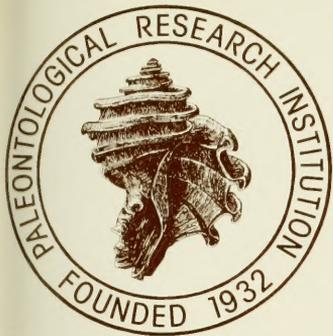


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VOLUME 98, NUMBER 333

JUNE 5, 1990

Latest Ordovician to Earliest Silurian
Solitary Rugose Corals of the
East-Central United States

by

Robert J. McAuley

and

Robert J. Elias

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1259 Trumansburg Road
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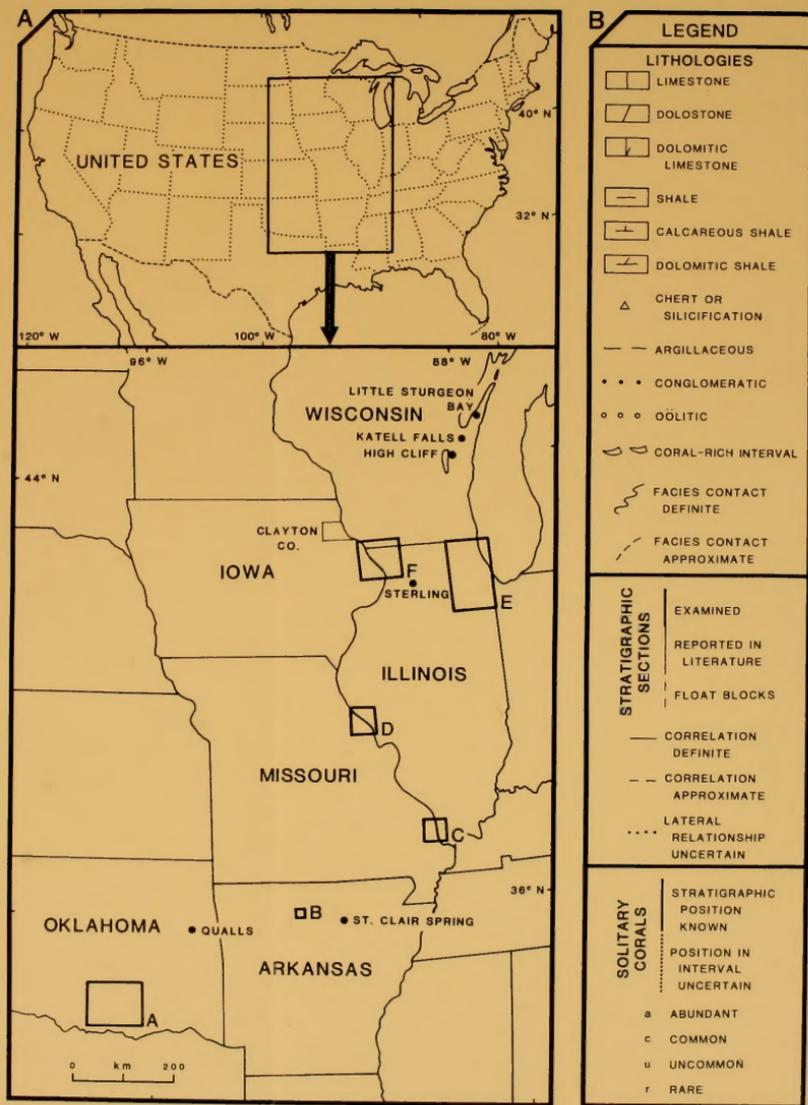
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Text-figure 1.—A, Index map showing study region in east-central United States, and detail map showing outcrop areas (A–F) of uppermost Ordovician and lowermost Silurian strata within the Edgewood Province, and other localities mentioned in text; details of areas A–F are shown in Text-figures 2–5, 7, 8. B, Legend of symbols for Text-figures 2–5, 7, 8.



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Library of Congress Card Number: 90-61316

Printed in the United States of America
Allen Press, Inc.
Lawrence, KS 66044 U.S.A.

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LATEST ORDOVICIAN TO EARLIEST SILURIAN
SOLITARY RUGOSE CORALS OF THE
EAST-CENTRAL UNITED STATES

By

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ABSTRACT

Four solitary rugosan assemblages are recognized within the uppermost Ordovician–lowermost Silurian sequence in the east-central United States: (1) Late Ordovician “epicontinental” assemblage (Richmondian); (2) Late Ordovician “continental margin” assemblage (Gamachian); (3) Edgewood assemblage (Gamachian–early Early Llandovery); and (4) Silurian assemblage (post-Edgewood Llandovery). A Late Ordovician “epicontinental” assemblage is present in the upper Maquoketa Group (Richmondian). *Salvadora randi* (Elias, 1981) occurs in southern Illinois, northwestern Illinois, and eastern Iowa. *Grewingkia canadensis* (Billings, 1862) has been identified in eastern Wisconsin. These species represent the Red River–Stony Mountain and Richmond solitary rugose coral provinces, respectively. They became extinct when the epicontinental sea withdrew at the end of Richmondian time, due to a major glacio-eustatic sea-level drop. A Late Ordovician “continental margin” assemblage is represented by *Rhegmaphyllum* sp. in the Cason oölite (Gamachian) of eastern north-central Arkansas.

This study is focused on the Edgewood assemblage, situated stratigraphically above the Late Ordovician “epicontinental” assemblage and geographically lateral to the “continental margin” assemblage. The Keel Formation of south-central Oklahoma contains *Streptelasma subregulare* (Savage, 1913b), *Streptelasma amsdeni*, n. sp., *Streptelasma leemonense* Elias, 1982a, *Streptelasma* sp. cf. *S. leemonense* Elias, 1982a, *Grewingkia* sp. A, and *Keelophyllum oklahomense*, n. gen., n. sp. *Streptelasma* sp. cf. *S. subregulare* (Savage, 1913b) and *S. leemonense* occur in the Cason shale of western north-central Arkansas. In southern Illinois and southeastern Missouri, species within the Leemon Formation are *S. subregulare*, *S. leemonense*, and *Bodophyllum shorti* Elias, 1982a. *Streptelasma* sp. A is present in the Noix Limestone of northeastern Missouri. The overlying Bryant Knob Formation yields *S. subregulare* from the unnamed member, and *S. subregulare*, *S. leemonense*, and *Grewingkia* sp. A from the Kissenger Limestone Member. The Cyrene Formation, which is the lateral equivalent of the Noix and Bryant Knob, contains *S. subregulare* in the middle part. *Streptelasma subregulare* is present in the Schweizer and Birds members of the Wilhelmi Formation in northeastern Illinois, and has been identified from the middle portion of the Mosalem Formation in northwestern Illinois. These taxa comprise the Edgewood Solitary Rugose Coral Province. The overall assemblage, in which 97.8 percent of specimens belong to *S. subregulare*, *S. amsdeni*, and *S. leemonense*, seems to be most similar to that in the *Dalmanitina* Beds (Hirnantian) or possibly earliest Llandovery beds of Östergötland, Sweden, and the Guanyinqiao Beds (*Dalmanitina* Beds; Hirnantian) of Guizhou Province, China.

The Keel Formation, Cason shale, Leemon Formation, Noix Limestone, and lower to middle Cyrene Formation are considered to be Late Ordovician (Gamachian) in age. The lower Schweizer Member of the Wilhelmi Formation and lower Mosalem Formation may also be Gamachian. The upper Schweizer Member and the Birds Member of the Wilhelmi Formation, and the middle Mosalem Formation are Early Silurian (early Early Llandovery). The Bryant Knob Formation and upper Cyrene Formation may also be early Early Llandovery. Thus, the Edgewood assemblage spans the time interval from Gamachian to early Early Llandovery, and solitary Rugosa cannot be used to delineate the Ordovician–Silurian boundary in the east-central United States. Gamachian units in the southern portion of the Edgewood Province mark the regressive phase corresponding to the glacial maximum, but could have been deposited during minor transgressions if sea level fluctuated during that time interval. The Gamachian(?) to Early Llandovery sediments of northern Illinois were deposited during the major latest Gamachian–Early Llandovery transgression associated with deglaciation. The Edgewood solitary Rugosa were not derived from corals of the Late Ordovician “epicontinental” assemblage. Their resemblance to some taxa previously restricted to the continental margin suggests that they originated from such forms.

Stratigraphically above the Edgewood is an assemblage characterized by genera typical of the Early to Middle Silurian. *Dinophyllum* sp., *Dalmanophyllum* sp., *Cyathactis?* sp., and *Rhegmaphyllum* sp. are found in the Bowling Green Dolomite (late Early Llandovery) of northeastern Missouri, the Elwood Formation (late Early to Middle Llandovery) of northeastern Illinois, and the upper Mosalem Formation (late Early Llandovery) in northwestern Illinois. *Cyathactis?* sp. is present in the Cochrane Formation (Llandovery) of south-central Oklahoma, and *Dalmanophyllum* sp. occurs in the Sexton Creek Limestone (Llandovery) of southeastern Missouri. These corals were not derived from Edgewood taxa, and must have been introduced from elsewhere. *Rhegmaphyllum* Wedekind, 1927, was confined to areas near the North American continental margin in the Richmondian and Gamachian. As water depth and temperature increased during the Early Llandovery transgression related to deglaciation, the Silurian assemblage succeeded the Edgewood assemblage, possibly after a minor regressive event.

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INTRODUCTION

The uppermost Ordovician to lowermost Silurian sequence in the east-central United States (Text-fig. 1A) comprises Late Ordovician, Maysvillian-Richmondian strata that are primarily shales, succeeded by dominantly carbonate units that are typically thin and of limited areal extent. The latter units were considered to be Early Silurian and were assigned to the Alexandrian Series by Savage (papers from 1908a through 1926, inclusive) and Reeds (1911). More recently, it has been recognized that they include latest Ordovician as well as Early Silurian deposits, based on studies of conodonts (*e.g.*, Craig, 1969; Thompson and Satterfield, 1975; Barrick, 1986) and brachiopods (Amsden, 1971b, 1974, 1986), and preliminary work on solitary rugose corals (Elias, 1982a; McAuley, Elias, and Mattison, 1986).

Although there has been a renewal of interest in these units and their biotas since the early 1970's, precise correlations and ages, as well as facies relationships and paleoenvironments, remain uncertain to varying degrees within outcrop areas and on a regional scale. The time interval represented by these deposits merits special attention. Climatic and sea-level changes during the Late Ordovician to earliest Silurian glacial epoch (see Hambrey, 1985) have been related to major global changes in sedimentation and biotas (*e.g.*, Berry and Boucot, 1973; Brenchley and Newall, 1984; Brenchley, 1984; Sheehan, 1988). The changeover from Ordovician to Silurian coral faunas is poorly understood because those of latest Ordovician to earliest Silurian age are inadequately known (Hill, 1981, pp. 51, 53).

Elias (1982a, pp. 47-52, fig. 24) studied Late Ordovician solitary Rugosa from the upper, Richmondian portion of the Maquoketa Group in the east-central United States. The corals from southern and northwestern Illinois and eastern Iowa belong to the Red River-Stony Mountain Province, and those from eastern Wisconsin were assigned to the Richmond Province. The Edgewood Province was proposed for solitary Rugosa from units situated immediately above the Maquoketa in southeastern and northeastern Missouri and northeastern Illinois. The province was tentatively extended to include south-central Oklahoma. In the present comprehensive study, we precisely document the full stratigraphic and geographic distribution of the Edgewood corals, consider their biostratigraphic and biogeographic significance, investigate their paleobiology and paleoecology, and thereby contribute to the solution of geologic problems and to our knowledge of corals in latest Ordovician to earliest Silurian time.

Solitary rugose corals of the latest Ordovician (Ga-

machian) to earliest Silurian (early Early Llandovery) Edgewood Province occur in six outcrop areas (Text-fig. 1A). The 30 stratigraphic sections that we selected for this study provide representative geographic coverage in each area; all but one have been described in previous literature, and fossils have been listed from most (see *Appendix: Stratigraphic Sections*). Every section was thoroughly examined for solitary coralla, which were found at 26 of them. All specimens seen were collected, except from a few intervals in which they were so numerous that this was impractical. Additional specimens from some of these as well as other sections were incorporated into our study from collections made by T. W. Amsden in south-central Oklahoma, W. W. Craig in north-central Arkansas, and T. E. Savage in southern and northeastern Illinois and northeastern Missouri. A total of 709 Edgewood solitary coralla are identified to the species level and described herein.

Solitary rugosan coralla were also collected from a Gamachian unit at St. Clair Spring in eastern north-central Arkansas (see *Appendix: Stratigraphic Sections*), and from later Llandovery strata situated immediately above those containing the Edgewood corals. However, these collections are not extensive, and most of the Silurian specimens are poorly preserved. We identified the best material to the generic level. Twenty-two of these coralla are documented herein because of their importance in delineating the geographic and stratigraphic limits of the Edgewood assemblage, and in interpreting biogeography and events.

This monograph represents the culmination of a project that began as part of a Ph.D. dissertation by Elias (1979). Following publication of those results (Elias, 1982a), research continued with two B.Sc. theses (Mattison, 1983; McAuley, 1983) and a M.Sc. thesis (McAuley, 1985) directed by Elias. The present publication is based largely on McAuley's M.Sc. thesis, and on subsequent work by Elias and McAuley. We share responsibility for all the contents.

ACKNOWLEDGMENTS

This project was funded by grants to R.J.E. from the Natural Sciences and Engineering Research Council of Canada, and a University of Manitoba Graduate Fellowship and Canadian Society of Petroleum Geologists Graduate Student Scholarship to R.J.M. B. W. Mattison and R. G. Zeilstra (University of Manitoba, Winnipeg, Manitoba) assisted in the field. They and L. M. McFarland (University of Manitoba) prepared many of the thin sections. R. G. Zeilstra and C. J. Buttler (née Knapp; University of Manitoba) photographed some of the specimens.

T. W. Amsden (Oklahoma Geological Survey, Nor-

man, Oklahoma), W. Kuntz (Louisiana, Missouri), and D. R. Babb (Belvidere, Illinois) provided assistance during field work in south-central Oklahoma, at Higinbotham Farm in northeastern Missouri, and at Belvidere South in northeastern Illinois, respectively. G. P. Wahlman (University of Cincinnati, Cincinnati, Ohio), and D. S. Brandt and A.-M. Welcher (Eastern Michigan University, Ypsilanti, Michigan) contributed to R.J.E.'s collections in Missouri and at Belvidere South in Illinois, respectively.

T. W. Amsden, W. W. Craig (University of New Orleans, New Orleans, Louisiana), and R. D. Norby (Illinois State Geological Survey, Champaign, Illinois) supplied information on stratigraphic sections in Oklahoma, Arkansas, and northeastern Illinois, respectively. D. L. Meyer (University of Cincinnati, Cincinnati, Ohio) and D. B. Blake (University of Illinois at Urbana-Champaign, Urbana, Illinois) arranged the loan of specimens from repositories in their charge. A. A. Petryk (Ministère de l'Énergie et des Ressources, Québec, Québec) and C. W. Stock (University of Alabama, University, Alabama) provided R.J.E. with collections from Québec, and Alabama and Georgia, respectively.

This publication benefitted greatly from comments on R.J.M.'s M.Sc. thesis by R. A. McLean (Amoco Canada Petroleum Company Limited, Calgary, Alberta) and T. W. Amsden, from reviews of the sub-

mitted manuscript by W. A. Oliver, Jr. (United States Geological Survey, Washington, DC) and J. E. Sorauf (State University of New York at Binghamton, Binghamton, New York), and from the editorial work of P. R. Hoover (Paleontological Research Institution, Ithaca, New York). Publication of this study was made possible by grants from the Department of Geological Sciences and the Faculty of Science at The University of Manitoba.

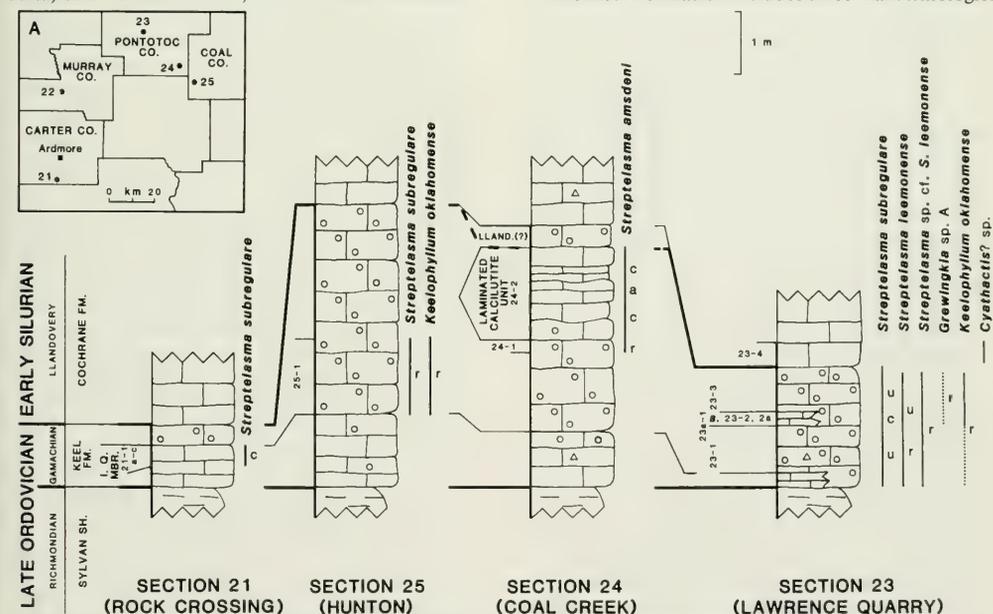
STRATIGRAPHY AND SOLITARY RUGOSE CORALS

SOUTH-CENTRAL OKLAHOMA

Lithostratigraphy

The lithostratigraphic terminology we use (Text-fig. 2) follows Amsden (1967), who summarized earlier nomenclature (Amsden, 1957, pp. 3-7, figs. 2, 3). The type section of the Keel Formation and Ideal Quarry Member is Section 23 (Lawrence Quarry) (Maxwell, 1936, p. 50; Amsden, 1957, pp. 9, 11). The areal distribution of the formation was shown by Amsden (1960, fig. 12; 1974, fig. 19; 1986, fig. 4). The Keel has a maximum thickness of 4.5 m, but is generally much thinner (Amsden, 1960, p. 44, fig. 12).

The Keel Formation includes three main lithologies.



Text-figure 2.—Stratigraphic sections (to scale) and locality map (A) in south-central Oklahoma (see Text-fig. 1A). For legend, see Text-figure 1B (foldout inside front cover). I.Q. = Ideal Quarry; B. = *Brevilamnella* beds. For references and precise locations of sections, see Appendix.

Most of the formation is an oölite, which is commonly silicified (Amsden, 1960, pl. 10, figs. 4–6, pl. 11, figs. 1–6; Amsden, 1986, pl. 1, figs. 1, 3, 5, 6, pl. 3, fig. 3, pl. 6, figs. 1–3). Some pisolitic beds are present at Section 23 (Lawrence Quarry). The second lithology is the oölitic, bioclastic calcarenite of the Ideal Quarry Member (Amsden, 1960, pl. 10, figs. 1–3; Amsden, 1986, pl. 3, fig. 1, pl. 6, fig. 3). It is situated at the base of the Keel, and is present at most outcrops (Amsden, 1960, pp. 33, 35). The *Brevilammulella* beds between the lower and upper oölitic of the Keel Formation at Section 23 are also composed of oölitic, bioclastic calcarenite (Amsden, 1986, pl. 2, fig. 1, pl. 3, fig. 2). The third lithology is a laminated calcilitite unit situated between oölitic of the Keel at a few outcrops, including Section 24 (Coal Creek) (Amsden, 1960, p. 40; Pl. 6, fig. 9).

The Keel Formation overlies the Sylvan Shale with apparent conformity (Amsden, 1986, p. 6), and is unconformably overlain by glauconitic, bioclastic calcarenite of the Cochrane Formation.

Biota

Fossils have been reported from the Keel Formation by a number of previous workers: Reeds (1911, pp. 259, 261, 267 [the oölitic member of the Chimneyhill Limestone therein is the Keel]), Maxwell (1936, tables 1, 2 [the Hawkins Limestone therein is the Ideal Quarry Member]), Amsden (1957, pp. 10–12, 15; 1960, pp. 30, 31, 35, 44; 1971b, p. 22; 1974; 1986, pp. 10, 11, figs. 7, 12; 1988, p. 24), Peel (1977), and Barrick (1986). Present in the Ideal Quarry Member, Keel oölite, and *Brevilammulella* beds are pelmatozoans, brachiopods, bryozoans, gastropods, pelecypods, trilobites, ostracodes, tabulate corals, and solitary rugose corals. Pelmatozoans, brachiopods, trilobites, ostracodes, and solitary rugose corals occur in the laminated calcilitite unit. Algal-coated grains have been recognized in the Ideal Quarry Member. The Keel Formation, including the Ideal Quarry Member and laminated calcilitite unit, has yielded conodonts. A monoplacophoran was described from oölite of the Keel Formation.

In addition to previously reported fossils, we identify the siphonous green alga *Dimorphosiphon* sp. in thin sections of samples from the Ideal Quarry Member at Section 21 (Rock Crossing). Colonial rugose corals were observed in the *Brevilammulella* beds of the Keel Formation at Section 23 (Lawrence Quarry). One solitary rugosan corallum from those beds has an incrustation that was probably produced by an alga or stromatopore. Cornulitids occur in the laminated calcilitite unit at Section 24 (Coal Creek).

The solitary rugose corals *Streptelasma subregulare* (Savage, 1913b), *Streptelasma amsdeni*, n. sp., *Streptelasma leemonense* Elias, 1982a, *Streptelasma* sp. cf.

S. leemonense Elias, 1982a, *Grewingkia* sp. A, and *Keelophyllum oklahomense*, n. gen., n. sp., are described herein from the Keel Formation. *Cyathactis?* sp. is present at the base of the overlying Cochrane Formation. The distribution of these corals is shown in Text-figure 2. Solitary coralla were not observed in the Keel Formation at Section 22 (Cedar Village), and are not known to occur in the Sylvan Shale.

The Pettit Formation (Amsden, 1980, pp. 23, 24) is an oölite less than 0.6 m thick that is locally present in northeastern Oklahoma (Amsden and Rowland, 1965, pp. 22–24, 26, 27, fig. 8, pl. 6, figs. 1–6). It has been tentatively correlated with the Keel Formation on the basis of lithology, stratigraphic relations, and position. Fossil debris, including pelmatozoans, is present in the Pettit, but no macrofossils have been recovered. Solitary coralla were not found in our study of this unit at section Ch4 of Amsden and Rowland (1965, pp. 24, 95, 96, fig. 7, pl. B), located about 100 m north of the type section near Qualls (see Text-figure 1A).

Age

Amsden (1967, p. 943, fig. 1) summarized the history of age assignments for the Keel Formation. The brachiopods were considered to be Late Ordovician (Hirnantian; i.e., late Gamachian) by Amsden (1971b, p. 22, fig. 1; 1974, p. 26; 1986, p. 18). Barrick (1986, pp. 64, 66) suggested that the *Noixodontus* conodont fauna of the Keel may be Hirnantian. He cited the association of *Noixodontus girardeauensis* (Satterfield, 1971) with brachiopods considered to be Hirnantian in the east-central United States, and the position of that species between the *Paraorthograptus pacificus* and *Glyptograptus persculptus* (?) graptolite zones at the Blackstone River section in the Yukon. He also stated that *Decoriconus costulatus* (Rexroad, 1967) of the *Noixodontus* fauna is typical of the earliest Silurian (Early Llandovery), but ranges down into the late Gamachian on Anticosti Island, Québec. It must be noted, however, that McCracken and Lenz (1987, pp. 648, 649) and McCracken (1987, p. 1452) considered strata bearing *N. girardeauensis* in the Blackstone River section to be of pre-Gamachian, late Richmondian age.

At Section 24 (Coal Creek) and one other locality, beds at the top of the Keel Formation (immediately above the laminated calcilitite unit) yielded a conodont fauna almost identical to that in the overlying Cochrane Formation (Barrick, 1986, p. 57). The presence of *Walliserodus curvatus* (Branson and Branson, 1947) and *Distomodus* elements was used to suggest a Llandovery (position uncertain) age for those beds (Barrick, 1986, p. 67). However, those taxa appear at and just above the base, respectively, of the *Oulodus? nathani* Conodont Zone on Anticosti Island (Mc-

Cracken and Barnes, 1981, p. 66, fig. 12), and the Ordovician-Silurian boundary defined as the base of the *Parakidograptus acuminatus* Graptolite Zone (Cocks, 1985) may be situated within the *O. nathani* Zone (Lespérance, 1985, figs. 3, 4; McCracken and Nowlan, 1988, p. 77).

Beneath the Keel Formation, the Sylvan Shale contains Late Ordovician (Maysvillian-Richmondian) graptolites of the *Dicellograptus complanatus* Zone in the lower to middle portion of the unit (Decker, 1935, pp. 698-700), conodonts that probably represent the *Amorphognathus ordovicicus* Zone (Sweet and Bergström, 1976, p. 146), and Late Ordovician chitinozoans throughout (Jenkins, 1970, pp. 284, 285). Above the Keel, the brachiopod *Triplesia alata* Ulrich and Cooper, 1936, apparently ranges through most of the Cochrane Formation (Amsden, 1971a, p. 145). Amsden (1986, p. 6) considered it to be Early Silurian (early Late Llandovery, C₁₋₂), but noted that it could be younger or older. The conodont fauna of the basal Cochrane was thought to be Llandovery (position uncertain) by Barrick (1986, pp. 57, 64, 67). Late Late Llandovery (C₃) species of the *Pterospathodus celloni* Conodont Zone were identified in the uppermost Cochrane by Barrick and Klapper (1976, p. 66).

Age assignments we follow are shown in Text-figure 2.

Paleoenvironment

Amsden (1960, pp. 41, 42, 160) considered the Keel oölite to have formed in warm, shallow, agitated but not strongly turbulent water within the zone of effective light penetration. It is inferred from the random orientation of solitary rugosan coralla in the *Brevilamnulella* beds and upper Keel oölite at Section 23 (Lawrence Quarry) that the directions of fluid motion may have been variable (Elias, McAuley, and Mattison, 1987, p. 810). Amsden (1986, pp. 10, 11, 42, 43) noted that fossils in the Keel are not in growth position and do not show excessive breakage, although the brachiopods are mostly disarticulated. He suggested that the energy level was moderately high. The gradational contact between the Ideal Quarry calcarenite and Keel oölite probably indicates shoaling (Amsden, 1960, p. 43). All or the vast majority of solitary coralla in collections from the Keel oölite, *Brevilamnulella* beds, and Ideal Quarry Member are nonabraded, suggesting rapid burial.

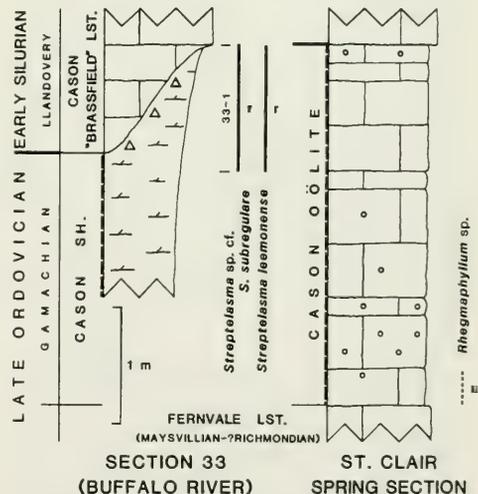
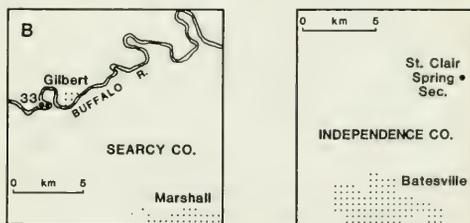
The lithology, bedding, and presence of articulated brachiopods in the laminated calcilitite unit indicate that it was deposited in lower energy conditions than other facies of the Keel Formation (Amsden, 1986, pp. 12, 13, 43). However, the parallel alignment of solitary rugosan coralla is likely a result of hydraulic action. The nonabraded condition of these coralla at Section 24 (Coal Creek) suggests a high sedimentation rate.

NORTH-CENTRAL ARKANSAS

Lithostratigraphy

The lithostratigraphic terminology we use (Text-fig. 3) is adapted from the following workers, who summarized the history of nomenclature: Craig (1969, 1975a, 1975b, 1984), Craig in Craig, Ethington, and Repetski (1986), Lemastus (1979), Craig, Wise, and McFarland (1984), and Amsden (1986, pp. 18-20, 22, 23).

Cason strata of Ordovician age are exposed in several areas of north-central Arkansas between Jasper (about 40 km west of Gilbert) in the west and St. Clair Spring in the east (Lemastus, 1979, pp. 14-28, 36, 37, 39-43, 46, fig. 1; Craig, Wise, and McFarland, 1984, pp. 11-13, fig. 3; see Text-figs. 1A, 3). Phosphatic shale, siltstone, and sandstone (Craig, 1975b, pl. 3, figs. a-h) are overlain locally and with apparent conformity by limestone that is predominantly an oölite but also includes bioclastic calcarenite and calcilitite (Craig,



Text-figure 3.—Stratigraphic sections (to scale) and locality maps (B and St. Clair Spring) in north-central Arkansas (see Text-fig. 1A). For legend, see Text-figure 1B (foldout inside front cover). For references and precise locations of sections, see Appendix.

1975b, pl. 4, figs. a, b, e, h). At the St. Clair Spring Section, the entire interval is limestone (Craig, 1975b, pl. 4, figs. c, d, f, g; Pl. 12, fig. 11). The Ordovician portion of the Cason is up to about 6 m thick. It unconformably overlies the Fernvale Limestone, and is unconformably overlain by the Cason "Brassfield" limestone or younger strata.

Biota

Fossils representing the following groups have been reported from phosphatic, clastic strata in the Ordovician portion of the Cason: pelmatozoans, articulate and inarticulate brachiopods, bryozoans, gastropods, pelecypods, cephalopods, trilobites, ostracodes, and conodonts (Craig, 1975b, pp. 73-75, 78; Lemastus, 1979, pp. 15, 36, 41, 42, 46, 90; Amsden, 1986, p. 20; Craig in Craig, Ethington, and Repetski, 1986, pp. 8, 18). Evidence indicating that these fossils were re-worked from the Fernvale Limestone was presented by Craig (1975b, pp. 74, 75) and Craig in Craig, Ethington, and Repetski (1986, pp. 8, 18). Conodonts that are likely indigenous occur in dolomitic shale of a section at Gilbert (Craig, 1975b, p. 80; Craig in Craig, Ethington, and Repetski, 1986, p. 18). Lemastus (1979, pp. 42, 88) reported silicified coralla from the uppermost dolomitic beds at Section 33 (Buffalo River). The following groups have been reported from limestone in the Ordovician portion of the Cason: pelmatozoans, brachiopods, bryozoans, gastropods, trilobites, ostracodes, conodonts, and corals (Craig, 1969, pp. 1623-1625; Craig, 1975b, pp. 75-77; Lemastus, 1979, pp. 24, 25, 36, 37, 42; Amsden, 1986, pp. 20, 22, fig. 18; Barrick, 1986, p. 64, table 7; Craig in Craig, Ethington, and Repetski, 1986, pp. 8, 9, 18, 19; Amsden, 1988, p. 24).

The solitary rugose corals *Streptelasma* sp. cf. *S. subregularis* (Savage, 1913b) and *Streptelasma leemonense* Elias, 1982a, are described herein from the uppermost, dolomitic and cherty beds of the Cason at Section 33 (Buffalo River), where a halysitid tabulate coral is also present. We found *Rhegmaphyllum* sp. in the Cason limestone at the St. Clair Spring Section. The distribution of these corals is shown in Text-figure 3.

Age

Conodonts in the Cason limestone and dolomitic shale that predate the "Brassfield" were considered to be latest Ordovician by Craig (1969, pp. 1624, 1625; 1975b, pp. 77, 80) and Craig in Craig, Ethington, and Repetski (1986, pp. 18, 19). Barrick (1986, pp. 64, 66) suggested that this *Noixodontus* conodont fauna may be Hirnantian (*i.e.*, late Gasmachian) in age. Amsden (1986, pp. 20, 22, 26) concluded that brachiopods in the lower 1 m of the Cason oölite at the St. Clair Spring

Section are Hirnantian. In the upper portion of the underlying Fernvale Limestone, conodonts represent upper Fauna 11 or 12 (Maysvillian-Richmondian) (Craig in Craig, Ethington, and Repetski, 1986, p. 18). The brachiopod *Lepidocyclus cooperi* Howe, 1966, in the upper Fernvale was considered to be Maysvillian by Amsden (1983, pp. 40, 42).

It has been suggested that conodonts in the lower, middle, and upper parts of the Cason "Brassfield" limestone are Llandovery and represent the *Distomodus kentuckyensis*, *Pterospathodus celloni*, and *Pterospathodus amorphognathoides* zones, respectively (Craig, 1969, pp. 1625, 1626; Craig in Craig, Ethington, and Repetski, 1986, pp. 25, 29). Barrick (1986, p. 67) assigned conodonts from the lowermost "Brassfield" at the St. Clair Spring Section to the Llandovery (position uncertain). The brachiopod *Triplezia alata* Ulrich and Cooper, 1936, in the "Brassfield" was considered to be Late Llandovery by Amsden (1971a).

Age assignments we follow are shown in Text-figure 3.

Paleoenvironment

Phosphatic, clastic beds of the lower Cason are considered to record a transgression over the eroded Fernvale surface (Craig, Wise, and McFarland, 1984, p. 12). The mainly oölitic carbonate sediments were deposited at the same time as clastics in shallow subtidal to intertidal environments, possibly primarily in tidal channels (Lemastus, 1979, pp. 27, 28; Amsden, 1986, pp. 23, 44).

SOUTHERN ILLINOIS AND SOUTHEASTERN MISSOURI

Lithostratigraphy

The lithostratigraphic terminology we use (Text-figure 4) follows Thompson and Satterfield (1975, pp. 73, 74, 77, 79, fig. 3). They summarized the history of nomenclature, as did Willman and Buschbach (1975, pp. 86, 87, fig. O-27) and Willman and Atherton (1975, p. 99, fig. S-10).

The Girardeau Limestone, which consists of irregularly bedded limestone with shale partings, overlies the Orchard Creek Shale with apparent conformity (Satterfield, 1971, p. 266). It is overlain unconformably by the Sexton Creek Limestone or, locally, the Leemon Formation. The type section of the Leemon is Section 20 (Short Farm) (Thompson and Satterfield, 1975, p. 77). The formation has a maximum exposed thickness of 3.8 m at Section 31 (Thebes North), but is locally absent.

Lithologies within the Leemon Formation include oölitic (Amsden, 1986, pl. 1, fig. 2, pl. 4, figs. 5, 6), oölitic bioclastic calcarenite (Pl. 8, figs. 1-4), and calcareous shale (Amsden, 1986, pl. 4, fig. 4). Small, biohermal mounds up to 0.5 m high occur at the base at

Section 19 (New Wells), and were described by Amsden (1974, pp. 21, 22; 1986, p. 33, pl. 4, fig. 1). Quartz sand grains (Amsden, 1986, pl. 1, fig. 4) are most common in the Illinois sections (Amsden, 1974, p. 24), and clasts of the Girardeau Limestone are generally present near the base. The Leemon Formation unconformably overlies the Orchard Creek Shale or, where present, the Girardeau. The Leemon is unconformably overlain by the Sexton Creek Limestone, which contains bands of chert nodules.

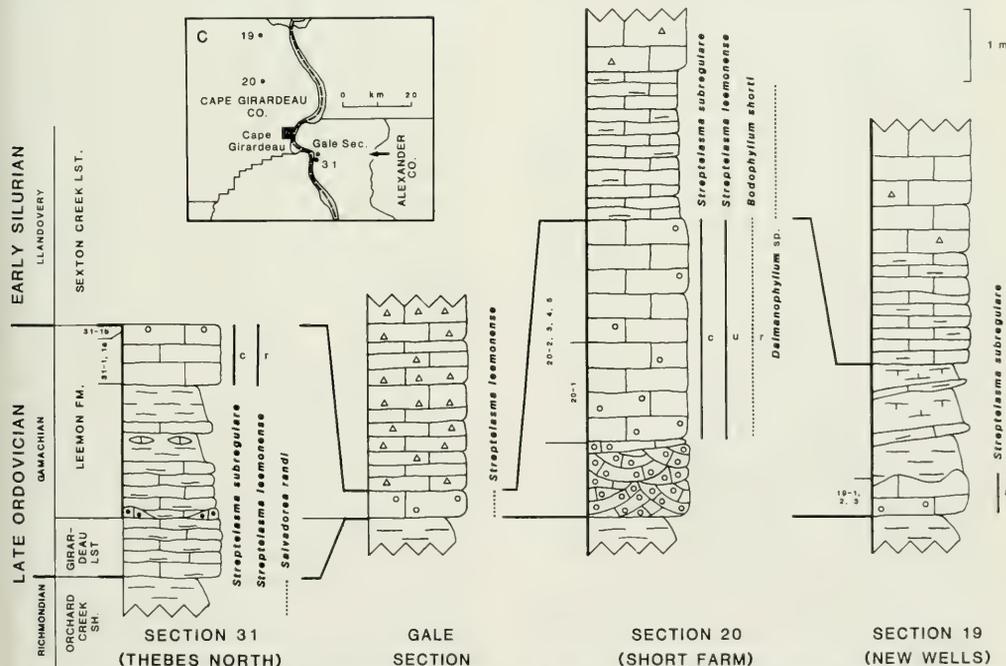
Biota

Fossils from the Girardeau Limestone, including crinoids and other echinoderms, brachiopods, bryozoans, gastropods, pelecypods, trilobites, cornulitids, and conodonts, were reported by Savage (1913a, pp. 358, 359; 1913b; 1917), Satterfield (1971), Brower (1973), Thompson and Satterfield (1975, figs. 6, 8), and Kolata and Guensburg (1979). Solitary Rugosa are not known from the Girardeau.

Pelmatozoans, brachiopods, bryozoans, gastropods, pelecypods, trilobites, ostracodes, conodonts, stromatoporoids, tabulate corals, and solitary rugose corals have been reported from the Leemon Formation by

the following workers: Savage (1913a, pp. 365, 366; 1913b; 1917 [the Cyrene Member of the Edgewood Formation therein is the Leemon]), Amsden (1971b [the basal Edgewood zone therein includes the Leemon]; 1974; 1986, p. 33, figs. 23, 24, 26, 27), and Thompson and Satterfield (1975, figs. 7-9). In addition, we recognize the siphonous green alga *Dimorphosiphon* sp. in thin sections of samples from the formation at Section 20 (Short Farm) (Pl. 8, figs. 2, 3) and a bioherm at Section 19 (New Wells). Several solitary rugosan coralla from Section 19 have algal coatings, and one has a boring we identify as *Trypanites* sp. that was probably produced by a polychaete annelid. Microborings of algal and/or fungal origin occur in a few solitary coralla from Section 20 and in some from Section 19.

Elias (1982a) documented the solitary corals *Streptelasma leemonense* Elias, 1982a, *Streptelasma* sp. [referred herein to *Streptelasma subregulare* (Savage, 1913b)], and *Bodophyllum shorti* Elias, 1982a, from the Leemon Formation at Section 20 (Short Farm), and *S. subregulare* from the Leemon bioherms at Section 19 (New Wells). During the present study, the latter species was also found at Section 20, and *S.*



Text-figure 4.—Stratigraphic sections (to scale) and locality map (C) in southern Illinois and southeastern Missouri (see Text-fig. 1A). For legend, see Text-figure 1B (foldout inside front cover). For references and precise locations of sections, see Appendix.

subregulare and *S. leemonense* were obtained at Section 31 (Thebes North). We identify *Streptelasma subregulare* and *S. leemonense* in Savage's collections from Section 31 and the Gale Section, respectively. *Dalmanophyllum* sp. occurs at the base of the Sexton Creek Limestone, which overlies the Leemon, at Section 20. *Salvadorea randi* (Elias, 1981) was described from the Orchard Creek Shale beneath the Girardeau Limestone at Section 31 by Elias (1982a, pp. 61, 62, pl. 6, fig. 9; 1985, p. 45). The distribution of these corals is shown in Text-figure 4.

