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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

BULLETIN 135

TYPE LITHOSTROTIONID CORALS FROM THE MISSISSIPPIAN OF WESTERN CANADA

E. W. Bamber

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PREFACE

Mississippian fossils collected from the Canadian Rocky Mountains have been studied and reported on by numerous palaeontologists in both the last and present centuries. As may be expected, the earlier nomenclature is in some confusion, many of the forms were inadequately figured and described, and some type specimens were either lost or not indicated.

In this report the author has considered one coral group and re-figured and described the original material, supplemented by specimens collected later, and established types where there was none previously. This kind of study is essential if our knowledge of the stratigraphy of the oil-bearing Mississippian rocks is to be refined and made more precise.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, September 30, 1964

Bulletin 135 — Typen von Lithostrotionid Korallen aus dem Mississippian Westkanadas. Von E. W. Bamber.

Бюллетень 135 — Типы Литостротионоидных Кораллов из миссисипских омложений Запад. Канады. Е. В. Бамбер.

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Abstract

Type specimens of the following lithostrotionid coral species are redescribed: *Lithostrotion* (*Siphonodendron*) *mutabile* (Kelly), *L.* (*S.*) *sinuosum* (Kelly), *Lithostrotionella microstylum* (White), *L. micra* Kelly, *L. banffensis* (Warren), *L. pennsylvanica* (Shimer), and *Thysanophyllum astraeiforme* (Warren).

Lithostrotionella jasperensis Kelly and *L. confluens* Easton are junior synonyms of *L. microstylum* (White).

Résumé

L'auteur décrit à nouveau les spécimens-types des espèces suivantes de coralliaires lithostrotionidés: *Lithostrotion* (*Siphonodendron*) *mutabile* (Kelly), *L.* (*S.*) *sinuosum* (Kelly), *Lithostrotionella microstylum* (White), *L. micra* Kelly, *L. banffensis* (Warren), *L. pennsylvanica* (Shimer), et *Thysanophyllum astraeiforme* (Warren).

Lithostrotionella jasperensis Kelly et *L. confluens* Easton sont des synonymes récents de *L. microstylum* (White).

INTRODUCTION

Historical Summary

Most of the type specimens included in this study are from the Mississippian Banff Formation and Rundle Group of the Rocky Mountains of Alberta and British Columbia. They have been described previously by several authors. Shimer (1926)[1] based the description of *Lithostrotion pennsylvanicum* on specimens from several localities at Lake Minnewanka near Banff, Alberta. Several other new species, including *Diphyphyllum astraeiforme, Lithostrotion banffense,* and *Lithostrotion flexuosum,* were described by Warren (1927) from the Rundle Group near Banff. Kelly (1942) assigned *L. pennsylvanicum, L. banffense,* and *D. astraeiforme* to the genus *Lithostrotionella* because of their lonsdaleoid septa, and erected a new name, *Diphyphyllum sinuosum,* to replace *Lithostrotion flexuosum* Warren (not *L. flexuosum* Trautschold, 1879). He placed the latter species in the genus *Diphyphyllum* because of the discontinuity of columellae in specimens from his own collections. Kelly also named the following species from the Mountain Park area: *Lithostrotionella micra, Lithostrotionella jasperensis,* and *Diphyphyllum mutabile.* Crickmay (1955) revised the generic designations of these species and used the combinations *Lithostrotion mutabile, Lithostrotion sinuosum, Lithostrotion banffense, Thysanophyllum astraeiforme,* and *Lonsdaleia pennsylvanica.*

The most comprehensive publication on Mississippian lithostrotionids from western Canada is that by Nelson (1960) in which sixteen species (including those mentioned above) are described and illustrated. He assigned *Lithostrotion banffense* and *Thysanophyllum astraeiforme* to *Lithostrotionella* because of their lonsdaleoid septa, *Lonsdaleia pennsylvanica* to *Lithostrotionella* because of its axial structure, and suggested that *Lithostrotionella jasperensis* Kelly and *Lithostrotionella confluens* Easton are junior synonyms of *Lithostrotionella microstylum* (White) from the Mississippi Valley. He showed that lithostrotionid corals are useful for zoning Mississippian rocks in the Canadian Rocky Mountain region.

[1] Names and/or dates in parentheses refer to *References* at end of report.

Primary type specimens of most of the previously mentioned species are in the type collection of the Geological Survey of Canada. This paper presents new information from additional thin sections of these specimens.

Age and Distribution

The coral names used here are given below with the ages and stratigraphic distribution of these corals in the Canadian Rocky Mountains from the Jasper area, Alberta, south to the Crowsnest Pass.

	Stratigraphic Distribution	*Age*
Thysanophyllum astraeiforme (Warren)	— upper Mount Head Fm., Rundle Gp.	late Meramecian
Lithostrotionella pennsylvanica (Shimer)	— middle and upper Mount Head Fm., Rundle Gp.	late Meramecian
Lithostrotionella banffensis (Warren)	— lower and middle? Mount Head Fm., Rundle Gp.	early or middle Meramecian
Lithostrotion (*Siphonodendron*) *sinuosum* (Kelly)	— upper 400′ of Livingstone Fm. and basal Mount Head Fm., Rundle Gp.	late Osagean to early Meramecian
Lithostrotionella micra Kelly	— upper Pekisko Fm. and lower Shunda Fm.	Osagean
Lithostrotion (*Siphonodendron*) *mutabile* (Kelly)	— lower Livingstone Fm. and uppermost Banff Fm.	early Osagean
Lithostrotionella microstylum (White)	— lowermost Pekisko Fm. and uppermost Banff Fm.	late Kinderhookian to early Osagean

Of these species, only *Lithostrotionella microstylum* (White) has been found in the Mississippi Valley region. In Missouri (Bowsher, 1961, pp. 959, 960) and (as interpreted here) in the eastern Cordillera from Mexico to northern Jasper Park, Alberta (Easton, *et al.*, 1958, p. 31; Armstrong, 1962, p. 39; Nelson, 1960, p. 112) it occurs in rocks of late Kinderhookian to early Osagean age.

Other occurrences of the above lithostrotionids are included in the text. They agree approximately with the sequence of zones established by Nelson (1960, Text-fig. 2).

Terminology

The morphological terms used here are, in general, adopted from Hill (1956, pp. 245-251). The following require explanation:

1. *Corallite diameter.* In the text the diameter of irregularly shaped cerioid corallites is given in terms of the largest and smallest transverse dimensions of each, measured through the axis. The average values given in the tables are derived from these two dimensions.

2. *Angle of slope.* In descriptions of tabulae, the angle of slope refers to the angle between a plane perpendicular to the corallite axis and the upper surface of the tabula.

Acknowledgments

The author is grateful to A. K. Armstrong, J. E. Brindle (Saskatchewan Department of Mineral Resources), S. J. Nelson (University of Alberta), J. E. Smith (Michigan State University), the authorities of the U.S. National Museum, and to the staff of the Department of Geology, University of Missouri who provided some of the type specimens used.

Helpful advice and information were contributed by H. Duncan, W. J. Sando, and S. J. Nelson during the preparation of the manuscript.

SYSTEMATIC PALAEONTOLOGY

Genus ***Lithostrotion*** Fleming, 1828

Subgenus *Siphonodendron* McCoy, 1849

Type species *Lithodendron pauciradialis* McCoy, 1844

Lithostrotion (*Siphonodendron*) *mutabile* (Kelly)

Plate I, figures 1a-e

Diphyphyllum mutabile Kelly, 1942, p. 358, Pl. 51, figs. 7, 8.
Diphyphyllum sp. Kelly, 1942, p. 359.
Lithostrotion [*Diphyphyllum*] *mutabile* (Kelly). Bassler, 1950, p. 221.
Lithostrotion mutabile (Kelly). Crickmay, 1955, 1961, p. 12.
Lithostrotion [*Diphyphyllum*] aff. *mutabile* Kelly. Sutherland, 1958, p. 96, Pl. 33, figs. 2a, b.
Lithostrotion mutabile (Kelly). Nelson, 1960, p. 120, Pl. 24, figs. 1-3.
Lithostrotion mutabile (Kelly). Nelson, 1961, Pl. 8, figs. 1, 2.

Material and Occurrence

Holotype — GSC No. 9642 — five fragments, and seven thin sections (GSC Nos. 9642a-g), "collected on the southwest slope of the mountain northwest of the junction of the McLeod River with Whitehorse Creek", Mountain Park area, Alberta (Kelly, 1942, p. 359; *see also* MacKay, 1929).

Hypotype — Two thin sections (GSC Nos. 10654 and 10655), collected at GSC locality 16603, Liard River, District of Mackenzie, east bank, 5 miles above Flett Rapids (Sutherland, 1958, pp. 39, 97), collector, C. O. Hage, 1944.

Other Occurrences

Rocky Mountains, southern British Columbia and Alberta, from lowermost Rundle Group and uppermost Banff Formation.

Description of Holotype

External features. "Corallum large, at least 2 feet in diameter and 1 foot in height" (Kelly, 1942, p. 358), holotype is a corallum fragment 12x8x5½ cm; growth form phaceloid; increase lateral.

Corallites approximately circular in transverse section, sinuous to slightly curved; corallite spacing irregular, commonly 2 to 5 mm. In several places two or three corallites are in contact over several millimetres of their lengths; corallite diameter 4 to 6 mm; ornamentation consists of indistinct septal grooves and closely spaced transverse striae upon irregularly spaced transverse rugae.

Internal features. Major septa number nineteen to twenty-five (commonly twenty-one to twenty-three), majors alternate with minor septa; length of major septa one quarter to two fifths (commonly slightly less than one third) corallite radius, variable within individual corallites; length of minor septa commonly two thirds to three quarters the length of major septa (varies from slightly less than one half to slightly more than three quarters); septa taper slightly from wall towards axis and are radially arranged.

Columella simple. Of the nineteen corallites sectioned transversely, seventeen show a columella and two do not. The columella is discontinuous in a corallite that was cut at two levels 3.3 cm apart (*see* Remarks). In transverse section the columella is thin, lens-shaped in some corallites, tabular in others. It is strongly developed and continuous wherever seen in longitudinal section, and is slightly to strongly sinuous.

Dissepimentarium discontinuous in all corallites studied; width varies within a given corallite but is commonly about one eighth of corallite radius; dissepiments in one row, strongly to moderately convex, elongate, moderately inclined to vertical; angle between dissepiments and wall commonly 40 to 50 degrees, rarely up to 85 degrees; six to eight dissepiments in 5 mm of corallite length.

