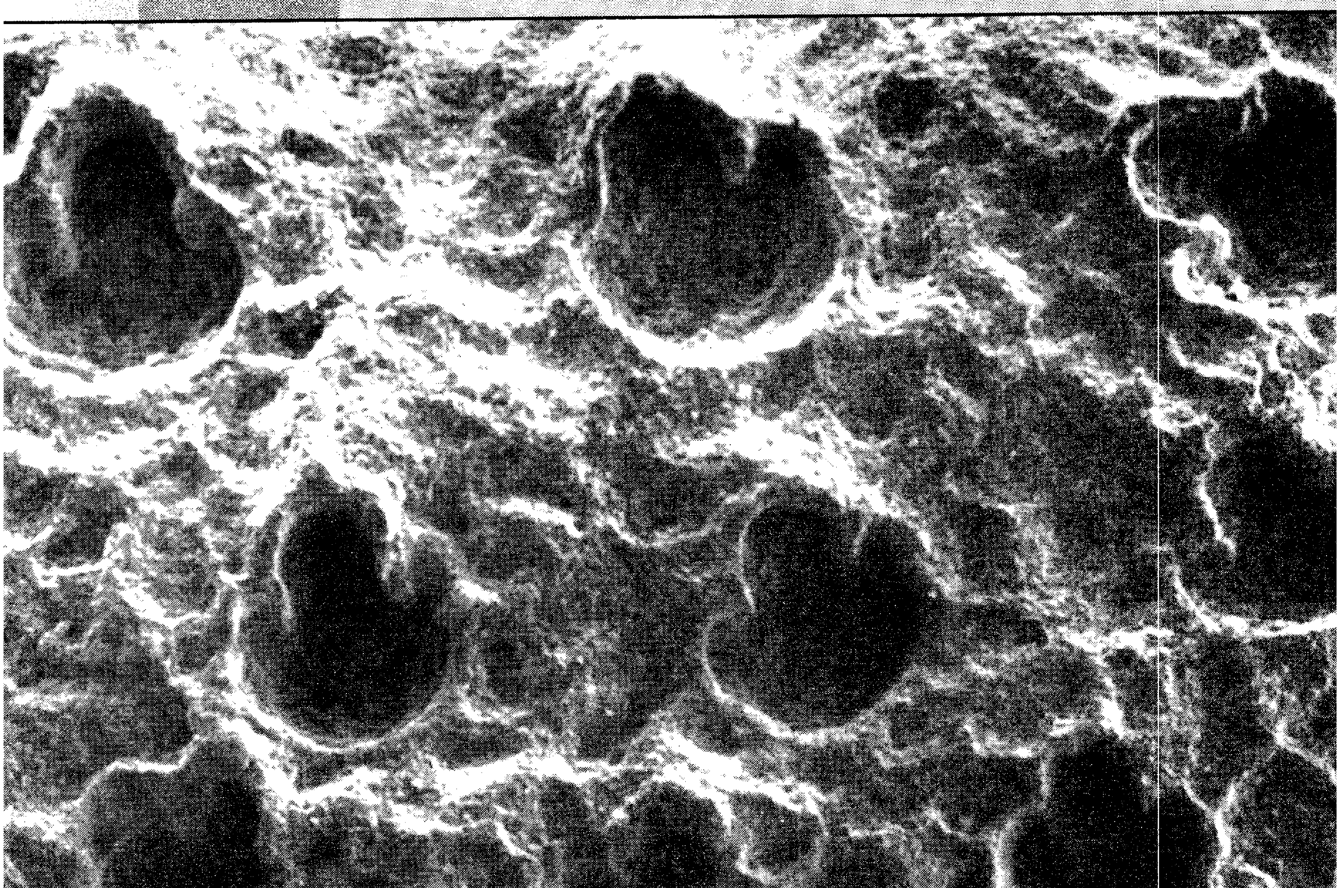
# OKLAHOMA GEOLOGY Notes



August, 1995

Vol. 55, No. 4

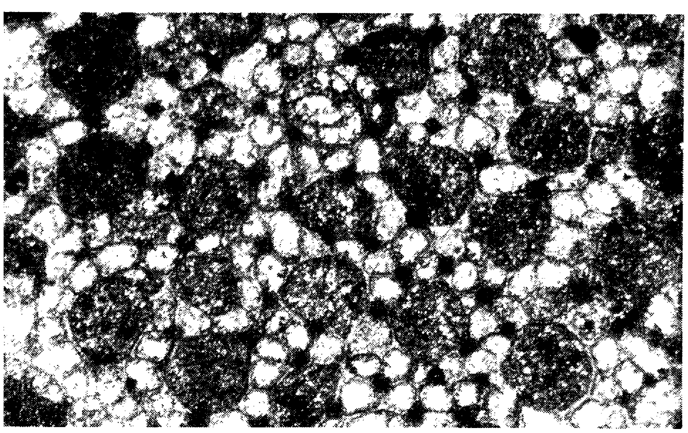
## On The Cover —

## Bryozoans from the Haragan Formation, Arbuckle Mountains

Scanning electron micrograph of *Fistuliporella quinquedentata*, one of the most common bryozoans found in the Haragan Formation of the Arbuckle Mountains region. This species has the typical morphologic features of fistuliporoid bryozoans: cylindrical tubelike zooecia, lunaria (horseshoe-shaped and hoodlike structures around the zooecial apertures), and cystopores (bubblelike structures between the zooecial tubes).

The inset photo (below) is a transmitted-light microscope photograph of an acetate peel section just below the surface of *Leioclema pulchellum*. This species is found in the Haragan Formation, but it is rare. It has the typical morphologic features of trepostome bryozoans: cylindrical tubelike zooecia, mesopores (thin tubes between zooecia), and acanthorods (spines projecting from the surface of the bryozoan colony).

*Clifford A. Cuffey, Roger J. Cuffey, Albert J. Robb III, and John T. Lembcke*



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OKLAHOMA GEOLOGY

# Notes

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# Reconnaissance Survey of the Haragan Formation Bryozoan Fauna and Its Paleoecology, Lower Devonian of South-Central Oklahoma

*Clifford A. Cuffey*[1], *Roger J. Cuffey*[2], *Albert J. Robb III*[3], *and John T. Lembcke*[4]

## Abstract

The Haragan Formation (Hunton Group, Lower Devonian) of the Arbuckle Mountains (south-central Oklahoma) contains an abundant and diverse bryozoan fauna totaling 22 species, including seven trepostomes, seven fenestrates, four fistuliporoids, one ceramoporoid, one tubuliporine, one ptilodictyoid, and one rhomboporoid. Five species numerically dominate the fauna and are ubiquitous: *Fistuliporella quinquedentata*, *Cyclotrypa mutabilis*, *Cyphotrypa corrugata*, *Fenestella idalia*, and *Leioclema subramosum*. Bryozoans occur both as free zoaria and as epizoans on the skeletons of other organisms, especially brachiopod shells. Free zoaria have diverse growth forms. Primary niche differentiation among the bryozoans is accomplished by tiering, based on heights of zoarial growth forms. Massive domes, hemispherical domes, mushroom-shaped buttons, unilaminar sheets, hollow ramose branches, delicate ramose branches, and bifoliate sticks are part of the lowest epifaunal tier, within 5 cm of the sediment/water interface. Robust ramose branches and fenestrate fronds are part of the next higher epifaunal tier, ranging from 5 to 20 cm above the sediment/water interface. One additional zoarial form, tiny encrusting disks, is epizoic only. The fauna contains a mixture of species previously reported from the Silurian and Devonian, in contrast to other invertebrate groups in the Haragan that are dominated by Devonian forms and have few Silurian holdovers.

## Introduction

Bryozoans were important, abundant, and diverse during the Devonian (Cuffey and McKinney, 1979). This period is especially noteworthy because of major, gradual interchanges in the balance among bryozoan orders during its 50 million years, particularly the decline of the trepostomes and concurrent expansion of the fenestrates.

The Haragan Formation (Fig. 1) of south-central Oklahoma dates from the Early Devonian (Gedinnian/Helderbergian) (Amsden, 1960,1988; Barrick and Klapper, 1992), and hence should document bryozoan diversity at a time more characteristic of earlier Paleozoic proportions than of later. That formation contains numer-

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ous bryozoans which, surprisingly, have never been described nor cataloged (Amsden, 1956), despite the fact that they are abundant and widespread, second only to brachiopods. Reports of bryozoans in the Oklahoma Haragan are limited to faunal lists (Girty, 1899; Reeds, 1911; Maxwell, 1936) and a single abstract noting their presence (Loeblich, 1947), in contrast to detailed description of other groups, including the brachiopods (Amsden, 1958), trilobites (Campbell, 1977), ostracods (Lundin, 1968), and crinoids (Strimple, 1963). Additionally, Amsden (1956) cataloged all then-described species from the Haragan.

Currently, Cuffey and others (1993, 1994, and in press) are examining bryozoans occurring as epizoans on the Haragan brachiopod *Meristella atoka* Girty. In gathering the data for that project, the authors obtained excellent representative samples of bryozoans from several Haragan localities. The purpose of this report is to document the bryozoan species found at those Haragan localities as a reconnaissance survey of this fauna. Each species is identified, diagnosed, and illustrated, and the important paleoecologic and biostratigraphic implications of the fauna are discussed.

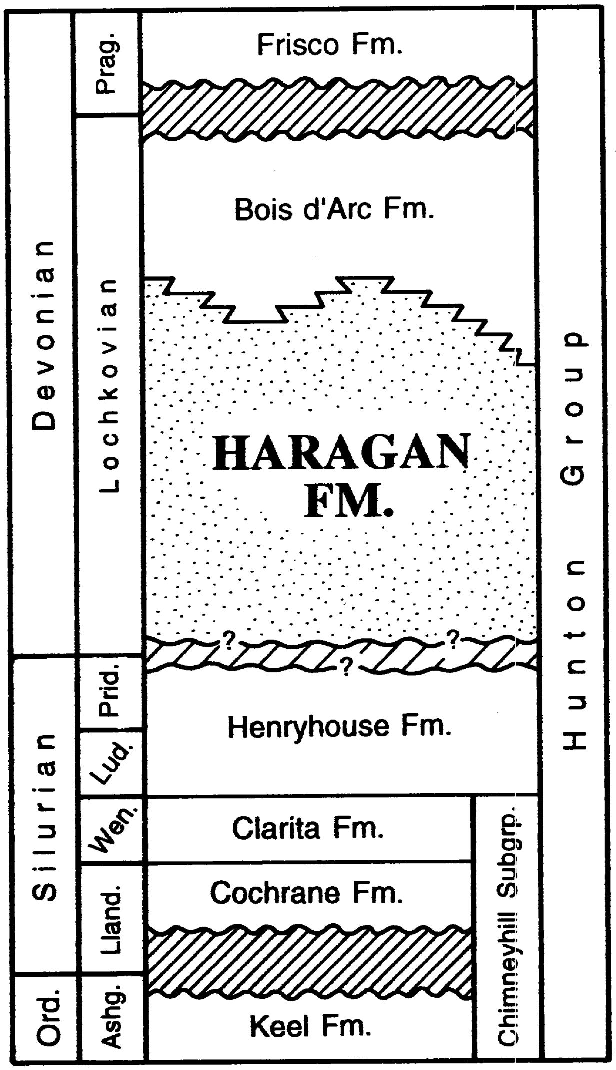

Figure 1. Stratigraphic column of the Hunton Group, Arbuckle Mountains region, south-central Oklahoma (modified from Amsden, 1960,1988; Barrick and Klapper, 1992).

The Haragan Formation (part of the Hunton Group) consists primarily of yellowish-gray, fossiliferous marlstone; rare thin layers of crinoidal and skeletal limestone are scattered throughout (Amsden, 1960). In addition to the bryozoans, the Haragan invertebrate fauna includes brachiopods, corals, trilobites, ostracods, gastropods, pelecypods, and crinoids.

