Geological Survey of Canada
Commission géologique du Canada

BULLETIN 379

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# PREFACE

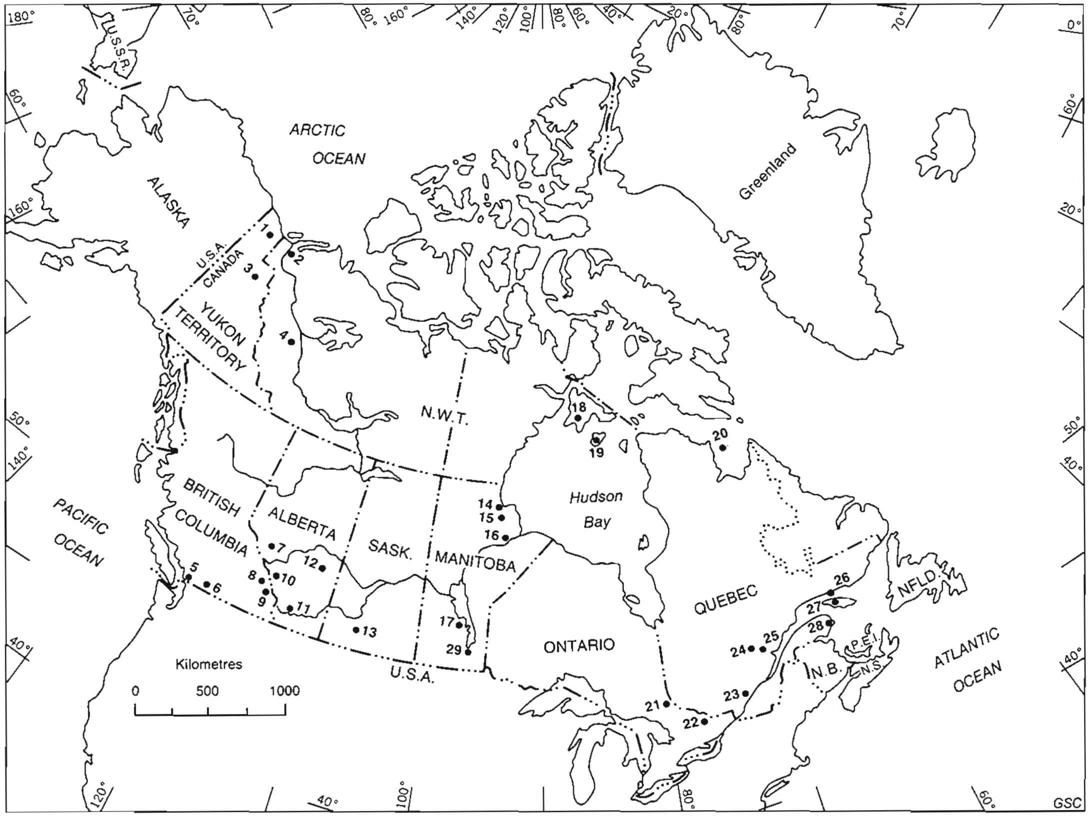
This bulletin contains six papers on paleontological topics that are being published together under the general title of *Contributions to Canadian Paleontology.* Early Paleozoic trilobites, stromatoporoids and corals are described, as well as a new species of lobster from the Jurassic, and two species of Upper Cretaceous/lower Tertiary fungi. Such detailed taxonomic studies provide information necessary for the accurate dating and correlation of strata within the sedimentary basins of Canada, thereby contributing significantly to the assessment of the economic potential of these rocks.

R.A. Price
Assistant Deputy Minister
Geological Survey of Canada

# PRÉFACE

Cette publication présente six articles sur la paléontologie réunis sous le titre générique *Contributions to Canadian Paleontology.* Ce travail de recherche donne des descriptions de trilobites, de stromatoporoïdes et de coraux du Paléozoïque inférieur; sont également décrites de nouvelles espèces de homards du Jurassique et deux espèces de fungi du Crétacé supérieur et du tertiaire inférieur. Ces études taxonomiques détaillées apportent des renseignements nécessaires pour une meilleure datation et corrélation des strates à l'intérieur des bassins sédimentaires du Canada, de ce fait, elles contribuent d'une façon marquée à l'évaluation du potentiel économique de ces roches.

R.A. Price, sous-ministre adoint,
Commission géologique du Canada



LEGEND

1. Yukon Coastal Plain: Big Fish River, Little Fish River, Aklak Creek (Kalgutkar and Sweet)
2. Caribou Hills (Kalgutkar and Sweet)
3. Bonnet Plume Basin (Kalgutkar and Sweet)
4. Tertiary Hills (Kalgutkar and Sweet)
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11. Southern Alberta Foothills: Oldman River (Kalgutkar and Sweet)
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***Figure A.*** *Locality map for all papers.*

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# LOWER ORDOVICIAN TRILOBITES FROM THE UPPERMOST McKAY GROUP AT ITS TYPE SECTION, SOUTHEASTERN BRITISH COLUMBIA

W.T. Dean[1]

*Dean, W.T, Lower Ordovician trilobites from the uppermost McKay Group at its type section, southeastern British Columbia; in Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 379, p. 1-15, 1988.*

## *Abstract*

Identifications based on a new collection of trilobites indicate a late Early Ordovician age for the uppermost McKay Group in its type area. The faunule includes *Ampyx walcotti* Kobayashi, 1955, *Protopliomerops*? *radiatus* Kobayashi, 1955, *Ptyocephalus* cf. *P. declevitus* (Ross, 1951), *Lachnostoma* sp. nov., *Presbynileus* (*Presbynileus*) sp. and kainellid gen. et sp. undet. The trilobites exhibit affinities with faunas in Utah and Nevada, and in the Main Ranges of the southern Canadian Rocky Mountains, where *P.*? *radiatus* occurs in the uppermost Outram Formation. In terms of the lettered zones established in Utah, the age of the assemblage is Zone J and the strata are coeval with the *Didymograptus protobifidus* Zone.

## *Résumé*

Les identifications établies d'une nouvelle collection de trilobites indiquent que le sommet du groupe de McKay, dans sa région type, date de l'Ordovicien inférieur. La faune locale comprend *Ampyx walcotti* Kobayashi, 1955, *Protopliomerops*? *radiatus* Kobayashi, 1955, *Ptyocephalus* cf. *P. declevitus* (Ross, 1951), *Lachnostoma* sp. nov., *Presbynileus* (*Presbynileus*) sp. et un genre et une espèce non déterminés de kainellidés. Les trilobites présentent des affinités avec des faunes de l'Utah et du Nevada, et celles des chaînons principaux du sud des Rocheuses canadiennes, où *P.*? *radiatus* se manifeste au sommet de la formation d'Outram. D'après les zones définies dans l'Utah, désignées par des lettres, l'âge de cet assemblage correspond à la zone J, et les strates sont contemporaines de la zone à *Didymograptus protobifidus*.

## INTRODUCTION

The trilobites were obtained from the uppermost part of the McKay Group in the vicinity of John McKay Creek, northeast of Radium Hot Springs, British Columbia (Fig.A, loc. 8). The area lies about 6 km northeast of the Columbia River and forms part of the Brisco Range in the eastern wall of the Rocky Mountain Trench, southern Canadian Rocky Mountains.

McKay Group, with its type section at McKay Creek, was introduced by Evans (1933, p. 126A) for a succession of alternating limestone and grey shale totalling at least 914 m (3000 ft.), and possibly 1220 m (4000 ft.), though part of the sequence was obscured and the base was not seen. According to Aitken, Fritz, and Norford (1972, p. 25), the base of the McKay Group corresponds to the base of the Bison Creek Formation elsewhere in the Canadian Rocky Mountains, and so is older than the base of the Survey Peak Formation, which is separated from the Bison Creek Formation by the Mistaya Formation. The highest portion of the McKay Group, overlain by the Wonah Quartzite, was said (Evans, 1933, p. 130A) to contain argillaceous strata that represent the lateral equivalent of the Glenogle Shales, a term proposed by Burling (1922, p. 456) for black graptolitic shale at Glenogle, situated in the valley of the Kicking Horse River, about 88 km northwest of Radium Hot Springs (Fig. 1.1). Five graptolite zones have been recognized in the Glenogle Shales (Aitken, Fritz, and Norford, 1972, p. 27), ranging from the *Didymograptus protobifidus* Zone (Arenig Series) to the *Nemagraptus gracilis* Zone (upper Llandeilo to basal Caradoc Series).

A section on Mount Sinclair, 8 km east of Radium Hot Springs, was chosen by Walcott (1924, p. 49) as the stratotype for his Wonah Quartzite. The unit was mapped and described by Evans (1933, p. 138A), who considered its junction with the underlying Glenogle Shales to be gradational at that point, even though the change in lithology appeared abrupt from a distance. The term was subsequently considered by Norford (1969, p. 28) to be obsolete and a synonym of Mount Wilson Quartzite, named earlier by Walcott (1923, p. 464), with its type section at Mount Wilson, midway between Banff and Jasper (Fig. 1.1). The Mount Wilson Quartzite, redescribed by Norford (1969, p. 25), was said by Aitken, Fritz, and Norford (1972, p. 28) to be underlain by Caradoc strata of the Glenogle Formation [= Shales] and probably overlain by Caradoc strata of the Beaverfoot Formation. In the most recent assessment of its age, the Mount Wilson Quartzite was assigned to the lower part of the Maysvillian Stage, Cincinnati Series, Upper Ordovician (Barnes, Norford, and Skevington, 1981, Chart 1), with the Beaverfoot Formation ranging from higher Maysvillian to the Gamachian Stage. In terms of the British series, the Mount Wilson would, in this interpretation, belong approximately to the lowest Ashgill Series, and the Beaverfoot Formation to the remainder of the Ashgill.

The strata in the valley of McKay Creek are folded to form an anticline with its axis aligned NNW-SSE. Evans (1933, Map 2327) showed the Mount Wilson Quartzite resting on the McKay Group on the southwest side of the valley, but on the Glenogle Shales on the northeast side, (Fig. 1.2) indicating an angular unconformity at the base of the Mount Wilson quartzite. A similar relationship was shown by Reesor (1973, Map 1326A), whose map forms the basis of Figure 1.1.

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The aim of the present study was to assess the age of the uppermost part of the McKay Group in its type area, with particular reference to the succession of the Lower Ordovician lettered zones first established in Utah and Nevada, and subsequently applied to successions at Mount Wilson and Wilcox Pass (Fig. 1.1). Trilobites were collected from light grey limestone between 26.8 m and 27.1 m (88 and 89 ft., GSC loc. 85784) below the base of the Mount Wilson Quartzite at a section about 350 m east-northeast of the summit of Mount Berland.

## Acknowledgments

The material was obtained as part of GSC Project 690006. B.S. Norford and I collected the material, and I am indebted to him for guidance in the field and for subsequent discussions, as well as for unpublished information on the stratigraphy of the Kananaskis Lakes area, British Columbia.

## Age and relationships of the trilobites

On the basis of C.S. Evans' collections of fossils from the McKay Group, Resser (in Evans, 1933, p. 129A) proposed the following eight zones, in ascending order: 1. *Dikelocephalus*; 2. *Symphysurina*; 3. *Kainella*; 4. *Ozarkispira* (a gastropod); 5. *Xenostegium*; 6. *Diplograptus*; 7. *Megalaspis*; and 8. *Ampyx*. Evans' material was re-examined by Kobayashi (1955), who proposed seven faunal assemblages in the McKay Group as follows: *Symphysurina* fauna; *Kainella-Evansaspis* fauna; *Ozarkispira-Raphistomina* faunule; *Apatokephalus-Peltura* faunule; Asaphid faunule; *Kirkella-Protopliomerops* fauna; and *Telephus-Ampyx* faunule. Of these, only the last two are relevant to the present discussion.

The *Telephus-Ampyx* faunule (termed also *Telephus* faunule; Kobayashi, 1955, p. 368) was recorded from only one place, in the Glenogle [Shales] at "Loc. 10 in the Vermilion basin" (the Vermilion River valley lies about 70 km southeast of Golden), and not from McKay Creek. The assemblage comprised: *Telephus pacificus*, *Ampyx* sp. and *Trinodus tardiformis*. The youngest assemblage reported from the McKay Creek section was the *Kirkella-Protopliomerops* fauna, said to occur at one unspecified locality near McKay Creek and at two localities within Evans' McKay Creek section, locs. 13 (GSC loc. 8139) and 21 (GSC loc. 8140) 35 m (115 ft.) and 43 m (139 ft.), respectively, below the Wonah (now Mount Wilson) Quartzite. Kobayashi's *Kirkella-Protopliomerops* fauna comprised the gastropod *Burnesella tympama* and the trilobites *Protopliomerops subquadratus*, *P. radiatus*, *P. longispinus*, *Kayseraspis*? *euclides*, *Kirkella* cf. *K. vigilans*, *Licnocephala longa*, *Lachnostoma*? sp., *Ampyx walcotti*, *A. walcotti* var. *stenorachis* and an asaphid pygidium. In the same work, Kobayashi (1955, p. 375) equated the "*Kirkella-Protopliomerops* beds" with zones H to J in the Pogonip Group of Utah. According to Kobayashi (1955, p. 368) loc. 13 is in Resser's zone 8, or *Ampyx* Zone, noted earlier. *Phyllograptus* was recorded by Ruedemann (in Evans, 1933, p. 127A) from a level 17.4 m (57 ft.) below the Wonah Quartzite.

The present study records the following taxa from GSC loc. 85784 at McKay Creek, about 8 m (26 ft.) above the higher of the two collections studied by Kobayashi:

*Ampyx walcotti* Kobayashi
*Protopliomerops*? *radiatus* Kobayashi
kainellid gen. et sp. undet.
*Lachnostoma* sp. nov.
*Presbynileus* (*Presbynileus*) sp.
*Ptyocephalus* cf. *P. declevitus* (Ross)
asaphid gen. et sp. undet.

Several of the trilobite genera are found also in Utah and Nevada and at Wilcox Pass, Alberta, and Ross's (1949, 1951) sequence of lettered zones forms the basis of the present discussion. At the species level, the position is less satisfactory and in only a single case could an identification be made with confidence from material outside the area of McKay Creek.

*Ptyocephalus* was founded by Whittington (1948) on *P. vigilans* from the Pogonip Formation in Nevada. The genus (as *Kirkella*, preoccupied) was subsequently described, using silicified specimens, by Ross (1951, p. 91-94) from Zone J and a level "appreciably lower than Zone H" and by Hintze (1953, p. 181-186) from Zones G-2, H, I and J. The McKay Creek material is both sparse and indifferently preserved, but is compared with *P. declevitus* (Ross, 1951) from Zone J, a species found at a similar level at Wilcox Pass.

*Presbynileus* (*Presbynileus*) was based by Hintze (1954) on silicified material of *Paranileus ibexensis* Hintze, 1953 from Zone I in Utah, where three species were described from Zones H, I and J. The specimens from McKay Creek are insufficient for specific determination, but at Wilcox Pass the subgenus occurs as a new species, which is most abundant in Zone J but extends downward into, probably, Zone I; *P.* (*Presbynileus*) is present only questionably in Zone G at Wilcox Pass (Dean, in press).

*Lachnostoma* is represented at McKay Creek by a new species, but the material is inadequate for a complete diagnosis. Ross (1951, p. 95) described a single species (the type), *L. latucelsum*, which was recorded only from Zone J, a level confirmed by Hintze (1953, p. 187). At Wilcox Pass, *Lachnostoma* occurs as another new species (Dean, in press) in the upper half of the Outram Formation and the lowest Skoki Formation, which contain *Carolinites genacinaca genacinaca* Ross, 1951, and *Pseudocybele nasuta* Ross, 1951, and belong to Zone J.

A single, fragmentary kainellid librigena contributes no evidence of age. Examples of generally similar type with a large genal notch are widespread and long-ranging in Lower Ordovician rocks. Of greater significance is *Protopliomerops*? *radiatus* Kobayashi, 1955, founded on material from a slightly lower horizon than GSC loc. 85784. This has been described from two levels at Wilcox Pass (Dean, in press) that fall within the stratigraphic range of *Pseudocybele nasuta*, which is indicative of Zone J. *Protopliomerops*? *radiatus* has not yet been recorded elsewhere. A *Protopliomerops* Zone, characterized by a fauna that included the type species *P. seisonensis*, was used by Kobayashi (1966, p. 37) for strata in South Korea. Whether the genus has any real stratigraphic significance is difficult to assess; *P. seisonensis* is in need of modern revision and several species originally assigned to *Protopliomerops* have since been made type species of other pliomerid genera.

No example of *Licnocephala longa* Kobayashi (1955, p. 448, Pl. 6, fig. 16; Pl. 8, fig. 13) was found. The type species, *L. bicornuta* from Zone G(2), was founded on the cranidium and librigenae, and a pygidium from the same horizon was assigned only tentatively to it (Ross, 1951, p. 110, Pl. 28, figs. 12-14; Pl. 30, ?fig. 25). *Licnocephala*? *cavigladius* Hintze (1953, p. 190, Pl. 10, figs. 1-5), from Zone G-2, has a pygidium with a short, triangular axis and conspicuously broad, smooth border, features by which it resembles the pygidium noted by Ross (loc. cit.). Kobayashi's two syntype pygidia of *L. longa* from McKay Creek are incomplete but each has a long, narrow axis and the deep

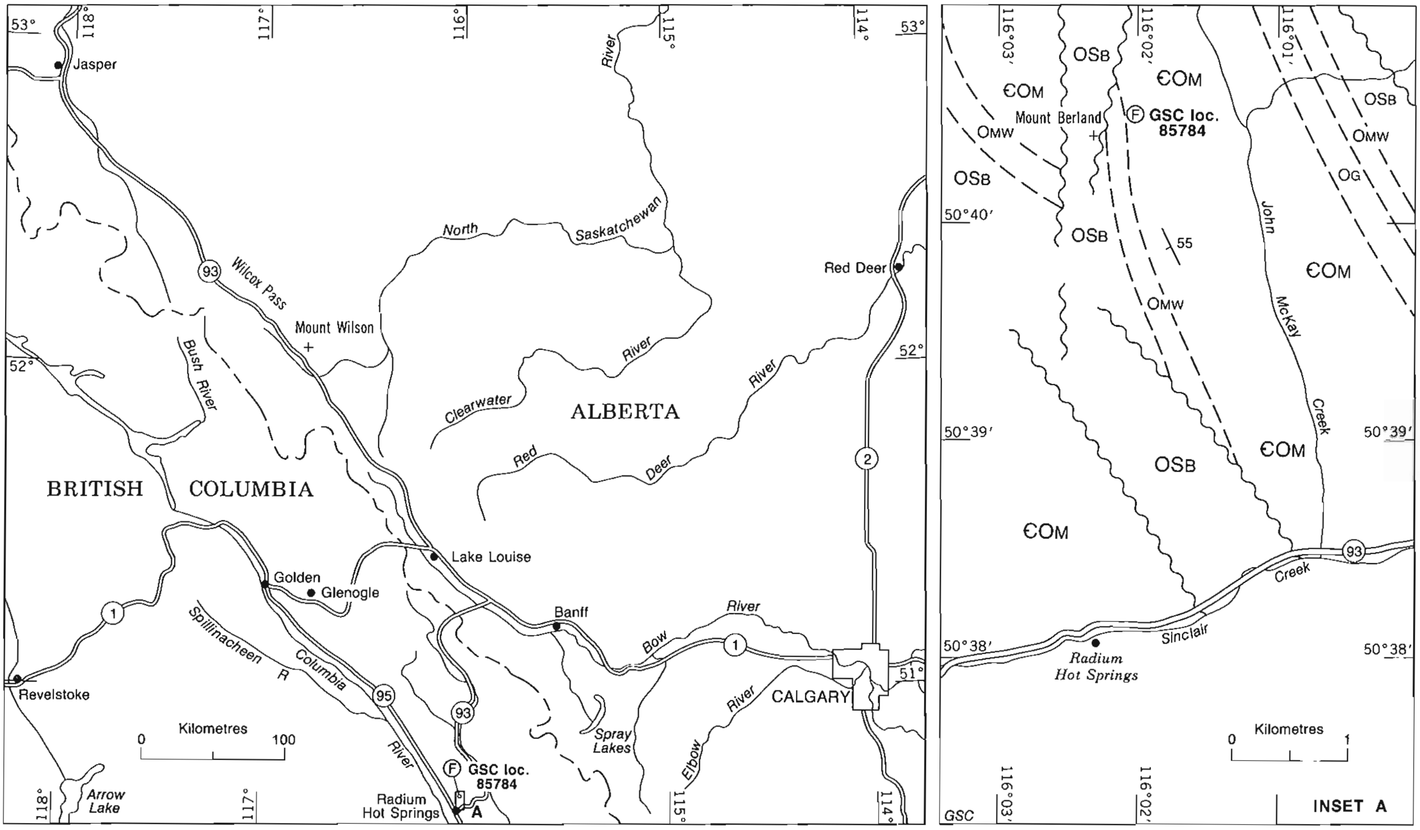


***Figure 1.1.*** *Place names cited in text.* OSB = *Beaverfoot Formation,* OMW= *Mount Wilson Quartzite,* OG = *Glenogle Shales,* ꞒOM = *McKay Group.*

pleural furrows extend almost to the margin. In these respects the material is closer to the Niobinaea, for example *Niobella*. *Licnocephala longa* is both inadequately known and of dubious stratigraphic value.

Little evidence of age is contributed by *Ampyx walcotti*, a species not yet recorded outside the McKay Creek area, though the genus is widely distributed. According to Whittington (1950, p. 554) *Ampyx* occurs only in the Lower and Middle Ordovician, and he noted species from the Llanvirn and Llandeilo series. The genus is known from the Arenig in France (Dean, 1966, p. 279), Spitzbergen (Fortey, 1975, p. 75 et seq.; 1980, p. 9), Bornholm (Poulsen, 1965, p. 98), Sweden (Tjernvik, 1956, p. 270), and China (Lu, 1975, p. 414).

*Ampyx* was not recorded in the faunas from Utah and Nevada described by Ross (1949, 1951) and Hintze (1953), nor has it been found in the Outram Formation at Mount Wilson (Aitken and Norford, 1967) and Wilcox Pass (Dean, 1978), both in the Main Ranges. Distribution was probably facies controlled and the presence of *Ampyx* at McKay Creek may reflect deeper marine conditions in the Western Ranges, to which area the stratigraphically overlying Glenogle facies essentially is confined (Aitken, Fritz and Norford, 1972, p. 26).

In the collections made for this study, no macrofossils were found in the McKay Group above GSC loc. 85784 but the record (Resser in Evans, 1933, p. 139A) of *Ampyx* sp., 3.35 m (11 ft.) below the Mount Wilson Quartzite suggests that there may be no significant age difference from the fauna described here.

The uppermost McKay Group can be correlated within the upper part of the Outram Formation at Wilcox Pass and Mount Wilson. At Mount Wilson, carbonates of the Owen Creek Formation (187.2 m, 614 ft.) and the Skoki Formation (139.9 m, 459 ft.) separate the Outram Formation and the Mount Wilson Quartzite. The base of the Quartzite, once said to be apparently conformable (Norford, 1969, p. 23), was shown later to be disconformable (Barnes, Norford and Skevington, 1981, Chart 1) and the McKay Creek Section underlines the magnitude of the discordance. ?*Trigonograptus* sp. (Jackson in Aitken and Norford, 1967, p. 189) was reported from talus from the top 73 m (239 ft.) of the Outram Formation at Mount Wilson; such a form probably indicates the interval *Isograptus victoriae lunatus* Subzone to *Oncograptus* Subzone (B.S. Norford, pers. comm.), i.e., Zones J to K of the Utah zonation. Zone J at Wilcox Pass and Mount Wilson contains *Carolinites genacinaca* Ross, 1951 (for discussion of this and other species of the genus see Jell and Stait, 1985, p. 40, 41). In Spitzbergen, the range of *C. genacinaca* was equated broadly with the *Didymograptus hirundo* Zone of the British Arenig by Fortey (1975, Fig. 1). The species was shown later (Fortey, 1980, Fig. 1) to extend from V1b to V2b of the faunal subdivisions in the Valhallfonna Formation, a range corresponding to the *Didymograptus protobifidus* and *D. bifidus* zones of North America and to the *D. nitidus* and *Isograptus gibberulus* zones of Great Britain (Fortey, 1980, Fig. 3).

In the Kananaskis Lakes area of southeastern British Columbia, B.S. Norford (pers. comm.) collected and determined *Carolinites* cf. *C. genacinaca* and *Didymograptus canadensis* Ruedemann from the Glenogle Shales at a section (GSC loc. C-108000) north of Bull River. The assemblage is considered by him to indicate the *D. protobifidus* Zone.

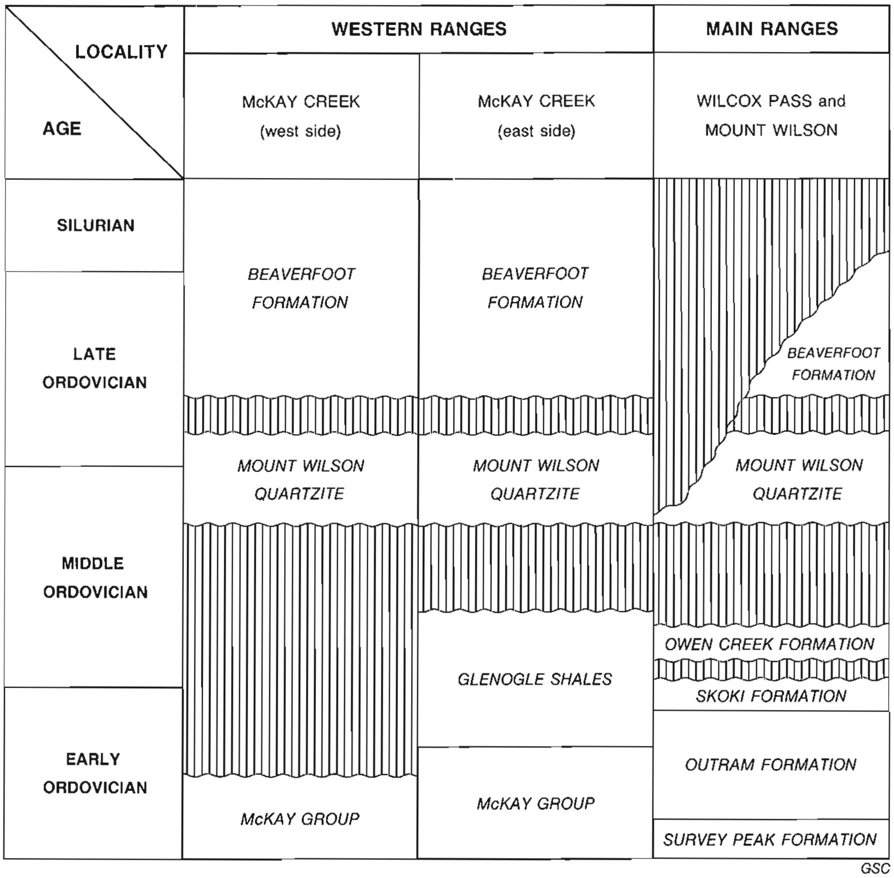


***Figure 1.2.*** *Stratigraphic successions in the Western and Main ranges.*

## SYSTEMATIC PALEONTOLOGY

Terminology is essentially that used in the Treatise on Invertebrate Paleontology (Harrington, Moore and Stubblefield in Moore, 1959, p. O124). All specimens are from GSC loc. 85784 (50°40'45"N, 116°02'30"W), in the upper part of the McKay Group near McKay Creek, from 26.8 m to 27.1 m below the base of the overlying Mount Wilson Quartzite, east-northeast of the summit of Mount Berland and 6.4 km north-northeast of Radium Hot Springs.

### Family RAPHIOPHORIDAE Angelin, 1854

### **Genus** *Ampyx* Dalman, 1827

Type species. *Ampyx nasutus* Dalman, 1827.

### *Ampyx walcotti* Kobayashi, 1955

Plate 1.1, figures 1-4, 6-8

*Ampyx walcotti* Kobayashi, 1955, p. 469-470, Pl. 8, figs. 1a, b, 2a, b, 3.

*Ampyx walcotti* var. *stenorachis* Kobayashi, 1955, p. 470, Pl. 8, figs. 4a, b, 5.

*Figured specimens.* GSC 85716 (Pl. 1.1, fig. 1), GSC 85717 (Pl. 1.1, fig. 2), GSC 85718 (Pl. 1.1, figs. 3, 4), GSC 85719 (Pl. 1.1, fig. 6), GSC 85720 (Pl. 1.1, fig. 7), GSC 85721 (Pl. 1.1, fig. 8).

*Description and discussion.* Kobayashi's description noted merely that the species was "similar to *Ampyx americanus* Safford and Vogdes but the cephalon and pygidium are broader". The neotype of the type species, *A. nasutus* from the upper Arenig of Sweden, was described by Whittington (1950, p. 554, Pl. 74, figs. 3-9, Textfigs. 6A, B) and differs from *A. walcotti* in only minor respects. In the Canadian species, the fixigenae are broader frontally and the facial suture is more sinuous; the posterior border is wider (exsag.), delimited by a wider, deeper border furrow with a pair of larger pits at its extremities; and the pygidium is proportionately shorter (length = 0.33 of breadth compared with 0.48). In Norwegian specimens assigned by Skjeseth (1952, p. 175, Pl. 5, figs. 2, 4b, 12-16) to the Swedish Arenig species *Ampyx pater* Holm, 1882, the cranidium generally resembles that of *A. walcotti* but, again, the pygidium is proportionately longer. Similar comments apply to another Arenig species, *Ampyx volborthi* Schmidt (1894, p. 80, Pl. 6, figs. 11-20). The latter was placed in *Lonchodomas* by Skjeseth (1952, p. 178), but is better retained in *Ampyx*; its pygidium is still longer than that of *A. walcotti* and in neither case does the pygidial outline resemble that of the type species of *Lonchodomas*, *L. rostratus* (Sars, 1835), illustrated by Whittington (1950, Pl. 74, fig. 15, Textfigs. 7B).

### Family PLIOMERIDAE Raymond, 1913

### **Genus** *Protopliomerops* Kobayashi, 1931

Type species. *Protopliomerops seisonensis* Kobayashi, 1931.

### *Protopliomerops*? *radiatus* Kobayashi, 1955

Plate 1.1, figures 9, 10?, 11-14;
Plate 1.3, figures 1, 3, 10

*Protopliomerops radiatus* Kobayashi, 1955, p. 416-417, Pl. 2, figs. 5a, b, 6.
*Protopliomerops*? *radiatus* Kobayashi, 1955. Dean (in press).

*Figured specimens.* GSC 85722 (Pl. 1.1, fig. 9), GSC 85723 (Pl. 1.1, fig. 10?), GSC 85724 (Pl. 1.1, figs. 11, 13, 14), GSC 85725 (Pl. 1.1, fig. 12), GSC 85726 (Pl. 1.3, fig. 1), GSC 85727 (Pl. 1.3, figs. 3, 10).

*Description and discussion.* The type specimens of *P.*? *radiatus* came from the McKay Group at John McKay Creek, and the type locality (no. 13 of Kobayashi, 1955, pp. 362, 368, 417) was said to be 35 m (115 ft.) below the base of the Wonah Quartzite. Elsewhere the species is reported only from Wilcox Pass, Alberta, where it was found in the uppermost part of the Outram Formation, in strata dated as Zone J. The generic position of *P.*? *radiatus* remains uncertain, due to the lack of detailed knowledge of *Protopliomerops seisonensis* Kobayashi (1934, p. 571, Pl. 7, figs. 11b-13; Pl. 8, figs. 16, 17), from the Tremadoc Series of South Korea. The Korean species appears to differ from *P.*? *radiatus* in having a broadly rounded frontal glabellar lobe, deeply incised 3p lateral glabellar furrows, and eyes opposite the 3p glabellar lobes, but further material is needed for an adequate comparison. *Protopliomerops* has been used more recently (Jell, 1985, p. 79) for Australian specimens that differ from *P.*? *radiatus* in the following respects: the fixigenae are proportionately smaller; the palpebral lobes are smaller, set closer to the axial furrows and are less divergent posteriorly; and the frontal glabellar lobe has no median indentation. Adequate comparison of all these species must await a detailed redescription of *P. seisonensis.*

## Family KAINELLIDAE Ulrich and Resser, 1930

### kainellid gen. et sp. undet.

Plate 1.1, figure 5

*Figured specimen.* GSC 85728.

*Description and discussion.* Though insufficient for generic determination, the single available left librigena generally resembles various kainellid genera. That of the type species of *Menoparia*, *M. genalunata* Ross (1951, Pl. 20, fig. 29) from Zone G in Utah, has a genal notch of comparable length (exsag.), but less acute, and the genal spine curves farther abaxially before turning posteriorly. Comparison with the geographically widespread *Apatokephalus* is less clear. The type species, *A. serratus* (Boeck, 1838), was founded on a pygidium from the Tremadoc of Norway (Størmer, 1940, p. 139). A cephalon illustrated by Whittington (in Moore, 1959, Fig. 243, 2a) shows no genal notch, and the anterior branches of the facial suture appear only moderately divergent foward. On the other hand, Tjernvik (1956, p. 204, Pl. 2, figs. 7, 8; Textfig. 32A) indicated a deep genal notch, though he pointed out that the species is still incompletely known. Comparison may also be made with the librigena of *Blossyropsis billingsi* Whittington (1965, p. 378, Pl. 42, figs. 9, 10), from the Table Head Formation of western Newfoundland, but in that species, the eye and lateral border are in much closer proximity.

## Family ASAPHIDAE Burmeister, 1843

## Subfamily ISOTELINAE Angelin, 1851

### **Genus** *Lachnostoma* Ross, 1951

Type species. *Lachnostoma latucelsum* Ross, 1951.

### *Lachnostoma* sp. nov.

Plate 1.3, figures 4, 5?, 6-9, 11

*Figured specimens.* GSC 85729 (Pl. 1.3, figs. 4, 6, 8), GSC 85730 (Pl. 1.3, fig. 5), GSC 85731 (Pl. 1.3, fig. 7), GSC 85732 (Pl. 1.3, fig. 9), GSC 85733 (Pl. 1.3, fig. 11).

*Description and discussion.* The most complete specimen, a large cranidium 17 mm long (Pl. 1.3, figs. 4, 6, 8), resembles *L. latucelsum* Ross (1951, p. 95, Pl. 21, figs. 13-25; Pl. 22, fig. 3; Pl. 23, figs. 5, 6), from Zone J in Utah, in having small, steeply inclined palpebral lobes sited opposite the rearmost part of the glabella, and a median glabellar tubercle just in front of the occipital furrow; the glabella is narrowest (tr.) opposite the anterior ends of the palpebral lobes and widens slightly toward the occipital furrow. The remains of the exoskeletal surface show large 1p and smaller 2p glabellar lobes bounded by conspicuous, broad (exsag.) 1p and 2p furrows, while the diminutive occipital ring is poorly defined and narrows (exsag.) abaxially (Pl. 1.3, fig. 7). The Canadian cranidium is clearly distinguished from that of *L. latucelsum* by the pronounced widening of the anterior half of the glabella, the abaxial margins of which extend close to the anterior branches of the facial suture. By contrast, in *L. latucelsum* each fixigena has an anterior area whose breadth (tr.) is 0.45 that of the glabella.

A fragmentary pygidium (Pl. 1.3, fig. 11) shows a slight break in the outline of the axis, and the remains of at least three narrow (sag.), transversely straight axial rings. The convex terminal piece ends at the concave posterior border, which is underlain by a doublure ornamented with conspicuous terrace lines.

### **Genus** *Presbynileus* Hintze, 1954

Type species. *Paranileus ibexensis* Hintze, 1953.

Objective synonym. *Paranileus* Hintze, 1953 non Kobayashi, 1951.

### **Subgenus** *Presbynileus* Hintze, 1954

### *Presbynileus* (*Presbynileus*) sp.

Plate 1.2, figures 1-6, 10;
Plate 1.3, figures 2, 12-15

*Figured specimens.* GSC 85734 (Pl. 1.2, fig. 1), GSC 85735 (Pl. 1.2, figs. 2, 3), GSC 85736 (Pl. 1.2, fig. 4), GSC 85737 (Pl. 1.2, fig. 5), GSC 85738 (Pl. 1.2, fig. 6), GSC 85739 (Pl. 1.2, fig. 10), GSC 85740 (Pl. 1.3, fig. 2), GSC 85741 (Pl. 1.3, fig. 12), GSC 85742 (Pl. 1.3, fig. 13), GSC 85743 (Pl. 1.3, fig. 14), GSC 85744 (Pl. 1.3, fig. 15).

*Description and discussion.* Two incomplete, small cranidia generally resemble the holotype of *P.* (*P.*) *ibexensis* (Hintze, 1953, Pl. 12, figs. 9a-c) but have a low, narrow (sag.) rim-like anterior border and the palpebral lobes are proportionately longer (approx. 0.4 of projected cranidial length compared with 0.32. Librigenae (Pl. 1.2, figs. 2, 3, 5) are broadly comparable with those of *P.* (*P.*) *ibexensis* (Hintze, 1953, Pl. 12, figs. 6a-c, 7) and *P.* (*P.*) *elongatus* (Hintze, 1953, Pl. 12, fig. 5a, b), from Zones I and H, respectively, in Utah. In all cases the doublure is ornamented with terrace lines and has a conspicuous vincular notch just in front of the genal angle. An incomplete large thoracic segment (Pl. 1.2, fig. 4) shows that the doublure has a sharply indented adaxial margin, and its ventral surface carries a small but well defined circular panderian protuberance, which presumably acted as a stop during enrollment. Only incomplete pygidia are available, but they show the doublure to be widest anteriorly and to carry a small panderian protuberance on the sagittal line just in front of the posterior margin. A similar form of doublure is seen in *P.* (*Presbynileus*) sp. nov. from Zone J in the Outram Formation of Wilcox Pass; the feature is less clear in a paratype of *P.* (*P.*) *ibexensis* (Hintze, 1953, Pl. 12, fig. 10a), a specimen that appears to be broken, but may occur in a less incomplete example of *P.* (*P.*) *elongatus* (Hintze, 1953, Pl. 12, fig. 3).

Five small pygidia (Pl. 1.3, figs. 2, 12-15), with maximum breadth up to 6.4 mm and median length from 0.6 to 0.67 of the overall breadth, bear a superficial resemblance to the pygidium of *Lachnostoma latucelsum* Ross (1951, Pl. 21, figs. 17, 21, 24) from Zone J in Utah, but are distinguished by the lack of a clearly differentiated border and the presence of faint pleural furrows on the pleural fields. One specimen (Pl. 1.3, fig. 12) shows the anteriorly wide doublure, which extends almost to the axial furrow, as in large specimens of *P.* (*Presbynileus*); by contrast the doublure of *L. latucelsum* is of moderate width (Ross, 1951, Pl. 23, fig. 5) and extends only midway across the anterior part of the pleural regions.

### **Genus** *Ptyocephalus* Whittington, 1948

Type species. *Ptyocephalus vigilans* Whittington, 1948.

Subjective synonym. *Kirkella* Kobayashi, 1942 non Gunnell, 1933.

### *Ptyocephalus* cf. *P. declevitus* (Ross, 1951)

Plate 1.2, figures 7, 12, 14, 15

*Kirkella declevita* Ross, 1951, p. 91-94; Pl. 21, figs. 1-12; Pl. 22, figs. 4, 5; Pl. 23, figs. 1-3

*Figured specimens.* GSC 85745 (Pl. 1.2, fig. 7), GSC 85746 (Pl. 1.2, fig. 12), GSC 85747 (Pl. 1.2, fig. 14), GSC 85748 (Pl. 1.2, fig. 15).

*Description and discussion.* A cranidium and two left librigenae, all incomplete, show good agreement with silicified material from Zone J in Utah illustrated by Ross (1951, Pl. 21, figs. 9-12). The single available hypostoma shows transverse, anastomosing ridges like those of *P. vigilans* Whittington (1948, Pl. 83, fig. 8), but differs from that species in having a narrower posterior notch and wider posterior wings, the lateral margins of which are abaxially convex as opposed to straight. Ross (1951, p. 92, Pl. 21, fig. 6) drew attention to the development along each posterolateral margin of a rim that extended anterolaterally as a small protuberance. The specimen from McKay Creek shows a suggestion of a rim, but the location of the protuberances, if developed, is not preserved.

### Asaphid gen. et sp. undet.

Plate 1.2, figures 8, 9, 11, 13, 16

*Figured specimens.* GSC 85749 (Pl. 1.2, figs. 8, 11), GSC 85750 (Pl. 1.2, fig. 9), GSC 85751 (Pl. 1.2, fig. 13), GSC 85752 (Pl. 1.2, fig. 16).

*Description and discussion.* A number of incompletely preserved asaphid hypostomata are not compatible with any of the above genera; they cannot be identified with confidence at the generic level, but are being illustrated for documentation purposes.

## REFERENCES

Aitken, J.D. and Norford, B.S.
1967: Lower Ordovician Survey Peak and Outram formations, southern Rocky Mountains of Alberta; Bulletin of Canadian Petroleum Geology, v. 15, p. 150-207.

Aitken, J.D., Fritz, W.H., and Norford, B.S.
1972: Cambrian and Ordovician biostratigraphy of the southern Canadian Rocky Mountains; 24th International Geological Congress, Montreal, Field Excursion A-19, Guidebook, 57 p.

Angelin, N.P.
1851-1878: Palaeontologia Scandinavica; Academiae Regiae Scientiarum Suecanae (Holmiae). Pars I. Crustacea formationis transitionis, p. 1-24 [1851]; Pars II. p. i-ix, 21-92 [1854]; republished in combined and revised form, G. Lindström (ed.), x + 96 p. [1878].

Barnes, C.R., Norford, B.S., and Skevington, D.
1981: The Ordovician System in Canada. Correlation chart and explanatory notes; International Union of Geological Sciences, Publication no. 8, 27 p.

Boeck, C.
1838: Uebersicht der bisher in Norwegen gefunden Formen der Trilobiten-Familie; in Keilhau, B.M., Gaea Norwegica, Heft 1, p. 138-145, Christiania.

Burling, L.D.
1922: A Cambro-Ordovician section in the Beaverfoot Range, near Golden, British Columbia; Geological Magazine, v. 59, p. 452-461.

Burmeister, H.
1843: Die Organisation der Trilobiten aus ihren lebenden Verwandten entwickelt; nebst einer systematischen Uebersicht aller zeither beschriebenen Arten; xii + 147 p., Berlin.

Dalman, J.W.
1827: Om Palaeaderna eller de så kallade Trilobiterna; Kungliga Svenska Vetenskakademiens Handlingar, v. 1, p. 226-294.

Dean, W.T.
1966: The Lower Ordovician stratigraphy and trilobites of the Landeyran Valley and the neighbouring district of the Montagne Noire, south-western France; Bulletin of the British Museum (natural History), Geology, v. 12, p. 245-353.

Dean, W.T.
1978: Preliminary account of the trilobite biostratigraphy of the Survey Peak and Outram formations (late Cambrian, early Ordovician) at Wilcox Pass, southern Canadian Rocky Mountains, Alberta; Geological Survey of Canada, Paper 76-34, 10 p.

in press: Trilobites from the Survey Peak, Outram and Skoki formations (Upper Cambrian-Lower Ordovician) at Wilcox Pass, Jasper National Park, Alberta, Canada; Geological Survey of Canada, Bulletin.

Evans, C.S.
1933: Brisco-Dogtooth map-area, British Columbia; Canadian Department of Mines, Geological Survey, Summary Report for 1932, part A II, p. 106-187.

Fortey, R.A.
1975: The Ordovician trilobites of Spitzbergen, II. Asaphidae, Nileidae, Raphiophoridae and Telephinidae of the Valhallfonna Formation; Norsk Polarinstitutt Skrifter, no. 162, 207 p.

1980: The Ordovician trilobites of Spitzbergen, III. Remaining trilobites of the Valhallfonna Formation; Norsk Polarinstitutt Skrifter, no. 171, 163 p.

Gunnell, F.H.
1933: Conodonts and fish remains from the Cherokee, Kansas City, and Wabaunsee Groups of Missouri and Kansas; Journal of Paleontology, v. 7, p. 261-297.

Hintze, L.F.
1953: Lower Ordovician trilobites from western Utah and eastern Nevada; Utah Geological and Mineralogical Survey, Bulletin 48, p. 1-249 (dated 1952).

1954: *Presbynileus* and *Protopresbynileus*, new generic names for *Pseudonileus* and *Paranileus* Hintze, preoccupied; Journal of Paleontology, v. 28, p. 119.

Holm, G.
1882: Ueber einige Trilobiten aus dem Phyllograptusschiefer Dalekarliens; Kungliga Svenska Vetenskapsakademien. Bihang till handlingar, Band 6, no. 9.

Jell, P.A.
1985: Tremadoc trilobites of the Digger Formation, Waratah Bay, Victoria; Memoirs of the Museum of Victoria, v. 46, p. 53-88.

Jell, P.A. and Stait, B.
1985: Revision of an early Arenig trilobite faunule from the Caroline Creek Sandstone, near Latrobe, Tasmania; Memoirs of the Museum of Victoria, v. 46, p. 35-51.

Kobayashi, T.
1931: Studies of the stratigraphy and palaeontology of the Cambro-Ordovician formations of Hua-lien-chai and Nin-hain-tai, South Manchuria; Japanese Journal of Geology and Geography, v. 8, p. 131-189.

Kobayashi, T.
1934: The Cambro-Ordovician formations and faunas of South Chosen. Palaeontology. Part II. Lower Ordovician faunas; Journal of the Faculty of Science, Imperial University of Tokyo, Section II, Geology, Mineralogy, Geography, Seismology, v. 3, p. 521-585.

1942: Miscellaneous notes on the Cambro-Ordovician Geology and Palaeontology. III. Two new trilobite genera, *Hamashania* and *Kirkella*; Journal of the Geological Society of Japan, v. 49, p. 118-121.

1951: On the Ordovician trilobites in central China; Journal of the Faculty of Science, Imperial University of Tokyo, section 2, v. 7, p. 1-74.

1955: The Ordovician fossils from the McKay Group in British Columbia, western Canada, with a note on the Early Ordovician palaeogeography; Journal of the Faculty of Science, University of Tokyo, section 2, v. 9, p. 355-493.

1966: The Cambro-Ordovician formations and faunas of South Korea. Part X. Stratigraphy of the Chosen Group in Korea and South Manchuria and its relation to the Cambro-Ordovician formations of other areas. Section A. The Chosen Group of South Korea; Journal of the Faculty of Science, University of Tokyo, section 2, v. 16, p. 1-84.

Lu, Yanhao.
1975: Ordovician trilobite faunas of central and southwestern China; Palaeontologia Sinica, v. 11, p. 1-484.

Moore, R.C. (ed.)
1959: Treatise on Invertebrate Paleontology. Part O. Arthropoda 1; Geological Society of America and University of Kansas Press, xix + 560 p.

Norford, B.S.
1969: Ordovician and Silurian stratigraphy of the southern Rocky Mountains; Geological Survey of Canada, Bulletin 176, 90 p.

Poulsen, V.
1965: An Early Ordovician trilobite fauna from Bornholm; Meddelelser fra Dansk Geologisk Forening, v. 16, p. 49-113.

Raymond, P.E.
1913: Notes on some old and new trilobites in the Victoria Memorial Museum; Victoria Memorial Museum of the Geological Survey of Canada, Bulletin 1, p. 33-39.

Reesor, J.E.
1973: Geology of the Lardeau map-area, east-half, British Columbia; Geological Survey of Canada, Memoir 369 and Map 1326A.

Ross, R.J., jr.
1949: Stratigraphy and trilobite faunal zones of the Garden City Formation, northeastern Utah; American Journal of Science, v. 247, p. 471-491.

1951: Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas; Peabody Museum of Natural History, Yale University, Bulletin 6, 161 p.

Sars, M.
1835: Ueber einige neue oder unvollständig bekannte Trilobiten; Isis, oder Encyclopädische Zeitung von Oken, Jena, v. 28, p. 333-343.

Schmidt, F.
1894: Revision der ostbaltischen silurischen Trilobiten, Abt. 4; Mémoires de l'Académie Impériale de Sciences de St-Petersbourg, ser. 7, v. 42.

Skjeseth, S.
1952: On the Lower *Didymograptus* Zone (3B) at Ringsaker, and contemporaneous deposits in Scandinavia; Norsk Geologisk Tidsskrift, v. 30, p. 138-182.

Størmer, L.
1940: Early descriptions of Norwegian trilobites. The type specimens of C. Boeck, M. Sars and M. Esmark; Norsk Geologisk Tidsskrift, v. 20, p. 113-151.

Tjernvik, T.
1956: On the early Ordovician of Sweden. I. Stratigraphy and fauna; Bulletin of the Geological Institutions of the University of Uppsala, v. 36, p. 107-284.

Ulrich, E.O. and Resser, C.E.
1930: The Cambrian of the upper Mississippi Valley. Part I. Trilobita; Dikelocephalinae and Osceolinae; Bulletin of the Public Museum of the City of Milwaukee, v. 12, p. 1-122.

Walcott, C.D.
1923: Nomenclature of some post Cambrian and Cambrian Cordilleran formations (2); Smithsonian Miscellaneous Collections, Washington, v. 67, no. 8.

1924: Geological formations of Beaverfoot-Brisco-Stanford Range, British Columbia, Canada; Smithsonian Miscellaneous Collections, Washington, v. 75, no. 1.

Whittington, H.B.
1948: A new Lower Ordovician trilobite; Journal of Paleontology, v. 22, p. 567-572.

1950: Sixteen Ordovician genotype trilobites; Journal of Paleontology, v. 24, p. 531-565.

1965: Trilobites of the Ordovician Table Head Formation, western Newfoundland; Bulletin of the Museum of Comparative Zoology, Harvard University, v. 132, p. 275-442.

## PLATES 1.1 to 1.3

All specimens are from GSC loc. 85784 and are housed in the type collection of the Geological Survey of Canada, Ottawa. Material was whitened with ammonium chloride sublimate before being photographed. Photographs were taken by the author.

## PLATE 1.1

Figures 1-4, 6-8. *Ampyx walcotti* Kobayashi, 1955

1. Incomplete cranidium showing part of frontal spine, GSC 85716, x5.

2. Part of cranidium, showing left branch of facial suture, GSC 85717, x5.

3, 4. Plan and right anterolateral views of fragment of cranidium showing axial furrows and lobes, and circular cross-section of frontal spine, GSC 85718, x5.

6. Partly exfoliated pygidium, GSC 85719, x6.

7. Partly exfoliated pygidium, GSC 85720, x8.

8. Latex cast of fragment of pygidium showing axial furrows and lateral border, GSC 85721, x8.

Figure 5. Kainellid gen. et sp. undet.

Incomplete, partly exfoliated left librigenal spine, GSC 85728, x6.

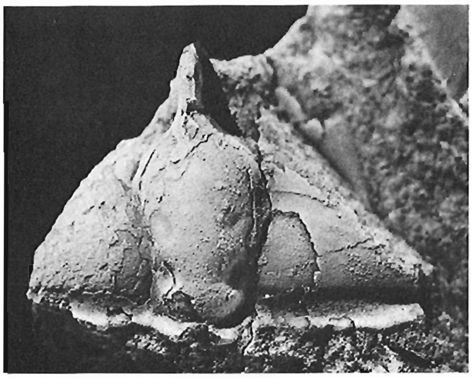
Figures 9, 10?, 11-14. *Protopliomerops*? *radiatus* Kobayashi, 1955

9. Abraded internal mould of incomplete pygidium, GSC 85722, x7.

10. Internal mould of fragmentary hypostoma assigned questionably to the species, GSC 85723, x10.

11, 13, 14. Plan, left lateral and anterior views of incomplete internal mould of cranidium, GSC 85724, x5.

12. Left librigena, GSC 85725, x8.



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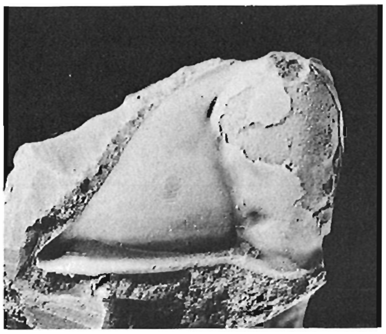

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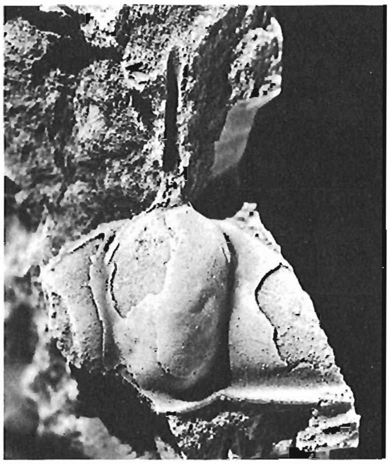

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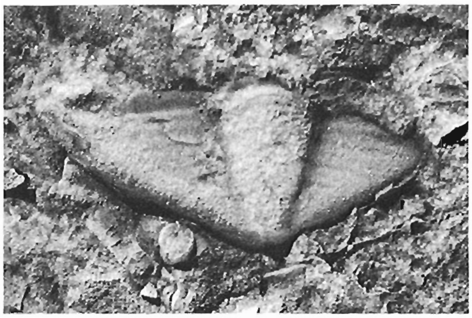

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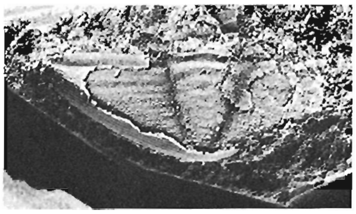

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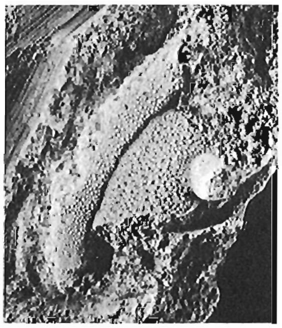

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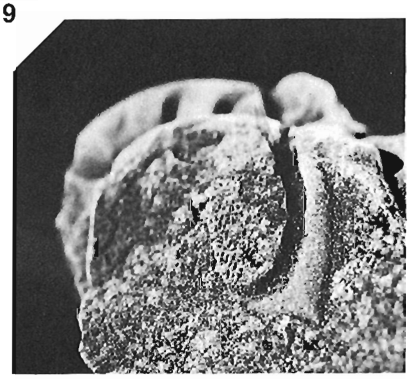

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## PLATE 1.2

Figures 1-6, 10. *Presbynileus* (*Presbynileus*) sp.

1. Large pygidium showing doublure, partly *in situ* and partly preserved as external mould of ventral surface, GSC 85734, x2.

2, 3. Left librigena showing ventral surface and its external mould, GSC 85735, x3.

4. Incomplete thoracic segment with partial external mould of doublure showing its adaxial margin and panderian protuberance, GSC 85736, x3.

5. Latex cast of right librigena, GSC 85737, x2.5.

6. Incomplete pygidium with external mould of ventral surface of doublure and median panderian protuberance, GSC 85738, x3.

10. Lateral view of right librigena, GSC 85739, x6.

Figures 7, 12, 14, 15. *Ptyocephalus* cf. *P. declevitus* (Ross, 1951)

7. Latex cast of left librigena, GSC 85745, x3.5

12. Partly exfoliated, incomplete left librigena, GSC 85746, x5.

14. Incomplete hypostoma, GSC 85747, x6.

15. Almost exfoliated glabella and occipital ring, GSC 85748, x4.

Figures 8, 9, 11, 13, 16. Asaphid gen. et sp. undet.

8, 11. Partly exfoliated hypostoma and its latex cast, GSC 85749, x4.

9. Incomplete hypostoma, GSC 85750, x5.

13. Exfoliated hypostoma, GSC 85751, x4.

16. Almost complete, exfoliated hypostoma, GSC 85752, x2.5.


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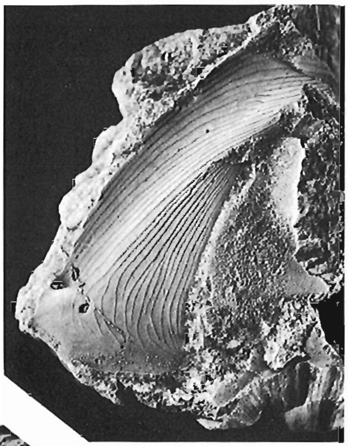
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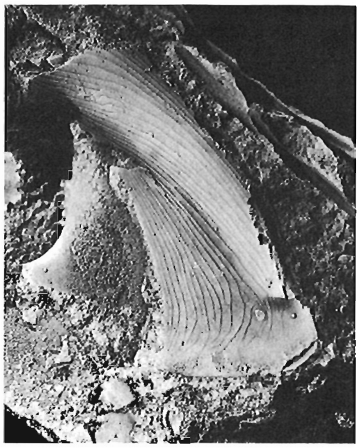
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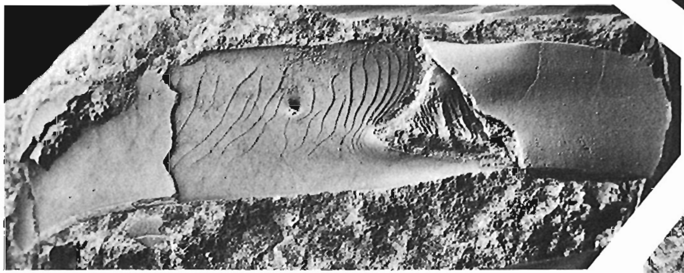
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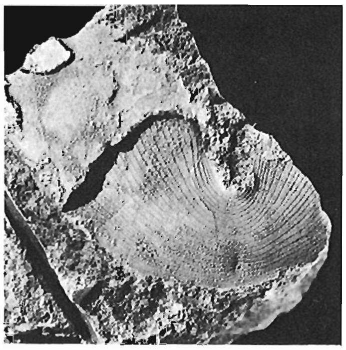
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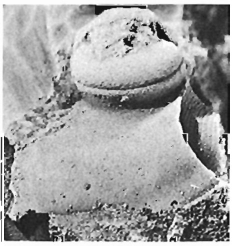
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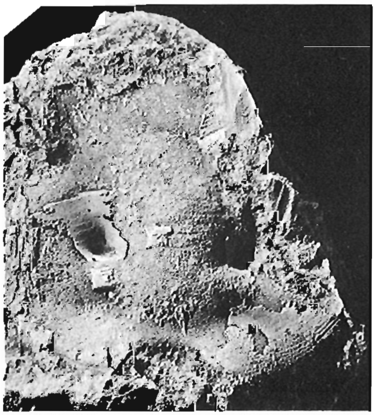
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## PLATE 1.3

Figures 1, 3, 10. *Protopliomerops*? *radiatus* Kobayashi, 1955

1. Incomplete, dorsally compressed cranidium, GSC 85726, x5.

3, 10. Right anterolateral and plan views of incomplete cranidium showing right palpebral lobe and furrow, GSC 85727, x5.

Figures 2, 12-15. *Presbynileus* (*Presbynileus*) sp.

2. Partly exfoliated pygidium, GSC 85740, x6.

12. Pygidium showing part of left side of doublure, GSC 85741, x6.

13. Pygidium, GSC 85742, x6.

14. Fragment of small cranidium showing narrow (sag.) anterior border, GSC 85743, x6.

15. Partly exfoliated cranidium showing left posterior branch of facial suture, GSC 85744, x6.

Figures 4, 5(?), 6-9, 11. *Lachnostoma* sp. nov.

4, 6, 8. Anterior, left lateral, and dorsal views of incomplete, large cranidium that lacks most of exoskeleton. Note median glabellar tubercle and faint glabellar furrows, GSC 85729, x3.

5. Incomplete right librigena assigned questionably to species, GSC 85730, x2.5.

7. Rear half of small cranidium showing glabellar lobes and furrows, GSC 85731, x6.

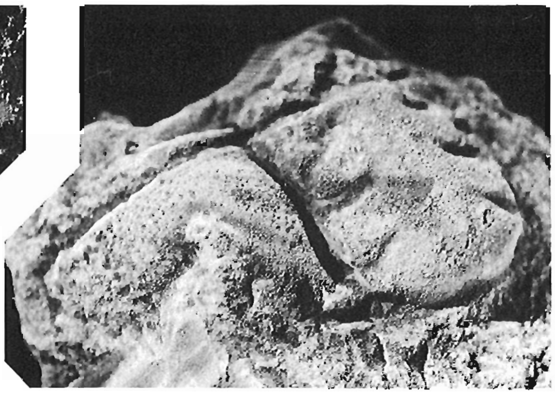
9. Fragment of cranidium showing low, narrow (exsag.) posterior border, GSC 85732, x3.

11. Incomplete pygidium, GSC 85733, x3.

PLATE 1.3


1


2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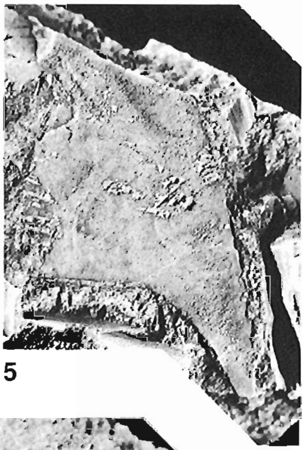
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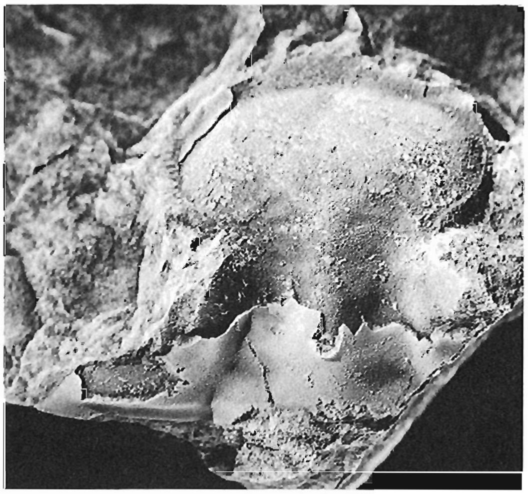
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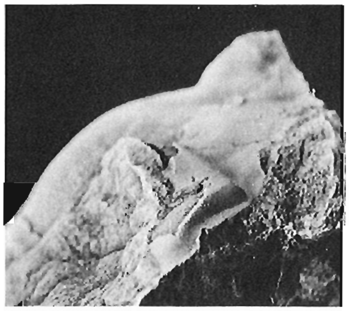
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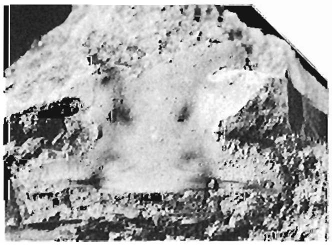
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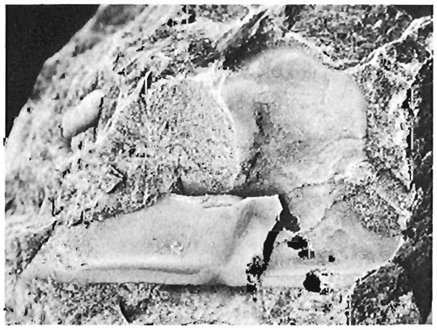
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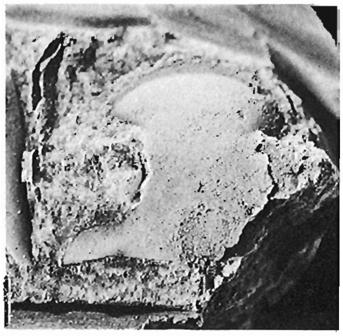
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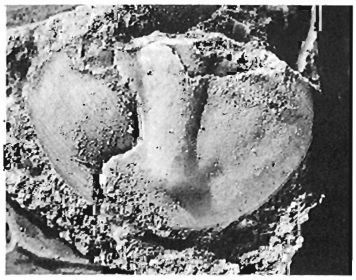
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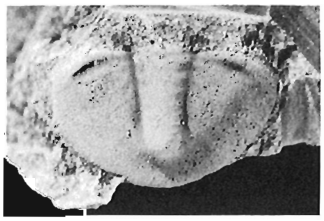
13


14

# STROMATOPOROIDEA FROM THE ORDOVICIAN ROCKS OF CENTRAL AND EASTERN CANADA

T.E. Bolton[1]

*Bolton, T.E., Stromatoporoidea from the Ordovician rocks of central and eastern Canada; in Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 379, p. 17-45, 1988.*

## *Abstract*

The stromatoporoid faunas that characterize the Ordovician rocks of Québec, Ontario, Manitoba and Hudson Bay basin are described. Labechiidae (*Labechia, Stromatocerium, Cystistroma, Pachystylostroma*), Rosenellidae (*Cystostroma*) and Aulaceridae (*Aulacera, Cryptophragmus*), are the dominant forms occurring throughout the Ordovician of this region. Ecclimadictyidae (*Ecclimadictyon*) appear in the Upper Ordovician Edenian of northeastern Manitoba and northern Ontario, and Clathrodictyidae (*Clathrodictyon*) in the Upper Ordovician Richmondian of southern and northeastern Manitoba, and Anticosti Island, Québec.

## *Résumé*

Dans le présent rapport, on décrit les faunes de stromatoporoïdés qui caractérisent les roches ordoviciennes du Québec, de l'Ontario, du Manitoba et du bassin de la baie d'Hudson. Les Labechiidae (*Labechia, Stromatocerium, Cystistroma, Pachystylostroma*), les Rosenellidae (*Cystostroma*) et les Aulaceridae (*Aulacera, Cryptophragmus*), sont les formes dominantes que l'on rencontre dans tout l'Ordovicien de cette région. Les Ecclimadictyidae (*Ecclimadictyon*) se manifestent dans l'Edénien (Ordovicien supérieur) du nord-est du Manitoba et du nord de l'Ontario, et les Clathrodictyidae (*Clathrodictyon*) dans le Richmondien (Ordovicien supérieur) du sud et du nord-est Manitoba, et de l'île d'Anticosti au Québec.

## INTRODUCTION

Knowledge of the stromatoporoids found within the Ordovician rocks of central and eastern Canada is based on the studies of Billings (1857, 1866), Nicholson (1886a, b, 1889, 1891), Whiteaves (1895, 1897), Parks (1910), Foerste (1924), Wilson (1948) and Galloway and St. Jean (1961). In more recent years, Ordovician stromatoporoids have been described and/or illustrated by Nelson (1963) from northeastern Manitoba; Bolton and Copeland (1972) and Copper (1978) from Manitoulin Island, Ontario; Workum et al. (1976) from Akpatok Island, District of Franklin; Bolton (1972, 1980, 1981a) from Anticosti Island and Gaspé Peninsula, Québec; and Copeland and Bolton (1977) from western Newfoundland. The aulacerid forms of Anticosti Island, have been studied by Petryk (1981, 1982).

The present paper will describe Ordovician stromatoporoids collected from Southampton Island and Coats Island, District of Keewatin; northeastern and southern Manitoba; Lake Timiskaming and Ottawa regions, Ontario; and Anticosti Island, Québec (Table 2.1). In all these regions, however, stromatoporoids rarely are the dominant faunal element. The only exceptions are the aulacerid biostromes within the Upper Ordovician Vaureal Formation of Anticosti Island (Petryk, 1981, 1982); the stromatoporoid–coral bioherms of the Upper Ordovician Ellis Bay Formation of Anticosti Island (Bolton, 1981b; Copper, 1974); and biostromes of the Cloche Island (Copper and Morrison, 1978), Kagawong and Meaford formations (Copper and Grawbarger, 1978) of Manitoulin Island, and the Bobcaygeon (Leray) Formation of southern Ontario and St. Lawrence Lowlands.

The majority of the material studied was collected by S.J. Nelson in 1950 and 1951, B.V. Sanford in 1969 and 1970, L.M. Cumming in 1967, and T.E. Bolton between 1957 and 1982. Older collections by D.B. Dowling, J.B. Tyrrell and T.C. Weston are included in the southern Manitoba study. R.J. Elias, University of Manitoba, provided material recently collected from southern Manitoba and the Gaspé Peninsula, Québec. Preliminary identification of one suite of northeastern Manitoba specimens was undertaken by C.W. Stearn, McGill University. Reviews by C.W. Stearn, C.W. Stock, University of Alabama, and M.J. Copeland, Geological Survey of Canada, were most helpful.

### Southampton Island - Coats Island, District of Keewatin (Fig. A, locs. 18, 19)

The 525 ft. (160 m) thick Ordovician carbonate sequence of Southampton and Coats islands, in ascending order, has been divided into the Bad Cache Rapids Group, Churchill River Group and Red Head Rapids Formation (Heywood and Sanford, 1976). The abundant coral-brachiopod-cephalopod megafaunas that distinguish each group are of late Middle to Late Ordovician age, and can be correlated with those described from northeastern Manitoba (Nelson, 1963). Stromatoporoids, however, are rare in the Ordovician strata of this northern region of Hudson Bay. The Bad Cache Rapids Group provided one coenosteum of *Labechia huronensis* (Billings) (Pl. 2.1, fig. 8) from the lower beds of Coats Island (Fig. A, loc. 19); and the Churchill River Group on Southampton Island (Fig. A, loc. 18) provided one large coenosteum of *Cystostroma* sp. 1 (Pl. 2.4, fig. 1), associated with the halysitid coral *Manipora* sp., *Cyrtophyllum pattersoni* (Roy), *Palaeophyllum halysitoides* (Troedsson), and *Calapoecia ungava* (Cox).