Tabulae flat to gently sloping near axis in most corallites, deflected slightly upward at columella, strongly downward near dissepimentarium; angle between tabulae and columella 12 to 84 degrees, commonly 30 to 50, but can vary by as much as 45 degrees in a given tabula; slope of tabulae decreases at one third tabularium radius from columella to angles of zero in some tabulae, and 10 degrees or less in most, although in one corallite the angle of slope is between 20 and 30 degrees over the inner two thirds to three quarters of the tabularium; slope increases abruptly two thirds to three quarters tabularium radius from columella to angles between 50 and 80 degrees (rarely up to 90 degrees) and there many tabulae terminate on underlying tabulae. Most tabulae reach the dissepimentarium, however, and in these the angle of slope decreases near the tabularium wall to near zero degrees and is rarely reversed. Depressed peripheral parts of tabulae extend downward for 1 to 1½ mm; seven to nine (commonly seven to eight) tabulae in 5 mm of corallite length.

Immature corallites are similar to mature corallites, but have steeper slopes in the central parts of their tabulae.

Table I

Diameter of Corallite (D) and Number of Major Septa (N)

GSC No. 9642			
D (mm)	N	D (mm)	N
4	19	5½	22 (2)
4	20 (3)	5½	23
4½	21	5½	25
4½	22 (3)	6	23
5	21 (2)	6	24
5	22 (3)		
5	23 (2)		
5	24		

(Number of corallites given in parentheses where data apply to more than one.)

Remarks

This description is based on the holotype of *L.* (*S.*) *mutabile* (Kelly) (GSC No. 9642), which has also been described by Nelson (1960, pp. 120, 122). Nelson redescribed the longitudinal features and pointed out the discontinuity of the dissepimentarium. He assigned the species to *Lithostrotion* because of the presence of a strong columella, as had Crickmay (1955).

Several new longitudinal sections of the holotype are given on Plate I, figures 1a-e, and show the variability of the tabulae. In some corallites the central parts of tabulae slope steeply (Pl. I, fig. 1c), whereas in most the tabulae are nearly horizontal except where they turn up at the columella and down near the dissepimentarium. Also, the slopes of tabulae vary along a given corallite.

In the transverse section of the holotype (Kelly, 1942, Pl. 51, fig. 8) three corallites show no columellae. Lower in one of these corallites a columella is present, and is therefore discontinuous. The continuity of columellae in other corallites has not been investigated.

Nelson (1960, p. 121) discussed the difference between *L.* (*S.*) *mutabile* and *L.* (*S.*) *warreni* Nelson. The two species differ in the shape of their tabulae, those of *L.* (*S.*) *warreni* being more steeply inclined and less sharply depressed near the dissepimentarium than are those of *L.* (*S.*) *mutabile*. A longitudinal section of the holotype of *L.* (*S.*) *warreni* (Univ. of Alberta, No. 338) is illustrated for comparison (Pl. I, fig. 2).

The differences between *L.* (*S.*) *mutabile* and *L.* (*S.*) *oculinum* Sando have been discussed by Sando (1963, p. 1076). The two species differ in the slopes of their tabulae. Also, near the dissepimentarium the tabulae extend downward past the shoulders of underlying tabulae to a greater extent in *L.* (*S.*) *oculinum* than in *L.* (*S.*) *mutabile*.

As interpreted here, *L.* (*S.*) *mutabile* includes forms with weakly developed or discontinuous columellae, small corallite diameters and correspondingly few septa, such as Sutherland's *Lithostrotion* [*Diphyphyllum*] aff. *mutabile* Kelly (Sutherland, 1958, p. 96, Pl. 33, figs. 2a, b).

Lithostrotion (*Siphonodendron*) *sinuosum* (Kelly)

Plate I, figures 3, 4

Lithostrotion flexuosum Warren, 1927, p. 47, Pl. 3, fig. 7; Pl. 6, fig. 2.
[Non] *L. flexuosum* Trautschold, 1879, p. 37, Pl. 5, figs. 7a, b.
Diphyphyllum sinuousum Kelly, 1942, p. 358.
Lithostrotion [*Diphyphyllum*] *sinuosum* (Kelly). Bassler, 1950, p. 221.
Lithostrotion sinuosum Kelly. Crickmay, 1955, 1961, p. 12.
Lithostrotion cf. *pauciradiale* (McCoy). Sutherland, 1958, p. 92, Pl. 32, figs. 1, 2, 3a-c.
Lithostrotion sinuosum (Kelly). Nelson, 1960, p. 121, Pl. 24, figs. 4-10.
Lithostrotion sinuosum (Kelly). Nelson, 1961, Pl. 11, figs. 1-7.

Material and Occurrence

Lectotype (here chosen) — GSC No. 8913 — one piece, two thin sections (GSC Nos. 8913b, c).

Syntype — GSC No. 8913a — three pieces, one thin section (GSC No. 8913e), one peel (GSC 8913d).

GSC Nos. 8913 and 8913a from "upper beds of Rundle limestone on Stoney Squaw Mountain", Banff area, Alberta. (Warren, 1927, p. 121)

Hypotype — GSC No. 18813 — eight pieces, seven thin sections (GSC Nos. 18813a-g), three peels (GSC Nos. 18813h-j), collected from GSC locality 60203, 1,345 feet below top of Prophet Formation, just north of Peace River, at longitude 123°12′W and latitude 56°02′N, northeastern British Columbia.

Hypotypes — GSC Nos. 10649-51 — four thin sections from GSC locality 16030, Member B, Prophet Formation, Section 8 on Bull Creek, Prophet-Muskwa Rivers area, northeastern British Columbia — *Lithostrotion* cf. *pauciradiale* (McCoy). (Sutherland, 1958, p. 93)

Other Occurrences

1. GSC locality 60204, northeastern British Columbia, just north of Peace River, at longitude 123°12′W and latitude 56°02′N, 1,425 feet below the top of the Prophet Formation.

2. Upper 400 feet of the Livingstone Formation and basal Mount Head Formation, Rocky Mountains of southern British Columbia and Alberta. (Nelson, 1960, p. 121)

Remarks

Lithostrotion (*S.*) *sinuosum* (Kelly) is well described and illustrated by Nelson (1960, p. 121, Pl. 24, figs. 4-10; 1961, Pl. 11, figs. 1-7). The structure and preservation are closely similar in Warren's syntypes (GSC Nos. 8913 and 8913a), but the specimens do not fit together and cannot be shown to come from the same corallum. Also, Warren (1927, p. 47) refers to more than one type specimen in his remarks on the species. GSC syntype 8913 is figured by Warren (1927, Pl. 6, fig. 2) and is therefore chosen as lectotype of *L.* (*S.*) *sinuosum* (Kelly).

In a corallite from GSC syntype 8913a (Pl. I, fig. 3) the tabulae are less steeply inclined and more complete than are those in the corallite from GSC syntype 8913 illustrated by Nelson (1960, Pl. 24, fig. 5; 1961, Pl. 11, fig. 2). The former corallite resembles Nelson's hypotypes (1960, Pl. 24, figs. 6, 7, 8, 10; 1961, Pl. 11, figs. 4, 5, 6) more closely than does the latter.

In transverse sections from *L.* (*S.*) *sinuosum* the degree of axial extension of major septa appears to differ greatly between corallites belonging to the same corallum. The majors of some corallites reach the columella, and those of others do not. The last-mentioned septa commonly terminate axially on intercepts of tabulae. The transverse sections of a corallum from northeastern British Columbia (GSC hypotype No. 18813), which were cut from levels within 2 mm of each other through the same corallites, show that major septa that do not reach the columella at one level, do so at the other (Pl. I, figs. 4a, b). Several longitudinal peels, taken in a series from near the wall of the axis of a corallite from GSC No. 18813, show that major septa are withdrawn from the columella between tabulae. The septa become vertically discontinuous towards the axis and approach the columella as ridges on the tops of tabulae (Pl. I, figs. 4e-i). These ridges are represented in the figures by short upward projections on the surfaces of the tabulae. A series of longitudinal features similar to this was seen during the cutting of a centred longitudinal section from GSC No. 8913a (Pl. I, fig. 3).

Because corallites originate at different levels in the corallum, the variable positions of the axial edges of septa cause the septal length to differ from corallite to corallite at a given level. This length variation, seen in transverse thin sections, reflects structural changes along individual corallites, rather than morphological differences between these corallites.

Table II

Diameter of Corallite (D) and Number of Major Septa (N)

GSC No. 8913		GSC No. 8913a		GSC No. 18813	
D (mm)	N	D (mm)	N	D (mm)	N
3	16 (2)	3	16 (5)	2	14
3½	16	3½	16 (2)	2½	16 (2)
3½	17 (2)	4	17 (3)	2½	17
4	16 (3)			3	16 (4)
				3	17 (3)
				3½	16 (9)
				3½	17 (3)
				3½	18
				4	16 (2)
				4	17
				4	19
				4½	17

(Number of corallites given in parentheses where data apply to more than one.)

Genus ***Lithostrotionella*** Yabe and Hayasaka, 1915

Type species: *Lithostrotionella unica* Yabe and Hayasaka, 1915

Lithostrotionella microstylum (White)

Plate I, figures 5a-g; Plate II, figures 1-3; Plate III, figures 1-3

Lithostrotion microstylum White, 1880, p. 159, Pl. 40, fig. 7a.
Lithostrotion microstylum White, 1883, p. 159, Pl. 40, fig. 7a.
Lithostrotion microstylum White. Keyes, 1894, p. 124.
Lithostrotionella jasperensis Kelly, 1942, pp. 356, 357, Pl. 51, figs. 3, 6.
Lithostrotion microstylum White. Easton, 1944, pp. 53, 54, Pl. 13, figs. 1-3; Pl. 17, fig. 1.
Lithostrotion [Lithostrotionella] jasperensis (Kelly). Bassler, 1950, p. 221.
Lithostrotionella confluens Easton, 1958, pp. 31-33, Pl. 1, fig. 12; Pl. 2, figs. 8, 9.
Lithostrotionella jasperensis Kelly. Nelson, 1960, pp. 112, 113, Pl. 21, figs. 1-4.
Lithostrotionella jasperensis Kelly. Stensaas and Langenheim, 1960, pp. 184, 186, text-figs. 9a, b, 10a, b.
Lithostrotionella jasperensis Kelly. Nelson, 1961, Pl. 1, figs. 1-3.
Lithostrotionella microstyla (White). Bowsher, 1961, Pl. 110, figs. 4, 5a-c.
Lithostrotionella confluens Easton. Armstrong, 1962, p. 39, text-fig. 18, Pl. 4, figs. 1-5.