Age

Age determinations of earlier workers were summarized by Willman and Buschbach (1975, pp. 86, 87, fig. O-27) and Willman and Atherton (1975, p. 94, fig. S-10). Liebe was evidently first to conclude that conodonts in the Girardeau Limestone are Ordovician (Liebe, oral commun., 1961, cited in Berry and Boucot, 1970, p. 154; Liebe, 1962, pp. 9, 35). Satterfield (1971) and Thompson and Satterfield (1975, pp. 69, 70) assigned that unit to the very late Ordovician on the basis of stratigraphic relations and conodonts representing the *Prioniodus ferrarius* fauna. Brower (1973, p. 264) reported that the Girardeau brachiopods were being studied by R. Parkinson, who was "inclined toward a latest Ordovician grouping (Gamachian stage)." The crinoids suggested a Richmondian or younger Ordovician (Gamachian) age to Brower (1973, p. 265). On the basis of conspecific crinoids, Kolata and Guensburg (1979, p. 1122) considered it probable that the underlying Orchard Creek Shale is Richmondian. Ross (in Pryor and Ross, 1962, p. 9) found the "characteristic Cincinnati" graptolite *Climacograptus putillus* (Hall, 1865) in that unit. A late Maysvillian-Richmondian age for the Orchard Creek has been suggested on the basis of conodonts and stratigraphic position (Sweet and Bergström, 1976, p. 147).

Brachiopods of the Leemon Formation were considered to be Late Ordovician (Hirnantian; i.e., late Gamachian) by Amsden (1971b, p. 21 [the basal Edgewood zone therein includes the Leemon]; 1974, pp. 19, 22, 24). He noted that the assemblage at Section 19 (New Wells) "comprises fairly typical pre-Hirnantian genera, Hirnantian genera, and post-Hirnantian Silurian genera" (Amsden, 1986, p. 34). Thompson and Satterfield (1975, p. 79) also considered the unit to be Late Ordovician, based on abundance of the conodont *Amorhognathus ordovicicus* Branson and Mehl, 1933. *Noixodontus girardeauensis* (Satterfield, 1971), which occurs in the Leemon as well as the Girardeau, may be restricted to the Hirnantian (Barrick, 1986, pp. 64, 66).

From the Sexton Creek Limestone at a section in Alexander County, Illinois, the Early Silurian (early

Late Llandovery, C_{1-2}) brachiopod *Stricklandia protriplesiana* (Amsden, 1966) was identified by Amsden (1974, p. 24; 1986, p. 26; 1988, p. 26). Within the lower Sexton Creek in Cape Girardeau County, Missouri, Thompson and Satterfield (1975, p. 70, figs. 6, 7, 9) reported conodonts of the Early Silurian *Paltodus dyscritus* fauna, which corresponds to the *Icriodina irregularis* Zone of Nicoll and Rexroad (1968) and the *Distomodus kentuckyensis* Zone of Cooper (1975).

Age assignments we follow are shown in Text-figure 4.

Paleoenvironment

Brower (1973, pp. 266, 268, 269) suggested that limestone beds in the Girardeau Limestone were generally deposited in quiet water, with organisms precluded by low levels of oxygen or unsuitable substrates. The fossiliferous shaly partings represent higher energy conditions with favorable oxygen levels and substrates.

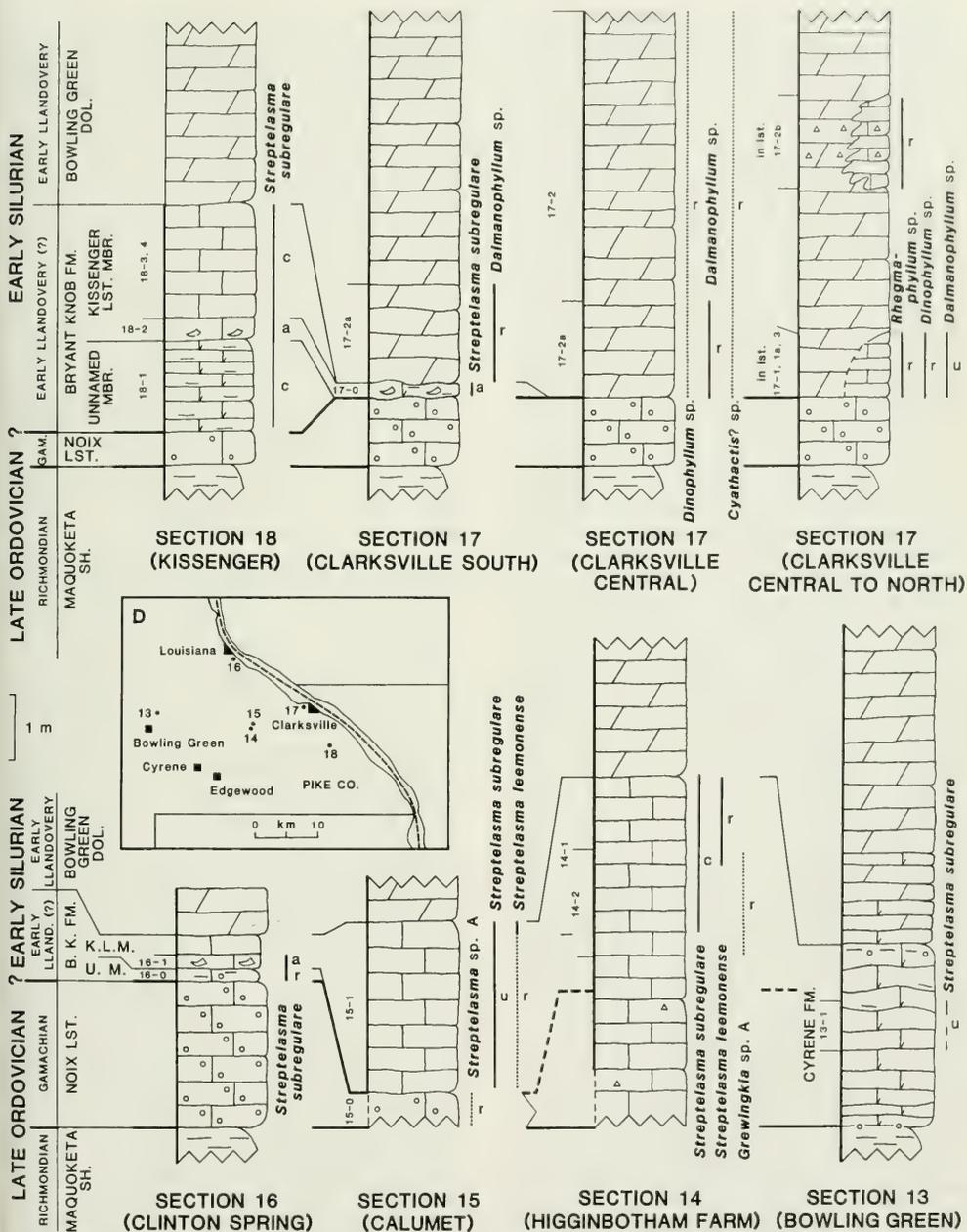
The Leemon Formation of southern Illinois was deposited in a channel that was cut into the Girardeau Limestone during an earlier period of exposure, according to Savage (1910, p. 331; 1913b, pp. 20, 21; 1917, pp. 77, 79 [the Edgewood Formation therein]). Amsden (1974, p. 24) noted that the presence of quartz sand and silt in the Leemon of Illinois and Missouri indicates deposition near a source area. He observed that brachiopods show little fragmentation and are commonly articulated, and inferred moderate energy environments. The majority of solitary rugosan coralla at Sections 31 (Thebes North) and 19 (New Wells) are nonabraded, whereas most at Section 20 (Short Farm) are abraded. This could reflect a lower sedimentation rate and/or higher energy conditions at Section 20. The development of small bioherms at Section 19 suggests open, normal marine conditions. A boring (*Trypanites* sp.) we observed in one bioherm passes through the matrix before entering a solitary corallum, indicating that the substrate was hard.

NORTHEASTERN MISSOURI

Lithostratigraphy

The lithostratigraphic terminology we use (Text-figure 5) largely follows Thompson and Satterfield (1975, pp. 81-85, 87, 89, 93, 95-100, fig. 3; but see *Correlation*, p. 15). They summarized the history of nomenclature. The Noix Limestone and Bowling Green Dolomite also occur across the Mississippi River in Illinois, where the Bryant Knob Formation is apparently absent (Savage, 1914, p. 29 [the upper part of the oölite therein is the Bryant Knob]; Rubey, 1952, pp. 25, 27; Amsden, 1974, p. 18).

The Noix Limestone of the Edgewood Group occurs in a northwest-trending outcrop belt that is about 75



Text-figure 5.—Stratigraphic sections (to scale) and locality map (D) in northeastern Missouri (see Text-fig. 1A). For legend, see Text-figure 1B (foldout inside front cover). Gam. = Gamachian, B.K. = Bryant Knob, U.M. = unnamed mbr., K.L.M. = Kissenger Lst. Mbr. For references and precise locations of sections, see Appendix.

km long and at least 11 km wide (Thompson and Satterfield, 1975, p. 89). The type section of the Noix is Section 16 (Clinton Spring). This unit is up to about 2 m thick, and is thickest along the west bank of the Mississippi River. It is typically a light gray oölite (Amsden, 1974, pl. 28, figs. 5, 6), and is cross-bedded in places. At a few localities, it is in part argillaceous, phosphatic, and conglomeratic (Thompson and Satterfield, 1975, p. 87, fig. 10). The Noix overlies the Maquoketa Shale unconformably, and is overlain by the Bryant Knob Formation or Bowling Green Dolomite. It is a lateral equivalent of part of the Cyrene Formation, which is located to the west (Thompson and Satterfield, 1975, pp. 85, 103).

Geographically, the distribution of the Bryant Knob Formation coincides approximately with that of the Noix (Thompson and Satterfield, 1975, p. 85). The type section of this formation and the Kissenger Limestone Member is Section 18 (Kissenger) (Thompson and Satterfield, 1975, p. 98). An unnamed member that occurs at the base of the Bryant Knob at the type section, and locally elsewhere, overlies the Noix with apparent conformity (Thompson and Satterfield, 1975, p. 103). This member consists of up to 2 m of dolomitic limestone and/or shale. The Kissenger Limestone Member, up to perhaps 5 m thick, is a light gray, medium- to coarse-grained, massively bedded, bioclastic calcarenite (Amsden, 1974, pl. 28, figs. 3, 4). It overlies the unnamed member with apparent conformity where both members are present, and overlies the Noix unconformably where the unnamed member is absent. The Bryant Knob Formation is overlain unconformably by the Bowling Green Dolomite.

The Cyrene Formation occurs immediately west of the Noix and Bryant Knob. The type section is about 4 km northeast of Edgewood, Missouri, and Section 13 (Bowling Green) is an excellent reference section (Thompson and Satterfield, 1975, pp. 82, 96). This unit is about 2 m thick. It is a brown to bluish gray, fine- to medium-grained, dolomitic limestone (Amsden, 1974, pl. 27, figs. 1a, b, 2a, b). The Cyrene overlies the Maquoketa Shale, and is overlain by the Bowling Green Dolomite. The latter contact is inconspicuous in the vicinity of Section 13 (Savage, 1914, p. 29; Rowley, 1916, p. 317; Amsden, 1974, p. 11).

The Bowling Green Dolomite is the upper unit of the Edgewood Group. The type section is located about 1 km east-northeast of Section 13 (Bowling Green), which is a principal reference section (Thompson and Satterfield, 1975, p. 99). This unit has an average thickness of 6 to 9 m in Pike County, Missouri (Krey, 1924, p. 27). It consists of buff, earthy, massive dolostone (Amsden, 1974, pl. 28, figs. 1, 2), locally with beds of chert nodules in the upper two-thirds. In the eastern part of this area, the Bowling Green unconformably

overlies the Noix Limestone or Bryant Knob Formation. To the west, it overlies the Cyrene Formation. The Bowling Green Dolomite is overlain unconformably by the Sexton Creek Limestone or younger strata.

Biota

The following workers identified fossils from strata in Missouri that probably represent the Noix Limestone, Bryant Knob Formation, and Cyrene Formation: Rowley (1904 [see Ausich, 1987]; 1908, p. 23 [the oölitic limestone therein is probably the Noix and Bryant Knob, and the brown earthy limestone therein is probably the Cyrene]) and Savage (1913b, pp. 24, 25; 1917, pp. 82, 83 [the Noix oölite therein is the Noix and Bryant Knob, and the Edgewood limestone near Edgewood therein is probably the Cyrene]). Those authors recognized crinoids, brachiopods, gastropods, pelecypods, cephalopods, trilobites, stromatoporoids, tabulate corals, and solitary rugose corals. In addition, cystoid plates and tentaculitids, and conularids and cornulitids, were reported from strata that probably represent the Noix and Bryant Knob, respectively. Stromatoporoids from the coral-rich interval at the base of the Kissenger Limestone Member, Bryant Knob Formation, were described by Birkhead (1967 [the Cyrene Member of the Edgewood Formation at loc. 1 therein]). In Illinois, Rubey (1952, p. 170) listed brachiopods and solitary rugose corals from the Noix Limestone, and brachiopods, bryozoans, gastropods, pelecypods, trilobites, tentaculitids, cornulitids, tabulate corals, and solitary rugose corals from the Bowling Green Dolomite.

Amsden documented brachiopods from the Noix Limestone, Bryant Knob Formation, and Cyrene Formation of the Edgewood Group in Missouri and Illinois (Amsden, 1971b, pp. 21, 22 [included in the basal and younger Edgewood zones therein]; Amsden, 1974 [the Bryant Knob at loc. D and lower Bowling Green at loc. C therein are considered to be Cyrene herein]; Amsden, 1988, p. 24). In addition to brachiopods, Amsden (1974, fig. 9; 1986, figs. 29, 30) identified pelmatozoans, bryozoans, gastropods, trilobites, ostracodes, and corals from the Noix and Cyrene, as well as pelecypods and tentaculitids from the Noix. Conodonts have been reported from the Noix Limestone, both members of the Bryant Knob Formation, and Cyrene Formation in Missouri by Thompson and Satterfield (1975, figs. 10–15) and McCracken and Barnes (1982). Graptolites occur in the unnamed member of the Bryant Knob (Thompson and Satterfield, 1975, pp. 97, 98).

In addition to fossils reported previously from the Bryant Knob Formation, we recognize the siphonous green alga *Dimorphosiphon* sp. in thin sections of samples from the unnamed member at Section 18 (Kis-

senger), and the coral-rich interval at the base of the Kissenger Limestone Member at Sections 17 (Clarksville) and 16 (Clinton Spring) (Pl. 3, fig. 16). Algal coatings are rare on solitary rugosan coralla in the unnamed member, but are relatively common in the coral-rich interval of the Kissenger. Microborings that were likely produced by algae occur in some coralla from the coral-rich interval, but are rare in those from overlying strata. Borings we identify as *Trypanites* sp., which were probably formed by polychaete annelids, are rare in solitary coralla from the Kissenger Limestone.

Elias (1982a) described the holotype of *Streptelasma subregulare* (Savage, 1913b) from the Cyrene Formation near Edgewood, Missouri. During the present study, *S. subregulare* was found elsewhere in the Cyrene, as well as in both members of the Bryant Knob Formation. *Streptelasma* sp. A occurs in the Noix Limestone, and *Streptelasma leemonense* Elias, 1982a, and *Grewingkia* sp. A are present in the Kissenger Limestone. *Dinophyllum* sp., *Dalmanophyllum* sp., and *Cyathactis?* sp. are identified from the Bowling Green Dolomite, and *Rhegmaphyllum* sp., *Dinophyllum* sp., and *Dalmanophyllum* sp. are recognized in limestone patches of the Bowling Green. The distribution of these corals is shown in Text-figure 5.

Correlation

Early workers reported that the Bryant Knob Formation (upper part of the "oölite" in their terminology) at exposures in eastern Pike County, Missouri, contained abundant solitary and colonial coralla, as did the upper portion of the Cyrene Formation (which includes the Watson Limestone of Rowley) at western sections in the vicinity of Edgewood (Rowley, 1908, pp. 20, 21; Rowley, 1916, pp. 319, 320; Savage, 1913b, p. 22; Savage, 1917, p. 80). Savage (1913b, p. 25; 1917, p. 83) considered the "oölite" to correspond to the upper half or two-thirds of the Cyrene. Thompson and Satterfield (1975, pp. 85, 87, 103) interpreted the Noix Limestone (which underlies the Bryant Knob) as a facies of the upper part of the Cyrene Formation, although conodonts used to correlate the Cyrene with the Maquoketa Shale also occur in one section of the Bryant Knob (Thompson and Satterfield, 1975, p. 96, figs. 10, 11). On the basis of brachiopods and lithologic similarity, Amsden (1974, pp. 9, 11, 14, 15) tentatively considered the upper half of the Cyrene of Thompson and Satterfield at Section 13 (Bowling Green), as well as the Watson Limestone of Rowley, to be Bryant Knob. However, subsequent collecting has reduced the distinction between Noix–Cyrene and Bryant Knob brachiopod assemblages (Amsden, 1986, p. 29).

We follow the interpretation that the Cyrene Formation is a facies equivalent of the combined Noix

Limestone and Bryant Knob Formation. The conodont *Noixodontus girardeauensis* (Satterfield, 1971) is present in the upper middle portion of the Cyrene at Section 13 (Bowling Green) (see Thompson and Satterfield, 1975, fig. 11) and in the Noix. The *Paltodus dyscritus* conodont fauna first appears definitely in the upper portion of the Cyrene (Thompson and Satterfield, 1975, p. 101) and in the Bryant Knob. *Streptelasma subregulare* (Savage, 1913b) occurs in the Cyrene Formation (just below and within the interval containing *N. girardeauensis*) and in the Bryant Knob Formation.

Strata overlying the Maquoketa Shale in a quarry located 1.5 km north-northwest of Section 13 (Bowling Green) were assigned to the Bowling Green Dolomite by Amsden (1974, p. 8). The lower 3 m were tentatively correlated with the Noix Limestone on the basis of brachiopods (Amsden, 1974, pp. 15, 18). We suggest that these beds, now covered by water, correspond to the Cyrene Formation (see also Amsden, 1988, p. 36).

Amsden (1974, pp. 16–18, figs. 12, 13) considered two hypotheses for the relationship between the Bryant Knob Formation and Bowling Green Dolomite. On the basis of lithostratigraphic data, he favored the interpretation that these units are laterally and vertically intergrading facies, rather than discrete units having separate depositional histories (see also Amsden, 1986, pp. 36, 37, fig. 34). Amsden inferred that basal strata of the Bowling Green at Section 17 (Clarksville) are equivalent to the unnamed member comprising the lower portion of the Bryant Knob at Section 18 (Kissenger), and to the Kissenger Limestone Member of the Bryant Knob at Section 16 (Clinton Spring).

At Section 18 (Kissenger), a thin interval containing abundant solitary rugosan coralla is present at the base of the Kissenger Limestone Member, immediately above the unnamed member of the Bryant Knob Formation (see Text-fig. 5). This coral-rich interval also occurs in the Bryant Knob at Section 16 (Clinton Spring) (see Birkhead, 1967, fig. 7), immediately above a thin, shale-bounded carbonate bed. The latter bed did not yield conodonts, but was included in the Noix Limestone by Thompson and Satterfield (1975, fig. 12, sample 9), presumably because it contained some oöids. Elias (1982a, p. 40, fig. 21) placed this bed in the Kissenger because it contained the same solitary rugosan species as the overlying coral-rich interval, and considered the oöids to be reworked from the Noix. On the basis of lithology and stratigraphic position, we conclude that this bed represents the unnamed member of the Bryant Knob, and the coral-rich interval above it marks the base of the Kissenger. The coral-rich interval has been reported at a locality about 2 km southeast of Section 16 (Rowley, 1908, p. 20). We also found the interval containing abundant solitary

coralla at the extreme southern end of Section 17 (Clarksville). There it occurs as a bed that is shale-bound in places, overlies the Noix along an irregular contact, is overlain by the Bowling Green Dolomite along an undulatory surface, and pinches out northward along the exposure (Text-figs. 5, 6). This bed is assigned to the Kissenger.

The coral-rich interval of the Kissenger Limestone contains solitary rugosan coralla that are abraded, have algal coatings, and have microborings of probable algal origin associated with micritized surfaces. We consider it to be a lag deposit that is likely isochronous. *Strep-telasma subregulare* (Savage, 1913b), the only solitary rugosan species in the interval, also occurs in the unnamed member as well as other strata included in the Kissenger Limestone Member of the Bryant Knob Formation. The solitary coral assemblage in the basal Bowling Green Dolomite at Section 17 (Clarksville), both above and lateral to the coral-rich bed, is entirely different. We infer that the unnamed member of the Bryant Knob is older than the Kissenger Limestone Member, which in turn is older than the Bowling Green Dolomite.

This interpretation, based on the distribution of solitary Rugosa, is consistent with the nature of contacts between the various units in this sequence. Where the unnamed member of the Bryant Knob Formation is present (e.g., Section 18), it overlies the Noix Limestone with apparent conformity (Thompson and Satterfield, 1975, p. 103). Where the coral-rich interval at the base of the Kissenger Limestone Member of the Bryant Knob overlies the Noix, the contact is unconformable (Section 17). The contact between the Kissenger Limestone and Bowling Green Dolomite is unconformable at some sections (e.g., Sections 17, 18; see Thompson and Satterfield, 1975, pp. 98, 103). We conclude that both members of the Bryant Knob Formation as well as the Bowling Green Dolomite are discrete units, as recognized by Thompson and Satterfield (1975, p. 103).

Thompson and Satterfield (1975, pp. 89, 100, figs. 13, 14) reported an unnamed unit composed of soft, white limestone present locally at the base of the Bowling Green Dolomite. It was described as thin "lenses" on the Bryant Knob Formation at Section 18 (Kissenger), and as two low "mounds" on the Noix Limestone at Section 17 (Clarksville). Thompson and Satterfield noted that the "mound" at the north end of the latter section was associated with an irregularity along the upper surface of the Noix, and was enclosed by a thin shale seam. This unit was not exposed at Section 18 during the present study, but two "mounds" were observed on weathered faces of the exposure at Section 17. One was at the north end, and the other was located toward the south. It is uncertain whether these are the

same "mounds" reported by Thompson and Satterfield. In 1983, slumping along parts of Section 17 exposed fresh surfaces. Two irregular patches composed of soft, white limestone that was indistinguishable from the "mounds" were observed within the Bowling Green Dolomite about 3 m above the Noix. One was situated above, and separated from, the southern "mound". The other, found farther north along part of an inclined joint or fracture, contained chert nodules at the same stratigraphic positions as the surrounding dolostone. These observations suggest that areas of limestone at the base of, and within, the Bowling Green represent undolomitized portions of this unit, rather than a discrete stratigraphic interval. *Dalmanophyllum* sp. and *Dinophyllum* sp. were found in both lithologies. Although *Rhegmaphyllum* sp. is recognized only in the limestone and *Cyathactis?* sp. is known only from the dolostone, these apparent differences may be related to the overall rarity of solitary coralla in the Bowling Green, and the relatively poor preservation of fossils in the dolostone.

Age

Berry and Marshall (1971) identified graptolites of the *Dicellograptus complanatus* var. *ornatus* Zone from an exposure of the Maquoketa Formation in eastern Missouri. The age of these Late Ordovician strata was considered to be within the late Maysvillian to Richmondian interval.

Before the 1970's, workers followed Savage's assignment of Edgewood strata in northeastern Missouri to the Early Silurian Alexandrian Series (Savage, 1913a, p. 352; Thompson and Satterfield, 1975, fig. 1). Liebe (1962, pp. 10, 35) was evidently first to recognize that conodonts in the Noix Limestone are Ordovician. *Amorphognathus ordovicicus* Branson and Mehl, 1933,



Text-figure 6.—Contacts between Kissenger Limestone Member of the Bryant Knob Formation and underlying Noix Limestone (thumb), and overlying Bowling Green Dolomite (forefinger), extreme southern end of Section 17 (Clarksville), Pike County, Missouri (photographed in 1983).

and other taxa indicate a Late Ordovician age (Thompson and Satterfield, 1975, p. 87). McCracken and Barnes (1982, p. 1477) considered the Noix conodont fauna to be late Richmondian (see also McCracken and Lenz, 1987, p. 649). However, Barrick (1986, pp. 64, 66) suggested that *Noixodontus girardeauensis* (Satterfield, 1971) may be restricted to the Hirnantian Stage (*i.e.*, late Gamachian).

Thompson and Satterfield (1975, p. 93) reported the Late Ordovician *Prioniodus ferrarius* conodont fauna from strata at Section 14 (Higginbotham Farm) that were assigned to the Bryant Knob Formation by Amsden (1974, p. 83, loc. A) and by us. Conodonts in the unnamed member at the base of the Bryant Knob include representatives of *Amorphognathus ordovicicus* Branson and Mehl, 1933, *Icriodella?* sp., and the *Paltodus dyscritus* fauna (Thompson and Satterfield, 1975, p. 97, figs. 10, 14). These conodonts, as well as graptolites (Berry, written commun., 1971, cited in Thompson and Satterfield, 1975, pp. 97, 98), were considered to indicate an Early Silurian age (Thompson and Satterfield, 1975, pp. 72, 101). The overlying Kissenger Limestone Member of the Bryant Knob contains *A. ordovicicus* as well as the *Prioniodus ferrarius* and *Paltodus dyscritus* faunas, and was also assigned an Early Silurian age (Thompson and Satterfield, 1975, p. 101, figs. 10, 12, 14, 15). However, Nowlan (*in* Bolton and Nowlan, 1979, pp. 5, 21) suggested that mixed faunas including *A. ordovicicus* and *P. dyscritus* Rexroad, 1967, might be Late Ordovician, based on an occurrence in undoubtedly Ordovician strata in the District of Keewatin. The Bryant Knob Formation was tentatively assigned to the Early Silurian (Early Llandovery) by Amsden (1971b, pp. 21, 22 [the younger Edgewood zone therein includes the Bryant Knob]; 1974, p. 14). He based this primarily on stratigraphic position and the absence of certain characteristic Noix brachiopods, but subsequent collecting demonstrated that some of the species previously thought to have been confined to the Bryant Knob are also present in Noix-Cyrene strata (Amsden, 1986, p. 29).

Thompson and Satterfield (1975, p. 96, fig. 11) reported *Amorphognathus ordovicicus* Branson and Mehl, 1933, as well as the *Prioniodus ferrarius* and *Paltodus dyscritus* conodont faunas in the Cyrene Formation. They considered this unit to be Late Ordovician, but we equate it with the combined Noix Limestone and Bryant Knob Formation. The conodont *Noixodontus girardeauensis* (Satterfield, 1971) is present in the upper middle portion of the Cyrene at Section 13 (Bowling Green) (see Thompson and Satterfield, 1975, fig. 11) and in the Noix. The *Paltodus dyscritus* fauna first appears definitely in the upper portion of the Cyrene (Thompson and Satterfield, 1975, p. 101) and in the Bryant Knob. Brachiopods in the Cyrene Formation

as recognized by us were tentatively assigned Late Ordovician and Early Llandovery ages by Amsden (1974, pp. 14, 15 [locs. C and D therein]).

Thompson and Satterfield (1975, pp. 96, 97, 101, 103) identified the *Paltodus dyscritus* fauna in the Bowling Green Dolomite (including the unnamed unit of those authors), and concluded that this formation is Early Silurian. They considered conodonts in eastern exposures to be younger than those in western sections on the basis of three specimens identified as *Neospathognathodus celloni* (Walliser, 1964). McCracken and Barnes (1982, p. 1475) suggested that the latter conodonts represent *Oulodus?* cf. *O.?* *nathani* McCracken and Barnes, 1981, of which they found one specimen in the Bowling Green. They inferred that the fauna in this unit may represent the Early Llandovery *Oulodus?* *nathani* or *Distomodus kentuckyensis* conodont zones (McCracken and Barnes, 1982, pp. 1474, 1477). However, the Ordovician-Silurian boundary defined as the base of the *Parakidograptus acuminatus* Graptolite Zone (Cocks, 1985) may be situated within the *O.?* *nathani* Zone (Lespérance, 1985, figs. 3, 4; McCracken and Nowlan, 1988, p. 77).

The brachiopod *Platyerella manniensis* Foerste, 1909, was reported at the base of the Sexton Creek Limestone (Kankakee Formation), which locally overlies the Bowling Green Dolomite, by Savage (1913b, p. 30; 1917, p. 88), Willman (1973, p. 16), and Willman and Atherton (1975, p. 97). This zone was placed in the Middle Llandovery by Berry and Boucot (1970, pl. 2). Specimens of *Stricklandia triplesiana* (Foerste, 1890), with an interior similar to *Stricklandia lens ultima* Williams, 1951, from the Sexton Creek in Illinois were considered to be Late Llandovery (C_{4-5}) by Amsden (1974, pp. 18, 24; 1986, p. 41).

Age assignments we follow are shown in Text-figure 5, and discussed further on pp. 25, 26.

Paleoenvironment

Savage (1914, p. 30) concluded from the lithostratigraphic record that the sea in which the lower Edgewood Group formed was deepest in the west, where the Cyrene Formation accumulated, and became progressively shallower toward the eastern margin, where the Noix Limestone and Bryant Knob Formation were deposited. The shoreline gradually receded westward, reaching a position a few km west of Louisiana, Missouri. Deposition of the Bowling Green Dolomite was initiated by a slight uplift west of the basin, accompanied by subsidence resulting in an eastward overlap on the Noix and Bryant Knob surface. Sedimentation was uninterrupted to the west, where the Bowling Green overlies the Cyrene.

Thompson and Satterfield (1975, pp. 93, 103, fig. 16) interpreted the coarse, bioclastic limestone at Sec-

tion 14 (Higginbotham Farm) as a bioherm situated beneath the Bryant Knob Formation. We consider these strata to be a coquina and include them in the Bryant Knob (see also Amsden, 1974, p. 83, loc. A). They suggested that this deposit may have been a source of nuclei for ooids that formed to the east, and acted as a barrier that separated Noix and Cyrene deposition.

Conodont assemblages indicate that the Noix Limestone formed in relatively shallow water, and the Bowling Green Dolomite was deposited during a transgression (McCracken and Barnes, 1982, p. 1477). On the basis of conodont data, Thompson and Satterfield (1975, p. 97) concluded that deposition of the Bowling Green began earlier at Section 13 (Bowling Green) in the west than at Section 17 (Clarksville) in the east. However, McCracken and Barnes (1982, pp. 1475, 1477) considered conodonts from the latter section to represent an earlier zone than that indicated by Thompson and Satterfield. Local structural movements possibly contributed to the complex facies relations and unconformities in the Edgewood sequence (Thompson and Satterfield, 1975, p. 103).

Most solitary rugose coralla in the Bryant Knob Formation are abraded, suggesting relatively high energy levels and comparatively low sedimentation rates. The highest proportions of abraded specimens observed in this study are from the coral-rich interval at the base of the Kissenger Limestone Member. Algal coatings are relatively common on solitary coralla and bioclastic grains in that interval, and some of the coralla have probable algal microborings associated with micritized surfaces. These features suggest transportation and prolonged exposure before burial, and we interpret the coral-rich interval as a lag deposit. The directional orientation pattern for solitary coralla in this interval at Section 16 (Clinton Spring) indicates that they were rolled almost perpendicular to water flow or nearly parallel to wave crests, with currents from the northwest (Elias, McAuley, and Mattison, 1987, p. 810). The paleocurrent direction is parallel to depositional strike of the Bryant Knob and to the inferred shoreline, suggesting longshore currents and perhaps waves.

NORTHEASTERN ILLINOIS

Lithostratigraphy

The lithostratigraphic terminology we use (Text-fig. 7) follows Willman (1973, pp. 6, 9, 12-17, fig. 6), who summarized the history of nomenclature (see also Willman and Buschbach, 1975, p. 86, fig. O-27; Willman and Atherton, 1975, pp. 96, 97, fig. S-7).

The type section of the Wilhelmi Formation, as well as the Schweizer Member, is Section 4 (Schweizer West), and the type section of the Birds Member is Sections

4 and 5 (Schweizer North) (Willman, 1973, pp. 12-14). The Wilhelmi is up to 30 m thick where it fills or nearly fills channels eroded into the underlying Maquoketa Group, but is thin or absent elsewhere in the area. The Schweizer Member, which is up to 24 m thick, is generally present only where the formation is relatively thick. The lower portion consists primarily of gray, dolomitic shale, whereas the upper part is very argillaceous, silty, thinly bedded dolostone. This unit is overlain conformably by the Birds Member, which is up to 6 m thick. The Birds is a gray, slightly argillaceous, typically flaggy dolostone. At Section 3 (Garden Prairie), the basal bed above the Maquoketa and the overlying flaggy dolostone were identified as the Wilhelmi Formation by Willman (1973, p. 12) and are assigned to the Birds Member by us.

The Wilhelmi Formation unconformably overlies strata of the Maquoketa Group, ranging from the uppermost unit, the Neda Formation, down to the top of the Fort Atkinson Limestone, which underlies the Brainard Shale. The Wilhelmi is overlain conformably by slightly argillaceous to pure dolostone of the Elwood Formation, which contains numerous layers of chert (Willman, 1973, p. 14). Dolostone of the Kankakee Formation overlies the Elwood conformably.

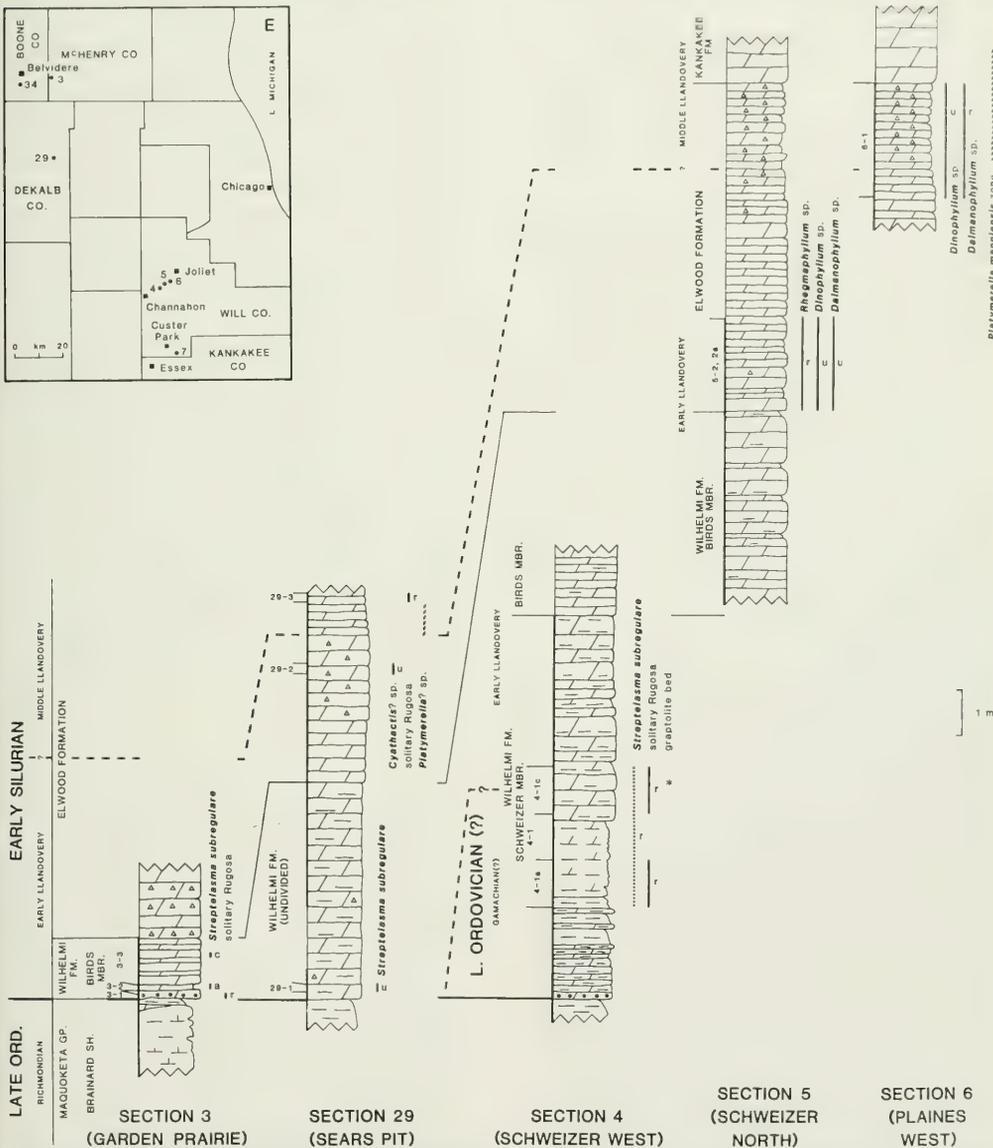
Biota

Fossils from the Wilhelmi Formation at exposures along Des Plaines River about 1.6 km, 3.2 km, and 5.6 km to the south of Channahon were identified by Savage (1913b, pp. 26, 27; 1914, p. 31; 1917, pp. 84, 85 [the Channahon Limestone therein]). He recognized brachiopods, gastropods, pelecypods, cephalopods, trilobites, ostracodes, tabulate corals, and solitary rugose corals. Fisher (1925, pp. 26, 27 [the Edgewood therein]) reported brachiopods and trilobites from a section of platy dolostone, which possibly represents the Birds Member of the Wilhelmi, along Du Page River about 7 km north of Channahon. The section south of Belvidere that was described by Savage (1926, p. 518 [the Edgewood limestone therein]) is very similar to Sections 34 (Belvidere South) and 3 (Garden Prairie). He identified solitary rugose corals from unit 3 (his terminology), which we assign to the Birds Member.

The following groups have been listed from the Wilhelmi Formation along Horse Creek about 2.4 km east of Essex: brachiopods, gastropods, pelecypods, algae?, tentaculitids, cornulitids, conularids, tabulate corals, and solitary rugose corals (Savage, 1913b, p. 29; Savage, 1917, p. 87; Athy, 1928, pp. 40, 41 [the Essex Limestone therein]). From the same unit along Horse Creek 0.4 km west of Custer Park, Athy (1928, p. 41) reported brachiopods, trilobites, algae?, and tentaculitids.

Ross (1962 [the Edgewood Formation therein]) described graptolites from a silty dolostone bed situated 7.6 m (shown at 4.6 m in his fig. 1) above the base of the Wilhelmi Formation, in the upper part of the

Schweizer Member at Section 4 (Schweizer West). Scelocodont fragments were reported in the Wilhelmi-Elwood sequence of northeastern Illinois by Buschbach (1964, p. 59 [the Edgewood Formation therein]). Liebe



Text-figure 7.—Stratigraphic sections (to scale) and locality map (E) in northeastern Illinois (see Text-figure 1A). For legend, see Text-figure 1B (foldout inside front cover). For references and precise locations of sections, see *Appendix*.

and Rexroad (1977, figs. 2, 4) listed conodonts from the Schweizer Member of the Wilhelmi Formation at Section 4, and from the Birds Member at Sections 4 and 5 (Schweizer North) and National Quarry on the south side of Joliet. Mikulic *et al.* (1985, pp. 10, 32, 33) also reported conodonts from the Wilhelmi at National Quarry, and noted inarticulate brachiopods, trilobites, and trace fossils in the basal, shaly strata, and pelmatozoan debris, brachiopods, bryozoans, gastropods, cephalopods, and trilobites in the upper, dolomitic strata. Conodonts, brachiopods, gastropods, and trilobites are present in the Wilhelmi at Section 29 (Sears Pit) (Mikulic *et al.*, 1985, p. 23).