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# TABLE 2.1

Ordovician formations, members, and stromatoporoid species mentioned in text

| SERIES | STAGES | SOUTHAMPTON AND COATS ISLANDS | | NORTHERN MANITOBA | | SOUTHERN MANITOBA | | LAKE TIMISKAMING, ONTARIO | | SOUTHERN ONTARIO | | CHICOUTIMI, MINGAN, AND ANTICOSTI IS., QUEBEC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UPPER ORDOVICIAN (CINCINNATIAN) | GAMACHIAN | RED HEAD RAPIDS FORMATION | | RED HEAD RAPIDS FORMATION | | STONEWALL FORMATION | | | | | | ELLIS BAY FORMATION | *Aulacera radiata*<br>*Clathrodictyon* aff. *C. boreale*<br>*Aulacera nodulifera*<br>*Aulacera undulata* |
| | RICHMONDIAN | CHURCHILL RIVER GROUP<br>? | *Cystostroma* sp. 1 | CHASM CREEK FORMATION<br>CAUTION CREEK FM<br>? | *Cystostroma* sp. 3<br>*Cystostroma* sp. 2 | STONY MOUNTAIN FORMATION<br>RED RIVER FM. Fort Garry Mbr.<br>? | *Clathrodictyon* sp. 3 | | | | | VAUREAL FORMATION | *Aulacera undulata*<br>*Aulacera radiata*<br>*Aulacera nodulosa*<br>*Aulacera nodulifera*<br>*Aulacera cylindrica*<br>*Clathrodictyon* sp. 1 |
| | MAYSVILLIAN | | | ? | | ? | | DAWSON POINT FM.<br>? | | | | | |
| | EDENIAN | BAD CACHE RAPIDS GROUP | *Labechia huronensis* | SURPRISE CREEK FORMATION<br>?<br>PORTAGE CHUTE FORMATION | *Cystostroma* sp. 2<br>*Ecclimadictyon* sp. | RED RIVER FM.<br>Dog Head, Cat Head, and Selkirk members<br>? | *Cystostroma* sp. 1<br>*Cystostroma* sp. 2<br>*Stromatocerium* sp. 1 | *Cystostroma fritzae*<br>FARR FORMATION | *Labechia huronensis*<br>*Ecclimadictyon* sp.<br>*Pachystylostroma? copelandi* | | | ? | |
| MIDDLE ORDOVICIAN (CHAMPLAINIAN) | TRENTONIAN | ? | | ? | | | | ?<br>?<br>BUCKE FM. | | ?<br>BOBCAYGEON FORMATION | *Stromatocerium rugosum*<br>*Labechia* cf. *L. prima* | ? | |
| | BLACK-RIVERIAN | | | | | | | ?<br>GUIGUES FM.<br>? | | ?<br>GULL RIVER FORMATION<br>?<br>SHADOW L. FM.<br>? | *Cystistroma canadense*<br>*Cryptophragmus antiquatus*<br>*Pachystylostroma? miriamae* | "Simard beds"<br>? | *Cystistroma canadense* |
| | ? CHAZYAN | | | | | | | | | | | ?<br>MINGAN FORMATION<br>? | *Labechia prima* |
| | ? WHITE-ROCKIAN | | | | | | | | | | | | |

GSC

### North Knife-South Knife-Churchill-Nelson rivers region, northeastern Manitoba (Fig. A, locs. 14, 15, 16)

The 405 ft. (123.5 m) thick carbonate sequence has been chosen as the standard for the Hudson Bay region (Nelson, 1981, p. 4). In ascending order, it is divided into the Bad Cache Rapids Group (Portage Chute and Surprise Creek formations), Churchill River Group (Caution Creek and Chasm Creek formations) and Red Head Rapids Formation (Nelson, 1963, 1964). Stromatoporoids are more abundant here than in the equivalent rocks of Southampton and Coats islands. Nelson (1963) reported *Beatricea nodulosa* Billings, *B. clarki* Nelson, and *Aulacera undulata* (Billings) from the Surprise Creek, Caution Creek and Chasm Creek formations, most abundant in the youngest strata. Cumming (1975) reported stromatoporoids from the Chasm Creek Formation of Angling River (Station 198CE, Cumming, 1975, p. 38 = the heliolitid corals *Ellisites astomata* (Flower) and *E. glyptum* (Parks) – see Dixon et al., 1986), and *Stromatocerium* sp. from Upper Ordovician rocks exposed near Shammattawa village in the Gods River map area (Cumming, 1975, p. 39).

Additional stromatoporoids reported here include: *Ecclimadictyon* sp. (2 coenostea; Pl. 2.6, fig. 5) from member 1, and *Cystostroma* sp. 2 (3 coenostea; Pl. 2.4, figs. 3, 4, 6, 9, 10) from member 2 of the Portage Chute Formation; *Clathrodictyon* sp. 2 (Pl. 2.6, fig. 9) from member 1 of the Chasm Creek Formation, and *Cystostroma* sp. 3 (Pl. 2.4, fig. 8) also of the Chasm Creek.

### Southern Manitoba (Fig. A, loc. 17)

The Ordovician sequence in southern Manitoba, in ascending order, is divided into the Winnipeg Formation, Red River Formation (Dog Head, Cat Head, Selkirk, Fort Garry members), Stony Mountain Formation (Gunn, Penitentiary, Gunton members), and Stonewall Formation (McCabe, 1971). The only stromatoporoids recognized in this sequence were *Beatricea nodulosa* Billings, *B. undulata* Billings, *B.* cf. *B. nodulifera* Foerste and *B. intermedia* (Foerste) from the Gunton Member (Okulitch, 1943; Baillie, 1952, p. 32), and *B. undulata* (Billings) and *B. regularis* Stearn from the Stonewall Formation (Stearn, 1956, p. 53, 54). From the Cormorant Lake area west of Lake Winnipeg, McInnes (1913, p. 61) reported *Labechia ohioensis* Nicholson or *Stromatocerium huronense* (Billings) (Baillie, 1952, p. 35). Additional stromatoporoids recognized herein include *Cystostroma* sp. 1 and *Cystostroma* sp. 2, from the Selkirk Member (Pl. 2.4, figs. 2, 5), *Cystostroma* sp. 2, from the Dog Head Member (Pl. 2.4, fig. 11), *Stromatocerium* sp. 1 from the Cat Head Member(?) (Pl. 2.2, fig. 7), and *Clathrodictyon* sp. 3 from the Fort Garry Member (Pl. 2.7, figs. 3, 4).

### Akpatok Island, District of Franklin (Fig. A, loc. 20)

The 800 ft. (244 m) thick Edenian to Richmondian Ordovician sequence exposed on Akpatok Island has provided *Beatricea undulata* Billings (Foerste and Cox, 1936, p. 304) from 650 ft. (198 m) above sea level, *Labechia huronensis* (Billings) (Workum et al., 1976, Pl. 1, fig. 1; Pl. 2.1, fig. 7, herein) from 490 ft. (149 m) above sea level, *Beatricea* cf. *B. nodulifera* Foerste (Workum et al., 1976, p. 166) from 460 ft. (140 m) above sea level, and *Cystostroma*(?) sp. (Workum et al., 1976, p. 166) from sea level.

### Lake Timiskaming, Ontario (Fig. A, loc. 21)

The Ordovician sequence of the Lake Timiskaming area, in ascending order, is divided into the Guigues, Bucke, Farr and Dawson Point formations, of the Liskeard Group (Sinclair, 1965). Only *Cystostroma fritzae* Galloway and St. Jean has been recognized in the early Edenian Farr Formation (Galloway and St. Jean, 1961, p. 16, Pl. 2, fig. 1a, b; Ollerenshaw and Macqueen, 1960, p. 107, Table 1).

Recent collections from the upper beds of the Farr Formation have produced several specimens of *Labechia huronensis* (Billings) (Pl. 2.2, figs. 1-5) and one example of *Ecclimadictyon* sp. Two coenostea of *Pachystylostroma*? *copelandi* sp. nov. (Pl. 2.3, figs. 1-4, 6) were located in the basal nodular limestone beds in the Shipyards Quarry section (upper unit; Copeland, 1965, p. 2). No additional specimens of *Cystostroma fritzae* were identified.

### Ottawa Valley region, Ontario (Fig. A, loc. 22)

Wilson (1948) recorded *Cryptophragmus antiquatus* Raymond, *C.*? *rochensis* Wilson (= poorly preserved cephalopod; Steele and Sinclair, 1971, p. 42), and *Dermatostroma ottawaense* Wilson from the Black River-equivalent beds of the Ottawa Formation, and *Stromatocerium rugosum*, *S. tumidum* Wilson (= in part *Solenopora*), *Labechia antiqua* Wilson and *L. subcylindrica* Jones? from the Black River-Trenton (Chaumont-Rockland) equivalent Paquette Rapids beds. *Stromatocerium canadense* Nicholson and Murie has also been reported from these beds (Parks, 1910, p. 19, Pl. 21, fig. 8; Galloway and St. Jean, 1961, p. 62). Steele and Sinclair (1971, p. 41) illustrated *Cryptophragmus* sp. from the Chaumont-equivalent Braeside beds (Steele-Petrovich, 1986). All specimens are silicified and structures are obscure.

*Cryptophragmus antiquatus* is a characteristic form of the Pamelia beds, Ottawa Formation at the base of the Black River Group in the Ottawa Valley (holotype, GSC 5390) and equivalent beds of the Gull River Formation, lower member, west of Lake Simcoe in Carden township (paratypes, GSC 4329a-e, 7832; hypotypes, GSC 85074, 85075, Pl. 2.7, figs. 1, 2, herein). *Pachystylostroma*? *miriamae* sp. nov. has been identified in the Pamelia beds south of Chesterville (Pl. 2.7, figs. 7, 8), and in the Scott Street Transitway cut in Ottawa (Pl. 2.8, figs. 5-7), and *Cystistroma canadense* (Nicholson and Murie) from the Bobcaygeon Formation (Chaumont beds, Ottawa Formation) exposed in the Eganville – Cobden Highway 8 roadcut at Pine Hill (hypotypes, GSC 85080, 85081) and the roadcut on Highway 44, 5 miles (8 km) from the junction of Highway 17, east of Almonte (hypotype, GSC 85082). Several well preserved examples of *Labechia* cf. *L. prima* Kapp and Stearn (5 coenostea; Pl. 2.1, figs. 3-6) and a *Stromatocerium rugosum* Hall (Pl. 2.2, fig. 6) are also illustrated herein, collected from the uppermost Chaumont-lowermost Rockland equivalent beds exposed southwest of Arnprior, Ontario.

### St. Lawrence Lowland – Lac St. Jean-Chicoutimi–Mingan Islands, Québec (Fig. A, locs. 23, 24, 25, 26)

Stromatoporoids are rare in the Ordovician rocks of this region. *Stromatocerium canadense* Nicholson and Murie, *S. canadense* cf. var. *minimum* Parks, and *S. rugosum* Hall have been reported by Okulitch (1935, p. 103; 1939) and Clark (1972, p. 79, Table 12), and *Rosenella cumingsi* Galloway and St. Jean, 1961 was described from the Black River Group exposed from Montreal to Québec City.

From the Simard beds (Paquette Rapids beds equivalent) north of Chicoutimi, Québec, Sinclair (1953, p. 545) reported *Stromatocerium rugosum* Hall. Large stromatoporoid colonies (Harland et al., 1985, p. 251, fig. 11D) within the subtidal shoal sediments (Simard beds) of this same area are badly preserved, but traces of long thin pillars and low cysts permit assignment of these forms to *Stromatocerium* sp. indet. Coenostea up to 9 mm across and 21 mm high of *Cystistroma canadense* (Nicholson and Murie) (Pl. 2.8, figs. 2-4) have been collected recently by S. Desbiens from the upper Simard limestones exposed in the abandoned Plourde Quarry north of Chicoutimi, Quebec, along with poorly preserved coenostea of *Cystostroma*(?) sp. and *Stromatocerium*(?) sp., and tabulate coral coralla of *Paratetradium* sp., *Lichenaria* sp. and *Quepora quebecensis* (Lambe). *Beatricea undulata* Billings has been reported from the highest beds on Snake Island, Lac St. Jean (Foerste, 1916, p. 156).

Although stromatoporoids are common in the organic mounds of the Chazy Group of the Lake Champlain region of New York and Vermont (Kapp and Stearn, 1975), such forms have not been reported previously from the equivalent beds of the Mingan Islands, Québec. One coenosteum of *Labechia prima* Kapp and Stearn, 1975 was collected recently by A.L. Desrochers from reef flank facies in the Mingan Formation and is illustrated herein (Pl. 2.1, figs. 1, 2).

### Anticosti Island, Québec (Fig. A, loc. 27)

The Ordovician strata exposed on Anticosti Island are subdivided, in ascending order, into the Vaureal and Ellis Bay formations (Bolton, 1972, 1981). Aulacerids are the dominant stromatoporoids throughout the sequence with the greatest concentrations in the upper Vaureal bioherms – biostromes (Twenhofel, 1928; Bolton, 1972, 1981; Petryk, 1981, 1982). Four species have been identified (Twenhofel, 1928; Galloway and St. Jean, 1961; Bolton, 1981): *Beatricea undulata* Billings, *B. nodulosa* Billings, *B. nodulifera* Foerste, and *Aulacera radiata* Galloway and St. Jean.

The present study has confirmed the presence of *Aulacera undulata* throughout the Vaureal (Pl. 2.5, figs. 1, 3, 9) and Ellis Bay (Pl. 2.4, fig. 7; Pl. 2.5, fig. 8) formations, *A. nodulosa* (Pl. 2.5, fig. 5), *A. cylindrica* (Pl. 2.5, fig. 2), *A. nodulifera* (Pl. 2.5, figs. 4, 10) and *A. radiata* in the upper beds of the Vaureal Formation, and *A. nodulifera* (Pl. 2.5, fig. 6) and *A. radiata* (Pl. 2.5, fig. 7) in the Ellis Bay Formation of Anticosti Island.

According to Twenhofel (1928, p. 107) "*Clathrodictyon vesiculosum* appears in the top of the Vaureal formation and persists to the very top of the Chicotte formation." No specimens of *C. vesiculosum* were recognized in the recent studies. Rather, *Clathrodictyon* aff. *C. boreale* group of Nestor, 1964 (Bolton, 1981, p. 42, Pl. I, fig. 8; Pl. 2.6, figs. 1-4, 6, herein) is the sole representative in the uppermost Ordovician (Gamachian) bioherms and inter-biohermal beds of member 6, as well as in members 5 and 4 (bioherm), of the Ellis Bay Formation, and *Clathrodictyon* sp. 1 (Pl. 2.6, figs. 7, 8) in the Richmondian upper Vaureal Formation biostrome. Forms originally assigned to *Labechia* sp. nov. aff. *L. mirabilis – L. banksi* group (Bolton, 1981, p. 42, Pl. I, fig. 4; Pl. II, figs. 1, 2) have subsequently been included in the heliolitid coral *Ellisites labechioides* Dixon, Bolton and Copper, 1986.

The classification of Stromatoporoidea followed herein is the same as that proposed by Stearn (1980).

## SYSTEMATIC PALEONTOLOGY

### Class STROMATOPOROIDEA Nicholson and Murie, 1879

### Family LABECHIIDAE Nicholson, 1879
emend. Stearn, 1980

### Genus *Labechia* Milne – Edwards and Haime, 1851

Type species. *Monticularia conferta* Lonsdale, 1839.

### *Labechia prima* Kapp and Stearn, 1975

Plate 2.1, figures 1, 2

*Labechia prima* Kapp and Stearn, 1975, p. 184, Pl. 4, figs. 5, 6; Pl. 6, figs. 4, 5.

*Description.* Coenosteum laminar, 140 cm long, 70 cm wide, and up to 20 mm thick. In vertical section, low cysts are 0.10 to 0.20 mm high and from 0.40 to 1.00 mm long, overlapping only slightly to one third of adjacent cysts, 10 to 11 in 2 mm vertically; normal solid pillars are throughgoing, 0.10 to 0.30 mm thick, 3 to 7 in 2 mm horizontally.

*Discussion.* The *L. prima* group (Webby, 1979a, 1979b) includes *Labechia* in which the horizontal elements dominate over the vertical. The type material from the Crown Point Formation, Chazy Group of the Lake Champlain region varies slightly from the Mingan Islands specimen in that the cysts are slightly larger, 9 to 10 occurring vertically in 2 mm (10 to 13 in 2 mm by Webby, 1979b, p. 244) and 3 to 4 horizontally with the pillars spaced 3 to 4 in 2 mm horizontally. In *L. huronensis* (Billings) there are 7 to 9 cysts in 2 mm vertically and the round pillars are 0.15 to 0.40 mm in diameter with 3 to 5 present in 2 mm horizontally. *Labechia aldonensis* Webby, 1977, from slightly younger beds in Scotland, has fewer pillars, and slightly longer and higher cysts.

*Type and occurrence.* Hypotype, GSC 82905, Mingan Formation, reef flank facies, west side Île Nue de Mingan near Le Havre, lat. 50°12'35"N, long. 64°8'10"W, Mingan Islands, Québec.

### *Labechia* cf. *L. prima* Kapp and Stearn, 1975

Plate 2.1, figures 3-6

*Description.* Coenostea hemispherical, up to 30 mm high, latilaminate. In vertical section, cysts are low arched overlapping to elongate and laminate (Pl. 2.1, figs. 4, 6), 0.10 to 0.40 mm high, 6 to 10 in 2 mm vertically; pillars range from solid to clear to wall-less, recording various degrees of diagenetic replacement (Klapp and Stearn, 1975, p. 167, 168), 0.08 to 0.16 mm in diameter, up to 4.8 mm in length, 2 to 5 in 2 mm horizontally. In tangential section, round clear pillars are up to 0.24 mm in diameter and united by curved cyst plates (Pl. 2.1, fig. 3).

*Discussion. Labechia antiqua* Wilson, 1948 from the Leray–Rockland beds of the Ottawa Valley differs from these specimens collected from equivalent beds by possessing shorter pillars extending through one to three rows of vesicular tissue only, and by the more distinct development of laminae. *Labechia huronensis* (Billings) possesses thicker pillars and regularly overlapping cysts. With its broad and only slightly curved cysts, *L.* cf. *L. prima* resembles *Stromatocerium rugosum* Hall, but that species possesses plate-like pillars.

*Types and occurrence.* Hypotypes, GSC 82906-82908, uppermost Chaumont – lowermost Rockland equivalents, Ottawa Formation (Bobcaygeon Formation, Ottawa Group, Williams et al., 1984), GSC locality 97705A, small quarry at top of ridge, southeast of Clay Bank, Pakenham township, southwest of Arnprior, Ontario.

### *Labechia huronensis* (Billings, 1865)

Plate 2.1, figures 7, 8;
Plate 2.2, figures 1-5

*Labechia huronensis* (Billings). Galloway and St. Jean, 1961, p. 50, Pl. 7, figs. 3a, b, 4a, b (for complete synonymy).
*Labechia huronensis* (Billings). Workum, Bolton and Barnes, 1976, p. 166, Pl. 1, fig. 1.

*Description.*

1. Coats Island (Pl. 2.1, fig. 8). Coenosteum thin, laminar (fragment). In vertical section, cysts are low and long from 0.25 to 0.60 mm high, 5 to 6 occurring in 2 mm vertically, laminate; clear round pillars are never abundant, 0.10 to 0.40 mm in diameter (0.20 to 0.52 mm in tangential section), 1.20 to 2.80 mm long, 2 to 4 in 2 mm horizontally.

2. Akpatok Island (Pl. 2.1, fig. 7). Coenosteum massive (fragment). In vertical section, cysts vary from slightly arched, 0.30 to 0.45 mm high, to low, flat, 0.20 to 0.30 mm high, 9 to 11 in 2 mm vertically; clear round pillars are never abundant, 0.15 to 0.45 mm in diameter, 1.0 to 2.4 mm long, 2 to 3 in 2 mm horizontally.

3. Lake Timiskaming. Hypotype GSC 82910 (Pl. 2.2, figs. 1, 2). Coenosteum massive, 12 mm high. In vertical section, cysts are low and long, 0.10 to 0.30 mm high, 7 to 10 in 2 mm vertically; clear round pillars are never abundant, 0.10 to 0.30 mm in diameter (0.16 to 0.40 mm in tangential section – Pl. 2.2, fig. 2), 2 to 3 in 2 mm horizontally.

Hypotype GSC 82911 (Pl. 2.2, fig. 4). Coenosteum massive, fragment 40 mm thick. In vertical section, cysts are more pronounced than in previous specimens, but mainly low and long, 7 to 8 in 2 mm vertically; clear pillars are a little more abundant, 0.10 to 0.30 mm in diameter, 0.40 to 3.0 mm long, 2 to 4 in 2 mm horizontally.

Hypotype GSC 82912 (Pl. 2.2, fig. 3). Coenosteum hemispherical, 70 mm thick, 230+ mm wide, surface with small mamelons. In vertical section, cysts are well arched, 0.20 to 0.50 mm high, 6 to 8 in 2 mm vertically; pillars even more abundant, 0.10 to 0.45 mm in diameter, 0.60 to 5.2 mm long, 2 to 4 in 2 mm horizontally.

Hypotype GSC 82913 (Pl. 2.2, fig. 5). Coenosteum hemispherical, 50 mm thick and 250 mm wide, surface with abundant large and small mamelons. In vertical section, arched cysts are more prevalent than flat forms, 0.15 to 0.35 mm high, 9 to 10 in 2 mm vertically; pillars are abundant, 0.15 to 0.40 mm in diameter, 4 to 10.6 mm in length, 2 to 4 in 2 mm horizontally.

*Discussion.* The slight variations in the spacing of cysts and pillars, distinguishing characters in *Labechia* species identification, are believed to be consistent with the variability presented by the type material. There is a wide variation in the number of cysts in 2 mm vertically in the specimens described herein, ranging from 5 in 2 mm in the Coats Island form to 11 in 2 mm in the Akpatok Island form, compared with 7 to 9 in 2 mm in the standard material, but the other characteristic features correspond; the large number of long pillars in one of the Lake Timiskaming coenostea is the extreme in this character (compare with *L.* cf. *L. pustulosa* (Safford) of Kapp and Stearn, 1975, Pl. 4, fig. 3). The low, long cysts, when aligned in rows, are difficult to distinguish from laminae in some of the coenostea, a feature more common in *L. pustulosa* (Safford).

*Types and occurrence.* Hypotypes, GSC 82909, Bad Cache Rapids Group (Edenian), GSC locality 85505, lat. 62°51'25"N, long. 82°20'5"W, Coats Island, District of Keewatin; hypotype, GSC 41174, Upper Ordovician (Maysvillian-Richmondian), section II 490 ft. (149 m) above sea level, gully immediately east of Premium Homestead Akpatok L-26 wellsite, lat. 60°25'40"N, long. 68°20'3"W, west-central coast of Akpatok Island, District of Franklin; hypotypes, GSC 82910, Farr Formation (Edenian), GSC locality 37150, north-south road west of Farr Quarry; GSC 82911, GSC locality 37134, Farr Quarry; GSC 82912, GSC locality 37149, concession V/VI road just east of lot 6/7 road, Bucke township, and GSC 82913, GSC locality 37136, lot 4 south of concession I/II road, Dymond township, Lake Timiskaming area, Ontario.

## **Genus *Stromatocerium* Hall, 1847**

Type species. *Stromatocerium rugosum* Hall, 1847.

### *Stromatocerium rugosum* Hall, 1847

Plate 2.2, figure 6; Plate 2.7, figures 5, 6

*Stromatocerium rugosum* Hall. Galloway and St. Jean, 1961, p. 56, Pl. 8, figs. 2a-c (for complete synonymy).

*Description.* Coenostea nodular (fragment), 17 mm thick to domal 55 mm high and 70 mm wide. In vertical section, abundant cysts are low arched to flat and long, somewhat laminate, 0.10 to 0.30 mm high and 0.50 to 4.0 mm long, 8 to 12 in 2 mm vertically; pillars are abundant, 0.04 to 0.20 mm thick, 0.6 to 6.0 mm long, 2 to 4 in 2 mm horizontally.

*Discussion.* These specimens differ from the type only in the greater number of smaller arched cysts (8 to 12 compared with 7 to 10 in 2 mm) and shorter pillars, features to be expected in smaller coenostea. It is much closer to *Stromatocerium tumidum* Wilson from the equivalent beds of Paquette Rapids, Ottawa River, as determined by Galloway and St. Jean (1961, p. 59, Pl. 8, fig. 3; cysts 10 in 2 mm and pillars 5 in 2 mm). Wilson's illustrations of the type specimen, however, are of a species of *Solenopora*.

*Stromatocerium rugosum* is common to the biostromal complex (Liberty, 1969, p. 47) Bobcaygeon Formation throughout central Ontario (Pl. 2.7, figs. 5, 6) and equivalent Leray-Chaumont beds of the Ottawa Valley–St. Lawrence Lowlands. Additional stromatoporoids common to this complex include *Cystistroma canadense* Nicholson and Murie (Pl. 2.7, fig. 9) and *Cystostroma minimum* Parks (Pl. 2.7, fig. 10).

*Types and occurrence.* Hypotype, GSC 82914, lowermost Rockland equivalent, Ottawa Formation (Bobcaygeon Formation, Ottawa Group; Williams et al., 1984), GSC locality 97705A, small quarry at top of ridge, southeast of Clay Bank, Pakenham township, southwest of Arnprior; hypotype, GSC 85077, Bobcaygeon Formation, GSC locality 21762, debris cut at tailrace of power house, Healey Falls, Ontario.

### *Stromatocerium* sp. 1

Plate 2.2, figure 7; Plate 2.8, figure 1

*Description.* Coenostea oval, 90 to 95 mm diameter and 35 to 60 mm thick. In vertical section, cysts are well developed, low arched overlapping to flat, 0.10 to 0.30 mm high and 0.20 to 2.4 mm long, 7 to 11 in 2 mm vertically, laminae rare, best developed in basal regions; pillars are thin (0.04 to 0.08 mm) to thick (0.10 to 0.20 mm), laterally extending into dissepiments, in a few places branching, short (0.10 to 0.80 mm) to very long (4.7 to 10.6 mm), 4 to 6 in 2 mm horizontally. In tangential section, pillars are plate-like, short, rarely flanged.

*Discussion.* The specimens display many *Labechia* characteristics but the pillars are not rounded (Pl. 2.8, fig. 1). Cysts are well developed in *S. leiperense* Galloway and Ehlers, 1961 and *S. australe* Parks, 1910, both Upper Ordovician Maysvillian species. *Stromatocerium* sp. 1 lacks the pillar vacuoles characteristic of *S. leiperense* but does have branching pillars; the cysts are more dominant and regular, and the pillars are more isolated than in *S. australe*, which it most closely resembles (Galloway and St. Jean, 1961, Pl. 9, fig. 3a, b; not Nestor, 1976, Pl. 5, figs. 1a, b, 2a, b).

*Types and occurrence.* Hypotypes, GSC 82915, 82916, Cat Head Member(?), Red River Formation (Edenian), Outer Sturgeon Island, Lake Winnipeg, Manitoba.

### Genus *Cystistroma* Etheridge, 1895

Type species. *Labechia*(?) (*Cystistroma*) *donnellii* Etheridge, 1895.

### *Cystistroma canadense* (Nicholson and Murie, 1878)

Plate 2.7, figure 9; Plate 2.8, figures 2-4

*Stromatocerium canadense* Nicholson and Murie. Galloway and St. Jean, 1961, p. 60, Pl. 9, fig. 1a, b (for complete synonymy).

*Description.* Coenosteum domal, at least 80 to 120 mm across, and more than 100 mm high, with prominent low, broad mamelons. In vertical section, convex cysts vary considerably in size, 2 to 8 in 2 mm vertically, with the lowest and smallest located in the zones of well developed pillars; pillars randomly developed, locally concentrated, mainly short, ranging from 0.50 to 0.80 mm with the most continuous 2.7 mm in length, 0.08 to 0.15 mm thick; long narrow denticles mainly based on cysts. In tangential section, pillars round to slightly irregular.

*Discussion.* The species is characterized by the considerable variation in cyst size within a coenosteum and the development of both pillars and denticles, the latter structure consigning the taxon to *Cystistroma* rather than *Labechia* or *Stromatocerium* (see Webby, 1979b, p. 248).

*Types and occurrence.* Hypotypes, GSC 85079, GSC locality 20933, behind farm south of highway, 1/4 mile (0.4 km) west of abandoned quarry on the Burleigh Falls–Buckhorn Highway 36, GSC 85080, 85081, GSC locality 90184, Eganville – Cobden roadcut at Pine Hill, and GSC 85082, GSC locality 90216, roadcut on Highway 44, 5 miles (8 km) from junction of Highway 17, east of Almonte, Ontario; Bobcaygeon Formation (Leray–Chaumont), Middle Ordovician. Hypotypes, GSC 85892, 85893, GSC locality 102125, abandoned Plourde Quarry south of Saint-Honoré, lat. 48°28'37"N, long. 71°5'22"W, Chicoutimi area, Quebec; Simard beds (Leray–Chaumont), Middle Ordovician.

### Genus *Pachystylostroma* Nestor, 1964

Type species. *Stromatopora ungerni* Rosen, 1867.

### *Pachystylostroma*(?) *copelandi* sp. nov.

Plate 2.3, figures 1-4, 6

*Description.* Coenostea massive, 49 mm thick, mamelons abundant, 5 to 7 mm in diameter and at least 3 mm high. In vertical section, abundant cysts of variable length and height, ranging from 0.90 mm long and 0.30 mm high at edge of mamelons to 3.6 mm long and 0.90 mm high in troughs, usually 4 to 5 but up to 8 in 2 mm vertically, rare development of denticled laminae and/or cysts; clear pillars, some open to chambers, some with distinct walls, are never abundant, best radially developed in mamelon columns, 0.10 to 0.70 mm thick and 0.8 to 6.0 mm long. In tangential section, cysts are grouped around mamelons, more irregular between them, pillars round to oval.

*Discussion.* The laminae are poorly defined in this species and accordingly its inclusion in *Pachystylostroma* rather than *Labechia* (laminae absent) is not definite; the presence of outwardly radiating pillars within the mamelon columns and denticles suggest the former genus. Nestor (1964) described one species (*P. fragosum*) from the Upper Ordovician and seven from the Lower Silurian of Estonia. *Pachystylostroma*(?) *copelandi* sp. nov. is closest to the Silurian form *P. exile* Nestor characterized by large cysts 1 to 1.2 mm high and 5 to 6 mm long, sparse denticulation and small mamelon columns with radial pillars. An additional seven species were assigned to *Pachystylostroma* by Nestor in 1976, including *P.*? *woyuense* (Ozaki, 1938) from the Upper Ordovician of China. Webby (1979a, p. 94) rejected this assignment. Kapp and Stearn (1975) described five new species from the Middle Ordovician (Chazyan) of New York State; *P. champlainense* Kapp and Stearn is very similar to the Lake Timiskaming species, but it is more distinctly laminate and displays smaller mamelons.

*Types and occurrence.* Holotype, GSC 82917 and paratype, GSC 82918; Farr Formation, lower nodular unit, Liskeard Group, Upper Ordovician (Edenian), GSC localities 82541 and 37137, Shipyards (Match Factory) Quarry, Lake Timiskaming area, Ontario.

### *Pachystylostroma* (?) *miriamae* sp. nov.

Plate 2.7, figures 7, 8; Plate 2.8, figures 5-7

*Description.* Coenosteum composite, sheet forms up to 70 mm high and 50 mm wide with high, narrow mamelons widely spaced. In vertical section, zones of large and small cysts vary horizontally and vertically, with low, small cysts 0.20 to 0.50 mm long and 0.08 to 0.15 mm high, in bands 0.15 to 0.55 mm thick, extending as continuous laminae; and large cysts 0.90 to 3.0 mm long and 0.35 to 0.80 mm high arranged in random patterns, but best developed in the troughs between mamelons; narrow denticles and/or short, solid pillars sporadically developed on slopes and within mamelons, arising from both cysts and laminae, normally extending through 1 to 6 cysts, but cutting up to 14 cysts within narrower zones.

*Discussion.* The laminae are more distinct in this specimen than in *P.*(?) *copelandi* sp. nov. from the Liskeard Group or *P. champlainense* Kapp and Stearn from the Chazy Group, and all other structures are finer. Although the laminae are ill-defined in all three species, their recognition suggests their assignment to *Pachystylostroma* rather than *Labechia.*

*Types and occurrence.* Holotype, GSC 85290, Pamelia beds, Ottawa Formation (Shadow Lake), about 100 cm below the top of the cut and 45 cm below the base of the stromatolitic unit exposed at the west end of the Scott Street Transitway cut, west of Churchill Avenue close to the Western Parkway, Ottawa; collector: H. Miriam Steele-Petrovich, 1986; paratype, GSC 85078, Pamelia beds, GSC locality 3372, McMillan's Quarry south of Chesterville, Ontario; collector: R.W. Ells, 1899.

## Family ROSENELLIDAE Yavorsky, 1973

### **Genus** *Cystostroma* Galloway and St. Jean, 1957

Type species. *Cystostroma vermontense* Galloway and St. Jean, 1957.

*Discussion. Cystostroma* was erected for labechiids composed of small, regularly imbricating, curved plates, and lacking laminae, pillars and villi or denticles (some villi present, however). Four species were recognized ranging from the Middle (Chazyan) to Upper (Edenian) Ordovician. Yavorsky in 1961 added two species (*C. rarus, C. sarytschelekense*) from the Upper Ordovician of the U.S.S.R., and in 1963 along with *C. undosum* (Ivanov) from the Ordovician, four new species from the Lower Silurian (*C. simplex* var. *sibirica, C. tortuosum, C. kozhimense* and *C. regulare*). *Cystostroma ordovikense* and *C. vexativum* were added by Yavorsky in 1968. In more recent years, Nestor (1976, p. 15) recognized thirteen Ordovician species of *Cystostroma* (including *C. estoniense* Nestor, 1964) and Webby (1969) erected *C. cliefdenense* from the Middle Ordovician of Australia. Some of these species display denticles (e.g., *C. estoniense* Nestor see Webby, 1979a, p. 87; *C. minimum* (Parks) - Pl. 2.3, figs. 5, 7, herein).

### *Cystostroma* sp. 1

Plate 2.4, figure 1

*Description.* Coenosteum domal, 50 mm thick and 200 mm wide. In vertical section, small overlapping cysts dominate, 0.20 to 0.35 mm high and 0.60 to 0.70 mm long, but a few larger cysts may occur at the base above latilaminae, 0.60 mm high and 1.30 mm long, normally 8 to 10 in 2 cm vertically, no villi or pillars, low, broad mamelons.

*Discussion.* This species is very similar to *C. fritzae* Galloway and St. Jean from the Farr Formation (Edenian) of the Lake Timiskaming area, Ontario, which, like *C. cliefdenense* Webby, is generally composed of smaller cysts.

*Types and occurrence.* Hypotype, GSC 82919, Churchill River Group (Richmondian), GSC locality 84561, Rocky Brook, lat. 64°2'30"N, long. 83°31'W, Southampton Island, District of Keewatin; hypotype, GSC 82920, Selkirk Member, Red River Formation (Edenian-Maysvillian), Gillis Quarries Limited Quarry, NW sec. 3, tp. 13, rge. 6W1, Garson, Manitoba.

### *Cystostroma* sp. 2

Plate 2.4, figures 2-6, 9-11

*Description.* Coenostea domal (fragments), up to 40 mm thick and 110 mm wide. In vertical section, overlapping cysts are variable in size, from 0.10 to 0.50 mm high and 0.55 to 3.0 mm long, 4 to 9 in 2 mm vertically, rare, low villi 0.24 mm high and 0.8 mm wide at base.

*Discussion.* In overall appearance, this species is much like *C. vermontense* Galloway and St. Jean, but in the type species the cysts are frequently narrower and higher; *C. fritzae* has smaller cysts in general.

*Types and occurrence.* Hypotypes, GSC 82921, 82922, Portage Chute Formation (Edenian), GSC locality 25257, upper limestone rapids on Nelson River, lat. 56°30'N, long. 94°10'W; hypotypes, GSC 82923, 82924, Selkirk Member, Red River Formation (Edenian-Maysvillian), GSC locality 87416, Gillis Quarries Limited Quarry, NW sec. 3, tp. 13, rge. 6W1, Garson, Manitoba; and hypotype, GSC 82925, GSC locality 11583, East Selkirk, lat. 50°08'N., long. 96°50'30"W; hypotype, GSC 82926, Dog Head Member, Red River Formation (Edenian), GSC locality 2951, Swampy or Berens Island, Lake Winnipeg, Manitoba.

### *Cystostroma* sp. 3

Plate 2.4, figure 8

*Description.* Coenosteum laminar (fragment), 27 mm thick. In vertical section, large and small overlapping cysts ranging from 0.20 to 0.70 mm in height and 0.55 to 2.50 mm in length, there are 4 to 9 in 2 mm vertically, no villi.

*Discussion. Cystostroma* sp. 3 resembles *C. sarytschelekense* Yavorsky by its variation in cyst size, but overall its cysts are lower and longer; the cysts are basically larger than in *Cystostroma* sp. 2.

*Type and occurrence.* Hypotype, GSC 82927, Chasm Creek Formation (Richmondian), GSC locality 25290, just upstream from Red Head Rapids, Churchill River, lat. 58°20'N, long. 94°40'W, Manitoba.

## Family AULACERIDAE Kuhn, 1927

### **Genus** *Aulacera* Plummer, 1843

Type species. *Aulacera plummeri* Galloway and St. Jean, 1957.

*Discussion.* The history of the two generic names *Beatricea* and *Aulacera* was presented by Galloway and St. Jean (1961, p. 21-23); their decision to regard *Beatricea* (type species *B. nodulosa* Billings, 1857) as a junior synonym of *Aulacera* (type species *A. plummeri* Galloway and St. Jean, 1957 based only on topotypic material) was in error. With the lack of primary material and without having been used in primary literature for 76 years (Schuchert, 1919), the taxon *Aulacera* should have been declared *nomen oblitum*. Both genera have been applied since 1957, but there has been a swing to *Aulacera* in recent years.

Columnar coenostea, so abundant in the Ordovician rocks of Anticosti Island, Québec, were assigned by Billings (1857) to either *Beatricea nodulosa* or *B. undulata*; the former species is characterized by vertical rows of large mamelons or nodes, small cysts and sporadic pillars, whereas the latter species is characterized by sharp, longitudinal to slightly spiral, discontinuous ridges, larger cysts and no pillars. Stearn (1956) added *B. regularis*, characterized by small nodose coenostea and a large axial column (8 mm), Galloway and St. Jean (1961) recognized in all fifteen species of *Aulacera*, Nelson (1963) erected *B. clarki* for subtriangular nodose coenostea, and Yavorsky (1963) described three more species of *Beatricea*. Finally, Nestor (1976, p. 32, 33) accepted twelve species within *Aulacera*, making several of them synonyms.

Aulacerids are present but rare in equivalent strata in the Gaspé region. *Beatricea* aff. *Aulacera plummeri* Galloway and St. Jean (Bolton, 1980, p. 13, Pl. 2.1, fig. 8; Pl. 2.3, figs. 2, 6) has been reported from the Honorat Group north of Carleton, Québec, and *Aulacera radiata* Galloway and St. Jean from the southern Gaspé (Petryk, 1985, p. 11). In addition, *Aulacera undulata – A. radiata* was collected in 1984 by R.J. Elias from the White Head Formation on the Priest's Road near Percé (hypotype, GSC 85084).

The separation of species within the aulacerid forms in the Upper Ordovician of Anticosti Island is difficult. More detailed studies of these forms, by A.A. Petryk, are under way. During the present study, coenostea displaying characteristics of *A. undulata* (Billings), *A. nodulosa* (Billings), *A. undulata* and *A. nodulosa* in combination, *A. nodulifera* (Foerste), *A. cylindrica* (Foerste) and *A. radiata* Galloway and St. Jean have all been identified. Some of these species are illustrated here.

### *Aulacera undulata* (Billings, 1857)

Plate 2.4, figure 7;
Plate 2.5, figures 1, 3, 8, 9

*Description.* This is the most common species, with large coenostea more than 1.5 m long and greater than 15 cm in diameter, occurring in both the Western Carbonate and Eastern Transitional Carbonate – Siliciclastic – Platform Facies regions of Anticosti Island (Petryk, 1981, 1982), but slightly more numerous in the Vaureal Formation than in the Ellis Bay Formation (Petryk, 1981, p. 102; 1982, p. 393). Vertically oriented coenostea *in situ* are common. *Aulacera undulata* has sharp ridges of varying length, continuous or with small nodes (Pl. 2.5, fig. 3). Hypotype, GSC 82929 is strongly angulate resembling a specimen of *Aulacera plummeri* Galloway and St. Jean from the Upper Ordovician Liberty Formation of Kentucky. Internally, a central core or axial column 3 to 5 mm in diameter, composed of large arched plates may be surrounded by a 2 mm thick zone of large cysts, with the remainder of the coenosteum composed of smaller overlapping cysts slightly laminar (Pl. 2.4, fig. 7), 0.25 to 0.30 mm high and 0.55 to 1.00 mm long. Ridges or radial pillars and trough structures are usually confined to the outermost regions, but some pillars composed of a single row of cysts 0.35 mm high and 0.80 mm wide may extend a considerable distance inward.

*Types and occurrence.* Lectotype, GSC 1969g, Vaureal Formation (Richmondian), GSC locality 2583, near West Point lighthouse; hypotypes, GSC 82929-82931, members 3 and 1, Ellis Bay Formation (Gamachian), GSC locality 33630 (BF17-4), south bank of Salmon River 3.06 miles (4.92 km) from mouth and GSC locality 62248 (BF149), eastern end of tote road to east off Jupiter River road (1964), 2.5 miles (4 km) south of main highway; hypotypes, GSC 82932, 82933, 82949, Vaureal Formation (Richmondian), GSC locality 76091 (BF 229B), Loon Lake road 0.1 miles (0.16 km) south of main highway, GSC locality 66781 (BF 188A), main highway 1 to 1.5 miles (1.6 to 2.4 km) east of Jupiter River road (1964), and GSC locality 2672, Battery Point, Anticosti Island, Québec.

### *Aulacera nodulosa* (Billings, 1857)

Plate 2.5, figure 5

*Description.* Coenostea at least 65 mm in diameter with large nodes or mamelons, loosely arranged in vertical rows. Internally, a central tube with large cysts is surrounded by a zone of many small low cysts with short, thin, clear pillars extending throughout.

*Types and occurrence.* Syntype, GSC 1971, Vaureal Formation (Richmondian), Battery Point; hypotypes, GSC 82934, 82935, Vaureal Formation, GSC localities 66774 (BF 188) and 66781 (BF 188A), main highway 0.6 to 1 mile (0.96 to 1.6 km) and 1 to 1.5 miles (1.6 to 2.4 km) east of Jupiter River road (1964), Anticosti Island, Québec.

### *Aulacera nodulifera* (Foerste, 1909)

Plate 2.5, figures 4, 6, 10

*Description.* Coenostea 28 to 45 mm in diameter with abundant small nodes or mamelons aligned in loosely spiral rows. Internally, the large central core 12 to 14 mm in diameter, composed of large, high cysts, is surrounded by a 0.92 mm wide zone of medium-sized cysts; remainder of the coenosteum is composed of small overlapping cysts 0.20 to 0.24 mm high, rarely 0.56 mm, and 0.44 to 1.04 mm long; traces of short, white pillars are present in the central zone, and nodular ridges are confined to a thin, outer layer.

*Types and occurrence.* Hypotypes, GSC 29638 and GSC 82936, members 4 and 3, Ellis Bay Formation (Gamachian), GSC localities 84344 (BF 400A), main highway just west of Vaureal River, and 62170 (BF 122A), La Loutre road 1 mile (1.6 km) south of main highway; hypotypes, GSC 82937-82941, Vaureal Formation (Richmondian), GSC locality 76091 (BF 229B), Loon Lake road 0.1 miles (0.16 km) south of main highway, GSC locality 36145 (BF 31A), road cut on main highway just west of Lake Faure road, GSC locality 33709 (BF 23), main highway 17 miles (27 km) from Port Menier, just east of Becscie River road, GSC locality 98585 (BF 565), tote road west of airport, 5.45 km from main highway, and GSC locality 2672, Battery Point, Anticosti Island, Québec.

### *Aulacera cylindrica* (Foerste, 1909)

Plate 2.5, figure 2

*Description.* Coenostea cylindrical, 10 to 17 mm diameter, surface smooth to minutely nodose. Internally, axial column 5 to 8 mm in diameter with large, high, axial cysts surrounded by small, overlapping cysts, 0.20 to 0.35 mm high and 0.40 to 0.55 mm long.

*Types and occurrence.* Hypotypes, GSC 82942, 82943, Vaureal Formation (Richmondian), GSC locality 36131 (BF 11), roadcut main highway 9 miles (14.5 km) from Port Menier at south end of Lake Princeton, GSC 82944, GSC locality 36145 (BF 31A), main highway just west of Lake Faure road, and GSC 82945, GSC locality 66811 (BF 215A), Loon Lake-Bear Lake road 1.40 to 1.47 miles (2.25 to 2.36 km) south of main highway, Anticosti Island, Québec.

### *Aulacera radiata* Galloway and St. Jean, 1961

Plate 2.5, figure 7

*Description.* Coenostea cylindrical, 120+ mm long, 40 to 70 mm diameter, surface covered with long, sharp, discontinuous ridges, slightly spiral, like *A. undulata*. Internally, a central core 12 to 20 mm in diameter is surrounded by cysts of variable height and length, in which undulating latilaminae and radial ridges are well developed, especially in the outer 13.6 mm of the coenostea; regular overlapping cysts are 0.20 to 0.30 mm high and 0.55 to 0.80 mm long, whereas in troughs and the outer zone, the cysts are 0.15 to 0.50 mm high and 0.60 to 1.20 mm long; denticles or short pillars abundant, 0.20 mm wide at base and 0.25 mm high; radial ridges composed of a single row of cysts 0.16 mm high and 0.25 mm long.

*Types and occurrence.* Hypotypes, GSC 82946, 82947, Vaureal Formation (Richmondian), GSC localities 66782 (BF 188B) and 62242 (BF 229), main highway west and east of Beaver Cove road; hypotype, GSC 82948, member 5, Ellis Bay Formation (Gamachian), GSC locality 98443 (BF 560), Baie de la Tour road 9.9 km north of main highway, Anticosti Island, Québec.

## Family CLATHRODICTYIDAE Kühn, 1927

### **Genus** *Clathrodictyon* Nicholson and Murie, 1879

Type species. *Clathrodictyon vesiculosum* Nicholson and Murie, 1879.

### *Clathrodictyon* aff. *C. boreale* group of Nestor, 1964

Plate 2.6, figures 1-4, 6

*Clathrodictyon* aff. *C. boreale* group of Nestor, 1964. Bolton, 1981, p. 42, Pl. I, fig. 8.

*Description.* Coenostea round, nodular to turbinate, most are 40 to 50 mm wide and 35 to 55 mm high, with the largest measuring 120 mm wide and 80 mm high. In vertical section, pillars are straight to curved extending down from laminae, confined to an interlaminar space (Pl. 2.6, fig. 1), galleries range from 0.20 mm high and 0.30 mm wide to 0.50 mm high and 1.15 mm wide, with 11 to 14 regular to gently undulating laminae in 2 mm vertically. In tangential section, dot-like pillars and astrorhizae well displayed (Pl. 2.6, fig. 6).

*Discussion.* Within the *C. boreale* group, this form is closer to *C. boreale* Riabinin, 1951 from the Llandovery of Estonia than to the Ordovician representative *C. gregale* Nestor, 1964 or any species within the solely Ordovician *C. microundulatum* group of Nestor, 1964 [*C. vormsiense* Riabinin, 1951, *C. microundulatum* Nestor, 1964, *C. mammillatum* (Schmidt, 1858)].

*Types and occurrence.* Hypotypes, GSC 82950-82952, member 6 (bioherm), Ellis Bay Formation (Gamachian), GSC localities 98434 (BF 553) and 98451 (BF 554), Baie de la Tour road, 6.0 to 6.4 km and 6.75 km north of main highway; hypotype, GSC 67020, member 6 (interbiohermal), Ellis Bay Formation, GSC locality 36350 (BF 86), Jupiter River road (1958), 5.3 km south of east branch Oil River crossing; hypotypes, GSC 82953, 82954, uppermost beds of member 6, Ellis Bay Formation (with *Zygospiraella planoconvexa* (Hall), Early Silurian Anticostian), GSC locality 62148 (BF 126F), La Loutre road, 4.9 miles (7.9 km) south of main highway; hypotype, GSC 82955, Ellis Bay Formation, west side of Gamache or Ellis Bay (collector: T.C. Weston, 1865); hypotype, GSC 82956, member 6 (bioherm), Ellis Bay Formation, Pointe Laframboise; hypotypes, GSC 82957-82959, member 6 (basal beds of bioherm), Ellis Bay Formation, GSC locality 33639 (BF 29-1), north bank, Salmon River 7.4 miles (11.9 km) from mouth; hypotype, GSC 82960, member 5, Ellis Bay Formation, GSC locality 91457 (BF 509a), Salmon River road, 1.9 miles (3.1 km) from mouth of river; and hypotype, GSC 82961, member 4 (bioherm), Ellis Bay Formation, GSC locality 92401 (BF 403), east bank, Vaureal River, second bend above bridge, Anticosti Island, Québec.

### *Clathrodictyon* sp. 1

Plate 2.6, figures 7, 8

*Description.* Coenosteum small, nodular. In vertical section, preservation spotty, pillars are both vertical and inverted conical with triangular spaces below laminae, confined to an interlaminar space, not superimposed, 6 to 7 in 2 mm horizontally; galleries generally 0.20 mm high and 0.65 mm wide; laminae regular and continuous laterally, 8 to 13 in 2 mm vertically.

*Discussion.* This form is distinguished by the dominance of laminae, as in the early Silurian forms *Clathrodictyon kudriavzevi* Riabinin and *C. lennuki* Nestor of Estonia or some *Intexodictyon* species. It is similar to *C. plicatum* Webby and Banks from the Upper Ordovician of Tasmania, but slightly coarser.

The Y-shaped nature of some of the pillars in both *Clathrodictyon* sp. 1, and to a lesser degree in *Clathrodictyon* sp. 2, suggests a relationship with the Lower Silurian genus, *Intexodictyon*, and in particular with *I. avitum* Nestor (see Stearn, 1969, p. 761). However, the dominance of simple, unbranched pillars favours *Clathrodictyon*.

*Type and occurrence.* Hypotype, GSC 82962, Vaureal Formation (Richmondian), bioherm on main highway south of Lac Ste. Marie, Anticosti Island, Québec.

### *Clathrodictyon* sp. 2

Plate 2.6, figure 9

*Description.* Coenosteum laminar (fragment). In vertical section, 2 to 4 thick pillars occur in 2 mm horizontally, confined to an interlaminar space, not superimposed; galleries generally 0.24 mm high and 0.48 mm wide; laminae regular and continuous laterally, 5 to 6 in 2 mm vertically.

*Discussion.* Laminae dominate in this form as in coenosteum of *Clathrodictyon* sp. 1, from the Vaureal Formation, but the wider laminae and pillar spacing distinguish it from other Ordovician clathrodictyids.

*Type and occurrence.* Hypotype, GSC 82963, member 1, Chasm Creek Formation (Richmondian), GSC locality 25281, north of Chasm Creek, Churchill River, lat. 58°N, long. 94°55'W, Manitoba.

### *Clathrodictyon* sp. 3

Plate 2.7, figures 3, 4

*Description.* Coenosteum laminar (fragment), at least 80 mm wide and 30 mm high. In vertical section, preservation spotty, 5 to 7 pillars occur in 2 mm horizontally, not superimposed; galleries range from 0.25 to 0.30 mm in height and 0.15 to 0.55 mm, rarely 1.10 mm, in width; laminae continuous laterally, 6 to 8 in 2 mm vertically.

*Discussion.* In its abundance of pillars, this specimen resembles *Clathrodictyon* sp. 1, but is closer to *Clathrodictyon* sp. 2 in other features.

*Types and occurrence.* Hypotypes, GSC 85076, and 85076 a-d, Fort Garry Member, Red River Formation (Richmondian), Mowat Farm Quarry (Mulder Brothers pit no. 2), sec. 27, tp. 13, rge. 3W1, about 20 km north of Winnipeg, Manitoba.

## Family ECCLIMADICTYIDAE Stearn, 1980

### **Genus** *Ecclimadictyon* Nestor, 1964

Type species. *Clathrodictyon fastigiatum* Nicholson, 1886.

### *Ecclimadictyon* sp.

Plate 2.6, figure 5

*Description.* Coenosteum massive (fragment). In vertical section, zigzag-shaped or chevron-folded continuous laminae well developed, 8 to 10 in 2 mm vertically, no true pillars observed; dissepiments long and short; suggestion of astrorhizae tubes up to 1 mm long.

*Discussion.* Only *Ecclimadictyon koigiense* Nestor from the Porkuni Stage, uppermost Ordovician of Estonia has 7 to 8 laminae in 2 mm, but it is more open and coarser. These Canadian forms resemble a coarser, more open *E. fastigiatum* (Nicholson) (10 to 12 laminae in 2 mm vertically), but differ in showing traces of astrorhizae and dissepiments.

*Types and occurrence.* Hypotype, GSC 82964, member 1, Portage Chute Formation (Edenian), GSC locality 25315, North Knife River, lat. 58°45'N, long. 94°55'W, Manitoba; hypotype, GSC 82965, Farr Formation (Edenian), Liskeard Group, GSC locality 37134, Farr Quarry, 1/2 mile (0.8 km) west of Haileybury, Lake Timiskaming area, Ontario.

## REFERENCES

Baillie, A.D.
1952: Ordovician geology of Lake Winnipeg and adjacent areas, Manitoba; Manitoba Department of Mines and Natural Resources Mines Branch, Publication 51-6, 64 p.

Billings, E.
1857: New species of fossils from the Silurian rocks of Canada; Geological Survey of Canada, Report of Progress for the years 1853-54-55-56, p. 256-345.

1866: Catalogues of the Silurian fossils of the island of Anticosti, with descriptions of some new genera and species; Geological Survey of Canada, 93 p.

Bolton, T.E.
1972: Geological map and notes on the Ordovician and Silurian litho- and biostratigraphy, Anticosti Island, Québec; Geological Survey of Canada, Paper 71-19, 20 p.

1980: Colonial coral assemblages and associated fossils from the Late Ordovician Honorat Group and White Head Formation, Gaspé Peninsula, Québec; Geological Survey of Canada, Paper 80-1C, p. 13-28.

1981a: Ordovician and Silurian biostratigraphy, Anticosti Island, Québec; in International Union of Geological Sciences Subcommission on Silurian Stratigraphy, Ordovician-Silurian Boundary Working Group, Field Meeting, Anticosti-Gaspé, Québec 1981, v. II: Stratigraphy and Paleontology, p. 41-59.

1981b: Late Ordovician and Early Silurian Anthozoa of Anticosti Island, Québec; in International Union of Geological Sciences Subcommission on Silurian Stratigraphy, Ordovician-Silurian Boundary Working Group, Field Meeting, Anticosti-Gaspé, Québec 1981, v. II: Stratigraphy and Paleontology, p. 107-135.

Bolton, T.E. and Copeland, M.J.
1972: Manitoulin Island Ordovician and Silurian fossils; in Geology and Scenery North Shore of Lake Huron Region, J.A. Robertson, and K.D. Card (eds.); Ontario Division of Mines, Geological Guidebook No. 4, p. 54-61.

Clark, T.H.
1972: Montreal area; Québec Ministère des Richesses naturelles, Geological Report 152, 244 p.

Copeland, M.J.
1965: Ordovician Ostracoda from Lake Timiskaming, Ontario; Geological Survey of Canada, Bulletin 127, 52 p.

Copeland, M.J. and Bolton, T.E.
1977: Additional paleontological observations bearing on the age of the Lourdes Formation (Ordovician), Port au Port Peninsula, western Newfoundland; Geological Survey of Canada, Paper 77-1B, p. 1-13.

Copper, P.
1974: Structure and development of early Paleozoic reefs; Proceedings of the Second International Coral Reef Symposium, Brisbane, p. 365-386.

Copper, P.
1978: Paleoenvironments and paleocommunities in the Ordovician – Silurian sequence of Manitoulin Island; Michigan Basin Geological Society, Special Paper No. 3, p. 47-61.

Copper, P. and Grawbarger, D.J.
1978: Paleoecological succession leading to a late Ordovician biostrome on Manitoulin Island, Ontario; Canadian Journal of Earth Sciences, v. 15, no. 12, p. 1987-2005.

Copper, P. and Morrison, R.
1978: Morphology and paleoecology of Ordovician tetradiid corals from the Manitoulin District, northern Ontario; Canadian Journal of Earth Sciences, v. 15, no. 12, p. 2006-2020.

Cumming, L.M.
1975: Ordovician strata of the Hudson Bay Lowlands; Geological Survey of Canada, Paper 74-28, 93 p.

Dixon, O.A., Bolton, T.E., and Copper P.
1986: *Ellisites*, an Upper Ordovician heliolitid coral intermediate between coccoserids and proporids; Palaeontology, v. 29, pt. 2, p. 391-413.

Foerste, A.F.
1916: Upper Ordovician formations in Ontario and Quebec; Geological Survey of Canada, Memoir 83, 269 p.

1924: Upper Ordovician faunas of Ontario and Quebec; Geological Survey of Canada, Memoir 138, 255 p.

Foerste, A.F. and Cox, I.H.
1936: Cephalopods and a Beatricea from Akpatok Island; Geological Magazine, v. 73, no. 865, p. 289-307.

Galloway, J.J.
1957: Structure and classification of the Stromatoporoidea; Bulletins of American Paleontology, v. 37, no. 164, p. 345-480.

Galloway, J.J. and St. Jean, J., Jr.
1961: Ordovician Stromatoporoidea of North America; Bulletins of American Paleontology, v. 43, no. 194, 103 p.

Harland, T.L., Pickerill, R.K., and Fillion, D.
1985: Ordovician intracratonic sediments from the Lac-St-Jean and Chicoutimi areas, Québec, eastern Canada; Canadian Journal of Earth Sciences, v. 22, no. 2, p. 240-255.

Heywood, W.W. and Sanford, B.V.
1976: Geology of Southampton, Coats, and Mansel Islands, District of Keewatin, Northwest Territories; Geological Survey of Canada, Memoir 382, 35 p. (issued 1978).

Kapp, U.S. and Stearn, C.W.
1975: Stromatoporoids of the Chazy Group (Middle Ordovician), Lake Champlain, Vermont and New York; Journal of Paleontology, v. 49, no. 1, p. 163-186.

Liberty, B.A.
1969: Palaeozoic geology of the Lake Simcoe area, Ontario; Geological Survey of Canada, Memoir 355, 197 p.

McCabe, H.R.
1971: Stratigraphy of Manitoba, an introduction and review; Geological Association of Canada, Special Paper 9, p. 167-187.

McInnes, W.
1913: The basins of Nelson and Churchill rivers; Geological Survey of Canada, Memoir 30, 138 p.

Nelson, S.J.
1963: Ordovician paleontology of the northern Hudson Bay Lowland; Geological Society of America, Memoir 90, 152 p.

1964: Ordovician stratigraphy of northern Hudson Bay Lowland, Manitoba; Geological Survey of Canada, Bulletin 108, 36 p.

Nelson, S.J.
1981: Solitary streptelasmatid corals, Ordovician of northern Hudson Bay Lowland, Manitoba, Canada; Palaeontographica, Abt. A, Bd. 172, 71 p.

Nestor, H.E.
1964: Ordovician and Llandoverian stromatoporoids of Estonia; Institute of Geology of the Academy of Sciences of Estonia SSR, 112 p.

1976: Early Paleozoic stromatoporoids from the Moiero Basin (North Siberian Platform); Institute of Geology of the Academy of Sciences of Estonia SSR, 95 p.

Nicholson, H.A.
1886a: A monograph of the British stromatoporoids, Part I – General Introduction; Palaeontographical Society of London, p. 1-130.

1886b: On some new and imperfectly described species of stromatoporoids – Part II; The Annals and Magazine of Natural History; v. XVII-Fifth Series, p. 225-239.

1889: A monograph of the British stromatoporoids, Part II – Description of species; Palaeontographical Society of London, p. 131-158.

1891: A monograph of the British stromatoporoids, Part III – Description of species; Palaeontographical Society of London, p. 159-202.

Okulitch, V.J.
1935: Faunas of the Black River Group in the vicinity of Montreal; The Canadian Field Naturalist, v. 49, no. 6, p. 96-107.

1939: The Black River Group in the region between Montreal and Quebec; American Journal of Science, v. 237, p. 81-93.

1943: The Stony Mountain Formation of Manitoba; Transactions of the Royal Society of Canada, series 3, v. 17, sec. 4, p. 59-73.

Ollerenshaw, N.C. and Macqueen, R.W.
1960: Ordovician and Silurian of the Lake Timiskaming area; Proceedings of the Geological Association of Canada, v. 12, p. 105-115.

Parks, W.A.
1910: Ordovician stromatoporoids of America; University of Toronto, Geological Series No. 7, 52 p.

Petryk, A.A.

1981: Aulacerid ecostratigraphy and its bearing on the Ordovician - Silurian boundary on Anticosti Island, Quebec; in International Union of Geological Sciences Subcommission on Silurian Stratigraphy, Ordovician-Silurian Boundary Working Group, Field Meeting, Anticosti-Gaspé, Québec 1981, v. II: Stratigraphy and Paleontology, p. 101-105.

1982: Aulacerid ecostratigraphy of Anticosti Island, and its bearing on the Ordovician-Silurian boundary and the Upper Ordovician glacial episode; Third North American Paleontological Convention, Proceedings v. 2, p. 393-399.

1985: The discovery of aulocerid stromatoporoids in the Honorat Group of southern Québec, Gaspé Peninsula; Canadian Paleontology and Biostratigraphy Seminar, Programme with Abstracts, Québec City, Sept. 28-29, 1985, p. 11.

Schuchert, C.

1919: The proper name for the hydroid *Beatricea*; American Journal of Science, v. 47, p. 293-296.

Sinclair, G.W.

1953: Middle Ordovician beds in the Saguenay Valley, Quebec; American Journal of Science, v. 251, p. 841-854.

1965: Succession of Ordovician rocks at Lake Timiskaming; Geological Survey of Canada, Paper 65-34, 6 p.

Stearn, C.W.

1956: Stratigraphy and palaeontology of the Interlake Group and Stonewall Formation of southern Manitoba; Geological Survey of Canada, Memoir 281, 126 p.

1969: The stromatoporoid genera *Tienodictyon*, *Intexodictyon*, *Hammatostroma* and *Plexodictyon*; Journal of Paleontology, v. 43, no. 3, p. 753-766.

1980: Classification of the Paleozoic stromatoporoids; Journal of Paleontology, v. 54, no. 5, p. 881-902.

Steele, H.M. and Sinclair, G.W.

1971: A Middle Ordovician fauna from Braeside, Ottawa Valley, Ontario; Geological Survey of Canada, Bulletin 211, 97 p.

Steele-Petrovich, H.M.

1986: Lithostratigraphy and a summary of the paleoenvironments of the lower Middle Ordovician sedimentary rocks, upper Ottawa Valley, Ontario; Geological Survey of Canada, Paper 86-1B, p. 493-506.

Twenhofel, W.H.

1928: Geology of Anticosti Island; Geological Survey of Canada, Memoir 154, 351 p. (1927).

Webby, B.D.

1969: Ordovician stromatoporoids from New South Wales; Palaeontology, v. 12, pt. 4, p. 637-662.

1979a: The Ordovician stromatoporoids; Proceedings of the Linnean Society of New South Wales, v. 103, no. 2, p. 83-121.

1979b: The oldest Ordovician stromatoporoids from Australia; Alcheringa, v. 3, p. 237-251.

Whiteaves, J.F.

1895: Systematic list, with references, of the fossils of the Hudson River or Cincinnati Formation at Stony Mountain, Manitoba; Geological Survey of Canada, Palaeozoic Fossils, v. III, pt. II, p. 111-128.

1897: Canadian stromatoporoids with reference to the literature of each species described from Canada; Canadian Record of Science, v. 7, p. 129-146.

Williams, D.A., Wolf, R.R., and Rae, A.M.

1984: Paleozoic geology Arnprior – Quyon area, southern Ontario; Ontario Geological Survey, Geological Series – Preliminary Map P. 2726.

Wilson, A.E.

1948: Miscellaneous classes of fossils, Ottawa Formation, Ottawa – St. Lawrence valley; Geological Survey of Canada, Bulletin 11, 116 p.

Workum, R.H., Bolton, T.E., and Barnes, C.R.

1976: Ordovician geology of Akpatok Island, Ungava Bay, District of Franklin; Canadian Journal of Earth Sciences, v. 13, no. 1, p. 157-178.

Yavorsky, V.I.

1961: Stromatoporoidea of the Soviet Union, Part 3; Ministry of Geology and Conservation of Mineral Resources, Transactions of the All-Union Scientific Research Geological Institute (VSEGEI) USSR, n. ser., v. 44, 144 p.

1963: Stromatoporoidea of the Soviet Union, Part 4; State Geological Committee of the USSR, Transactions of the All-Union Scientific Research Geological Institute (VSEGEI) USSR, n. ser., v. 87, 160 p.

1968: Some Late Ordovician stromatoporoids in Tuva; Annual, All-Union Palaeontological Society, v. 18, p. 49-59.

## PLATES 2.1 to 2.8

## PLATE 2.1

Figures 1, 2. *Labechia prima* Kapp and Stearn

Mingan Formation, St. Charles Island, Mingan Islands, Québec.

1, 2. Vertical sections showing variation in abundance of pillars within a colony, hypotype, GSC 82905, x10 and x20.

Figures 3-6. *Labechia* cf. *L. prima* Kapp and Stearn

Bobcaygeon Formation, GSC locality 97705A, small quarry at top of ridge, southeast of Clay Bank, Ontario.

3, 4. Tangential and vertical sections, hypotype, GSC 82906, x10.

5. Vertical section with short pillars and arched cysts, hypotype, GSC 82907, x36.

6. Vertical section with laminate, elongate cyst plates, hypotype, GSC 82908, x10.

Figures 7, 8. *Labechia huronensis* (Billings)

Vertical sections showing few pillars, x10.

7. Hypotype, GSC 41174, Upper Ordovician, section II, west-central Akpatok Island, District of Franklin.

8. Hypotype, GSC 82909, GSC locality 85505, Bad Cache Rapids Group, Coats Island, District of Keewatin.


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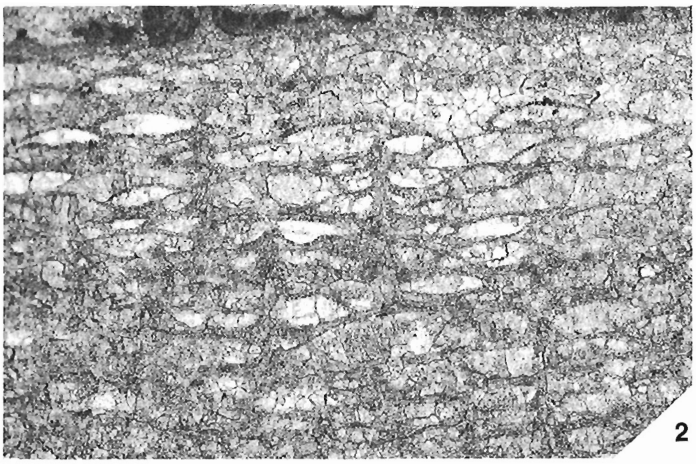
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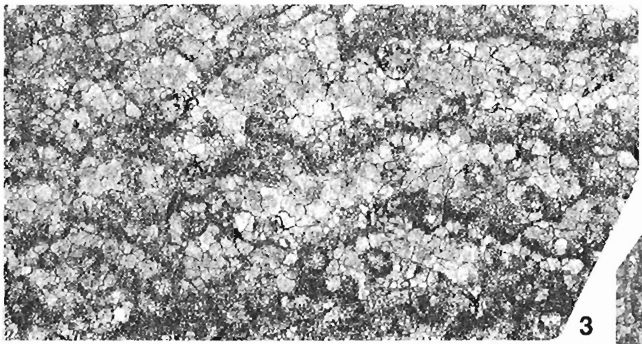
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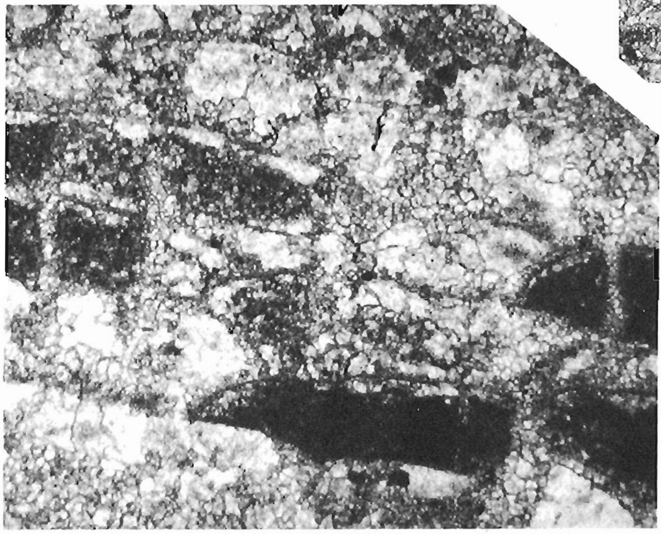
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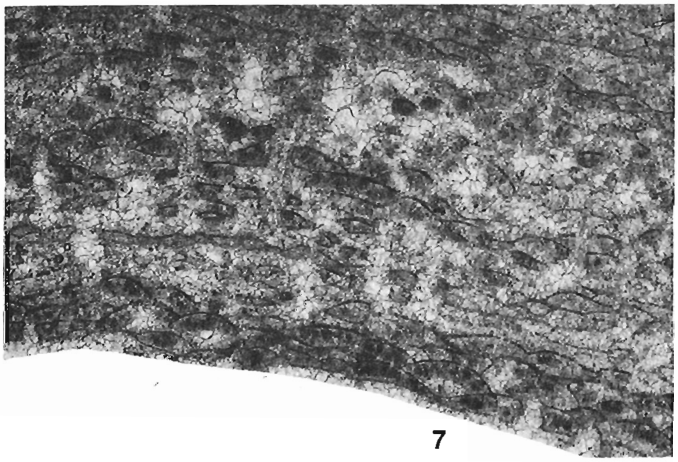
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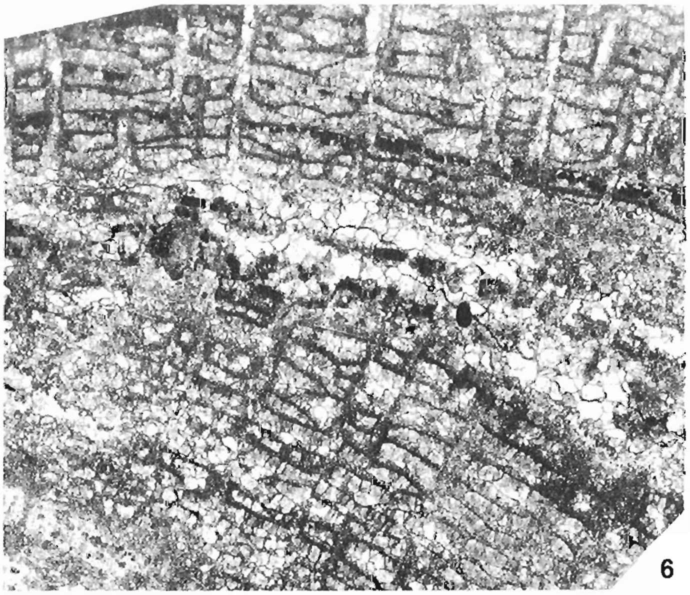
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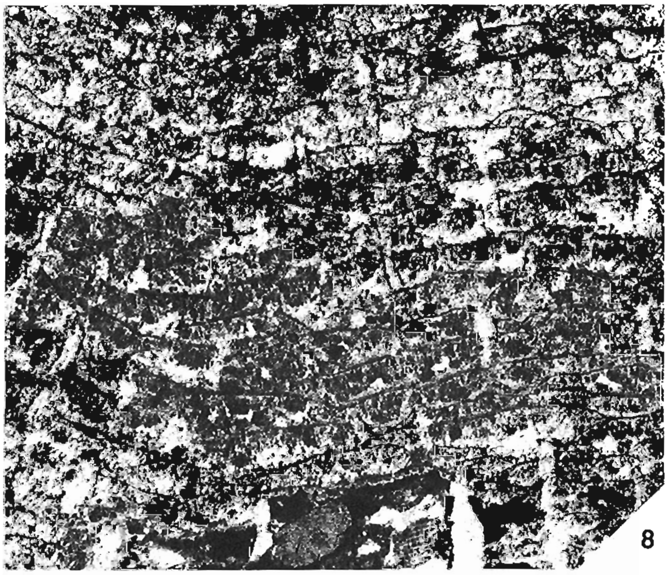
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## PLATE 2.2

Figures 1-5. *Labechia huronensis* (Billings)

Farr Formation, Lake Timiskaming area, Ontario.