Material and Occurrence

Lithostrotionella jasperensis Kelly

Holotype — GSC No. 9647 — one thin section, collected "just below the summit of the northeast end of the spur east of the watershed of Rocky Pass, Mountain Park area, Alberta". (Kelly, 1942, p. 356)

Hypotype — GSC No. 9646 — three pieces, two thin sections (GSC Nos. 9646c, d), collected from the 3rd horizon of the Rundle, Lindsay Creek, Mountain Park area (Kelly, 1942, p. 357). "Lindsay Creek" is not a recognized geographic name and its location is in doubt. The specimen may have come from Deception Creek, which runs along the base of Mount Lindsay.

Hypotype — University of Alberta No. 340 — two thin sections, which are in the GSC type collection and bear GSC Nos. 16840 and 16840a, from Cripple Creek, Alberta, latitude 52°12′, longitude 116°00′ (Nelson, 1960, p. 113).

Lithostrotionella confluens Easton

Holotype — U.S. National Museum No. 127939 — Represo Formation, 1¼ miles west-northwest of Bisani, Sonora, Mexico.

Lithostrotionella microstylum (White)

Plesiotype — University of Missouri No. 1357 — Chouteau Limestone (unrestricted) near Sedalia, Missouri (Easton, 1944, p. 54).

Hypotype — U.S. National Museum No. 66838 — five pieces, and five thin sections from a silicified, nearly complete corallum, collected from the Chouteau Group, Sedalia, Missouri.

Hypotype — GSC No. 18812 — ten pieces, five thin sections (GSC Nos. 18812a-e), collected from GSC loc. 42144 from the top 50-100 feet of the Banff Formation on the northwest side of The Rajah, Jasper Park, Alberta (longitude 118°36′W, latitude 53°16′N); collector, E. W. Mountjoy, 1960.

Other Occurrences

1. *Lithostrotionella jasperensis* Kelly — "Middle and Upper Joana limestone at Dutch John Mountain . . ., Lincoln county, Nevada; Ward Mountain,

White Pine county, Nevada; Sunnyside, Lincoln county, Nevada; and Cave Valley, White Pine county, Nevada." (Stensaas and Langenheim, 1960, p. 186)

2. *Lithostrotionella confluens* Easton — According to Armstrong (1962, p. 39), "This species is very abundant in Member A of the Keating Formation throughout its area of exposure in southwestern New Mexico and at Blue Mountain, Chiricahua Mountains, Arizona. It is also present in the Andrecito Member of the Lake Valley Formation in the southern part of the Black Range, New Mexico."

Nelson (1962, pp. 170, 171) and Bowsher (1961, pp. 959, 960) discussed the stratigraphic and geographic distribution of *Lithostrotionella microstylum* (White) and its synonyms. The species is restricted to late Kinderhookian and early Osagean rocks in the Mississippi Valley and appears to occupy this stratigraphic position in the Rocky Mountains from Mexico to northeastern British Columbia.

Description of Hypotype (U.S. National Museum No. 66838)

External features. Corallum height 8 cm (youngest part of corallum missing), maximum width 20 cm, minimum width 13 cm; growth form cerioid; increase intermural.

Corallites elongate to almost equidimensional in transverse section, straight to slightly curved; smallest corallite diameter commonly 10 mm, rarely as low as 7 mm and as high as 13 mm; greatest diameter commonly 10 to 12 mm, rarely up to 16 mm; ornamentation not preserved, but wall very sinuous in transverse section, suggesting strong longitudinal grooves.

Calicular platform slightly below top of corallite wall, occupies peripheral two thirds of calice; on the platform, septa form ridges that run from the axial edge of the platform to the wall; calicular pit occupies axial one third of calice, is 3 to 4 mm deep, has a nearly vertical wall formed by edges of septa, and bears an axial boss which is formed by the columella and axial ends of major septa.

Columella styliform, rises to just below level of calicular platform; axial ends of major septa extend as ridges on columella for a short distance above floor of calicular pit; walls bordering calices are sinuous and thick.

Internal features. Major septa number eighteen to twenty-one, rarely seventeen or twenty-two, minor septa alternate with majors; major septa all extend to columella, all extend into dissepimentarium and are lonsdaleoid, some reach wall in every corallite cut by section; minor septa one half to three quarters length of majors and extend into dissepimentarium, but few reach wall; septa slightly sinuous, taper strongly from tabularium wall into dissepimentarium, slightly from tabularium wall towards axis; major septa thickened in tabularia of most corallites, axial one tenth of major septa very thin in some corallites. In several corallites the major septa converge on the axial parts of the cardinal and counter septa to give rough bilateral symmetry.

An apparently simple columella is present in all corallites with tabularia preserved. In transverse section the columella is thick, lens-shaped, and elongate in the cardinal-counter plane (slightly elongate in some, greatly so in others). In longitudinal section it is straight, thick, and continuous (*see* Remarks).

Dissepimentarium continuous, width between three fifths and two thirds corallite radius; dissepiments vary greatly in size, small ones strongly convex, large ones slightly to strongly convex; dissepiments horizontal to slightly inclined (up to 30 degrees below horizontal), except near tabularium where they are steeply inclined to vertical; eleven to fifteen dissepiments in 5 mm of corallite length; number of rows ranges from one to ten because of size variation.

Tabulae are commonly incomplete, roughly S-shaped, convex upward near columella and concave upward near dissepimentarium; angle between tabulae and columella commonly 50 to 80 degrees, rarely as low as 40; angle of slope 10 to 40 degrees (commonly 10 to 20) in axial parts of tabulae, and increases to between 60 and 80 degrees at one half to three quarters tabularium radius from columella; near dissepimentarium, angle decreases to zero in a few tabulae and is reversed in the rest; incomplete tabulae common, tabellae numerous near columella and dissepimentarium, convex upward near columella, concave upward near dissepimentarium. Some axial tabellae slope more steeply than do axial parts of complete tabulae, and others are partly concave upward; seven or eight tabulae in 5 mm of corallite length.

Immature corallites are similar to mature corallites, but have a smaller diameter and fewer septa (*see* Table III).

Table III

Average Diameter of Corallite (D mm) and Number of Major Septa (N)

USNM No. 66838		GSC No. 9646b		GSC No. 18812		Univ. of Alberta No. 340		USNM No. 127939		Univ. of Missouri No. 1357	
D	N	D	N	D	N	D	N	D	N	D	N
5½	15	4	15	3½	12	4½	15	7	18	7½	16
8	17	4½	17	4½	15	6	15	8	21	8½	18
9½	18	5	16	5	17	6	16	9½	20	9	18
9½	20	5½	16	5½	17	6½	16	10½	20	9½	20
9½	20	7	20	6	18	6	17(3)	11	21(2)		
10	17	8	20(2)	6½	16	7	17	11½	24		
10	18	9½	22	7½	18	7	19	12	24		
10	19	10½	20	8½	17	8	18	12½	20		
10½	18	10½	23	9	18(3)	8½	20	13	22(2)		
11	18			9	19	9	19(2)				
11½	18(2)			9½	17(2)	9½	19				
11½	20			9½	20	9½	21				
12	17			10	18	10	19				
12	18			10½	20(2)	10	20				
12½	18					10	21				
12½	19(4)					10½	21				
12½	20										
12½	22										
13	19(3)										
13	22										
14	19										
14	21										

(Number of corallites given in parentheses where data apply to more than one.)

Remarks

The tabularia of nearly all corallites in U.S. National Museum No. 66838 are replaced by quartz and coarsely crystalline calcite, except near the upper surface of the corallum, where the axial parts of most corallites are at least partly preserved. Because of this replacement the detailed structure of the columellae cannot be determined and their proximal continuity cannot be demonstrated, but there is no flattening of the tabulae or other indication that the columellae were originally absent. Gradations can be seen (Pl. I, fig. 5a) between unreplaced and totally replaced tabularia, which indicates that the tabulae and columellae were originally present in those parts of tabularia that are now completely filled with calcite. The specimen has the lonsdaleoid septa typical of *Lithostrotionella*.

According to Easton (1944, p. 54), the holotype of *Lithostrotionella microstylum* (White) was probably lost in a fire. He studied two specimens from the Chouteau Group, collected near Sedalia, Missouri, and illustrated one of these (op. cit., Pl. 13, figs. 1-3; Pl. 17, fig. 1). This corallum (Univ. of Missouri No. 1357) is illustrated in Plate II, figures 2a-c. It closely resembles the U.S. National Museum specimen (No. 66838) described here, both in skeletal structure and in mode of preservation. Because of poor preservation, the nature of the corallite boundaries is not clear in the University of Missouri specimen, but there appear to be thick walls surrounding the corallites (Pl. II, figs. 2a-c). These walls have been illustrated by Easton (1944, Pl. 13, figs. 2 and 3) and indicate that the coral is cerioid rather than plocoid or aphroid, the growth forms suggested by Easton (op. cit., p. 53). Eighteen to twenty major septa alternate with minors. The majors reach the columella, which is thick, apparently simple, and circular to oblong in transverse section. Easton stressed the circular outlines of the columellae as a distinctive feature of the species (1963, p. 298), but the poor preservation of this specimen makes it difficult to determine the original shapes of its silicified columellae. As already stated, U.S. National Museum No. 66838, collected from the same general locality as was Easton's specimen, has lens-shaped rather than circular columellae.

The tabulae of University of Missouri No. 1357 are only partly preserved and appear indistinctly on two cut surfaces. They are incomplete and doubly curved as are those shown in Plate I, figures 5b-g. The dissepiments are more steeply inclined than are those in the U.S. National Museum corallum (Easton, 1944, Pl. 13, figs. 2 and 3).

Only the figured longitudinal thin section of the holotype of *Lithostrotionella jasperensis* Kelly (Kelly, 1942, Pl. 51, fig. 6) is present in the Geological Survey of Canada type collection (GSC holotype No. 9647). Part of this section is illustrated here (Pl. II, figs. 1a, b). The dissepimentaria have been crushed and their widths cannot be judged from the longitudinal section, but Kelly's illustration of a transverse section (Kelly, 1942, Pl. 51, fig. 3) shows several corallites with wide dissepimentaria and large cystose dissepiments. Another specimen from the Mountain Park area, Alberta (GSC No. 9646b), identified as *L. jasperensis* by

Kelly, has dissepimentaria similar to those figured by Nelson (1960, Pl. 21, figs. 2, 3, 4).

The growth form of the holotype of *L. jasperensis* is unknown. The columellae are thinner than are those of *L. microstylum* from the Mississippi Valley, but otherwise the internal features of the two forms are closely similar. This similarity has been pointed out by Nelson (1960, p. 113; 1961, p. 21; 1962, p. 170), who illustrated and described *L. jasperensis* from western Canada. His illustrations (1960, Pl. 21, fig. 1; 1961, Pl. 1, fig. 1) show corallites with up to twenty major septa.

