1991).

The Bunkers Sandstone consists of calcareous sandstone and sandy limestone (Daily 1956; Clarke 1990; Gravestock & Hibburt 1991), the base of which corresponds with the lowstand base of the C1.3 transgressive cycle of Gravestock & Hibburt (1991). During this transgressive cycle bioherm complexes and reefs rimmed the deeper waters (James & Gravestock 1990). The sediments and fauna contained within the boundstones and rudstones of the Moorowie Formation and upper Wilkawillina Limestone, reflect shallower areas. The interfingering upper Mernmerna Formation and Oraparinna Shale represent deeper water facies, and are also present in the Moorowie Mine region (Gravestock & Hibburt 1991).

2.2 Biostratigraphy and Regional correlations

F. bowmani has been found in bioherms in the lower Oraparinna Shale at Ten Mile Creek (Figs 1 & 3), as well as near the Moorowie Mine. Archaeocyaths attached to *F. bowmani* at Moorowie, include the colonial form *Ajacicyathus aequitriens*, which is a principal reef builder at this locality (Lafuste *et al.* 1991). At Ten Mile Creek, trilobite and echinoderm fragments form hash beds in the Oraparinna Shale, and associated archaeocyaths include four species of *Pycnoidocyathus*, as well as one species each of both *Erugatocyathus* and *Thalamocyathus.* These stratigraphic levels correlate with Faunal Assemblage 9 of Daily (1956), with additional fossil fauna having been recognized in Unit 8 of Mount (1970), which underlies and interfigures with the megabreccia containing the coral colonies at Moorowie. Lafuste *et al.* (1991) equate this stratigraphic level with the *Pararaia janeae* Zone of Jell (1990).

2.3 International Correlations

In his re-evaluation of the biostratigraphy of the Early Cambrian, non-archaeocyathan fossil assemblages of the Flinders Ranges, Jell (1990) erected four distinct assemblage Zones dominated by trilobites which are widely recognized in the local Early Cambrian. The *Abadiella huoi* Zone, followed by the *Pararaia tatei* Zone, occur above the base to about the middle of the Mernmerna Formation in the Flinders Ranges and the Parara Limestone on Yorke Peninsula. These zones include Daily's (1956) Faunal Assemblages 3,5,6, and 4 and 7 respectively, and correlate with the *Parabadiella* and *Eoredlichia* Zones of China. The South Australian zones have also been correlated with the *Egyngolia* Zone of Mongolia and the *Prouktaspis* Zone of Siberia, as well as assemblages containing similar small skeletal fossils in Morocco. The local zones evidently overlap with the latest Atdabanian (Jell 1990).

The *Pararaia bunyerooensis* Zone occurs immediately above the *P. tatei* Zone in the Flinders Ranges. This zone includes Daily's F.A. 8 but cannot as yet be correlated outside Australia, while the *Pararaia janeae* Zone (F.A. 9,11,12) can only be correlated by the association of the trilobites *Serrodiscus, Atops* and *Kootenia*. These trilobites occur within zones in Russia, China and America, and together with monoplacophoran molluscs, indicate a late Botomian age (Jell 1990; Jell *et al.* 1992).

2.4 Bioherm complexes

Bioherm complexes which form a major part of the of the Moorowie Formation, upper Wilkawillina and Ajax Limestones are composed predominantly of archaeocyaths, the calcimicrobes *Renalcis*, *Epiphyton* and *Girvanella*, as well as sponges and spongiomorphs. Five different kinds of build-ups have been recognized by James & Gravestock (1990), based on the predominance of one or more of the above fauna. The abundance or scarcity of these taxa tends to reflect a spatial zonation, controlled by environmental factors on either the platform or shelf (James & Gravestock 1990).

Type 1.

Calcimicrobe boundstones, complex intergrowths of *Renalcis* and *Botomaella*, situated on platform interiors of lowest water energy. These buildups are common in the Andamooka Limestone and rare in the upper Wilkawillina Limestone.

Type 2.

Archaeocyath boundstones, composed of archaeocyaths, usually encrusted by spongiomorphs, *Girvanella* and *Renalcis,* situated on the interior outer platform and signalling slightly more energetic environments.

Type 3.

Archaeocyath-*Renalcis* boundstones may be either

1. Renalcis dominant

2. Archaeocyath dominant, occurring on low-energy inner shelf locations, constituting the most common buildups in the Wilkawillina Limestone.

Type 4.

Epiphyton-archaeocyath boundstones, common in high energy open shelf locations, but not as common as *Renacis* dominated buildups.

Type 5.

Girvanella-Epiphyton-Renalcis boundstones, complex intergrowths of archaeocyaths, and *Girvanella*, with less abundant *Epiphyton* and *Renalcis*. Common to high energy outer shelf margins.

The talus blocks of the Moorowie Formation including the coral remains were derived from Type 5 shelf margin buildups (James & Gravestock 1990; Lafuste *et al.* 1991). The high energy marine environment was responsible for the influxes of sediment burying the framework of the live coral colonies, as well as abrading surfaces, evident on corallites and calcimicrobes.

CHAPTER 3
THE MOOROWIE FORMATION

3.1 Local geology

The Moorowie Formation, is interpreted by Lafuste *et al.* (1991), as being part of a prograding shoreline, comprising `near shore shale and siltstone, shelf margin oolite and reef limestone, dissected by high energy shallow submarine channels' (Lafuste *et al.* 1991; p.699). This stratigraphic level represents part of a suggested third transgressive/highstand phase of the Early Cambrian, associated with the onset of tectonic activity (Gravestock & Hibburt 1991), with synsedimentary faulting creating numerous fractures, on-shelf depressions and islands which shed terrigenous clastic sediments (James & Gravestock 1990).

The lithological units which form the Moorowie Formation, reflect varying depositional environments, varying from shallow intertidal to deep water basin facies (Mount 1970; Hart 1989; Savarese *et al.* 1993; Polito 1993).

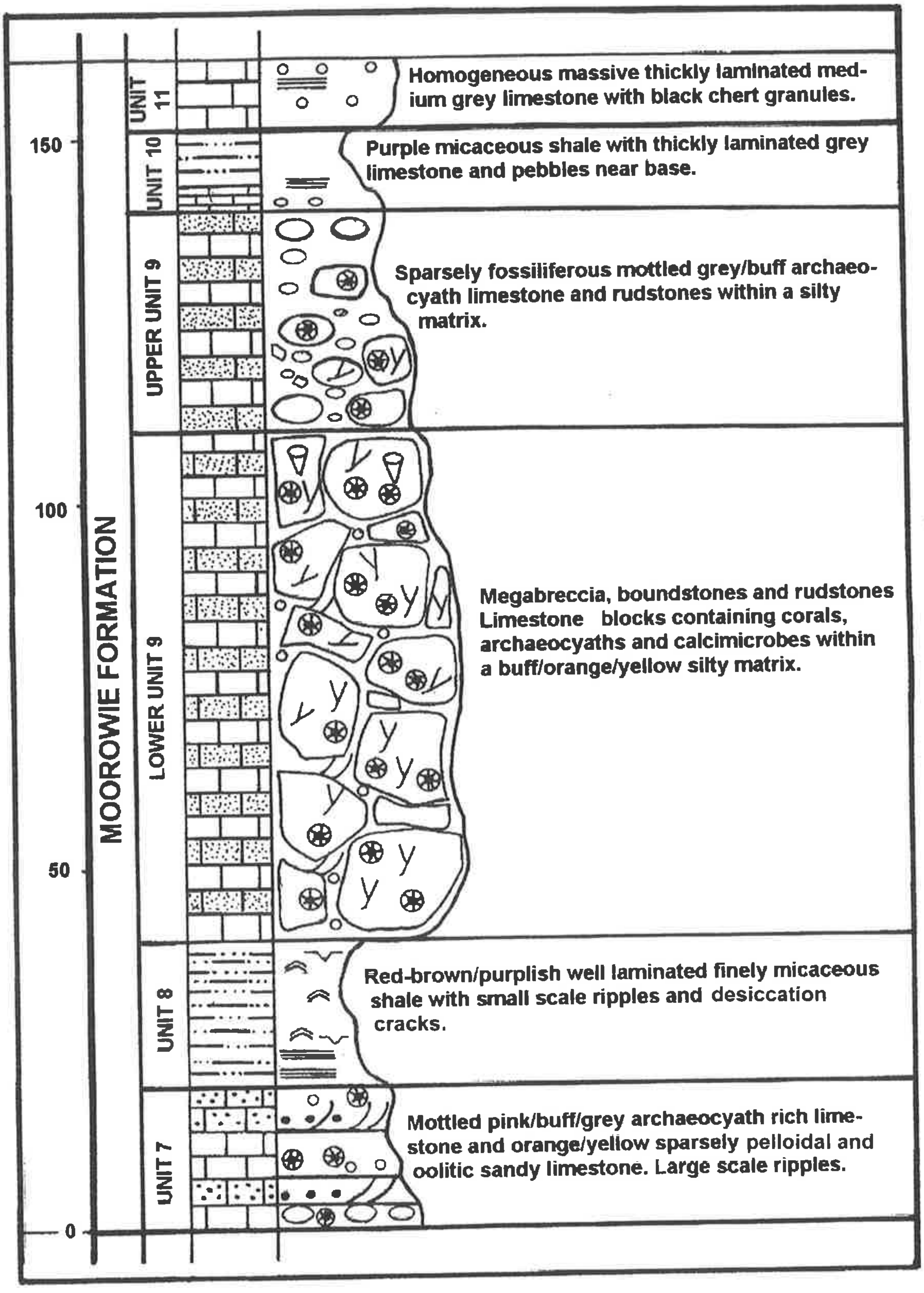
The Moorowie Formation was divided into five informal members, (units 7-11) by Mount (1970), the Pinyatta Member; Wookata shale Member; Kandramooka Member (which comprises the megabreccia); Pack Creek Member and the Brillig Catch Member (Mount 1970; Polito 1992). The Moorowie Formation stratigraphically overlies a lower six older units [units 1-6 (Mount 1970)], comprising (in upward stratigraphic order) the upper Wilkawillina Limestone (unit 1), the lower Parara Limestone (=lower Mernmerna Formation) (unit 2), the Bendiuta Formation (unit 3), and the upper Parara Limestone (=upper Mernmerna Formation), which includes units 4,5 and 6.

The Moorowie Formation is stratigraphically overlain by the early Middle Cambrian Edeowie Limestone Member and Billy Creek Formation (Mount 1970).

Figure 4. The Moorowie Formation which includes units 7-11 of Mount (1970). Megabreccia occurs in the middle of the Formation, at section G (Mount 1970), measuring approximately 99 metres in thickness.

LEGEND

▽	corals	⋀	small scale ripples
⊛	archaeocyaths	//	large scale ripples
y	calcimicrobes	●	oolites/pellets
⌵	desiccation cracks	○	granules
≡	laminations	⬭	pebbles
		⬭	cobbles



Measurements in metres.

Adapted from section G (Mount 1970)

The units within the Moorowie Formation commonly exhibit rapid lateral facies changes, with the megabreccia present in only few localities.

Section G of Mount (1970) contains the thickest megabreccia sequence and is used as the reference section for stratigraphy (Fig. 4).

Unit 7 of Mount (1970), the lowest unit in the Moorowie Formation, is thickly bedded silty to sandy archaeocyathan limestone.

This unit is followed by a **Unit 8**, which comprises red-brown to purplish coloured micaceous shale. The beds are well laminated and contain ripple, marks indicative of shallow water deposition. Fossils within this unit correlated with Daily's F.A. 9 (Mount 1970).

Unit 9 comprising the megabreccia, forms the middle part of the Moorowie Formation and is divided into lower and upper sub-units. The corals occur in upper parts of the lower sub-unit within reefal boundstones that have slid or tumbled as large talus blocks into a more basinal setting. (Mount 1970; Hart 1989; Lafuste *et al.* 1991; Savarese *et al.* 1993; Fuller & Jenkins 1994).

Unit 10 within the Moorowie Formation comprises purple micaceous shales with thickly laminated grey limestone above a conglomerate base, with archaeocyaths and rare cobbles (Mount 1970).

Unit 11 is the upper unit of the Moorowie Formation. This unit consists of massive grey limestone with minor interbedded intraclast conglomerates and/or chert granules (Mount 1970; Polito 1993). This unit probably equates with the upper Oraparinna Shale, as it is overlain by the Edeowie Limestone and the early Middle Cambrian Billy Creek Formation.

The reefal system of unit 9, formed on a high energy shelf margin, and is composed of type 5 buildups (James & Gravestock 1990). Savarese *et al.*

(1993) interpreted the reefal system as being established in a high energy marine environment encroaching over marginal fans. The fans formed from coarse breccia are suggested to have resulted from local uplift which unroofed the Moorowie diapir. The reef structures do not appear to be in their original placement, but several distinct lithofacies and biofacies associations have been recognized. These are represented individually in jumbled and displaced talus blocks that were derived from a markedly zoned reefal complex (Fuller & Jenkins 1994). As such it is not presently possible to reconstruct the different talus associations back into their original palimspastic placement.

Seven major clast lithologies are recognized within the megabreccia by Hart (1989).

1. A pseudofenestral boundstone, comprising proportionally about 10% of the talus, being dark to medium grey in colour and containing 30-60% cavities and *Renalcis*.
2. Less than 15% of the megabreccia is stromatolitic-archaeocyath boundstone, a massive dark to medium grey, rarely red limestone, containing up to 40% archaeocyaths and sparse colonies of *Renalcis*.
3. Less than 3% of the megabreccia is an archaeocyath dominated (~50%), archaeocyath-*Renalcis* boundstone.
4. A massive dark grey, *Epiphyton* boundstone containing about 50% calcimicrobes and rare archaeocyaths, together with the following *Epiphyton*-archaeocyath boundstones, comprise about 70% of the megabreccia.
5. The *Epiphyton*-archaeocyath boundstones contain the corals which are described herein. The percentage of archaeocyaths and calcimicrobes both vary between one and sixty percent of the content.
6. A stromatactis mudstone comprising <1%, of the megabreccia.
7. Carbonate sandstone, comprising >2% of the megabreccia.

The corals, together with archaeocyaths and the calcimicrobes, *Renalcis*, *Girvanella* and *Epiphyton* occur in closely associated reefal blocks, which reach to about 10m in maximum dimension. Within individual blocks, the organisms are commonly preserved in life position, the corals commonly form encrusting to upright tall often pagoda-shaped colonies, the latter up to 60-70 cms high. The blocks containing the corals are still predominantly `right way up' and hence it may be inferred that they slid sideways rather than tumbled to their present position near the approximate top of the talus pile. Their close juxtaposition side by side implies that their total down slope movement occurred over no great distance, and these megaclasts may even represent a para autochthonous part of the reef complex. Individual colonies tend to be widely spaced, with the dominant associated faunal elements varying markedly.

3.2 Interpretation of the Megabreccia

The above lithological variations within the megabreccia reflect a zoned reef complex. The Archaeocyath-*Renalcis* boundstones indicate a type 3 archaeocyathan dominated assemblage, representative of moderate to high energy open shelf environments (James & Gravestock 1990). The *Epiphyton* boundstone is possibly equivalent to a type 4 assemblage, representing high energy open shelf to shelf margin environments, while the *Epiphyton*-Archaeocyath boundstone is indicative of high energy shelf margin type 5 buildups (James & Gravestock 1990). The stromatactis mudstone may be compared with the stromatactoid mud mounds of James & Gravestock (1990), and the carbonate sandstone comprised a peritidal deposit.

The above facies for the megabreccia at Moorowie, have close counterparts in the model cross section of a carbonate platform and reefal buildups proposed by James & Gravestock (1990 p. 476), for the time of the Hawker Group.

It appears possible that the reef at Moorowie may have formed on or around the Moorowie diapir and represent a relatively small zoned reef complex. The distinctive biofacies possibly formed in areas some hundreds of metres broad implying that the main reef front had a fringing geometry.

Lemon (1985), theorized that with uplift of a diapir, basins are created adjacent to it, deepening, with increased subsidence due to salt withdrawal in response to upward movement of the central diapiric core.

The different lithologies within the present megabreccia probably reflect the mass collapse of different parts of the reef as a result of tectonic movement or progradation of the platform. The rapid slumping of the talus into deeper water in the adjacent basins evidently protected the carbonate frameworks from vadose diagenesis, resulting in the remarkably pristine preservation of the fauna.

CHAPTER 4
THE CORALS

4.1 Preservation

The available material containing the coral specimens, was mainly collected some years ago by Mr. Brent Bowman, then a technical assistant at the University of Adelaide. It is not known whether any of the six corals occur together, but it is known that they were principally collected from a relatively small area spanning a linear distance of 150m or so, and over an apparent stratigraphic interval of no more than a few metres. Sorauf & Savarese (1995) indicate that *F. bowmani* occurs at a higher stratigraphic level than *M. chamberensis.*

The corals from the Moorowie Mine locality, show a very similar mode of preservation. All their skeletal structures have been recrystallized, while domains within many corallites are either ferroan sparry calcite or recrystallized fine sediment, which appears similar to that surrounding the colonies. During life, colonies appear to have been repeatedly, but partially covered by centimetre thick layers of fine sediment. Many corallites were incompletely smothered, causing the death of zooids and allowing only a limited number to continue their growth. The survivors rejuvenated new parts of the corallum and with subsequent growth, corallites grew either inclined or spread laterally above the lenses of sediment. Evidence of smothering is particularly noticeable in specimens of *A. fromensis* (Fig. 5), *A. cancelli* (Figs 12A,B,C), *A. lafustei* (Figs 14C & 15A) and *F. uldanami* (Fig. 16C). These taxa commonly exhibit the above growth patterns either as shelves across sediment filled cavities, or by forming new colonies which appear to arise from one or a few remaining corallites. Isolated areas in few corallites contain fine sediment, which may have resulted from infiltrated into damaged areas of corallites while still occupied by the living organism, or after life.

The ferroan calcite, particularly evident in specimens of *B. hawkerensis*, precipitated as an authigenic component during diagenesis. It varies in colour from light to darker fawn, or is sometimes orange-brown to dark brown, commonly giving a multi-hewed appearance to the colony. In longitudinal section, corallites are commonly partially filled by the ferroan calcite to a depth of up to three centimetres (Figs 18C,D). Adjacent corallites may be coloured to a similar depth or alternatively only two or three spaces between tabulae may be filled by ferroan calcite. In transverse section calices replaced by ferroan calcite often form blocks or meandering lines, although others are randomly filled (Figs 18A,B).

Cavities within and surrounding the various colonies are commonly lined with calcimicrobe encrustations of *Renalcis*, *Girvanella* and *Epiphyton* (Figs 5,9,12A,B,C). These not only encrusted live colonies, but may have provided a substrate on which some colonies formed.

Small archaeocyaths are commonly associated with the coral colonies. Some archaeocyaths appear to be in life position and adjacent to parts of colonies, indicating that either the corals and/or the archaeocyaths may be providing a substrate for the other. Other archaeocyaths appear to have been transported, being contained within sediment filled cavities, lying on their side relative to bedding (Fig. 5).

Periodic, energetic influxes of sediment appear to have eroded some exposed skeletal parts of corals with broken or truncated calices common. The effects of this erosion is also apparent on colonies of calcimicrobes and archaeocyaths (Fuller and Jenkins 1994; 1995).

Most of the specimens examined contain fine fractures, possibly related to post diagenetic deformation of the corallum. Fine fractures in the holotypes and paratypes of *A. fromensis, A. cancelli, A. lafustei, F. uldanami*, *B. hawkerensis* are generally re-cemented with calcite, while a larger fracture in the holotype of

M. chamberensis is filled with fine sediment. This fracture continues across both corallites and the cavities between them, while the material filling the fracture appears to originate from a small pocket immediately adjacent to one side of the corallum.

The available longitudinal and transverse cut thin sections, generally have areas where the corallites are oblique in section, with only limited areas in true longitudinal or transverse relief. Oblique sections commonly present geometries that exaggerate particular dimensions or morphological characteristics of corallites. This may occur due to the overall irregular shape of the corallum, or when corallites diverge outward, sometimes being steeply inclined. Oblique corallites observed in transverse cut thin sections, tend to look more meandroid, while those in longitudinal cut, are usually observed to be shorter.

4.2 SYSTEMATIC PALAEONTOLOGY

Phylum: CNIDARIA
Class: ANTHOZOA
Order: ?TABULATA OR ?TABULACONIDA

The ordinal classification of the Moorowie corals is unclear. Skeletal characteristics are tabulate-like and these corals are possibly early representatives of the Tabulata. However, Scrutton (1997), has proposed a new Order, Tabulaconida, for Early Cambrian `true corals', and postulated that these evolved from closely related non-skeletonized polyp-like organisms and became extinct during the Middle to Late Cambrian. Into this group he has placed the two previously described Moorowie corals, *Moorowipora chamberensis* and *Arrowipora fromensis*, with *Flindersipora bowmani* being a questionable member. However, it is possible that total extinction of this group did not occur in the Cambrian and this division continued through the Cambrian and was the ancestors of Ordovician tabulate corals.

***Type specimens**:* The specimens described in this paper are held in the palaeontology collection at the South Australian Museum (SAM).

4.2:1

Family: uncertain
Genus: *Arrowipora* Fuller & Jenkins 1995
Type species*:* *Arrowipora fromensis* Fuller & Jenkins 1995
Early Cambrian (Late Botomian) Moorowie Formation
Flinders Ranges South Australia

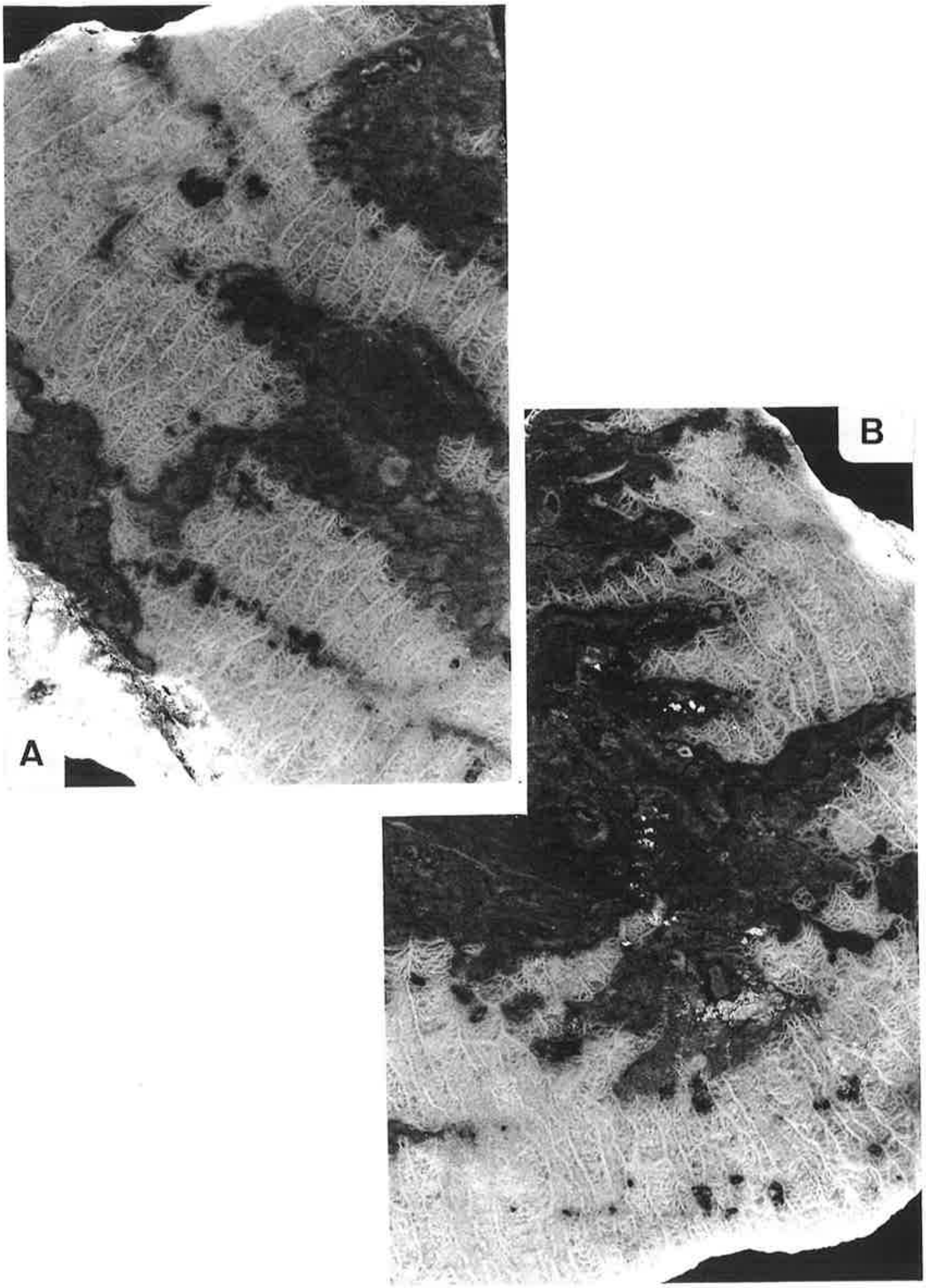
Figure 5.

Arrowipora fromensis

Fuller & Jenkins (1995)
Figs. 2 & 3

5A. Holotype SAM P34167 (complete specimen), illustrating sub-rectangular shelves extending from a large colony (x1.4).

5B. Holotype SAM P34167 (reverse side of A), with shelf-like projections over adjacent sediment (x1.4).


A
B

Etymology: For the Arrowie Basin, an Early Cambrian shallow marine basin extending over much of the area of the present Flinders Ranges.

Diagnosis: Corallum large, massive cerioid, comprising polygonal corallites; corallites prismatic and irregularly cylindrical; walls divided by a medial plane, thick, wavy to crenate, sometimes almost straight; tabulae numerous, rarely complete, commonly dissepiment-like tabellae; septa numerous or absent, numbering up to 35 in each corallite; where present, septa form short wedge to spine-like projections into the lumen; mural pores absent.

Arrowipora fromensis Fuller & Jenkins 1995

FIGS 5 - 7; TABLE 1

1995 *Arrowipora fromensis* FULLER & JENKINS, figs 2-5
1997 *Arrowipora fromensis* SCRUTTON, figs 19k-19m.

Etymology: For nearby Lake Frome.
Diagnosis: As for genus.

Material

Two sets of polished slab counterparts, and numerous smaller pieces. One set comprises triangular shaped polished slabs approximately 25 cm tall and 23 cm wide (Fig. 5), the other set, two triangular polished slabs approximately 34 cm normal to bedding and 28 cm parallel to bedding. Both contain either two or more coralla or the disjunct parts of one large corallum which formed numerous irregularly rectangular platy shelves. The material was collected from the Moorowie Formation, near the Moorowie Mine.

Type specimens: Holotype SAM P34167, a polished slab of a broken part of a corallum and thin sections SAM P34167-1, SAM P34167-2. Paratypes: SAM P31962-1, SAM P31962-2, polished slab counterparts; and thin section SAM P34168-1.

Figure 6.

Arrowipora fromensis

Fuller & Jenkins (1995)
Fig. 4

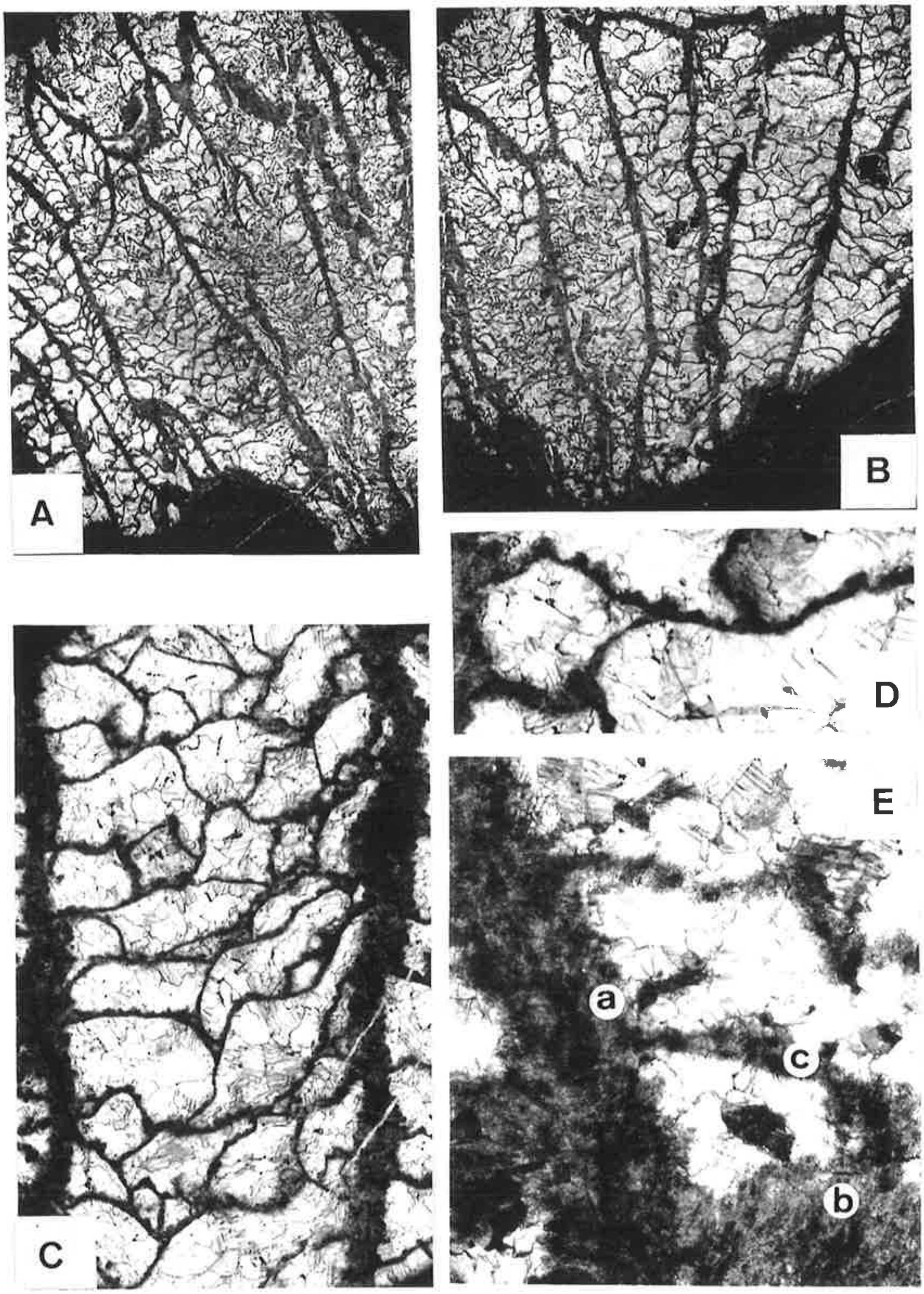
Longitudinal sections of Holotype SAM P34167.

6A & B. (Adjoining sections) illustrating general shape of the corallites, tabulae, vertical and basal corallite walls (x2.4).

6C. Illustrating the irregular surface of the walls and upper surface of tabulae. Two fractures which post date growth are observed mid to lower right of figure, together with the recrystallized fabric within the corallite. (x10.6).

6D. Enlarged section (x2.4) of corallite (lower right Fig. 5B) illustrating tabulae with possible septal spinules on the upper surface.

6E. Higher magnification (x40) of a corallite section illustrating diverging fibres of a vertical wall (a); and the similar structure of the basal wall of parricidal corallites which continue to grow following increase (b); and tabulae (c).


A
B
C
D
E
a
c
b

Description

Colony large, more than 24 cm tall and extending laterally well in excess of 23 cm: the described material represents fragments broken either from one colony or possibly several associated colonies. In longitudinal section the corallum may broaden upward, or more commonly, wide shelves extend laterally over adjacent sediment. Shelves are either irregularly rectangular in shape, with corallites tending to diverge slightly, or are plate-like with corallites often more inclined. Individual shelves measure up to 70 mm high and 130 mm in width (Fig. 5). The upper surface of the shelves is irregularly horizontal to concave, and calices may extend up to 7 mm past the upper-most tabellae. In transverse section (Figs 7A,B,C), the cerioid corallites, are seen as 5-8 (generally 6) sided polygons, varying between 6.5 and 14 mm in diameter, being generally 7 - 11 mm.