1, 2. Vertical and tangential sections, hypotype, GSC 82910, x20, GSC locality 37150.

3. Vertical section with abundant arched cysts, hypotype, GSC 82912, x10, GSC locality 37149.

4. Vertical section with laminate, elongate cyst plates, hypotype, GSC 82911, x10, GSC locality 37134.

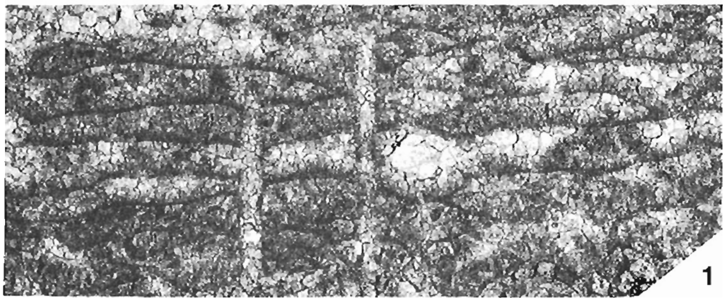
5. Vertical section with abundant long pillars, hypotype, GSC 82913, x10, GSC locality 37136.

Figure 6. *Stromatocerium rugosum* Hall

Vertical section, hypotype, GSC 82914, x10, Bobcaygeon Formation, GSC locality 97705A, small quarry at top of ridge, southeast of Clay Bank, Ontario.

Figure 7. *Stromatocerium* sp. 1

Vertical section near bottom of colony showing branching pillars, hypotype, GSC 82915, x20, Cat Head Member(?), Red River Formation, Outer Sturgeon Island, Lake Winnipeg, Manitoba.



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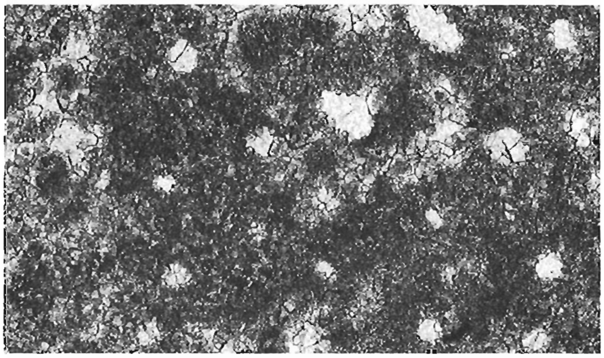

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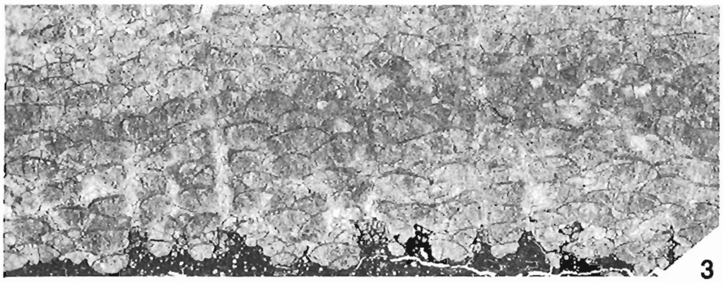

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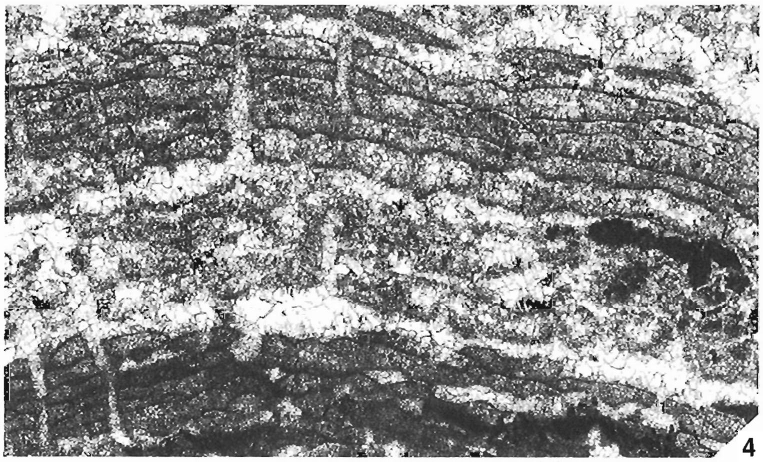

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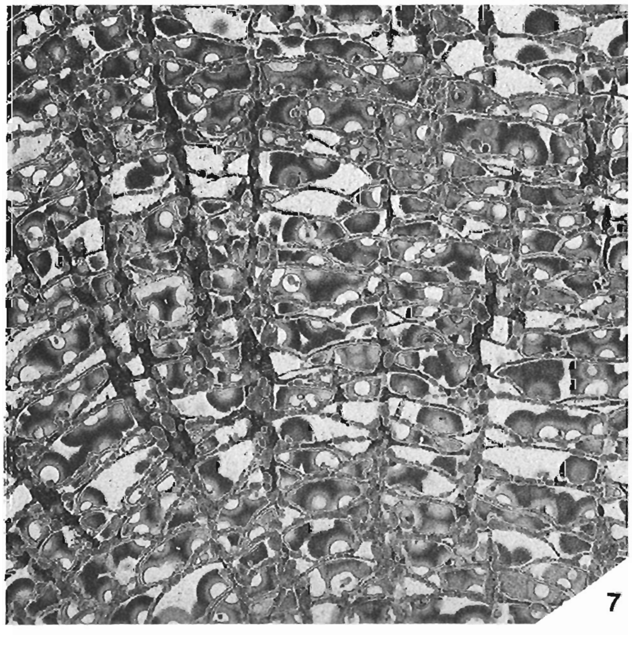

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## PLATE 2.3

Figures 1-4, 6. *Pachystylostroma*(?) *copelandi* sp. nov.

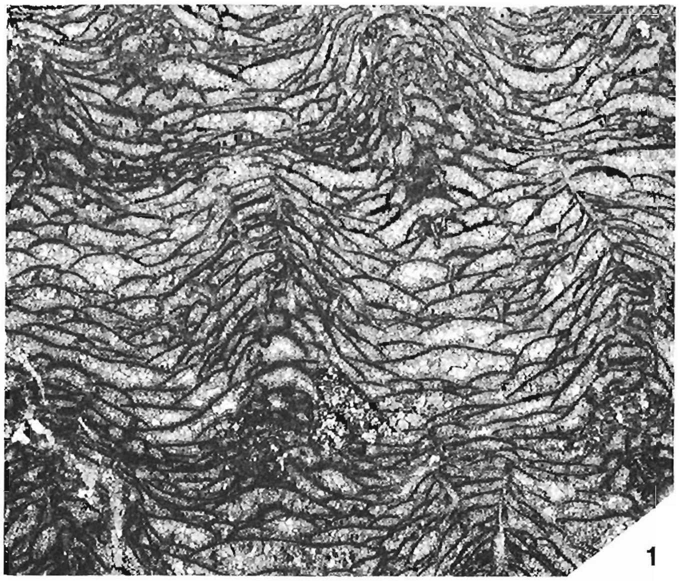
Farr Formation, Lake Timiskaming area, Ontario.

1, 2. Vertical sections, showing variable cysts, denticles or villi, and pillars in mamelons, paratype, GSC 82918, x5 and x10, GSC locality 37137, Shipyards or Match Factory Quarry.

3, 4, 6. Vertical sections (figs. 3, 4) showing variable cysts with some lamination of smaller plates, short pillars and denticles or villi, x5 and x10, and tangential section (fig. 6) showing oval pillars and cysts grouped around mamelons, x5, holotype, GSC 82917, GSC locality 82541, Shipyards or Match Factory Quarry.

Figures 5, 7. *Cystostroma minimum* (Parks)

Vertical section showing large mamelon cysts and possible short pillars at latilamina level in lower coenosteum, hypotype, GSC 27676, x10, and tangential section showing mamelon surrounded by cysts, x10, Verulam Formation, roadcut north end of Goat Island, Manitoulin Island district, Ontario.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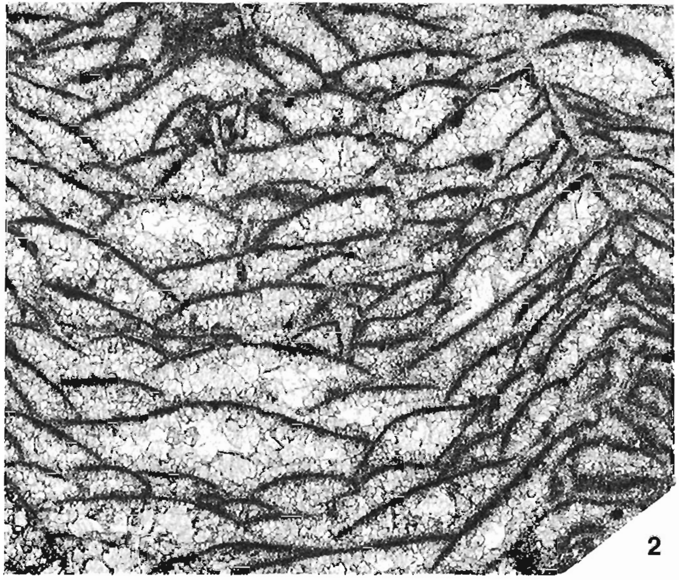
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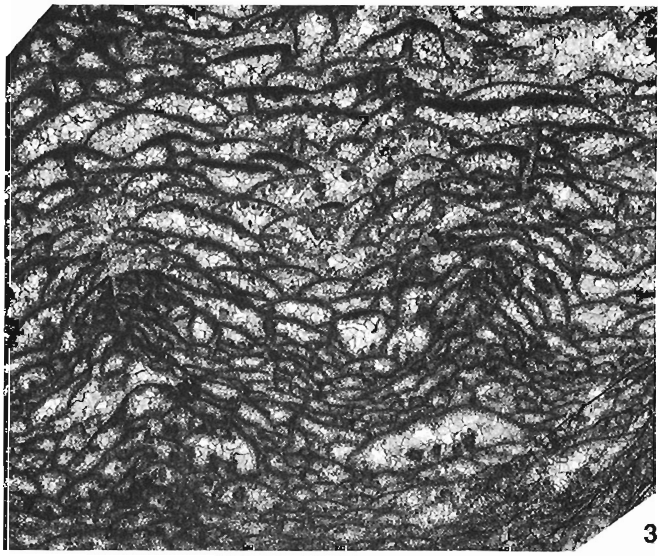
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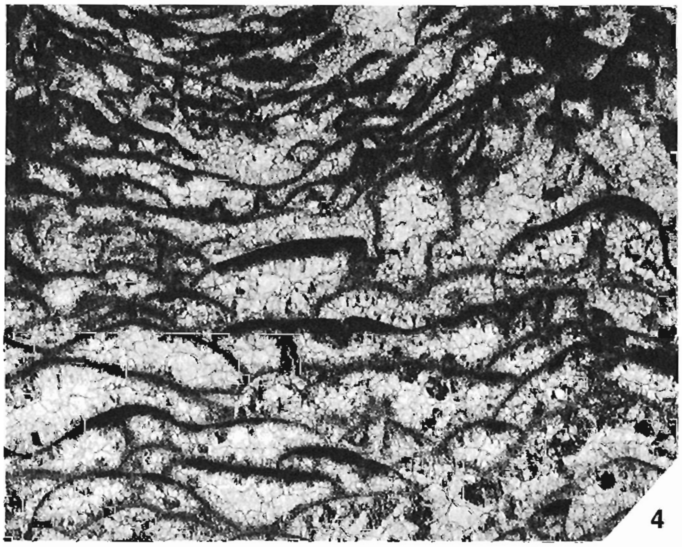
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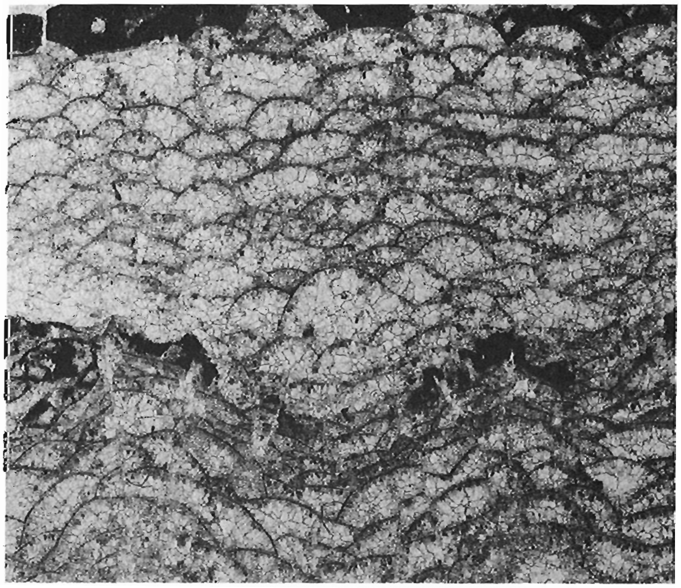
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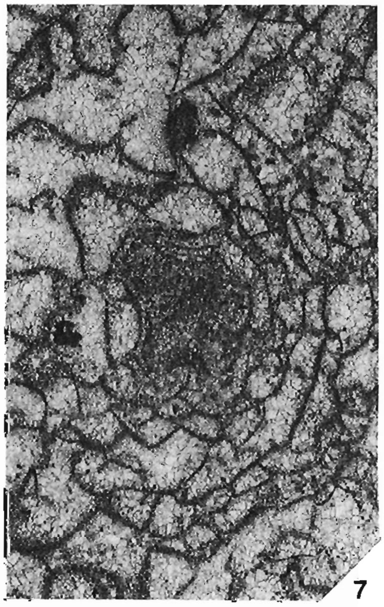
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## PLATE 2.4

Figure 1. *Cystostroma* sp. 1

Vertical section showing large cysts at base of coenosteum passing upward into smaller cysts, hypotype, GSC 82919, x10, Churchill River Group, GSC locality 84561, Rocky Brook, Southampton Island, District of Keewatin.

Figures 2-6, 9-11. *Cystostroma* sp. 2

2. Vertical section showing zone of abundant villi, hypotype, GSC 82923, x20, Selkirk Member, Red River Formation, GSC locality 87416, Gillis Quarries Limited Quarry, Garson, Manitoba.

3, 9. Vertical section, two levels, showing scattered villi, hypotype, GSC 82921, x5, Portage Chute Formation, GSC locality 25257, Nelson River, Manitoba.

4, 6, 10. Vertical sections from different levels in a coenosteum composed mainly of small cysts, hypotype, GSC 82922, x5, x20, and x5, respectively, same locality as fig. 3.

5. Vertical section showing abundant villi on larger cysts, hypotype, GSC 82924, x10, same locality as fig. 2.

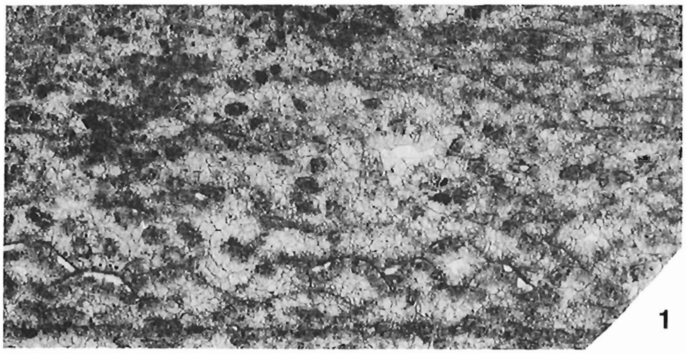
11. Vertical section, hypotype, GSC 82926, x10, Dog Head Member, Red River Formation, GSC locality 2951, Berens Island, Manitoba.

Figure 8. *Cystostroma* sp. 3

Vertical section showing large and small cysts, hypotype, GSC 82927, x5, Chasm Creek Formation, GSC locality 25290, Churchill River, Manitoba.

Figure 7. *Aulacera undulata* (Billings)

Cross-section showing central core surrounded by zone of large cysts and an outer zone of smaller cysts, hypotype, GSC 82931, x10, Ellis Bay Formation, GSC locality 62248, Anticosti Island, Québec.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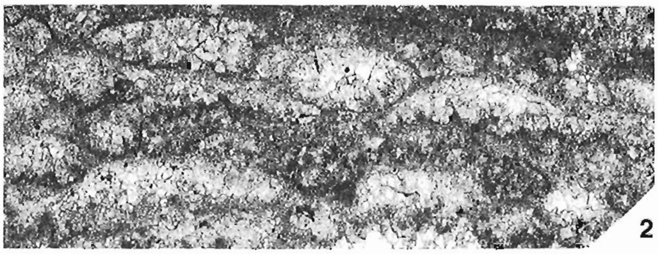
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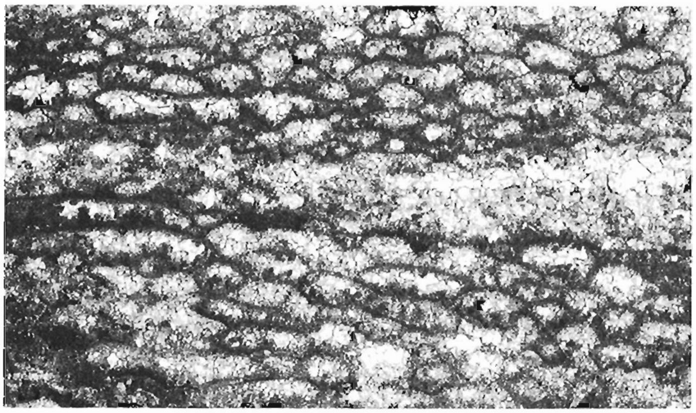
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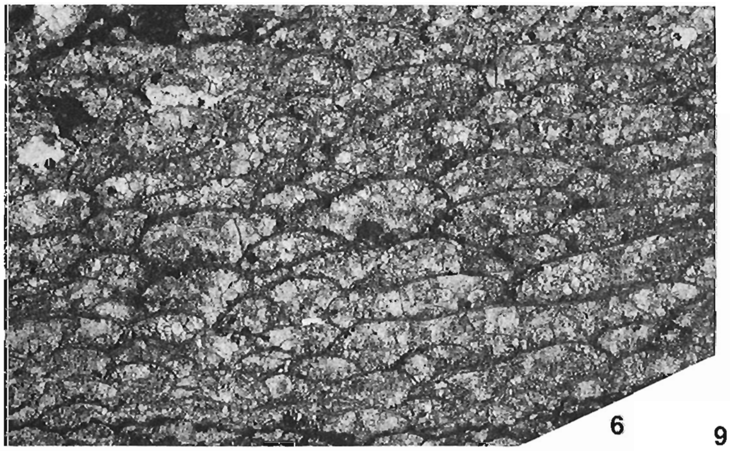
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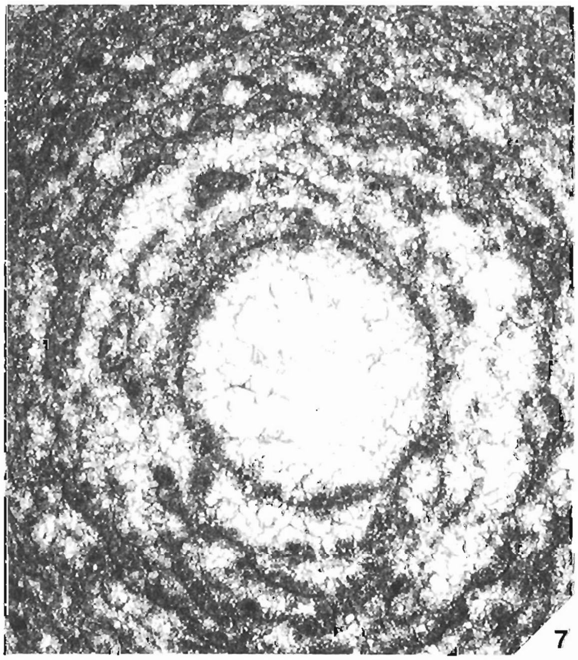
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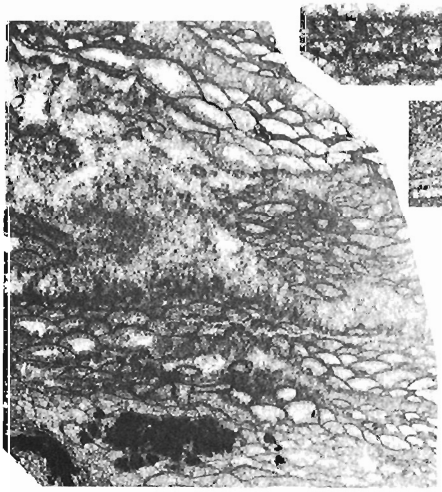
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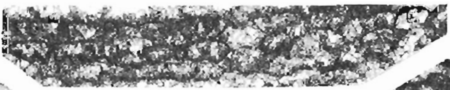
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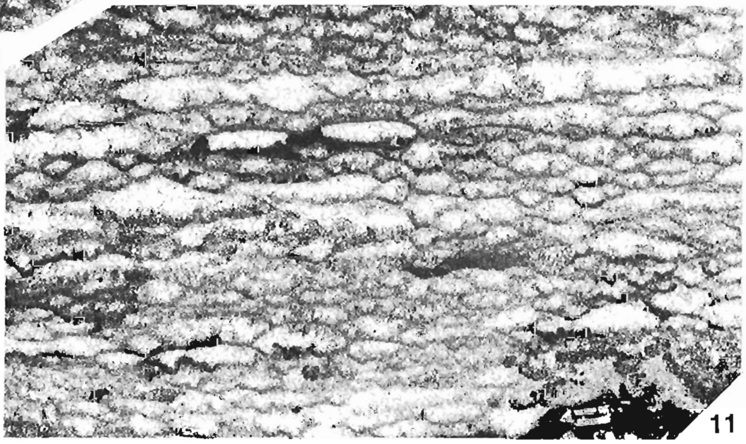
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## PLATE 2.5

Figures 1, 3, 8, 9. *Aulacera undulata* (Billings)

Anticosti Island, Québec

1. Coenostea, hypotype, GSC 82933, x1, Vaureal Formation (Richmondian), GSC locality 66781, main highway 1 to 1.5 miles (1.6 to 2.4 km) east of Jupiter River road (1964).

3. Coenostea, x1, hypotype, GSC 82949, GSC locality 2672, Battery Point.

8. Transverse section of angulate coenosteum, hypotype, GSC 82929, x20, Ellis Bay Formation (Gamachian), GSC locality 33630, south bank Salmon River 3.06 miles (4.92 km) from mouth.

9. Transverse section showing radial pillars and troughs, hypotype, GSC 82932, x10, Vaureal Formation, GSC locality 76091, Loon Lake road 0.1 miles (0.16 km) south of main highway.

Figure 2. *Aulacera cylindrica* (Foerste)

Coenosteum, hypotype, GSC 82945, x1, Vaureal Formation, GSC locality 66811, Loon Lake – Bear Lake road 1.40 to 1.47 miles (2.25 to 2.36 km) south of main highway.

Figures 4, 6, 10. *Aulacera nodulifera* (Foerste)

4. Natural vertical section, hypotype, GSC 82939, x1, Vaureal Formation, GSC locality 33709, main highway 17 miles (27.3 km) from Port Menier.

6. Natural vertical section, hypotype, GSC 29638, x1, Ellis Bay Formation, GSC locality 84344, main highway just west of Vaureal River.

10. Coenosteum, hypotype, GSC 82941, x1, Vaureal Formation, GSC locality 2672, Battery Point.

Figure 5. *Aulacera nodulosa* (Billings)

Coenosteum, hypotype, GSC 82935, x1, Vaureal Formation, GSC locality 66781, main highway 1 to 1.5 miles (1.6 to 2.4 km) east of Jupiter River road (1964).

Figure 7. *Aulacera radiata* Galloway and St. Jean

Transverse section showing radial ridges of single cysts and variation in size of cysts, hypotype, GSC 82948, x10, Ellis Bay Formation, GSC locality 98443, Baie de la Tour road 9.9 km north of main highway.


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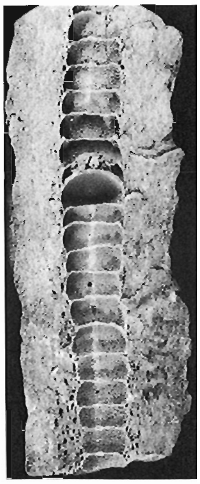
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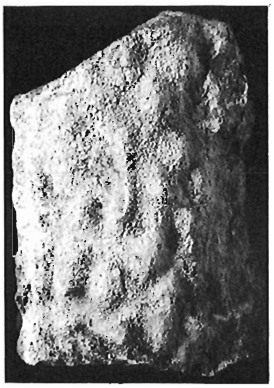
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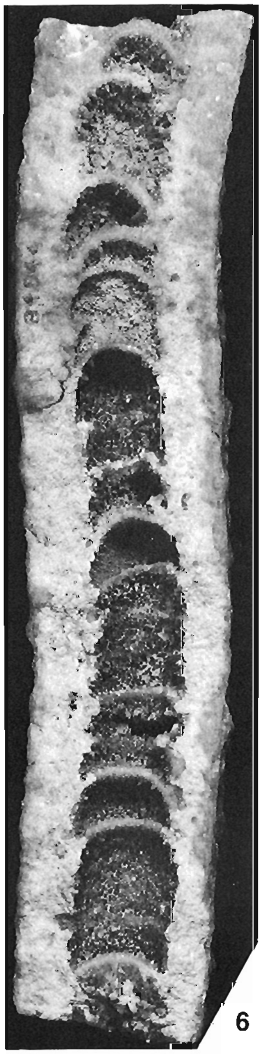
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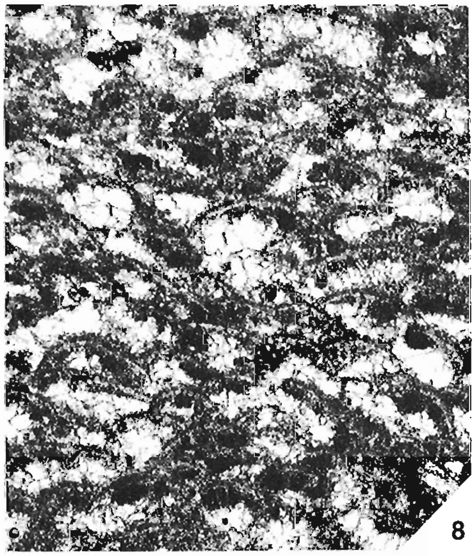
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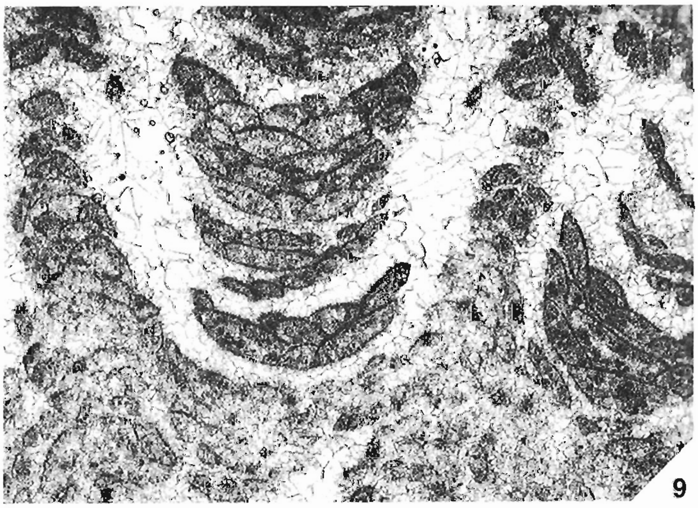
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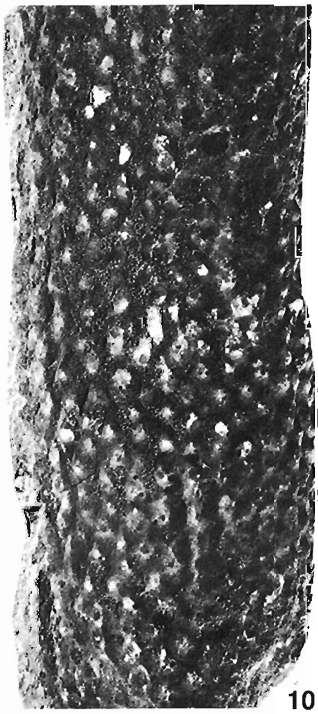
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## PLATE 2.6

Figures 1-4, 6. *Clathrodictyon* aff. *C. boreale* group of Nestor, 1964

Ellis Bay Formation (Gamachian), Anticosti Island, Québec.

1. Vertical section, hypotype, GSC 82956, x40, Pointe Laframboise.
2. Vertical section, hypotype, GSC 82955, x10, west side of Gamache or Ellis Bay.
3. Vertical section, hypotype, GSC 82960, x10, GSC locality 91457, Salmon River road, 1.9 miles (3.05 km) from mouth of river.
4. Vertical section, hypotype, GSC 82950, x10, GSC locality 98434, Baie de la Tour road, 6.0 to 6.4 km north of main highway.
6. Tangential section, hypotype, GSC 82952, GSC locality 98451, Baie de la Tour road, 6.75 km north of main highway.

Figure 5. *Ecclimadictyon* sp.

Vertical section, hypotype, GSC 82964, x10, Portage Chute Formation (Edenian), GSC locality 25315, North Knife River, Manitoba.

Figures 7, 8. *Clathrodictyon* sp. 1

Vertical sections from different levels, hypotype, GSC 82962, x20 and x10, Vaureal Formation (Richmondian), bioherm on main highway south of Lac Ste. Marie, Anticosti Island, Québec.

Figure 9. *Clathrodictyon* sp. 2

Vertical section, hypotype, GSC 82963, x10, Chasm Creek Formation (Richmondian), Churchill River, Manitoba.


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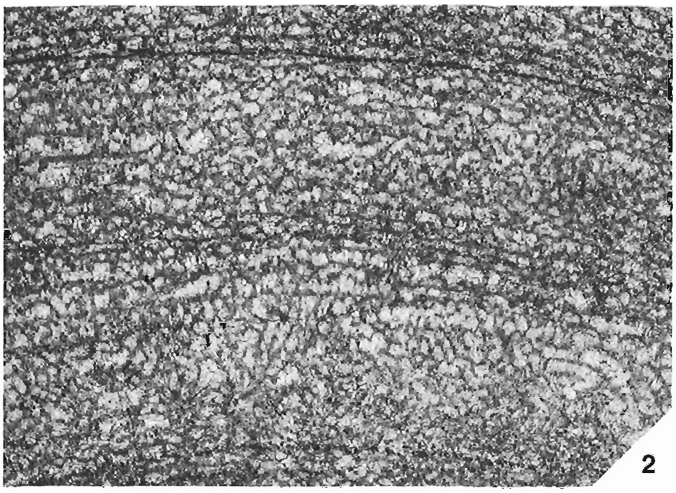
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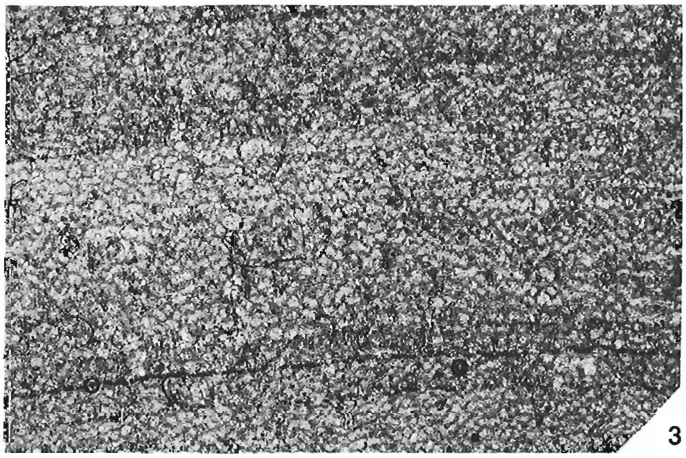
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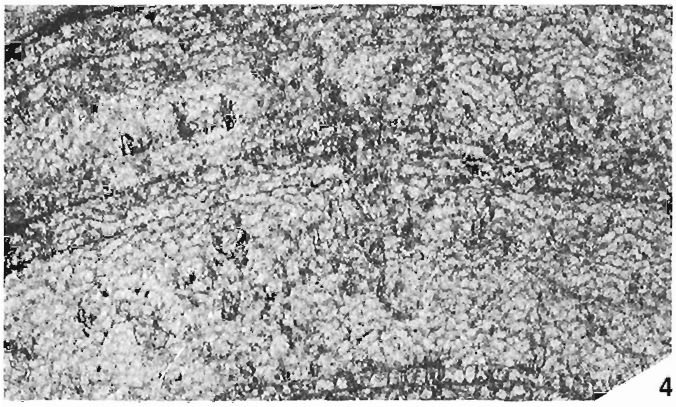
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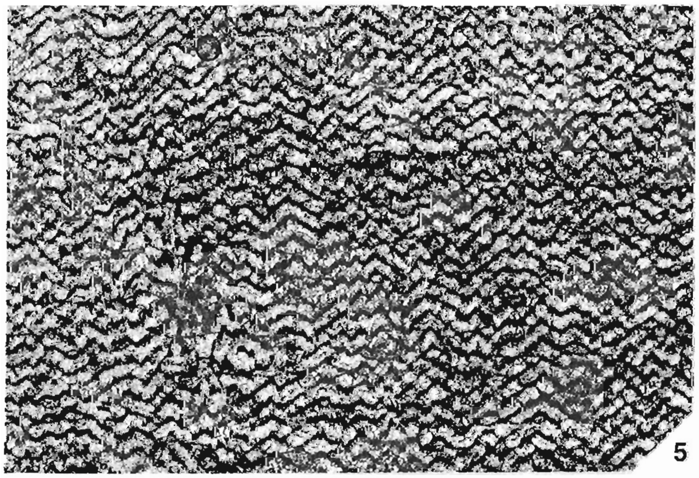
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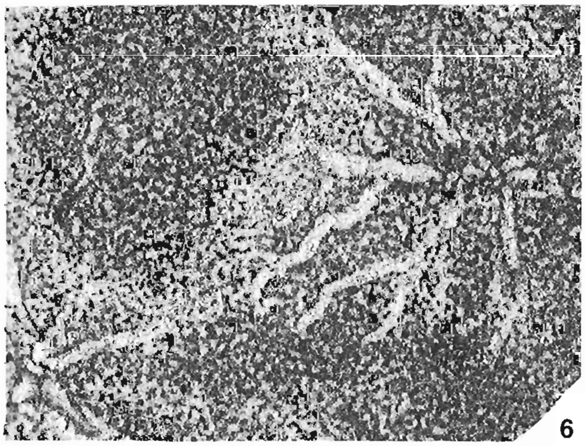
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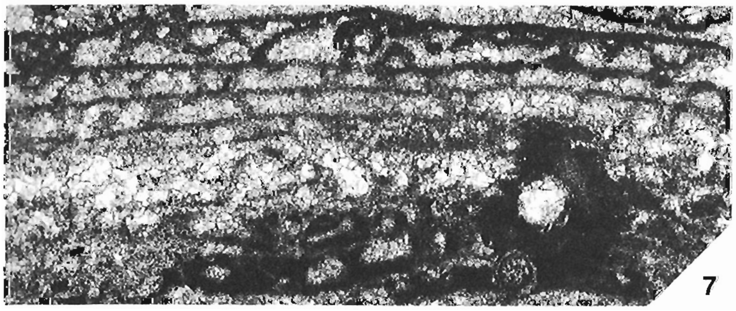
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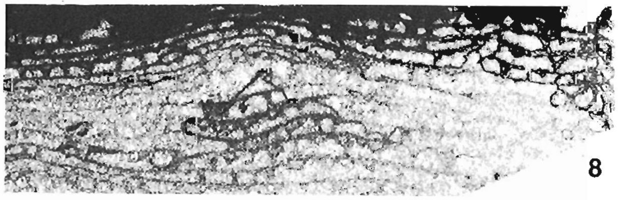
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## PLATE 2.7

Figures 1, 2. *Cryptophragmus antiquatus* Raymond

Cylindrical coenostea displaying hemispherical cysts of various sizes and spacing and a thin layer of small wall cysts (upper end, fig. 1), hypotypes, GSC 85074, 85075, x1, Gull River Formation (Pamelia), Carden Township, Ontario.

Figures 3, 4. *Clathrodictyon* sp. 3

Tangential and vertical sections, hypotype, GSC 85076, x10 and x20, Fort Garry Member, Red River Formation, Mowat Farm Quarry, about 20 km north of Winnipeg, Manitoba.

Figures 5, 6. *Stromatocerium rugosum* Hall

Transverse and vertical sections, hypotype, GSC 85077, x5 and x10, Bobcaygeon Formation, GSC locality 21762, Healy Falls, Ontario.

Figures 7, 8. *Pachystylostroma*(?) *miriamae* sp. nov.

Vertical section, paratype, GSC 85078, x10 and x20, Gull River Formation (Pamelia), GSC locality 3372, McMillan's Quarry south of Chesterville, Ontario.

Figure 9. *Cystistroma canadense* (Nicholson and Murie)

Vertical section showing variation in cyst size, denticles and pillars, hypotype, GSC 85079, x5, Bobcaygeon Formation, GSC locality 20933, north of Burleigh Falls – Buckhorn Highway 36, Ontario.

Figure 10. *Cystostroma minimum* (Parks)

Vertical section, hypotype, GSC 85083, x5, Bobcaygeon Formation, GSC locality 9095, lots 24-25, concession 9, Carden Township, Ontario.


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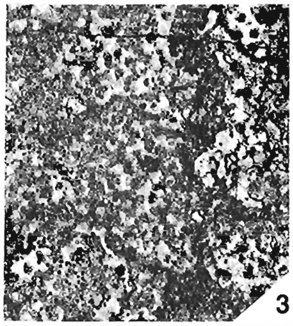
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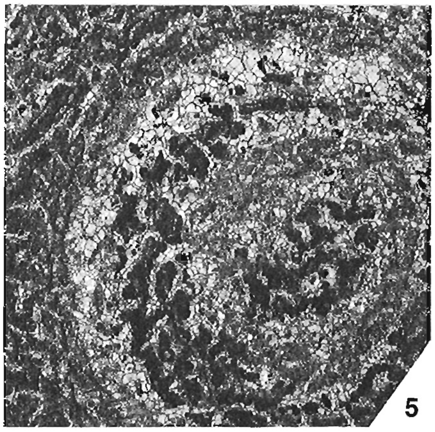
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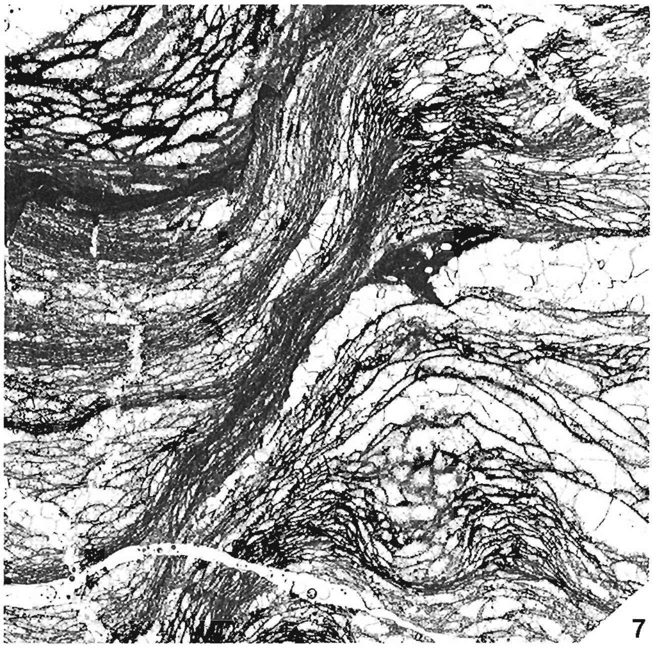
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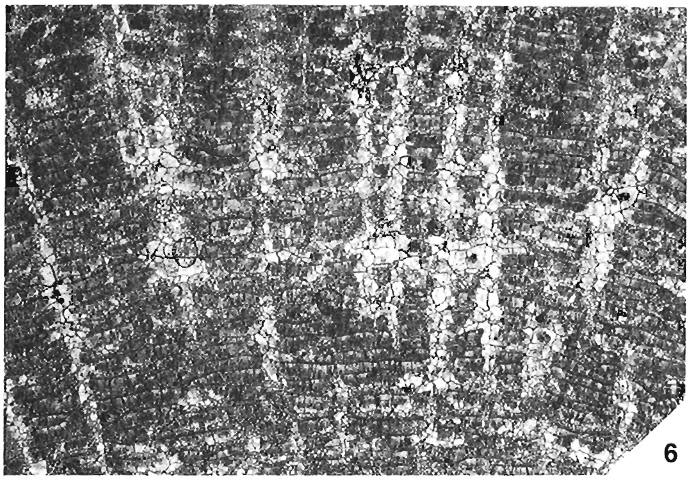
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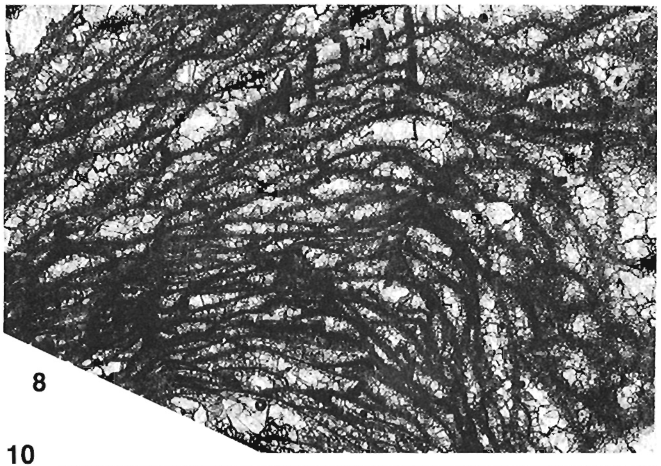
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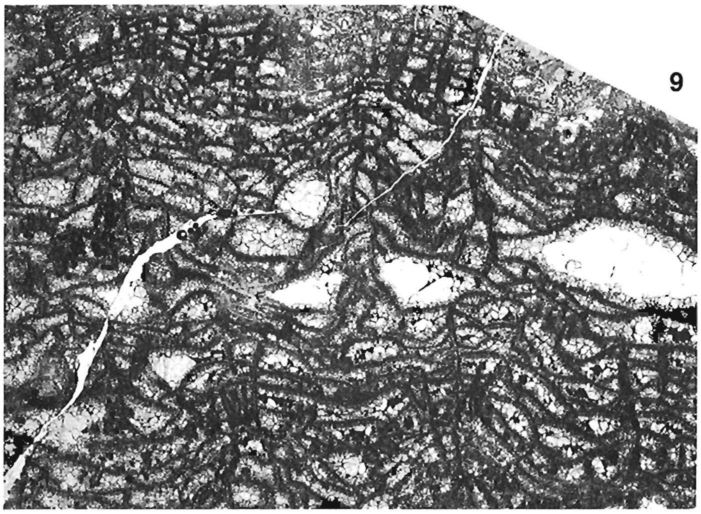
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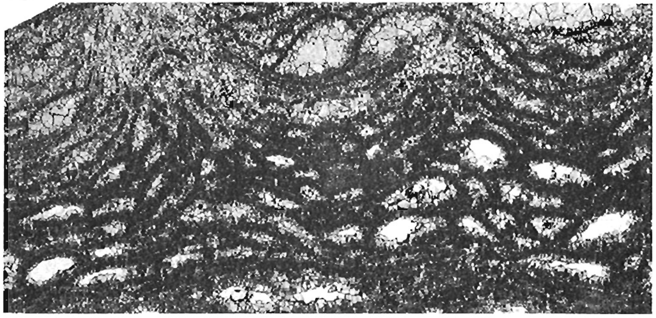
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## PLATE 2.8

Figure 1. *Stromatocerium* sp. 1

Cat Head Member (?), Red River Formation, Outer Sturgeon Island, Lake Winnipeg, Manitoba.

Tangential section showing isolated short plate-like pillar ends, hypotype, GSC 82916, x20.

Figures 2, 3. *Cystistroma canadense* (Nicholson and Murie)

Simard beds, Plourde Quarry, Chicoutimi area, Quebec.

Tangential-vertical views showing oval pillars and pillars of variable length, hypotype, GSC 85892, x10, and vertical section with three long pillars, x20.

Figure 4. *Cystistroma canadense* (Nicholson and Murie)

Same locality as figure 2.

Vertical section displaying long and short pillars and rare denticles, hypotype, GSC 85893, x10.

Figures 5, 6. *Pachystylostroma*(?) *miriamae* sp. nov.

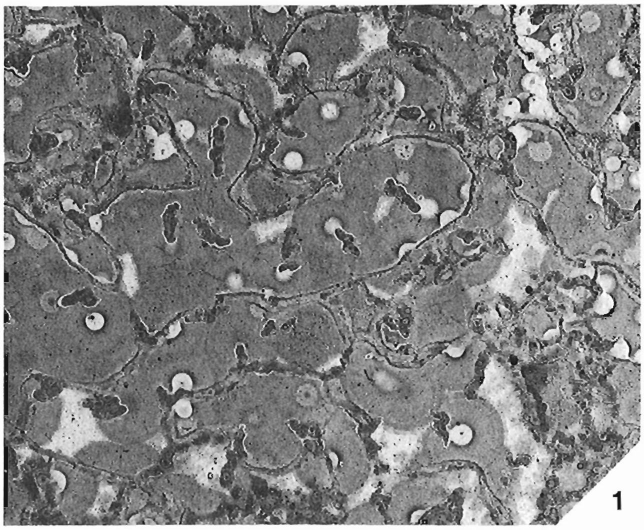
Ottawa Formation, west end Scott Street Transitway cut, Ottawa, Ontario.

Vertical sections from different levels of a coenosteum showing small denticles and rare short pillars, holotype, GSC 85290, x10.

Figure 7. *Pachystylostroma*(?) *miriamae* sp. nov.

Same locality as figure 5.

Tangential section, holotype, GSC 85290, x20.



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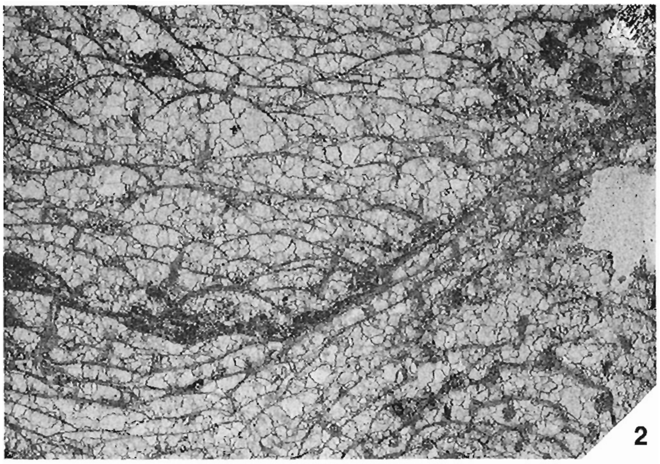

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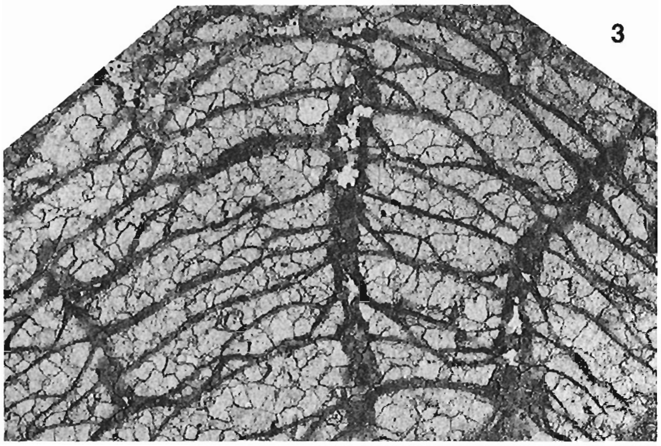

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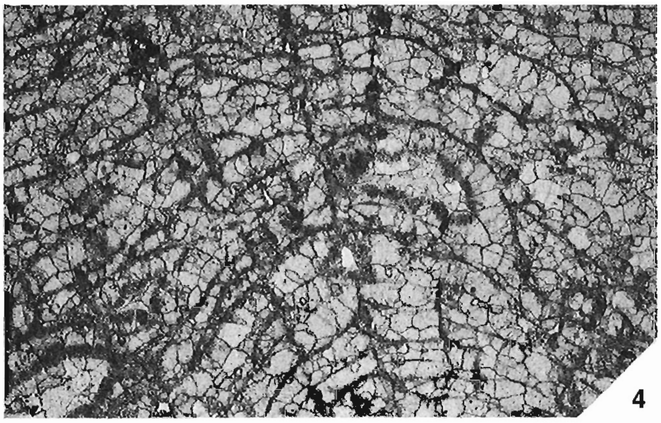

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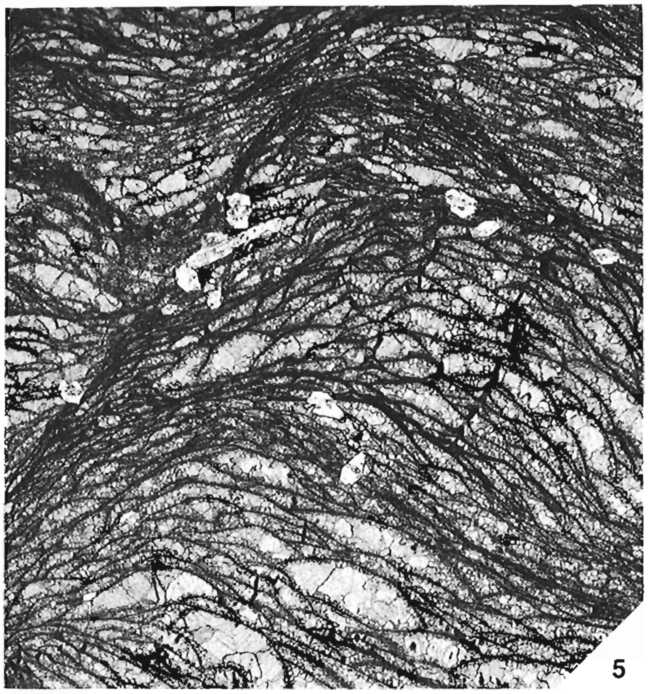

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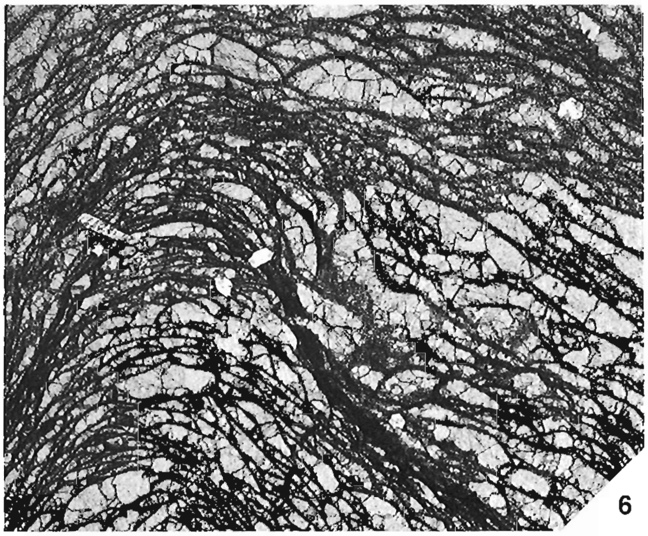

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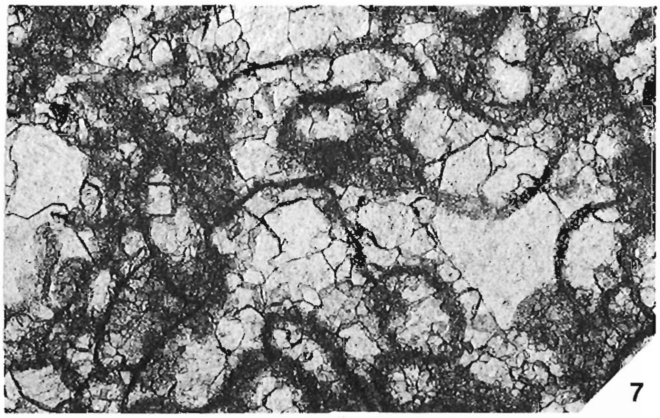

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# UPPER ORDOVICIAN TO LOWERMOST SILURIAN SOLITARY RUGOSE CORALS FROM THE BEAVERFOOT FORMATION, SOUTHERN ROCKY MOUNTAINS, BRITISH COLUMBIA AND ALBERTA

**Caroline J. Buttler[1], Robert J. Elias[2], and B.S. Norford[3]**

*Buttler, C.J., Elias, R.J., and Norford, B.S., Upper Ordovician to Lowermost Silurian solitary rugose corals from the Beaverfoot Formation, southern Rocky Mountains, British Columbia and Alberta; in Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 379, p. 47-91, 1988.*

## *Abstract*

*Salvadorea distincta distincta* (Wilson, 1926), *Salvadorea* sp. 2 of Nelson, 1981, *Bighornia patella* (Wilson, 1926), *B.* cf. *B. bottei* Nelson, 1963, *Grewingkia haysii haysii* (Meek, 1865), and *Deiracorallium prolongatum* (Wilson, 1926) are present within the Upper Ordovician *Bighornia-Thaerodonta* Zone of the Beaverfoot Formation. *Bighornia wilsonae* sp. nov., is recognized from the Montoya Group (Second Value Dolomite) of New Mexico and Texas, and the Red River Formation (Selkirk Member) of southern Manitoba.

Paleoecological analyses suggest that *Grewingkia haysii haysii* and *Deiracorallium prolongatum* inhabited higher energy environments than *Salvadorea distincta distincta* and *Bighornia patella*, but all taxa probably lived in close proximity.

The Beaverfoot Formation accumulated within the Red River-Stony Mountain Solitary Coral Province. Solitary rugosan species in the *Bighornia-Thaerodonta* Zone represent an "epicontinental" assemblage, and all occur in the Hudson Bay Basin. The absence of "continental margin" taxa could indicate that the formation was deposited some distance from the edge of the continent, or could reflect environmental factors or geographic barriers.

The lowest occurrence of solitary Rugosa defines the base of the *Bighornia-Thaerodonta* Zone in the Beaverfoot Formation (Whisky Trail Member). Elsewhere, such *Salvadorea*-dominated coral assemblages first appear in Maysvillian to middle Richmondian strata. The zone has been traced to 420 feet (128 m) above the base of the Beaverfoot at Akutlak Creek; its top is probably Richmondian, but could be Gamachian.

Solitary Rugosa in the thick, combined "poorly fossiliferous interval" and *Eostropheodonta* Zone of the Beaverfoot Formation are completely different from those of the underlying *Bighornia-Thaerodonta* Zone. *Rhegmaphyllum* could be Upper Ordovician (Richmondian, Gamachian) to Lower Silurian (Lower Llandovery); *Dinophyllum* could be Lower to Middle Llandovery. *Streptelasma* is also present.

## *Résumé*

Dans la zone à *Bighornia-Thaerodonta* de la formation de Beaverfoot, d'âge ordovicien supérieur, on trouve *Salvadorea distincta distincta* (Wilson, 1926), *Salvadorea* sp. 2 de Nelson, 1981, *Bighornia patella* (Wilson, 1926), *B.* cf. *B. bottei* Nelson, 1963, *Grewingkia haysii haysii* (Meek, 1865) et *Deiracorallium prolongatum* (Wilson, 1926). On décrit *Bighornia wilsonae* sp. nov. du groupe de Montoya au Nouveau Mexique et au Texas, et de la formation de Red River (membre de Selkirk) dans le sud du Manitoba.

Les analyses paléoécologiques semblent indiquer que *Grewingkia haysii haysii* et *Deiracorallium prolongatum* vivaient dans des milieux de plus grande énergie que *Salvadorea distincta distincta* et *Bighornia patella*, mais tous ces taxons vivaient probablement à très grande proximité les uns des autres.

Les sédiments de la formation de Beaverfoot se sont accumulés dans la province à coraux solitaires de Red River et Stony Mountain. Ces coraux solitaires représentent un assemblage "épicontinental", et se manifestent tous dans le bassin de la baie d'Hudson. L'absence de taxons de "marge continentale" pourrait indiquer que les sédiments de cette formation se sont déposés à une certaine distance du bord du continent, ou pourrait refléter l'influence d'anciens facteurs environnementaux ou d'anciennes barrières géographiques.

Le niveau le plus bas où se manifestent les coraux solitaires Rugosa définit la base de la zone à *Bighornia-Thaerodonta* dans la formation de Beaverfoot (membre de Whiskey Trail). Ailleurs, de tels assemblages coralliens dominés par *Salvadorea* apparaissent tout d'abord dans les strates comprises entre le Maysvillien et le Richmondien moyen. La zone se prolonge jusqu'à 128 m (420 pi) au-dessus de la base de la formation de Beaverfoot dans la section d'Akutlak; son sommet est probablement d'âge richmondien, mais pourrait appartenir au Gamachien.

Les coraux solitaires Rugosa que l'on rencontre dans l'épaisse couche comprenant à la fois "l'intervalle faiblement fossilifère" et la zone à *Eostropheodonta* de la formation de Beaverfoot, diffèrent entièrement de ceux présents dans la zone à *Bighornia-Thaerodonta* sous-jacente. *Rhegmaphyllum* pourrait dater de l'Ordovicien supérieur ou du Silurien inférieur (Llandovérien inférieur), et *Dinophyllum*, du Llandovérien inférieur ou moyen. On rencontre aussi *Streptelasma*.

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## INTRODUCTION

The Beaverfoot Formation of Late Ordovician to Early Silurian age outcrops in the southern Rocky Mountains of British Columbia and Alberta (Fig. A, loc. 9; Fig. 3.1). Within this area, the original depositional strike as well as trends of thrust sheets, mountain ranges, and outcrops are all approximately parallel, trending northwest-southeast. The formation represents carbonate deposition on a broad platform inboard of the early Paleozoic continental margin of western North America. Various faunal zones have been recognized within the Beaverfoot, but the only descriptive paleontological study is by Wilson (1926).

The purposes of this study are to describe, using modern techniques, the solitary rugose corals of the Upper Ordovician *Bighornia-Thaerodonta* Zone in the Beaverfoot Formation, to document their geographic and stratigraphic distribution, to provide paleoecological interpretations, and to examine their paleobiogeographic relationships and evolution. Uppermost Ordovician to lowermost Silurian solitary Rugosa in the lower portion of the succeeding, combined "poorly fossiliferous interval" and *Eostropheodonta* Zone in the Beaverfoot are identified. The biostratigraphic significance of these fossils is considered using comparisons with corals described from elsewhere in North America (Nelson, 1963, 1981; Laub, 1979; Elias, 1981, 1982a, 1983a, 1983b, 1985, 1986a; Elias and Potter, 1984; McAuley, 1985), and a chronostratigraphic framework based primarily on conodont data (Sweet, 1979, 1984; McCracken and Barnes, 1981; Barrick, 1986; see Elias, 1985, and McAuley, 1985).

Biometric and other data relevant to this paper were presented by Knapp (1985, appendices 2-5).

### Abbreviations

The following abbreviations are used in referring to depositories of specimens: GSC = Geological Survey of Canada, Ottawa, Ontario; MMH = Museum mineralogicum hafniensis, Geologisk Museum, Copenhagen, Denmark; PMO = Paleontologisk Museum, Oslo, Norway; USNM = National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A.

### Acknowledgments

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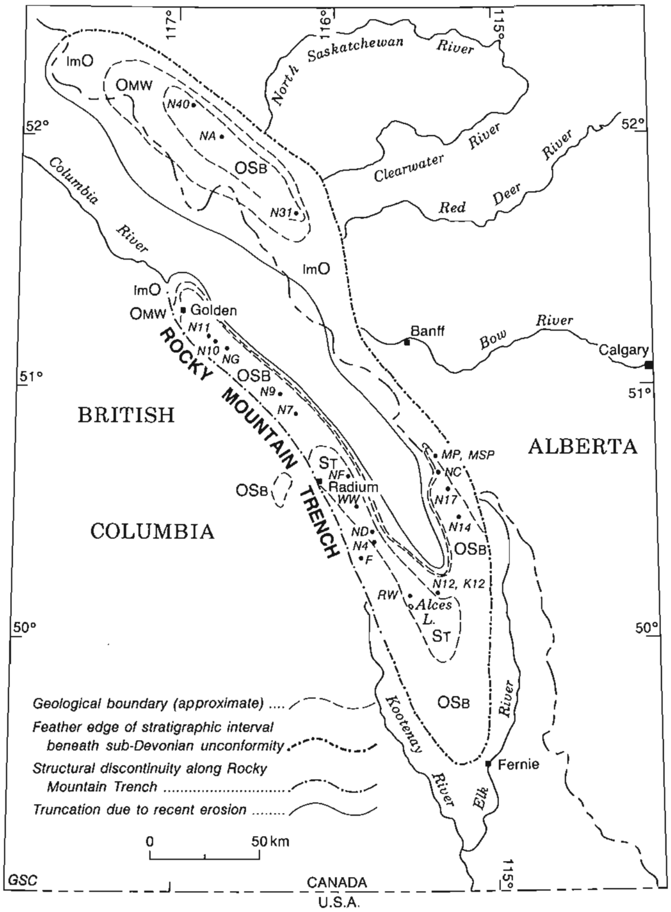

***Figure 3.1.*** *Geological map of part of the southern Rocky Mountains (from Norford, 1969, Fig. 6)* ST = *Tegart Formation (Silurian),* OSB = *Beaverfoot Formation (Upper Ordovician to Lower Silurian),* OMW = *Mount Wilson Quartzite (Middle-Upper Ordovician),* lmO = *upper Lower to Middle Ordovician (Owen Creek Formation, Skoki Formation, Tipperary Quartzite, Glenogle Shales, upper parts of Outram Formation and McKay Group). Solitary rugose corals were collected from the Beaverfoot Formation at 21 locations, as follows:* ***MP*** *= Palliser Pass,* ***WW*** *= Windermere Creek,* ***MSP*** *= between Spray and Palliser rivers,* ***F*** *= Fairmont Springs,* ***RW*** *= White Knight Mountain,* ***NA*** *= Mount Wilson,* ***NC*** *= Tipperary Lake,* ***ND*** *= Pedley Pass,* ***NF*** *= Mount Sinclair,* ***NG*** *= Carbonate Creek,* ***N4*** *= Indianhead Mountain,* ***N7*** *= Pinnacle Creek,* ***N9*** *= Hatch Creek,* ***N10*** *= Pagliaro Creek,* ***N11*** *= Horse Creek,* ***N12*** *= Blackfoot Creek,* ***N14*** *= Shatch Mountain,* ***N17*** *= Mount Onslow,* ***N31*** *= Pipestone River,* ***N40*** *= Cirrus Mountain,* ***K12*** *= Akutlak Creek.*

## GENERAL GEOLOGY

### Lithostratigraphy

The history of Ordovician-Silurian stratigraphic nomenclature in the southern Rocky Mountains of British Columbia and Alberta has been summarized by Norford (1969, p. 5, 8, 9; Figs. 4, 5).

The contact of the Beaverfoot Formation with the underlying Middle to Upper Ordovician Mount Wilson Quartzite is not visible at the type section of the Beaverfoot (Carbonate Creek). The contact at the standard section (Pedley Pass) is irregular but concordant, as it is throughout most of the southern Rockies. At Pinnacle Creek, shallow erosional surfaces are present between the Beaverfoot and Mount Wilson. In the south and southeast, the Beaverfoot Formation overlaps the Mount Wilson Quartzite to rest on older Ordovician and Cambrian rocks (Fig. 3.1), and thus a sub-Beaverfoot hiatus may be present throughout the region. The thickness of the Beaverfoot Formation at Pedley Pass, where it is overlain by the Silurian Tegart Formation, is 1661 feet (506.3 m). Eastward the Beaverfoot is truncated beneath a regional sub-Devonian unconformity.

The Whiskey Trail Member at the base of the Beaverfoot Formation is of variable thickness: 93 feet (28.3 m) thick at the type section of the member (Carbonate Creek), 105 feet (30.1 m) at Akutlak Creek, but only 7 feet (2.1 m) thick at Tipperary Lake. The Whiskey Trail is not present where the main part of the Beaverfoot overlaps the Mount Wilson Quartzite. The distribution pattern of this member more closely resembles that of the Mount Wilson than that of the main Beaverfoot, and the contact with the main part of the Beaverfoot Formation probably is regionally disconformable but within the span of the *Bighornia-Thaerodonta* Zone. The Whiskey Trail Member consists of dolomitic quartz sandstone with minor and typically thin bedded quartzite layers, arenaceous and argillaceous dolostone, dolostone with echinoderm debris, and olive-grey mudstone.

The main part of the Beaverfoot Formation is composed of medium and thick bedded, resistant dolostone, which weathers in colours ranging from pale yellowish brown to light grey and olive. The dolostone is composed of silt-sized grains to finely crystalline mosaics. Some beds contain siliceous material and rarely quartz silt. At Pedley Pass and near Blackfoot Creek, limestone and dolomitic limestone are preserved. The limestone is aphanitic and weathers light grey. The Silurian Tegart Formation conformably overlies the Beaverfoot Formation in the southwestern part of the southern Rocky Mountains, but elsewhere is absent, and Devonian rocks rest unconformably on various horizons within the Beaverfoot and below.

### Biostratigraphy

Some time ago (Norford, 1969, p. 38), a "conodont zone" was recognized comprising the Whiskey Trail Member of the Beaverfoot Formation and the underlying uppermost beds of the Mount Wilson Quartzite. The term came from the report of a prolific conodont fauna recovered from one sample taken 9 feet (2.7 m) above the base of the Whiskey Trail Member at Pedley Pass, which yielded species of *Belodina*, *Cordylodus*, *Cyrtoniodus*, *Drepanodus*, *Euprioniodina*(?), *Ligonodina*, *Lonchodus*, *Panderodus*, *Prioniodina*, *Oistodus*, *Ozarkodina*, *Roundya*, *Spathognathodus*, and *Zygognathus* (Sanders in Norford, 1962a, p. 450; and Norford, 1969, p. 38). At Pedley Pass, conodonts from 4 to 14 feet (1-4 m) above the base of the Whiskey Trail Member (GSC loc. C-45551; C.R. Barnes, pers. comm.) indicate an early Maysvillian to Richmondian age and include:

*Aphelognathus pyramidalis* (Branson, Mehl, and Branson)
*Drepanodus suberectus* (Branson and Mehl)
*Oulodus ulrichi* (Stone and Furnish)
*Panderodus* sp.
*P. gracilis* (Branson and Mehl)
*Pseudobelodina kirki*? Ethington and Furnish

On cursory examination, the macrofossils (primarily brachiopods and corals) in the "conodont zone" were thought to be distinct from those of the overlying *Bighornia-Thaerodonta* Zone (Norford, 1969, p. 30, 31). Recent collections from the upper 16 feet (5 m) of the 105 foot (30.1 m) thick Whiskey Trail Member at Akutlak Creek (GSC locs. C-107994, C-107995; intervals A14 to A16 of Fig. 3.4), have yielded the following biota (bryozoans identified by T.E. Bolton):

echinoderm fragments
*Hallopora* aff. *H. dumalis* (Ulrich) and other bryozoans
*Receptaculites* sp. and other algae
*Bighornia patella* (Wilson)
*Deiracorallium prolongatum* (Wilson)
*Grewingkia haysii haysii* (Meek)
*Salvadorea distincta distincta* (Wilson)
*Catenipora* aff. *C. workmanae* Flower
*Favistina* sp.
?*Mendacella* sp.
*Oepikina* sp.
*Platystrophia* aff. *P. elegantula* McEwan
*Zygospira* aff. *Z. sulcata* Howe

Although the brachiopods are different from those of the *Bighornia-Thaerodonta* Zone in the overlying carbonates of the basal beds of the main part of the Beaverfoot Formation, the solitary corals are characteristic of that zone. The upper beds of the Whiskey Trail Member are therefore included within the lower part of the *Bighornia-Thaerodonta* Zone.

In the main part of the Beaverfoot Formation, four assemblage zones can be recognized, based on corals, brachiopods and trilobites, in ascending stratigraphic order: the rest of the *Bighornia-Thaerodonta* Zone, *Eostropheodonta* Zone, *Pentamerus* Zone, and the *Eophacops-Cheirurus* Zone. The first two, and the intervening "poorly fossiliferous interval", are relevant to the present study.