In a thin section (GSC No. 16840) cut from Nelson's hypotype (Univ. of Alberta No. 340) eighteen to twenty-one major septa are present in mature corallites (Pl. III, fig. 2a; Table III). In this section, the major septa reach the columella in most corallites, but are slightly withdrawn from that structure in several. In the last-mentioned corallites the columella shows short projections. Withdrawal of the major septa from the columella has not been observed in the coralla from Missouri, but their few well-preserved tabularia have not been sectioned serially.

Axial features similar to those of Nelson's hypotype (Univ. of Alberta No. 340) are shown by Kelly's illustration of the holotype (1942, Pl. 51, fig. 3) and can be seen in acetate peels from the surface of a transverse cut through the holotype of *Lithostrotionella confluens* Easton (U.S. National Museum No. 127939). Projections from the columella seen in transverse section do not represent septal lamellae (Hill, 1956, p. 250). They are intercepts of the axial edges of major septa that are partly withdrawn from the columella but reach it along the tops of tabulae. A series of transverse sections cut from GSC hypotype No. 18812, illustrate this variability in length of major septa (Pl. III, figs. 3a, b). Because the tabulae slope upwards towards the axis, a given transverse section may cut not only the withdrawn axial edges of septa, but also those parts of the septa that reach the columella along the tops of underlying tabulae and appear in transverse section as short radial projections from the columellae.

In GSC No. 18812 the columella generally is thickest where the major septa touch it and thins considerably where they do not. This is so in Nelson's hypotype (Univ. of Alberta No. 340) and appears to be so in the holotype (Kelly, 1942, Pl. 51, fig. 2). The differences noted by Easton (1963, p. 297) in the axial structures of these two coralla appear to reflect structural variations common to the corallites of both coralla, and are probably not significant morphological differences.

Easton (ibid.) referred to a difference in the number of "septal spines" on the dissepiments of University of Alberta No. 340 and the holotype (GSC No. 9647). These "spines" are the intercepts, in transverse section, of vertically discontinuous peripheral parts of lonsdaleoid septa that extend towards the walls as ridges on the tops of dissepiments, as previously described by Smith (1917, p. 225, text-fig. 1) and Hayasaka (1936, p. 54). The intercepts have little value for differentiation of species, because their number and length depend upon the position of the transverse section and the slope of the dissepiments.

Lithostrotionella confluens Easton (1958, pp. 31-33; Pl. 1, fig. 12; Pl. 2, figs. 8, 9) is closely similar to *L. microstylum* (White) in: corallite walls (thick and sinuous in both), shapes of calices, corallite diameter, number and shape of septa, width of dissepimentarium, number of dissepiments, septal length and pattern, shape and incompleteness of tabulae. Easton's specimens and those described by Armstrong (1962, p. 39) have twenty-four to twenty-six septa in some corallites, but according to Easton (1958, p. 52), "the calyces most often have about 20 major septa" (also *see* Table III for number of septa in holotype — U.S. National Museum No. 127939). The dissepiments of the holotype are, in general, less inflated and more steeply sloping than are those of the Mississippi Valley specimens (Pl. III, figs. 1a, b). Other coralla from the southwestern United States, however, have dissepiments that show considerable inflation and slope much less steeply than do those in Easton's holotype (Armstrong, 1962, Pl. 4, figs. 4 and 5; Bowsher, 1961, Pl. 110, fig. 5c). The columellae of the holotype of *L. confluens* have approximately the same range of shape and size as have those in U.S. National Museum No. 66838, but are considerably narrower than in Easton's plesiotype (Univ. of Missouri No. 1357). These shape differences, however, may be the result of differences in preservation.

Lithostrotionella micra Kelly

Plate III, figures 4a-e

Lithostrotionella micra Kelly, 1942, p. 357, Pl. 50, fig. 7.
Lithostrotion [*Lithostrotionella*] *micra* (Kelly). Bassler, 1950, p. 221.
Lithostrotionella micra Kelly. Nelson, 1960, p. 113, Pl. 21, figs. 5, 6.
Lithostrotion micra (Kelly). Brindle, 1960, Pl. 10, fig. 2.
Lithostrotionella micra Kelly. Nelson, 1961, Pl. 6, figs. 1-3.

Material and Occurrence

Holotype — GSC No. 9648 — one piece, 4½x5½x2½ cm, three small fragments, eight thin sections (GSC Nos. 9648a-h), collected from "just below the summit of the northeast end of the spur east of the watershed of Rocky Pass, Mountain Park area, Alberta". (Kelly, 1942, p. 357)

Other Occurrences

1. Southeastern Saskatchewan subsurface, from the Tilston Beds, at 3,640 feet in the McCarty and Coleman, Pederson No. 4-35 well (Brindle, 1960, pp. 19, 43, 68).

2. Rocky Mountains of southern British Columbia and Alberta — *L. micra* occurs in the lower Shunda Fm. and upper Pekisko Fm.

Description of Holotype

External features. Growth form cerioid; increase intermural; corallites polygonal, non-equidimensional in transverse section, straight to slightly curved;

smallest corallite diameter 2 to 4 mm (commonly 3 mm), greatest diameter 4 to 6 mm (commonly 5 mm); ornamentation not preserved.

Internal features. Major septa number thirteen or fourteen (rarely twelve), minors alternate with majors; majors apparently reach the columella intermittently as ridges on the tops of tabulae. In about four fifths of the corallites cut by Kelly's transverse section, most majors reach the columella, but in the remainder all septa are withdrawn except the counter septum, which rarely extends to the columella (*see* Remarks); septa are lonsdaleoid. In transverse thin section the majors rarely reach the wall. All extend into the dissepimentarium in most corallites, but are completely confined to the tabularium in the rest; minor septa one fourth to two thirds (commonly one third to one half) length of majors; septa slightly curved, rarely sinuous, thickened in peripheral part of tabularium, become thinner towards axis and into dissepimentarium; axial ends of majors commonly very thin near columella. Two or more major septa commonly converge on the axial parts of the cardinal and counter septa to give a rough bilateral symmetry to many corallites. In some corallites the major septa form groups, each of which contains two or three septa joined along their axial edges to form one septum that extends to the columella. Rarely minor septa curve to join major septa.

Columella simple, present in all corallites with axial parts preserved (some replaced by coarsely crystalline calcite). In transverse section it is lens-shaped to tabular, elongate in counter-cardinal plane, very thin and sinuous in some corallites, and thick with short projections in others (*see* Remarks). Columella slightly sinuous, strong, continuous in longitudinal section, varies in thickness along a given corallite.

Dissepimentarium discontinuous, absent for short distances along four of the eight longitudinally sectioned corallites; width commonly one third to one half corallite radius (rarely as low as one sixth), varies considerably along lengths and around peripheries of corallites; one row of dissepiments with little size variation, moderately to strongly convex. Most are steeply inclined to vertical, but some have nearly quadrate longitudinal profiles. Near the wall the upper surfaces of some dissepiments slope downward towards periphery; commonly four to six dissepiments in 5 mm of corallite length.

Tabulae moderately steeply sloping, variable in outline, concave upward near dissepimentarium, most are slightly convex upward near columella, but some have several slight flexures between the columella and the dissepimentarium. Almost all are complete; angle between tabulae and columella commonly 30 to 60 degrees but varies greatly between 10 and 80 degrees; angle of slope 0 to 60 degrees (commonly 30 and 45) near columella, increases at approximately one half tabularium radius from columella to 40 to 90 degrees (commonly 45 to 65) in those tabulae which are convex upward, remains constant or decreases slightly in others; near dissepimentarium the angle decreases slightly in some, decreases to near zero in most and is reversed in the rest. Incomplete tabulae rare, but present in seven of the eight corallites sectioned. Peripheral tabellae are concave upward and more numerous than axial tabellae, which are convex upward or doubly curved; commonly nine to eleven tabulae in 5 mm of corallite length. Immature corallites similar to mature corallites in transverse section, but have smaller diameter and fewer septa, no immature corallites cut longitudinally.

Table IV

Average Diameter of Corallite (D) and Number of Major Septa (N)

GSC No. 9648			
D (mm)	N	D (mm)	N
2½	11(2)	4½	13(4)
2½	12	4	14(3)
3	12(2)	4½	13(5)
3	13	4½	14
3½	12(2)	5	13
3½	13(2)	5	14(5)
3½	14		

(Number of corallites given in parentheses where data apply to more than one.)

Remarks

The description is based on a specimen marked ". . . fragment of holotype, from 3rd horizon of the Rundle", which was found in W. A. Kelly's collection at Michigan State University by J. E. Smith, and is now in the GSC type collection. The specimen is partly silicified and several corallites have been partly replaced by coarsely crystalline calcite.

University of Alberta hypotype No. 339 (Nelson, 1960, Pl. 21, figs. 5, 6) has slightly smaller dissepiments than does GSC No. 9648, and the major septa in Nelson's specimen reach the columella more consistently than do those in the holotype. The internal structures of the two specimens match closely in other respects.

The specimen of *Lithostrotionella micra* figured by Brindle (1960, Pl. 10, fig. 2) differs only slightly from the holotype in having up to sixteen major septa in some corallites.

Lithostrotionella lochmanae Armstrong is similar to *L. micra* in corallite diameter, number and arrangement of major septa, and shape of tabulae, but has longer minor septa, many of which have their axial edges curved to join major septa. Furthermore the major septa of Armstrong's holotype reach the columella consistently in all transverse sections seen by the writer. Its dissepiments are relatively small, form two rows in several corallites, and interrupt the peripheral edges of septa to a lesser extent than do the large, strongly lonsdaleoid dissepiments of *L. micra*.

Several of the columellae from which the major septa are withdrawn in Kelly's transverse section, show short, irregular projections. These probably represent the axial parts of major septa reaching the columellae as ridges on the tops of tabulae immediately underlying the level from which the section was cut. The structure of the inner parts of the tabularia of *L. micra* appears to be analogous with that of *Lithostrotion* (*Siphonodendron*) *sinuosum* (Kelly) and *Lithostrotionella microstylum* (White), but no serial sections have been cut to confirm this.

Lithostrotionella banffensis (Warren)

Plate III, figure 5

Lithostrotion banffense Warren, 1927, p. 46, Pl. 3, figs. 5, 6; Pl. 5.
Lithostrotionella banffensis (Warren). Kelly, 1942, p. 354.
Lithostrotion banffense Warren. Crickmay, 1955, 1961, p. 12, Pl. 1, figs. 13, 14.
Lithostrotionella banffense (Warren). Nelson, 1960, p. 119, Pl. 23, figs. 4, 5.
Lithostrotionella banffense (Warren). Nelson, 1961, Pl. 17, figs. 1, 2.