## Materials and Methods

Extensive collections of bryozoans were obtained from locality M2 (of Amsden, 1960) near White Mound, Oklahoma, and supplemental collections were obtained from localities M9, M10, and C1 (of Amsden, 1960), and the 107.2 Cut (new locality; see Appendix, p. 149) (Fig. 2). Four of these localities (M2, M9, M10, 107.2 Cut) are in the central Arbuckle Mountains, and the fifth (C1) is on the Lawrence uplift. Thus, a suite of geographically representative samples was obtained.

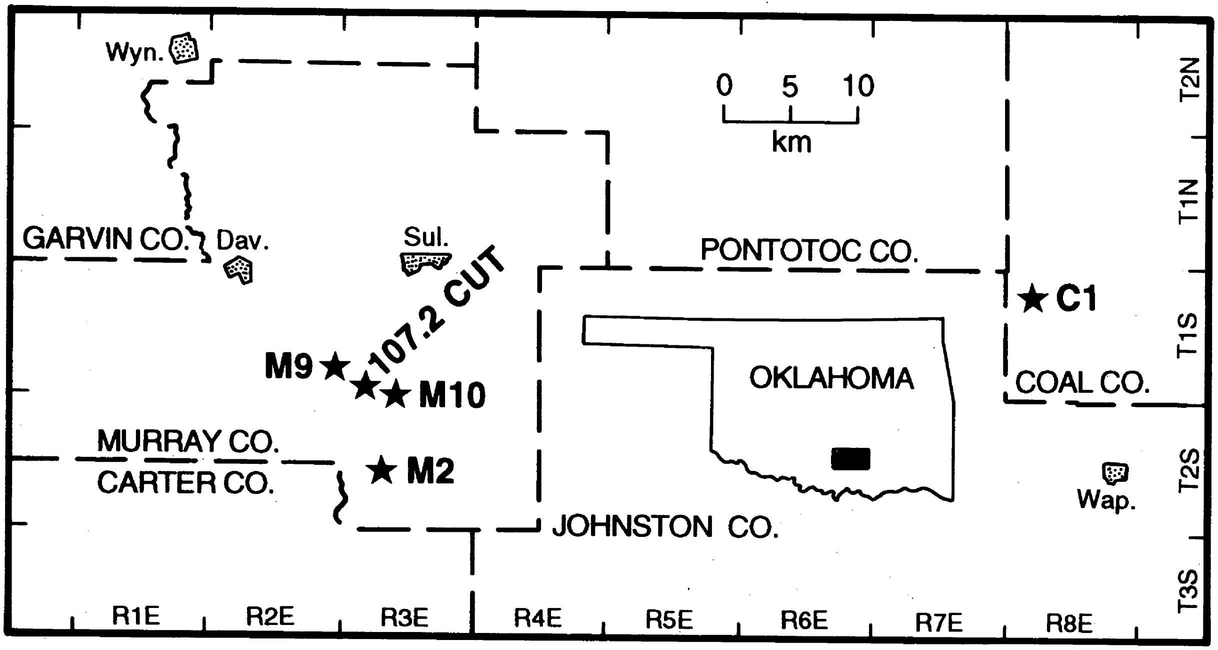


Figure 2. Map of Arbuckle Mountains region showing sampling localities. See Appendix (p. 149) and Amsden (1960) for specific locality data.

The bryozoans were identified by examining the surface of each zoarium with a binocular dissecting microscope. Species initially were discriminated and identified based on external features. Then, for positive confirmation, tangential, longitudinal, and transverse acetate peel sections of representative specimens were prepared. Mode of occurrence (whether epizoic or free) and zoarial form were noted for each specimen to aid in analysis of the paleoecology of the bryozoan fauna. Finally, the known stratigraphic distribution of each species was compiled in order to consider their biostratigraphic implications. The bryozoan specimens are deposited in the Paleobryozoological Research Collection at Pennsylvania State University (PBRC-PSU); figured specimens are numbered.

## Results

A total of 2,021 bryozoan zoaria were examined for this project. From these, 22 species are identified, including seven trepostomes, seven fenestrates, four fistuliporoids, one ceramoporoid, one tubuliporine, one ptilodictyoid, and one rhomboporoid. Their distribution is summarized in Table 1. Three species, *Fistuliporella quinquedentata, Cyclotrypa mutabilis,* and *Cyphotrypa corrugata* are abundant; two more, *Fenestella idalia* and *Leioclema subramosum,* are common. These five species occur at all five localities. The remaining 17 species all are much rarer and do not occur at every locality. Because it was the most intensely sampled, locality M2 produced the largest number of zoaria, including 21 of the 22 species. Samples from the other localities contain fewer individuals, primarily of the five common species.

The majority (1,483; 73%) of the Haragan bryozoans lived as epizoic zoaria (Table 1) and are preserved attached to skeletal remains of other organisms. The remaining zoaria lived free-lying on the sea floor. The most common host was *Mer-*

TABLE 1.—DISTRIBUTION OF BRYOZOAN SPECIES AMONG THE FIVE HARAGAN LOCALITIES, ARBUCKLE MOUNTAINS

| Species | M2 | | M9 | | M10 | | 107.2 Cut | | C1 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TREPOSTOMES | | | | | | | | | | | | |
| *Batostomella interporosa* | 2 | (—) | — | (—) | — | (—) | — | (—) | — | (—) | 2 | (—) |
| *Callotrypa macropora* | 2 | (—) | — | (—) | — | (—) | — | (—) | — | (—) | 2 | (—) |
| *Cyphotrypa corrugata* | 70 | (325) | — | (1) | 1 | (—) | 6 | (3) | 2 | (10) | 79 | (339) |
| *Leioclema elasmaticum* | 2 | (—) | — | (—) | — | (—) | — | (—) | 2 | (—) | 4 | (—) |
| *Leioclema pulchellum* | 3 | (44) | — | (—) | — | (—) | 4 | (—) | 1 | (3) | 8 | (47) |
| *Leioclema subramosum* | 15 | (88) | 2 | (—) | 2 | (1) | — | (2) | 2 | (7) | 21 | (98) |
| *Stromatotrypa globularis* | 2 | (11) | 1 | (—) | — | (—) | — | (1) | — | (—) | 3 | (12) |
| CERAMOPOROID | | | | | | | | | | | | |
| *Ceramopora imbricata* | 9 | (226) | — | (—) | — | (2) | 2 | (—) | — | (7) | 11 | (235) |
| FISTULIPOROIDS | | | | | | | | | | | | |
| *Coelocaulis* aff. *venusta* | 3 | (5) | — | (—) | — | (—) | 1 | (—) | — | (—) | 4 | (5) |
| *Cyclotrypa mutabilis* | 147 | (81) | 3 | (1) | 2 | (1) | 8 | (—) | 9 | (1) | 169 | (84) |
| *Fistuliporella maynardi* | 9 | (54) | 1 | (—) | 1 | (1) | 1 | (3) | — | (—) | 12 | (58) |
| *Fistuliporella quinquedentata* | 99 | (405) | 8 | (—) | 4 | (3) | 4 | (11) | 1 | (7) | 116 | (426) |
| TUBULIPORINE | | | | | | | | | | | | |
| *Flabellotrypa rugulosa* | — | (5) | — | (—) | — | (—) | — | (—) | — | (1) | — | (6) |
| RHOMBOPOROID | | | | | | | | | | | | |
| rhomboporoid gen. et sp. indet. | 2 | (—) | — | (—) | — | (—) | 1 | (—) | — | (—) | 3 | (—) |
| PTILODICTYOID | | | | | | | | | | | | |
| *Ptilodictya tenella* | 3 | (7) | — | (—) | — | (—) | 2 | (—) | — | (—) | 5 | (7) |
| FENESTRATES | | | | | | | | | | | | |
| *Fenestella idalia* | 60 | (1) | 1 | (—) | 4 | (—) | 15 | (—) | 2 | (—) | 82 | (1) |
| *Fenestella*? cf. *lilia* | 1 | (—) | — | (—) | 1 | (—) | 2 | (—) | — | (—) | 4 | (—) |
| *Fenestella sinuosa* | 3 | (—) | — | (—) | — | (—) | — | (—) | — | (—) | 3 | (—) |
| *Fenestella stellata* | — | (—) | — | (—) | — | (—) | — | (—) | 1 | (—) | 1 | (—) |
| *Polypora distans* | 4 | (—) | — | (—) | — | (—) | — | (—) | — | (—) | 4 | (—) |
| *Thamniscus* cf. *regularis* | 2 | (—) | — | (—) | — | (—) | — | (—) | — | (—) | 2 | (—) |
| *Thamniscus variolata* | 3 | (—) | — | (—) | — | (—) | — | (—) | — | (—) | 3 | (—) |
| fenestrates indeterminate | — | (165) | — | (—) | — | (—) | — | (—) | — | (—) | — | (165) |
| TOTAL | 441 | (1,417) | 16 | (2) | 15 | (8) | 46 | (20) | 20 | (36) | 538 | (1,483) |

NOTES: First column for each locality = number of free-lying zoaria collected. Second column for each locality = number of epizoic zoaria found. Dash indicates that a species was absent from a locality.

*istella atoka* Girty, and the relationship between it and the bryozoans is discussed elsewhere (Cuffey and others, 1993,1994, and in press). The bryozoans also encrusted other brachiopods, other bryozoans, corals (both favositids and solitary rugosans), crinoids, gastropods, and trilobites. Certain species were preferentially epizoic; *Ceramopora imbricata, Cyphotrypa corrugata, Fistuliporella maynardi, Fistuliporella quinquedentata, Flabellotrypa rugulosa, Leioclema pulchellum, Leioclema subramosum,* and *Stromatotrypa globularis* all are more common as epizoans than as free zoaria (Cuffey and others, 1993,1994, and in press).

The bryozoans of the Haragan grew into diverse zoarial forms (Table 2). Among free zoaria, each species is characterized predominantly by one zoarial form, but may appear rarely as another.

**Massive domes** are the most abundant Haragan zoarial growth form. They are mound-shaped with flat or slightly concave bases and gently to strongly convex upper surfaces; most are wider than high. This form is represented by most *Cyclotrypa mutabilis* and *Fistuliporella quinquedentata,* and by rare *Ceramopora imbricata* and *Fistuliporella maynardi.*

Two additional zoarial forms are common. **Mushroom-shaped buttons** are characterized by their small size (diameter <1.5 cm) and have more or less stalk-shaped and expanding bases capped by a gently convex, subcircular surface bearing the zooecial apertures. This zoarial form is represented by *Cyphotrypa corrugata.* **Fenestrate fronds** consist of funnels constructed of thin, erect, radiating branches connected by thin, transverse dissepiments. *Fenestella* spp. and *Polypora distans* represent this growth form.