The thickness of the *Bighornia-Thaerodonta* Zone is uncertain because of the sparsity of fossils in overlying beds and in the lower beds of the Whiskey Trail Member. The zone is documented at Mount Sinclair as about 212 feet (65 m) thick and at Akutlak Creek as about 420 feet (128 m) thick. Corals are abundant and distinctive. The conodonts in the following regional composite faunal list (from beds above the Whiskey Trail Member) were identified by C.R. Barnes and T.T. Uyeno:

*Bighornia* cf. *B. bottei* Nelson
*Bighornia patella* (Wilson)
*Deiracorallium prolongatum* (Wilson)
*Grewingkia haysii haysii* (Meek)
*Salvadorea distincta distincta* (Wilson)
*Salvadorea* sp. 2 of Nelson (1981)
*Catenipora robustus* (Wilson)
*Catenipora delicatulus* (Wilson)

*Favistina alveolata stellaris* (Wilson)
*Favistina* aff. *F. stellata* (Hall)
*Paleofavosites* sp.
*Palaeophyllum halysitoides* (Wilson)
*Palaeophyllum primum* (Wilson)
*Palaeophyllum* sp.
*Sarcinula burlingi* (Wilson)
*Sarcinula* sp.
*Diceromyonia* aff. *D. tersa* (Sardeson)
*Plaesiomys columbia* (Wilson)
*Plaesiomys rockymontana* (Wilson)
*Rhynchotrema increbescens occidens* Wilson
*Rhynchotrema kananaskia* Wilson
*Rhynchotrema windermeris* Wilson
*Thaerodonta* aff. *T. saxea* (Sardeson)
*Acontiodus*? sp.
*Drepanodus*? sp.
*Drepanoistodus suberectus* (Branson and Mehl)
*Oulodus ulrichi* (Stone and Furnish)
*Panderodus* cf. *P. feulneri* (Glenister)
*Panderodus gracilis* (Branson and Mehl)
*Prioniodina* cf. *P. oregonia* Branson, Mehl, and Branson
*Pseudobelodina kirki*? Ethington and Furnish

A "poorly fossiliferous interval" was recognized in the Beaverfoot Formation between the *Bighornia-Thaerodonta* Zone and the *Eostropheodonta* Zone (Norford, 1969, p. 39). It is 405 feet (123.4 m) thick at Pedley Pass and 800 feet (243.8 m) thick at Mount Sinclair, but, by its very nature, some parts probably belong to the two zones. Fauna 12 conodonts (identified by C.R. Barnes and T.T. Uyeno) are present in the *Bighornia-Thaerodonta* Zone at Pedley Pass and some species extend some 62 feet (19 m) higher. Nondiagnostic elements are present above this horizon, 228 feet (69.5 m) above the base of the Beaverfoot.

The *Eostropheodonta* Zone (Lower Silurian, Middle or possibly Lower Llandovery) was measured as about 837 feet (255 m) thick at Pedley Pass and at least 300 feet (90 m) thick at Mount Sinclair, where the stratigraphic section ends at a fault within the zone. Recent collections made by James Mott, from northeast of White River, reveal that fossils indicating this zone occur less than 328 feet (100 m) above the *Bighornia-Thaerodonta* Zone. Fossils are sparse in this thick stratigraphic interval, and the overlap of the *Eostropheodonta* Zone with the "poorly fossiliferous interval" is probably significant from section to section. Recognition as a formal zone seems to have been premature, and biostratigraphic assessment requires more detailed sampling of the faunas of the whole interval between the *Bighornia-Thaerodonta* Zone and the *Pentamerus* Zone. A composite regional faunal list for the combined "poorly fossiliferous interval" and *Eostropheodonta* Zone includes:

*Dinophyllum* sp.
*Rhegmaphyllum* sp.
*Streptelasma fragile* Wilson
*Streptelasma* sp.
?*Aulaporella* sp.
*Catenipora* sp.
*Favosites* sp.
*Paleofavosites* sp.
"*Syringopora*" *columbiana* Wilson
*Alispira* sp.
*Dalmanella* sp.
*Hesperorthis* sp.
*Leptostrophia* (*Eostropheodonta*) sp.
*Nondia* sp.
?*Virgiana* sp.
*Eophacops* sp.
*Encrinurus* sp.

### Geological history

Early Paleozoic sediments preserved in the southern Rocky Mountains of British Columbia and Alberta accumulated along a passive continental margin. The Whiskey Trail Member of the Beaverfoot Formation was probably deposited during a marine transgression across a surface that was mantled by detritus of the Mount Wilson Quartzite. The variable thickness of this member could reflect the presence of local pockets of debris, or topographic irregularities. An alternative hypothesis is that the Whiskey Trail represents a continuation of the Mount Wilson transgressive phase, with deposition in deeper water.

No detailed studies have been made of the depositional environments of the Beaverfoot Formation. During Late Ordovician and most of Early Silurian time, a broad belt of shelf-type carbonate sediments extended beyond the limits of the Mount Wilson Quartzite and probably covered the entire area now preserved in the southern Rocky Mountains, extending westward beyond the site of the present Rocky Mountain Trench (Fig. 3.1).

## SOLITARY RUGOSE CORALS OF THE *BIGHORNIA-THAERODONTA* ZONE

### Previous work

Kirk (in Walcott, 1924, p. 13) identified *Streptelasma rusticum* (Billings) and apparently also *S. trilobatum* Whiteaves from the Beaverfoot Formation. Several solitary corals of the Beaverfoot Formation were described by Wilson (1926, p. 2, 11-13) on the basis of collections made by J.R. Marshall, E.M. Kindle, J.F. Walker, and L.D. Burling (see also Walker, 1926, p. 32, 33, and Evans, 1933, p. 140, 141). Wilson assigned these specimens to four new species: *Streptelasma fragile*, *S. prolongatum*, *S. distinctum*, and *S. patellum*, considering them to be Late Ordovician (Richmondian) in age. Kirk (1927, p. 287), reviewing Wilson's paper, stated that *S. fragile* was from Silurian strata, as later confirmed by Norford (1962a, p. 450; 1969, p. 39, *Eostropheodonta* Zone).

From beds in the lower part of the Beaverfoot Formation, considered Richmondian, Howell (in Henderson, 1954, p. 70, 75) identified *Streptelasma* sp., *S. fragile*, *S. prolongatum*, and *S. distinctum*, and Bolton (in Leech, 1954, p. 20-24) reported *Streptelasma* sp., *S. prolongatum*, *S. distinctum*, and *S. trilobatum*.

### Present material

A total of 391 solitary rugose corals from the *Bighornia-Thaerodonta* Zone of the Beaverfoot Formation at 21 locations in the southern Rocky Mountains of British Columbia and Alberta were examined during this study (Table 3.1, Fig. 3.1). Material was obtained from the following sources: 21 specimens from the early collections described by Wilson (1926), 5 specimens from the collection of Root (1955), 197 specimens collected by Norford (mostly documented in Norford, 1969), and 168 specimens (161 *in situ*, 7 from outcrop rubble and talus) collected especially for the present study from the basal 420 feet (128 m) of the Beaverfoot Formation at Akutlak Creek (sections K12A and

K12B, Fig. 3.2). This location was selected for detailed study because the Beaverfoot there is not dolomitized, is relatively fossiliferous, and its fossils are comparatively well preserved. The strata are nearly vertical (Fig. 3.3). The lower 115 feet (35 m) of section were measured along the ridge crest, and an additional 305 feet (93 m) were measured along the base of the ridge. The continuous exposure was carefully examined for solitary corals, and all specimens seen were collected. Therefore, the data in Figure 3.4 provide an indication of relative abundance.

### Preservation

Specimens from almost all locations are silicified and are in poor condition. The best material is from the Akutlak Creek area, where many coralla have some fibrous microstructure preserved in calcite.

### Identification and relative abundance of taxa

Solitary rugose corals of the *Bighornia-Thaerodonta* Zone can be divided into the following three groups on the basis of external form: typically trochoid, subcalceoloid, and triangulate to trilobate. On the basis of ontogeny and internal structures, virtually all of the typically trochoid specimens that have approximately circular cross-sections are assigned to *Salvadorea distincta distincta* (Wilson, 1926) (Pl. 3.1, figs. 1-15; Pl. 3.2, figs. 1, 2). One corallum with unusually thin septa is identified as *Salvadorea* sp. 2 of Nelson, 1981 (Pl. 3.2, figs. 3-6). The subcalceoloid, depressed corals have a concave cardinal side. Small to medium-sized individuals are *Bighornia patella* (Wilson, 1926) (Pl. 3.2, figs. 7-11; Pl. 3.3, figs. 1-12; Pl. 3.4, fig. 1). Two large coralla are identified as *B.* cf. *B. bottei* Nelson, 1963 (Pl. 3.4, figs. 6-11). Two subgroups of specimens having triangulate to trilobate cross-sections can be recognized. The markedly trilobate, usually depressed individuals are *Grewingkia haysii haysii* (Meek, 1865) (Pl. 3.5, figs. 1-9; Pl. 3.6, figs. 1-4). Small, triangulate to very slightly trilobate, greatly compressed coralla are *Deiracorallium prolongatum* (Wilson, 1926) (Pl. 3.7, figs. 1-11; Pl. 3.8, figs. 1-3). However, because of the external variability within these two species, an examination of internal structures is necessary to confirm identifications for some specimens. The axial structure of *G. haysii haysii* is large, whereas that of *D. prolongatum* is small or undeveloped. It is often impossible to distinguish *S. distincta distincta*, *G. haysii haysii*, and *D. prolongatum* when dealing with very small coralla representing the earliest ontogenetic stages, as preservation is usually poor.

Of the 391 solitary corals studied, 180 (46%) could be identified conclusively at the species level, 68 (17%) were assigned with less certainty, and 143 (37%) were unidentifiable. Relative abundances of taxa are indicated by the totals in Table 3.1 and Figure 3.4. *Salvadorea distincta distincta* is most common, *B. patella* and *G. haysii haysii* are common, *D. prolongatum* is rare, *B.* cf. *B. bottei* is represented by only two specimens, and *Salvadorea* sp. 2 by one.

### Geographic and stratigraphic distribution

Solitary rugose corals occur throughout the outcrop belt of the Beaverfoot Formation (Fig. 3.1). Specimens identified with various degrees of certainty as *Salvadorea distincta*

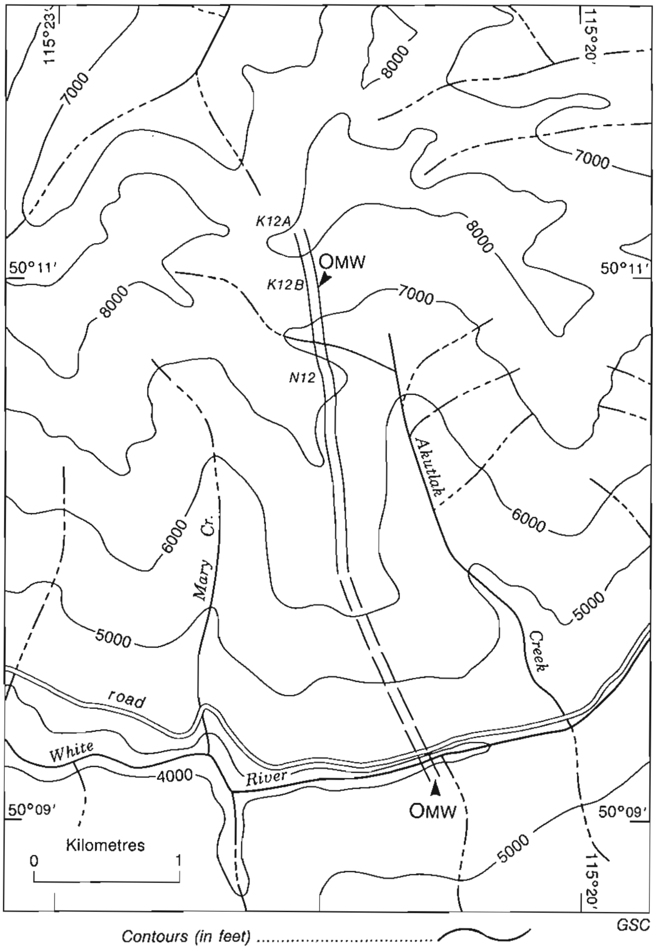

*Figure 3.2. Map showing locations **N12**, **K12A**, and **K12B**; contour interval 1000 feet (305 m), OMW = Mount Wilson Quartzite.*

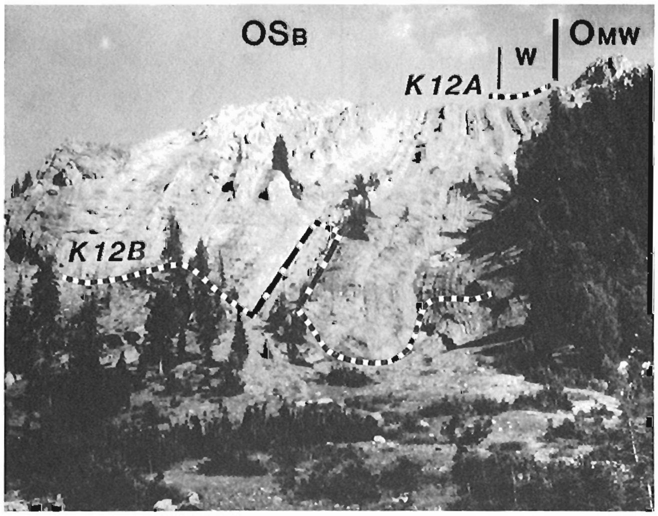

*Figure 3.3. Akutlak Creek location viewed from south, showing lines of sections **K12A** and **K12B** (dotted); OMW = Mount Wilson Quartzite, OSB = Beaverfoot Formation, W = Whiskey Trail Member of Beaverfoot (see Figs. 3.1 and 3.2 for location).*

## TABLE 3.1

Stratigraphic and geographic distribution and frequency of 391 solitary rugose corals from the *Bighornia-Thaerodonta* Zone, Beaverfoot Formation(refer to Figs. 3.1 and 3.2 for geographic locations, and Fig. 3.4 for stratigraphic positions of intervals at location K12; all positions measured from base of Beaverfoot Formation).

| Location | Coordinates | Interval[1, 2] | Position | *Salvadorea distincta distincta* | Probably *S. distincta distincta* | Possibly *S. distincta distincta* | *Salvadorea* sp. 2 | *Bighornia patella* | Probably *B. patella* | Possibly *B. patella* | *Bighornia* cf. *B. bottei* | *Grewingkia haysii haysii* | Probably *G. haysii haysii* | Possibly *G. haysii haysii* | *Deiracorallium prolongatum* | Probably *D. prolongatum* | Possibly *D. prolongatum* | *G. haysii haysii* or *S. distincta distincta* | *G. haysii haysii* or *D. prolongatum* | Unidentifiable | Total number of solitary corals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MP | 50°42.5'N,<br>115°23'W | 7561 | ? | 1 | | | | 1 | | | | | | | 1 | | | | | | 3 |
| | | 7563 | ? | 4 | | | | | | | | 1 | | | 1 | | | 1 | | | 7 |
| WW | ? | 7933 | 163 ft.<br>(49.7 m) | | | 1 | | | | | | | | | | | | | | | 1 |
| | | 7935 | 50 ft.<br>(15.2 m) | | | | | 1 | | | | | | | | | | | | | 1 |
| MSP | ? | 7969 | ? | 1 | | | | | | | | | | | | | | | | | 1 |
| F | ? | 7793 or 7851 | ? | 1 | | | | | | | | | | | | | | | | | 1 |
| RW | 50°02'N,<br>115°30.5'W | - | ? | 2 | | | | 2 | | | | 1 | | | | | | | | | 5 |
| NA | 52°00'N,<br>116°45'W | 56107 | 16-24 ft.<br>(4.9-7.3 m) | 1 | 1 | | 1 | 1 | | | | 1 | | | | | | | | 3 | 8 |
| NC | 50°40'N,<br>115°21'W | 47410 | 8-22 ft.<br>(2.4-6.7 m) | | 1 | | | | | | | | | | | | | | | 1 | 2 |
| | | 57209 | 7-16 ft.<br>(2.1-4.9 m) | 3 | | | | | | | | | | | 1 | | 1 | | | | 5 |
| ND | 50°27'N,<br>115°46'W | 47398 | 149-164 ft.<br>(45.4-50.0 m) | | | | | | | | | | | 1 | | | | | | 1 | 2 |
| NG | 51°10.5'N,<br>116°44'W | 5062 | 139 ft.<br>(42.4 m) | | | | | 4 | 2 | 1 | | | | 1 | | | | | | 17 | 25 |
| | | 5063 | 129 ft.<br>(39.3 m) | 2 | | | | 1 | | 1 | | | | | | | | | | 7 | 11 |
| | | 5064 W | 82-83 ft.<br>(25.0-25.2 m) | | | | | 1 | 3 | | | | | | | | | | | 1 | 5 |
| NF | 50°44'N,<br>115°55'W | 45612 | 202-212 ft.<br>(61.6-64.6 m) | | | | | | | | | | | | | | | | | 1 | 1 |
| N4 | 50°23'N,<br>115°48'W | 64584 | 6-12 ft.<br>(1.8-3.7 m) | 1 | | | | | | | | 1 | | 1 | 1 | | | | | | 4 |
| N7 | 50°53'N,<br>116°13'W | 56076 | 105-109 ft.<br>(32.0-33.2 m) | 3 | 2 | | | 1 | | | | 1 | | | | | | | | 5 | 12 |
| | | 56075 | 72-80 ft.<br>(21.9-24.4 m) | | | | | 3 | | | | | | | | | | | | | 3 |
| | | 56073 | 45-46 ft.<br>(13.7-14.0 m) | | | | | | | | | | | | | | | | | 2 | 2 |
| N9 | 50°00.5'N,<br>116°24'W | 52171 | 211-222 ft.<br>(64.3-67.7 m) | | | 1 | | | | | | | | | | | | | | | 1 |
| | | 45606 | 170-178 ft.<br>(51.8-54.3 m) | 2 | | | | 1 | | | | | | | | | | | | 2 | 5 |
| | | 8043 | 77 ft.<br>(23.5 m) | | | | | | | | | | 1 | | | | | | | | 1 |
| | | 45604 | 68-69 ft.<br>(20.7-21.0 m) | 1 | | | | | | | | | | | | | | | | 1 | 2 |
| N10 | 51°12'N,<br>116°49'W | 52183 | 97-117 ft.<br>(29.5-35.7 m) | 1 | | 1 | | 3 | 2 | 1 | 1 | | | 1 | | | | 1 | | 6 | 17 |
| N11 | 51°13'N,<br>116°49'W | 69839 | 107-121 ft.<br>(32.6-36.9 m) | | | | | 5 | 1 | 1 | 1 | | | | | | | | | 3 | 11 |
| | | 69844 W | 0-107 ft.<br>(0.0-32.6 m) | | | | | | | | | | | | | | | | | 3 | 3 |
| N12 | 50°11'N,<br>115°21.5'W | 45582 | 300-500 ft.<br>(91.4-152.4 m) | 1 | | | | | | | | | | | | | | | | | 1 |
| | | 52160 | 328-331 ft.<br>(100-100.9 m) | 1 | | | | | | | | | | | | | | | | 1 | 2 |
| | | 45580 | 275-280 ft.<br>(83.8-85.3 m) | | | | | 1 | | | | | | | | | | | | | 1 |

*distincta* are known from 17 of the 21 locations for which data are available (Table 3.1). Corresponding figures for the other taxa are: *Bighornia patella* and *Grewingkia haysii haysii* from 14 locations, *Deiracorallium prolongatum* from six, *B.* cf. *B. bottei* from two, and *Salvadorea* sp. 2 from one. Differences such as these are to be expected, given the differing relative abundances of taxa and the comparatively small sample sizes from all locations except Akutlak Creek. It seems likely that all species were distributed throughout the area of Beaverfoot deposition.

In the Akutlak Creek section, *S. distincta distincta*, *B. patella*, *G. haysii haysii*, and *D. prolongatum* first appear 82 feet (25.0 m) above the base of the Beaverfoot Formation, within the 99 foot (30.1 m) thick Whiskey Trail Member (Fig. 3.4). At Carbonate Creek, where this member is 93 feet (28.3 m) thick, specimens occur from 82 to 83 feet (25.0-25.2 m) above the base (Table 3.1). In general, solitary corals are most common within the lower 164 feet (50 m) of the Beaverfoot Formation, but above the Whiskey Trail Member where it is present. Above 230 feet (70 m) at Akutlak Creek, they are uncommon, and barren intervals are thicker and more frequent. *Salvadorea distincta distincta*, *B. patella*, and *G. haysii haysii* are present in the uppermost interval at the 420 foot (128 m) thick Akutlak Creek section. This is the highest known occurrence of solitary corals that are characteristic of the *Bighornia-Thaerodonta* Zone (Table 3.1).

There are 20 or more solitary rugose corals that could be identified with various degrees of certainty in only two stratigraphic intervals, both in the Akutlak Creek section (Fig. 3.4, intervals A14/15, B5). In each case, *S. distincta distincta*, *B. patella*, *G. haysii haysii*, and *D. prolongatum* are present. The only other intervals from which all four taxa are known are B2 at Akutlak Creek and the lower 31 feet (9.4 m) of the Beaverfoot Formation at Shatch Mountain (GSC loc. 58188, Table 3.1). The absence of one or more species in other collections may reflect a combination of small sample size and low relative abundance of some taxa.

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 47414 | 100-300 ft.<br>(30.5-91.4 m) | | | | | | | | | 1 | | | | | | | | 3 | 4 |
| | | 45579 | 97-110 ft.<br>(29.6-33.5 m) | | | | | 1 | | | | | | | | | | | | 1 | 2 |
| | | 52158 | 91-104 ft.<br>(27.7-31.7 m) | | | 1 | | | | | | | 1 | | | | | | | | 2 |
| | | 45578 | 82-92 ft.<br>(25.0-28.0 m) | | | | | | | | | 4 | | | | | | | | 3 | 7 |
| | | 52159 | 80-81 ft.<br>(24.4-24.7 m) | | | | | | | | | 2 | | | | | | | | 1 | 3 |
| N14 | 50°28'N,<br>115°15'W | 58186 | 81-82 ft.<br>(24.7-25.0 m) | | 1 | | | | | | | | | | | | | | | 1 | 2 |
| | | 58187 | 67-77 ft.<br>(20.4-23.5 m) | | | | | | | | | | | 1 | | | | | | | 1 |
| | | 58188 | 0-31 ft.<br>(0.0-9.4 m) | 2 | 1 | | | 1 | 1 | | | 1 | | | 2 | 1 | | | 1 | 3 | 13 |
| N17 | 50°35.5'N,<br>115°18'W | 47426 | 15-40 ft.<br>(4.6-12.2 m) | | | | | | | | | 1 | | | | | | | | | 1 |
| N31 | 51°41'N,<br>116°13'W | 52186 | 144-147 ft.<br>(43.9-44.8 m) | 2 | | | | | | | | | | | | | | | 1 | 5 | 8 |
| | | 52185 | 75-81 ft.<br>(22.9-24.7 m) | | | | | 1 | | | | | | | | | | | | 1 | 2 |
| N40 | 52°08'N,<br>116°59'W | 70016 | 35-53 ft.<br>(10.7-16.2 m) | | | | | 1 | | | | | | | 2 | | 1 | | 3 | 7 | 14 |
| | | 70015 | 17-27 ft.<br>(5.2-8.2 m) | 2 | | | | 1 | | | | | | | | | | | | 7 | 10 |
| | | 42017 | 17-40 ft.<br>(5.2-12.2 m) | | | | | | | | | | | 1 | | | | | | | 1 |
| | | 42018 | 17-40 ft.<br>(5.2-12.2 m) | | | | | | | 1 | | | | | | | 1 | | | 4 | 6 |
| | | 42026 | 17-40 ft.<br>(5.2-12.2 m) | 1 | | | | | | | | 1 | | | | | | | | 2 | 4 |
| K12 | 50°11.5'N,<br>115°21.5'W | BT (talus) | ? | 1 | | | | | | | | | | | | | | | | | 1 |
| | | B25 | 383-420 ft.<br>(116.7-128.0 m) | 2 | 3 | | | 3 | | | | 2 | | | | | | | | 2 | 12 |
| | | B24 | 364-383 ft.<br>(110.9-116.7 m) | | | | | 3 | | | | | | | | | | | | 3 | 6 |
| | | B23 | 358-364 ft.<br>(109.2-110.9 m) | 1 | | | | | | | | 1 | | | | | | | | | 2 |
| | | B21 | 345-350 ft.<br>(105.3-106.8 m) | | | | | | | | | | 1 | | | | | | | | 1 |
| | | B20 | 339-345 ft.<br>(103.3-105.3 m) | 1 | | | | | | | | | | | | | | | | | 1 |
| | | B16 | 283-329 ft.<br>(86.2-100.2 m) | 1 | | | | 1 | | | | | | | | | | | | 1 | 3 |
| | | B12 | 263-267 ft.<br>(80.3-81.3 m) | | | | | | | | | | | | | | | | | 3 | 3 |
| | | B10 | 248-258 ft.<br>(75.7-78.7 m) | | | | | 1 | | | | | | | | | | | | | 1 |
| | | B7 | 188-231 ft.<br>(57.4-70.4 m) | 2 | | | | | | | | 1 | | | | | | | 2 | 5 | 10 |
| | | B6 | 182-188 ft.<br>(55.4-57.4 m) | 2 | 1 | | | 1 | | | | 2 | 1 | | | | | | | 2 | 9 |
| | | B5 | 156-182 ft.<br>(47.4-55.4 m) | 4 | 2 | | | 6 | | | | 6 | 1 | | 1 | | | | | 11 | 31 |
| | | B3 | 153-155 ft.<br>(46.6-47.3 m) | | | | | | | | | 1 | | | | | | | | 1 | 2 |
| | | B2 | 125-153 ft.<br>(38.1-46.6 m) | | 2 | | | 1 | | | | 1 | 4 | | 1 | | | | | 2 | 11 |
| | | B1 | 115-125 ft.<br>(35.1-38.1 m) | 2 | 1 | | | | | | | 1 | | | | | | | | 6 | 10 |
| | | AR (rubble) | near A18 | 3 | | | | | | | | 1 | 1 | | | | | | | 1 | 6 |
| | | A18 | 105-115 ft.<br>(32.1-35.1 m) | 2 | | | | | | | | 10 | 1 | | | | | | | 7 | 20 |
| | | A15/16 W | 90-105 ft.<br>(27.4-30.1 m) | 1 | 1 | | | | | | | 1 | 1 | | | | | | | | 4 |
| | | A14/15 W | 82-90 ft.<br>(25.1-27.4 m) | 12 | 1 | | | 6 | | | | 3 | 1 | | 4 | | | | 1 | 7 | 35 |
| | | | | 66 | 17 | 4 | 1 | 52 | 9 | 5 | 2 | 45 | 13 | 6 | 14 | 1 | 3 | 2 | 8 | 143 | 391 |
| | | | | 36.6% | | | 0.6% | 28.9% | | | 1.1% | 25.0% | | | 7.8% | | | | | | |
| | | | | 36.6% | | | 0.4% | 27.7% | | | 0.8% | 26.9% | | | 7.6% | | | | | | |

[1] GSC Locality numbers, except at location K12.
[2] W = Whiskey Trail Member.

## Paleoecology and biostratinomy (C.J. Buttler and R.J. Elias)

### *Attachment structures*

Attachment structures were not observed on specimens of *Salvadorea distincta distincta*, *Grewingkia haysii haysii*, or *Deiracorallium prolongatum* from the Beaverfoot Formation. Seven (20%) of 35 coralla representing *Bighornia patella*, and the two individuals of *B.* cf. *B. bottei*, have a spoon-shaped depression rising from the apex on the concave cardinal side (Pl. 3.3, figs. 1-3, 6-12; Pl. 3.4, figs. 6-11). Similar structures have been observed on *B. patella* and *B. bottei* from other units (Nelson, 1963, p. 42, Pl. 9, figs. 5, 6, Pl. 11, figs. 5, 6, Pl. 12, figs. 2-4; Elias, 1982a, p. 80, Pl. 14, figs. 19, 23, Pl. 15, fig. 7; Elias, 1982b, p. 1588; Elias, 1983a, Fig. 16a, b, h). Two of the specimens of *B. patella* from the Beaverfoot Formation have lateral flanges that increase the width of the spoon-shaped area (Pl. 3.3, figs. 6, 7, 10-12). In order to secrete such a projection, it seems likely that the polyp was in contact with a surface over which it could spread. On well preserved specimens of *B. wilsonae* (a species closely related to *B. patella*) from the Red River Formation in southern Manitoba, and on a coral from the Cape Calhoun Formation of northwestern Greenland (MMH 2995; probably *B. patella* or *B. wilsonae*), growth ridges do not extend into the spoon-shaped depression. These lines of evidence support the interpretation of these structures as sites where the corals were fixed to smooth, curved surfaces, such as cephalopod shells (Elias, 1981, p. 5; Elias, 1984b, p. 534, Fig. 2k). However, attached specimens either have not been found or have not been recognized. Selective early dissolution of aragonitic host shells is a possible reason, and is suggested by the preservation of molluscs as casts in the Red River Formation (see Kendall, 1977, p. 493, 494). Alternatively, it is possible that the hosts lacked hard parts, and, therefore, were not preserved. The variable proportions of *Bighornia* corals with attachment sites in different stratigraphic units may reflect the availability of suitable objects.

The overall rarity of attachment sites on solitary rugose corals of the *Bighornia-Thaerodonta* Zone in the Beaverfoot Formation indicates that most of them behaved as unattached objects on soft substrates. Where attachment structures are present, their location is consistent with the hypothesis that larvae became fixed to substrates by their cardinal side (Elias, 1984b, p. 534).

### *Abrasion*

For a total of 42 solitary corals, it was possible to determine whether the epitheca and stereozone were present or absent. The information presented in Table 3.2 is based on an examination of 65 transverse thin sections. The absence of part or all of the coral wall is considered to be the result of abrasion. In *Salvadorea distincta distincta* and *Bighornia patella*, the epitheca is present on most coralla. It is not preserved on any specimens of *Grewingkia haysii haysii*, which commonly lack part or all of the stereozone. There are too few data from *Deiracorallium prolongatum* for a meaningful comparison.

The degree of abrasion of coral exteriors could reflect the duration and/or intensity of the process. Elias (1982b, p. 1590) found that large corals tend to be more highly abraded than small individuals. This was related to the duration of exposure before burial, and therefore to sedimentation rate. In the Beaverfoot Formation, corals of the smallest species (*B. patella*) are least abraded, whereas those of the largest (*G. haysii haysii*) are most abraded. However, these differences could be related, at least in part, to energy of the environment. If *G. haysii haysii* had been subjected to higher energy conditions than *S. distincta distincta* and *B. patella*, the greater degree of abrasion would be expected.

### *Orientation*

Prior to the removal of 161 solitary corals found in the Akutlak Creek section, their orientations with respect to bedding were noted. Virtually all were lying sideways in what would have been stable depositional positions following transport (Elias and Buttler, 1986, Fig. 1a, b). The absence of high-angle bends in these corals suggests that the polyps could not redirect their growth axis after being overturned, and such an event may have killed them. This is typical of Upper Ordovician solitary Rugosa in the Red River-Stony Mountain Solitary Coral Province of North America (Elias, 1984b, p. 534).

Two specimens found within interval B5 (see Fig. 3.4) were almost certainly preserved in life position (Elias and Buttler, 1986). They occur beneath large colonial corals, and were thus shielded from high energy events that apparently resulted in the overturning and transporting of other individuals. Their orientations confirm previous hypotheses that greatly curved solitary corals (*Grewingkia haysii haysii* in this case) lay in the sediment with the concave side facing up and at least partly exposed, whereas slightly curved forms (*Salvadorea distincta distincta* in this case) were oriented in a more upright position during life (Elias, 1980, p. 275, 276, Fig. 5; Elias, 1981, p. 5, 6, Fig. 4; Elias, 1982b, p. 1587, 1588, 1595, Fig. 5a-d; Elias, 1984b, p. 534, Fig. 2; Elias and Buttler, 1986, Fig. 1c, d).

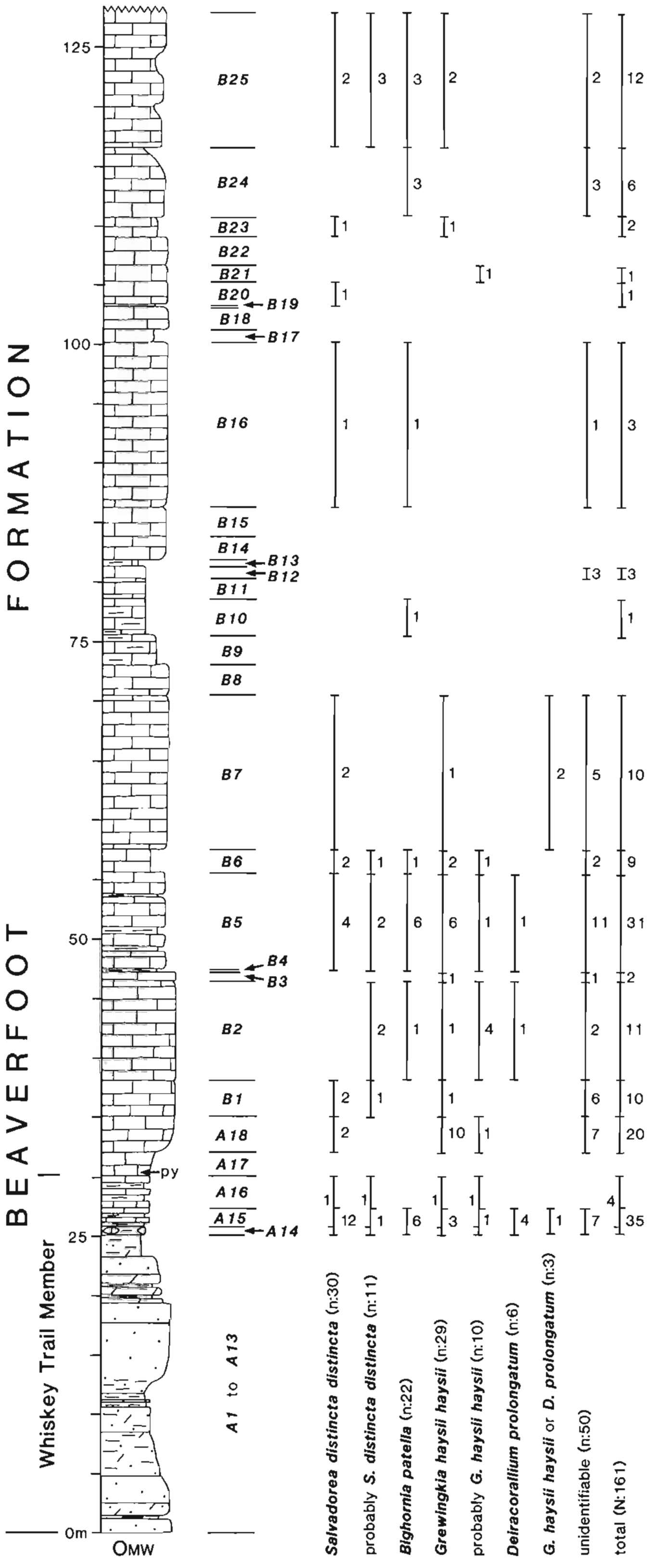

*Figure 3.4* *Stratigraphic section at Akutlak Creek, showing distribution and frequency of solitary rugose corals. Lithotypes are indicated by standard symbols,* **py** *= pyrite,* OMW*= Mount Wilson Quartzite. A1 to A18 and B1 to B25 are stratigraphic intervals at sections K12A and K12B, respectively (see Figs. 3.1 to 3.3 for location).*

## TABLE 3.2

Features of solitary rugose corals from the *Bighornia-Thaerodonta* Zone, Beaverfoot Formation.

| Taxa | Size[1] | Curvature[2] | Nature of exterior | | | Epizoans | | | | | | Borings | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Bryozoans | | | Colonial corals | | | *Trypanites* | | |
| | | | With epitheca | Without epitheca | Without part or all of stereozone | Without[3] | With[4] | Location[5] | Without[3] | With[4] | Location[5] | Without[3] | With[4] | Location[5] |
| *Salvadorea distincta distincta* | M | A | 9 (64%) | 3 (22%) | 2 (14%) | 39 (91%) | 4 (9%) | 1C (33%)<br>1A (33%)<br>1C-A (33%) | 43 (100%) | 0 | - | 42 (98%) | 1 (2%) | 2A (67%)<br>1K (33%) |
| *Bighornia patella* | S | B | 10 (91%) | 1 (9%) | - | 30 (97%) | 1 (3%) | 1C-A (100%) | 31 (100%) | 0 | - | 27 (87%) | 4 (13%) | 3C (50%)<br>3A (50%) |
| *Grewingkia haysii haysii* | L | C | - | 6 (43%) | 8 (57%) | 30 (97%) | 1 (3%) | 1K (100%) | 25 (81%) | 6 (19%) | 1C (17%)<br>1C-A (17%)<br>1A (17%)<br>1K-A (17%)<br>2K (32%) | 15 (48%) | 16 (52%) | 13C (22%)<br>22A (39%)<br>22K (39%) |
| *Deiracorallium prolongatum* | M | - | 2 (67%) | - | 1 (33%) | 9 (90%) | 1 (10%) | 1K (100%) | 10 (100%) | 0 | - | 6 (60%) | 4 (40%) | 3C (20%)<br>5A (33%)<br>7K (47%) |

[1] S = small, M = medium, L = large.
[2] A = very slightly curved, B = slightly curved, C = moderately to greatly curved.
[3] Number of corals without epizoans/borings.
[4] Number of corals with epizoans/borings.
[5] Location of all epizoans/borings on corals (C = cardinal side, A = alar side, K = counter side).

### *Paleoecological associations*

Based on the degree of abrasion, it is possible that coralla of *Grewingkia haysii haysii* were subjected to higher energy conditions than *Salvadorea distincta distincta* and *Bighornia patella*. Individuals of *G. haysii haysii* are moderately to greatly curved, whereas *S. distincta distincta* and *B. patella* are very slightly to slightly curved (Table 3.2). Curvature of *Deiracorallium prolongatum* could not be determined from the available specimens. Paleoecological studies suggest that there is a positive correlation between increase in the degree of curvature and the current energy (Elias, 1981, p. 5, 6; Elias, 1984b, p. 534; Elias, 1985, p. 14). The specimen of *G. haysii haysii* that is preserved in life position is lying on its convex side (Elias and Buttler, 1986, Fig. 2a-d), whereas that of *S. distincta distincta* is upright (Elias and Buttler, 1986, Fig. 2e). These orientations are thought to be the result of the polyps being exposed to relatively strong and weak currents, respectively (Elias, 1984b, Fig. 2b, d). The above lines of evidence suggest that *Grewingkia* inhabited relatively high energy environments, whereas *Salvadorea* and *Bighornia* favoured low energy niches. The latter group was dominant in the solitary coral assemblage of the *Bighornia-Thaerodonta* Zone. The ecological position of *Deiracorallium* will be considered in a subsequent section. Corals representing all taxa are found together in the Beaverfoot Formation. They probably lived in close proximity, and were torn loose and mixed during unusually high energy events, such as severe storms.

Relationships similar to those noted above have been observed elsewhere. In the Stony Mountain Formation of southern Manitoba, Elias (1982b, p. 1586, 1587) recognized close ecological ties between *Helicelasma* (species assigned to *Salvadorea* in Elias, 1985, p. 45) and *Bighornia* (specimens assigned to *B. patella* herein), and between *Lobocorallium* (species similar to *G. haysii haysii*) and *Deiracorallium*. The *Salvadorea-Bighornia* group is dominant in that unit. From analyses of corals in the Aleman Formation of the Montoya Group in New Mexico and Texas, Elias (1985, p. 14) inferred that *S. kingae kingae* (herein considered to be a synonym of *S. distincta distincta*), the dominant taxon, lived in lower energy environments than species of *Grewingkia* that are similar to *G. haysii haysii*.

### *Paleoenvironments and paleobathymetry*

Solitary Rugosa are not known to occur in sandstones or sandy carbonate beds within the Whiskey Trail Member of the Beaverfoot Formation. All specimens from that member are in silty or argillaceous carbonates (e.g., Fig. 3.4). These fossils are common and widespread in clean carbonates of the main Beaverfoot above the Whiskey Trail. Similarly, solitary corals are uncommon within the Cable Canyon Sandstone Member at the base of the Second Value Dolomite, Montoya Group, in New Mexico and Texas, but are common in overlying beds of the Upham Dolomite Member (Elias, 1985, Fig. 2). These organisms did not care for environments with coarse clastic sediments.

Above the lower part of the main portion of the Beaverfoot Formation, solitary corals become uncommon, and barren intervals are thicker and more frequent. Within the Stony Mountain Formation of southern Manitoba, Elias (1982b, p. 1586, Fig. 2) noted a general upward decrease in the abundance of these fossils. Corresponding changes in Stony Mountain lithotypes and sedimentary structures indicate a transition from open, normal marine environments to restricted, hypersaline conditions. In the Aleman Formation and Cutter Dolomite of the Montoya Group, occurrences of solitary corals coincide with relative abundance peaks of conodonts inferred to be "shallow water" forms (Elias, 1985, p. 14-16, Fig. 2). "Deep water" conodonts are more common in intervals lacking corals. However, sedimentological evidence suggests that the principal limiting variable was not water depth, but the degree of environmental restriction (factors such as limited circulation, greater salinity, and possibly less oxygen and higher temperatures). It is inferred that occurrences of solitary Rugosa in the Beaverfoot Formation could indicate shallow water maxima and/or open, normal marine conditions.

## **Close biotic associates** (C.J. Buttler and R.J. Elias)

### *Epizoans and borings*

A total of 115 solitary corals were examined for the presence of epizoans and borings. The observations recorded in Table 3.2 are based on 172 transverse thin sections. Epizoans are rare. Bryozoans occur on *Salvadorea distincta distincta* (Pl. 3.2, fig. 2), *Bighornia patella*, *Grewingkia haysii haysii*, and *Deiracorallium prolongatum*. Colonial corals have been found only on *G. haysii haysii*, the largest species (Elias and Buttler, 1986, Fig. 2a-d) (Pl. 3.6, fig. 3).

*Trypanites* borings, probably produced as dwelling structures by polychaete annelids (see Elias, 1980, p. 275, and Elias, 1986b, p. 33), occur in *S. distincta distincta*, *B. patella*, *G. haysii haysii*, and *D. prolongatum* (Table 3.2). They are predominantly in the concave counter side and the alar sides of *Salvadorea*, *Grewingkia* (Pl. 3.6, fig. 3), and *Deiracorallium* (Pl. 3.7, figs. 10, 11; Pl. 3.8, fig. 3), and only in the concave cardinal side and the alar sides of *Bighornia*. Those surfaces were exposed above the substrate and probably faced into currents while the corals were in growth position (see Elias, 1980, p. 275, 276, Fig. 5; Elias, 1982b, p. 1587, 1588, Fig. 5a-d; Elias, 1986b, p. 35; Elias and Buttler, 1986, Fig. 1c, d). The observed distribution of *Trypanites* would be expected if the producers usually became associated with live hosts.

*Trypanites* borings are most common in *G. haysii haysii*, the largest species. Elias (1982b, p. 1594) found that the frequency of borings increases with coral size, which determined the surface area available for settlement as well as the duration of exposure before burial. However, the distribution of *Trypanites* in solitary Rugosa of the Beaverfoot Formation could also reflect environmental preferences of the annelids. These borings are least common in *Salvadorea* and *Bighornia*, the two taxa that lived in relatively quiet water, and most common in *Grewingkia*, which inhabited higher energy environments. This is consistent with the hypothesis that organisms producing *Trypanites* selected sites where currents were comparatively strong or persistent (Kobluk and Nemcsok, 1982, p. 685, 686; Nield, 1984, p. 239, 240, 242; Elias, 1986b, p. 35). Although the sample size is small, data suggest that borings are relatively common in specimens of *Deiracorallium*, which are comparable in size to *Salvadorea* (Table 3.2). *Deiracorallium* and *Grewingkia* may have lived in similar environments. Close ecological ties between *Deiracorallium* and a species of *Lobocorallium* that resembles *G. haysii haysii* were noted in a previous section.

### *Objects within coralla*

A total of 172 transverse thin sections of 115 solitary Rugosa, as well as 14 longitudinal thin sections from 11 of these specimens, were examined for the presence of foreign objects of the type described by Elias (1984a, p. 105, 107, Fig. 3). Four corals, and possibly a fifth, contain ostracodes, as follows: *Salvadorea distincta distincta* (GSC 85567), one in cardinal fossula, one in first interseptal chamber on one side of cardinal fossula, one in interseptal chamber on one alar side of coral; *S. distincta distincta* (Pl. 3.2, fig. 1), one in cardinal fossula; *Deiracorallium prolongatum* (Pl. 3.7, fig. 6), one in cardinal fossula; *Grewingkia haysii haysii* (GSC 85674), one about midway between cardinal fossula and one alar fossula, possibly one in cardinal fossula; *G. haysii haysii* (Pl. 3.5, fig. 6), possible recrystallized ostracode in one alar fossula. Septa and/or tabulae are diverted around the objects in all these corals.

Two hypotheses have been proposed to account for the inclusion of an ostracode within a coral (Elias, 1984a, p. 105, 107, Fig. 4). In the first, it entered the calice when a portion of the polyp temporarily detached from the corallum and contracted radially. The second, less likely, hypothesis is that an ostracode entered the polyp's central cavity through the mouth. It was suggested that ostracodes may have been captured for food (Elias, 1984a, p. 107). Another possibility is that these crustaceans lived in the gastric cavity of polyps. Stasek (1958, p. 119, 124, 125) reported on modern amphipod crustaceans that dwell within anemones. In both the above hypotheses, a close association between solitary Rugosa and Ostracoda is implied.

Elias (1984a, p. 105, Table 4) found that ostracodes and other less common foreign objects are generally situated within or near the cardinal and alar fossulae, as observed in corals from the Beaverfoot Formation. He noted that foreign objects are more common in species of Edenian-Maysvillian age than in their Richmondian descendants within the Red River-Stony Mountain Solitary Coral Province (Elias, 1984a, p. 110, 111). The rarity of ostracodes in Beaverfoot specimens is consistent with that observation.

## **Paleobiogeography** (C.J. Buttler and R.J. Elias)

The paleobiogeography of North American Upper Ordovician solitary rugose corals has been discussed by Elias (1981, p. 2, 8, 10; 1982a, p. 47-52, Fig. 24, Table 3; 1983a, p. 927-931, Fig. 1; 1983b, p. 6; 1984b, Fig. 1; 1985, p. 16-20, Fig. 3) and Elias and Potter (1984, p. 1205, 1206). The Red River-Stony Mountain Solitary Coral Province of Edenian to Gamachian age occupied most of North America. Characteristic taxa are *Grewingkia* (species in which at least some coralla have triangulate to trilobate form), *Lobocorallium*, *Deiracorallium*, *Bighornia*, and *Salvadorea*. The presence of *G. haysii haysii*, *D. prolongatum*, *B. patella*, *B.* cf. *B. bottei*, *S. distincta distincta*, and *Salvadorea* sp. 2 within the *Bighornia-Thaerodonta* Zone of the Beaverfoot Formation indicates that the area preserved in the southern Rocky Mountains of British Columbia and Alberta was situated within the Red River-Stony Mountain Province.

Elias (1985, p. 16) recognized two types of solitary coral assemblages in the Red River-Stony Mountain Province. One is associated with epicontinental seas thought to have had slightly elevated temperatures and salinities, and the other with normal, open marine environments along the continental margin. "Epicontinental" assemblages are dominated by, or composed exclusively of, the characteristic taxa, which are listed in the preceding paragraph. These may be present or absent in "continental margin" assemblages, which include genera such as *Bodophyllum* and *Streptelasma*, and species of *Grewingkia* and *Streptelasma* that are similar to forms in northwestern Europe. Solitary Rugosa of the *Bighornia-Thaerodonta* Zone in the Beaverfoot Formation represent an exclusively "epicontinental" assemblage. All six species also occur in northern Manitoba. This further substantiates the statement by Elias (1983a, p. 953) that solitary corals in western Canada and northern North America appear to be most closely related to those of the Hudson Bay Basin. Two of the Beaverfoot species, *Bighornia patella* and *Salvadorea distincta distincta*, are present in New Mexico and Texas. Only *B. patella*, known from southern Manitoba and northern Wyoming, has been found in the Williston Basin. None of the Beaverfoot species occurs in the eastern Klamath Mountains of northern California, where "continental margin" corals that apparently lived in an island arc setting relatively near North America are found in an allochthonous terrane.

The Beaverfoot Formation was probably deposited near the margin of North America, although its exact paleoposition is uncertain because Upper Ordovician rocks representing basinal facies are unknown in southeastern British Columbia. Even the outcrops west of the Rocky Mountain Trench are typical Beaverfoot dolostones. The absence of "continental margin" taxa in the Beaverfoot is somewhat surprising. Budge (1977) listed *Bodophyllum* and *Streptelasma*, as well as cf. *Grewingkia*, *Lobocorallium*, *Deiracorallium*, and *Bighornia*, from upper Upper Ordovician strata in Nevada and Utah, which were presumably deposited in a similar setting. One "continental margin" taxon, *Neotryplasma*, is known from lower Upper Ordovician strata in the Montoya Group of westernmost Texas (Elias, 1986a), but all species in the upper Upper Ordovician part are "epicontinental" (Elias, 1985, p. 16, 20). The Montoya corals lived several hundred kilometres from the Ouachita Geocline. The Beaverfoot Formation probably was deposited at some distance from the edge of the continent. Alternatively, "continental margin" taxa could have been excluded by environmental factors or geographic barriers.

## **Evolution** (C.J. Buttler and R.J. Elias)

### *Salvadorea*

Elias (1985, p. 19) noted that speciation events within *Salvadorea* in the New Mexico-Texas area and Williston Basin coincided with onsets of clastic deposition. Clastic units are not present within the Churchill River Group in northern Manitoba, where *S. distincta distincta* remained unchanged (Nelson, 1981, p. 17, 46). Similarly, this species did not undergo recognizable evolutionary changes in the Beaverfoot Formation, which lacks significant, widespread clastic intervals above the basal Whiskey Trail Member. The ranges of cross-sectional shape, degree of septal dilation, number of septa, length of minor septa, and complexity of the axial structure appear to be constant for specimens found throughout the Akutlak Creek section.

The evolutionary relationship between *S. distincta distincta* and *Salvadorea* sp. 2 is not understood.

### *Bighornia*

*Bighornia wilsonae*, a new species recognized herein from the Second Value Dolomite of the Montoya Group in New Mexico and Texas, and the Selkirk Member of the Red River Formation in southern Manitoba, was ancestral to *B. patella*. The transition involved shortening of the cardinal septum in earlier ontogenetic stages, and a change in orientation of septal fibres (as viewed in transverse sections) from those that curve outward in the direction of the coral axis to those that are perpendicular to the sides of the septa.

There is another group of North American Upper Ordovician solitary Rugosa within the genus *Bighornia*. Corals in this group expand more rapidly above the apex and attain greater heights than *B. wilsonae* and *B. patella*. Within this large size category, only *B. bottei* from the Chasm Creek Formation of the Churchill River Group in northern Manitoba is well known. In northern and southern Manitoba, and perhaps elsewhere as well, these corals range into younger strata than *B. patella*. Their relationship to the *B. wilsonae*-*B. patella* group is unknown, but the microstructure of *B.* cf. *B. bottei* in the Beaverfoot Formation resembles that of *B. patella*.

### *Grewingkia*

*Grewingkia haysii haysii* is thought to have arisen from *G. robusta* and given rise to *Lobocorallium trilobatum trilobatum* (Elias, 1985, p. 17, 18).

### *Deiracorallium*

*Deiracorallium angulatum angulatum*, *D. angulatum gunni*, *D. manitobense manitobense*, and *D. manitobense churchillense* occur in strata coeval with those containing *D. prolongatum*. They are distinguished from the latter species by their small size and short cardinal septum. *Deiracorallium manitobense* may prove to be a synonym of *D. angulatum* (Elias, 1983a, p. 941). The relationship of these corals to *D. prolongatum* is not known.

*Deiracorallium harveyi* and *D. delicatum* are comparable in size to *D. prolongatum* and may be ancestral to the younger species of *Deiracorallium*. These earlier taxa differ from *D. prolongatum* and *D. angulatum* in having comparatively large, complex axial structures.

### Biostratigraphy

*Salvadorea distincta distincta*, *Bighornia patella*, *Grewingkia haysii haysii*, and *Deiracorallium prolongatum* occur in the upper part of the Whiskey Trail Member and in overlying strata of the lower Beaverfoot Formation, where *Salvadorea* sp. 2 and *B.* cf. *B. bottei* are also known. The base of the *Bighornia-Thaerodonta* Zone, previously located at the bottom of the main portion of the Beaverfoot (Norford, 1969, p. 38), is herein placed at the first appearance of this solitary coral assemblage within the Whiskey Trail, 82 feet (25.1 m) above its base in the Akutlak Creek section. A close historical relationship between deposition of clastic sediments that constitute the Whiskey Trail Member and carbonates of the main Beaverfoot Formation is inferred.

The diagnostic species *B. patella*, together with *S. distincta distincta* and *G. haysii haysii*, are documented 338 feet (102.9 m) higher at the top of the Akutlak Creek section (Fig. 3.4), giving a minimum thickness for the Zone at this location. *Salvadorea distincta distincta* is the most common solitary coral in this zone.

Within the Late Ordovician Red River-Stony Mountain Solitary Coral Province, a *Grewingkia*-dominated assemblage is succeeded by a *Salvadorea*-dominated assemblage (Elias, 1985, p. 20, 21). This change is not synchronous throughout the province, when analyzed in a framework of correlations based primarily on conodont biostratigraphy (Sweet, 1979, Fig. 4; Sweet, 1984, Fig. 3; Elias, 1985, p. 7, 10). The *Salvadorea*-dominated assemblage had definitely appeared by late Maysvillian time, and possibly during the early to middle Maysvillian, near the continental margin in New Mexico and Texas. Within the continental interior, this assemblage is first found in lower middle Richmondian strata in the Williston Basin (Elias, Nowlan, and Bolton, in press). Its earliest known occurrence in the Hudson Bay Basin is middle Richmondian. Because the solitary corals in the *Bighornia-Thaerodonta* Zone of the Beaverfoot Formation are a *Salvadorea*-dominated assemblage, deposition of the Beaverfoot could have begun within the interval Maysvillian to middle Richmondian. If the *Salvadorea*-dominated assemblage originated earlier near the continental margin than in epicontinental areas, a relatively early age is possible for the onset of deposition of the Beaverfoot. However, all six solitary rugosan species present in the *Bighornia-Thaerodonta* Zone also occur in middle to upper Richmondian strata of the Churchill River Group in the Hudson Bay Basin, suggesting that the zone is probably no older than Richmondian.

The uppermost portion of the *Bighornia-Thaerodonta* Zone is probably Richmondian in age. Elsewhere, *Deiracorallium* and trilobed species of *Grewingkia* (as well as *Lobocorallium*) are not known to occur in strata younger than late Richmondian. On Anticosti Island, Québec, for example, *Deiracorallium* and *Lobocorallium* are present in the upper Vauréal Formation (late Richmondian), but not in the overlying Ellis Bay Formation of Gamachian age (see Elias, 1982a, Fig. 22). However, the range of *Salvadorea* on Anticosti Island extends into the Ellis Bay Formation, and *Bighornia* is probably present in the Stonewall Formation of southern Manitoba (see Elias, 1985, p. 18, 19). According to conodont biostratigraphy studies, these strata are Gamachian, and latest Richmondian to Gamachian in age, respectively (McCracken and Barnes, 1981, p. 64, Fig. 12; Sweet, 1979, p. 54, Fig. 4; Sweet, 1984, Fig. 3).

## SOLITARY RUGOSE CORALS OF THE COMBINED "POORLY FOSSILIFEROUS INTERVAL" AND *EOSTROPHEODONTA* ZONE

### Identification of taxa

Solitary corals found above the *Bighornia-Thaerodonta* Zone earlier were identified as *Streptelasma* sp. and *Streptelasma fragile* (Norford, 1962a, p. 449; 1969, p. 39). For the present study, 43 specimens collected by Norford from the lower portion of the combined "poorly fossiliferous interval" and *Eostropheodonta* Zone were examined. These corals are generally small and poorly preserved, but it is possible to identify 20 (47%) at the generic level (Table 3.3).

## TABLE 3.3

Stratigraphic and geographic distribution and frequency of 43 solitary rugose corals from the lower portion of the combined "poorly fossiliferous interval" and *Eostropheodonta* Zone, Beaverfoot Formation (refer to Fig. 3.1 for geographic locations; all positions measured from base of Beaverfoot Formation).

| Location | Coordinates | GSC Locality | Position | *Streptelasma* | *Rhegmaphyllum* | *Dinophyllum* | Unidentified | Total number of solitary corals |
|---|---|---|---|---|---|---|---|---|
| ND | 50°27'N,<br>115°46'W | 45570 | 1003.0-1003.5 ft.<br>(305.7-305.9 m) | 2 | - | - | 1 | 3 |
| | | 47404 | 569-573 ft.<br>(173.4-174.7 m) | 1 | 4 | - | 11 | 16 |
| | | 45574 | 1159-1160 ft.<br>(353.3-353.6 m) | - | - | 2 | 1 | 3 |
| N7 | 50°53'N,<br>116°13'W | 56080 | 511-512 ft.<br>(155.8-156.1 m) | 3 | 1 | - | - | 4 |
| | | 56079 | 507-508 ft.<br>(154.5-154.8 m) | - | - | - | 1 | 1 |
| | | 56078 | 438-439 ft.<br>(133.5-133.8 m) | - | 1 | - | 1 | 2 |
| N11 | 51°13'N,<br>116°49'W | 69837 | 594-621 ft.<br>(181.0-189.3 m) | 5 | - | 1 | 8 | 14 |

Eleven individuals are assigned to *Streptelasma*: GSC 85537, 85538 (Pl. 3.8, figs. 9-11), GSC loc. C-45570, GSC 85539 (Pl. 3.8, figs. 6, 7), GSC loc. 47404, Pedley Pass; GSC 85540, 85541 (Pl. 3.8, figs. 4, 5), GSC 85542, GSC loc. 56080, Pinnacle Creek; GSC 85543, 85544 (Pl. 3.8, fig. 8), GSC 85545-85547, GSC loc. 69837, Horse Creek. The major septa are thin throughout ontogeny. They meet in groups at or near the axis, but an axial structure is not developed. A conspicuous cardinal fossula is seldom present. It is possible that more than one species is represented in this collection.

Six specimens are referred to *Rhegmaphyllum*: GSC 85548-85550, 85551 (Pl. 3.8, figs. 14, 15), GSC loc. 47404, Pedley Pass; GSC 85552, GSC loc. 56080, GSC 85553 (Pl. 3.8, figs. 12, 13), GSC loc. 56078, Pinnacle Creek. The thick major septa reach the axis without converging in conspicuous groups, and commonly form a counterclockwise whorl. The prominent cardinal fossula has parallel sides, and the cardinal septum becomes short in the calice (cf. Laub, 1979, p. 93). It is not known if these specimens all belong to a single species.

Three corals, which appear to be conspecific, are assigned to *Dinophyllum*: GSC 85554 (Pl. 3.8, fig. 16), GSC loc. 69837, Horse Creek; GSC 85555 (Pl. 3.8, figs. 17-19), GSC 85556 (Pl. 3.8, fig. 20), GSC loc. C-45574, Pedley Pass. They resemble a specimen of *D. hoskinsoni* (Foerste, 1890) from the Brassfield Formation of Kentucky (Laub, 1979, Pl. 13, figs. 4, 5) by the nature and arrangement of septa and tabulae, and by having a thin wall. However, the cardinal septum is longer than in *D. hoskinsoni*.

### Biostratigraphy

Solitary Rugosa of the combined "poorly fossiliferous interval" and *Eostropheodonta* Zone are completely different, even at the generic level, from those of the underlying *Bighornia-Thaerodonta* Zone in the Beaverfoot Formation. The corals assigned to *Streptelasma* are not of biostratigraphic value at the present time. The first known occurrence of *Dinophyllum* in the Beaverfoot is at 594 to 621 feet (181.0-189.3 m) above the base of the formation at Horse Creek (Table 3.3), and the specimen resembles *D. hoskinsoni* from the mid-Llandovery of Kentucky. Elsewhere, the earliest record of *Dinophyllum* is from strata considered to be Early Llandovery in age (Bowling Green Dolomite in northeastern Missouri, Elwood Formation in northeastern Illinois, and upper Mosalem Formation in northwestern Illinois) (McAuley, 1985; Elias and McAuley, unpublished data). The species of *Dinophyllum* in the Beaverfoot Formation could be Early to Middle Llandovery. Conodonts from 659 to 749 feet (200.9-228.3 m) above the base of the Beaverfoot at Mount Sinclair indicate a Silurian age for apparently slightly higher strata (Norford, 1969, p. 39). Bolton (in Leech, 1954, p. 23, 24) reported solitary corals in collections considered to be Ordovician, from about 900 feet (274 m) and about 1000 feet (305 m) above the base of the formation at two locations (GSC locs. 23859, 23862) approximately 5 miles (8 km) northwest of White Knight Mountain. Unfortunately, the material from GSC loc. 23862 has been mislaid and corals are not present among the existing specimens from GSC loc. 23859. However, the other material from GSC loc. 23859 includes *Eostropheodonta* sp. and the collection is Silurian.

The lowest and highest records of *Rhegmaphyllum* in the Beaverfoot are at 438 to 439 feet (133.5-133.8 m) and 569 to 573 feet (173.4-174.7 m) above the base of the formation at Pinnacle Creek and Pedley Pass, respectively (Table 3.3). In the North American interior, the earliest known occurrence of this genus is in strata considered to be of Early Llandovery age (Bowling Green Dolomite in northeastern Missouri, Elwood Formation in northeastern Illinois, and upper Mosalem Formation in northwestern Illinois) (McAuley, 1985; Elias and McAuley, unpublished data). Near the continental margin, *Rhegmaphyllum* appears earlier. At Pointe Laframboise on Anticosti Island, Québec, it first occurs in the lowest 3 feet (1 m) of the Becscie Formation (Elias and Petryk, unpublished data; see Petryk, 1981, Fig. 11). This is about 3 feet (1 m) above the Ordovician-Silurian (Gamachian-Llandovery) boundary based on conodonts (McCracken and Barnes, 1981), but strata equivalent in age to the basal Silurian *Parakidograptus acuminatus* Graptolite Zone may be much higher in the sequence (Lespérance, 1985, Fig. 3; McCracken and Nowlan, 1986, p. 143, Fig. 3). At St. Clair Spring in Arkansas, *Rhegmaphyllum* is present in an oolitic pelmatozoan limestone at the base of the Cason Oolite (Elias and McAuley, unpublished data; see Amsden, 1986, Fig. 19). Brachiopods and conodonts from this unit indicate a latest Ordovician (Hirnantian, Gamachian) age (Amsden, 1986, p. 20, 22; Barrick, 1986, p. 64, 66). In the southeastern United States, *Rhegmaphyllum* occurs in strata considered to be Richmondian (Elias and Stock, unpublished data). It has been found in the Sequatchie Formation at Birmingham, Alabama (see Drahovzal and Neathery, 1971, p. 25, 237, Stop 10), and in the Shellmound Formation at Pope Spring, Georgia (see Milici and Wedow, 1977, p. 8, 9, 33, section 26b). *Rhegmaphyllum* and *Dinophyllum* have not yet been found together in the same stratigraphic interval of the Beaverfoot Formation. Strata bearing *Rhegmaphyllum* could be older than those containing *Dinophyllum*, and could be Late Ordovician (Richmondian, Gamachian) to Early Silurian (Early Llandovery).

The Ordovician-Silurian boundary is situated somewhere between the top of the *Bighornia-Thaerodonta* Zone, which has been traced to a height of 420 feet (128 m) above the base of the Beaverfoot Formation at Akutlak Creek, and the lowest known occurrence of *Dinophyllum*, at 594 to 621 feet (181.0-189.3 m) above the base at Horse Creek. Sedimentation may have been essentially continuous from the beginning of the deposition of Beaverfoot strata in the Maysvillian or Richmondian, through the Gamachian, and into the Llandovery.

## SYSTEMATIC PALEONTOLOGY

(C.J. Buttler and R.J. Elias)

### Subclass RUGOSA Milne Edwards and Haime, 1850

### Order STAURIIDA Verrill, 1865

### Suborder STREPTELASMATINA Wedekind, 1927

### Family STREPTELASMATIDAE Nicholson *in* Nicholson and Lydekker, 1889

### Subfamily STREPTELASMATINAE Nicholson *in* Nicholson and Lydekker, 1889

### Genus *Salvadorea* Nelson, 1981

*Salvadorea* Nelson, 1981, p. 45; Elias, 1985, p. 43, 45.

*Helicelasma* Neuman, 1969. Elias, 1981, p. 19, 20 (*part.*); Elias, 1982a, p. 60, 61 (*part.*); Elias, 1983a, p. 934 (*part.*).

Type species. *Salvadorea kingae kingae* Nelson, 1981, herein considered to be a junior synonym of *S. distincta distincta* (Wilson, 1926).

### *Salvadorea distincta distincta* (Wilson, 1926)

Plate 3.1, figures 1-15; Plate 3.2, figures 1, 2

*Streptelasma distinctum* Wilson, 1926, p. 12, 13 (*part.*), Pl. 1, fig. 7, *non* Pl. 1, fig. 6.

*Streptelasma prolongatum* Wilson, 1926, p. 11, 12 (*part.*), Pl. 1, fig. 5, (?) Pl. 2, fig. 2, *non* Pl. 1, figs. 3, 4.

(?) *Streptelasma* sp. cf. *S. distinctum* Wilson, 1926. Pestana, 1960, p. 866, Pl. 109, fig. 6.

(?) *Streptelasma distinctum* Wilson, 1926. Kaljo and Klaamann, 1965, p. 418, 419, Pl. 1, figs. 8, 9.

*non Streptelasma* cf. *distinctum* Wilson, 1926. Ho, 1978, p. 10, 11, Pl. 1, fig. 3a-d.

*Salvadorea kingae* Nelson, 1981, p. 45-47, fig. 12, Pl. 3, figs. 1-10, Pl. 4, figs. 1-14, Pl. 5, figs. 1-7.

*Salvadorea*? sp. 1. Nelson, 1981, p. 47, 48, Pl. 5, figs. 8-12.

*Salvadorea kingae kingae* Nelson, 1981. Elias, 1985, p. 45-48, Figs. 19.1-19.24.

*Lectotype*. Designated herein: GSC 6731a (Wilson, 1926, Pl. 1, fig. 7), uncertain stratigraphic position, Beaverfoot Formation, GSC loc. 7561, 0.5 miles (0.8 km) east of the trail over Palliser Pass, J.R. Marshall collection (for location, see Fig. 3.1).

*Additional specimens described herein*. All from the Beaverfoot Formation (for locations, see Fig. 3.1; for stratigraphic positions, see Table 3.1).

Early collections: GSC 6729a (Wilson, 1926, Pl. 1, fig. 5), GSC 85557, GSC loc. 7563, 0.75 miles (1.2 km) east of the trail over Palliser Pass, J.R. Marshall collection; GSC 85558, GSC loc. 7969, between Spray and Palliser rivers, from the western slope of a knoll between Mount Sir Douglas and Mount Munro (elevation 7800 ft., 2377 m), J.R. Marshall collection; GSC 85559, 85560, GSC loc. 5063, Carbonate Creek, L.D. Burling collection.

Root collection: GSC 85561, 85562, White Knight Mountain.

Norford collection: GSC 85563, GSC loc. 56107, Mount Wilson; GSC 85564-85566, GSC loc. 57209, Tipperary Lake; GSC 85567, GSC loc. 64584, 4 miles (6.4 km) south-southeast of Indianhead Mountain; GSC 85568-85570, GSC loc. 56076, Pinnacle Creek; GSC 85571, 85572, GSC loc. 45606, GSC 85573 (Pl. 3.1, fig. 2), GSC loc. 45604, Hatch Creek; GSC 85574 (Pl. 3.1, fig. 3), GSC loc. 52183, Pagliaro Creek; GSC 85575 (Pl. 3.1, fig. 8), GSC loc. 45582, GSC 85576, GSC loc. 52160, Blackfoot Creek; GSC 85577, 85578, GSC loc. 58188, Shatch Mountain; GSC 85579 (Pl. 3.1, fig. 1), GSC loc. 52186, Pipestone River; GSC 85580 (Pl. 3.1, fig. 7), GSC loc. 42026, Cirrus Mountain.

Present collection (all from Akutlak Creek; see Figs. 3.2, 3.4): GSC 85581-85583, 85584 (Pl. 3.1, figs. 10-15), GSC 85585 (Pl. 3.1, fig. 9), GSC 85586-85589, 85590 (Pl. 3.1, figs. 5, 6), GSC 85591, 85592, interval A14/15; GSC 85593, interval A15/16; GSC 85594, 85595, interval A18; GSC 85596-85598, rubble near interval A18; GSC 85599 (Pl. 3.1, fig. 4), interval B1; GSC 78350 (Elias and Buttler, 1986, fig. 2e), GSC 85600-85602, interval B5; GSC 85603, 85604, interval B6; GSC 85605, 85606, interval B7; GSC 85607, interval B16; GSC 85608, interval B20; GSC 85609, interval B23; GSC 85610, interval B24; GSC 85611, 85612, interval B25; GSC 85613 (Pl. 3.2, figs. 1, 2), talus.

*Occurrences.* Upper Ordovician: *Bighornia-Thaerodonta* Zone (Richmondian, and possibly Maysvillian and Gamachian, strata), Beaverfoot Formation including Whiskey Trail Member, southern Rocky Mountains, British Columbia and Alberta; Caution Creek and Chasm Creek formations (middle-upper Richmondian), northern Manitoba; Aleman Formation (upper Maysvillian to lower Richmondian strata, and possibly lower-middle Maysvillian strata), southern New Mexico and westernmost Texas.

*Diagnosis.* Corallum trochoid, circular or rarely triangulate in cross-section. Septa moderately to completely dilated in early stages, degree of dilation decreasing during ontogeny to nondilated in late stages. Major septa converge axially in groups, generally forming a slight counterclockwise whorl. Axial structure highly variable in late stages, from small, comprising a few septal lobes, to large with numerous long, contorted septal lobes and lamellae; commonly of intermediate size with septal lobes and few lamellae. Cardinal fossula broad with enlarged axial end, cardinal septum typically short in late stages. Minor septa confined to, or extend a short distance beyond, moderately broad stereozone. Tabulae greatly convex upward, greatly depressed in cardinal fossula.

*Description of coralla.* The largest specimen is 56 mm long and has a maximum diameter of 29 mm, but the base and top are missing (GSC 85613). The coralla are slightly curved with a convex cardinal side, and are trochoid (Pl. 3.1, figs. 10, 11) to rarely ceratoid (Pl. 3.2, fig. 1). The majority have circular cross-sections, but 3 of 17 individuals are slightly triangulate in late ontogenetic stages (Pl. 3.1, fig. 7). Septal grooves and interseptal ridges are preserved on a few specimens. Depth of the calice is 40 per cent of the coral length in one individual (GSC 78350, length = 42 mm; Elias and Buttler, 1986, Fig. 2e), and 49 per cent in another (GSC 85593, length = 45 mm).

