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SOLITARY RUGOSE CORALS OF THE SELKIRK MEMBER, RED RIVER FORMATION (LATE MIDDLE OR UPPER ORDOVICIAN), SOUTHERN MANITOBA

ROBERT J. ELIAS

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Preface

The Red River or "Arctic" Ordovician fauna has long been noted for the diversity and large size of species, and its widespread distribution from New Mexico to northwestern Greenland. In Canada, this assemblage occurs in the Williston and Hudson Bay basins, and the Arctic Islands. There has been considerable controversy regarding the precise age of the fauna, and speculation concerning the environmental conditions under which these organisms lived. This report presents a detailed taxonomic, morphologic, paleoecologic, biostratigraphic, and biogeographic analysis of the solitary rugose corals, based on new data from classic localities in southern Manitoba. It serves as a standard with which corals of other areas can be compared in order to determine depositional environments and provides precise paleontological correlations of Red River strata. Information such as this is essential in reconstructing the geological framework and history of Canadian sedimentary basins and thus aids in evaluating our hydrocarbon resources.

D.J. McLaren
Director General
Geological Survey of Canada

OTTAWA, August 1980

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SOLITARY RUGOSE CORALS OF THE SELKIRK MEMBER, RED RIVER FORMATION (UPPER MIDDLE OR UPPER ORDOVICIAN), SOUTHERN MANITOBA

Abstract

Solitary rugose corals of the Red River Formation in southern Manitoba are sufficiently common and well preserved for detailed study only in the Selkirk Member. The following taxa are recognized: Family Streptelasmatidae – ***Grewingkia crassa*** *n. sp.,* ***G. dilata*** *n. sp.,* ***G. robusta*** *(Whiteaves, 1896),* ***G. haysii*** *(Meek, 1865),* ***G. lamellosa*** *n. sp.,* ***Helicelasma randi*** *n. sp.,* ***Deiracorallium delicatum*** *n. sp., and* ***Bighornia*** *cf.* ***B. patella*** *(Wilson, 1926); Family Complexophyllidae n. fam. –* ***Complexophyllum leithi*** *n. gen., n. sp.*

The predominance of algal and annelid borings and epizoic colonial corals and stromatoporoids on the counter side of host solitary corals suggests that during life the convex cardinal side was in the sediment and the concave counter side faced upward, with the calice in a nearly horizontal position. The compressed and unique triangulate to trilobate shape of many corals in the Red River-Stony Mountain faunal province may have served to increase their stability during life.

In the Red River-Stony Mountain province, evolutionary trends in the ***Grewingkia-Lobocorallium*** *lineage are toward increased trilobation and an increase in the degree of septal dilation throughout ontogeny. This is accompanied by disappearance of lamellae from the stereozone and a change from weakly fibrous, nontrabeculate septa to trabeculate septa with well-developed fibers. The trends appear to be of value in dating corals of this faunal province.*

Red River solitary corals of Hudson Bay Lowland, Northwest Territories, and northwestern Greenland are similar to those of southern Manitoba, although there are some differences at the specific level.

Résumé

Les coraux rugueux solitaires de la formation de Red River au Manitoba ne sont suffisamment communs et bien conservés pour une étude détaillée que dans le membre de Selkirk. On y a identifié les taxa suivants: Famille Streptelasmatidae – ***Grewingkia crassa*** *n. sp.,* ***G. dilata*** *n. sp.,* ***G. robusta*** *(Whiteaves, 1896),* ***G. haysii*** *(Meek, 1865),* ***G. lamellosa*** *n. sp.,* ***Helicelasma randi*** *n. sp.,* ***Deiracorallium delicatum*** *n. sp., et* ***Bighornia*** *cf.* ***B. patella*** *(Wilson, 1926); Famille Complexophyllidae n. fam. –* ***Complexophyllum leithi*** *n. gen., n. sp.*

La prépondérance de cavités creusées par des algues et des annélides, et de coraux coloniaux épizoiques et stromatoporidés sur la paroi antipode des coraux rugueux solitaires qui leur servaient de support, semble indiquer que pendant leur existence, ces coraux rugueux reposaient sur leur côté cardinal convexe dans le sédiment, leur côté antipode concave étant tourné vers le haut et leur calice pratiquement disposé à l'horizontale. La forme exceptionnelle, comprimée, triangulaire à trilobée de nombreux coraux de la province faunique de Red River et Stony Mountain assurait probablement leur stabilisation pendant leur existence.

Dans la province de Red River et Stony Mountain, la lignée ***Grewingkia-Lobocorallium*** *présente une tendance évolutive à la trilobation et à l'accroissement du degré de dilatation des septa tout au cours de l'ontogénèse. On observe en même temps la disparition des lamellae de la stéréozone et un passage progressif de septa légèrement fibreux, non trabéculés, à des septa trabéculés à fibres bien développées. Il semble que ces tendances évolutives puissent servir à dater les coraux de cette province faunique.*

Dans les basses-terres de la baie d'Hudson, les territoires du Nord-Ouest et le nord-ouest du Groenland, les coraux solitaires de Red River sont semblables à ceux du sud du Manitoba, bien qu'ils présentent quelques différences au niveau spécifique.

INTRODUCTION

The Red River-Stony Mountain faunal province, named after geographic areas in southern Manitoba where the Red River and overlying Stony Mountain formations outcrop, is recognized from New Mexico to northwestern Greenland (see Flower, 1965, fig. 5). The faunal and lithologic similarity throughout this belt indicates that all depositional basins were interconnected (Foerste, 1929, 1932, p. 52, 53; Flower, 1961, p. 8). The age of Red River sediments is uncertain; Trentonian (late Middle Ordovician) to Richmondian (late Late Ordovician) assignments have been made on the basis of faunal and lithologic correlations (Twenhofel et al., 1954, p. 281, 282). Flower (1961, p. 7-11) considered the deposits to be late Trentonian and Edenian. Conodonts have indicated an Edenian-Maysvillian age (Barnes and Munro, 1973). However, conodont faunas 10 and 11 of Sweet et al. (1971) are present, and fauna 10 first appeared in the Shermanian (Barnes et al., 1976, p. 219, fig. 5). The Shermanian is now considered the latest Middle Ordovician stage (Sweet and Bergström, 1971). Bolton (1977) regarded the Red River fauna as late Middle Ordovician Barneveldian (Shermanian).

Solitary rugose corals of the Red River-Stony Mountain province are unique in their development of triangulate to trilobate external form, but few major studies have dealt with them. Troedsson (1928) described and illustrated specimens from the Cape Calhoun Formation of northwestern

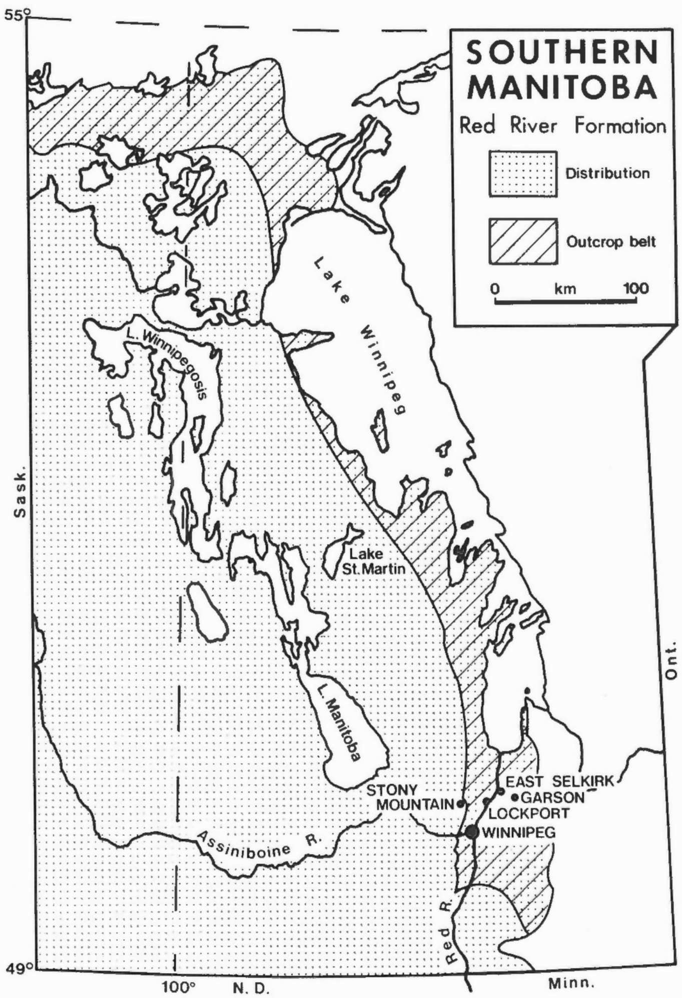

Figure 1. Localities and distribution in outcrop and subsurface of the Red River Formation in southern Manitoba (from McCabe, 1971, fig. 3).

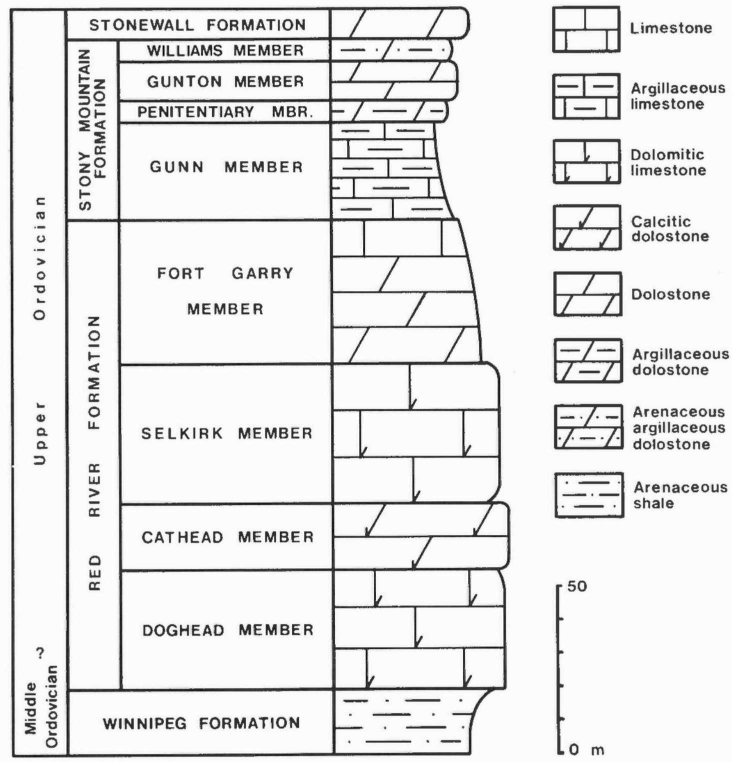

Figure 2. Ordovician stratigraphy in the vicinity of Winnipeg, Manitoba (modified from Cowan, 1971, fig. 2).

Greenland. Cox (1937) employed thin sections in his re-evaluation of species mainly from Arctic Canada and Greenland. The genus **Bighornia** was proposed and discussed by Duncan (1957). Solitary corals from Hudson Bay Lowland were described and illustrated by Nelson (1963; in press).

The Red River Formation of southern Manitoba was deposited on the northeastern flank of the Williston Basin (Fig. 1, 2). The general geology has been discussed by Dowling (1900), Goudge (1945), Baillie (1952), Andrichuk (1959), and Cowan (1971). Solitary corals are sufficiently common and well preserved for detailed study only in the Selkirk Member. This massive, light yellowish grey biomicrite and minor biosparite with greyish brown dolomitic mottles was deposited in a shallow marine environment (Cowan, 1971, p. 239).

The Selkirk Member rarely occurs in natural outcrops. Most corals examined herein are from large quarries at Garson, 55 km northeast of Winnipeg, Manitoba (50°04'40"N, 96°42'20"W; Garson Limestone Co. Ltd. quarry in SW corner, sec. 10, T13N, R6E; Gillis Quarries Ltd. quarry in NW corner, sec. 3, T13N, R6E). A section 8 m thick is exposed in these quarries, the lowest level being 6 m above the base of the Selkirk Member (Kendall, 1977, fig. 1). Solitary corals often occur in lenses of biosparite grading upward into biomicrite. These lenses are generally 1 to 4 m wide and 4 to 12 cm thick. They sometimes contain micrite intraclasts and large, randomly oriented fossils such as cephalopods and colonial corals. Deposition occurred after periods of high turbulence possibly caused by storms. Several solitary corals from near the top of the Selkirk Member have been collected at the following localities: East Selkirk (50°08'N, 96°50'30"W; before 1900, quarries were operated south of town in vicinity of Cooks Creek), Lockport (50°05'05"N, 96°56'20"W; outcrops on bank of Red River no longer exposed), and Lower Fort Garry (50°06'40"N, 96°55'40"W; exposures on west bank of Red River, 3 km north of Lockport).

Prior to this study, **Grewingkia robusta** (Whiteaves, 1896) was the only solitary coral described from the Red River Formation. The following species of Rugosa, representing the Family Streptelasmatidae, are now recognized from the Selkirk Member: **Grewingkia crassa** n. sp., **G. dilata** n. sp., **G. robusta** (Whiteaves, 1896), **G. haysii** (Meek, 1865), **G. lamellosa** n. sp., **Helicelasma randi** n. sp., **Deiracorallium delicatum** n. sp., and **Bighornia** cf. **B. patella** (Wilson, 1926). One species of the Family Complexophyllidae n. fam., **Complexophyllum leithi** n. gen., n. sp., is present.

The following abbreviations are used in referring to repositories of specimens: GSC – Geological Survey of Canada, Ottawa; USNM – National Museum of Natural History, Smithsonian Institution, Washington, D.C.; MMH – Museum mineralogicum hafniensis, Geologisk Museum, Copenhagen; MGUH – Museum geologicum Universitatis hafniensis, Geologisk Museum, Copenhagen.

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I thank the Garson Limestone Co. Ltd. and Gillis Quarries Ltd. for access to their properties in Garson and Winnipeg, Manitoba, and for permission to collect samples. I am grateful to the following for providing specimens on loan: Edward I. Leith (University of Manitoba), Thomas E. Bolton (Geological Survey of Canada), Frederick J. Collier (National Museum of Natural History, Washington, D.C.), and Søren Floris (Geologisk Museum, Copenhagen). Thin sections of the lectotype of **Grewingkia haysii** were made available by William A. Oliver, Jr. (U.S. Geological Survey). Other thin sections were prepared by Per-Erik Litz (University of Cincinnati) and Irene H. Berta (University of Manitoba).

The manuscript was reviewed by K.E. Caster and David L. Meyer (University of Cincinnati), T.E. Bolton, Murray J. Copeland, and Brian S. Norford (Geological Survey of Canada), and Björn Neuman (University of Bergen, Norway). W.A. Oliver, Jr. provided helpful suggestions.

TERMINOLOGY

The morphological terminology used in this paper generally corresponds to that of Hill (1935, 1956). Terms referring to microstructure follow Wang (1950) and Kato (1963). A number of new terms are introduced herein, and some previously used terms require explanation.

The cardinal and counter septa lie in the <u>cardinal-counter surface</u> (not necessarily planar), which is the surface of bilateral symmetry that divides the coral into two <u>alar sides</u>. The <u>cardinal side</u> contains the alar septa, cardinal septum, and all septa between these. The side containing the counter septum and all septa between it and alar septa is termed the <u>counter side</u>.

Corals are <u>triangulate</u> (Cox, 1937, p. 7) when an angulation is present in the position of the cardinal septum and immediately on the counter side of the alar septa (see Fig. 4c, and Pl. 2). They are <u>trilobate</u> (Whiteaves, 1895, p. 113) when a broad indentation at the position of, or slightly on the cardinal side of the alar septa produces lobate cardinal and alar sides (Cox included trilobation in his term "triangulate") (see Fig. 4d, and Pl. 6). Corals are <u>compressed</u> when the cardinal-counter length in cross-section is greater than the maximum width perpendicular to it (Easton, 1951, p. 381, 383; Oliver, 1958, p. 816) (see Fig. 4b, and Pl. 9, fig. 12-19). If the cardinal-counter distance is less than that perpendicular to it, the term <u>depressed</u> is used (Oliver, 1958, p. 816) (see Pl. 10).

The <u>septal region</u> is that part of the coral in which major septa (but not septal lobes) are present. The <u>axial region</u> is the central area where major septa are absent and an axial structure and/or tabularium may be present. The <u>axis</u> is an imaginary line along the centre of the coral. In cross-section it is represented by the point at which major septa meet, or the centre of the axial region if present.

Use of the terms septal lobe and septal lamella corresponds to Neuman (1969, p. 5, fig. 2f). A <u>septal lobe</u> is an "irregularly lobate and undulate axial edge of a [major] septum, strongly bent in quite a different direction from that of the main growth direction of the septum". A <u>septal lamella</u> is a longitudinal plate in the axial region that is not joined to a septum. An <u>interseptal chamber</u> is the space between two adjacent septa (Neuman, 1969, fig. 2e). The term <u>cardinal fossula</u> has been used in various ways by different authors. Herein it refers to the relatively prominent interseptal chamber on both sides of the cardinal septum (Hill, 1956, p. F246).

The term <u>tabella</u> (Hill, 1956, p. F251) is used herein for a small, convex upward plate with ends that abut against other tabellae or tabulae. Tabellae do not extend completely across a region of the coral. A <u>complete tabula</u> (Hill, 1956, p. F246) extends completely across a region of the coral.

BIOMETRICAL METHODS

Biometrical data for solitary rugose corals discussed in this paper are tabulated in Elias (1976). In order to quantitatively examine some aspects of coral morphology and ontogeny, a number of new methods are introduced.

Coral length from the tip to the top of a specimen and height to a particular growth stage have been measured in various ways by different authors. Unfortunately, the method used has not always been stated. Length and height have often been measured externally along the convex or concave sides of curved corals (Easton, 1975, p. 679). Sando (1961, p. 65, fig. 1b) and Neuman (1969, p. 4, fig. 1a) defined length as the linear distance between the tip and the top of the calice on the convex side. Rowett and Sutherland (1964, p. 16) defined height as the linear distance between the tip and the axis at any growth stage.

True length or height should be measured upward from the tip along the axis, because it was along this line that the centre of the polyp's basal disc moved during growth. This value is independent of the rate of expansion and degree of curvature of the coral. In this study, length and height (<u>h</u>) are measured on photographs of an alar side of corals, taken with the cardinal-counter surface (in which the axis lies) parallel to the film. The distance is measured using a piece of flexible wire laid along the external trace of the alar septum, which is very close to or identical in position with the axis when viewed in this way. Corals <3 cm in length are termed small, those from 7 to 8 cm are moderate, those from 8 to 9 cm are moderately large, and those >9 cm are of large size.

In longitudinal sections of these corals, the top of the calicular boss can be recognized with greater accuracy than the position of the bottom of the calice. Therefore, calicular depth is measured along the axis from the top of the boss to the top of the specimen. The ratio of calicular depth to coral length is used for comparison of different specimens and species. Corals with a ratio of <0.2 are considered to have a shallow calice, those from 0.2 to 0.3 are moderately deep, and those >0.3 have a deep calice.

The degree of compression or depression is calculated using the ratio of cross-sectional length to width.

Since the work of Voynovskiy-Kriger (1954; Chilingar, 1956) numerous authors have plotted graphically some relationship indicating the rate of septal development in corals. This has been done to study ontogeny, to show intraspecific variation, and to distinguish species. Commonly, the number of major septa is plotted against cross-sectional diameter. If the coral is circular in cross-section, diameter is a measure of the size of the polyp's basal disc and is therefore related to growth. However, the term diameter is meaningless if the coral is compressed, depressed, triangulate, or trilobate. The cardinal-counter length or width perpendicular to it are not good measures of growth if the cross-sectional shape changes during ontogeny.

In this study, cross-sectional area (a̲) in a plane perpendicular to the axis is used as a measure of size and growth of a polyp secreting a noncircular coral. Cross-sectional area is determined for species of **Grewingkia, Helicelasma,** and **Deiracorallium** by tracing the outline of a section on heavy paper or mylar, cutting this out and weighing it, and converting the weight to area using the weight of a known area of material. If part of a cross-section is missing due to pre-depositional abrasion or breakage of the coral, it is reconstructed in as reasonable a manner as possible. Sources of error include: 1) reconstruction of abraded and broken specimens, 2) cross-sections not perpendicular to the axis, 3) the process of tracing and cutting out the cross-section replica, 4) paper or mylar of nonuniform weight across its surface, and 5) errors incurred in weighing the cross-section replicas. The generally small scatter within a species on plots of the number of major septa (n̲) against cross-sectional area suggests that these errors are small (Fig. 8b-14b). Area of the axial region (a̲', measured by the above method) and width of the stereozone plus epitheca if preserved (s̲) are also plotted against cross-sectional area in order to show their rate of development (Fig. 8c-14c, 8d-14d).

Within species occurring in the Selkirk Member there is little variation in the number of septa at a particular cross-sectional area (**G. haysii** is the only exception), and this value differs, though sometimes only slightly, among the species (Fig. 3). An increase in the number of septa per unit of cross-sectional area from **Grewingkia crassa** to **G. dilata** to **G. robusta** is accompanied by a change in the axial structure from coarse to fine.

Another measure of coral growth is height. Rowett and Sutherland (1964) plotted the number of major septa against height in order to evaluate septal insertion. This method is seldom used because specimens with complete tips are required. The tips of specimens of **Grewingkia, Helicelasma,** and **Deiracorallium** from the Selkirk Member are generally rounded due to abrasion, but they have been reconstructed in as reasonable a manner as possible on photographs of the alar side in order to measure length and height. Plots of cross-sectional area against height show that area generally increases linearly with height throughout the length of the coral; only three specimens tend to become cylindrical near the top (GSC 60712, 60721, 60726) (Fig. 8a-14a). Therefore, plots of any variable against cross-sectional area and height

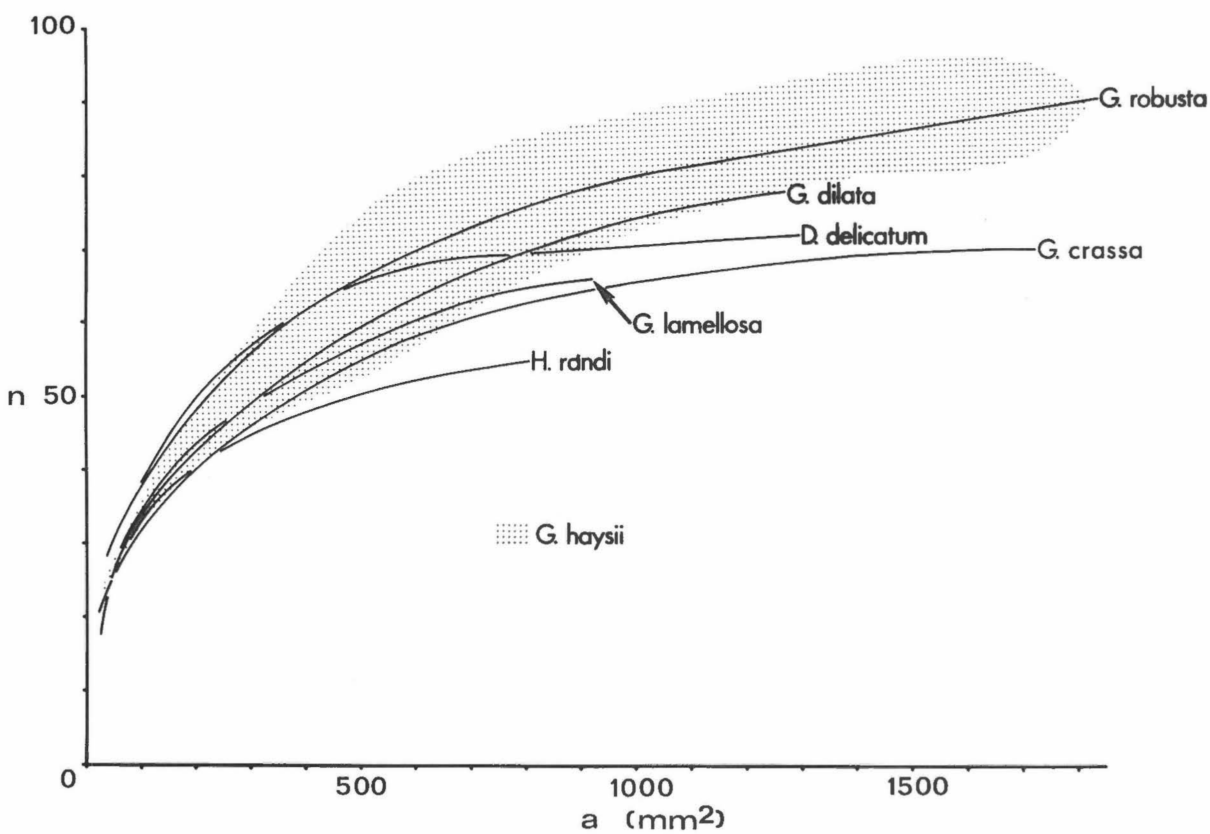

Figure 3. Relation of the number of major septa (n̲) and coral cross-sectional area (a̲) for Selkirk Member species of ***Grewingkia, Helicelasma,*** *and* ***Deiracorallium.*** *Curves are averages prepared by inspection of data in Fig. 8b-10b and 12b-14b. An area is shown for* ***G. haysii*** *because of greater intraspecific variation (Fig. 11b).*

Table 1. Seventy-five epizoic organisms on 51 solitary rugose corals of the Selkirk Member

Epizoans	Number of occurrences	Number of occurrences on counter side of host
Colonial rugose corals	8	8
Heliolitid corals and stromatoporoids	11	9
Corals and stromatoporoids	19 (25% of total epizoans)	17 (89% of corals and stromatoporoids)
Bryozoans	56 (75% of total epizoans)	31 (55% of bryozoans)

are similar. It is felt that more error is involved in measuring height than area because of uncertainty in reconstructing the tips of specimens belonging to these genera, and therefore only plots involving area are illustrated. Area is not measured for small corals of **Bighornia.** However, their tips are well preserved, and the number of major septa is plotted against height (Fig. 15).