Other zoarial forms are very rare. **Hemispherical domes** are characterized by their small size (diameter <1.5 cm), circular outline, slightly concave base, and strongly convex upper surface with zooecial apertures. *Stromatotrypa globularis,* most *Leioclema subramosum,* and rare *Leioclema pulchellum* represent this form. **Unilaminar sheets** consist of a single, thin layer of zooecia. Most are relatively flat, but some are very irregular. Most *Fistuliporella maynardi* and *Ceramopora imbricata,* as well as rare *Cyclotrypa mutabilis, Fistuliporella quinquedentata,* and *Leioclema pulchellum* represent this zoarial form. **Hollow ramose branches** consist of small, erect branching zoaria, the central axes of which are hollow. This form is represented by *Coelocaulis* aff. *venusta.* **Delicate ramose branches** are characterized by erect, cylindrical branching zoaria with very thin (diameter <2 mm) branches. This form is represented by *Callotrypa macropora, Thamniscus* cf. *regularis, Thamniscus variolata,* and rhomboporoid gen. et sp. indet. **Robust ramose branches** are characterized by erect, cylindrical branching zoaria with relatively thick (diameter >5 mm) branches. This form is represented by *Batostomella interporosa, Leioclema elasmaticum,* some *Leioclema subramosum,* and rare *Leioclema pulchellum.* **Bifoliate sticks** consist of small, narrow, nonbranching, erect bifoliate zoaria. This form is represented by *Ptilodictya tenella.*

Zoarial forms of epizoic species generally are more varied and depend on the size and shape of the host. **Unilaminar sheets, massive domes, hemispherical domes,** and **fenestrate fronds** also occur as epizoans. One zoarial form, **tiny encrusting disks,** only occurs as epizoans and is represented by *Flabellotrypa rugulosa.* This form consists of tiny (diameter <0.5 cm), very thin, disk-shaped zoaria in which the zooecia are horizontally oriented.

The Haragan bryozoan fauna consists of species previously known from both the Silurian and Devonian (Table 3). Of the five most common species in the fauna,

## TABLE 2.—DISTRIBUTION OF ZOARIAL FORMS AMONG THE HARAGAN BRYOZOAN SPECIES

| Species | Massive domes | Hemi-spherical domes | Mushroom-shaped buttons | Unilaminar sheets | Hollow ramose branches | Delicate ramose branches | Robust ramose branches | Bifoliate sticks | Fenestrate fronds | Tiny encrusting disks |
|---|---|---|---|---|---|---|---|---|---|---|
| TREPOSTOMES | | | | | | | | | | |
| *Batostomella interporosa* | — | — | — | — | — | — | R | — | — | — |
| *Callotrypa macropora* | — | — | — | — | — | R | — | — | — | — |
| *Cyphotrypa corrugata* | — | — | C | E | — | — | — | — | — | — |
| *Leioclema elasmaticum* | — | — | — | — | — | — | R | — | — | — |
| *Leioclema pulchellum* | — | R,E | — | R | — | — | R | — | — | — |
| *Leioclema subramosum* | — | C,E | — | E | — | — | R | — | — | — |
| *Stromatotrypa globularis* | — | R | — | E | — | — | — | — | — | — |
| CERAMOPOROID | | | | | | | | | | |
| *Ceramopora imbricata* | R,E | — | — | R,E | — | — | — | — | — | — |
| FISTULIPOROIDS | | | | | | | | | | |
| *Coelocaulis* aff. *venusta* | — | — | — | E | R | — | — | — | — | — |
| *Cyclotrypa mutabilis* | C,E | E | — | R,E | — | — | — | — | — | — |
| *Fistuliporella maynardi* | R | — | — | R,E | — | — | — | — | — | — |
| *Fistuliporella quinquedentata* | C,E | E | — | R,E | — | — | — | — | — | — |
| TUBULIPORINE | | | | | | | | | | |
| *Flabellotrypa rugulosa* | — | — | — | — | — | — | — | — | — | E |
| RHOMBOPOROID | | | | | | | | | | |
| rhomboporoid gen. et sp. indet. | — | — | — | — | — | R | — | — | — | — |
| PTILODICTYOID | | | | | | | | | | |
| *Ptilodictya tenella* | — | — | — | — | — | — | — | R,E | — | — |
| FENESTRATES | | | | | | | | | | |
| *Fenestella idalia* | — | — | — | — | — | — | — | — | C,E | — |
| *Fenestella*? cf. *lilia* | — | — | — | — | — | — | — | — | R | — |
| *Fenestella sinuosa* | — | — | — | — | — | — | — | — | R | — |
| *Fenestella stellata* | — | — | — | — | — | — | — | — | R | — |
| *Polypora distans* | — | — | — | — | — | — | — | — | R | — |
| *Thamniscus* cf. *regularis* | — | — | — | — | — | R | — | — | — | — |
| *Thamniscus variolata* | — | — | — | — | — | R | — | — | — | — |
| fenestrates indeterminate | — | — | — | — | — | — | — | — | E | — |

NOTES: R = zoarial form rare as free-lying zoaria. E = zoarial form occurs as epizoans. C = zoarial form common as free-lying zoaria. Dashes = zoarial form not found in this species.

**TABLE 3.—PREVIOUSLY REPORTED STRATIGRAPHIC DISTRIBUTION OF THE HARAGAN BRYOZOAN SPECIES**

| Species | Stage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wenlockian (Middle Silurian) | Ludlovian (Late Silurian) | Pridolian (Late Silurian) | Lochkovian (Early Devonian) | Pragian (Early Devonian) | Emsian (Early Devonian) | Eifelian (Middle Devonian) | Givetian (Middle Devonian) |
| TREPOSTOMES | | | | | | | | |
| *Batostomella interporosa* | — | — | X | — | — | — | — | — |
| *Callotrypa macropora* | — | — | — | X | — | — | — | — |
| *Cyphotrypa corrugata* | — | — | X | — | — | — | — | — |
| *Leioclema elasmaticum* | — | — | — | — | — | — | — | X |
| *Leioclema pulchellum* | — | — | X | — | — | — | — | — |
| *Leioclema subramosum* | — | — | X | — | — | — | — | — |
| *Stromatotrypa globularis* | — | — | X | — | — | — | — | — |
| CERAMOPOROID | | | | | | | | |
| *Ceramopora imbricata* | X | — | — | — | — | — | — | — |
| FISTULIPOROIDS | | | | | | | | |
| *Coelocaulis* aff. *venusta* | — | — | — | X | — | — | — | — |
| *Cyclotrypa mutabilis* | — | X | — | — | — | — | — | — |
| *Fistuliporella maynardi* | — | — | X | — | — | — | — | — |
| *Fistuliporella quinquedentata* | — | — | X | — | — | — | — | — |
| TUBULIPORINE | | | | | | | | |
| *Flabellotrypa rugulosa* | — | — | — | X | — | — | — | — |
| RHOMBOPOROID | | | | | | | | |
| rhomboporoid gen.et sp. indet. | ? | ? | ? | ? | ? | ? | ? | ? |
| PTILODICTYOID | | | | | | | | |
| *Ptilodictyat enella* | — | — | X | — | — | — | — | — |
| FENESTRATES | | | | | | | | |
| *Fenestella idalia* | — | — | — | X | — | — | — | — |
| *Fenestella*? cf. *lilia* | — | — | — | X | — | — | — | — |
| *Fenestella sinuosa* | — | — | — | — | — | — | — | — |
| *Fenestella stellata* | — | — | — | — | — | — | X | X |
| *Polypora distans* | — | — | — | — | — | — | X | — |
| *Thamniscus* cf. *regularis* | — | — | X | — | — | — | X | — |
| *Thamniscus variolata* | — | — | — | X | — | — | — | — |

NOTES: X = previously reported. Dash = not reported.

four previously were known from the Late Silurian (Ludlovian and Pridolian). *Cyclotrypa mutabilis* was known from the Ludlovian of Gotland (Hennig, 1908) and the Canadian Arctic (Bolton, 1966); *Fistuliporella quinquedentata, Cyphotrypa corrugata,* and *Leioclema subramosum* were known from the Keyser Limestone and equivalents (Pridolian) of the central Appalachians (Weller, 1903; Ulrich and Bassler, 1913; Miller, 1979,1982; Miller and Cuffey, 1980). The fifth (*Fenestella idalia*) previously was known from the Early Devonian (Lochkovian) Helderberg Group of the central Appalachians (Hall and Simpson, 1887; Ulrich and Bassler, 1913). Of the remaining species, one was known from the Middle Silurian (Wenlockian) (Hall, 1852; Bassler, 1906,1953; Utgaard, 1983), six from the Late Silurian (Pridolian) (Ulrich and Bassler, 1913; Miller, 1979), five from the Early Devonian (Lochkovian) (Hall and Simpson, 1887; Ulrich and Bassler, 1913; Bassler, 1952, 1953; Utgaard, 1983), and four from the Middle Devonian (Eifelian and Givetian) (Hall and Simpson, 1887; Boardman, 1960; Ellison, 1965).

## Discussion

The zoarial forms can be related directly to the paleoenvironment of the Haragan Formation and to the concept of tiering in suspension-feeding communities (Bottjer and Ausich, 1986; Ausich and Bottjer, 1991). The Haragan was deposited in offshore, quiet-water environments (Amsden, 1960). The lack of sedimentary structures indicative of nearly continuous turbulence is evident that depths certainly were below fair-weather wave base (Amsden, 1960). The thin, skeletal-rich layers may be tempestites, which suggests that deposition possibly took place above storm-wave base. The substratum typically was fine grained, consisting of clay- and silt-sized terrigenous and carbonate mud (Amsden, 1960). The abundance of epifaunal suspension-feeding organisms, some of which secreted nearly flat base plates (bryozoans and favositid corals) or were globularly shaped (*Meristella atoka* Girty, for example), suggests that the substratum must have been relatively firm (but probably not firmgrounds or hardgrounds) and not thixotropic.

Throughout the Phanerozoic, suspension-feeding communities had vertical structure, called tiering (originally termed "stratification"); each tier was inhabited by organisms that grew to specific heights above, or burrowed to specific depths below, the sediment/water interface (Bottjer and Ausich, 1986; Ausich and Bottjer, 1991). For most of the Paleozoic, there were four epifaunal tiers, 0–5, 5–20, 20–50, and 50–100 cm above the sediment/water interface (Bottjer and Ausich, 1986; Ausich and Bottjer, 1991).

The relative heights of zoarial forms indicate that tiering was used by the bryozoans as a method of primary niche differentiation (Ausich and Bottjer, 1991). The Haragan bryozoans were partitioned into the two lowest epifaunal tiers (Fig. 3). In the 0–5 cm tier were **massive domes, hemispherical domes, mushroom-shaped buttons, unilaminar sheets, hollow ramose branches, bifoliate sticks**, and **delicate ramose branches.** In the 5–20 cm tier were the **robust ramose branches** and **fenestrate fronds.** Within each tier, different paleoenvironmental parameters acted as limiting factors on bryozoan growth.