*Ontogeny and internal structures.* The relationship between number of septa and coral diameter is shown in Figure 3.5. In early ontogenetic stages (Pl. 3.1, figs. 1, 3-5), major septa are moderately to completely dilated. Dilation decreases gradually during intermediate stages (Pl. 3.1, figs. 2, 6, 14), and septa are nondilated by late stages (Pl. 3.1, figs. 7-9, 15; Pl. 3.2, fig. 2). During early to intermediate stages, groups of adjacent septa join a short distance from the axis. Septal lobes arising from these groups extend to the axis, and become increasingly prominent in the axial region. In late stages, major septa continue to converge into groups, and commonly form a slight counterclockwise whorl (Pl. 3.1, fig. 8). The radius of the axial region ranges from 23 per cent (GSC 85559) to 41 per cent of the coral radius (GSC 85613). The axial structure varies from a few septal lobes extending from the groups of septa in corals with a small axial region (Pl. 3.1, figs. 7, 8), to a complex structure of numerous long, contorted septal lobes and lamellae in those with a large axial structure (Pl. 3.2, fig. 2). There is a complete gradation between these end members; axial structures of intermediate size with septal lobes and a few lamellae are most common (Pl. 3.1, figs. 9, 15).

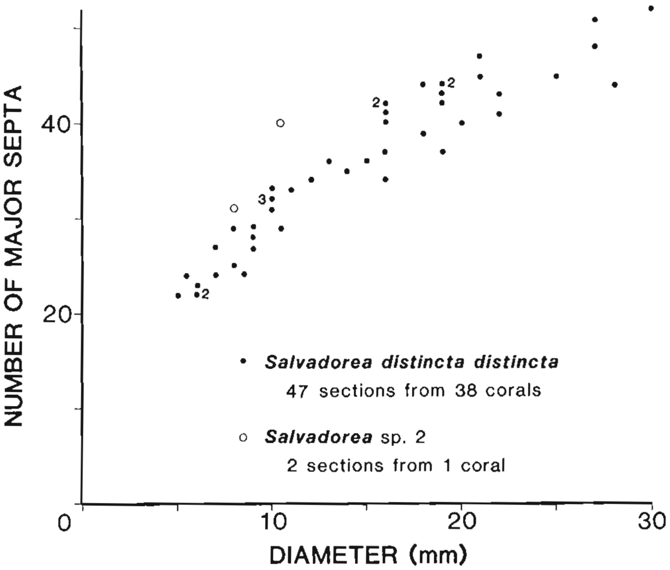

***Figure 3.5.*** *Relationship between number of major septa and coral diameter in* ***Salvadorea distincta distincta*** *and* ***Salvadorea*** *sp. 2 from* ***Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta, and Alberta, respectively.*

The cardinal septum is long in early to intermediate stages, when it becomes thinner than the other major septa (Pl. 3.1, figs. 6, 14). In cross-sections through late stages, the middle portion of this septum is generally absent, leaving a short septum and a projection from the axis (Pl. 3.1, figs. 7, 8; Pl. 3.2, fig. 2). At the base of the calice, this axial projection disappears (Pl. 3.1, fig. 9). The cardinal septum becomes short in 11 of 17 specimens (65%). The greatest diameter at which a long cardinal septum is present is 21 mm (GSC 85594), and the smallest diameter with a short cardinal septum is 11 mm (GSC 85612). The cardinal fossula is broad in late stages and expands at the axial end.

The length of minor septa in late stages varies from 20 per cent (GSC 85613) to 30 per cent of the corallum radius (GSC 85585). Minor septa are confined to the stereozone during late stages in 8 of 16 specimens. In the remainder, up to 50 per cent of the length of the minor septa extends beyond the stereozone (GSC 85613). Thickness of the stereozone ranges from 14 per cent (GSC 85613) to 33 per cent of the corallum radius (GSC 85611).

The complete and incomplete tabulae are greatly convex upward and greatly depressed in the cardinal fossula, where they decline from the axis at an angle of approximately 60° (Pl. 3.1, figs. 12, 13; Pl. 3.2, fig. 1). Spacing of tabulae varies from 0.4 mm (GSC 85584) to 2.4 mm (GSC 85613).

*Microstructure.* In transverse thin sections, the major septa are fibrous (e.g., Elias, 1981, Fig. 5a, and Elias, 1983a, Fig. 7a). From a medial position in the septum, fibres typically curve outward in the direction of the coral axis. In one individual (GSC 85575), the fibres appear to be perpendicular to the medial line. In the stereozone during intermediate to late stages, U-shaped lamellae with concave sides facing the coral axis are present between the major and minor septa. A contorted suture extends through the lamellae in a medial position between the septa. The epitheca consists of short, indistinct fibres that are approximately perpendicular to the surface of the corallum. In longitudinal thin sections, septal fibres are slightly inclined from the coral wall toward the axis.

*Discussion.* *Streptelasma distinctum* was originally described from the Beaverfoot Formation in British Columbia by Wilson (1926). She did not identify type specimens, but illustrated two corals. One of them is herein designated as the lectotype of *Salvadorea distincta distincta* (Wilson, 1926) (GSC 6731a; Wilson, 1926, Pl. 1, fig. 7). The other is reassigned to *Bighornia patella* (Wilson, 1926). Another coral illustrated by Wilson (1926, Pl. 1, fig. 5; GSC 6729a) is circular to slightly triangulate in cross-section. The dashed line added to the published figure incorrectly implies that the cardinal side of the specimen is incomplete, and that the corallum is greatly compressed. This individual was originally identified as *Streptelasma prolongatum* Wilson, 1926, but is herein reassigned to *Salvadorea distincta distincta*. The specimen with an oblique polished surface that was illustrated as *Streptelasma prolongatum* may be *Salvadorea distincta distincta* (GSC 6730; Wilson, 1926, Pl. 2, fig. 2).

The corals described herein cannot be distinguished morphologically from those previously assigned to *Salvadorea kingae kingae* Nelson, 1981 (which includes *Salvadorea*? sp. 1 of Nelson, 1981; see Elias, 1985, p. 48). The latter taxon has been documented from the Caution Creek and Chasm Creek formations of the Churchill River Group in Manitoba (Nelson, 1981), and the Aleman Formation of the Montoya Group in New Mexico and Texas (Elias, 1985). Ranges of variability involving the degree of septal dilation, size and nature of the axial structure, size and shape of the cardinal fossula, length of the minor septa, and thickness of the stereozone, are similar. Variability in the number of septa is essentially the same for specimens from the Beaverfoot Formation and Churchill River Group, but the number of septa in corals from the Aleman Formation tends to be in the higher half of the range (compare Fig. 3.5 with Elias, 1985, Fig. 20). The proportion of coralla in which the cardinal septum becomes short below the calice does not differ significantly among specimens from the Beaverfoot Formation, the Caution Creek and Chasm Creek formations, and the Aleman Formation (using a chi-square test for proportions, with $\alpha = 0.05$; see Elias, 1985, Table 3).

The only distinguishing characteristic of the specimens from the Beaverfoot Formation is that a small proportion of individuals are slightly triangulate in late stages, whereas all the corals known from elsewhere are circular in cross-section. However, some slightly triangulate individuals have also been reported in *Salvadorea distincta cutterensis* Elias, 1985, from the Cutter Dolomite (lower-middle Richmondian) of the Montoya Group in New Mexico and Texas (Elias, 1985, p. 50, Figs. 21.13, 21.17-21.19). This feature alone is considered insufficient to allow the discrimination of *S. distincta distincta* from the separate taxon *S. kingae kingae*, and the latter is herein regarded as a junior synonym. Most specimens of *S. distincta cutterensis* lie within the range of variability in *S. distincta distincta*. However, the axial structure is always very small, comprising a few septal lobes only, and the minor septa are generally longer.

Pestana (1960) identified a single, small specimen from the Johnson Spring Formation (Middle Ordovician; Rocklandian-Kirkfieldian) of California as *Streptelasma* sp. cf. *S. distinctum*. He noted that "it is probably a distinct species but available material is not adequate for a specific description" (Pestana, 1960, p. 866).

Kaljo and Klaamann (1965) identified *Streptelasma distinctum* from the Portrane Limestone (Upper Ordovician; Ashgill) of Ireland. Their description and illustrations of poorly preserved, silicified material do not provide enough information to confirm the taxonomic assignment. They considered *Streptelasma bystrowi* Reiman, 1958, from the Vormsi Horizon (Upper Ordovician; upper Caradoc) of the Estonian S.S.R. to be a junior synonym of *S. distinctum*. However, that species is insufficiently known for such a conclusion to be verified (Reiman, 1958, p. 33, 34, Pl. 1, figs. 4-6).

Ho (1978) reported *Streptelasma* cf. *distinctum* from the Guanyinqiao beds (Upper Ordovician; Ashgill, Hirnantian) within the Wufeng Formation in the Guizhou Province of China. Unlike in *Salvadorea distincta*, a large, open axial region appears to develop in late stages (Ho, 1978, Pl. 1, fig. 3c).

One specimen from the Beaverfoot Formation resembles *S. distincta distincta*, but has nondilated and more numerous major septa, and a narrow stereozone. It is identified as *Salvadorea* sp. 2 of Nelson, 1981.

### *Salvadorea* sp. 2 of Nelson, 1981

Plate 3.2, figures 3-6

*Salvadorea* sp. 2. Nelson, 1981, p. 48, Pl. 5, figs. 13-17.

*Specimen described herein.* GSC 85614, Beaverfoot Formation, GSC loc. 56107, Mount Wilson (for location, see Fig. 3.1; for stratigraphic position, see Table 3.1).

*Occurrences.* Upper Ordovician: member 2, Chasm Creek Formation (middle-upper Richmondian), northern Manitoba; *Bighornia-Thaerodonta* Zone (Richmondian, or possibly Maysvillian, strata), Beaverfoot Formation, southern Rocky Mountains, Alberta.

*Description.* The small, silicified specimen has a maximum diameter of 10.5 mm. It is trochoid, and circular in cross-section. The relationship between number of septa and coral diameter is shown in Figure 3.5. The major septa are nondilated in the early stage, and appear to meet at the axis (Pl. 3.2, fig. 4). In intermediate and late stages (Pl. 3.2, figs. 5, 6), adjacent septa join a short distance from the axis. Lobes arising from these groups extend to the axis, forming a small, simple axial structure with a radius that is 33 per cent of the corallum radius in the late stage. The cardinal septum is long, and the cardinal fossula is moderately broad. Minor septa cannot be recognized; if present, they are confined to the relatively narrow stereozone. Tabulae are moderately convex upward, and slightly depressed in the cardinal fossula (Pl. 3.2, fig. 3).

*Discussion.* Except for its smaller size, the specimen described herein cannot be distinguished from two individuals found in Manitoba and identified as *Salvadorea* sp. 2 by Nelson (1981). These corals differ from *S. distincta distincta* (Wilson, 1926) in having nondilated and more numerous major septa (refer to Fig. 3.5), and a narrow stereozone. Nelson (1981, p. 48) considered them to be either aberrant representatives of *S. distincta distincta*, or a new species. Because of this uncertainty, and the small amount of material, a specific name has not be assigned.

### **Genus *Bighornia* Duncan, 1957**

*Bighornia* Duncan, 1957, p. 608-611; Nelson, 1963, p. 39, 40; Neuman, 1977, p. 75; Elias, 1981, p. 24, 25; Elias, 1982a, p. 79, 80; Elias, 1983a, p. 948.

Type species. *Bighornia parva* Duncan, 1957, herein considered to be a junior synonym of *B. patella* (Wilson, 1926).

*Diagnosis.* Corallum typically depressed and subcalceoloid, with concave cardinal side. Cross-sectional shape in early stages depressed and triangulate, or oval with flattened counter side, or crescentic with concave cardinal side; in later stages slightly depressed and triangulate, or oval, or round. Axial structure includes solid columella elongate in cardinal-counter direction and contiguous with counter septum, plus a few septal lobes and, rarely, lamellae. Cardinal fossula moderately broad to broad in late stages.

*Discussion.* The relationship between coral height and average cross-sectional dimension for *Bighornia* is shown in Figure 3.6. Two groups of specimens can be identified. One consists of small to medium sized individuals, and the other of corals that expand rapidly above the apex and attain a large size. Duncan (1957, p. 613) and Nelson (1963, p. 39-41) distinguished species within the small to medium size category on the basis of external form, number of septa, and length of minor septa. Subsequent studies (Elias, 1981, 1982a, 1983a, 1985; present study) have documented the ranges of variability involving external form and its relation to internal morphology, including the number of septa and their arrangement. Elias (1981, p. 25, 26; 1982a, p. 81, 82; 1983a, p. 952; 1985, p. 41, 43) recognized the close similarity of all corals in the small to medium size group, and tentatively referred to them as *B.* cf. *B. patella* (Wilson, 1926) because *B. patella* from the type area was poorly known. However, consistent differences involving length of the cardinal septum and the orientation of septal fibres were noted between Edenian-Maysvillian and Richmondian collections (Elias, 1985, p. 18). Material described herein from the Beaverfoot Formation provides sufficient data for a taxonomic revision. The small to medium sized upper Upper Ordovician corals, including those described as *B. parva* by Duncan (1957), are assigned to *B. patella* (Wilson, 1926). *Bighornia wilsonae* Buttler and Elias, sp. nov., is proposed for the lower Upper Ordovician forms.

With the exception of *B. bottei* Nelson, 1963, taxa included definitely or tentatively in the large size category of the genus are poorly known. They are listed below.

*Streptelasma integriseptatum* Parks, 1915, p. 13-15, Pl. 5, figs. 1-3; Churchill River Group (middle-upper Richmondian), lower rapids, Shamattawa (Gods) River, northern Manitoba.

*Streptelasma haysii* (Meek, 1865). Cox, 1937, p. 8, 9 (*part.*), Pl. 2, fig. 4a, b; Cape Frazier, Ellesmere Island, District of Franklin.

(?) *Streptelasma*? *oppletum* Teichert, 1937, p. 51, 52, Pl. 2, figs. 5-8, Pl. 3, figs. 1-4; Uglerlarsuk, Ungerlodjan, and Iglulik Island, east coast, Melville Peninsula, District of Franklin, and Cape Calhoun Formation (Upper Ordovician), Cape Calhoun, northwestern Greenland.

(?) *Streptelasma*? *latum* Teichert, 1937, p. 52, 53, Pl. 2, figs. 3, 4, 9; drift, Cape Griffith, Baffin Island, District of Franklin.

(?) *Streptelasma* cf. *integriseptatum* Parks, 1915. Stearn, 1956, p. 88, 89; Stonewall Formation (uppermost Richmondian to Gamachian), near The Pas, Manitoba.

*Bighornia* sp. Nelson, 1959, Pl. 4, figs. 3a-d; Nelson, 1975, Pl. 8, figs. 4-7; Chasm Creek Formation (middle-upper Richmondian), northern Manitoba.

*Bighornia bottei* Nelson, 1963, p. 41-43, Pl. 5, fig. 6, Pl. 9, figs. 5, 6a-d, Pl. 11, figs. 5a, b, 6a-c, 7, 8, Pl. 12, figs. 1, 2a-g, 3a, b, 4a-c; Chasm Creek Formation (middle-upper Richmondian), northern Manitoba.

*Bighornia* cf. *B. bottei* Nelson, 1963. Described herein; *Bighornia-Thaerodonta* Zone (Richmondian, or possibly Maysvillian, strata), Beaverfoot Formation, southern Rocky Mountains, British Columbia.

### *Bighornia patella* (Wilson, 1926)

Plate 3.2, figures 7-11; Plate 3.3, figures 1-12;
Plate 3.4, figure 1

*Streptelasma patellum* Wilson, 1926, p. 13, Pl. 2, fig. 1.

*Streptelasma distinctum* Wilson, 1926, p. 12, 13 (*part.*), Pl. 1, fig. 6, *non* Pl. 1, fig. 7.

(?) *Streptelasma* aff. *breve* Ulrich in Winchell and Schuchert, 1895. Troedsson, 1928, p. 109, Pl. 26, figs. 6, 7.

*Lindströmia solearis* Ladd, 1929, p. 397-399, Pl. 4, figs. 6-12.

? *Holophragma scheii* Cox, 1937, p. 15-17, Pl. 2, figs. 14-16.

*Holophragma anticonvexa* Okulitch, 1943, p. 68, 69, Pl. 1, figs. 11, 12.

"*Holophragma*" sp. Ross, 1957, Pl. 37, figs. 3, 5-7.

*Bighornia parva* Duncan, 1957, p. 611-614, Pl. 70, figs. 1-18; Norford, 1962b, Pl. 6, figs. 12, 16; Norford et al., in Douglas, 1970, Pl. 5, figs. 3, 11.

*Bighornia patella* (Wilson, 1926). Nelson, 1963, p. 40, 41, Pl. 11, figs. 1a-c, 2, 3a-d.

*Bighornia solearis* (Ladd, 1929). Nelson, 1963, p. 41, Pl. 11, fig. 4a-d.

(?) *Bighornia* sp. Norford and Macqueen, 1975, Pl. 9, figs. 9, 10; Oliver in Oliver, Merriam, and Churkin, 1975, Pl. 5, fig. 6.

*Bighornia* cf. *B. patella* (Wilson, 1926). Elias, 1981, p. 25, 26 (*part.*), *non* Pl. 10, figs. 1-21; Elias, 1982a, p. 80-82 (*part.*), Pl. 14, figs. 17-24, Pl. 15, figs. 1-11; Elias, 1983a, p. 948, 950-952 (*part.*), Figs. 7d, 14e-t, 16a-o.

*Bighornia* sp. cf. *B. patella* (Wilson, 1926). Elias, 1985, p. 40, 41, 43 (*part.*), Figs. 16.14-16.16, *non* Figs. 16.1-16.13, 17.

*Lectotype.* Designated herein: GSC 6732 (Wilson, 1926, Pl. 2, fig. 1; Pl. 3.2, fig. 7), 50 feet (15.2 m) above the base, Beaverfoot Formation, GSC loc. 7935, near head of Windermere Creek, J.F. Walker collection (for location, see Fig. 3.1).

*Additional specimens described herein.* All from the Beaverfoot Formation (for locations, see Fig. 3.1; for stratigraphic positions, see Table 3.1).

Early collections: GSC 6731 (Wilson, 1926, Pl. 1, fig. 6), GSC loc. 7561, 0.5 miles (0.8 km) east of the trail over Palliser Pass, J.R. Marshall collection; GSC 85615, GSC loc. 5064, GSC 85616, GSC loc. 5063, GSC 85617-85619, GSC loc. 5062, Carbonate Creek, L.D. Burling collection.

Root collection: GSC 85620, 85621, White Knight Mountain.

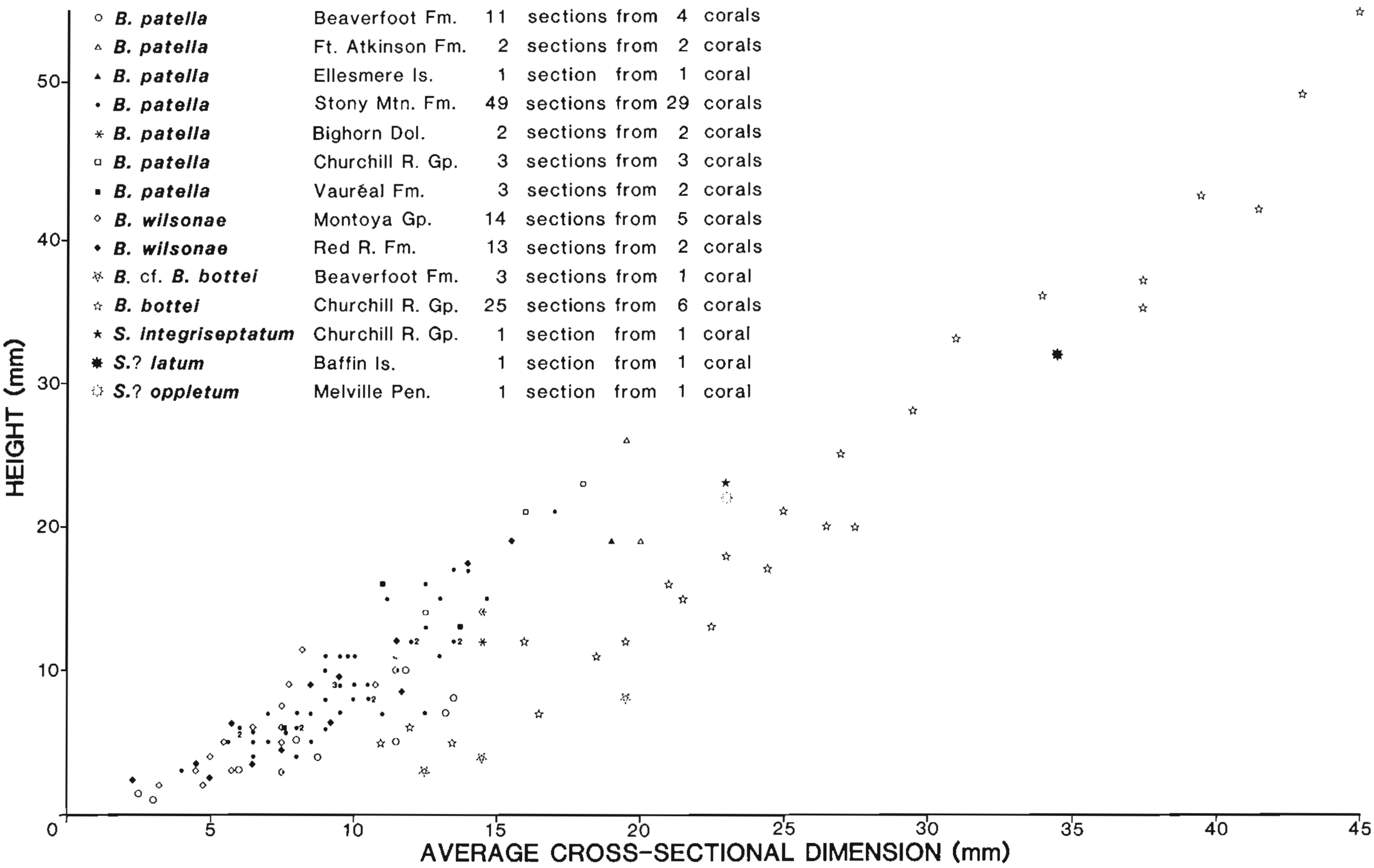

*Figure 3.6. Relationship between coral height and average cross-sectional dimension (average of cardinal-counter and alar-alar dimensions) in* ***Bighornia***. ***Bighornia patella:*** ***Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta; Fort Atkinson Formation, Maquoketa Group, Iowa; Ellesmere Island, District of Franklin (Cox, 1937, p. 16); Gunn and Penitentiary members, Stony Mountain Formation, Manitoba; upper Bighorn Dolomite, Wyoming (Duncan, 1957, p. 611, 612, Pl. 70, figs. 8, 14); Caution Creek and Chasm Creek formations, Churchill River Group, Manitoba (Nelson, 1963, Pl. 11, figs. 1b, c, 3b, c, 4b, c); lower member, Vauréal Formation, Québec.* ***Bighornia wilsonae:*** *Upham Dolomite Member, Second Value Dolomite, Montoya Group, New Mexico and Texas; Selkirk Member, Red River Formation, Manitoba.* ***Bighornia cf. B. bottei:*** ***Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia.* ***Bighornia bottei:*** *Chasm Creek Formation, Churchill River Group, Manitoba (Nelson, 1963, p. 42, 43).* ***Streptelasma integriseptatum:*** *Churchill River Group, lower rapids, Shamattawa (Gods) River, Manitoba.* ***Streptelasma? latum:*** *drift, Baffin Island, District of Franklin (Teichert, 1937, Pl. 2, figs. 3, 4).* ***Streptelasma? oppletum:*** *Melville Peninsula, District of Franklin (Teichert, 1937, Pl. 2, figs. 6, 8).*

Norford collection: GSC 85622-85624, GSC loc. 52183, Pagliaro Creek; GSC 85625 (Pl. 3.2, figs. 8-11), GSC 85626-85628, GSC loc. 69839, Horse Creek; GSC 85629 (Pl. 3.3, figs. 6-9), GSC loc. 45579, GSC 85630, GSC loc. 45580, Blackfoot Creek; GSC 85631, GSC loc. 58188, Shatch Mountain; GSC 85632, GSC loc. 42026, Cirrus Mountain.

Present collection (all from Akutlak Creek; see Figs. 3.2, 3.4): GSC 85633 (Pl. 3.3, figs. 4, 5), GSC 85634-85638, interval A14/15; GSC 85639, interval B2; GSC 85640, 85641 (Pl. 3.3, figs. 10-12), GSC 85642, interval B5; GSC 85643 (Pl. 3.4, fig. 1), interval B6; GSC 85644, interval B16; GSC 85645, 85646 (Pl. 3.3, figs. 1-3), interval B24; GSC 85647, 85648, interval B25.

*Occurrences.* Upper Ordovician: *Bighornia-Thaerodonta* Zone (Richmondian, and possibly Maysvillian and Gamachian, strata), Beaverfoot Formation including Whiskey Trail Member, southern Rocky Mountains, British Columbia and Alberta; Fort Atkinson Formation (Richmondian), Ossian, Iowa; Strandpilaren, Norman Lockyer Island, Princess Marie Bay, Ellesmere Island, District of Franklin; Gunn and Penitentiary members (middle-upper Richmondian), Stony Mountain Formation, Stony Mountain, Manitoba; shaly beds at the top of Bighorn Dolomite (middle-upper Richmondian), Johnson County, Wyoming; Caution Creek and Chasm Creek formations (middle-upper Richmondian strata), northern Manitoba; lower member, Vauréal Formation (Richmondian), Anticosti Island, Québec; Cutter Dolomite (middle Richmondian strata), Texas.

*Diagnosis.* Corallum of small to medium size. Axial structure composed of prominent columella, plus septal lobes and rarely a few lamellae in late stages. Cardinal septum becomes thin and decreases in length during intermediate stages, and moderately broad cardinal fossula develops. In transverse sections, septal fibres are oriented perpendicular to medial line within septum. Tabulae in incompletely dilated stages convex upward, greatly depressed in cardinal fossula.

*Description of coralla.* Alar-alar and cardinal-counter dimensions across the calice rim of the largest individual are 22 mm and 19 mm, respectively (GSC 85620). The height of

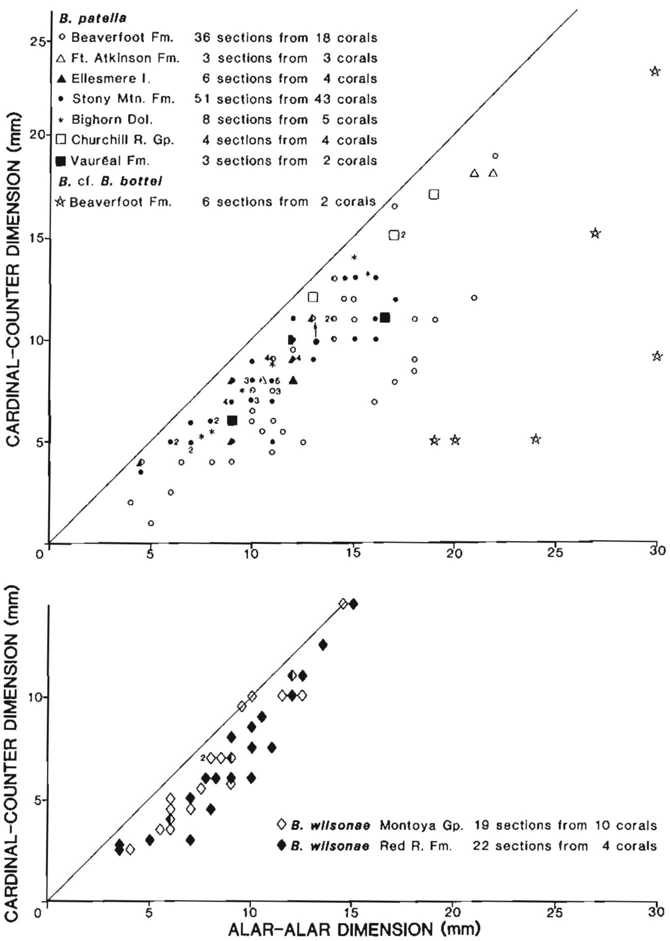

***Figure 3.7.*** *Relationship between cardinal-counter and alar-alar cross-sectional dimensions in* ***Bighornia. Bighornia patella: Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta; Fort Atkinson Formation, Maquoketa Group, Iowa; Ellesmere Island, District of Franklin; Gunn and Penitentiary members, Stony Mountain Formation, Manitoba; upper Bighorn Dolomite, Wyoming (Duncan, 1957, p. 611-613); Caution Creek and Chasm Creek formations, Churchill River Group, Manitoba (Nelson, 1963, Pl. 11, figs. 1c, 2, 3c, 4c); lower member, Vauréal Formation, Québec.* ***Bighornia cf. B. bottei: Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia.* ***Bighornia wilsonae:*** *Upham Dolomite Member, Second Value Dolomite, Montoya Group, New Mexico and Texas; Selkirk Member, Red River Formation, Manitoba. Equidimensional corals plot on the line, depressed corals plot below the line.*

this specimen is about 20 mm, but the apex is missing. The relationship between coral height and average cross-sectional dimension for the species is shown in Figure 3.6. The coralla are subcalceoloid in form, and slightly curved with a concave cardinal side. They are depressed throughout ontogeny (Fig. 3.7).

Cross-sectional shapes are highly variable, but intergradational. Of 35 specimens, 54 per cent are triangulate with a flattened counter side and angulate cardinal side (Pl. 3.2, figs. 8-11). The degree of triangulation decreases during ontogeny. In one of these corals, the counter side is slightly concave (GSC 85648). The flattened cardinal side in the apical portion of two specimens is thought to represent an attachment site (Pl. 3.3, figs. 1-3). The shape of 32 per cent of the specimens is suboval (Pl. 3.3, figs. 4, 5). One of these is subrectangular in early stages (GSC 85644). The shape of cross-sections in 14 per cent of the corals is crescentic (Pl. 3.3, figs. 10-12), becoming subrectangular to suboval in one individual (Pl. 3.3, figs. 6-9). In all of these cases, a slight ridge is centred along the cardinal septum. Lateral flanges increase the width of the concave indentation in two coralla (Pl. 3.3, figs. 6, 7, 10-12). These spoon-shaped structures are considered to be attachment sites. The form of the coral returns to normal above such a structure (Pl. 3.3, figs. 8, 9).

Within the calice, a prominent columella rises from a low boss formed by other elements of the axial structure (Pl. 3.4, fig. 1).

*Ontogeny and internal structures.* The relationship between number of septa and average cross-sectional dimension of the coral is shown in Figure 3.8. Individuals with the highest number of septa also have the most depressed cross-sectional shapes (GSC 85644, 85648). Of 18 specimens, 67 per cent have very greatly to completely dilated septa until just below the base of the calice (Pl. 3.2, figs. 8-11; Pl. 3.3, figs. 4, 5). In 11 per cent, dilation begins to decrease during intermediate stages (Pl. 3.3, figs. 1-3). All of these corals are triangulate to suboval in form. In the remaining 22 per cent, septa are nondilated to moderately dilated in all known ontogenetic stages (Pl. 3.3, figs. 6-12). Each of these individuals has a spoon-shaped indentation on the cardinal side.

In early ontogenetic stages, major septa meet at the axis of slightly depressed coralla (Pl. 3.2, fig. 8), or along a zone that is elongate in the alar-alar direction of more depressed individuals (Pl. 3.3, figs. 1, 6, 10). During intermediate stages (Pl. 3.2, fig. 9; Pl. 3, figs. 2, 4, 7, 11), a columella develops at the axis. It is an extension of the counter septum, and is lenticular in cross-section and elongate in the cardinal-counter direction. The columella is comparatively small in markedly depressed corals. The cardinal septum becomes thin, detaches from the columella, and remains very short thereafter. In 11 specimens, it was verified that the cardinal septum becomes short below the level at which sediment fills interseptal spaces. The cardinal septum is long at higher levels only in two individuals. The cardinal fossula is moderately broad, with an expanded axial end. In intermediate to late stages (Pl. 3.2, figs. 10, 11; Pl. 3.3, figs. 3, 5, 8, 9, 12), the major septa join in groups axially, and septal lobes, as well as, rarely, a few lamellae, appear on both alar sides of the columella. Minor septa are confined to the stereozone until the base of the calice, where some extend a very short distance beyond it in many corals. Thickness of the stereozone at the base of the calice ranges from 17 per cent (GSC 85633) to 31 per cent of the average cross-sectional radius (GSC 85625).

Tabulae are not apparent in the majority of specimens, which have completely dilated septa until near the base of the calice. In coralla having incompletely dilated septa in earlier stages, tabulae are greatly convex upward. They are greatly depressed in the cardinal fossula, and decline from the axis at an angle of approximately 80° (Pl. 3.4, fig. 1).

*Microstructure.* In transverse thin sections, the major septa and axial structure are fibrous (e.g., Elias, 1983a, Figs. 7d, 16g). The fibres almost always extend perpendicularly from a medial line in the septum, and radiate from a medial position in the columella. A contorted suture extends between the major and minor septa where they are in lateral contact. The epitheca consists of short, indistinct fibres that are approximately perpendicular to the surface of the corallum. In a longitudinal thin section (GSC 85643), septal fibres are slightly inclined from the coral wall toward the axis, and fibres are inclined upward from a medial position in the columella.

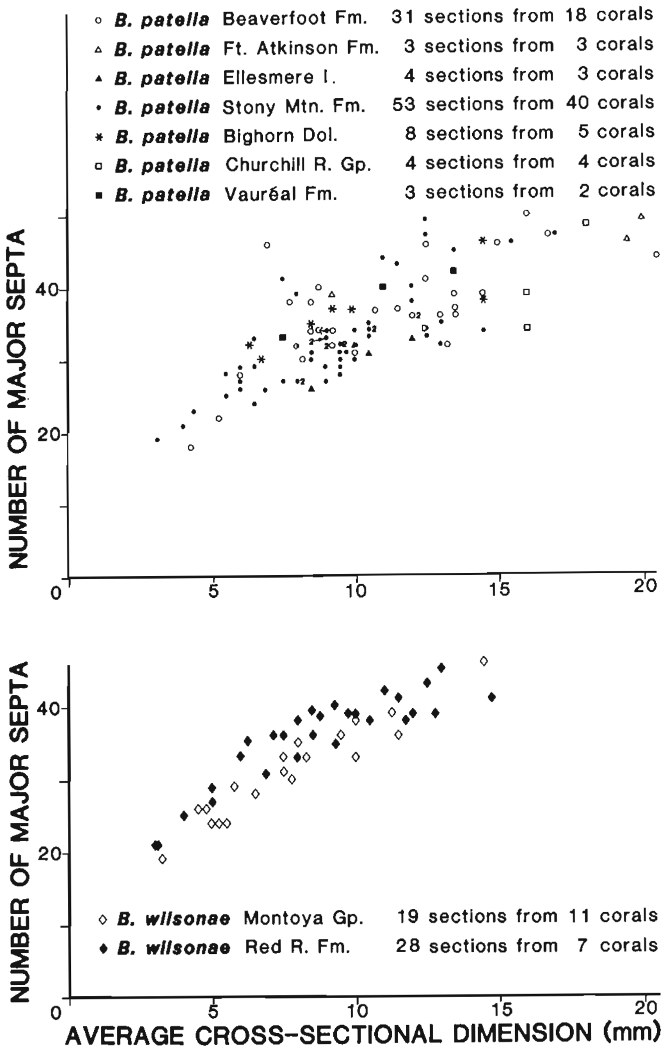

*Figure 3.8. Relationship between number of major septa and average cross-sectional dimension of coral (average of cardinal-counter and alar-alar cross-sectional dimensions) in* ***Bighornia.*** ***Bighornia patella: Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta; Fort Atkinson Formation, Maquoketa Group, Iowa; Ellesmere Island, District of Franklin; Gunn and Penitentiary members, Stony Mountain Formation, Manitoba; upper Bighorn Dolomite, Wyoming (Duncan, 1957, p. 611-613); Caution Creek and Chasm Creek formations, Churchill River Group, Manitoba (Nelson, 1963, Pl. 11, figs. 1c, 2, 3c, 4c); lower member, Vauréal Formation, Québec.* ***Bighornia wilsonae:*** *Upham Dolomite Member, Second Value Dolomite, Montoya Group, New Mexico and Texas; Selkirk Member, Red River Formation, Manitoba.*

*Discussion. Streptelasma patellum* was first described from the Beaverfoot Formation in British Columbia by Wilson (1926). She did not identify type specimens, but illustrated one coral, which is herein designated as the lectotype of *Bighornia patella* (Wilson, 1926) (GSC 6732; Wilson, 1926, Pl. 2, fig. 1; Pl. 3.2, fig. 7). Another individual that was illustrated by Wilson (1926, Pl. 1, fig. 6; GSC 6731) is depressed, and the cardinal septum is located on the concave side. It was originally identified as *Streptelasma distinctum* Wilson, 1926, but is reassigned to *B. patella.*

The material described herein cannot be distinguished from well preserved specimens from an unknown unit on Ellesmere Island (Cox, 1937; PMO A 10585-10588 examined in this study), the Stony Mountain Formation (Okulitch, 1943; Elias, 1983a), the upper Bighorn Dolomite (Ross, 1957; Duncan, 1957; see also Norford, 1962b, and Norford et al., in Douglas, 1970), and the Vauréal Formation (Elias, 1982a). All these corals lie within the range of variability that has been documented for large collections from the Stony Mountain and Beaverfoot formations, involving size and shape of the corallum, number and arrangement of septa, degree of septal dilation, length of the cardinal septum and minor septa, type of septal microstructure, size and shape of the cardinal fossula, and size and nature of the axial structure.

In this taxon, the length of the cardinal septum decreases during intermediate ontogenetic stages. It has been verified that the cardinal septum becomes short below the level at which sediment fills interseptal spaces in 24 specimens (11 from the Beaverfoot Formation, seven from the Stony Mountain Formation, three from Ellesmere Island, two from the Bighorn Dolomite, and one from the Vauréal Formation). Only two corals, both from the Beaverfoot Formation, are known to have a long cardinal septum at levels where sediment fills interseptal spaces. Septal fibres are oriented perpendicular to a medial line within the septum in transverse thin sections (Elias, 1983a, Fig. 7d). The microstructure of silicified individuals from the Fort Atkinson Formation (Ladd, 1929; Elias, 1982a), Churchill River Group (Nelson, 1963), and Cutter Dolomite (Elias, 1985) is not known, but in other respects these specimens cannot be distinguished from those discussed above. *Streptelasma patellum* was the earliest name proposed, and all these corals are herein assigned to *Bighornia patella.*

*Bighornia wilsonae* Buttler and Elias, sp. nov., is similar to *B. patella* (see Figs. 3.6-3.8; Pl. 3.4, figs. 2-5), but the cardinal septum remains long until just below the base of the calice, and septal fibres curve outward in the direction of the coral axis, from a medial position within the septum. Specimens of *Bighornia* from the following Upper Ordovician units probably belong to one of these species, but cannot be assigned with certainty because the microstructure and nature of the cardinal septum below the calice are unknown: Cape Calhoun Formation in northwestern Greenland (Troedsson, 1928; MMH 2994, 2995 examined in this study), basal and middle members of the Mount Kindle Formation in the District of Mackenzie (Norford and Macqueen, 1975), and an unnamed unit in east-central Alaska (Oliver in Oliver et al., 1975).

Two specimens from the Beaverfoot Formation that are representatives of *Bighornia* attain a substantially larger size, expand more rapidly above the apex, and are more depressed than coralla assigned to *B. patella* (Figs. 3.6, 3.7; Pl. 3.4, figs. 6-11). They are identified as *B.* cf. *B. bottei* Nelson, 1963.

### *Bighornia wilsonae* Buttler and Elias, sp. nov.

Plate 3.4, figures 2-5

(?) *Streptelasma* aff. *breve* Ulrich in Winchell and Schuchert, 1895. Troedsson, 1928, p. 109, Pl. 26, figs. 6, 7.

(?) *Bighornia* sp. Norford and Macqueen, 1975, Pl. 9, figs. 9, 10; Oliver in Oliver, Merriam, and Churkin, 1975, Pl. 5, fig. 6.

*Bighornia* sp. cf. *B. patella* (Wilson, 1926). Elias, 1981, p. 25, 26 (*part.*), Pl. 10, figs. 1-21; Elias, 1982a, p. 80-82 (*part.*), *non* Pl. 14, figs. 17-24, Pl. 15, figs. 1-11; Elias, 1983a, p. 948, 950-952 (*part.*), *non* Figs. 7d, 14e-t, 16a-o.

*Bighornia* sp. cf. *B. patella* (Wilson, 1926). Elias, 1985, p. 40, 41, 43 (*part.*), Figs. 16.1-16.13, 17, *non* Figs. 16.14-16.16.

*Derivation of name.* The species is named after Alice E. Wilson, who first described fossils from the Beaverfoot Formation.

*Holotype.* Designated herein: USNM 381185 (Elias, 1985, Figs. 16.1-16.7, 17), Upham Dolomite Member, Second Value Dolomite, Montoya Group, Cooks Range, Luna County, New Mexico (interval RHF-CR2, section 4 of Elias, 1985).

*Paratypes.* Designated herein (all from the Upham Dolomite Member, Second Value Dolomite, Montoya Group): USNM 381190 (Elias, 1985, Figs. 16.11-16.13), Alamo Canyon, Otero County, New Mexico (interval AC2, section 7 of Elias, 1985); USNM 381201 (Elias, 1985, Fig. 16.10), USNM 381202 (Elias, 1985, Figs. 16.8, 16.9), Scenic Drive, El Paso County, Texas (interval SD1, section 11 of Elias, 1985).

*Specimens examined herein.* All from the Selkirk Member, Red River Formation, Garson, Manitoba. GSC 85649 (Pl. 3.4, figs. 2, 3), Rand collection; GSC 85650, Garson Limestone Co. Ltd. quarry, Elias collection; GSC 85651 (Pl. 3.4, figs. 4, 5), Gillis Quarries Ltd. quarry, Elias collection.

*Occurrences.* Upper Ordovician: Selkirk Member (middle Maysvillian strata), Red River Formation, Garson, Manitoba; Upham Dolomite Member (middle Edenian to lowermost Maysvillian), Second Value Dolomite, New Mexico and Texas.

*Diagnosis.* Like *Bighornia patella* (Wilson, 1926), but cardinal septum remains long until immediately below base of calice in late stages. In transverse sections, septal fibres curve outward in direction of coral axis from a medial position in septum.

*Description.* Collections of *Bighornia* from the Red River Formation and Second Value Dolomite, assigned herein to *B. wilsonae*, have been described by Elias (1981, p. 25; 1985, p. 41).

*Discussion. Bighornia wilsonae* Buttler and Elias, sp. nov., resembles *B. patella* (Wilson, 1926) in external form (see Figs. 3.6, 3.7). The internal morphology of these taxa is similar (see Fig. 3.8; Pl. 3.2, figs. 8-11; Pl. 3.3, figs. 1-12), but in *B. wilsonae* the cardinal septum is long until just below the base of the calice. It has been verified that this septum remains long until above the level at which sediment begins to fill interseptal spaces in 11 specimens (seven from the Red River Formation, and four from the Second Value Dolomite). In *B. patella*, the cardinal septum becomes short earlier in ontogeny (compare Pl. 3.4, figs. 2, 3 with Pl. 3.2, figs. 10, 11, and Pl. 3.4, figs. 4, 5 with Pl. 3.3, figs. 11, 12). The microstructure in transverse sections of these species is also different. Septal fibres in *B. wilsonae* curve outward in the direction of the coral axis from a medial position within the septum (Elias, 1985, Fig. 17). In *B. patella*, the fibres are perpendicular to the medial line. Uncertainty concerning the specific identity of specimens from Greenland, District of Mackenzie, and Alaska, was discussed under *Bighornia patella*.

### *Bighornia* cf. *B. bottei* Nelson, 1963

Plate 3.4, figures 6-11

(cf.) *Bighornia* sp. Nelson, 1959, Pl. 4, figs. 3a-d; Nelson, 1975, Pl. 8, figs. 4-7.

(cf.) *Bighornia bottei* Nelson, 1963, p. 41-43, Pl. 5, fig. 6, Pl. 9, figs. 5, 6a-d, Pl. 11, figs. 5a, b, 6a-c, 7, 8, Pl. 12, figs. 1, 2a-g, 3a, b, 4a-c.

*Specimens described herein.* All from the Beaverfoot Formation. Norford collection (for locations, see Fig. 3.1; for stratigraphic positions, see Table 3.1): GSC 85652 (Pl. 3.4, figs. 9-11), GSC loc. 52183, Pagliaro Creek; GSC 85653 (Pl. 3.4, figs. 6-8), GSC loc. 69839, Horse Creek.

*Occurrence.* Upper Ordovician: *Bighornia-Thaerodonta* Zone (Richmondian, or possibly Maysvillian, strata), Beaverfoot Formation, southern Rocky Mountains, British Columbia.

*Description of coralla.* Both specimens are poorly preserved, and are affected by silicification and recrystallization. The height of one is estimated to be about 25 mm (GSC 85653), but the apical end is terminated along a stylolitic surface. The coralla expand rapidly above the apex (Fig. 3.6). Alar-alar dimensions across the calice rim are approximately 33 mm (GSC 85653) and 35 mm (GSC 85652). Both corals are depressed (Fig. 3.7), with a spoon-shaped indentation rising from the apex on the cardinal side. A ridge along the cardinal septum is prominent in one individual (Pl. 3.4, figs. 9-11). The other specimen becomes suboval in cross-section above the indentation (Pl. 3.4, figs. 6-8).

*Ontogeny and internal structures.* One corallum is estimated to have 52 major septa at an alar-alar dimension of 27 mm (GSC 85653). In early stages, the major septa are moderately to greatly dilated, and meet along a zone that is elongate in the alar-alar direction (Pl. 3.4, figs. 6, 9). During intermediate stages, the thin cardinal septum becomes short, and a broad cardinal fossula with an expanded axial end develops (Pl. 3.4, figs. 7, 10). A columellar structure that is apparently continuous with the counter septum can be detected in one specimen (GSC 85653). Septal lobes and lamellae are present in the axial region during late stages (Pl. 3.4, figs. 8, 11). A prominent, lenticular columella can be seen in one individual (GSC 85653). A few minor septa extend a short distance beyond the stereozone in both corals.

Numerous tabulae are visible in transverse sections of one individual (Pl. 3.4, figs. 6, 7).

*Microstructure.* The microstructure is preserved in parts of one specimen (GSC 85653). In transverse thin sections, septal fibres extend perpendicularly from a medial line in the septum. A contorted suture extends between the major and minor septa where they are in lateral contact.

*Discussion.* Compared with coralla assigned to *Bighornia patella* (Wilson, 1926), these two specimens are substantially larger, expand more rapidly above the apex (Fig. 3.6), and are more depressed (Fig. 3.7). They are considered to represent the large size group of *Bighornia*. The better preserved coral (GSC 85653) is similar to *B. bottei* Nelson, 1963, which was described from the Chasm Creek Formation (middle-upper Richmondian) of the Churchill River Group in northern Manitoba. It resembles the latter species in external form, number as well as dilation and arrangement of septa, nature of the cardinal fossula, type of axial structure, and development of tabulae. The other specimen (GSC 85652) is more depressed than the types of *B. bottei*, which were measured by Nelson (1963, p. 42, 43). Because of the limited amount of data, and the poor understanding of other taxa included in the large size category of the genus, these corals from the Beaverfoot Formation are identified as *Bighornia* cf. *B. bottei*.

Genus *Grewingkia* Dybowski, 1873

*Grewingkia haysii haysii* (Meek, 1865)

Plate 3.5, figures 1-9; Plate 3.6, figures 1-4

*Zaphrentis haysii* Meek, 1865, p. 32.

*Streptelasma haysii* (Meek, 1865). Kirk, 1925, p. 445; Ladd, 1929, p. 396, 397, Pl. 4, figs. 3-5, (?) 1, 2; Cox, 1937, p. 8, 9 (*part.*), *non* Pl. 2, fig. 4a, b.

*Streptelasma prolongatum* Wilson, 1926, p. 11, 12 (*part.*), Pl. 1, fig. 3, *non* Pl. 1, figs. 4, 5, Pl. 2, fig. 2.

*Streptelasma foerstei* Troedsson, 1928, p. 109, Pl. 25, figs. 1, 3, Pl. 26, fig. 5; Cox, 1937, p. 6-8, Pl. 1, figs. 10, 11, (?) 12-16.

*Streptelasma goniophylloides* Teichert, 1937, p. 49, 50, Pl. 3, figs. 5-11.

*Streptelasma trilobatum* (Whiteaves, 1895) var. Nelson, 1959, Pl. 3, fig. 3a, b.

*Streptelasma prolongatum* Wilson, 1926. Norford, 1962b, Pl. 6, figs. 13, 14.

*Lobocorallium trilobatum* var. *major* Nelson, 1963, p. 35-37, Pl. 5, fig. 1, Pl. 8, fig. 4, Pl. 10, figs. 1, 2a-h.

*Lobocorallium trilobatum* (Whiteaves, 1895). Nelson, 1975, Pl. 8, figs. 2, 3.

(?) *Lobocorallium* cf. *L. trilobatum major* Nelson, 1963. Norford and Macqueen, 1975, Pl. 9, fig. 17.

*Lobocorallium major* Nelson, 1963. Bolton and Nowlan, 1979, Pl. 1, fig. 2.

*Lobocorallium trilobatum major* Nelson, 1963. Nelson, 1981, p. 51, 52, fig. 13, Pl. 6, figs. 9-11, Pl. 7, figs. 1-5.

*Lobocorallium prolongatum* (Wilson, 1926). Norford et al., in Douglas, 1970, Pl. 5, fig. 1.

*Grewingkia haysii* (Meek, 1865). Elias, 1981, p. 17, 18 (*part.*), Pl. 5, figs. 1-5, *non* Pl. 5, figs. 6-15, Pl. 6, figs. 1-12.

*Grewingkia haysii haysii* (Meek, 1865). Elias, 1985, p. 28, 29, 31.

*Lectotype*. Designated by Ladd (1929, p. 396, 397): USNM 25683 (Ladd, 1929, Pl. 4, figs. 3-5; Elias, 1981, Pl. 5, figs. 1-5), Cape Frazier, Ellesmere Island, District of Franklin.

*Specimens described herein*. All from the Beaverfoot Formation (for locations, see Fig. 3.1; for stratigraphic positions, see Table 3.1).

Early collection: GSC 6729, GSC loc. 7563, 0.75 miles (1.2 km) east of the trail over Palliser Pass, J.R. Marshall collection.

Root collection: GSC 85654 (Pl. 3.6, fig. 4), White Knight Mountain.

Norford collection: GSC 85655, GSC loc. 64584, 4 miles (6.4 km) south-southeast of Indianhead Mountain; GSC 85656, GSC loc. 56076, Pinnacle Creek; GSC 85657, GSC loc. 52159, GSC 85658-85661, GSC loc. 45578, GSC 85662 (Pl. 3.6, figs. 1-3), GSC loc. 47414, Blackfoot Creek; GSC 85663, GSC loc. 47426, Mount Onslow; GSC 16917 (Norford, 1962b, Pl. 6, figs. 13, 14; Norford et al., in Douglas, 1970, Pl. 5, fig. 1; Pl. 3.5, fig. 1), GSC loc. 42026, Cirrus Mountain.

Present collection (all from Akutlak Creek; see Figs. 3.2, 3.4): GSC 85664 (Pl. 3.5, figs. 2, 3), GSC 85665, 85666 (Pl. 3.5, fig. 4), interval A14/15; GSC 85667, interval A15/16; GSC 85668, 85669, 85670 (Pl. 3.5, figs. 7-9), GSC 85671-85674, interval A18; GSC 85675, rubble near interval A18; GSC 85676, interval B1; GSC 85677, interval B2; GSC 85678, interval B3; GSC 78349 (Elias and Buttler, 1986, Fig. 2a-d), GSC 85679-85682, interval B5; GSC 85683 (Pl. 3.5, figs. 5, 6), interval B6; GSC 85684, interval B7; GSC 85685, interval B23; GSC 85686, interval B25.

*Occurrences*. Upper Ordovician: Cape Frazier on Ellesmere Island and Mount Nautilus on Baffin Island, District of Franklin; Cape Calhoun Formation (Upper Ordovician), Cape Calhoun, northwestern Greenland; Caution Creek and Chasm Creek formations (middle-upper Richmondian), northern Manitoba; Richmondian outlier north of Aberdeen Lake, District of Keewatin; *Bighornia-Thaerodonta* Zone (Richmondian, and possibly Maysvillian and Gamachian, strata), Beaverfoot Formation including Whiskey Trail Member, southern Rocky Mountains, British Columbia and Alberta.

*Diagnosis*. Corallum slightly to markedly trilobate, trilobation most pronounced in intermediate stages. Cross-section generally depressed to equidimensional. Major septa completely dilated in early stages, degree of dilation decreases gradually during ontogeny. Axial structure large and complex, with septal lobes in periphery and contorted septal lamellae concentrated axially.

*Description of coralla*. The longest coral has a length of 150 mm, but the base and part of the calice rim are missing (Pl. 3.6, fig. 1). The upper portion is nearly cylindrical, with a maximum average cross-sectional dimension of 52 mm. Another individual has an average cross-sectional dimension of 64 mm just below the base of the calice (GSC 85674), and two incomplete specimens are even larger (GSC 85654, 85658). The corals are trochoid and moderately to greatly curved. They vary from depressed to compressed; most are depressed to equidimensional throughout ontogeny (Fig. 3.9).

The cross-sectional shape is triangulate in early stages, and becomes trilobate early in intermediate stages. The maximum degree of trilobation, attained during intermediate stages, varies from slight to pronounced. It decreases during late stages, and the shape of some individuals returns to triangulate. A convex calicular boss corresponding to the axial structure begins to develop during intermediate stages (Pl. 3.5, fig. 1), and is large in late stages. Depth of the calice is approximately 27 per cent of the coral length (GSC 78349, length = 75 mm; Pl. 3.5, fig. 1).

One specimen has an outer wall irregularity of the type described and interpreted by Elias (1984a, p. 103-105, Fig. 1; Pl. 3.6, fig. 3, alar position on left side).

*Ontogeny and internal structures*. The relationship between number of septa and average cross-sectional dimension of the corallum is shown in Figure 3.10. In early ontogenetic stages, the major septa are greatly to usually completely dilated (Pl. 3.5, fig. 2). The degree of dilation decreases gradually during intermediate (Pl. 3.5, figs. 3, 5; Pl. 3.6, fig. 2) and late stages (Pl. 3.5, figs. 4, 6, 9; Pl. 3.6, figs. 3, 4). By late stages, these septa vary from nondilated to moderately dilated, but remain completely dilated in the peripheral portion of the septal region in some corals. Major septa extend to the axis in early stages. During intermediate stages, a few septal lobes followed by lobes and a few lamellae form the axial structure. They are moderately to generally greatly dilated. A median lamella is present only in two specimens (GSC 85664, 85679). During late stages, the large, complex axial structure consists of septal lobes at the periphery plus numerous, nondilated to moderately dilated, generally long and contorted septal lamellae concentrated axially. The shapes of the axial region and coral exterior are similar in cross-section. In late stages, the average radius of the axial region varies from 38 per cent (GSC 85669) to 57 per cent of the average corallum radius (GSC 85662).

The cardinal septum is long, and becomes thinner than other major septa toward the base of the calice. In one specimen, it becomes short at the base of the calice (GSC 85667). The relatively narrow cardinal fossula is conspicuous in intermediate to late stages. In some individuals it is slightly expanded at the axis. In corals with nondilated major septa in the latest stages, some minor septa extend beyond the relatively narrow stereozone. The maximum length of these septa is 19 per cent of the average corallum radius, in a specimen where the corresponding thickness of the stereozone is 8 per cent of the radius (GSC 85665).

The complete and incomplete tabulae are moderately to greatly convex upward in the axial region, and spaced 0.3 to 1.6 mm apart (Pl. 3.5, figs. 7, 8). Tabellae in the septal region are spaced up to 2.8 mm apart.

*Microstructure*. In transverse thin sections, the major septa, septal lobes, and lamellae are fibrous (e.g., Nelson, 1981, Fig. 14; Elias, 1981, Fig. 5a, b). From a medial position in the septum, fibres curve outward in the direction of the coral axis. A contorted suture extends between septa of both orders where they are in lateral contact in the stereozone. In incompletely dilated stages, U-shaped lamellae with concave sides facing the coral axis appear between septa in the stereozone. A contorted suture extends through the lamellae in a medial position between the septa.

*Discussion*. In her work on the Beaverfoot fauna, Wilson (1926) did not describe a taxon to include the type of corals documented above. However, one specimen that she illustrated as *Streptelasma prolongatum* Wilson, 1926, is trilobed and has an axial structure (GSC 6729; Wilson, 1926, Pl. 1, fig. 3). The individual illustrated in Norford (1962b) and Douglas (1970) and identified as *S. prolongatum* and *Lobocorallium prolongatum*, respectively, is also trilobed and has an axial structure (Pl. 3.5, fig. 1). These corals are herein assigned to *Grewingkia haysii haysii* (Meek, 1865).

These solitary Rugosa from the Beaverfoot Formation cannot be distinguished from those included in the synonymy and assigned to *G. haysii haysii* by Elias (1985). Previously, the range of variability in this taxon had been established primarily on the basis of a relatively large collection from the Churchill River Group (Nelson, 1963, 1981; Figs. 3.9, 3.10). The Beaverfoot material described herein provides additional information on variability involving external form and internal morphology. Norford and Macqueen (1975) illustrated a transverse section cut through the calice of a large coral from the basal member (Upper Ordovician) of the Mount Kindle Formation in the District of Mackenzie. It is triangulate in shape and has a *Grewingkia*-type axial structure. This specimen could represent *G. haysii haysii*, but a definite specific assignment is not possible until earlier ontogenetic stages are studied.

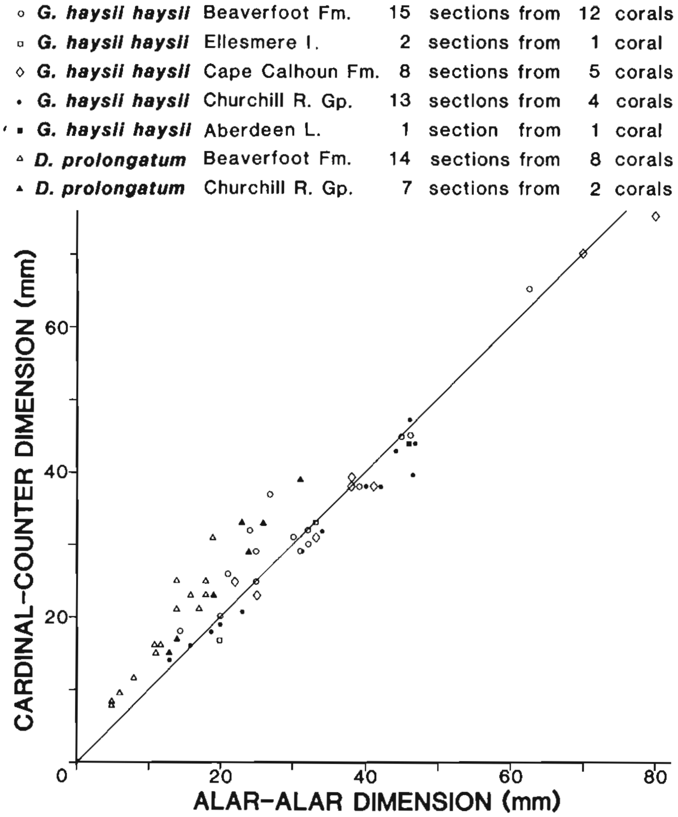

***Figure 3.9.*** *Relationship between cardinal-counter and alar-alar cross-sectional dimensions in* ***Grewingkia*** *and* ***Deiracorallium. Grewingkia haysii haysii: Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta; Ellesmere Island, District of Franklin; Cape Calhoun Formation, northwestern Greenland; Caution Creek and Chasm Creek formations, Churchill River Group, Manitoba; outlier north of Aberdeen Lake, District of Keewatin (except for Beaverfoot Formation, sources of data cited in Elias, 1985, Fig. 10).* ***Deiracorallium prolongatum: Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta; Chasm Creek Formation, Churchill River Group, Manitoba (Nelson, 1963, p. 39, Pl. 13, fig. 6a-c; Nelson, 1981, Pl. 8, figs. 15-17). Equidimensional corals plot on the line; compressed and depressed corals plot above and below the line, respectively.*

On the basis of external form, it can be difficult to distinguish relatively small, compressed specimens of *G. haysii haysii* from mature corals of *Deiracorallium prolongatum* (Wilson, 1926) in collections from the Beaverfoot Formation. However, individuals of the latter species are generally more compressed (Fig. 3.9), are triangulate to only very slightly trilobate, and rarely have an axial structure, which is comparatively small. Tiny corals representing early ontogenetic stages of these taxa are commonly poorly preserved, and can seldom be identified at the specific level. It appears that such specimens belonging to *D. prolongatum* are more compressed than *G. haysii haysii*.

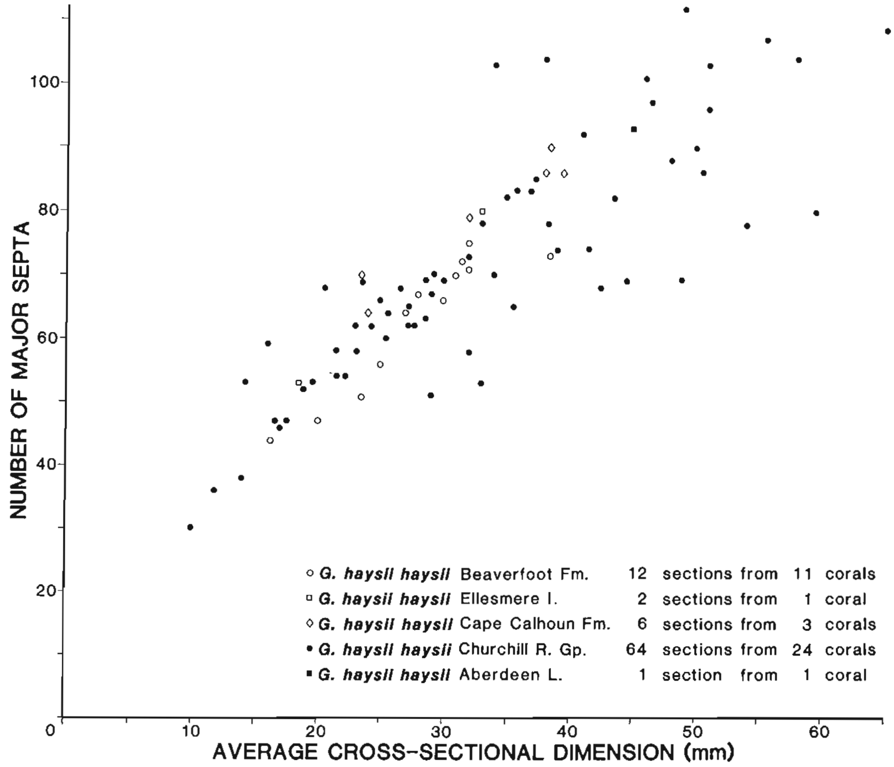

***Figure 3.10.*** *Relationship between number of major septa and average cross-sectional dimension of coral (average of cardinal-counter and alar-alar dimensions) in* ***Grewingkia haysii haysii:*** ***Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta; Ellesmere Island, District of Franklin; Cape Calhoun Formation, northwestern Greenland; Caution Creek and Chasm Creek formations, Churchill River Group, Manitoba; outlier north of Aberdeen Lake, District of Keewatin (except for Beaverfoot Formation, sources of data cited in Elias, 1985, Fig. 9).*

### Genus *Deiracorallium* Nelson, 1963

### *Deiracorallium prolongatum* (Wilson, 1926)

Plate 3.7, figures 1-11; Plate 3.8, figures 1-3

*Streptelasma prolongatum* Wilson, 1926, p. 11, 12, Pl. 1, fig. 4, *non* Pl. 1, figs. 3, 5, (?) Pl. 2, fig. 2.

*non Streptelasma* sp. cf. *S. prolongatum* Wilson, 1926. Pestana, 1960, p. 866, 867, Pl. 109, fig. 1.

*non Streptelasma prolongatum* Wilson, 1926. Norford, 1962b, Pl. 6, figs. 13, 14.

*Deiracorallium giganteum* Nelson, 1963, p. 38, 39, Pl. 13, figs. 4a, b, 5, 6a-c; Nelson, 1981, p. 54, 55, fig. 13, Pl. 8, figs. 8-11, 15-17.

*non Lobocorallium prolongatum* (Wilson, 1926). Norford et al., in Douglas, 1970, Pl. 5, fig. 1.

*Lectotype.* Designated herein: GSC 6729b (Wilson, 1926, Pl. 1, fig. 4), uncertain stratigraphic position, Beaverfoot Formation, GSC loc. 7563, 0.75 miles (1.2 km) east of the trail over Palliser Pass, J.R. Marshall collection (for location, see Fig. 3.1).

*Additional specimens described herein.* All from the Beaverfoot Formation (for locations, see Fig. 3.1; for stratigraphic positions, see Table 3.1).

Early collection: GSC 85687, GSC loc. 7561, 0.5 miles (0.8 km) east of the trail over Palliser Pass, J.R. Marshall collection.

Norford collection: GSC 85688, GSC loc. 57209, Tipperary Lake; GSC 85689, GSC loc. 64584, 4 miles (6.4 km) south-southeast of Indianhead Mountain; GSC 85690, 85691, GSC loc. 58188, Shatch Mountain; GSC 85692, 85693, GSC loc. 70016, Cirrus Mountain.

Present collection (all from Akutlak Creek, see Figs. 3.2, 3.4): GSC 85694 (Pl. 3.8, figs. 1-3), GSC 85695, 85696 (Pl. 3.7, figs. 1-6), GSC 85697 (Pl. 3.7, figs. 8-11), interval A14/15; GSC 85698, interval B2; GSC 85699 (Pl. 3.7, fig. 7), interval B5.

*Occurrences.* Upper Ordovician: *Bighornia-Thaerodonta* Zone (Richmondian, and possibly Maysvillian, strata), Beaverfoot Formation including Whisky Trail Member, southern Rocky Mountains, British Columbia and Alberta; Chasm Creek Formation (middle-upper Richmondian), northern Manitoba.

*Diagnosis.* Corallum of medium size, greatly compressed, triangulate to very slightly trilobate. Septa greatly to generally completely dilated in early stages, degree of dilation decreases during intermediate or late stages. Major septa converge axially along zone, elongate in cardinal-counter direction, or several septal lobes develop along axis, or rarely a small axial structure of short septal lobes and lamellae forms. Cardinal and counter septa long throughout ontogeny, cardinal fossula long and narrow.

*Description of coralla.* Cardinal-counter and alar-alar dimensions at the top of the lectotype are 36 mm and 26.5 mm, respectively (Wilson, 1926, Pl. 1, fig. 4). Corresponding dimensions across the calice rim of another large individual are 37 mm and 23 mm (Pl. 3.7, figs. 1, 2). Coral lengths are unknown because both of these specimens are incomplete. The coralla are trochoid in alar view, and compressed throughout ontogeny (Fig. 3.9). They are triangulate, and in some cases very slightly trilobate in intermediate and/or late stages. The calice is comparatively shallow (Pl. 3.7, fig. 4).

*Ontogeny and internal structures.* The relationship between number of septa and average cross-sectional dimension of the coral is shown in Figure 3.11. In early stages (Pl. 3.7, figs. 7, 8; Pl. 3.8, fig. 1), the major septa are greatly to generally completed dilated. In some individuals, septa become moderately dilated during intermediate stages (Pl. 3.7, fig. 5; Pl. 3.8, fig. 2) and slightly dilated to nondilated in late stages (Pl. 3.7, fig. 6; Pl. 3.8, fig. 3). In others, they remain completely dilated through intermediate stages (Pl. 3.7, fig. 9), and dilation does not decrease until near the base of the calice in late stages (Pl. 3.7, figs. 10, 11). During early to intermediate stages, the major septa extend to the axis. Those on alar sides of the corallum meet along a zone that is elongate in the cardinal-counter direction. This septal arrangement continues through late stages in some specimens (Pl. 3.7, fig. 6). In others, several septal lobes develop at the axis (Pl. 3.7, figs. 10, 11). In one individual, septal lobes plus a few lamellae form a small axial structure with an average radius that is 19 per cent that of the corallum (Pl. 3.8, fig. 3).

The cardinal and counter septa are longer than the other major septa throughout ontogeny. In six specimens, it was verified that the cardinal septum remains long above the level at which sediment fills interseptal spaces. The cardinal septum becomes relatively thin during intermediate stages, when a narrow but long and conspicuous cardinal fossula develops. Minor septa are confined to the stereozone until above the base of the calice. Their length is up to 28 per cent of the average corallum radius (GSC 85696). Thickness of the stereozone at the base of the calice is 11 per cent of the average corallum radius in one individual (GSC 85695), and 15 per cent in another (GSC 85697).

Complete and incomplete tabulae are approximately horizontal in the axial part of the corallum (Pl. 3.7, figs. 3, 4). Their spacing varies from 0.2 to 0.6 mm. Tabellae in the peripheral portion are moderately to steeply inclined from the wall toward the axis, and are spaced 0.3 to 0.9 mm apart.

*Microstructure.* In transverse thin sections, the major septa are fibrous (e.g., Elias, 1983a, Fig. 7c). From a medial position in the septum, the fibres curve outward in the direction of the coral axis.

*Discussion. Streptelasma prolongatum* Wilson, 1926, was proposed for solitary corals from the Beaverfoot Formation that have an elongate cardinal side with a long cardinal septum and fossula, but that lack pronounced alar lobes. Wilson did not identify type specimens, but illustrated four individuals. One of these is markedly compressed with an elongate cardinal side (GSC 6729b; Wilson, 1926, Pl. 1, fig. 4), and herein is designated as the lectotype of *Deiracorallium prolongatum* (Wilson, 1926). Of the other three specimens, one is *Grewingkia haysii haysii* (Meek, 1865), another is *Salvadorea distincta distincta* (Wilson, 1926), and the third may be *S. distincta distincta*. The coral illustrated in Norford (1962b) and Douglas (1970) and identified as *Streptelasma prolongatum* and *Lobocorallium prolongatum*, respectively, is *G. haysii haysii* (Meek, 1865).