Many morphological features are described qualitatively (for example "strongly curved", "weakly trilobate", "moderately convex", "closely spaced"). Relative terms such as these are used to compare specimens within the scope of this study, and their meaning is made clear by examination of the plates.

ABRASION

Abrasion of the surface of solitary corals in the Selkirk Member was first noted by Whiteaves (1896, p. 390), who remarked that the corals were "often so much worn, apparently prior to fossilization, as to be almost smooth". The epitheca with growth lines has been removed from almost all specimens, and part of the stereozone is missing from most and is completely missing from a few. The degree of abrasion is often greater on the cardinal side than on the counter side, and decreases upward from the tip, which is almost always rounded. Straight or very weakly curved corals generally show less abrasion than more strongly curved forms.

ATTACHMENT OF CORALS

Of 202 solitary corals of the genera **Grewingkia, Helicelasma, Deiracorallium,** and **Complexophyllum,** only one specimen of **H. randi** has an area of attachment (GSC 60733) (Pl. 9, fig. 1, 2). It is a flattened area on the cardinal side at the tip with the impression of a bryozoan on it. Except for this specimen, the corals were apparently free during life.

Three of the 9 specimens of **Bighornia** cf. **B. patella** have spoon-shaped depressions on the concave cardinal side at the tip (GSC 60752, 60754, 60755) (Pl. 10, fig. 1, 2). These depressions are interpreted as areas of attachment because the surfaces are smooth – growth lines do not extend onto these areas. The shape of these depressions suggests that the corals may have been attached to cylindrical surfaces such as cephalopod shells.

BORINGS AND EPIZOANS

Borings in solitary corals of the Selkirk Member were described by Elias (1980). Boring algae produced **Dictyoporus garsonensis** Elias, 1980, which comprises irregular dendritic to reticulate networks of fine channels along the surface and tunnels penetrating very shallowly into the epitheca and coral wall (Fig. 7b). Thirty-eight occurrences of algal borings are present in 35 of 202 solitary corals examined (17 per cent). Seventy-four per cent are in the concave counter side of the corals, 24 per cent in the convex cardinal side, and two per cent extend into both sides. (**Bighornia** is the only genus in the Selkirk Member having a convex counter side. It is excluded from this discussion because no borings are present in the nine specimens examined.)

Cylindrical **Trypanites weisei** Mägdefrau, 1932 borings made by polychaete annelids are up to several millimetres in diameter and are generally perpendicular to the host's surface (Pl. 5, fig. 2). A total of 452 borings are present in 108 of 202 corals examined (53 per cent). Sixty-seven per cent of the annelid borings are in the concave counter side of the corals and 33 per cent are in the convex cardinal side. Five of 20 straight or very weakly curved corals have borings in them (25 per cent), compared with 102 of 182 curved specimens (56 per cent).

Seventy-five epizoic colonial corals, stromatoporoids, and bryozoans are present on 51 of 202 solitary corals examined (25 per cent) (Table 1). Colonial corals and stromatoporoids comprise 25 per cent of the epizoans; 89 per cent of these are located on the counter side of the host. Epizoic bryozoans, including lacy, thin encrusting, and massive forms, comprise 75 per cent of the epizoans; 55 per cent of these are located on the counter side of the solitary corals.

ORIENTATION AND GROWTH

The abrasion of Selkirk Member corals and their common occurrence within graded beds suggest that they were transported before final deposition and burial. Most were deposited on their sides, but some were inclined and a few oriented vertically with calices facing up and down. Cross-sections of 47 corals lying sideways in the horizontal strata were observed on walls of the Garson Limestone Co. Ltd. quarry at Garson, Manitoba. In 77 per cent, the cardinal-counter surface was within 45 degrees of horizontal. The cardinal side was tilted upward in 45 per cent, the counter side in 55 per cent.

A number of possible growth orientations have been hypothesized for unattached solitary rugose corals (Weissermel, 1897; Bernard, 1904; Yakovlev, 1917; Schindewolf, 1932; Wells, 1937, 1957; Easton, 1951; Spasskiy, 1967). The cardinal-counter surface is generally accepted as having been vertical (Wright, 1969). The location of borings and epizoans provides information concerning growth orientation of corals in the Selkirk Member (see Elias, 1980). If boring and epizoic organisms became associated with the corals as oriented after deposition, nearly equal numbers would be expected on the cardinal and counter sides. The predominance of boring algae and annelids and epizoic colonial corals and stromatoporoids on the counter side, however, suggests that the corals became hosts prior to transportation and deposition, while in life position. The observed distribution of borings and epizoans would be expected if unattached curved corals lay with most of the convex cardinal side in the sediment and the exposed concave counter side facing upward, as hypothesized by Bernard (1904) and illustrated by Elias (1980, fig. 5). The approximately equal number of epizoic bryozoans on the counter and cardinal sides may indicate that they had no preference for a particular location on live hosts, or that they became associated with the corals after deposition. If unattached, straight, conical solitary corals were oriented upright in the sediment during life (Wells, 1957), they would be less suitable as hosts and have fewer annelid borings, as observed.

In three species of Selkirk Member corals (**Grewingkia crassa**, **G. robusta**, and **Helicelasma randi**), dilation of the major septa is often stronger on the cardinal side than on the counter side within several centimetres of the tip. This may have served to strengthen the coral (Neuman, 1969, p. 33, 34) or add weight to its lower side for increased stability during life.

Curvature of solitary corals apparently resulted from attempts to bring the oral surface of the polyp into a horizontal position. The degree of curvature may be related to current intensity (Spasskiy, 1967). Straight to weakly curved corals in the Selkirk Member show less abrasion than more strongly curved specimens, suggesting that they were present in lower energy environments where abrasion was not as severe.

A coral with an irregular and contorted cardinal-counter surface may have fallen over during growth. The polyp attempted to re-orient itself with respect to the substrate by growing upward (Wells, 1937, p. 11). Cardinal-counter surfaces of Selkirk Member corals are very nearly planar, suggesting that they remained in a stable position throughout life. Perhaps being overturned and transported by currents prior to final burial killed them. Calice rims were broken and repaired during the life of several corals, indicating that they were able to survive some crises (GSC 60714, 60721, 60740) (Pl. 4, fig. 10, 11; Pl. 7, fig. 1).

The ichnospecies represented by borings in solitary corals of the Selkirk Member suggest that the hosts lived in very shallow marine environments (Elias, 1980).

EXTERNAL FORM AND EVOLUTION

Most taxa of solitary rugose corals are circular in cross-section. Several genera including depressed species are known from the Ordovician to at least the Mississippian (Oliver, 1958, p. 818). This shape may have provided a straight hingeline for operculate corals, or a flat resting surface; in others it may represent a genetic trend and not a response to the environment (Oliver, 1958, p. 817, 818). **Bighornia** cf. **B. patella** is depressed, non-operculate, and generally has a flattened convex counter side. Several specimens have a spoon-shaped area of attachment on the concave cardinal side, suggesting that the counter side did not serve as a resting surface. Duncan (1957, p. 608) interpreted the flattening of the counter side as genetically controlled.

Compressed species representing several genera are known from the Ordovician to Mississippian (Oliver, 1958, p. 818). Easton (1951, p. 385) concluded that this shape offered less water resistance to corals that grew upward and faced the current. Oliver (1958, p. 818) suggested that it was apparently non-adaptive in some species. Corals of the genus **Deiracorallium** are compressed. If they were oriented during life with the cardinal side in the sediment acting as a keel, these unattached corals would have had greater stability than those with a circular cross-section (Fig. 4a, b).

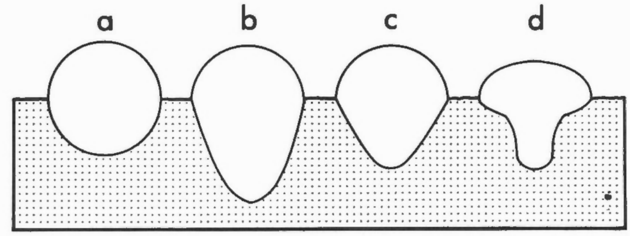

Figure 4. *Cross-sections of corals with the cardinal side in sediment: a, circular cross-section; b, compressed; c, triangulate; d, trilobate.*

The triangulate to trilobate forms developed in **Grewingkia**, **Lobocorallium**, and to a lesser degree in **Deiracorallium** of the Red River-Stony Mountain faunal province are unique. As with compression, triangulation and especially trilobation would have provided greater stability (Fig. 4c, d). Trilobation may also have prevented the coral from sinking into soft sediment. **Grewingkia crassa** and **G. robusta** range from circular to triangulate to weakly trilobate in cross-section. The polyps apparently could modify their external shape in order to adapt to slightly different substrate or current conditions. This ability may have been genetically controlled because it is restricted to the Red River-Stony Mountain province.

Easton (1951, p. 383) noted that "the [compressed] shape reaches its acme at about the same time in different genetic strains", and "particular strains which are [compressed] or [depressed] become so just before their disappearance". Similarly, triangulation and trilobation appeared in species of **Grewingkia** and **Deiracorallium** during deposition of the Red River Formation, and became more strongly developed in taxa of the younger Stony Mountain Formation in which these forms and the short-lived **Lobocorallium** apparently became extinct.

Kirk (1925, p. 446) stated that the weakly trilobate **Grewingkia haysii** marked the beginning of an evolutionary line that culminated in the strongly trilobate **Lobocorallium trilobatum** of the Stony Mountain Formation. Nelson (1963, p. 34), in his study of Hudson Bay Lowland corals, recognized a "direct evolutionary series tending toward increased trilobation". The ancestral **Grewingkia robusta** rapidly evolved into Nelson's **Lobocorallium goniophylloides** (=**G. robusta**), which probably gave rise to his **L. trilobatum** var. **major** (=**G. haysii**).

Solitary corals with the form of **Lobocorallium trilobatum** have been used by stratigraphers as a guide to the Stony Mountain Formation and its equivalents (Duncan, 1956, p. 226; Nelson, 1959, p. 52). Brown, in commenting on a coral resembling **L. trilobatum** from the Red River Formation in Saskatchewan, first suggested that strong trilobation "should not necessarily be regarded as an infallible guide to the Stony Mountain" (Kupsch, 1952, p. 24). There is considerable variation in external form within several solitary coral species from the Selkirk Member, and weakly trilobate **Grewingkia crassa** and **G. robusta** are fairly common. **G. haysii** is weakly to strongly trilobate – one specimen (GSC 60728) is almost identical externally to **L. trilobatum**. It is possible that, by selection of strongly trilobate forms, **G. robusta** evolved into **L. trilobatum**, with **G. haysii** as an intermediate form.

SEPTAL DILATION, MICROSTRUCTURE, AND EVOLUTION

Transverse and longitudinal thin sections were examined for the following specimens, representing all species known from the Selkirk Member of the Red River Formation: **Grewingkia crassa** (GSC 60707), **G. dilata**

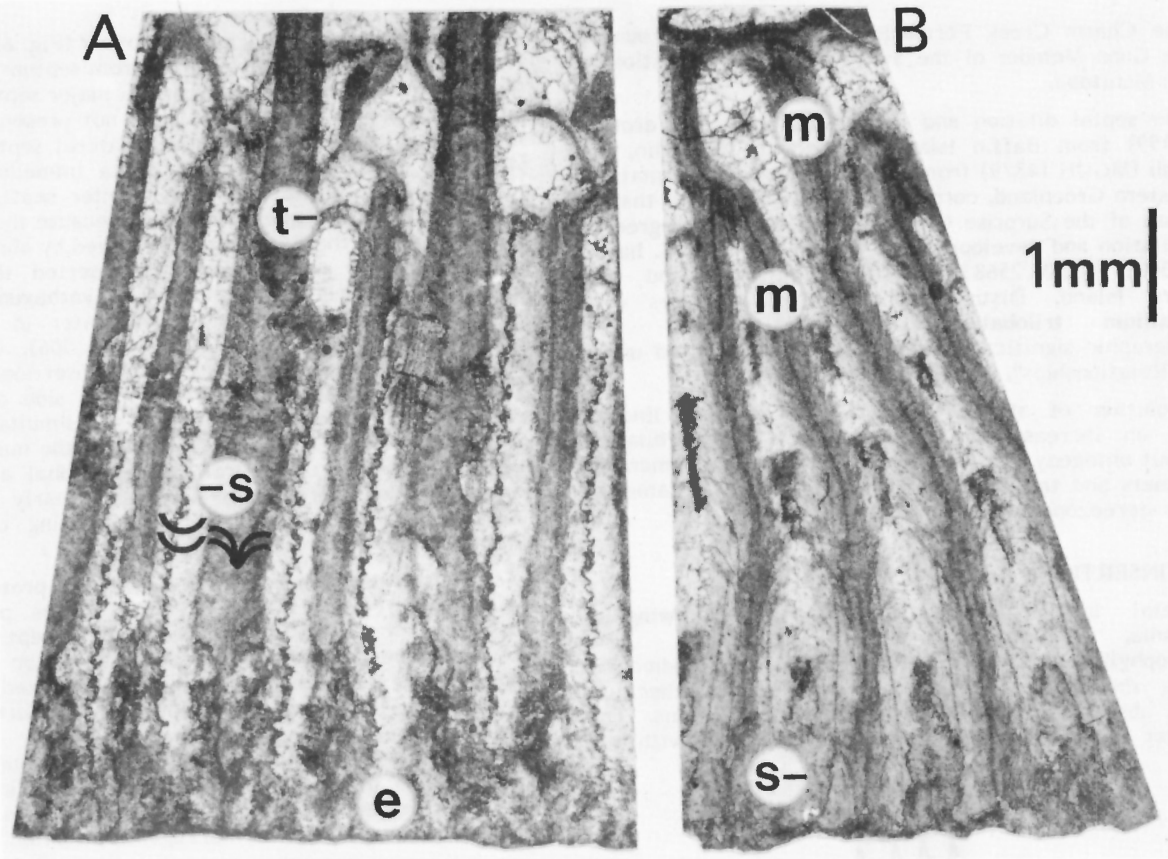

Figure 5. *Microstructure of **Grewingkia crassa** n. sp. (GSC 60707). A, Transverse thin section at loc. 9, Pl. 1, fig. 1: e, epitheca; s, stereozone between major and minor septa composed of U-shaped lamellae as indicated, with median suture; lines in major septum indicate orientation of fibers seen only in polarized light; t, tabella. B, Transverse thin section at loc. 4, Pl. 1, fig. 1: m, strongly dilated major septa with distinct fibers; s, stereozone poorly defined.*

(GSC 60716), **G. robusta** (GSC 60721), **G. haysii** (GSC 60727, 60728), **G. lamellosa** (GSC 60740), **Helicelasma randi** (GSC 60729), **Deiracorallium delicatum** (GSC 60745), **Bighornia** cf. **B. patella** (GSC 60754), and **Complexophyllum leithi** (GSC 60756). All have similar microstructure. In transverse sections, the epitheca consists of tiny, irregular clusters of radiating fibers. Epitheca and tabellae appear to be structurally continuous with the septa. In stages when the major septa are nondilated to moderately dilated, structures cannot be distinguished in the septa, septal lobes and lamellae, or tabellae when viewed in plane light (Fig. 5a). Between each major and minor septum the stereozone consists of U-shaped lamellae with the concave sides facing the coral axis and a contorted median suture parallel to the septa. Extinction trends in polarized light usually show a median axial surface in each septum with fibers on both sides curving outward in the direction of the coral axis. The septal lobes and lamellae, and tabellae are also fibrous. The microstructure is of the type shown diagrammatically for **Streptelasma corniculum** by Wang (1950, Pl. 5, fig. 23). Kato (1963, fig. 10/9) diagrammatically figured a septum of **Grewingkia robusta** with lamello-trabecular microstructure; this is not seen in the present study. In polarized light, extinction in longitudinal thin sections of major septa has trends perpendicular to the coral axis. These may represent very weak trabeculae, but they cannot be distinguished in plane light. In transverse sections of early ontogenetic stages with strongly to completely dilated major septa, the septa appear fibrous even in plane light (Fig. 5b). If the septa are in lateral contact, lamellae are not developed in the stereozone. Thus, the development of septal fibers and lamellae in the stereozone is related to the degree of septal dilation.

Lobocorallium trilobatum (GSC 60757) from the Gunn Member of the overlying Stony Mountain Formation has completely dilated septa that are clearly fibrous throughout their lengths, even when viewed in plane light. No lamellae are present in the stereozone. Trabeculae, inclined slightly up toward the coral axis, can be distinguished in plane light. Caramanica (1973, p. 102, 103) first remarked on the change from nontrabeculate microstructure in corals of the Red River Formation to trabeculate in specimens from the Stony Mountain Formation, and suggested that this may have some potential in dating coral faunas.

Examination of material from Hudson Bay Lowland indicates that a similar increase in the degree of septal dilation and change in microstructure occurred there as well. **Grewingkia robusta** (GSC 10807d, f) from the Portage Chute Formation, which may correlate with the Selkirk Member of the Red River Formation, has septal dilation and microstructure similar to that of corals from the Selkirk Member. The fibrous structure of the septa is indistinct in plane light, and lamellae are present in the stereozone in weakly dilated stages. In **G. robusta** (GSC 10793a, c) from the overlying Surprise Creek Formation, which may correlate with the Fort Garry Member of the Red River Formation, the septal fibers are more distinct and lamellae are seldom developed in the stereozone. **G. haysii** (GSC 10796a, i, m) has stronger dilation throughout ontogeny, and the septal fibers are more distinct than those in **Lobocorallium trilobatum.** Lamellae are not present in the stereozone. The specimen is from the Chasm Creek Formation, which may be younger than the Gunn Member of the Stony Mountain Formation in southern Manitoba.

The septal dilation and microstructure in **G. arctica** (GSC 6499) from Baffin Island, District of Franklin, and **G. haysii** (MGUH 14879) from the Cape Calhoun Formation, northwestern Greenland, correspond approximately to that in **G. robusta** of the Surprise Creek Formation. The degree of septal dilation and development of septal fibers in **G. haysii** (MMH 3368; USNM 25683a, b) from Baffin Island and Ellesmere Island, District of Franklin, compares with **Lobocorallium trilobatum** (Pl. 5, fig. 3, 4). The biostratigraphic significance of this will be discussed under "Faunal Relationships".

Evolution of the **Grewingkia-Lobocorallium** lineage involved an increase in the degree of septal dilation throughout ontogeny, accompanied by better development of septal fibers and trabeculae, and disappearance of lamellae from the stereozone.

SEPTAL INSERTION

Septal insertion in all species of **Grewingkia, Helicelasma, Deiracorallium, Bighornia,** and **Complexophyllum** in the Selkirk Member was studied by observing the septa on coral exteriors (the epitheca is generally absent due to abrasion) and in cross-sections. The new major septum is initially contiguous axially with the adjacent earlier-formed major septum (Fig. 6). It becomes free at a later time, which varies from septum to septum and coral to coral. After insertion of a major septum, the minor septum appears. Minor septa are not present between the cardinal septum and the cardinal-lateral septa, or between the alar septa and the major septa immediately on their counter sides (or between the counter septa and counter-lateral septa in **Complexophyllum**). Because the outer portion near the tip of these corals was removed by abrasion, it is not known whether minor septa are inserted throughout the metasepta insertion sequence (**"Cyathaxonia"** type of Hill, 1935, p. 505) or first appear later in the sequence (**"Zaphrentis"** type of Hill, 1935, p. 505, 506). Observation of septa on coral exteriors indicates that insertion on either side of the cardinal septum (and on either side of the counter septa in **Complexophyllum**) can occur simultaneously or at different times (Fig. 7a, b). Graphs of the number of major septa at a particular coral cross-sectional area or height show that septa are rapidly inserted in early stages (Fig. 3, 8b-14b, 15, 16). The rate slows during ontogeny, and insertion may eventually cease.

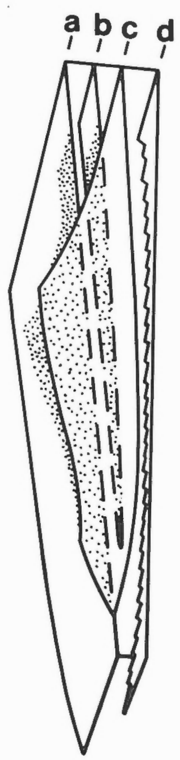

*Figure 6. Septal insertion in solitary rugose corals of the Selkirk Member. The cut-away septum (d) is a cardinal or alar septum (or one of the counter septa in **Complexophyllum**). Insertion takes place on either side of the cardinal septum and on the counter side of the alar septa (and on either side of the counter septa in **Complexophyllum**). The new major septum (c) is initially contiguous axially with the earlier formed major septum adjacent to it (a). The minor septum (b) appears after insertion of the major septum. The stereozone is not shown.*

After development of the first six protosepta, septal insertion in solitary rugose corals takes place in four positions – on either side of the cardinal septum and on the counter side of both alar septa. Insertion at additional positions on the counter side has been reported, but is poorly documented and has not been confirmed by further work (see Hill, 1935, p. 505; Oliver, 1980, p. 150-152). Oliver (1980, p. 152) considered most probable the conclusion that "all descriptions of the insertion of metasepta in the counter sectors are based on erroneous interpretations and all cited examples actually had normal rugosan insertion".

In the only known specimen of **Complexophyllum leithi**, major septa appear to be inserted at eight positions. Insertion occurs on either side of the cardinal septum and on the counter side of the alar septa (as is characteristic of the Rugosa), and on either side of a pair of major septa in the counter position. An additional major septum develops on either side of the coral between the first major septum inserted adjacent to the alar septum and the first major septum inserted in the counter fossula (Fig. 7).

FAUNAL RELATIONSHIPS

The Red River-Stony Mountain faunal province coincides with a belt of carbonate rocks extending from western Texas and New Mexico through Colorado, Nevada, Wyoming, and North and South Dakota to southern Manitoba, and northward to Hudson Bay Lowland, Northwest Territories, Alaska, and northwestern Greenland (Foerste, 1929, 1932, p. 52, 53; Flower, 1965, fig. 5). Faunal similarity throughout the province suggests that all depositional basins were interconnected (Flower, 1961, p. 8). Comparison of solitary rugose corals at the specific level, however, indicates some differentiation from region to region during Red River time.

Complete references to the data from Northwest Territories and northwestern Greenland summarized below are provided under the appropriate taxa in "Systematic Paleontology".

New Mexico

In the southern portion of the faunal province solitary corals are not as common as elsewhere, although colonial corals are conspicuous. Flower (1961, p. 12) noted that few solitary corals, representing **Grewingkia, Streptelasma** [?], and possibly **Bighornia**, are present in the Second Value Formation of the Montoya Group. Hill (1959, p. 10) described one fragment referred to as **Streptelasma** ? sp.

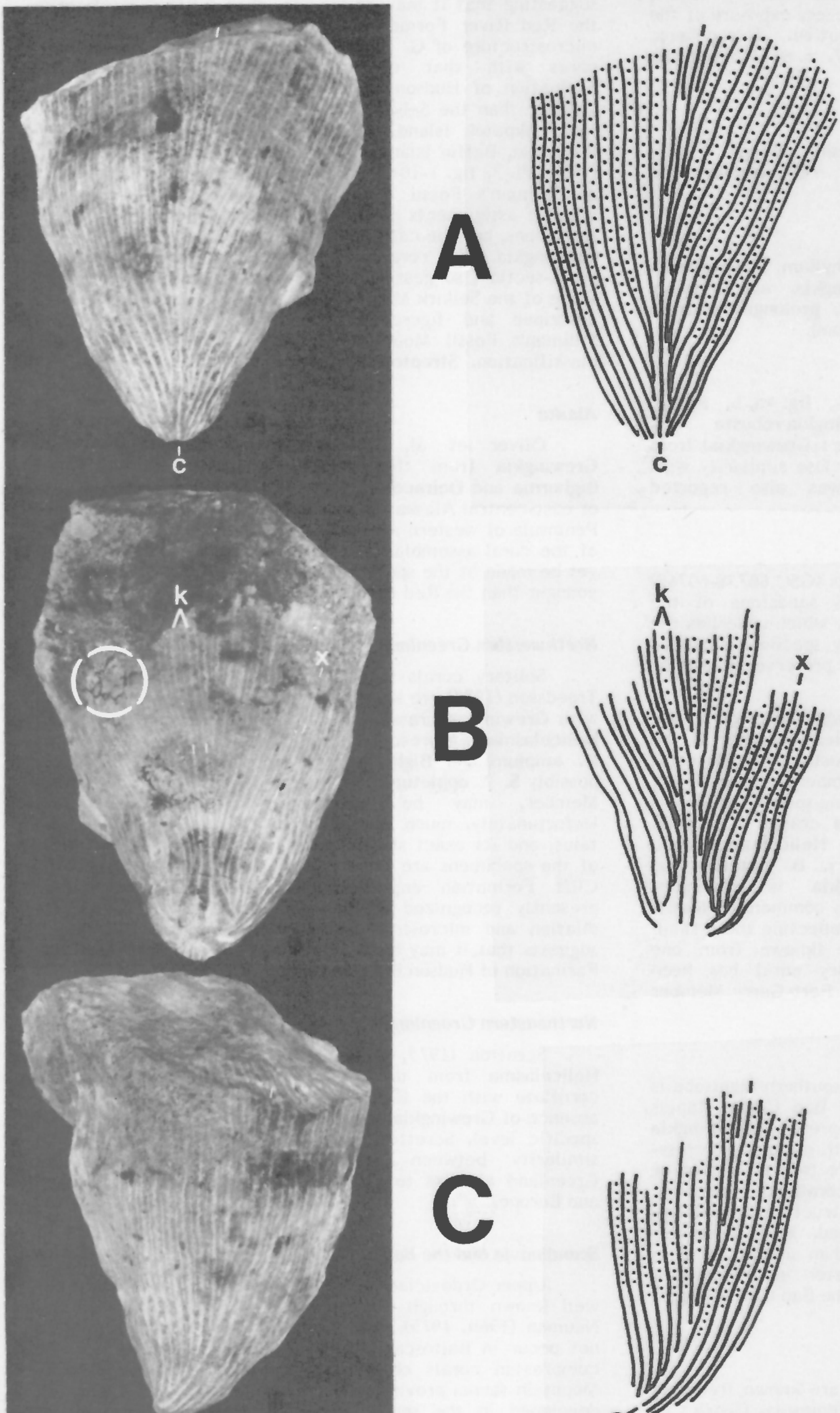

Figure 7

Septal insertion seen on exterior of ***Complexophyllum leithi*** *n. gen., n. sp. (GSC 60756), x2. Major septa represented by solid lines, minor septa dotted. A, Cardinal side: c, cardinal septum. B, Counter side: k, counter septa; x, major septum appearing between first major septum inserted adjacent to alar septum (on right) and first major septum inserted in counter fossula (on left); dendritic traces in circle are* ***Dictyoporus garsonensis*** *Elias, 1980, produced by boring alga. C, Alar side: a, alar septum.*

Colorado

Sweet (1954, p. 300, 301) reported solitary corals, identified as **Streptelasma** sp., in nearly every exposure of the massive member of the Fremont Formation. This generic assignment is uncertain. Duncan (1957, p. 611) noted the presence of **Bighornia.**

Nevada

From the eastern Great Basin, Budge (1977) reported **"Streptelasma" goniophylloides, "S." haysii,** and **"S." robustum** var. **amplum.**

California

Pestana (1960) described **Lambeophyllum, Streptelasma** (+ **Brachyelasma), Coelostylis** ?, **Grewingkia,** and possibly **Deiracorallium (Streptelasma** sp. cf. **S. prolongatum)** from the Johnson Spring Formation (? Trentonian).