Walls vary between 0.1 and 1.0 mm, and are wavy to almost straight. The inner surfaces of the walls are irregular, due to the insertion of numerous tabellae and septal spines. In thin sections, a medial line divides the walls of adjoining corallites (Figs 7A,C).

In transverse section, at low magnifications (up to X 40) straight to slightly diverging fibres crossing the walls between adjacent corallites are commonly interrupted by the medial line (Figs 7A-D). In longitudinal section, fibrous elements diverge outward and upwards from the medial line and commonly protrude into the lumen giving the walls an irregular appearance. The walls which truncate parent corallites and form the base of subsequent corallites, are composed of vertical to slightly inclined fibres. They arise from the vertical walls and are usually V-shaped, but may be undulating horizontal or inclined (Figs 6C,D,E).

In longitudinal section (Figs 5 & 6A,B,C), individual corallites are prismatic to irregularly cylindrical and up to 14 mm wide and 47.5 mm long. Corallites vary little in diameter and length, prior to the addition of new corallites (increase).

Figure 7.

Arrowipora fromensis

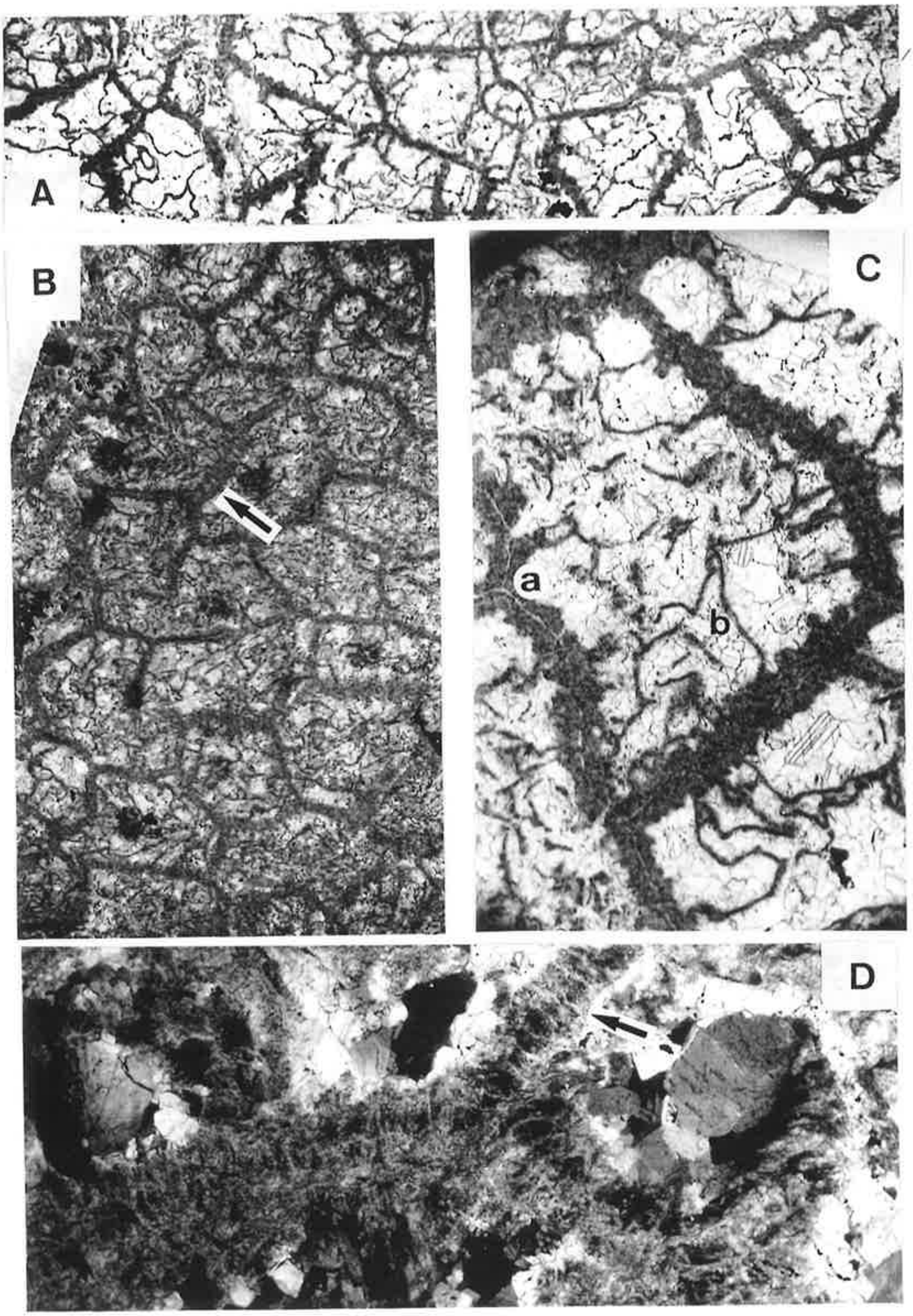
Fuller & Jenkins (1995)
Fig. 5

7A. Transverse section of Holotype SAM P34167 (x3.2).

7B. (x3.2), transverse section of Paratype SAM P34168; showing variation in corallite shape and septa. Tabulae are observed as irregular lines within the corallites: the midline of the wall (arrowed) may be seen in some adjoining corallites.

7C. Enlarged section (x10.5) of 5A illustrating septa, wall irregularities, midline (a) and tabulae (b). The recrystallized fabric is observed within the corallite.

7D. Corallite walls (x40) showing the bundles of fibres transverse to the wall (arrowed) in sections of the specimen.


A
B
C
a
b
D

Increase is both lateral and peripheral intracalicular, parricidal within the established body of the colony (Figs 5 & 6A,B).

Tabulae are numerous, commonly formed by incomplete, globose and dissepiment-like tabellae. Uncommonly, some are continuous across very narrow corallites. Tabellae may arise from the wall, or from adjacent tabellae, extending inward and curving downwards to meet upon other tabellae. They are very thin, generally less than 0.06mm, often wavy and rarely straight. Small projections often occur on the upper surface of tabulae (Fig. 6D). In transverse section, tabellae are seen as wavy and crenate lines arising from the walls and anastomosing with adjacent tabellae (Figs 7A,B,C). At low magnification, the fibrous structure of the tabellae is similar to that of the walls, with some bundles extending to give the small projections on the upper surface. In longitudinal section, the fibrous elements are normal to the base of the tabellae.

In transverse section, septal spines are either numerous or absent, numbering 35 or less, and tend to be difficult to distinguish from other irregularities on the wall (Figs 7A,B,C). Where present, they are short (up to 0.25 mm in length), blunt triangular or spine-like in shape, generally equal in length, and distance from each other (about 0.25 to 0.5 mm). They are commonly present on some walls while absent on others within a single corallite. Septal spines appear to be the continuation of bundles of fibres extending from the fibrous wall, usually terminating as, or being seen as fan-shaped tufts (see preservation). In longitudinal section, the generally upturned septal spines are observed to occasionally form short vertical rows on corallite walls.

4.2:2

Family: uncertain
Genus: *Moorowipora* Fuller & Jenkins 1994
Type species: *Moorowipora chamberensis* Fuller & Jenkins 1994
Early Cambrian (Late Botomian) Moorowie Formation
Flinders Ranges South Australia

Etymology: For the type locality near the Moorowie Mine in the eastern Flinders Ranges.

Diagnosis: Corallum small, varying from massive cerioid to fasciculate, comprising polygonal, oval or rounded corallites. Corallites are long, tuberoid to irregularly cylindrical. Walls are thin, wavy to crenate, rarely straight. Tabulae are irregularly spaced, mostly complete, concave upwards to undulating horizontal. Septa absent, or number up to 20 in each corallite. Where present, septa are randomly spaced, short and form wedge to spine-like projections into corallites, arising from inward angulations of the wall. Pores appear to be absent.

Moorowipora chamberensis Fuller & Jenkins 1994

FIGS 8 - 11; TABLE 1

1994 *Moorowipora chamberensis* FULLER & JENKINS, figs 2-7
1995 *Moorowipora chamberensis* SOROUF & SAVARESE, pts 1-3
1997 *Moorowipora chamberensis* SCRUTTON, figs 19g,19h,19j.

Etymology: For nearby Mt Chambers.
Diagnosis: As for genus.

Material

The holotype, paratypes and several other colonies come from one rock sample measuring 270 mm long, 230 mm wide and 120 mm thick: taken from a large

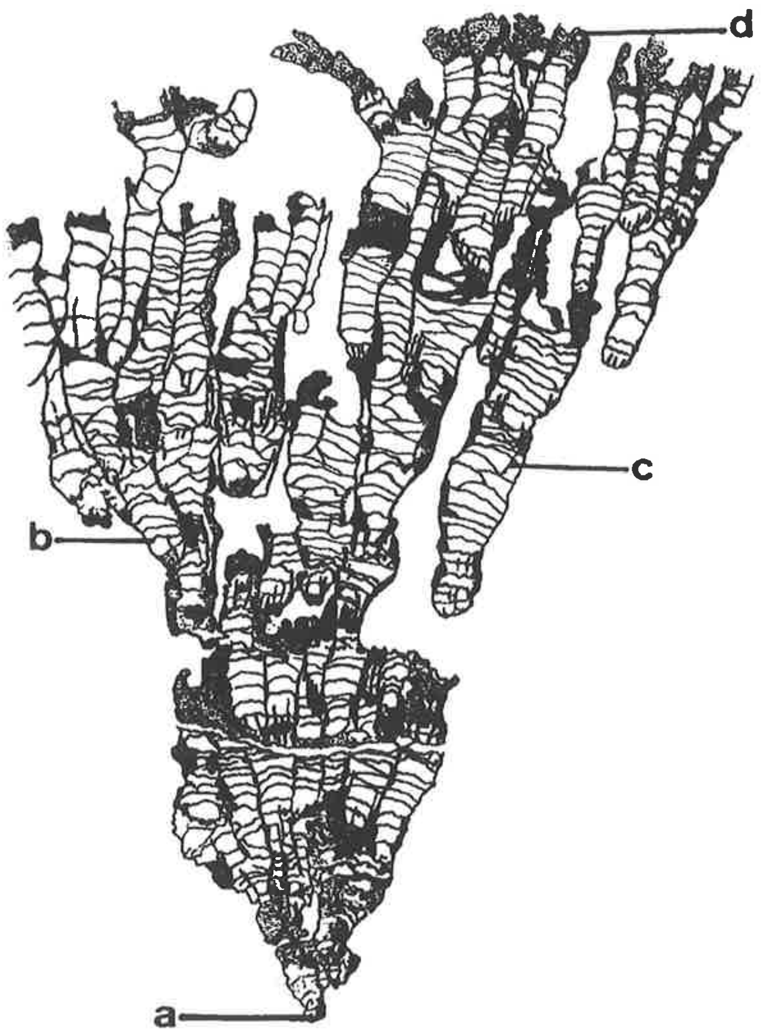


Figure 8.

Moorowipora chamberensis

Fuller & Jenkins (1994)
Fig. 2

Interpretive sketch (longitudinal section) of holotype **SAM P34165;** illustrating cone to fan shaped colony; the form of individual corallites and protocorallite (a), tabulae (b), septa (c), calice (d), lateral increase (top centre & right) and peripheral intracalicular increase (x 2.5).

Figure 9.

Moorowipora chamberensis

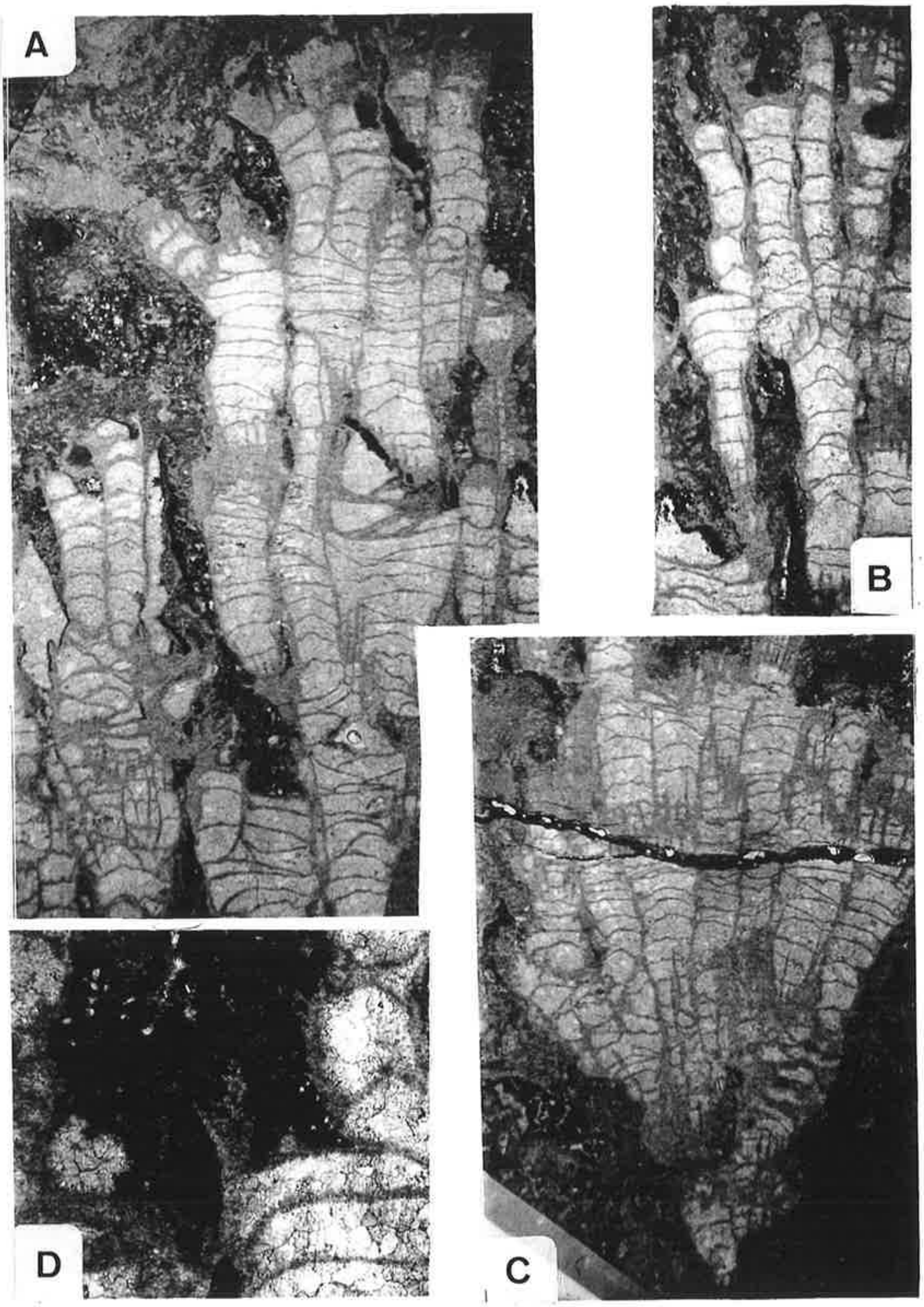
Fuller & Jenkins (1994)
Fig. 3

Longitudinal sections of holotype SAM P34165; illustrating areas of the colony.

9A & B. Upper part of the colony with walls extending above the corallum, showing manner of increase and corallite structure evident (x4.)

9C. Base of colony (x 4).

9D. Higher magnification of (B) showing normal and thickened tabulae (lower left), and oblique projections of outer wall (centre right x 15).


A
B
C
D

boulder within the Moorowie Formation, near the Moorowie Mine in the eastern Flinders Ranges. Individual colonies are small, the holotype being less than 50 mm tall and about 30 mm wide. Colonies appear to be isolated from each other, surrounded by an orange-fawn silty limestone matrix.

Type specimens: Holotype SAM P34165, four thin sections, SAM P34165-1; SAM P34165-2; Paratypes SAM P34166-1; SAM P34166-2.

Description

In transverse section (Fig. 10), corallites show gradation into two distinct habits, massive cerioid and fasciculate dendroid. In fasciculate habit, corallites rarely touch, are circular to slightly oval in shape and vary in diameter from 0.95 to 3.75 mm. Corallites with massive habit are rather irregularly shaped 5 or 6 sided polygons, sometimes oval or rectangular, rarely circular; they vary individually in diameter from 0.77 to 3.5 mm.

Walls are thin, varying between 0.1 and 0.15 mm in thickness and show a relic fibrous structure (Figs 9 &10). A midline is apparent between many adjoining corallites. Walls are wavy to slightly crenate, being rounded in isolation or adjacent to small spaces in the corallum, with a tendency to become straighter and less distinct where they merge with the walls of adjoining corallites.

In longitudinal section (Figs 8 & 9), each colony is generally small, numbering from 2 or 3 to about 16 corallites. Colonies are either cone to fan shaped, diverging outward from a single protocorallite; or more rectangular, where they appear to arise from several adjacent corallites. Increase is both lateral and peripheral intracalicular, producing one, two or more off-sets (Figs 8 &9).

Individual corallites are tuberoid to irregularly cylindrical in shape and vary greatly in width and length (up to 19.5 mm), prior to increase (formation of a new corallite). The base is rounded and blunt, the protocorallite producing 3 or 4 short septa prior to the formation of an initial tabulae.

Figure 10.

Moorowipora chamberensis

Fuller & Jenkins (1994)
Figs. 4 & 5

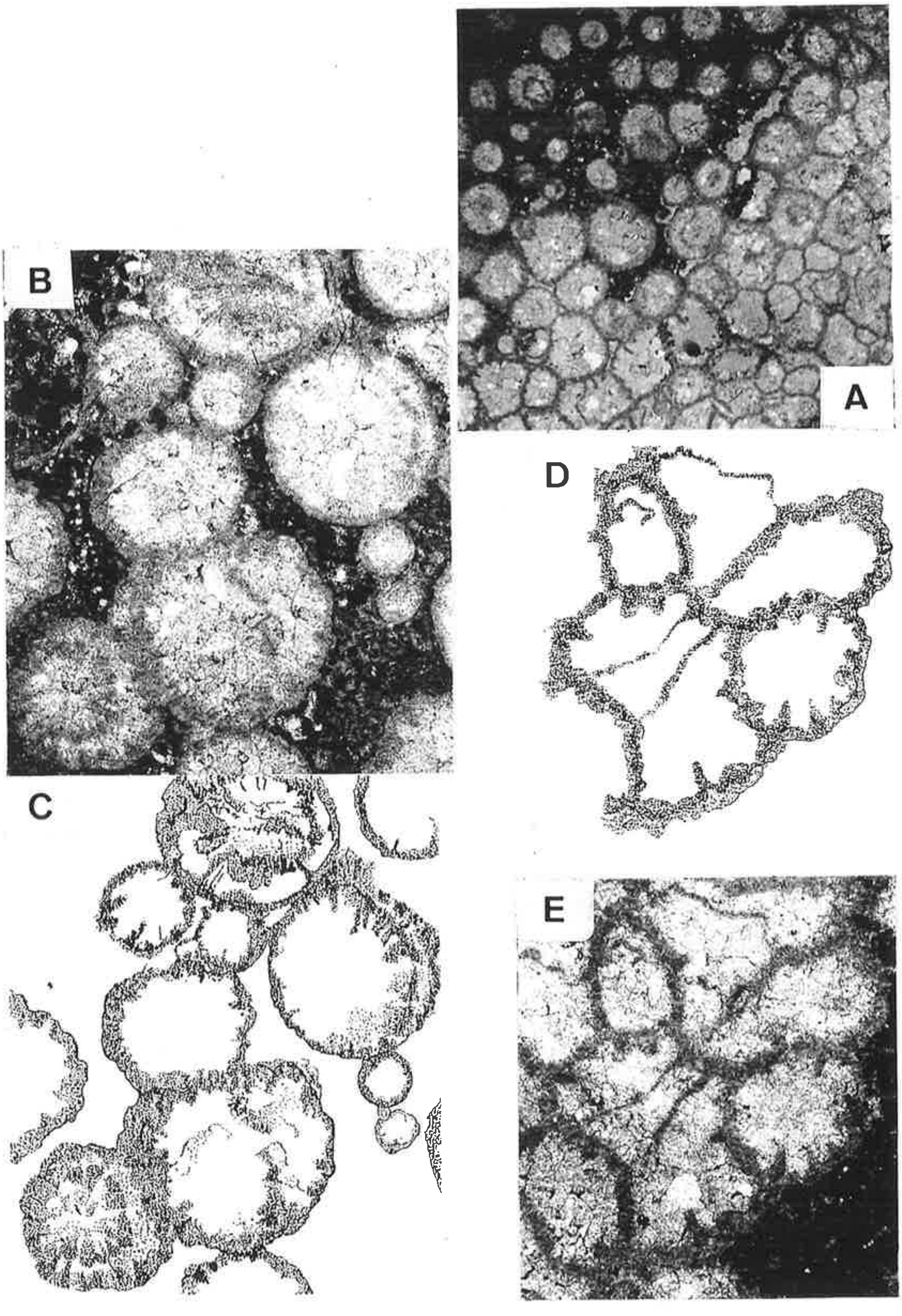
Transverse sections and interpretive sketches of holotype SAM P34165.

10A. Transverse section of holotype SAM P34165; part of corallum showing both cerioid and fasciculate areas (x 3.3).

10B & C. Fasciculate (x 10)

10D & E. Cerioid areas of the corallum.

Differences can be seen in corallite shape, septa, (x 10.5) and new walls divides corallites formed during offset formation. Rejuvenation of corallites (C & D) is evident top right and bottom centre.


A
B
C
D
E

The calice is prominent extending between 2.5 and 4.75 mm past the last tabulae (Figs 9B,D).

Tabulae are mostly complete, mainly convex upward or undulating horizontal, often down turned where they meet the wall (Figs 8 & 9). They are irregularly spaced, but commonly occur at the same level in adjacent corallites. The distance between them is highly variable (0.35-2.1 mm), while the thickness of tabulae varies from 0.002 to 0.01 mm.

Septa number up to 20 in fasciculate corallites, are very short (0.01-0.2 mm), generally equal in length, triangular to wedge shaped, often indistinct. They form protrusions on the wall of the corallite at sites of inward creasing (Fig. 10). In massive, cerioid corallites in the main body of the corallum, there may be up to 10 septa or septa may be absent. Septa are randomly spaced; long and short septa may alternate, or only long or short septa may be present. Septa are wedge to spine like in shape. Septa are generally longer than in the fasciculate corallites. In longitudinal section septa are observed as continuous vertical laminar plates intersecting normally with tabulae.

Microstructure

The microstructure was studied at magnifications up to X 200, and photographs were taken under polarized light. In transverse section at low magnification (Fig. 10), relic fibrous elements, which form the sclerenchyma and apparently represent indications of original biocrystals, appear as continuous lineae across the wall and into the septa. At higher magnification (Figs 11A,B) the interlocking fibrous elements form triangular to rectangular shaped bundles, composed of narrow parallel-sided and blade-like geniculate structures up to 164 *u*m long and 37 *u*m wide. These are angled upwards and outwards from the centre of each corallum. The bundles have the appearance of crossing, or being stacked over underlying layers.

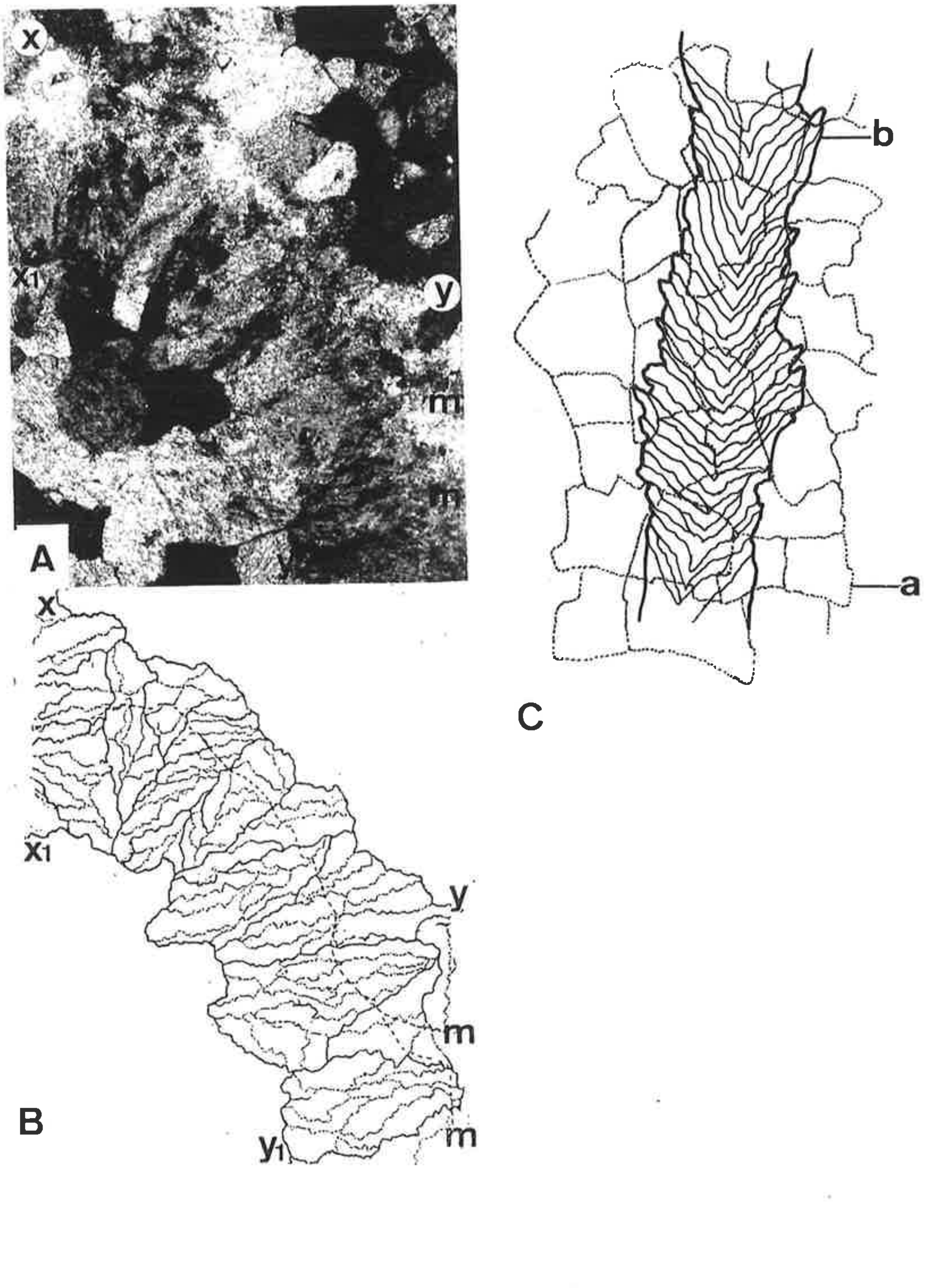
Figure 11.

Moorowipora chamberensis

Fuller & Jenkins (1994)
Figs. 6 & 7

11A & B. Transverse section and interpretive sketch of holotype SAM P34165; illustrating triangular to rectangular bundles of fibres extending across the walls of the corallite. Notations x-x1 and y-y1 define boundaries of illustration, m is midline of the wall (x 44).

11C. Longitudinal section (cartoon sketch) showing large crystals of the recrystallization fabric (a) incorporating the wall of compound corallites (b). Relic biocrystal fibres diverge upward and outward.


x
x_1
y
m
m
A
x
x_1
y
m
B
m
y_1
b
a
C

Near the midline of walls the fibres are often less oblique and have a slightly different orientation, appearing to be broader and more randomly oriented.

In longitudinal section at magnifications of X100 to X200, the mid-plane of the wall seems to have been composed of irregularly shaped, crenate, interlocking platelets which individually represent the fibrous lineae of transverse cuts. Platelets may be almost rectangular, vertical to slightly inclined, occasionally almost horizontal in the middle of the wall. They commonly diverge outward towards the top of corallites (Fig. 11C). Wall platelets are more elongate and wider than the fibre bundles seen in transverse section, being up to 190 *u*m in length and 138 *u*m in width.

Tabulae are continuous with the inner edge of the wall, which converges slightly around them. The structure of the tabulae is similar to the septa and wall in transverse section, with bundles of fibres being mainly triangular, or irregularly shaped. Triangular bundles of fibres are up to 360 *u*m in length, and 308 *u*m in width. In tabulae of normal thickness, adjoining triangular bundles interlock forming a crenate upper and lower surface. A more complicated interlocking pattern is formed in thickened tabulae.

4.2:3

Family: uncertain
Genus: *Adelaideipora* gen. nov.
Early Cambrian (Late Botomian) Moorowie Formation
Flinders Ranges South Australia

Etymology: For Adelaide the capital city of South Australia.

Diagnosis: Corallum small, massive cerioid to fasciculate; with oval, rounded polygonal or slightly meandroid corallites which are prismatic, long, and cylindrical or sometimes cone-shaped. Walls are thin, often parallel to each other, straight to slightly curved, with short segments between septa and separated by a medial plane. Septa are plate like and number up to 18, are either long or short, and may or may not alternate. Tabulae are regularly spaced, occasionally irregular. Tabulae vary little in thickness, are generally complete and commonly horizontal, occasionally slightly concave up or undulate. Pores if present, are few in number.

Type species: *Adelaideipora cancelli* sp. nov.
FIGS 12 & 13; TABLE 2

Etymology:_ Cancelli, Latin for lattice or grating, in referring to the shape and placement of tabulae, giving a lattice like appearance to the coral in longitudinal section.

Diagnosis: Tabulae generally horizontal, strongly developed and evenly spaced, septa number up to 18, corallite diameter up to 3.75mm.

Material:

The holotype and paratype are from the same rock sample measuring 150 mm long, 95 mm wide and 100 mm thick evidently taken from a larger boulder of

Figure 12.

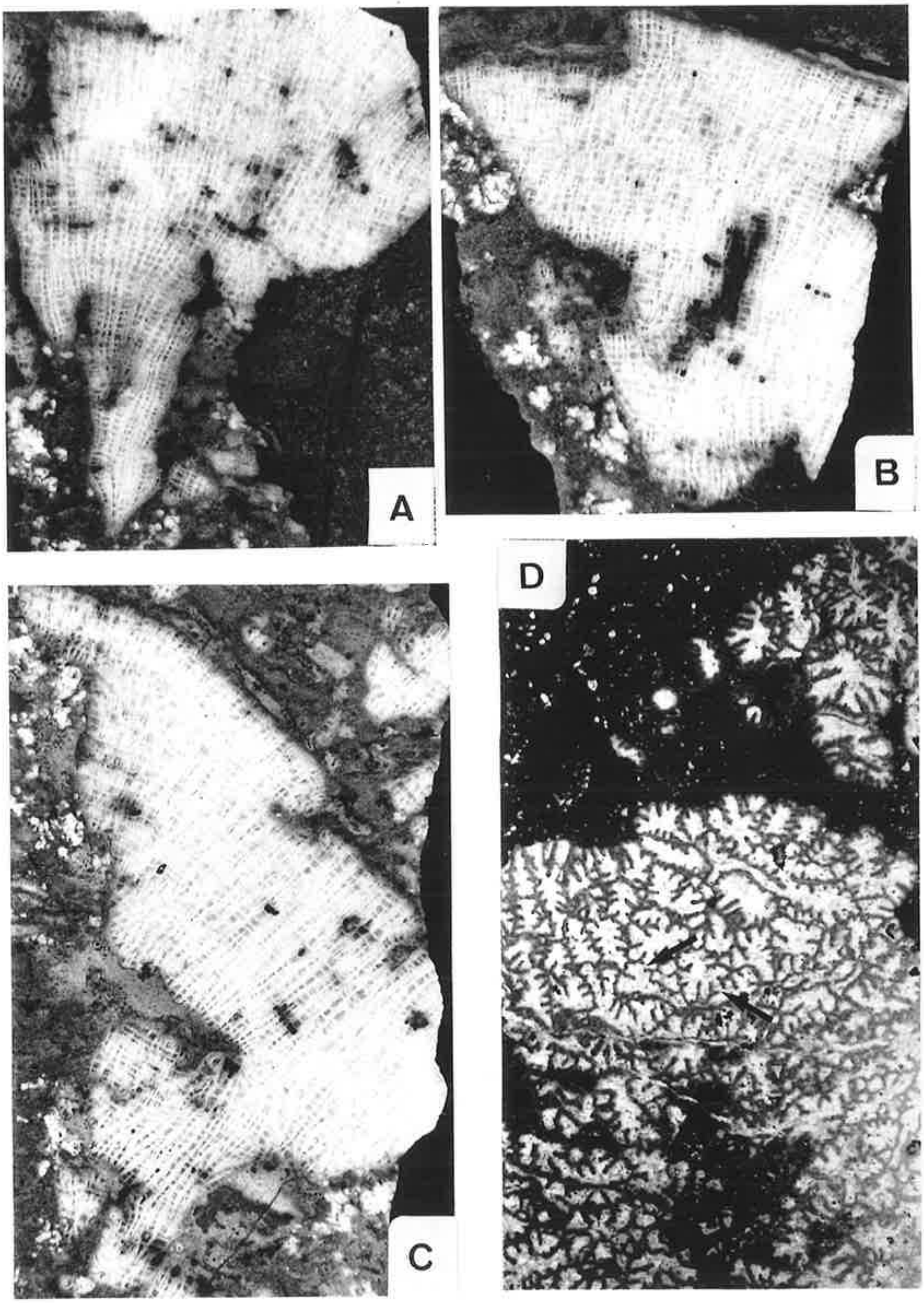
Adelaideipora cancelli

12A. Holotype SAM P34169 (rock slab), illustrating part of a larger colony arising from a single corallite after smothering of Paratype SAM P34170, situated stratigraphically below the holotype (x 1.4).