Material and Occurrence

Lectotype (Nelson, 1960, p. 119) — GSC No. 8912 — one large, irregularly shaped fragment (12x9x3½ cm), four smaller fragments and five thin sections (GSC Nos. 8912b-f). According to Warren (1927, p. 47), the type material comes from "near top of Rundle limestone on Stoney Squaw Mountain". Nelson (1960, p. 119) "is of the opinion that the holotype was derived from the upper *Lithostrotionella* beds (lower Mt. Head formation)."

Description of Lectotype

External features. Growth form cerioid; increase intermural; corallites polygonal, commonly nearly equidimensional, some considerably elongate in transverse section, gently curved; smallest corallite diameter 7 to 9 mm, rarely 6 mm, greatest diameter commonly 9 to 11 mm, rarely 13 mm; ornamentation not preserved.

Calicular platform occupies outer two thirds to three quarters of calice and slopes steeply downward from wall towards axis; on the platform, major septa form ridges that run from the axial edge of the platform to the wall; minor septa form very low, barely distinguishable ridges which do not reach axial edge of platform. The calicular pit occupies the inner one quarter to one third of the calyx, is 1 to 2 mm deep, has nearly vertical walls, and contains an axial boss formed by the conical top of a tabula and the columella; columellae styliform, all are broken off, but longest rises almost to level of axial edge of calicular platform; major septa rarely form low ridges reaching columellae on floor of pit; walls bordering calices are thin and sinuous.

Internal features. Major septa number eighteen to twenty-three, commonly twenty-one to twenty-three, minors alternate with and are equal in number to majors in some corallites at the surface of the colony, but are developed between only a few majors in many corallites and are absent from the rest. In a given transverse section major septa all reach the columella in some corallites, but are slightly withdrawn from the columella in the others (*see* Remarks). All septa are lonsdaleoid and rarely join the wall in any transverse section; minor septa are very short, but definitely present, commonly less than one sixth and rarely up to one third the length of the majors; septa thin, straight to slightly sinuous, some slightly curved near columella. They taper from tabularium wall towards axis and into dissepimentarium; septa radially arranged. Commonly two adjacent major septa unite very near the columella and join that structure as one septum.

Simple columella present in all corallites. In transverse section it is lens-shaped, elongate in cardinal-counter plane, and shows short projections where major septa are withdrawn from it. These projections represent ridges made by axial edges of major septa running up sloping tabulae to join the columella at or just below the plane of the section. In longitudinal section the columella is straight to gently curved, strong and continuous.

Dissepimentarium continuous, width one quarter to one half corallite radius (commonly slightly less than one half), varies considerably around the periphery of most corallites; dissepiments show considerable size variation; most are strongly convex, some only slightly so; most are moderately inclined, rarely vertical next to tabularium. Many dissepiments are concave upward in part. There are five to seven in 5 mm of corallite length, one or two rows, rarely up to three.

Tabulae slope steeply, convex upward except near columella and dissepimentarium, where they are concave upward, commonly incomplete; angle between tabulae and columella commonly 30 to 35 degrees, but ranges from 14 to 66 degrees. Angle of slope 24 to 76 degrees (commonly 55 to 66) near columella, decreases to 0 to 40 degrees (commonly 10 to 20) approximately one third tabularium radius from columella; increases to 50 to 86 degrees (commonly 55 to 65) approximately one half tabularium radius from columella; near dissepimentarium angle decreases slightly in most tabulae, decreases to near zero degree in others and is rarely reversed; incomplete tabulae common, most numerous tabellae near dissepimentarium. Most axial tabellae are doubly curved, but some are concave upward and others are convex upward; most peripheral tabellae concave upward. Commonly there are nine to eleven tabulae in 5 mm of corallite length. Immature corallites are similar to mature corallites, but have smaller diameters, fewer septa and more complete tabulae.

Table V

Average Diameter of Corallite (D) and Number of Major Septa (N)

GSC No. 8912			
D (mm)	N	D (mm)	N
3½	15	7½	21
4	15 (2)	8	19
4	16	8	20
4	17 (2)	8	21
4½	16	8½	20 (2)
4½	17 (2)	8½	21 (2)
4½	18 (2)	9	20 (2)
5	17	9	21 (3)
5	18	9	22 (3)
5½	18 (2)	9	23 (2)
6½	19 (2)	9½	22
6½	20 (2)	10	23
7½	18		

(Number of corallites given in parentheses where data apply to more than one.)

Remarks

The description is based on a partly silicified corallum (GSC No. 8912) and five thin sections, two of which are illustrated by Nelson (1960, Pl. 23, figs. 4, 5; 1961, Pl. 17, figs. 1, 2). As was stated by Nelson (1960, p. 119), the transverse section that he illustrated is obliquely oriented. Additional transverse cuts have since been made at right angles to several corallites (Pl. III, fig. 5).

Transverse sections at two levels in the corallum show that the degree of axial extension of major septa varies along individual corallites. This variation is reflected by differences in septal length between corallites in transverse section.

The differences between *Lithostrotionella banffensis* and *L. pennsylvanica* (Shimer) are discussed on page 23.

L. banffensis (Warren) has shorter, more weakly developed minor septa and narrower dissepimentaria than does *L. microstylum* (White). The tabulae in Warren's species are commonly more complete, more steeply inclined near the columella, and much less commonly turned up at their peripheral edges than are those of *L. microstylum.*

Lithostrotionella pennsylvanica (Shimer)

Plate IV, figures 1, 2

Lithostrotion pennsylvanicum Shimer, 1926, p. 27, Pl. 5, figs. 3, 4, 5.
[?] *Lithostrotionella pennsylvanica* (Shimer). Kelly, 1942, p. 352, Pl. 50, figs. 1, 2, 5, 6, 8.
Lithostrotion [*Lithostrotionella*] *pennsylvanicum* (Shimer). Bassler, 1950, p. 221.
Lonsdaleia pennsylvanica Shimer. Crickmay, 1955, 1961, p. 13, Pl. 1, figs. 11, 12.
Lithostrotionella pennsylvanicum (Shimer). Nelson, 1960, p. 117, Pl. 22, figs. 4-6.
Lithostrotionella pennsylvanicum (Shimer). Nelson, 1961, Pl. 17, figs. 3, 4.
[?] *Lithostrotionella shimeri* (Crickmay). Nations, 1963, Pl. 176, figs. 1, 2.

Material and Occurrence

Lectotype (Nelson, 1960, p. 117) — GSC Nos. 4459a, b — two fragments of a corallum, two thin sections (GSC Nos. 4459o, p), two peels (GSC Nos. 4459q, r), collected from unit 4 of Shimer's section 3a on Mount Aylmer near Lake Minnewanka, Banff area, Alberta (Shimer, 1926, p. 22; Crickmay, 1955, p. 13).

Syntypes — GSC No. 4459 — one piece, two thin sections (GSC Nos. 4459s, t), collected from same locality as lectotype (GSC Nos. 4459a, b). GSC No. 4462b — three pieces, four thin sections (GSC Nos. 4462d-g), collected from unit 6 of Shimer's section 2 on the north shore of Lake Minnewanka, near Banff, Alberta (Shimer, 1926, p. 15; Crickmay, 1955, chart 2).

Other Occurrences

1. Middle and upper Mount Head Formation in the Rocky Mountains of southern British Columbia and Alberta.
2. The corallum figured by Nations (1963, Pl. 176, figs. 1, 2) comes from either the uppermost Escabrosa Limestone or the lowermost Black Prince Limestone. Its stratigraphic position is not clear from the text.
3. Talus specimen from GSC locality 60205, 130 feet below the top of the

Prophet Formation in northeastern British Columbia (longitude 123°12′W, latitude 56°02′N).

Description of Lectotype (GSC Nos. 4459a, b)

External features. Growth form cerioid; increase intermural; corallites straight to slightly curved, polygonal. Most are approximately equidimensional, but some are slightly elongate in transverse section; smallest corallite diameter 10 to 14 mm, greatest diameter 14 to 17 mm; ornamentation not preserved.

In several corallites, the calicular platform occupies the peripheral one half to two thirds of calice, is slightly below the upper edge of the corallite wall and bears low ridges formed by major and minor septa; ridges poorly preserved and their peripheral extent cannot be determined. Those formed by minor septa are present only near the axial edge of the platform. The calicular pit occupies axial one third to one half of corallite, is 4 to 7 mm deep, and bears an axial boss formed by an axial plate, steepened tabulae and septal elements (*see* Remarks). Strong ridges formed by the axial edges of major septa alternate with low ridges formed by minor septa on the vertical peripheral wall of the calicular pit. The axial structures are broken in all corallites, but the longest reaches at least one half the distance from the floor to the top of the calicular pit. In one well-preserved calice the major septa extend across the floor of the calicular pit as ridges. Most of these stop short of the axial boss, but several reach this structure and run upward along it.

Internal structures. Major septa number twenty to twenty-two, minors alternate with majors. In transverse section the major septa extend only a short distance into the dissepimentarium. The counter septum joins the axial plate in several corallites. Other majors extend one half to two thirds the distance from the tabularium wall to the centre of corallite (*see* description of calice). Minor septa are very short and appear to be absent in parts of several corallites. As stated, however, the calices of several corallites show major and minor septa to alternate; septa commonly curved or sinuous, thickened in the peripheral part of the tabularium, become thinner towards axis and into dissepimentarium; septa radially arranged except for slight curvature of some majors towards the counter-cardinal plane.

The axial structure consists of upturned axial parts of tabulae surrounding a tabular columella which shows short projections in transverse section, some of which represent ridges extending from the axial edges of major septa to the columella, and others of which may be septal lamellae (*see* Remarks); columella present in all corallites studied, sinuous, strong and continuous in longitudinal sections.

Dissepimentarium continuous, width commonly one half to slightly more than one half corallite diameter; dissepiments show considerable size variation, commonly strongly convex except near corallite wall, where most are slightly concave upward; surfaces of dissepiments slope at low angle from wall towards axis and turn abruptly down to become vertical or slightly convex inward next to tabularium; one to two rows. In the longitudinal thin sections from GSC Nos.

4459a, b the corallite wall stops short of the top of the corallite and the dissepimentarium is continuous over it (*see* Remarks).