Wyoming

Duncan (1956, p. 218-220, Pl. 21, fig. 4a, b, Pl. 22, fig. 3a, b) schematically illustrated **Grewingkia robusta** and **Streptelasma** aff. **S. goniophylloides** (=**Grewingkia**) from the lower Bighorn Dolomite, indicating close similarity with the Selkirk Member. **Bighornia** was also reported (Duncan, 1957, p. 611).

Southern Manitoba

Several small solitary rugose corals (GSC 60758-60762) have been collected from argillaceous sandstone of the Winnipeg Formation (Middle Ordovician), which underlies the Red River Formation (Fig. 2). The only specimen that has been sectioned (GSC 60759) is too poorly preserved to permit generic assignment.

Whiteaves (1897, p. 154) questionably referred a few small, imperfect corals from the Dog Head Member of the Red River Formation to **Grewingkia robusta.** A single coral that has been seen in the Cat Head Member was too poorly preserved for classification. The following species are known from the Selkirk Member: **Grewingkia crassa, G. dilata, G. robusta, G. haysii, G. lamellosa, Helicelasma randi, Deiracorallium delicatum, Bighornia** cf. **B. patella,** and **Complexophyllum leithi. Grewingkia** is dominant, **Helicelasma** common, **Deiracorallium** less common, **Bighornia** uncommon (this may be due to bias in collecting these small corals), and **Complexophyllum** is rare (known from one specimen). One unidentifiable solitary coral has been observed in the generally unfossiliferous Fort Garry Member of the Red River Formation.

Hudson Bay Lowland

Close similarity with the fauna of southern Manitoba is indicated by the following taxa in the Bad Cache Rapids Group, being described by Nelson (in press): **Grewingkia robusta,** a new species of **Grewingkia** with circular cross-section and a finer axial structure than **G. crassa** or **G. dilata,** and a new species of **Deiracorallium** resembling **D. delicatum** but having a coarser axial structure and tabulae that are more convex and distantly spaced. Both these new species have broader cardinal fossulae than similar forms in southern Manitoba. Diversity is greater in the Selkirk Member, Red River Formation, than in the Bad Cache Rapids Group.

Northwest Territories

Grewingkia crassa and **G. robusta** are known from the Bad Cache Rapids Formation, Melville Peninsula, District of Franklin. The stratigraphic position of most solitary corals of Red River affinity described from localities in the District of Franklin is unknown. The microstructure of **G. haysii** from Ellesmere Island and Baffin Island is similar to **Lobocorallium trilobatum** of the Stony Mountain Formation, suggesting that it may be younger than solitary corals from the Red River Formation. The septal dilation and microstructure of **G. arctica** from Baffin Island compares with that of **G. robusta** in the Surprise Creek Formation of Hudson Bay Lowland, which may be slightly younger than the Selkirk Member. **G. crassa** is recognized from Akpatok Island. **Bighornia** is known from Melville Peninsula, Baffin Island, and Ellesmere Island. Miller et al. (1954, Pl. 7, fig. 1-10) figured **Streptelasma** spp. from shale at Silliman's Fossil Mount, Baffin Island. Generic and specific assignments cannot be made without sectioning the specimens, but the calice in their Plate 7, figure 6 resembles **Grewingkia.** The corals vary from circular to triangulate in cross-section, suggesting a similar stage of development as those of the Selkirk Member. Roy (1941, p. 68, 69, fig. 34a-f) described and figured **Streptelasma** sp. I-III also from Silliman's Fossil Mount. Again, sections are needed for classification. **Streptelasma** sp. II is trilobate.

Alaska

Oliver et al. (1975, p. 13-15, 23, 24) reported **Grewingkia** from the Yukon-Nation Rivers area, and **Bighornia** and **Deiracorallium** from the Porcupine River area of east-central Alaska. **Bighornia** was listed from the Seward Peninsula of western Alaska. The Bighorn-Red River affinity of the coral assemblages was noted, but comparison cannot yet be made at the specific level. These occurrences may be younger than the Red River Formation.

Northwestern Greenland

Solitary corals from the Cape Calhoun Formation of Troedsson (1928) are similar to those of the Selkirk Member, with **Grewingkia crassa** and **G. haysii** present in both units. **Helicelasma** is represented by **H. poulseni, Deiracorallium** by **D. amplum,** and **Bighornia** by **Streptelasma** aff. **S. breve** and possibly **S. ? oppletum. Streptelasma,** absent in the Selkirk Member, may be represented by **S. cylindricum.** Unfortunately, much of this material was collected from talus, and its exact stratigraphic position is unknown. Most of the specimens are from the upper part of the Troedsson Cliff Formation and the Cape Calhoun Formation as presently recognized (Peel and Hurst, 1980). The septal dilation and microstructure of one specimen of **G. haysii** suggests that it may be the same age as the Surprise Creek Formation of Hudson Bay Lowland.

Northeastern Greenland

Scrutton (1975, p. 15-17) described **Streptelasma** and **Helicelasma** from the Centrum Formation, which may correlate with the Red River Formation. Notable is the absence of **Grewingkia** and presence of **Streptelasma.** At the specific level, Scrutton (1975, p. 12) noted that the faunal similarity between North America and northeastern Greenland appears to be stronger than between Greenland and Europe.

Scandinavia and the Baltic Region

Upper Ordovician solitary rugose corals of this area are well known through the work of Kaljo (1960, 1961) and Neuman (1969, 1975). **Deiracorallium** and **Lobocorallium** do not occur in Baltoscandia. The triangulate, trilobate, and compressed corals characteristic of the Red River-Stony Mountain faunal province are not present. Tabellae are well developed in the septal region of Red River species of **Grewingkia** and **Helicelasma,** but are absent or poorly developed in Baltoscandian species of these genera. In general, Red River corals are larger than those present in Baltoscandia.

SYSTEMATIC PALEONTOLOGY

Order Rugosa Milne-Edwards and Haime, 1850

Suborder Streptelasmatina Wedekind, 1927

Superfamily Zaphrenticae Milne-Edwards and Haime, 1850

Family Streptelasmatidae Nicholson in Nicholson and Lydekker, 1889

Genus **Grewingkia** Dybowski, 1873

1969 **Grewingkia** Dybowski. Neuman, p. 33-36.

1974 **Grewingkia** Dybowski. McLean, p. 42-44.

Type species (by subsequent designation). **Clisiophyllum buceros** Eichwald, 1856, p. 108; selected by Sherzer (1891, p. 284) (see Kaljo, 1961, p. 53).

Diagnosis. Coral solitary, ceratoid to trochoid or cylindrical, weakly to strongly curved, of small to large size. Cross-section generally circular, but may be triangulate to trilobate and compressed. Calice shallow to deep, usually with weakly to very strongly convex calicular boss.

Cardinal septum on convex side of coral. Major septa moderately to completely dilated in early ontogenetic stages, rarely dilated in later stages. Minor septa confined to or extend well beyond a narrow to broad stereozone. Large, coarse to fine axial structure of numerous septal lobes and lamellae in later stages. Tabellae may occur in septal region. Tabulae in axial region usually complete, numerous, and weakly to strongly convex upward.

Species and occurrences. **Grewingkia** is known from the Middle Ordovician of Scandinavia (B. Neuman, personal communication, 1976), upper Middle (?) and Upper Ordovician of North America, Upper Ordovician of Scotland, Ireland, Sweden, Norway, Estonia, Russian Platform, Tadzhikistan, Kazakstan, Sayans, Altai (Kaljo and Klaamann, 1973), southern China (Yi, 1974), and New South Wales, and Lower Silurian of New South Wales, western North Greenland, Iran, and possibly Tadzhikistan. The following species can be assigned to the genus (modified and expanded from Neuman, 1969, p. 33):

1856 **Clisiophyllum buceros** Eichwald, p. 108.

Type stratum and locality unknown (Kaljo, 1961, p. 54). Upper Ordovician: Pirgu and possibly Porkuni formations, Estonia; Division 5a, Oslo region, Ringerike area, and Skien-Langesund area, Norway.

1858 **Petraia rustica** Billings, p. 168, 169.

Upper Ordovician: "Hudson River Group", Snake Island, Lake St. John, Quebec.

1860 **Clisiophyllum eminens** Eichwald, p. 552, 553, Pl. 29, fig. 15.

[partim] = **Streptelasma giganteum** Kaljo, 1958
[partim] = **Grewingkia europaeum hosholmensis** Kaljo, 1961 (see Fedorowski and Gorianov, 1973, p. 6-11). Upper Ordovician: Estonia.

1861 **Streptelasma europaeum** Roemer, p. 16, Pl. 4, fig. 1a-f.

Upper Ordovician: Vormsi and Pirgu formations, Estonia; Stinchar Limestone Group, Girvan, Scotland; Portrane Limestone, Ireland.

1862 **Zaphrentis canadensis** Billings, p. 105, 106, fig. 93a-c.

Upper Ordovician: Drummond Island, Michigan, U.S.A.

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

Upper Middle or Upper Ordovician: Cape Frazier, Ellesmere Island, and Mt. Nautilus, Baffin Island, District of Franklin; Selkirk Member, Red River Formation, southern Manitoba; Caution Creek and Chasm Creek formations, Hudson Bay Lowland, northern Manitoba; Cape Calhoun Formation, Cape Calhoun, north-western Greenland.

1873 **Grewingkia anthelion** Dybowski, p. 388, Pl. 2, fig. 6, a.

Upper Ordovician: Vormsi Formation, Estonia.

1873 **Grewingkia formosa** Dybowski, p. 388-390, Pl. 2, fig. 5, a, b.

Upper Ordovician: Estonia.

1896 **Streptelasma robustum** Whiteaves, p. 390, 391.

Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, southern Manitoba; members 1 and 2, Portage Chute Formation, and member 1 and lower member, Surprise Creek Formation, Hudson Bay Lowland, northern Manitoba; Bad Cache Rapids Formation, Melville Peninsula, District of Franklin.

1931 **Streptelasma ? arcticum** Wilson, p. 292, 293, Pl. 2, figs. 1-5.

Upper Middle or Upper Ordovician: drift, Lake Nettilling at Anderson Headland, Fossil Island, Snowgoose Bay, Koukjuak Bay, Amadjuak Lake, Camp Kungovik, all on Baffin Island, District of Franklin; Akpatok Island, District of Franklin.

1933 **Kiaerophyllum anguineum** Scheffen, p. 23, Pl. 3, fig. 3, 4.

Upper Ordovician: Division 5a, Ringerike area, Norway.

1958 **Grewingkia lutkevitschi** Reiman, p. 35, 36, Pl. 1, fig. 1-3.

Upper Ordovician: Rakvere Formation, Leningrad region, Russian Platform, U.S.S.R.

1960 **Grewingkia whitei** Pestana, p. 868, Pl. 111, fig. 1, 2, 6.

Upper Middle (?) Ordovician: Johnson Spring Formation, Independence Quadrangle, California, U.S.A.

1960 **Brachyelasma altaica** Tcherepnina, p. 387, 388, Pl. 0-10, fig. 3a, b.

Upper Ordovician: Altai Gornoy (Upper Caradocian, Altai and Salair, southwestern Siberia, U.S.S.R.) (McLean, 1974, p. 47).

1961 **Streptelasma (Grewingkia) europaeum hosholmensis** Kaljo, p. 58, 59, fig. 3, Pl. 3, fig. 1-15.

Upper Ordovician: Pirgu Formation, Estonia.

1965 **Grewingkia hibernica** Kaljo and Klaamann, p. 420, 421, Pl. 1, fig. 12-14.

Upper Ordovician: Portrane Limestone, Ireland.

1969 **Grewingkia bilateralis** Neuman, p. 39-43, fig. 31a-j, 32a-g, 33a, b.

Upper Ordovician: Boda Limestone, Siljan district, Sweden.

1969 **Grewingkia contexta** Neuman, p. 43-48, fig. 34a-f, 35a-c, 36a-f, 37a-k, 38.

Upper Ordovician: Boda Limestone, Siljan district, Sweden.

1970 **Grewingkia alternata** Saleh in Flügel and Saleh, p. 293, 294, fig. 4, Pl. 2, fig. 4.

Llandovery: Niur Formation, northeastern Iran.

1971 **Grewingkia dentiseptata** Lavrusevich, p. 49, 50, Pl. 1, fig. 2a, b.

Upper Ashgill or lower Llandovery (McLean, 1974, p. 43): horizon B, Zeravshan-Gissar region, Tadzhikistan, U.S.S.R.

1974 **Grewingkia parva** McLean, p. 44, 45, fig. 2a, b, Pl. 1, fig. 7-10.

Upper lower or lower middle Llandovery: Brown Mudstone horizon, Angullong district, New South Wales, Australia.

1974 **Grewingkia neumani** McLean, p. 46, 47, fig. 3, Pl. 1, fig. 11, 12, Pl. 2, fig. 1.

Upper lower or lower middle Llandovery: Brown Mudstone horizon, Angullong district, New South Wales, Australia.

1975 **Grewingkia** sp. McLean and Webby, p. 235, Pl. 26, fig. 9-12.

Upper Ordovician: limestone breccia in Malachi's Hill beds and limestone lens in Angullong Tuff, central New South Wales, Australia.

1975 **Grewingkia granosa** Lavrusevich, p. 26, 27, Pl. 1, fig. 1a-d.

Upper Ordovician: Zeravshan-Gissar region, Tadzhikistan, U.S.S.R.

1975 **Grewingkia contexta gissarensis** Lavrusevich, p. 29, Pl. 1, fig. 2a, b, 3.

Upper Ordovician: Zeravshan-Gissar region, Tadzhikistan, U.S.S.R.

1975 **Grewingkia voruense** Lavrusevich, p. 29, 30, Pl. 1, fig. 4a-c.

Upper Ordovician: Zeravshan-Gissar region, Tadzhikistan, U.S.S.R.

1975 **Grewingkia obichundensis** Lavrusevich, p. 30, 31, Pl. 1, fig. 5a, b.

Upper Ordovician: Zeravshan-Gissar region, Tadzhikistan, U.S.S.R.

1975 **Grewingkia** sp. Oliver, Merriam and Churkin, Pl. 5, fig. 4, 5.

Upper Ordovician: Yukon-Nation Rivers area, east-central Alaska, U.S.A.

1977 **Grewingkia cuneata** McLean, p. 11, 12, Pl. 1, fig. 8, 10, 12.

Upper Llandovery: Cape Schuchert Formation, western North Greenland.

1979 **Grewingkia** sp. Bolton in Bolton and Nowlan, p. 6, Pl. 1, fig. 1, 3, 4.

Upper Upper Ordovician: outlier north of Aberdeen Lake, District of Keewatin.

Grewingkia crassa n. sp.

Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, southern Manitoba; Bad Cache Rapids Formation, Melville Peninsula, District of Franklin; Akpatok Island, District of Franklin; Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

Grewingkia dilata n. sp.

Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, southern Manitoba.

Grewingkia lamellosa n. sp.

Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, southern Manitoba.

Discussion. **Lobocorallium** Nelson (1963, p. 34, 35) was proposed to include the trilobate corals **Streptelasma rusticum** var. **trilobatum** (type species), **S. goniophylloides**, and **Lobocorallium trilobatum** var. **major.** The last two species have ontogenies and axial structures characteristic of **Grewingkia**, as discussed under **G. haysii**. Trilobation appears within several species of **Grewingkia** and **Deiracorallium**, as well as in **Lobocorallium.** The following material of **Streptelasma rusticum** var. **trilobatum** Whiteaves, 1895 from the Stony Mountain Formation at Stony Mountain, southern Manitoba, has been examined: GSC 6825 (collected by T.C. Weston in 1884; this specimen is probably a syntype), 60757, 60763-60771. Unlike **Grewingkia**, the major septa are completely dilated until immediately below the calice, and the axial structure in later stages consists of only a few strongly to completely dilated septal lobes. **Lobocorallium trilobatum** is the only known species of the genus.

Grewingkia differs from other Ordovician genera in having a large axial structure composed of numerous septal lobes and lamellae. In **Densigrewingkia** Neuman, 1969 the cardinal septum is on the concave side of the coral and the septal lobes and lamellae are connected by stereoplasmatic deposits until late ontogenetic stages.

Grewingkia crassa n. sp.

(Plate 1, fig. 1-10)

1901 **Streptelasma robustum** Whiteaves. Lambe, Pl. 7, fig. 1.

1928 **Streptelasma rusticum** (Billings). Troedsson [partim], Pl. 24, fig. 9.

1937 **Streptelasma robustum** Whiteaves. Cox, p. 10, 11, Pl. 2, fig. 1, 3, [?] 2.

1977 **Streptelasma oppletum** Teichert. Bolton, p. 28, Pl. 1, fig. 3-5.

Derivation of name. The specific name refers to the coarse axial structure.

Holotype. GSC 60707, Garson, Manitoba (Pl. 1, fig. 1-10).

Paratypes. GSC 60708-60710, Garson, Manitoba. GSC 60711, 60712, Garson, Manitoba, Rand Collection. GSC 60713, Garson, Manitoba, Elias Collection. GSC 60714, 60715, Garson Limestone Co. Ltd. quarry, Garson, Manitoba, Elias Collection.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson, East Selkirk and Lower Fort Garry, southern Manitoba; Bad Cache Rapids Formation, Melville Peninsula, District of Franklin; Akpatok Island, District of Franklin; Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

Diagnosis. Coral trochoid, weakly to strongly curved, and attains large size. Cross-section circular to triangulate to weakly trilobate. Calice of moderate depth with weakly to moderately convex calicular boss.

Coarse axial structure of septal lobes and lamellae. Major septa moderately dilated near tip. Minor septa usually extend a short distance beyond a narrow to moderately broad stereozone. Tabellae in septal region. Tabulae in axial region mostly complete, thin, numerous, relatively widely spaced, and weakly to moderately convex upward.

Description of corals. The largest specimen examined (GSC 60707) is 10 cm long and has a cross-sectional area of 1726 mm^2 immediately below the calice where 71 major septa are present. The corals are trochoid, and only GSC 60712 tends to become cylindrical in later stages (Fig. 8a). Curvature is weak (GSC 60708) to strong (GSC 60712). In cross-section the corals vary from circular (GSC 60714) to triangulate (GSC 60707) to weakly trilobate (GSC 60710). GSC 60708 is unique in being strongly lobate on one alar side but semicircular to angulate on the other alar side. Maximum triangulation or trilobation is at about 2.25 cm; above this it decreases and usually disappears. Rugae are sometimes preserved on the epitheca. The calice has a depth equal to 0.2 (GSC 60707, 60710) to 0.3 of the coral length (GSC 60708, 60714). The calicular boss is weakly (GSC 60712) to moderately convex (GSC 60710).

Ontogeny and internal structures. Up to a height of about 0.8 cm the major septa extend to the axis. Above this a coarse axial structure of septal lobes appears, followed by lobes and lamellae. GSC 60712 is unique in that above about 4.4 cm the major septa become short and the axial region becomes large with a few septal lobes in the periphery and thin septal lamellae concentrated axially. In GSC 60708 the major septa extend to the axis until immediately below the calice, where a coarse axial structure of septal lobes and lamellae is present.

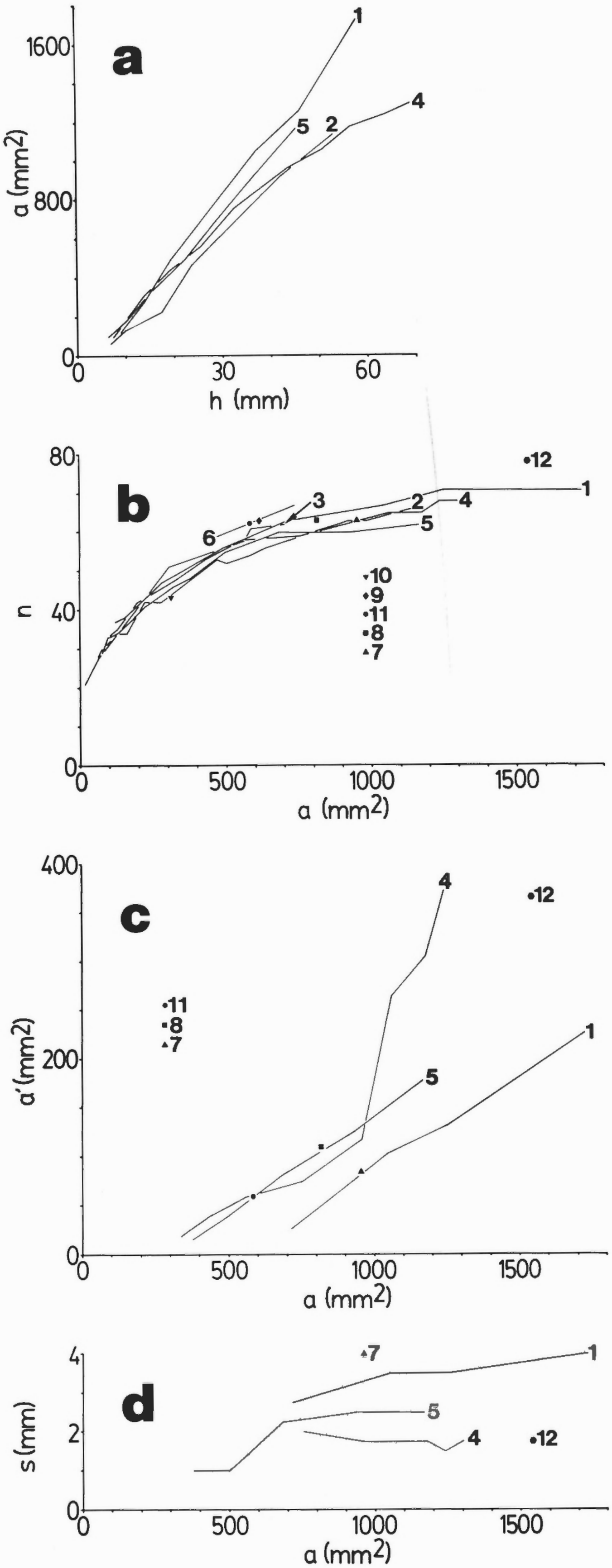

Figure 8. Biometrical relationships, ***Grewingkia crassa*** *n. sp. a, Coral cross-sectional area vs. height; b, number of major septa vs. coral cross-sectional area; c, cross-sectional area of axial structure vs. coral cross-sectional area; d, width of stereozone plus epitheca if preserved vs. coral cross-sectional area. GSC 60707, 60708, 60710, 60712, 60714, 60715 (1-6), Selkirk Member, Garson, Manitoba. Lambe, 1901 (7), Selkirk Member, East Selkirk, Manitoba. Sedgwick Mus., Cambridge, No. A7863 (8), Selkirk Member, Lower Fort Garry, Manitoba. GSC 42906, 42907 (9, 10), Bad Cache Rapids Formation, Melville Peninsula, District of Franklin. Sedgwick Mus. No. A7865 (11), Akpatok Island, District of Franklin. MMH 2982 (12), Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.*

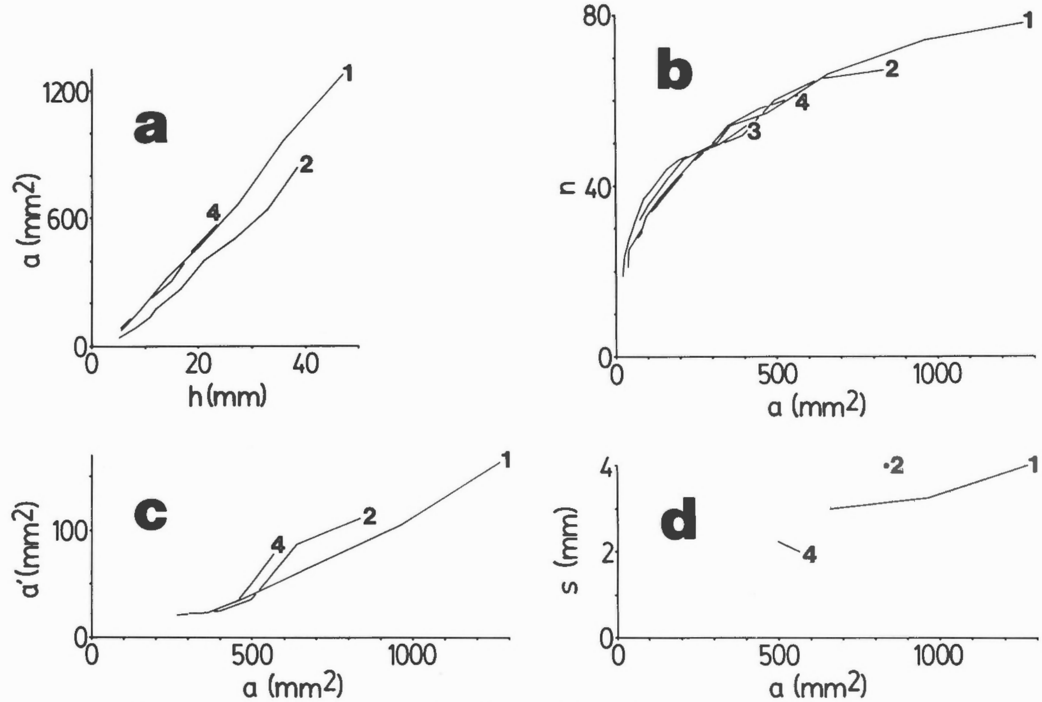

Figure 9. *Biometrical relationships,* ***Grewingkia dilata*** *n. sp. a, Coral cross-sectional area vs. height; b, number of major septa vs. coral cross-sectional area; c, cross-sectional area of axial structure vs. coral cross-sectional area; d, width of stereozone plus epitheca if preserved vs. coral cross-sectional area. GSC 60716, 60717, 60719, 60720 (1-4), Selkirk Member, Garson, Manitoba.*

Up to 1 cm above the tip the major septa are almost completely dilated. Dilation decreases upward, and tends to be strongest on the cardinal side (especially in GSC 60714). Septa in GSC 60708 are strongly dilated until immediately below the calice. Dilation of the counter septum is stronger than the other septa near the calice in GSC 60712. The cardinal septum is long and the cardinal fossula is narrow. Minor septa usually extend a short distance beyond the stereozone, but may be confined to the stereozone or extend beyond it for a distance equal to its width. The stereozone is narrow (GSC 60712) to moderately broad (GSC 60707) (Fig. 8d).