12B. Paratype SAM P34170, (rock slab), illustrating rectangular shelves extending from the colony, truncated and smothered across the corallum (x 1.4).

12C. Paratype SAM P34171 (rock slab), with shelf-like projections across adjacent sediment and smothering of corallites at the top of the corallum (x 1.4).

12D. Holotype SAM P34169, transverse section of the corallum, showing cerioid corallites and pores (arrowed) (x 4.3).


A
B
C
D

reef talus within the Moorowie Formation, near the Moorowie Mine. The holotype comprises a corallum, measuring about 70 mm tall and about 75 mm wide, arising from a single corallite. The lower part of the colony is cut in longitudinal section, while the upper part is more oblique. The corallum is truncated, with corallites broken and covered by sediment.

The paratype measures more than 55 mm high and 55 mm wide and is part of a larger colony positioned at a lower level in than the holotype in the rock specimen.

A second rock specimen has part of one colony and small fragments of possibly 3 other coralla, the preservation of which is similar to that of the holotype and paratype.

Type specimens: Holotype: P34169, two thin sections SAM P34169-1: SAM P34169-2: Paratype 1: SAM P34170-1: Paratype 2: SAM P34171 (rock specimen).

Description:

In longitudinal section the corallum of the holotype broadens outward from a single corallite, forming a narrow cone shape (Fig. 12A). The part of the corallite appears to have been broken and dislocated laterally over adjacent sediment, forming a shelf, while the opposite side of the colony has been covered with sediment. The colony continued to grow from this point, diverging outward, where it is more oblique in section. The paratypes have shelf-like projections over the underlying sediment where corallites have diverged outward and have subsequently been truncated (Figs 12B,C) A `stepped' appearance is shown by both colonies (Figs 12B,C).

In transverse section (Figs 12D & 13A) cerioid corallites are seen as irregularly circular to oval, varying in individual diameter between 2.20 and 3.75 mm.

Figure 13.

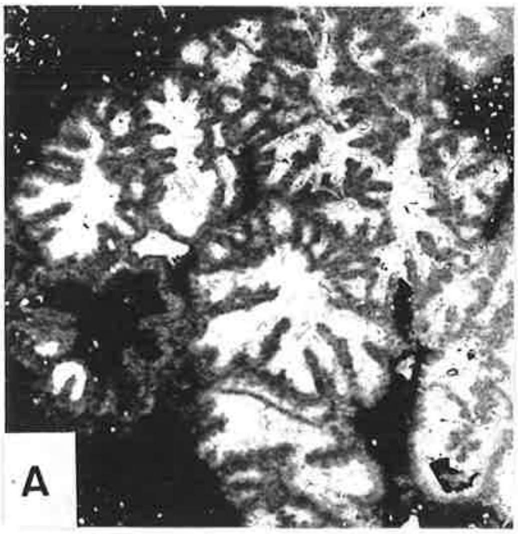
Adelaideipora cancelli

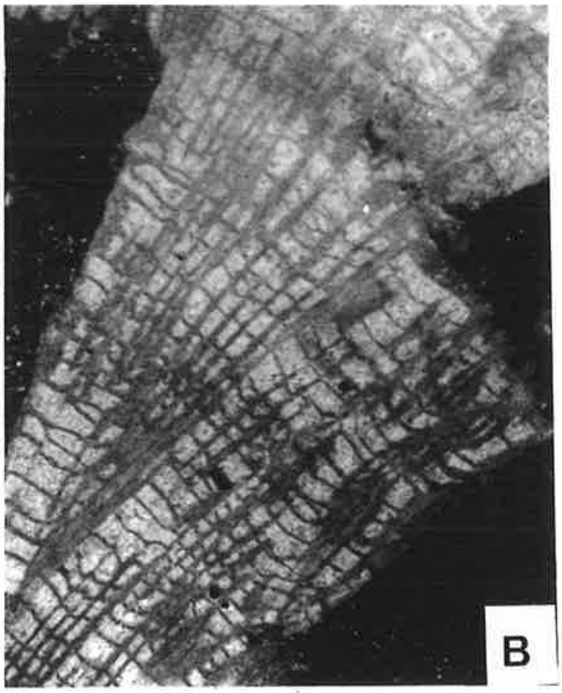
13A. Holotype SAM P34169, transverse section, illustrating form of corallites and septal insertion (x 8.4).

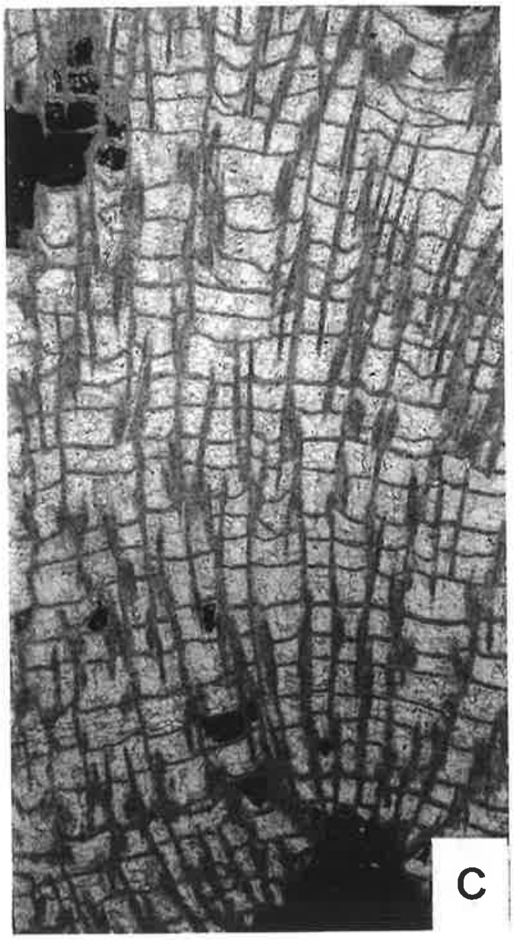
13B. Holotype SAM P34169, longitudinal section of part of the colony showing straight walls, tabulae and septal plates and peripheral intracalicular increase (arrow)(x 4.6).

13C. Paratype SAM P34170. Longitudinal section of part of the colony showing straight walls, tabulae and septal plates (x 5.6).

13D. Holotype SAM P34169. Enlarged longitudinal section illustrating mid-line in the walls (arrowed and at bottom left side) and septal plates (x 16.7).


A


B


C


D

Meandroid corallites are polygonal or rectangular in shape, the latter being up to 3.60 mm long and 0.90 mm in width.

Walls are thin, varying between 0.10 and 0.30 mm in thickness, and are wavy to crenate, particularly the exterior walls of corallites at the margins of the colony. Walls form short segments between the many septa bases, with a medial line apparent between most adjoining corallites (Fig. 13A).

In longitudinal section (Figs 13B,C), the walls of individual corallites are straight to slightly curved, the shape of corallites being long, narrow cylindrical or occasionally cone-shaped when arising from the base of the colony and broadening. Corallites are approximately 6.3 to 11.2 mm in length in the holotype, and up to 25 mm long in the paratype, prior to increase (addition of new corallites). At increase up to four daughter corallites may be produced. Increase is both lateral and peripheral intracalicular, but does not appear to be parricidal as the original corallite continues grow (Fig.13B).

Vertical walls tend to be slightly curved or straight and are relatively smooth. However, in some corallites small protuberances jut out into the lumen (Fig. 13D). This irregular surface appears to be caused by the biocrystal structure of the wall. Even at low magnification (x20), a medial line and biocrystal fibres can be seen in the walls, diverging outward at an angle towards the calice (Fig. 13D). Vertical alternating light and dark elements are also apparent and occur predominantly where walls are slightly thickened.

Tabulae mostly complete, horizontal, straight to slightly curved, rarely wavy or concave down (Figs 13B,C). Tabulae are also strongly developed and evenly spaced, level with those in both individual corallites, as well as seeming to extend through adjoining corallites. The regular spacing gives the colony a 'lattice' appearance. The distance between tabulae varies from 0.20 to 0.90 mm, (up to 1.05 mm in the paratype), but is usually between 0.65 and 0.75 mm. Thickness of the tabulae is between 0.06 and 0.20 mm, but generally between

0.10 and 0.16mm. Tabulae at the base of the holotype are in the upper range of thickness (0.18 to 0.20 mm), being generally thicker than tabulae towards the top of the corallum or in the paratype.

Septa number from 5 to 18, although 7 to 12 is more common (Figs 12D & 13A). Septa vary in length from 0.15 to 0.73 mm, being generally between 0.30 and 0.65 mm, and vary between 0.09 and 0.15 mm in thickness (0.12 to 0.15 mm average). Long and short septa may or may not alternate. Septa in the meandroid corallites are commonly short and more similar in length than those of the cerioid corallites. Septa may be either slightly curved or straight, arising at inward creasing of the walls, sometimes bearing blunt spines at their axial margins. In longitudinal section septa are observed as vertical laminate plates intersecting normally with tabulae (Figs 13B,C). Pores are rare, their individual diameters measuring between 0.11 and 0.30 mm.

4.2:4

Type species: *Adelaideipora lafustei* sp. nov.

FIGS 14 - 15B; TABLE 2

Etymology: For the late Jean G. Lafuste, of the Museum National d'Histoire Naturelle, Paris, France, who described *Flindersipora bowmani*, the first coral from the Moorowie Formation.

Diagnosis: Septa number up to 14, tabulae are usually down turned, sometimes undulating horizontal and regularly spaced for the most part, sometimes more randomly inserted, and corallite diameter is generally less than *A. cancelli.*

Material

The holotype and paratype are colonies from two different rock samples taken from a larger boulder of reef talus within the Moorowie Formation, near the Moorowie Mine.

Type specimens: Holotype: P36699, two thin sections SAM P36699-1: SAM P36699-2: Paratype 1: SAM P36700-1: SAM P36700-2.

Description:

In longitudinal section, the holotype comprises a rejuvenated fan shaped corallum, measuring 25 mm tall and 37 mm wide, positioned higher in the sediment above another corallum which is more than 29 mm tall and more than 33 mm wide (Fig. 14C). The upper corallum arises from a single corallite from the lower; the upper corallum is viewed mostly in longitudinal section, while the lower is oblique.

Figure 14.

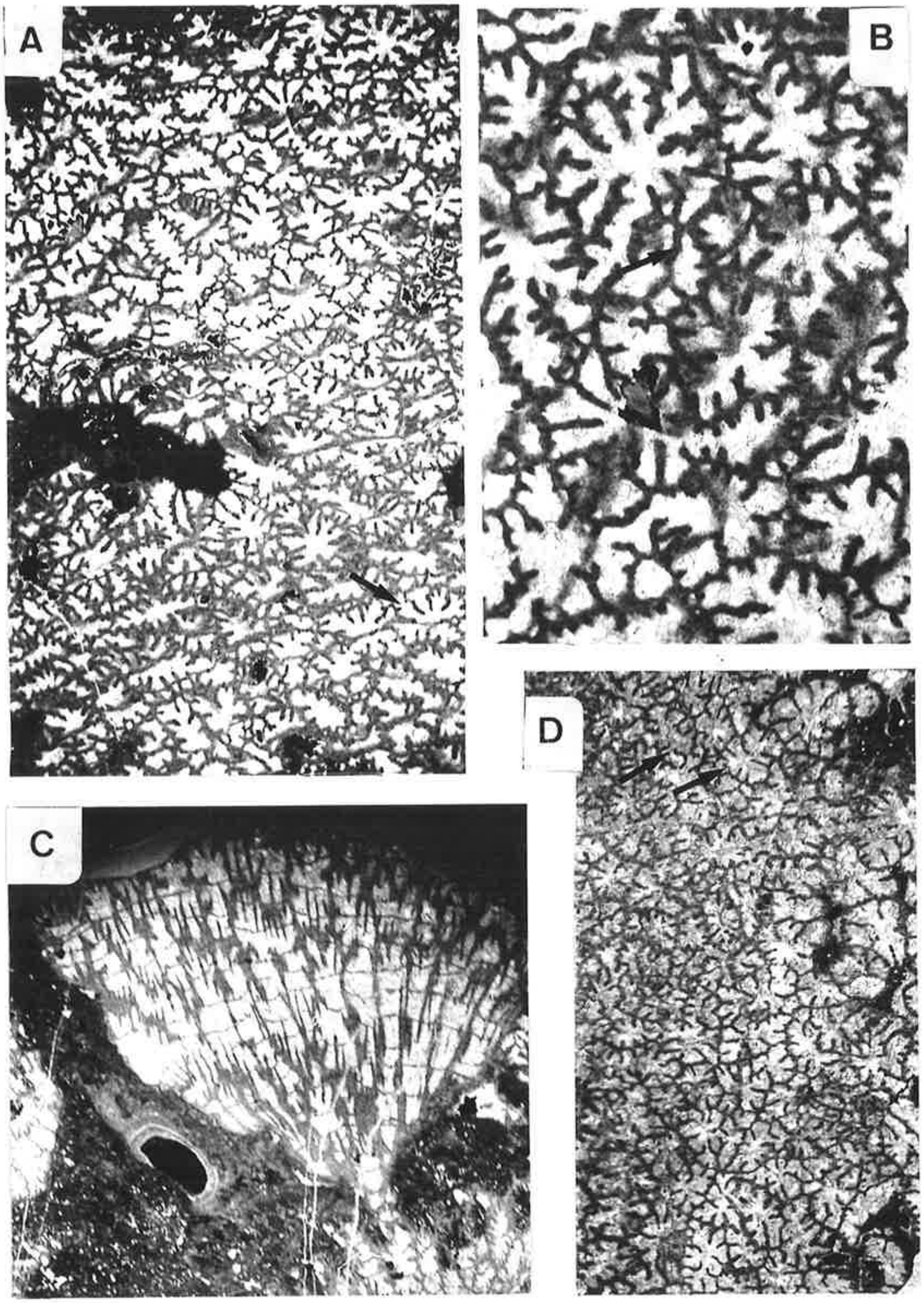
Adelaideipora lafustei

14A. Holotype **SAM P36699,** transverse section, illustrating form of corallites and septal insertion and pores (arrowed) (x 4).

14B. Holotype **SAM P36699**. Enlarged transverse section showing faint midline in the wall (arrowed), crenate walls and spine-like septa (x 8.2).

14C. Holotype **SAM P36699.** Longitudinal section of part of the fan–shaped colony arising from a single corallite and smothered corallites of a colony stratigraphically below (x 3.7).

14D. Paratype **SAM P36700.** Transverse section of part of the colony showing form of the corallites, septal insertion and pores (arrowed) (x 3.7).


A
B
C
D

The upper corallum is truncated, with corallites broken at the edge of the specimen, while those in the lower appear to have been partially smothered, with some corallites extending into the sediment about 1.7 mm above the last tabulae (Fig. 14C). The paratype is part of a larger colony measuring more than 33 mm tall and 51 mm wide (Fig. 15A). The centre of the colony is viewed in longitudinal section, becoming more oblique towards the edges due to the inclination of the corallites. Corallites are generally truncated at the top of the specimen; a few smothered corallites near the middle extend into the sediment about 1.8 mm past the last tabulae (Fig. 15D).

In transverse section (Figs 14A,B), the cerioid corallites of the holotype are generally irregular polygons, sometimes oval, varying in individual diameter between 1.30 and 3.41 mm, in the paratype, 1.25 to 3.54 mm (Fig. 14D). Meandroid corallites are elongated polygonal or rectangular in shape, this often reflecting a cut section that is somewhat oblique.

Walls are thin, varying between 0.11 and 0.20 mm (generally 0.15-0.16 mm) in the holotype; 0.09-0.15 mm and generally 0.14-0.15 mm in the paratype. They are wavy to crenate, sometimes straighter between meandroid corallites (Figs 14A,B,D). Walls form short segments between the many septa bases, with a medial line occasionally visible between adjoining corallites (Fig. 14B).

In longitudinal section (Figs 14C & 15A), corallites are long, irregularly cylindrical and usually diverge outwards. Increase is both peripheral intracalicular and lateral at the edges of the colony.

Vertical walls tend to be slightly wavy, sometimes straight, commonly appearing jagged where septa, observed as continuous vertical laminar plates, join the wall.

Tabulae complete, slightly concave down, sometimes straight, rarely wavy. Tabulae are narrow and evenly spaced within individual corallites and often across adjoining corallites (Figs 14C & 15A). The distance between tabulae varies from 0.30 to 2.46 mm, (generally 1.0 to 1.5 mm) in the holotype and 0.57 to 1.65 mm (generally 0.80 to 1.20 mm in the paratype). Thickness of the tabulae is between 0.06 and 0.12 mm, but generally 0.06 mm in the holotype, and 0.06 to 0.14 mm (generally 0.06 to 0.07 mm) in the paratype.

Septa number from 6 to 14, in both the holotype and paratype, although 9 to 13 is more common (Figs 14A,B,D). Septa are strongly developed and vary in length from 0.20 to 1.35 mm (0.45 to 1.50 mm in the paratype), the thickness varying between 0.15 and 0.25 mm (generally 0.15 mm) in the holotype, and 0.10 to 0.21 mm (generally 0.12 to 0.16 mm) in the paratype. Long and short septa may or may not alternate, or only long septa may be present in a corallite. Septa are vertical laminar plates and may be either slightly curved or straight, arising at inward creasing of the walls, occasionally bearing small spines. Pores are rare, their individual diameter measuring between 0.14 and 0.33 mm in the both the holotype and paratype (Figs 14B,C).

Figures 15A & 15B

Adelaideipora lafustei

15A. Paratype **SAM P36700**, longitudinal section, showing corallites extending above part of the corallum, walls and evenly spaced tabulae (x 3.3).

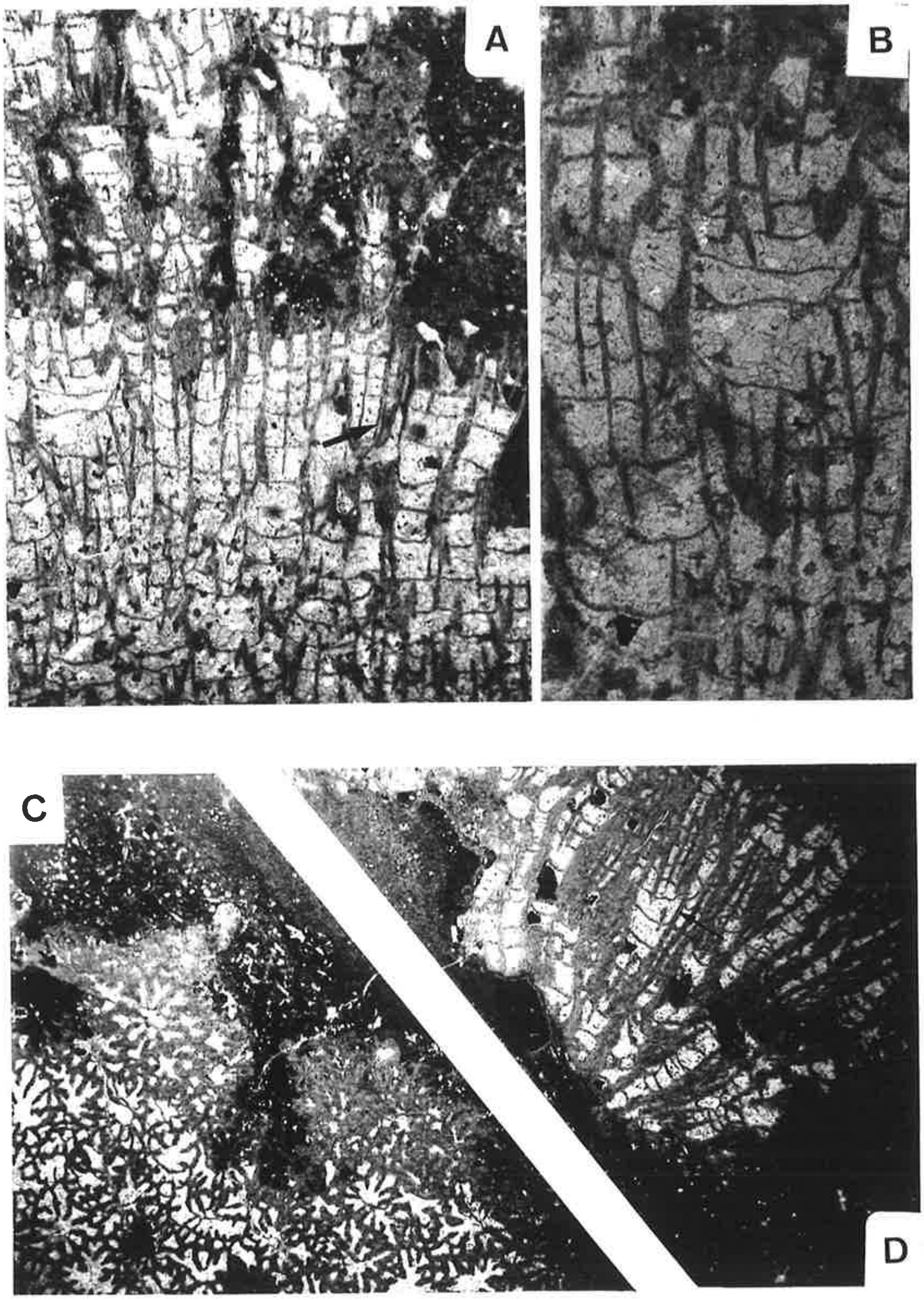
15B. Paratype **SAM P36700**. Enlarged longitudinal section, showing tabulae and septal plates (x 9.5).

Figures 15C & 15D

Flindersipora uldanami

15C. Paratype **SAM P34173**. Transverse part of the colony illustrating form of the corallum and spine-like septa (x 3.7).

15D. Paratype **SAM P34173**. Longitudinal part of the colony situated adjacent to transverse section (C), showing walls, tabulae and septal plates (x 3.7).


A
B
C
D

4.2:5

Family: uncertain
Genus: *Flindersipora* Lafuste 1991
Early Cambrian (Late Botomian) Moorowie Formation
Flinders Ranges South Australia

Type species: *Flindersipora uldanami* sp. nov.
FIGS 15C - 16D; TABLE 3

Etymology: Uldanami, the name of a mythical aboriginal from a legend centred around Moorowie and Mt. Chambers Gorge.

Diagnosis: Corallum small, massive cerioid to meandroid; comprising oval, rounded polygonal or slightly meandroid corallites which are prismatic, long, irregularly cylindrical to tuberoid. Commonly fine wavy often discontinuous threads of sclerenchyma cross the lumen. Walls are thin, wavy to crenate, rarely straight, with short segments between septa and separated by a medial plane. Septa are vertical laminar plates and number up to 16, are either long or short, and may or may not alternate. Tabulae are irregularly spaced, generally complete, undulating horizontal to concave, relatively even in thickness. Pores are few in number.

Material

The holotype and paratype are different colonies from rock samples taken from a larger boulder of reef talus within the Moorowie Formation, near the Moorowie Mine. The holotype measures more than 100 mm tall and 120 mm wide and is part of a larger corallum. The paratype comprises 2-3 small fan-shaped coralla (in longitudinal section) and shows part of one of these in transverse section. The largest fan shaped corallum measures more than 55 mm tall and 55 mm wide.

Figure 16

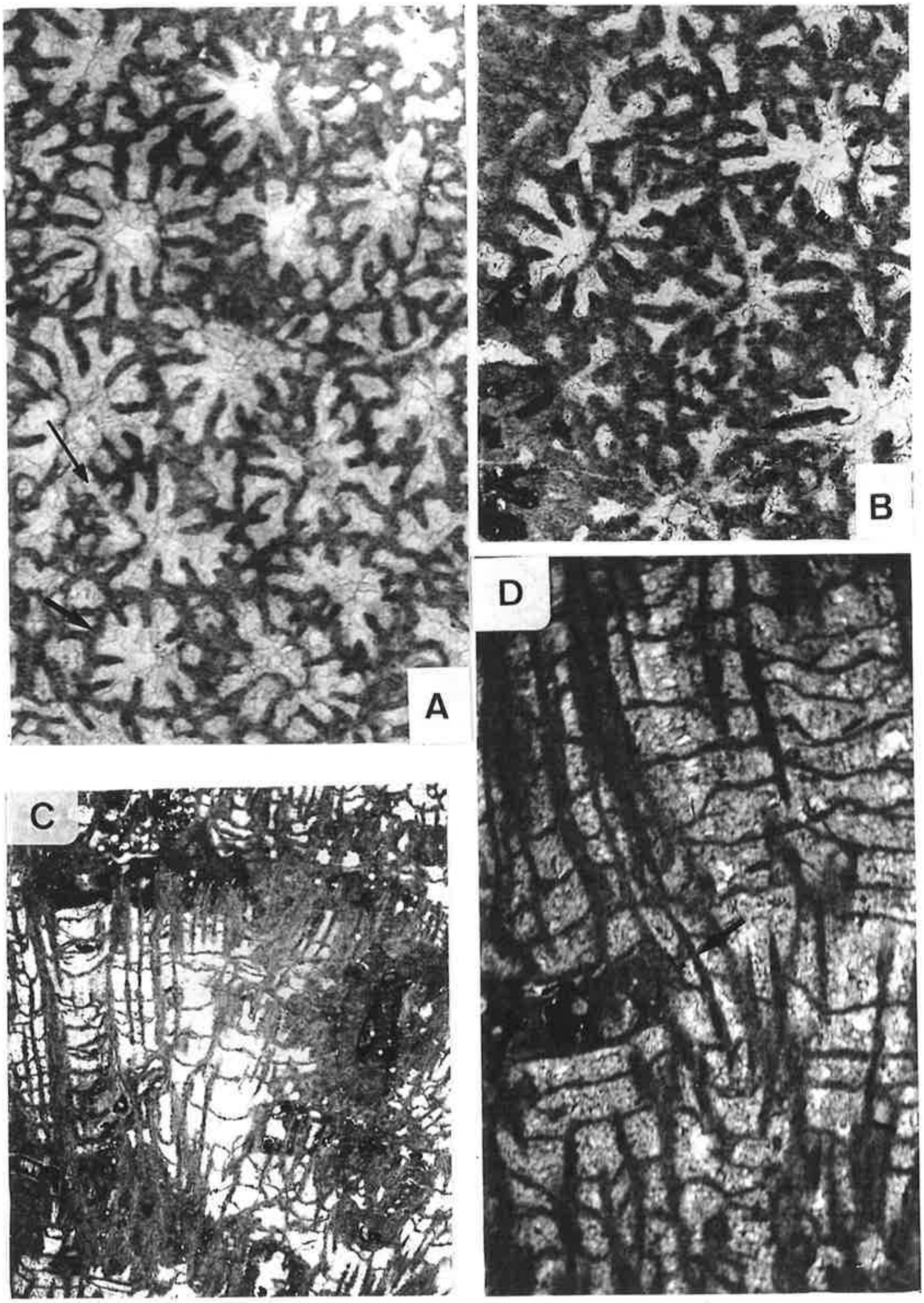
Flindersipora uldanami

16A. Holotype **SAM P34172**, transverse section illustrating spine-like septa, pores (thin arrow), midline in the wall (thick arrow) and thin sclerenchyma threads across the lumen (x 7.4).

16B. Holotype **SAM P34172**. Enlarged transverse section illustrating spine-like septa and thin sclerenchyma threads across the lumen (x 10.4).

16C. Holotype **SAM P34172**. Longitudinal section of part of the colony showing walls, tabulae, septal plates and corallites extending above the corallum (x 3.5).

16D. Holotype **SAM P34172**. Enlarged longitudinal section of part of the colony showing walls with midline (arrowed), tabulae and septal plates (x 7.2).


A
B
C
D

Type specimens: Holotype: P34172, two thin sections SAM P34172-1: SAM P34172-2: Paratype: SAM P34173-1.

Description:

The holotype is part of a massive colony, apparently more or less dome shaped. The paratype is seen in transverse, longitudinal and oblique sections (Figs 15C,D). In longitudinal section, a corallum fans outwards from a narrower base adjacent to the transverse section, probably arising from the side of the colony observed in transverse cut.

In transverse section (Figs 15C & 16A,B), corallites are cerioid to meandroid, mostly rounded polygonal, sometimes elongated polygonal in shape at the margins of the colony. Individual corallite diameter varies between 1.50 and 3.00 mm, while meandroid corallites may be up to 3.75 mm. Walls are thin, varying between 0.10 and 0.22 mm in thickness. They are wavy to crenate, particularly on the exterior walls of corallites at the margin of the colony, but commonly straighter between meandroid corallites. Walls form short segments between the base of septa, with a medial line apparent between most adjoining corallites (Figs 16A,D).

In longitudinal section (Figs 15D & 16C,D), individual corallites are long, irregularly cylindrical to tuberoid, generally increasing in diameter prior to increase (addition of new corallites). It appears that only one or two daughter corallites are produced at a time. Increase is peripheral intracalicular or lateral at the margins of colonies. Vertical walls tend to be wavy or curved, rarely straight, and relatively smooth (Figs 15D, 16D), they are commonly thickened and difficult to distinguish due to vertical lines in longitudinal section mainly representing septa.

Tabulae mostly complete, undulating horizontal or concave down, occasionally dissepiment-like. Tabulae strongly developed and rather evenly spaced.

The distance between tabulae varies from 0.14 to 1.25 mm, being more evenly spaced at 0.19 to 0.80mm in the paratype. Thickness of the tabulae is between 0.05 and 0.14 mm, or generally between 0.09 and 0.11mm (Figs 15D & 16C,D). Septa number from 9 to 16, although 11 to 14 is more common, and vary in length from 0.15 to 0.85 mm, being generally between 0.45 and 0.75 mm, and are between 0.10mm and 0.22 mm in thickness, (generally 0.15 mm to 0.20 mm). Septa tend to be approximately the same length in individual corallites, some of which may have more than two smaller septa together along the same wall, or occasionally alternate. Septa in the meandroid corallites are often smaller and similar in length. Septa are spine-like and may be either slightly curved or straight, arising at an inward creasing of the walls, sometimes bearing small spines (Figs 16A,B). In longitudinal section septa are observed as vertical laminate plates intersecting normally with tabulae, commonly appearing to thicken the walls of the corallites (Fig. 16D). Fine wavy and often discontinuous lines evident in the lumen (in transverse section) and probably represent sections of uneven or dissepiment-like tabulae (Figs 15C & 16A,B). Pores are rare, individually measuring between 0.12 mm and 0.15 mm in diameter.