Within the 0–5 cm tier, the two limiting factors, firmness of substrate and sedimentation rate, operated at the sediment/water interface. The relatively wide bases of the **massive domes** probably supported their weight on the muddy substratum. Furthermore, their height of several centimeters prevented burial by sedimenta-

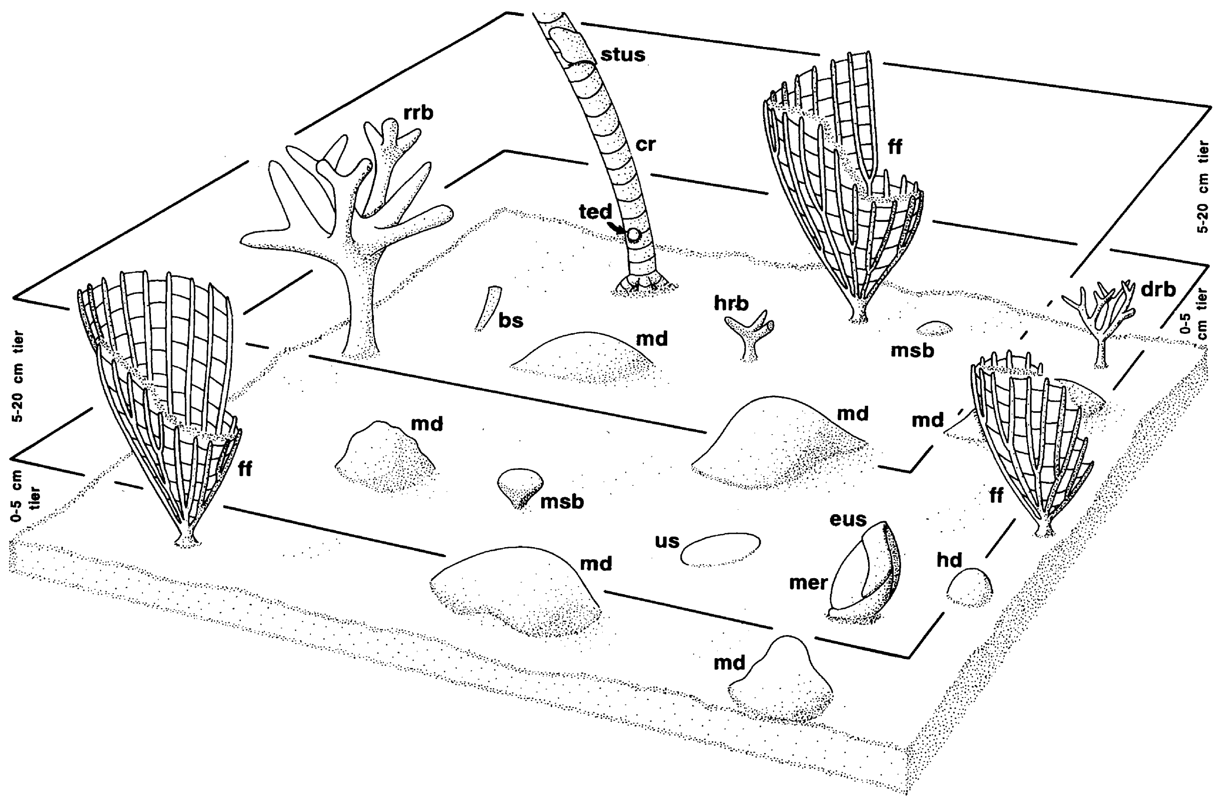


Figure 3. Block diagram reconstruction illustrating the Haragan sea floor with bryozoan zoarial forms in inferred life position and segregated into tiers; bs = bifoliate stick; cr = crinoid (Echinodermata); drb = delicate ramose branch; eus = unilaminar sheet (epizoic on *Meristella atoka*); ff = fenestrate fronds; hd = hemispherical dome; hrb = hollow ramose branch; md = massive domes; mer = *Meristella atoka* Girty (Brachiopoda); msb = mushroom-shaped buttons; rrb = robust ramose branch; stus = unilaminar sheet (epizoic on crinoid and secondary tierer); ted = tiny encrusting disk (epizoic on crinoid); us = unilaminar sheet.

tion, which explains the abundance of this zoarial form. The **mushroom-shaped buttons** and **hemispherical domes** probably were sufficiently lightweight (due to their small size) that they did not sink into the substrate, but they probably were somewhat more susceptible to burial by sedimentation (than the massive domes) because they did not grow very tall. The stalklike, expanding bases of the **mushroom-shaped buttons** probably are an indication of continued upward growth as a response to sedimentation. Most of the free **unilaminar sheets** probably were attached directly on the substratum (many more were epizoic, as discussed later). Their wide bases supported their weight on the substratum. However, their very low height made them very susceptible to burial by sedimentation, which probably explains their rarity. All of the erect forms within this tier were lightweight and tall enough to avoid the hazards of this tier. Additionally, there may have been some second-order niche differentiation between the domal/laminar and erect zoaria. The flow of ambient water currents across the different zoaria may have varied and, thus, produced some food particle selectivity.

Within the 5–20 cm tier, the primary limiting factor probably was the availability of food resources within ambient currents. There may have been some degree of secondary niche differentiation among the zoaria in this tier. First, **robust ramose branches** and **fenestrate fronds** may have influenced the flow of water around the respective zoaria in different ways. Second, among the **fenestrate fronds,** there are two sizes of fenestrules, small and large. Most zoaria have small-sized fenestrules (*Fenestella* spp.), whereas one species (*Polypora distans*) has much larger fenestrules. Fenestrule size would have affected the flow of water through the frond (Stratton and Horowitz, 1974), possibly permitting feeding on different food resources; each fenestrule size, and hence frond, is adapted for optimal feeding on differently sized food particles. Similar second-order niche partitioning occurs in Mississippian crinoids. Different crinoid clades are characterized by different densities of the feeding net, as indicated by the numbers and arrangement of arms and pinnules (Ausich, 1980).

The disproportionately large number of epizoic occurrences of certain species is partly a function of zoarial growth form. Those species that are characterized by small size, low relief, and nonerect zoaria when they are free-lying are more common as epizoans. The epizoic form is interpreted as a way to gain enough elevation above the substratum to avoid burial by sedimentation. Piggybacking on other organisms was necessary because independently the zoaria were not tall enough to avoid burial. **Tiny encrusting disks** apparently were so small that they were exclusively epizoic.

Most of the host organisms (brachiopods, most bryozoans, corals, gastropods, trilobites) inhabited the 0–5 cm tier. The various bryozoan species that encrusted *Meristella atoka* have different distributional patterns, which indicate different responses to the brachiopod's life mode and life history (Cuffey and others, 1993, 1994, and in press). Some hosts (crinoids and fenestrate bryozoans) inhabited the 5–20 cm tier. The zoarial forms that commonly used crinoids and fenestrates as hosts normally were limited to the 0–5 cm tier when free-lying. Their zoarial form did not grow above that tier; hence, they could not inhabit the 5–20 cm tier independently. Such epizoic bryozoans that inhabited the 5–20 cm tier only by piggybacking on crinoids and fenestrates are known as secondary tierers (Bottjer and Ausich, 1986). Finally, some **unilaminar sheets** are quite irregular in shape, even folded into tubes, which suggests that they may have encrusted some sort of algae or other soft-tissued organism not preserved.

The Haragan bryozoan fauna has significant biostratigraphic implications. The occurrence of many of the species in the Haragan Formation significantly expands both their known stratigraphic and geographic distribution. Additionally, the presence of numerous Silurian species, including four of the most common species, is significant because most other Haragan invertebrate groups show very pronounced affinities with Devonian faunas and have very few Silurian holdovers (Amsden, 1958,1960; Lundin, 1968). Few Early Devonian bryozoan faunas from North America have been described; hence, for many of these species, the total stratigraphic range is known very incompletely in comparison with the ranges of organisms such as the brachiopods that have been studied more thoroughly. However, the presence of numerous Silurian species in the Haragan Formation is consistent with recent work that suggests the magnitude of the Silurian–Devonian unconformity (Amsden, 1960,1988) is much less than previously thought (Barrick and Klapper, 1992).

## Systematic Paleontology

Order Trepostomida Ulrich, 1882
**Batostomella interporosa** Ulrich and Bassler, 1913
Figures 5E,F

*Batostomella interporosa* ULRICH AND BASSLER, 1913, p. 270, 271, pl. 45, figs. 1,2, pl. 48, fig. 5.

*Distinguishing characteristics.*—Zoarial form robust ramose branches; zooecial apertures oval, small; zooecia with no diaphragms; zooecial walls extremely thick; acanthorods numerous, large, but entirely contained within zooecial walls; mesopores subcircular, tiny; mesopores with abundant diaphragms.

**Callotrypa macropora** (Hall, 1874)
Figure 8J

*Callopora macropora* HALL, 1874, p. 101.

*Callopora (Callotrypa) macropora.* HALL AND SIMPSON, 1887, p. 24, 25, pl. 11, figs. 23–29.

*Callotrypa macropora.* ULRICH AND BASSLER, 1913, p. 271, 272, pl. 50, figs. 9,10.

*Distinguishing characteristics.*—Zoarial form delicate ramose branches; zooecial apertures polygonal, small.

**Cyphotrypa corrugata** (Weller, 1903)
Figures 4A,B; 5A

*Monotrypa corrugata* WELLER, 1903, p. 223, 224, pl. 18, figs. 1–5.

*Cyphotrypa corrugata.* ULRICH AND BASSLER, 1913, p. 269, 270, pl. 42, figs. 5–9, pl. 44, fig. 4, pl. 52, figs. 1,2.

*Distinguishing characteristics.*—Zoarial form unilaminar sheets or mushroom-shaped buttons; zooecial apertures polygonal (commonly hexagonal), large; zooecia with rare diaphragms; zooecial walls somewhat crenulated in longitudinal section; mesopores absent; acanthorods absent.

**Leioclema elasmaticum** Boardman, 1960
Figures 4C,D; 5B

*Leioclema elasmaticum* BOARDMAN, 1960, p. 48, pl. 4, figs. 5–8.

*Distinguishing characteristics.*—Zoarial form robust ramose branches; zooecial apertures circular, large; zooecia with rare diaphragms; acanthorods absent; one row of large, rectangular mesopores separating the zooecial apertures; mesopores with abundant diaphragms.

**Leioclema pulchellum** Ulrich and Bassler, 1913
Figures 4E,F; 5C

*Lioclema pulchellum* ULRICH AND BASSLER, 1913, p. 274, 275, pl. 43, figs. 9–12.

*Distinguishing characteristics.*—Zoarial form hemispherical domes, unilaminar sheets, or robust ramose branches; zooecial apertures circular, small to large; zooecia with rare diaphragms; two or more rows of small, polygonal mesopores separating the zooecial apertures; mesopores with abundant diaphragms; large acanthorods common around both zooecial apertures and mesopores.

**Leioclema subramosum** Ulrich and Bassler, 1913
Figures 4G,H; 5D

*Lioclema subramosum* ULRICH AND BASSLER, 1913, p. 273, 274, pl. 43, figs. 1–4, pl. 44, fig. 5.

*Distinguishing characteristics.*—Zoarial form hemispherical domes, robust ramose branches, or unilaminar sheets; zooecial apertures polygonal, small; zooecia with rare diaphragms; numerous small, polygonal mesopores separating the zooecial apertures; mesopores with abundant diaphragms; large acanthorods abundant everywhere on zoarium.

**Stromatotrypa globularis** Ulrich and Bassler, 1913
Figures 5G; 8F

*Stromatotrypa globularis* ULRICH AND BASSLER, 1913, p. 279, 280, pl. 42, figs. 1–4, pl. 46, figs. 8,9.

*Distinguishing characteristics.*—Zoarial form unilaminar sheets or hemispherical domes; zooecial apertures circular, medium-sized, encircled by low peristome; thin row of small mesopores separating zooecial apertures.

Order Cystoporida Astrova, 1964
Suborder Ceramoporina Bassler, 1913
**Ceramopora imbricata** Hall, 1852
Figures 5H; 6G,H

*Ceramopora imbricata* HALL, 1852, p. 169, pl. 40E, fig. 1; BASSLER, 1906, p. 19, pl. 6, figs. 1–10; BASSLER, 1953, p. 81, fig. 43.1; UTGAARD, 1983, p. 358, 359, fig. 156.1.

*Distinguishing characteristics.*—Zoarial form unilaminar sheets or massive domes; zooecia oriented obliquely and imbricating; zooecia without diaphragms; zooecial apertures elongate-oval to diamond-shaped and culvertlike, large; lunaria hoodlike, large; some zoaria with a single row of polygonal mesopores between zooecial apertures.

Suborder Fistuliporina Astrova, 1964
**Coelocaulis aff. venusta** (Hall, 1874)
Figure 8G

*Callopora venusta* HALL, 1874, p. 101, 102.

*Callopora (Coelocaulis) venusta.* HALL AND SIMPSON, 1887, p. 23, pl. 12, figs. 20–24, pl. 23A, figs. 1–5.

*Coelocaulis venusta.* BASSLER, 1953, p. 84, fig. 50.4; UTGAARD, 1983, p. 385, fig. 177.2.

*Distinguishing characteristics.*—Zoarial form hollow ramose branches; zooecial apertures circular, small, encircled by low, nodose peristome.