Tabellae appear less than 1 cm above the tip in the septal region. They are thin and very steeply inclined up toward the axis in early stages and become less steeply inclined with increased height in the coral. They are approximately horizontal near the calice in GSC 60712. In the upper portion of the coral the tabellae are widely spaced. Tabellae are present in the cardinal fossula.

A few thick, irregular tabulae are present in the axial region in early stages. Between about 2.3 cm (GSC 60714) and 3.5 cm above the tip (GSC 60712) thin tabulae appear in the axial region. They appear at about 5 cm in GSC 60708. They are mostly complete, numerous, relatively widely spaced, and weakly (GSC 60712) to moderately convex upward (GSC 60707), but may be somewhat irregular (GSC 60708, 60710).

Discussion. Lambe (1901, Pl. 7, fig. 1) figured a cross-section of **Streptelasma robustum** from East Selkirk that has a similar number of septa at a particular cross-sectional area as **Grewingkia crassa** (Fig. 8b). It is included in this species, although it has a slightly finer axial structure than is typical. Troedsson's (1928, Pl. 24, fig. 9) cross-section identified as **Streptelasma rusticum** from Greenland has a similar axial structure and number of septa at a particular area as **G. crassa** (Fig. 8b). Cox (1937, Pl. 2, fig. 1, 3) figured cross-sections of **S. robustum** from Lower Fort Garry and Akpatok Island having the axial structure and number of septa at a particular area characteristic of this species (Fig. 8b), but his longitudinal section (Cox, 1937, Pl. 2, fig. 2) from Tyndall, near Garson, Manitoba, cannot be assigned with certainty. **Streptelasma oppletum**, described and illustrated from Melville Peninsula by Bolton (1977), has the axial structure and number of septa at a particular area characteristic of **G. crassa** (Fig. 8b).

Grewingkia crassa differs from other species of the genus in having a very coarse axial structure. **G. dilata** has stronger septal dilation in early stages, a finer axial structure, and more septa at a particular cross-sectional area (Fig. 3, 8b, 9b). A new species of **Grewingkia** being described from the Bad Cache Rapids Group in Hudson Bay Lowland (Nelson, in press) is circular in cross-section and has a finer axial structure and broader cardinal fossula.

Grewingkia dilata n. sp.

(Plate 2, fig. 1-18)

Derivation of name. The specific name refers to the strongly to completely dilated major septa in early ontogenetic stages.

Holotype. GSC 60716, Garson, Manitoba (Pl. 2, fig. 1-8).

Paratypes. GSC 60717 (Pl. 2, fig. 9-18), 60718-60720, Garson, Manitoba, Rand Collection.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson, southern Manitoba.

Diagnosis. Coral trochoid, moderately to strongly curved, weakly triangulate, and attains moderately large size. Calice of moderate depth with weakly to very strongly convex calicular boss.

Moderately coarse axial structure with septal lobes in periphery and septal lamellae axially. Major septa strongly to completely dilated near tip. Minor septa generally confined to a moderately broad stereozone. Tabellae in septal region. Tabulae in axial region mostly complete, thin, numerous, fairly closely spaced, and weakly to moderately convex upward.

Description of corals. The largest specimen examined (GSC 60716) is 8.3 cm long and has a cross-sectional area of 1270 mm^2 two cm below the calice where 78 major septa are present. The corals are trochoid and moderately (GSC 60720) to strongly curved (GSC 60717). They are weakly triangulate. Maximum triangulation is at a height of about 1.5 cm; above this it decreases but does not completely disappear. Rugae and growth lines are preserved, particularly on the smaller corals. The calice has a depth equal to 0.2 (GSC 60716) to 0.25 of the coral length (GSC 60720). The calicular boss is weakly (GSC 60716) to very strongly convex (GSC 60720).

Ontogeny and internal structures. Up to a height of about 0.6 cm the major septa extend to the axis. Above this a moderately coarse axial structure of septal lobes appears, followed by lobes and lamellae. Above about 4 cm very few septal lobes are present in the periphery of the axial structure, and septal lamellae are concentrated axially.

Up to about 1.7 cm (GSC 60716, 60720) to 2.1 cm above the tip (GSC 60717) the major septa are very strongly to completely dilated. Dilation gradually decreases upward. The cardinal septum is long and the cardinal fossula is narrow. Minor septa are generally confined to the stereozone, but may extend a very short distance beyond it (GSC 60716). The stereozone is moderately broad (Fig. 9d).

Tabellae appear less than 0.5 cm above the tip in the septal region. They are thin, steeply inclined upward toward the axis in early stages and become less steeply inclined with increased height in the coral. They are approximately horizontal near the calice of GSC 60716. In later stages the tabellae are moderately to widely spaced. Tabellae are present in the cardinal fossula.

A few thick, irregular tabulae are present in the axial region in early stages. Between about 2.2 cm (GSC 60716) and 4.1 cm above the tip (GSC 60717) thin tabulae appear in the axial region. They are mostly complete, numerous, fairly closely spaced, and weakly (GSC 60716) to moderately convex upward (GSC 60717).

Discussion. **Grewingkia dilata** differs from **G. robusta** in having stronger septal dilation in early stages, a coarser axial structure, and fewer septa at any particular cross-sectional area (Fig. 3, 9b, 10b). A new species of **Grewingkia** being described from the Bad Cache Rapids Group in Hudson Bay Lowland (Nelson, in press) is circular in cross-section and has a finer axial structure and broader cardinal fossula.

Grewingkia robusta (Whiteaves, 1896)

(Plate 3, fig. 1-12; Plate 4, fig. 1-14)

1881 **Streptelasma corniculum** ? Hall. Whiteaves, p. 57c.

1896 **Streptelasma robustum** Whiteaves, p. 390, 391.

1897 **Streptelasma robustum** Whiteaves. Whiteaves, p. 153-155, Pl. 18, fig. 1, a.

1901 [non] **Streptelasma robustum** Whiteaves. Lambe, Pl. 7, fig. 1.

1937 [non] **Streptelasma robustum** Whiteaves. Cox, p. 10, 11, Pl. 2, fig. 1-3.

1959 **Grewingkia robusta** (Whiteaves). Nelson, Pl. 1, fig. 2a, b.

1963 **Grewingkia robusta** (Whiteaves). Nelson, p. 33, 34, Pl. 8, fig. 1a, b, 2, 3a-f.

1963 **Lobocorallium goniophylloides** (Teichert). Nelson, p. 35, Pl. 9, fig. 1a, b, 2a-c, 3a, b, 4.

1977 **Grewingkia robusta** (Whiteaves). Bolton, p. 28, Pl. 1, fig. 1, 8-10.

Figures of the following are insufficient for assignment to this species:

1928 **Streptelasma robustum** Whiteaves. Troedsson, Pl. 24, fig. 1, 2, 4, 6-8, Pl. 25, fig. 2.

Upper Middle or Upper Ordovician: Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

1931 **Streptelasma** cf. **robustum** Whiteaves. Wilson, p. 294, Pl. 1, fig. 7.

Upper Middle or Upper Ordovician: drift, Snowgoose Bay and Lake Nettilling, Baffin Island, District of Franklin.

1960 **Grewingkia** cf. **robusta** (Whiteaves). Brindle, p. 15, Pl. 1, fig. 1, 2.

Upper Middle or Upper Ordovician: Yeoman Formation, southern Saskatchewan.

The species has been listed from the following localities, but assignment is impossible because the specimens were not sectioned:

1899 **Streptelasma robustum** Whiteaves. Whiteaves, p. 433, 434.

Upper Middle or Upper Ordovician: Akpatok Island, District of Franklin.

1907 **Streptelasma robustum** Whiteaves. Lambe, p. 6.

Upper Middle or Upper Ordovician: Southampton Island, District of Keewatin.

1957 **Streptelasma (Grewingkia) robustum** (Whiteaves). Ross, p. 453.

Upper Middle or Upper Ordovician: Bighorn Group, Dawson County, Montana, U.S.A.

Lectotype (designated herein). GSC 6886, East Selkirk, Manitoba, collected by A. McCharles, 1884 (Whiteaves, 1897, Pl. 18, fig. 1, a; Pl. 3, fig. 1-3 herein).

Other specimens. GSC 60721, Garson, Manitoba (Pl. 4, fig. 5-14). GSC 60722, 60723 (Pl. 3, fig. 4-12), Garson, Manitoba, Elias Collection. GSC 60724, Garson Limestone Co. Ltd. quarry, Garson, Manitoba, Elias Collection. GSC 60725, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection (Pl. 4, fig. 1-4).

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, East Selkirk and Garson, southern Manitoba; members 1 and 2, Portage Chute Formation, and member 1 and lower member, Surprise Creek Formation, Hudson Bay Lowland, northern Manitoba; Bad Cache Rapids Formation, Melville Peninsula, District of Franklin.

Whiteaves (1897, p. 154) reported "a few comparatively small and very imperfect specimens, which may be referable to this species" from the Dog Head Member, Red River Formation, western shore and islands of Lake Winnipeg.

Diagnosis. Coral trochoid, moderately to strongly curved, and attains large size. Cross-section circular to weakly triangulate to weakly trilobate. Calice shallow to moderately deep with weakly to moderately convex calicular boss.

Large, fine axial structure with septal lobes in periphery and septal lamellae axially. Major septa moderately to strongly dilated near tip. Minor septa extend beyond a narrow stereozone. Tabellae in septal region. Tabulae in axial region mostly complete, thin, numerous, closely spaced, and weakly to moderately convex upward.

Description of corals. The largest specimen examined (GSC 6886) is 14 cm long and has a cross-sectional area of approximately 1825 mm^2 at a height of 8.5 cm where about 92 major septa are present. The corals are trochoid; GSC 6886 and 60721 tend to become cylindrical above 8.5 and 4.6 cm respectively (Fig. 10a). They are moderately (GSC 60721) to strongly curved (GSC 60723). In cross-section the corals vary from circular (GSC 60723) to weakly triangulate (GSC 6886, 60722) to weakly trilobate (GSC 60721, 60725). Maximum triangulation or trilobation is at about 2.5 cm above the tip; above this it decreases but does not usually completely disappear. GSC 60721 is slightly compressed throughout its length, with maximum compression at about 6.3 cm where the cross-sectional length-width ratio is 1.18. Rugae are sometimes preserved on the epitheca. The calice has a depth equal to 0.1 (estimated in GSC 60722) to 0.25 of the coral length (GSC 60723). The calicular boss is weakly (presumably in GSC 60721) to moderately convex (GSC 60723).

Ontogeny and internal structures. Up to a height of about 0.4 cm the major septa extend to the axis. Above this a fine or coarse (GSC 60725) axial structure of septal lobes appears, followed soon by lobes and lamellae. Above about 2.5 cm (GSC 60722, 60723, 60725) or 3.5 cm (GSC 60721) thin septal lobes are present in the periphery of the axial structure and a dense concentration of fine septal lamellae occurs axially.

Near the tip the major septa are moderately to very strongly dilated. Dilation decreases upward, and is generally strongest on the cardinal side. Dilation of the cardinal and counter septa is usually stronger than the other septa in GSC 60721. The cardinal septum is long and the cardinal fossula is narrow. Minor septa are confined to the stereozone in early stages. In later stages they extend beyond it for a short distance (GSC 6886) to a distance equal to or slightly greater than its width (GSC 60722). The stereozone is narrow (Fig. 10d).

Tabellae appear less than 0.5 cm above the tip in the septal region. They are thin and steeply inclined upward toward the axis in early stages and become less steeply inclined with increased height in the coral. They are approximately horizontal in the uppermost portion of GSC 60721. In the upper portion of the coral the tabellae are closely to moderately spaced. Tabellae are present in the cardinal fossula.

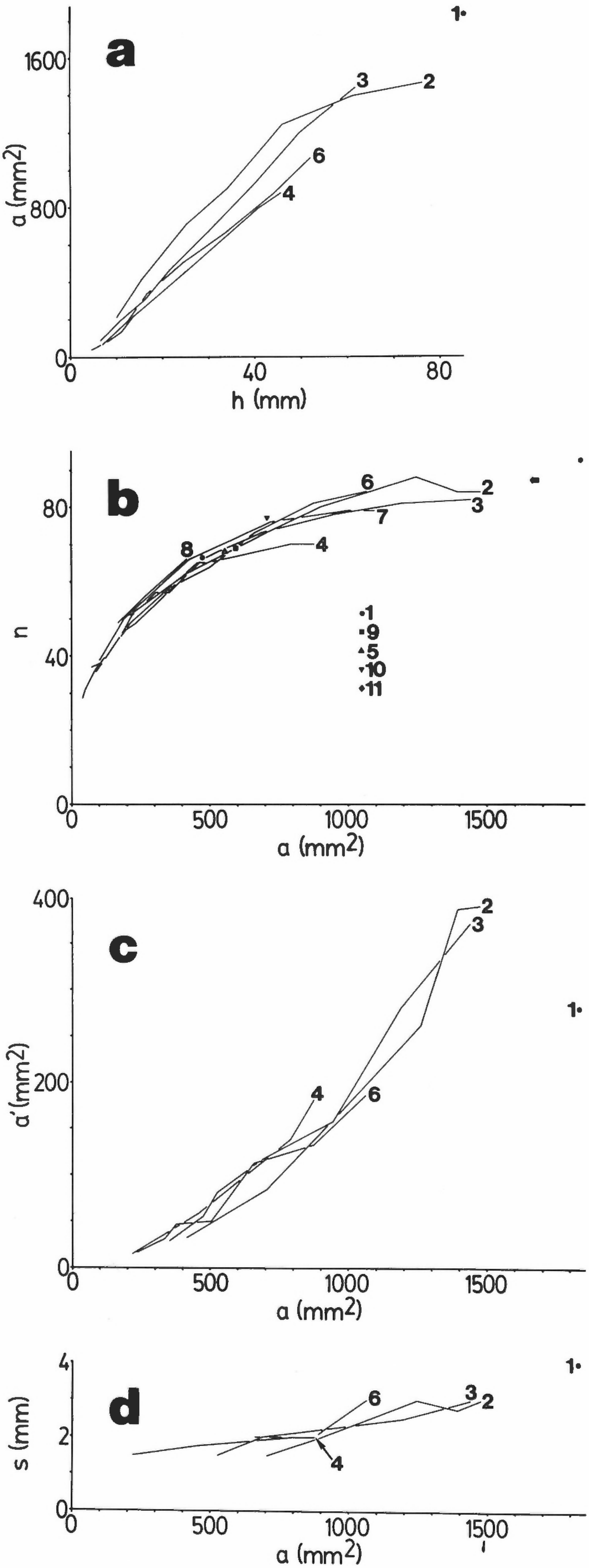

*Figure 10. Biometrical relationships, **Grewingkia robusta** (Whiteaves, 1896). a, Coral cross-sectional area vs. height; b, number of major septa vs. coral cross-sectional area; c, cross-sectional area of axial structure vs. coral cross-sectional area; d, width of stereozone plus epitheca if preserved vs. coral cross-sectional area. GSC 6886 (1), Selkirk Member, East Selkirk, Manitoba. GSC 60721-60725 (2-6), Selkirk Member, Garson, Manitoba. GSC 10807 (7), member 2, Portage Chute Formation, northern Manitoba. GSC 10793, 10795 (8, 9), member 1, Surprise Creek Formation, northern Manitoba. GSC 42902, 42903 (10, 11), Bad Cache Rapids Formation, Melville Peninsula, District of Franklin.*

A few thick, irregular tabulae are present in the axial region in the lower portion of the coral. Between about 2.5 cm (GSC 60725) and 4.0 cm above the tip (GSC 6886) thin tabulae appear in the axial region. They are mostly complete, numerous, closely spaced, and weakly (GSC 60721) to moderately convex upward (GSC 60723). They are somewhat irregular in GSC 6886.

Discussion. **Streptelasma robustum** of Lambe (1901) and Cox (1937) is included in **Grewingkia crassa**. **G. robusta** described by Nelson (1963) from the Portage Chute Formation of northern Manitoba is conspecific with the form in southern Manitoba. Nelson (1963, p. 34) distinguished the triangulate **G. robusta** and his weakly trilobate **Lobocorallium goniophylloides** of the Surprise Creek Formation on the basis of external form, noting that they are very similar internally. This range of external form is found within **G. robusta** in the Selkirk Member, and **L. goniophylloides** of Nelson (1963) is considered conspecific with it. **G. robusta** from Melville Peninsula (Bolton, 1977) has an axial structure and number of septa at a particular cross-sectional area (Fig. 10b) similar to corals from the type locality.

G. robusta differs from other species of the genus in having an axial structure composed of thin septal lobes in the periphery and a dense concentration of fine septal lamellae axially. **G. haysii** has a similar axial structure but dilation of the septa is stronger throughout ontogeny.

Grewingkia haysii (Meek, 1865)

(Plate 5, fig. 1-15; Plate 6, fig. 1-12)

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

1925 **Streptelasma haysii** (Meek). Kirk, p. 445.

1928 **Streptelasma foerstei** Troedsson, p. 109, Pl. 25, fig. 1, 3, Pl. 26, fig. 5.

1929 **Streptelasma haysii** (Meek). Ladd, p. 396, 397, Pl. 4, fig. 3-5, [?] 1, 2.

1937 **Streptelasma foerstei** Troedsson. Cox, Pl. 1, fig. 10, 11, [?] 12-16.

1937 **Streptelasma haysii** (Meek). Cox [partim], p. 8, 9, non Pl. 2, fig. 4a, b.

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

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

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

Lectotype (designated by Ladd, 1929, p. 396, 397). USNM 25683, Cape Frazier, Ellesmere Island, District of Franklin (Pl. 5, fig. 1-5).

Other specimens. GSC 60726 (Pl. 5, fig. 6-15), 60727, Garson, Manitoba. GSC 60728 (Pl. 6, fig. 1-12), Lockport, Manitoba, Rand Collection.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson and Lockport, southern Manitoba; Caution Creek and Chasm Creek formations, Hudson Bay Lowland, northern Manitoba; Mt. Nautilus, Baffin Island, and Cape Frazier, Ellesmere Island, District of Franklin; Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

Diagnosis. Coral trochoid, weakly to strongly curved, and attains large size. Cross-section weakly to strongly trilobate. Calice shallow to moderately deep with moderately convex calicular boss.

Axial structure initially coarse with septal lobes and lamellae, becoming finer with septal lobes in periphery and dense septal lamellae axially. Major septa completely dilated near tip, dilation decreases slightly during ontogeny. Minor septa sometimes extend a short distance beyond the narrow to moderately broad stereozone. Tabellae in septal region. Tabulae in axial region mostly complete and moderately convex upward.

Description of corals. The largest specimen examined (GSC 60728) is 10 cm long and has a cross-sectional area of 1547 mm^2 immediately below the calice where 97 major septa are present. The corals are trochoid and weakly (GSC 60726) to moderately curved (GSC 60727, 60728). They are compressed throughout their length, with strongest compression at about 2.4 cm above the tip. The maximum cross-sectional length-width ratio is 1.16 (GSC 60728) to 1.27 (GSC 60727). In cross-section the corals vary from weakly (GSC 60727) to strongly trilobate (GSC 60728), with maximum development at a height of 2 cm (GSC 60726) to 3.5 cm (GSC 60727). Above this, trilobation decreases; GSC 60726 and 60727 are triangulate at the top, whereas GSC 60728 remains trilobate. Rugae are sometimes preserved on the epitheca. The calice has a depth equal to 0.16 (GSC 60726) and 0.31 of the coral length (GSC 60728). The calicular boss is moderately convex.

Ontogeny and internal structures. Up to a height of 0.4 to 0.8 cm the major septa extend to the axis. Above this a coarse axial structure of septal lobes appears, followed by lobes and lamellae. The axial structure becomes finer upward. Above 4 cm (GSC 60726, 60727) and 5.3 cm (GSC 60728) septal lobes occur in the periphery of the axial structure, and dense septal lamellae are concentrated axially.

The major septa are completely dilated near the tip and dilation decreases slightly during ontogeny. In GSC 60726 the septa are nondilated immediately below the calice. In GSC 60727 dilation immediately below the calice is slight, and in GSC 60728 it is pronounced throughout the length of the coral. The cardinal septum is long, and the cardinal fossula is narrow. In strongly trilobate sections the first several major septa on the counter side of the alar septa are short and abut against the alar septa. In nondilated to weakly dilated stages the minor septa extend a short distance beyond the stereozone. Width of the stereozone in nondilated to weakly dilated stages ranges from narrow (GSC 60726) to moderate (GSC 60727) (Fig. 11d).

Tabellae appear less than 0.5 cm above the tip in the septal region. They are thin and steeply inclined upward toward the axis in early stages and become less steeply inclined with increased height in the coral. They are approximately horizontal and widely spaced near the calice. Tabellae are present in the cardinal fossula.

A few thick, irregular tabulae are present in the axial region in early stages. Moderately convex upward, mostly complete tabulae appear in the axial region at 3.2 cm (GSC 60726), 4.9 cm (GSC 60728), and 5.4 cm above the tip (GSC 60727). They are thin, numerous, and closely spaced in GSC 60726 and 60728, and thicker, more distantly spaced, and more irregular in GSC 60727.

Discussion. Transverse thin sections of the lectotype of **Zaphrentis haysii** indicate that this species is a **Grewingkia**. The major septa are completely dilated in early stages and dilation decreases slightly during ontogeny. The axial structure initially consists of a few very coarse septal lobes. In later stages, the septal lobes are confined to the periphery of the axial structure and septal lamellae occur centrally, becoming finer at the coral axis. Ladd (1929, Pl. 4, fig. 1, 2) identified the species from the Maquoketa Formation of Iowa, but this remains uncertain because the specimen has not been sectioned. The coral from Meek's material figured by Cox (1937, Pl. 2, fig. 4a, b) is **Bighornia**, having the cardinal septum on the concave side.

A paratype of **Streptelasma foerstei** from the Cape Calhoun Formation at Cape Calhoun, northwestern Greenland (MGUH 14879), has been sectioned and appears to be conspecific with the holotype of the species, in which internal structures can be seen in the calice. Cox (1937) sectioned several paratypes of this species. Those in his Plate 1, figures 10 and 11 are conspecific with the specimen sectioned herein – those in his Plate 1, figures 12-16 may be conspecific. Sections of **G. haysii** are very similar to those at corresponding ontogenetic stages of **S. foerstei,** and **S. foerstei** is herein referred to **G. haysii.**

The holotype and only specimen of **Streptelasma goniophylloides** from Mt. Nautilus, Baffin Island, District of Franklin (MMH 3367-3370), is somewhat irregular in external form, as described by Teichert (1937, p. 49, 50). On the basis of internal structures, it is referred to **G. haysii.**

Lobocorallium trilobatum var. **major** from the Caution Creek and Chasm Creek formations of Hudson Bay Lowland, northern Manitoba, is similar ontogenetically to **G. haysii** (Nelson, 1963, Pl. 10, fig. 2a-h). The later ontogenetic stages of **L. trilobatum** var. **major** and **G. haysii** from northwestern Greenland are very similar. **L. trilobatum** var. **major** is herein referred to **G. haysii.**

The three specimens from the Selkirk Member described herein resemble **G. robusta,** but have stronger septal dilation as in **G. haysii.** Because intermediate forms between these specimens and **G. robusta** have not been found, they are referred to **G. haysii.** GSC 60728 is very similar externally to **Lobocorallium trilobatum,** but the septa and axial structure are not completely dilated throughout ontogeny. Intermediate forms between this specimen and **L. trilobatum** have not been found.

Specimens of **G. haysii** show more variation in the number of major septa at a particular cross-sectional area than other species from the Selkirk Member (Fig. 3, 11b). In general, the values are similar to those of **G. robusta** (Fig. 10b).