4.2:6

Family: uncertain
Genus: *Flindersipora* Lafuste 1991
Early Cambrian (Late Botomian) Moorowie Formation
Flinders Ranges South Australia

Type species*:* *Flindersipora bowmani* Lafuste 1991
FIGS 17 A & B*;* TABLE 3

1991 *Flindersipora bowmani* LAFUSTE ET AL. , Pls 6&7, Figs 3-9
1992 *Flindersipora bowmani* SCRUTTON
1994 *Flindersipora bowmani* FULLER & JENKINS
1995 *Flindersipora bowmani* FULLER & JENKINS
1995 *Flindersipora bowmani* SOROUF & SAVARESE
1997 *Flindersipora bowmani* SCRUTTON Figs 18a & b.

Diagnosis*:* Massive cerioid corallum made of rounded polygonal or slightly meandroid corallites. Walls are rather thin, scarcely straight, generally crenulated, in short segments between septal bases. Septa are vertical laminae, strongly developed, varying in number from 6 to 16 in each corallite; they may or may not show alternation in length; their edges bear very blunt spines. Tabulae are irregularly spaced, variable in density; they are generally incomplete and for the most part concave upward. Pores are reduced in diameter and few in number. The sclerenchyma, identical in wall and septa is made of vertical to inclined biocrystals strongly embossed which for the greatest part are plane or slightly folded platelets. The skeleton is abundantly spotted by dark specks generally transverse to wall and septa (Lafuste *et al.* 1991; p.708).

Figure 17

Flindersipora bowmani

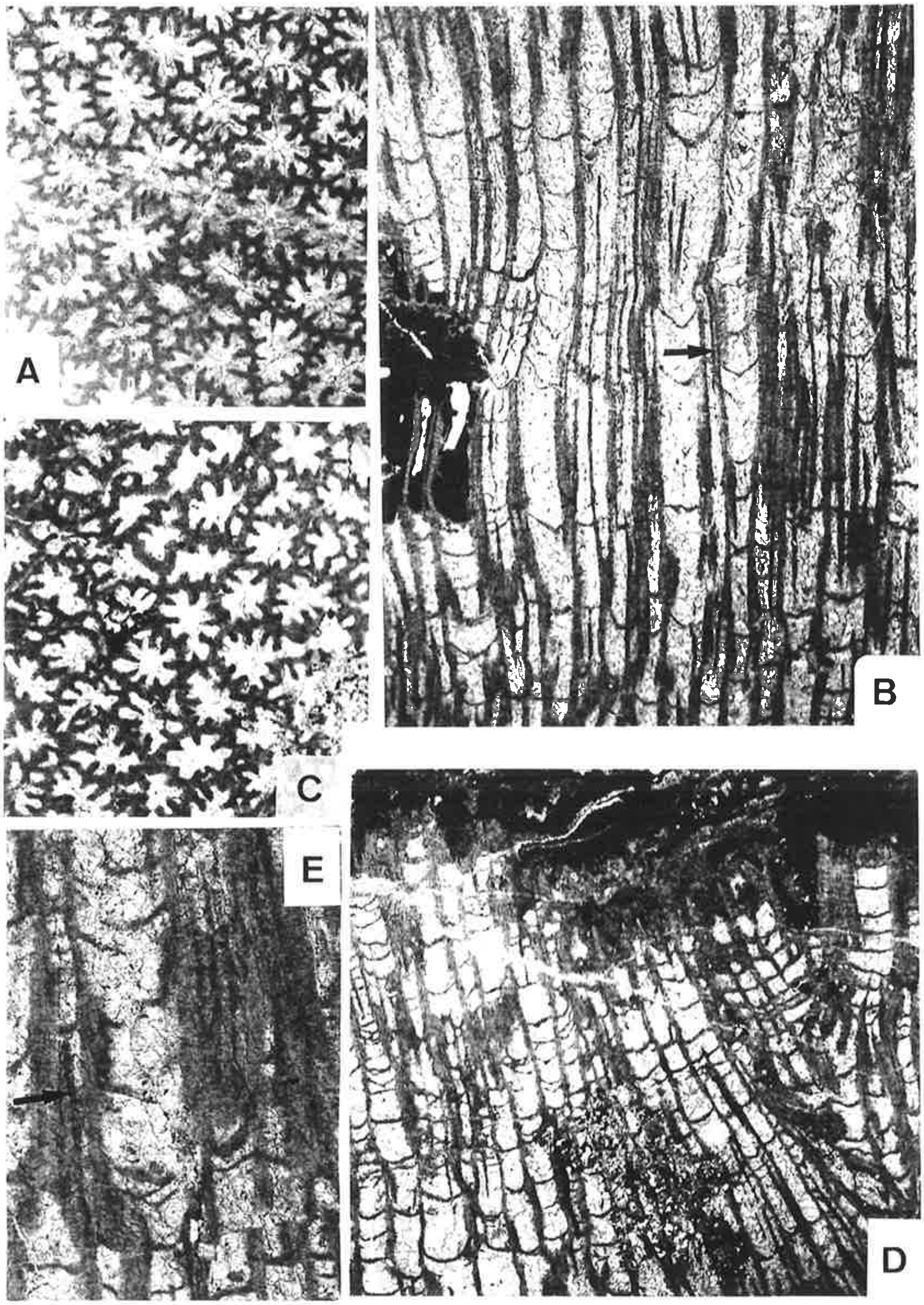
17A. Holotype SAM P31576, transverse part of the colony illustrating the form of corallites and septal insertion (x 6.0).

17B. Holotype SAM P31576. Longitudinal section of part of the colony showing walls, tabulae, septal plates and midline of the walls (arrowed) (x 4.0).

17C. SAM P34174, transverse section of part of the colony illustrating the form of corallites, septal insertion, being similar in form to the holotype (A), (x 6.3).

17D. SAM P34174. Longitudinal section of part of the colony showing waqlls, tabulae, septal plates, coralllties which extend above the corallum and lateral increase (right of colony), (x 4.0).

17E. SAM P34174. Enlarged longitudinal section of part of the colony (D), showing midline of the walls (arrowed), tabulae and septal plates (x 8.7).


A
B
C
E
D

Flindersipora bowmani (P34174)

FIGS 17 C - E; TABLE 3

Material

Numerous pieces broken from a larger colony of unknown size, part of which is inclined at about 40 degrees to the bedding, SAM P34174, two thin sections SAM P34174-1: SAM P34174-2.

Description

In transverse section (Fig. 17C) corallites are cerioid to meandroid, mostly rounded polygonal, sometimes elongated polygonal in shape at the edges of the colony. Individual corallites vary between 1.22 and 2.08 mm in diameter. In longitudinal section (Fig. 17D), individual corallites are long, irregularly cylindrical to tuberoid, generally increasing in diameter prior to increase (addition of new corallites). Increase is peripheral intracalicular or lateral, particularly at the margins of colonies. (Fig. 17D). Vertical walls are generally relatively straight and smooth, or sometimes curved or wavy. Walls vary between 0.14 and 0.30 mm in thickness, and are wavy to crenate, commonly straighter between meandroid corallites. Walls form short segments between the base of septa, with a medial line often visible between some adjoining corallites (Fig. 17E). Tabulae strongly developed and rather evenly spaced, mostly complete, mainly concave upward or undulating horizontal. The distance between them varies from 0.04 and 1.80 mm (generally 0.90 to 1.20 mm). Thickness of the tabulae is between 0.09 and 0.25 mm.

Septa vary in number from 6 to 12, while septal length is between 0.20 and 0.50 mm; long and short may or may not alternate. Septa are usually straight or may be slightly curved, arising at a inward creasing of the walls (Fig. 17C). In longitudinal section septa are observed as vertical laminate plates intersecting normally with tabulae. (Figs 17C,D).

4.2:7

Family: uncertain
Genus: *Blinmanipora* gen. nov.
Type species: *Blinmanipora hawkerensis* sp. nov.
Early Cambrian (Late Botomian) Moorowie Formation
Flinders Ranges South Australia

Etymology: For the nearby town of Blinman.

Diagnosis: Corallum large, massive cerioid, comprising irregularly polygonal, sometimes meandroid corallites; corallites long, slender, generally parallel sided to irregularly cylindrical; walls thin, sometimes straight, generally wavy to crenate: tabulae regularly spaced, usually complete, may be undulating horizontal to concaveup or concavedown and dissepiment-like; septal spines are rare and poorly developed, generally absent; mural pores probably absent.

Blinmanipora hawkerensis **sp. nov.**

FIG 18; TABLE 1

Etymology: For the town of Hawker in the Central Flinders Ranges.
Diagnosis. Septa often absent or number up to 7, corallite diameter up to 4mm.

Material

The material shows sections of probably one colony broken from a larger specimen, attached to or growing around small archaeocyaths. The calcimicrobe *Girvanella* encrusts part of the colony. The corallum is truncated abruptly, most corallites are white recrystallized spar, but many are ferroan calcite of varying colours (see preservation). The walls and structures within the corallites are generally white and are prominent against the darker sections.

Figure 18

Blinmanipora hawkerensis

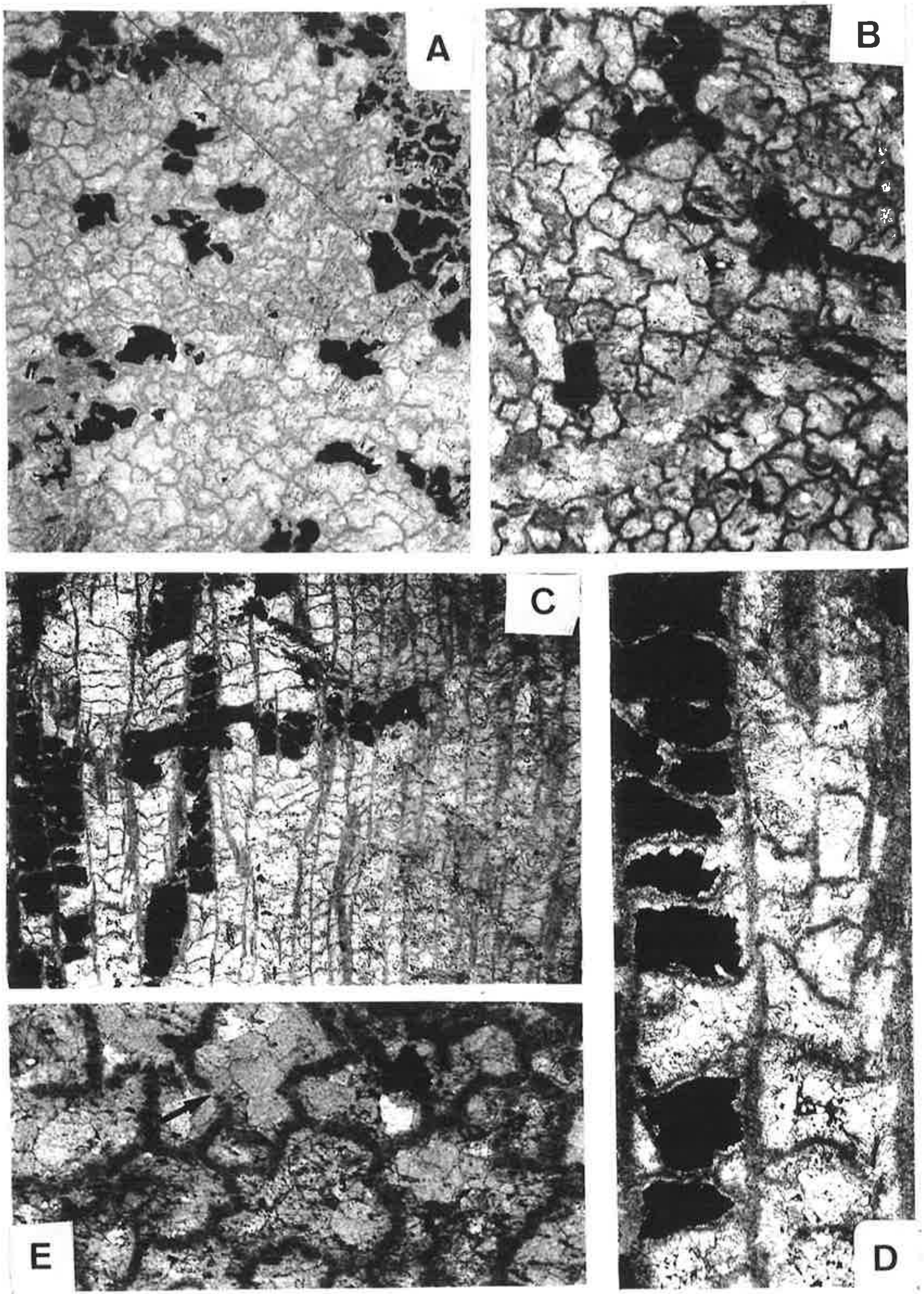
18A. Holotype SAM P36387-1, (x 4.0) and

18B. Holotype SAM P36387-2, transverse section of part of the colony illustrating the form of corallites, sometimes filled with ferroan calcite, and incomplete walls (x 6.8).

18C. Holotype SAM P36387. Longitudinal section of part of the colony showing walls, the variation in the insertion of tabulae and septal plates. The lumen is often filled with ferroan calcite (x 3.5).

18D. Enlarged longitudinal section of part of the colony (C), illustrating light and dark elements visible in some walls which may be an indication of a midline, and clacite biocrystals which extend into the ferroan calcite filled lumen (x 12.0).

18E. Enlarged transverse section of the colony (B), illustrating `pore-like' gaps in corallite walls which may represent incomplete walls (x 12.5).


A
B
C
D
E

Type specimens: Holotype: P36387, three thin sections SAM P36387-1: SAM P36387-2: SAM P36387-3.

Description

The described material comprise fragments about 130 mm wide and 50 mm tall broken from one larger colony. The colony is massive with no indication of overall shape.

In transverse section (Figs 18A,B), corallites are seen as irregularly shaped 4-8 sided meandroid polygons varying between 0.9 and 4.0 mm in diameter, but generally being between 1.0 and 2.5 mm. Walls are thin, varying between 0.12 and 0.25 mm thick, and are crenate to wavy, rarely straight. A medial line is sometimes present between the walls of adjoining corallites. Incomplete walls are common, creating a gap between either new walls growing across the corallite approaching original walls, or where two new walls grow towards each other and have not met (Fig.18E). The gap between walls appears `pore like' when observed in transverse section.

In longitudinal section (Figs 18C,D), individual corallites vary little in diameter and length. They are long and slender, parallel sided or irregularly cylindrical. Corallites are generally between 1.0 and 2.5 mm in width and in excess of 40 mm in length prior to the addition of new corallites (increase). Walls are rarely straight with corallites tending to follow the shape of those adjoining.

Tabulae are numerous and most are regularly spaced, commonly complete, undulating horizontal or concave upward; alternatively, tabulae may be globose and dissepiment-like tabellae (Figs 18C,D). Tabellae may arise from the wall, extend inward and curve downwards to meet other tabellae. Tabulae are thin, varying in thickness from 0.05 to 0.13 mm, while the distance between complete tabulae varies between 0.28 and 1.40 mm.

In transverse section, septa are generally absent, but rarely up to 7 may occur in larger corallites (Figs 18A,B). Where septa are present, they form short spines (up to 0.20 mm in length), being slightly curved or straight, arising from inward creasing of the walls. Septa-like protuberances are usually inward extensions of the corallite wall growing across the corallite during axial intracalicular increase, which may be unequal bipartite (Figs 18A,B,E).

TABLE 1

	M. chamberensis (holotype)	***A. fromensis*** (holotype)	***B. hawkerensis*** (holotype)
Corallite (D)	2.95-3.75	6.5-14.0 (7-11)	0.9-4.0
Walls (T)	0.10-0.15	0.10-1.00	0.12-0.25
Septa (N)	0-20	0-35	0-7
Septa (L)	0.01-0.02	<0.25	<0.20
Septa (T)	0.10-0.30	0.09-0.20	0.12-0.25
Tabulae (S)	0.35-2.1	Var.	0.25-1.40
Tabulae (T)	0.002-0.01	<0.06	0.05-0.13
Pores (W)			?

Dimensions of the main skeletal characteristics of corals.

Figures in brackets are average or more general measurements.

(D) Diameter (W) Width (L) Length (N) Number
(S) Spacing between (T) Thickness

Measurements in mm,

TABLE 2

	A. cancelli (holotype)	***A. lafustei*** (holotype)	***A. lafustei*** (paratype)
Corallite (D)	2.20-3.75	1.30-3.40	1.25-3.54
Walls (T)	0.10-0.30	0.11-0.20	0.09-0.15
Septa (N)	5-18 (7-12)	6-14 (9-13)	6-14 (9-13)
Septa (L)	0.15-1.35 (0.30-0.65)	0.20-1.35	0.14-1.15 (0.55-1.15)
Septa (T)	0.09-0.15 (0.12-0.15)	0.15-0.25 (0.15)	0.10-0.21 (0.12-0.16)
Tabulae (S)	0.20-0.90 (0.65-0.75)	0.30-2.46 (1.50)	0.57-1.65 (0.80-1.20)
Tabulae (T)	0.09-0.16 (0.10-0.12)	0.06-0.12 (0.06-0.10)	0.06-0.14 (0.06-0.07)
Pores (W)	0.11-0.30	0.14-0.33	0.14-0.33

Dimensions of the main skeletal characteristics of corals.

Figures in brackets are average or more general measurements.

(D) Diameter (W) Width (L) Length (N) Number
(S) Spacing between (T) Thickness

Measurements in mm.

TABLE 3

	F. bowmani (holotype)	***F. bowmani*** (34174)	***F. uldanami*** (holotype)
Corallite (D)	2.5-3.0	1.2-2.9	1.5-3.0
Walls (T)	0.15-0.25	0.14-0.30	0.10-0.22
Septa (N)	6-18 (12-18)	6-12 (7-9)	9-16 (11-14)
Septa (L)	0.60-0.80	0.20-0.50	0.15-0.85 (0.45-0.75)
Septa (T)	0.20-0.25	0.12-0.21 (0.19-0.20)	0.10-0.22 (0.15-0.20)
Tabulae (S)	0.20-8.0 (0.25-0.30)	0.04-1.80 (0.90-1.20)	0.14-0.25
Tabulae (T)	<0.30 (0.15)	0.9-0.25	0.05-0.14 (0.09-0.11)
Pores (W)	0.13-0.40	0.13-0.18	0.12-0.15

Dimensions of the main skeletal characteristics of corals.

Figures in brackets are average or more general measurements.

(D) Diameter (W) Width (L) Length (N) Number
(S) Spacing between (T) Thickness

Measurements in mm.

4.3 Microstructure

Complete recrystallization of the colonies has occurred, and some of the skeletal structures observed may be artefacts of diagenesis. However, an indication of the primary microstructure of the skeleton can be seen in some patchy domains within most of the colonies of *M. chamberensis*, *A. fromensis*, *A. cancelli, A. lafustei* and *F. uldanami*. The microstructure of these taxa are generally similar, although *A. fromensis* has additional fibrous elements not observed in the other three genera.

The edges of the possible primary biocrystal platelets are distinguished by crenate, to wavy lines of minute inclusions within the much coarser crystals comprising the recrystallized fabric (Fig. 10). Narrow, lath-like zones, showing irregular extinction under polarized light occur at some places approximately transverse to skeletal elements where secondary carbonate crystals penetrate the coral skeleton. This suggests a residual overprint of the original mineralogy disturbing the optical continuity of the subsequent recrystallization. These relic, rather robust fibrous elements, which evidently formed the sclerenchyma (calcareous skeleton of corallites), are seen as either lineations across the walls of corallites (in transverse section) and/or divergent bundles (in longitudinal section) giving walls a `feather like' appearance. The fibrous elements can be seen at low magnifications (X 20) and appear to be similar in *M. chamberensis*, *A. fromensis, A. cancelli, A. lafustei* and *F. uldanami*. A similar microstructure has been documented in *F. bowmani*. No primary biocrystal platelets have been observed in *B. hawkerensis*.

Elements of *A. fromensis* also show fan-shaped arrays of possible `biofibres' which protrude into the lumen of corallites. In longitudinal section, upturned spines along some corallite walls (Figs 6C,E), and spines situated on the upper surface of some tabulae (Fig. 6D) are represented by bundled fibres, giving both the wall and tabulae a bumpy appearance. In transverse section, most septa appear to terminate in fan-shaped arrays of fibres, or similar arrays arise from the walls (Fig. 7D). The bundled fibres resemble trabeculae, though fan-shaped tufts in carbonates can result from diagenesis (Oekentorp 1989). By comparison with the other taxa examined, a primary origin for the present structures is preferred.

4.4 Dimorphism and Dimetrism

Dimorphism and dimetrism commonly occur in tabulate corals. The former may be shown as differences in corallite size, shape and internal structures, while dimetrism includes variation (of measurements) in the thickness and length of septa, thickness of walls and tabulae, the distance between tabulae and the present/absence of squamlae (Oliver 1968; 1975; Scrutton 1989). Dimetrism in favositid corals appears to be more common in colonies which are rapidly expanding with diverging corallites, than within more parallel, converging colonies (Scrutton & Powell 1981; Scrutton 1989).

Intracolonial and intraspecific differences in morphology are probably environmentally controlled and may reflect a particular micro-environment. The factors which contribute to these variations, include the adjacent sediment and the position of corallites in the colony. Intracolonial variation in corallites may also result from;

1. cyclomorphic variation, with the tissue density of corals reflected as seasonal growth banding. In less dense zones septal structures may be weakly developed or absent, tabulae more widely spaced, and walls thinner than the darker, denser zones;

2. astogenetic variation, where the internal structures and colony form may vary with the growth of corallites at the early stages, older age or lateral spread of the colony;

3. topomorphic variation, resulting from a disturbance to the colony, like sediment smothering or re-orientation. The corallites subsequently produced, or those at the peripheral part of the colony, may be different to those with more vertical growth, or near the central part of the colony (Oliver 1968; Scrutton 1988).

Interspecific variation is more likely controlled genetically, with some structures in tabulate corals being constrained, while others are highly variable. However, the internal structures of some tabulate corals are so simple, that differentiating species is difficult (Scrutton 1988).

The two different morphological forms observed mainly in *M. chamberensis,* probably reflect the mode of increase, which appears to be dimorphic, being related to the position of individual corallites within the corallum. Corallites within the fasciculate area, which generally occurs at the periphery of the colony, appear to have resulted from lateral increase. Offsets branch away from the main colony producing isolated corallites which rarely touch and are therefore unaffected by crowding (Figs 8 - 11). Such corallites are thus round to slightly oval in transverse section. Peripheral intracalicular increase is most common in the massive, cerioid parts, and where a solitary corallite has become established (Figs 8 & 9). Usually one, two or more offsets are produced at the same time, with new walls growing from sites of septal insertion across the calice. Both methods of increase commonly occur at different stages of growth within the same corallite, and are probably related to the amount of space surrounding it. This kind of dimorphism corresponds to the astogenic variation of Oliver (1968) and Scrutton (1988).

The variable distance between tabulae and the presence or absence of septa do not appear to be linked to any particular stage of growth, a comparable characteristic noted to occur in some tabulates (Hill, 1981).

In *M. chamberensis,* septa are primarily represented in the protocorallite and immature corallites, while at other stages of growth they may or may not be present.

CHAPTER 5
STATISTICAL ANALYSIS OF THE MOOROWIE CORALS

5.1 Previous studies

Measurement of the cross-section corallites has been suggested as a possible taxonomic character to distinguish tabulate coral species. This character is believed to be less variable and least affected by diagenesis than the number and thickness of septa, and thickness of tabulae and walls (Sutton 1966; Stel 1978; Scrutton & Powell 1981; Scrutton 1981; Lee & Noble 1988). The average diameter of `adult' corallites has been used by Sutton (1966) and Lee & Noble (1988), while Stel (1978), Scrutton & Powell (1981) and Scrutton (1981), advocate using a electronic or mechanical planimeter to measure the mean area of corallites to achieve more accurate results.

The above studies involved measurements of `mature' corallites from serial thin sections taken at various levels in coral colonies. The corallite diameters of *Favosites multipora* and *Palaeofavosites rugosus*, together with other morphological characters, were examined by Scrutton & Powell (1981) to determine the periodic development of dimetrism. Lee & Noble (1988) studied two specimens of both *Favosites forbesi* and *Paleofavosites sp.* taken from different stratigraphic levels from the West Point Formation of Quebec.

5.2 Material and method

The average corallite diameter method was used in this study to determine if this morphological character could be useful in statistically distinguishing between genera and/or species of the Moorowie corals. Serial thin sections of the various colonies were not available due to the scarcity of some of the material. Seven available transverse thin sections were used, one from each of the following corals; *M. chamberensis* (holotype); *A. cancelli* (holotype); *A. lafustei* (holotype and paratype); *F. bowmani* (holotype); *F. bowmani* (34174); *F. uldanami* (holotype).

A. fromensis, *F. uldanami* (paratype), and *B. hawkerensis* were not used in the study, because:

1. corallites in the former are much larger in diameter (up to 14 mm), this being a distinguishing character;
2. the thin section of *F. uldanami* (paratype), is small, has only six corallites which fit the specifications (below), and is thus unsuitable;
3. *B. hawkerensis* shows little similarity in cross section to the seven above samples and may not be a coral.

In three of the thin sections, twenty five, was the lowest number of corallites available for measuring, therefore, each sample or set of measurements contains the measured diameters of 25 individual corallites from the seven different coralla. The largest and least elongate or meandroid corallites were measured from each thin section. The largest corallites were chosen because they were most likely to be at the `mature' stage, while elongated or meandroid corallites could be oblique in section, thus affecting results.

Maximum and minimum diameters were taken from the exterior wall of each corallite (midline), or where this was not visible, at a medial position relative to the thickness of the measured corallite's wall. The maximum diameter was taken at the widest point, and where the minimum diameter varied, the average between and widest and narrowest minimum diameter was used.

Measurements were taken using a microscope and callipers to 1/1000 mm then rounded to two decimal places. The twenty five mean diameters of each thin section were placed into 0.25 mm classes and used for the resulting histograms (Figs 19A-G).

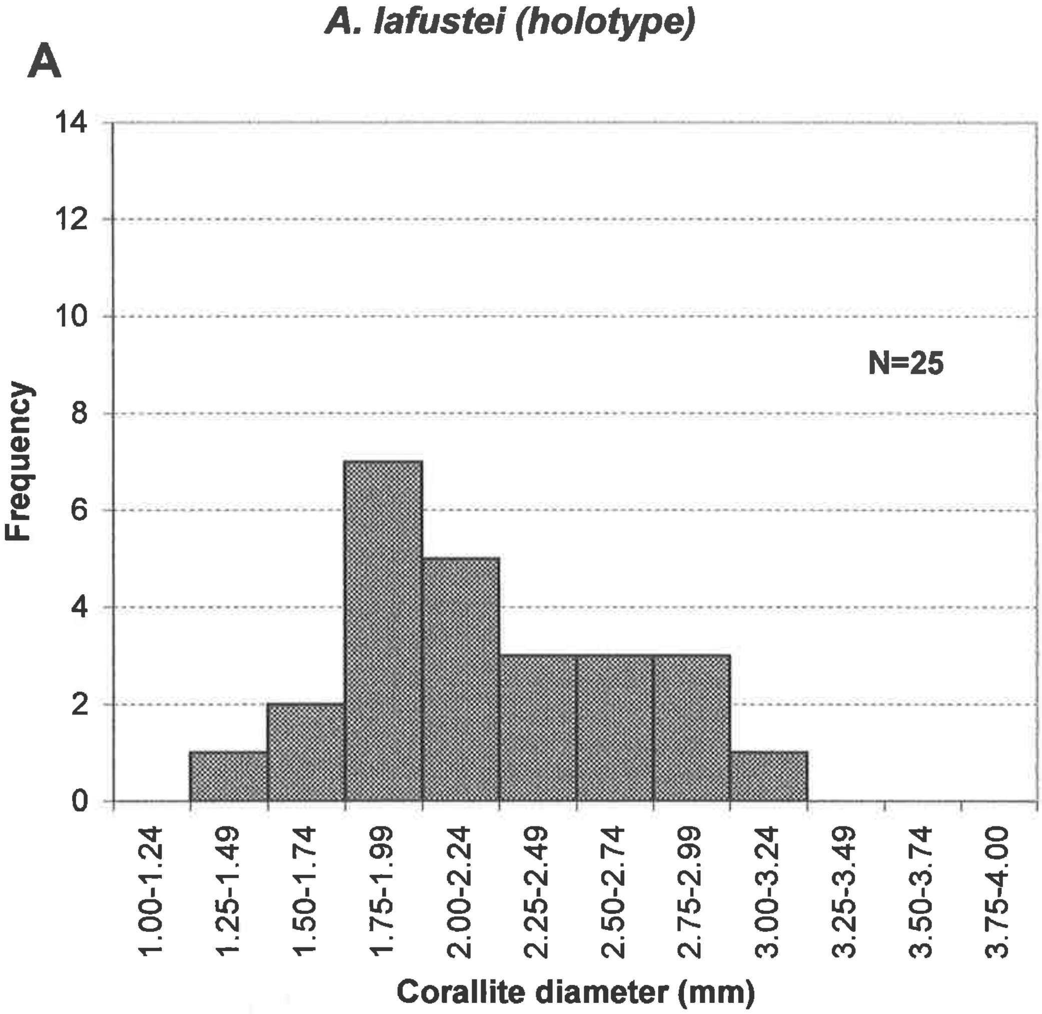


Figure 19A. Histogram of *Adelaideipora lafustei* (holotype), showing frequencies of mean corallite diameter taken at 0.25 mm intervals. Average mean diameter is 2.21 mm, with a variance of 0.2027 (Table 4).

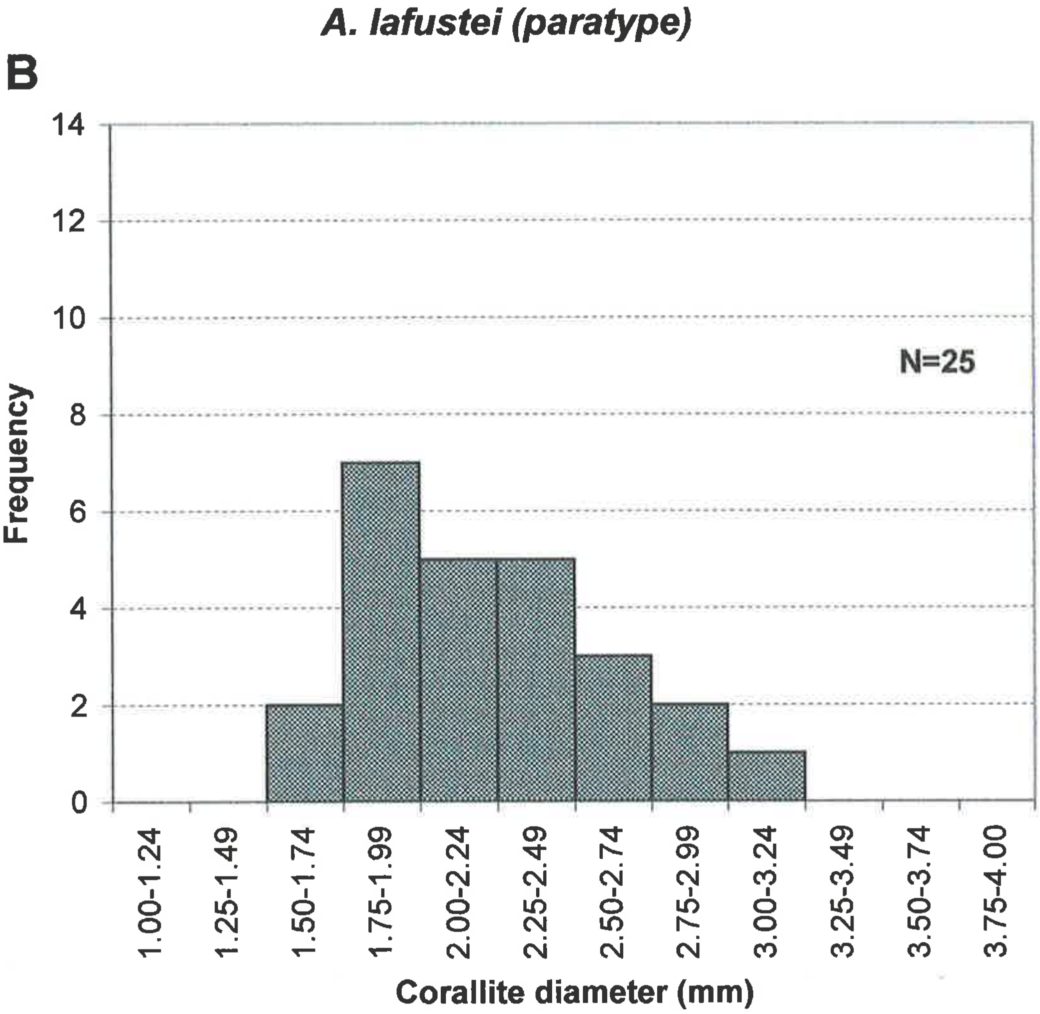


Figure 19B. Histogram of *Adelaideipora lafustei* (paratype), showing frequencies of mean corallite diameter taken at 0.25 mm intervals. Average mean diameter is 2.20 mm, with a variance of 0.1401 (Table 4).