Elias (1982a) studied two collections of solitary rugosan coralla made by Savage from the unit he termed Channahon Limestone. These included specimens that Savage (1913b) identified and illustrated as two new species, *Zaphrentis ambigua* and *Zaphrentis subregularis*. Elias concluded that they represent one species, *Streptelasma subregularare* (Savage, 1913b). Savage (1913b, p. 26; 1917, p. 84) reported numerous solitary coralla in unit 2 (his terminology) of the Channahon Limestone at a section located 1.6 km southeast of Channahon. He noted that corresponding strata are exposed above Maquoketa shale 1.6 km farther south (Savage, 1914, p. 31; see also Savage, 1916, p. 306), suggesting a position near the base of the Wilhelmi Formation. Elias (1982a, p. 40) assumed that Savage's specimens came from Wilhelmi beds that lie stratigraphically above the graptolite bed of Ross, based on statements by Ross (1962, p. 1385) and Willman (1973, pp. 12, 13). From collections made during the present study at Section 4 (Schweizer West), it is apparent that *S. subregularare* occurs in the Schweizer Member, below and above the position of the graptolite bed. Brachiopods, bryozoans, gastropods, trilobites, cornulitids, colonial corals, and solitary corals were observed at the latter locality.

During the present study, we examined additional solitary coralla obtained by Savage in the vicinity of Channahon. *Streptelasma subregularare* (Savage, 1913b) is the only taxon that is represented. The same species occurs in his collections made along Horse Creek and near Belvidere, and is common in a bed of the Birds Member, Wilhelmi Formation, exposed on the quarry floor at Section 34 (Belvidere South; interval 34-1). *Streptelasma subregularare* was also found in the Birds Member at Section 3 (Garden Prairie) and at the base of the undivided Wilhelmi at Section 29 (Sears Pit). Solitary coralla were not observed in the Birds Member at Section 5 (Schweizer North). *Rhegmaphyllum* sp., *Dinophyllum* sp., and *Dalmanophyllum* sp. appear at the base of the Elwood Formation at Section 5, and the latter two occur in the upper Elwood at Section 6 (Plaines West). In the Elwood at Section 29, *Cyathac-*

titis? sp. is present. At Section 7 (Kankakee River), solitary coralla were not found in the 0.3-m-thick Wilhelmi Formation, or in the underlying Neda Formation of the Maquoketa Group. The Kankakee Formation overlies the Wilhelmi at that location. The distribution of solitary corals in northeastern Illinois is shown in Text-figure 7.

In eastern Wisconsin at High Cliff Park (see Text-fig. 1A), Willman (1973, p. 13) noted that the lower 3 m of the Mayville Dolomite, which overlies the Maquoketa Shale, resemble the Wilhelmi Formation, and the overlying 6 m of Mayville are like the Elwood Formation. During the present study, solitary rugosan coralla were not observed in that basal 3-m-thick unit, or in immediately overlying strata, of the Mayville. Willman (1973, p. 13) stated that the Mayville Dolomite at Katell Falls (see Text-fig. 1A) consists largely of Kankakee lithology, but that approximately the lower 1 m overlying the Neda Formation is similar to the Wilhelmi. Solitary coralla were not found in the lower 1 m of the Mayville or in the Neda at that section during the present study. Katell Falls is the only locality at which the Neda is known to contain fossils (Savage and Ross, 1916, p. 191; Mikulic and Kluessendorf, 1983, p. 29), but solitary corals have not been reported. Beneath the Mayville in the vicinity of Little Sturgeon Bay (see Text-fig. 1A), E. O. Ulrich observed a coral-rich dolostone unit up to 2 m thick that apparently fills a channel at the top of the Maquoketa shale and is in places overlain by a thin interval of the Neda (Mikulic and Kluessendorf, 1983, p. 36, figs. 27, 28). Elias (1982a, pp. 29, 67, fig. 18, pl. 10, fig. 8) identified the solitary rugosan species *Grewinkia canadensis* (Billings, 1862) in Ulrich's collection from the coral-rich unit.

Age

The history of age assignments for Maquoketa strata in Illinois was summarized by Willman and Buschbach (1975, pp. 81, 83, 84, fig. O-27). It is inferred that the Maquoketa Group in northern Illinois is probably primarily Maysvillian and Richmondian, based mainly on conodont data (Kolata and Graese, 1983, pp. 5, 6; Mikulic *et al.*, 1985, pp. 6, 8). Savage and Ross (1916, p. 191) and Savage (1916, p. 309) reported that fossils from an undisturbed zone in the Neda Formation of eastern Wisconsin show little evidence of wear, are characteristic of the Maquoketa shale, and indicate a Richmondian age. Mikulic (1979; see Mikulic and Kluessendorf, 1983, p. 3) found occurrences of Brainard-like deposits overlying the Neda, suggesting a relation to Maquoketa sedimentation.

The history of age assignments for strata overlying the Maquoketa Group in northeastern Illinois was summarized by Willman (1973, pp. 3, 5, fig. 6) and

Willman and Atherton (1975, fig. S-7). Ross (1962) considered graptolites from a bed in the upper part of the Schweizer Member, Wilhelmi Formation, to represent a subzone at the top of the *Parakidograptus acuminatus* Zone in Wales or the basal part of the *Orthograptus vesiculosus* Zone in Scotland. An Early Silurian (Early Llandovery) age was confirmed by Berry (in Berry and Boucot, 1970, p. 145). Conodonts of the Schweizer have been assigned to the *Panderodus simplex* Zone, inferred to be Early Llandovery, by Liebe and Rexroad (1977, pp. 848, 849, fig. 5) and Rexroad and Droste (1982, pp. 10, 12, fig. 6). However, correlation and age assignments on the basis of these conodonts are unreliable because diagnostic, biostratigraphically important taxa are not present (Liebe and Rexroad, 1977, p. 848; Mikulic *et al.*, 1985, p. 16). Conodonts in the Birds Member of the Wilhelmi Formation and the overlying Elwood Formation were assigned to the *Ozarkodina hassi* interval, which was included at the base of the *Icriodina irregularis* Zone (= *Paltodus dyscritus* fauna of Thompson and Satterfield, 1975; = *Distomodus kentuckyensis* Zone of Cooper, 1975). Mikulic *et al.* (1985, p. 10) noted that *O. hassi* (Pollock, Rexroad, and Nicoll, 1970) suggests a Middle to early Late Llandovery age, but the range of that taxon may extend down into the latest Ordovician (McCracken and Nowlan, 1988, p. 77).

The brachiopod *Platyerella manniensis* Foerste, 1909, has been reported from the upper Elwood Formation and basal Kankakee Formation by Savage (1913b, p. 31; 1917, p. 89 [the Sexton Creek Limestone therein]), Willman (1973, pp. 14, 15), and Willman and Atherton (1975, p. 97). This zone was placed in the Middle Llandovery by Berry and Boucot (1970, pl. 2).

Age assignments we follow are shown in Text-figure 7, and discussed further on pp. 25, 26.

Paleoenvironment

The Wilhelmi Formation was deposited during a transgression that followed a period of erosion, as recognized by Savage (1913b, pp. 34, 35; 1916, p. 314; 1917, p. 92 [the Edgewood therein]). Willman (1973, p. 12) noted that this unit occupies channels that had been cut into the Maquoketa Group. The irregular surface of the Maquoketa exhibits more than 30 m of relief in places (Mikulic *et al.*, 1985, p. 9). The basal bed of the Wilhelmi is conglomeratic at Section 4 (Schweizer West), and contains clasts of Maquoketa shale at Section 3 (Garden Prairie). The Schweizer Member, which is very argillaceous and silty, occurs only in the deeper parts of major channels (Willman, 1973, p. 13). As the surface of the Maquoketa became covered, the amount of argillaceous material in the overlying deposits decreased. The Birds Member of

the Wilhelmi is slightly argillaceous and the overlying Elwood Formation contains little or no clastic material. Liebe and Rexroad (1977, p. 844) reported that reworked Ordovician conodonts decrease in abundance upward in the Schweizer, and occur sporadically above it.

The lithologies and bedding in the Wilhelmi Formation suggest deposition in relatively low energy conditions. All solitary rugosan coralla from the Wilhelmi in the vicinity of Channahon and at Section 34 (Belvidere South) are nonabraded, also suggesting a low energy environment and perhaps a high sedimentation rate.

NORTHWESTERN ILLINOIS AND EASTERN IOWA

Lithostratigraphy

The lithostratigraphic terminology we use (Text-fig. 8) follows Willman (1973, pp. 26, 27, 29, 31–36, fig. 9), who summarized the history of nomenclature (see also Willman and Atherton, 1975, pp. 98, 99, fig. S-8).

The type section of the Mosalem Formation is Section 8 (King) (Willman, 1973, p. 32). The Mosalem is up to 30 m thick where it fills channels eroded into the underlying Maquoketa Group, but thins almost to absence above paleotopographic highs (Brown and Whitlow, 1960, pp. 34, 36–39, figs. 9, 10; Whitlow and Brown, 1963, pp. 11, 13, fig. 6.2.2; Willman, 1973, pp. 31–33). Where the Mosalem is relatively thick, the lower part is composed of gray, dolomitic shale and very argillaceous dolostone. The clastic content decreases upward. The upper portion of the unit consists of slightly argillaceous dolostone with a few bands of chert. Where the Mosalem is comparatively thin, only the upper, dolomitic portion is present. This formation unconformably overlies strata of the Maquoketa Group ranging from the Neda Formation, preserved on paleotopographic highs, down into the underlying Brainerd Shale. Within channels, the base of the Mosalem is characterized by a thin, persistent conglomerate containing clasts derived from the Maquoketa.

The Mosalem Formation is overlain with apparent conformity by massive, vuggy, pure dolostone of the Tete des Morts Formation in the northern part of this area, and by relatively pure, cherty dolostone of the Blanding Formation in the south.

Biota

Brachiopods and trilobites from the Mosalem Formation in the vicinity of Section 26 (Bellevue) were reported by Savage (1906, p. 601 [the transition beds therein]). From a locality near Section 9 (Winston), he listed inarticulate and articulate brachiopods, and trilobites (Savage, 1914, p. 34 [the Winston Limestone therein]). Brachiopods, trilobites, and solitary rugose corals from near the base of the Mosalem in the vicinity

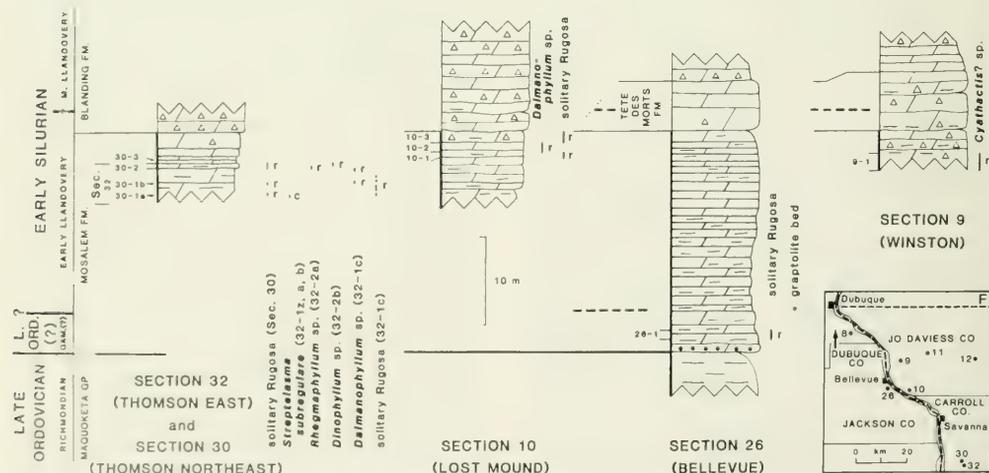
of Section 30 (Thomson Northeast) were listed by Savage (1926, p. 527 [the lower part of the Edgewood Limestone therein]).

Brown and Whitlow (1960, pp. 37–39) stated that brachiopods, bryozoans, and trilobites are the dominant fossils in the Mosalem Formation of Dubuque County, Iowa. They noted minute objects that are probably conodonts, especially in the basal 1.5 m where burrow mottling is common. At localities where the Mosalem is thin, possible algal stromatolites were reported at the base. In the lowermost bed of the formation at one section, small phosphatic fossils resembling the “depauperate fauna” at the base of the Maquoketa Group were observed. Comminuted fossil fragments from the *Cornulites* zone in the upper Brainard Shale were noted within the basal conglomerate of the Mosalem.

Ross (1964) documented graptolites from a horizon situated about 3.4 m above the base of the Mosalem Formation as currently recognized at Section 26 (Bellevue) (see Rose, 1967, p. 45, fig. 21). He reported typical Maquoketa fossils from the basal 0.6-m-thick conglomeratic, silty, dolomitic calcarenite of the Mosalem at that locality (Ross, 1964, p. 1107), but it is not known if they were reworked. Whitlow and Brown (1963, p. 13) noted phosphatic fossil fragments in that bed.

During the present study, three solitary rugosan coralla were collected from an interval situated 1.8 to 2.4 m above the base of the Mosalem Formation at Section 26 (Bellevue). Unfortunately, they are too poorly pre-

served for identification, as are specimens at Section 30 (Thomson Northeast). At Section 32 (Thomson East), *Streptelasma subregulare* (Savage, 1913b) is rare 0.65 to 0.70 m above the base of the Mosalem exposure (interval 32-1a). Lateral to those coralla are local channels that cut down from a position 0.8 m above the base of the section (interval 32-1b). They are filled with argillaceous dolostone, are shale-bounded, and contain uncommon specimens of *S. subregulare* and abundant remains of fasciculate colonial rugose corals we identify as *Pycnostylus?* sp. (Text-fig. 9). *Streptelasma subregulare* is common with tabulate corals in a bed exposed on the old quarry floor to the west (interval 32-1c). That bed appears to be at about the same stratigraphic position as intervals 32-1a and 32-1b. *Dalmanophyllum* sp. occurs at heights of 2.2 and 3.75 m above the base of the exposure, *Rhegmaphyllum* sp. is present at 3.95 m, and *Dinophyllum* sp. was recovered between 3.95 and 4.45 m. *Dalmanophyllum* sp. and *Cyathactis?* sp. were found near the top of the Mosalem at Sections 10 (Lost Mound) and 9 (Winston), respectively. The distribution of these solitary corals is shown in Text-figure 8. One unidentifiable specimen was also found in the upper 2 m of the Mosalem at Section 11 (Schapville). Solitary coralla were not observed in this formation at Sections 8 (King) and 12 (Stockton). *Salvadorea randi* (Elias, 1981) was described from the Brainard Shale of the Maquoketa Group at Sterling, Illinois, and in Clayton County, Iowa, by Elias (1982a, pp. 61, 62, pl. 6, figs. 1–7; 1985, p. 45; see Text-fig. 1A).



Text-figure 8. — Stratigraphic sections (to scale) and locality map (F) in northwestern Illinois and eastern Iowa (see Text-fig. 1A). For legend, see Text-figure 1B (foldout inside front cover). Gam. = Gamachian. For references and precise locations of sections, see Appendix.

Age

The history of age assignments for Maquoketa strata in Illinois was summarized by Willman and Buschbach (1975, pp. 81, 83, 84, fig. O-27). Faunal and lithostratigraphic correlation of the upper Brainard Shale and uppermost *Cornulites* zone of the Brainard in Iowa and Illinois with the Late Ordovician (latest Richmondian) "Elkhorn" strata in the Cincinnati Arch region was considered highly probable by Ladd (1929, pp. 369, 370) and Templeton and Willman (1963, pp. 132, 133). On the basis of conodonts, Glenister (1957, pp. 720, 721) assigned the Maquoketa Group of eastern Iowa to the Maysvillian through Richmondian. Specimens of the Maysvillian–Richmondian solitary rugosan species *Salvadorea randi* (Elias, 1981) in the Brainard Shale are considered to be Richmondian on the basis of their position above the Fort Atkinson Formation, which contains the Richmondian species *Bighornia patella* (Wilson, 1926) (see Elias, 1987).

The history of age assignments for strata overlying the Maquoketa Group in northwestern Illinois and the adjacent area in Iowa was summarized by Willman (1973, pp. 29, 31, fig. 9) and Willman and Atherton (1975, fig. S-8). Ross (1964) noted that graptolites from a bed about 3.4 m above the base of the Mosalem Formation apparently represent the same Early Silurian (Early Llandovery) zone as those in the Schweizer Member of the Wilhelmi Formation in northeastern Illinois. The age of units overlying the Mosalem Formation is imprecisely known, because important biostratigraphic marker zones are absent.

Age assignments we follow are shown in Text-figure 8, and discussed further on pp. 25, 26.

Paleoenvironment

The Mosalem Formation was deposited during a transgression, as recognized by Savage (1914, p. 34 [the Winston Limestone therein]; 1926, p. 528 [the Edgewood Limestone therein]). Brown and Whitlow (1960, p. 36) concluded that the Mosalem was deposited in a shallow marine environment as a sea advanced over the eroded Maquoketa surface. While sediment accumulated in low areas, topographic highs continued to be eroded, either above or below sea level. The detrital content of the Mosalem decreased as the summits became covered with marine deposits. Erosional relief on the Maquoketa is 41 m in Dubuque County, south of Dubuque, Iowa (Brown and Whitlow, 1960, p. 23; Whitlow and Brown, 1963, p. 11). Small, local channels in the upper Mosalem at Section 32 (Thomson East) may record a minor regressive event during the transgressive phase.

SOLITARY RUGOSE CORAL ASSEMBLAGES

Four solitary rugosan assemblages are recognized in the uppermost Ordovician–lowermost Silurian sequence within the study region in the east-central United States: (1) Late Ordovician "epicontinental" assemblage (Richmondian); (2) Late Ordovician "continental margin" assemblage (Gamachian); (3) Edgewood assemblage (Gamachian–early Early Llandovery); and (4) Silurian assemblage (post-Edgewood Llandovery) (Text-fig. 10, Table 1). The lowest is a Late Ordovician "epicontinental" assemblage in the upper Maquoketa Group. *Salvadorea randi* (Elias, 1981), a Maysvillian–Richmondian species (Elias, 1985, p. 45), is present in the Orchard Creek and Brainard shales (Elias, 1982a, pp. 35, 36). *Grewingia canadensis* (Billings, 1862) occurs immediately below the Neda Formation in eastern Wisconsin (Elias, 1982a, p. 29). It is a Richmondian species (Elias, 1982a, p. 67).

The upper, Silurian assemblage includes *Dinophyllum* sp., *Dalmanophyllum* sp., *Cyathactis?* sp., and *Rhegnaphyllum* sp. These genera are typical of the Early to Middle Silurian (Hill, 1981, pp. 159–161, 163, 308), and are present in the late Early to Late(?) Llandovery Brassfield Formation of the Cincinnati Arch region in Kentucky–Indiana–Ohio (Laub, 1979).

One of the genera in the Silurian assemblage has recently been found in Late Ordovician deposits near the North American continental margin. At Pointe Laframboise on Anticosti Island, Québec, *Rhegnaphyllum* sp. appears in the basal 1 m of the Becscie Formation (Elias and Petryk, unpublished data; see Petryk, 1981a, fig. 11), in beds considered to be late Gamachian. The specimens occur about 1 m above the Ordovician–Silurian boundary of conodont workers (McCracken and Barnes, 1981), but strata equiv-



Text-figure 9.—Small, local channel within Mosalem Formation at Section 32 (Thomson East), Carroll County, Illinois (assistant pointing to base and top of channel, photographed in 1986).

alent in age to the basal Silurian *Parakidograptus acuminatus* Graptolite Zone may be much higher in the sequence (Lespérance, 1985, fig. 3; McCracken and Nowlan, 1988, p. 77). Coralla of *Rhegmaphyllum* sp. are associated with *Grewingkia pulchella* (Billings, 1865), a species that is also present in the Ellis Bay Formation (Gamachian) and upper member of the Vauréal Formation (Richmondian) on Anticosti Island (Elias, 1982a, p. 45). In the southeastern United States, *Rhegmaphyllum* sp. occurs in strata considered to be Richmondian (Elias and Stock, unpublished data). It has been found, together with *Grewingkia* sp. cf. *G. pulchella* (Billings, 1865), in the Sequatchie Formation at Birmingham, Alabama (see Drahovzal and Neathery, 1971, pp. 25, 237, stop 10), and in the Shellmound Formation at Pope Spring, Georgia (see Milici and Wedow, 1977, pp. 8, 9, 33, sec. 26b) (for age of strata, see also Colbath, 1986, p. 945). In the Beaverfoot Formation of southeastern British Columbia, *Rhegmaphyllum* sp. and *Streptelasma* sp. are present in latest Ordovician or possibly earliest Silurian strata above the *Bighornia-Thaerodonta* Assemblage Zone, which is probably entirely Richmondian (Butler, Elias, and Norford, 1988, pp. 59, 60). At the St. Clair Spring Section in eastern north-central Arkansas, *Rhegmaphyllum* sp. is the only solitary coral in the Cason oölite, which is considered to be Gamachian (Hirnantian) in age (Amsden, 1986, pp. 20, 22, 26; Barrick, 1986, pp. 64, 66). This occurrence represents the Late Ordovician "continental margin" assemblage within the present study region.

Our study is focused on the assemblage that is here termed the Edgewood. It is situated stratigraphically between the Late Ordovician "epicontinental" and the Silurian assemblages, and geographically lateral to the "continental margin" assemblage. Of the 709 specimens identified at the species level, percentages representing the various taxa are as follows: *Streptelasma subregulare* (Savage, 1913b), 83.1%; *Streptelasma* sp. cf. *S. subregulare* (Savage, 1913b), 0.1%; *Streptelasma amsdeni*, n. sp., 10.0%; *Streptelasma leemonense* Elias, 1982a, 4.7%; *Streptelasma* sp. cf. *S. leemonense* Elias, 1982a, 0.4%; *Keelophyllum oklahomense*, n. gen., n. sp., 0.9%; *Streptelasma* sp. A, 0.4%; *Grewingkia* sp. A, 0.3%; and *Bodophyllum shorti* Elias, 1982a, 0.1%. *Streptelasma subregulare* is the most widely distributed species, followed by *S. leemonense*.

AGE OF UNITS AND REGIONAL CORRELATION

The stratigraphic position of the Edgewood solitary rugosan assemblage between Late Ordovician (Richmondian) and typical Early to Middle Silurian assemblages suggests an age in the range of latest Ordovician to earliest Silurian. The species are comparable pri-

Table 1.—Latest Ordovician to earliest Silurian solitary rugose corals in the study region, east-central United States.

Silurian Assemblage	
Suborder Streptelasmatina	Family Streptelasmatinae
	Subfamily Streptelasmatinae
	<i>Rhegmaphyllum</i> sp.
	Subfamily Dinophyllinae
	<i>Dinophyllum</i> sp.
	Subfamily Dalmanophyllinae
	<i>Dalmanophyllum</i> sp.
Suborder Cyathophyllina	Family Ptychophyllidae
	<i>Cyathactis?</i> sp.
Edgewood Assemblage [Edgewood Province]	
Suborder Streptelasmatina	Family Streptelasmatinae
	Subfamily Streptelasmatinae
	<i>Streptelasma subregulare</i>
	<i>Streptelasma</i> sp. cf. <i>S. subregulare</i>
	<i>Streptelasma amsdeni</i>
	<i>Streptelasma leemonense</i>
	<i>Streptelasma</i> sp. cf. <i>S. leemonense</i>
	<i>Streptelasma</i> sp. A
	<i>Grewingkia</i> sp. A
	Subfamily Dalmanophyllinae
	<i>Bodophyllum shorti</i>
Suborder Monacanthina	Family Lambelasmatinae
	Subfamily Coelostylinae
	<i>Keelophyllum oklahomense</i>
Late Ordovician "Continental Margin" Assemblage	
Suborder Streptelasmatina	Family Streptelasmatinae
	Subfamily Streptelasmatinae
	<i>Rhegmaphyllum</i> sp.
Late Ordovician "Epicontinental" Assemblage	
Suborder Streptelasmatina	Family Streptelasmatinae
	Subfamily Streptelasmatinae
	<i>Salvadorea randi</i> [Red River-Stony Mountain Province]
	<i>Grewingkia canadensis</i> [Richmond Province]

marily to taxa from various Late Ordovician (Richmondian-Gamachian; Ashgill, including Hirnantian) and Early Silurian (Llandovery) units in North America and Baltoscandia, and a latest Ordovician (Hirnantian) unit in China (see pp. 40-49, 53). However, the overall assemblage, in which 97.8 percent of specimens belong to *Streptelasma subregulare* (Savage, 1913b), *Streptelasma amsdeni*, n. sp., and *Streptelasma leemonense* Elias, 1982a, seems to be most similar to that in the *Dalmanitina* Beds (Hirnantian) or possibly earliest Llandovery beds of Östergötland, Sweden, and the Guanyingqiao Beds (*Dalmanitina* Beds; Hirnantian) of Guizhou Province, China. Of the four species comprising the Swedish assemblage (see Neuman, 1975, p. 336), three are similar to some speci-

mens of *S. subregulare* (*Streptelasma unicum* Neuman, 1975, *Helicelasma simplex* Neuman, 1969, and *Bor-elasma crassitangens* Neuman, 1969), one resembles *S. amsdeni* (*S. unicum*), and one is comparable to *S. leemonense* (*Streptelasma ostrogothicum* Neuman, 1969). Many coralla from the Chinese assemblage, illustrated by He (1978, 1985), resemble specimens of *S. subregulare* and *S. amsdeni* (see pp. 42, 45).

Amsden (1971b, pp. 21, 22; 1974, p. 26) considered the Keel-Edgewood brachiopod assemblage in south-central Oklahoma, southern Illinois and southeastern Missouri, and northeastern Missouri and west-central Illinois to be characteristic of the latest Ordovician (late Ashgill) to earliest Silurian (Early Llandovery). He noted that brachiopods in the Keel Formation, Leemon Formation, and Noix Limestone most closely resemble the latest Ordovician *Hirnantia* fauna, but the species are different. It was suggested that this may be due, at least in part, to ecologic factors. Amsden (1986, pp. 18, 20, 22, 41, 42) concluded that brachiopods in the Keel, Cason oölite, Leemon, Noix, and Cyrene formations indicate a latest Ordovician Hirnantian (*i.e.*, late Gamachian) age. The brachiopod assemblage in the Bryant Knob Formation, which overlies the Noix in northeastern Missouri, was initially thought to be different in some respects, and was tentatively assigned to the Early Llandovery almost entirely on the basis of associated conodonts (Amsden, 1971b, p. 22; Amsden, 1974, p. 26). However, subsequent collecting demonstrated that some of the species previously thought to have been confined to the Bryant Knob are also present in Noix-Cyrene strata (Amsden, 1986, p. 29).

Brachiopods of the lower Edgewood assemblage were provisionally considered to be post-Hirnantian by Lespérance (1974, p. 22). Lespérance and Sheehan (1976, pp. 719, 720) noted that these brachiopods could represent a latest Ordovician endemic North American fauna, with species derived from the *Hirnantia* community and other North European Province species. However, they suggested that it was most likely a Silurian fauna with a few holdovers from the Late Ordovician North American Province. A Hirnantian age was accepted by Jaanusson (1979, p. 154), based on a trilobite and "other indications" from beds in Illinois.

In view of the presence of Ordovician (possibly Hirnantian) conodonts in the lower Keel Formation, Leemon Formation, Noix Limestone, and middle Cyrene Formation (Thompson and Satterfield, 1975; McCracken and Barnes, 1982; Barrick, 1986), the Hirnantian aspect of the brachiopods and solitary corals, and the position of these beds above Late Ordovician (Richmondian) strata, we accept a latest Ordovician (Gamachian) age, as suggested and discussed by Elias (1982a, pp. 38, 39) (Text-fig. 10). If the Hirnantian is

equivalent to the upper part of the Gamachian in the North American succession (Cocks and Copper, 1981, p. 1033; Lespérance, 1985, p. 844, fig. 4; McCracken, 1987, p. 1454, fig. 2), assignment of Keel-Edgewood strata to the Hirnantian implies an unconformable relationship with the underlying Sylvan-Maquoqueta beds, which are accepted as Richmondian. Although this contact is clearly unconformable in most areas, Amsden (1980, p. 10; 1986, p. 6) indicated that deposition may have been continuous from the Sylvan to the Keel. Therefore, use of the term Gamachian is followed herein for this North American sequence. *Streptelasma subregulare* (Savage, 1913b), *Streptelasma leemonense* Elias, 1982a, *Grewingia* sp. A, and other solitary corals in the Keel, Leemon, Noix, and middle Cyrene, are considered to have first appeared in the east-central United States during Gamachian time.

Correlation of the Keel-Edgewood with strata in north-central Arkansas is indicated by the following: Ordovician (possibly Hirnantian) conodonts in the Cason oölite and dolomitic shale (Craig, 1969; Craig, 1975b, pp. 77, 80, 85; Craig in Craig, Ethington, and Repetski, 1986, pp. 18, 19; Barrick, 1986); brachiopods of Hirnantian aspect in the Cason oölite (Amsden, 1986, pp. 20, 22, 26); and the presence of *Streptelasma leemonense* Elias, 1982a, and *Streptelasma* sp. cf. *S. subregulare* (Savage, 1913b) in Cason dolomitic shale. The Cason oölite, which contains *Rhegmaphyl-lum* sp., and dolomitic shale are considered Gamachian in age (Text-fig. 10).

In northeastern Illinois, *Streptelasma subregulare* (Savage, 1913b) is present in the Schweizer and Birds members of the Wilhelmi Formation. It occurs both below and above a bed in the upper Schweizer that contains Early Llandovery graptolites, which possibly represent the *Parakidograptus acuminatus* Zone (Ross, 1962, p. 1383; Berry in Berry and Boucot, 1970, p. 145). Therefore, we conclude that the range of *S. subregulare* extends into the Silurian. Neuman (1982, p. 34) noted that several solitary rugosan species in Norway range from the Ashgill into the Early Llandovery. It remains a possibility that lower Schweizer strata infilling the deepest channels in the eroded Maquoqueta, below the position of the graptolite bed, may be Gamachian in age, as suggested by Elias (1982a, p. 40, fig. 21) (Text-fig. 10).

The lower part of the Wilhelmi Formation has been correlated with the lower portion of the Mosalem Formation in northwestern Illinois and eastern Iowa on the basis of graptolites (Ross, 1964, p. 1107) and lithology (Willman, 1973, pp. 13, 31, fig. 2). Graptolites near the base of the Mosalem apparently represent the same zone as those in the Wilhelmi, and are Early Llandovery in age (Ross, 1964). *Streptelasma subregulare* (Savage, 1913b) occurs at a higher stratigraphic

position in the formation. We suggest that lower Mosalem strata infilling the deepest channels eroded into the Maquoketa, below the position of the graptolite bed, may be Gamachian in age (Text-fig. 10).

In northeastern Illinois, corals of the Silurian assemblage appear at the base of the Elwood Formation and occur with the brachiopod *Platyerella manniensis* Foerste, 1909, in the upper Elwood. The *Platyerella* zone includes the upper Elwood and base of the overlying Kankakee Formation (Savage, 1913b, p. 30; Savage, 1917, p. 88; Willman, 1973, pp. 14, 15; Willman and Atherton, 1975, p. 97). It was considered to be Middle Llandovery in age by Berry and Boucot (1970, pl. 2). In northwestern Illinois, this solitary rugosan assemblage appears in the upper part of the Mosalem Formation, just above the stratigraphic position of local channels at Section 32 (Thomson East) that contain *Streptelasma subregulare* (Savage, 1913b) and Silurian fasciculate rugose corals identified as *Pycnostylus?* sp. (see Hill, 1981, p. 140). We consider the upper Mosalem to be younger than the upper part of the Wilhelmi Formation because *S. subregulare* occurs in the Birds Member of the Wilhelmi, whereas the Silurian assemblage is present in the upper Mosalem. The Edgewood and Silurian solitary rugosan assemblages are not known to co-occur. Although Willman (1973, pp. 15–17, 35, 36) tentatively correlated the Elwood with the Blanding Formation of northwestern Illinois on the basis of lithology, he noted that the Tete des Morts Formation as well as the Blanding could correlate with the lower Kankakee. From the coral evidence, we infer that the upper Mosalem must be equivalent to at least the lower part of the Elwood (Text-fig. 10). Johnson, Rong, and Yang (1985, fig. 5) placed the Mosalem, Tete des Morts, and lower Blanding in the Early Llandovery (Rhuddanian) on the basis of correlations involving sea-level curves.

In northeastern Missouri, the Silurian coral assemblage occurs in the Bowling Green Dolomite at an eastern exposure. The *Platyerella manniensis* zone, considered to be Middle Llandovery, is present at the base of the Sexton Creek Limestone, which overlies the Bowling Green (Savage, 1913b, p. 30; Savage, 1917, p. 88; Willman, 1973, p. 16; Willman and Atherton, 1975, p. 97). Therefore, we correlate the Bowling Green with the lower Elwood and upper Mosalem and consider it to be Early Llandovery in age (Text-fig. 10).

Corals of the Edgewood assemblage in the Bryant Knob Formation, which overlies the Noix Limestone and underlies the Bowling Green Dolomite in northeastern Missouri, could be Gamachian or Early Llandovery in age. *Streptelasma subregulare* (Savage, 1913b), *Streptelasma leemonense* Elias, 1982a, and *Grewinkia* sp. A are also known from the Keel Formation (Gamachian), and *S. subregulare* and *S. le-*

monense occur in the Leemon Formation (Gamachian). However, the range of *S. subregulare* is known to extend into Early Llandovery strata of the Wilhelmi and Mosalem formations, in which the other species are not represented. The Bryant Knob is tentatively considered to be Early Llandovery on the basis of conodonts (Thompson and Satterfield, 1975) and graptolites (Berry, written commun., 1971, cited in Thompson and Satterfield, 1975). However, this remains questionable because some of the conodont collections could be Ordovician (Nowlan in Bolton and Nowlan, 1979, pp. 5, 21) and the graptolites were not identified to the species level. The upper portion of the Cyrene Formation immediately to the west is equated with the Bryant Knob (Text-fig. 10). The evidence for this correlation, based on conodonts, brachiopods, and lithologic similarity, was discussed on p. 15.

The lower part of the Sexton Creek Limestone in southeastern Missouri and southern Illinois could be as old as the Bowling Green Dolomite (Early Llandovery). Both units contain conodonts representing the *Paltodus dyscritus* fauna (Thompson and Satterfield, 1975, figs. 6, 7, 9, 11–15) and solitary corals of the Silurian assemblage. The Silurian solitary coral assemblage is also represented in basal beds of the Cochrane Formation in south-central Oklahoma (Text-fig. 10). Conodonts in the lower Cochrane were thought to be Llandovery (position uncertain) by Barrick (1986, pp. 57, 67). Amsden (1986, p. 6) considered the brachiopod *Triplesia alata* Ulrich and Cooper, 1936, which apparently ranges through most of the Cochrane (Amsden, 1971a, p. 145), to indicate an early Late Llandovery C_{1-2} age. However, he noted that it could be younger or older.

The Edgewood solitary coral assemblage is latest Ordovician (Gamachian) to earliest Silurian (early Early Llandovery; early Rhuddanian) in age, and therefore these Rugosa cannot be used to delineate the Ordovician–Silurian boundary in the east-central United States. In Illinois and Missouri, they occur in strata that were included within the Alexandrian Series by Savage (papers from 1908a through 1926, inclusive). Reeds (1911) extended the use of that term for correlative beds in Oklahoma. This series was proposed by Savage (1908a, pp. 433, 434; 1908b, pp. 110, 111) to include strata, thought to be earliest Silurian in age, situated between the Richmondian Stage of the Cincinnati Series (Ordovician) and the Niagan Series (Silurian). It has been recommended that Alexandrian be discontinued as a series term because of synonymies (Fisher, 1954, pp. 1982, 1984), and because outcrops in the type area are meager, the units are not especially fossiliferous, and unconformities are present within the sequence (Amsden, 1974, p. 5).

BIOGEOGRAPHY AND EVENTS

Two biogeographic provinces are represented by solitary rugose corals of the Late Ordovician "epicontinental" assemblage in the upper Maquoketa Group. *Salvadorea randi* (Elias, 1981) in Illinois and Iowa is also known from middle Maysvillian strata in the Selkirk Member (see Elias, 1985, p. 45) and middle Richmondian beds in the Fort Garry Member of the Red River Formation in southern Manitoba (Elias, Nowlan, and Bolton, 1988, pl. 1, figs. 4-7). It belongs to the Red River-Stony Mountain Solitary Rugose Coral Province (Elias, 1982a, p. 48; Text-fig. 11). The distribution of this species indicates dispersion across the Transcontinental Arch between the Williston Basin and the area of Maquoketa deposition. *Grewingia canadensis* (Billings, 1862), which is present in the upper Maquoketa Group of eastern Wisconsin, is characteristic of the Richmond Solitary Rugose Coral Province (Elias, 1982a, pp. 49, 50; Text-fig. 11). Elias (1982a, p. 29) suggested that this occurrence, in an apparent channel-fill deposit at the top of the Maquoketa shale but beneath the Neda Formation, represents a westward shift in the geographic range of this species associated with the regression during late Richmondian time.

Solitary Rugosa of the Red River-Stony Mountain and Richmond provinces in east-central North America became extinct during the terminal Richmondian regression of the epicontinental sea caused by a major glacio-eustatic sea-level drop (Elias, 1982a, pp. 48, 51). In northern Illinois and eastern Iowa, the presence of 30-m-deep channels eroded into the upper, Richmondian portion of the Maquoketa Group and subsequently filled with Gamachian(?) and Early Llandovery deposits of the Wilhelmi and Mosalem formations suggests a period of post-Richmondian emergence, at least in the northern portion of the study region. To the east, the Cincinnati Arch region likely remained emergent until late Early Llandovery time (Grahm and Bergström, 1985, pp. 178, 179). On Anticosti Island, Québec, where deposition near the continental margin was essentially continuous from Richmondian time into the Silurian, the Richmondian-Gamachian boundary (placed at the contact of the Vauréal and Ellis Bay formations) appears to coincide with a major regression (Johnson, Cocks, and Copper, 1981, fig. 3; Petryk, 1981b, fig. 1; Long and Copper, 1987, pp. 1829, 1830).