Grewingkia lamellosa n. sp.

(Plate 7, fig. 1-15)

Derivation of name. The specific name refers to the median septal lamella and fine septal lamellae of the axial structure.

Holotype. GSC 60740, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection (Pl. 7, fig. 1-15).

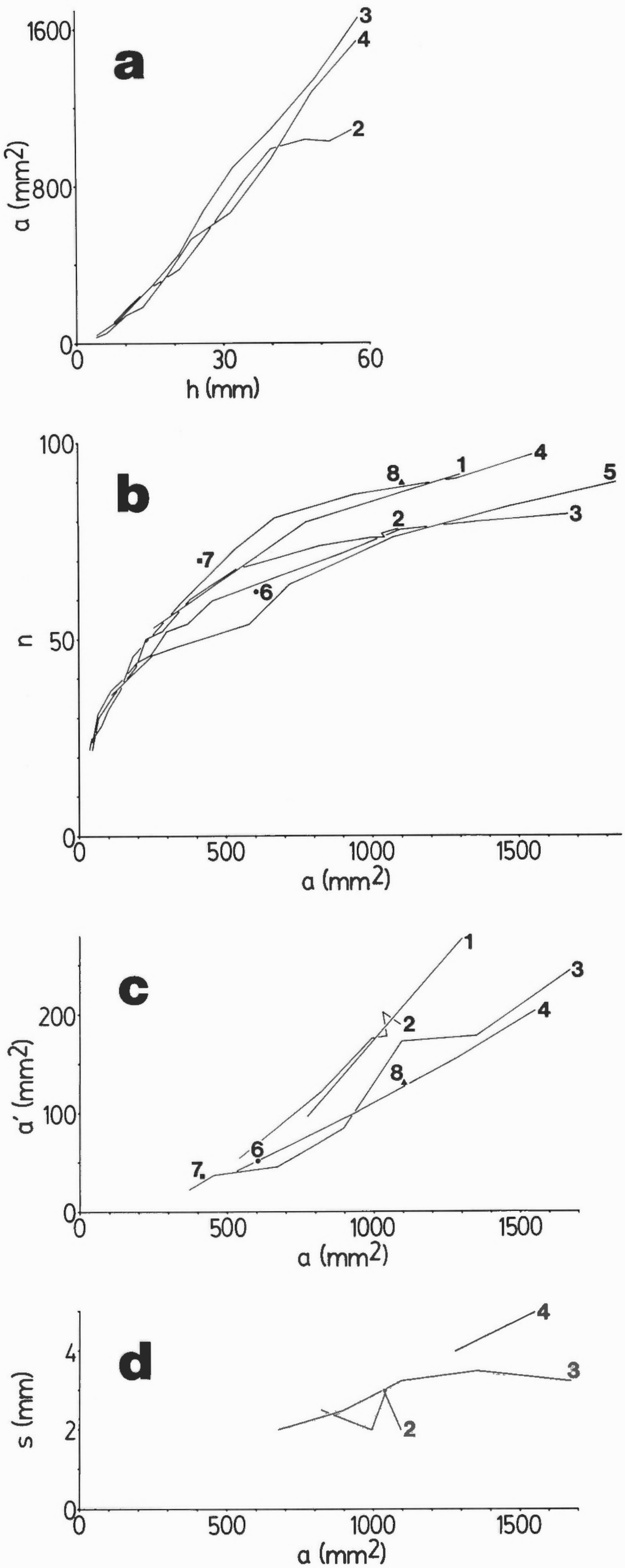

Figure 11. *Biometrical relationships,* ***Grewingkia haysii*** *(Meek, 1865). a, Coral cross-sectional area vs. height; b, number of major septa vs. coral cross-sectional area; c, cross-sectional area of axial structure vs. coral cross-sectional area; d, width of stereozone plus epitheca if preserved vs. coral cross-sectional area. USNM 25683 (1), Cape Frazier, Ellesmere Island, District of Franklin. GSC 60726, 60727 (2, 3), Selkirk Member, Garson, Manitoba. GSC 60728 (4), Selkirk Member, Lockport, Manitoba. GSC 10796 (5), member 3, Chasm Creek Formation, northern Manitoba. MMH 3368 (6), Mt. Nautilus, Baffin Island, District of Franklin. MMH 3332, 3333 (7, 8), Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.*

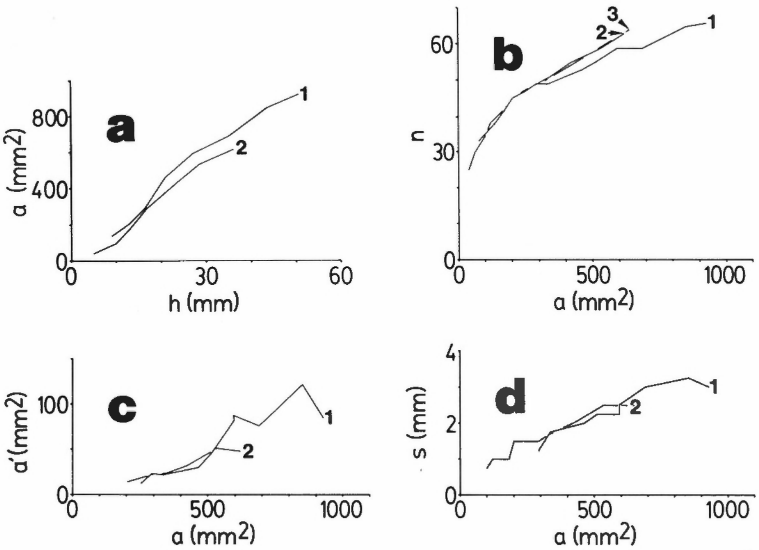

Figure 12

Biometrical relationships, ***Grewingkia lamellosa*** *n. sp. a, Coral cross-sectional area vs. height; b, number of major septa vs. coral cross-sectional area; c, cross-sectional area of axial structure vs. coral cross-sectional area; d, width of stereozone plus epitheca if preserved vs. coral cross-sectional area. GSC 60740-60742 (1-3), Selkirk Member, Garson, Manitoba.*

Paratypes. GSC 60741, 60742, Garson Limestone Co. Ltd. quarry, Garson, Manitoba, Elias Collection. GSC 60743, 60744, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson, southern Manitoba.

Diagnosis. Coral trochoid, moderately curved, and attains moderately large size. Cross-section circular to weakly triangulate, sometimes slightly compressed. Epitheca with weak septal grooves and interseptal ridges. Calice of moderate depth with moderately convex calicular boss.

Fine axial structure of a few septal lobes and lamellae, with a median septal lamella in cardinal-counter surface. Major septa moderately to strongly dilated at tip. Minor septa confined to a moderately broad stereozone or extend a short distance beyond it. Tabellae in septal region. Tabulae in axial region mostly complete, thin, fairly closely spaced, and weakly to moderately convex upward.

Description of corals. The largest specimen examined (GSC 60740) is 8.5 cm long and has a cross-sectional area of 927 mm^2 immediately below the calice where 66 major septa are present. The corals are trochoid and moderately curved. In cross-section they are circular (GSC 60740, 60741) to weakly triangulate (GSC 60742-60744). GSC 60742 is slightly compressed. Septal grooves corresponding to the major and minor septa, and interseptal ridges are weakly developed on the epitheca. Growth lines and rugae are preserved. The calice has a depth equal to 0.24 of the coral length (GSC 60740). The calicular boss is moderately convex (GSC 60740).

The holotype (GSC 60740) is unique among the Selkirk Member solitary corals examined in having an irregular lobation on one alar side beginning 1.5 cm above the tip and disappearing upwards. This feature is not a characteristic of the species.

Ontogeny and internal structures. For several millimetres above the tip the major septa extend to the axis. Upward to about 1.8 cm the axial region is open with only a few septal lobes, or may be closed because of dilation. Above about 1.8 cm an axial structure of a few fine septal lobes and lamellae develops, with septal lamellae becoming dominant upward. A median septal lamella in the cardinal-counter surface is present in most stages. Sometimes this structure is contiguous with the cardinal septum.

Near the tip, interseptal chambers may be almost absent because of septal dilation, which decreases upward to about 1.8 cm. Dilation around the open axial region produces a halo-like effect. The cardinal septum is long, and the cardinal fossula is narrow. Minor septa are confined to the moderately broad stereozone (Fig. 12d) or extend a short distance beyond it.

Tabellae appear less than 0.5 cm above the tip in the septal region. They are thin and steeply inclined upward toward the axis in early stages and become less steeply inclined with increased height in the coral. They are approximately horizontal near the calice in GSC 60741. In later stages of GSC 60740 the tabellae are widely spaced. Tabellae are present in the cardinal fossula.

A few thick, irregular tabulae are present in the axial region in early stages. At about 1.7 cm above the tip (GSC 60741) thin tabulae appear in the axial region. They are mostly complete, fairly closely spaced, and weakly (GSC 60741) to moderately convex upward (GSC 60740).

Discussion. **Grewingkia lamellosa** and **G. bilateralis** differ from other species of the genus in having a median septal lamella in the axial structure. **G. lamellosa** has a finer, less strongly dilated axial structure than **G. bilateralis.**

Genus **Helicelasma** Neuman, 1969

1969 **Helicelasma** Neuman, p. 28, 29.

Type species (by original designation). **Helicelasma simplex** Neuman, 1969, p. 29.

Diagnosis. Coral solitary, ceratoid to trochoid or cylindrical, straight to strongly curved, cross-section circular, of small to moderately large size. Calice generally deep. Calicular boss usually absent, but is weakly to strongly convex if developed.

Cardinal septum on convex side of coral. Major septa strongly to usually completely dilated near tip. Minor septa sometimes extend a short distance beyond a narrow to broad stereozone. In early ontogenetic stages major septa join at axis without contortion. In later stages a few septal lobes generally form a loose axial structure, and a few septal lamellae may be present. Tabellae in septal region. Mostly complete, slightly to moderately convex upward tabulae may be present in axial region in later stages.

Species and occurrences. **Helicelasma** is known from the upper Middle and Upper Ordovician of North America, Upper Ordovician of Scotland, Sweden, and New South Wales, and Lower Silurian of England and Iran. The following species can be assigned to the genus (modified and expanded from Neuman, 1969, p. 28, 29; 1977, p. 71):

1930 **Streptelasma whittardi** Smith, p. 312-315, fig. 7, Pl. 27, fig. 14, Pl. 28, fig. 1-20.

Lower Silurian: **Pentamerus** beds, Shropshire, southern England.

1937 **Streptelasma corniculum** Hall. Cox, p. 2-4, Pl. 1, fig. 1-4.

Upper Middle Ordovician: Middleville, New York, U.S.A.; Ottawa and Cornwall, Ontario.

1937 **Streptelasma poulseni** Cox, p. 9, 10, Pl. 2, fig. 8, 9 [see McLean and Webby, 1975, p. 233].

Upper Middle or Upper Ordovician: Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

1961 **Streptelasma tungussensis** Ivanovskiy [see Neuman, 1977, p. 71].

1969 **Helicelasma simplex** Neuman, p. 29-33, fig. 23a-g, 24a-j, 25a-f, 26.

Upper Ordovician: **Dalmanitina** beds, Borenshult, Ostergotland, Sweden.

1970 **Streptelasma ruttneri** Saleh in Flugel and Saleh, p. 287-289, fig. 1, Pl. 1, fig. 6 [see McLean and Webby, 1977, p. 233].

Lower Silurian: Niur Formation, northeastern Iran.

1975 **Helicelasma** sp. A Scrutton, p. 16, 17, Pl. 2, fig. 4, 5.

Upper Ordovician: Centrum Formation, northeastern Greenland.

1975 **Helicelasma** sp. McLean and Webby, p. 233, 234, fig. 2, Pl. 26, fig. 6-8.

Upper Ordovician: Cargo Creek Limestone, central New South Wales, Australia.

Helicelasma randi n. sp.

Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, southern Manitoba.

Discussion. Neuman (1969, p. 28, 29) stated that a loose axial structure with a few septal lamellae can be present in **Helicelasma**. **H. randi** is larger than previously described species, and a larger axial region is to be expected. An axial region is not developed in some corals of **H. randi**, but ranges up to the dimensions of **Grewingkia** in others (Fig. 13c). Unlike **Grewingkia**, the axial structure, if present, consists of only a few septal lobes and lamellae. A calicular boss is developed in corals that have an axial structure.

Helicelasma differs from **Streptelasma** Hall, 1847 in having strongly to completely dilated major septa in early ontogenetic stages and generally having a loose axial structure in later stages. **Borelasma** Neuman, 1969 usually has completely dilated major septa in early stages, but in later stages the major septa are short and an axial structure is not present.

Helicelasma randi n. sp.

(Plate 8, fig. 1-18; Plate 9, fig. 1-11)

Derivation of name. The species is named for H. Rand, former Keeper of the Manitoba Museum in Winnipeg, who collected many of the specimens referred to in this study.

Holotype. GSC 60735, Garson, Manitoba, Rand Collection (Pl. 8, fig. 1-8).

Paratypes. GSC 60730 (Pl. 9, fig. 3-11), 60731, 60732, 60733 (Pl. 9, fig. 1, 2), Garson, Manitoba. GSC 60729 (Pl. 8, fig. 9-18), 60734, Garson, Manitoba, Rand Collection. GSC 60736, Garson, Manitoba, Elias Collection. GSC 60737, 60738, Garson Limestone Co. Ltd. quarry, Garson, Manitoba, Elias Collection. GSC 60739, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson, southern Manitoba.

Diagnosis. Coral generally trochoid, rarely ceratoid, straight to strongly curved, cross-section circular, and attains moderate size. Epitheca with septal grooves and interseptal ridges. Calice deep. Calicular boss generally weakly to strongly convex, but not always developed.

Loose axial structure of a few septal lobes and lamellae usually present. Dilation of major septa almost absent to complete in early stages, with maximum dilation often at some height above the tip. Cardinal fossula broad, and cardinal septum thinner than other major septa. Minor septa generally confined to a narrow to broad stereozone. Tabellae in septal region. Mostly complete, thin, relatively widely spaced, weakly to moderately convex upward tabulae sometimes present in axial region.

Description of corals. The largest specimen examined (GSC 60729) is 7.25 cm long and has a cross-sectional area of 811 mm^2 immediately below the calice where 55 major septa are present. The corals are generally trochoid, but GSC 60739 is ceratoid. They are straight (GSC 60730) to weakly curved (GSC 60739) to strongly curved (GSC 60729). In cross-section the corals are circular. The epitheca has septal grooves corresponding to the major and minor septa, and interseptal ridges – these are sometimes prominent (GSC 60730, 60737). Rugae and growth lines are preserved on some specimens. At the tip on the cardinal side, GSC 60733 has a flat area of attachment with the impression of the surface of a massive bryozoan on it. The calice has a depth equal to 0.3 (GSC 60729) to 0.5 of the coral length (GSC 60735). There is complete gradation from corals lacking a calicular boss (GSC 60738) to those having a weakly (GSC 60729) to strongly convex boss (GSC 60735). A calicular boss is developed in most specimens.

Ontogeny and internal structures. Up to a height of 0.6 to 1.3 cm the major septa extend to the axis, or groups of two or more major septa converge near the axis as they often do in later stages. Above this there is complete gradation from corals lacking an axial structure (GSC 60738) to those in which a few septal lobes, followed by lobes and a few lamellae, form a loose, coarse structure. A simple axial structure is developed in most specimens. GSC 60730 has the

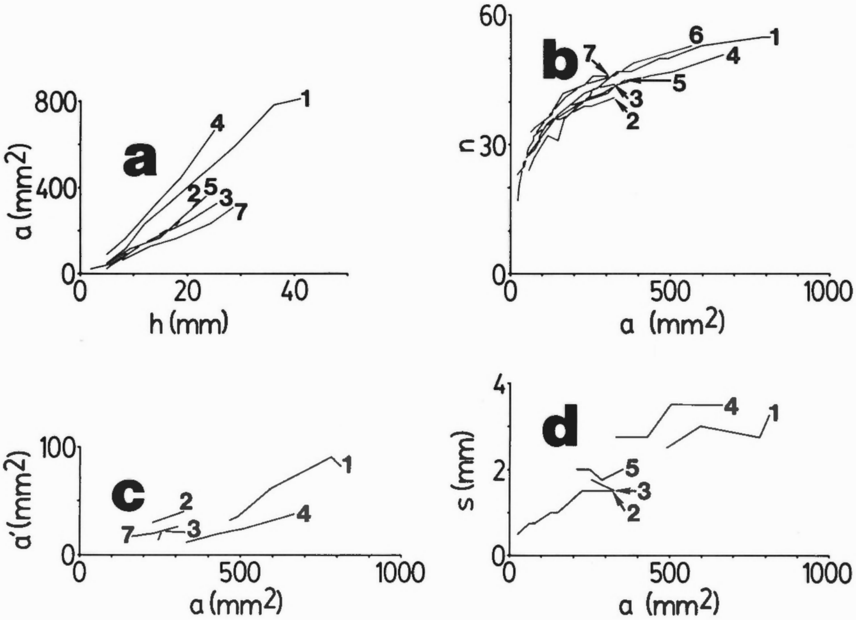

Figure 13

Biometrical relationships, ***Helicelasma randi*** *n. sp. a, Coral cross-sectional area vs. height; b, number of major septa vs. coral cross-sectional area; c, cross-sectional area of axial structure vs. coral cross-sectional area; d, width of stereozone plus epitheca if preserved vs. coral cross-sectional area. GSC 60729, 60730, 60732, 60735, 60737-60739 (1-7), Selkirk Member, Garson, Manitoba.*

largest axial region of the specimens examined (Fig. 13c). Immediately below the calice in GSC 60729 the axial structure includes isolated very short lamellae.

Septal dilation near the tip varies from complete (GSC 60732, 60739) to almost absent (GSC 60730). Dilation near the axis sometimes produces a solid axial region (for example GSC 60729). The maximum dilation often occurs at some height above the tip (GSC 60729, 60730, 60735, 60737). In several cross-sections of GSC 60732, 60737, and 60739, dilation is slightly stronger on the cardinal side than on the counter side.

The cardinal septum is usually long and, especially in later stages, is thinner than the other major septa. The cardinal fossula is broad, especially in later stages. Minor septa are generally confined to the stereozone, but may extend a very short distance beyond it. The stereozone ranges from narrow (GSC 60732) to broad (GSC 60735) (Fig. 13d).

Tabellae appear less than 0.5 cm above the tip in the septal region of most specimens. They are thin and steeply inclined upward toward the axis in the lower portion of the corals; in GSC 60729 they become less steeply inclined with increased height. In the upper portion of the corals the tabellae may be numerous and fairly closely spaced (GSC 60729). Tabellae are rare in GSC 60738. Tabellae are present in the cardinal fossula.

A few thick, irregular tabulae are present in the axial region in early stages. At 2.1 cm (GSC 60730) and 3.7 cm above the tip (GSC 60729) thin tabulae appear in the axial region. They are mostly complete, relatively widely spaced, and weakly to moderately convex upward. These tabulae are not present in GSC 60732, 60735, 60737, and 60739, which range from about 3.0 to 3.3 cm in height to the top of the calicular boss.

Discussion. **Helicelasma randi** closely resembles **H. whittardi** from the Lower Silurian of England. Both species have a similar number of septa at a particular cross-sectional area, and a broad cardinal fossula with a cardinal septum that is thinner than the other major septa. However, in **H. whittardi** the tabulae may be flat or concave upward, whereas they are convex upward when present in **H. randi.** A new species is being described by Nelson (in press) from the Churchill River Group of Hudson Bay Lowland, which correlates with the Stony Mountain Formation of southern Manitoba. It is very similar to **H. randi,** but strong septal dilation near the axis in early stages is not as pronounced or consistently developed, and the cardinal septum becomes short during ontogeny.

Streptelasma cylindricum Troedsson, 1928 from the Cape Calhoun Formation of northwestern Greenland has an area of attachment similar in position to, but more irregular than that of GSC 60733 (**H. randi**) from the Selkirk Member.

Genus **Deiracorallium** Nelson, 1963

1963 **Deiracorallium** Nelson, p. 37.

Type species (by original designation). **Deiracorallium manitobense** Nelson, 1963, p. 37.

Diagnosis. Coral solitary, trochoid, weakly to moderately curved, compressed, triangulate to weakly trilobate, of small to moderately large size. Calice moderately deep to deep, with weakly convex calicular boss if axial structure is present.

Cardinal septum on convex side of coral. Septa numerous – major septa may be strongly to completely dilated near tip, minor septa confined to or extend well beyond the stereozone, which may be broad. In small species and early ontogenetic stages of larger species, major septa join at axis without contortion. In larger species, a small axial structure of septal lobes and lamellae develops during ontogeny. Tabellae may be present in septal region. Tabulae mostly complete, thin, closely spaced, and slightly convex upward.

Species and occurrences. **Deiracorallium** is known from the Middle (?) and Upper Ordovician of North America. The following species can be assigned to the genus:

1926 **Streptelasma prolongatum** Wilson, p. 11, 12, Pl. 1, fig. 3-5, Pl. 2, fig. 2 [see Norford, 1962, Pl. 6, fig. 13, 14, and Norford et al., 1970, Pl. 5, fig. 1].

Upper Ordovician: Beaverfoot Formation, southeastern British Columbia and southwestern Alberta.

1928 **Streptelasma robustum** var. **amplum** Troedsson [partim], Pl. 26, fig. 4a, b.

Upper Middle or Upper Ordovician: Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

1943 **Streptelasma trilobatum** (Whiteaves). Okulitch, Pl. 1, fig. 13, 14.

Upper Ordovician: Stony Mountain Formation, southern Manitoba.

1956 **Streptelasma** aff. **S. prolongatum** Wilson. Duncan, Pl. 22, fig. 2a, b.

Upper Ordovician: Kinnikinic Quartzite, northwestern United States.

1959 "**Streptelasma angulatum** (Billings)". Nelson, Pl. 4, fig. 2a, b.

Upper Ordovician: Gunn Member, Stony Mountain Formation, southern Manitoba.

1960 [?] **Streptelasma** sp. cf. **S. prolongatum** Wilson. Pestana, p. 866, 867, Pl. 109, fig. 1.

Upper Middle (?) Ordovician: Johnson Spring Formation, Independence Quadrangle, California, U.S.A.

1963 **Deiracorallium manitobense** Nelson, p. 37, 38, Pl. 13, fig. 1, 2a, b.

Upper Middle or Upper Ordovician: member 1 and upper member, Caution Creek Formation, and member 1, Chasm Creek Formation, Hudson Bay Lowland, northern Manitoba. Upper Ordovician: Gunn Member, Stony Mountain Formation, southern Manitoba.

1963 **Deiracorallium manitobense** var. **churchillense** Nelson, p. 38, Pl. 13, fig. 3a, b.

Upper Middle or Upper Ordovician: member 1, Chasm Creek Formation, Hudson Bay Lowland, northern Manitoba.

1963 **Deiracorallium giganteum** Nelson, p. 38, 39, Pl. 13, fig. 4a, b, 5, 6a-c.

Upper Middle or Upper Ordovician: member 2, Chasm Creek Formation, Hudson Bay Lowland, northern Manitoba.

1975 **Deiracorallium** sp. Oliver, Merriam and Churkin, Pl. 5, fig. 3.

Upper Ordovician: Porcupine River area, east-central Alaska, U.S.A.

Deiracorallium delicatum n. sp.

Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, southern Manitoba.

Discussion. The original description of **Deiracorallium** was based on **D. manitobense** and **D. giganteum.** The former species attains a length of 2 cm and lacks an axial structure. The latter exceeds 4 cm in length and has a very small axial structure of septal lobes. **D. delicatum** exceeds 8 cm in length, and its larger axial region is to be expected. The axial structure consists of septal lobes and lamellae. A relatively large species being described by Nelson (in press) also has an axial structure of lobes and lamellae. Therefore, the diagnosis of **Deiracorallium** is expanded to include compressed corals with a small axial structure.

The description and figures of **Streptelasma prolongatum** in Wilson (1926) and the figures in Norford (1962) and Norford et al. (1970) indicate that it has the form, septal arrangement, and axial structure characteristic of **Deiracorallium.**

Troedsson (1928, p. 108, Pl. 26, fig. 1-4) described **Streptelasma robustum** var. **amplum,** but did not designate a holotype. He figured four specimens. The septa and axial structure can be seen in the calice of two corals (Pl. 26, fig. 3, 4b). The largest specimen (MMH 2992; Pl. 26, fig. 4a, b) is trilobate and has a deep calice in which about 92 major septa are present. Minor septa are long, and the stereozone is moderately broad. The axial structure is very small. This coral possesses the characteristics of **Deiracorallium,** and is herein designated as the lectotype of **D. amplum** (Troedsson, 1928). The specimen in Troedsson's Plate 26, figure 3 has a large, coarse axial structure and is not trilobate; it is a **Grewingkia.**

Pestana (1960) reported a single specimen resembling **Streptelasma prolongatum** from California. On the basis of his figure, definite assignment to **Deiracorallium** is not possible.

Nelson (1963, p. 38) examined three specimens assigned to **Streptelasma trilobatum** by Okulitch (1943) and referred the smallest to **Deiracorallium manitobense.** This may not be the specimen figured by Okulitch because Nelson did not include the figure in his synonymy. On the basis of external form, the figured specimen appears to belong to **Deiracorallium.**

Nelson (1963, p. 38) stated that **Deiracorallium manitobense** may be conspecific with **Streptelasma angulatum** (Billings, 1862) from the "English Head" and Vaureal formations of Anticosti Island, Quebec, primarily on the basis of external form.

Deiracorallium differs from **Grewingkia** in that the corals are compressed and the axial structure, if developed, is smaller (Fig. 14c).

Deiracorallium delicatum n. sp.

(Plate 9, fig. 12-24)

Derivation of name. The specific name refers to the delicate nature of the fine septal lobes and lamellae comprising the axial structure.