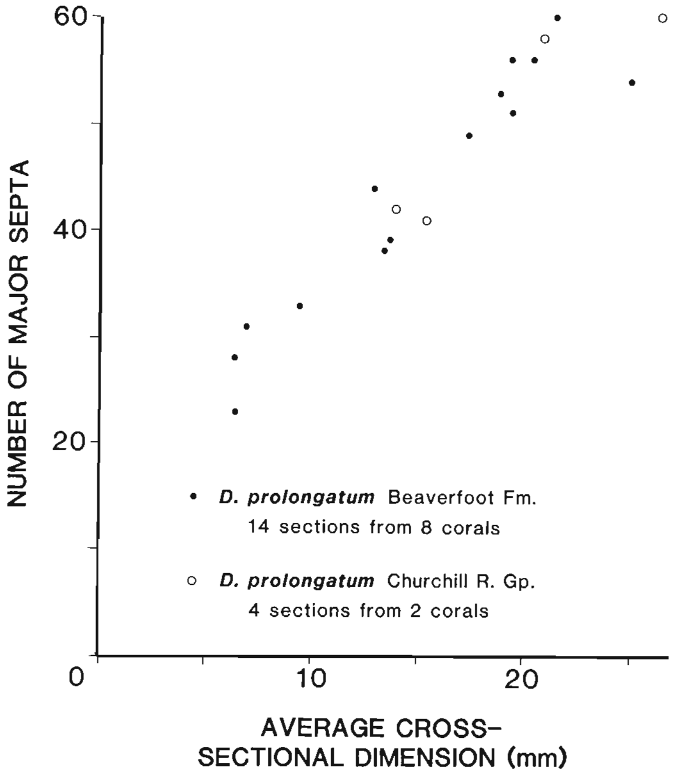

*Figure 3.11. Relationship between number of major septa and average cross-sectional dimension of coral (average of cardinal-counter and alar-alar dimensions) in* ***Deiracorallium prolongatum: Bighornia-Thaerodonta*** *Zone, Beaverfoot Formation, British Columbia and Alberta; Chasm Creek Formation, Churchill River Group, Manitoba (Nelson, 1963, Pl. 13, fig. 6a-c; Nelson, 1981, Pl. 8, figs. 15-17).*

*Deiracorallium giganteum* Nelson, 1963, was based on two specimens from the Chasm Creek Formation (middle-upper Richmondian) of the Churchill River Group in northern Manitoba. They lie within the range of variability documented herein for *D. prolongatum*, involving shape (Fig. 3.9), arrangement and number of septa (Fig. 3.11), degree of septal dilation, size and shape of the fossula, and thickness of the stereozone. *Deiracorallium giganteum* is considered to be a junior synonym of *D. prolongatum*.

Pestana (1960) identified a single specimen from the Johnson Spring Formation (Middle Ordovician; Rocklandian-Kirkfieldian) in California as *Streptelasma* sp. cf. *S. prolongatum*. It differs from *D. prolongatum* in having a larger axial structure, and minor septa that extend beyond the stereozone below the base of the calice.

*Deiracorallium prolongatum* resembles *D. angulatum angulatum* (Billings, 1862) and *D. angulatum gunni* Elias, 1983a, known from the upper member (upper Richmondian) of the Vauréal Formation on Anticosti Island in Québec, and the Gunn and Penitentiary members (middle-upper Richmondian) of the Stony Mountain Formation in southern Manitoba, respectively (Elias, 1982a, p. 64, 65, Pl. 6, figs. 21-33; Elias, 1983a, p. 938, 939, 941, 942, Fig. 11a-t). *Deiracorallium angulatum* differs in being small, and having a short cardinal septum in late stages. It has been verified that the cardinal septum decreases in length below the level at which sediment fills interseptal spaces in ten specimens (two from the Vauréal Formation, and eight from the Stony Mountain Formation). *Deiracorallium manitobense manitobense* Nelson, 1963, from the Caution Creek and Chasm Creek formations (middle-upper Richmondian) in northern Manitoba, and *D. manitobense churchillense* from the Chasm Creek Formation, may belong to *D. angulatum* (Nelson, 1963, p. 37, 38, Pl. 13, figs. 1, 2a, b, 3a, b; Nelson, 1981, p. 53, 54, Fig. 13, Pl. 8, figs. 12-14; see Elias, 1982a, p. 65, and Elias, 1983a, p. 941).

*Deiracorallium prolongatum* is similar to *D. harveyi* Nelson, 1981, and *D. delicatum* Elias, 1981, which occur in the Portage Chute and Surprise Creek formations (?Edenian to lower Richmondian) of the Bad Cache Rapids Group in northern Manitoba, and the Selkirk Member (middle Maysvillian strata) of the Red River Formation in southern Manitoba, respectively (Nelson, 1981, p. 53, Fig. 13, Pl. 7, figs. 6-9, Pl. 8, figs. 1-7; Elias, 1981, p. 22, 23, Pl. 9, figs. 12-24). Corals belonging to these three taxa are medium sized, but *D. harveyi* and *D. delicatum* differ from *D. prolongatum* in having comparatively large, complex axial structures. *Deiracorallium amplum* (Troedsson, 1928), from the Cape Calhoun Formation (Upper Ordovician) of northwestern Greenland, is poorly known (Troedsson, 1928, Pl. 26, fig. 4a, b; Elias, 1981, p. 22). It has a small axial structure, but attains greater cross-sectional dimensions and has more septa than other species of the genus.

The difficulty in distinguishing some specimens of *D. prolongatum* and *G. haysii haysii* in Beaverfoot collections was discussed under the latter species.

## REFERENCES

Amsden, T.W.
1986: Part I – Paleoenvironment of the Keel-Edgewood oolitic province and the Hirnantian strata of Europe, U.S.S.R., and China; in Late Ordovician-Early Silurian strata in the central United States and the Hirnantian Stage, T.W. Amsden and J.E. Barrick; Oklahoma Geological Survey, Bulletin 139, p. 1-55.

Barrick, J.E.
1986: Part II – Conodont faunas of the Keel and Cason formations; in Late Ordovician-Early Silurian strata in the central United States and the Hirnantian Stage, T.W. Amsden and J.E. Barrick; Oklahoma Geological Survey, Bulletin 139, p. 57-73.

Billings, E.
1862: New species of fossils from different parts of the Lower, Middle, and Upper Silurian rocks of Canada; Geological Survey of Canada, Palaeozoic Fossils, v. 1, no. 4, p. 96-185.

Bolton, T.E. and Nowlan, G.S.
1979: A Late Ordovician fossil assemblage from an outlier north of Aberdeen Lake, District of Keewatin; Geological Survey of Canada, Bulletin 321, p. 1-26.

Budge, D.R.
1977: Biostratigraphy, biochronology, and some tectonic implications of Late Ordovician corals from the eastern Great Basin; Geological Society of America, Abstracts with Programs, v. 9, no. 6, p. 712.

Cox, I,
1937: Arctic and some other species of *Streptelasma*; Geological Magazine, v. 74, no. 1, p. 1-19.

Douglas, R.J.W. (ed.)
1970: Geology and economic minerals of Canada; Geological Survey of Canada, Economic Geology Report No. 1, 838 p.

Drahovzal, J.A. and Neathery, T.L. (eds.)
1971: The Middle and Upper Ordovician of the Alabama Appalachians; Guidebook, Ninth Annual Field Trip, Alabama Geological Society, December 3-4, 1971, 240 p.

Duncan, H.
1957: *Bighornia*, a new Ordovician coral genus; Journal of Paleontology, v. 31, no. 3, p. 607-615.

Dybowski, W.
1873: Monographie der Zoantharia Sclerodermata Rugosa aus der Silurformation Estlands, Nord-Livlands und der Insel Gotland. Archiv für die Naturkunde Liv-, Ehst- und Kurlands, ser. 1, v. 5, no. 3, p. 257-414.

Elias, R.J.
1980: Borings in solitary rugose corals of the Selkirk Member, Red River Formation (late Middle or Upper Ordovician), southern Manitoba; Canadian Journal of Earth Sciences, v. 17, no. 2, p. 272-277.

1981: Solitary rugose corals of the Selkirk Member, Red River Formation (late Middle or Upper Ordovician), southern Manitoba; Geological Survey of Canada, Bulletin 344, 53 p.

1982a: Latest Ordovician solitary rugose corals of eastern North America; Bulletins of American Paleontology, v. 81, no. 314, 116 p.

1982b: Paleoecology and biostratinomy of solitary rugose corals in the Stony Mountain Formation (Upper Ordovician), Stony Mountain, Manitoba; Canadian Journal of Earth Sciences, v. 19, no. 8, p. 1582-1598.

1983a: Late Ordovician solitary rugose corals of the Stony Mountain Formation, southern Manitoba, and its equivalents; Journal of Paleontology, v. 57, no. 5, p. 924-956.

1983b: Middle and Late Ordovician solitary rugose corals of the Cincinnati Arch region; United States Geological Survey, Professional Paper 1066-N, 13 p.

Elias, R.J.
1984a: Paleobiologic significance of fossulae in North American Late Ordovician solitary rugose corals; Paleobiology, v. 10, no. 1, p. 102-114.

1984b: Paleobiology of solitary rugose corals, Late Ordovician of North America; in Recent Advances in the Paleobiology and Geology of the Cnidaria (Proceedings of the Fourth International Symposium on Fossil Cnidaria (and Archaeocyathids and Stromatoporoids) held in Washington, D.C., U.S.A., August, 1983), W.A. Oliver, Jr., W.J. Sando, S.D. Cairns, et al. (eds.); Palaeontographica Americana, no. 54, p. 533-537.

1985: Solitary rugose corals of the Upper Ordovician Montoya Group, southern New Mexico and westernmost Texas; Paleontological Society, Memoir 16, 58 p.

1986a: New Late Ordovician solitary rugose coral with perforate septa; Journal of Paleontology, v. 60, no. 1, p. 14-25.

1986b: Symbiotic relationships between worms and solitary rugose corals in the Late Ordovician; Paleobiology, v. 12, no. 1, p. 32-45.

Elias, R.J. and Buttler, C.J.
1986: Late Ordovician solitary rugose corals preserved in life position; Canadian Journal of Earth Sciences, v. 23, no. 5, p. 739-742.

Elias, R.J., Nowlan, G.S., and Bolton, T.E.
in press: Paleontology of the type section, Fort Garry Member, Red River Formation (Upper Ordovician), southern Manitoba; New Mexico Bureau of Mines and Mineral Resources, Memoir.

Elias, R.J. and Potter, A.W.
1984: Late Ordovician solitary rugose corals of the eastern Klamath Mountains, northern California; Journal of Paleontology, v. 58, no. 5, p. 1203-1214.

Evans, C.S.
1933: Brisco-Dogtooth map-area, British Columbia; Geological Survey of Canada, Summary Report 1932, pt. A II, p. 106-176.

Foerste, A.F.
1890: Notes on Clinton Group fossils, with special reference to collections from Indiana, Tennessee and Georgia; Boston Society of Natural History, Proceedings, v. 24 (1889), p. 263-355.

Henderson, G.G.L.
1954: Geology of the Stanford Range of the Rocky Mountains, Kootenay District, British Columbia; British Columbia Department of Mines, Bulletin 35, 84 p.

Ho Xin-yi
1978: Tetracoral fauna of the Late Ordovician Guanyinqiao Formation, Bijie, Guizhou Province; Chinese Academy of Geological Sciences, Professional Papers of Stratigraphy and Palaeontology, no. 6, p. 1-45.

Kaljo, D. and Klaamann, E.
1965: The fauna of the Portrane Limestone, III: the corals; Bulletin of the British Museum (Natural History), Geology, v. 10, no. 11, p. 413-434.

Kendall, A.C.
1977: Origin of dolomite mottling in Ordovician limestones from Saskatchewan and Manitoba; Bulletin of Canadian Petroleum Geology, v. 25, no. 3, p. 480-504.

Kirk, E.
1925: Notes on an early collection of Paleozoic fossils from Ellesmereland; American Journal of Science, ser. 5, v. 210, no. 59, p. 445-447.

1927: Review of "An Upper Ordovician fauna from the Rocky Mountains, British Columbia" by Alice E. Wilson; Journal of Geology, v. 35, no. 3, p. 286-288.

Knapp, C.J.
1985: Late Ordovician solitary rugose corals of the Beaverfoot Formation, southern Rocky Mountains, British Columbia and Alberta; M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, 171 p.

Kobluk, D.R. and Nemcsok, S.
1982: The macroboring ichnofossil *Trypanites* in colonies of the Middle Ordovician bryozoan *Prasopora*: population behaviour and reaction to environmental influences; Canadian Journal of Earth Sciences, v. 19, no. 4, p. 679-688.

Ladd, H.S.
1929: The stratigraphy and paleontology of the Maquoketa Shale of Iowa, Part I; Iowa Geological Survey, Annual Report (1928), v. 34, p. 305-448.

Laub, R.S.
1979: The corals of the Brassfield Formation (mid-Llandovery; Lower Silurian) in the Cincinnati Arch region; Bulletins of American Paleontology, v. 75, no. 305, 457 p.

Leech, G.B.
1954: Canal Flats, British Columbia; Geological Survey of Canada, Paper 54-7, 32 p.

Lespérance, P.J.
1985: Faunal distributions across the Ordovician-Silurian boundary, Anticosti Island and Percé, Québec, Canada; Canadian Journal of Earth Sciences, v. 22, no. 6, p. 838-849.

McAuley, R.J.
1985: Uppermost Ordovician and lowermost Silurian stratigraphy and solitary rugose corals of the east-central United States; M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, 243 p.

McCracken, A.D. and Barnes, C.R.
1981: Conodont biostratigraphy and paleoecology of the Ellis Bay Formation, Anticosti Island, Québec, with special reference to Late Ordovician-Early Silurian chronostratigraphy and the systemic boundary; Geological Survey of Canada, Bulletin 329, p. 51-134.

McCracken, A.D. and Nowlan, G.S.
1986: The Gamachian Stage and Fauna 13; Preprint for the Canadian Paleontology and Biostratigraphy Seminar, September 26-29, 1986, Albany, N.Y., p. 132-148.

Meek, F.B.
1865: Preliminary notice of a small collection of fossils found by Dr. Hays, on the west shore of Kennedy Channel, at the highest northern localities ever explored; American Journal of Science, ser. 2, v. 40, p. 31-34.

Milici, R.C. and Wedow, H., Jr.
1977: Upper Ordovician and Silurian stratigraphy in Sequatchie Valley and parts of the adjacent Valley and Ridge, Tennessee; United States Geological Survey, Professional Paper 996, 38 p.

Milne Edwards, H. and Haime, J.
1850: A monograph of the British fossil corals, First part: Introduction; Palaeontographical Society, London, 85 p.

Nelson, S.J.
1959: Guide fossils of the Red River and Stony Mountain equivalents (Ordovician); Alberta Society of Petroleum Geologists, Journal, v. 7, no. 3, p. 51-61.

1963: Ordovician paleontology of the northern Hudson Bay Lowland; Geological Society of America, Memoir 90, 152 p.

1975: Paleontological field guides, northern Canada and Alaska; Bulletin of Canadian Petroleum Geology, v. 23, no. 3, p. 428-683.

1981: Solitary streptelasmatid corals, Ordovician of northern Hudson Bay Lowland, Manitoba, Canada; Palaeontographica, Abteilung A, v. 172, no. 1-3, p. 1-71.

Neuman, B.
1969: Upper Ordovician streptelasmatid corals from Scandinavia; University of Uppsala Geological Institutions, Bulletin, new ser., v. 1, p. 1-73.

1977: On the taxonomy of lower Palaeozoic solitary streptelasmatids; in Second International Symposium on Corals and Fossil Coral Reefs, Paris, September 1975; France, Bureau de Recherches Géologiques et Minières, Mémoires 89, p. 69-77.

Nicholson, H.A. and Lydekker, R.
1889: A manual of palaeontology for the use of students, 3rd edition; William Blackwood and Sons, Edinburgh and London, v. 1, p. 1-885, v. 2, p. 886-1624.

Nield, E.W.
1984: The boring of Silurian stromatoporoids – towards an understanding of larval behaviour in the *Trypanites* organism; Palaeogeography, Palaeoclimatology, Palaeoecology, v. 48, no. 2-4, p. 229-243.

Norford, B.S.
1962a: The Beaverfoot-Brisco Formation in the Stanford Range, British Columbia; Alberta Society of Petroleum Geologists, Journal, v. 10, no. 7, p. 443-453.

1962b: Illustrations of Canadian fossils: Cambrian, Ordovician and Silurian of the western Cordillera; Geological Survey of Canada, Paper 62-14, 25 p.

Norford, B.S
1969: Ordovician and Silurian stratigraphy of the southern Rocky Mountains; Geological Survey of Canada, Bulletin 176, 90 p.

Norford, B.S. and Macqueen, R.W.
1975: Lower Paleozoic Franklin Mountain and Mount Kindle formations, District of Mackenzie: their type sections and regional development; Geological Survey of Canada, Paper 74-34, 37 p.

Okulitch, V.J.
1943: The Stony Mountain Formation of Manitoba; Transactions of the Royal Society of Canada, ser. 3, v. 37, no. 4, p. 59-74.

Oliver, W.A., Jr., Merriam, C.W., and Churkin, M., Jr.
1975: Ordovician, Silurian, and Devonian corals of Alaska; United States Geological Survey, Professional Paper 823-B, p. 13-44.

Parks, W.A.
1915: Palaeozoic fossils from a region southwest of Hudson Bay; Transactions of the Royal Canadian Institute, v. 11, no. 1, p. 3-95.

Pestana, H.R.
1960: Fossils from the Johnson Spring Formation, Middle Ordovician, Independence Quadrangle, California; Journal of Paleontology, v. 34, no. 5, p. 862-873.

Petryk, A.A.
1981: Stratigraphy, sedimentology and paleogeography of the Upper Ordovician-Lower Silurian of Anticosti Island, Québec; in Field Meeting, Anticosti-Gaspé, Québec, 1981, volume II: Stratigraphy and Paleontology, P.J. Lespérance (ed.); Département de géologie, Université de Montréal, p. 11-39.

Reiman, V.M.
1958: Novya rugozy iz verchnyordovikskik i Llandoveriyskik otlochenia pribaltiki; Eesti NSV Teaduste Akadeemia, Geoloogia Instituudi Uurimused, Trudy Instituta Geologii, v. 2, p. 33-47.

Root, S.
1955: The Paleozoic geology of the Canal Flats area, British Columbia; M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, 132 p.

Ross, R.J., Jr.
1957: Ordovician fossils from wells in Williston Basin, eastern Montana; United States Geological Survey, Bulletin 1021-M, p. 439-510.

Stasek, C.R.
1958: A new species of *Allogaussia* (Amphipoda, Lysianassidae) found living within the gastrovascular cavity of the sea-anemone *Anthopleura elegantissima*; Journal of the Washington Academy of Sciences, v. 48, no. 4, p. 119-126.

Stearn, C.W.
1956: Stratigraphy and palaeontology of the Interlake Group and Stonewall Formation of southern Manitoba; Geological Survey of Canada, Memoir 281, 162 p.

Sweet, W.C.
1979: Late Ordovician conodonts and biostratigraphy of the western Midcontinent Province; in Conodont Biostratigraphy of the Great Basin and Rocky Mountains, C.A. Sandberg and D.L. Clark (eds.); Brigham Young University, Geology Studies, v. 26, no. 3, p. 45-85.

1984: Graphic correlation of upper Middle and Upper Ordovician rocks, North American Midcontinent Province, U.S.A.; in Aspects of the Ordovician System, D.L. Bruton (ed.); Palaeontological Contributions from the University of Oslo, no. 295, p. 23-35.

Teichert, C.
1937: Ordovician and Silurian faunas from arctic Canada; Report of the Fifth Thule Expedition, 1921-1924, v. 1, no. 5, 169 p.

Troedsson, G.T.
1928: On the Middle and Upper Ordovician faunas of northern Greenland, Part II; Meddelelser om Grønland, v. 72 (Første Afdeling, pt. 1), 197 p.

Verrill, A.E.
1865: Classification of polyps (Extract condensed from a synopsis of the polypi of the North Pacific Exploring Expedition, under Captains Ringgold and Rodgers, U.S.N.); Essex Institute, Proceedings, v. 4, p. 145-149.

Walcott, C.D.
1924: Geological formations of Beaverfoot-Brisco-Stanford Range, British Columbia, Canada; Smithsonian Miscellaneous Collections, v. 75, no. 1, p. 1-51.

Walker, J.F.
1926: Geology and mineral deposits of Windermere map-area, British Columbia; Geological Survey of Canada, Memoir 148, 69 p.

Wedekind, R.
1927: Die Zoantharia Rugosa von Gotland (besonders Nordgotland): Nebst Bemerkungen zur Biostratigraphie des Gotlandium; Sveriges Geologiska Undersökning, ser. Ca, v. 19, 94 p.

Whiteaves, J.F.
1895: Systematic list, with references, of the fossils of the Hudson River or Cincinnati formation at Stony Mountain, Manitoba; Geological Survey of Canada, Palaeozoic Fossils, v. 3, no. 2, p. 111-128.

Wilson, A.E.
1926: An Upper Ordovician fauna from the Rocky Mountains, British Columbia; Canada, Department of Mines, Museum Bulletin 44, Geological Series, no. 46, p. 1-34, 100-115.

Winchell, N.H. and Schuchert, C.
1895: Sponges, graptolites, and corals from the Lower Silurian of Minnesota; in The Geology of Minnesota, v. 3, no. 1, Paleontology; Minnesota Geological and Natural History Survey, p. 55-95.

## PLATES 3.1 to 3.8

Specimens were coated with ammonium chloride, for photographs of coral exteriors. All illustrations of transverse and longitudinal sections were prepared using the thin sections as negatives in a photographic enlarger. Transverse sections are oriented as they appear looking down from the calical end toward the apical end of the corallum, with the cardinal side facing the bottom of the page. All longitudinal sections are oriented with the calical end facing the top of the page. Arrows and small numbers beside exterior views indicate the position of sections illustrated in the same plate.

## PLATE 3.1

Figures 1-15. *Salvadorea distincta distincta* (Wilson, 1926)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia and Alberta.

1. View of calice (stereopair), GSC 85579, x3.5.

2. View of calice (stereopair), GSC 85573, x3.

3. Transverse section, GSC 85574, x6.

4. Transverse section, GSC 85599, x4.5.

5, 6. Transverse sections, GSC 85590, x6, x3.

7. Transverse section, GSC 85580, x3.

8. Transverse section, GSC 85575, x2.25.

9. Transverse section, GSC 85585, x2.25.

10. Cardinal view, GSC 85584, x1.

11. Alar view (cardinal side left), GSC 85584, x1.

12, 13. Longitudinal sections (cardinal side left), GSC 85584, x2.25.

14, 15. Transverse sections, GSC 85584, x3.

PLATE 3.1


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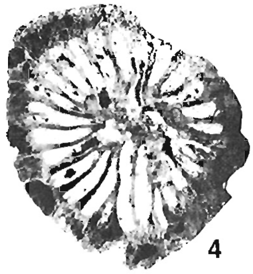
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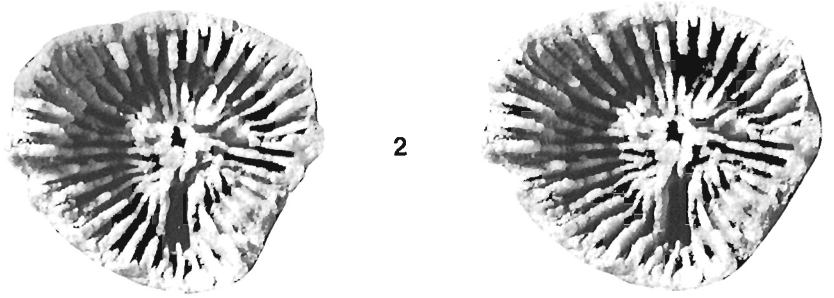
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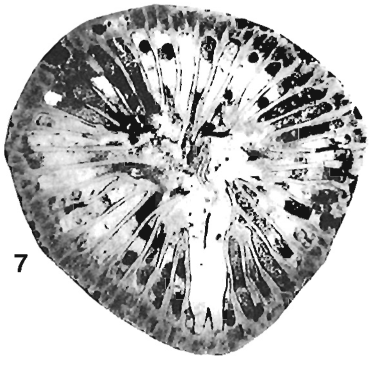
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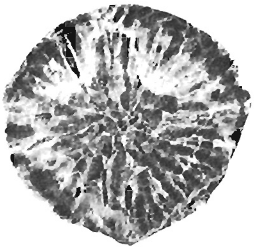
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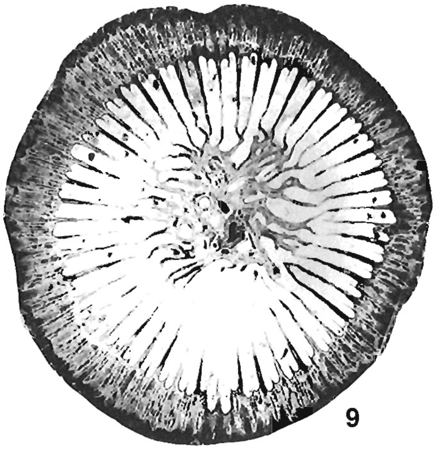
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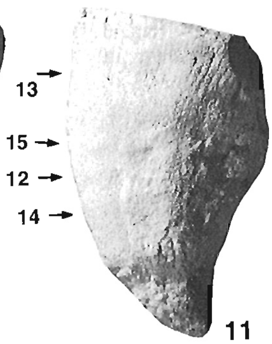

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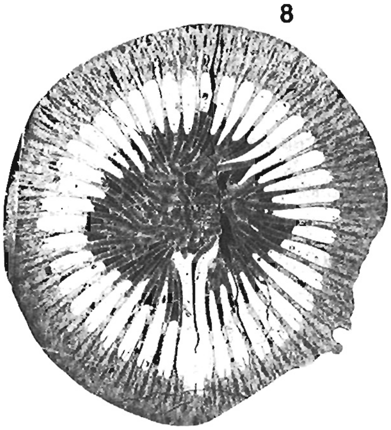
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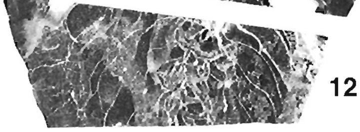
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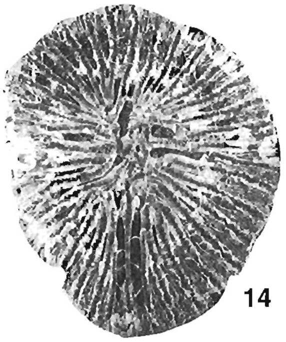
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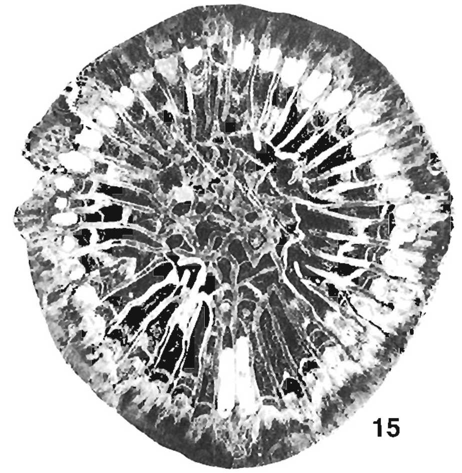
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## PLATE 3.2

Figures 1, 2. *Salvadorea distincta distincta* (Wilson, 1926)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

1. Longitudinal section (cardinal side right; two arrows point to one ostracode), GSC 85613, x2.25.

2. Transverse section (arrows point to an epizoic bryozoan), GSC 85613, x2.25; positioned at top of longitudinal section shown in fig. 1.

Figures 3-6. *Salvadorea* sp. 2 of Nelson, 1981

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, Alberta.

3. Longitudinal section (cardinal side right), GSC 85614, x4.

4-6. Transverse sections, GSC 85614, x7.5, x4, x4 (fig. 6 positioned at base of longitudinal section shown in fig. 3).

Figures 7-11. *Bighornia patella* (Wilson, 1926)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

7. View of calice (stereopair; calice rim in lower left faces inward as a result of damage to specimen), GSC 6732 (lectotype), x2.5.

8-11. Transverse sections, GSC 85625, x5.

PLATE 3.2


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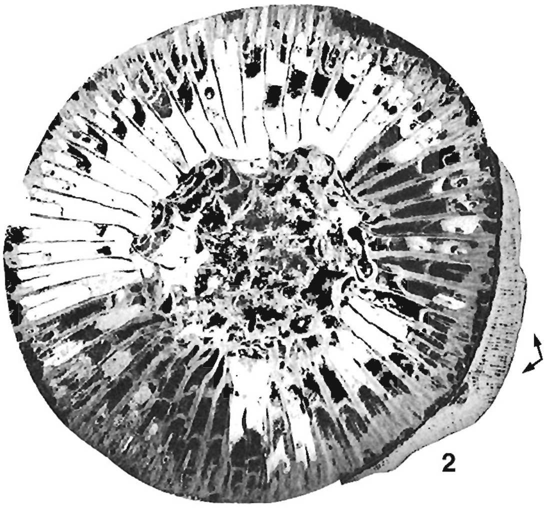
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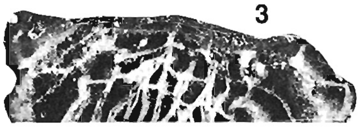
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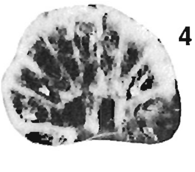
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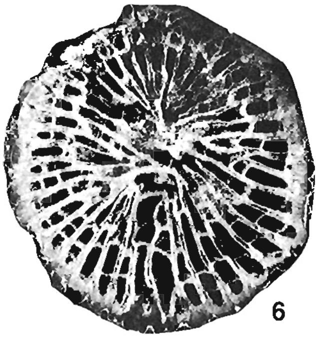
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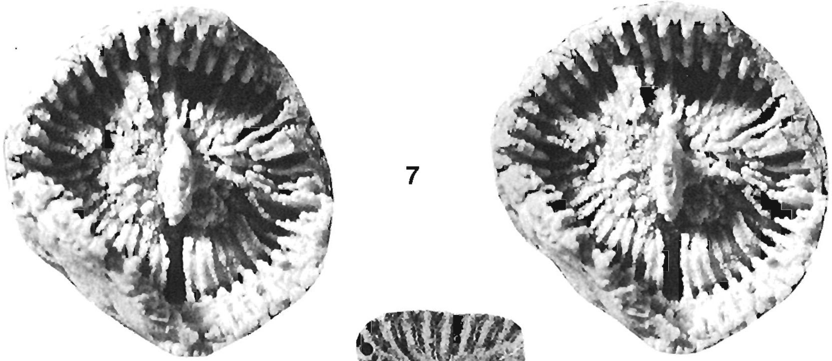
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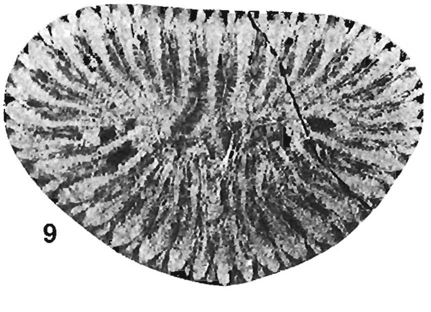
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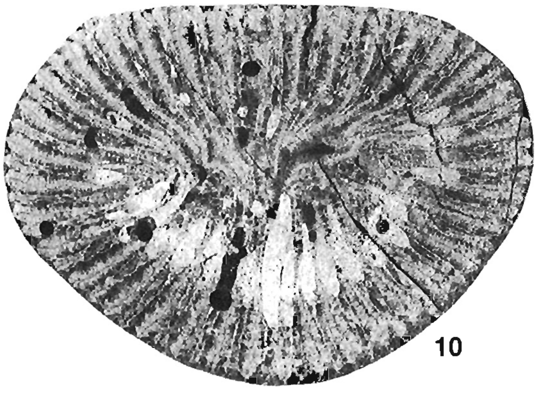
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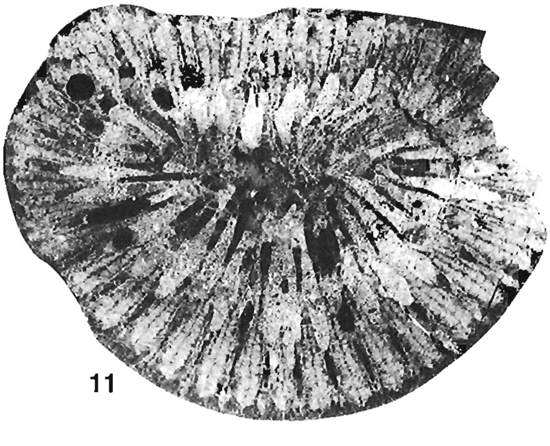
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## PLATE 3.3

Figures 1-12. *Bighornia patella* (Wilson, 1926)

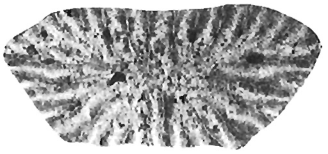
*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

1-3. Transverse sections, GSC 85646, x5.

4, 5. Transverse sections, GSC 85633, x5.

6-9. Transverse sections, GSC 85629, x5.

10-12. Transverse sections, GSC 85641, x5.



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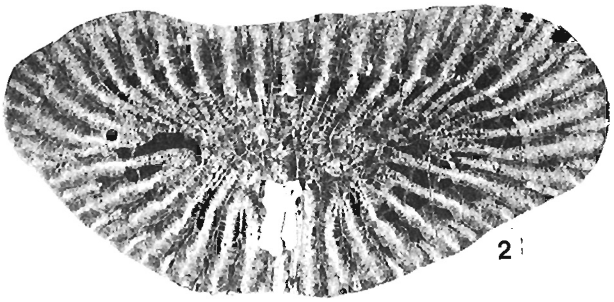

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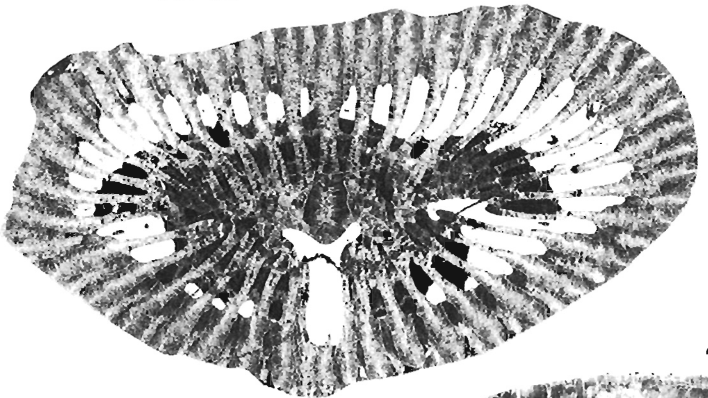

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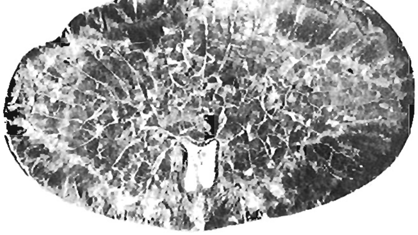

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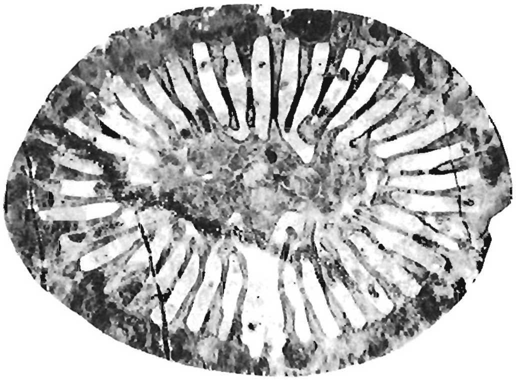

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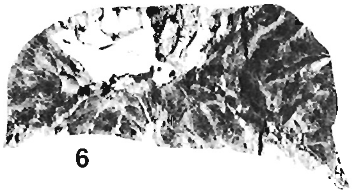

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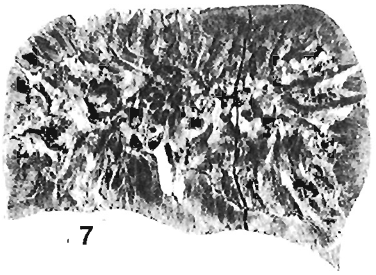

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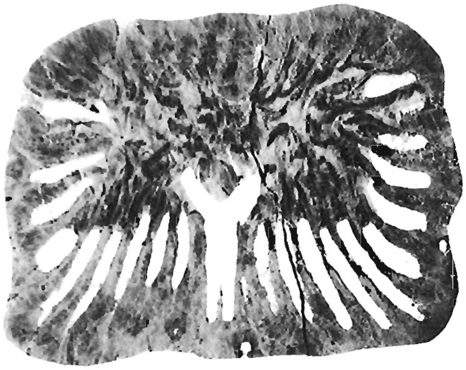

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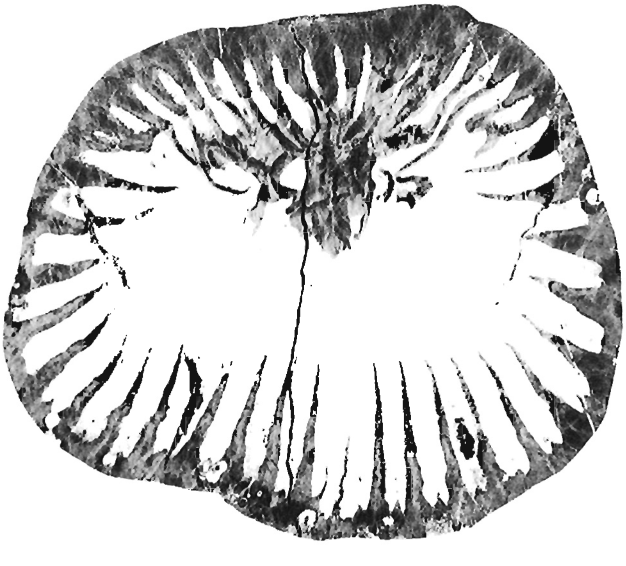

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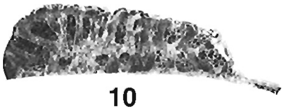

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## PLATE 3.4

Figure 1. *Bighornia patella* (Wilson, 1926)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

1. Longitudinal section (cardinal side right), GSC 85643, x5.

Figures 2-5. *Bighornia wilsonae* Buttler and Elias, sp. nov.

Selkirk Member, Red River Formation, Manitoba.

2, 3. Transverse sections, GSC 85649, x5.25.

4, 5. Transverse sections, GSC 85651, x5.25.

Figures 6-11. *Bighornia* cf. *B. bottei* Nelson, 1981

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

6-8. Transverse sections, GSC 85653, x2.5.

9-11. Transverse sections, GSC 85652, x2.5.

PLATE 3.4


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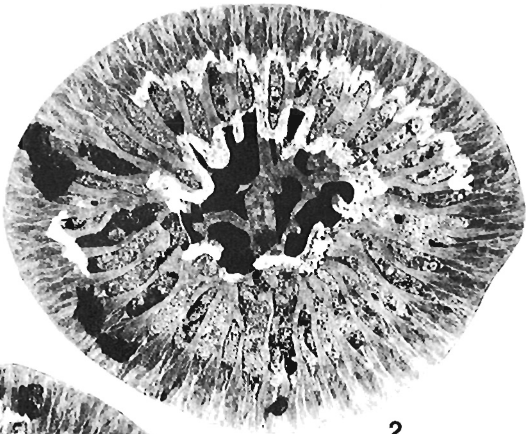
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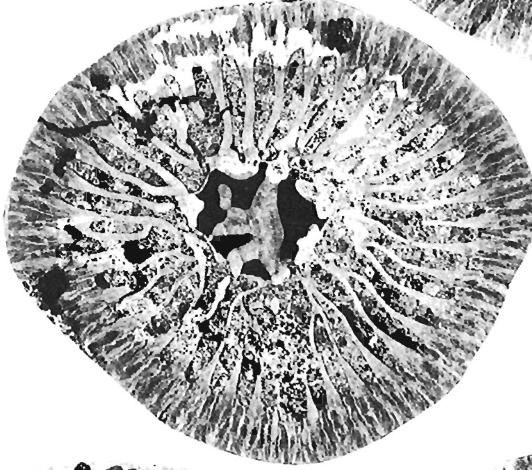
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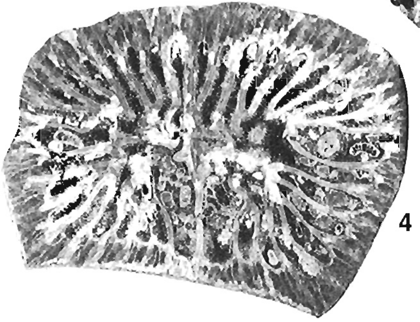
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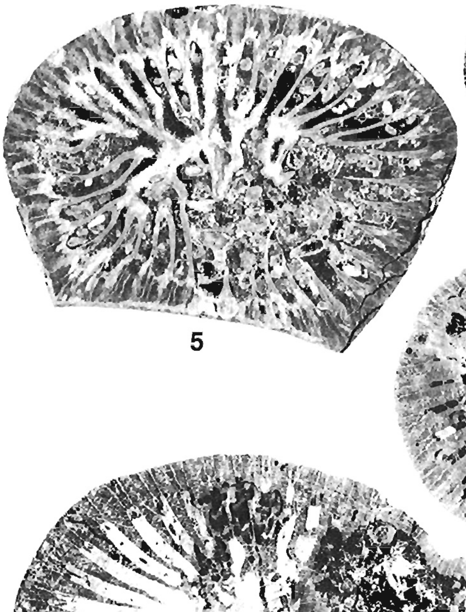
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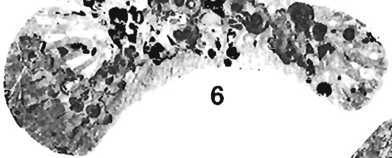
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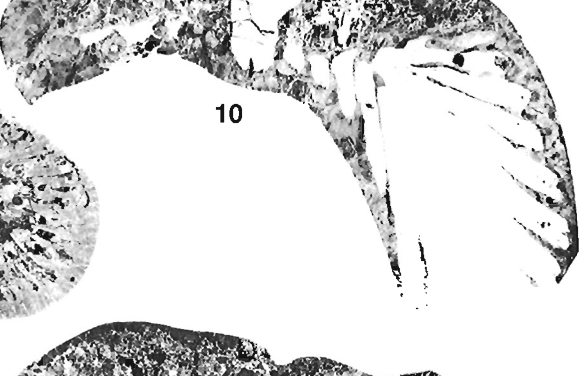
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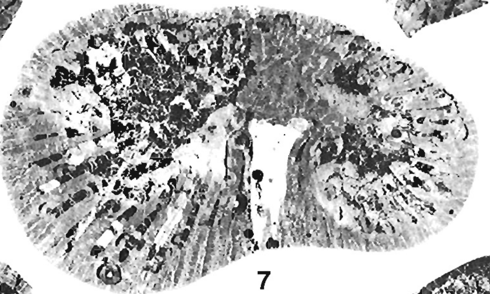
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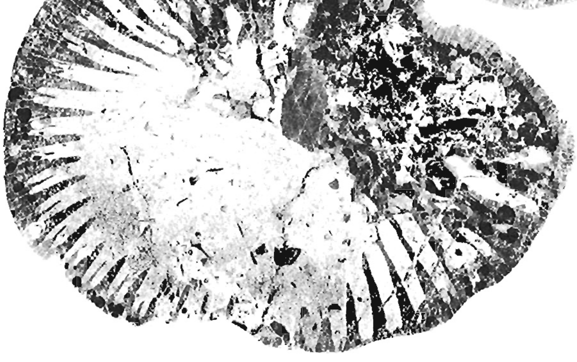
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## PLATE 3.5

Figures 1-9. *Grewingkia haysii haysii* (Meek, 1865)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia and Alberta.

1. View of calice (stereopair), GSC 16917, x2.

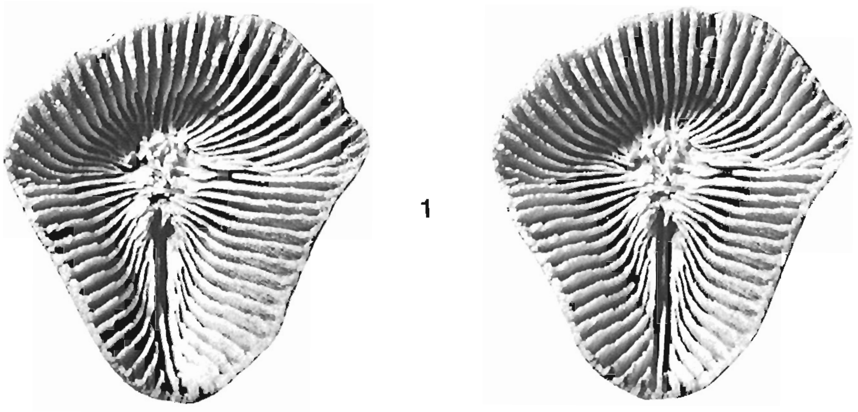
2, 3. Transverse sections, GSC 85664, x4.5, x3.

4. Transverse section, GSC 85666, x2.25.

5, 6. Transverse sections (two arrows point to one possible ostracode in fig. 6), GSC 85683, x2.25.

7, 8. Longitudinal sections (cardinal side right), GSC 85670, x2.25.

9. Transverse section, GSC 85670, x2.25; positioned at base of longitudinal section shown in fig. 8.



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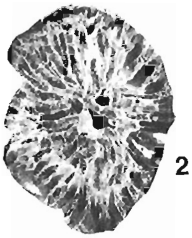

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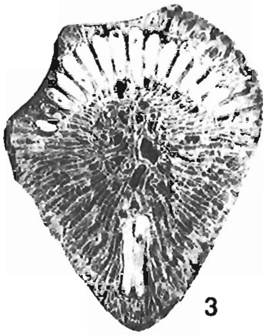

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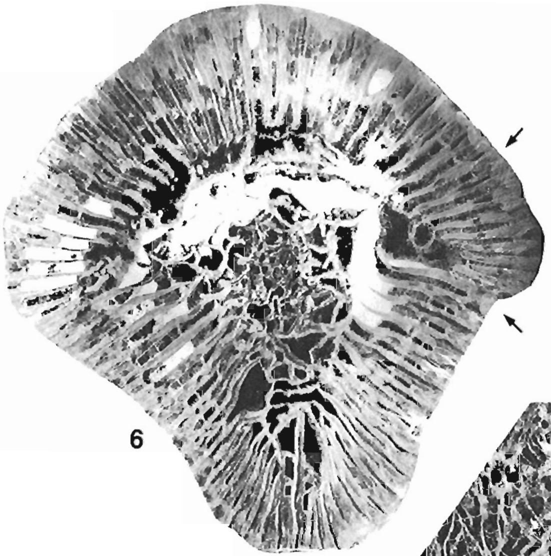

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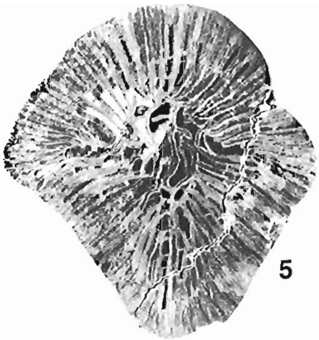

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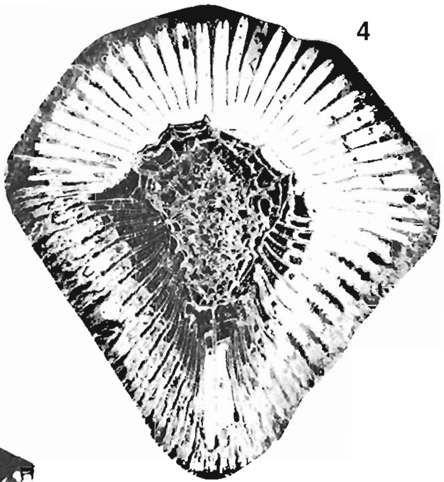

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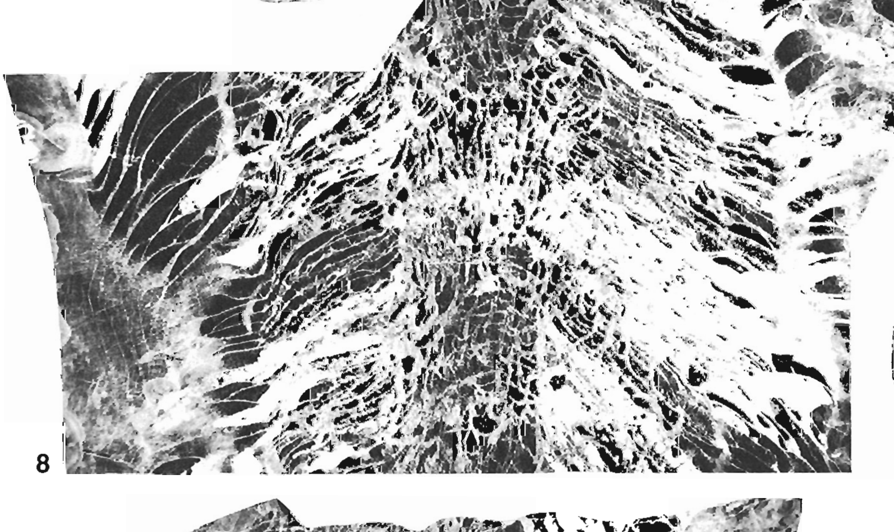

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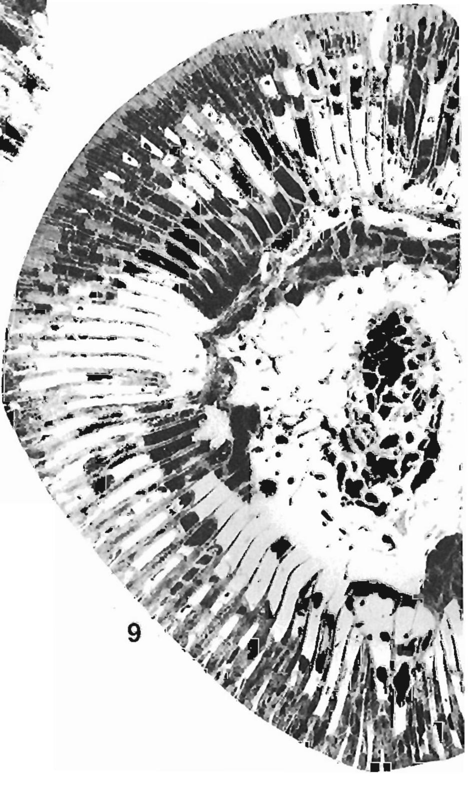

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## PLATE 3.6

Figures 1-4. *Grewingkia haysii haysii* (Meek, 1865)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

1. Alar view (cardinal side left), GSC 85662, x1.

2, 3. Transverse sections (arrows point to two *Trypanites* borings in fig. 3), GSC 85662, x2.25.

4. Transverse section, GSC 85654, x1.5.

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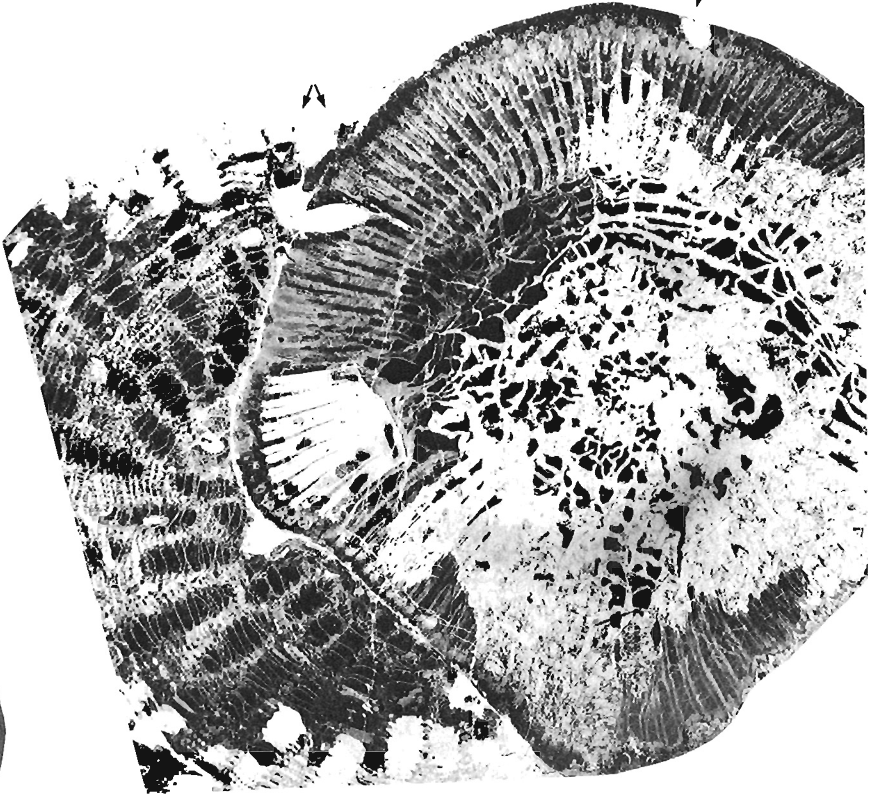

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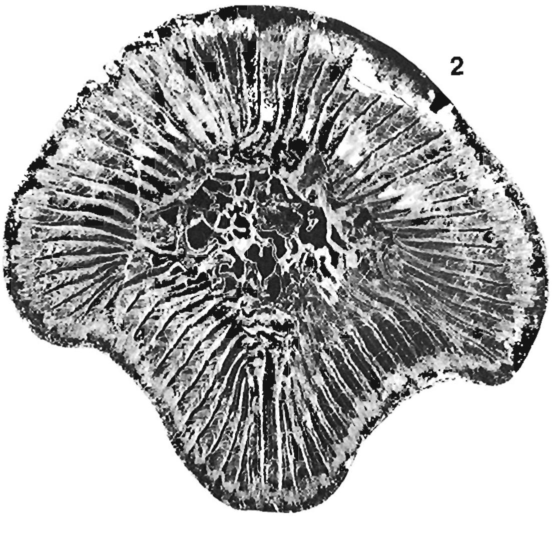

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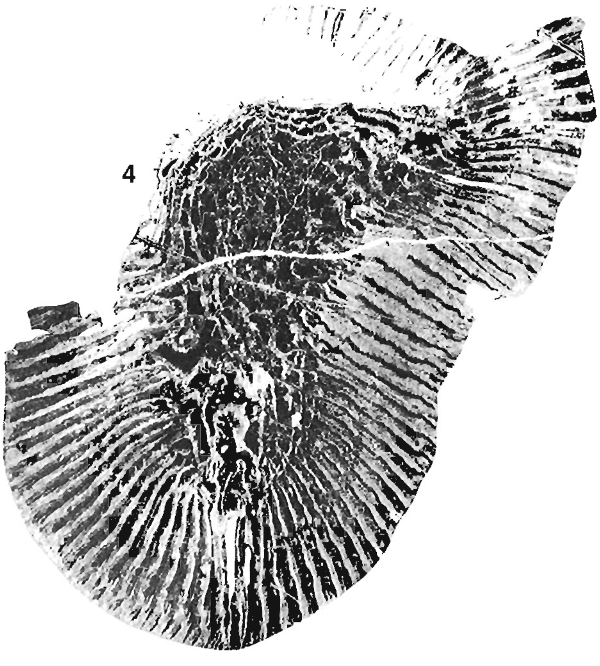


## PLATE 3.7

Figures 1-11. *Deiracorallium prolongatum* (Wilson, 1926)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

1. Cardinal view, GSC 85696, x1.

2. Alar view (cardinal side left), GSC 85696, x1.

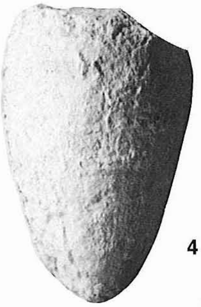
3, 4. Longitudinal sections (cardinal side left), GSC 85696, x3.

5, 6. Transverse sections (two arrows point to one ostracode in fig. 6), GSC 85696, x3.

7. Transverse section, GSC 85699, x4.5.

8-11. Transverse sections (arrows point to four *Trypanites* borings in figs. 10, 11), GSC 85697, x3.75.

PLATE 3.7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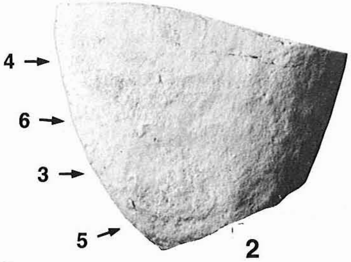

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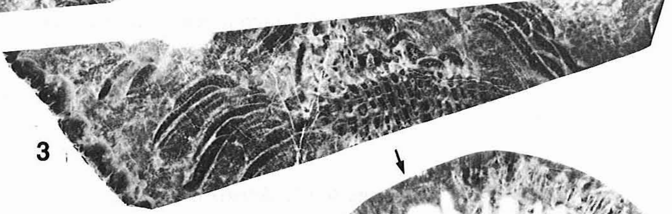
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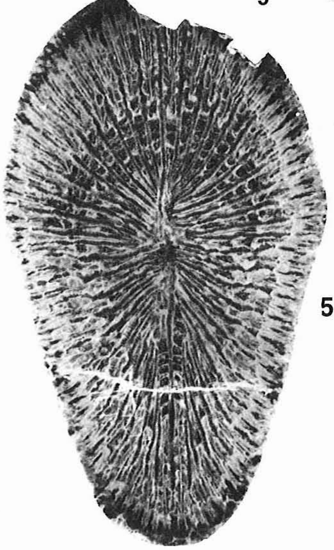
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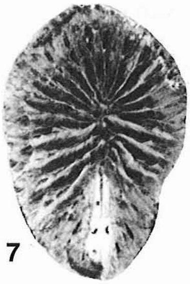
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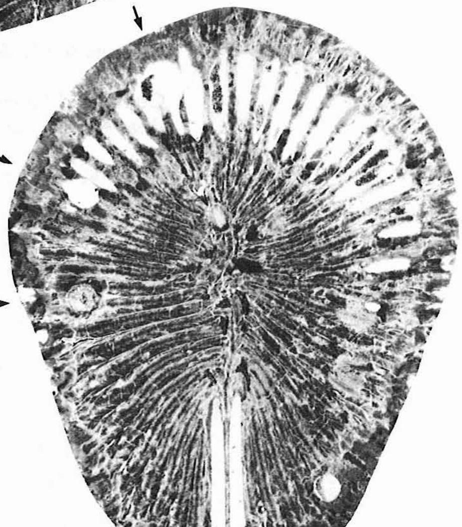
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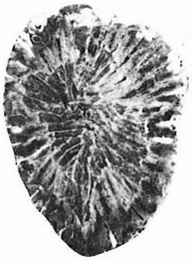
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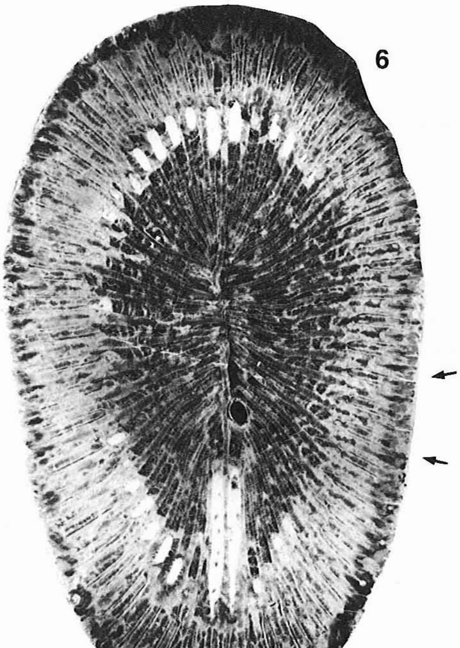
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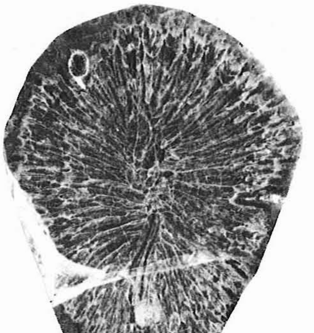
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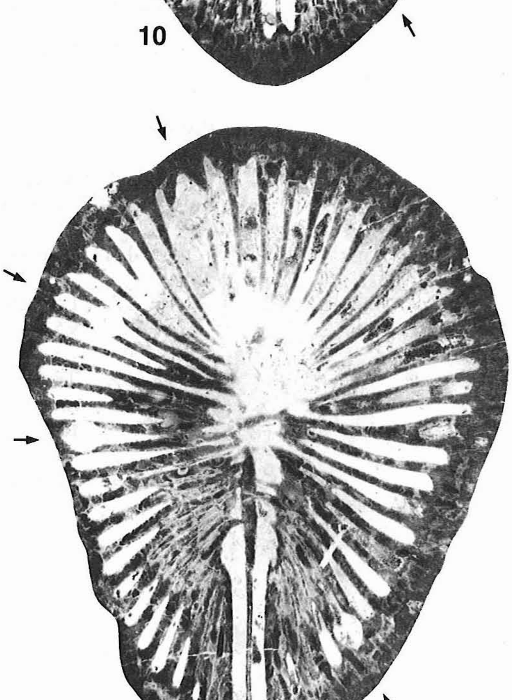
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## PLATE 3.8

Figures 1-3. *Deiracorallium prolongatum* (Wilson, 1926)

*Bighornia-Thaerodonta* Zone, Beaverfoot Formation, British Columbia.

1-3. Transverse sections (arrows point to three *Trypanites* borings in fig. 3), GSC 85694, x 3.75.

Figures 4-11. *Streptelasma* sp.

Combined "poorly fossiliferous interval" and *Eostropheodonta* Zone, Beaverfoot Formation, British Columbia.

4, 5. Transverse sections, GSC 85541, x7.

6, 7. Transverse sections, GSC 85539, x7.

8. Transverse section, GSC 85544, x7.

9-11. Transverse sections, GSC 85538, x7.

Figures 12-15. *Rhegmaphyllum* sp.

Combined "poorly fossiliferous interval" and *Eostropheodonta* Zone, Beaverfoot Formation, British Columbia.

12, 13. Transverse sections, GSC 85553, x6.

14, 15. Transverse sections, GSC 85551, x6.

Figures 16-20. *Dinophyllum* sp.

Combined "poorly fossiliferous interval" and *Eostropheodonta* Zone, Beaverfoot Formation, British Columbia.

16. Transverse section, GSC 85554, x5.

17. Longitudinal section (cardinal side right), GSC 85555, x5.

18, 19. Transverse sections, GSC 85555, x5; positioned at base and top, respectively, of longitudinal section shown in fig. 17.

20. Transverse section, GSC 85556, x5.

PLATE 3.8


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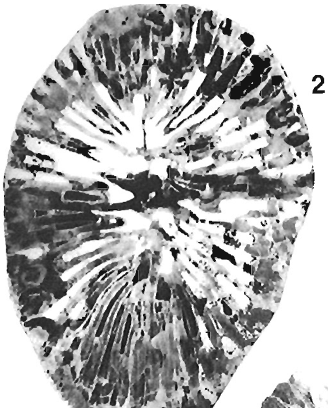
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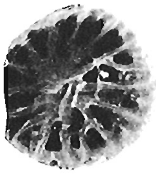
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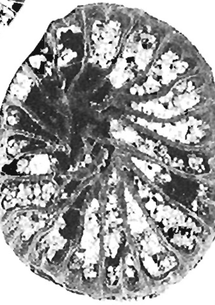
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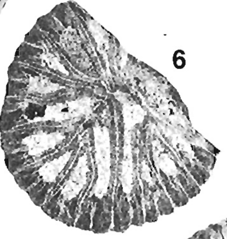
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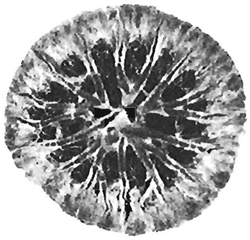
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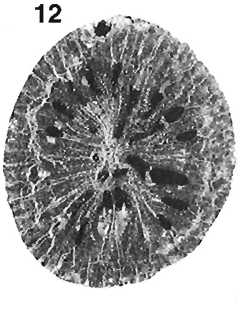
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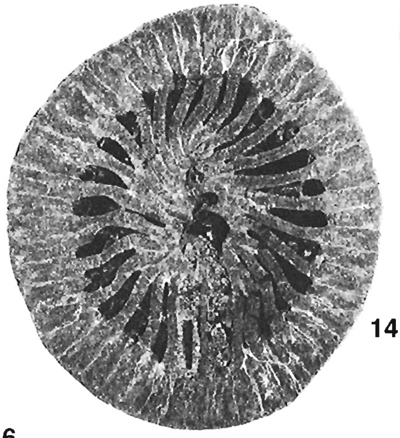
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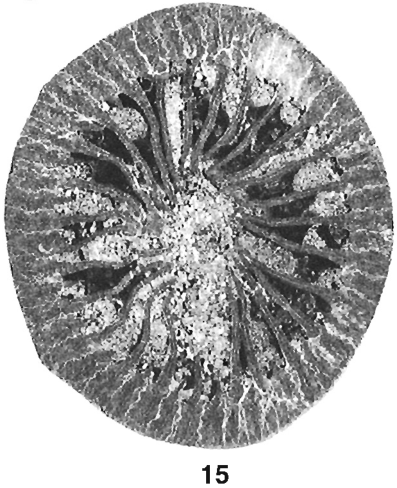
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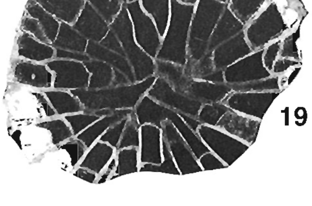
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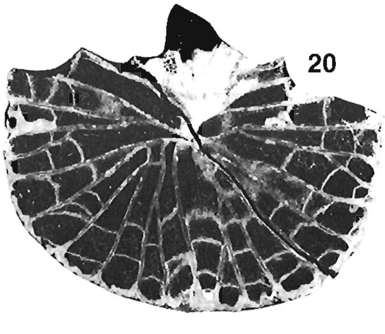
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# A NEW SPECIES OF ERYMID LOBSTER FROM LOWER JURASSIC STRATA (SINEMURIAN/PLIENSBACHIAN), FERNIE FORMATION, SOUTHWESTERN ALBERTA

**Rodney M. Feldmann**[1] and **M.J. Copeland**[2]

*Feldmann, R.M. and Copeland, M.J., A new species of erymid lobster from Lower Jurassic strata (Sinemurian/Pliensbachian), Fernie Formation, southern Alberta; in Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 379, p. 93-101, 1988.*

## *Abstract*

A new species of erymid decapod, ?*Eryma ollerenshawi*, is described from the Jurassic Fernie Formation of southwestern Alberta in strata of Sinemurian/Pliensbachian age. This is only the fourth recorded geographic occurrence of a Jurassic macruran in North America.

## *Résumé*

Dans la formation jurassique de Fernie, située dans des strates d'âge sinémurien et pliensbachien du sud-ouest de l'Alberta, on a découvert et décrit une nouvelle espèce de décapode érymidé, ?*Eryma ollerenshawi*. Il s'agit là seulement de la quatrième découverte, avec note de l'emplacement géographique, de macroures d'âge jurassique en Amérique du Nord.

## INTRODUCTION

Jurassic decapods are rare in North America, mainly because of the paucity of marine sediments of that age. Copeland (1960) described *Erymastacus bordenensis* (=*Eryma bordenensis*) from Sinemurian rocks of Borden Island, District of Franklin. Feldmann and McPherson (1980, p. 8) described *Glyphea robusta* from Sinemurian to Lower Cretaceous rocks on Borden, Melville and Prince Patrick islands, District of Franklin, and from the northern Richardson Mountains, northwestern District of Mackenzie. Herrick and Schram (1978) described a decapod fauna of Callovian age from the Sundance Formation, Wyoming, U.S.A. That fauna consisted of five taxa: two penaeid shrimps, *Antrimpos* sp. and *Bombur* sp.; two glypheoid lobsters, *Mecochirus* sp. and another species of indeterminate genus; and one unidentifiable macruran. Feldmann (1979) added a new species of erymid lobster, *Eryma foersteri*, to the decapods described from the Sundance. The preservation of the Sundance material is poor, and precise identification of taxa is difficult; however, the fauna is important in that it is the earliest reported occurrence of these genera from North America.

The presence of ?*Eryma ollerenshawi* sp. nov. in the Fernie Formation of Alberta (Fig. A, loc. 10; Fig. 4.1) represents the fourth recorded geographic occurrence of macruran from Jurassic rocks in North America and is remarkable because the single specimen appears to be either a moulted integument or a post-moult, "soft-shelled" individual.

## SYSTEMATIC PALEONTOLOGY

Class MALACOSTRACA Latreille, 1806

Order DECAPODA Latreille, 1803

Infraorder ASTACIDEA Latreille, 1803

Family ERYMIDAE Van Straelen, 1924

### **Genus** *Eryma* von Meyer, 1840

### ?*Eryma ollerenshawi* sp. nov.

Plate 4.1, figures 1, 2;
Plate 4.2, figures 1, 2

*Material.* The holotype, and sole specimen, consisting of the flattened part and counterpart, GSC 80067a and b, is deposited in the National Type Fossil Collection, Geological Survey of Canada, Ottawa, Ontario.

*Occurrence.* The holotype was collected from GSC locality 75402 on Bighorn Creek, above a small waterfall, latitude 51°44'28"N, longitude 115°32'27"W, from the lower 60-90 m of the exposed Fernie Formation (Fig. A, loc. 10; Fig. 4.2; see Frebold, 1957, p. 85, 86). The age of the beds is Sinemurian/Pliensbachian (Early Jurassic).

---

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*Approved for publication: 87.11.09*

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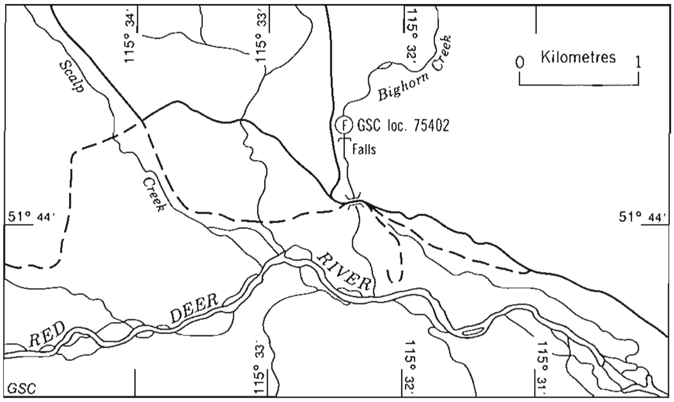


*Figure 4.1. Detailed locality map (see Figure A, locality 10) showing the site from which the holotype, and sole specimen, of ?**Eryma ollerenshawi** was collected.*

According to Ollerenshaw (pers. comm., 1987), the specimen was collected from a unit of platy, very dark grey to black, silty limestone, 13-21 ft (4-6.4 m) above the base of the Fernie Formation; equivalent to the central part of the interval identified by Frebold (1969, Fig. 1, Sec. 10) as "Upper Pliensbachian".

No other fauna is associated with the present specimen. Frebold (1957, p. 86) listed gastropods, the bivalves *Pleuromya* sp. indet., *Discina*?, *Ostrea*, and *Pecten* and some indeterminable ammonites with almost straight, apparently undivided ribs in basal beds of the Fernie Formation from the Bighorn Creek section. He concluded that, "This part of the Fernie is a Lower Jurassic horizon of uncertain age."