Solitary Rugosa of the Edgewood assemblage represent the Edgewood Solitary Rugose Coral Province (Elias, 1982a, pp. 51, 52; Text-fig. 11). The inclusion of south-central Oklahoma in this province is confirmed herein, and the boundary is extended to include western north-central Arkansas and northwestern Il-

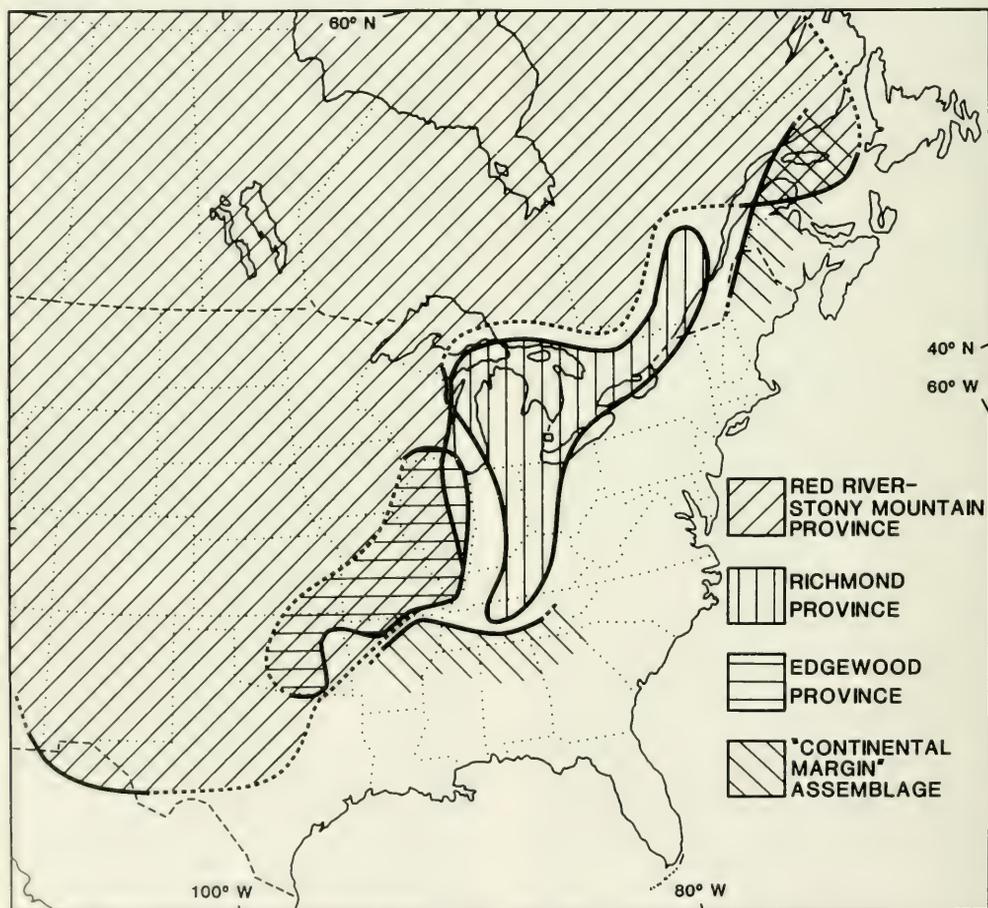
linois. Units containing the Edgewood assemblage record a succession of oscillatory transgressions that reached progressively farther north, according to Savage (1913a, p. 374; 1913b, pp. 34, 35; 1917, p. 92). Amsden (1986, pp. 2, 45) considered the Keel-Edgewood oölitic deposits to represent a regressive sedimentary cycle reflecting eustatic lowering of sea level due to glaciation. Both interpretations may be in part correct. The Edgewood assemblage is Gamachian to earliest Llandovery in age. The major glacio-eustatic sea-level drop during Gamachian/Hirnantian time was followed by a rapid rise in the latest Gamachian/Hirnantian (e.g., Brenchley and Newall, 1980, fig. 22; Johnson, Cocks, and Copper, 1981, fig. 3; Petryk, 1981b, fig. 1; Woodcock and Smallwood, 1987, p. 393). The Keel-Edgewood oölitic in Oklahoma and Missouri likely mark the regressive phase, but could have been deposited during minor transgressions if sea level fluctuated during that time interval (see Brenchley and Newall, 1980, pp. 29, 30, fig. 22). A number of oscillations are evidently recorded in the latest Richmondian to latest Gamachian regressive phase on Anticosti Island (Petryk, 1981b, fig. 1). Channel-fill sediments of the Wilhelmi and Mosalem formations in northern Illinois and eastern Iowa were likely deposited during the major latest Gamachian/Hirnantian-earliest Silurian transgression associated with deglaciation.

The Edgewood solitary rugosan species were not derived from corals of the Late Ordovician "epicontinental" assemblage in this region. Their resemblance to some taxa previously restricted to the continental margin of North America suggests that they originated from such forms. Within the Edgewood Province, diversity is highest in Oklahoma, intermediate in southern Illinois and Missouri, and lowest in northern Illinois (western north-central Arkansas is excluded because only two identifiable specimens are known) (Text-fig. 10). This apparent northward decrease in diversity corresponds to an environmental gradient from relatively open conditions near the continental margin to increasingly restricted conditions in the continental interior. It is noteworthy that specimens of *Rhegmaphyllum* sp., but no representatives of the Edgewood solitary coral assemblage, are present in the Cason oölitic at the St. Clair Spring Section in eastern north-central Arkansas. The associated conodonts and brachiopods comprise a typical Keel-Edgewood assemblage (Craig, 1969, pp. 1624, 1625; Craig, 1975b, p. 77; Craig in Craig, Ethington, and Repetski, 1986, p. 19; Amsden, 1986, pp. 20, 22; Barrick, 1986, p. 64). *Streptelasma leomonense* Elias, 1982a, and *Streptelasma* sp. cf. *S. subregulare* (Savage, 1913b), both Edgewood solitary Rugosa, occur in the Cason about 100 km to the west at Section 33 (Buffalo River). Thus, it is possible to place the boundary of the Edgewood

Solitary Rugose Coral Province and the area inhabited by the Late Ordovician "continental margin" solitary rugosan assemblage between these two sections (Text-fig. 11).

Genera recognized in the Silurian assemblage were not derived from Edgewood taxa. They must have originated elsewhere and been introduced to this region. Laub (1975, p. 280; 1979, p. 45) noted that rugosan species in the late Early to Late(?) Llandovery Brassfield Formation of the Cincinnati Arch region are not

known in pre-Brassfield strata of North America, but some occur in the Baltic area, the Siberian platform, and possibly Venezuela. Recent work indicates that *Rhegmaphyllum* Wedekind, 1927, was confined to areas near the North American continental margin in the Richmondian and Gamachian (see *Solitary Rugose Coral Assemblages*, pp. 23, 24). During Early Llandovery time, the Silurian assemblage, including *Dinophyllum* sp., *Dalmanophyllum* sp., *Cyathactis?* sp., and *Rhegmaphyllum* sp., succeeded the Edgewood as-



Text-figure 11 — Biogeography of North American Late Ordovician to earliest Silurian solitary Rugosa. Red River-Stony Mountain Province of Edenian to Gamachian age (Elias, 1981, pp. 2, 8, 10; Elias, 1982a, pp. 48, 49; Elias, 1983a, pp. 927-931; Elias, 1985, pp. 16-20; Elias, unpubl. data). Richmond Province of Richmondian age (Elias, 1982a, pp. 49-51). Edgewood Province of Gamachian to early Early Llandovery age (Elias, 1982a, pp. 51, 52, present study). Late Ordovician "continental margin" assemblage of Richmondian-Gamachian age (for discussion of taxa in eastern Quebec and northern Maine, see Elias, 1982a, pp. 48, 49; present study). Solid and dashed lines show established and uncertain boundaries, respectively.

semblage. This occurred as water depth (and temperature) increased during the Early Llandovery transgression related to deglaciation (see Johnson, Rong, and Yang, 1985, fig. 5, eastern Iowa). However, the appearance of the Silurian solitary rugosan assemblage above local channels containing Edgewood corals within the Mosalem Formation at Section 32 (Thomson East), and the unconformity between the Bryant Knob Formation and Bowling Green Dolomite at some sections in northeastern Missouri, suggest that Silurian solitary Rugosa were introduced after a minor regressive event.

THE EDGEWOOD SOLITARY RUGOSE CORALS

GROWTH

A small minority of solitary rugose corals in the Edgewood Province were attached throughout ontogeny to surfaces such as bryozoans, colonial corals, and possibly other solitary coralla. These epizoans belong to *Streptelasma* sp. A (Pl. 9, figs. 8, 9, Pl. 10, figs. 1-5), *Grewingkia* sp. A (Pl. 10, fig. 8), *Bodophyllum shorti* Elias, 1982a (Elias, 1982a, pl. 13, fig. 10), *Keelophyllum oklahomense*, n. gen., n. sp. (Pl. 12, figs. 4-6), and possibly *Streptelasma leemonense* Elias, 1982a (Pl. 7, fig. 9). The vast majority of individuals, belonging to *Streptelasma subregulare* (Savage, 1913b) and *Streptelasma amsdeni*, n. sp., behaved as unattached objects on the substrate. A few specimens representing the latter two species have right-angle bends, indicating that the polyp had the ability to redirect its growth axis after being fully overturned (Elias, 1984b, pp. 534, 535; Pl. 1, fig. 17, Pl. 6, fig. 11). These are the earliest North American species presently known that could do so. The ability to survive such events, which apparently resulted in the death of polyps belonging to other taxa, must have been advantageous. Although specimens of *S. leemonense* lack right-angle bends, this species was able to produce offsets that diverged from the parent at a high angle (Pl. 8, figs. 1-4). They could have performed a function analogous to redirection of the growth axis.

Prominent constrictions of the coral at apparently regularly spaced intervals are known only from one specimen of *Streptelasma amsdeni*, n. sp. (Pl. 6, fig. 11; identified as *Streptelasma* sp. in Elias, 1984b, p. 535). Seven consecutive constrictions are 6 to 7 mm apart (average, 6.8 mm). Apparent periodicity involving tabulae was observed only in one specimen of *Streptelasma subregulare* (Savage, 1913b) (Pl. 3, figs. 2-4). Four thick tabulae, separated from one another by one to three thin tabulae, occur at intervals of 4 to 6 mm (average, 5.2 mm). Elias (1984b, pp. 535, 536) documented comparable examples of periodic growth

involving constrictions and dilated tabulae at intervals of 3 to 13 mm in Late Ordovician (Richmondian-Gamachian) taxa from Anticosti Island, Québec. It is possible that these figures represent annual growth rates (see Risk, Pagani, and Elias, 1987, pp. 328, 329). Elias (1984b, p. 536) reported an unusually high growth rate for three coralla identified as *Streptelasma* sp. [referred herein to *S. amsdeni*], based on the relatively wide spacing of fine growth ridges. Following an examination of additional material during the present study, we conclude that all growth increments may not be preserved on those specimens.

ABRASION

During life, these solitary Rugosa produced septal grooves and interseptal ridges covered by a very thin epitheca with fine growth ridges on the outer wall (Elias, 1982a, pl. 4, figs. 10, 11, 14, 15, 19; Pl. 1, fig. 17, Pl. 4, figs. 4, 10, Pl. 5, fig. 2, Pl. 6, figs. 1, 10, 11, Pl. 9, figs. 1, 2, Pl. 11, fig. 6). Nonweathered, well-preserved specimens lacking these features are considered to have been abraded prior to burial. The degree of abrasion was related to the duration and intensity of this process. The length of time a corallum was exposed on the substrate was determined by the sedimentation rate. The intensity of abrasion prior to burial of the specimen was determined by the energy level of the environment.

The proportion of nonabraded and abraded Edgewood coralla in various stratigraphic units is shown in Table 2. All or the majority of specimens in the Keel Formation, Leemon Formation at Sections 31 (Thebes North) and 19 (New Wells), and Wilhelmi Formation are nonabraded. Lithologies of the laminated calcilitite unit of the Keel, the Leemon at Section 19, and the Wilhelmi suggest deposition in comparatively low energy conditions. However, the other Keel facies and the Leemon at Section 31 were apparently deposited in higher energy environments, and a higher proportion of abraded coralla might be expected. A relatively high sedimentation rate could have resulted in quick burial of these individuals, thus protecting them from abrasion.

Most coralla in the Bryant Knob Formation, and in the Leemon Formation at Section 20 (Short Farm), are abraded. The lithologies of these units suggest that energy levels were relatively high, but probably not significantly higher than those in which facies of the Keel Formation other than the laminated calcilitite unit were deposited. The high proportions of abraded specimens in these strata are likely a reflection of comparatively low sedimentation rates. The coral-rich interval of the Kissenger Limestone Member, Bryant Knob Formation, contains the highest observed proportions of abraded specimens.

ALGAL COATINGS

Coatings having micritic, oncolitic, and *Girvanella*-like appearances in thin section were observed on *Streptelasma subregulare* (Savage, 1913b) from bioherms in the Leemon Formation at Section 19 (New Wells), the unnamed member of the Bryant Knob Formation at Section 18 (Kissenger), and the coral-rich interval at the base of the Kissenger Limestone Member, Bryant Knob Formation, at Sections 18 (Pl. 2, fig. 6), 17 (Clarksville), and 16 (Clinton Spring) (Pl. 3, figs. 14-18). Such coatings, presumed to be of algal origin, are rare except in the coral-rich interval of the Kissenger, where they are relatively common on solitary rugosan coralla and bioclastic grains. The coating usually completely surrounds the corallum, although in some cases it is thicker on one side. Coatings were observed

Table 2.—Condition of corallum exterior, for specimens of *Streptelasma subregulare* (Savage, 1913b) unless otherwise noted, determined from an examination of the corallum and/or transverse thin section(s). Nonabraded if growth ridges, apotheca, and/or septal grooves and interseptal ridges are present; abraded if those features are absent on nonweathered, well-preserved material.

unit section-interval	nonabraded	abraded
Keel Fm.		
23-2a and 23-3, and 23a-1	14 (93%) ¹	1 (7%)
Keel Fm., Ideal Quarry Mbr.		
21	16 (100%)	0 (0%)
Keel Fm., <i>Brevilamnulella</i> beds		
23-2	16 (100%)	0 (0%)
Keel Fm., laminated calcilutite unit		
24-2	68 (100%) ²	0 (0%)
Leemon Fm.		
31	14 (70%)	6 (30%) ¹
20	12 (41%) ¹	17 (59%) ²
19 (bioherms)	72 (87%)	11 (13%)
Bryant Knob Fm., unnamed mbr.		
18-1	4 (40%)	6 (60%)
Bryant Knob Fm., Kissenger Lst. Mbr.		
18-2 (coral-rich interval) and 18-3	4 (24%)	13 (76%)
17-0 (coral-rich interval)	7 (39%)	11 (61%)
16-1 (coral-rich interval)	3 (16%)	16 (84%)
15-1	5 (42%)	7 (58%) ¹
14-1	5 (45%)	6 (55%)
Wilhelmi Fm., Schweizer Mbr.		
Channahon	25 (100%)	0 (0%)
Wilhelmi Fm., Birds Mbr.		
34	31 (100%)	0 (0%)

¹ includes three specimens of *Streptelasma leemonense* Elias, 1982a, and two of *Streptelasma* sp. cf. *S. leemonense* Elias, 1982a.

² all *Streptelasma amsdeni*, n. sp.

³ includes one specimen of *S. leemonense*.

⁴ includes four specimens of *S. leemonense*.

to extend into the calices of two individuals. In most specimens, the corallum surface under the coating is abraded. We conclude that coatings generally developed during post-mortem transport, when coralla were rolled along the substrate.

One silicified corallum of *Streptelasma subregulare* (Savage, 1913b) from the *Brevilamnulella* beds of the Keel Formation at Section 23 (Lawrence Quarry) has a lamellar incrustation that covers the calice. It probably represents an alga or a stromatoporoid. A specimen of *S. subregulare* from the Mosalem Formation at Section 32 (Thomson East) has an unidentifiable lamellar incrustation on one side.

EPIZOANS

Bryozoans rarely incrust algal coatings on *Streptelasma subregulare* (Savage, 1913b) in the coral-rich interval at the base of the Kissenger Limestone Member, Bryant Knob Formation, at Section 16 (Clinton Spring) (Pl. 3, fig. 15). They became associated with the host after the algal coating developed during transportation. In bioherms of the Leemon Formation at Section 19 (New Wells), these epizoans are common on the same species (Pl. 2, fig. 3). In one case, the bryozoan incrusts an algal coating on a corallum. The bryozoans observed on 21 coralla are situated on seven counter sides, 20 alar sides (there are two alar sides per corallum), and seven cardinal sides, suggesting a random distribution. An incrusting bryozoan is present on one specimen of *S. subregulare* from Section 32 (Thomson East). Epizoic bryozoans were found in a cluster of *Streptelasma leemonense* Elias, 1982a, from the Leemon Formation at Section 20 (Short Farm) (Pl. 8, figs. 1, 4). An epizoan that is possibly a bryozoan is present on a specimen of *Keelophyllum oklahomense*, n. gen., n. sp., from the Keel Formation at Section 23 (Lawrence Quarry) (Pl. 12, fig. 6).

BORINGS

Vermiform borings were observed in transverse thin sections of three coralla assigned to *Streptelasma subregulare* (Savage, 1913b). We identify them as *Trypanites* sp., and they were probably produced by polychaete annelids (see Elias, 1986b, p. 33). In one specimen from a bioherm in the Leemon Formation at Section 19 (New Wells) (Pl. 1, fig. 18), the boring has a maximum observed diameter of 0.6 mm. It passes through the matrix as well as a thin algal coating on the corallum, indicating that the substrate was hard. The other two borings have maximum observed diameters of 0.25 mm. One is from the coral-rich interval at the base of the Kissenger Limestone Member of the Bryant Knob Formation at Section 18 (Kissenger), and the other is from the Kissenger at Section 15 (Calumet). This type of boring is rare in the Edgewood Province,

but occurs in solitary rugosan coralla from many stratigraphic units and localities in the Red River-Stony Mountain and Richmond provinces (Elias, 1986b, table 1).

Microborings about 5 μm in diameter were observed in the outer wall of some specimens of *Streptelasma subregulare* (Savage, 1913b) from bioherms in the Leemon Formation at Section 19 (New Wells) (Pl. 2, fig. 4), and possibly in one or two from the Leemon at Section 20 (Short Farm). These small borings could be algal or fungal (see Bromley, 1970, pp. 54, 55; Golubic, Perkins, and Lukas, 1975, p. 243). They occur beneath epizoic bryozoans in two coralla and beneath an algal coating in one, indicating that the borers became associated with these hosts relatively early. Similar borings have been reported in Richmondian solitary rugosan coralla from the Richmond and Red River-Stony Mountain provinces (e.g., Elias, 1982a, pl. 9, fig. 20; Elias, 1982b, fig. 4h).

A second type of microborings, with branches having highly variable diameters of up to 50 μm , was probably produced by algae (Pl. 4, figs. 1, 2). Such borings were observed in a few coralla of *Streptelasma subregulare* (Savage, 1913b) from the Leemon Formation at Section 20 (Short Farm), and from the Kissenger Limestone Member of the Bryant Knob Formation at Sections 18 (Kissenger), 17 (Clarksville), and 16 (Clinton Spring). All but one of the Kissenger specimens are from the basal coral-rich interval, and most are from Section 16. The exterior surface of the corallum was micritized in almost all cases, and the borings occur beneath algal coatings in some individuals and within the calice in two. Such borings and associated micritization have not been observed in Richmondian solitary rugosan coralla.

ORIENTATION

Virtually all of the solitary rugosan coralla found during this study were lying sideways within the strata, in what would have been stable depositional orientations after being overturned and possibly transported. Several clusters representing colonies and/or pseudocolonies of *Streptelasma leemonense* Elias, 1982a, include corallites oriented with calices facing upward, as they would have during life. These may have been preserved in growth position. The greater size and weight of the clusters likely made them more stable than individual coralla. Such specimens were found at Sections 23 (Lawrence Quarry), 20 (Short Farm), and 15 (Calumet).

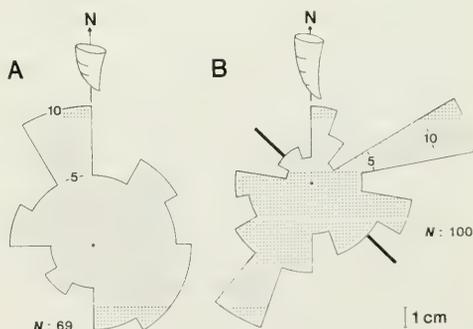
Data sets large enough to permit statistical analysis of directional orientations were obtained for solitary rugosan coralla in the upper half of the Keel Formation, including the *Brevilamnulella* beds, at Section 23 (Lawrence Quarry), and the coral-rich interval at the base

of the Kissenger Limestone Member, Bryant Knob Formation, at Section 16 (Clinton Spring). These distributions were interpreted by Elias, McAuley, and Mattison (1987, p. 810), and the results are summarized below.

Coralla at Section 23 are considered to be randomly oriented (Text-fig. 12A). Although the energy level was probably high enough to transport these objects, the directions of fluid motion may have been sufficiently variable that a preferred orientation pattern did not result. It seems unlikely that an initial pattern was subsequently obscured by the activity of burrowers, because there is minimal evidence for bioturbation.

Coralla at Section 16 are preferentially oriented, and the distribution is bimodal (Text-fig. 12B). Peaks in the northeast and southwest are opposite one another but skewed slightly toward the southeast. These individuals were rolled almost perpendicular to water flow or nearly parallel to wave crests, with the apical end facing either way but directed slightly into currents from the northwest. The current direction is parallel to depositional strike of the Bryant Knob and the inferred shoreline, suggesting that coralla were oriented by longshore currents and perhaps waves.

From an examination of loose slabs, it is apparent that cylindrical coralla of *Streptelasma amsdeni*, n. sp., in the laminated calcituff unit of the Keel Formation at Section 24 (Coal Creek) are generally aligned parallel to one another (Pl. 6, figs. 9, 10). This is considered to be a result of hydraulic action. Unfortunately, too few specimens were found *in situ* to conduct a paleocurrent analysis.



Text-figure 12.—Rose diagrams showing directional orientations of solitary rugosan coralla (N = sample size). Orientation convention is illustrated using the north arrow and a typical specimen (to scale). **A**, Mostly *Streptelasma subregulare* (Savage, 1913b), intervals 23-2 (*Brevilamnulella* beds), 23-2a, 23-3, Keel Formation, Section 23 (Lawrence Quarry). **B**, *Streptelasma subregulare*, interval 16-1 (coral-rich interval), Kissenger Limestone Member, Bryant Knob Formation, Section 16 (Clinton Spring); thick line represents depositional strike of Bryant Knob Formation.

PALEOECOLOGY

Solitary rugose corals of the Edgewood Province are absent or rare in units representing the highest energy environments. They are absent in the cross-bedded oölite at the base of the Leemon Formation at Section 20 (Short Farm). These fossils are generally absent or rare in relatively pure oölitic portions of the Keel Formation, such as below and above the laminated calcilitite unit at Section 24 (Coal Creek), in which *Streptelasma amsdeni*, n. sp., is abundant. *Streptelasma* sp. A, the only taxon known from the oölite comprising the Noix Limestone, is rare at Section 15 (Calumet). This small, epizoic species may have been protected by its position on a larger bryozoan colony. Edgewood solitary Rugosa are also absent or rare in argillaceous units considered to represent the lowest energy environments. They are absent in the Leemon Formation above the basal bioherms at Section 19 (New Wells), in which *Streptelasma subregulare* (Savage, 1913b) is abundant. These corals are absent or rare in Wilhelmi and Mosalem strata, except near the base of the Wilhelmi at a few localities and on one bedding surface in the Mosalem at a single locality. *Streptelasma subregulare* is the only Edgewood species known from the Wilhelmi and Mosalem formations.

Edgewood solitary rugosan species generally occur in relatively pure bioclastic calcarenite beds, such as those in the Keel Formation at Sections 21 (Rock Crossing) and 23 (Lawrence Quarry), the upper Leemon Formation at Sections 31 (Thebes North) and 20 (Short Farm), and the Bryant Knob Formation. This suggests that they favored clear water, moderate energy, normal marine conditions. *Streptelasma subregulare* (Savage, 1913b), by far the most common and widely distributed species (see Text-figs. 2-5, 7, 8), was evidently able to inhabit a wider range of environments than the other taxa. *Streptelasma leemonense* Elias, 1982a, and *Grewingkia* sp. A are the second and third most widely distributed species, respectively.

Deposition of the Kissenger Limestone Member at Sections 18 (Kissenger), 17 (Clarksville), and 16 (Clinton Spring) occurred nearer to shore and possibly in shallower water than at Sections 15 (Calumet) and 14 (Higginbotham Farm) (Text-fig. 5). This is inferred from the southeast-northwest depositional strike of the Bryant Knob Formation, and the apparent position of a shoreline immediately to the northeast. *Streptelasma subregulare* (Savage, 1913b) is the only solitary coral at Sections 18, 17, and 16, but it occurs together with *Streptelasma leemonense* Elias, 1982a, at Sections 15 and 14, and also with *Grewingkia* sp. A at Section 14. Perhaps the distribution of Edgewood taxa was determined by proximity to shore and/or water depth. *Streptelasma subregulare* is the only species present in

northern Illinois (Text-figs. 7, 8), where deposition evidently occurred in the most restricted conditions, farthest from the continental margin. Evidence indicating that the distribution of solitary rugosan species in the Richmond and Red River-Stony Mountain provinces was related to water depth and/or the degree of environmental restriction was presented by Elias (1982a, pp. 13, 26; 1983b, pp. 2, 3; 1985, pp. 14-16) and Elias, Zeilstra, and Bayer (1988, p. 33).

INTRASPECIFIC VARIATION AND EVOLUTION

Streptelasma subregulare (Savage, 1913b) is a highly variable species. The continuous spectrum of values for measurements of numerous characteristics indicates that there are no morphologic discontinuities among the 589 specimens assigned to the species. Those characteristics exhibiting anomalous trends at certain sections or in particular stratigraphic intervals (Table 3) fall within or overlap the range of values for coralla from elsewhere. Such features could reflect genetic differences among populations and/or environmental differences that are not understood at present, given the limited amount of detailed paleontologic and sedimentologic work that has been done on these units.

Morphologic characteristics of coralla from the laminated calcilitite unit of the Keel Formation at Section 24 (Coal Creek), and a specimen from the underlying Keel oölite, generally lie within the range of variability of *Streptelasma subregulare* (Savage, 1913b), but most are not typical of that species (Table 3). The most striking features are the long, cylindrical growth form and thin septa. We consider these coralla to represent a distinct taxon, *Streptelasma amsdeni*, n. sp., because of the consistent differences. It is inferred that *S. amsdeni* was derived from *S. subregulare* by geographic speciation. This is the only evolutionary event recognized within the Edgewood Province.

SYSTEMATIC PALEONTOLOGY

INTRODUCTION

Our morphologic terminology follows Hill (1981) and Elias (1981, p. 3). Most of the biometric and other data used to prepare Text-figures 13-23 and Tables 4, 6, and 7 were presented by McAuley (1985, appendixes 1-4). The synonymies include only forms considered identical to the one under discussion.

The suprageneric classification followed herein is that of Hill (1981) for Streptelasmatina Wedekind, 1927, and Cyathophyllina Nicholson in Nicholson and Lydekker, 1889, and Neuman (1984) for Monacanthina Neuman, 1984. Generic treatments are included where our study increases understanding of an established genus, or requires erection of a new one.

Table 3.—Morphologic characteristics of *Streptelasma subregulare* (Savage, 1913b) and the closely related species *Streptelasma amsdeni* n. sp., for sections with relatively large sample sizes, based on an inspection of corallum lengths and data in Tables 4-6 and Text-figure 17. Unusually high frequency (H), typical frequency (T), unusually low frequency (L), insufficient data (—; fewer than 10 data points for comparison, except for "closely spaced tabulae," where all points were used).

characteristics	sections													S. ams- deni	
	21	23	31	20	19	18 (in- tervals 1 and 2)	18 (in- tervals 3 and 4)	17	16	15	14	34	32		24
	<i>Streptelasma subregulare</i>														
long coralla	T	T	H	H	H	T	H	T	T	T	T	T	T	T	H
trochoid coralla	—	H	T	H	T	T	T	L	L	H	L	T	H	L	L
cylindrical coralla	—	T	T	T	T	T	T	T	T	T	T	T	T	H	H
noncurved coralla	—	T	T	L	T	L	T	T	T	H	L	L	T	T	T
greatly curved coralla	—	T	H	T	T	T	L	T	L	T	L	T	T	T	L
numerous septa	L	T	H	H	L	T	T	T	T	T	T	T	T	T	L
long major septa	T	T	T	T	T	T	H	T	T	T	T	T	T	T	T
thin major septa	T	T	H	H	H	L	L	T	T	T	L	T	H	H	H
long cardinal septum	H	T	H	T	T	T	L	L	L	L	L	T	T	T	T
thick cardinal septum	H	T	T	T	T	T	T	T	T	T	T	T	T	T	T
wide cardinal fossula	T	T	T	T	H	H	H	T	T	T	T	T	T	T	T
closely spaced tabulae	T	—	T	T	T	T	T	H	T	T	T	T	T	T	L

Coates (1984) summarized recent advances in taxonomic methods applied to living and fossil scleractinian coral species. The recognition and documentation of intraspecific variability based on large numbers of coralla is critical. In modern studies of Early Paleozoic solitary rugose corals, the ontogeny of individuals as well as intraspecific variability are of fundamental importance (see Neuman, 1974, 1977).

A total of 731 specimens are identified herein. External features of the corallum, ontogeny and internal structures, and microstructure are documented as completely as possible for 709 coralla representing the Edgewood assemblage. Biometric and other data are presented and analyzed in graphic and tabular form where feasible. The named species that we recognize are considered valid because they are separated from others by morphologic gaps. A continuous spectrum of features among coralla included in a species indicates that there are no discontinuities. The range of characteristics developed during ontogeny of individuals aids in the confirmation of intraspecific variability. In some cases, assignment of specimens to a named species is uncertain because their ontogeny or range of variability is incompletely known. We use "sp. cf." to qualify such identifications. A letter designation (sp. A) is given if there are insufficient data to assign a group of conspecific coralla to an existing species or a new one.

Two specimens representing the Late Ordovician "continental margin" assemblage and 20 from the Silurian assemblage are documented briefly. The generic name is followed by "sp." alone, because we are not certain that all the included coralla are conspecific.

ABBREVIATIONS OF REPOSITORIES

- UCGM: University of Cincinnati Geological Museum, Cincinnati, OH, U.S.A.
 UI: University of Illinois at Urbana-Champaign, Urbana, IL, U.S.A.
 USNM: National Museum of Natural History, Smithsonian Institution, Washington, DC, U.S.A.

ABBREVIATIONS OF COLLECTIONS

- A coll.: T. W. Amsden.
 C coll.: W. W. Craig.
 E1 coll.: R. J. Elias (1978).
 E2 coll.: R. J. Elias (1988).
 EM coll.: R. J. Elias and R. J. McAuley (1983).
 EMM coll.: R. J. Elias, B. W. Mattison, and R. J. McAuley (1982).
 EMZ coll.: R. J. Elias, R. J. McAuley, and R. G. Zeilstra (1985).
 EZ coll.: R. J. Elias and R. G. Zeilstra (1986).
 S coll.: T. E. Savage.

- Suborder **STREPTELASMATINA** Wedekind, 1927
 Family **STREPTELASMATIDAE** Nicholson *in* Nicholson and Lydekker, 1889
 Subfamily **STREPTELASMATINAE** Nicholson *in* Nicholson and Lydekker, 1889

Genus **STREPTELASMA** Hall, 1847

Streptelasma Hall, 1847, p. 17 (as *Streptoplasma*), and page facing p. 338; Neuman, 1969, pp. 8-10; McLean, 1974, pp. 38-41; Laub, 1979, pp. 59-61; Elias, 1982a, p. 52.

Type species.—Designated by Roemer (1861, p. 19):

Streptelasma corniculum Hall, 1847; lower Trenton Limestone (upper Middle Ordovician), Middleville, New York.

Diagnosis.—Solitary or with few offsets. Septa non-dilated to completely dilated in early stage, dilation usually decreases during ontogeny. Major septa straight or wavy, generally extending to axis in early stage and become shorter during intermediate to late stages. Axial structure, if present, typically simple, composed of septal lobes and rarely lamellae in intermediate and/or late stages. Cardinal septum and fossula inconspicuous to prominent.

Discussion.—Neuman's (1969, pp. 8–11) study of the lectotype of *Streptelasma corniculum* Hall, 1847, formed a basis for the generally accepted concept of *Streptelasma* Hall, 1847. This genus was considered to include streptelasmatids with major septa that are long, thin to moderately thick, and usually joined to form a simple axial structure during early to intermediate stages. These septa become shorter and thinner in late stages, when an axial structure is seldom present. However, because intraspecific variability of the type species is unknown, *Streptelasma* remains poorly understood. Furthermore, most species presently included in the genus are based on small collections.

McLean (1974, pp. 38–41) stated that *Streptelasma* Hall, 1847, *Dinophyllum* Lindström, 1882, and *Porfiriviella* Ivanovskiy, 1963, may prove to be synonymous. He also noted that many species resembling *Streptelasma* in late stages are not well enough known in earlier stages to be included in the genus with certainty. Elias (1982a, p. 52) indicated that further study may demonstrate the synonymy of *Streptelasma*, *Helicelasma* Neuman, 1969, *Borelasma* Neuman, 1969, and *Grewingkia* Dybowski, 1873. He showed that in *Streptelasma divaricans* (Nicholson, 1875) there is complete gradation from coralla with open axial regions to those with axial structures similar to *Grewingkia* (Elias, 1982a, pp. 52, 55, 56, pl. 1, figs. 1–19). Neuman (1986, p. 352) considered the North American fauna to show an extreme range of variation not representative of most other areas, including Baltoscandia.

Streptelasma subregulare (Savage, 1913b), described in this study on the basis of a large collection, is important in establishing the range of variability in *Streptelasma* Hall, 1847. In this highly variable species there is continuous gradation from coralla that closely resemble *Streptelasma corniculum* Hall, 1847, to those that are similar to *Helicelasma* Neuman, 1969, *Borelasma* Neuman, 1969, and *Ullernelasma* Neuman, 1975. Within some individuals, different ontogenetic stages would be assigned to different genera if they were

considered independently. We therefore broaden the diagnosis of *Streptelasma* to include all representatives of *S. subregulare*.

Neuman (1986, p. 352) stated that the only fossular structures characteristic of *Streptelasma* Hall, 1847, are a pseudofossula (lacking tabular depression) or a septofossula (shortened cardinal septum). The cardinal fossula in *Streptelasma subregulare* (Savage, 1913b) is highly variable, and the tabulae are markedly depressed in some specimens (including the lectotype; Elias, 1982a, pl. 4, fig. 7).

***Streptelasma subregulare* (Savage, 1913b)**

Plate 1, figures 1–19; Plate 2, figures 1–12;

Plate 3, figures 1–18; Plate 4, figures 1–13;

Plate 5, figures 1–10

Zaphrentis subregularis Savage, 1913b, p. 62, pl. 3, fig. 5, pl. 7, fig. 1; Savage, 1917, p. 113, pl. 5, fig. 5, pl. 9, fig. 1.

Zaphrentis ambigua Savage, 1913b, pp. 109, 110, pl. 7, fig. 2; Savage, 1917, p. 149, pl. 9, fig. 2.

Streptelasma sp. Elias, 1982a, pp. 56, 57, pl. 4, figs. 4–6.

Streptelasma subregulare (Savage, 1913b). Elias, 1982a, pp. 57, 58, pl. 4, figs. 7–22.

Holotype.—By original designation: UI X-851 (Savage, 1913b, pl. 3, fig. 5; Savage, 1917, pl. 5, fig. 5; Elias, 1982a, pl. 4, figs. 7, 8), S coll., Cyrene Formation, near Edgewood, Pike County, Missouri.

Additional material.—USNM 422831, 422832, interval 21-1, EMM coll., USNM 422833–422836, interval 21-1a, EM coll., USNM 422837–422842, interval 21-1b, EM coll., USNM 422843–422852, interval 21-1c, EM coll., Ideal Quarry Member, Keel Formation, Section 21 (Rock Crossing), Carter County, Oklahoma; USNM 422853–422856, interval 25-1, EMM coll., Keel Formation, Section 25 (Hunton), Coal County, Oklahoma; USNM 422857, interval 23-1, EMM coll., USNM 422858–422909, interval 23-2 (*Brevilammulella* beds), EMM coll., USNM 422910–422912, interval 23-2a, EM coll., USNM 422913, 422914, interval 23-3, EMM coll., USNM 422915–422932, interval 23-3, EM coll., USNM 422933–422935, interval 23a-1, EM coll., Keel Formation, Section 23 (Lawrence Quarry), Pontotoc County, Oklahoma; UI X-6683, X-6684, S coll. [labelled "Edgewood", "near Thebes"], USNM 422936–422952, interval 31-1, EMZ coll., USNM 422953–422965, interval 31-1a, EMZ coll., USNM 422966, interval 31-1b, EMZ coll., Leemon Formation, Section 31 (Thebes North), Alexander County, Illinois; USNM 365919, 422967–422978, interval 20-1, EMM coll., USNM 422979–422981, interval 20-1, EM coll., USNM 422982, 422983, interval 20-2, EMM coll., USNM 422984–422992, interval 20-3, EM coll., USNM 422993, 422994, interval 20-4, EM coll., USNM 422995–423004, interval 20-5, EM coll., UCGM

45616, same interval as 20-3, 20-4, 20-5, E1 coll., Leemon Formation, Section 20 (Short Farm), Cape Girardeau County, Missouri; UCGM 45618–45634, E1 coll., USNM 365918, 423005–423018, interval 19-1, EMM coll., USNM 423019–423041, interval 19-2, EMM coll., USNM 423042–423083, interval 19-3, EMM coll., Leemon Formation, Section 19 (New Wells), Cape Girardeau County, Missouri; USNM 423084–423103, interval 18-1, EMM coll., USNM 423104–423108, interval 18-1, EM coll., unnamed member, Bryant Knob Formation, Section 18 (Kissenger), Pike County, Missouri; USNM 423109–423126, interval 18-2, EMM coll., USNM 423127–423137, interval 18-3, EMM coll., USNM 423138–423145, interval 18-3, EM coll., USNM 423146, interval 18-4, EM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 18 (Kissenger), Pike County, Missouri; USNM 423147–423183, interval 17-0, EM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 17 (Clarksville), Pike County, Missouri; UCGM 45643, USNM 423184, interval 16-0, E1 coll., unnamed member, Bryant Knob Formation, Section 16 (Clinton Spring), Pike County, Missouri; UCGM 45644, 45645, USNM 423185–423187, interval 16-1, E1 coll., USNM 423188–423234, interval 16-1, EMM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 16 (Clinton Spring), Pike County, Missouri; USNM 423235–423241, interval 15-1, EMM coll., USNM 423242–423252, interval 15-1, EM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 15 (Calumet), Pike County, Missouri; USNM 423253–423280, interval 14-1, EM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 14 (Higginbotham Farm), Pike County, Missouri; USNM 423281–423285, interval 13-1, EMM coll., Cyrene Formation, Section 13 (Bowling Green), Pike County, Missouri; UI C-864 [labelled “*Zaphrentis*”], S coll., Cyrene Formation [labelled “Edgewood”], Edgewood, Pike County, Missouri; UI C-2258 [labelled “*Zaphrentis* cf. *subregularis*”], S coll., Wilhelmi Formation [labelled “Essex”], Horse Creek, about 2.4 km east of Essex, Kankakee County, Illinois; UI C-1581 [five specimens labelled “*Zaphrentis subregularis*”], S coll., Wilhelmi Formation [labelled “Channahon”], southeast of Channahon, Will County, Illinois; UI C-1560 [seven specimens labelled “*Zaphrentis channahonensis*”], UI C-1563 [one specimen, a slab with one specimen, and a slab with three specimens, labelled “*Zaphrentis ambigua*”], S coll., Wilhelmi Formation [labelled “Edgewood” and “Channahon”], respectively, Channahon, Will County, Illinois; UI C-1547 [slab with two specimens labelled “*Zaphrentis channahonensis*”], UI C-1561 [10 specimens labelled “*Zaphrentis subregularis*”], UI

X-947 [type specimens of *Zaphrentis ambigua*, one specimen and a slab with five specimens, one figured by Savage, 1913b, pl. 7, fig. 2, and Savage, 1917, pl. 9, fig. 2], S coll., Wilhelmi Formation [labelled “Edgewood”], near Channahon, Will County, Illinois; UI X-926 [two specimens labelled “*Zaphrentis subregularis*”], one figured by Savage, 1913b, pl. 7, fig. 1, and Savage, 1917, pl. 9, fig. 1], S coll., Wilhelmi Formation [labelled “Edgewood”, “Channahon”], Will County, Illinois; USNM 423286–423291, interval 4-1, EMM coll., Schweizer Member, Wilhelmi Formation, Section 4 (Schweizer West), Will County, Illinois; USNM 423292, interval 29-1, EMZ coll., Wilhelmi Formation, Section 29 (Sears Pit), De Kalb County, Illinois; USNM 423293–423296, interval 3-2, EMM coll., USNM 423297–423303, interval 3-3, EM coll., Birds Member, Wilhelmi Formation, Section 3 (Garden Prairie), McHenry County, Illinois; UI C-1619 [six specimens labelled “*Zaphrentis subregularis*”], S coll., Birds Member, Wilhelmi Formation [labelled “Channahon”], near Belvidere, Boone County, Illinois; USNM 431136–431166, interval 34-1, E2 coll., Birds Member, Wilhelmi Formation, Section 34 (Belvidere South), Boone County, Illinois; USNM 423304, interval 32-0a, EZ coll., USNM 431167–431173, interval 32-1z, E2 coll., USNM 423305, 423306, interval 32-1a, EZ coll., USNM 431174–431177, interval 32-1b, E2 coll., Mosalem Formation, Section 32 (Thomson East), Carroll County, Illinois.