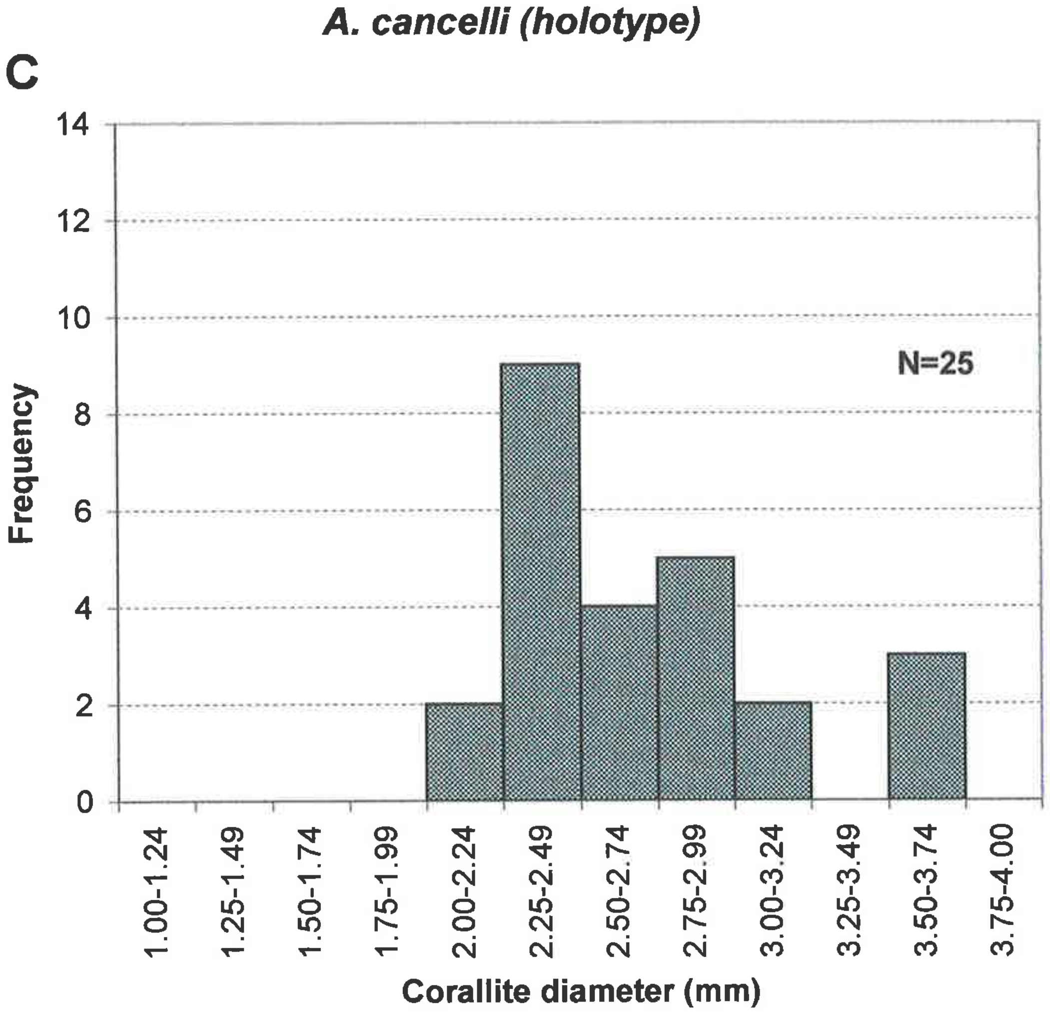


Figure 19C. Histogram of *Adelaideipora cancelli* (holotype), showing frequencies of mean corallite diameter taken at 0.25 mm intervals. Average mean diameter is 2.58 mm, with a variance of 0.1704 (Table 4).

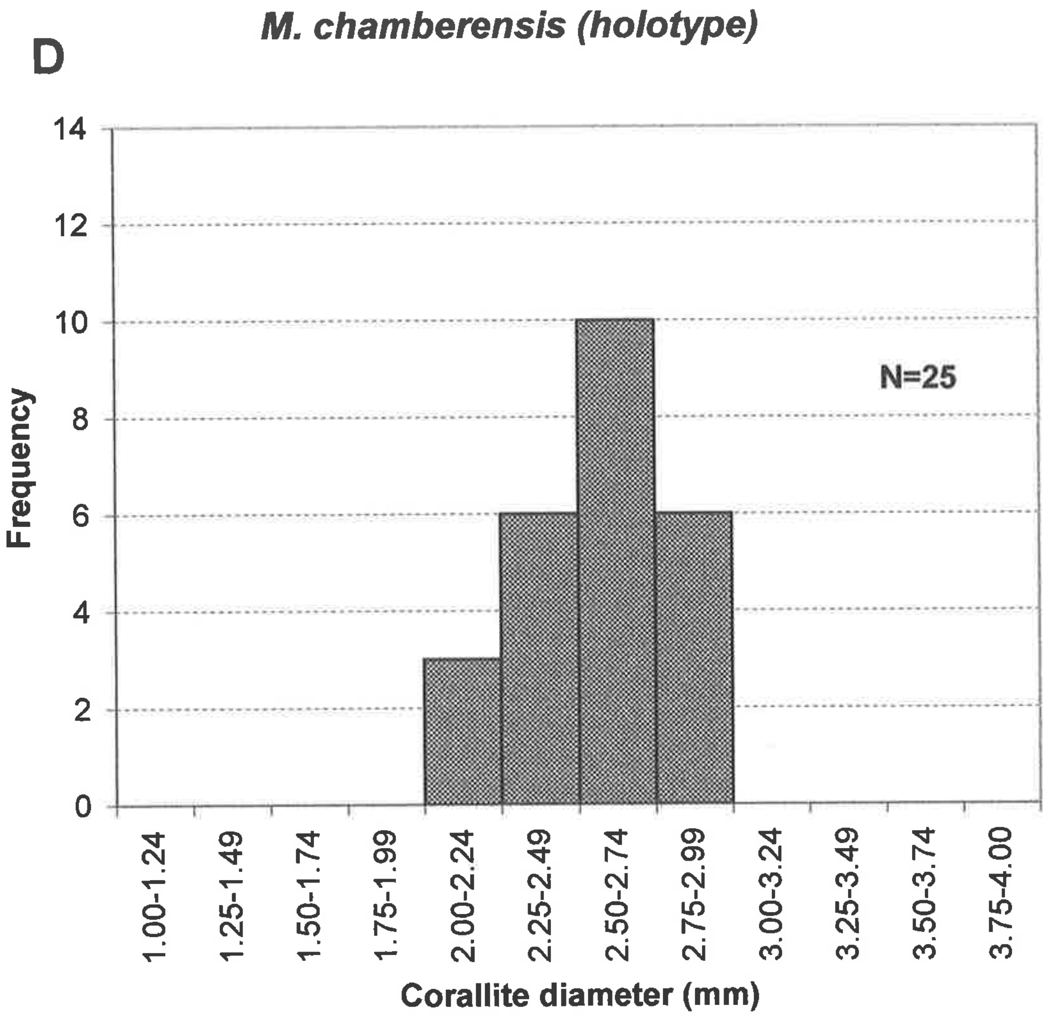


Figure 19D. Histogram of *Moorowipora chamberensis* (holotype), showing frequencies of mean corallite diameter taken at 0.25 mm intervals. Average mean diameter is 2.57 mm with a variance of 0.0540 (Table 4).

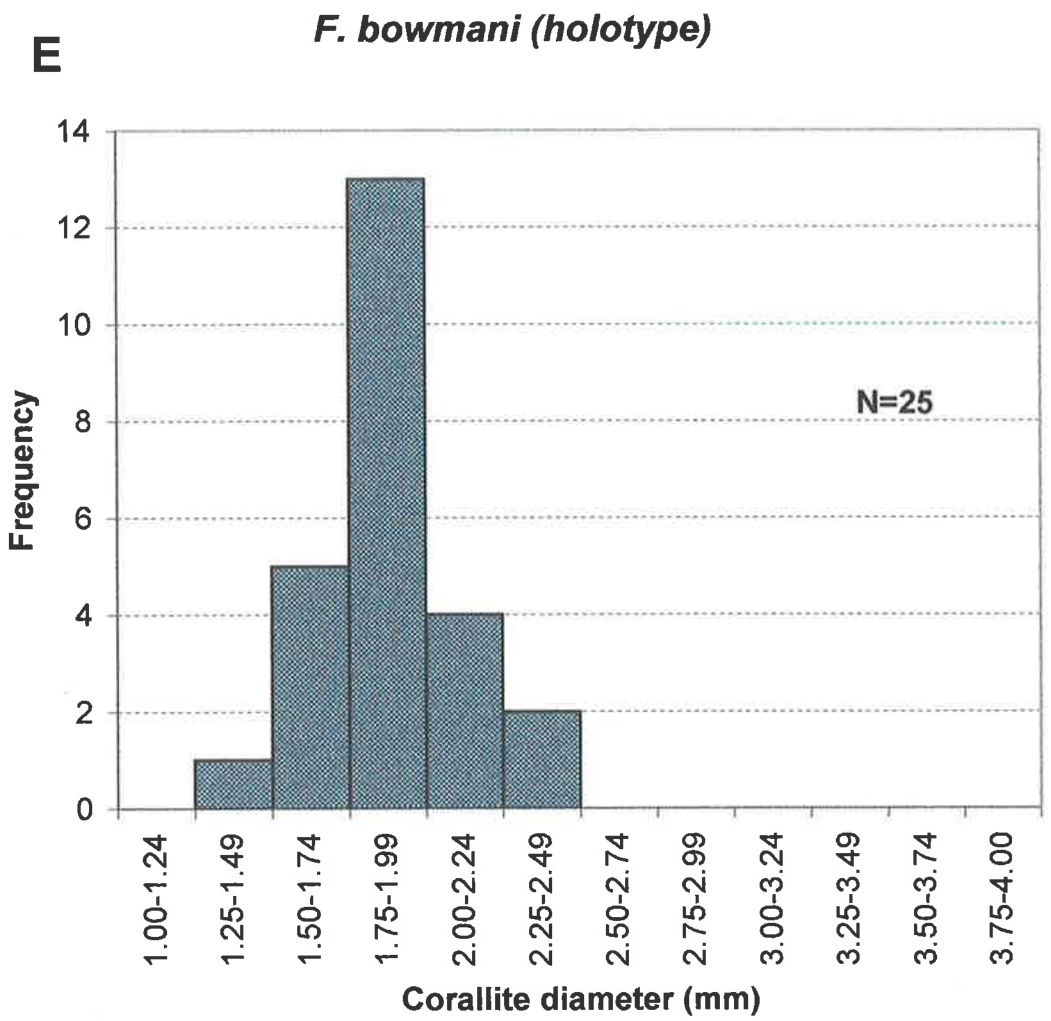


Figure 19E. Histogram of *Flindersipora bowmani* (holotype), showing frequencies of mean corallite diameter taken at 0.25 mm intervals. Average mean diameter is 1.87 mm, with a variance of 0.0510 (Table 4).

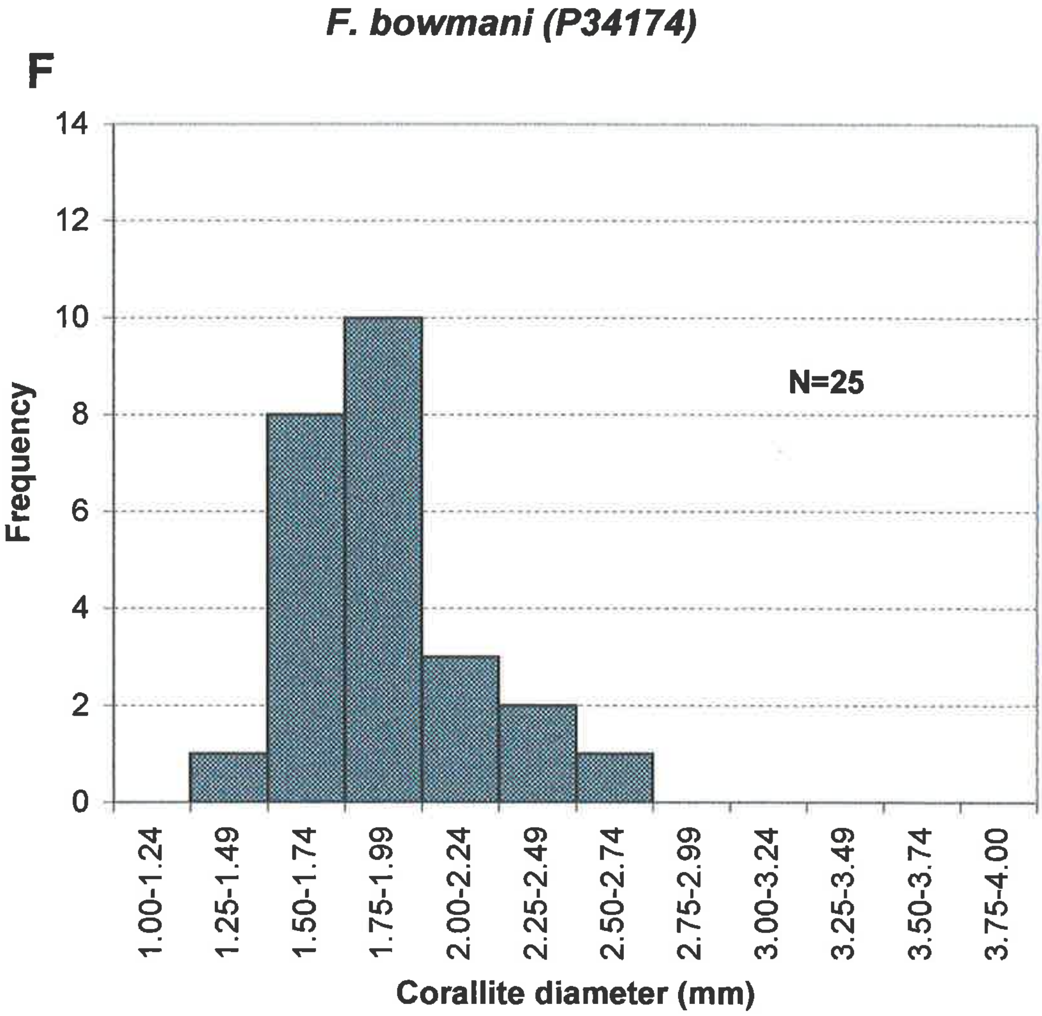


Figure 19F. Histogram of *Flindersipora bowmani (P34174),* Showing frequencies of mean corallite diameter taken at 0.25 Mm intervals. Average mean diameter is 1.89 mm with a variance of 0.0823 (Table 4).

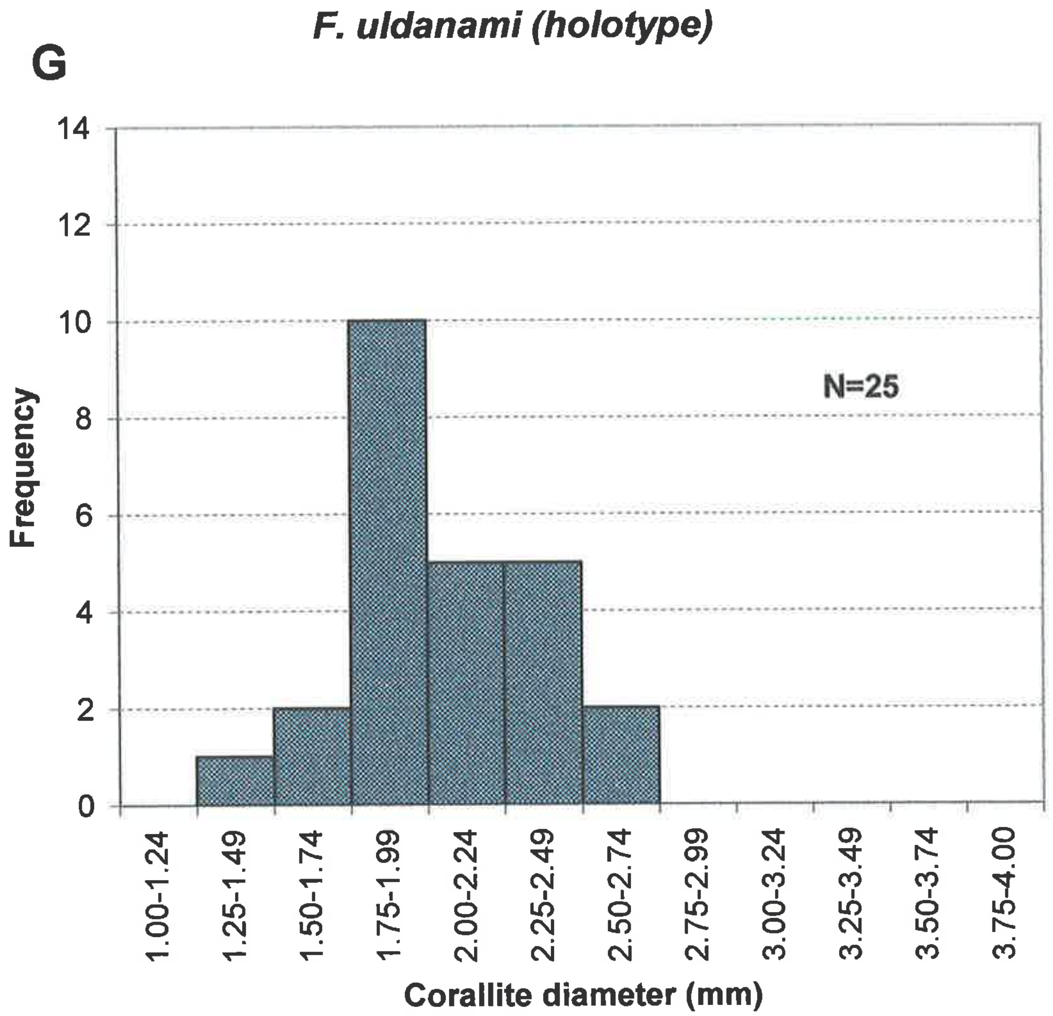


Figure 19G. Histogram of *Flindersipora uldanami* (holotype), showing frequencies of mean corallite diameter taken at 0.25 mm intervals. Average mean diameter is 2.06 mm with a variance of 0.0915 (Table 4).

Two statistical tests were used to ascertain similarities or differences between the seven measured taxa:

Test 1. Cumulative distribution function (cdf) graphs, combined with the Kolmogorov-Smirnov `two-sample' test, which can be based on a small number of samples (Cheeney 1983), were used to compare the seven classes. Cumulative proportions, based on the frequency distribution of mean corallite diameter (from the histograms) were plotted, with two classes appearing on each graph (Figs 20 A-M). The test statistic for the Kolmogorov-Smirnov `two-sample' test, is maximum discrepancy (D), measured on the vertical scale between the two cdf's.

At a=0.05 (a is the size of the critical region, a regression constant), the critical value of D is 0.34.

D=0.34 is derived from 1.22N' (one-tail application at a=0.05), where

N'= square root of $[(N_1+N_2)/(N_1 \times N_2)]$,

N_1 being the number of measurements in the first group and

N_2 being the number of measurements in the second group.

The critical region contains all the values of D=0.34 and above.

When comparing the maximum discrepancy between two curves, if the value of `D' falls into the critical region the hypothesis that `the sets of measurements are from identical populations and discrepancies are due to fluctuations in sampling' is rejected.

Test 2. Computer analysis using ANOVA (one-way Analysis of Variance), indicated that there were statistically significant differences between the seven sets of measurements of data, [F(6,168)=21.77. p<.001], where

F (is the measure of differences between the sets of measurements);

6 (the number of sets -1);

168 (sum of the seven sets -1 {175-7});

21.77 (value of F);

p<.001 (probability of getting F value <1:1000).

TABLE 4

	N	M.D.(mm)	A.(mm)	S^2
M. chamberensis (h)	25	2.08 - 2.91	2.57	0.0540
A. cancelli (h)	25	2.16 - 3.73	2.58	0.1704
A. lafustei (h)	25	1.29 - 2.91	2.21	0.2027
A. lafustei (p)	25	1.63 - 3.01	2.20	0.1401
F. bowmani (h)	25	1.61 - 2.15	1.87	0.0510
F. bowmani (34174)	25	1.36 - 2.57	1.89	0.0823
F. uldanami (h)	25	1.48 - 2.68	2.06	0.0915

N. = Number of adult corallites sampled.

M.D. = Range of mean diameters. Mean of maximum diameter and minimum diameter (min. diam. taken normal to first measurement).

A. = Average Mean Diameter,

S^2. = Variance.

(mm) = millimeters.

TABLE 5

Table of significant differences.

(Tukey HSD approach)

	Fb(h)	***Fb(5)***	***Fu(h)***	***Ac(h)***	***Al(h)***	***Al(p)***	***Mc(h)***
Fb(h)		1.0	0.47	0.00*	0.01*	0.01*	0.00*
Fb(5)			0.60	0.00*	0.02*	0.02*	0.00*
Fu(h)				0.00*	0.72	0.69	0.00*
Ac(h)					0.00*	0.00*	0.66
Al(h)						1.0	0.01*
Al(p)							0.01*
Mc(h)							

The asterisk indicates a statistically significant difference at a=0.05.

The numbers refer to the p value, ie. the probability that the finding could have been obtained purely by chance when there is no significant difference in fact present.

Therefore a low figure (the lowest is 0), suggests a real difference and a large figure (maximum of 1), suggests no difference, ie. there is just chance involved.

The value of F = 21.77, indicates a real difference between the sets of measurements which are not due to chance.

In order to find which measurement sets were different from each other, the Tukey's Honestly Significant Difference (HSD) approach for significant differences (for $p<0.05$, the probability of chance or not at 1:20 (Tabachnick & Fidell 1996), produced the results which appear on Table 5.

In the above test a low figure (lowest is 0) indicates a real difference, while a large figure (maximum 1.0) suggest no difference, that is, only chance involved.

5.3 Results and Discussion

(Figs 19A-G; 20A-M) & Table 5

The two statistical tests produced similar results from the seven sets of measurements. An obvious and excellent correlation exists between the holotype and paratype of *A. lafustei*, where D=0.04 (Fig 20A) and there is a p value of 1.0 (Table 5). These two specimens differ significantly from *A. cancelli*, the p value being 0.00 (Table 5), and D=0.52 (Fig. 20B). From the statistical analysis, two species of *Adelaideipora* can be differentiated, with the added confirmation of a very close correlation between the holotype and paratype of *A. lafustei*.

A. *lafustei* also differs significantly from *M. chamberensis* and *F. bowmani* (Figs 20C,D; Table 5), although the results indicate little difference between *A. lafustei* and *F. uldanami* (Fig. 20E; Table 5). *A. cancelli*, however, differs significantly from *F. uldanami* (Fig. 20F; Table 5), and *F. bowmani* (Figs 20F,G; Table 5), although little difference is observed between *A. cancelli* and *M. chamberensis* (Fig. 20H; Table 5).

The results also indicate no significant difference between *F. bowmani* (holotype), and specimen P34174 (Fig. 20I; Table 5).

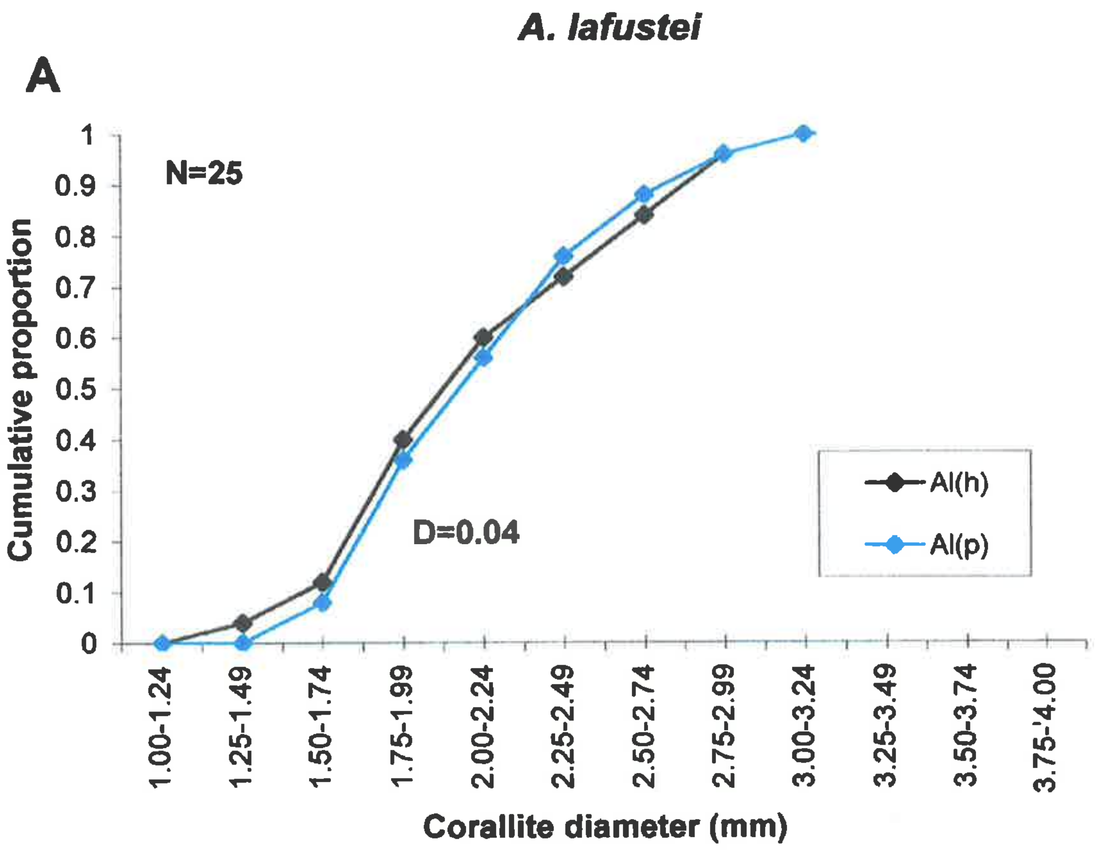


Figure 20A. Cumulative distribution function (cdf) graph *of Adelaideipora lafustei* (holotype and paratype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19A & B. The maximum discrepancy (D) =0.04, well below the critical value of D=0.34 (see method), and a Tukey HSD value of p=1.0 (Table 5), indicates that the two samples come from a single taxon.

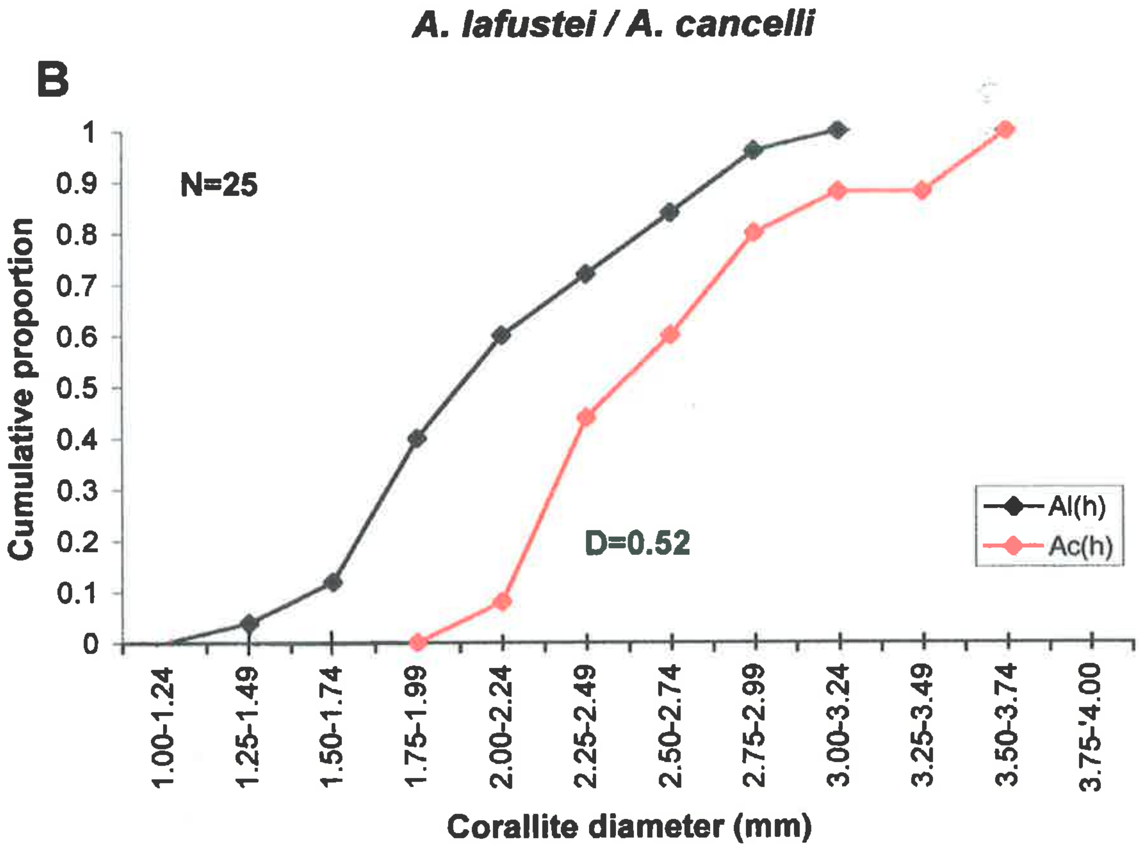


Figure 20B. Cumulative distribution function (cdf) graph of *Adelaideipora lafustei* (holotype) and *Adelaideipora cancelli* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19A & C. The maximum discrepancy (D) =0.52, well outside the critical value of D=0.34 (see method), and a Tukey HSD value of p=0.00 (Table 5), indicates that the two samples are significantly different.