**Cyclotrypa mutabilis** (Hennig, 1908)
Figures 6A,B; 7A

*Fistulipora mutabilis* HENNIG, 1908, p. 19–22, text-figs. 21–23, pl. 2, figs. 1–7, pl. 7, figs. 3,4.

*Fistulipora? mutabilis.* BOLTON, 1966, p. 520, 521, pl. 82, figs. 2,5,7,8.

*Distinguishing characteristics.*—Zoarial form massive domes or unilaminar sheets; zooecia oriented approximately vertically; zooecia with rare diaphragms; zooecial apertures circular, large; lunaria low to absent, hoodlike; cystopores polygonal in transverse section, large.

**Fistuliporella maynardi** Ulrich and Bassler, 1913
Figures 6C,D; 7B

*Fistuliporella maynardi* ULRICH AND BASSLER, 1913, p. 266, 267, pl. 46, figs. 3–7.

*Distinguishing characteristics.*—Zoarial form unilaminar sheets or massive domes; zooecia oriented approximately vertically; zooecia with rare diaphragms; zooecial apertures irregular and subcircular, large; lunaria hook-shaped, small; cystopores irregular in transverse section, small.

**Fistuliporella quinquedentata** Ulrich and Bassler, 1913
Figures 6E,F; 7C

*Fistuliporella quinquedentata* ULRICH AND BASSLER, 1913, p. 264, 265, pl. 41, figs. 6–8.

*Distinguishing characteristics.*—Zoarial form massive domes or unilaminar sheets; zooecia oriented approximately vertically; zooecia with rare diaphragms; zooecial apertures trilobed, small; lunaria horseshoe-shaped, large; cystopores polygonal in transverse section, small.

Order Cyclostomida Busk, 1852
Suborder Tubuliporina Milne-Edwards, 1838
**Flabellotrypa rugulosa** Bassler, 1952
Figure 8E

*Flabellotrypa rugulosa* BASSLER, 1952, p. 381, fig. 1; BASSLER, 1953, p. 43, fig. 13.11.

*Distinguishing characteristics.*—Zoarial form tiny encrusting disks; zooecia oriented horizontally, with small, circular apertures opening only around outer margin of zoarium.

Order Cryptostomida Vine, 1883
Suborder Rhabdomesina Astrova and Morozova, 1956
rhomboporoid gen. et sp. indet.

*Distinguishing characteristics.*—Zoarial form delicate ramose branches; zooecial apertures rectangular, tiny, arranged in parallel rows.

Suborder Ptilodictyina Astrova and Morozova, 1956
**Ptilodictya tenella** Ulrich and Bassler, 1913
Figure 8H

*Ptilodictya tenella* ULRICH AND BASSLER, 1913, p. 288, 289, pl. 42, fig. 10, pl. 48, figs. 7,8.

*Distinguishing characteristics.*—Zoarial form bifoliate sticks, unbranched; zooecial apertures rectangular, tiny, arranged in parallel rows.

Suborder Fenestrina Elias and Condra, 1957
**Fenestella idalia** Hall, 1874
Figures 7G; 8A

*Fenestella idalia* HALL, 1874, p. 95, 96; HALL AND SIMPSON, 1887, p. 52, 53, pl. 21, figs. 6–9.
*Fenestella? idalia.* ULRICH AND BASSLER, 1913, p. 281, 282, pl. 52, figs. 9–11.

*Distinguishing characteristics.*—Zoarial form fenestrate fronds; branches with tuning-fork branching pattern; frontal surface with two rows of small zooecial apertures separated by a thin prominent carina; reverse surface finely striated; fenestrules rectangular, small.

**Fenestella? cf. lilia** (Hall, 1874)
Figure 8D

*Polypora lilia* HALL, 1874, p. 96, 97.
*Fenestella (Polypora) lilaea.* HALL AND SIMPSON, 1887, p. 62, pl. 18, figs. 19–22.

*Distinguishing characteristics.*—Zoarial form fenestrate fronds; branches with irregular branching pattern; branches not distinct from dissepiments; fenestrules subpolygonal, small.

**Fenestella sinuosa** Hall, 1886
Figure 8B

*Fenestella sinuosa* HALL, 1886, expl. of pl. 44, figs. 5,6; HALL AND SIMPSON, 1887, p. 116, pl. 44, figs. 5,6.
*Fenestella* cf. *F. sinuosa.* ELLISON, 1965, p. 55, pl. 4, fig. 9.

*Distinguishing characteristics.*—Zoarial form fenestrate fronds; branches sinuous and anastamosing; fenestrules diamond-shaped, medium-sized.

**Fenestella stellata** Hall, 1883
Figure 7D

*Fenestella stellata* HALL, 1883, p. 170, 171; HALL AND SIMPSON, 1887, p. 109, pl. 45, figs. 14,15; pl. 47, figs. 20–36.

*Distinguishing characteristics.*—Zoarial form fenestrate fronds; two rows of small zooecial apertures along frontal surface of branches, with additional very large apertures at junction of branches and dissepiments; fenestrules rectangular, small.

**Polypora distans** (Hall, 1883)
Figure 8C

*Fenestella distans* HALL, 1883, p. 165.
*Fenestella (Polypora) distans.* HALL AND SIMPSON, 1887, p. 161, pl. 37, figs. 2–10,15, 17, pl. 44, fig. 7.

*Distinguishing characteristics.*—Zoarial form fenestrate fronds; branches with tuning-fork branching pattern; fenestrules rectangular, large.

**Thamniscus cf. regularis** Ulrich and Bassler, 1913
Figure 7E

*Thamniscus regularis* ULRICH AND BASSLER, 1913, p. 286, pl. 47, figs. 4–6.

*Distinguishing characteristics.*—Zoarial form delicate ramose branches; branches bifurcating at regular intervals, and as branching point is approached, branch width increasing gradually; branches comparatively wide; reverse surface finely striated.

**Thamniscus variolata** Hall, 1879
Figures 7F; 8I

*Thamniscus variolata* HALL, 1879, p. 175; HALL AND SIMPSON, 1887, p. 41, 42, pl. 22, figs. 34–46.

*Distinguishing characteristics.*—Zoarial form delicate ramose branches; branching pattern irregular; branches comparatively thin; frontal surface with irregularly scattered, small, circular zooecial apertures; reverse surface smooth.

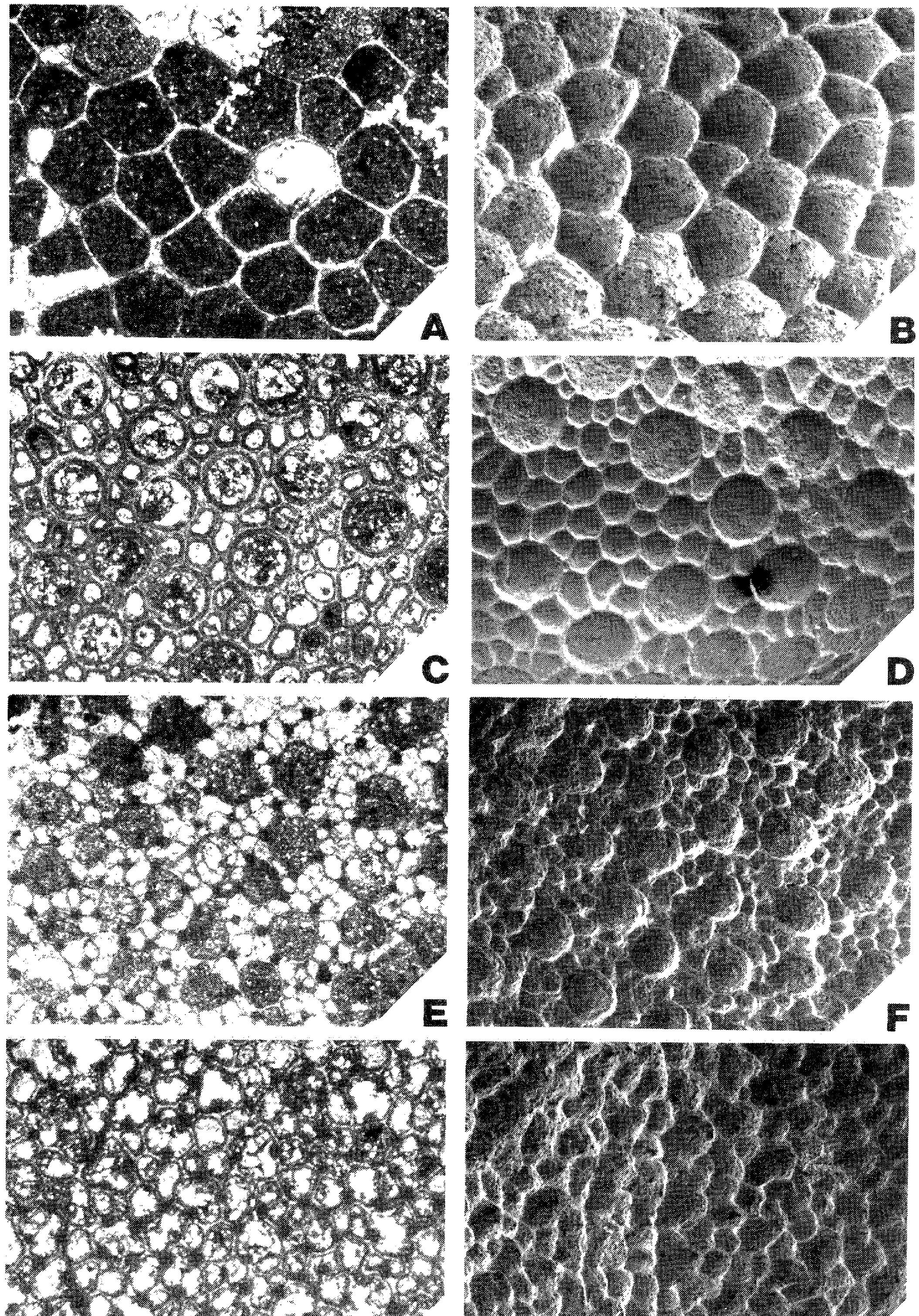


Figure 4. *A,B—Cyphotrypa corrugata*; *A*—tangential section, ×20 (OKLMUR-M2-201); *B*—external surface, ×20 (OKLMUR-M2-202). *C,D—Leioclema elasmaticum*; *C*—tangential section, ×20 (OKLCOA-C1-203); *D*—external surface, ×20 (OKLMUR-M2-204). *E,F—Leioclema pulchellum*; *E*—tangential section, ×20 (OKLCOA-C1-205); *F*—external surface, ×20 (OKLCOA-C1-205). *G,H—Leioclema subramosum*; *G*—tangential section, ×30 (OKLCOA-C1-206); *H*—external surface, ×30 (OKLMUR-107.2-207).