Occurrences.—Uppermost Ordovician (Gamachian): Keel Formation including Ideal Quarry Member, south-central Oklahoma; Leemon Formation, southeastern Missouri and southern Illinois; middle Cyrene Formation, northeastern Missouri. Uppermost Ordovician (?) (Gamachian(?)) to lowermost Silurian (lower Lower Llandovery): Schweizer Member, Wilhelmi Formation, northeastern Illinois. Lowermost Silurian (?) (lower Lower Llandovery (?)): Bryant Knob Formation including unnamed member and Kissenger Limestone Member, northeastern Missouri. Lowermost Silurian (lower Lower Llandovery): Birds Member, Wilhelmi Formation, northeastern Illinois; middle Mosalem Formation, northwestern Illinois.

Diagnosis.—Solitary, usually ceratoid. In early stages, major septa generally moderately to greatly dilated and extend to axis, where distal ends join. During intermediate to late stages, septal length and dilation decrease, axial region opens. Cardinal septum commonly conspicuous in late stages. Cardinal fossula usually inconspicuous, less commonly very broad or distinctively shaped. Minor septa typically extend a short distance beyond relatively narrow stereozone. Tabulae generally moderately to widely spaced, commonly depressed in cardinal fossula.

Description of coralla.—The largest specimen is 102 mm long and 44 mm in diameter at the calice rim (USNM 423146). Growth form is trochoid (Pl. 4, fig. 10) to ceratoid (Pl. 5, fig. 2) to rarely subcylindrical, and coralla vary from straight to moderately curved (Pl. 4, fig. 4) to gradually curved through 90 degrees (Table 4). Among curved coralla, the cardinal side is typically convex, but there are irregular exceptions (Pl. 4, fig. 4). Several coralla have slight to moderate bends in two different directions. A few individuals have single right-angle bends (Pl. 1, fig. 17), but none have more than one such bend. Corallum shape in transverse section is generally circular, but is irregular in a few cases (Pl. 2, fig. 6). Well-preserved specimens show prominent septal grooves and interseptal ridges, as well as growth lines. Coarse rugae are present on some individuals. Rejuvenations, if present on a corallum, are few in number and not pronounced. On the convex cardinal side at the apex, two specimens have small grooves (USNM 422910, 422935) and one has a small expansion with a flat surface (USNM 422941). These are interpreted as attachment structures. Depth of the calice is commonly about 50 percent of the corallum

length, but varies from 30 percent to perhaps as much as 90 percent in several individuals that have unusually short major septa throughout ontogeny (USNM 423006, 423009, 423025, 423034, 423075).

Ontogeny and internal structures.—The relationship between number of septa and corallum diameter is shown in Text-figure 13 and Table 5. Major septa generally extend to or near the axis, where their distal ends meet in small groups, during early ontogenetic stages (Pl. 1, figs. 1, 13, Pl. 2, fig. 10, Pl. 3, figs. 7, 10, 11, 16, Pl. 4, fig. 5, Pl. 5, figs. 3, 7, 9). Septa are shorter in some specimens, but only rarely extend less than half the corallum radius. The septa usually decrease in length gradually during intermediate stages (Pl. 1, figs. 2, 4, 6–11, 14, 15, 18, Pl. 2, figs. 1, 5, 11, Pl. 3, figs. 8, 9, 12, 17, Pl. 4, figs. 6, 8, 11, 12, Pl. 5, figs. 4, 5, 8) and late stages (Pl. 1, figs. 3, 5, 12, 16, 19, Pl. 2, figs. 2, 3, 6, 12, Pl. 3, figs. 13, 18, Pl. 4, figs. 3, 7, 9, 13, Pl. 5, figs. 6, 10) (Text-figure 14, Table 5). However, they remain long in some coralla, and rapidly decrease in length in others. Septa are relatively straight to wavy in transverse sections. A few septal lobes are present in some individuals (Pl. 1, fig. 15, Pl. 2, fig. 12), but

Table 4.—Growth form and curvature of specimens of *Streptelasma subregulare* (Savage, 1913b), *Streptelasma amsdeni*, n. sp., *Streptelasma leemonense* Elias, 1982a (and two specimens of *Streptelasma* sp. cf. *S. leemonense* Elias, 1982a, from Section 23), and *Keelophyllum oklahomense*, n. gen., n. sp.

section	growth form			curvature		
	trochoid	ceratoid	cylindrical	non-curved ¹	moderately curved ²	greatly curved ³
<i>Streptelasma subregulare</i>						
21	4 (80%)	1 (20%)	0 (0%)	2 (40%)	3 (60%)	0 (0%)
25	3 (100%)	0 (0%)	0 (0%)	2 (67%)	1 (33%)	0 (0%)
23	44 (80%)	11 (20%)	0 (0%)	26 (47%)	26 (47%)	3 (5%)
31	10 (56%)	8 (44%)	0 (0%)	8 (47%)	6 (35%)	3 (18%)
20	19 (76%)	6 (24%)	0 (0%)	6 (26%)	15 (65%)	2 (9%)
19	26 (29%)	60 (67%)	3 (3%)	42 (48%)	41 (47%)	5 (6%)
18 (intervals 1 and 2)	4 (36%)	7 (64%)	0 (0%)	3 (27%)	7 (64%)	1 (9%)
18 (intervals 3 and 4)	6 (50%)	6 (50%)	0 (0%)	5 (42%)	7 (58%)	0 (0%)
17	6 (18%)	26 (79%)	1 (3%)	13 (43%)	14 (47%)	3 (10%)
16	8 (20%)	33 (80%)	0 (0%)	20 (50%)	17 (43%)	3 (8%)
15	9 (75%)	3 (25%)	0 (0%)	7 (58%)	5 (42%)	0 (0%)
14	4 (18%)	18 (82%)	0 (0%)	3 (17%)	14 (78%)	1 (6%)
13, Cyrene, and Edgewood	4 (100%)	0 (0%)	0 (0%)	3 (75%)	1 (25%)	0 (0%)
4 and Channahon	15 (56%)	12 (44%)	0 (0%)	6 (22%)	20 (74%)	1 (4%)
34	17 (59%)	12 (41%)	0 (0%)	3 (14%)	17 (81%)	1 (5%)
32	10 (100%)	0 (0%)	0 (0%)	5 (50%)	4 (40%)	1 (10%)
<i>Streptelasma amsdeni</i>						
24	0 (0%)	25 (53%)	22 (47%)	22 (48%)	23 (50%)	1 (2%)
<i>Streptelasma leemonense</i> (and <i>S.</i> sp. cf. <i>S. leemonense</i>)						
23, Gale, 20, 15, and 14	9 (43%)	10 (48%)	2 (10%)	8 (38%)	13 (62%)	0 (0%)
<i>Keelophyllum oklahomense</i>						
25 and 23	1 (20%)	4 (80%)	0 (0%)	3 (60%)	1 (20%)	1 (20%)

0–10° curvature of growth axis.

11–70° curvature of growth axis.

71–90° curvature of growth axis.

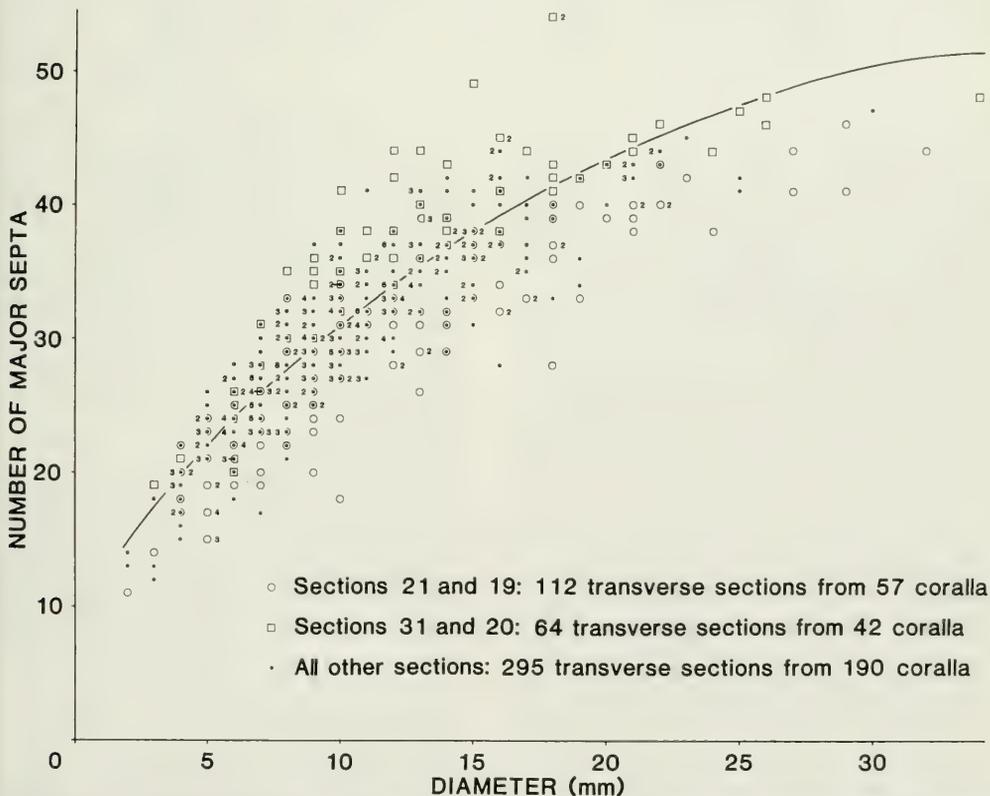
paliform septal lamellae are rare (Pl. 1, fig. 10).

The degree of septal dilation is typically moderate to great in early stages and decreases during ontogeny, but the range among specimens is from nondilated to completely dilated in all stages. The actual thickness of septa generally increases in early to intermediate stages, and then decreases (Text-fig. 15, Table 5). However, in some coralla the septa decrease in thickness throughout ontogeny, and in others their thickness remains about the same.

The cardinal septum is most commonly inconspicuous, being the same length and thickness as other major septa (Table 6). However, this septum is distinct if it is relatively short or long, and/or thin or thick. Its prominence varies among coralla, and from stage to stage within some individuals. In many specimens, the cardinal septum becomes relatively short and thin in late stages near the base of the calice. In early to in-

termediate stages of a few individuals, the cardinal and counter septa are longer than other major septa (Pl. 4, fig. 12). The cardinal fossula is usually inconspicuous, having the same width and shape as other pairs of interseptal spaces. However, it becomes very broad in some coralla (Text-fig. 16, Table 5). Five basic intergradational shapes are recognized in transverse sections, as follows: (1) width decreases from periphery toward corallum axis; (2) width constant; (3) width increases toward axis; (4) biconvex with maximum width midway between periphery and axial end; and (5) hourglass-shaped with constriction midway between periphery and axial end (Table 7). Shapes (3) to (5) are especially distinctive in many cases.

Minor septa extend a short distance beyond the stereozone in ontogenetic stages where major septa are nondilated to slightly dilated. In a few individuals, the minor septa immediately adjacent to the counter sep-



Text-figure 13.—Relationship between number of major septa and corallum diameter in *Streptelasma subregulare* (Savage, 1913b). Data for "All other sections" are from Sections 25, 23, 13-18, 4, 3, 34, and 32. Numbers beside data points indicate frequencies greater than one. Arbitrary line was used to derive proportions shown in part of Table 5.

Table 5.—Frequency of data points above (A), or on and below (B), arbitrary lines drawn in Text-figures 13–16 and 18–21, for characteristics of major septa and cardinal fossula in *Streptelasma subregulare* (Savage, 1913b) and *Streptelasma amsdeni*, n. sp.

section	number of septa		length of septa		thickness of septa		width of fossula	
	A	B	A	B	A	B	A	B
<i>Streptelasma subregulare</i>								
21	3 (12%)	22 (88%)	1 (4%)	24 (96%)	12 (48%)	13 (52%)	0 (0%)	25 (100%)
25	0 (0%)	3 (100%)	0 (0%)	2 (100%)	1 (50%)	1 (50%)	0 (0%)	1 (100%)
23	8 (29%)	35 (81%)	13 (25%)	40 (75%)	23 (45%)	28 (55%)	1 (2%)	40 (98%)
31	17 (68%)	8 (32%)	0 (0%)	25 (100%)	4 (16%)	21 (84%)	3 (14%)	19 (86%)
20	30 (77%)	9 (23%)	8 (20%)	33 (80%)	9 (22%)	32 (78%)	1 (3%)	34 (97%)
19	8 (9%)	79 (91%)	5 (5%)	89 (95%)	11 (12%)	81 (88%)	31 (38%)	51 (62%)
18 (interval 1)	5 (36%)	9 (64%)	1 (7%)	13 (93%)	10 (71%)	4 (29%)	9 (69%)	4 (31%)
18 (interval 2)	6 (38%)	10 (63%)	1 (6%)	15 (94%)	10 (63%)	6 (38%)	5 (36%)	9 (64%)
18 (intervals 3 and 4)	9 (32%)	19 (68%)	20 (69%)	9 (31%)	20 (69%)	9 (31%)	7 (26%)	20 (74%)
17	29 (59%)	20 (41%)	6 (11%)	47 (89%)	27 (51%)	26 (49%)	2 (4%)	52 (96%)
16	12 (33%)	24 (67%)	9 (20%)	36 (80%)	27 (61%)	17 (39%)	2 (5%)	38 (95%)
15	3 (23%)	10 (77%)	3 (23%)	10 (77%)	6 (46%)	7 (54%)	0 (0%)	13 (100%)
14	7 (29%)	17 (71%)	5 (27%)	25 (83%)	21 (72%)	8 (28%)	2 (8%)	23 (92%)
13	3 (43%)	4 (57%)	0 (0%)	7 (100%)	2 (29%)	5 (71%)	0 (0%)	6 (100%)
4	5 (45%)	6 (55%)	1 (14%)	6 (86%)	3 (33%)	6 (67%)	1 (11%)	8 (89%)
3	3 (43%)	4 (57%)	1 (11%)	8 (89%)	4 (44%)	5 (56%)	0 (0%)	5 (100%)
34	6 (23%)	20 (77%)	0 (0%)	30 (100%)	11 (38%)	18 (62%)	1 (7%)	14 (93%)
32	8 (44%)	10 (56%)	1 (6%)	16 (94%)	1 (6%)	16 (94%)	0 (0%)	14 (100%)
<i>Streptelasma amsdeni</i>								
24	2 (4%)	52 (96%)	4 (8%)	49 (92%)	0 (0%)	52 (100%)	8 (17%)	38 (83%)

tum are anomalous in being longer than the other minor septa, and in some of these are almost as long as the major septa (Elias, 1982a, pl. 4, fig. 13; Pl. 2, figs. 2, 3, 12). Thickness of the stereozone ranges from 5 to 15 percent of the corallum radius. Specimens with thick septa tend to have thick stereozone.

Tabulae are commonly complete and thin (Pl. 2, figs. 7–9; Pl. 3, figs. 2–6, 14, 15). They are usually convex upward in the septal region, and less commonly flat or rarely concave upward. In the axial region, they are concave or flat. Tabulae are generally moderately to widely spaced, but in some cases are very closely spaced (Text-fig. 17). They are usually depressed in the cardinal fossula (Elias, 1982a, pl. 4, fig. 7; Pl. 2, figs. 8, 9).

Microstructure.—In transverse thin sections, the major septa are fibrous in all ontogenetic stages. However, fibers are difficult to discern if septa are thin. The fibers originate at the median line within the septum, and curve outward in the direction of the corallum axis so that their convex sides face axially. Where the major septa are greatly to completely dilated, minor septa appear as triangular wedges between them (Pl. 5, fig. 1). Where major septa are nondilated to slightly dilated, U-shaped lamellae with concave sides facing the corallum axis form the stereozone between adjacent major and minor septa (Pl. 3, fig. 1). A contorted suture extends through the lamellae in a medial position between adjacent septa. The epitheca is composed of short fibers oriented approximately perpendicular to

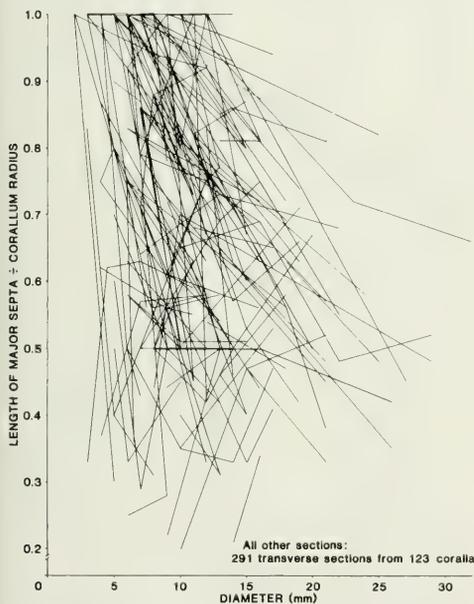
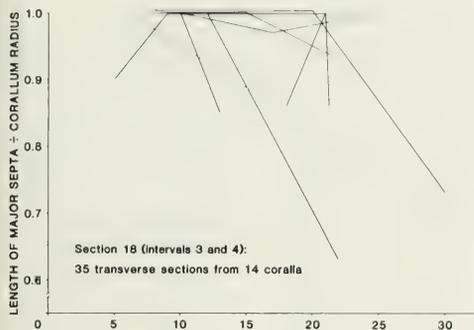
the outer surface of the corallum. In longitudinal thin sections, septal fibers are inclined from the periphery of the corallum toward the axis at an angle of about 40 degrees.

Discussion.—Savage (1913a) mentioned “*Zaphrentis subregularis*” and “*Zaphrentis ambigua*” in his text and tables, but descriptions and illustrations of these species were published later (Savage, 1913b, 1917). Elias (1982a, p. 57) established that *Z. ambigua* Savage, 1913b, is a synonym of *Z. subregularis* Savage, 1913b, and assigned the species to *Streptelasma* Hall, 1847.

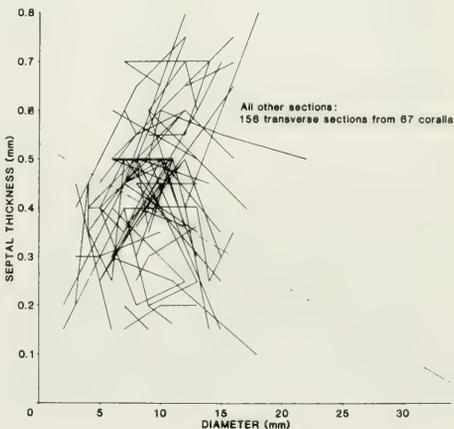
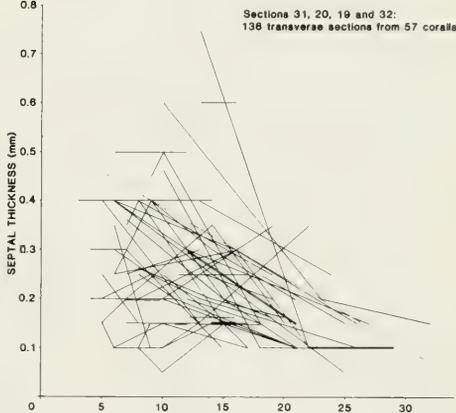
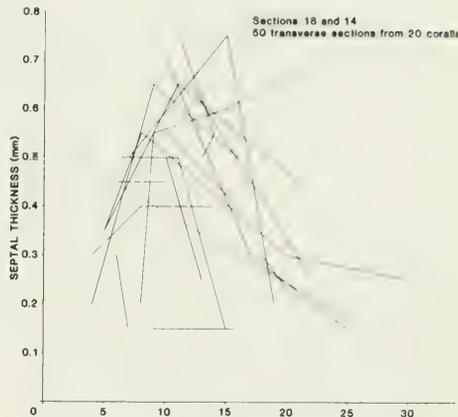
“*Zaphrentis channahonensis*, n. sp.” was listed in a table by Savage (1912, pp. 98, 99), but he did not provide a description or illustrations, and the species was not mentioned in subsequent literature. Therefore, this is a *nomen nudem*. Specimens labelled “*Zaphrentis channahonensis*” by Savage were examined in our study. They are from the same unit and location as others that he identified as *Zaphrentis subregularis* and *Zaphrentis ambigua*. Thin sections of one reveal that it is *Streptelasma subregulare* (Savage, 1913b) (Pl. 5, figs. 3–5).

A small, incomplete corallum from the Leemon Formation at Section 20 (Short Farm) was identified by Elias (1982a, pp. 56, 57) as *Streptelasma* sp. Comparison with the numerous specimens subsequently obtained at that locality indicates that it is *Streptelasma subregulare* (Savage, 1913b).

The continuous spectrum of values for the numerous



Text-figure 14.—Relationship between length of major septa and corallum diameter in *Streptelasma subregulare* (Savage, 1913b), for specimens yielding more than one transverse thin section. The length of a typical septum was measured and divided by the corallum radius, yielding a ratio less than or equal to 1.0. Data for "All other sections" are from Sections 21, 23, 31, 20, 19, 18 (intervals 1 and 2), 13-17, 4, 3, 34, and 32. Arbitrary line (dotted) was used to derive proportions shown in part of Table 5.



Text-figure 15.—Relationship between thickness of major septa and corallum diameter in *Streptelasma subregulare* (Savage, 1913b), for specimens yielding more than one transverse thin section. Septal thickness was measured in transverse thin sections halfway between the axial and peripheral ends of a typical septum on the counter side (usually the counter septum). Data for "All other sections" are from Sections 21, 23, 15-17, 13, 4, 3, and 34. Arbitrary line (dotted) was used to derive proportions shown in part of Table 5.

Table 6.—Length and thickness of cardinal septum, compared with other typical major septa, in transverse thin sections of *Streptelasma subregulare* (Savage, 1913b) and *Streptelasma amsdeni*, n. sp.

section	length of cardinal septum			thickness of cardinal septum		
	shorter	same	longer	thinner	same	thicker
<i>Streptelasma subregulare</i>						
21	1 (4%)	8 (35%)	14 (61%)	7 (29%)	10 (42%)	7 (29%)
23	5 (12%)	20 (48%)	17 (40%)	16 (33%)	26 (54%)	6 (13%)
31	4 (16%)	3 (12%)	18 (72%)	15 (60%)	9 (36%)	1 (4%)
20	4 (10%)	16 (41%)	19 (49%)	9 (23%)	28 (72%)	2 (5%)
19	19 (22%)	34 (40%)	32 (38%)	23 (27%)	57 (68%)	4 (5%)
18 (intervals 1 and 2)	5 (20%)	11 (44%)	9 (36%)	10 (37%)	15 (56%)	2 (7%)
18 (intervals 3 and 4)	5 (17%)	19 (66%)	5 (17%)	6 (21%)	20 (69%)	3 (10%)
17	8 (16%)	31 (63%)	10 (20%)	18 (37%)	25 (51%)	6 (12%)
16	5 (15%)	27 (79%)	2 (6%)	7 (21%)	24 (71%)	3 (9%)
15	1 (10%)	8 (80%)	1 (10%)	2 (20%)	7 (70%)	1 (10%)
14	3 (12%)	19 (73%)	4 (15%)	6 (23%)	17 (65%)	3 (12%)
13	2 (40%)	2 (40%)	1 (20%)	2 (40%)	2 (40%)	1 (20%)
4	1 (11%)	3 (33%)	5 (56%)	3 (33%)	5 (56%)	1 (11%)
3	0 (0%)	6 (100%)	0 (0%)	1 (17%)	3 (50%)	2 (33%)
34	5 (25%)	8 (40%)	7 (35%)	12 (60%)	7 (35%)	1 (5%)
32	4 (25%)	4 (25%)	8 (50%)	7 (44%)	9 (56%)	0 (0%)
<i>Streptelasma amsdeni</i>						
24	0 (0%)	26 (53%)	23 (47%)	0 (0%)	48 (98%)	1 (2%)

Table 7.—Frequency of each type of shape for the cardinal fossula in transverse thin sections of *Streptelasma subregulare* (Savage, 1913b) and *Streptelasma amsdeni*, n. sp. In cases where the shape on either side of a fossula is different, each side was counted as one-half. Fossula shapes (1–5) are described on p. 37.

section	fossula shape				
	(1)	(2)	(3)	(4)	(5)
<i>Streptelasma subregulare</i>					
21	1.0 (4%)	11.5 (46%)	3.5 (14%)	7.0 (28%)	2.0 (8%)
23	6.0 (15%)	15.0 (37%)	8.5 (21%)	8.5 (21%)	3.0 (7%)
31	2.5 (12%)	6.5 (31%)	1.5 (7%)	7.0 (33%)	3.5 (17%)
20	0.5 (1%)	10.0 (28%)	6.0 (17%)	12.5 (35%)	7.0 (19%)
19	17.0 (21%)	17.5 (21%)	15.5 (19%)	18.5 (23%)	13.5 (16%)
18 (intervals 1 and 2)	2.5 (9%)	7.5 (28%)	6.0 (22%)	3.5 (13%)	7.5 (28%)
18 (intervals 3 and 4)	1.5 (6%)	12.0 (44%)	7.0 (26%)	1.0 (4%)	5.5 (20%)
17	16.0 (31%)	20.5 (39%)	7.5 (14%)	5.0 (10%)	3.0 (6%)
16	24.0 (56%)	7.5 (17%)	8.5 (20%)	1.0 (2%)	2.0 (5%)
15	0.0 (0%)	4.0 (31%)	4.0 (31%)	1.0 (8%)	4.0 (31%)
14	6.0 (24%)	4.0 (16%)	6.5 (26%)	3.0 (12%)	5.5 (22%)
13	0.0 (0%)	0.5 (8%)	3.0 (50%)	1.0 (17%)	1.5 (8%)
4	0.0 (0%)	1.0 (11%)	2.5 (28%)	2.0 (22%)	3.5 (39%)
3	1.0 (20%)	1.0 (20%)	3.0 (60%)	0.0 (0%)	0.0 (0%)
34	0.5 (3%)	7.0 (46%)	1.0 (7%)	4.0 (27%)	2.5 (17%)
32	0.5 (4%)	7.0 (54%)	0.5 (4%)	1.0 (7%)	4.0 (31%)
<i>Streptelasma amsdeni</i>					
24	19.0 (42%)	4.5 (10%)	1.0 (2%)	7.5 (17%)	13.0 (29%)

features measured and compared in our study indicates that there are no morphologic discontinuities among the 589 specimens described above. Those characteristics exhibiting anomalous trends at certain localities or in particular stratigraphic intervals (Table 3) fall within or overlap the range of values for coralla from elsewhere. We conclude that *Streptelasma subregulare* (Savage, 1913b) is a highly variable species. An important confirmation of this intraspecific variability is

the great range of characteristics developed during the ontogeny of some individuals.

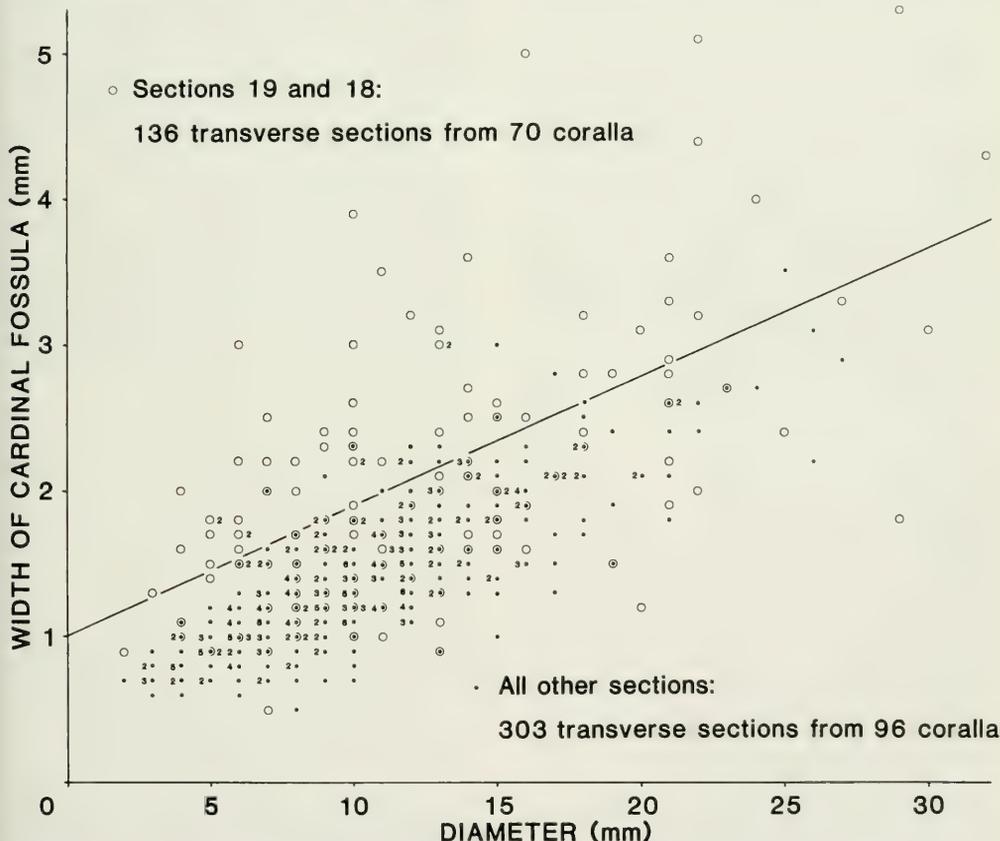
Solitary coralla from the Keel Formation at Section 24 (Coal Creek) generally lie within the range of variability for this taxon, but most of the individual characteristics are atypical (Table 3). They are considered to represent a different species, *Streptelasma amsdeni*, n. sp.

Some specimens of *Streptelasma subregulare* (Sav-

age, 1913b) with moderately dilated septa closely resemble the lectotype of *Streptelasma corniculum* Hall, 1847, from the Trenton Limestone (upper Middle Ordovician) of New York (Neuman, 1969, pp. 10, 11, figs. 5, 6). The number of septa, width of the cardinal fossula, and spacing of tabulae in the latter corallum are about average for *S. subregulare*. However, the major septa are slightly longer than usual, and the degree of septal dilation is greater on the cardinal side than on the counter side. Further comparison is not possible at this time because the range of variability in *S. corniculum* is unknown.

Some representatives of *Streptelasma subregulare* (Savage, 1913b) with thin, wavy septa are similar to the following taxa: *Streptelasma affine* (Billings, 1865)

from the Vauréal Formation (Richmondian) and Ellis Bay Formation (Gamachian) on Anticosti Island, Québec (Bolton, 1981, pl. 3, figs. 3-8; Elias, 1982a, pp. 59, 60, pl. 5, figs. 4-18); *Streptelasma primum* (Wedekind, 1927) in Stage 5a (Ashgill) of Norway, the Boda Limestone (Ashgill; Hirnantian) of Sweden, and the Pirgu Stage (Ashgill; Hirnantian) of the Estonian S.S.R. (Neuman, 1969, pp. 11-17, figs. 7a-c, e-h, 8-10; see also Neuman, 1975, pp. 357, 358); *Streptelasma cf. primum* (Wedekind, 1927) from boulders (Upper Ordovician; sub-Hirnantian, possibly Pirguan) in Sweden (Neuman, 1986, pp. 353, 355, 358, figs. 5-8); and *Streptelasma unicum* Neuman, 1975, from the *Dalmanitina* Beds (Ashgill; Hirnantian) or possibly the lowermost Llandovery of Sweden (Neuman, 1975, pp. 353, 356-358,



Text-figure 16.—Relationship between width of cardinal fossula and corallum diameter in *Streptelasma subregulare* (Savage, 1913b). Width of cardinal fossula was measured between median lines of septa immediately adjacent to the fossula, midway between axial and peripheral ends of septa bounding the fossula. Data for "All other sections" are from Sections 21, 25, 23, 31, 20, 13-17, 4, 3, 34, and 32. Numbers beside data points indicate frequencies greater than one. Arbitrary line was used to derive proportions shown in part of Table 5.

figs. 15, 16). However, in *S. affine* and *S. primum* the cardinal septum is always indistinct, and a cardinal fossula is never developed. In *S. unicum*, the cardinal septum becomes short and the fossula is conspicuous in late stages, but early ontogenetic stages and intra-specific variability are unknown. Minor septa are longer in *S. affine* than in the other three species.

A few individuals of *Streptelasma subregulare* (Savage, 1913b) resemble *Helicelasma simplex* Neuman, 1969, from the *Dalmanitina* Beds (Ashgill; Hirnantian) or possibly the lowermost Llandovery of Sweden (Neuman, 1969, pp. 29–33, figs. 23–26; Neuman, 1975, pp. 335, 336). In *H. simplex*, major septa are greatly to completely dilated in early stages, and gradually become thinner during ontogeny. A simple axial structure of fused septal tips is formed during the intermediate and late stages. The cardinal septum and fossula are conspicuous in *H. simplex*, but are most commonly inconspicuous in comparable coralla belonging to *S. subregulare*.

Like some specimens of *Streptelasma subregulare* (Savage, 1913b), *Borelasma crassitangens* Neuman, 1969, from the *Dalmanitina* Beds (Ashgill; Hirnantian) or possibly the lowermost Llandovery of Sweden (Neuman, 1975, pp. 335, 336) has thick major septa that are greatly to completely dilated in early stages and decrease in length during ontogeny (Neuman, 1969, pp. 66–69, figs. 57–59). A diagnostic characteristic of this taxon is the long cardinal and counter septa in

early stages, a feature that is rare in *S. subregulare*. The cardinal septum and fossula are inconspicuous in late stages. *Borelasma* spp. a and b were reported from Stages 6b and 6c (Llandovery; Rhuddanian–Idwian) and Stage 6c (Idwian), respectively, of Norway (Neuman, 1982, pl. 1, figs. 14–19). They are similar to *B. crassitangens*, but the cardinal septum becomes short and a fossula is developed in late stages.

Coralla of *Streptelasma subregulare* (Savage, 1913b) with a few distantly spaced tabulae, and thick septa that are greatly to completely dilated in early stages, resemble *Ullernelasma svartoeyensis* Neuman, 1975, from Stage 5b (Ashgill; Hirnantian) and Stage 6a (lowermost Llandovery; Rhuddanian) of Norway (Neuman, 1975, pp. 348, 350–353, figs. 10–13; Neuman, 1982, p. 34). In *U. svartoeyensis*, the cardinal septum is distinct and becomes short in late stages, and the cardinal fossula is conspicuous. Those features are less common in similar individuals of *S. subregulare*. Neuman noted that a few incomplete tabulae seem to be present in *U. svartoeyensis*. Tabulae in *S. subregulare* are complete, but their presence is not always revealed in transverse sections of coralla in which they are widely spaced and approximately horizontal.

Solitary Rugosa from the Guanyinqiao Beds (*Dalmanitina* Beds) (Ashgill; Hirnantian) in the northern Guizhou Province of China have been documented by He (1978, 1985). The following illustrated specimens resemble some coralla of *Streptelasma subregulare* (Savage, 1913b), but the available information is insufficient for a thorough comparison of these taxa:

- Streptelasma insolitum* He, 1978, pl. 1, figs. 1a–d, 2a, b.
- Streptelasma* cf. *distinctum* Wilson, 1926, of He, 1978, pl. 1, fig. 3a–d.
- Streptelasma* sp. of He, 1978, pl. 3, fig. 1a–c.
- Brachyelasma lindstroemophylloides* He, 1978, pl. 2, figs. 1a–g, 3a–c; He, 1985, pl. 1, fig. 4a–c.
- Brachyelasma irregularis* He, 1978, pl. 2, figs. 2a–d, 4a–c.
- Brachyelasma primum* (Wedekind, 1927) of He, 1978, pl. 3, figs. 2a–c, 3a, b.
- Brachyelasma yentzekouense* He, 1985, pl. 1, figs. 1a–g, 2a–c, 3a–c, 5a, b.
- Borelasma cornicum* He, 1978, pl. 5, fig. 1a–f.
- Borelasma sinensis* He, 1978, pl. 5, figs. 2a–c, 3a–c, 4a–c, 5a, b.
- Crassilasma polytabulatum* He, 1985, pl. 5, figs. 1a, b, 7a, b; see also He, 1978, pl. 7, figs. 1a–g, 2a–c.

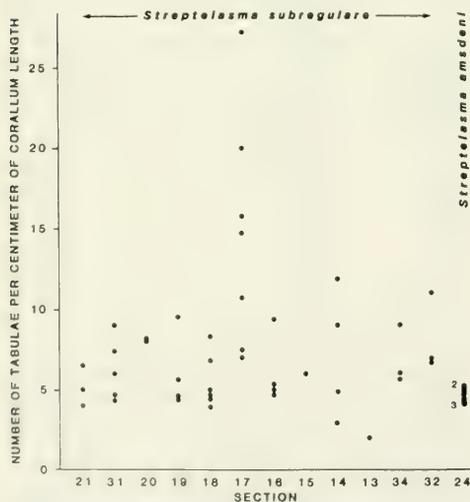
Streptelasma* species cf. *S. subregulare (Savage, 1913b)

Plate 5, figures 11, 12

Material.—USNM 423307, interval 33-1, C coll.

Occurrence.—Uppermost Ordovician (Gamachian): Cason shale, Section 33 (Buffalo River), Searcy County, western north-central Arkansas.

Description.—This small specimen is incomplete and the outer wall is not preserved. The major septa are nondilated and withdrawn from the axis, leaving an



Text-figure 17.—Number of tabulae (counted along corallum axis) per cm of corallum length in longitudinal thin sections of *Streptelasma subregulare* (Savage, 1913b) and *Streptelasma amsdeni*, n. sp. Numbers beside data points indicate frequencies greater than one.

open axial region possibly with several septal lobes. The cardinal septum appears to be shorter than the other major septa.

Discussion.—The septal arrangement of this specimen appears to lie within the range of variability documented herein for *Streptelasma subregulare* (Savage, 1913b). However, because it is incomplete, poorly preserved, and the only corallum of this kind known from north-central Arkansas, it cannot be positively identified. We therefore refer to it as *Streptelasma* sp. cf. *S. subregulare* (Savage, 1913b).

Streptelasma amsdeni, new species

Plate 5, figures 13–22; Plate 6, figures 1–11

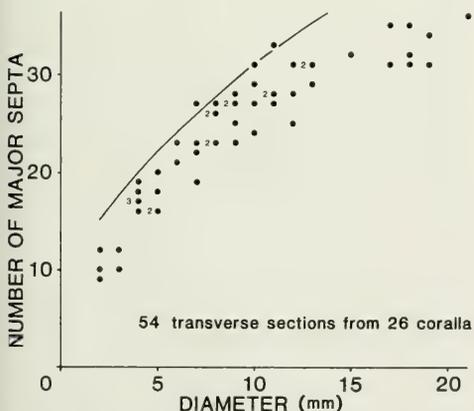
Derivation of name.—The species name honors Thomas W. Amsden of the Oklahoma Geological Survey, who collected some of the specimens described herein.

Holotype.—USNM 423308, interval 24-2, EMM coll.

Paratypes.—USNM 423309, interval 24-1, EMM coll., USNM 365920, 423310–423312, interval 24-2, A coll., USNM 423313–423317, interval 24-2, EMM coll.

Additional material.—USNM 423318–423320 [three specimens on slab], 423321–423329, interval 24-2, A coll., USNM 423330–423377, interval 24-2, EMM coll.