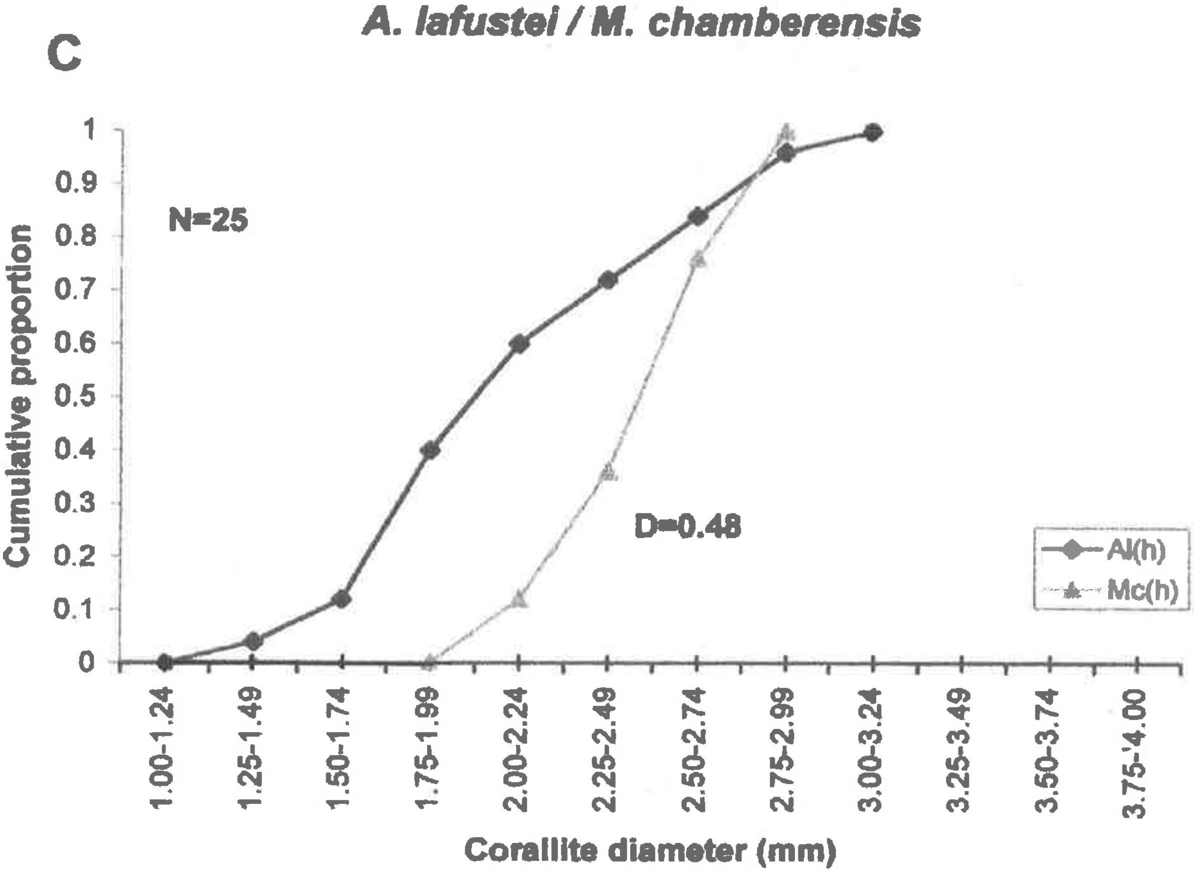


Figure 20C.Cumulative distribution function (cdf) graph *of Adelaideipora lafustei* (holotype) and *Moorowipora chamberensis* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19A & D. The maximum discrepancy (D) =0.48, is outside the critical value of D=0.34 (see method), while the Tukey HSD value of p=0.01 (Table 5), indicates that the two samples are significantly different.

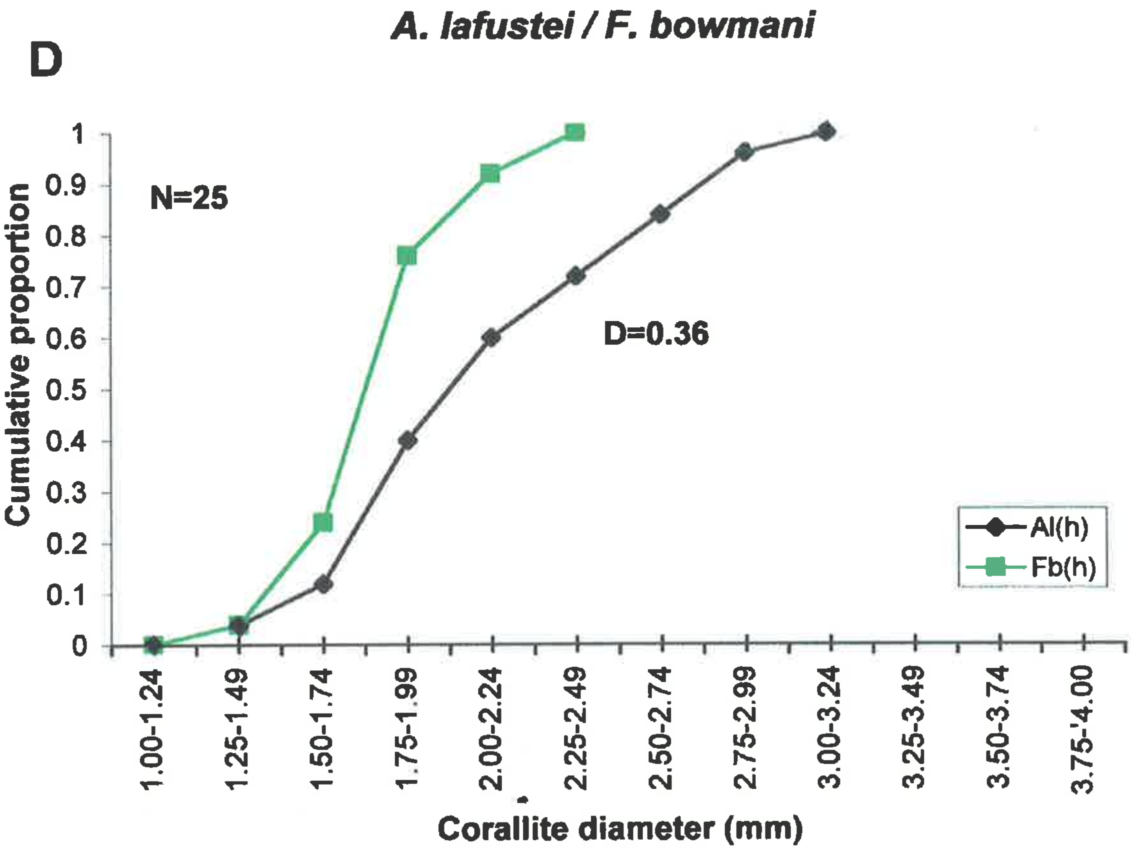


Figure 20D. Cumulative distribution function (cdf) graph of *Adelaideipora lafustei* (holotype) and *Flindersipora bowmani* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19A & E. The maximum discrepancy (D) =0.36, is outside the critical value of D=0.34 (see method), while the Tukey HSD value of p=0.01 (Table 5), indicates that the two samples are significantly different.

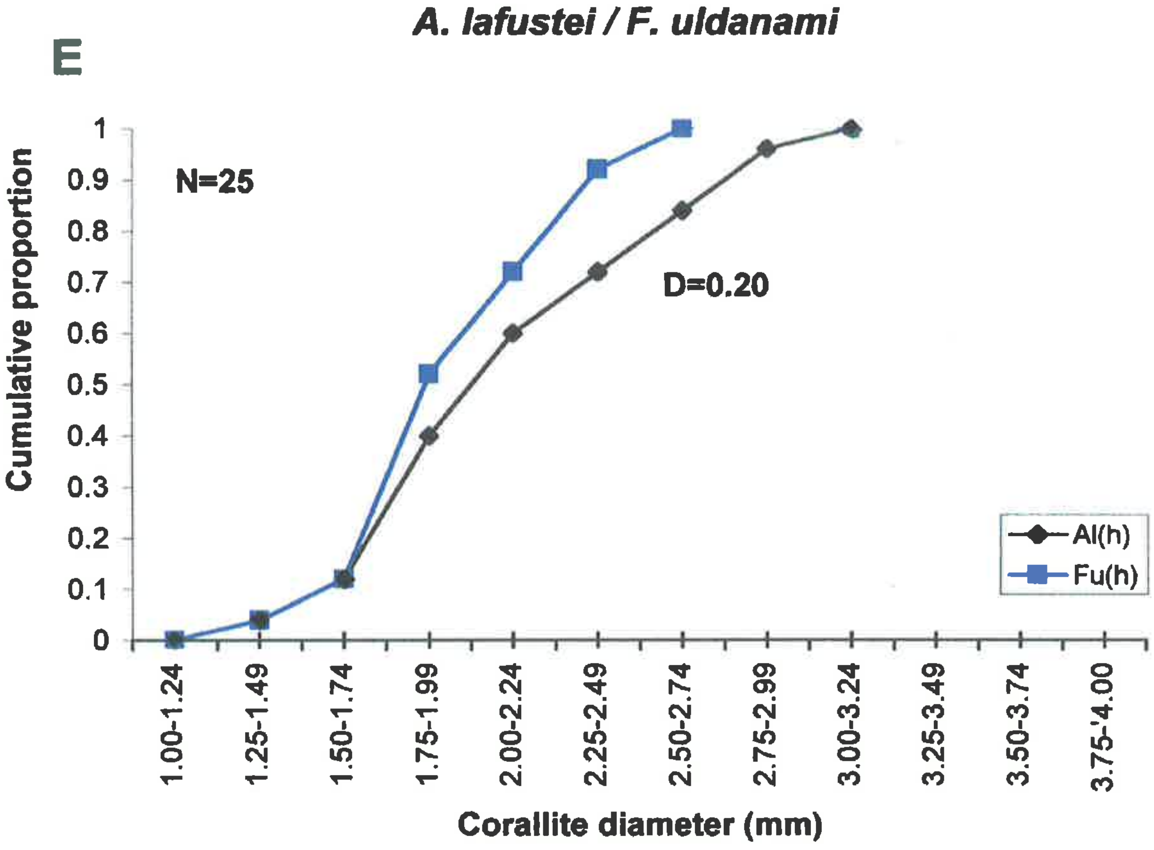


Figure 20E. Cumulative distribution function (cdf) graph of *Adelaideipora lafustei* (holotype) and *Flindersipora uldanami* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19A & G. The maximum discrepancy (D) =0.20, is below the critical value of D=0.34 (see method), and the Tukey HSD value of p=0.72 (Table 5), indicates that the two samples could come from the one taxon based on mean corallite diameter.

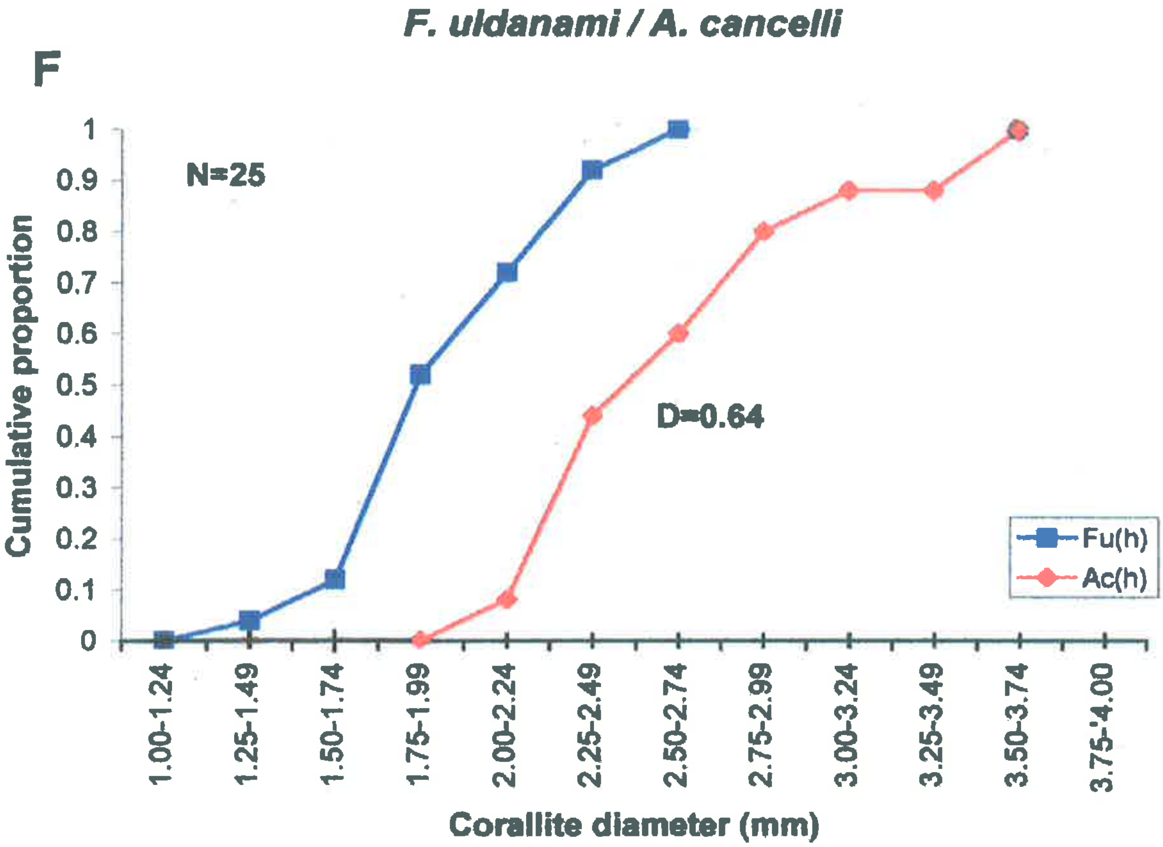


Figure 20F. Cumulative distribution function (cdf) graph of *Adelaideipora cancelli* (holotype) and *Flindersipora uldanami* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19C & G. The maximum discrepancy (D) =0.64, is well outside the critical value of D=0.34 (see method), while the Tukey HSD value of p=0.00 (Table 5), indicates that the two samples are significantly different.

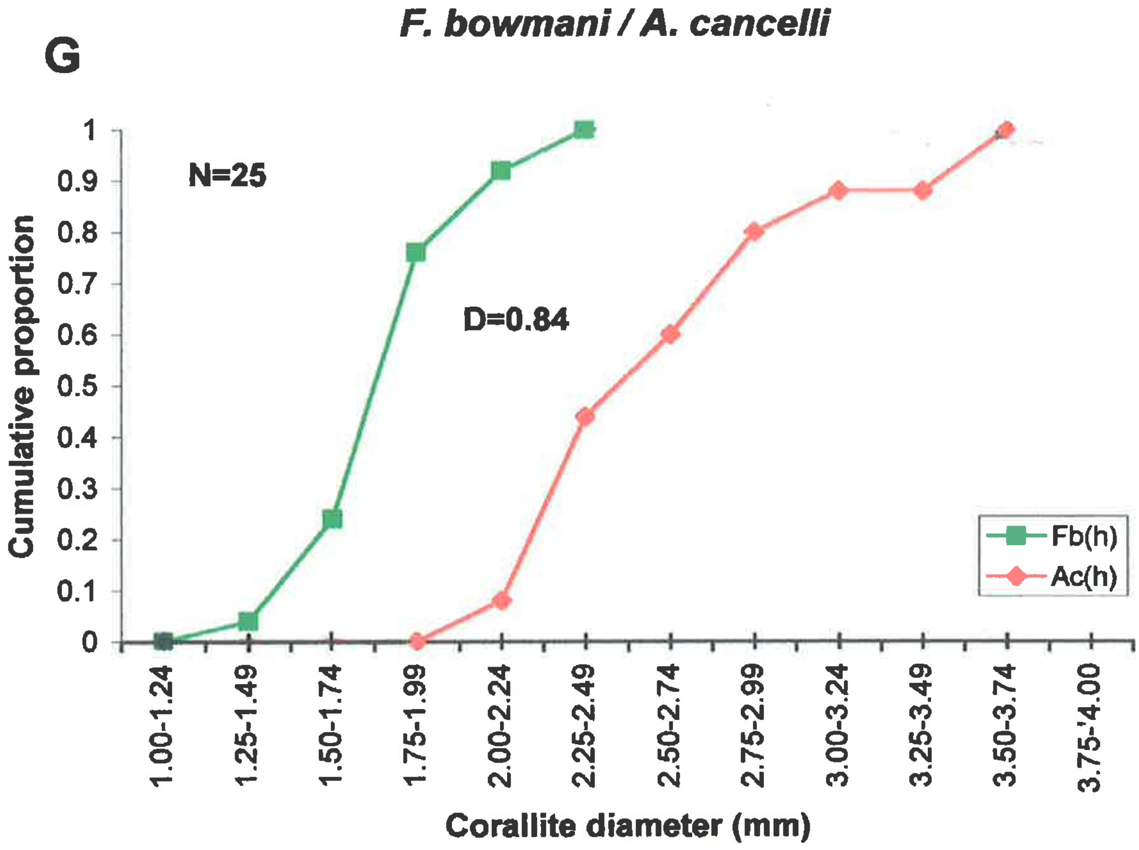


Figure 20G. Cumulative distribution function (cdf) graph of *Adelaideipora cancelli* (holotype) and *Flindersipora bowmani* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19C & E. The maximum discrepancy (D) =0.84, is well outside the critical value of D=0.34 (see method), while the Tukey HSD value of p=0.00 (Table 5), indicates that the two samples are significantly different.

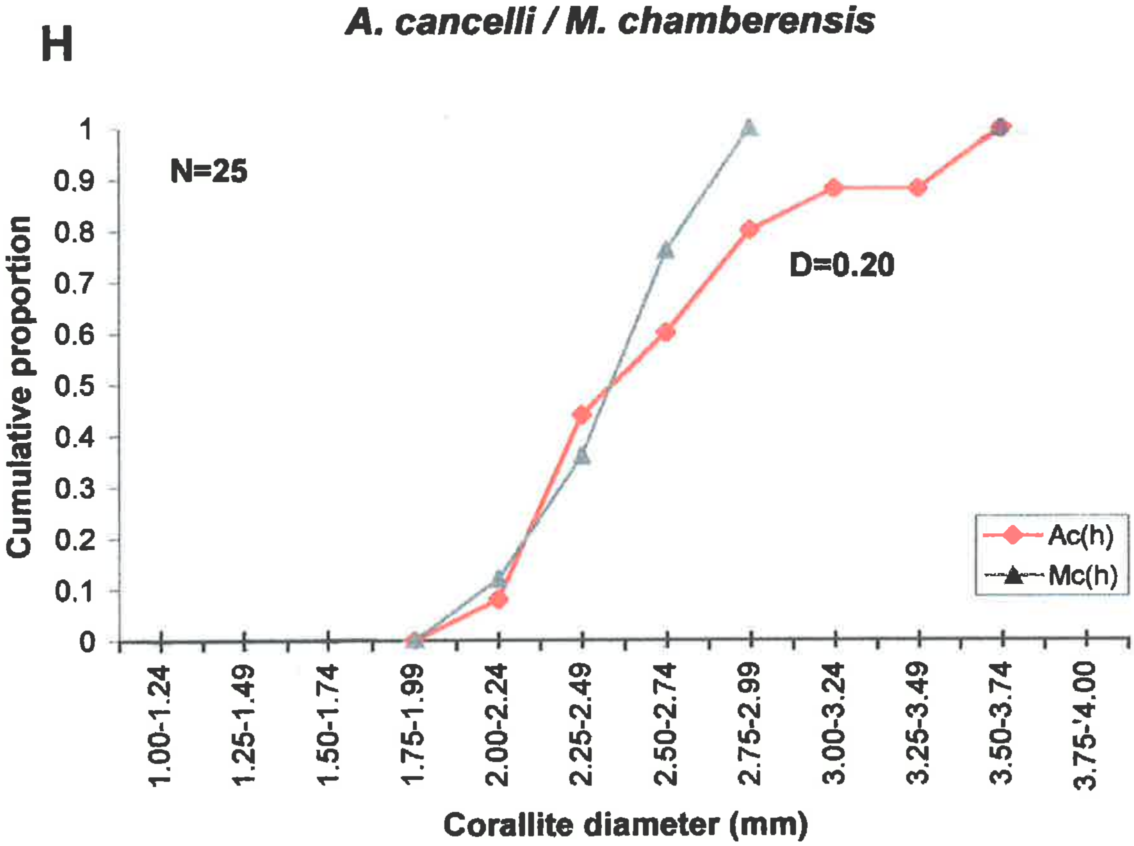


Figure 20H. Cumulative distribution function (cdf) graph of *Adelaideipora cancelli* (holotype) and *Moorowipora chamberensis* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19C & D. The maximum discrepancy (D)=0.20, is below the critical value of D=0.34 (see method), and the Tukey HSD value of p=0.66 (Table 5), indicates that the two samples could come from the same taxon based on mean corallite diameter only.

I

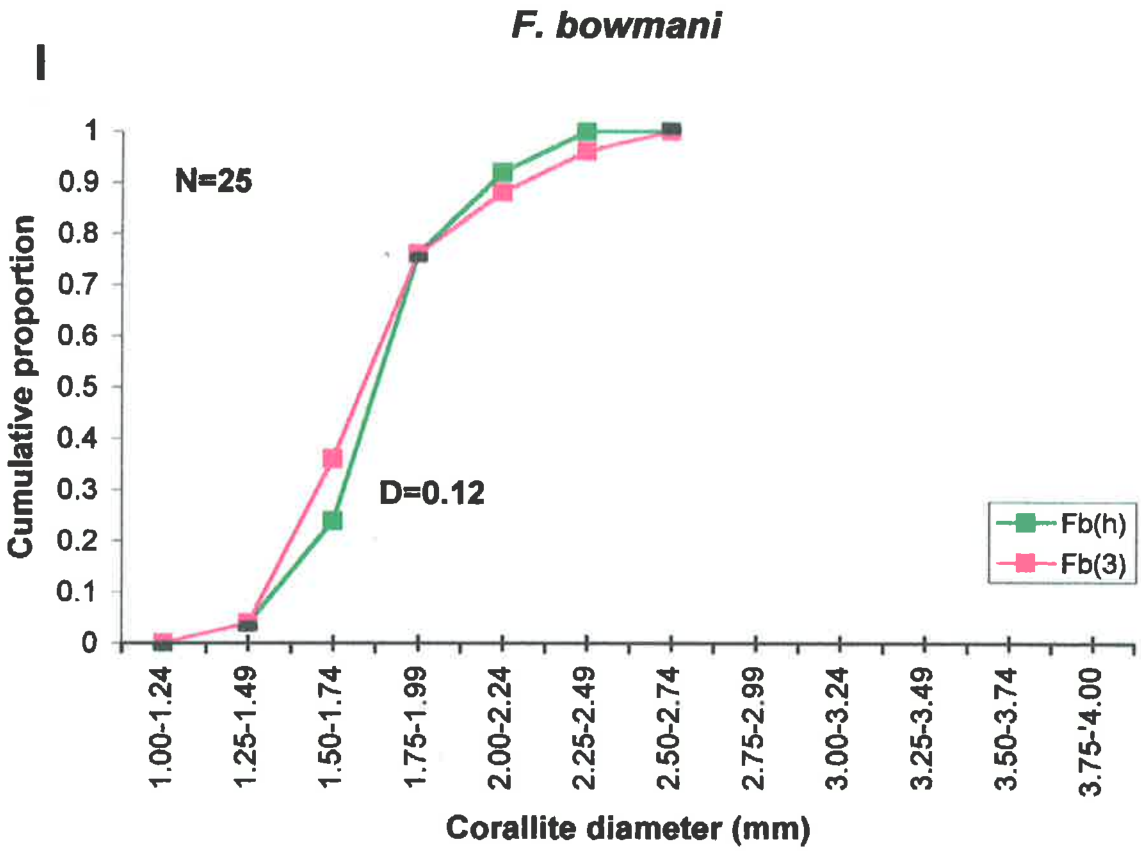


Figure 20I. Cumulative distribution function (cdf) graph of *Flindersipora bowmani* (holotype and P34174). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19E & F. The maximum discrepancy (D)=0.12, well below the critical value of D=0.34 (see method), and a Tukey HSD value of p=1.0 (Table 5), indicate that the two samples come from the one taxon.

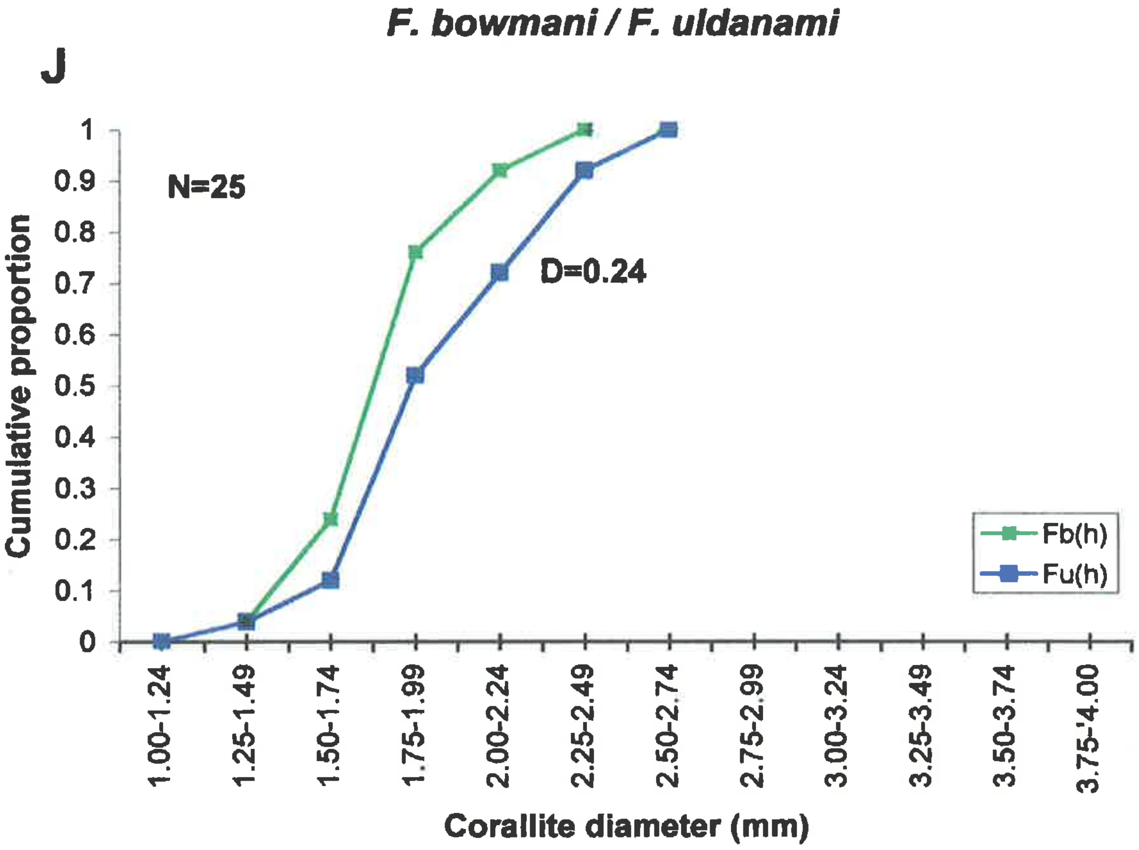


Figure 20J. Cumulative distribution function (cdf) graph of *Flindersipora bowmani* (holotype) and *Flindersipora uldanami* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19E & G. The maximum discrepancy (D) =0.24, is below the critical value of D=0.34 (see method), and the Tukey HSD value of p=0.47 (Table 5), indicate that the two samples could come from the one taxon based on mean corallite diameter.

K

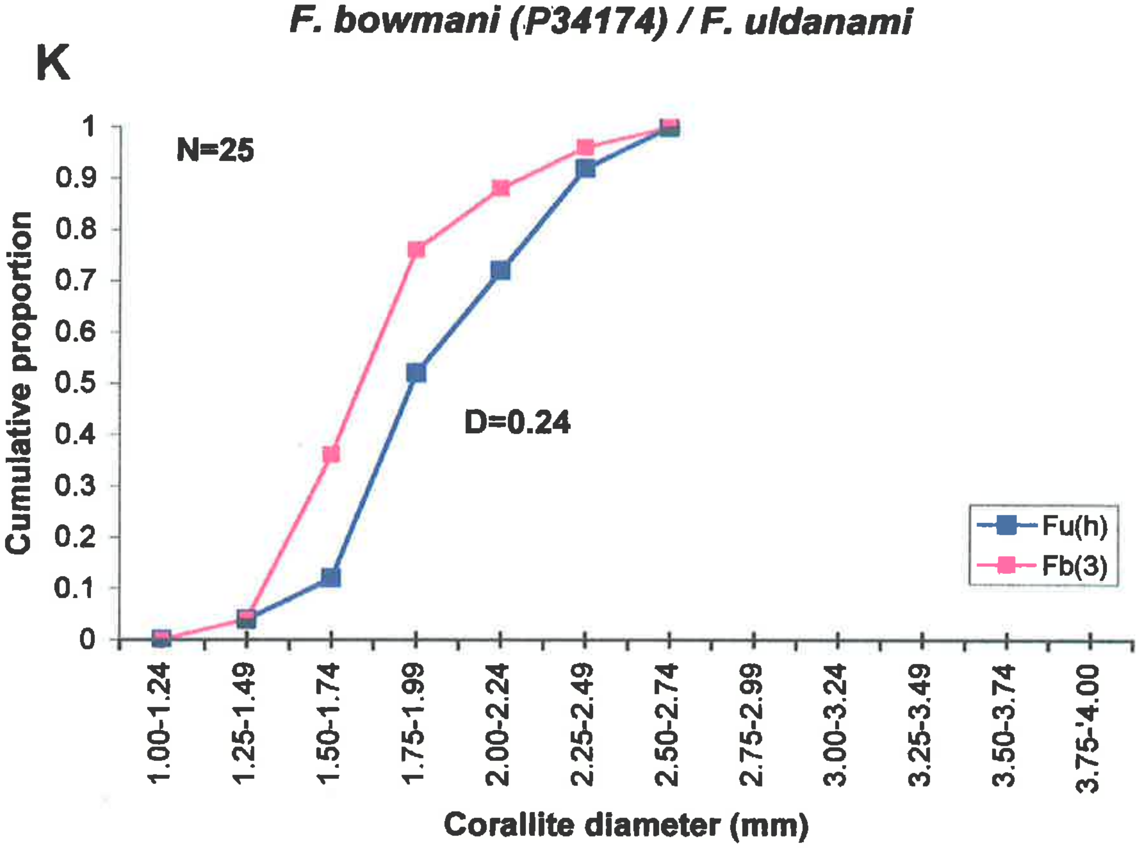


Figure 20K. Cumulative distribution function (cdf) graph of *Flindersipora bowmani* (P34174) and *Flindersipora uldanami* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19F & G. The maximum discrepancy (D) =0.24, is below the critical value of D=0.34 (see method), and the Tukey HSD value of p=0.60 (Table 5), indicate that the two samples could come from the one taxon based on mean corallite diameter.

L

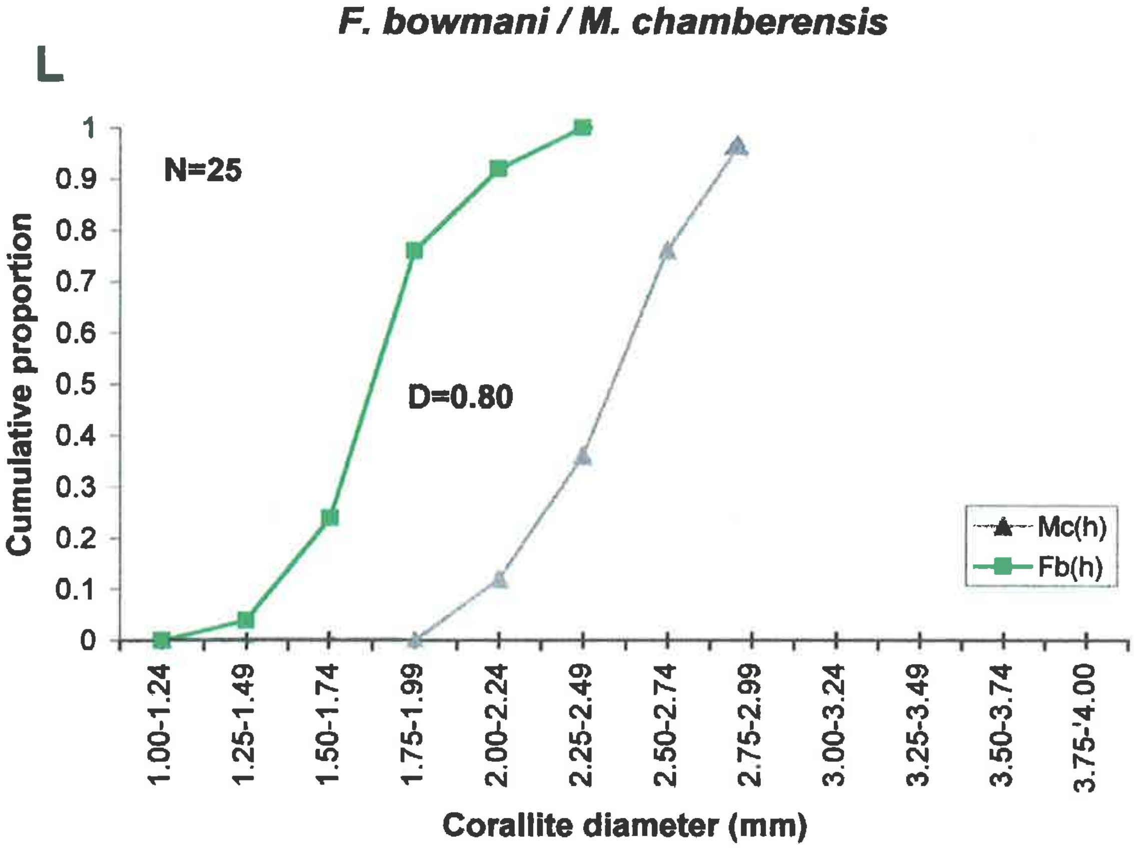


Figure 20L. Cumulative distribution function (cdf) graph of *Flindersipora bowmani* (holotype) and *Moorowipora chamberensis* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19D & E. The maximum discrepancy (D)=0.80, is well outside the critical value of D=0.34 (see method), while the Tukey HSD value of p=0.00 (Table 5), indicates that the two samples are significantly different.