Holotype. GSC 60745, Garson, Manitoba, Rand Collection (Pl. 9, fig. 12-21).

Paratypes. GSC 60746 (Pl. 9, fig. 22-24), 60747-60750, Garson, Manitoba. GSC 60751, Garson, Manitoba, Rand Collection.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson, southern Manitoba.

Diagnosis. Coral trochoid, moderately curved, triangulate to very weakly trilobate, compressed, and attains moderately large size. Calice of moderate depth with weakly convex calicular boss.

Small, fine, dense axial structure of septal lobes and lamellae. Major septa strongly to completely dilated near tip. Minor septa long, extending well beyond a broad stereozone. Tabellae in septal region. Tabulae in axial region mostly complete, thin, closely spaced, and slightly convex upward.

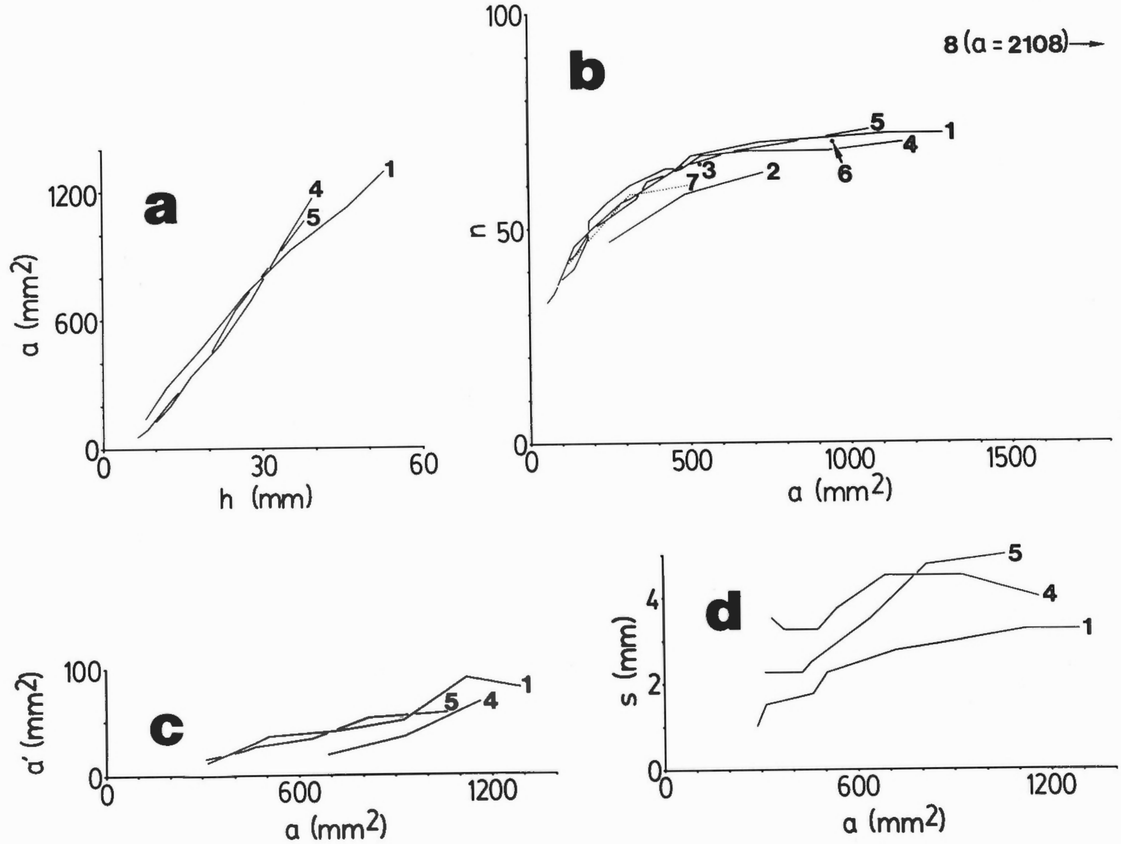

Figure 14. *Biometrical relationships,* ***Deiracorallium delicatum*** *n. sp.,* ***D. giganteum*** *Nelson, 1963, and* ***D. amplum*** *(Troedsson, 1928). a, Coral cross-sectional area vs. height; b, number of major septa vs. coral cross-sectional area; c, cross-sectional area of axial structure vs. coral cross-sectional area; d, width of stereozone plus epitheca if preserved vs. coral cross-sectional area.* ***D. delicatum:*** *GSC 60745, 60746, 60748-60751 (1-6), Selkirk Member, Garson, Manitoba.* ***D. giganteum:*** *GSC 10848 (7), member 2, Chasm Creek Formation, northern Manitoba.* ***D. amplum:*** *MMH 2992 (8), Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.*

Description of corals. The largest specimen examined (GSC 60745) is 8.75 cm long and has a cross-sectional area of 1290 mm^2 immediately below the calice. GSC 60750 has the maximum number of major septa, 73 at a cross-sectional area of 1061 mm^2 immediately below the calice. The corals are trochoid and moderately curved. They are compressed throughout ontogeny. Maximum compression is at a height of 2.5 cm (GSC 60749), 4.0 cm (GSC 60750 immediately below the calice), and 4.8 cm (GSC 60745). The largest cross-sectional length-width ratio is 1.2 (GSC 60749, 60750) and 1.4 (GSC 60745). Corals are triangulate (GSC 60745) to very weakly trilobate (GSC 60749, 60750). Maximum triangulation or trilobation is at a height of about 2 cm, and disappears upward. Rugae are sometimes preserved on the epitheca. The calice has a depth equal to 0.2 (GSC 60745) to 0.3 of the coral length (GSC 60749). The calicular boss is weakly convex.

Ontogeny and internal structures. Up to a height of about 1.2 cm the major septa extend to the axis. Above this a fine, dense axial structure of septal lobes and lamellae appears. Above about 3 cm, septal lamellae are dominant. The axial structure is elongate parallel to the cardinal-counter surface and has a small cross-sectional area with respect to coral cross-sectional area (Fig. 14c).

The major septa are almost completely dilated near the tip, but interseptal chambers are generally present near the stereozone. Dilation near the tip is complete in GSC 60748. The cardinal septum is long, and the cardinal fossula is narrow. Minor septa are confined to the stereozone initially, but later extend beyond it for a distance that may be greater than its width. The stereozone is broad (Fig. 14d).

Tabellae appear less than 0.5 cm above the tip in the septal region. They are thin and steeply inclined upward toward the axis in early stages and become less steeply inclined with increased height in the corals. They are approximately horizontal and widely spaced near the calice of all specimens examined. Tabellae are present in the cardinal fossula.

Thin, irregular tabulae are present in the axial region in early stages. Beginning at about 2.2 cm above the tip, tabulae in the axial region are mostly complete, closely spaced, and slightly convex upward.

Discussion. **Deiracorallium delicatum** resembles **D. giganteum**, but has a larger axial structure and generally more septa at a particular cross-sectional area in later ontogenetic stages. **D. amplum** has more septa and attains a greater cross-sectional area than **D. delicatum** (Fig. 14b). A new species of **Deiracorallium** being described from the Bad Cache Rapids Group in Hudson Bay Lowland (Nelson, in press) is similar to **D. delicatum** but has a coarser axial structure, broader cardinal fossula, and more convex and distantly spaced tabulae.

Genus **Bighornia** Duncan, 1957

1957 **Bighornia** Duncan, p. 608-611.

1963 **Bighornia** Duncan. Nelson, p. 39, 40.

1977 **Bighornia** Duncan. Neuman, p. 75.

Type species (by original designation). **Bighornia parva** Duncan, 1957, p. 611-614, Pl. 70, figs. 1-18.

Diagnosis. Coral solitary, usually depressed and subcalceoloid but may be ceratoid to trochoid. Generally small but may attain large size. Cross-section in early stages depressed and triangulate or oval with a flattened counter side, or crescentic with a concave cardinal side. In later stages cross-section slightly depressed and weakly triangulate or oval, or round. Calice generally deep. Calicular boss often very strongly convex.

Short cardinal septum on concave side of coral in broad cardinal fossula. Major septa generally completely dilated in early ontogenetic stages, and sometimes strongly dilated even in later stages. Minor septa sometimes extend a short distance beyond the stereozone which may be moderately broad in nondilated or weakly dilated stages. Axial structure generally consists of a solid columella elongate in the cardinal-counter surface and contiguous with the counter septum. A few coarse septal lobes and lamellae sometimes present, or form axial structure if a columella is not developed. Tabellae present in septal region of larger species. Tabulae uncommon in small species or dilated stages of larger species, but present in axial region of larger species.

Species and occurrences. **Bighornia** is known from the upper Middle (?) and Upper Ordovician of North America, and possibly from the Upper Ordovician of Estonia. The following forms can be assigned to the genus (modified and expanded from Duncan, 1957, p. 610):

1915 **Streptelasma integriseptatum** Parks, p. 13-15, Pl. 5, fig. 1-3.

Upper Ordovician: lower rapids, Shamattawa [Gods] River, northern Manitoba.

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

Upper Ordovician: Beaverfoot Formation, south-eastern British Columbia.

1928 **Streptelasma** aff. **breve** Ulrich in Winchell and Schuchert. Troedsson, p. 109, Pl. 26, fig. 6, 7.

Upper Middle or Upper Ordovician: Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

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

Upper Ordovician: Fort Atkinson Formation, Ossian, Iowa, U.S.A.

1937 **Streptelasma haysii** (Meek). Cox [partim], p. 8, 9, Pl. 2, fig. 4a, b.

Upper Ordovician: Cape Frazier, Ellesmere Island, District of Franklin.

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

Upper Middle or Upper Ordovician: Strandpilaren, Norman Lockyer Island, Princess Marie Bay, Ellesmere Island, District of Franklin.

1937 [?] **Streptelasma ? oppletum** Teichert, p. 51, 52, Pl. 2, fig. 5-8, Pl. 3, fig. 1-4.

Upper Middle Ordovician: Uglerlarsuk, Ungerlodjan, and Iglulik Island, east coast, Melville Peninsula, District of Franklin. Upper Middle or Upper Ordovician: Cape Calhoun Formation, Cape Calhoun, northwestern Greenland.

1937 [?] **Streptelasma ? latum** Teichert, p. 52, 53, Pl. 2, fig. 3, 4, 9.

Upper Middle or Upper Ordovician: drift, Cape Griffith, Baffin Island, District of Franklin.

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

Upper Ordovician: Gunn Member, Stony Mountain Formation, southern Manitoba.

1956 **Streptelasma** cf. **integriseptatum** Parks. Stearn, p. 88, 89.

Upper Ordovician: Stonewall Formation, near The Pas, Manitoba.

1956 "**Holophragma**" sp. Duncan, Pl. 22, fig. 1a-c.

Upper Ordovician: top of Bighorn Dolomite, Wyoming, U.S.A.; Stony Mountain Formation, southern Manitoba.

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

Upper Ordovician: shaly beds at top of Bighorn Dolomite, Johnson Co., Wyoming, U.S.A.

1957 **Bighornia parva** Duncan, p. 611-614, Pl. 70, fig. 1-18.

Upper Ordovician: shaly beds at top of Bighorn Dolomite, Johnson Co., Wyoming, U.S.A.

1959 **Bighornia patella** (Wilson). Nelson, Pl. 4, fig. 1a-d.

Upper Ordovician: Gunn Member, Stony Mountain Formation, southern Manitoba.

1959 **Bighornia** sp. Nelson, Pl. 4, fig. 3a-d.

Upper Ordovician: Gunton Member, Stony Mountain Formation, southern Manitoba.

1960 [?] **Bighornia orvikui** Kaljo, p. 251-253, fig. 1, Pl. 1, fig. 1-11.

Upper Ordovician: Pirgu Formation, Estonia.

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

Upper Middle or Upper Ordovician: members 1 and 3 and upper member, Caution Creek Formation, and member 1, Chasm Creek Formation, Hudson Bay Lowland, northern Manitoba.

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

Upper Ordovician: member 1, Chasm Creek Formation, Churchill River, northern Manitoba.

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

Upper Ordovician: members 1, 2, and 3, Chasm Creek Formation, Hudson Bay Lowland, northern Manitoba.

1975 **Bighornia** sp. Oliver, Merriam and Churkin, Pl. 5, fig. 6.

Upper Ordovician: Porcupine River area, east-central Alaska, U.S.A.

1975 **Bighornia** sp. Norford and Macqueen, Pl. 9, fig. 9, 10.

Upper Ordovician: basal and resistant members, Mount Kindle Formation, Franklin Mountains, District of Mackenzie.

Bighornia cf. **B. patella** (Wilson).

Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, southern Manitoba.

Discussion. Cox (1937, p. 8, 9, Pl. 2, fig. 4a, b) described and illustrated one of the types of **Streptelasma haysii** having a wide cardinal fossula on the concave side. This specimen is a **Bighornia**; the lectotype of that species is a **Grewingkia**. As noted by Duncan (1957, p. 610) "most of the species [of **Bighornia**] are not sufficiently well characterized nor illustrated for evaluation", and hence the total number of species of this genus is unknown. Several of the species listed above are herein referred to as **Bighornia** cf. **B. patella**.

Duncan (1957, p. 611) reported undescribed species of this genus in the Kinnikinic Quartzite, basal Bighorn Dolomite, Maquoketa Shale of Iowa and Minnesota, Saturday Mountain Formation of central Idaho, Fish Haven Dolomite of Idaho and Utah, Fremont Limestone of Colorado, Hanson Creek Formation of Nevada, Ely Springs Dolomite of Nevada and California, and Montoya Limestone of Texas, U.S.A.

Two other Ordovician genera have the cardinal septum on the concave side of the coral. **Kenophyllum** Dybowski, 1873 differs from **Bighornia** in lacking a solid, elongate columella. In **Densigrewingkia** Neuman, 1969 the broad axial structure is composed of numerous septal lobes and lamellae that are connected by stereoplasmatic deposits until late ontogenetic stages.

Bighornia cf. **B. patella** (Wilson, 1926)

(Plate 10, fig. 1-21)

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

1928 [?] **Streptelasma** aff. **breve** Ulrich in Winchell and Schuchert. Troedsson, p. 109, Pl. 26, fig. 6, 7.

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

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

1956 "**Holophragma**" sp. Duncan, Pl. 22, fig. 1a-c.

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

1957 **Bighornia parva** Duncan, p. 611-614, Pl. 70, fig. 1-18.

1959 **Bighornia patella** (Wilson). Nelson, Pl. 4, fig. 1a-d.

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

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

1975 **Bighornia** sp. Norford and Macqueen, Pl. 9, fig. 9, 10.

Specimens. GSC 60752, 60753 (Pl. 10, fig. 15-21), Garson, Manitoba. GSC 60754 (Pl. 10, fig. 1-14), 60755, Garson Limestone Co. Ltd. quarry, Garson, Manitoba, Elias Collection.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson, southern Manitoba.

Description of corals. The largest specimen examined (GSC 60754) is 3.0 cm long. GSC 60752 has the maximum number of major septa, 45 at a height of 10.2 mm immediately below the calice. The corals are trochoid and generally weakly curved. They are depressed throughout their length, but especially in early stages. The maximum cross-sectional length-width ratio varies from 1.4 (GSC 60753) to 2.0 (GSC 60752, 60755), and occurs at heights ranging from 2.5 mm (GSC 60752) to 4.2 mm (GSC 60754). GSC 60752, 60754, and 60755 have concave spoon-shaped areas of attachment on the cardinal side near the tip. GSC 60752, 60753, and 60754 become triangulate during ontogeny; GSC 60755 is oval in cross-section. GSC 60754 becomes cylindrical. Growth lines are sometimes preserved on the epitheca. The calice has a depth equal to 0.25 (GSC 60754) to 0.35 of the coral length (GSC 60752). The calicular boss is moderately convex (GSC 60754).

Ontogeny and internal structures. Up to a height of about 3.5 mm (GSC 60752), 6.0 mm (GSC 60755), and 7.0 mm (GSC 60753, 60754) the major septa extend to the axis. Above this an axial structure initially composed of a few completely dilated septal lobes appears, followed by a few septal lamellae. A dilated median lamella in the cardinal-counter surface appears at 7.3 mm (GSC 60755), 8.7 mm (GSC 60754), 8.8 mm (GSC 60753), and possibly at 10.2 mm (GSC 60752). In later stages, dilation of the axial structure decreases slightly. Near the calice of GSC 60754 the axial structure is separated from the septal region. The axial structure is elongate perpendicular to the cardinal-counter surface.

The major septa are completely dilated to a height of 1.3 mm (GSC 60755), 4.0 mm (GSC 60753), and 5.5 mm (GSC 60754). In GSC 60752 the septa are strongly dilated to a height of 3.5 mm; from 3.5 to 5.0 mm they are completely dilated. Dilation of the septa generally decreases upward. Dilation is strongest on the cardinal side near the tip in GSC 60755, and on the counter side in GSC 60753. The cardinal fossula is moderately broad and is open near the tip where other interseptal chambers are closed because of dilation. The cardinal septum is often thinner than the other major septa, especially in later stages. It becomes short in the calice. Minor septa are confined to a moderately broad stereozone.

The few tabellae in the septal region in incompletely dilated stages are steeply inclined upward toward the axis. Thin, widely spaced, complete tabulae are present in the axial region of GSC 60754 above 16.6 mm.

Discussion. **Streptelasma patellum** and the corals listed in the synonymy have a dilated median septal lamella. Their ontogeny is virtually unknown. With the exception of two paratypes of **Bighornia parva** (Duncan, 1957, Pl. 70, fig. 1-7), none have been sectioned. Duncan (1957, p. 613) and Nelson (1963, p. 40, 41) attempted to distinguish species on the basis of size, external form, and number of septa. The significance of size and form for distinguishing these similar corals is doubtful. The ranges in the number of septa overlap (Fig. 15). These forms appear to have similar axial

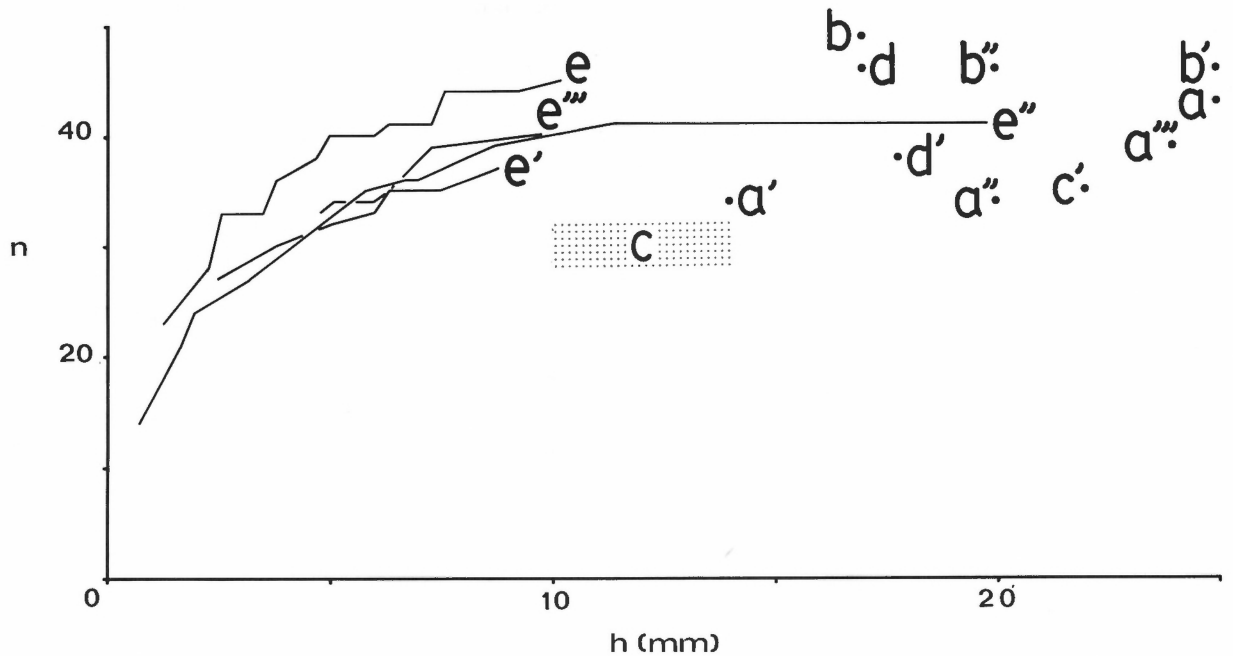

*Figure 15. Number of major septa vs. height, **Bighornia patella** (Wilson, 1926) and **B.** cf. **B. patella**. **B. patella**: GSC 6732 (a), Beaverfoot Formation, southeastern British Columbia. **B.** cf. **B. patella**: GSC 10872 (a') [**B. patella**], member 1, Caution Creek Formation, northern Manitoba; GSC 10873 (a'') and 10874 (a''') [**B. patella**], member 1, Chasm Creek Formation, northern Manitoba; State Univ. Iowa No. 2-051 (b) and USNM 71926 (b') [**Lindstromia solearis**], Fort Atkinson Formation, Ossian, Iowa; GSC 10870 (b'') [**B. solearis**], member 1, Chasm Creek Formation, northern Manitoba; Okulitch, 1943 (c) and Nelson, 1963 (c') [**Holophragma anticonvexa**], Gunn Member, Stony Mountain Formation, Stony Mountain, Manitoba; USNM 127574 (d), 124801 (d') [**B. parva**], upper Bighorn Dolomite, Bighorn Mountains, Wyoming; GSC 60752-60755 (e-e'''), Selkirk Member, Garson, Manitoba.*

structures, as seen in figures of calices. **Streptelasma** aff. **breve** of Troedsson (1928) resembles these corals, but details of the axial structure are unknown. With this limited knowledge, these specimens and **Bighornia** of the Selkirk Member cannot be distinguished. **Streptelasma patellum** was the first species described, and Selkirk Member specimens and other species listed in the synonymy are referred to as **B.** cf. **B. patella** until the type specimen and topotype material are better known.

Family Complexophyllidae n. fam.

Type and only genus. **Complexophyllum** n. gen.

Diagnosis. Coral solitary, with marginarium consisting of a septal stereozone. Major septa inserted on either side of cardinal septum, on counter side of alar septa, and on either side of a pair of major septa in the counter position. An additional major septum appears on either side of the coral between the first major septum inserted adjacent to the alar septum and the first major septum inserted in the counter fossula.

Discussion. In **Complexophyllum**, septal insertion on either side of the cardinal septum and on the counter side of the alar septa is characteristic of the order Rugosa. The septal stereozone and axial structure are typical of the suborder Streptelasmatina and superfamily Zaphrenticae. The genus differs from all other Rugosa in having two major septa in the counter position, and septal insertion at four positions on the counter side. Therefore, a new family is proposed, with affinities closest to the family Streptelasmatidae.

Genus **Complexophyllum** n. gen.

Derivation of name. The generic name refers to the complex ontogeny and internal structures of the coral.

Type and only species. **Complexophyllum leithi** n. sp.

Occurrence. Upper Middle or Upper Ordovician: Selkirk Member, Red River Formation, Garson, southern Manitoba.

Diagnosis. Coral solitary, trochoid, weakly curved, counter side flattened in early stages but cross-section circular in late stages, of moderately small size. Calicular boss weakly convex.

Cardinal septum on convex side of coral. Four ontogenetic stages are recognized:

1. In earliest stage major septa are nondilated and extend to or almost to axis. Two major septa are symmetrical about counter position, and are termed counter septa. Counter fossula large. Major septa inserted in the four positions characteristic of order Rugosa.
2. Counter septa unite at axis. Septal insertion in counter fossula begins. Additional major septum appears on either side of coral between first major septum inserted adjacent to alar septum and first major septum inserted in counter fossula. During this stage major septa shorten, leaving an open axial region.
3. Major septa become moderately to strongly dilated. Generally irregularly shaped axial structure appears, consisting of a narrow, solid periphery and a central "spongy" area of usually very fine lamellae. Tabellae appear in septal region.

4. Major septa initially strongly dilated, later becoming weakly to moderately dilated. Axial structure consists of septal lamellae and a few septal lobes. Minor septa long, extending beyond a stereozone. Tabellae in septal region and cardinal fossula. Irregular, widely spaced tabulae in axial region.

Discussion. The axial structure in stage 3 is unlike that of other rugose corals. In stage 4, the axial structure resembles **Grewingkia**, but is not as large.

Complexophyllum leithi n. sp.

(Fig. 7a-c; Plate 11, fig. 1-20)

Derivation of name. The species is named for Edward Isaac Leith, Department of Earth Sciences, University of Manitoba, in recognition of his work on Ordovician colonial corals of southern Manitoba.

Holotype and only specimen. GSC 60756, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection.

Occurrence and diagnosis. Same as for the genus.

Description of coral. The coral is abraded to a high degree – the counter side is missing to 2.4 mm above the tip, and to 8 mm the stereozone is missing. The rim of the calice was broken prior to final burial. Therefore, cross-sectional area, length, heights, and depth of the calice cannot be determined.

The incomplete specimen is 3.2 cm long. Sixty-four major septa are present immediately below the calice, where the diameter is 2.3 cm. The coral is trochoid and weakly curved. In cross-section it is flattened on the counter side to 9.8 mm above the tip. Above this the cross-section becomes circular. The calicular boss is weakly convex.

Ontogeny and internal structures. Because the ontogeny and internal structures of this specimen are complex, the following detailed description is given. Figure numbers refer to Plate 11. Heights are measured from the base of the coral. The ontogenetic stages are summarized in the generic diagnosis. The number of major septa at a particular height is shown in Fig. 16.