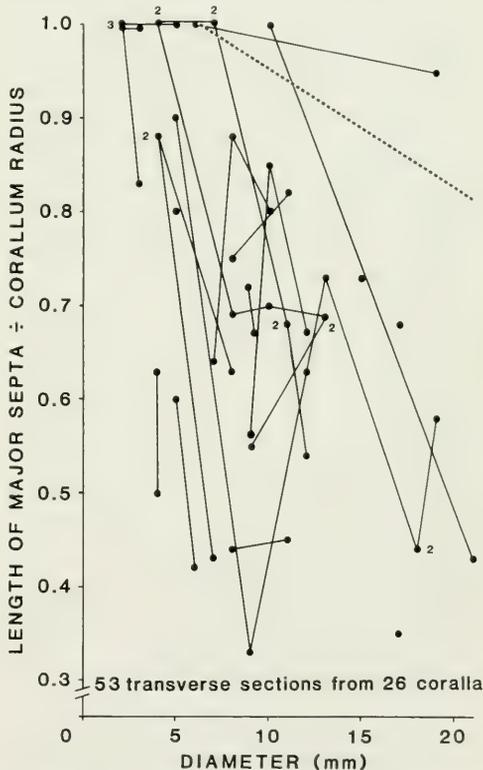
Occurrence.—Uppermost Ordovician (Gamachian): lower oölitic and middle laminated calcilitite units (intervals 24-1 and 24-2, respectively) of the Keel Formation, Section 24 (Coal Creek), Pontotoc County, south-central Oklahoma.



Text-figure 18.—Relationship between number of major septa and corallum diameter in *Streptelasma amsdeni*, n. sp. Numbers beside data points indicate frequencies greater than one. Arbitrary line [in same position as that for *Streptelasma subregulare* (Savage, 1913b) in Text-fig. 13] was used to derive proportions shown in part of Table 5.

Diagnosis.—Solitary, slender ceratoid to cylindrical. Major septa thin, nondilated to slightly dilated and extend to axis in early stages, gradually withdraw from axis during ontogeny. Cardinal septum indistinct to relatively long and conspicuous. Cardinal fossula usually inconspicuous, less commonly distinctively shaped. Minor septa typically extend a short distance beyond very narrow stereozone. Tabulae widely spaced.

Description of coralla.—The greatest observed length and diameter are 155 mm (USNM 423319, incomplete at both ends; Pl. 6, fig. 10) and 23 mm (USNM 423377, incomplete calice), respectively. In early ontogenetic stages, the majority of coralla are slenderly ceratoid in form, with moderate or slight curvature. The cardinal side is not always convex (Pl. 6, fig. 1). The typical

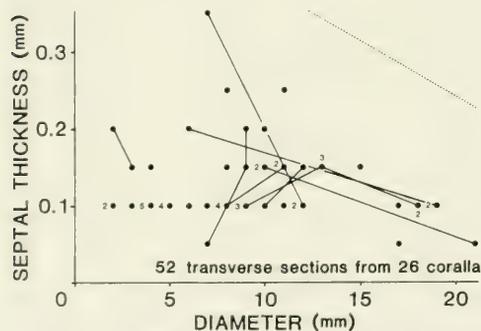


Text-figure 19.—Relationship between length of major septa and corallum diameter in *Streptelasma amsdeni*, n. sp. The length of a typical septum was measured and divided by the corallum radius, yielding a ratio less than or equal to 1.0. Lines join data points from individual specimens. Numbers beside data points indicate frequencies greater than one. Arbitrary line [dotted, in same position as that for *Streptelasma subregulare* (Savage, 1913b) in Text-fig. 14] was used to derive proportions shown in part of Table 5.

adult form is long and cylindrical, but some remain slenderly ceratoid (Table 4). Specimens are generally relatively straight, but have slight to moderate bends as well as several constrictions and rejuvenations (Pl. 6, fig. 10). A few have right-angle bends. Periodicity of growth has been observed only in the straight portion of one individual, where six successive constrictions are spaced 6 to 7 mm apart (average, 6.8 mm; Pl. 6, fig. 11). Septal grooves and interseptal ridges, as well as growth lines, are preserved on all specimens. Attachment structures are not present. Depth of the calice is estimated to be about 20 percent of the corallum length in small individuals, and is probably less than 10 percent in adults.

Ontogeny and internal structures.—The relationship between number of septa and corallum diameter is shown in Text-figure 18. In early ontogenetic stages (Pl. 5, figs. 17–20, Pl. 6, fig. 5), major septa extend to or almost to the axis, where they meet. The septa withdraw from the axis, leaving an open axial region, during intermediate stages (Pl. 5, figs. 14–16, 21, Pl. 6, figs. 6, 7). They shorten to half the corallum radius or less in late stages (Pl. 5, fig. 22, Pl. 6, fig. 8; Text-fig. 19). Major septa are generally straight to slightly curved in early stages, and become wavy by late stages in many individuals. They are thin throughout ontogeny (Text-fig. 20; Pl. 6, fig. 9), but in some cases are slightly dilated in early stages.

Compared with other major septa, the cardinal septum is the same length or longer, and almost always the same thickness, during all stages (Table 6). The



Text-figure 20.—Relationship between thickness of major septa and corallum diameter in *Streptelasma amsdeni*, n. sp. Septal thickness was measured in transverse thin sections halfway between the axial and peripheral ends of a typical septum on the counter side (usually the counter septum). Changes in septal thickness within individual specimens are shown by lines joining data points. Numbers beside data points indicate frequencies greater than one. Arbitrary line [dotted, in same position as that for *Streptelasma subregulare* (Savage, 1913b) in Text-fig. 15] was used to derive proportions shown in part of Table 5.

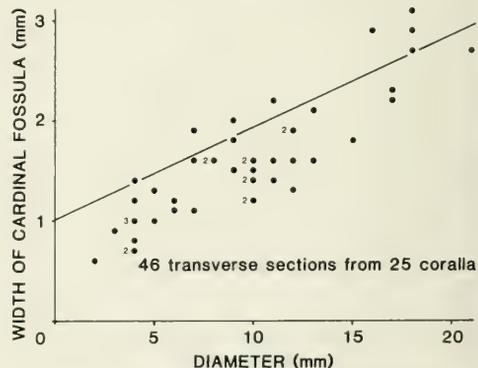
cardinal fossula is about the same width as other pairs of interseptal chambers in most specimens, but is somewhat wider in intermediate and late stages of a few (Text-fig. 21). Shapes of the fossula are as described for *Streptelasma subregulare* (Savage, 1913b) (Table 7). Minor septa generally project a short distance beyond the very narrow stereozone.

Throughout ontogeny, tabulae are usually complete, very thin, and relatively widely spaced (Pl. 5, fig. 13, Pl. 6, figs. 2–4; Text-fig. 17). They are most commonly convex upward in the septal region, but some are flat. In the axial region, they are flat to concave upward.

Microstructure.—The microstructure in transverse and longitudinal thin sections is the same as described for specimens of *Streptelasma subregulare* (Savage, 1913b) having nondilated to slightly dilated septa.

Discussion.—There is relatively little variation among the 71 coralla described above. Morphologic characteristics generally lie within the range of variability in *Streptelasma subregulare* (Savage, 1913b), but are not typical of that species (Table 3). The most striking features are the long, cylindrical growth form and thin septa. We consider these coralla to represent a distinct taxon, *Streptelasma amsdeni*, n. sp., because of these consistent differences. In previous paleobiologic studies, this species was referred to as *Streptelasma* sp. (Elias, 1984a, tables 1, 3–5; Elias, 1984b, pp. 535, 536).

Streptelasma amsdeni, n. sp., resembles *Streptelasma primum* (Wedekind, 1927), *Streptelasma* cf. *primum* (Wedekind, 1927) of Neuman, 1986, and *Streptelasma unicum* Neuman, 1975, which were discussed



Text-figure 21.—Relationship between width of cardinal fossula and corallum diameter in *Streptelasma amsdeni*, n. sp. Width of cardinal fossula was measured between median lines of septa immediately adjacent to the fossula, midway between axial and peripheral ends of septa bounding the fossula. Numbers beside data points indicate frequencies greater than one. Arbitrary line [in same position as that for *Streptelasma subregulare* (Savage, 1913b) in Text-fig. 16] was used to derive proportions shown in part of Table 5.

under *Streptelasma subregularare* (Savage, 1913b). However, the new species is distinct in having more widely spaced tabulae. The cardinal septum does not become short, as in *S. unicum*.

The following illustrated specimens from the Guanyinqiao Beds (*Dalmanitina* Beds) (Ashgill; Hirnantian) in the northern Guizhou Province of China have a septal arrangement, tabulae, and thin stereozone that resemble *Streptelasma amsdeni*, n. sp., but the septa are thicker than in the latter species:

Brachyelasma? simplotabulatum He, 1978, pl. 2, figs. 5a, b, 6.
Paramplexoides cylindricus He, 1978, pl. 9, figs. 1a–g, 5, 6, pl. 10, figs. 1a–c, 2a, b, 3a, b, 4a–c, 5, 6.

Paramplexoides attenuatum He, 1978, pl. 9, figs. 7a–c, 8a, 9.

***Streptelasma leemonense* Elias, 1982a**

Plate 7, figures 1–14; Plate 8, figures 1–4;

Plate 9, figures 1, 2

Streptelasma leemonense Elias, 1982a, p. 56, pl. 4, figs. 1–3.

Holotype.—UCGM 45614 (Elias, 1982a, pl. 4, figs. 1, 2), same interval as 20-3, 20-4, 20-5, E1 coll., Leemon Formation, Section 20 (Short Farm), Cape Girardeau County, Missouri.

Paratype.—UCGM 45615 (Elias, 1982a, pl. 4, fig. 3), same interval as 20-3, 20-4, 20-5, E1 coll., Leemon Formation, Section 20 (Short Farm), Cape Girardeau County, Missouri.

Additional material.—USNM 423378, 423379, interval 23-2 (*Brevilamnulella* beds), EMM coll., USNM 423380, interval 23-2a, EM coll., USNM 423381–423389, interval 23-3, EMM coll., USNM 423390, 423391, interval 23-3, EM coll., USNM 423392, 423393, interval 23a-1, EM coll., Keel Formation, Section 23 (Lawrence Quarry), Pontotoc County, Oklahoma; USNM 423394, interval 33-1, C coll., Cason shale, Section 33 (Buffalo River), Searcy County, Arkansas; USNM 423395, interval 31-1, EMZ coll., USNM 423396, interval 31-1b, EMZ coll., Leemon Formation, Section 31 (Thebes North), Alexander County, Illinois; UI C-1448a, S coll., Leemon Formation [labelled “Edgewood”], Gale Section, Alexander County, Illinois; USNM 423397, 423398, interval 20-1, EMM coll., USNM 423399, 423400, interval 20-1, EM coll., USNM 423401, interval 20-3, EM coll., USNM 423402, interval 20-4, EM coll., Leemon Formation, Section 20 (Short Farm), Cape Girardeau County, Missouri; USNM 423403, 423404, interval 15-1, EM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 15 (Calumet), Pike County, Missouri; USNM 423405–423407, interval 14-1, EM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 14 (Higginbotham Farm), Pike County, Missouri.

Occurrences.—Uppermost Ordovician (Gamach-

ian): Keel Formation, south-central Oklahoma; Cason shale, western north-central Arkansas; Leemon Formation, southern Illinois and southeastern Missouri. Lowermost Silurian (?) (lower Lower Llandovery (?)): Kissenger Limestone Member, Bryant Knob Formation, northeastern Missouri.

Diagnosis.—Solitary or with peripheral offsets, generally ceratoid. Major septa typically thin, extend to or almost to axis throughout ontogeny. Cardinal septum indistinct to relatively long, cardinal fossula usually inconspicuous. Minor septa at least half the length of major septa, commonly contracted to contraingent, extend beyond narrow to very broad stereozone. Tabulae moderately to closely spaced.

Description of coralla.—The greatest observed length and diameter are 55 mm (USNM 423387, incomplete at both ends) and 20 mm (USNM 423401, at base of calice), respectively. Of 12 individuals, six are ceratoid, three are trochoid, and three are cylindrical (Pl. 7, fig. 1). Two are straight and ten are slightly to moderately curved; the cardinal side is not always convex (Pl. 7, fig. 1). Corallum shape in transverse section is generally circular, but is irregular in some cases (Pl. 8, fig. 4). The presence of septal grooves and interseptal ridges has been verified in transverse thin sections of specimens enclosed in matrix. The measured depth of the calice is approximately 10 percent of the corallum length, but calice rims in those individuals are poorly preserved and may be incomplete.

Clusters of up to about 20 individuals were collected at Sections 23, 20, and 15 (USNM 423391, 423401, 423403). Smaller clusters were also found, consisting of at least six coralla at Section 14 and five at Section 20 (USNM 423405, 423400). Enclosure in matrix or poor preservation makes it difficult to establish whether they represent true colonies or pseudocolonies. Evidence from one large cluster and several other coralla indicates that budding did occur (USNM 423378, 423382, 423401; Pl. 8, figs. 1–4). Definite peripheral offsets are located between the older and younger walls at constrictions, and are initially oriented approximately parallel to the protocorallite. Some diverge outward in later stages. Offsets are found on alar, counter, and cardinal quadrants of the parents with about equal frequency. One specimen has at least seven at the same height, and they are distributed over about 75 percent of the circumference (USNM 423382). Some offsets become quite large. In one cluster, several of the big individuals with numerous offsets began as buds themselves (Pl. 8, figs. 1–4).

Other specimens could represent budding or a gregarious, epizoic habit (Pl. 7, fig. 9). In two clusters, several relatively small coralla located on only one side of a larger individual are oriented approximately perpendicular to it (USNM 423400, 423403). They may

Llandovery of Sweden (Neuman, 1969, pp. 21–23, figs. 13, 14; Neuman, 1975, pp. 335, 336). All have relatively long minor septa, thin major septa that commonly meet in groups axially and in some cases form an axial whorl, a cardinal septum that is indistinct to long, and a typically inconspicuous cardinal fossula. However, tabulae are convex upward in *S. etnaense* and *S. eccentricum*, offsets are intracalicular in *S. etnaense* and *S. ostrogothicum* and lacking in *S. eccentricum*, septal lobes form a very small axial structure in *S. etnaense*, and in *S. eccentricum* the axis is displaced toward the counter side during late stages and the stereozone is very thin. The maximum length of minor septa in *S. leemonense* is greater than in the other three species.

***Streptelasma* species cf. *S. leemonense* Elias, 1982a**
Plate 9, figures 3–7

Material.—USNM 423408, interval 23-2a, EM coll., USNM 423409, interval 23-3, EM coll., USNM 423410, interval 23a-1, EM coll.

Occurrence.—Uppermost Ordovician (Gamachian): Keel Formation, Section 23 (Lawrence Quarry), Pontotoc County, south-central Oklahoma.

Description of coralla.—The greatest length and diameter are estimated to be 30 mm and 22 mm, respectively (USNM 423410, incomplete apex and calice rim). Growth form is slenderly ceratoid and slightly curved (USNM 423409), to questionably trochoid (USNM 423410). Septal grooves and interseptal ridges are present (USNM 423408).

Ontogeny and internal structures.—The relationship between number of septa and corallum diameter is shown in Text-figure 22. Major septa extend to or near the axis, where some meet in pairs or small groups, in early (Pl. 9, fig. 6) to intermediate ontogenetic stages (Pl. 9, fig. 4). All except the cardinal and counter septa withdraw from the axis during late stages (Pl. 9, figs. 5, 7). Major septa are straight to usually slightly curved. They are nondilated to slightly dilated during early to intermediate stages, and thin in late stages.

The cardinal and counter septa are longer than other major septa throughout ontogeny. They are joined to form a median lamella during early to intermediate stages, and become disconnected and gradually withdraw from the axis in late stages. Their axial ends are dilated. The cardinal fossula is inconspicuous. Minor septa are long, but their length is less than half the corallum radius. They are seldom contraclined or contraingent. Minor septa extend beyond the stereozone, which has a thickness that is about 10 to 30 percent of the corallum radius.

Tabulae are convex upward in the septal region, and flat to concave upward in the axial region (Pl. 9, fig. 3).

Microstructure.—The microstructure in transverse and longitudinal thin sections appears to be the same as described for *Streptelasma leemonense* Elias, 1982a.

Discussion.—The three specimens described above are distinguished by their cardinal and counter septa, which form a median lamella during early to intermediate stages and remain longer than other major septa in late stages. Other characteristics lie within the range of variability documented herein for *Streptelasma leemonense* Elias, 1982a, although the number of septa is comparatively high (Text-fig. 22) and the minor septa are relatively short. These three incomplete specimens were found together with *S. leemonense*, but it is uncertain whether they are atypical coralla of that species, or represent a closely related new species that is rare in the Keel Formation at Section 23 (Lawrence Quarry). We therefore identify them as *Streptelasma* sp. cf. *S. leemonense* Elias, 1982a.

***Streptelasma* species A**

Plate 9, figures 8, 9; Plate 10, figures 1–5

Material.—USNM 423411–423413, interval 15-0, EM coll.

Occurrence.—Uppermost Ordovician (Gamachian): Noix Limestone, Section 15 (Calumet), Pike County, northeastern Missouri.

Description of coralla.—All three individuals are epizoic, less than 3 mm in diameter, and probably less than 5 mm in length. They are located on what is apparently the upper side of a single, horizontally oriented bryozoan (Pl. 9, figs. 8, 9, Pl. 10, figs. 1–5). Two are spaced about 11 mm apart, and the third is situated approximately 20 mm from the others on what is likely the same colony. The coralla grew subparallel and then perpendicular to the surface of the bryozoan. They are probably attached by their cardinal sides. The apical part of the attached side is flattened and conforms to the shape of the host, whereas unattached portions are round in transverse section, with septal grooves and interseptal ridges. The bryozoan colony eventually grew around the sides of the epizoic coralla.

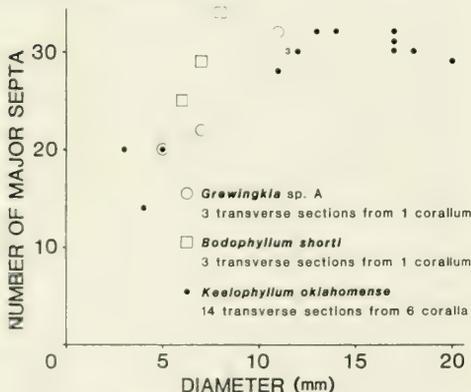
Ontogeny and internal structures.—Major septa numbering 12 to 17 are present at diameters of 2 to 3 mm. In early ontogenetic stages they can be as little as 50 percent of the corallum radius in length (Pl. 10, fig. 3), or extend to the axis (Pl. 10, fig. 1). During intermediate to late stages, they meet at the axis in one individual (Pl. 10, figs. 4, 5). In another, a few fine septal lobes at the axis occupy less than 10 percent of the corallum diameter (Pl. 9, figs. 8, 9). The third has several coarse septal lobes occupying almost 20 percent of the corallum diameter (Pl. 10, fig. 2). Major septa vary from relatively straight to wavy, and are thin throughout ontogeny.

In one specimen, what may be the cardinal septum is longer than other major septa (USNM 423412). The cardinal fossula is indistinct. Minor septa, where present, are very short. Thickness of the stereozone varies from less than 5 percent to about 8 percent of the corallum radius.

Tabulae appear to be present in the late stage of one individual (Pl. 10, fig. 5), but longitudinal sections could not be prepared for confirmation.

Microstructure.—The microstructure could not be distinguished in transverse thin sections of these small coralla having very thin septa and stereozones.

Discussion.—The epizoic habit and morphology of the three specimens described above are similar to *Streptelasma divaricans* (Nicholson, 1875). The latter, highly variable species is known from the Upham Dolomite Member of the Second Value Dolomite (middle Edenian to lowermost Maysvillian), Montoya Group, New Mexico and Texas (Elias, 1985, pp. 37, 38, 40, figs. 14.1–14.12), and the following Richmondian units: Dillsboro Formation, Whitewater Formation, and Rowland, Bardstown, Saluda Dolomite, and Preachersville members of the Drakes Formation, Cincinnati Arch region, Kentucky–Indiana–Ohio; Bay de Noc Member, Stonington Formation, Michigan; and Meaford and Kagawong beds, upper member, Georgian Bay Formation, Ontario (Elias, 1982a, pp. 53–56, pl. 1, figs. 1–41, pl. 2, figs. 1–16, pl. 3, figs. 1–23; Elias, 1983b, pp. 9, 10, pl. 2, figs. 16–33). Although coralla of *S. divaricans* are small (Elias, 1982a, fig. 14), the individuals from the Noix Limestone are even smaller. However, it is uncertain whether they are mature because only three are known, and all are probably attached to the same host.



Text-figure 23.—Relationship between number of major septa and corallum diameter in *Grewingkia* sp. A, *Bodophyllum shorti* Elias, 1982a, and *Keelophyllum oklahomense*, n. gen., n. sp. Number beside datum point indicates frequency greater than one.

Streptelasma (?) *parasiticum* Ulrich in Winchell and Schuchert, 1895, from the upper Middle Ordovician “Trenton limestone” (= Platteville Limestone; Blackriveran) and “Trenton shales” (= Decorah Shale; Rocklandian) of Minnesota, forms pseudocolonies or colonies attached to bryozoans (Winchell and Schuchert, 1895, pp. 89, 90, fig. 6; see Bassler, 1950, pp. 14, 15). The coralla are only several mm long, but internal structures are unknown.

We identify the specimens described herein as *Streptelasma* sp. A because of the uncertainties stated above.

Genus GREWINGKIA Dybowski, 1873

Grewingkia species A

Plate 10, figures 6–10

Material.—USNM 423414, interval 23-3, EM coll., Keel Formation, Section 23 (Lawrence Quarry), Pontotoc County, Oklahoma; USNM 423415, interval 14-2, EM coll., Kissenger Limestone Member, Bryant Knob Formation, Section 14 (Higginbotham Farm), Pike County, Missouri.

Occurrences.—Uppermost Ordovician (Gamachian); Keel Formation, south-central Oklahoma. Lowermost Silurian (?) (lower Lower Llandovery (?)); Kissenger Limestone Member, Bryant Knob Formation, northeastern Missouri.

Description of coralla.—The largest specimen is 25 mm long and 14 mm in diameter (USNM 423415, apex and calice incomplete). Its growth form is trochoid and curved. An attachment structure is located on what is almost certainly a cardinal-alar quadrant (Pl. 10, fig. 8).

Ontogeny and internal structures.—The relationship between number of septa and corallum diameter is shown in Text-figure 23. In early ontogenetic stages, a few septal lobes are present at the axis (Pl. 10, fig. 7). An axial structure of septal lobes and lamellae develops during intermediate stages (Pl. 10, figs. 8, 9). In late stages, major septa become relatively short, and the moderately complex axial structure comprising long, curved to contorted septal lobes and lamellae has a radius that is 40 to 50 percent of the corallum radius (Pl. 10, figs. 6, 10). The septa are straight to slightly curved and thin to moderately thick in all known stages.

The cardinal septum and fossula are inconspicuous. In late stages, the length of minor septa is 40 percent of the corallum radius. Minor septa extend beyond the stereozone, which has a thickness of 10 to 20 percent of the corallum radius.

Several tabulae are apparent in one transverse section (Pl. 10, fig. 6).

Microstructure.—The specimens are poorly preserved, but in transverse thin sections the septa appear to be fibrous.

Discussion.—Although the coralla described above are poorly preserved, they clearly differ from other streptelasmatids documented herein in having a large axial structure of septal lobes and lamellae. That structure is characteristic of *Grewingkia* Dybowski, 1873 (see Elias, 1981, pp. 11, 12; Elias, 1982a, pp. 65, 66).

The nature and arrangement of major septa and length of minor septa in these specimens are similar to those of the following species: *Grewingkia penobscotensis* Elias, 1982a, from Upper Ordovician (Ashgill) strata within an unnamed formation in Penobscot County, Maine (Elias, 1982a, pp. 72, 73, pl. 12, figs. 1-6), and within the Horseshoe Gulch unit in the eastern Klamath Mountains of California (Elias and Potter, 1984, pp. 1209, 1210, fig. 2h-l); *Grewingkia anguinea* (Scheffen, 1933) from Stage 5a (Ashgill) in Norway (Neuman, 1969, pp. 48-50, figs. 39-41); and *Grewingkia contexta* Neuman, 1969, from the Boda Limestone (Ashgill; Hirnantian) of Sweden (Neuman, 1969, pp. 43, 45-48, figs. 34-38). However, in late stages the axial structure is simpler with fewer lamellae in *G. penobscotensis*, septal lamellae are typically shorter in *G. anguinea*, and lamellae are more numerous and the axial structure is more complex in *G. contexta*. We refer to them as *Grewingkia* sp. A because of the limited amount of data available from the two coralla described above.

Genus **RHEGMAPHYLLUM** Wedekind, 1927

Rhegmaphyllum species

Plate 12, figures 7-11; Plate 13, figures 1-9

Material.—USNM 423422, 423423, EMZ coll., basal 0.3 m, Cason oölite, St. Clair Spring Section, Independence County, Arkansas; USNM 423424, interval 17-1a, EM coll., USNM 423425, interval 17-3, EM coll., limestone facies at base of Bowling Green Dolomite, Section 17 (Clarksville), Pike County, Missouri; USNM 423426, interval 17-2b, EM coll., limestone facies within Bowling Green Dolomite, Section 17 (Clarksville), Pike County, Missouri; USNM 423427, 423428, interval 5-2, EMZ coll., Elwood Formation, Section 5 (Schweizer North), Will County, Illinois; USNM 423429, interval 32-2a, EZ coll., Mosalem Formation, Section 32 (Thomson East), Carroll County, Illinois.

Occurrences.—Uppermost Ordovician (Gamachian): Cason oölite, eastern north-central Arkansas. Lower Silurian (upper Lower Llanoverly): Bowling Green Dolomite, northeastern Missouri; Elwood Formation, northeastern Illinois; upper Mosalem Formation, northwestern Illinois.

Description.—These small solitary coralla have a convex cardinal side. The major septa extend to or near the axis, where they meet in small groups. In some

cases, they form a slight counterclockwise whorl. Septal dilation is great to complete in early ontogenetic stages, and generally decreases in later stages. Septal carinae are apparent in a mold of the calice (Pl. 13, fig. 6). The cardinal septum becomes thin and short near the base of the calice (Pl. 12, fig. 9), and the fossula has parallel sides. The counter septum is long in some sections (Pl. 12, fig. 9, Pl. 13, fig. 7). The minor septa are short. Tabulae are present in most specimens.

Discussion.—The features described above are characteristic of *Rhegmaphyllum* Wedekind, 1927 (see Weyer, 1974, pp. 159-162; Neuman, 1977, p. 73; Laub, 1979, pp. 92-95). A lengthened counter septum has been reported in *R. daytonensis* (Foerste, 1890), from the Brassfield Formation (Llanoverly) of Ohio and Kentucky, by Laub (1979, p. 98). Of the two coralla from north-central Arkansas documented herein, one is attached to grains of sediment (Pl. 12, fig. 7) and the other is an attachment site for several smaller individuals that likely belong to the same species (Pl. 12, fig. 11). Attachment structures have not been reported previously in this genus (Laub, 1979, p. 93; see also Neuman, 1988, p. 101).

Because of the small number of specimens, the range of variability at each locality is unknown. Therefore, we are unable to determine the number of species represented in this collection, or to assign specimens to existing species. We refer to these coralla as *Rhegmaphyllum* sp.

Subfamily **DINOPHYLLINAE** Wang, 1947

Genus **DINOPHYLLUM** Lindström, 1882

Dinophyllum species

Plate 13, figures 10-16

Material.—USNM 423430, interval 17-3, EM coll., limestone facies at base of Bowling Green Dolomite, Section 17 (Clarksville), Pike County, Missouri; USNM 423431, interval 17-2, EMM coll., Bowling Green Dolomite, Section 17 (Clarksville), Pike County, Missouri; USNM 423432, interval 5-2, EMZ coll., Elwood Formation, Section 5 (Schweizer North), Will County, Illinois; USNM 423433, interval 32-2b, EZ coll., Mosalem Formation, Section 32 (Thomson East), Carroll County, Illinois.

Occurrences.—Lower Silurian (upper Lower Llanoverly): Bowling Green Dolomite, northeastern Missouri; Elwood Formation, northeastern Illinois; upper Mosalem Formation, northwestern Illinois.

Description.—These medium-sized solitary coralla have a convex cardinal side. The major septa are non-dilated in late ontogenetic stages, and form a generally conspicuous counterclockwise whorl near the axis. The cardinal fossula is distinct and moderately deep. The minor septa are short. Longitudinal sections of one

specimen reveal tabulae that are steeply convex upward (Pl. 13, figs. 10, 11).

Discussion.—The features described above are characteristic of *Dinophyllum* Lindström, 1882 (see Laub, 1979, pp. 63, 64). The number of specimens is small and the ontogeny of some is incompletely known. Therefore, we are unable to determine the number of species represented, or assign them to existing species. We refer to these coralla as *Dinophyllum* sp.

Subfamily DALMANOPHYLLINAE
Lecompte, 1952

Genus DALMANOPHYLLUM
Lang and Smith, 1939

Dalmanophyllum species
Plate 14, figures 1–8

Material.—UCGM 45639, E1 coll., basal 2 m of Sexton Creek Limestone, Section 20 (Short Farm), Cape Girardeau County, Missouri; USNM 423434, interval 17-1, EMM coll., limestone facies at base of Bowling Green Dolomite, Section 17 (Clarksville), Pike County, Missouri; USNM 423435, interval 17-2a, EM coll., Bowling Green Dolomite, Section 17 (Clarksville), Pike County, Missouri; USNM 423436, interval 6-1, EMM coll., Elwood Formation, Section 6 (Plaines West), Will County, Illinois; USNM 423437, interval 32-1c, EZ coll., Mosalem Formation, Section 32 (Thomson East), Carroll County, Illinois; USNM 423438, interval 10-2, EMM coll., Mosalem Formation, Section 10 (Lost Mound), Jo Daviess County, Illinois.

Occurrences.—Lower Silurian (Llandovery): Sexton Creek Formation, southeastern Missouri. Lower Silurian (upper Lower Llandovery): Bowling Green Dolomite, northeastern Missouri; upper Mosalem Formation, northwestern Illinois. Lower Silurian (upper Lower to Middle Llandovery): Elwood Formation, northeastern Illinois.

Description.—These small solitary coralla have a convex cardinal side. The major septa are long and relatively thick. The cardinal and counter septa are joined to a prominent median columella that is elliptical in transverse sections. A few septal lobes arise from major septa around the columella. The cardinal septum is much shorter than adjacent major septa a small distance above the base of the calice in one specimen (UCGM 45639). The minor septa are short. Tabulae are recognizable in several specimens.

Discussion.—The features described above are characteristic of *Dalmanophyllum* Lang and Smith, 1939 (see Neuman, 1977, p. 74; Laub, 1979, pp. 79–81). In this genus, the cardinal septum becomes short just below and within the calice. *Bodophyllum* Neuman, 1969, was proposed to include similar coralla having a long

cardinal septum throughout ontogeny (Neuman, 1969, pp. 54–56). However, it is not certain that recognition of two genera is warranted (McLean, 1974, p. 43; Neuman, 1977, p. 74). With the generally poorly preserved material examined herein, it is not possible to demonstrate that the cardinal septum becomes short below the calice. However, in one specimen it is short a small distance above the base of the calice. Because the number of individuals is small and their ontogeny is incompletely known, we are unable to determine that they are conspecific or assign them to existing species. We refer to these coralla as *Dalmanophyllum* sp.

Genus BODOPHYLLUM Neuman, 1969

Bodophyllum shorti Elias, 1982a

Bodophyllum shorti Elias, 1982a, pp. 77, 78, pl. 13, figs. 10–14.

Holotype.—UCGM 45613, same interval as 20-3, 20-4, 20-5, E1 coll.

Occurrence.—Uppermost Ordovician (Gamachian): Leeman Formation, Section 20 (Short Farm), Cape Girardeau County, southeastern Missouri.

Diagnosis.—

Bodophyllum with solid axial structure in early stage and a prominent dilated median septal lamella in intermediate stage. In late stage a few septal lobes and lamellae are present in axial structure, and median lamella is slightly dilated, irregular, and not connected to cardinal or counter septa. Minor septa long, extending well beyond stereozone (Elias, 1982a, p. 78).

Description of corallum.—

The coral is about 15 mm long and has a diameter of 8 mm a short distance below the calice where 34 major septa are present. It is straight. The base of attachment is on the cardinal side, and the specimen was attached to a bryozoan. Depth of the calice is about 40 percent of the coral length (Elias, 1982a, p. 78).

Ontogeny and internal structures.—

The axial structure is solid in early stages. In intermediate stages a prominent dilated median septal lamella is connected to the long cardinal and counter septa and a few dilated septal lobes and rare septal lamellae are present. In late stages the elements of the axial structure are slightly dilated. The median lamella is irregular and discontinuous, and is not connected to the cardinal or counter septa. A few other septal lamellae and septal lobes are present. The major septa are slightly dilated in early stages, and non-dilated in later stages. A cardinal fossula is not developed (Elias, 1982a, p. 78).

The cardinal septum is about the same length as adjacent major septa well up in the calice.

The minor septa are long, extending well beyond the narrow stereozone. Tabulae are present (Elias, 1982a, p. 78).

Microstructure.—In transverse thin sections, the major septa are fibrous in all ontogenetic stages, although fibers are difficult to discern because the septa are generally thin. The fibers appear to originate at the median

line within the septum, and extend outward in the direction of the corallum axis. In the stereozone, major and minor septa are expanded into lateral contact along a contorted suture.

Discussion.—Additional material was not found during the present study. This specimen was assigned to *Bodophyllum* Neuman, 1969, because it has a solid axial structure in early ontogenetic stages and a prominent dilated median septal lamella in intermediate stages (Elias, 1982a, p. 78). However, it was noted that, unlike *Bodophyllum shorti* Elias, 1982a, other species of the genus have a solid axial structure in late stages as well. It is possible that this corallum represents a genus in the Subfamily Streptelasmatinae Nicholson in Nicholson and Lydekker, 1889. The arrangement of septa and length of minor septa are similar to *Grewingkia* sp. A, but in *B. shorti* the number of septa is greater (Text-fig. 23), more tabulae are present in transverse sections, and the axial structure differs in being solid in early stages, including a median lamella in intermediate stages, and being comparatively small in late stages.

Suborder **CYATHOPHYLLINA** Nicholson in
Nicholson and Lydekker, 1889

Family **PTYCHOPHYLLIDAE** Dybowski, 1873

Genus **CYATHACTIS** Soshkina
in Ivanova *et al.*, 1955

Cyathactis? species

Plate 14, figures 9–14

Material.—USNM 423439, interval 23-4, EM coll., Cochrane Formation, Section 23 (Lawrence Quarry), Pontotoc County, Oklahoma; USNM 423440, interval 17-2, EMM coll., Bowling Green Dolomite, Section 17 (Clarksville), Pike County, Missouri; USNM 423441, interval 29-2, EMZ coll., Elwood Formation, Section 29 (Sears Pit), De Kalb County, Illinois; USNM 423442, interval 9-1, EMM coll., Mosalem Formation, Section 9 (Winston), Jo Daviess County, Illinois.

Occurrences.—Lower Silurian (Llandovery): Cochrane Formation, south-central Oklahoma. Lower Silurian (upper Lower Llandovery): Bowling Green Dolomite, northeastern Missouri; Elwood Formation, northeastern Illinois; upper Mosalem Formation, northwestern Illinois.

Description.—These moderately large solitary coralla have a convex cardinal side. The numerous major septa are long and thin in all known stages. A few septal lobes are present at the axis. The minor septa are long, and generally contraclined to contratrigent. Tabulae and a dissepimentarium are present.

Discussion.—The coralla described above differ from all others documented herein in having dissepiments.

That feature, and in particular the long, thin septa and weakly developed axial structure, are characteristic of *Cyathactis* Soshkina in Ivanova *et al.*, 1955 (see Laub, 1979, pp. 142, 143). However, the degree of septal dilation in early stages of these incomplete, poorly preserved specimens is unknown. It is possible that more than one species is represented in this small collection. Because of these uncertainties, we refer to the specimens as *Cyathactis?* sp.

Suborder **MONACANTHINA** Neuman, 1984
Family **LAMBELASMATIDAE** Weyer, 1973
Subfamily **COELOSTYLINAE** Weyer, 1973

Genus **KEELOPHYLLUM**, new genus

Derivation of name.—The generic name refers to the landowner after whom the Keel Formation was named by Maxwell (1936, p. 50).

Type and only species.—*Keelophyllum oklahomense*, n. sp.; Keel Formation (uppermost Ordovician; Garmachian), south-central Oklahoma.

Diagnosis.—Solitary, ceratoid to trochoid, cardinal side convex. Septa monacanthine, imperforate, radially arranged, taper axially, some with irregularly arranged small carinae. Minor septa very long. Axial structure of moderate size and complexity, with septal lobes and lamellae. Tabulae numerous.

Discussion.—We include *Keelophyllum*, n. gen., in the Suborder Monacanthina Neuman, 1984, because of its monacanthine microstructure. Placement within the Family Lambelasmataidae Weyer, 1973, is justified by the ceratoid to trochoid growth form, and lack of dissepiments (refer to Neuman, 1984, p. 125; Elias, 1986a, p. 15). This family was originally intended to include corals with porous septa (Weyer, 1973, p. 33). However, the presence of perforations requires verification in most of the included genera (see Hill, 1981, pp. 183–185). *Keelophyllum* may be related to the Neotryplasmataidae Elias, 1986a. Its septal arrangement, axial structure, and long minor septa are similar to *Neotryplasma* Kaljo, 1957, but it differs in having imperforate septa and lacking dissepiments. *Neotryplasma* is known from the upper Middle and Upper Ordovician of the Ural region, U.S.S.R., and the Upper Ordovician of the Estonian S.S.R. and Texas (Elias, 1986a, p. 16).

The subfamilies of Lambelasmataidae Weyer, 1973, were reviewed by Neuman (1984, p. 125). We place *Keelophyllum*, n. gen., within the Coelostylinae Weyer, 1973, because of its long, radially arranged septa, convex cardinal side, and tabulae. It most closely resembles *Rectigrewingkia* Kaljo, 1961, known from the Upper Ordovician of Baltoscandia (see Neuman, 1986, pp. 358–364). However, the axial structure in *Rectigrewingkia* is larger than in *Keelophyllum*. *Keelophyl-*

lum oklahomense, n. gen., n. sp., does not appear to have the "granular" axial structure seen in Swedish specimens of *Rectigrewingkia anthelion* (Dybowski, 1873), which is the type and only well-known species of that genus (Neuman, 1986, figs. 11a-l, 13c). However, monacanthids seem to be somewhat less conspicuous in a corallum from the type locality in the Estonian S.S.R. (Neuman, 1986, fig. 13e-g). The radial arrangement of axially tapering septa is more pronounced in *Keelophyllum* than in *Rectigrewingkia*. In transverse sections, some septa in *Keelophyllum* have small, irregularly arranged carinae, whereas septa in *Rectigrewingkia* have relatively smooth sides. Tabulae are numerous in *Keelophyllum*, but sparse or absent in *Rectigrewingkia* (Neuman, 1986, p. 361, fig. 13d).

Keelophyllum oklahomense, new species

Plate 11, figures 1-12; Plate 12, figures 1-6

Derivation of name.—The specific name refers to the state in which the specimens were found.

Holotype.—USNM 423416, interval 23-3, EM coll., Section 23 (Lawrence Quarry), Pontotoc County, Oklahoma.

Paratypes.—USNM 423417, interval 25-1, EMM coll., Section 25 (Hunton), Coal County, Oklahoma; USNM 423418, interval 23-3, EMM coll., USNM 423419, 423420, interval 23-3, EM coll., USNM 423421, interval 23a-1, EM coll., Section 23 (Lawrence Quarry), Pontotoc County, Oklahoma.

Occurrence.—Uppermost Ordovician (Gamachian): Keel Formation, south-central Oklahoma.

Diagnosis.—Septa thin to moderately thick, in lateral contact at periphery to form moderately thick stereozone. Cardinal septum and fossula inconspicuous. Minor septa more than two-thirds the length of major septa. Axial structure in late stages consists of septal lobes and numerous paliform to long and contorted septal lamellae in some cases thickened by sclerenchyme; occupies about one-third of corallum radius. Tabulae convex upward in septal region, generally with upturned peripheral edges; slightly concave to greatly convex upward in axial region.