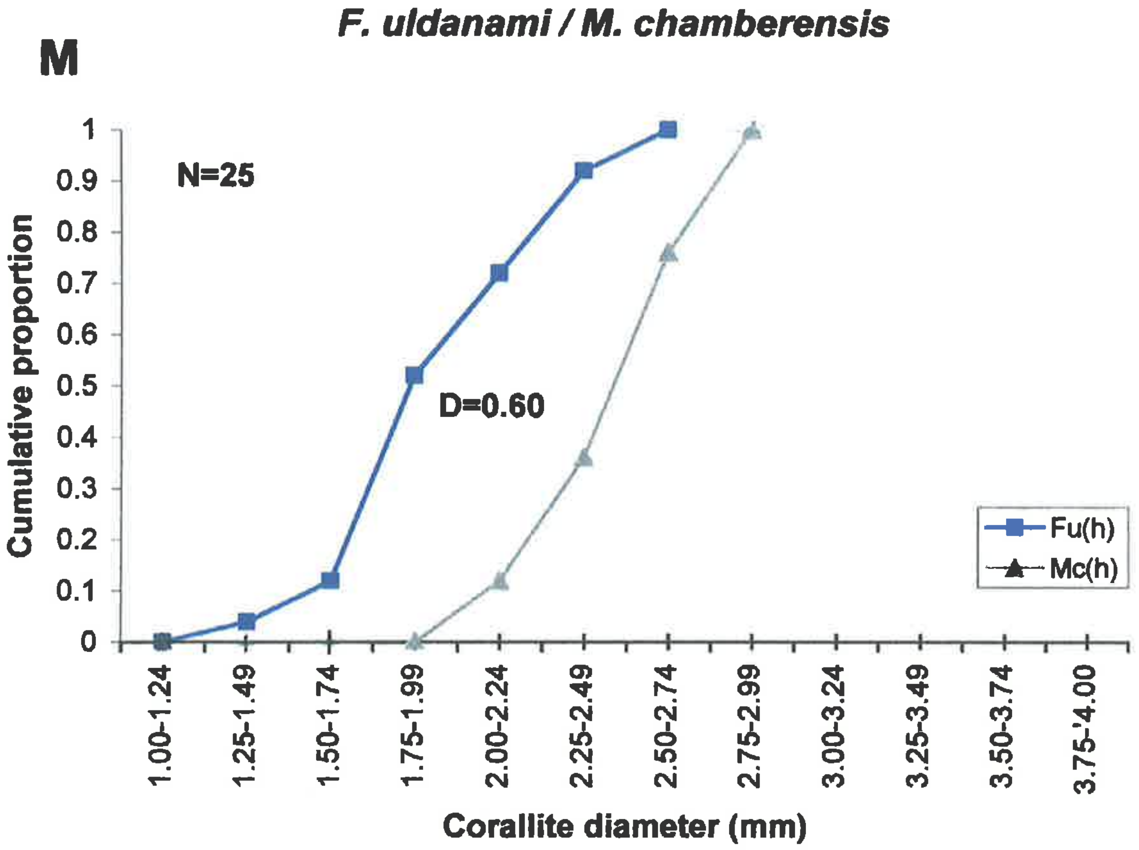


Figure 20M. Cumulative distribution function (cdf) graph of *Flindersipora uldanami* (holotype) and *Moorowipora chamberensis* (holotype). Cumulative proportions are based on the frequency distribution of mean corallite diameter, from histograms 19D & G. The maximum discrepancy (D)=0.60, is well outside the critical value of D=0.34 (see method), while the Tukey HSD value of p=0.00 (Table 5), indicates that the two samples are significantly different.

A similar, but less significant result, is observed between both specimens of *F. bowmani* and *F. uldanami* (Figs 20J,K; Table 5), while both these classes differ significantly from *M. chamberensis* (Figs 20L, M; Table 5).

From the results it appears that statistical analysis of mean corallite diameter may have a valid use in discriminating between some genera and/or species, but not others. The results tend to support the systematic examination of the Moorowie corals in that there is a significant difference between *Moorowipora* and the two species of *Flindersipora*, as well *A. lafustei.* The similarity between *M. chamberensis* and *A. cancelli* as well as between *A. lafustei* and *F. uldanami,* is predominantly in the diameter of the corallites (see discussion and Tables 1 - 4), with other morphological characteristics being different. The statistical analysis of mean corallite diameter would therefore probably be of little value in differentiating these taxa.

The two *Flindersipora spp.*, while observed to be morphologically different, also have characteristics in common, (see discussion and Tables 3 & 4). Dimetrism and dimorphism through the adaptation to a wide range of environmental conditions, may affect the size of corallites. Lee & Noble (1988) found that corallite size is too variable to be used, and species cannot be discriminated by mean corallite diameter. However, this method may be helpful in the final designation of genera or species.

CHAPTER 6
DISCUSSION
THE MOOROWIE CORALS

6.1 General affinities

Until recently, it was considered that the genus *Lichenaria* which has a time range from the basal to the early/Late Ordovician was the most ancient tabulate coral. Its colonial form is cerioid and simple in morphology, it has tabulae, is aseptate, and may have rare mural pores (Bassler 1950; Flower 1961; Mcleod 1979; Scrutton 1984; Laub 1984). *M. chamberensis, A. fromensis*, the genera *Adelaideipora* and *Flindersipora* have skeletal characteristics which demonstrate an affinity to the tabulates (including septa, which are not present in lichenarids). These are (1) the cerioid and/or fasciculate form of the colony; (2) walls separated by a medial line reflecting individual corallites (Scrutton 1987); (3) the spine-like to wedge shaped septa occasionally situated in longitudinal rows (Hill 1981); (4) individual corallites which spread above the pockets of sediment within the colony, this habit being usual for cnidarians following influxes of sediment (Scrutton 1979); (5) lateral increase common, with peripheral intracalicular increase being described in some Favositidae by Hill (1981).

The observed relic microstructure in *M. chamberensis* and *A. fromensis* appears to be similar to the pinnate (clinogonal) fibrous structure of some tabulates (Hill, 1981; p.F452), including lichenarids, although the extent of the modifying influence of diagenesis is uncertain.

F. bowmani is regarded as being a `doubtful coral' by Scrutton (1992; 1997), and not recognized as a tabulate, a view supported by Zhuravlev *et al.* (1993), and Sorauf & Savarese (1995). This is mainly due to the apparent lack of a mid-line in the wall; the method of increase (longitudinal fission, more commonly associated with Ordovician tetradiids which have been removed from the

Cnidaria); and the arrangement of septa, being unlike most tabulate corals (Scrutton 1992; 1997). Tabulae are also regarded as `sparse' (Scrutton 1997). While *F. bowmani* may not be regarded as a tabulate, P34174 (and other specimens) do have some morphological characteristics (not observed in the thin sections of holotype) which appear to be more `coral-like'. P34174 shows possible evidence of peripheral increase near the edges of the colony, and extension of corallites above the final tabulae (Fig. 16D). Sections of the colony also appear to have continued growing after sediment fouling. The mid-line in the wall, although not as obvious as seen in *M. chamberensis, A. fromensis* and *Adelaideipora*, is sometimes faintly seen between some of the corallites, while tabulae are not always sparse; those in P34174 are relatively evenly spaced and often close together.

M. chamberensis and *A. fromensis* have been accepted as `undisputed corals', but together with other Early and Middle Cambrian corals are not regarded as tabulates. They are also considered by Scrutton (1997), not to be ancestral to the Ordovician tabulate corals, and to have a mode of increase more characteristic of rugose corals.

The Moorowie corals with their tabulate-like characteristics may be either early representatives of the tabulates, or belong to a new group of corals with convergent evolution contributing to their similarities. These alternatives have been suggested by Lafuste *et al.* (1991) for *F. bowmani*. Scrutton (1992; 1997), regards the latter possibility as most likely, with skeletal cnidarians being derived from closely related non-skeletonized anemones, which were possibly present in both during the Early Cambrian and Ordovician. The skeletal descendants of the Early Cambrian corals are suggested to have become extinct by the end of the Cambrian. However, it is possible that the corals did not become totally extinct, and due to either the mode of preservation and/or the incomplete fossil record, the corals are not recognized, but were ancestral to the Ordovician tabulate corals. Without further evidence of corals in the fossil record, particularly those represented in the Early and Middle Cambrian being recognized from the Late Cambrian, Scrutton's theory above, appears to be a possible explanation.

Two orders are proposed by Scrutton (1997), for the Cambrian coral clades. Tabulaconida, which includes the `true corals' of the Early Cambrian, and Cothoniida, the Middle Cambrian corals, while the doubtful or unassigned coral-like organisms are regarded as coralomorphs. The term Coralomorpha has been used for the group of coral-like Cambrian organisms of doubtful coral affinities (Scrutton 1997).

6.2 Comparisons with other corals

A. fromensis is unlike any of the previously described Cambrian corals suggested by Scrutton (1979) to have tabulate affinities, but does have skeletal characteristics in common with some of the Late Silurian to Late Permian micheliniids.

The diagnostic characteristics for the genus *Michelinia* De Koninck 1841, include thin to moderately thick walls with a medial suture, short septal trabeculae, tabulae incomplete and globose sometimes with septal spinules on the upper surface, and large mural pores (Hill, 1981). The walls and tabulae are similar to those seen in *A. fromensis*, but, this taxon lacks mural pores.

Michelinia expansa White, 1883 *(=Tabellaephyllum peculiare* Stumm, 1948) from the Early Carboniferous of Arizona, is similar to *A. fromensis* with respect to the form of the colony, the size and shape of corallites and the arrangement of tabellae. Corallites are up to 15 mm in diameter in the former and 14 mm in the latter. Corallites are also of a similar shape, being generally 4, 5, or 6 sided, but differ by the lack of septa in *M. expansa*. A noticeable similarity between the two is the placement, size and shape of the tabellae. They are incomplete and globose and are arranged in similar manner in both taxa, arising from either the walls or adjacent tabellae. The tabellae in *A. fromensis*, appear to be less globose, spaced slightly further apart, and have a more irregular and wavy surfaces.

Although *A. fromensis* resembles some of the micheliniids, because of the long time separation between them (about 120 million years) it is highly unlikely that they are related and it is more probable their skeletal similarities result from convergent evolution. *A. fromensis* may belong in the Family Micheliniidae, but its inclusion would imply a time range well outside the confidence limits based on Carboniferous occurrences.

When compared with other Cambrian corals suggested to have tabulate affinities (Scrutton 1979), *Moorowipora chamberensis* is closest in its morphology to *Tabulaconus kordae* Handfield 1969, from the Early Cambrian (Botomian) of east central Alaska and British Columbia. In vertical section, *M. chamberensis* and *T. kordae* differ in shape of the corallites, which are more tubular in appearance in the former. Height and width vary, with mature corallites being up to 19.5 mm long and 5.0 mm wide in *M. chamberensis*, while *T. kordae* corallites are up to 65 mm long and 27 mm in width in the colonial form (Debrenne *et al.* 1987). The tabulae also differ, being undulating horizontal to concave upward in *M. chamberensis* and either horizontal or slightly concave downward in *T. kordae.* Incomplete tabulae are more dissepiment like and walls are generally thicker in the latter (Handfield 1969; Debrenne *et al.* 1987). The microstructure of both corals is significantly different in transverse section, being geniculate fibres in *M. chamberensis*, and concentric light and dark wavy laminations in *T. kordae* (Debrenne *et al.* 1987). Tabulae also differ, being formed from bundles of fibres extending upward and downward from a medial line in the former, unlike the two layered light and dark zones of *T. kordae* (Debrenne *et al.* 1987). However, platelets (longitudinal section) in the walls of *M. chamberensis* are of similar shape, but generally larger. *M. chamberensis* may belong in the family Tabulaconidae, a view supported by Sorauf and Savarese (1995) and Scrutton (1997).

M. chamberensis is distinguished from *Lipopora lissa* and *L. daseia* Jell & Jell 1976, from the early Middle Cambrian of western New South Wales, by the presence of tabulae and the shape and arrangement of septa, although the corallites of *L. lissa* are of similar length and width. *Cambrotrypa montanensis* Fritz & Howell 1955, from the Middle Cambrian of British Colombia, is distinguished from *M. chamberensis* by the more slender corallites and the absence of tabulae and septa. According to Zhuravlev et al. (1993; p. 369), most of the Early Cambrian coralomorphs `described by Korde (1963; 1984,a,b;1986;1990), are partly synonyms of already described khasaktiids or hydroconozoans and partly *nomina dubia* or *nulla*'.

The corals within the genus *Adelaideipora*, bare some resemblance to the genus *Nyctopora* Nicholson, 1879, species of which have time ranges from the ?early Ordovician to the early Silurian, with different taxa collected from most continents, including central eastern Australia (Hill 1981).

The most notable similarity between the two genera is the placement and shape of the tabulae, which are in almost horizontal rows, and horizontal to slightly curved downward in shape. In *Nyctopora*, tabulae also tend to vary between closely crowded parts and sections where they are widely spaced, interpreted as marking immature and mature sections of the colony (Bassler 1950). This is observed to a minor degree in *A. cancelli*, with little evidence of this in *A. lafustei*. The number of septa in *Nyctopora* tends to occur in a primary series of 8, with a secondary series (Bassler 1950), while in *A. cancelli* they number up to 18, and *A. lafustei*, up to 14, generally being randomly dispersed.

B. hawkerensis some has more morphological characteristics in common with lichenarid corals, than the other described species from Moorowie. Septa are absent in corals assigned to the genus *Lichenaria*, and are usually absent, or present commonly as new walls in *B. hawkerensis*. Placement and shape of tabulae in the two genera differ, being sparse, horizontal and complete in *Lichenaria,* while in *B. hawkerensis* they are common, and variable in distance and shape.

Lichenaria was originally assigned to the order CHAETETIDA (Okulitch 1936), with the majority of this group now recognized as being closer in morphology to sponges, than corals. *Lichenaria,* however, still seems to be recognized as an early Ordivician coral (Scrutton 1997). Due to the similarities which exist (although there are differences) between the two above genera, *B. hawkerensis* is precariously regarded as a coral, but with further investigation may be regarded as a coralomorph.

6.3 The Moorowie Corals

(Figs. 21 A, B & C; Tables 1-4)

When comparing the seven Early Cambrian corals from the Moorowie location, it is apparent that the genera *Flindersipora* and *Adelaideipora* have some skeletal characteristics in common, while the other three genera *Arrowipora, Moorowipora* and *Blinmanipora*, are different from each other and as well as from *Flindersipora* and *Adelaideipora.* Placement of the seven taxa in two dimensional character fields (Figs 21A,B,C), show that, although separated by variations in their measured characters, *F. bowmani, F. uldanami, A. cancelli* and *A. lafustei*, tend to cluster away from *Arrowipora, Moorowipora* and *Blinmanipora.*

A. fromensis is the coral most unlike the other six taxa, with its large corallites and dissepiment-like tabulae. *A. fromensis* is distinguished from the genus *Flindersipora* by the size and general form of the colony, the position and shape of tabulae and septa, as well as the mode of increase.

The main differences between *A. fromensis* and *M. chamberensis* are in the size and form of the colonies, the size and shape of the corallites, and the arrangement and shape of tabulae. Although both are cerioid in colonial form, the former is much larger and usually has parallel corallites, while those in *M. chamberensis* are generally divergent. Corallites are prismatic to cylindrical and up to 14 mm in diameter and 47.5 mm in length in *A. fromensis*, but much smaller (up to 5 mm in diameter and 19.5 mm in length), and tuberoid to irregularly cylindrical in *M. chamberensis*. The presence or absence of septal spines is common to both corals; when present they are about the same size and shape.

Tabulae differ greatly, being incomplete, globose and dissepiment-like (tabellae) in *A. fromensis* and complete, undulating horizontal to concave up-ward in *M. chamberensis.* Although the microstructure has not been studied at high magnification there are some similarities between the above corals at low

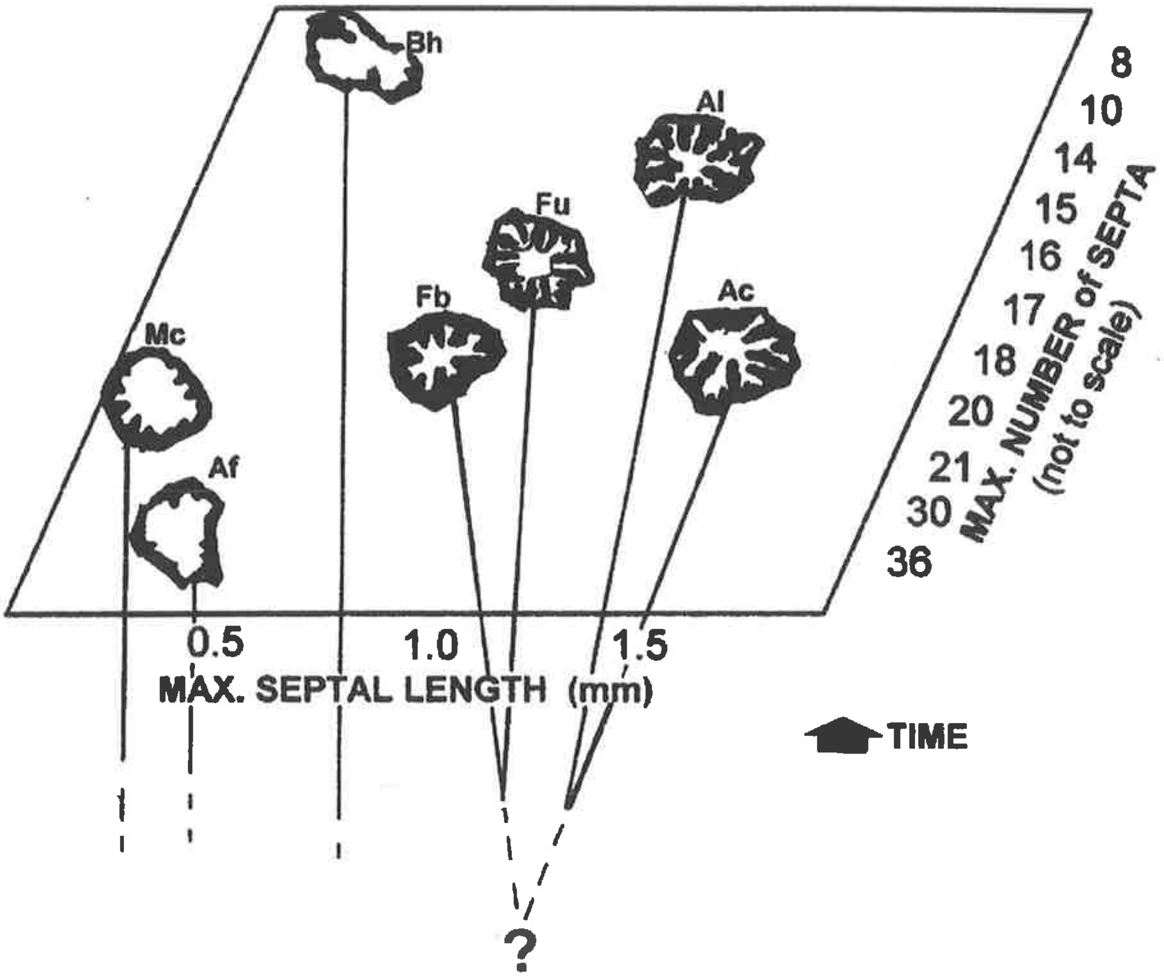


Figure 21 A. Cartoon sketch illustrating the placement of the seven Moorowie Corals in a two dimensional character field, based on maximum septal length and maximum number of septal.

Mc	Moorowipora chamberensis
Af	Arrowipora fromensis
Bh	Blinmanipora hawkerensis
Al	Adelaideipora lafustei
Ac	Adelaideipora cancelli
Fb	Flindersipora bowmani
Fu	Flindersipora uldanami

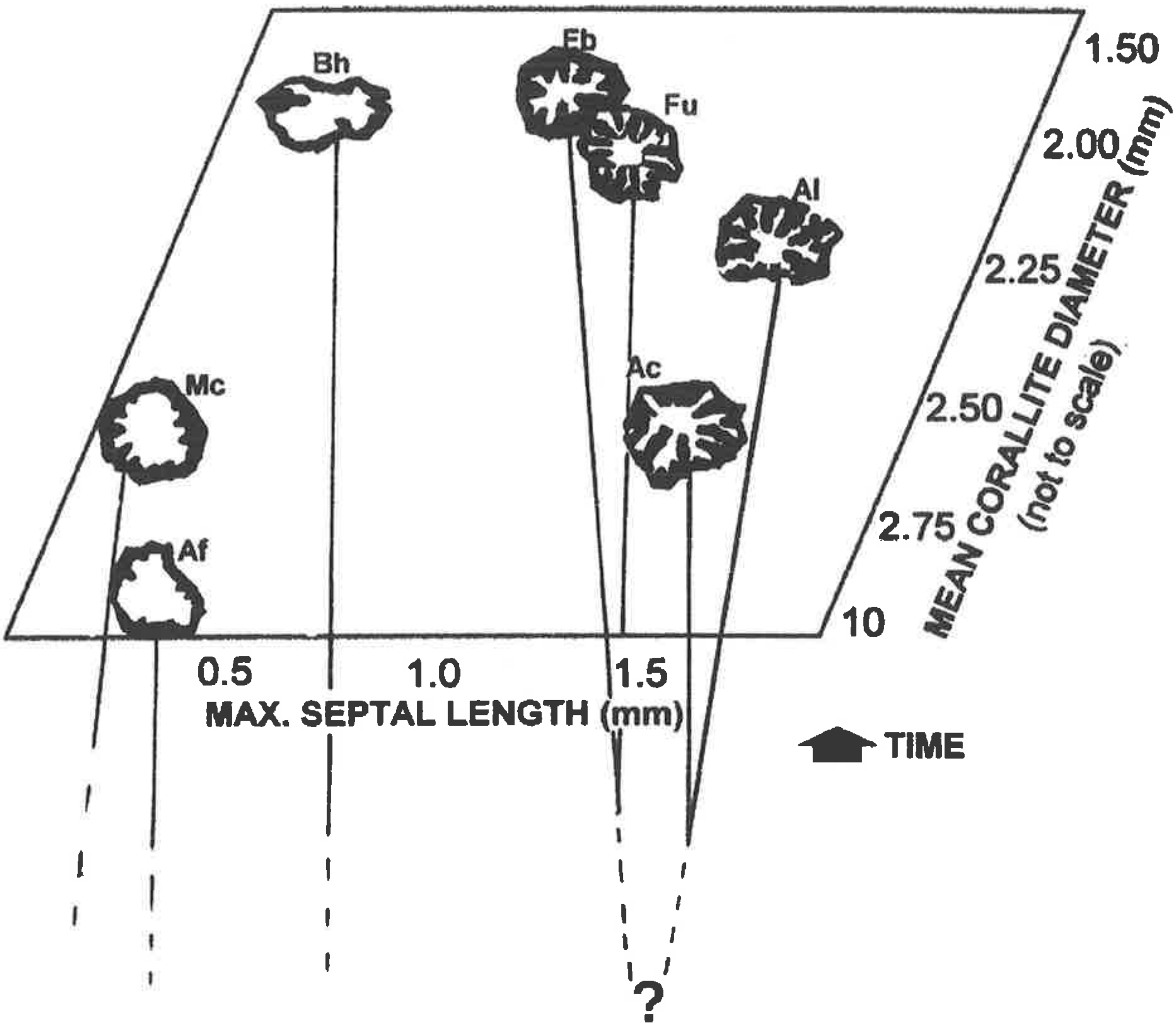


Figure 21 B. Cartoon sketch illustrating the placement of the seven Moorowie Corals in a two dimensional character field, based on mean corallite diameter and maximum septal length.

Mc	Moorowipora chamberensis
Af	Arrowipora fromensis
Bh	Blinmanipora hawkerensis
Al	Adelaideipora lafustei
Ac	Adelaideipora cancelli
Fb	Flindersipora bowmani
Fu	Flindersipora uldanami

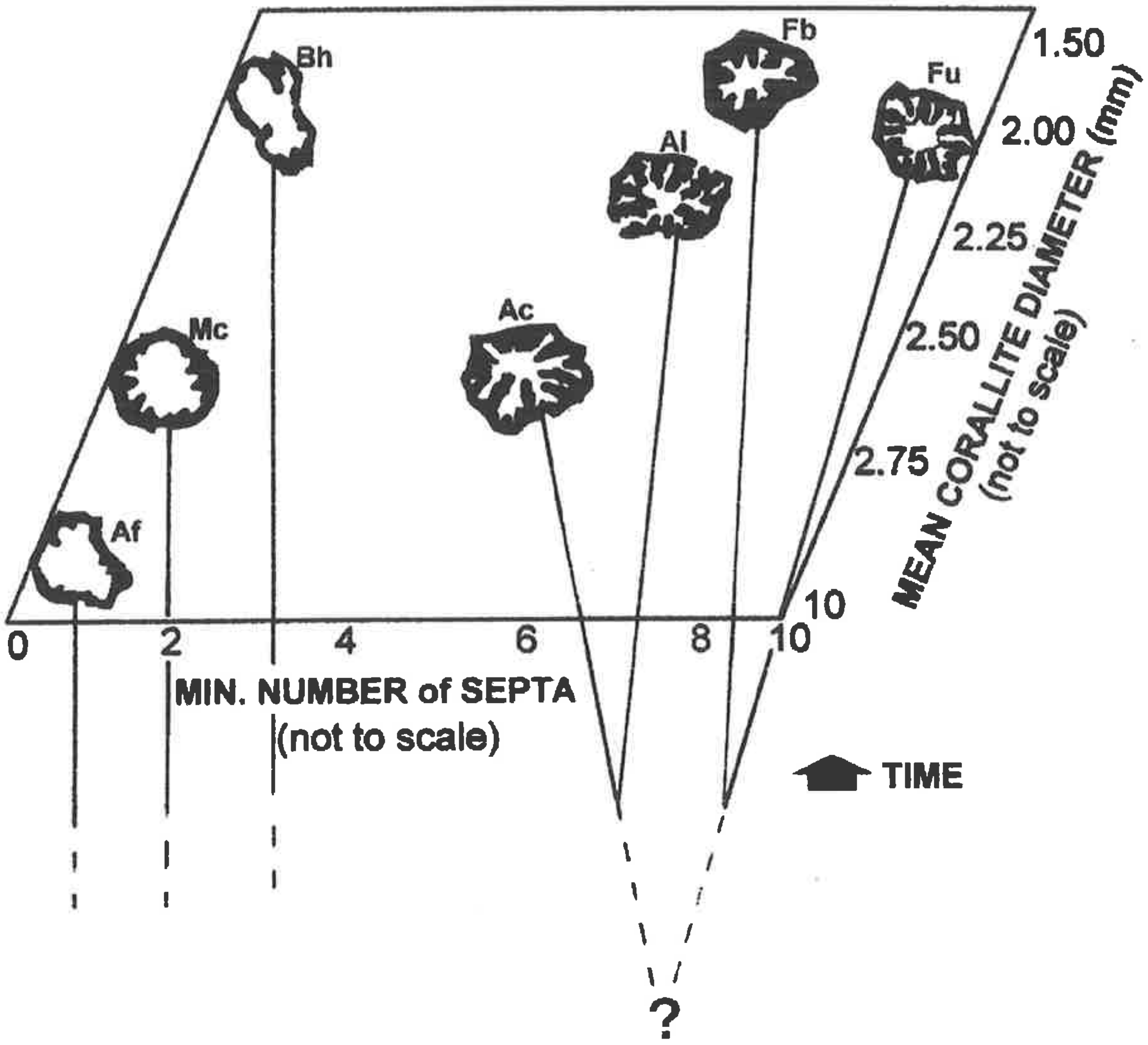


Figure 21 C. Cartoon sketch illustrating the placement of the seven Moorowie Corals in a two dimensional character field, based on mean corallite diameter and minimum number of septa.

Mc	Moorowipora chamberensis
Af	Arrowipora fromensis
Bh	Blinmanipora hawkerensis
Al	Adelaideipora lafustei
Ac	Adelaideipora cancelli
Fb	Flindersipora bowmani
Fu	Flindersipora uldanami

magnification. These include the parallel fibrous elements of the sclerenchyma evident in transverse section, and the parallel to diverging fibrous elements in longitudinal section. Fan-like arrays of fibres are not present in *M. chamberensis.*

A medial line within walls of adjacent corallite occurs in all the corals. Medial lines in the walls are common in tabulate corals, and represent the external epitheca (Hill, 1981).

M. chamberensis also differs from the genus *Flindersipora* Lafuste 1991, although there are some similarities in microstructure. *M. chamberensis* is cerioid to fasciculate and has wedge to spine shaped septa up to 0.2 mm in length arising from continuous walls 0.1 to 0.15 mm thick. In contrast *F. bowmani* is meandroid to cerioid, and has 6 - 18 strongly developed, straight to slightly curved septa up to 0.8 mm in length, with the edges of septa bearing very short blunt spines. Walls form very short segments between the septa and are 0.15 to 0.25 mm in thickness (Lafuste *et al.*, 1991). In *F. bowmani* tabulae are mostly concave downward, and closely spaced (0.2 to 0.3 mm), but are undulating horizontal to concave and more regularly spaced in *M. chamberensis.* The mode of increase is by longitudinal fission in the former while both lateral and intracalicular peripheral increase occurs in the latter.

In transverse section, the microstructure of both corals is similar, with walls consisting of geniculate fibres which diverge and converge in two directions. In vertical section, platelets in *M. chamberensis* are less elongate and broader when compared with *F. bowmani (*Lafuste *et al.* 1991).

The holotype of *F. bowmani* was examined in order to determine the differences which may exist between it and the new species, *F. uldanami,* as well as additional specimens of *F. bowmani* (P34174), and the genus *Adelaideipora.* In *F. bowmani* (holotype), tabulae are mostly complete and concave, there are 6-

18 strongly developed slightly curved septa, the edges of which bear very short blunt spines; the walls are very short segments between the septa. Increase is by longitudinal fission (Lafuste *et. al* 1991).

The genera *Flindersipora* and *Adelaideipora* are very similar in transverse section, the form of the coralla being cerioid to fasciculate, in both. Corallites are rounded polygonal to meandroid, and similar in size except for *A. cancelli* where they are larger (Table 2.). Corallite walls in *F. uldanami* are thinner than those of *F. bowmani*. The number of septa falls within the approximate variability of *F. bowmani*, while septal length varies little between the species. Septal width is more variable in *F. uldanami*, being generally narrower in *F. bowmani*.

Variations in the thickness of walls, spacing and thickness of tabulae as well as the thickness and length of septa, in the *Flindersipora* corals might, on their own, be seen as intercolonial morphological traits, due to environmental factors and not of taxonomic importance. However, the most important differences between *F. uldanami* and *F. bowmani,* are the shape of the corallites in longitudinal section, as well as the shape and pattern of insertion of the tabulae. Corallites in *F. bowmani* are long, slender and sub-parallel. Tabulae very irregularly spaced 0.20 to 8.0 mm in the holotype, (with only some being 0.2 to 0.3 mm apart); they are generally complete, mostly concave upward, sometimes regular but scarcely horizontal (Lafuste *et al.* 1991). Corallites in *F. uldanami* are long irregularly cylindrical to tuberoid and more bulbous in shape than *F. bowmani* (holotype). The distance between tabulae is commonly variable but not as great as in *F. bowmani.* Tabulae are crenate to wavy horizontal, concave down, or dissepiment-like. They are rarely straight, the corallites have a `disordered' appearance when compared to *F. bowmani*

There are morphological similarities between the corals, but the above variations are considered to indicate that *F. bowmani* and *F. uldanami* are different species.