*Description.* Specimen moderate in size for genus, preserved as part and counterpart of ventral surface of cephalothoracic region and left lateral surface of abdomen.

Cephalothorax not preserved or, alternatively, represented by two triangular, wrinkled structures on same bedding plane as, but disassociated from, remainder of exoskeleton. Ventral surface apparently with narrow sternal structure, based upon points of origin of pereiopods.

Abdomen with six somites preserved. Axial length of somites 1 and 6 somewhat shorter than remainder, which are of approximately equal length. Tergal surfaces irregularly rugose, evidence of axial keel found only on fifth somite as ridge on anterior half of midline; lateral termination of terga with ovoid, domed region defined by narrow depression. Pleura poorly preserved; pleural margins of somites 2 and 3 rectangular with small posteriorly directed spine at posterolateral corner; margins of pleura 4 and 5 triangular with ventrally directed, spined terminations. Pleuron 6 triangular in outline, outer margins with tiny spine, surface irregularly wrinkled, with tiny pustules. Telson broad, tapering slightly posteriorly, apparently well sclerotized throughout, termination unknown; surface with approximately four narrow, well-defined longitudinal sulci bounded by tiny pustules or transverse corrugations. Uropods large, well-developed, triangular in outline; each element bears medial longitudinal sulcus and subtle longitudinal corrugations defining positions of setal pits; exopod with diaeresis.

Pereiopods represented by chelipeds and portions of four right and left walking legs. Chelipeds isochelous, large, propodus length about equal that of cephalothorax; spatulate in outline. Merus stout, long, ornamented by at least one longitudinal row each of notes and pits; carpus nearly square, ornamented by longitudinal rows of nodes and pits; propodus elongate, slightly concave outline on outer surface, straight on inner surface, finger length about equal that of hand, terminating in sharp, curved tip, which lies below similar structure on dactylus when claw is closed; inner and outer surfaces of propodus weakly nodose; occlusal surface apparently smooth; surface of hand with row of nodes and row of pits extending from near outer proximal corner to propodus-dactylus joint, remainder of surface smooth to finely wrinkled. Dactylus stout, similar in form to fixed finger, smooth to slightly wrinkled; occlusal surface smooth.

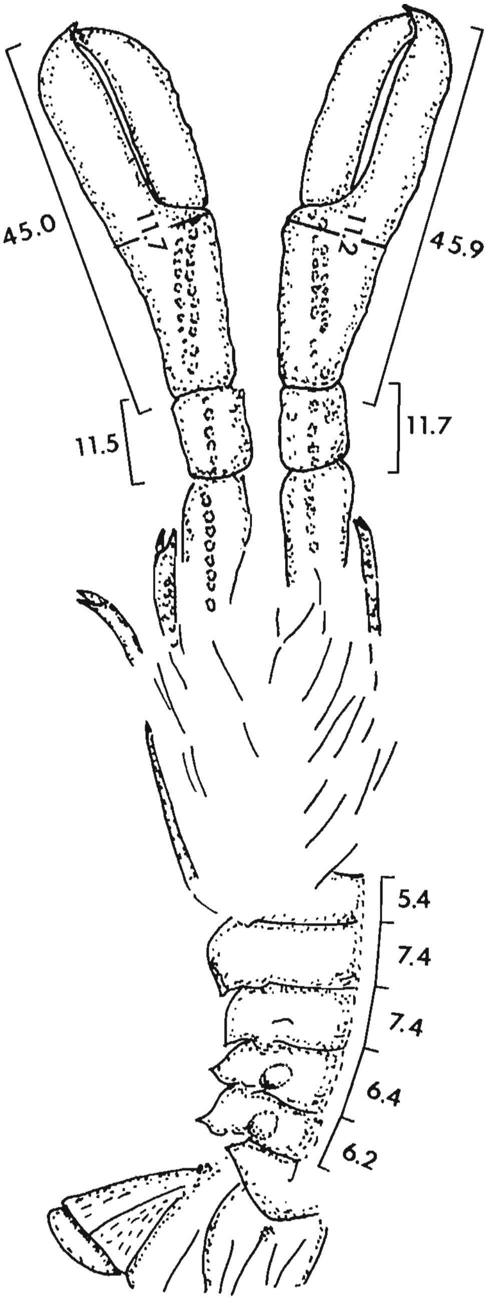


*Figure 4.2. Line drawing of ?**Eryma ollerenshawi** showing the measurements (in mm) taken of the specimen.*

Remaining pereiopods much smaller, approximately equal in size, ornamented by longitudinal rows of nodes; pereiopods 2 and 3 chelate; dactyli of pereiopods 4 and 5 short, triangular.

*Measurements.* Measurements, in millimetres, are given in Figure 4.2.

*Derivation of name.* The species name is given to honour Dr. N.C. Ollerenshaw, Geological Survey of Canada, Calgary, Alberta, who collected the specimen in 1966.

*Remarks.* Placement in the Astacidea can be done with relative certainty. Possession of three pairs of chelate pereiopods (Plate 4.2, fig. 2), the first of which is largest; well-developed pleura on the abdominal somites (Plate 4.2, fig. 2); and a diaeresis on the uropods (Plate 4.2, fig. 2) are key characters to this placement (Glaessner, 1969, p. R455, should be corrected to note that the first, not the third, pereiopod bears the largest chela). Assignment to *Eryma* must be made with caution because of the absence of well preserved carapace material. The conformation of groove patterns on the cephalothorax is the single most important criterion for generic distinction. Elements that may be remains of the carapace are so poorly preserved that they do not aid in confirming the generic identity.

Certain early and mid-Mesozoic genera can be eliminated on morphological grounds. Representatives of the Clytiopsinae, such as *Clytiopsis* and *Paraclitiopsis*, are distinguished from the remainder of the erymids by having the first pereiopod reduced so that it is nearly the same size as that of the second and third pereiopods (Forster, 1966; Glaessner, 1969). *Enoploclytia*, *Paleastacus*, and *Phlyctisoma* are all characterized by stronger and more coarsely ornamented chelae than those of the present specimen (Forster, 1966). *Eryma* embraces species with a wide range in claw morphology from the nearly smooth and edentate claws of *E. ventrosa* (H. von Meyer) (Forster, 1966, p. 108, Pl. 14, fig. 3) to the more closely ornamented claws of *E. stricklandi* (Phillips) (Forster, 1966, p. 111, Pl. 15, fig. 3), and the specimen does exhibit morphology within this spectrum. Genera within the Platychelidae, including *Platychela* and ?*Platypleon* possess three chelate pereiopods that decrease in size posteriorly (Glaessner, 1969, p. R458). The Nephropidae embraces only one genus that occurs below the Cretaceous, *Palaeophoberus*, which is recognized by its elongate, strong chelae and truncated abdominal pleura. The development of the chelae in the Palinura is not generally comparable to that of the Astacidea, eliminating them from consideration.

The uniqueness of ?*Eryma ollerenshawi* can be demonstrated by comparing its claw morphology with that of previously described species. The arms of *E. bordenensis* and *E. foersteri* are covered by granules of approximately equal size, whereas the arms of ?*E. ollerenshawi* possess obvious rows of coarse nodes and pits on a smoother field. *Eryma foersteri* also has claws that are much shorter relative to the length of the cephalothorax and stouter than the claws of ?*E. ollerenshawi*. The spatulate outline of the claws and the development of the rows of nodes and pits on the hands and arms of the new species serve to distinguish it from all others.

Several aspects of the mode of preservation are of interest. The organism is completely flattened, with the ventral surface of the cephalothoracic region and the left lateral surface of the abdomen exposed (Plate 4.1). The rotation of the two regions, relative to one another, strongly indicates that the specimen represents a moult of an individual rather than a corpse. Perhaps even more unusual is that the cephalothoracic region is compressed dorsoventrally, rather than laterally. This preservational orientation is unusual in the Astacidea because the carapace of most astacideans is cylindrical or laterally compressed and the sternal region is narrow. The reverse is the case in the Palinura; many forms are broad and have a very broad, triangular sternum and, therefore, many specimens are preserved with the dorsal surface parallel to the bedding planes.

Preservation of the ventral, rather than the dorsal, surface of the cephalothorax contributes to making the generic identification uncertain; no comparative material of the dorsum is available for study. There are two triangular plates preserved on the same bedding plane, which may represent two halves of the carapace, cleft down the midline. However, the preservation of these elements is poor, no structure can be seen on their surfaces, with the exception of some fine pustules, and neither plate is intimately associated with the specimen. Therefore, even if they are interpreted as halves of the cephalothoracic shield, the only information they provide is that a medial suture that facilitated moulting is present. This character would be consistent with placement in *Eryma*.

The final aspect of the preservational style reenforcing the suggestion that the flattened specimen represents either a moulted specimen or a post-moult, "soft-shell" lobster is that the surface of the claws, abdomen, telson, and uropods is delicately wrinkled as if it were little more than a thin membrane. The carapace of a corpse, in the intermoult condition, would generally be rigid and brittle. Coupled with the observation that the abdomen has been rotated relative to the cephalothorax, the evidence of the wrinkled surface indicates that the specimen represents a moulted carapace.

No evidence of predation or scavenging of the remains is apparent. The black shale of the Fernie Formation probably was deposited in an environment characterized by low oxygen levels, at least at the sediment-water interface. This foul condition probably substantially reduced the number and variety of benthic predators and scavengers, and enhanced the prospects for preservation of delicate material.

## REFERENCES

Copeland, M.J.
1960: *Erymastacus bordenensis*, a new Mesozoic decapod from the Canadian arctic; Geological Survey of Canada, Bulletin 60, p. 55-57.

Feldmann, R.M.
1979: *Eryma foersteri*, a new species of lobster (Decapoda: Erymidae) from the Callovian (Upper Jurassic) of Wyoming; American Museum Novitates no. 2668, p. 1-6.

Feldmann, R.M. and McPherson, C.B.
1980: Fossil decapod crustaceans of Canada; Geological Survey of Canada, Paper 79-16, p. 1-20.

Förster, R.
1966: Ueber die Erymiden, eine alte konservative Familie der mesozoischen Dekapoden; Palaeontographica, Abt. A, Bd. 125, p. 61-175.

Frebold, H.
1957: The Jurassic Fernie Group in the Canadian Rocky Mountains and Foothills; Geological Survey of Canada, Memoir 287, 197 p.

1969: Subdivision and facies of Lower Jurassic rocks in the southern Canadian Rocky Mountains and Foothills; Geological Association of Canada, Proceedings, v. 20, p. 76-93.

Glaessner, M.F.
1969: Decapoda; in Treatise on Invertebrate Paleontology, Part R, Arthropoda 4, R.C. Moore, (ed.); Geological Society of America and University of Kansas Press, v. 4(2), p. R399-R651.

Herrick, E.M. and Schram, F.R.
1978: Malacostracan crustacean fauna from the Sundance Formation (Jurassic) of Wyoming; American Museum Novitates, no. 2652, p. 1-12.

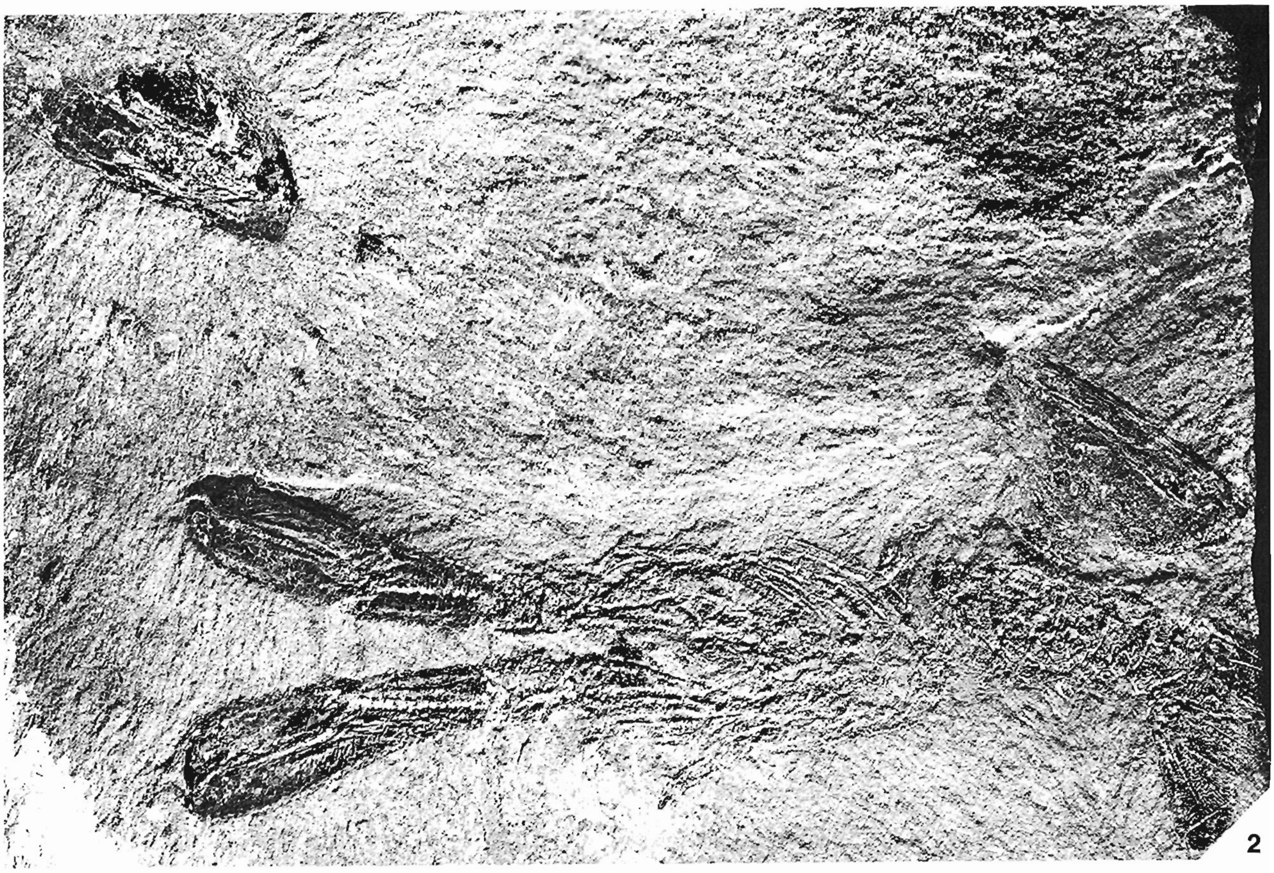
PLATES 4.1 to 4.2

## PLATE 4.1

Figures 1, 2. ?*Eryma ollerenshawi* sp. nov., x1

1. Holotype counterpart, GSC 80067b.
2. Holotype part, GSC 80067a.

PLATE 4.1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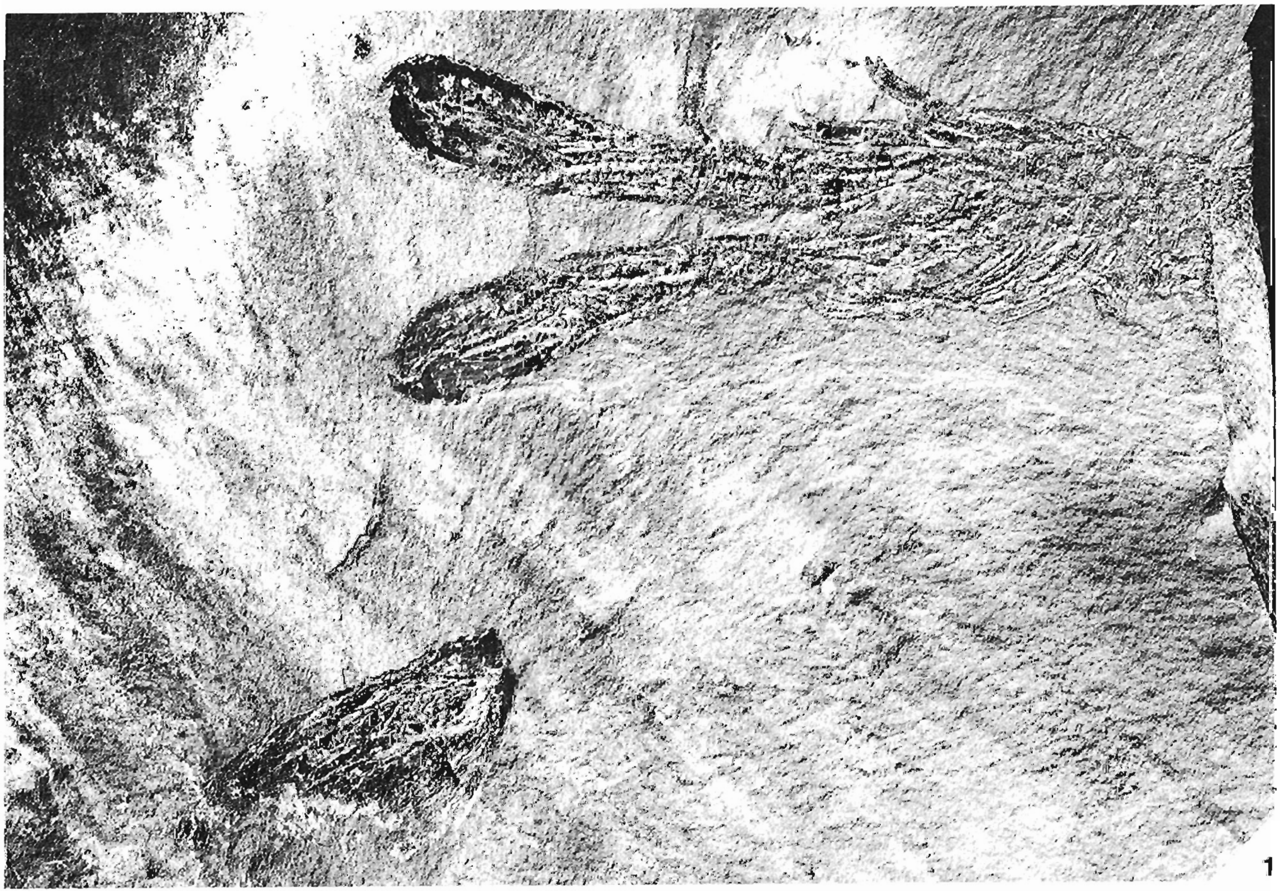
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## PLATE 4.2

Figures 1, 2. ?*Eryma ollerenshawi* sp. nov.

1. Holotype, counterpart, GSC 80067b, x1.9. Note the row of nodes and pits that extend the length of the ischium, merus and hand, and the terminations of the propodus and dactylus.
2. Holotype, part, GSC 80067a, x1.6. Showing pereiopods 2 and 3 interpreted as chelate (arrows), and the telson and uropods.


1


2

# NEW MOLLUSCAN FAUNAS FROM THE LATE JURASSIC (KIMMERIDGIAN AND EARLY TITHONIAN) OF WESTERN CANADA

**T.P. Poulton[1], A. Zeiss[2], and J.A. Jeletzky[3]**

*Poulton, T.P., Zeiss, A., and Jeletzky, J.A., New molluscan faunas from the Late Jurassic (Kimmeridgian and Early Tithonian) of western Canada; in Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 379, p. 103-115, 1988.*

### *Abstract*

Kimmeridgian and Lower Tithonian molluscan faunas recently discovered in Manning Provincial Park, southwestern British Columbia, contain a mixture of Boreal [*Buchia concentrica*], intermediate [*Ochetoceras (Suboxydiscites) manningense* subgen. nov., sp. nov.], and Tethyan/East Pacific species [*Discosphinctoides*(?) aff. *D. neohispanicum* (Burckhardt), *Lithacoceras*(?) sp., *L.*(?) (*Subplanites*?) sp., *Physodoceras* sp., *Phylloceras* cf. *P. mazenoti* Joly]. This association results from a mixing of Boreal and southern faunas with a broad range of overlap along the west coast of North America.

### *Résumé*

Des faunes de mollusques d'âge kimméridgien et tithonien inférieur, récemment découvertes dans le parc Provincial de Manning, dans le sud-ouest de la Colombie-Britannique, contiennent un mélange d'espèces boréales [*Buchia concentrica*], d'espèces intermédiaires [*Ochetoceras (Suboxydiscites) manningense* subgen. nov., sp., nov.] et d'espèces originaires de la mer Téthys et de l'Est du Pacifique [*Discosphinctoides*(?) aff. *D. neohispanicum* (Burckhardt), *Lithacoceras*(?) sp., *L.*(?) (*Subplanites*?) sp., *Physodoceras* sp., *Phylloceras* cf. *P. mazenoti* Joly]. Cette association résulte d'un mélange de faunes boréales et de faunes du sud, qui se recouvrent amplement le long de la côte ouest de l'Amérique du Nord.

## INTRODUCTION

Kimmeridgian and Lower Tithonian molluscan faunas new to Canada were discovered in southwestern British Columbia in 1985 by the authors and Jennifer O'Brien. The faunas are unusual and significant because they include ammonites characteristic of the East Pacific and Tethyan faunal realms together with the bivalve *Buchia*, which characterizes the Boreal Realm. The Manning Park fauna thus has significance for interprovincial correlation. The *Buchia* zones (Imlay, 1980; Jeletzky, 1965, 1984) of the Upper Jurassic and Lower Cretaceous of the Boreal Realm generally contain few ammonites that permit them to be correlated in detail with the Tethyan ammonite zones. Hence any fauna, such as that described in this report, contributes to resolving some of the long-standing problems of inter-provincial faunal correlation.

The fossils described in this report were collected from talus derived from bluffs directly above the talus slopes, on the north side of Thunder Lake at its west end, in southwestern Manning Provincial Park (GSC localities 68706, C-128986; lat. 49°01'30"N, long. 120°57'30"W; Fig. A, loc. 6; Fig. 5.1). The fossils come from black, rusty weathering, medium grained greywacke beds that were assigned to the Dewdney Creek Group by Coates (1974, p. 126) and to the "Thunder Lake Sequence" by O'Brien (1986). Although found in talus, the fossils collected by the authors (GSC locality C-128986) appear to represent two assemblages from a narrow stratigraphic interval, which could not be examined in outcrop, because the bluffs are inaccessible without climbing equipment. Although the Upper Oxfordian to Tithonian Thunder Lake Sequence may be as thick as 350 m in the western Thunder Lake area (O'Brien, 1986), and about 150 m of Upper Jurassic and Cretaceous rocks are exposed in the bluffs in the immediate area (Coates, 1974), the Jurassic fossils described here are from an interval within 50 m of the base of the disconformably overlying Lower Cretaceous (Hauterivian or Barremian) Jackass Mountain strata. They are the sole contributors to the uppermost, and westernmost parts of the talus. The fossils collected earlier by Coates (1974, p. 126; GSC loc. 68706) include an admixture of Hauterivian-Barremian (e.g., *Inoceramus colonicus*, *Hoplocrioceras*? sp. indet., and *Aulacoteuthis*? cf. *A. impressa*) and probably Upper Tithonian (*Buchia fischeriana trigonoides* of Jeletzky, 1984) fossils. These younger fossils were derived from the overlying strata that are present in the same bluffs and appear low on the talus slope near the lake. If Upper Tithonian beds are indeed present, they must be thin, because the probable source beds for the Kimmeridgian and Lower Tithonian fossils are separated from the Hauterivian-Barremian strata by less than 50 m. The various strata are not sufficiently distinct to permit recognition of the units on lithological criteria.

## AGE AND CORRELATION

Although the fossils described in this report are from rocks of uniform lithology and a narrow stratigraphic interval, they appear to give conflicting evidence regarding their age, and are now thought to come from beds of at least two different ages.

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*Figure 5.1.* *J.A. Jeletzky and A. Zeiss collecting the fossils described in this report from talus below bluffs of the Dewdney Creek Group and Cretaceous greywackes, Thunder Lake, Manning Park, southwestern British Columbia. Photograph no. ISPG 2564-4.*

The *Buchia* specimens figured are in part diagnostic of Late Oxfordian to Mid-Kimmeridgian ages, as indicated by *B. concentrica*. Its variety, *erringtoni*, also figured, is probably Early to Mid-Kimmeridgian in age, which is the most likely age for all members of the species at this locality. The Canadian *Ochetoceras* (*Suboxydiscites*) species appear to be closer to Middle Kimmeridgian, or possibly uppermost Lower Kimmeridgian, species of *Ochetoceras* s.s. than to other species. The presence of both the *Phylloceras* and *Physodoceras* specimens also suggests a Kimmeridgian age, but a more precise date cannot be determined.

The *Discosphinctoides neohispanicus* fauna of Mexico is clearly of Early Tithonian age (e.g., Imlay, 1980) and the various perisphinctids described in this report are consistent with that, and can be correlated with the *Hybonotum*, and perhaps the *Subplanitoides* fauna of southern Germany as well.

## PALEOBIOGEOGRAPHIC COMMENTS

The overall distribution of *Buchia* is Boreal. The *Buchia*-bearing seas in western North America extended as far south as California.

All the ammonites described in this report are of Tethyan/East Pacific affinity, and represent the northernmost well developed Kimmeridgian/Tithonian Tethyan faunas known so far in North America. Tethyan/East Pacific ammonites of these ages are otherwise sparsely represented by a few individual fragments in *Buchia*-rich beds in northern Manning Park (unpublished data), Taseko Lakes (Jeletzky, 1965; Jeletzky and Tipper, 1968), and perhaps Spatsizi areas of British Columbia. Some specimens of *Phylloceras* and *Lytoceras* from Alaska were mentioned by Imlay (1961, p. D11) and Imlay and Detterman (1973, p. 21). The "*Dichotomosphinctes/Buchia concentrica*" fauna of Alaska is apparently somewhat older (see Imlay, 1980, p. 30). This is also evident from the specimen figured as "*Perisphinctes* (*Dichotomosphinctes*) sp. cf. *P.* (*D.*) *muehlbachi* Hyatt" (Imlay, 1961, pl. 4, fig. 6), which is a representative of the genus *Orthosphinctes*, of latest Oxfordian/earliest Kimmeridgian age.

In general, the mixed Boreal and Tethyan/East Pacific faunas of western North America reflect a broad zone of faunal mixing. This was perhaps due to several short-lived northerly and southerly shifts of the interface between opposing water masses. Additionally, and perhaps more importantly, they may be a result of the effects of north-south oriented coastal currents along a geographically complicated, tectonically active, continental margin.

The western North American margin appears, at present, to have been the most likely migration route for *Ochetoceras* into Boreal seas, where they were considerably modified from Tethyan *Ochetoceras* s.s. species. Middle American Upper Oxfordian species are likely ancestors for *O.* (*Suboxydiscites*) *manningense*, and *O.* (*S.*) *elgense* and *O.* (*S.*) *taimyrense* may be its Middle and Upper Kimmeridgian Boreal descendants, respectively.

## SYSTEMATIC PALEONTOLOGY

All figured specimens are stored in the type collection of the Geological Survey of Canada, Ottawa, Canada.

### Class CEPHALOPODA Leach, 1817

### Order AMMONOIDEA Zittel, 1884

### Superfamily HAPLOCERATACEAE Zittel, 1884

### Family OPPELIIDAE Bonarelli, 1894

### **Genus** *Ochetoceras* Haug, 1885

### **Subgenus** *Suboxydiscites* subgen. nov.

Type species. *Ochetoceras* (*Suboxydiscites*) *manningense* sp. nov.

*Diagnosis*. A subgenus of *Ochetoceras* with a very narrow umbilicus, normal coiling, a serrated, non-undulating keel, very weak internal ribs, and retrocostate, single, external ribs. In microconchs, a lateral channel may be present, as well as a short protrusion of the mouth border at the end of the channel, which perhaps marks the beginning of a lateral lappet, and somewhat denser ribbing at the mouth border.

*Remarks*. *Oxydiscites* has an undulating keel and more distinct internal ribs. The ribs are denser, mostly bifurcating, and continuous on the flanks; they may weaken somewhat in the middle of the flanks (see Geyer, 1960).

*Ochetoceras* s.s. has a wider umbilicus and more falcoid, often bifurcating, external ribs. *Hildoglochiceras* and *Salinites* also have a notably wider umbilicus, more falcoid ribs, and a broader, more rounded venter like that of *Glochiceras*, but with a median, partly serrated, keel. *Streblites* has secondary (auxiliary) ribs between the primary external ribs. *Neochetoceras* also exhibits this character, but has no distinct median keel. Other species of the new subgenus are *O.* (*S.*) *taimyrensis* (Mesezhnikov) and *O.* (*S.*) *elgense* (Sej and Kalacheva).

### *Ochetoceras* (*Suboxydiscites*) *manningense* sp. nov.

Plate 5.1, figures 1-14; Plate 5.3, figure 10

? *Streblites*? (*Oxydiscites*?) cf. *taimyrensis* Mesezhnikov. Callomon and Birkelund, 1980, Pl. 3, figs. 5a, b.

Oppeliid ammonites closely resembling *Sanmartinoceras* (*Theganoceras*?) sp. Jeletzky, in Coates, 1974, p. 126.

*Holotype*. GSC 83491 (Pl. 5.1, figs. 1-4).

*Description*. The largest specimen is 5.2 cm in diameter, and another fragment was probably septate to a diameter of about 6 cm; most specimens are smaller.

The shell is oxycone, strongly compressed. The flanks are very gently convex. The venter is acute with a finely serrated keel. The ventrolateral edge is broadly rounded and indistinct (Pl. 5.1, figs. 1, 5, 7, 8, 11, 14).

The umbilicus is small but not minute, with low, steep, smooth walls. The umbilical edge is sharp.

A spiral groove or channel located halfway up the flank can be observed in some specimens (Pl. 5.1, figs. 7, 14; Pl. 5.3, fig. 10). In one specimen (Pl. 5.1, fig. 1) it is restricted to the end of the body chamber. There is no spiral ridge.

The ribs are falcate. The internal half of the flank is smooth, or has very fine, prorsiradiate growth lines, which on the adoral portions of only three specimens are widely enough spaced to be called weak primary ribs. On the external half of the flank, the ribs are stronger. They are rursiradiate, i.e. curving backward over most of their length, becoming stronger, more widely spaced and adorally gently concave toward the venter. Approaching the venter they curve sharply forward at their tips in some specimens, or more commonly they fade rapidly so that a narrow smooth space separates their terminations from the keel. The ribs become stronger in larger growth stages.

The adult mouth border of macroconchs is not known; at intermediate growth stages or in microconchs, the growth lines follow the ribs, or replace them adorally. In those stages the mouth border is best seen (Pl. 5.1, fig. 1; Pl. 5.3, fig. 10) and it is also falcoid, like the ribs and growth lines. There is a short prolongation at the end of the radial groove.

No sutures can be seen.

*Discussion*. None of the specimens from Manning Park is as large as the macroconchs from the U.S.S.R. figured as "*Oxydiscites*" *taimyrensis* (Mesezhnikov, 1984, Pl. VI, VII, LVII), and all of them are assumed to be microconchs. Only two smaller specimens from there (*ibid*. Pl. VII, figs. 3-4) are directly comparable. The one shown in figure 3 is somewhat similar to the supposed microconchs from Thunder Lake, while the other (fig. 4) is more densely ribbed, as on small macroconchs. The main difference is that *O. taimyrensis* has less falcoid ribs; also the microconchs have higher whorl sections, are more densely ribbed, and there appear to be no channels present. Another similar form, in shape and size of ribbing, is *Ochetoceras elgense* from the far eastern U.S.S.R. (Sej and Kalacheva, 1983, Pl. 3), but its ribs are less numerous and more coarse. The microconchs of that species are not as densely ribbed as in *O. manningense*. Sej and Kalacheva (1983, p. 68) have made detailed comparisons of *O. elgense* with other somewhat similar species of *Ochetoceras*.

Some European and Cuban species of *Ochetoceras* are similar, such as *O. canaliculatum* (d'Orbigny) and *O. semifalcatum*. Although the mouth border is the same, the ribbing is concave, sometimes bifurcating in these species. Also, the umbilicus is not as narrow as in the Canadian species (see also Sej and Kalacheva, 1983, p. 64).

The coarse spacing of the ribs, their strength, and the general form of the shell of the Manning Park specimens are similar to one specimen from the lower Mutabilis beds of East Greenland (Callomon and Birkelund, 1980, Pl. III, figs. 5a, b) but for the most part, the Greenland specimens are not sufficiently well preserved to be definitively compared.

*Ochetoceras* (*S.*) *manningense* sp. nov. seems to be an intermediate form, preserving some characteristics of the more typical Tethyan *Ochetoceras* that do not appear in those species from the mainly Boreal fauna in Greenland and Siberia. This may indicate a northward migration of *Suboxydiscites* from Cuba or Mexico via western North America, giving rise to the somewhat modified Boreal species of East Greenland, northern Siberia, and perhaps also the far eastern U.S.S.R.

## Superfamily PHYLLOCERATACEAE Zittel, 1884

## Family PHYLLOCERATIDAE Zittel, 1884

### **Genus *Phylloceras* Suess, 1865**

### *Phylloceras* cf. *P. mazenoti* Joly

Plate 5.1, figures 15-19

cf. *Phylloceras mazenoti* Joly, 1976, Pl. 6, fig. 1.

*Description*. The largest specimen has a whorl height of 6 cm, at which size it is non-septate; other small fragments have coarser ribbing, suggesting that they represent specimens that attained a larger size, if in fact they belong to the same species. The specimens available have differing whorl cross-sections, due at least partly to crushing, and the original cross-section of the shell cannot be confidently determined. Nevertheless, the venter is clearly rounded.

The ribs are gently flexed forward over the venter. Very faint, irregularly spaced folds occur on the lower half of the flank. No mouth border, constrictions, flares, or suture line can be seen.

*Discussion*. Besides *P. mazenoti* Joly, 1976, of Kimmeridgian age, the Manning Park specimens are similar to *Phylloceras subplicatius* Burckhardt, 1912 from Mexico, also Kimmeridgian, and to Tithonian specimens described as *Phylloceras* cf. *P. consanguinum* Gemmellaro, 1876 by Rossi (1984, Pl. 30, fig. 1).

## Superfamily PERISPHINCTACEAE Steinmann, 1890

## Family ASPIDOCERATIDAE Zittel, 1895

### **Genus** *Physodoceras* Hyatt, 1900

### *Physodoceras* sp.

Plate 5.1, figures 20, 21

*Description.* The single specimen is strongly distorted. Approximate reconstruction of its original shape indicates that it reached a diameter of about 6 to 7 cm. No sutures can be seen and the entire outer whorl preserved may well be the body chamber, although it is possible that a ventral groove or break in the shell, even in its most adoral parts, represents the siphuncle in the phragmocone of a considerably larger specimen than that preserved. There is a suggestion of uncoiling of the last few centimetres. The shell was probably fairly depressed, with rounded whorl cross-section. The umbilicus is tiny. Faint, fine ribbing over the venter can be seen on the oralmost 2 cm. A single row of inward-facing spines, spaced about 0.5 to 1 cm apart, occurs around the umbilicus. On the internal mould they are preserved only as subtle rounded protuberances and therefore are not well shown in the photograph (Pl. 5.1, fig. 21). No sutures can be seen.

*Discussion.* The most similar described species include *Aspidoceras acanthophalotum* Zittel (Canavari, 1903, Pl. I [XXVI], figs. 3a-c) from the Middle Kimmeridgian Acanthicus beds throughout Southern Europe and *A.* (*Physodoceras*) cf. *A. altenense* (d'Orbigny) (Quenstedt, 1887-8, Pl. 116, fig. 4) of the southern German Weisser Jura Gamma beds (middle and upper *Tenuilobatus* Zone; *Mutabilis* and *Cymodoce* Zones). A smaller species (3-5 cm diameter) with a ventral furrow has been assigned to *A. hermanni* Berckhemer from the Upper Kimmeridgian of central Europe (see Hölder and Ziegler, 1959, Pl. 19, fig. 4).

## Family ATAXIOCERATIDAE Buckman, 1921

## Subfamily LITHACOCERATINAE Zeiss, 1968

*Discussion.* Small specimens with lateral lappets (microconchs), intermediate sized specimens (e.g., Pl. 5.3, fig. 3) and large specimens are present. They may be micro- and macroconchs of the same species, but this would need to be verified by collecting from a single horizon. The inner whorls of the large specimens cannot be observed sufficiently well to prove their morphological similarity to the small specimens. Because of these difficulties, the different morphotypes are treated here as different morphospecies, belonging to different morphological genera.

The assignment of the specimens collected, especially the microconchs, to existing genera is difficult. They exhibit characteristics that are represented to varying degrees in several existing genera and subgenera, in particular, *Subplanitoides*, *Discosphinctoides*, *Pseudodiscosphinctes* and *Torquatisphinctes*. However, the characteristics fit none of these taxa completely. Considering that the macroconchs resemble *Lithacoceras* quite well in shape and style of ribbing, it would be reasonable to assign the smaller microconchs to *Subplanites*, which is thought generally to be the microconch counterpart of *Lithacoceras* (including *Virgatolithacoceras*). The trouble is that the microconchs corresponding to the true *Lithacoceras* (*L. ulmense* Group) of the lower and middle *Hybonotum* Zone have not been described in detail, except for a few specimens (e.g., in Berckhemer and Hölder, 1959; Ohmert and Zeiss, 1980; Schairer and Barthel, 1981). All those specimens were treated informally, e.g.: "*Lithacoceras*? (*Subplanites*?) sp.," "*Perisphinctidae* sp. et gen. indet.", "*Perisphinctes*". Only a monographic study could show the variety of those forms. It would be possible to describe the Manning Park microconchs as a new, dichotomous, rather densely ribbed group of *Subplanites*, but this would lead to an undesirable enlargement of the original diagnosis of this genus. Alternatively, it may well be that the recently established genus *Discosphinctoides* includes these forms (see Oloriz, 1978, p. 482-484). Therefore, at the present status of our knowledge, it seems appropriate to assign the Manning Park microconchs to *Discosphinctoides*(?), especially as we can only assume that the micro- and macroconchs come from the same horizon.

The generic names used in this section are those of morphotaxa. Their true relationships will only be deciphered after a monographic study of the contemporaneous micro-and macro-conchs in Europe and America.

### **Genus** *Discosphinctoides* Oloriz

### *Discophinctoides* (?) aff. *D. neohispanicum* Burckhardt

Plate 5.3, figures 1, 2, 4-9

*Pectinatites* (*Paraberriasella*) ex gr. *blondeti* (Donzé). Jeletzky in Coates (1974, p. 126).

?*Pectinatites* (*Paraberriasella*) ex gr. *blondeti* (Donzé). Jeletzky, 1984, p. 188, Pl. IV, figs. 14a, b.

aff. *Idoceras neohispanicus* Burckhardt, 1912, Pl. XXIX.

aff. *Perisphinctes* (*Aulacosphinctes*) *neohispanicus* (Burckhardt), 1919, Pl. 10, figs. 1-7.

aff. *Perisphinctes* (*Dichotomosphinctes*) *neohispanicus*. Muñoz, 1964, p. 11, Pl. 3, figs. 3,4.

aff. *Perisphinctes* (*Dichotomosphinctes*) *neohispanicus guadalupensis* Muñoz, 1964, p. 12, Pl. 3, figs. 1, 2, Pl. 4, figs. 3, 4.

*Description.* The microconchs reach a diameter of 8 cm. They are moderately evolute. The cross-section appears to vary from subcircular, at a diameter of 5 mm, to compressed subquadrate, at a diameter of 8 cm, but it cannot be seen clearly because all the specimens are crushed to some degree. The venter is rounded and simple. The umbilical edge is rounded and the umbilical wall is low, steep, and smooth, or with fine, wiry extensions of the ribs.

The smallest size at which ribs can be described confidently is at a whorl height of 1 cm, where nearly all the ribs bifurcate about halfway up the flank. From this stage, to the largest size of the microconch (whorl height 2.3 cm), there is a gradual admixture of simple ribs until about every third to fifth one is simple; trifurcating ribs are rare. The ribs are straight and radial, passing straight over the venter, except in the adoralmost 3 cm, where they become slightly prorsiradiate. No sutures can be seen.

On one fragmentary small specimen (Pl. 5.3, fig. 8), the ribs are more finely spaced than on the other perisphinctids described above, and they are perhaps more sinuous and certainly more irregular. There is not enough material available to attach great taxonomic or biostratigraphic significance to these attributes. Similar differences in Mexican collections led Muñoz (1964) to create a new subspecies of "*Perisphinctes*" *neohispanicus* (Burckhardt): "*P.*" *neohispanicus guadalupensis*.

The body chamber appears to occupy about seven-eighths of a whorl. Two constrictions, which are very weakly developed, are seen on one specimen only. A well developed constriction on the internal mould, a flare adoral to it, and prominent lateral lappets form the mouth border. On the external shell surface, the ribbing is unchanged at the mouth border, except for being slightly inclined forward.

*Discussion.* The specimen collected by J.A. Coates and illustrated by Jeletzky (1984, p. 188, Pl. IV, fig. 14a, b) drew the writers' attention to the Manning Park locality, where further specimens, those described here, were collected. The original identification of Coates' specimen as *Pectinatites* is questionable because of the complete lack of well defined virgatotome ribbing in any of the specimens. The original specimen compares well with the variety of forms from the later collection. In *Pectinatites* Buckman, as in the Manning Park specimens, the ribbing is entirely bifurcating in small intermediate growth stages, but in the larger intermediate growth stages, the secondaries appear to develop additionally by intercalation of simple ribs, and by bidichotomous splitting. The polygyrate ribbing also distinguishes *Subplanites* Spath (1925), another similar genus, from the Manning Park specimens. One of the specimens is similar to certain forms of *Subplanitoides* Zeiss, 1968.

"*Idoceras*" *neohispanicus* Burckhardt (1912, Pl. XXIX) from the Kimmeridgian of Mexico is very similar to the Manning Park specimens. It was subsequently assigned to "*Aulacosphinctes*" by Burckhardt (1919), and to "*Perisphinctes* (*Dichotomosphinctes*)" by Muñoz (1964), who illustrated an assemblage that includes more finely ribbed varieties (his var. *guadalupensis*) that more closely resemble the more finely ribbed component of the Manning Park fauna (Pl. 5.3, fig. 8). *Discosphinctoides neohispanicus guadalupensis* differs from most of the Manning Park specimens by its finer, more flexuous, and more prorsiradiate ribs and by the slightly smaller whorl height. Most of the Mexican specimens are slightly more involute than the Canadian species, and have differently shaped ribs. Other small species from Mexico described and illustrated by Imlay (1939, p. 34, 35, Pl. 9, figs. 1, 2) as "*Torquatisphinctes*?" sp. and "*T.*?" aff. *bangei* (Burckhardt) are apparently also indistinguishable from the Manning Park species.

### **Genus** *Lithacoceras* Hyatt

*Lithacoceras* (?) sp.

Plate 5.2, figures 1-5

*Description.* On two specimens, the primary ribs at a whorl height of 6 to 7 cm are subdued, represented by vague swellings relatively finely spaced on one (Pl. 5.2, figs. 3, 4), more distantly spaced on another (Pl. 5.2, fig. 5). Multiple, finely, and evenly spaced secondaries cover the outer part of the flank. At intermediate growth stages, constrictions remain insignificant.

The largest growth stage seen is represented by a small fragment with a whorl height of 11 cm (Pl. 5.2, figs. 1, 2). At this size, the umbilical wall is high, vertical, and smooth. The flanks converge toward the venter, which is broadly rounded. Strong radial bullae around the umbilicus fade ventrally, and the ventral half of the flank is smooth. The oralmost part of the shell is possibly represented on one fragment (unfigured, whorl height 9.5 cm; preserved length 15.5 cm), indicated by gentle forward inclination, weakening, and irregular spacing of the primary ribs on the oralmost preserved 10 cm. No secondaries are visible. No sutures can be seen.

*Discussion.* Systematic attribution of these large forms is particularly difficult because of the fragmentary preservation. The style of ribbing and shell shape are similar to representatives of *Lithacoceras*, especially *L. ulmensis* (Oppel) (see Berckhemer and Hölder, 1969; Ohmert and Zeiss, 1980). *Lithacosphinctes* is also somewhat similar, but the locus of bifurcation of the ribs in this genus is generally halfway up the whorl, while it is much lower on the outer whorls of *Lithacoceras*.

### **Subgenus** *Subplanites* Spath

*Lithacoceras*(?) (*Subplanites*?) sp.

Plate 5.3, figure 3

One specimen, represented by part of a whorl from an intermediate growth stage of a macroconch may be distinguished from the other perisphinctids from Thunder Lake by its irregular polygyrate and bidichotomous style of ribbing. The primary ribs are swollen and bent slightly forward along the umbilical edge. Just below halfway up the flank some of the ribs subdivide into two or three secondaries and some intercalated secondaries are present. Just above halfway up the flank, many of the ribs split again, so that there are variably three or four secondaries to each primary. A similar specimen has been figured from Europe, as *S. rueppellianus* (Quenstedt) by Schairer and Barthel (1981). The ribbing style is also similar to certain forms of the contemporaneous genus *Ilowaiskya*.

## Class BIVALVIA Linné, 1758

### Family BUCHIIDAE Cox, 1953

### **Genus** *Buchia* Rouillier, 1845

(=*Aucella* Keyserling, 1846; suppressed by Opinion 492 of the International Commission on Zoological Nomenclature, 1957).

### **Subgenus** *Anaucella* Pchelintseva, 1955

*Discussion.* This subgenus is characterized by an essentially *Meleagrinella*-like structure of its byssus ear combined with either a strong development of the radial ornament or its prevalence over the concentric ornament. Jeletzky (1965, p. 4, 8) discussed the morphology and status of *Anaucella*.

### *Buchia* (*Anaucella*) *concentrica* (Sowerby)

Plate 5.3, figures 13-20

See Zakharov (1981, p. 64, 65) for the Eurasian synonymy and Imlay (1959, p. 157) for the North American synonymy.

*Description.* Seven specimens are available. They are complete to fragmentary internal casts of individual valves including six left and one right (Pl. 5.3, figs. 19, 20).

The shell is moderately to pronouncedly oblique posteriorly in relation to the short hinge line. The posterior wing varies from prominent and angular (Pl. 5.3, fig. 17) to being a barely visible, rounded protuberance (Pl. 5.3, fig. 15). The anterior wing does not exist in the left valve and is transformed into a characteristic *Meleagrinella*-like ear in the right valve. Both valves are either equally feebly convex or nearly flat, except for the beak part of the left valve, which is considerably more convex, more elevated, and distinctly to markedly elongated. Consequently, the left beak overhangs the slightly elevated, very small right beak. The left beak is slightly (Pl. 5.3, fig. 13) to markedly (Pl. 5.3, fig. 17) incurved to the right (i.e., opisthogyrous).

The right valve is an elongated oval, pronouncedly oblique posteriorly (Pl. 5.3, fig. 19). The outline of the left valve is extremely variable. One morphological extreme is characterized by a short beak part that widens posteriorly and curves in markedly to the right. The rest of the valve is a widened, elongated oval shape, pronouncedly oblique posteriorly (Pl. 5.3, fig. 17). This extreme variant is only represented by one valve in our material. However, it appears to be dominant in the central Russian and north Siberian population samples of *B.* (*A.*) *concentrica* (e.g., Zakharov, 1981, Pl. III, IV). The other morphological extreme is characterized by a much longer and a much more slender left beak that expands gradually and more or less evenly in the posterior direction. This results in a fairly strongly elongated, posteriorly oblique pear-like shape of the left valve. The flanks of this pear-shaped variant are only slightly to feebly convex, while its lower posterior, and posterior, margins are more or less regularly and broadly rounded. The maximum width of the left valve is situated near the lower margin in this variant (Pl. 5.3, figs. 13, 15). This extreme variant is prevalent in our material. It was designated "*Aucella*" *erringtoni* by Meek (1865, p. 479, Appendix B, Pl. 1, figs. 1-3, 5). The specimen reproduced in Plate 1, figure 2a of that publication is typical of this taxon, which is treated here as a mere morphological variant of *Buchia* (*Anaucella*) *concentrica*, because the two occur together and intergrade in all North American collections studied. However, typical representatives of *B.* (*A.*) *concentrica* var. *erringtoni* appear to be extremely rare among the hitherto figured Eurasian representatives of the species (e.g., Sokolov, 1902, Pl. XIV, fig. 6). If it is found that this variety is largely or perhaps entirely restricted to North American populations of *B.* (*A.*) *concentrica*, its varietal status proposed here would have to be reconsidered.

The shell surface of both valves is covered by thin and sharp-topped, closely to moderately closely spaced concentric ribs that are mostly fairly regularly spaced (e.g., Pl. 5.3, fig. 13). Five to eight such ribs occur per centimetre in most of the specimens available (e.g., Pl. 5.3, figs. 13, 15). However, the concentric ribs may be considerably less regular and more closely spaced in some other specimens (e.g., Pl. 5.3, fig. 17). The normally prominent, fine and closely spaced radial striation is either invisible or only locally visible (e.g., Pl. 5.3, fig. 13) in our specimens because of their internal cast preservation. Study of shell-covered specimens of *B.* (*A.*) *concentrica* from other localities indicates that their radial ornamentation is much more strongly developed on the shell surface than on the internal cast. However, even in specimens with the shell preserved, this ornamentation is considerably less prominent than the concentric ribbing.

No parts of the hinge are preserved in any of the left valves studied. However, the poorly preserved hinge of the only available right valve (Pl. 5.3, fig. 19) appears to have a *Meleagrinella*-like, simply furrowed byssus ear of the type described and figured by Jeletzky (1965, p. 4, 8; Pl. I, figs. 1, 2, 10).

## Family ENTOLIIDAE Korobkov, 1960

### **Genus** *Camptonectes* Agassiz, 1864

### *Camptonectes* sp.

Plate 5.3, figure 12

The single available fragment is not well enough preserved, nor are the taxonomy and distribution of the many named species well enough known, for it to be assigned to a particular species with any confidence.

### **Subgenus** *Mclearnia* Crickmay, 1930

### *Camptonectes* (*Mclearnia*) sp.

Plate 5.3, figure 11

The single specimen available is not sufficiently well preserved to allow assignment to any of the several closely similar species known.

## REFERENCES

Berckhemer, F. and Hölder, H.
1959: Ammoniten aus dem Oberen Weissen Jura Süddeutschlands; Beihefte zum Geologischen Jahrbuch, Heft 35, 135 p., 27 pl.

Burckhardt, C.
1912: Faunes jurassiques et crétaciques de San Pedro del Gallo; Instituto Geológico de Mexico, Boletín número 29, 2 vol, 264 p., 45 pl.

1919: Faunas jurásicas de Symon (Zacatecas) y faunas cretácicas de Zumpango del Río (Guerrero); Instituto Geológico de Mexico, Boletín número 33, 135 p., 21 pl.

Callomon, J.H. and Birkelund, T.
1980: The Jurassic transgression and mid-late Jurassic succession in Milne Land, central East Greenland; Geological Magazine, v. 117, p. 211-310.

Canavari, M.
1903: La fauna degli strati con *Aspidoceras acanthicum* di Monti Serra presso Camerino; Palaeontographia Italica, vol. IX, Parte Quinta, p. 1(89)-17(105), pl. I-IX(XXVI-XXXIV).

Coates, J.A.
1974: Geology of the Manning Park area, British Columbia; Geological Survey of Canada, Bulletin 238, 177 p.

Geyer, O.F.
1960: Ueber *Oxydiscites* Dacqué; Neues Jahrbuch für Geologie und Paläontologie, Monatshefte 1960, p. 417-425.

Holder, H. and Ziegler, B.
1959: Stratigraphische und faunistische Beziehungen im Weissen Jura (Kimmeridgien) zwischen Süddeutschland und Ardèche; Neues Jahrbuch für Geologie und Paläontologie, v. 108, p. 150-214, pl. 17-22.

Imlay, R.W.
1939: Upper Jurassic ammonites from Mexico; Bulletin of the Geological Society of America, v. 50, p. 1-78, 18 pl., 7 figs.

1959: Succession and speciation of the pelecypod *Aucella*; United States Geological Survey, Professional Paper 314-G, p. 155-167, 4 pls.

1961: Late Jurassic ammonites from the Western Sierra Nevada, California; United States Geological Survey, Professional Paper 374-D, p. 1-30, pl. 1-6.

1980: Jurassic paleobiogeography of the conterminous United States in its continental setting; United States Geological Survey, Professional Paper 1062, 134 p.

Imlay, R.W. and Detterman, R.L.
1973: Jurassic paleobiogeography of Alaska; United States Geological Survey, Professional Paper 801, 34 p.

Jeletzky, J.A.
1965: Late Upper Jurassic and early Lower Cretaceous fossil zones of the Canadian Western Cordillera, British Columbia; Geological Survey of Canada, Bulletin 103, 70 p., 22 pls.

1984: Jurassic-Cretaceous boundary beds of Western and Arctic Canada and the problem of the Tithonian-Berriasian stages in the boreal realm; in Jurassic-Cretaceous biochronology and paleogeography of North America, G.E.G. Westermann (ed.); Geological Association of Canada, Special Paper 27, p. 175-256.

Jeletzky, J.A. and Tipper, H.W.
1968: Upper Jurassic and Cretaceous rocks of Taseko Lakes map area and their bearing on the geological history of southwestern British Columbia; Geological Survey of Canada, Paper 67-54.

Joly, B.
1976: Les Phylloceratidae malgaches au Jurassique. Generalités sur les Phylloceratidae et quelques Juraphyllitidae; Documents des laboratoires de géologie de la Faculté des Sciences de Lyon, no. 67, 741 p.

Meek, F.B.
1865: Description of fossils from the auriferous slates of California; Geological Survey of California. Geology, Vol. I, Appendix B, p. 477-482, 1 pl.

Mesezhnikov, M.S.
1984: Kimmeridgian and Volgian stages of the northern U.S.S.R.; Nedra, Leningradskoe otdelenie, Leningrad, 166 p., 57 pl.

Muñoz, M.J.P.
1964: Amonitas del jurásico superior y del cretácico inferior del extremo oriental del estado de Durango, Mexico; Paleontología Mexicana Número 20, p. 1-33, 10 pl.

O'Brien, J.
1986: Jurassic stratigraphy of the Methow Trough, southwestern British Columbia; in Current Research, Part B, Geological Survey of Canada, Paper 86-1B, p. 749-756.

Ohmert, W. and Zeiss, A.
1980: Ammoniten aus den Hangenden Bankkalken (Unter-Tithon) der Schwäbischen Alb (Sudwestdeutschland); Abhandlungen Baden-Wurttemberg, Geologisches Landesamt, Heft 9, p. 5-50, 14 pl.

Oloriz, F.
1978: Kimmeridgiense-Tithonico inferior en el sector central de las Cordilleras Beticas (Zona Subbetica). Paleontología, Bioestratigrafía; PhD thesis, University of Granada, 2 vols., 758 p., 57 pl.

Quenstedt, F.A.
1887: Die Ammoniten des Schwäbischen Jura. 3: Der Weisse Jura; E. Schweizerbart, Stuttgart, p. 817-1140, 34 pl.

Rossi, F.
1984: Ammoniti del Kimmeridgiano superiore-Berriasiano inferiore del Passo del Furlo (Appenino Umbro-Marchigiano); Memorie della Societá Italiana di Scienze Naturali e del Museo civico di Storia naturale, Milano, v. XXIII, fasc. 3, p. 75-136, pl. 30-37.

Schairer, G. and Barthel, K.W.
1981: Die cephalopoden des Korallenkalkes aus dem Oberen Jura von Laisacker bei Neuberg a.d Donau; V. Bayerische Staatssammlung für Paläontologie und Historische Geologie; Mitteilungen, v. 21, p. 3-21, pl. 1-5.

Sej, I.I. and Kalacheva, E.
1983: Ob invasijach tetitsheskich ammonitov v borealyne pozdnejurskie bassejny vostoko SSSR; Trudy Instituta Geologi i Geofiziki; Akademia Nauk SSSR, Sibirskoe otdelenie, v. 555, p. 61-72, 3 pl.

Sokolov, D.N.
1902: Ueber einige Aucellen ans Ost-Russlands; Bulletin de la Société Impériale des Naturalistes de Moscou, n. ser., t. XVI, p. 371-379, 14 pl.

Weaver, C.E.
1931: Paleontology of the Jurassic and Cretaceous of west central Argentina; Memoirs of the University of Washington, v. 1, 469 p., 62 pl.

Zakharov, V.A.
1981: Buchiids and the biostratigraphy of the Boreal Upper Jurassic and Neocomian. Akademiya Nauk SSSR Sibirskoye Otdelenie, Institut Geologii i Geofiziki, Trudy no. 458; "Nauka" Press, Moscow, 271 p., 60 pl.

## PLATE 5.1

All specimens from GSC locality C-128986, southwestern British Columbia; x1, except figure 4 (x3).

Figures 1-14. *Ochetoceras (Suboxydiscites) manningense* sp. nov.

1-4. Right lateral, ventral, left lateral and enlarged (x3) views, holotype GSC 83491.

5-14. Lateral views of figured specimens GSC 83492-83501.

Figures 15-19. *Phylloceras* cf. *P. mazenoti* Joly

15, 17. Lateral views of small fragments, figured specimens GSC 83502 and 83503.

16. Ventral view of small fragment, figured specimen GSC 83504.

18, 19. Lateral and ventral views of figured specimen GSC 83505.

Figures 20, 21. *Physodoceras* sp.

Ventral and lateral views of crushed figured specimen GSC 83506. The umbilical spines are not well shown because of exfoliation of the shell away from the internal mould.


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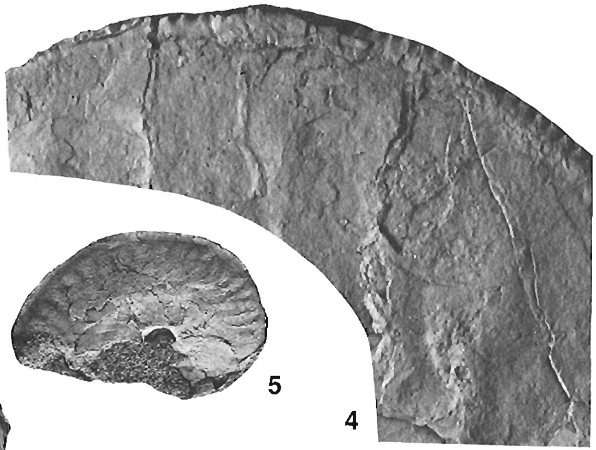
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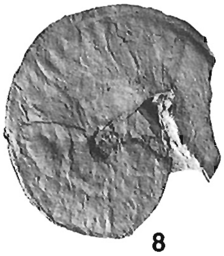
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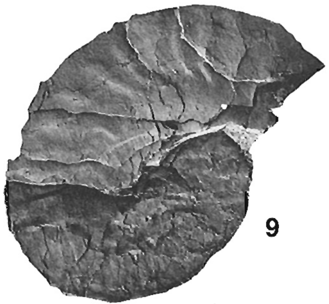
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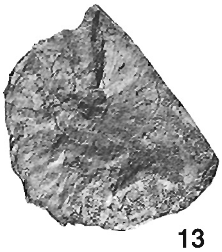
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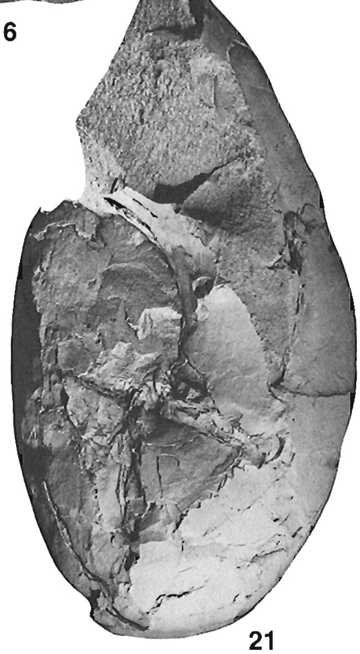
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## PLATE 5.2

All specimens are from GSC locality C-128986, southwestern British Columbia; x1.

Figures 1-5. *Lithacoceras* (?) sp.

1, 2. Lateral and ventral views of fragment, figured specimen GSC 83507. Large growth stage, macroconch.

3, 4. Ventral and lateral views of fragment, figured specimen GSC 83508. Large intermediate growth stage, macroconch.

5. Lateral view, crushed figured specimen GSC 83509. Larger intermediate growth stage, macroconch.

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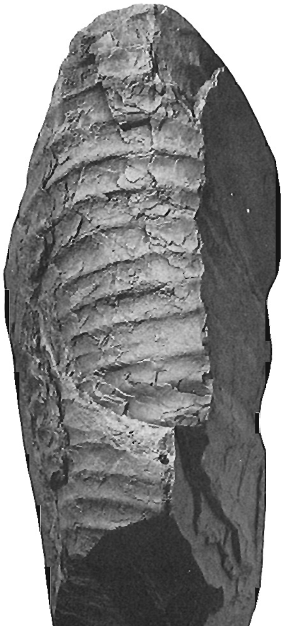

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## PLATE 5.3

All specimens are from GSC locality C-128986, southwestern British Columbia; x1.

Figures 1, 2, 4-9. *Discosphinctoides* (?) aff. *D. neohispanicum* (Burckhardt)

1, 2. Lateral and ventral views, figured specimen GSC 83510, adult microconch with lateral lappet (impression of reverse side).

4. Lateral view, figured specimen GSC 83512, small intermediate growth stage.

6. Lateral view, figured specimen GSC 83513, adult microconch with lateral lappet.

5, 7, 9. Lateral views, figured specimens GSC 83514-83516, small to small intermediate growth stages.

8. Lateral view, figured specimen GSC 83517.

Figure 3. *Lithacoceras* (?) (*Subplanites*?) sp.

Lateral view, figured specimen GSC 83511, smaller intermediate growth stage of macroconch, showing incipient ataxioceratan ribbing habit.

Figure 10. *Ochetoceras* (*Suboxydiscites*) *manningense* sp. nov.

Lateral view, figured specimen GSC 83524, showing well developed radial groove.

Figure 11. *Camptonectes* (*Mclearnia*) sp.

Figured specimen GSC 83518.

Figure 12. *Camptonectes* sp.

Figured specimen GSC 83519.

Figures 13-16. *Buchia concentrica* (Sowerby) var. *erringtoni* (Meek)

13. Figured specimen GSC 83520, left lateral (outside) view of left valve.

14. Same specimen as in figure 13, anterior view of left valve.

15. Figured specimen GSC 83521, left lateral (outside) view of left valve.

16. Same specimen as in figure 14, beak part and hinge margin of left valve viewed from above.

Figures 17-20. *Buchia concentrica* (Sowerby) f. typ.

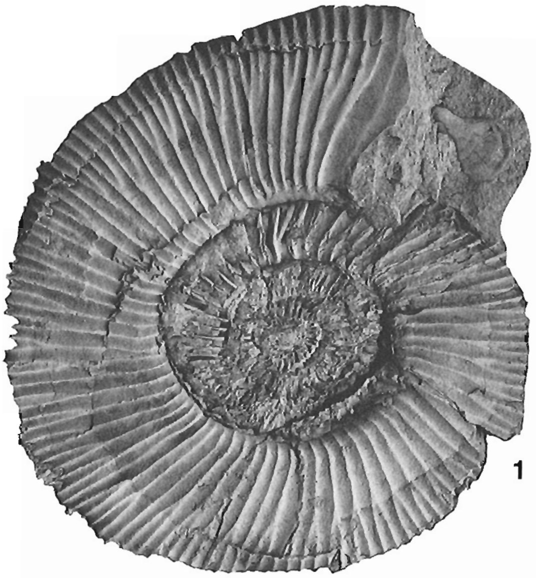
17. Figured specimen GSC 83522, half grown, left lateral (outside) view of left valve.

18. Same specimen as in figure 17, half grown, left lateral (outside) view of left valve.

19. Figured specimen GSC 83523, half grown, right lateral (outside) view of right valve.

20. Same specimen as in figure 19, dorsal view of right valve (x2); byssus ear extends down and left from beak.

PLATE 5.3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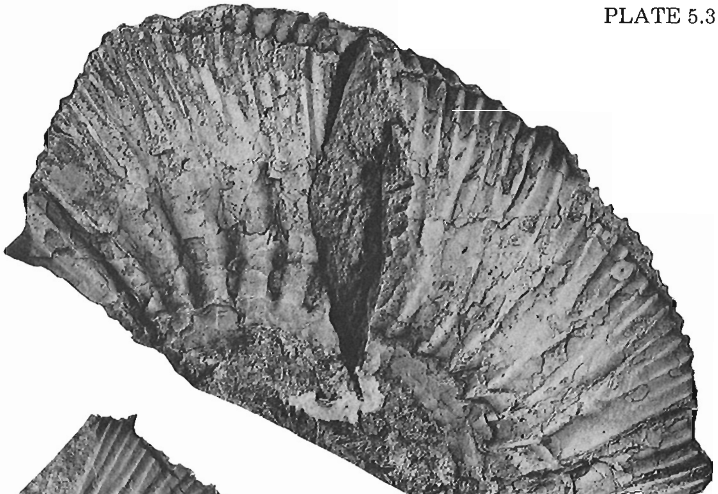
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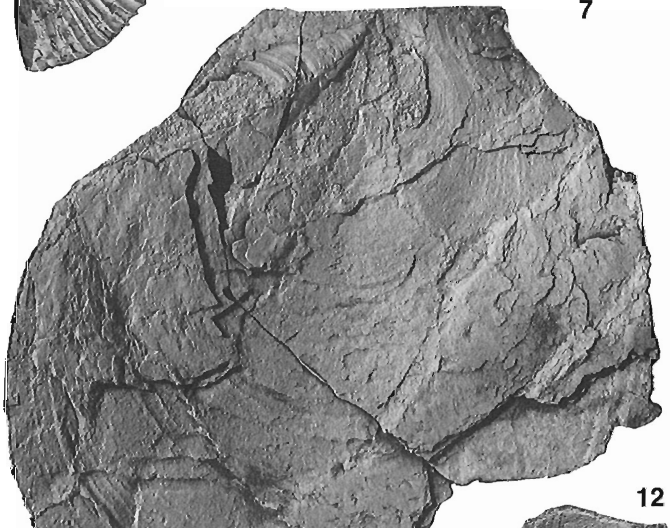
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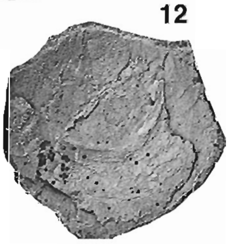
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# MORPHOLOGY, TAXONOMY AND PHYLOGENY OF THE FOSSIL FUNGAL GENUS *PESAVIS* FROM NORTHWESTERN CANADA

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## *Abstract*

The occurrence of the fungal genus *Pesavis* in the Maastrichtian is fully documented. A detailed study of over 200 specimens from disparate geographic localities ranging in age from Maastrichtian to Eocene allows new conclusions to be made about the ontogeny and phylogeny of *Pesavis*. The most conspicuous trend with time is an increase in overall size. The new species *P. parva* is described and the biostratigraphic significance of it and *P. tagluensis* is discussed.

## *Résumé*

Le présent rapport décrit de façon complète la présence du champignon du genre *Pesavis* dans les strates du Maastrichtien. Une étude détaillée de plus de 200 spécimens provenant de localités géographiques disparates, et dont l'âge se situe entre le Maastrichtien et l'Éocène, permet de tirer de nouvelles conclusions sur l'ontogénie et la phylogénie de *Pesavis*. La tendance la plus évidente est une augmentation de la taille générale avec le temps. On décrit la nouvelle espèce *P. parva* et son importance d'un point de vue stratigraphique, ainsi que celle de *P. tagluensis*.

## INTRODUCTION

During the course of collecting samples for a general palynological investigation from localities in western and northern Canada, we found sufficiently large numbers of specimens of *Pesavis* to facilitate studies on its morphology, taxonomy and stratigraphic range. Previously, *Pesavis* had been recovered from Paleogene deposits in western, northern and eastern offshore North America (Elsik and Jansonius, 1974; Jansonius, 1976, pers. comm., 1986; Staplin, 1976; Rouse, 1977; Ioannides and McIntyre, 1980; Norris, 1982, 1986; Sepulveda and Norris, 1982; Mathews and Rouse, 1984; Young and McNeil, 1984; Mudie, 1985), southern Australia (Lange, 1978), and Britain (Smith and Crane, 1979; Wilkinson and Boulter, 1980). Sweet (1978) illustrated *Pesavis* from the Cuesta Creek Member of the Tent Island Formation, Big Fish River, which he concluded was most likely to be of Maastrichtian age, and Jerzykiewicz and Sweet (1986a) illustrated it as part of a late Maastrichtian assemblage from the Central Alberta Foothills.

In this study, the stratigraphic range of *Pesavis* is extended with certainty into the Cretaceous, with occurrences recorded in samples of Maastrichtian age from the Big Fish River area on the Yukon Coastal Plain, from the Bonnet Plume Basin in central Yukon, the central Alberta Foothills, and southwestern Saskatchewan (Fig. A, locs. 1, 3, 7; Fig. 6.1). In addition to these Maastrichtian occurrences, *Pesavis* was recovered from early and middle Paleocene localities from southern and central Alberta, the Brackett Basin located in west central District of Mackenzie, along Big Fish River and Aklak Creek located on the Yukon Coastal Plain (Fig. A, locs. 11, 12, 4, 1); and from late Paleocene and Eocene localities in southwestern British Columbia, the Bonnet Plume Basin, the Caribou Hills bordering the Mackenzie River, and Aklak Creek (Fig. A, locs. 5, 3, 2, 1). These records enable a comparison to be made between the Maastrichtian forms of *Pesavis*, the Paleogene species, *Pesavis tagluensis* Elsik & Jansonius, 1974, and intermediate forms from the early and middle Paleocene.

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## COMMENTS ON THE BIOSTRATIGRAPHIC USEFULNESS OF FUNGI

The importance of fossil fungi in biostratigraphy has not yet been fully established. This may be partly due to their fragmentary fossil record, and because fossil fungi usually occur as mycelial fragments, dispersed spores, or as scattered fruiting bodies, leaving their affinities to extant forms uncertain. In addition, attempts to interpret dispersed fungal spores have proved difficult because mycologists seldom describe spores with the precision characteristic of a palynologist's analysis of the pollen and spores of plants (Pirozynski, 1976). Moreover, spores of a great variety of living fungi have in common a limited range of basic morphological characteristics, and those of particular species are often very variable, not stereotyped like pollen (Lange, 1978).