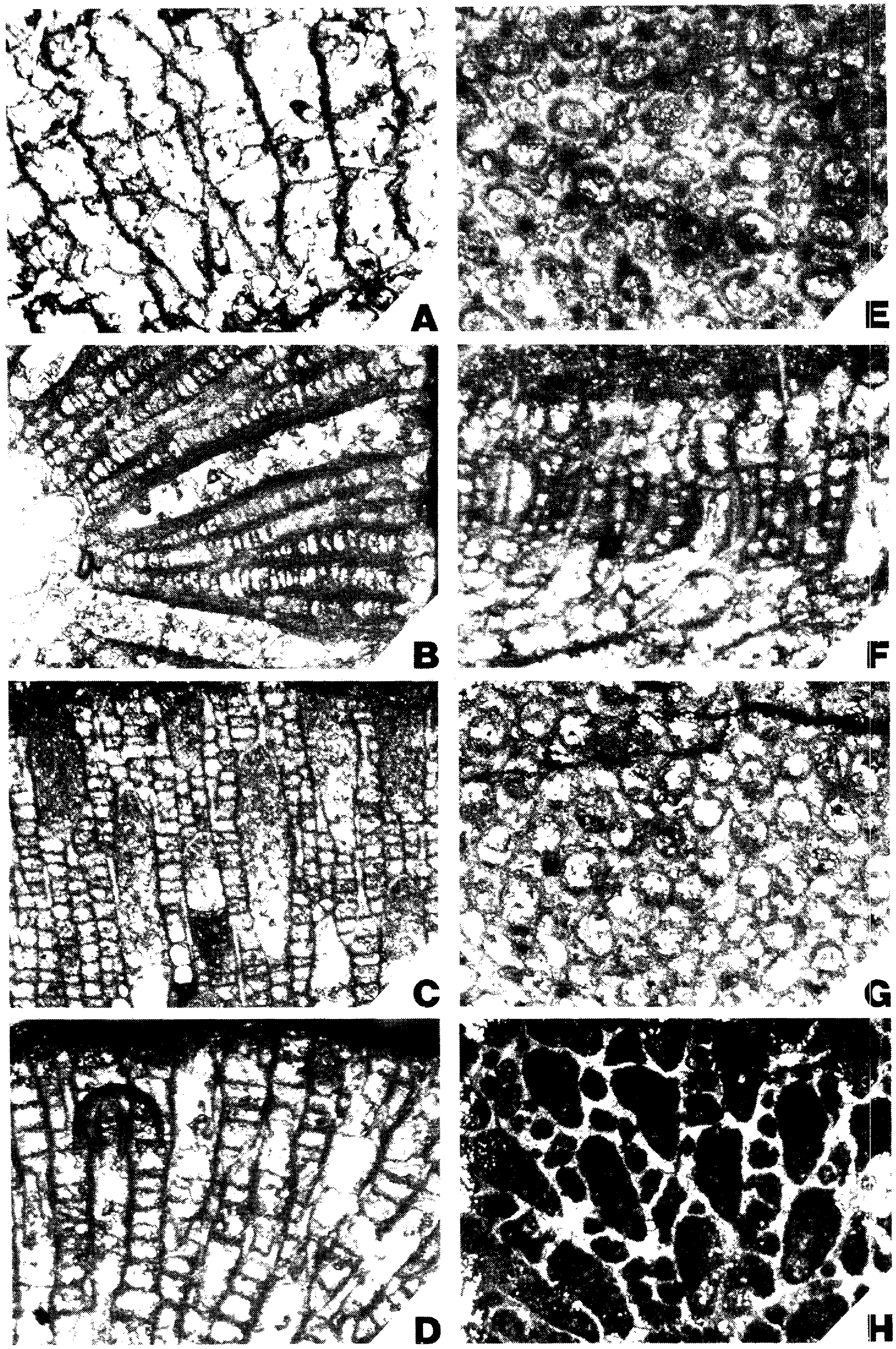

Figure 5. *A—Cyphotrypa corrugata*, longitudinal section, ×20 (OKLMUR-M2-201). *B—Leioclema elasmaticum*, transverse section, ×20 (OKLCOA-C1-203). *C—Leioclema pulchellum*, longitudinal section, ×20 (OKLCOA-C1-205). *D—Leioclema subramosum*, transverse section, ×30 (OKLCOA-C1-206). *E,F—Batostomella interporosa*; *E*—tangential section, ×30 (OKLMUR-M2-208); *F*—longitudinal section, ×30 (OKLMUR-M2-208). *G—Stromatotrypa globularis*, tangential section, ×20 (OKLMUR-M2-209). *H—Ceramopora imbricata*, tangential section, ×20 (OKLMUR-M2-210).

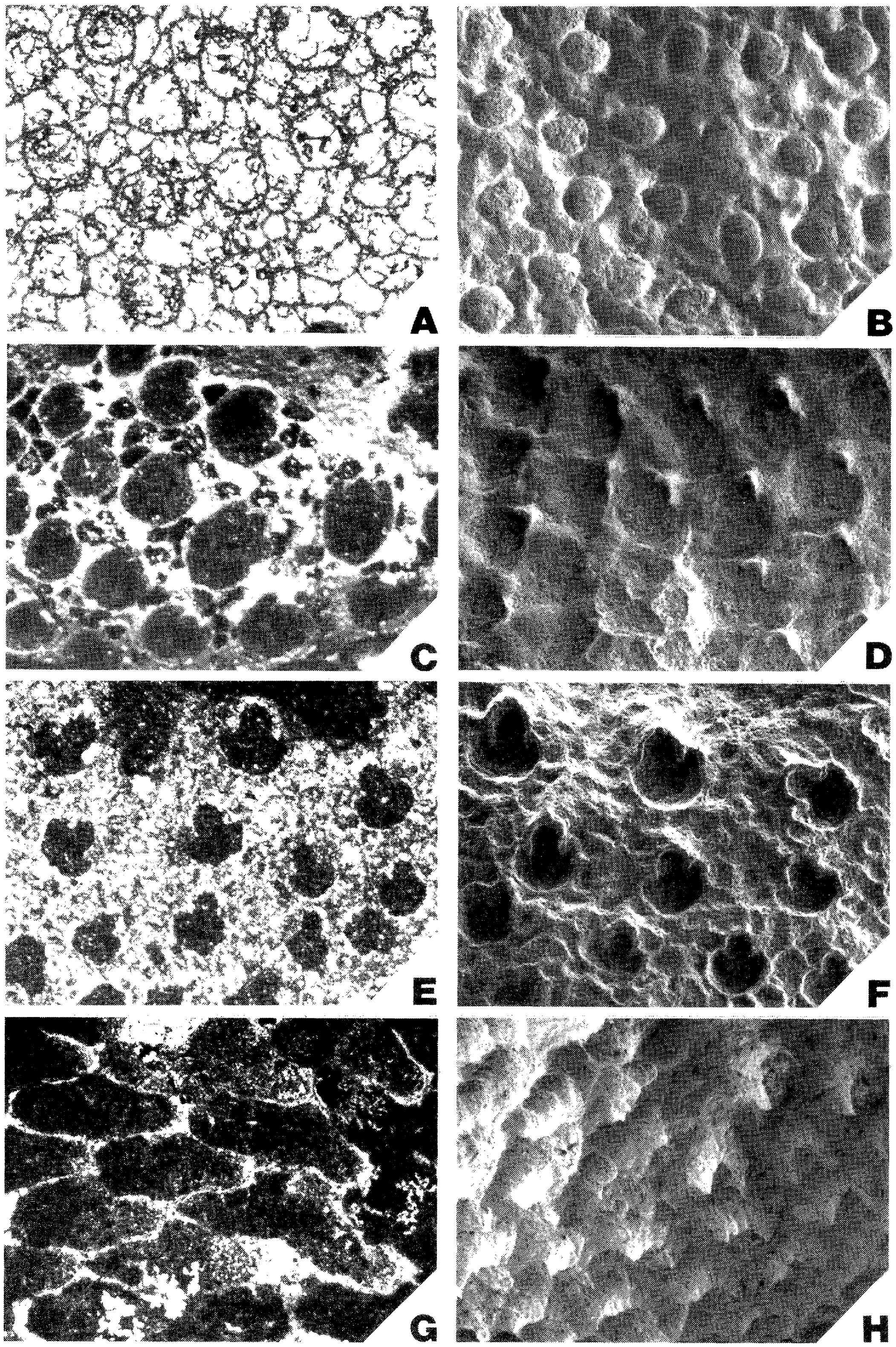


Figure 6. *A,B—Cyclotrypa mutabilis*; *A*—tangential section, ×20 (OKLMUR-M2-211); *B*—external surface, ×20 (OKLMUR-M2-212). *C,D—Fistuliporella maynardi*; *C*—tangential section, ×20 (OKLMUR-M2-213); *D*—external surface, ×20 (OKLMUR-M2-214). *E,F—Fistuliporella quinquedentata*; *E*—tangential section, ×30 (OKLMUR-M2-215); *F*—external surface, ×30 (OKLMUR-M2-216). *G,H—Ceramopora imbricata*; *G*—tangential section, ×20 (OKLMUR-M2-217); *H*—external surface, ×20 (OKLCOA-C1-218).

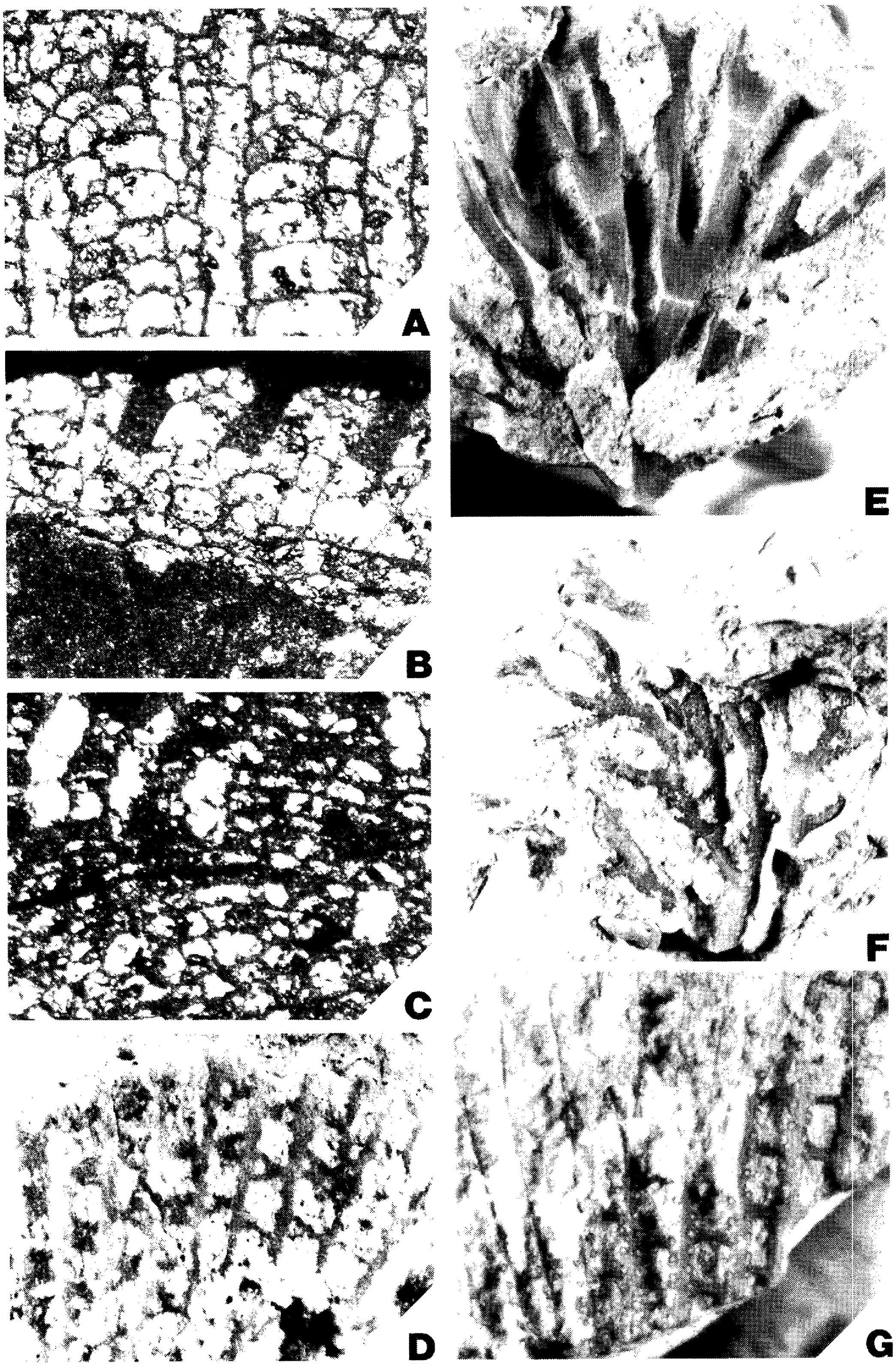


Figure 7. *A—Cyclotrypa mutabilis*, longitudinal section, ×20 (OKLMUR-M2-219). *B—Fistuliporella maynardi*, longitudinal section, ×20 (OKLMUR-M2-214). *C—Fistuliporella quinquedentata*, longitudinal section, ×30 (OKLMUR-M2-220). *D—Fenestella stellata*, frontal surface, ×10 (OKLCOA-C1-221). *E—Thamniscus* cf. *regularis*, reverse surface, ×6 (OKLMUR-M2-222). *F—Thamniscus variolata*, reverse surface, ×6 (OKLMUR-M2-223). *G—Fenestella idalia*, frontal surface, ×10 (OKLMUR-M2-224).