The specimen of *F. bowmani* (P34174), described above, differs slightly from the holotype described by Lafuste (1991). These differences include variation in wall thickness, distance between tabulae and septal length. Corallite diameter shows little variation in P34174, being 1.27 to 2.91 mm, while in the holotype the diameter varies from 2.5 to 3.00 mm. The thickness of the walls is fractionally more variable in P34174, being between 0.14 and 0.30 mm, while wall thickness in the holotype varies from 0.15 to 0.25 mm.

The distance between tabulae is greater and more variable in the holotype, being from 0.20 mm and up to 7-8 mm; while the distance between tabulae in specimen P34174 varies between 0.04 and 1.80 mm. However, tabulae are thinner in the latter specimen (0.09 to 0.25 mm) than the holotype, which varies between 0.15 and 0.30 mm. Septa tend to be longer in the holotype, being between 0.60 and 0.80 mm, while they are 0.20 to 0.50 mm in length in P34174. The septal number is 6-16 in the holotype and 6-12 in P34174, the latter falling into the range described for the holotype.

The variation observed in the distance between tabulae, thickness of walls and length of septa in the holotype and other specimens of *F. bowmani,* may be due to dimetrism, with environmental conditions affecting growth. Smaller corallite diameter, closer spacing of tabulae, thicker walls and smaller septa have been linked together as internal structures reflecting dimetrism in tabulate corals (Scrutton & Powell 1981; Scrutton 1988).

Corallites in *A. cancelli* and *A. lafustei,* are not as long and slender as in *F. bowmani,* they tend to be more uneven in width and often diverge outward. Tabulae in both *Adelaideipora* species are straight, rarely wavy, often fractionally curve downward, but in all specimens examined are not concave upward to the degree evident in *F. bowmani.* The spacing of tabulae in both the holotype and paratype of *A. cancelli* is even and regular with little variation in the distance between them, although varying more in *A. lafustei.*

A. cancelli is distinguished from *A. lafustei* by the length and number of septa, being 5-18 (generally 7-12) in the former and 6-14 (generally 9-13) in both the holotype and paratype of the latter. Septal length is usually shorter in *A. cancelli* being generally 0.30-0.65 mm (sometimes up to 1.35 mm), while the septa in *A. lafustei,* measure up to 1.35 mm, the width generally being about the same. The tabulae are relatively evenly spaced in both species, being 0.80 to 1.50 mm in *A. lafustei*, and 0.20 to 0.90 mm in *A. cancelli,* the latter being more consistently even, with tabulae usually 0.65 to 0.75 mm apart. The shape of the tabulae varies, however, tabulae in *A. lafustei* they are usually slightly curved downward or sometimes straight, while those in *A. cancelli* are usually straight or wavy, rarely curved downward. Walls and tabulae are slightly thinner in *A. lafustei*, tabulae being generally 0.06 to 0.10 mm thick, and usually 0.10 to 0.12 mm thick in *A. cancelli.* The slight morphological variations which exist between these two taxa are probably not a result of environmental conditions, but are more likely a reflection of genetic variation.

The two above species do not resemble *A. fromensis* with the only characteristics in common with *M. chamberensis,* being the similar shape and size of corallites.

When compared with the other Moorowie corals, *B. hawkerensis* has some general morphological characteristics in common with *A. fromensis.* In transverse section, corallites in the former are more irregularly shaped, some-times meandroid, often having very wavy and crenulate walls, and are thinner (0.12 to 0.25 mm); while walls in *A. fromensis* tend to be straighter and thicker (0.1 to 1.00 mm). The diameter of corallites is much smaller in *B. hawkerensis,* being between 0.90 and 4.00 mm, while they vary between 6.5 and 14 mm in *A. fromensis.* Septa may be absent in both taxa. However when present, they number up to seven in *B. hawkerensis* and 35 in *A. fromensis,* although the length is similar. In longitudinal section in both taxa, corallites are long irregularly cylindrical, up to 40 mm long in *B. hawkerensis* and up to 47.5 mm long in *A. fromensis*, but tend to be more parallel in the former. Tabulae are randomly oriented, being complete, undulating horizontal or concave upward, occasionally globose and dissepiment-like in *B. hawkerensis*, which differs from *A. fromensis* where they are always globose and dissepiment-like tabellae. *B. hawkerensis* does not appear to have the distinctive mid-line in corallite walls (unlike *A. fromensis*), although a mid-line is sometimes faintly observed. The available specimens of *B. hawkerensis* are truncated, and do not show evidence of corallites extending above the corallum.

A relatively close relationship appears to exist between the genera *Flindersipora* and *Adelaideipora* indicating that the four taxa may have originated from a common ancestor prior to the late Early Cambrian. However, divergence probably occurred early in the evolution of these corals, as variations in corallite size, the insertion of tabulae together with the length and number of septa are different in the four taxa. The other three genera *Arrowipora, Moorowipora* and *Blinmanipora* probably evolved from different ancestral polyps as advocated by Scrutton (1997).

CHAPTER 7
CONCLUSIONS

The variation observed in the corals from this ancient reefal environment, indicates that during the Early Cambrian, there was rapid diversification in their skeletal morphology, or near concurrent skeletonization among several related anemone-like cnidarians.

The five coral genera from the Moorowie Formation, *Arrowipora, Moorowipora Adelaideipora, Flindersipora,* and *Blinmanipora,* are different in the general form and detailed architecture of their skeleton. The first two genera in particular have tabulate-like characteristics in common with some Ordovician tabulates. While *F. bowmani* has been acknowledge `as a doubtful coral' by Scrutton (1992;1997), further specimens indicate this species does have coral-like skeletal characteristics. The skeletal morphology of *B. hawkerensis* ex-hibits structures observed in many of the more `primitive' Ordovician tabulates, some of which have now, however, been removed from the Cnidaria. Thus this genus may possibly be regarded as a coralomorph, not a true coral.

The results of statistical analysis carried out on seven of the Moorowie corals, using the average diameter of `mature' corallites, indicate that this may be a valid method of discriminating between some early Cambrian coral genera and \or species. The graphs show that *Adelaideipora, Flindersipora* and *Moorowipora* are distinct taxa, while the holotype and paratype of *A. lafustei* are also observed to be almost identical, while being discriminated from *A. cancelli.*

Although much of the general architecture is similar, differences in the skeletal morphology of the Early Cambrian and Ordovician tabulate corals (particularly septal insertion), appears to exist (Scrutton 1997). The time gap between the Early Cambrian and the Early Ordovician, together with the paucity of fossil coral evidence from the Middle and Late Cambrian (Scrutton 1997), indicates, that it is probably reasonable that Cambrian corals be grouped into a separate order.

BIBLIOGRAPHY

BASSLER R. S. (1950) Faunal Lists and description of Palaeozoic Corals. *Geol. Soc. of Am. Mem.* **44**, 1-315.

BEDFORD, R. & BEDFORD, J. (1936) Further notes on Cyathospongia (Archaeocyathi) and other organisms from the Lower Cambrian of Beltana, South Australia. *Kyancutta Museum. Mem.* **3**, 21-26.

BEDFORD, R. & BEDFORD, J. (1937) Further notes on Archaeos (Pleospongia) from the Lower Cambrian of South Australia. *Kyancutta Museum. Mem.* **4**, 27-38.

BEDFORD, R. & BEDFORD, J. (1939) Development and classification of Archaeos (Pleospongia). *Kyancutta Museum. Mem.* **6**, 67-82.

BEDFORD, R. & BEDFORD, W.R. (1934) New species of Archaeocyathinae and other organisms from the Lower Cambrian of Beltana, South Australia. *Kyancutta Museum. Mem.* **1**, 1-7.

BEDFORD, R. & BEDFORD, W.R. (1936) Further notes on Archaeocyathi (Cyathospongia) and other organisms from the Lower Cambrian of Beltana, South Australia. *Kyancutta Museum. Mem.* **2,** 9-20.

BENGTSON, S. , CONWAY MORRIS S., COOPER, B.J., JELL, P.A. & RUNNEGAR, B.N. (1990). Early Cambrian fossils from South Australia. *Assoc. of Australas. Pal. Mem.* **9**, 14-19.

BORNEMANN, J. G. (1886) Die Versteinerungendes cambrischen Schichten systems der Insel Sardiniens, Keis Leop. Corol. *Deutsche Acad. Naturfursch.* **51**, 16.

CHAPMAN, F. (1940) On a New Genus of sponges from the Cambrian of the Flinders Ranges, South Australia. *Trans. R. Soc. S. Aust.* **64**,(1)
101-108.

CHEENEY, R.F. (1983) Statistical methods in Geology for Field and Laboratory decisions. Allen & Unwin, London.

CLARKE, J.D.A. (1990) Slope facies deposition and diagenesis of the Early Cambrian Parara Limestone, Wilkawillina Gorge, South Australia. *In* J.B Jago & P.S. Moore (Ed) The Evolution of a Late Pre-Cambrian early Palaeozoic rift complex: The Adelaide Geosyncline. *Spec. Publ. geol. Soc. Aust.* **16**, 230-246.

DAILY, B. (1956) The Cambrian in South Australia. 20th. Intern. Geol. Congress Mexico **2**, 91-147.

DAILY, B. (1963) The fossiliferous Cambrian succession on Fleurieu Peninsula, South Australia. *South Australian Museum. Rec,* **14**(3) 579-601.

DAILY, B. (1969) Fossiliferous Cambrian Sediments and low-grade metamorphics, Fleurieu Peninsula, South Australia. *In:* Daily, B., (Ed), *Geological excursions handbook. ANZAAS,* Section **3**, 49-54.

DAILY, B. (1972) The base of the Cambrian and the first Cambrian faunas. *Univ. of Adelaide. Centre for Precambrian research. Special Paper,* **1**, 13-41.

DAILY, B. (1976a) Norye danne ob osnovanii Kern Yozhnay Australii (New data on the base of the Cambrian in South Australia). *Izvestiya A N Seruja geol oicheskaya* **3,** 45-52.

DAILY, B. (1976b) The base of the Cambrian in Australia. *In: 25th. Intern. Geol. Congress, Sydney, 1976. Abstact,* **857**.

DAILY, B. (1976c) The Cambrian of the Flinders Ranges. *In:* Thompson, B. P., Daily, B., Coats, R. P. and Forbes, B. G. (Complilers), Late Precambrian and Cambrian geology of the Adelaide `Geosyncline' and the Stuart Shelf, South Australia. *25th. Intern. Geol. Congress, Sydney, 1976. Excursion Guide,* **33A**, 15-19.

DAILY, B. (1990) Cambrian Stratigraphy of Yorke Peninsula. *Geol. Soc. of Aust., Special Publ.,* **16**, 215-229.

DALGARNO, C. R. (1964) Lower Cambrian stratigraphy of the Flinders Ranges. *Trans. R. Soc. S. Aust.* **88**, 129-144.

DALGARNO, C. R., & JOHNSON J. E. (1962) Cambrian sequence of the western Flinders Ranges. Quart. geol. Notes, *Geol. Surv. S. Aust.* **4**, 2-3.

DEBRENNE, F. M. (1969) Lower Cambrian Archaeocyatha from the Ajax Mine, Beltana, South Australia. *British Museum of Nat. Hist. Bull. (Geol.).* **17**, 295-376.

DEBRENNE, F. M. (1970) A Revision of Australian general of Archaeocyatha. *Trans. R. Soc. S. Aust.* **94**, 21-49.

DEBRENNE, F. M. (1973) Modification de la porosite primaire de al muraille externe chez les archeocyathes reguliers. *Annales de Paleotologie (Invertebres).* **59**, 3-24.

DEBRENNE, F. M. (1974a) Les archeocyathes irreguliers d'Ajax Mine (Cambrien inferieur, Australie du Sud). *National Museum of Nat. Hist., Paris. Bulletin 195, Sciences de la Terre.* **33**, 185-258.

DEBRENNE, F. M. (1974b) Anatomie et systematique des archeocyathes reguliers sans plancher d'Ajax Mine (Cambrien inferieur, Australie du Sud). *Geobios*. **7**, 91-138.

DEBRENNE, F. M., GANGLOFF, R. A., & LAFUSTE, J. G. (1987) *Tabulaconus* HANDFIELD: Microstructure and its implication in the taxonomy of primitive corals. *Jour. of Pal.* **61**, 1-9.

ETHERIDGE, R. (1889) On some Australian species of the Family Archaeocyathinae. *Trans. R. Soc. Aust.* **13**, 10-22.

ETHERIDGE, R., (1905) Additions to the Cambrian fauna of South Austraila. *Trans. R. Soc. Aust.* **29**, 246-251.

ETHERIDGE, R., (1919) The Cambrian trilobites of Australia and Tasmania. *Trans. R. Soc. Aust.* **43**, 373-393.

FLOWER, R. H. (1961) Montoya and related Colonial Corals *New Mex. Ins. of Tech. Mem.* **7**, 1-97.

FRITZ, M. A. & HOWELL, B. F. (1955) An Upper Cambrian coral from Montana. *Jour. of Pal.* **29**, 181-183.

FULLER, M.K. & JENKINS, R. J. F. (1994) *Moorowipora chamberensis,* a new coral from the Early Cambrian Moorowie Formation, Flinders Ranges, South Australia. *Trans. R. Soc. S. Aust.* **118**(4), 227-235.

FULLER, M. K. & JENKINS, R. J. F. (1995) *Arrowipora fromensis* a new genus of Tabulate-like coral from the Early Cambrian Moorowie Formation, Flinders Ranges, South Australia. *Trans. R. Soc. Aust.* **119**(2), 75-82.

GRAVESTOCK, D. I. (1984) Archaeocyatha from lower parts of the Lower Cambrian carbonate sequence in South Australia. *Assoc. of Australas. Pal. Mem..* **2**, 1-139.

GRAVESTOCK, D. I., & HIBBURT, J. E. (1991) Sequence stratigraphy of the eastern Officer and Arrowie Basins: a framework for Cambrian oil search. *APEA Jour.* **31**, 177-190.

HANDFIELD R. C. (1969) Early Cambrian coral-like fossils from the Northern Cordillera of Western Canada. *Can. Jour. of Earth Sc.* **6**, 782-785.

HART, J. (1989) Lower Cambrian corals from Archaeocyathan-*Epiphyton* clasts within the Moorowie Formation megabreccia, northern Flinders Ranges, South Australia. *B.Sc. Hon. thesis* The University of Adelaide (unpubl.)

HASLETT, P. G. (1975) The Woodendinna Dolomite and Wirrapowie Limestone - two new Lower Cambrian formations, Flinders Ranges, South Australia. *Trans. R. Soc. S. Aust.* **99**, 211-220.

HILL, D. (1981) Rugosa and Tabulata. *In* C. Teichert (ed.) Treatise of invertebrate paleontology. Part F, Coelenterata. Supplement **1**, 1-762, (Geol. Soc. Am. & Uni. Kansas), Boulder Colorado.

HOWCHIN, W. (1897) On the occurrence of Lower Cambrian fossils in the Mount Lofty Ranges. *Trans. R. Soc. S. Aust.* **21**, 74-86.

HOWCHIN, W. (1907) A general description of the Cambrian Series f South Australia. *Aust. Assoc. for the Advancement of Science. Report,* **11**, 414-422.

HOWCHIN, W. (1922) A geological traverse of the Flinders Range from the Parachilna Gorge to the Lake Frome Plains. *Trans. R. Soc. S. Aust.* **46**, 46-82.

JAMES, N. P. & GRAVESTOCK, D. I. (1990) Lower Cambrian shelf and shelf margin buildups, Flinders Ranges, South Australia. *Sedimentology.* **37**, 455-480.

JELL, P. A. & JELL, J. S. (1976) Early Middle Cambrian corals from western New South Wales. *Alcheringa.* **1**, 181-195.

JELL, P. A. (1990) Biostratigraphy. *In* Bengtson, S., Conway Morris, S., Cooper, B.J., Jell, P.A. & Runnegar, B.N. Early Cambrian fossils from South Australia. *Assoc. of Australas. Pal. Mem.* **9**, 14-19.

JELL, P. A., JAGO, J.B. & GEHLING, J.G. (1992) A New Conocoryphid Trilobite from the Lower Cambrian of The Flinders Ranges, South Australia. *Alcheringa.* **16**, 189-200.

JENKINS, R.F. (1990) The Adelaide Fold Belt: Tectonic reappraisal. In J.B Jago & P.S. Moore (Ed) The Evolution of a Late Pre-Cambrian early Palaeozoic rift complex: The Adelaide Geosyncline. *Spec. Publ. geol. Soc. Aust.* **16**, 396-421.

KORDE, K. B., (1963) Hydroconozoa- A new class of Coelenterata. *Akad. Nauk. SSSR, Palaeont. Zhurnal.* **2**, 20-25.

KORDE, K. B., (1984a) Novaya nakhodka predstaviteley roda Inessia Pjankovskaya 1981. *In* Sokolov B. S. (ed.) Problematiki paleozoyai mezozoya; SSSR *Tr Inst. Geol. Geofix. Sibirsk. Otdel. Akad. Nauk.* **597** 73-76.

KORDE, K. B., (1984b) Opredkakh Scyphozoai otryade Edelsteiniida *In* Sokolov B.S. (ed). Fanerozoyskie I Korally SSSR (*Trudy Vsesoyuznogo Simpozium pokorallum I rifam, Dushanbe 1983)* 20-23.

KORDE, K. B., (1990) Edelsteiniida-byvshie problematuki. *In* Sokolov B. S. & Zhuravleva I. T. (eds). Iskopaemye problematiki SSSR- Tr. *Inst. Geol. Geofix. Sibirsk Otdel. Akad. Nauk SSSR* **783,** 50-69.

KONINCK, de L. G. (1841) Description des Animaux fossiles qui se trouvent dans le Terrain Carbonifere de Belgique . **IV** + 650.

LAFUSTE, J., DEBRENNE, F., GANDIN, A., & GRAVESTOCK D. (1991) The oldest tabulate coral and the associated Archaeocyatha, Lower Cambrian, Flinders Ranges, South Australia. *Geobios* **24**, 697-718.

LAUB, R. S. (1984) *Lichenaria* WINCHELL & SCHUCHERT, 1895? *Lamottia* RAYMOND, 1924, and the early history of the Tabulate Corals. IV International Symposium on Fossil Cnidaria. *Paleontogr. Amer.* **54**, 159-163.

LEE, D. J. & NOBLE, J. P. A. (1988) Evaluation of corallite size as a criterion for species discrimination in Favositids. *J. Palaeont.* **62**, (1), 32-40.

LEMON, N. M. (1985) Physical modelling of sedimentation adjacent to diapirs and comparisons with Late Precambrian Oratunga breccia body in Central Flinders Ranges, South Australia. *The Amer. Assoc. of Petrol. Geol. Bull.,* **69**, (9), 1327-1338.

MANCKTELOW, N.S. (1990) The Structure of the southern Adelaide Fold Belt, South Australia. In J.B Jago & P.S. Moore (Ed) The Evolution of a Late Pre-Cambrian early Palaeozoic rift complex: The Adelaide Geosyncline. *Spec. Publ. geol. Soc. Aust.* **16**, 369-395.

McLEOD, J. D. (1979) A Lower Ordovician (Canadian) Lichenarid coral from the Ozark uplift area. *Jour. of Pal.* **53**, 505-506.

MOUNT, T. J. (1970) Geology of the Mount Chambers Gorge region. *B.Sc. Hons. thesis.* The University of Adelaide (unpubl).

NICHOLSON, H. A., (1879) On the Structure and affinities of the `tabulate corals' of the Palaeozoic period. **XIII+,** 342. (Wm. Blackwood & Sons Edinburgh, London).

NICHOLSON, H. A. & ETHERIDGE, J. R. (1878) A monograph of the Silurian fossils of the Girvan district in Ayrshire: **Vol. 1 (1),** 1-135. (Wm. Blackwood & Sons Edinburgh, London).

OEKENTORP, K. (1989) Diagenesis in corals: syntaxial cements as evidence for post-mortem skeletal thickenings. 5th. Intern. Symp. on Fossil Cnidaria. *Fossil Cnidaria* **5**, 169-177.

OKULITCH, V. J., (1936) On the genera Heliolites, Tetradium & Chaetes: *Am. J. Sci.* **32**, 361-379.

OLIVER, W. A. Jr. (1968) Some aspect of colony development in corals. *Jour. of Pal.* 2, Suppl. **2**. 16-34.

OLIVER, W. A. Jr. (1975) Dimorphism in two genera of Devonian Tabulate Corals. *U.S. Geol. Surv. Prof. Paper* **743**-D, 1-11.

POLITO, P. (1993) The Geology and Geochemistry of the Moorowie Mine workings, Northern Flinders Ranges, South Australia. *B.Sc. Hons. thesis.* The University of Adelaide (unpubl).

PREISS, W.V. (1990) A stratigraphic and tectonic overview of the Adelaide Geosyncline, South Australia. In J.B Jago & P.S. Moore (Ed) The Evolution of a Late Pre-Cambrian early Palaeozoic rift complex: The Adelaide Geosyncline. *Spec. Publ. geol. Soc. Aust.* **16**, 1-33.

SAVARESE M., MOUNT, J. F., SORAUF, J. E. & BUCKLIN, L. (1993) Paleobiological and paleoenvironmental context of coral bearing Early Cambrian reefs: implications for Phanerozoic reef development. *Geology* **21**, 917-920.

SCRUTTON, C. T. (1979) Early fossil Cnidarians. pp. 161-207. *In* M. R. House Ed. "The origin of major invertebrate groups." (Ac. Press, London & New York).

SCRUTTON, C. T. (1981) The Measurement of corallite size in corals. *J. of Palaeont.* **5**, 687-689.

SCRUTTON, C. T. (1984) Origin and early evolution of Tabulate Corals. IV International Symposium on Fossil Cnidaria. *Paleont. Amer.* **54**, 110-118.

SCRUTTON, C. T. (1987) A review of favositid affinities. *Palaeont.* **30,** 485-492.

SCRUTTON, C. T. (1989) Intracolonial and intraspecific Variation in tabulate corals. V International Symposium on Fossil Cnidaria. *Mem. Assoc. Australas. Palaeontols.* **8**, 33-43.

SCRUTTON, C. T. (1992) *Flindersipora bowmani* LAFUSTE, and the early evolution of the tabulate corals. *Fossil Cnid. & Porifera* **21**, 29-33.

SCRUTTON, C. T. (1997) The Palaeozoic corals, 1: origins and relationships. *Yorkshire Geol. Soc.* **51**, (3), 177-208.

SCRUTTON, C. T. & POWELL, J. H. (1981) Periodic development of dimetrism in some favositid corals. Third International Symposium on Fossil Cnidarians. *Acta Palaeont. Polon.* **3-4**, 477-491.

SORAUF, J. E. & SAVARESE, M. (1995) A Lower Cambrian coral from South Australia. *Palaeont.* 38 (4), 757-770.

STEL, J. H., (1978) Studies on the palaeobiology of favostids. Stabo/All Round B. V., *Groninge* **VIII+** 247.

STUMM, E. R. (1948) Upper Devonian tetracorals from the Martin Limestone. *J. Palaeont.* **22**, 40-47.

SUTTON, I. D. (1966) The value of corallite size in the specific determination of the tabulate corals *Favosites* and *Palaeofavosites. Mercian geol.* **1**, 255-263.

TABACHNICK, B. G. & FIDELL, L. S. (1996) Using Multivariate Statistics. 3rd. Ed. Harper Collins, New York.

TATE, R. (1892) The Cambrian Fossils of South Australia. *Trans. R. Soc. S. Aust.* **15**(2), 183-189.

TAYLOR, T. G. (1910) The Archaeocyathinae from the Cambrian of South Australia wtih an account of the morphology and affinities of the whole class. *Trans. R. Soc. S. Aust. Mem.* **2**, 55-188.

TEPPER, J. G. O. (1879) Introduction to the cliffs and rocks at Ardrossan, Yorke's Peninsula. *Trans. R. Soc. S. Aust.* **2**, 71-79.

TEPPER, J. G. O. (1881) Sketch of a geological and physical history of Hundred Cunningham and neighbouring regions. *Trans. R. Soc. S. Aust.* **4**, 61-70.

TOTEFF, S. (1990) The Adelaide Supergroup-Kanmantoo Group contact, eastern Mount Lofty Ranges, South Australia. In J.B Jago & P.S. Moore (Ed) The Evolution of a Late Pre-Cambrian early Palaeozoic rift complex: The Adelaide Geosyncline. *Spec. Publ. geol. Soc. Aust.* **16**, 207-214.

VOLOGDIN, A. G., (1932) Archaeocyatha of Siberia pt. 2, Fauna of the Cambrian Limestone of the Altay. *NKTP-SSSR Vses Geol – Razued obed Moscow.* **16,** 46.

WAAGEN, W. H., & WENTZEL, J., (1883) Salt Lake Range fossils, V.1.Productus Limestone fossils; 6, Coelenterata: *Palaeontol. Indica, Ser* **13,** 235-924.

WALTER, M. R., (1967) Archaeocyatha & the biostratigraphy of the Lower Cambrian Hawker Group of South Australia. *J. Geol. Soc. Aust.,* **14,** (1), 139-152.

WELLMAN, P. & GREENHALGH, S. A. (1988) Flinders/Mount Lofty Ranges, South Australia. Their uplift, erosion and relationship to crustal structure. *Trans. R. Soc. S. Aust.* **112**(1), 11-19.

WHITE, C. A., (1883) Contributions to invertebrate palaeontology, No. 8 Fossils from the Carboniferous rock of the interior states: *U.S. Geol. Geogr. Surv. Territor. (Hayden),* 12th. Annu. Rep. **Pt. 1** 155-171.

ZHURAVLEV, A. H. DEBRENNE, F. & LAFUSTE, J. (1993) Early Cambrian microstructural diversification of Cnidaria. *Cour. Forsch. Inst. Senckenberg,* **164**, 365-372.

ZHURALEV, A. Yu. & GRAVESTOCK, D. I. (1994) Archaeocyaths from Yorke Peninsula, South Australia and archaeocyathan Early Cambrian zonation. *Alcheringa,* **18**, 1-54.

APPENDIX

CORALLITE DIAMETERS

Maximum, minimum and mean diameter measurements used in the statistical analysis of the Moorowie corals.

M. chamberensis (holotype)

A. cancelli (holotype)

A. lafustei (holotype)

A. lafustei (paratype)

F. bowmani (holotype)

F. bowmani (34174)

F. uldanami (holotype)

M. chamberensis (h)

MAX.DIAM.	MIN.DIAM.	MEAN
2.14	2.01	2.08
2.21	2.17	2.19
2.54	1.87	2.21
2.61	2.14	2.38
2.65	2.31	2.48
2.69	2.39	2.54
2.69	2.37	2.53
2.74	2.44	2.59
2.75	2.45	2.61
2.81	2.05	2.43
2.83	2.17	2.51
2.86	1.75	2.31
2.99	2.86	2.93
3.05	1.89	2.47
3.07	1.97	2.52
3.09	2.37	2.73
3.09	2.02	2.56
3.09	2.53	2.87
3.12	2.41	2.77
3.15	1.93	2.54
3.19	2.28	2.74
3.19	1.81	2.48
3.28	2.42	2.85
3.31	2.64	2.98
3.31	2.49	2.91

A. cancelli (h)

MAX.DIAM.	MIN.DIAM.	MEAN
2.21	2.11	2.16
2.42	2.42	2.42
2.59	2.31	2.45
2.61	2.28	2.45
2.61	2.44	2.53
2.61	2.15	2.38
2.61	2.31	2.46
2.68	2.28	2.48
2.71	2.59	2.65
2.71	1.76	2.24
2.81	2.15	2.48
2.86	2.71	2.79
2.92	1.89	2.41
2.94	1.88	2.41
3.02	2.21	2.62
3.25	2.82	3.04
3.26	2.42	2.84
3.31	2.49	2.91
3.38	2.54	2.96
3.41	1.95	2.68
3.51	2.15	2.83
3.52	3.21	3.66
3.63	3.41	3.52
3.75	2.51	3.13
3.75	3.71	3.73

A. lafustei (h)

MAX.DIAM.	MIN.DIAM.	MEAN
1.41	1.16	1.29
1.83	1.79	1.81
1.83	1.71	1.77
1.93	1.54	1.74
1.95	1.81	1.88
2.02	1.75	1.89
2.15	1.51	1.83
2.21	2.11	2.16
2.25	1.49	1.87
2.31	2.09	2.21
2.32	1.04	1.68
2.34	2.15	2.25
2.38	1.13	1.76
2.39	2.01	2.21
2.51	2.46	2.49
2.52	1.91	2.22
2.63	2.24	2.44
2.71	1.81	2.26
2.75	2.55	2.65
2.86	2.39	2.63
2.92	2.67	2.79
3.11	2.63	2.87
3.18	2.24	2.71
3.35	2.71	3.03
3.41	2.41	2.91

A. lafustei (p)

MAX.DIAM.	MIN.DIAM.	MEAN
1.75	1.51	1.63
1.78	1.78	1.78
1.78	1.78	1.78
1.86	1.86	1.86
1.91	1.59	1.75
1.93	1.81	1.87
1.93	1.85	1.89
1.96	1.71	1.84
2.13	1.63	1.88
2.27	1.78	2.03
2.29	1.71	2.01
2.46	1.73	2.09
2.51	1.89	2.21
2.57	1.93	2.25
2.61	2.04	2.33
2.71	1.97	2.34
2.75	1.78	2.27
2.76	1.86	2.31
2.77	2.07	2.42
2.81	2.29	2.55
2.91	2.39	2.65
3.01	3.01	3.01
3.18	2.46	2.82
3.54	2.21	2.88
3.54	2.49	3.01

Measurements in mm.

F. bowmani (h)

MAX.DIAM.	MIN.DIAM.	MEAN
1.75	1.46	1.61
1.79	1.48	1.64
1.85	1.14	1.49
1.85	1.28	1.57
1.89	1.66	1.78
1.91	1.81	1.86
1.91	1.67	1.79
1.94	1.52	1.73
1.94	1.57	1.76
1.98	1.46	1.72
2.01	1.56	1.79
2.01	1.88	1.95
2.06	1.47	1.77
2.07	1.95	2.01
2.09	1.54	1.82
2.11	1.49	1.81
2.16	1.35	1.76
2.25	1.51	1.88
2.41	1.47	1.94
2.41	1.41	1.91
2.61	1.81	2.21
2.69	1.95	2.32
2.79	2.05	2.42
2.85	1.42	2.14
2.94	1.35	2.15

F. bowmani (34174)

MAX.DIAM.	MIN.DIAM.	MEAN
1.57	1.14	1.36
1.75	1.55	1.65
1.76	1.51	1.64
1.83	1.71	1.77
1.85	1.54	1.69
1.89	1.32	1.61
1.89	1.42	1.66
2.01	1.09	1.55
2.01	1.59	1.81
2.02	1.88	1.95
2.03	1.88	1.96
2.09	1.11	1.61
2.12	1.52	1.82
2.17	1.72	1.95
2.19	1.85	2.02
2.21	1.82	2.02
2.29	1.14	1.72
2.32	1.52	1.92
2.32	1.65	1.99
2.44	2.02	2.23
2.47	1.42	1.95
2.49	1.49	1.99
2.62	2.13	2.38
2.67	2.29	2.48
2.91	2.22	2.57

F. uldanami (h)

MAX.DIAM.	MIN.DIAM.	MEAN
1.51	1.45	1.48
1.72	1.65	1.69
1.85	1.42	1.64
1.91	1.81	1.86
1.92	1.71	1.82
2.01	1.95	1.98
2.05	1.71	1.88
2.11	1.55	1.83
2.12	1.95	2.04
2.15	1.81	1.98
2.15	1.61	1.88
2.21	1.71	1.96
2.21	1.61	1.91
2.25	1.92	2.09
2.32	1.41	1.87
2.41	2.01	2.21
2.45	1.75	2.11
2.55	2.15	2.35
2.55	2.41	2.48
2.65	1.45	2.05
2.71	2.01	2.36
2.71	2.71	2.71
2.92	1.81	2.37
3.01	1.61	2.31
3.01	2.25	2.68

Measurements in mm.