Tabulae slope moderately steeply. Most turn upward slightly at the dissepimentarium. All turn upward at the columella — some very steeply so that they extend for a considerable distance along the columella; incomplete tabulae common; angle between tabulae and columella 11 to 50 degrees (commonly 20 to 35), varies greatly because columella sinuous, angle of slope 60 to 90 degrees (commonly 80 to 90) near columella. The slope angles of some are greater than 90 degrees so that the tabulae are slightly overturned near the columella; angle decreases to 25 to 32 degrees approximately one half tabularium radius from columella, decreases to zero degree approximately three quarters tabularium radius from columella and is reversed near dissepimentarium in most tabulae. Incomplete tabulae are common. Many tabulae terminate axially against steep axial parts of underlying tabulae. Others terminate peripherally against underlying tabulae. Well-defined axial tabellae are absent (*see* Remarks); seven to eleven tabulae in 5 mm of corallite length.

Immature corallites are similar in transverse section to mature corallites, but have smaller diameters and fewer septa; none seen in longitudinal section; minor septa present as low ridges on dissepiments of corallites with least diameters of 5 mm or more; no corallites under 5 mm diameter present on surface of corallum; major septa, dissepiments, axial structure and tabulae present in transverse section of a corallite with diameter of approximately 3x5 mm, no smaller corallites seen.

Table VI

Average Diameter of Corallite (D) and Number of Major Septa (N)

GSC No. 4459		GSC Nos. 4459a, b		GSC No. 4462b	
D (mm)	N	D (mm)	N	D (mm)	N
5	18	7	17	3	14
6½	22	12	21	8½	18
7½	21	13	20	8½	19
10½	23	14	20	9	20
10½	24	14½	22	10	19
13½	25			10½	20
13½	24			11½	23

Remarks

Shimer (1926, pp. 27, 28) cites no types in his description, but gives the dimensions of some coralla and lists several localities from which his material was collected. The following specimens come from these localities and presumably were studied by Shimer during his description of *L. pennsylvanica*: GSC Nos. 4463, 4463a, b, d, f, g, h, 4464, 4464a, b, c, d, 4462, 4462b, c, 4459, 4459a, b, d, e, f. These were all identified as *L. pennsylvanica* by Shimer and are therefore syntypes of the species. Shimer figured GSC Nos. 4459 and 4459a, and Nelson (1960, p. 117) chose GSC No. 4459a as lectotype for the species. Nelson has identified GSC No. 4459d as *Lithostrotionella shimeri* (Crickmay).

It has since been found that GSC No. 4459a and No. 4459b fit together and are part of the same corallum. Longitudinal and transverse thin sections have been cut from GSC Nos. 4459a and 4459b respectively (Pl. IV, figs. 1a-c), and the two fragments have been glued together. GSC No. 4459 (Shimer, 1926, Pl. 5, fig. 4) has been sectioned transversely (Pl. IV, fig. 2c) and longitudinally (Pl. IV, figs. 2a, b). In mode of preservation and internal structure it is closely similar to GSC Nos. 4459a-b and may be from the same corallum. One of the corallites in GSC No. 4459, with a diameter of approximately 12x15 mm has twenty-five major septa, a larger number than does any corallite in the lectotype. Also, the silicified upper surfaces of several corallites in GSC No. 4459 have ridges from both major and minor septa extending from the axial edge of the calicular platform to the corallite wall on the tops of dissepiments.

The rest of Shimer's syntypes have now been sectioned and only GSC No. 4462b matches the specimens figured by Shimer. The others have been identified by the author as *Lithostrotionella shimeri* (Crickmay) — 4459e, f, 4462, 4463, 4463a, b, d, f, g, h, 4464a, c; *Lithostrotionella* cf. *bailliei* Nelson — 4464; *Lithostrotionella* cf. *banffensis* (Warren) — 4464b. GSC Nos. 4462c and 4464d are too poorly preserved for identification.

L. pennsylvanica has been referred to *Lithostrotion* (Shimer, 1926, p. 27), *Lithostrotionella* (Kelly, 1942, p. 352; Nelson, 1960, p. 117), and *Lonsdaleia* (Crickmay, 1955, 1961, p. 13). As was stated by Nelson (ibid.) and Kelly (ibid.), its lonsdaleoid dissepimentarium removes it from *Lithostrotion.* The structure of its axial column is more typical of *Lithostrotionella* than of *Lonsdaleia.* The type species of *Lithostrotionella* is described as having a thin, lamellar columella (Yabe and Hayasaka, 1915, p. 133). The axial structure of *Lonsdaleia* is made up of an axial plate, septal lamellae, and numerous axial tabellae. Longitudinal sections of GSC Nos. 4459a and 4459 (Pl. IV, figs. 1a, b, 2a, b) show only one small plate near the axis which is not part of an axially steepened tabula. Well-developed axial tabellae, typical of *Lonsdaleia,* are absent.

As already stated, the silicified surface of GSC No. 4459a, b shows that some of the structures that project from the axial plate in transverse section represent thickened axial edges of major septa, which reach the axial plate as ridges on the tabulae and extend upward along the plate. Lack of well-preserved material has prevented further investigation of these structures with respect to their vertical continuity and their relationship to major septa.

Shimer's species is provisionally assigned to *Lithostrotionella,* but more extensive study of its axial structure is necessary because, according to Smith (1917, p. 232), some "septal lamellae" are continuous with major septa in *Lonsdaleia.* Also, there are cerioid forms variously assigned to *Lonsdaleia* and *Stylidophyllum* that have narrow axial structures with few axial tabellae (Hill, 1938-41, p. 152) and axially steepened tabulae similar to those described here (Smith, 1917, Pl. 19, fig. 11).

The abrupt distal termination of a corallite wall in GSC No. 4459a (Pl. IV, figs. 1a, b) has not been seen in other corallites of the type material, or in other coralla studied by the author. It does not appear to be a feature that can be used to distinguish the species.

L. pennsylvanica is similar to *Lithostrotionella shimeri* (Crickmay), but has shorter major and minor septa and a less strongly developed axial column than does that species. The tabulae of *L. shimeri* are commonly nearly horizontal or slope downward towards the columella over much of the tabularium. Many of them turn up sharply at the dissepimentarium. Those of *L. pennsylvanica* rarely turn up steeply at the dissepimentarium, and slope upward towards the columella over most of the tabularium.

The structure of the axial column, the axial steepening and overall shape of the tabulae, and the large corallite diameter in *L. pennsylvanica* separate it from *L. banffensis* (Warren). Also *L. pennsylvanica* has more numerous minor septa than does *L. banffensis*.

The corals illustrated by Kelly (1942, Pl. 50, figs. 1, 2, 5, 6, 8) have been identified as *Lithostrotionella shimeri* (Crickmay) by Nelson (1960, p. 114). The longitudinal sections (Kelly, 1942, Pl. 50, figs. 1, 2) appear to have missed the axis of the corallites and therefore may be misleading, especially in figure 1. Where the sections cut the axial column the slope of the tabulae is moderately steep. This feature, the short minor septa, and the weak development of septal elements in the axial column suggest a closer relationship to *L. pennsylvanica* than to *L. shimeri*.

The specimens figured as *L. shimeri* by Nations (1963, Pl. 176, figs. 1, 2) probably belong to *L. pennsylvanica*. Minor septa appear to be very short or absent and the axial structure weakly developed (although details in the latter are obscure). The tabulae are apparently similar to those in *L. pennsylvanica*, but their nature is not clearly shown by figure 1.

Genus ***Thysanophyllum*** Nicholson and Thomson, 1876

Type species: *Thysanophyllum orientale* Nicholson and Thomson, 1876

Thysanophyllum astraeiforme (Warren)

Plate IV, figures 3, 4

Diphyphyllum astraeiforme Warren, 1927, p. 44, Pl. 3, figs. 2, 3; Pl. 6, fig. 1.
Lithostrotion banffense Warren, 1927 (partim), p. 46.
Lithostrotionella astraeiformis (Warren). Kelly, 1942, p. 352.
Thysanophyllum astraeiforme Warren. Crickmay, 1955, 1961, p. 13.
Lithostrotionella (Thysanophyllum) astraeiformis (Warren). Nelson, 1960, p. 115, Pl. 22, figs. 7-10.
Lithostrotionella astraeiformis (Warren). Nelson, 1961, Pl. 18, figs. 1-3.

Material and Occurrence

Lectotype (here chosen) — GSC No. 8911 — two fragments, four thin sections (GSC Nos. 8911d-g), two peels (GSC Nos. 8911h, i). All are from one corallum illustrated by Warren (1927, Pl. 6, fig. 1).

Syntypes — GSC Nos. 8911a, b, c — number of coralla represented is unknown. GSC Nos. 8911 and 8911a, b, and c were collected from "near the top of the Rundle limestone on Tunnel Mountain", Banff, Alberta (Warren, 1927, p. 45). Nelson (1960, pp. 115, 116), who has collected material from Tunnel Mountain that is closely similar to the lectotype, considers the stratigraphic position of the type specimens probably to be 1,640 feet above the base of the Rundle Group.

Hypotype — GSC No. 8912a — two fragments, four thin sections (GSC Nos. 8912g, h, i, l), two peels (GSC Nos. 8912 j, k). All from one corallum, collected from the Rundle Group on Stoney Squaw Mountain, near Banff, Alberta (Warren, 1927, p. 47).

Other Occurrences

1. Upper Mount Head Formation, Rocky Mountains of southern British Columbia and Alberta.

Description of Lectotype (GSC No. 8911)

External features. Growth form cerioid; increase intermural; corallites polygonal, slightly sinuous to gently curved, most are slightly elongate in transverse section, but some are nearly equidimensional; smallest corallite diameter 7 to 10 mm, greatest diameter 9 to 11 mm, rarely 12 mm; ornamentation consists of strong longitudinal grooves and closely spaced rugae.

Internal features. Major septa number fourteen to seventeen, minors alternate with majors as low ridges on tops of dissepiments (*see* Remarks). Most majors extend approximately one third the distance from the periphery of the tabularium to the axis. They are rarely seen in dissepimentarium in transverse section, but extend to wall as ridges on tops of dissepiments (*see* Remarks). In most corallites one curved major septum extends to or past the axis; minor septa confined to dissepimentarium, septa form straight ridges on dissepiments, but most are slightly curved or sinuous in tabularium. The longest septum is strongly curved and in some corallites it curves back to touch the axial edges of other majors. Major septa are thin and most taper slightly from the tabularium wall towards the axis. The longest major septum of some corallites, however, is thickest near its axial edge. The septa are radially arranged.