Description of coralla.—The greatest observed length and diameter are 50 mm and 21 mm, respectively (USNM 423418, apex and calice incomplete). Coralla are generally trochoid (USNM 423416, 423420, two individuals in USNM 423421; Pl. 11, fig. 6) and curved (USNM 423418, 423421), but some are ceratoid (USNM 423417-423419; Pl. 12, fig. 1) and possibly straight (USNM 423417). Septal grooves, interseptal ridges, and rugae are preserved on most specimens. One corallum that is epizoic on a halysitid colonial corallum has two small individuals attached to itself (Pl. 12, figs. 4-6). They are possibly also epizoans; evidence to suggest an origin as offsets was not seen.

Attachment by the cardinal side is confirmed in the large corallum and in the uppermost epizoan. Another specimen has a sharp bend and possibly an attachment structure at the apex (Pl. 11, fig. 6). Depth of the calice could not be established accurately, but is likely less than 30 percent of the corallum length. A low calicular boss is formed by elements comprising the axial structure.

Ontogeny and internal structures.—The relationship between number of septa and corallum diameter is shown in Text-figure 23. Major septa extend to or almost to the axis, where they meet in groups that are commonly enclosed in sclerenchyme, in early ontogenetic stages (Pl. 11, fig. 10, Pl. 12, fig. 4) to early intermediate stages (Pl. 11, fig. 11, Pl. 12, fig. 5). The major septa withdraw from the axis and an axial structure develops during late intermediate stages (Pl. 11, fig. 1, Pl. 12, fig. 2) to late stages (Pl. 11, figs. 2, 12, Pl. 12, figs. 3, 6). The axial structure comprises septal lobes and numerous paliform to long and contorted septal lamellae in some cases thickened by sclerenchyme, and occupies about 30 percent of the corallum radius in late stages. Major septa are curved and somewhat irregularly oriented in early stages, but become straight and radially arranged in later stages. They are thin to moderately thick, and taper axially. Some have small, irregularly arranged carinae.

The cardinal septum is indistinct, but is slightly thicker than other major septa in one individual (USNM 423417). The cardinal fossula is inconspicuous. Minor septa are about two-thirds as long as major septa in early stages, and some are contraclined to contratingent. By late stages, they extend up to 95 percent of the length of major septa; very few are contraclined and none are contratingent. Minor septa extend beyond the stereozone, and taper axially. Thickness of the stereozone decreases during ontogeny, from 25 percent of the corallum radius in early stages to 15 percent in late stages.

The complete and incomplete tabulae are convex upward in the septal region, and commonly have upturned peripheral edges (Pl. 11, figs. 7-9, Pl. 12, fig. 1). In the axial region, they are slightly concave upward to greatly convex upward. The close spacing of tabulae within the cardinal fossula in one transverse section suggests that they are depressed within that structure (Pl. 11, fig. 1).

Microstructure.—In transverse thin sections (Pl. 11, fig. 3), adjacent septa are expanded into lateral contact along a contorted suture in the stereozone. The septal microstructure is clearly different from the fibrous type seen in associated specimens of *Streptelasma breguere* (Savage, 1913b) and *Streptelasma leemonense* Elias, 1982a, and appears to be trabeculate (compare Pl. 11, fig. 3, with *Neotryplasma floweri* Elias, 1986a

[Elias, 1986a, fig. 5.1]). Monacanthids can be recognized in some longitudinal thin sections, and are inclined from the periphery of the corallum toward the axis at an angle of about 40 degrees (Pl. 11, figs. 4, 5). The septa are imperforate, but the edges of some are acanthine (Pl. 12, fig. 1).

Discussion.—The six specimens described above differ from all others documented herein in having monacanthine microstructure, and we assign them to *Keelophyllum oklahomense*, n. gen., n. sp. The two specimens of *Grewingkia* sp. A differ in having a larger axial structure, shorter minor septa, and apparently fibrous microstructure.

The only previously described species having radially arranged wedge-shaped septa, very long minor septa, an axial structure of septal lobes and lamellae, and numerous tabulae that resemble *Keelophyllum oklahomense*, n. gen., n. sp., is *Grewingkia cuneata* McLean, 1977, based on a specimen from the Cape Schuchert Formation (lower Upper Llandovery) of northwestern Greenland (McLean, 1977, pp. 11, 12, pl. 1, figs. 8, 10, 12). *Grewingkia cuneata* differs in having more septa and developing an axial structure at smaller diameters. In the latest known stage, its axial structure consists of fine septal lamellae concentrated at the periphery and a few coarse lamellae at the axis. The microstructure of *G. cuneata* is not known, and its relationship to *K. oklahomense* is therefore uncertain.

APPENDIX

STRATIGRAPHIC SECTIONS

Introduction

The locations of stratigraphic sections are designated using United States Geological Survey topographic quadrangle maps (1:24,000 scale). Precise coordinates following the map name are measured first east and then north from the southwest corner of the map. Descriptions of the sections and lists of fossils are contained in the references cited under each entry.

Edgewood Province

The six outcrop areas (A–F) are outlined in Text-figure 1A. All the numbered sections (but not Gale Section) were examined during this study. Locations of sections, positions of collecting intervals, and stratigraphic and paleontologic data are shown in Text-figures 2–5, 7, and 8.

A. South-central Oklahoma

21 (*Rock Crossing*).—Overbrook, Oklahoma Quadrangle: 310 mm E, 348 mm N; SE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 35, T 5 S, R 1 E. Exposure on west bank of Hickory Creek, east side of road, 0.15 km south of bridge, Carter County, Oklahoma (Amsden, 1960, pp. 208–210, sec.

Ca11, panel 1; Barrick, 1986, fig. 39, sec. Ca11). Collecting intervals 21-1, 21-1a to 21-1c, each in a different lens of bioclastic limestone.

22 (*Cedar Village*).—Turner Falls, Oklahoma Quadrangle: 437 mm E, 326 mm N; SE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T 1 S, R 2 E. Cut on west side of U.S. Route 77, 0.5 km south of junction with Interstate Route 35, just north of Cedar Village, Murray County, Oklahoma (section enlarged and improved since description by Amsden, 1960, pp. 256–258, sec. M17, panel 1; Barrick, 1986, fig. 39, sec. M17; see also Amsden *in Ham*, 1973, fig. 35).

25 (*Hunton*).—Wapanucka North, Oklahoma Quadrangle: 14 mm E, 519 mm N; NE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T 1 S, R 8 E. Exposure 0.5 km south of northeast corner of section, Coal County, Oklahoma. Base of type section of Hunton Group (Amsden, 1960, pp. 182, 184–188, sec. C1, panel 2, pl. B).

24 (*Coal Creek*).—Harden City, Oklahoma Quadrangle: 253 mm E, 208 mm N; NW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T 1 N, R 7 E. Exposure on north bank of Coal Creek, 0.4 km east of Gobbler Knob, Pontotoc County, Oklahoma (Amsden, 1957, fig. 5; Amsden, 1960, pp. 279–282, sec. P9, panel 1; Amsden, 1961, fig. 25; Amsden, 1986, fig. 13; Barrick, 1986, fig. 39, sec. P9).

23 (*Lawrence Quarry*).—Ahloso, Oklahoma Quadrangle: 93 mm E, 302 mm N to 98 mm E, 296 mm N; NW $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T 3 N, R 5 E (northern site); and 92 mm E, 282 mm N; NW $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T 3 N, R 5 E (southern site). East side of Ideal Cement Company quarry at Lawrence, Pontotoc County, Oklahoma. Collecting intervals 23-1, 23-2, 23-2a, 23-3, 23-4 at northern site, 23a-1 at southern site. Type section of Keel Formation and Ideal Quarry Member (Amsden, 1960, pl. 1, figs. 1, 2, panel 2, pl. A; Amsden, 1974, p. 87, loc. P22; Amsden, 1986, figs. 5, 6, 15; Barrick, 1986, fig. 39, sec. AQL).

B. Western north-central Arkansas

33 (*Buffalo River*).—Marshall, Arkansas Quadrangle: 35 mm E, 512 mm N; NE $\frac{1}{4}$ SW $\frac{1}{4}$ and NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T 16 N, R 17 W. Exposure on north bank of Buffalo River, 0.5 km east of bridge on U.S. Route 65, Searcy County, Arkansas (Lemastus, 1979, pp. 86–88, pl. 1; Craig, 1984, p. 11, fig. 2).

C. Southern Illinois and southeastern Missouri

31 (*Thebes North*).—Thebes, Illinois–Missouri Quadrangle: 157 mm E, 506 mm N; SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T 15 S, R 3 W. Exposure on east bank of Mississippi River, 1.5 km southwest of Gale and 1.8 km north of Thebes, Alexander County, Illinois (Savage, 1910, pp. 331, 332, pl. 36, fig. a; Savage, 1913b, pp. 20, 21; Savage, 1917, pp. 77–79; Weller, 1940, pp. 8–10; Pryor and Ross, 1962, pp. 7–10, fig. 3; Satterfield, 1971, p. 266, fig. 1; Amsden, 1974, pp. 23, 24, 86, loc. M; Thompson and Satterfield, 1975, pp. 77, 78, sec. 1, fig. 8; Kolata and Guensburg, 1979, p. 1121, loc. 1, fig. 1; Amsden, 1986, pp. 29, 30, fig. 22). Collecting interval 31-1 *in situ* strata, 31-1a and 31-1b in loose blocks.

Gale Section.—Thebes, Illinois–Missouri Quadrangle: precise coordinates unknown; NE $\frac{1}{4}$ sec. 4, T 15 S, R 3 W. Abandoned quarry 0.4 km southeast of Gale, Alexander County, Illinois (Savage, 1910, pp. 332, 333, pl. 37, fig. a; Savage, 1913b, pp. 21, 22; Savage, 1917, p. 79) (for cut along State Route 3 in same vicinity, see Weller, 1940, pp. 8–10; Pryor and Ross, 1962, pp. 7–10, fig. 3; Cote, Reinertsen, and Killey, 1968, pp. 7–10, stop 1, figs. 6, 7; Amsden, 1974, pp. 23, 24, 86, loc. L; Amsden, 1986, p. 30).

20 (*Short Farm*).—Cape Girardeau NE, Missouri Quadrangle: 44 mm E, 276 mm N; SE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 21, T 32 N, R 13 E. Exposure along creek channel just east of barn, 0.25 km east of State Route W, Cape Girardeau County, Missouri. Collecting interval 20-1 *in situ* strata, 20-2 to 20-5 in loose blocks. Type section of Leemon Formation (Amsden, 1974, pp. 19, 85, 86, loc. K, fig. 16; Thompson

and Satterfield, 1975, sec. 3, fig. 7; Elias, 1982a, p. 39, fig. 21, loc. 20a; Amsden, 1986, pp. 31, 32, fig. 25).

19 (*New Wells*).—Neelys Landing, Missouri-Illinois Quadrangle: 24 mm E, 254 mm N; NW¼ SW¼ SW¼ sec. 9, T 33 N, R 13 E. Exposure along channel and east bank of Blue Shawnee Creek, 0.5 km east of New Wells, Cape Girardeau County, Missouri (Amsden, 1974, pp. 21, 22, 87, loc. U, fig. 17; Thompson and Satterfield, 1975, p. 79, sec. 4, fig. 9; Elias, 1982a, p. 39, fig. 21, loc. 20b; Amsden, 1986, pp. 32-34) (Note: coordinates of this section are incorrect in previous publications). Collecting interval 19-1 in northern part of exposure, 19-2 in southern part, 19-3 in loose blocks.

D. Northeastern Missouri

18 (*Kissenger*).—Annada, Missouri-Illinois Quadrangle: 15 mm E, 312 mm N; SW¼ sec. 35 (projected), T 53 N, R 1 E. Cut on west side of State Route 79, just west of Kissenger Hill and south of spring. Type section of Bryant Knob Formation and Kissenger Limestone Member (Amsden, 1974, pp. 84, 85, loc. F, fig. 4; Thompson and Satterfield, 1975, pp. 97-100, sec. 11, fig. 14; Amsden, 1986, figs. 32, 34, sec. F).

17 (*Clarksville*).—Clarksville, Missouri-Illinois and Pleasant Hill West, Illinois-Missouri quadrangles: 333 mm E, 564 mm N (Clarksville) to 313 mm E, 1 mm N (Pleasant Hill West); SW¼ sec. 9, T 53 N, R 1 E. Cut on west side of State Route 79, northern edge of Clarksville, Pike County, Missouri (Amsden, 1974, p. 84, loc. E, figs. 4-6; Thompson and Satterfield, 1975, pp. 99, 100, sec. 6, fig. 13; Elias, 1982a, p. 40, loc. 21a; McCracken and Barnes, 1982, fig. 2; Amsden, 1986, figs. 33, 34, sec. E). Collecting interval 17-0 at southern end of exposure, 17-2a from southern end to central portion, 17-1, 17-1a, 17-2 from central portion, 17-2b, 17-3 from northern end.

16 (*Clinton Spring*).—Louisiana, Missouri-Illinois Quadrangle: 312 mm E, 312 mm N; SW¼ NE¼ NW¼ sec. 20, T 54 N, R 1 W. Exposure just west of Clinton Spring on west side of State Route 79, southern edge of Louisiana, Pike County, Missouri. Type section of Noix Limestone (Laswell, 1957, pp. 18, 19, sec. 4; Koenig, Martin, and Collinson, 1961, p. 34, stop 8, figs. 21, 22; Birkhead, 1967, loc. I, fig. 4; Amsden, 1974, p. 83, loc. B, fig. 4; Thompson and Satterfield, 1975, p. 89, sec. 7, fig. 12; Elias, 1982a, p. 40, fig. 21, loc. 21b; Amsden, 1986, fig. 34, sec. B).

15 (*Calumet*).—Cyrene, Missouri Quadrangle: 415 mm E, 432 mm N, to 404 mm E, 434 mm N; S½ SE¼ sec. 21, T 53 N, R 1 W. Abandoned quarry east of Stark Cemetery, 0.5 km east of State Route D, Pike County, Missouri (Thompson and Satterfield, 1975, p. 93, sec. 5, figs. 15, 16). Collecting interval 15-0 in loose blocks, 15-1 in *in situ* strata.

14 (*Higginbotham Farm*).—Cyrene, Missouri Quadrangle: 391 mm E, 418 mm N, and 392 mm E, 424 mm N; W½ NW¼ NE¼ sec. 28, T 53 N, R 1 W. Exposures south (collecting interval 14-2) and north (collecting interval 14-1) of abandoned house, just east of State Route D, Pike County, Missouri (Laswell, 1957, p. 20, sec. 5; Amsden, 1974, p. 83, loc. A, fig. 4; Thompson and Satterfield, 1975, p. 93, fig. 16).

13 (*Bowling Green*).—Bowling Green, Missouri Quadrangle: 197 mm E, 497 mm N; NW¼ NW¼ sec. 24, T 53 N, R 3 W. Cut on north side of U.S. Route 54, 1.5 km northeast of junction with U.S. Route 61, Pike County, Missouri. Reference section of Cyrene Formation and Bowling Green Dolomite (Koenig, Martin, and Collinson, 1961, fig. 15; Amsden, 1974, p. 84, loc. D, figs. 4, 7; Thompson and Satterfield, 1975, pp. 96, 99, fig. 11, sec. 8; Elias, 1982a, fig. 21; Amsden, 1986, figs. 31, 34, sec. D).

E. Northeastern Illinois

7 (*Kankakee River*).—Bonfield, Illinois Quadrangle: 340 mm E,

401 mm N; NE¼ NW¼ SW¼ sec. 36, T 32 N, R 10 E. Exposure on north bank of Kankakee River, just southwest of Loop road in Kankakee River State Park campground, 0.3 km south of State Route 102 (Willman, 1962, pp. 82, 83, stop 2; Willman, 1973, p. 48, sec. 8).

4 (*Schweizer West*).—Channahon, Illinois Quadrangle: 302 mm E, 418 mm N; SW¼ SE¼ sec. 35, T 35 N, R 9 E. Cut on both sides of lower (western) railroad, southeast side of Des Plaines River valley, Will County, Illinois. Collecting intervals 4-1, 4-1a, 4-1c on west side of tracks. Type section of Wilhelmi Formation, and Schweizer and Birds (lower part) members (Ross, 1962, fig. 1; Willman, 1962, p. 84, stop 4; Willman, 1973, pp. 50, 51, sec. 17; Liebe and Rexroad, 1977, p. 854, loc. 8, fig. 1; Elias, 1982a, fig. 21, Will Co. sec.).

5 (*Schweizer North*).—Channahon, Illinois Quadrangle: 354 mm E, 449 mm N; SW¼ SW¼ NE¼ sec. 36, T 35 N, R 9 E. Cut on southeast side of lower (western) railroad, and ravine from there to southeast side of upper (eastern) railroad, at new concrete culvert, southeast side of Des Plaines River valley, Will County, Illinois. Type section of Birds Member (upper part) of Wilhelmi Formation, and Elwood Formation (Ross, 1962, fig. 1; Willman, 1973, p. 50, sec. 16; Liebe and Rexroad, 1977, p. 854, loc. 7, fig. 1; Elias, 1982a, fig. 21, Will Co. sec.).

6 (*Plaines West*).—Channahon, Illinois Quadrangle: 405 mm E, 491 mm N; NW¼ SE¼ SW¼ sec. 30, T 35 N, R 10 E. Cut on southeast side of lower (western) railroad, southeast side of Des Plaines River valley, Will County, Illinois. Type section of Drummond, Offerman, and Troutman (lower part) members, Kankakee Formation (Ross, 1962, fig. 1; Willman, 1973, pp. 49, 50, sec. 14; Liebe and Rexroad, 1977, p. 854, loc. 6, fig. 1; Elias, 1982a, fig. 21, Will Co. sec.).

29 (*Sears Pit*).—Sycamore, Illinois Quadrangle: 347 mm E, 336 mm N; SE¼ NW¼ and SW¼ NE¼ sec. 15, T 40 N, R 5 E. Northeast portion of quarry, southeast of intersection of Barber Greene Road and Airport Road, 4 km northeast of Cortland, De Kalb County, Illinois (Mikulic *et al.*, 1985, pp. 21-23, figs. 6, 7). Collecting interval 29-1 just below top of sump, 29-2, 29-3 in quarry wall along incline near pump.

3 (*Garden Prairie*).—Riley, Illinois Quadrangle: 179 mm E, 566 mm N; NE¼ SW¼ sec. 31, T 44 N, R 5 E. Abandoned quarry, 0.5 km south of U.S. Route 20, McHenry County, Illinois (Willman, 1973, pp. 12, 14).

34 (*Belvidere South*).—Belvidere South, Illinois Quadrangle: 63 mm E, 367 mm N; SE¼ SW¼ NW¼ sec. 14, T 43 N, R 3 E. Abandoned quarry 0.35 km east of Stone Quarry Road, 4 km south of Belvidere, Boone County, Illinois (vicinity of Savage, 1926, p. 518).

F. Northwestern Illinois and eastern Iowa

32 (*Thomson East*).—Thomson, Illinois Quadrangle: 270 mm E, 377 mm N; SE¼ NE¼ NW¼ sec. 28, T 23 N, R 4 E. Quarry on rise east of Johnson Creek, 4.5 km east of Thomson, Carroll County, Illinois. Collecting interval 32-0 in loose blocks, 32-1z, 32-1a to 32-1c, 32-2a, 32-2b in *in situ* strata.

30 (*Thomson Northeast*).—Thomson, Illinois Quadrangle: 207 mm E, 452 mm N; NW¼ NW¼ NE¼ sec. 20, T 23 N, R 4 E. Quarry at top of bluff west of Johnson Creek, 3 km northeast of Thomson, Carroll County, Illinois (vicinity of Savage, 1926, p. 527).

10 (*Lost Mound*).—Green Island, Iowa-Illinois Quadrangle: 288 mm E, 412 mm N; SW¼ NW¼ SW¼ sec. 28, T 26 N, R 2 E. East side of quarry in east bluff of Mississippi River valley, 1.3 km northwest of Lost Mound, Jo Daviess County, Illinois (Willman, 1973, pp. 52, 53, sec. 24).

26 (*Bellevue*).—Springbrook, Iowa-Illinois Quadrangle: 288 mm E, 559 mm N, to 262 mm E, 572 mm N; NE¼ sec. 19, T 86 N,

R 5 E. Exposure along west side of U.S. Route 52 and south side of road in Bellevue State Park, Jackson County, Iowa (Whitlow and Brown, 1963, p. 13; Ross, 1964, p. 1107, fig. 1; Rose, 1967, pp. 44, 45, stop 3, figs. 20, 21; Anderson, 1983, fig. 5.6).

9 (*Winston*).—Hanover, Illinois Quadrangle: 41 mm E, 461 mm N; SE $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 11, T 27 N, R 1 E. Quarry on east side of road, 1.8 km north of eastern end of Winston railroad tunnel, Jo Daviess County, Illinois (Willman, 1973, p. 55, sec. 34).

11 (*Schapyville*).—Elizabeth, Illinois Quadrangle: 92 mm E, 558 mm N; NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 1, T 27 N, R 2 E. Cut on east side of road, 3.2 km southwest of Schapyville, Jo Daviess County, Illinois (Willman, 1973, p. 54, sec. 30).

12 (*Stockton*).—Kent, Illinois Quadrangle: 148 mm E, 359 mm N; SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 17, T 27 N, R 5 E. Abandoned quarry at north edge of ridge, just south of road, 4 km southeast of Stockton, Jo Daviess County, Illinois (Willman, 1973, p. 54, sec. 32).

8 (*King*).—Menominee, Illinois-Iowa Quadrangle: 120 mm E, 105 mm N, to 113 mm E, 133 mm N; E $\frac{1}{2}$ SE $\frac{1}{4}$ sec. 27, T 88 N,

R 3 E. Cut on east side of U.S. Route 52, just south of King, Dubuque County, Iowa. Type section of Mosalem and Tete des Morts formations (Willman, 1973, p. 52, sec. 22).

Eastern north-central Arkansas

The location of the section examined during this study is shown in Text-figures 1A and 3. Stratigraphic and paleontologic data are shown in Text-figure 3.

St. Clair Spring Section.—Sulphur Rock, Arkansas Quadrangle: 209 mm E, 469 mm N; SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 18, T 14 N, R 5 W. Exposure 0.5 km northeast of St. Clair Spring, 0.4 km east of U.S. Route 167, Independence County, Arkansas (Craig, 1975b, pp. 75, 77, fig. 2; Lemastus, 1979, pp. 61–64, pl. 1; Craig, 1984, p. 10, fig. 2; Craig, Wise, and McFarland, 1984, p. 31, alternate stop A, fig. 7; Craig in Craig, Ethington, and Repetski, 1986, p. 40, stop 2, fig. 7; Amsden, 1986, pp. 20, 22, fig. 19; Barrick, 1986, p. 64, table 7).

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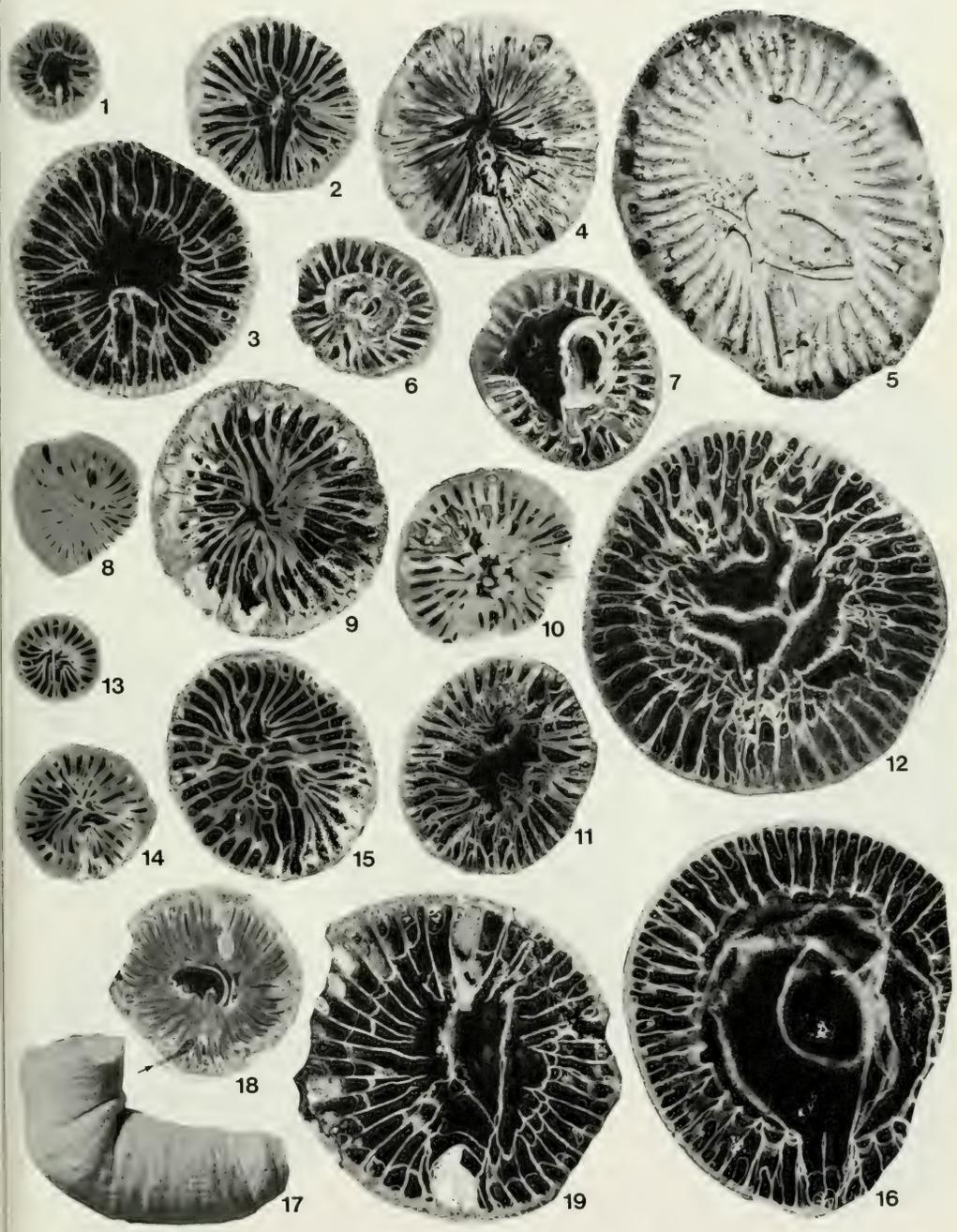
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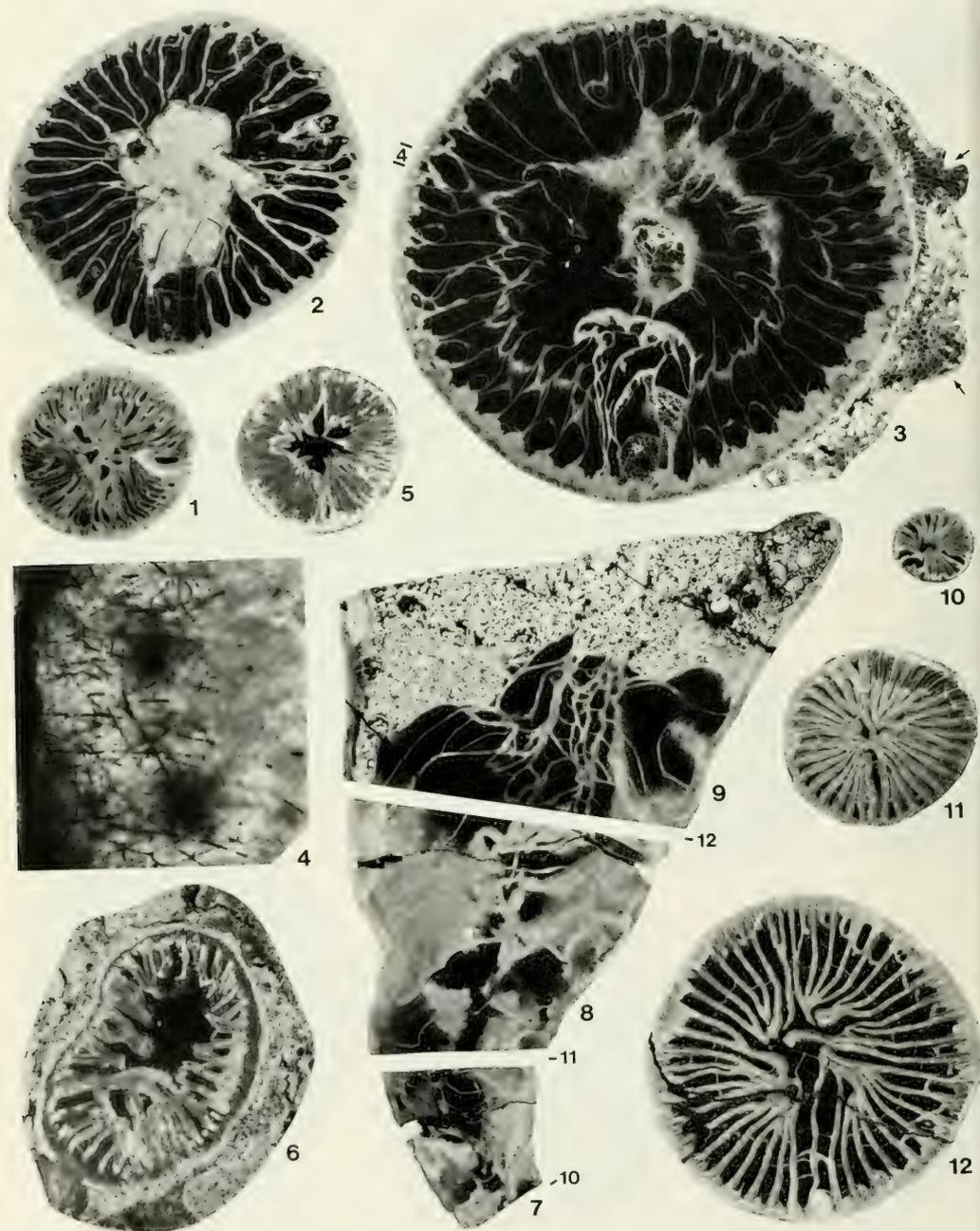
PLATES

Exterior views are of specimens coated with ammonium chloride. Transverse and longitudinal sections are negative prints prepared using thin sections as negatives in a photographic enlarger. Transverse and longitudinal photomicrographs of thin sections are positive prints. Transverse prints are oriented as they appear looking down from the calice toward the apex of the corallum, with the cardinal side facing the bottom of the page unless otherwise indicated. Longitudinal prints are oriented with the calical end facing the top of the page.

EXPLANATION OF PLATE I

Figure	Page
1-19. <i>Streptelasma subregulare</i> (Savage, 1913b).....	34
[1-3, Ideal Quarry Mbr., Keel Fm., Sec. 21 (Rock Crossing); 4, 5, Keel Fm., Sec. 25 (Hunton); 6-9, <i>Brevilamnulella</i> beds, Keel Fm., Sec. 23 (Lawrence Quarry); 10, Keel Fm., Sec. 23 (Lawrence Quarry); 11, 12, Leemon Fm., Sec. 31 (Thebes North); 13-16, Leemon Fm., Sec. 20 (Short Farm); 17-19, Leemon Fm., Sec. 19 (New Wells).]	
1. USNM 422832; transverse section, $\times 3$.	
2, 3. USNM 422833; transverse sections, $\times 3$.	
4, 5. USNM 422855; transverse sections, $\times 3$.	
6, 7. USNM 422885; transverse sections, $\times 3$.	
8, 9. USNM 422900; transverse sections, $\times 3$.	
10. USNM 422921; transverse section, $\times 3$.	
11, 12. USNM 422938; transverse sections, $\times 3$.	
13-15. USNM 422969; transverse sections, $\times 3$.	
16. USNM 422993; transverse section, $\times 3$.	
17. USNM 423054; exterior view, cardinal side unknown, $\times 3$.	
18, 19. USNM 423008; transverse sections, $\times 3$; arrow in figure 18 points to <i>Trypanites</i> sp. in matrix and corallum.	



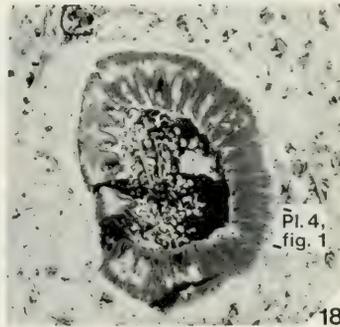
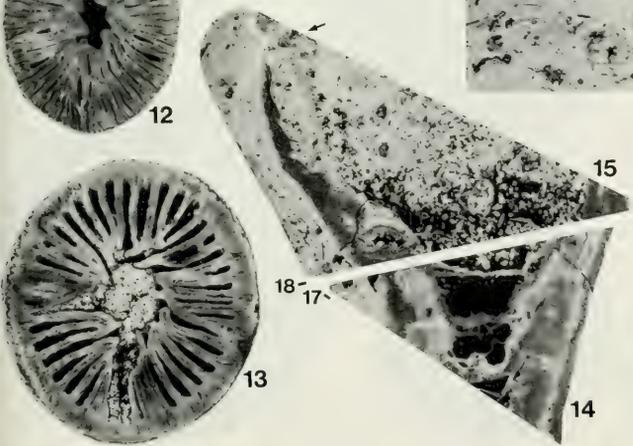
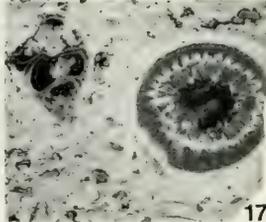
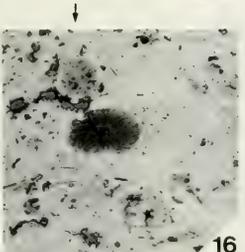
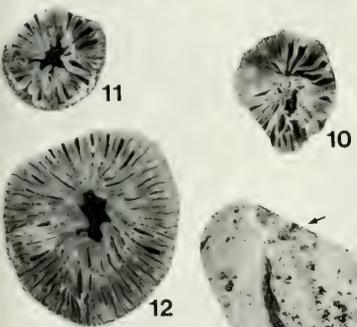
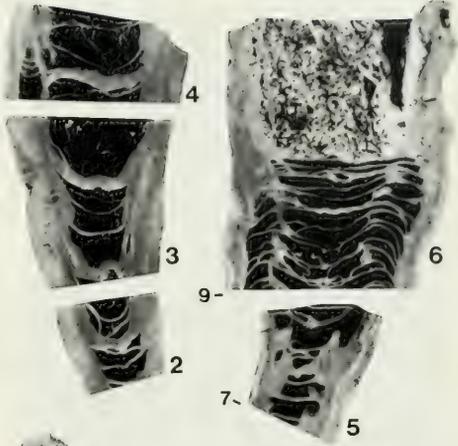
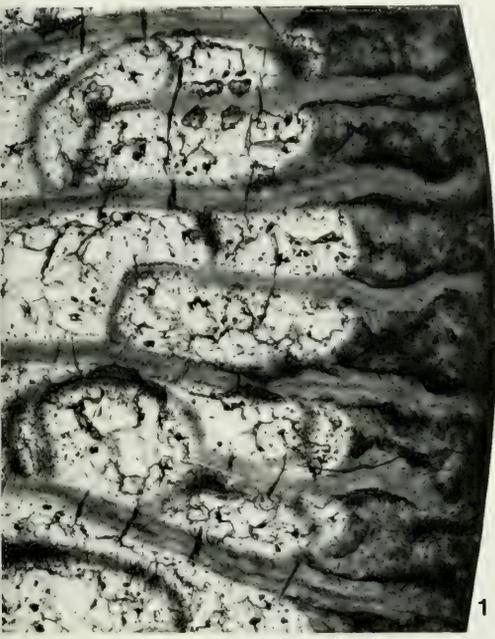


EXPLANATION OF PLATE 2

Figure	Page
1-12. <i>Streptelasma subregulare</i> (Savage, 1913b)	34
[1-4, Leemon Fm., Sec. 19 (New Wells); 5, unnamed mbr., Bryant Knob Fm., Sec. 18 (Kissenger); 6-12, Kissenger Lst. Mbr., Bryant Knob Fm., Sec. 18 (Kissenger).]	
1-4. USNM 423018; 1-3, transverse sections, $\times 3$; arrows in figure 3 point to epizoid bryozoans on corallum; 4, transverse photomicrograph showing microborings in outer wall of corallum, $\times 100$ (position of fig. 4 shown by small numeral at upper left of fig. 3).	
5. USNM 423105; transverse section, $\times 3$.	
6. USNM 423123; transverse section of corallum in matrix, showing algal coating around corallum, $\times 3$.	
7-12. USNM 423140; 7-9, longitudinal sections, cardinal side on left, $\times 3$; 10-12, transverse sections, $\times 3$ (positions of figs. 10-12 shown by small numerals beside figs. 7-9).	

EXPLANATION OF PLATE 3

Figure	Page
1-18. <i>Streptelasma subregularis</i> (Savage, 1913b)	34
[1, Kissenger Lst. Mbr., Bryant Knob Fm., Sec. 18 (Kissenger); 2-9, Kissenger Lst. Mbr., Bryant Knob Fm., Sec. 17 (Clarksville); 10, unnamed mbr., Bryant Knob Fm., Sec. 16 (Clinton Spring); 11-18, Kissenger Lst. Mbr., Bryant Knob Fm., Sec. 16 (Clinton Spring).]	
1. USNM 423141; transverse photomicrograph of wall and septa, $\times 20$ (counter side of corallum near left alar septum).	
2-4. USNM 423156; longitudinal sections, cardinal side on left, $\times 3$.	
5-9. USNM 423152; 5, 6, longitudinal sections, cardinal side on left, $\times 3$; 7-9, transverse sections, $\times 3$ (positions of figs. 7 and 9 shown by small numerals beside figs. 5 and 6).	
10. UCGM 45643; transverse section, $\times 3$.	
11-13. USNM 423216; transverse sections, $\times 3$.	
14-18. USNM 423192; 14, 15, longitudinal sections of corallum in matrix, showing algal coating on corallum wall and in calice (left side), cardinal side unknown, $\times 3$; arrow in figure 15 points to epizoic bryozoan on algal coating above calice rim; 16-18, transverse sections of corallum in matrix, showing algal coating around corallum, cardinal side unknown, $\times 3$; two arrows in figure 16 point to transverse section of <i>Dimorphosiphon</i> sp. (positions of figs. 17 and 18 shown by small numerals beside figs. 14 and 15).	