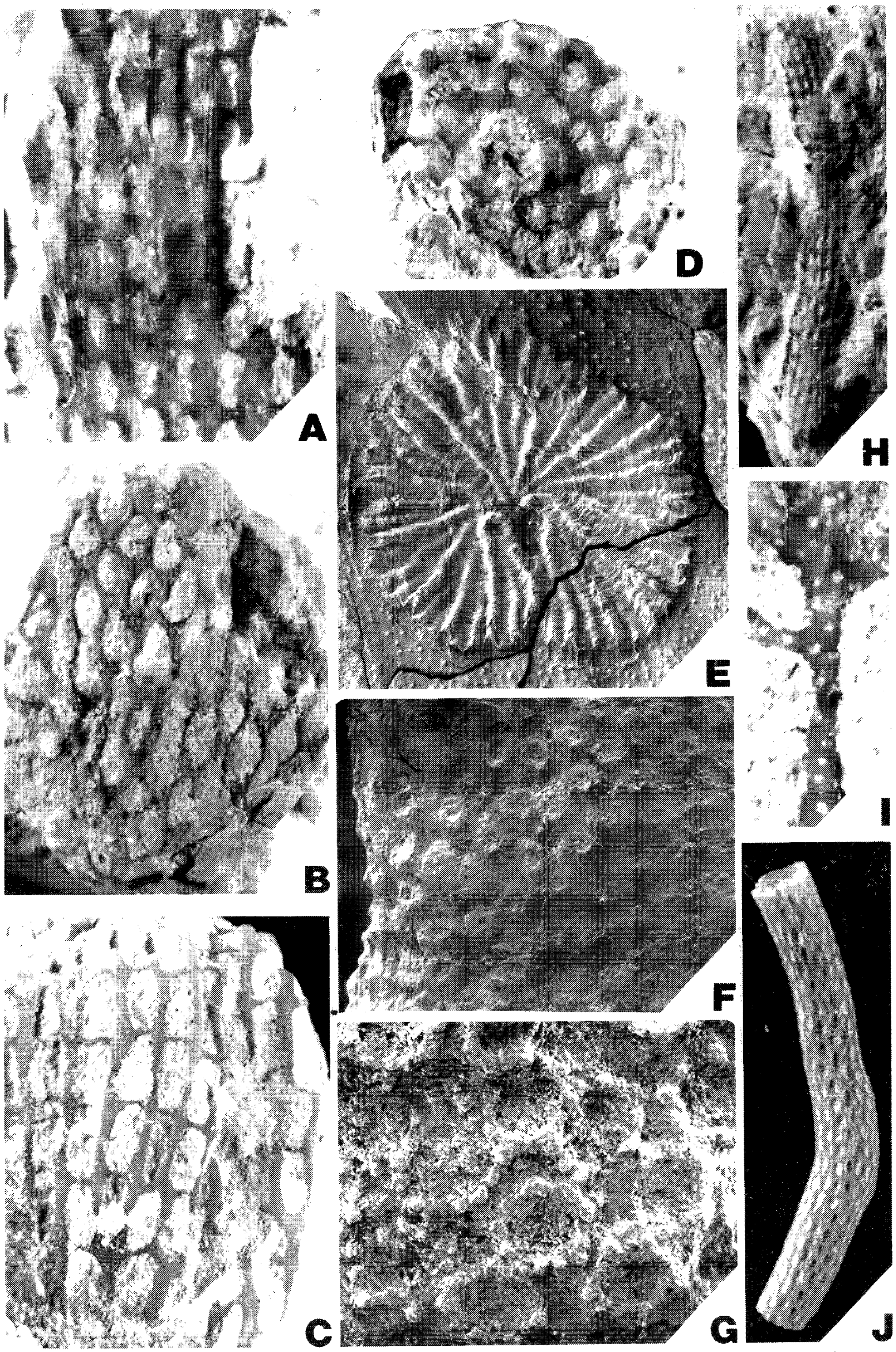


Figure 8. *A—Fenestella idalia*, reverse surface, ×10 (OKLMUR-M2-225). *B—Fenestella sinuosa*, reverse surface, ×6 (OKLMUR-M2-226). *C—Polypora distans*, reverse surface, ×6 (OKLMUR-M2-227). *D—Fenestella* aff. *lilia*, reverse surface, ×6 (OKLMUR-107.2-228). *E—Flabellotrypa rugulosa*, external surface, ×10 (OKLMUR-M2-229). *F—Stromatotrypa globularis*, external surface, ×20 (OKLMUR-M2-230). *G—Coelocaulis* aff. *venusta*, external surface, ×30 (OKLMUR-107.2-231). *H—Ptilodictya tenella*, external surface, ×6 (OKLMUR-107.2-232). *I—Thamniscus variolata*, frontal surface, ×10 (OKLMUR-M2-233). *J—Callotrypa macropora*, external surface, ×6 (OKLMUR-M2-234).

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## APPENDIX: New Locality

**107.2 CUT:** Road cut on north side of access road to the Goddard Youth Camp, ~2.5 mi northeast of Dougherty, Murray County, Oklahoma; SW¼NW¼ sec. 32, T. 1 S., R. 3 E.; Dougherty, Oklahoma, 1:24,000 scale topographic map (USGS).

# NEW OGS *Publication*

**GEOLOGIC MAP OF THE ADAMSON QUADRANGLE, PITTSBURG AND LATIMER COUNTIES, OKLAHOMA.** One sheet, scale 1:24,000. Xerox copy. Price: $6, rolled in tube.

The Ouachita STATEMAP project, which began in 1993, is a joint effort of the Oklahoma Geological Survey and the U.S. Geological Survey to prepare new 1:24,000 geologic maps of the Ouachita Mountains and Arkoma basin in Oklahoma. STATEMAP is part of the National Cooperative Geologic Mapping Program and replaces the successful COGEOMAP program, which began in 1984. Under COGEOMAP, the OGS completed and published 15 7.5′ geologic quadrangle maps along the northern part of the Ouachita Mountains frontal belt and southern part of the Arkoma basin.

During the first year of STATEMAP, in early 1994, the Oklahoma Geologic Mapping Advisory Committee, chaired by OGS associate director Kenneth S. Johnson, was established to recommend mapping priorities for the State. The committee recommended Pittsburg County, especially near McAlester, as an important area for OGS efforts. The committee chose the McAlester area for several reasons: (1) Coal has been a major resource in the area, and substantial reserves still are present. (2) A number of natural-gas fields have been discovered recently and others are being developed in this part of the Arkoma basin, and the giant Wilburton deep gas field was discovered in 1987 immediately east of the area. (3) Environmental problems resulting from open mine shafts, undocumented underground mines, and poor reclamation practices in the past may impact urban development near McAlester, as well as rural development throughout the region. (4) Several type localities of Arkoma basin formations are in the area, but are unmeasured or otherwise poorly documented.

The Adamson Quadrangle, by LeRoy A. Hemish, is the first of a series of STATEMAP geologic maps of Pittsburg County. It is now available as a black-and-white, author-prepared xerox copy, comprising geologic map, cross sections, description and correlation of units, and a list of gas wells. This map is an important addition to the series of previously mapped quadrangles because of its proximity to the expanding urban area of McAlester. Planners for new highway construction, building construction, and abandoned coal-mine reclamation will find the map useful in addressing environmental concerns. Lake Eufaula, with its recreational potential, extends into the quadrangle. Further economic assets of the area include gas reservoirs and documented coal reserves in several of Oklahoma's principal coal beds.

COGEOMAP and STATEMAP maps also are available for the Higgins, Damon, Baker Mountain, Panola, Wilburton, Red Oak, Leflore, Talihina, Leflore Southeast, Blackjack Ridge, Gowen, Summerfield, Hodgen, Hontubby/Loving, Wister, and Heavener/Bates Quadrangles.

COGEOMAP and STATEMAP geologic quadrangle maps can be purchased over the counter or by mail from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031 *or* (800) 330-3996, fax 405-325-7069. For mail orders of 1–10 maps, add $1.50 to the cost for postage and handling.

# AAPG Mid-Continent Section Meeting
# Tulsa, Oklahoma • October 8–10, 1995

**Our theme this year is *"Technology Transfer: Crossroads to the Future."* The Mid-Continent has experts in all aspects of petroleum geology. As more of us have become consultants, we are using our expertise anywhere and everywhere in the world, transferring the technology we have developed and used to other uses and locations. Technical sessions will focus on new technologies and innovative exploration techniques, domestic and international exploration and exploitation, reservoir characterization and engineering studies, environmental and hydrologic studies, business aspects of petroleum geology—domestic and foreign, and sequence stratigraphy.**

**—Jean R. Lemmon**
***General Chairman***

## *Schedule of Events*

### Technical Sessions

***October 9, Monday***

New Technologies and Innovative Exploration Techniques
Emerging Scientists/Student Papers
Geophysical Studies in Exploration and Development
Regional Geology and Recent Discoveries
Domestic and International Exploration and Exploitation—Opportunities and Comparisons of Methods
New Technologies and Innovative Exploration Techniques

***October 10, Tuesday***

Reservoir Characterization and Engineering Studies
Environmental and Hydrologic Studies
Business Aspects of Petroleum Geology—Domestic and Foreign
Sequence Stratigraphy in the Mid-Continent

### Short Courses

3-D Seismic: What Every Geologist Should Know About Acquisition and Processing
Mid-Continent Reservoir Core Workshop

### Field Trips

Reservoir Characteristics of the Bartlesville (Bluejacket) Sandstone, Oklahoma, *Oct. 5–8*
Geology and Resources of the Eastern Ouachita Mountains Frontal Belt and Southeastern Arkoma Basin, Oklahoma, *Oct. 10–12*

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For more information, contact AAPG, 1995 Mid-Continent Section Meeting, P.O. Box 979, Tulsa OK 74101-0979; phone (918) 584-2555, fax 918-560-2684. *The preregistration deadline is September 8.*

# ROCKHOUND WORKSHOP

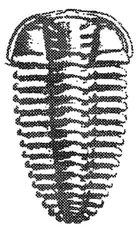
## Oklahoma City, Oklahoma
## October 28–29, 1995

A workshop for rockhounds, co-sponsored by the Oklahoma Geological Survey, the Gem and Mineral Clubs of Oklahoma, and Omniplex Science Museum, will be held Saturday and Sunday, October 28–29, at the Omniplex Science Museum in Oklahoma City.

The workshop is intended to bring together rockhounds, educators, representatives from government agencies, and the public to discuss topics of concern to amateurs collecting rocks, minerals, and fossils in Oklahoma and surrounding states. Rockhounding is a popular recreational activity throughout the United States, and this will be an opportunity to share information on how to collect, prepare, study, and display minerals and fossils. Kenneth S. Johnson and Neil H. Suneson, Oklahoma Geological Survey geologists, are the meeting co-chairs.