Columella formed by axial edge of one major septum (*see* Remarks), present in most, but not all corallites; dissepimentarium continuous, width one third to one half corallite radius, varies considerably around corallite peripheries; dissepiments show little size variation, most are large, all strongly convex, moderately steeply inclined. Many are subquadrate, with surfaces nearly horizontal or convex upward near the wall, and vertical or slightly convex inward next to the tabularium; commonly two or three, rarely four, in 5 mm of corallite length; one row.

Angle between tabulae and columella 28 to 112 degrees, commonly 45 to 75. In corallites with no columellae (Nelson, 1960, Pl. 22, fig. 7) the tabulae are horizontal near the axis. Some bend slightly downward near the dissepimentarium and others remain almost horizontal. Several slope upward from the axis toward the dissepimentarium at angles that increase to 21 to 48 degrees near the dissepimentarium. In corallites with columellae (Pl. IV, fig. 3b) the slopes of tabulae are similar to those where no axial structure is present, except that the tabulae commonly turn up to meet the columella and some slope steeply near the dissepimentarium (up to 75 degrees). The slopes of several of these are reversed near the tabularium wall, so that they slope downward and outward to join the dissepimentarium; one incomplete tabula seen (Pl. IV, fig. 3b), which slopes downward from dissepimentarium to join underlying tabula near axis; four to six tabulae in 5 mm of corallite length.

Several growth stages shown in one transverse section (Pl. IV, fig. 3a); a corallite 2 mm in diameter shows only the corallite walls; several at 3 to 4 mm diameter have well-developed dissepiments and traces of tabulae, but show no septa in the tabularium. A broken surface of a 4 mm diameter corallite has one dissepiment that shows several septa (ridges) on its upper surface; at 4 to 5 mm diameter several corallites have one long major septum and four to eight shorter majors; corallites of 4 to 5 mm diameter at the upper surface of GSC No. 8911 have eighteen to twenty ridges on the upper surfaces of their dissepiments, which represent nine or ten major septa with corresponding minors. All are vertically discontinuous within the dissepimentarium; in transverse thin section several corallites of 6 to 7 mm diameter show one long and eleven or twelve evenly distributed short major septa within the tabularium. The broken upper surfaces of corallites with 6 to 7 mm diameters show twelve to fourteen majors with intervening minors on the surfaces of their dissepiments. The number of septa increases with diameter as shown in Table VII.

Table VII

Average Diameter of Corallite (D) and Number of Major Septa (N)

GSC No. 8911		GSC No. 8912a (Pl. IV, fig. 4b) (Middle of specimen)		GSC No. 8912a (Pl. IV, fig. 4a) (Top of specimen)	
D (mm)	N	D (mm)	N	D (mm)	N
3½	0 (2)	3	10	3½	3
4	4	3½	6	4	6
4	6	3½	10	4	7
5	5	4	7	4½	6
5	6	5	12	4½	7 (2)
5	7	5	13	4½	10
5½	8	5½	15	6	13
5½	9	6	13	6½	13
6	14	6½	14	7	14
6½	12	6½	16	7½	14
8	15	8	16 (2)	8	17
8½	16 (2)	8½	16 (3)	8½	14
8½	17	9	16	8½	15
9	14			9	16
				10	15
				10½	16
				11	18

(Number of corallites given in parentheses where data apply to more than one.)

Remarks

Attention was first drawn to the columella in *Thysanophyllum astraeiforme* by Nelson (1960, p. 116), who referred the species to *Lithostrotionella.* A transverse thin section through GSC No. 8911 (Pl. IV, fig. 3a) shows that the columella is formed from the axial edge of a long major septum in several corallites.

Nelson (1960, p. 119) identified GSC No. 8912a as *Lithostrotionella* (*Thysanophyllum*) *astraeiformis* (Warren). The polished lower surface of this specimen shows structures closely similar to those in GSC No. 8911. A section cut approximately 1.5 mm higher in GSC hypotype No. 8912a, however, shows several corallites with strongly developed columellae, rare minor septa within the tabularium and the edges of steeply sloping tabulae and tabellae surrounding the columella (Pl. IV, fig. 4b; *see* Pl. IV, fig. 4c for longitudinal section of this part of the corallum). The columellae of these corallites show short projections in transverse section which may represent either low longitudinal ridges on the columella, not continuous with the major septa, or axial edges of long major septa extending to the columella as ridges on the tops of tabulae. Still higher, in a thin section from near the top of the specimen (Pl. IV, fig. 4a) — approximately 3.2 mm above the section illustrated in Plate IV, figure 4b — the tabularia are again closely similar to those in GSC No. 8911. It is not known if the intermittent development of such strong axial structures is common in other colonies of *T. astraeiforme.*

Warren's species is referred to *Thysanophyllum* rather than to *Lithostrotionella* because of the likeness of the axial structure to that of *Thysanophyllum orientale* Nicholson and Thomson (the genolectotype) and *T. minus* Nicholson and Thomson (Thomson, 1881, pp. 257, 258; Hill, 1938–41, pp. 162, 163). Hill (ibid., Pl. VIII, fig. 31) shows a corallite of *T. orientale* with a columella of the strength shown by corallites in GSC No. 8912a (Pl. IV, fig. 4b) and says that some corallites have a "smooth lath-like columella . . . sometimes continuous with the counter septum" (Hill, ibid., p. 162). According to Hill (ibid., p. 163), the counter septum of *T. minus* commonly extends beyond the axis, is "irregularly waved", and may bear septal lamellae and be joined by axial tabellae.

The upper surface of the GSC lectotype 8911 exposes several corallites with dissepiments bearing low radial ridges that extend from the wall to the tabularium. The number of such ridges in each corallite is approximately twice the number of major septa shown in section of corallites having corresponding diameters. Also, the major septa within the tabularia on the surface of the specimen line up with alternate ridges on the dissepiments. These ridges appear to be peripheral continuations of the major septa and those between represent vertically discontinuous minor septa.

T. astraeiforme is similar to *Lithostrotionella simplex* Hayasaka, but examination of the holotype of Hayasaka's species (U.S. National Museum No. 120249) has shown that it has a thick, lens-shaped columella in almost all corallites, minor septa that extend into the tabularium in transverse thin sections, strongly tapered septa, and tabulae that are less concave than are those of *T. astraeiforme.*

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PLATES I TO IV

Plate I

(Figures x2 unless otherwise stated)

Lithostrotion (Siphonodendron) mutabile (Kelly) (Page 4)

Figures 1a-e. Longitudinal sections of holotype, GSC No. 9642; 1e, immature corallite.

Lithostrotion (Siphonodendron) warreni Nelson (Page 6)

Figure 2. Longitudinal section of holotype, University of Alberta No. 338 (GSC No. 16838); compare tabulae with those in figures 1a-d.

Lithostrotion (Siphonodendron) sinuosum (Kelly) (Page 7)

Figure 3. Longitudinal section of syntype, GSC No. 8913a.

Figures 4a-i. Hypotype, GSC No. 18813; 4a, b, transverse sections cut at two levels in corallum, compare lengths of septa in corresponding corallites; 4c, d, longitudinal sections, x4; 4e-i, longitudinal peels through one corallite, 4e, near wall, 4i, through axis, x4.

Lithostrotionella microstylum (White) (Page 9)

Figures 5a-g. U.S. National Museum No. 66838; 5a, transverse section; 5b-g, longitudinal sections, 5b, d, f, retouched duplicates of 5c, e, g.

PLATE I

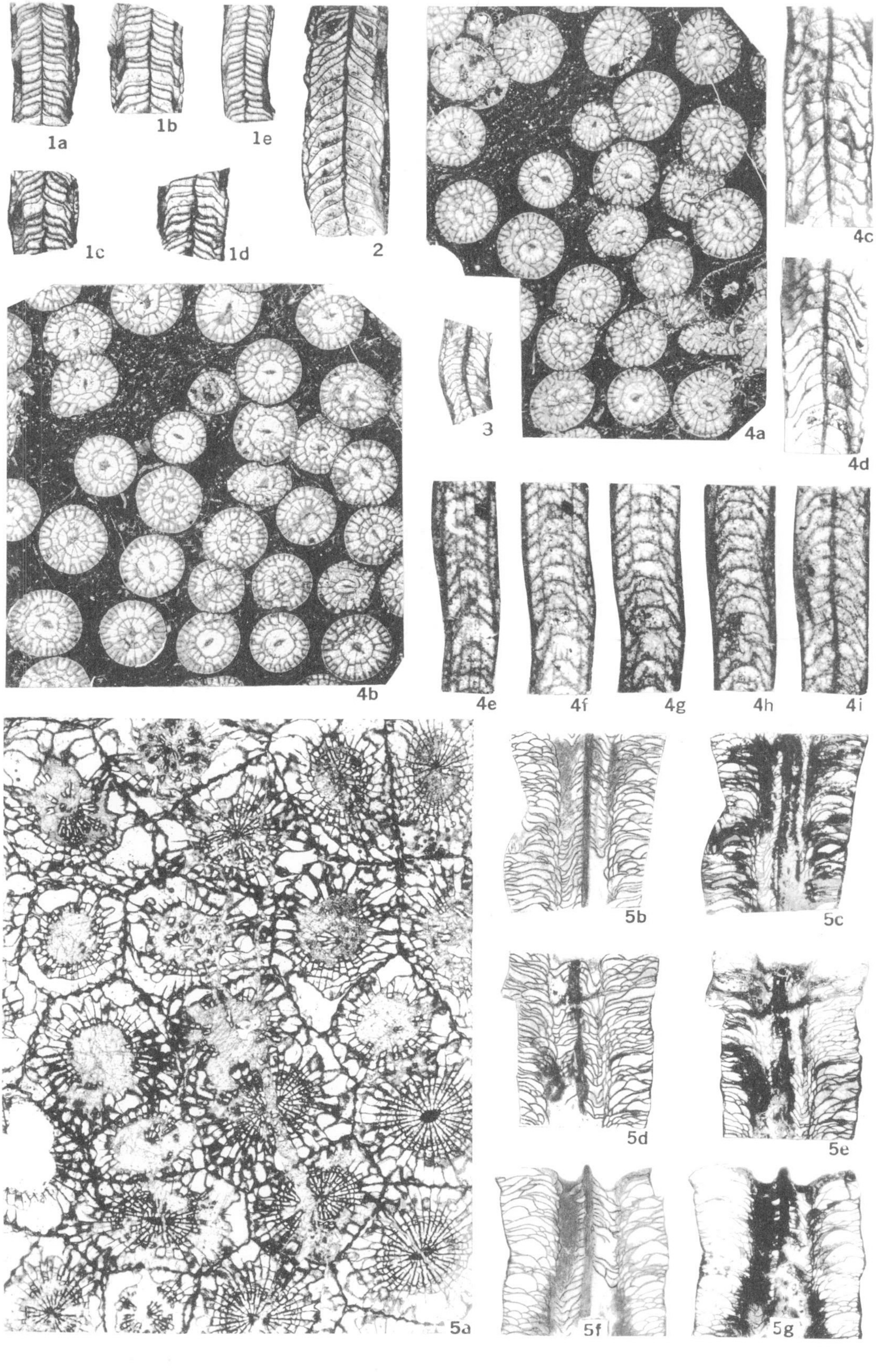

PLATE II

(Figures x2 unless otherwise stated)

Lithostrotionella microstylum (White) (Page 9)

Figures 1a, b. Longitudinal section of GSC No. 9647 (holotype of *L. jasperensis* Kelly); 1b, retouched duplicate of 1a, x4½.