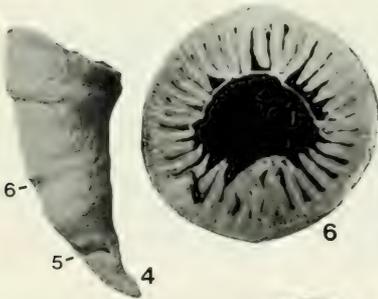
Pl. 4, fig. 1



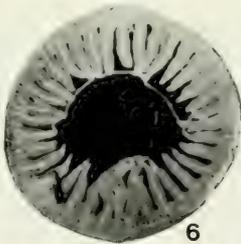
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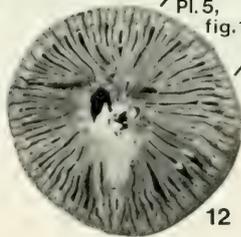


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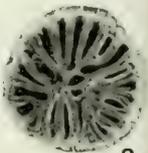
Pl. 5, fig. 1



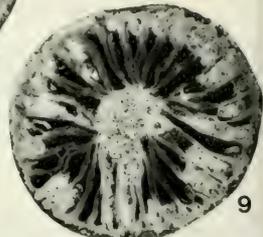
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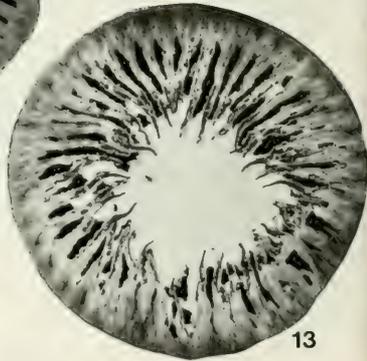
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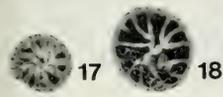
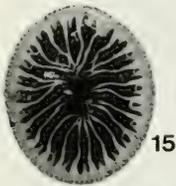
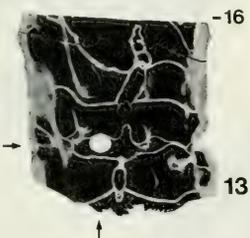
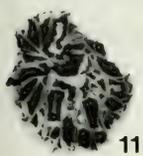
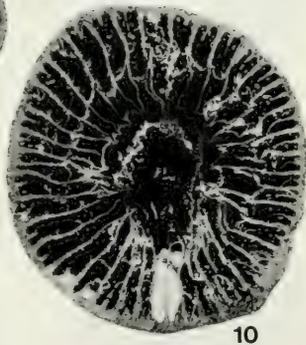
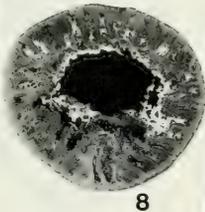
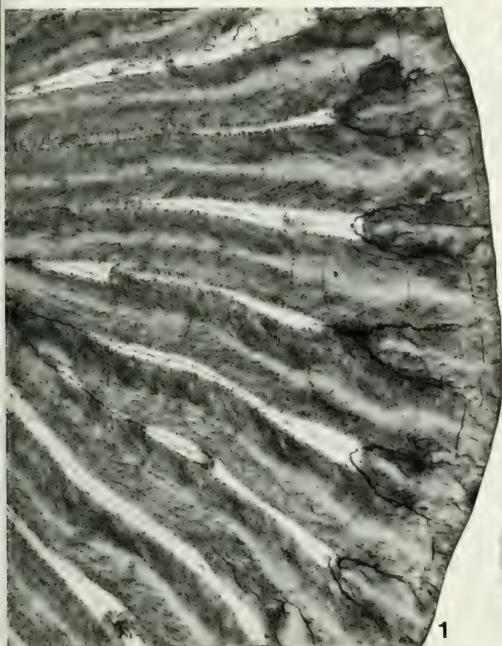
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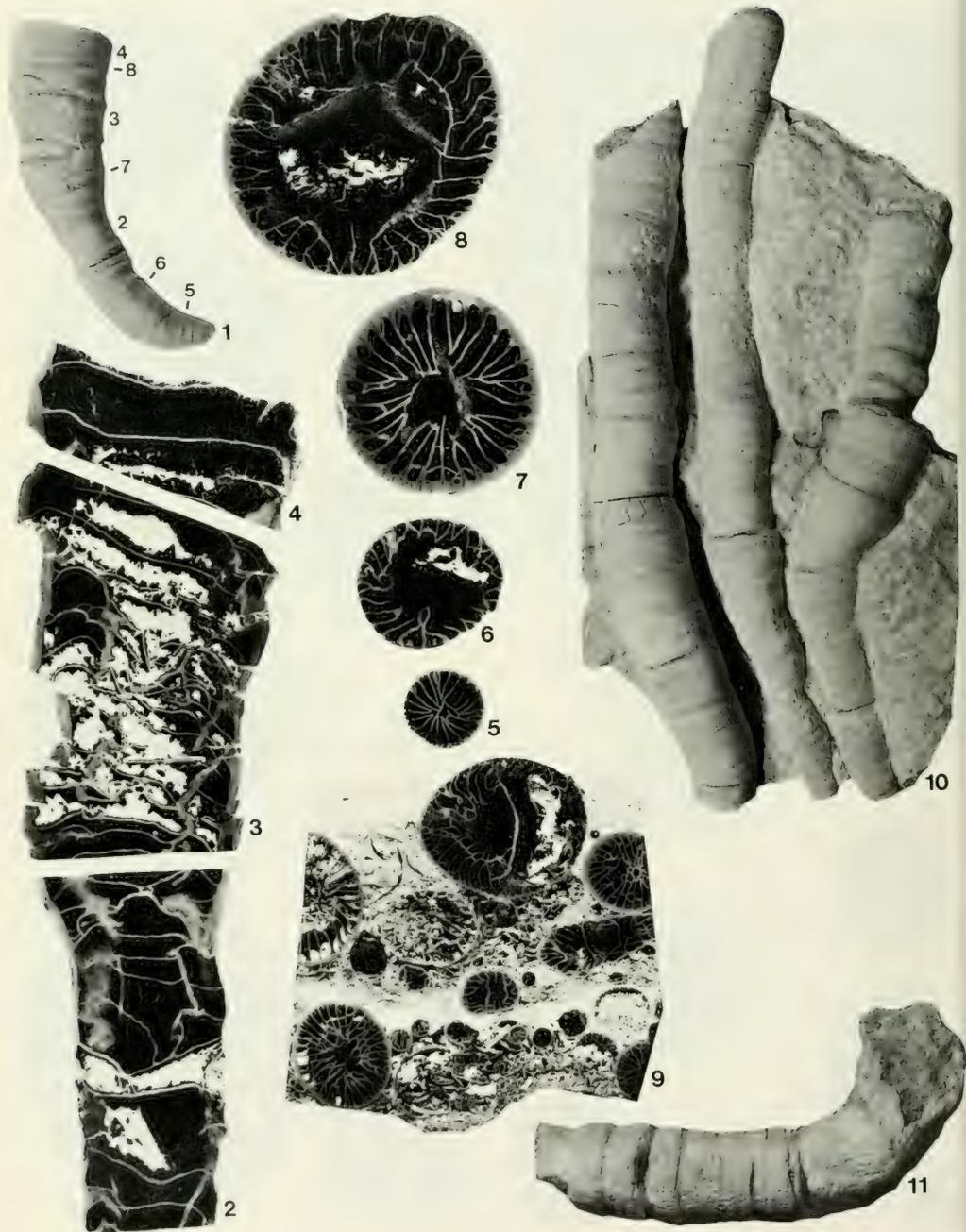
EXPLANATION OF PLATE 4

Figure	Page
1-13. <i>Streptelasma subregulare</i> (Savage, 1913b).....	34
[1, 2, Kissenger Lst. Mbr., Bryant Knob Fm., Sec. 16 (Clinton Spring); 3, Kissenger Lst. Mbr., Bryant Knob Fm., Sec. 15 (Calumet); 4-7, Kissenger Lst. Mbr., Bryant Knob Fm., Sec. 14 (Higginbotham Farm); 8, 9, Cyrene Fm., Sec. 13 (Bowling Green); 10-13, Wilhelmi Fm., southeast of Channahon.]	
1. USNM 423192; transverse photomicrograph showing microborings in corallum beneath micritized exterior and algal coating (at top) and micritized interior of calice (at bottom), $\times 32$ (position of section shown in Pl. 3, fig. 18).	
2. USNM 423198; transverse photomicrograph showing microborings in corallum beneath micritized exterior and algal coating (on right), $\times 32$.	
3. USNM 423246; transverse section, $\times 3$.	
4-6. USNM 423253; 4, exterior alar view, cardinal side on right, $\times 1$; 5, 6, transverse sections, $\times 3$ (positions of figs. 5 and 6 shown by small numerals beside fig. 4).	
7. USNM 423263; transverse section, $\times 3$.	
8, 9. USNM 423282; transverse sections, $\times 3$.	
10-13. UI C-1581a; 10, exterior cardinal view, $\times 1$; 11-13, transverse sections, $\times 3$ (positions of figs. 11-13 shown by small numerals beside fig. 10).	

EXPLANATION OF PLATE 5

Figure	Page
1-10. <i>Streptelasma subregulare</i> (Savage, 1913b)	34
[1, Wilhelmi Fm., southeast of Channahon; 2-5, Wilhelmi Fm., Channahon; 6, Schweizer Mbr., Wilhelmi Fm., Sec. 4 (Schweizer West); 7, 8, Birds Mbr., Wilhelmi Fm., Sec. 34 (Belvidere South); 9, 10, Mosalem Fm., Sec. 32 (Thomson East).]	
1. UI C-1581a; transverse photomicrograph of wall and septa, $\times 20$ (position of section shown in Pl. 4, fig. 12).	
2-5. UI C-1560a; 2, exterior cardinal view, $\times 1$; 3-5, transverse sections, $\times 3$ (positions of figs. 3-5 shown by small numerals beside fig. 2).	
6. USNM 423290; transverse section, $\times 3$.	
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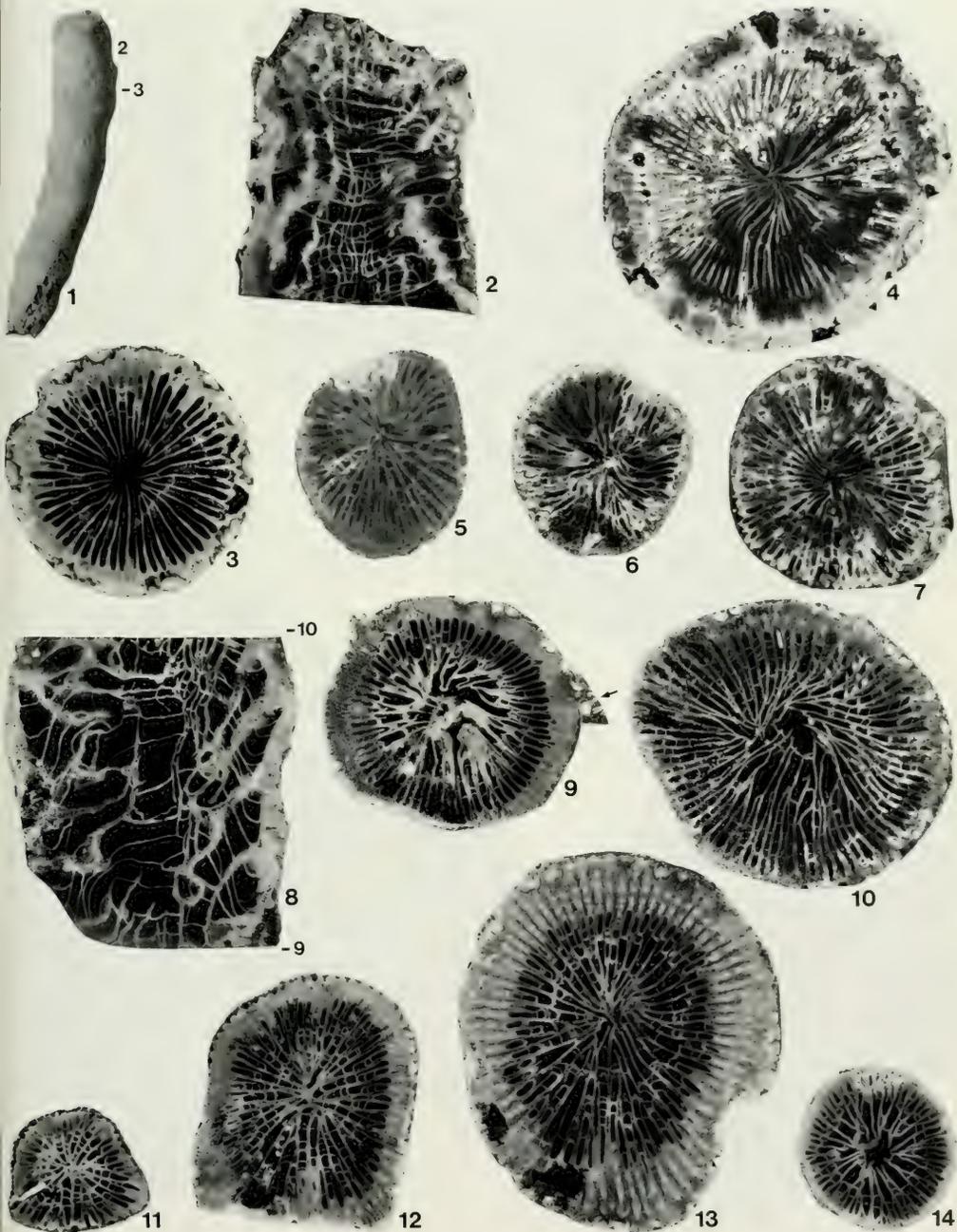


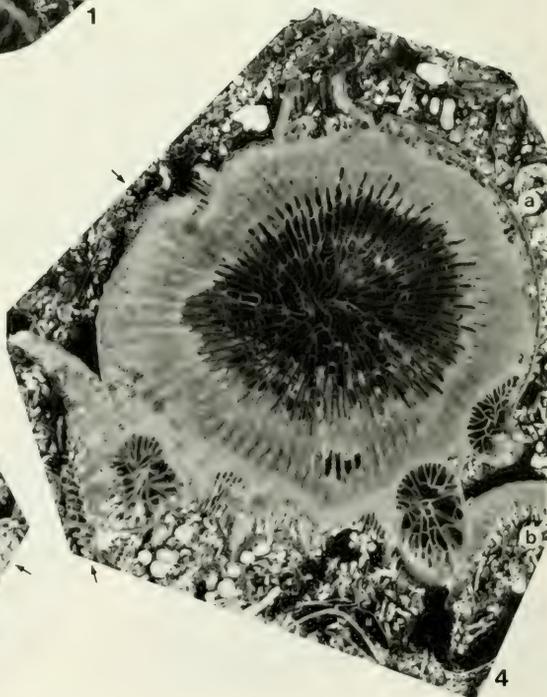
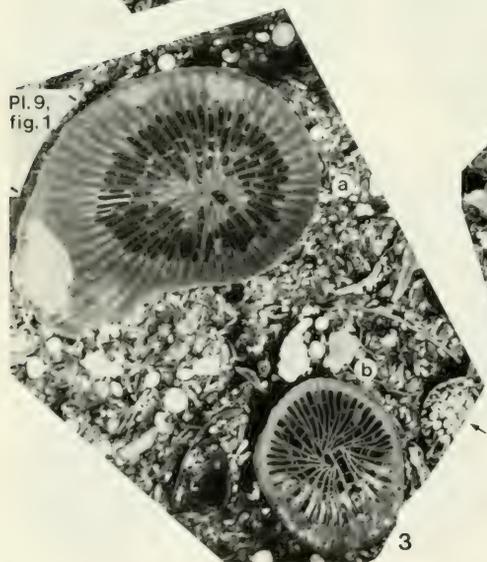
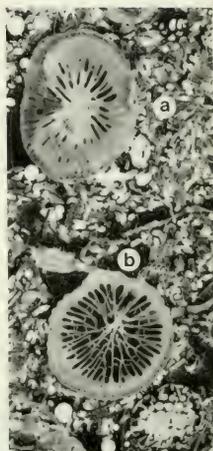
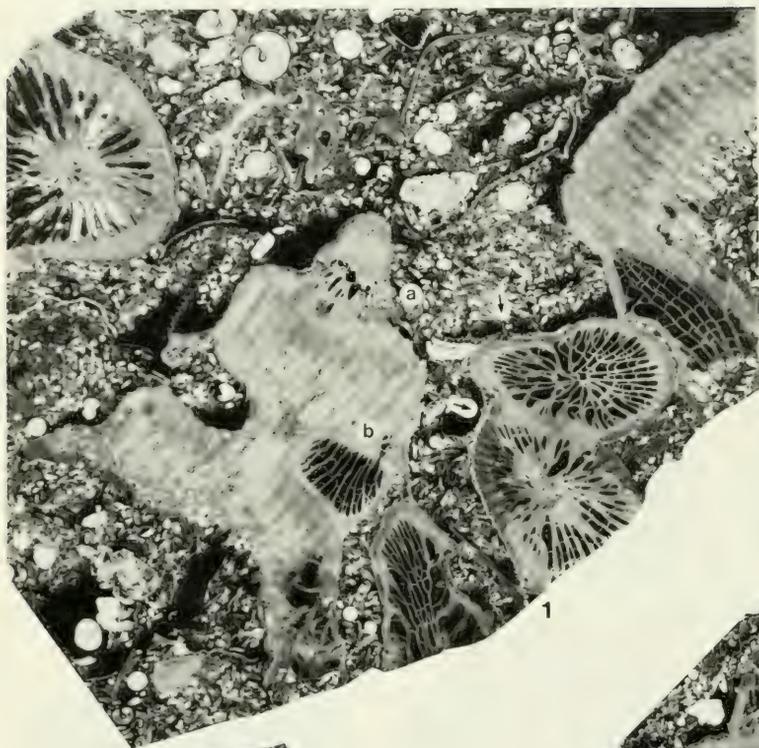
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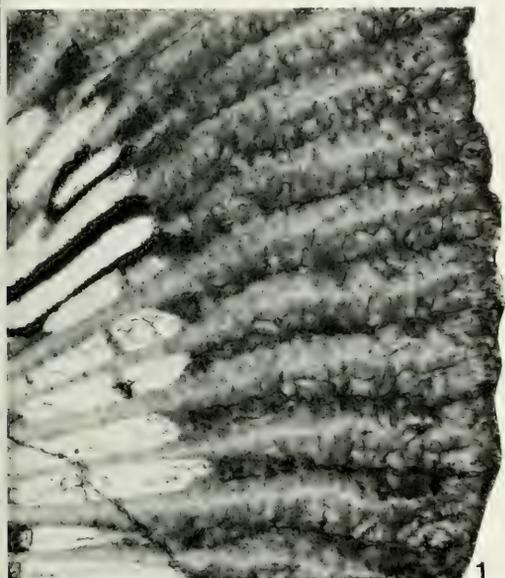


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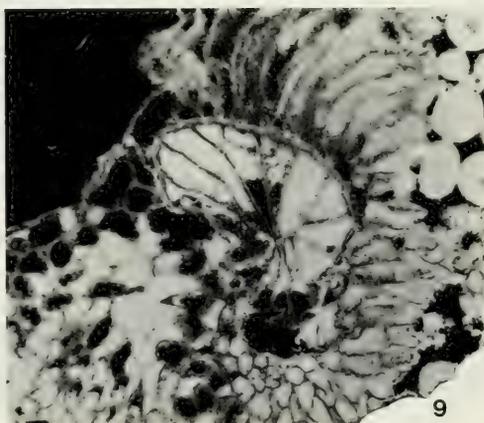
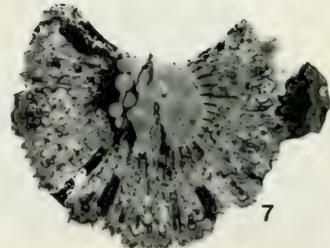
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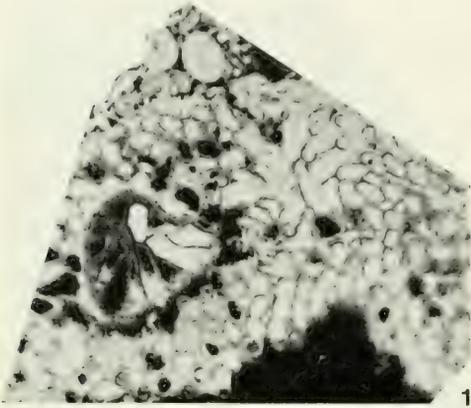
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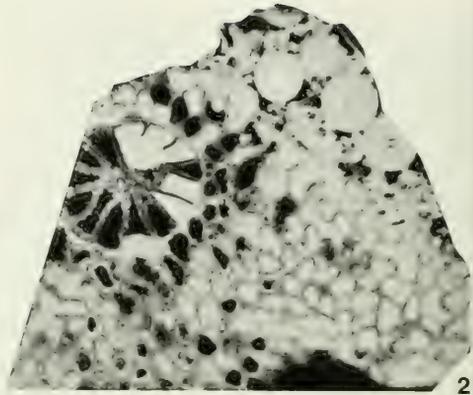


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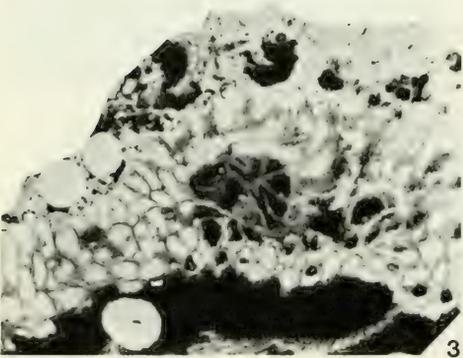




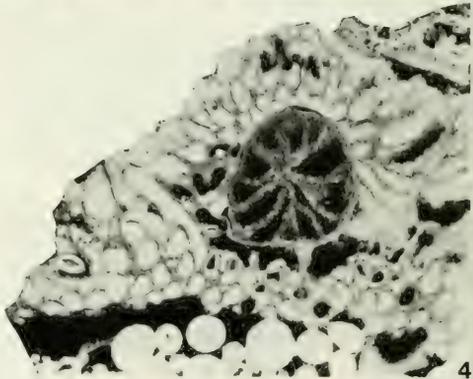
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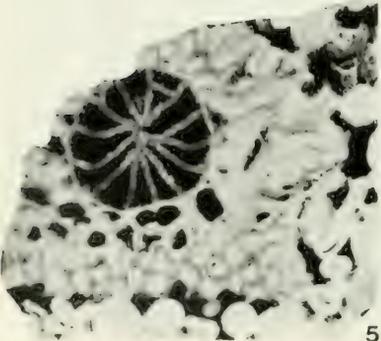
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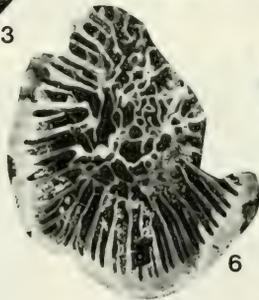
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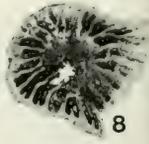
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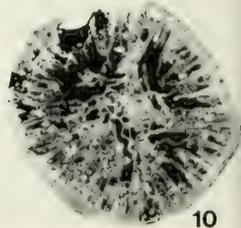
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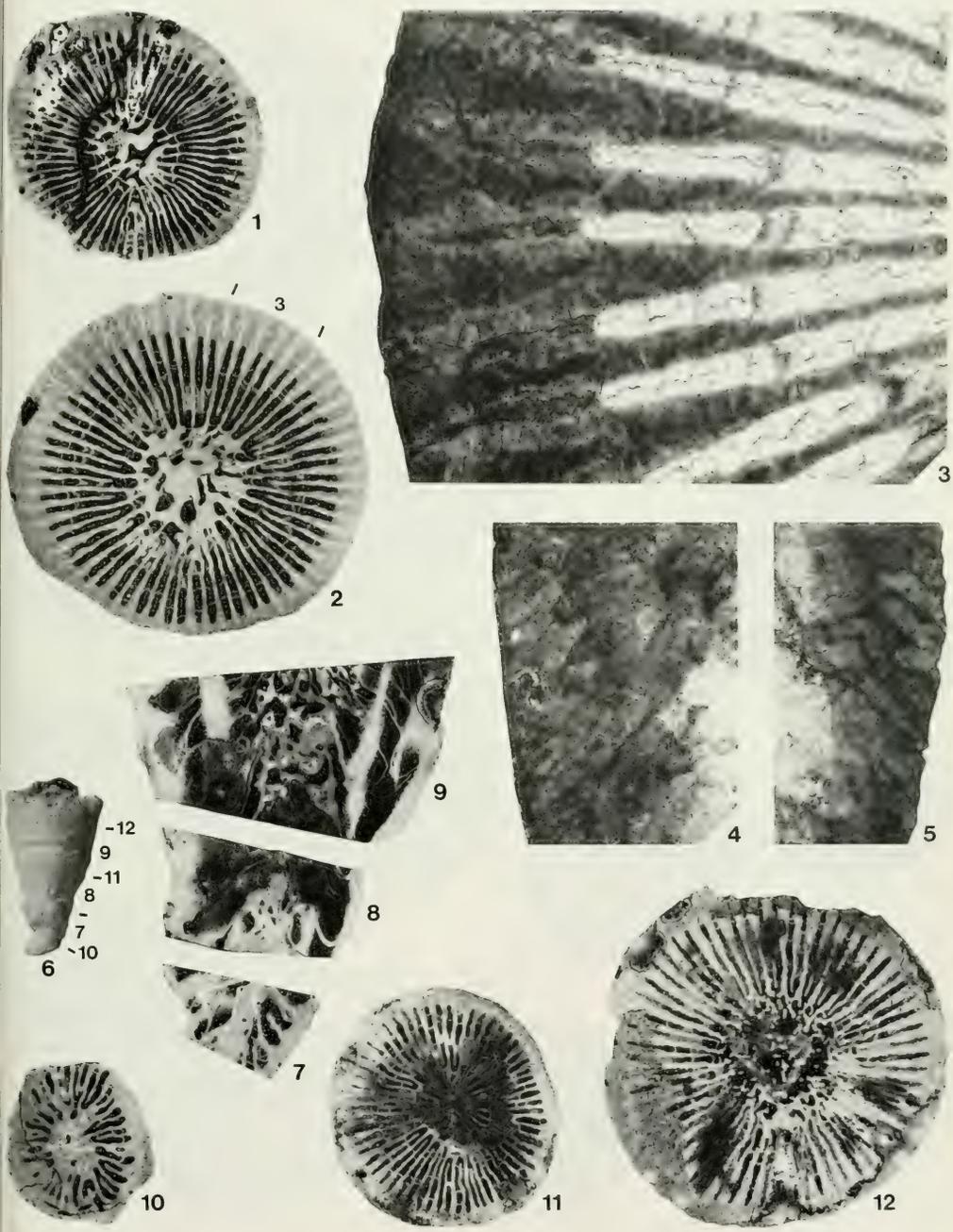
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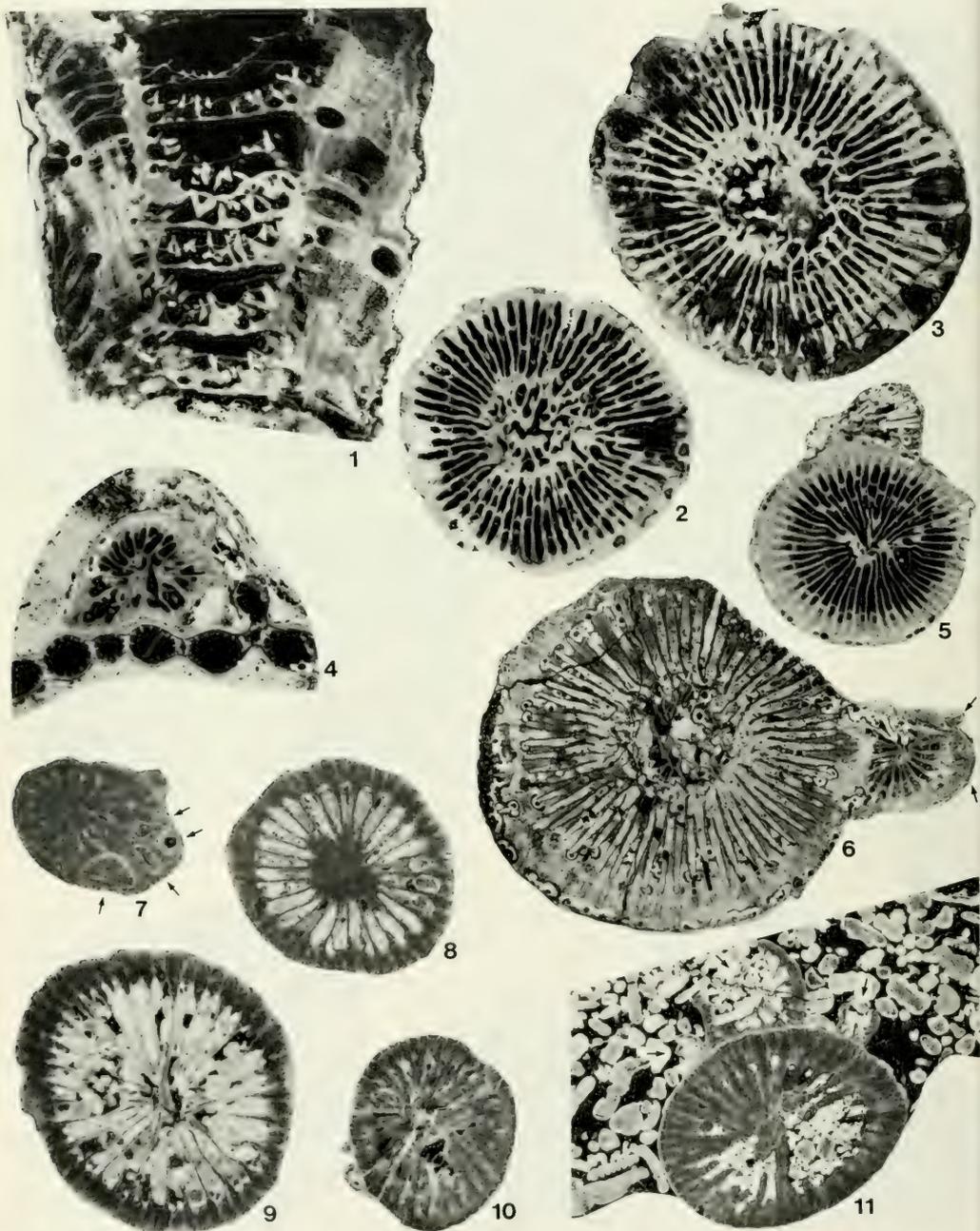
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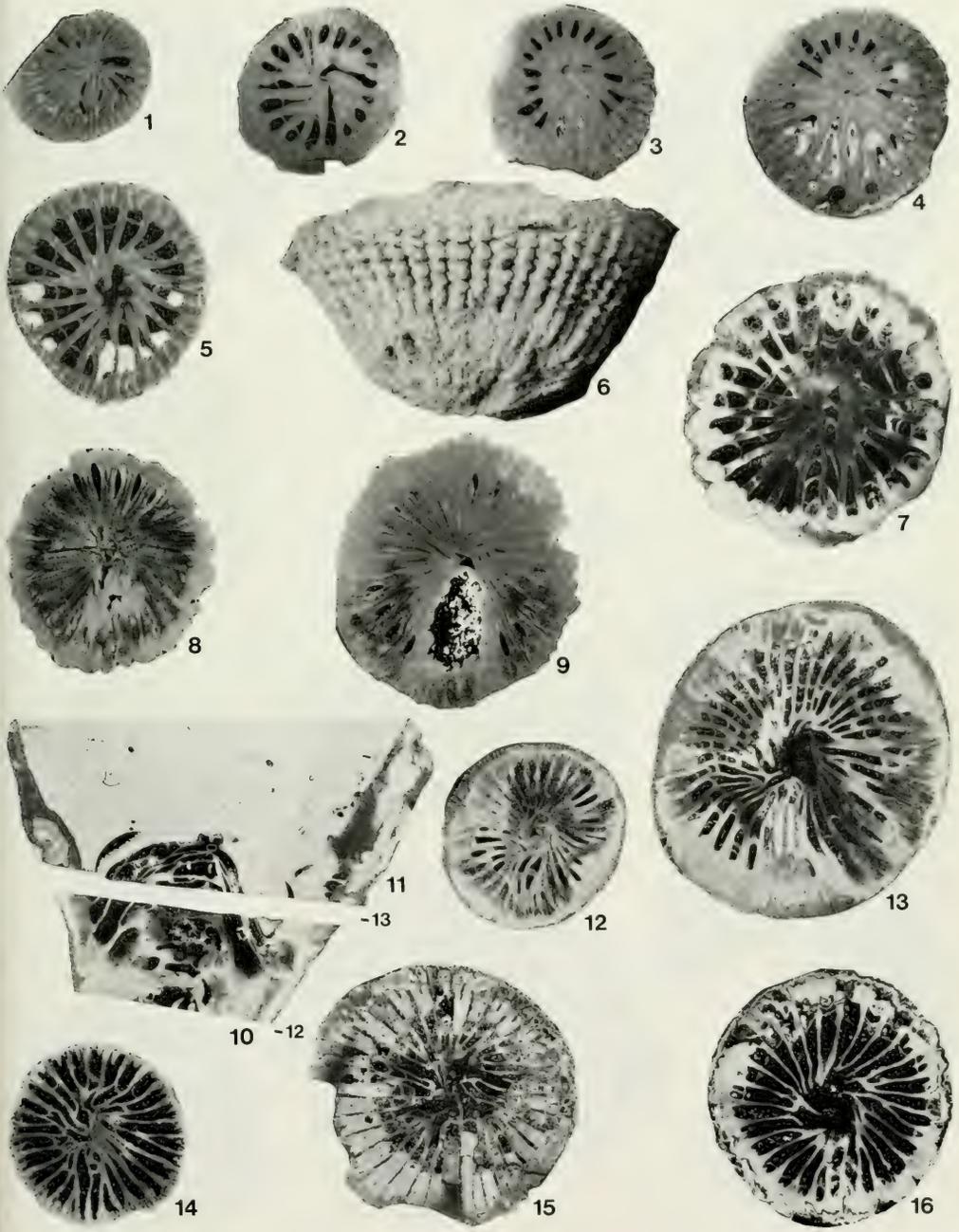


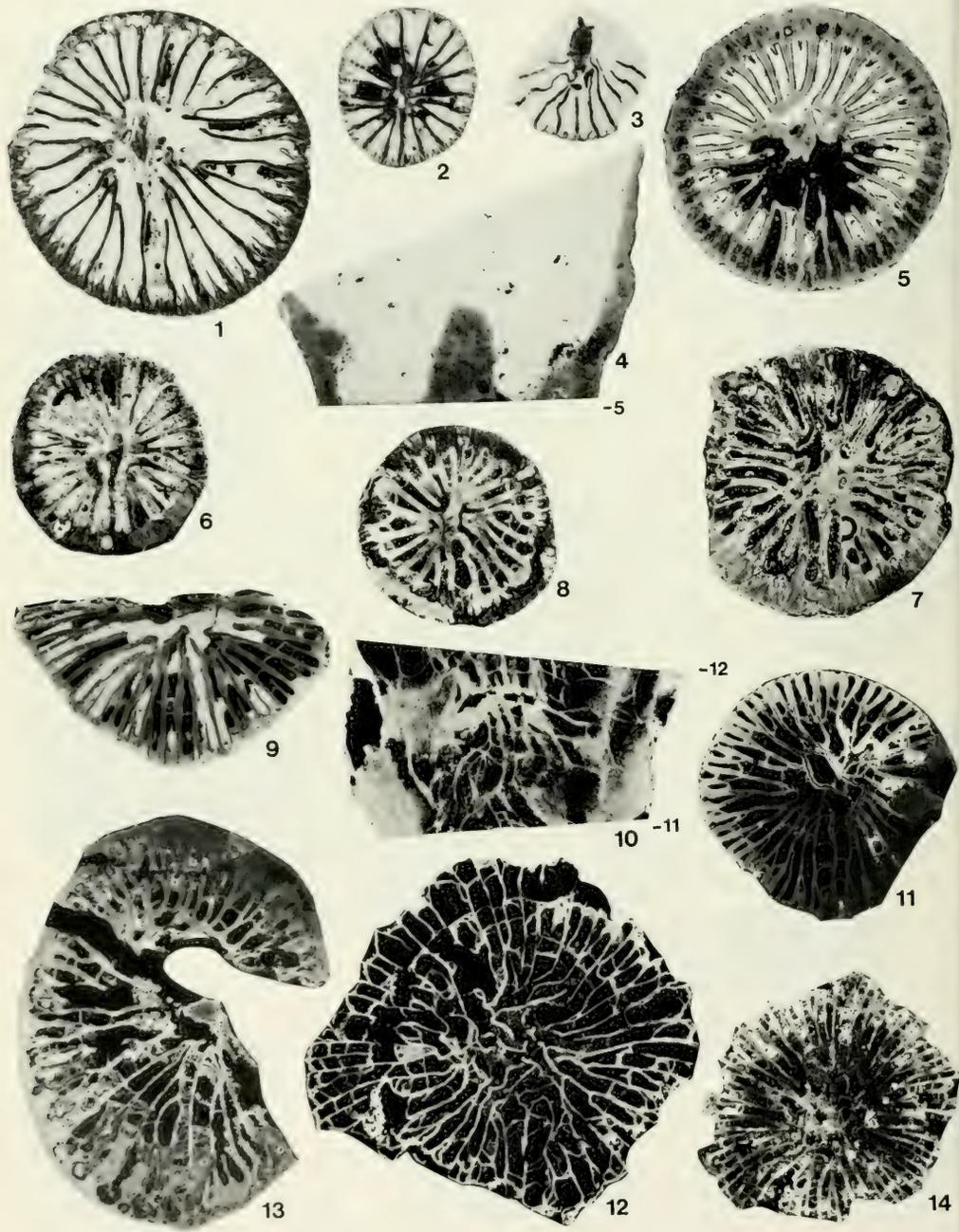
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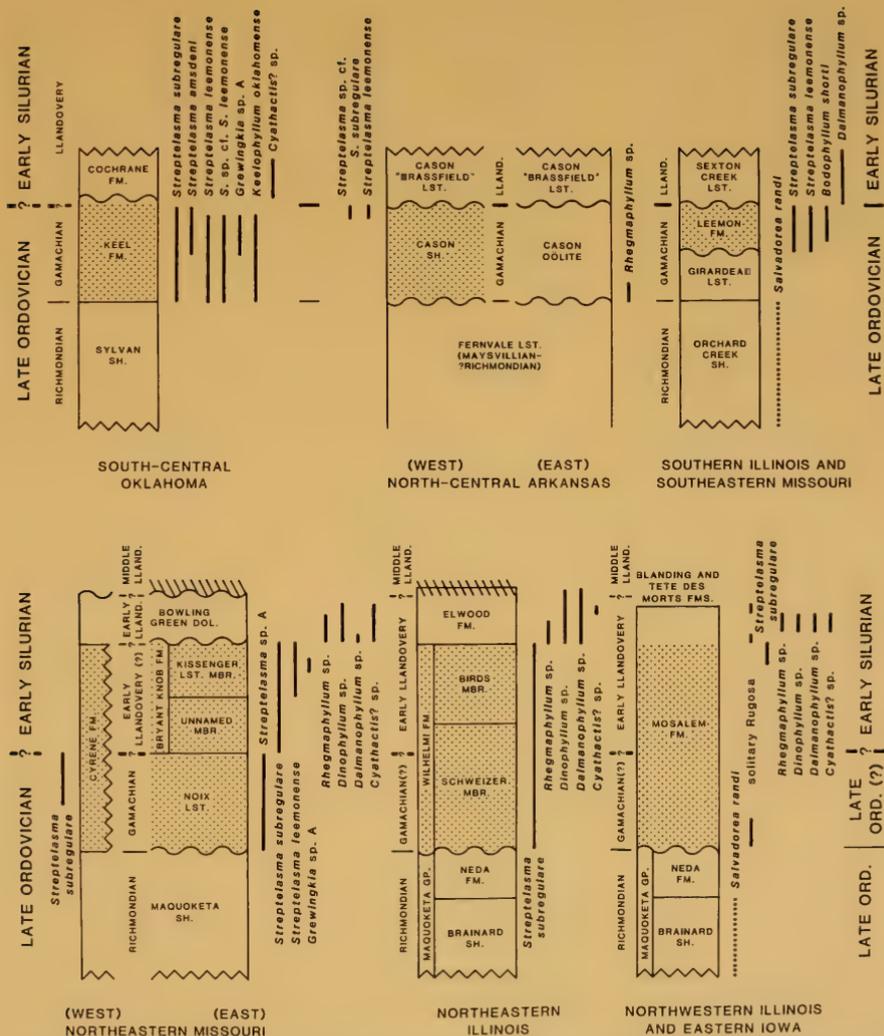
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Text-figure 10.—Composite stratigraphic sections showing age and correlation of uppermost Ordovician to lowermost Silurian units and distribution of solitary rugose corals in the east-central United States. Thicknesses of units are not to scale. Lines depicting ranges of taxa above the Richmondian show relative positions within the units, based on inspection of data in Text-figures 2-5, 7, 8. Units containing the Edgewood solitary coral assemblage (Gamachian to early Early Llandovery in age) are stippled. Hachures indicate the *Platynereella manntensis* zone.

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1962. *Size of lettering for text-figures*. *Journal of Paleontology*, vol. 36, p. 1402.



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(1864 - 1952)

Founder of the *Bulletins of American Paleontology* (1895)

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