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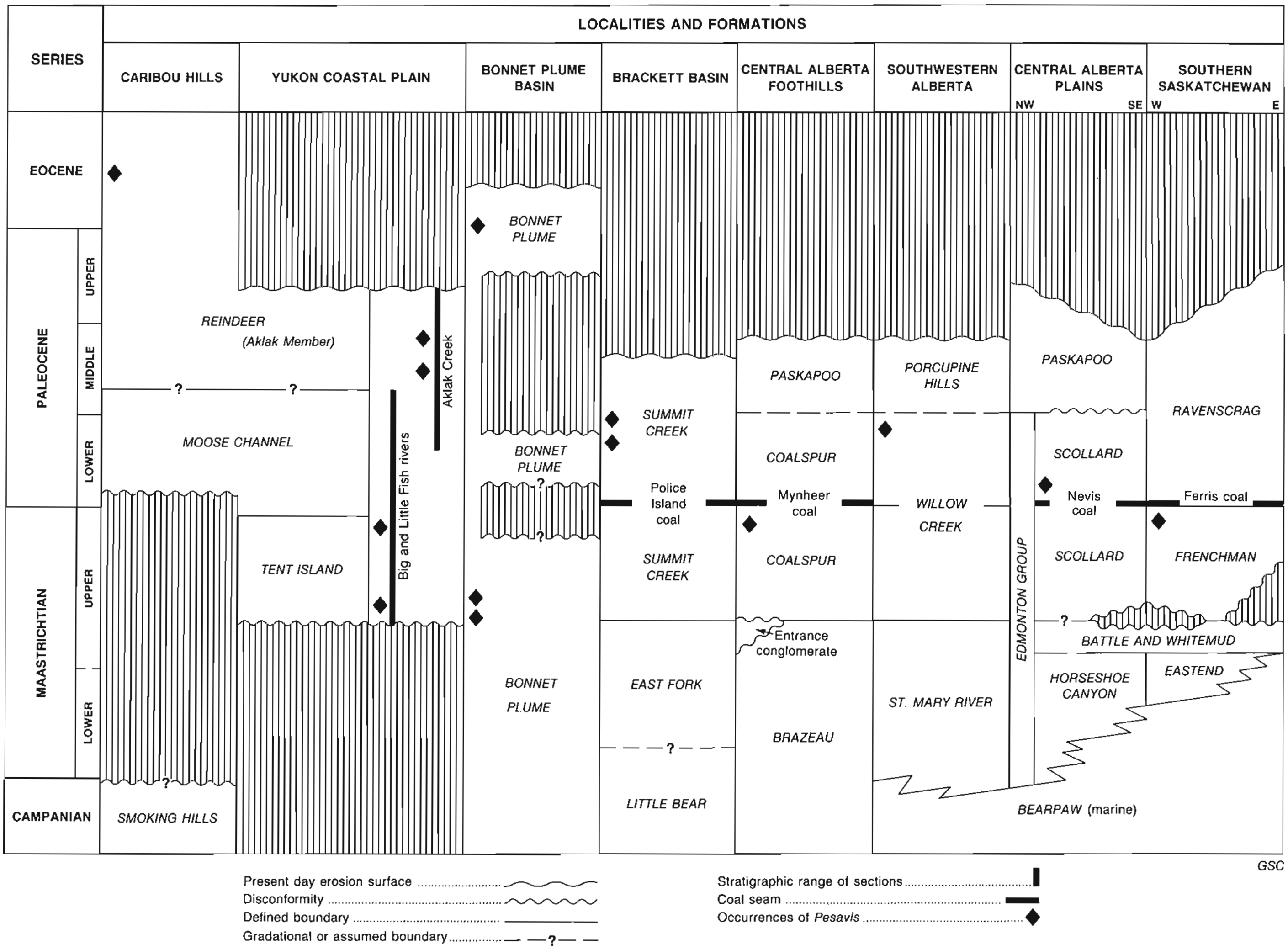

***Figure 6.1.*** *Table of Upper Cretaceous and lower Tertiary formations showing the occurrences of* ***Pesavis*** *from a stratigraphic perspective.*

Fungal spores usually exhibit great variability in their morphology. This is especially true of Fungi Imperfecti, where pleomorphism is much more common than generally realized (Wang, 1979). Pirozynski and Weresub (1979) discussed the history of ascomycetes and the development of their pleomorphism. They indicated that fossil fungal spores in their dispersed state are treated as autonomous form taxa in spite of the fact that different sexual and asexual propagules represent pleomorphic expressions of a single organism. Lange and Smith (1975) discussed the inherent difficulties of variability and overlap of characteristics encountered in describing the nomenclature and taxonomy of dispersed fungal spores, and urged that taxonomic distinctions and limits be drawn only on the basis of large-scale population studies. Smith (1978) suggested that the wide morphological variation he observed might be accommodated either by fifty or so new species, or by accepting the genetic concept of a single species with wide and continuous variation. Lange and Smith (1971), comparing dispersed fossil pollen with fungal spores, pointed out that, whereas pollen have a fixed morphology and size range typical of a single taxon, members of one species population of dispersed fungal spores may be quite dissimilar, while individuals of different species populations may appear identical.

Notwithstanding the above generalizations on their morphologic plasticity, some fungal spores are so distinctive and unique that they can be identified with unquestionable reliability. Such forms can conveniently be used in palynological stratigraphy. Illustration of this is the use of species of the distinctive genera *Ctenosporites, Fusiformisporites, Pesavis* and *Striadiporites* as index fossils in biostratigraphic studies (Elsik, 1969, 1970, 1976; Elsik and Jansonius, 1974; Jansonius, 1976; Staplin, 1976; and Norris, 1986).

Because of its uniqueness, *Pesavis tagluensis* in particular has been cited as an important species in palynological and stratigraphic studies (Jansonius, 1976; Staplin, 1976; Ioannides and McIntyre, 1980; Norris, 1982, 1986; Young and McNeil, 1984), often occurring together with diverse fungal spore assemblages. Elsik and Jansonius (1974) and Lange (1978) pointed out the importance of forms like *Pesavis tagluensis* and *Ctenosporites wolfei* in dating sediments in which other palynological fossils are rare. Jansonius (1976) reported the characteristic association of *Striadiporites* spores in the Beaufort region with *Pesavis tagluensis*, the highest occurrences of which were used to define the top of the *Pesavis* Zone, a major stratigraphic subdivision. In the same paper, Jansonius also cited an abundance of multicelled fungal spores in the *Pesavis* Zone, with the lower part of the zone exhibiting a great number and variety of septate, diporate ascospores, and the upper part an abundance of one-celled spores. The value of using such high relative abundances of major groups of taxa in identifying large stratigraphic intervals was pointed out by both Jansonius (1976) and Elsik (1976).

A similar observation on fungal populations in and above the *Pesavis* Zone was presented by Staplin (1976) in his research of Tertiary biostratigraphy in the Mackenzie Delta region of Canada. The characteristic fungal spores noted by Staplin were *Pesavis tagluensis* and *Striadiporites* cf. *S. reticulatus*. Ioannides and McIntyre (1980) cited the presence of *Pesavis tagluensis* along with *Fusiformisporites* and *Striadiporites* as an indication of late Paleocene to Middle Eocene age for outcrops in the Caribou Hills along the Mackenzie River, District of Mackenzie. Norris (1982, 1986) in his palynological study of Eocene to Pliocene strata in the Mackenzie Delta region of Canada, established a *Pesavis* Zone within the lower part of the Richards Formation of Middle Eocene age. The assemblage within the *Pesavis* Zone is dominated by fungal remains, including many types of fungal spores, of which *P. tagluensis* is the most distinctive. It has a very similar distribution to that of the dinoflagellates that serve as markers in the lowermost Richards Formation (Young and McNeil, 1984).

## *PESAVIS*

*Pesavis* represents an unusual and characteristic multicellular fungal form whose functional nature and affinities with extant fungi are uncertain. Elsik and Jansonius (1974) commented that the conidia of *Pesavis* may represent either spores, fruiting bodies, or snaring mechanisms of predatory parasitic fungi. They made comparisons with staurospores of some aquatic fungi like *Tribolites*, and stronger comparisons with blastoconidia of *Engelhardtiella alba*, a mycoparasite fungus described by Funk (1973). They also compared the secondary hyphal filaments of *P. tagluensis* to haustoria-like branches analogous to those found in *Engelhardtiella alba*. Another possible function of the secondary hyphae as propagules of vegetative mycelial multiplication was suggested later by Elsik (pers. comm., 1986).

A considerable amount of literature has appeared recently on the ecology of nematode-destroying fungi, the hyphomycetous Moniliales (Peach, 1950, 1952, 1954; Duddington, 1957; Cook, 1962a, b, 1963a, b; Barron, 1977). The Moniliales that are predacious, and capture nematodes or rotifers, develop interesting morphological adaptations to entangle and ensnare their prey. These include a sticky network of hyphal branches or knobs and constricting or nonconstricting hyphal rings. The profusely converging hyphal branches in the central cavity of *P. tagluensis* might be considered as such a trapping device, either for capturing nematodes if *P. tagluensis* were terrestrial, or rotifers if it were aquatic. However, the predacious nature of *P. tagluensis* is open to argument, because its modern equivalent is not available and the exact behaviour of the secondary hyphae cannot be studied.

Smith and Crane (1979) proposed that *P. tagluensis* was an aero-aquatic fungus found in sediments deposited under conditions of fluctuating water levels. They suggested that the inwardly protruding secondary hyphal branches of *P. tagluensis* probably served as an air-trapping mechanism, facilitating effective dispersal by keeping the conidium floating on the water. This would have been functionally similar to the tightly coiled, multiseptate filament forming the mature, helicoid spore in aerial-sporing, aero-aquatic hyphomycetes like *Helicodendron giganteum* (Glen-Bott, 1951).

Lange (1978), in spite of conducting an extensive search among leaf-fungi of the Australasian region, was unable to find an extant form comparable to *P. tagluensis*, but suggested that it was probably epiphyllic on terrestrial flora and therefore has potential value in paleoecological interpretations. Pirozynski and Weresub (1979) indicated that the fossil record shows that during the Paleogene there was a proliferation and diversification of ascomycotan propagules, both ascospores and conidia, which was associated with the emergence of flowering plants. They documented the appearance of epiphytic 'capnodiaceous' hyphae and spore types, such as fragments of *Sporidesmium*-type phragmoconidia or *Xylomyces* chlamydospores (*Pluricellaesporites*), helicoid conidia of *Cirrenalia* (*Involutisporonites*) and didymosporous ascospores (*Dyadosporites*), which dominated the fossil records of Cretaceous deposits. The above types of spores, together with epiphyllic microthyriaceous fructifications and *P. tagluensis* conidia, have also been found in the continental, late Paleocene to Middle Eocene sediments of the Bonnet Plume Formation (Kalgutkar, 1985, and unpublished data). These observations may help to support the possibility of *P. tagluensis* conidia being either epiphytic, epiphyllic ascomycetous, or terrestrial, epiphyllic hyphomycetous. In support of the latter possibility, the structural morphology seems to have been similar to that of forms belonging to the hyphomycetes, which have a terrestrial, saprophytic habit.

### Size distribution and morphological characteristics

The size distribution of specimens recovered from strata of Maastrichtian age is summarized in Figure 6.2a. Although the Bonnet Plume samples may be somewhat older than those of the Yukon Coastal Plain, there is no apparent difference in the size distribution of specimens from these two areas, except for the slightly greater upward size range within the Yukon Coastal Plain populations. The overall range of the 76 specimens measured varies between 21 and 39 µm. More than 90 per cent have a size range of 21 to 31 µm. Fifty of the 63 specimens from the Yukon Coastal Plain range in size between 21 and 30 µm.

A wide variation in morphology is displayed by Maastrichtian specimens, characterized by specimens from the Yukon Coastal Plain (Pl. 6.1, figs. 1-9). The smaller specimens (Pl. 6.1, figs. 1-6) generally have a large, irregularly shaped central cell with lateral arms consisting of only two to four cells. The arm cells are also broad and irregular. The oblique hilum, or the point of attachment, possibly to a conidiogenous cell or a conidiophore, is seen as a peripheral thickening on one side of the outer wall of the central cell. The transverse walls of the central cell and arm cells are generally thick walled with a central pore or aperture. The outer wall in all cells is comparatively thin. The lateral arm arising from the central cell nearest the scar at the point of attachment is generally shorter by one cell than the other lateral arm (Pl. 6.1, fig. 6). The arm cells are closely arranged and lack pores or secondary hyphae.

Larger specimens from both the Yukon Coastal Plain (Pl. 6.1, figs. 7-9) and Bonnet Plume Basin (Pl. 6.1, figs. 10-12) consist of a central cell with extended branches made up of four to six cells with pores and juvenile secondary filaments protruding in a small central cavity. The secondary filaments appear aseptate, thin-walled and unbranched. These specimens typically have one arm shorter than the other. Generally specimens from the Maastrichtian of the Bonnet Plume Basin are larger and more developed than those from the Yukon Coastal Plain. In some specimens a young terminal initial cell is seen (Pl. 6.1, fig. 11). Newly formed young cells of both lateral arms generally are devoid of pores and secondary hyphae in their early stages of development.

The early to middle Paleocene specimens show a wide range in overall diameter: 19 to 41 µm, with more than 87 per cent of specimens between 24 and 37 µm (Fig. 6.2b). The single specimen from immediately above the Cretaceous-Tertiary boundary in the Red Deer Valley is large (38.4 µm in diameter) compared with most others from the early Paleocene. Additional specimens are needed before this anomaly can be assessed. Specimens of earliest Paleocene age from Big Fish and Little Fish rivers are generally smaller, being 21 to 33 µm in diameter (Pl. 6.1, figs. 13-15), than most specimens from the Tertiary Hills (Pl. 6.1, figs. 16-20; Pl. 6.2, figs. 1-2) of early Paleocene age. The smallest and least developed specimens (Pl. 6.1, figs. 13 and 16) are similar in appearance and morphology to the small specimens from the Maastrichtian. They are made up of closely appressed, broad and thickened cells with one arm consisting of three cells and the other, shorter one of two cells.

Specimens from the Tertiary Hills (Pl. 6.1, figs. 17-20; Pl. 6.2, figs. 1-2) and those from Aklak Creek (Pl. 6.2, figs. 3-4) show a noteworthy sequence of morphological development. Their overall size and the range of between four and six arm cells corresponds to varying degrees of development in the secondary hyphae, which range from being small and aseptate to being more developed and septate. In a few specimens, tertiary buds can be seen emerging from the side of a secondary hypha (Pl. 6.1, fig.17).

Late Paleocene to Eocene populations of *Pesavis* were found primarily in samples from the Bonnet Plume Formation (Table 6.1). It is, therefore, not possible to ascertain whether there are different size distributions at disparate geographic localities (Fig. 6.2c). The specimens range in size between 28 and 58 µm. More than 73 per cent are 32 to 43 µm and less than eight per cent are 28 to 31 µm. All specimens are either in intermediate stages of development or are very mature. The incurving and usually unequal lateral arms have well extended cells, five to eight in number, with ends either overlapping or touching. The secondary branches arising in pairs from pores are short and aseptate in less developed specimens, whereas in more developed specimens they are longer, with two, three or more septa (Pl. 6.2, figs. 5-12).

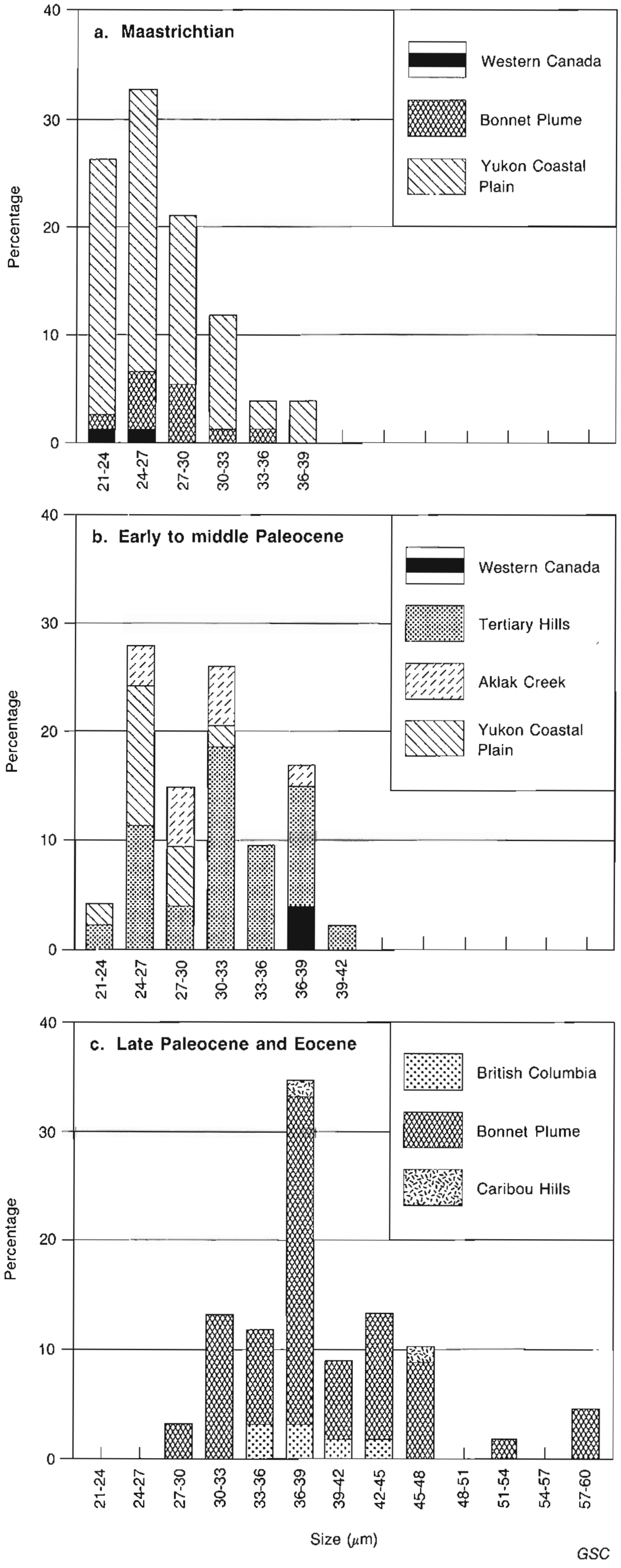

***Figure 6.2.*** *Percentage distribution of* ***Pesavis*** *size classes at different localities; a. Maastrichtian; b. early to middle Paleocene; c. late Paleocene and Eocene.*

## GENERAL COMMENTS

The above observations demonstrate that the sequence of developmental phases expressed by *Pesavis* varied over geological time. Smaller and less developed forms are prevalent in the Maastrichtian, intermediate phases are more common in the early to middle Paleocene, and larger, more extensively developed forms are characteristic of the late Paleocene and Eocene. No smaller or less developed specimens are known from samples of the youngest age.

These observed variations in size and form are not accompanied by any change in fundamental structural morphology. Most probably the observed variability is not a result of pleomorphism, but of the stages involved in the phylogeny leading to *P. tagluensis*. These stages are also reflected in its ontogeny by an extension in the number of developmental phases expressed in the preserved 'reproductive body'.

### TABLE 6.1.

Geographic and stratigraphic distribution of samples and specimens in this study

| | Number of samples | Number of specimens | |
|---|---|---|---|
| | | Measured | Total |
| **Maastrichtian** | | | |
| Western Canada | 2 | 2 | 2 |
| Bonnet Plume | 4 | 11 | 11 |
| Yukon Coastal Plain | 40 | 63 | 69 |
| Total | 46 | 76 | 82 |
| **Lower Paleocene** | | | |
| Western Canada | 2 | 2 | 2 |
| Tertiary Hills | 3 | 32 | 39 |
| Yukon Coastal Plain | | | |
| Big and Little Fish rivers | 5 | 12 | 13 |
| Aklak Creek | 5 | 9 | 9 |
| Total | 15 | 55 | 63 |
| **Uppermost Paleocene and Eocene** | | | |
| British Columbia | 1 | 6 | 6 |
| Bonnet Plume Basin | 4 | 61 | 66 |
| Caribou Hills | 1 | 2 | 2 |
| Total | 6 | 69 | 74 |
| Grand Total | 67 | 200 | 219 |

Specimens of *Pesavis* were recovered from samples ranging in lithology from coal through to silty mudstone (Appendix). Most samples were from swamp, probable lacustrine, floodplain and overbank terrestrial environments. As the recovery of *Pesavis* from coal samples is relatively rare, it appears that this type of fungus favoured either more open water habitats, or environments marginal to open water habitats. It is unlikely that *Pesavis* was saprophytic because of its infrequent presence in organic-rich samples (coals and coaly shales). Hence, an aero-aquatic habitat seems most likely for *Pesavis*, as proposed by Smith and Crane (1979). The *Pesavis* specimens in samples of the marine to marginally marine Tent Island Formation are considered to have been transported into this depositional setting from adjacent terrestrial niches, as were other pollen and spores recovered from the samples.

The presence of *P. tagluensis* in Paleogene strata from Britain and South Australia helps to establish their affinities with Tertiary deposits in North America. Lange (1978) referring to *Ctenosporites wolfei* and *P. tagluensis* wrote, "It is especially interesting when particular northern and southern hemisphere Tertiary deposits both contain such distinctive forms, because evidence that the fossil floras really shared the same species in life is at its most convincing level". He also suggested that this enigmatic and unique link between widely separated Paleogene floras merely reflects inadequate search for the forms elsewhere. This view is substantially supported by published literature, in which it is demonstrated that fossil fungal spores and fruiting bodies from Argentina (Sepulveda and Norris, 1982), China (Sung et al., 1978), India (Vishnu-Mittre, 1973; Kar and Saxena, 1976; Jain and Kar, 1979; Kar, 1979; Ramanujam, 1982) and Russia (Petros'yants, 1976) are species generally similar to those found in North America. Future studies may lead to further discoveries of specimens of *Ctenosporites* and *Pesavis*, confirming their cosmopolitan geographical distribution.

## MATERIAL AND METHODS

Two hundred and nineteen specimens of *Pesavis* from 67 samples (Table 6.1), collected from the localities listed in the Appendix and shown in Figure A (locs. 1-5, 7, 11-13), were studied. The ages of the individual collections were determined from the associated palynological assemblages. The table of relevant formations (Fig. 6.1) shows the occurrences of *Pesavis* from a lithostratigraphic perspective.

The overall diameter and number of cells in each arm were noted for 200 ideally oriented specimens, these being mainly from the Bonnet Plume Basin, the Tertiary Hills and the Yukon Coastal Plain (Fig. A, locs. 1, 3, 4; Table 6.1). The morphology of these specimens is compared with the Paleogene *Pesavis tagluensis* described by Elsik and Jansonius (1974) from North America, and specimens of the species described by Smith and Crane (1979) from Britain, and the one illustrated by Lange (1978) from South Australia.

A comparison is also made between *Pesavis* specimens found in rocks of Maastrichtian, early to middle Paleocene and late Paleocene to Eocene ages from the study area. The populations found in Maastrichtian strata, principally from the Yukon Coastal Plain, are compared with populations of early to middle Paleocene age from the Tertiary Hills and the Yukon Coastal Plain, and to those of late Paleocene to Eocene age from the Bonnet Plume Basin. Similarly, specimens of early to middle Paleocene age from the Tertiary Hills and the Yukon Coastal Plain are compared with those of late Paleocene to Eocene age from the Bonnet Plume Basin. The objective of these comparisons is to determine the variation in the morphology of specimens through a succession of ages, and to find out if such variation, if it existed, was consistent and continuous enough through geological time to warrant separation into different taxa, or if it was a mere representation of developmental stages, or only an expression of pleomorphism by one and the same species.

Standard palynological procedures were followed in the preparation of the samples, utilizing 25% hydrochloric acid, concentrated hydrofluoric acid, oxidation with Schulze's solution, base treatment with 10% ammonium hydroxide and heavy liquid separation with zinc bromide solution (sp. gr. 2). It was recognized that fungal material was susceptible to overoxidation. Even with little oxidation beyond the optimum required, many fungal spores were lost; in slightly underoxidized residues, the fungal material was better represented. Adding a small quantity of "Javex" or "Clorox" bleach to residues in Schulze's solution and allowing a reaction before heating the residues in a hot water bath proved effective in obtaining better and cleaner preparations. Residues were mounted on coverslips, using polyvinyl alcohol, and the coverslips were attached to the slides using bioplastic epoxy.

The slide coordinates given are from Leitz Ortholux transmitted light microscope no. 717633. Figured specimens of *Pesavis* are permanently stored in the type collection, Geological Survey of Canada, Ottawa. All other material used in this study is curated at the Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary.

## SYSTEMATIC PALEONTOLOGY

### Genus *Pesavis* Elsik & Jansonius 1974

1974 *Pesavis* Elsik & Jansonius, p. 955-956.

Type species. *Pesavis tagluensis* Elsik & Jansonius 1974.

*Description*: (Encompasses *Pesavis parva* sp. nov., in addition to *P. tagluensis* and *P. simplex* Elsik & Jansonius 1974). Fungal spore-like body or conidium consisting of a central stalk cell with two lateral arms, which curve around to form a central cavity (*P. parva* and *P. tagluensis*) or become straight (*P. simplex*). The lateral arms have variable numbers of cells usually within the range 3 to 10, with terminal cells of the opposing lateral arms either overlapping or meeting at their distal ends (*P. parva* and *P. tagluensis*) or remaining straight (*P. simplex*). Paired and inwardly projecting, convergent, thin walled, septate, secondary hyphae-like projections may emerge from two pores in the central stalk cell and all primary cells, except the terminal one (*P. parva* and *P. tagluensis*), or no secondary projections are present (*P. simplex*). The central cell bears a stalk with a circular peripheral thickening and a flattened distal end interpreted as an attachment scar. Overall diameter usually within the range of 20 to 70 µm (20 and 50 µm in *P. parva* and *P. tagluensis*, about 70 µm in *P. simplex*).

*Additional morphological features*: (based on *P. parva* and *P. tagluensis*). The stalk on the central cell intersects the plane of symmetry at a distinct angle. The lateral arm arising nearest the attachment scar is generally shorter by one cell than the other lateral arm (Pl. 6.2, figs. 5-8). It is possible that the lateral initials are not cut off from the central cell at the same time. The growth of the lateral arms is continued terminally by an apical initial (Pl. 6.1, fig. 12). The unequal number of cells in the lateral arms is maintained throughout the development of *Pesavis* until its maximum growth, when the two arms become almost equal in length.

*Pesavis* specimens from the upper Paleocene and Eocene exhibit a variety of developmental stages. Secondary hyphae show a pattern of growth with young, aseptate filaments emerging from pores in the younger terminal cells of the lateral arms and mature, septate hyphae in their advanced stage of growth from the older cells. Both of the paired secondary hyphae do not always emerge simultaneously and it is therefore not unusual to find only one hyphal filament arising from the pores of young cells. This repeats the apparent development of the central cell, where one lateral arm may develop as a one-cell growth before the development of the other arm is initiated.

The presence of a tertiary bud from the secondary filament (Pl. 6.1, fig. 17) is indicative of a third order of branching. The above observations demonstrate a sequence of phases in the ontogeny of *Pesavis*. The emergence of secondary hyphal branches from the pores in the primary arm cells may also indicate that each arm cell probably behaves like a potential spore, eventually germinating to give rise to a pair of branched septate mycelia.

*Remarks: Pesavis* was first described by Elsik and Jansonius (1974) from the Paleocene and Eocene. They recognized two species, *P. tagluensis* and *P. simplex*. *Pesavis tagluensis* may be the more common as only it has been recorded extensively since its initial description. *Triporicellaesporites elongatus* Ke & Shi in Sung et al. 1978 seems to be similar in appearance to *Pesavis simplex*. Its triporate nature is not clearly evident in the illustrated specimen (Sung et al. 1978, Pl. 5, fig. 17), although pores characterize *Triporicellaesporites*.

Smith and Crane (1979) cited the morphological dissimilarity in the conidia of *P. tagluensis* and *P. simplex* Elsik & Jansonius 1974 and the questionable inclusion of the latter in the genus *Pesavis*. They proposed that *P. simplex* was probably a dematiaceous hyphomycete like its closely similar living counterpart *Ceratosporella bicornis* (Pirozynski, 1976), which occurs on dead or dying plant material. In contrast, as discussed previously, they concluded that *P. tagluensis* was aero-aquatic. The above distinctions seem to indicate that *P. tagluensis* and *P. simplex* may not be related and therefore should not be grouped in the same genus.

In Figure 6.3, the size distribution of specimens belonging to the *P. tagluensis* complex from strata of varying ages is compared. There is a bimodal distribution together with a considerable overlap in size within the three age groups and a general increase in size from Maastrichtian to Eocene. The bimodality in part forms the justification for separating the *P. tagluensis* complex into two species, *P. tagluensis* and *P. parva* sp. nov. Most Maastrichtian specimens, and many from the early Paleocene, are grouped within *P. parva* and most specimens from the late Paleocene and Eocene are encompassed by *P. tagluensis*. Specimens falling within the intermediate size range of 28 to 32 µm should be termed preferably *Pesavis* cf. *P. parva* or, alternatively, *Pesavis* cf. *P. tagluensis*, depending upon which end of the spectrum they are closest to. As can be seen in Figure 6.3, the biostratigraphic significance of this size distinction is that very small specimens are most likely to be of Maastrichtian or early Paleocene age and very large specimens of late Paleocene or Eocene age, but that specimens of intermediate size occur throughout the late Maastrichtian to Eocene.

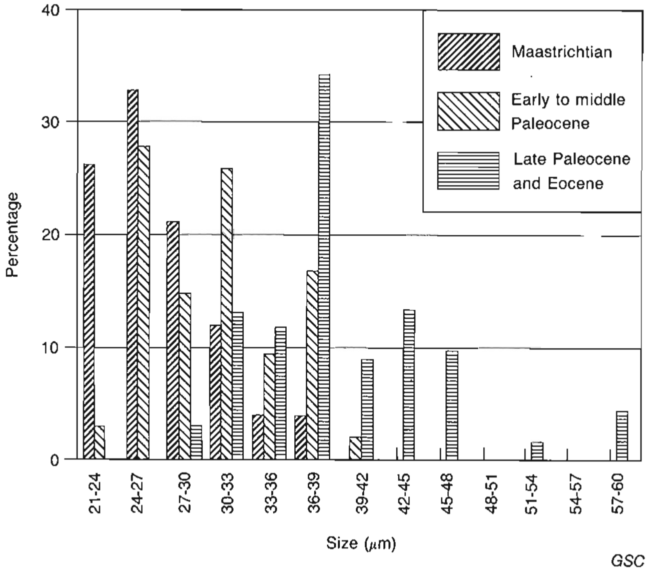

***Figure 6.3.*** *Comparison of* ***Pesavis*** *size distribution for different geological ages.*

### *Pesavis tagluensis* Elsik & Jansonius 1974

Plate 6.2, figures 6-12.

in part 1974 *Pesavis tagluensis* Elsik & Jansonius, Pl. 1, figs. 5-9, 11, p. 956 (not Pl. 1, fig. 10).

*Holotype*: IOE Taglu G-33; 8865 ft. (2748 m) (Elsik and Jansonius, Pl. 1, fig. 5).

*Description*: As for genus, except overall diameter is 30 µm or greater, and there are 5 to 8 arm cells.

*Occurrences*: Paleogene of North America, (Elsik and Jansonius, 1974; Jansonius, 1976; Staplin, 1976; Norris, 1986); Middle Eocene of South Australia (Lange, 1978); and the late Paleocene in Britain (Smith and Crane, 1979). Hills (1965) noted some specimens of *Pesavis tagluensis* from the Middle Eocene of British Columbia but reported them as "fern sporangia" (op. cit. Pl. 6, figs. 9, 12).

*Remarks: Pesavis* specimens from the late Paleocene and Eocene of the Bonnet Plume Basin correspond closely in general morphology to *Pesavis tagluensis.* They also are similar to specimens from the Middle Eocene of southern Australia and from the late Paleocene of England. Ioannides and McIntyre (1980) illustrated *Pesavis tagluensis* (Pl. 31.5, fig. 16) and *Pesavis* sp. (Pl. 31.5, fig. 15) from Paleogene (probably lower to middle Paleocene) strata in the Mackenzie Delta, Canada. The specimen in their Pl. 31.5, fig. 16 is about 29 µm in diameter, has developing secondary hyphae projecting into the central cavity and would therefore be best referred to as *Pesavis* cf. *P. tagluensis.* The specimen in their Pl. 31.5, fig. 15 is about 27 µm in diameter and consists of large, broad arm cells, enclosing a small cavity with one or two short secondary hyphae, and therefore conforms to *P. parva.* The questionable *Pesavis* sp. illustrated from a core in the Arctic Ocean (Mudie, 1985, Pl. 11.6, fig. 22) compares more closely to a cleistocarp-like fructification than to *Pesavis.*

### *Pesavis parva* sp. nov.

Plate 6.1, figures 6-12.

in part 1974 *Pesavis tagluensis* Elsik & Jansonius, Pl. 1, fig. 10.

1976 "*Pesavis parva*" Jansonius, Pl. 1, fig. 2.

1978 *Pesavis* sp. Sweet, Pl. 6.2, fig. 15.

in part 1979 *Pesavis tagluensis* Elsik & Jansonius in Smith and Crane, figs. 2, 3 (stated to resemble "*P. parva*" of Jansonius, 1976).

in part 1980 *Pesavis* sp. in Ioannides and McIntyre, Pl. 31.5, fig. 15.

1986a *Pesavis* sp. in Jerzykiewicz and Sweet, Pl. 1, fig. 7.

*Holotype*: GSC 83330, Big Fish River, Yukon Coastal Plain, locality C-71651, 68°31'30"N, 136°17'00"W. 310 m below top of formation, Plate 6.1, fig. 3.

*Description*: Fungal body made up of closely appressed or little extended, two to five lateral arm cells arising on either side of the central cell. Central cavity lacking, or small; secondary hyphal cells may be present, arising only from older cells through pores. In very young specimens, the central cell and lateral arm cells are broad and irregular in shape with conspicuously thick transverse walls and a comparatively thin and elongated outer wall. In slightly older and developing specimens, the lateral arm cells become separated on the inner side forming in profile or outline a small opening between the two lateral arms. Specimens mostly between 21 and 31 µm in overall size.

*Derivation of name*: Latin, *parvus*, little, small. Jansonius (1976) has referred to a specimen (Jansonius, 1976, Pl. 1, fig. 2) under the preliminary name, *Pesavis 'parva'.* As Jansonius did not intend to introduce this name formally in 1976, it had no status under the Code (Stafleu, 1983, I.C.B.N. Articles 12, 32, 34) hence is still available for introduction.

*Occurrences*: Previous records are from Maastrichtian and Paleocene sediments of western and northern Canada and Britain (see synonymy for references).

*Discussion: Pesavis parva* is characterized by its small size and low number of developmental stages. Its restriction to the Maastrichtian and early Paleocene has biostratigraphic significance.

It may be argued that in the Maastrichtian, conidia of *Pesavis parva* did not advance to the full, mature forms of their geologically younger relatives and continued to exist as small specimens. *Pesavis parva* therefore represents the ancestral state in which the genetic capacity for development was more limited than in the more evolved species *P. tagluensis.*

## REFERENCES

Barron, G.L.
1977: The nematode-destroying fungi; Topics in Mycobiology no. 1; Canadian Biological Publications Ltd., Guelph, Ontario, 144 p.

Cook, R.C.
1962a: The ecology of nematode-trapping fungi in the soil; Annals of Applied Biology, v. 50, p. 507-604.

1962b: The behaviour of nematode-trapping fungi during the decomposition of organic matter in the soil; Transactions of the British Mycological Society, v. 45, p. 314-319.

1963a: The predacious activity of nematode-trapping fungi added to soil; Annals of Applied Biology, v. 51, p. 295-299.

1963b: Ecological characteristics of nematode-trapping Hyphomycetes. I. Preliminary studies; Annals of Applied Biology, v. 52, p. 431-437.

Duddington, C.L.
1957: The friendly fungi. A new approach to the eelworm problem; Faber and Faber, London, 188 p.

Elsik, W.C.
1969: Late Neogene palynomorph diagrams, northern Gulf of Mexico; Transactions of the Gulf Coast Association Geological Society, v. 19, p. 509-528.

1970: Fungal spores in stratigraphy; Geological Society of America, Abstracts with programs, v. 4, p. 283.

Elsik, W.C.
1976: Microscopic fungal remains and Cenozoic palynostratigraphy; Geoscience and Man, v. 115, p. 115-120.

Elsik, W.C. and Jansonius, J.
1974: New genera of Paleogene fungal spores; Canadian Journal of Botany, v. 52, p. 953-958.

Funk, A.
1973: Some mycoparasites of western bark fungi; Canadian Journal of Botany, v. 51, p. 1643-1645.

Glen-Bott, J.I.
1951: *Helicodendron giganteum* n. sp. and other aerial-sporing hyphomycetes of submerged dead leaves; Transactions of the British Mycological Society, v. 34, p. 275-279.

Hills, L.V.
1965: Palynology and age of Early Tertiary basins, interior British Columbia; Ph.D. thesis, University of Alberta, Edmonton, Alberta.

Ioannides, N.S. and McIntyre, D.J.
1980: A preliminary palynological study of the Caribou Hills outcrop section along the Mackenzie River, District of Mackenzie; in Current Research, part A, Geological Survey of Canada, Paper 80-1A, p. 197-208.

Jain, K.P. and Kar, R.K.
1979: Palynology of Neogene sediments around Quilon and Varkala, Kerala Coast, South India 1. Fungal remains; The Palaeobotanist, v. 26, p. 105-118.

Jansonius, J.
1976: Paleogene fungal spores and fruiting bodies of the Canadian Arctic; Geoscience and Man, v. 15, p. 129-132.

Jerzykiewicz, T. and Sweet, A.R.
1986a: The Cretaceous-Tertiary boundary in the central Alberta Foothills. I. Stratigraphy; Canadian Journal of Earth Sciences, v. 23, p. 1356-1374.

1986b: Caliche and associated impoverished palynological assemblages – an innovative line of paleoclimatic research in the uppermost Cretaceous and Paleocene of southern Alberta; in Current Research, part B, Geological Survey of Canada, Paper 86-1B, p. 653-663.

Kalgutkar, R.M.
1985: Fungal fossil fructifications from Bonnet Plume Formation, Yukon Territory; in Current Research, part B, Geological Survey of Canada, Paper 85-1B, p. 259-268.

Kar, R.K.
1979: Palynological fossils from the Oligocene sediments and their biostratigraphy in the district of Kutch, Western India; The Palaeobotanist, v. 26, p. 16-49.

Kar, R.K. and Saxena, R.K.
1976: Algal and fungal microfossils from Matanomadh Formation (Palaeocene), Kutch, India; The Palaeobotanist, v. 23, p. 1-15.

Lange, R.T.
1978: Correlation of particular southern and northern hemisphere Paleogene floras by the unusual fungal spores *Ctenosporites* and *Pesavis tagluensis*; Pollen et Spores, v. 20, p. 399-403.

Lange, R.T. and Smith, P.H.
1971: The Maslin Bay Flora, South Australia. 3. Dispersed fungal spores; Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, v. 11, p. 663-681.

1975: *Ctenosporites* and other Paleogene fungal spores; Canadian Journal of Botany, v. 53, p. 1156-1157.

Mathews, W.H. and Rouse G.E.
1984: The Gang Ranch-Big Bar Area, South-Central British Columbia – stratigraphy, geochronology and palynology of the Tertiary beds and their relationship to the Fraser Fault; Canadian Journal of Earth Sciences, v. 21, p. 1132-1144.

Mudie, P.J.
1985: Palynology of the CESAR cores, Alpha Ridge, Initial geological report of CESAR – the Canadian expedition to study the Alpha Ridge, Arctic Ocean; Geological Survey of Canada, Paper 84-22, p. 149-174.

Norris, G.
1982: Spore-pollen evidence for early Oligocene high latitude cool climatic episode in northern Canada; Nature, v. 297, p. 387-389.

1986: Systematic and stratigraphic palynology of Eocene to Pliocene strata in the Imperial Nuktak C-22 well, Mackenzie Delta Region, District of Mackenzie, N.W.T.; Geological Survey of Canada, Bulletin 340, 89 p.

Peach, M.
1950: Aquatic predacious fungi; Transactions of the British Mycological Society, v. 33, p. 148-153.

1952: Aquatic predacious fungi II; Transactions of the British Mycological Society, v. 35, p. 19-23.

1954: Aquatic predacious fungi III; Transactions of the British Mycological Society, v. 37, p. 240-247.

Petros'yants, M.A.
1976: Fossil fungal remains in Turonian deposits in the northeastern VST-VRT and Aval regions: Proceedings, All Union Petroleum Scientific Research Institute of Geological Exploration, issue 192, p. 125-134 (in Russian, English translation).

Pirozynski, K.A.
1976: Fossil fungi; Annual Review of Phytopathology, v. 14, p. 237-246.

Pirozynski, K.A. and Weresub, L.K.
1979: The classification and nomenclature of fossil fungi; in The Whole Fungus, B. Kendrick (ed.); Proceedings of the Second International Mycological Conference, Calgary, Alberta. National Museum of Natural Sciences, National Museum of Canada, and the Kananaskis Foundation, v. 2, p. 653-688.

Ramanujam, C.G.K.
1982: Recent advances in the study of fossil fungi; in Recent Advances in Cryptogamic Botany, part II; The Palaeobotanical Society, Lucknow, India, p. 287-301.

Rouse, G.E.
1977: Paleogene palynomorph ranges in western and northern Canada; American Association of Stratigraphic Palynologists, Contributions, series no. 5A, p. 48-61.

Sepulveda, E.G. and Norris, G.
1982: A comparison of some Paleogene fungal palynomorphs from Arctic Canada and from Patagonia, southern Argentina; Ameghiniana, v. 19, p. 319-334.

Smith P.H.
1978: Fungal spores of the genus *Ctenosporites* from the Early Tertiary of southern England; Palaeontology, v. 21, p. 717-722.

Smith P.H. and Crane, P.R.
1979: Fungal spores of the genus *Pesavis* from the lower Tertiary of Britain; Botanical Journal of the Linnean Society, v. 79, p. 243-248.

Stafleu, F.A.
1983: International Code of Botanical Nomenclature, Adopted by the Thirteenth International Botanical Congress, Sydney, August, 1981; Dr. W. Junk (publisher), Boston, 472 p.

Staplin, F.L.
1976: Tertiary biostratigraphy, Mackenzie Delta Region, Canada; Bulletin of Canadian Petroleum Geology, v. 24, p. 117-136.

Sung, Z., Cao, L., Zhou, H., Guan, X., and Wang, K.
1978: in Early Tertiary spores and pollen grains from the coastal region of the Bohei; The Institute of Petroleum Exploration and Mining, Ministry of Petroleum Industry and Nanjing Institute of Geology and Paleontology, Academia Sinica (eds.); Science Publishers, 666 p. (in Chinese, English translation).

Sweet, A.R.
1978: Palynology of the lower part, type section, Tent Island Formation, Yukon Territory; in Current Research, part B, Geological Survey of Canada, Paper 78-1B, p. 31-37.

Sweet, A.R. and Hills, L.V.
1984: A palynological and sedimentological analysis of the Cretaceous-Tertiary boundary, Red Deer River Valley, Alberta, Canada (Abstract); Sixth International Palynological Conference, Calgary, 1984, p. 160.

Vishnu-Mittre,
1973: Studies of fungal remains from the Flandrian deposits in the Whittlesey Mere Region, Hunts., England; The Palaeobotanist, v. 22, p. 89-110.

Wang, C.J.K.
1979: Pleomorphic Fungi Imperfecti; in The Whole Fungus, B. Kendrick (ed.); Proceedings of the Second International Mycological Conference, Calgary, Alberta. National Museum of Natural Sciences, National Museum of Canada, and the Kananaskis Foundation, v. 1, p. 81-91.

Wilkinson, G.C. and Boulter M.C.
1980: Oligocene pollen and spores from the western part of the British Isles; Palaeontographica, Abt. B, v. 75, p. 27-83.

Young, F.G. and McNeil, D.H.
1984: Cenozoic stratigraphy of the Mackenzie Delta, Northwest Territories; Geological Survey of Canada; Bulletin 336, 63 p.

# APPENDIX

Only biostratigraphically significant taxa from given assemblages are included in the 'associated flora'.

## Description of sample localities, associated assemblages and age

### *I. Maastrichtian sample localities*

A. Frenchman Formation, Southwestern Saskatchewan, Wood Mountain Map Area (Fig. A, loc. 13)

*Locality.* Coal testhole, Wood Mountain 17; SW LSD 5, sec. 2, tp. 3, rge. 7, W. 3rd mer.; sidewall core sample C-34773; from 139 ft. (42.36 m) below the surface or about 39 ft. (11.89 m) below the top of the Frenchman Formation, which approximates the Cretaceous-Tertiary boundary.

*Lithology.* Light grey to grey siltstone within an interval barren of coal.

*Associated flora. Aquilapollenites attenuatus* Funkhouser 1961, *A. delicatus* var. *collaris* Tschudy & Leopold 1971, *A. reductus* Norton 1965, *Foraminisporis undulosus* Leffingwell 1971, *Paraalnipollenites alterniporus* (Simpson) Srivastava 1975, *Wodehouseia spinata* Stanley 1961 and rare dinoflagellates.

*Age.* Latest Maastrichtian.

B. Coalspur Formation, Central Alberta Foothills (Fig. A, loc. 7)

*Locality.* Manalta corehole, ME-111-81CD; LSD 3, sec. 17, tp. 48, rge. 21, W. 5th mer.; core sample C-108056; from 80.9 m below the surface or about 18 m below the top of the lower, barren member of the Coalspur Formation, which coincides with the Cretaceous-Tertiary boundary.

*Lithology.* Grey mudstone formed within a floodplain setting.

*Associated flora.* Species included *Aquilapollenites reductus, Cranwellia rumseyensis* Srivastava 1966, *Ephedripites multipartitus* (Chlonova) Gao & Zhao 1976 and *Wodehouseia spinata* (see Jerzykiewicz and Sweet, 1986a, Fig. 4 for a more complete list).

*Age.* Latest Maastrichtian.

C. Bonnet Plume Formation, Bonnet Plume Basin, Yukon Territory (Fig. A, loc. 3)

1. *Locality.* Outcrop section 77-LBA-W1 located along the Peel River; 65°52'N, 135°12'W; samples C-68131, C-68133, and C-68134; from between 70 and 90 m below the base of the upper conglomeratic unit, which approximates the position of the Cretaceous-Tertiary boundary.

*Lithology.* C-68131 and C-68134, light grey mudstone; C-68133, dark grey coaly shale formed within overbank and floodplain settings.

*Associated flora. Aquilapollenites quadrilobus* Rouse 1957, *A. validus* Srivastava 1968, *Callistopollenites radiatostriatus* (Mchedlishvili) Srivastava 1969, *Cranwellia rumseyensis, Kurtzipites trispissatus* Anderson 1960; *Orbiculapollis lucidus* Chlonova 1961, *Porosipollis porosus* (Mchedlishvili) Krutzsch 1969, *Pulcheripollenites krempii* Srivastava 1969, *Senipites drumhellerensis* Srivastava 1969, *Triprojectus unicus* Mchedlishvili 1961, *Wodehouseia* cf. *W. avita* Wiggins 1976, *W. gracilis* (Samoilovich) Pokrovaskaya 1966, *W. spinata.*

*Age.* Mid to late Maastrichtian.

2. *Locality.* Outcrop section 77-LBA-W2 located along the Peel River; 65°47'N, 135°13'W; sample C-68245; from about 75 m below the top of the section, or about 100 m below the Cretaceous-Tertiary boundary, as inferred by its correlation with section 77-LBA-W1.

*Lithology.* Light grey silty mudstone with root casts probably representing a fossil soil within an overbank or floodplain setting.

*Associated flora. Callistopollenites radiatostriatus, Cranwellia rumseyensis, Kurtzipites trispissatus, Mancicorpus vancampoi* Srivastava 1968, and *Pulcheripollenites* sp.

*Age.* Mid to late Maastrichtian.

D. Tent Island Formation, Yukon Coastal Plain, Yukon Territory (Fig. A, loc. 1)

1. *Localities.* Outcrop sections 77YA-10, 77YA-11 and SLA-1975-29 located along Big Fish River near the mouth of Little Fish River; 68°31'30" to 68°33'00"N, 136°15'50" to 136°17'00"W; C-47366, C-47368, C-47372 to 74, C-47380, C-47382, and C-47386, C-71651 to 54, C-71656 to 59, C-71670, C-71671, and C-71673 to 77; C-47366 through to C-47386, located from 0 to 60 m and C-71651 through C-71673 from 110 to 310 m below the top of the Tent Island Formation, which is the lowest probable position of the Cretaceous-Tertiary boundary.

*Lithology.* Grey mudstone to silty mudstone deposited within a marginal marine to continental setting.

*Associated flora. Aquilapollenites conatus* Norton 1965, *A. delicatus* Stanley 1961, *A. quadricretae* Chlonova 1961, *A. quadrilobus, A. reticulatus* (Mchedlishvili) Tschudy & Leopold 1971, *Cranwellia rumseyensis, Kurtzipites trispissatus, Porosipollis porosus, Triprojectus unicus, T. magnus* (Mchedlishvili) Stanley 1970, *Wodehouseia fimbriata* var. *constricta* Wiggins 1976, *W. octospina* Wiggins 1976, *W. spinata* and rare dinoflagellates.

*Age.* Latest Maastrichtian.

2. *Localities.* Outcrop sections SLA-1975-24 to 26; located along Little Fish River; 68°32'15" to 68°32'20"N, 136°12'00" to 136°11'38"W; C-47325, C-47326, C-47329 to 32, C-47334, C-47335, C-47338, C-47339, C-47341 to 45, C-47347 and C-47348; from about 20 to 90 m below the projected top of the Tent Island Formation, which approximates the lowest probable position of the Cretaceous-Tertiary boundary.

*Lithology, associated floras and age.* As for Big Fish River localities.

## *II. Early to mid-Paleocene sample localities*

### A. Scollard Formation, Central Alberta Plains (Fig. A, loc. 12)

*Locality.* Outcrop section SLA-1983-13A located on west side of the Red Deer River Valley near Huxley; LSD 5, sec. 2, tp. 34, rge. 22, W. 4th mer.; sample C-119669; from 0.77 to 0.87 m above the base of the Nevis coal seam, a horizon that coincides with the Cretaceous-Tertiary boundary.

*Lithology.* Grey to black shale, probably representing an ephemeral marsh deposit within a sequence of overbank deposits.

*Associated flora.* Assemblage is dominated by *Laevigatosporites* sp. (70%) and is of low overall diversity (for additional information on the flora in the underlying strata, see Sweet and Hills, 1984).

*Age.* Earliest Paleocene.

### B. Willow Creek Formation, member E, Southern Alberta Foothills (Fig. A, loc. 11)

*Locality.* Oldman River damsite, G-05 corehole; sec. 17, tp. 7, rge. 30, W. 4th mer.; sample C-131402; sample from 90.6 m below surface, about 35 m below interpreted top of Willow Creek Formation (Jerzykiewicz and Sweet, 1986b) or about 500 m above the Cretaceous-Tertiary boundary.

*Lithology.* Dark grey to black mudstone representing an ephemeral lake deposit within an alluvial plain setting.

*Associated flora. Brevicolporites colpella* Anderson 1961, *Kurtzipites trispissatus, Momipites wyomingensis* Nichols & Ott 1978, and *Ulmoideipites krempii* Anderson 1960 (for additional information see Jerzykiewicz and Sweet, 1986b).

*Age.* Early Paleocene.

### C. Summit Creek Formation, Tertiary Hills (Fig. A, loc. 4)

*Locality.* Outcrop section RAK-83-3, part of composite type section for the Summit Creek Formation, southeast end of Tertiary Hills; 64°27'30"N, 125°33'45"W.

1. Sample C-111528; from 6.3 m below base of upper coal zone or about 122 m above the Cretaceous-Tertiary boundary.

*Lithology.* Grey mudstone possibly deposited within a lacustrine environment.

*Associated flora.* Sample dominated by Taxodiaceae-Cupressaceae pollen, with accessory species including *Paraalnipollenites alterniporus* (Simpson) Srivastava 1975 and *Ericaeoipollenites rallus* Stanley 1965.

*Age.* Early Paleocene, based primarily on the relative stratigraphic position of the samples.

2. Sample C-111536; from 0.9 to 1.4 m below top of lower coal zone in section or about 75 m above the Cretaceous-Tertiary boundary.

*Lithology.* Coal.

*Associated flora.* Sample dominated by Taxodiaceae-Cupressaceae pollen, with accessory species including *Retitricolpites crassus* Samoilovich 1965.

*Age.* As for C-111528.

3. Sample C-111537; from parting 1.4 to 1.6 m below top of lower coal zone or about 75 m above the Cretaceous-Tertiary boundary.

*Lithology.* Mudstone representing a clastic influx into a forested swamp.

*Associated flora and age.* As for C-111536.

### D. Moose Channel Formation, basal sandstone member, Yukon Coastal Plain (Fig. A, loc. 1)

*Localities.* Outcrop sections SLA-1975-30, SLA-1976-42 and SLA-1976-50; located along Big Fish River; 68°33'40"N, 136°13'45"W to 68°36'21"N, 136°10'05"W; sample C-47389, C-47390, C-59637, C-59655 and C-59656; from about 150 to 550 m above the lowest possible position of the Cretaceous-Tertiary boundary.

*Lithology.* Ranges from black or brownish grey, silty or sandy mudstone (C-47389, C-47390 and C-59637) to black or brown shale (C-59655 and C-59656) from interbeds within a sequence of channel sandstone.

*Associated flora. Azolla schopfii* Dijkstra 1961 and *Paraalnipollenites alterniporus* from samples within and immediately below the interval given above.

*Age.* Early Paleocene.

### E. Moose Channel Formation, Ministicoog Member, Yukon Coastal Plain (Fig. A, loc. 1)

*General locality.* Outcrop sections located along Aklak Creek.

1. *Locality.* SLA-1975-21; 68°40'02"N, 136°20'50"W; sample C-47284; located about 80 m below top of Ministicoog Member.

2. *Locality.* SLA-1975-20; 68°40'30"N, 136°20'30"W; C-47300; located 5 m below contact with the Aklak Member of the Reindeer Formation.

*Lithology.* Grey mudstone and silty, grey mudstone, deposited within a marginal marine setting.

*Associated flora. Paraalnipollenites alterniporus* and *Ulmipollenites undulosus* Wolff 1934.

*Age.* Early or mid-Paleocene, based mainly on the relative stratigraphic position of the Ministicoog Member.

### F. Reindeer Formation, Aklak Member, Yukon Coastal Plain (Fig. A, loc. 1)

*General locality.* Outcrop sections located along Aklak Creek.

1. *Locality.* SLA-1975-2; 68°40'25"N, 136°20'35"W; samples C-47032 and C-47035; located about 25 and 29 m above the base of the Reindeer Formation.

*Lithology.* Both samples from brownish grey, shaly mudstone immediately overlying coal seams.

2. *Locality.* SLA-1975-4; 68°40'50"N, 136°20'50"W; C-47010; located about 103 m above the base of the Reindeer Formation.

*Lithology.* Coal and coaly shale at top of major coal zone.

*Associated flora. Alnus verus, Paraalnipollenites alterniporus, Pistillipollenites macgregorii* Rouse 1962 (at 190 m above the base of the Reindeer Formation), and *Ulmipollenites undulosus* Wolff 1934.

*Age.* Mid (?)-Paleocene (first evidence for late Paleocene is the occurrence of *Pistillipollenites* at 190 m above the base of the Reindeer Formation).

### *III. Uppermost Paleocene and Eocene sample localities*

A. Burrard Formation, Southwestern British Columbia (Fig. A, loc. 5).

*Locality.* Richfield Pure Point Roberts LSD 6, sec. 3, tp. 5, West Coast Meridian; 49°00'52"N, 123°05'00"W; core sample C-127694 at 2466.1 m (8088.8 ft.) below surface.

*Lithology.* Dark grey mudstone, deposited within a terrestrial setting.

*Associated flora. Fusiformisporites* sp., *Juglans* sp., *Momipites coryloides* Wodehouse 1933 emend. Nichols 1973, *Paraalnipollenites alterniporus, Pterocarya* sp., and *Striadiporites* sp.

*Age.* Undifferentiated Eocene.

B. Bonnet Plume Formation, Bonnet Plume Basin, Yukon Territory (Fig. A, loc. 3).

1. *Locality.* Outcrop section 77-LBA-W1; located along the Peel River; 65°52'N, 135°12'W; samples C-68174 and C-68190; samples located between approximately 50 and 100 m above the top of the Maastrichtian.

*Lithology.* Light grey mudstone and dark, brownish grey shale with plant fragments representing, respectively, probable lacustrine and swamp deposits.

*Associated flora. Carya viridifluminipites* (Wodehouse) Wilson & Webster 1946, *Momipites coryloides* Srivastava 1968, *M. amplus* (Leffingwell) Nichols 1973, *Paraalnipollenites alterniporus* (Simpson) Srivastava 1975, *Pterocarya stellatas* (Potonié) Martin & Rouse 1966, and from other samples within the same stratigraphic interval, *Juglans* sp. and *Pistillipollenites macgregorii* Rouse 1962.

*Age.* Most probably late Paleocene or Early Eocene.

2. *Locality.* Outcrop section 77-LBA-W4; located along the Peel River; 65°54'N, 135°04'W; samples C-68304 and C-68305; located about 50 m above the top of the Maastrichtian.

*Lithology.* Grey mudstone and brownish grey shale with abundant plant fragments representing, respectively, probable floodplain or lacustrine deposits.

*Associated flora and age.* No significant differences from those of C-68174 and C-68190.

C. Reindeer Formation, Caribou Hills (Fig. A, loc. 2)

*Locality.* Outcrop section 25 (Price et al., 1980); located just West of Reindeer Depot; 68°41'08"N, 134°07'40"W; sample C-79927; from approximately the middle of the Reindeer Formation.

*Lithology.* Light grey, silty mudstone, deposited within a terrestrial setting.

*Associated flora.* See Ioannides and McIntyre, 1980.

*Age.* Eocene, probably Early to early Middle Eocene (op. cit.)

## PLATES 6.1 to 6.2

In the explanation of figures, the species name is followed by the GSC type number, the slide number, stage co-ordinates, and the GSC locality number. Stage co-ordinates were obtained using Leitz Ortholux transmitted light microscope no. 717633. Magnification for all specimens is x1000.

Consistent with Smith and Crane (1979), the plate figures are oriented with the central cell down, which conforms to its being ontogenetically the initial or basal cell. The name *Pesavis* refers to the "bird's foot"-like shape seen in an inverted position.

## PLATE 6.1

Figures 1-16. *Pesavis parva* sp. nov.

Figures 1-6. Maastrichtian specimens from Big Fish River.

1. GSC 83328, P-1198-10e, 17.4 x 113.0, GSC locality C-47374.
2. Showing thick transverse walls, GSC 83329, P-1198-16b, 33.7 x 106.9, GSC locality C-47380.
3. Holotype GSC 83330, C-71651, P-2057-1g, 23.2 x 107.9, GSC locality C-71651.
4. GSC 83331, P-2058-5b, 29.1 x 112.5, GSC locality C-71657.
5. Specimen with cells showing pores and young secondary hyphae arising from older cells, GSC 83332, P-2096-9b, 27.2 x 110.5, GSC locality C-71677.
6. GSC 83333, P-2058-6b, 10.0 x 103.0, GSC locality C-71658.

Figures 7-9. Maastrichtian specimens from Little Fish River.

7. Specimen showing that the shortest lateral arm is nearest the point of attachment, GSC 83334, P-1197-3g, 41.5 x 104.0, GSC locality C-47343.
8. GSC 83335, P-1197-8g, 7.8 x 101.2, GSC locality C-47348.
9. GSC 83336, P-1197-3a, 38.3 x 113.0, GSC locality C-47343.

Figures 10-12. Maastrichtian specimens from Bonnet Plume Basin; larger specimens showing central cell and extended branches of 4 to 6 cells with pores and juvenile secondary filaments seen in a small central cavity.

10. GSC 83337, P-2096-28i, 37.1 x 108.8, GSC locality C-68133.
11. GSC 83338, P-2096-28g, 33.8 x 113.1, GSC locality C-68133.
12. GSC 83339, P-2096-28b, 16.8 x 111.0, GSC locality C-68133.

Figures 13-15. Lower Paleocene specimens from Big Fish River.

13. GSC 83340, P-1192-8a, 30.8 x 119.4, GSC locality C-59656.
14. GSC 83341, P-1198-25a, 41.3 x 109.5, GSC locality C-47389.
15. GSC 83342, P-1198-26g, 15.1 x 109.8, GSC locality C-47390.

Figure 16. Lower Paleocene specimen from the Tertiary Hills, GSC 83343, P-2667-18a, 24.1 x 110.3, GSC locality C-111536.

Figures 17-20. *Pesavis* cf. *P. tagluensis* Elsik & Jansonius 1974; lower to middle Paleocene specimens from Tertiary Hills.

17. Showing tertiary bud, GSC 83344, P-2667-18a, 7.9 x 109.7, GSC locality C-111536.
18. GSC 83345, P-2667-19a, 32.5 x 113.3, GSC locality C-111537.
19. Showing septation in older secondary hypha, GSC 83346, P-2667-19a, 9.9 x 101.0, GSC locality C-111537.
20. Showing a pair of secondary hyphae from the same cell and septation in older hyphae, GSC 83347, P-2667-19c, 22.9 x 119.4, GSC locality C-111537.

## Maastrichtian specimens


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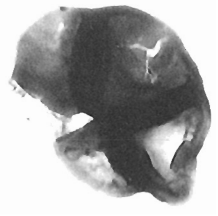
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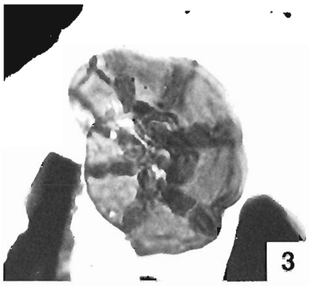
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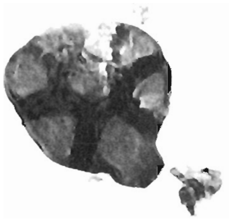
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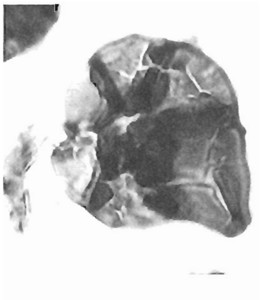
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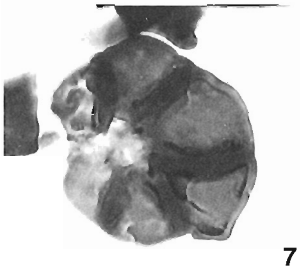
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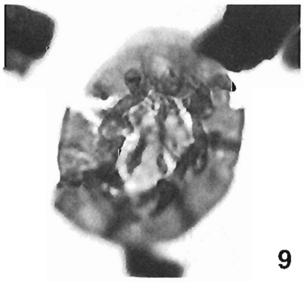
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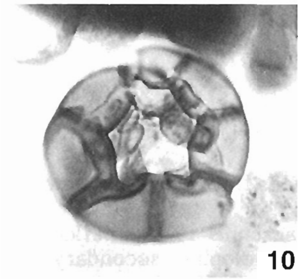
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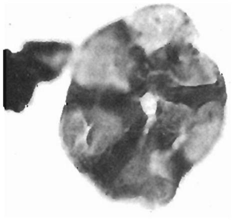
## Lower to middle Paleocene specimens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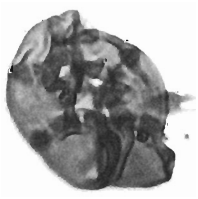
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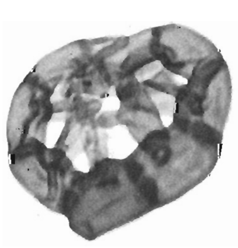
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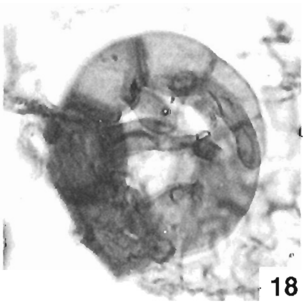
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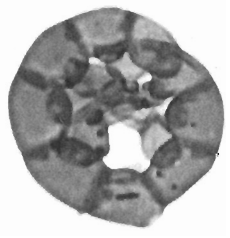
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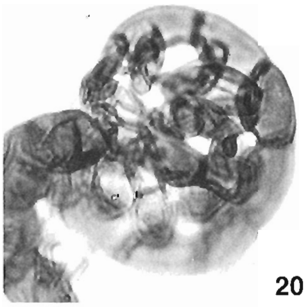
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## PLATE 6.2

Figures 1-2. *Pesavis* cf. *P. tagluensis* Elsik & Jansonius 1974 from the Tertiary Hills.

1. Showing young terminal cell, GSC 83348, P-2667-19c, 35.8 x 108.7, GSC locality C-111537.
2. Specimen with extended arm cells, GSC 83349, P-2667-19a, 14.6 x 114.9, GSC locality C-111537.

Figure 3. *Pesavis* cf. *P. parva* sp. nov. middle(?) Paleocene specimens from Aklak Creek; specimen showing circular peripheral attachment point, lateral arm nearest the point of attachment consisting of 3 cells, other arm of 4 cells, and young secondary filaments, GSC 83350, P-1025-52b, 12.8 x 104.6, GSC locality C-47010.

Figure 4. *Pesavis* cf. *P. tagluensis* Elsik & Jansonius 1974; middle(?) Paleocene; Aklak Creek; showing septate hypha, GSC 83351, P-1025-76a, 10.1 x 115.7, GSC locality C-47035.

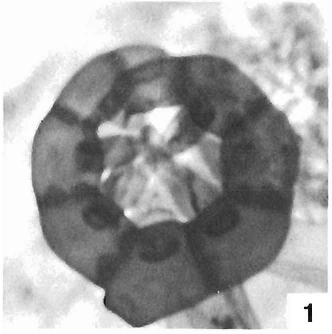
Figures 5-12. Upper Paleocene and Eocene specimens from Bonnet Plume Basin.

5. *Pesavis* cf. *P. tagluensis* Elsik & Jansonius 1974; smaller specimen over 28 µm in overall size, showing young developing secondary hyphae, GSC 83352, P-2096-3g, 40.3 x 111.9, GSC locality C-68190.

Figures 6-12. *Pesavis tagluensis* Elsik & Jansonius 1974.

6. GSC 83353, size over 36 µm, P-2096-64e, 42.9 x 117.4, GSC locality C-68304.
7. GSC 83354, size over 38 µm, P-2096-64e, 41.5 x 115.0, GSC locality C-68304.
8. GSC 83355, size over 42 µm, P-2096-64f, 21.0 x 105.2, GSC locality C-68304.
9. GSC 83356, size over 40 µm, P-2096-64e, 40.2 x 105.4, GSC locality C-68304.
10. GSC 83357, size over 46 µm, P-2096-64f, 33.7 x 101.6, GSC locality C-68304.
11. GSC 83358, mature specimen over 40 µm in overall size showing well developed septate hyphae, lateral arms with 6 to 7 cells, P-2096-15d, 29.6 x 111.7, GSC locality C-68174.
12. GSC 83359, large specimen with over 57 µm overall size, P-2096-63c, 31.0 x 114.8, GSC locality C-68305.

## Lower to middle Paleocene specimens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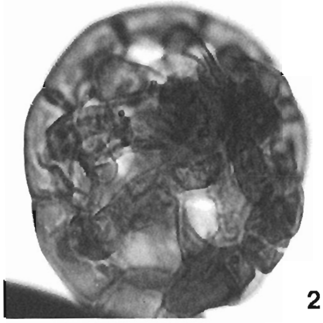
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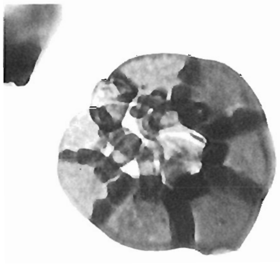
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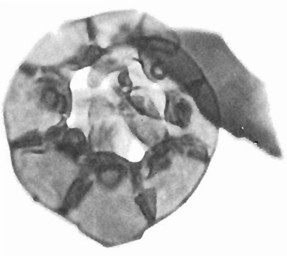
## Upper Paleocene and Eocene specimens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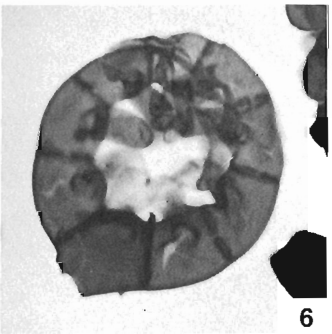
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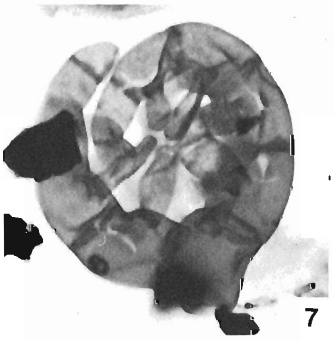
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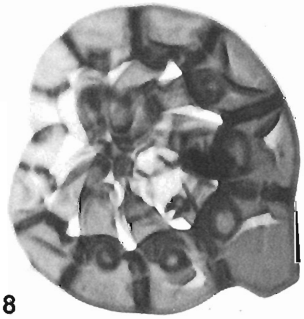
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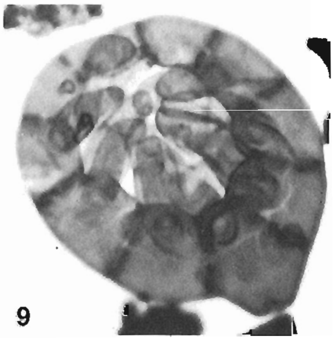
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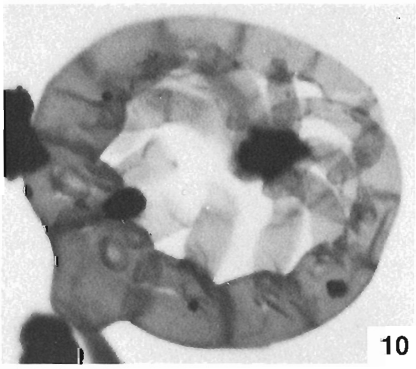
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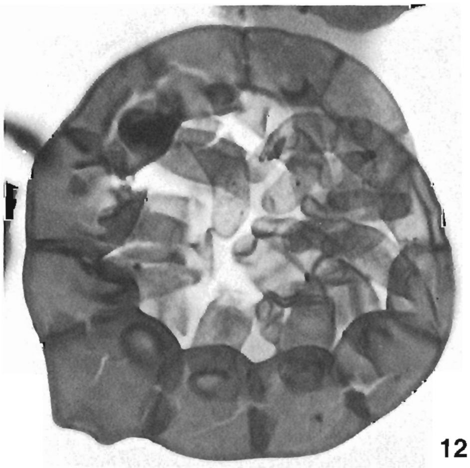
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