Figures 2a-c. University of Missouri No. 1357; 2a, transverse section; 2b, surface of corallum; 2c, enlarged duplicate of part of figure 2a to show corallite walls, x10.

Figures 3a, b. U.S. National Museum No. 66838; 3a, transverse section; 3b, surface of corallum.

PLATE II

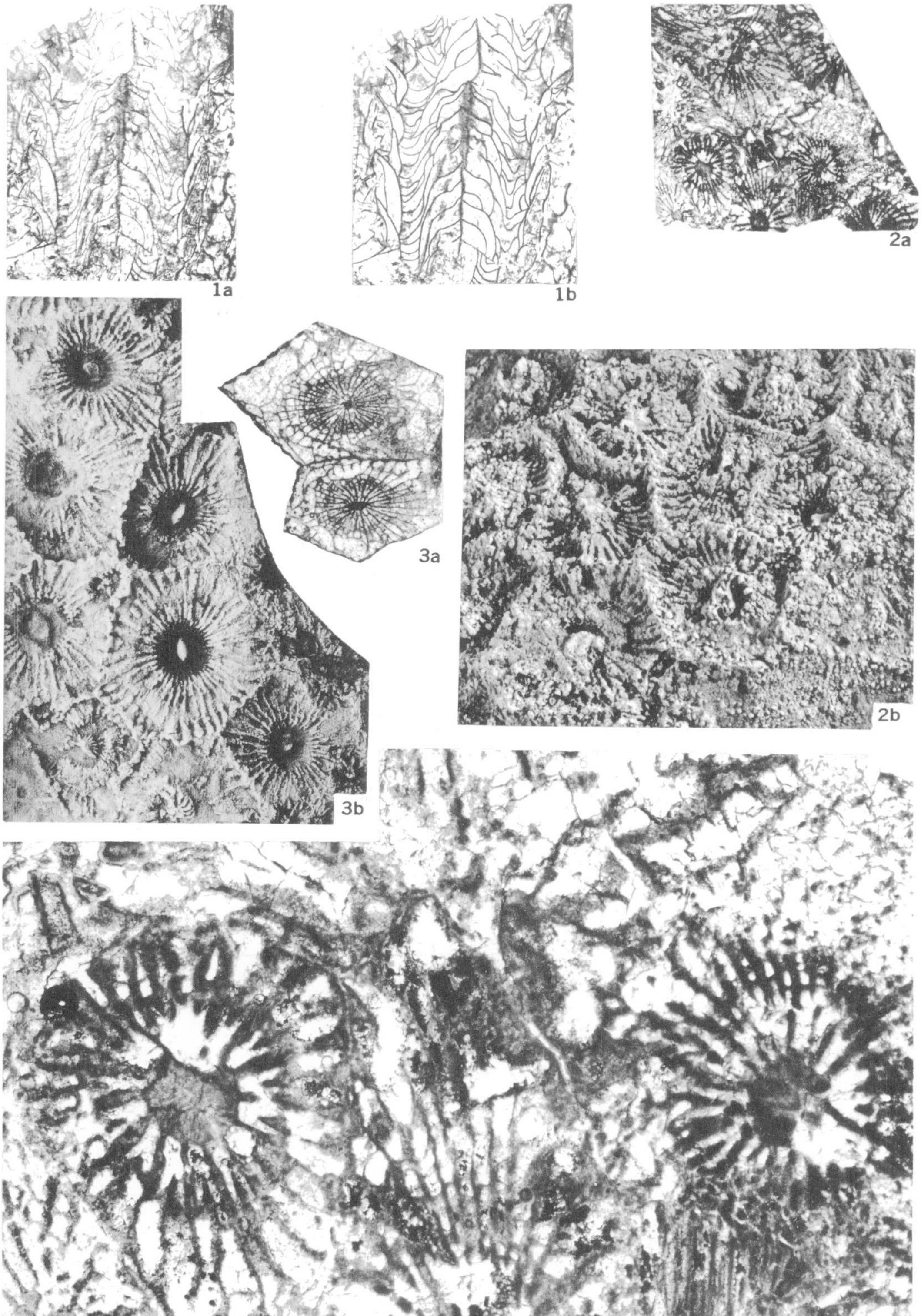

Plate III

Lithostrotionella microstylum (White) (Page 9)

Figures 1a, b. Longitudinal sections of U.S. National Museum No. 127939, x4 (holotype of *L. confluens* Easton).

Figures 2a, b. Transverse and longitudinal sections of University of Alberta hypotype 340 (GSC No. 16840), x2.

Figures 3a, b. GSC hypotype 18812, transverse sections of two corallites cut at different levels, x10, note differences in axial and peripheral features.

Lithostrotionella micra Kelly (Page 14)

Figures 4a-e. Longitudinal and transverse sections of holotype, GSC No. 9648, x4.

Lithostrotionella banffensis (Warren) (Page 17)

Figure 5. Transverse section of lectotype, GSC No. 8912, x3, note weakly developed minor septa.

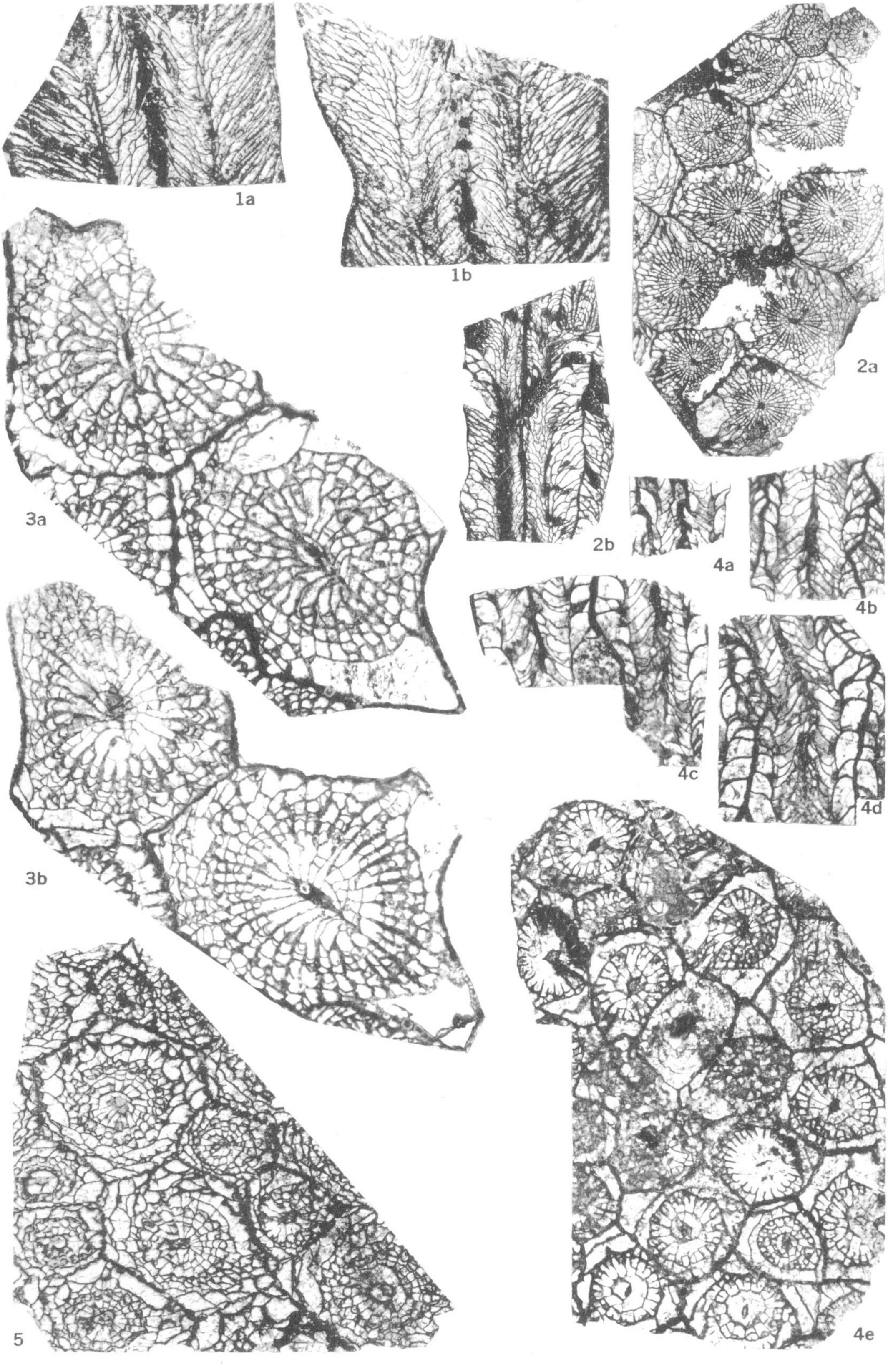
1a
1b
2a
2b
3a
4a
4b
3b
4c
4d
5
4e

Plate IV

(Figures x2 unless otherwise stated)

Lithostrotionella pennsylvanica (Shimer) (Page 19)

Figures 1a-c. Lectotype, GSC Nos. 4459a, b; 1a, longitudinal section of GSC No. 4459a; 1b, retouched duplicate of 1a, x5; 1c, transverse section of GSC No. 4459b.

Figures 2a-c. Syntype, GSC No. 4459; 2a, longitudinal section; 2b, retouched duplicate of 2a, x5; 2c, transverse section.

Thysanophyllum astraeiforme (Warren) (Page 23)

Figures 3a, b. Transverse and longitudinal sections of lectotype, GSC No. 8911 (in reflected light).

Figures 4a-c. Hypotype, GSC No. 8912a; 4a, transverse section; 4b, transverse section cut 3.2 mm below that in figure 4a (4a and 4b in reflected light); 4c, longitudinal section.

PLATE IV