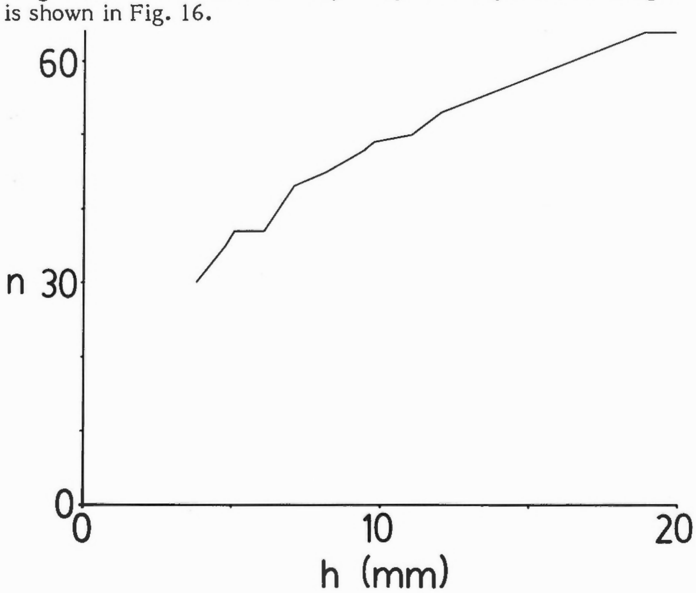

Figure 16. *Number of major septa vs. height,* ***Complexophyllum leithi*** *n. gen., n. sp. GSC 60756, Selkirk Member, Garson, Manitoba.*

Stage 1:

1.0 mm (fig. 2): major septa nondilated.

1.3 mm (fig. 3): major septa end just before reaching axis.

2.3 mm (fig. 4): groups of two or more major septa join at or just before reaching axis.

2.5 mm (fig. 5): two counter septa present; counter fossula large; septa on counter side of alars abut against alar septa.

Stage 2:

3.5 mm (fig. 6): the two moderately strongly dilated counter septa join at axis; septa inserted in counter fossula; major septa on cardinal side become contorted towards axis.

3.8 mm (fig. 7): counter septa bulge outward before converging at axis; septa inserted in counter fossula are especially contorted and irregular; major septum appears on either side of coral between first major septum inserted adjacent to alar septum and first major septum inserted in counter fossula; major septa meet at axis.

4.8 mm (fig. 8): major septa end just before reaching axis.

5.1 mm (fig. 9): major septa withdrawn from axis; axial region open.

Stage 3:

6.1 mm (fig. 10): irregularly shaped axial structure appears, with narrow, dense periphery, and "spongy" centre consisting of very fine lamellae – it is separated from the major septa on one side, but on the other side the septal ends enter the structure.

7.1 mm (fig. 11): counter septa no longer bulge outward; tabellae appear in septal region.

8.2 mm (fig. 12): dilation of major septa increases; major septa extend to axial structure; stereozone with minor septa preserved; axial structure larger, triangulate to weakly trilobate in the position of the cardinal septum and on the counter side of the alar septa – the narrow, solid periphery encloses dense, very fine lamellae surrounding an open central area.

8.5 mm (fig. 13): major septa moderately to strongly dilated; counter septa join within septal region and extend as one towards axis; axial structure of irregular shape, smaller, with solid periphery and a few coarser lamellae at centre; a few fine lamellae are present outside the main axial structure.

Stage 4:

9.5 mm (fig. 14): major septa strongly dilated; axial structure approximately circular, consisting of coarse septal lobes and lamellae.

9.8 mm (fig. 15): major septa moderately to strongly dilated, especially near cardinal and counter septa; axial structure consists mostly of lamellae with a few lobes.

11.1 and 12.1 mm (fig. 16 and 17): some minor septa extend beyond stereozone; a minor septum is present between the counter septa.

19 and 20 mm (fig. 18 and 19): major septa weakly to moderately dilated, especially near cardinal and counter septa; minor septa long; tabulae present in axial region.

Longitudinal section above 20 mm (fig. 20): tabellae in septal region inclined slightly upward or downward toward axis; thin, irregular, widely spaced tabulae in axial region.

Throughout the length of the coral, major septa are inserted on either side of the cardinal septum and on the counter side of both alar septa (Fig. 7a, c). Insertion in these positions, a characteristic of the order Rugosa, takes place by the method described in the text under "Septal Insertion". At 3.5 mm above the tip, insertion of major septa begins in the counter fossula by the same method as in the cardinal and alar fossulae. A minor septum is present between the two counter septa (Fig. 7b). At 3.75 mm an additional major septum appears on either side of the coral between the first major septum inserted adjacent to the alar septum (it arises from this septum) and the first major septum inserted in the counter fossula (Fig. 7b). A minor septum is present on both sides of this major septum.

Discussion. Because **Complexophyllum leithi** is represented by only one specimen of more than 200 solitary rugose corals examined from the Selkirk Member, it is either very rare or represents an abnormal individual of another species. Perhaps insertion at four places on the counter side was necessary in order to rapidly fill the large counter fossula, which for some reason was without septa. However, the presence of a pair of counter septa and the unique axial structure, as well as septal insertion at eight points, indicate that the polyp had a basal disc unlike that of any other species known from the Selkirk Member.

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PLATE 1

Figures 1-10

Grewingkia crassa n. sp. Holotype GSC 60707, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (1) Alar side x1, with location of sections 3-10. (2) Cardinal side x1. (3-9) Polished cross-sections[1] x1.5. (10) Polished section of cardinal-counter surface x1.5.

[1] Cross-sections in all plates are oriented as they would appear looking from the top of the coral towards the tip, with the cardinal side facing downward.

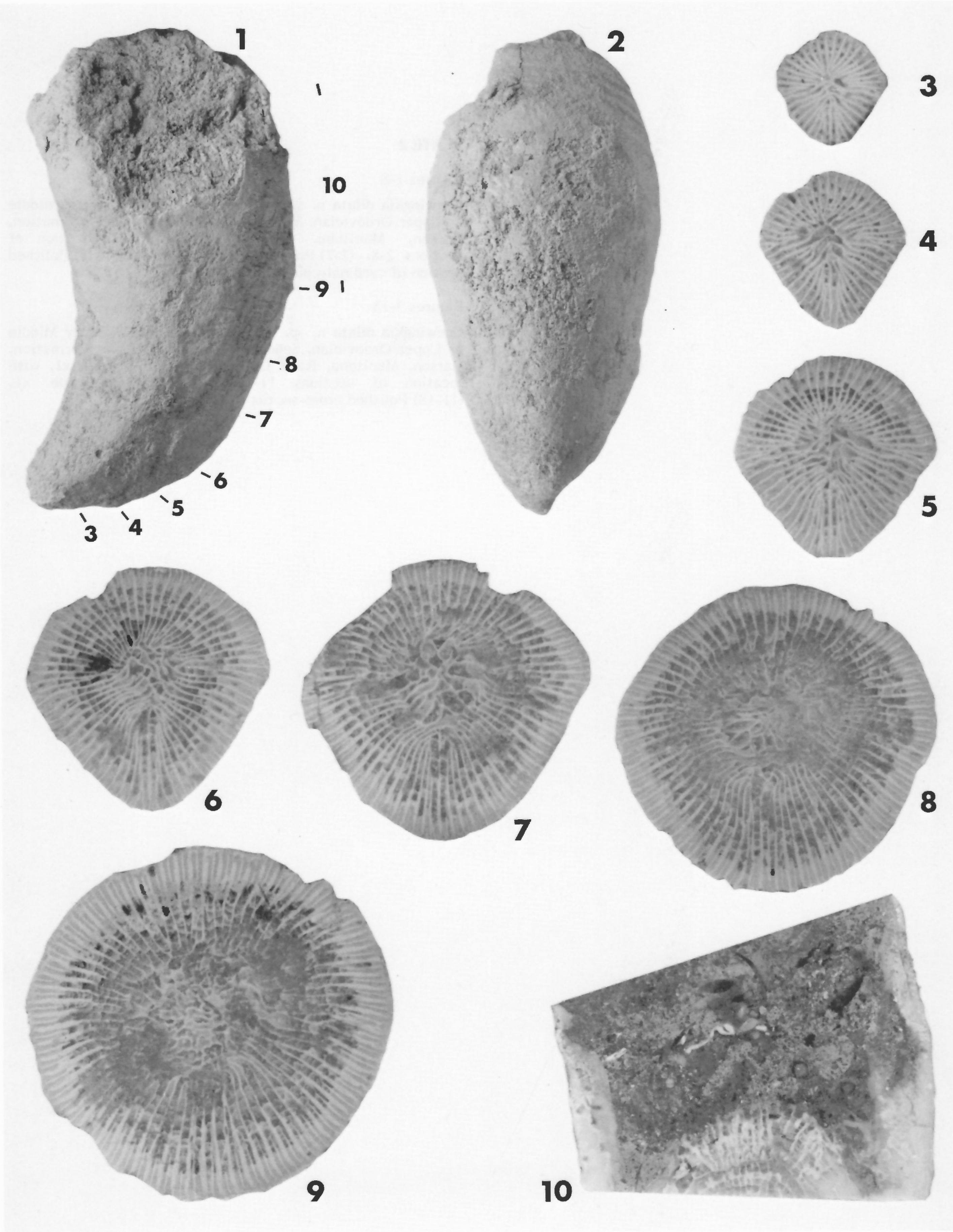
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PLATE 2

Figures 1-8

Grewingkia dilata n. sp. Holotype GSC 60716, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (1) Alar side x1, with location of sections 2-8. (2-7) Polished cross-sections x1.5. (8) Polished section of cardinal-counter surface x1.5.

Figures 9-18

Grewingkia dilata n. sp. Paratype GSC 60717, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba, Rand Collection. (9) Alar side x1, with location of sections 11-18. (10) Cardinal side x1. (11-18) Polished cross-sections x1.5.

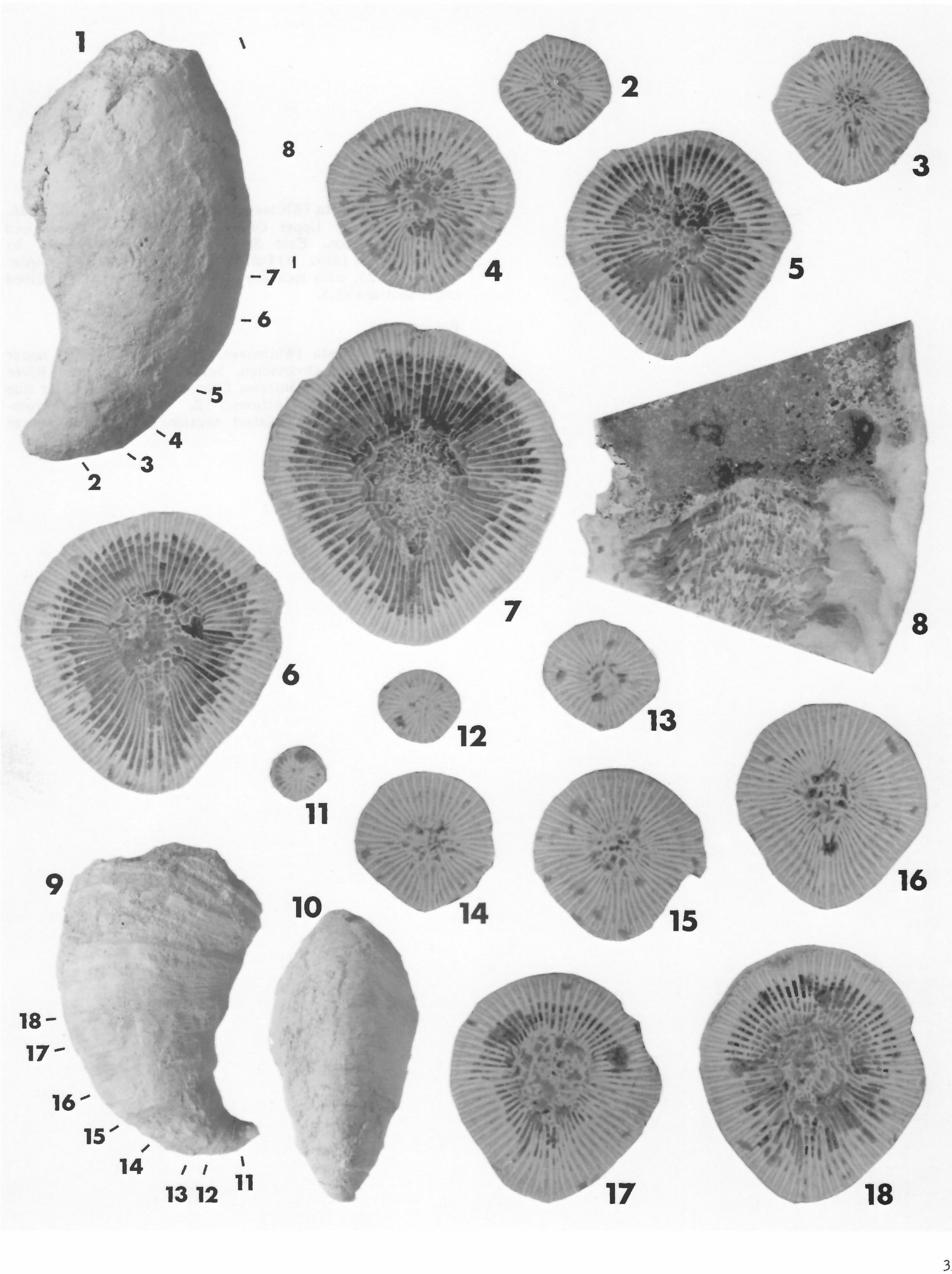
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PLATE 3

Figures 1-3

Grewingkia robusta (Whiteaves, 1896). Lectotype GSC 6886, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, East Selkirk, Manitoba, collected by A. McCharles, 1884. (1) Polished section of cardinal-counter surface x1.25, with location of sections 2, 3. (2, 3) Polished cross-sections x1.5.

Figures 4-12

Grewingkia robusta (Whiteaves, 1896). GSC 60723, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba, Elias Collection. (4) Alar side x1, with location of sections 5-12. (5-11) Polished cross-sections x1.5. (12) Polished section of cardinal-counter surface x1.5.

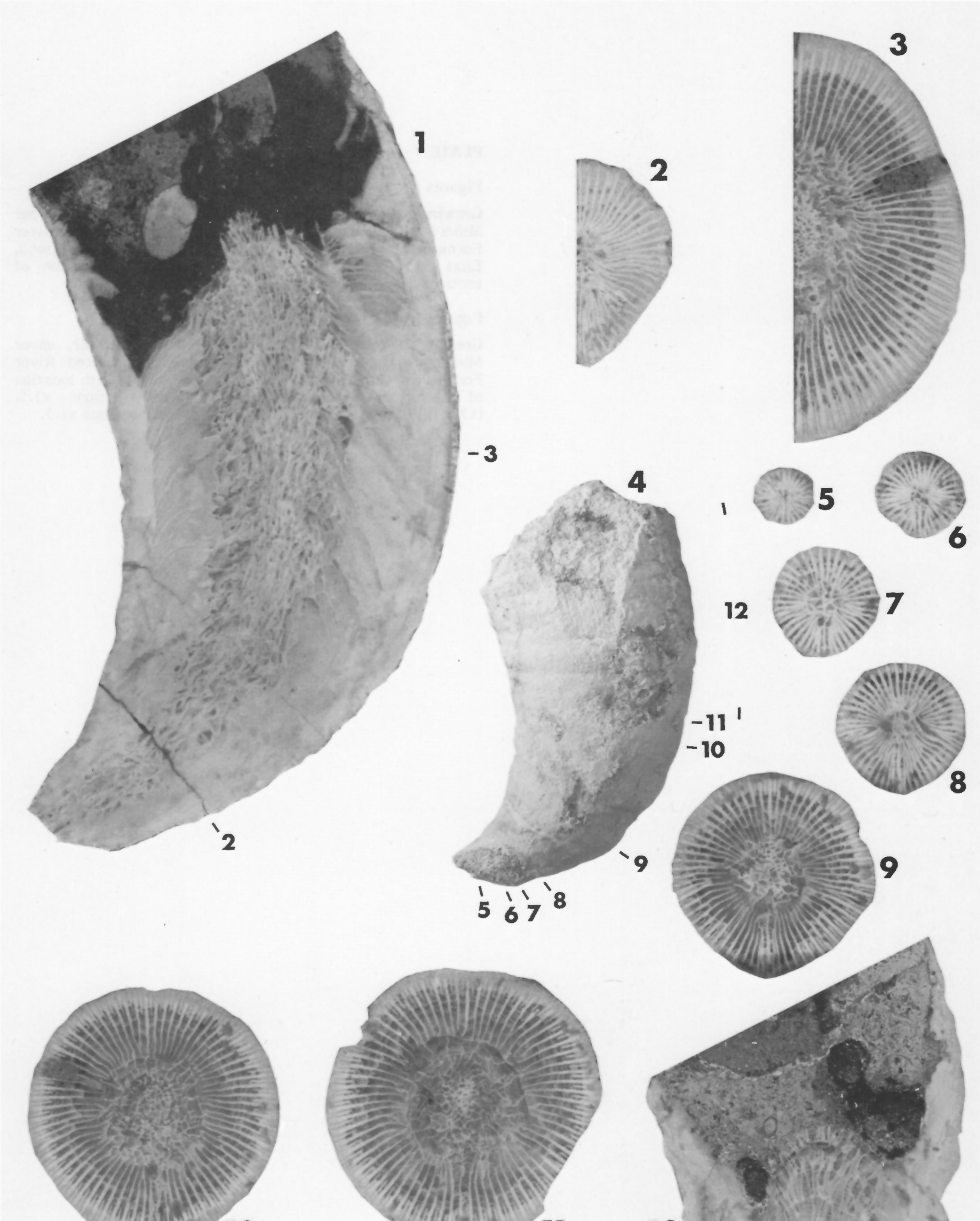
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PLATE 4

Figures 1-4

Grewingkia robusta (Whiteaves, 1896). GSC 60725, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection. (1) Alar side x1, with location of sections 2-4. (2-4) Polished cross-sections x1.5.

Figures 5-14

Grewingkia robusta (Whiteaves, 1896). GSC 60721, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (5) Alar side x1, with location of sections 6-14. (6-12) Polished cross-sections x1.5. (13, 14) Polished sections of cardinal-counter surface x1.5.

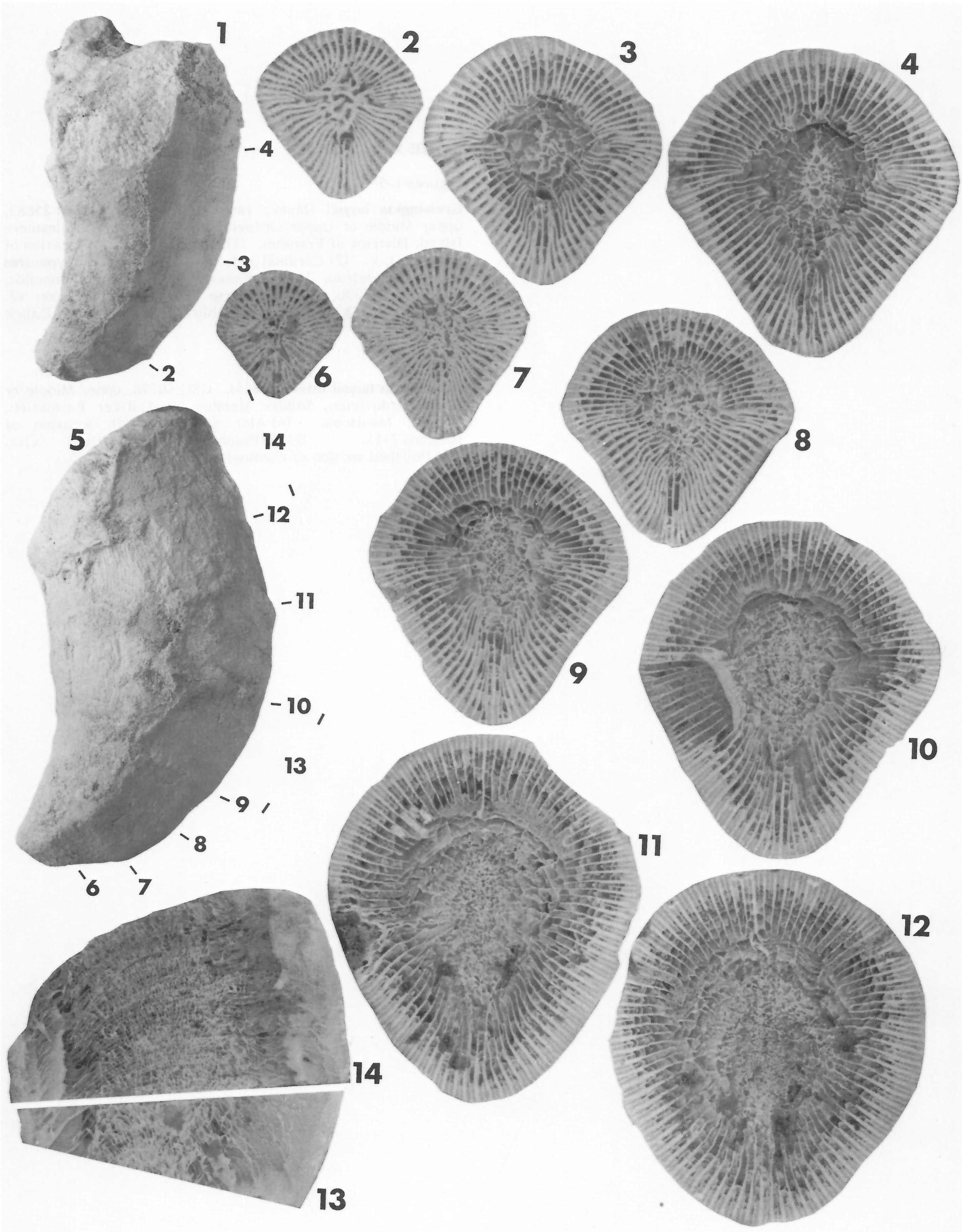
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PLATE 5

Figures 1-5

Grewingkia haysii (Meek, 1865). Lectotype USNM 25683, upper Middle or Upper Ordovician, Cape Frazier, Ellesmere Island, District of Franklin. (1) Alar side x1, with location of sections 3, 4. (2) Cardinal side x1. Borings are **Trypanites weisei** Mägdefrau, 1932, produced by polychaete annelids. (3) USNM 25683b, transverse thin section x2. (4) USNM 25683a, transverse thin section x2. (5) Calice stereopair x1.

Figures 6-15

Grewingkia haysii (Meek, 1865). GSC 60726, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (6) Alar side x1, with location of sections 7-15. (7-14) Polished cross-sections x1.5. (15) Polished section of cardinal-counter surface x1.5.

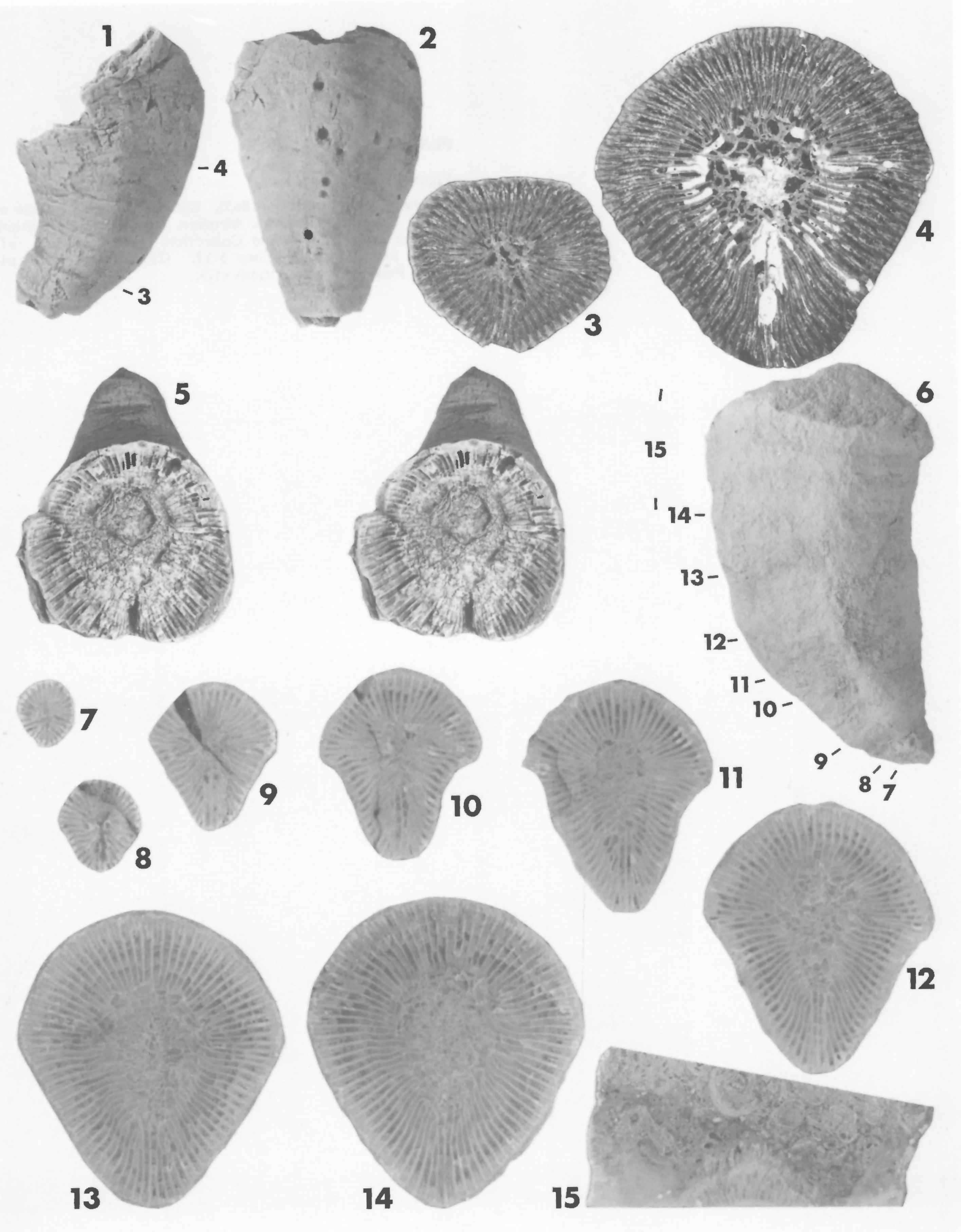
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PLATE 6

Figures 1-12

Grewingkia haysii (Meek, 1865). GSC 60728, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Lockport, Manitoba, Rand Collection. (1) Alar side x1, with location of sections 3-12. (2) Cardinal side x1. (3-12) Polished cross-sections x1.5.

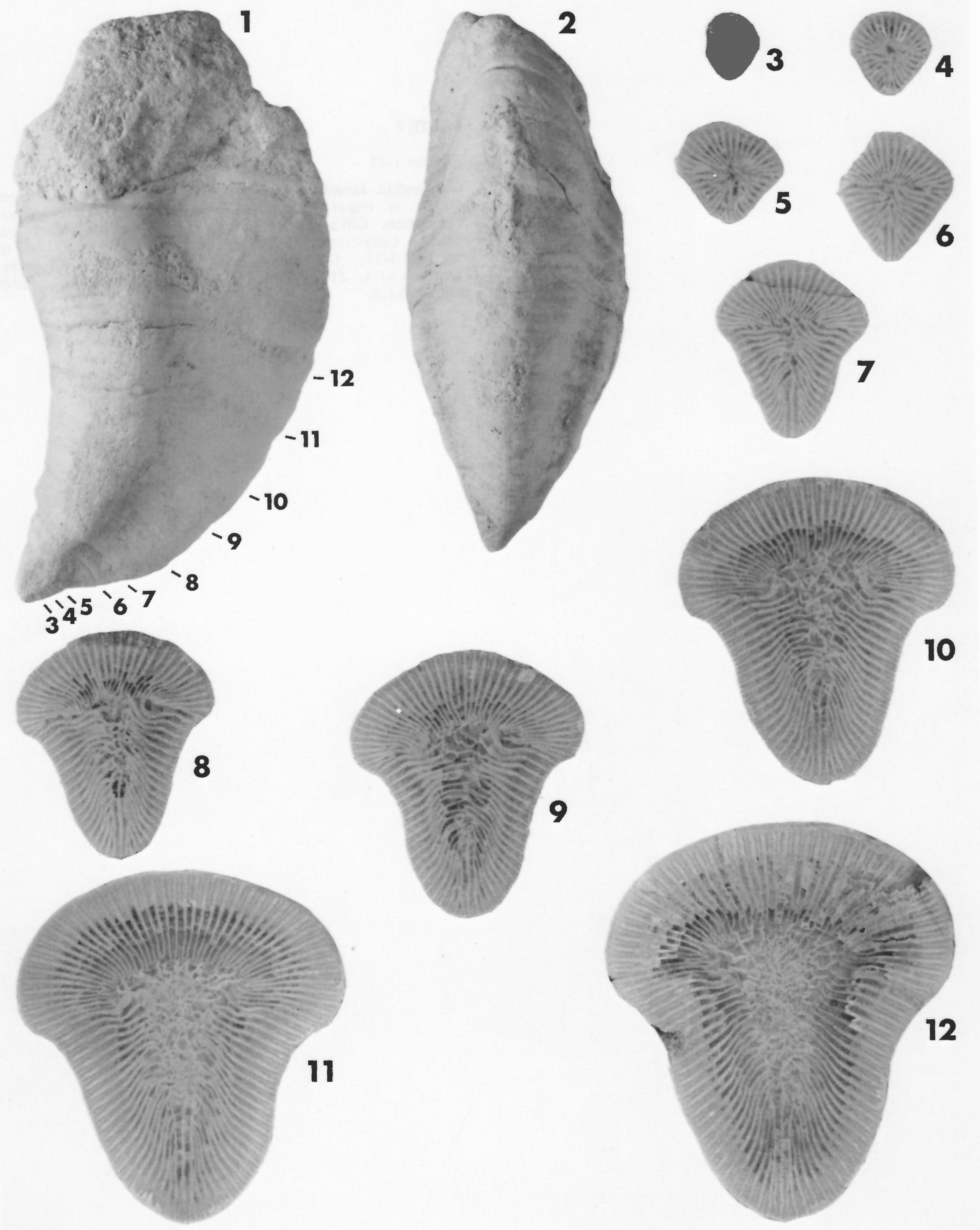
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PLATE 7

Figures 1-15

Grewingkia lamellosa n. sp. Holotype GSC 60740, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection. (1) Alar side x1, with location of sections 3-15. (2) Cardinal side x1. (3-13) Polished cross-sections x1.5. (14, 15) Polished sections of cardinal-counter surface x1.5.

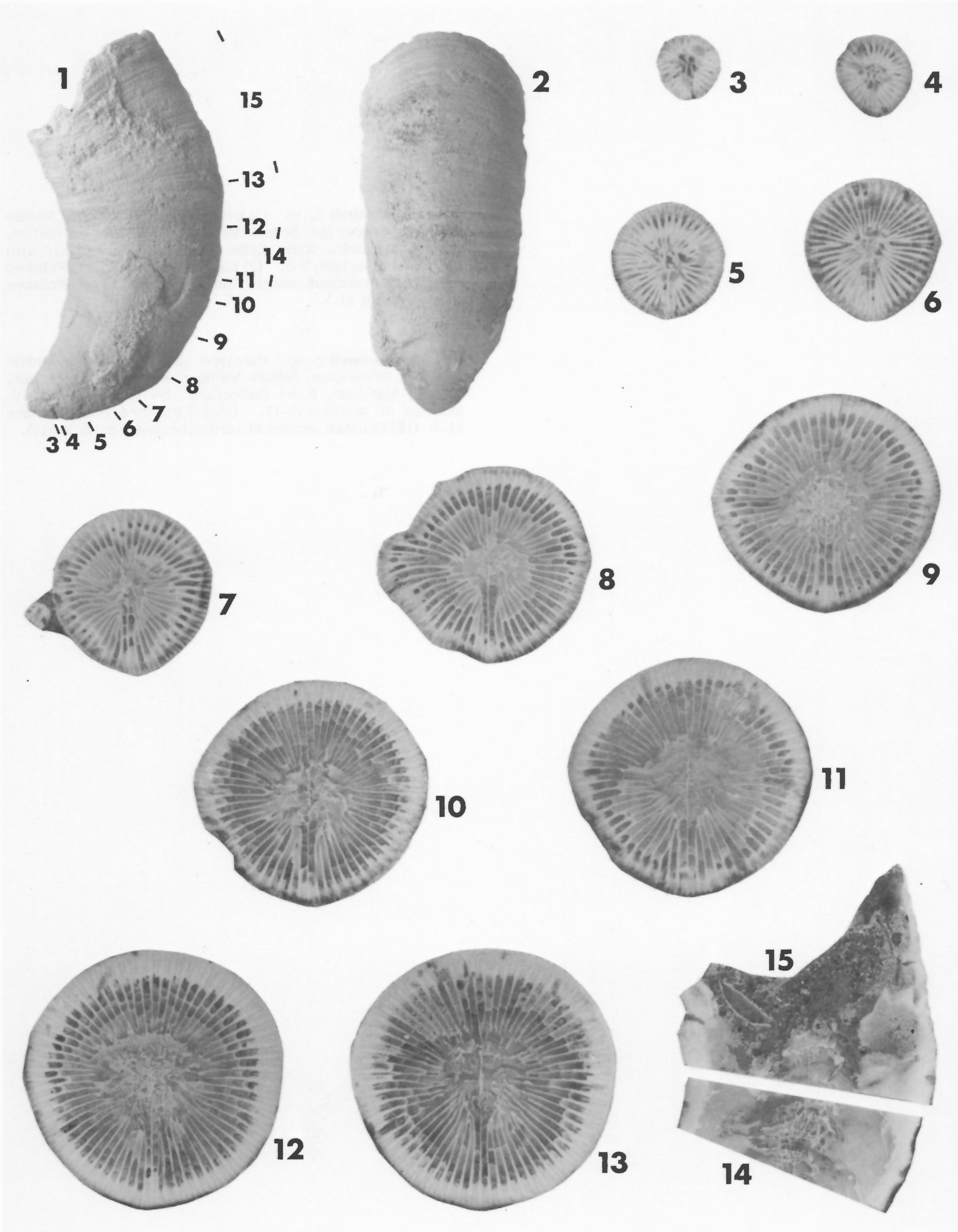
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PLATE 8

Figures 1-8

Helicelasma randi n. sp. Holotype GSC 60735, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba, Rand Collection. (1) Alar side x1, with location of sections 3-8. (2) Cardinal side x1. (3) Polished section of cardinal-counter surface x1.5. (4-8) Polished cross-sections x1.5.

Figures 9-18

Helicelasma randi n. sp. Paratype GSC 60729, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba, Rand Collection. (9) Alar side x1, with location of sections 10-18. (10-17) Polished cross-sections x1.5. (18) Polished section of cardinal-counter surface x1.5.

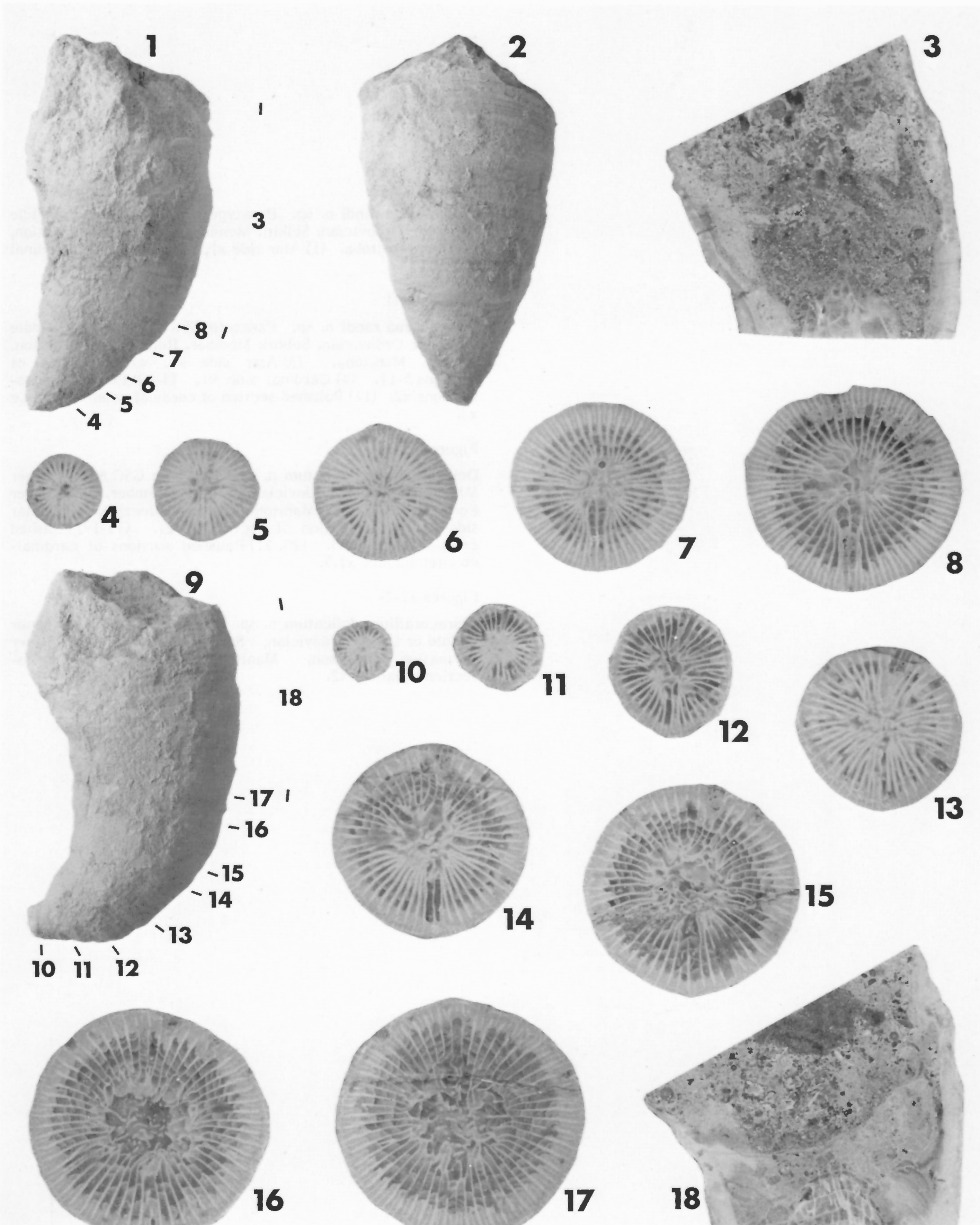
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PLATE 9

Figures 1, 2

Helicelasma randi n. sp. Paratype GSC 60733, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (1) Alar side x1, tip missing. (2) Cardinal side x1.

Figures 3-11

Helicelasma randi n. sp. Paratype GSC 60730, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (3) Alar side x1, with location of sections 5-11. (4) Cardinal side x1. (5-10) Polished cross-sections x2. (11) Polished section of cardinal-counter surface x2.

Figures 12-21

Deiracorallium delicatum n. sp. Holotype GSC 60745, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba, Rand Collection. (12) Alar side x1, with location of sections 13-21. (13-19) Polished cross-sections x1.5. (20, 21) Polished sections of cardinal-counter surface x1.5.

Figures 22-24

Deiracorallium delicatum n. sp. Paratype GSC 60746, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (22-24) Polished cross-sections near tip x2.

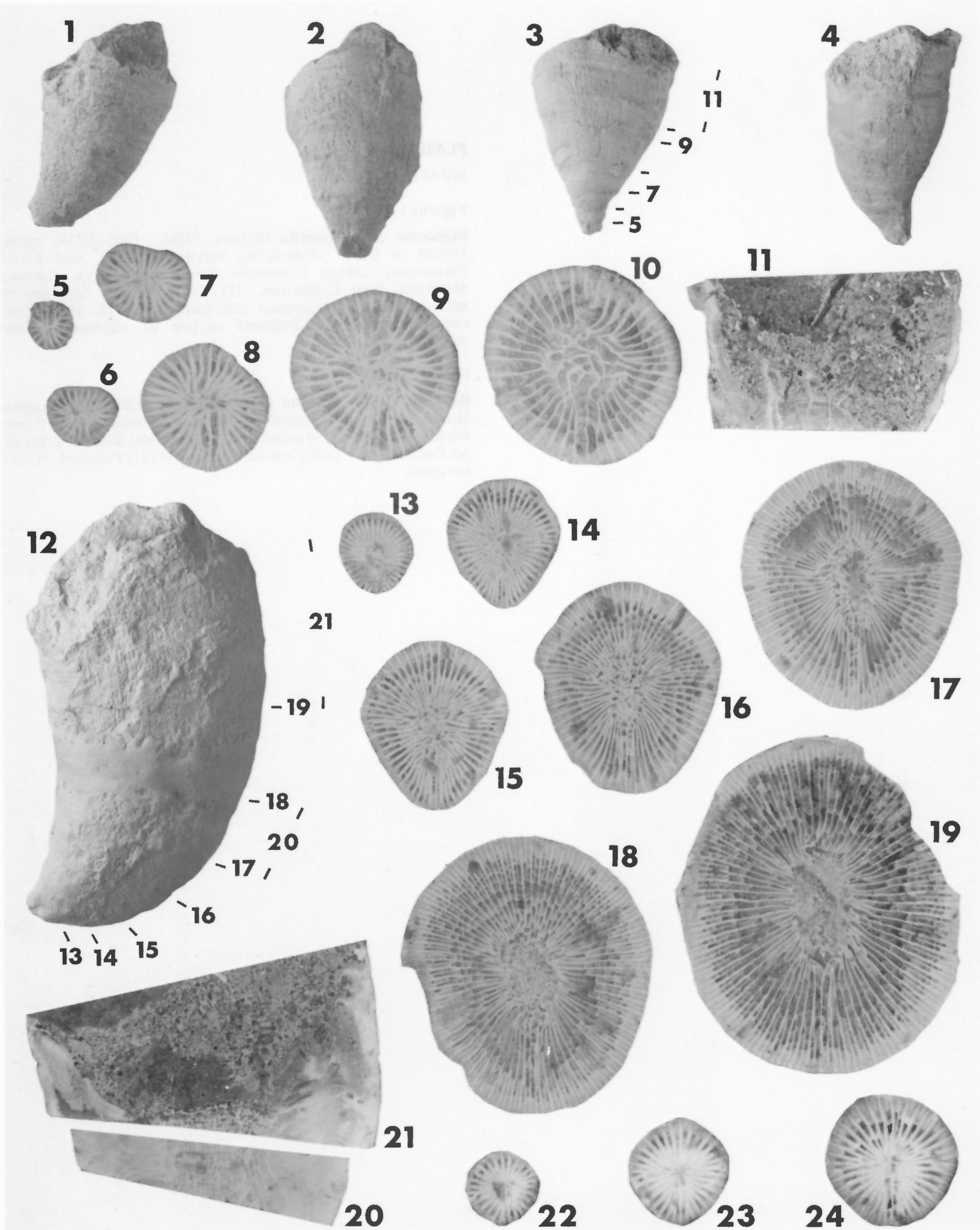
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PLATE 10

(all x2)

Figures 1-14

Bighornia cf. **B. patella** (Wilson, 1926). GSC 60754, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson Limestone Co. Ltd. quarry, Garson, Manitoba, Elias Collection. (1) Alar side, with location of sections 3-14. (2) Cardinal side stereopair. (3-13) Polished cross-sections. (14) Polished section of cardinal-counter surface.

Figures 15-21

Bighornia cf. **B. patella** (Wilson, 1926). GSC 60753, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Garson, Manitoba. (15) Alar side, with location of sections 17-21. (16) Cardinal side. (17-21) Polished cross-sections.

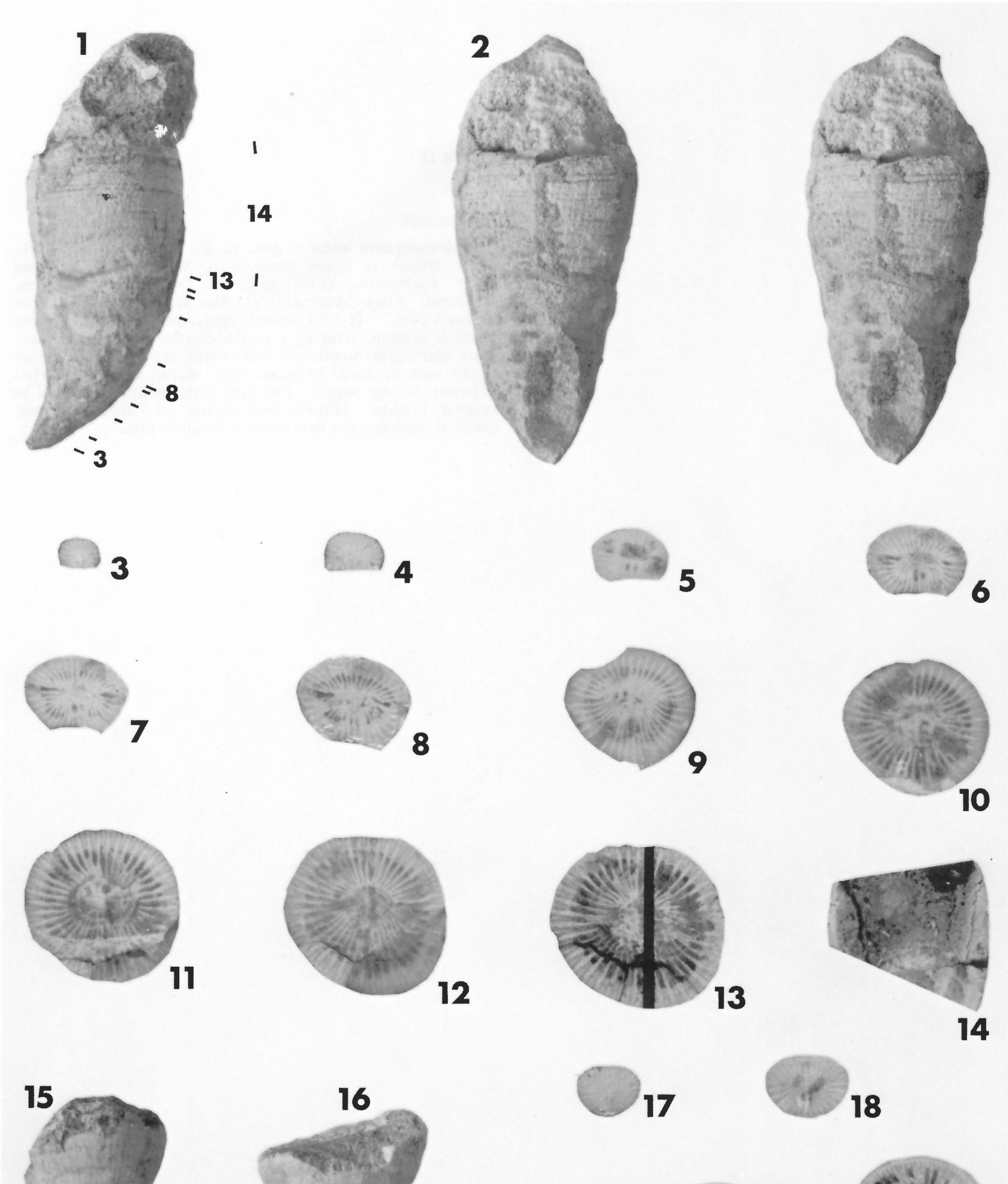
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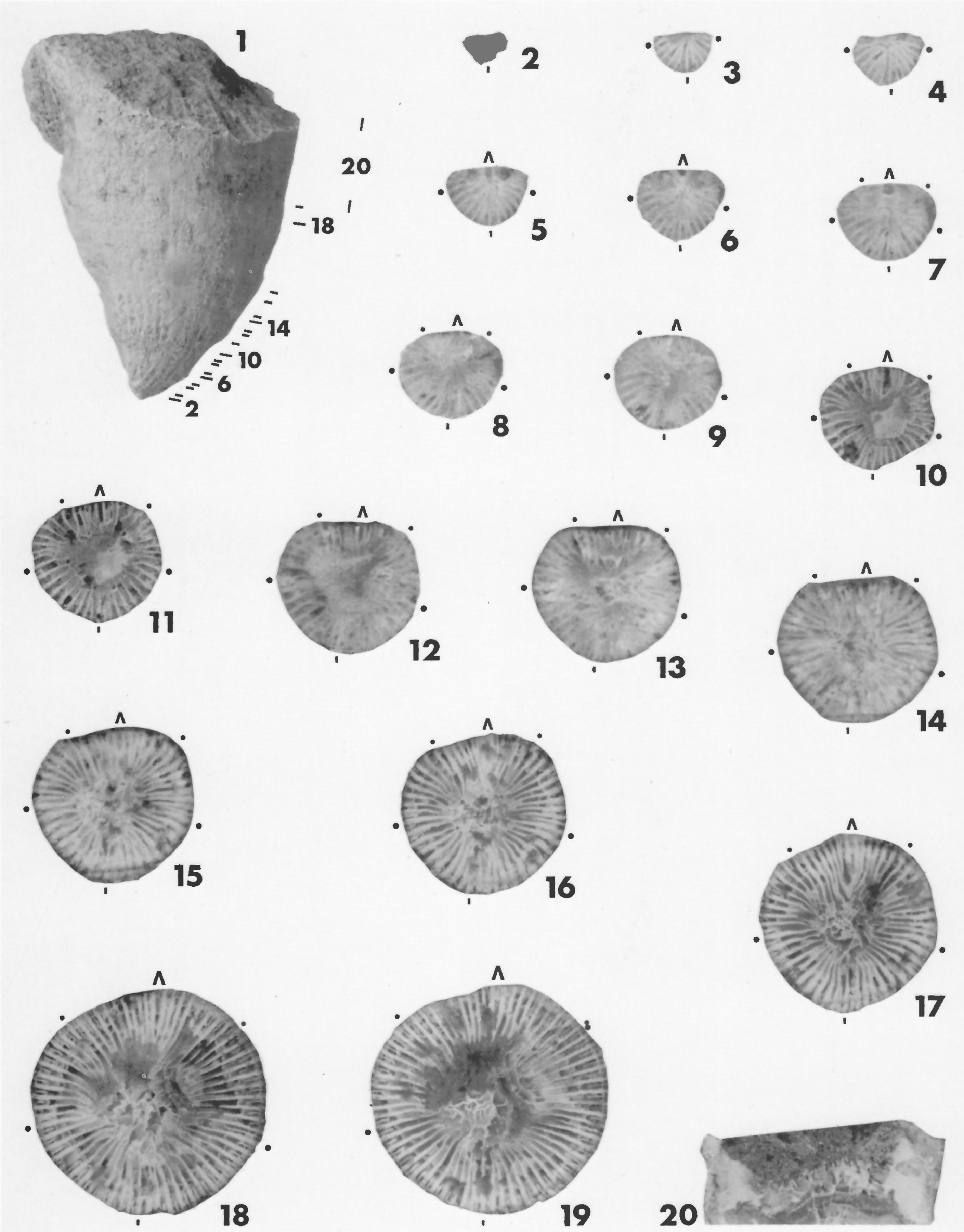
PLATE 11

(all x2)

Figures 1-20

Complexophyllum leithi n. gen., n. sp. Holotype GSC 60756, upper Middle or Upper Ordovician, Selkirk Member, Red River Formation, Gillis Quarries Ltd. quarry, Garson, Manitoba, Elias Collection. (1) Alar side, with location of sections 2-20. (2-19) Polished cross-sections; dash marks cardinal septum, inverted v marks counter septa, large dots mark alar septa, small dots mark major septum appearing on either side of coral between first major septum inserted adjacent to alar septum and first major septum inserted in counter fossula. (20) Polished section of cardinal-counter surface. Sections are described in detail in text.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