## PROGRAM

### October 28, Saturday



Geology of Oklahoma, by Ken Johnson, Oklahoma Geological Survey, Norman

Minerals of Oklahoma, by Leon Gilmore, Tahlequah and Tulsa Rock and Mineral Societies, Tahlequah

Fossils of Oklahoma, by Larry Simpson, Garber–Wellington Association, Oklahoma City

Mineral Collecting, Preparation, and Display, by David London, University of Oklahoma, School of Geology and Geophysics, Norman

Fossil Collecting, Preparation, and Display, by Richard and Linda Jaeger, Tulsa Memorial High School and Tulsa Rock and Mineral Society, Tulsa

Collecting Minerals and Fossils on Native American Lands, by Bruce Maytubby, Bureau of Indian Affairs, Anadarko; and Randy Trickey, Bureau of Indian Affairs, Muskogee

Ethics in Collecting Minerals and Fossils, by Dan Lingelbach, Regional Vice President of American Federation of Mineralogical Societies, Stillwater

Panel Discussion: "Rockhounds' Rights Versus Government Restrictions on Collecting Minerals and Fossils." Panelists are: John Alf, Director of American Lands Access Association and Tulsa Rock and Mineral Society, Bartlesville; John Nichols, Ouachita National Forest, Hot Springs, Arkansas; Bill Runnoe, Oklahoma Department of Tourism and Recreation, Oklahoma City; and Mike O'Neill, Bureau of Land Management, Albuquerque, New Mexico

### October 29, Sunday

Preparation of Vertebrate Fossils, by Richard Cifelli, Oklahoma Museum of Natural History, Norman

Preparation of Invertebrate Fossils with Pneumatic Tools, by Bob Carroll, American Association of Paleontological Suppliers and Ada Hardrock and Fossil Club, Ada

Collecting, Identifying, and Displaying Fossil Wood, by Dick Wilson, Emeritus Professor, University of Oklahoma, School of Geology and Geophysics, Norman

Experiments in Earth Sciences for Public-School Teachers, by David London, University of Oklahoma, School of Geology and Geophysics, Norman; and Carol Egger, Putnam City School District and Oklahoma Mineral and Gem Society, Bethany

Considerations in Getting Teachers and Students Interested in Rockhounding and Geology, by L. E. "Verne" Groves, Shawnee Gem and Mineral Club, McAlester

Advertising and Promoting Rockhounding and Earth-Science Activities in Oklahoma, by Tom Creider and Vicki Runnoe, Oklahoma Department of Tourism and Recreation, Oklahoma City and Norman

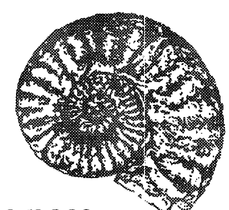
Interpreting Topographic Maps and Determining Specimen Locations, by Jim Chaplin, Oklahoma Geological Survey, Norman

Using Professional Literature as a Guide to Rockhounding, by LeRoy Hemish, Oklahoma Geological Survey, Norman; and Bob Shaha, Ada Hardrock and Fossil Club, Ada

Keeping a Field Book—Recording Data for Analysis and Future Use, by Susan Smith-Nash, University of Oklahoma, Department of English, Norman

Rockhound Information and Resources Available from Universities, Museums, Agencies, and Private Sources, by Neil Suneson, Oklahoma Geological Survey, Norman

## REGISTRATION FEES



The registration fee for the workshop is $7 per person before October 6, and $10 after October 6 or on-site. The fee covers the cost of the two-day program, coffee breaks, and a copy of the workshop proceedings volume to be published early in 1996. No group meals are planned. In addition to the workshop fee, registrants must pay $6 cash at Omniplex Science Museum for a pass that allows access to the museum during the two days of the workshop.

## FOR MORE INFORMATION

Kenneth S. Johnson *or* Neil H. Suneson
Oklahoma Geological Survey
100 E. Boyd, Room N-131
Norman, OK 73019
Phone: (405) 325-3031 *or* (800) 330-3996
FAX: (405) 325-7069

For registration forms, contact Tammie Creel at the address and phone numbers above.

# UPCOMING *Meetings*

**Oklahoma Mid-Continent Oil and Gas Association 76th Annual Meeting,** September 27–28, 1995, Oklahoma City, Oklahoma. Information: Pam Webb, Mid-Continent Oil and Gas Association, 501 W. Interstate 44, Suite 320, Oklahoma City, OK 73118; (405) 843-5741.

**SEPM Research Conference, "Alluvial Fans: Processes, Forms, Controls, Facies Models, and Use in Basin Analysis,"** October 17–21, 1995, Death Valley, California. Information: Myra Lee Rogers, Society for Sedimentary Geology, 1731 E. 71st St., Tulsa, OK 74136; (918) 493-3361 *or* (800) 865-9765, fax 918-493-2093.

**Minerals and Geotechnical Logging Society Sixth International Symposium on Borehole Geophysics for Minerals, Geotechnical, and Groundwater Applications,** October 22–25, 1995, Santa Fe, New Mexico. Information: Carol LaDelfe, EES-1, MS D462, Los Alamos National Laboratory, Los Alamos, NM 87545; (505) 667-8474, fax 505-665-3285.

**Society of Petroleum Engineers, Technical Conference and Exhibition,** October 22–25, 1995, Dallas, Texas. Information: SPE, Meetings and Exhibitions Dept., Box 833836, Richardson, TX 75083; (214) 952-9393, fax 214-952-9435.

**Gulf Coast Association of Geological Societies/Gulf Coast Section of SEPM, Annual Meeting,** October 25–27, 1995, Baton Rouge, Louisiana. Information: Arnold H. Bouma, Dept. of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70803; (504) 388-6186, fax 504-388-2302.

**Rockhound Workshop,** October 28–29, 1995, Oklahoma City, Oklahoma. Information: Kenneth S. Johnson or Neil H. Suneson, Oklahoma Geological Survey, 100 E. Boyd, Room N-131, Norman, OK 73019; (405) 325-3031 *or* (800) 330-3996, fax 405-325-7069. *For program, see page 152, this issue.*

**Society of Vertebrate Paleontology, Annual Meeting,** November 1–4, 1995, Pittsburgh, Pennsylvania. Information: Chris Beard or Mary Dawson, Section of Vertebrate Paleontology, Carnegie Museum of Natural History, Pittsburgh, PA 15213; (412) 622-3246 *or* 622-5782, fax 412-622-8837.

**North American Water Resources, Annual Conference,** November 5–9, 1995, Houston, Texas. Information: American Water Resources Association, 950 Herndon Pkwy., Suite 300, Herndon, VA 22070; (703) 904-1225, fax 703-904-1228.

**Geological Society of America, Annual Meeting,** November 6–9, 1995, New Orleans, Louisiana. Information: GSA Meetings Dept., Box 9140, Boulder, CO 80301; (303) 447-2020 *or* (800) 472-1988, fax 303-447-0648; E-mail: meetings@geosociety.org.

**American Petroleum Institute, Annual Meeting,** November 12–13, 1995, Houston, Texas. Information: API, 700 N. Pearl St., Suite 1840, Dallas, TX 75201; (214) 953-1101.

**Platform Carbonates in the Southern Midcontinent Workshop,** March 26–27, 1996, Norman, Oklahoma. *Abstracts due November 1, 1995.* Information: Kenneth S. Johnson, Oklahoma Geological Survey, 100 E. Boyd, Room N-131, Norman, OK 73019; (405) 325-3031 *or* (800) 330-3996, fax 405-325-7069.

**American Association of Petroleum Geologists, Annual Meeting,** May 19–22, 1996, San Diego, California. *Abstracts due October 13, 1995.* Information: AAPG Convention Dept., P.O. Box 979, Tulsa, OK; (303) 444-6405, fax 303-444-2260.

# *Oklahoma* ABSTRACTS

The Oklahoma Geological Survey thanks the American Association of Petroleum Geologists and the Geological Society of America for permission to reprint the following abstracts of interest to Oklahoma geologists.

## Importance of the Chestnut 18-4 Drill Core in Resolving the Origin of the Ames Structural Anomaly, Major County, Oklahoma

*CLIFFORD P. AMBERS* and *M. CHARLES GILBERT*, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019

The Ames structural anomaly is an approximately 10-km diameter, circular, structural disturbance, southeastern Major County, Oklahoma. Much of what is known has been determined by remote sensing and drill-hole logs in the effort to exploit the rich oil and gas resources of the feature. Emphasis on indirect information has led to conflicting interpretations for the structure including volcanic, diagenetic/hydrothermal dissolution, and extraterrestrial bolide impact models. Of some 300 wells drilled into the structure a remarkably small amount of rock has been recovered. The Oklahoma Geological Survey lists less than fifteen short core sections or sidewall borings available for examination. Of these, the Chestnut 18-4 drill core provides one of the most complete sections making up the most complex and enigmatic zone. Below the top of the Arbuckle Group, the normally monotonous stratigraphy found in the northern shelf area is profoundly disturbed. At the top of the Arbuckle Group, a peculiar, vesicular, melt rock containing abundant granite fragments occurs and is overlain by an upward fining unit of granule- to silt-sized granite fragments and dolomite-replaced glass shards. These rock units and a portion of the overlying Oil Creek Formation are represented in the Chestnut 18-4 core at a depth of 8948′–9042′ (~2.7 km). Detailed examination using petrography, cathodoluminescence, electron microprobe analysis, and x-ray diffraction provides new information.

Fabrics in the deformed/melted rocks include shock lamellae in quartz and feldspar, intense kinking of micas, vesiculation and flow fabrics in the edges of granitic fragments and matrix, relict perlitic cracks in quartz grains, millimeter-scale quartz bodies with delicate flow structures, shattered relic apatite and zircon in the granite fragments, and peculiar alteration of sphene to rutile and magnetite(?) to pyrite + chlorite in the granite fragments. Lack of sodic phases was noted in the melt rocks. Diagenetic alteration overprinted these materials. Devitrification of multicomponent glasses, argillization, isochemical recrystallization of glasses dominated by silica, and replacements/pore-fillings of dolomite, quartz, sulfides, chlorite, and K-feldspar add to the complexity of the rock.

We find no evidence in the Chestnut core that relates deformation/melting to terrestrial processes. Features are compatible with shock metamorphism and relate closely to impact meltrocks and ejecta associated with surface impact examples throughout the world. We conclude that the Ames structure is a deeply buried, ancient impact site. Drill core is essentially in the interpretation of subsurface geologic problems.

Reprinted as published in the Geological Society of America *1995 Abstracts with Programs*, v. 27, no. 3, p. 34.

## Anadarko Basin: Modeling the Megacompartments

*J. MILES MAXWELL, CHANGXING QIN, JUDY LUNARDINI, KHAIREDDINE SAKRANI,* and *PETER J. ORTOLEVA,* Dept. of Geological Sciences, Indiana University, Bloomington, IN 47405

CIRF.B3D, a three dimensional model of the generation of abnormal pressures and fluid migrations in the Anadarko basin, is presented. The model shows in detail how the sedimentary, stress and thermal history of the basin can lead to the development of the compartmented regions of abnormal pressure in the basin. Pressure seals are shown to arise by a combination of mechanical and pressure-solution mediated compaction. The latter in particular yields the tightly fitting fabrics that allow for the sub-nanodarcy permeabilities that can maintain significant pressure abnormalities on the 100 million year time frame.

The input to the CIRF.B3D model consists of a detailed sedimentologic and petrologic description of the basin, and of the reconstruction of its burial (tectonic and thermal) history. For this study of the Anadarko basin we used published data and our petrologic observations as well as those of Z. Al-Shaieb and J. Puckette of Oklahoma State University. The model then predicts the development of compartments defined as three dimensional domains isolated from the surroundings by very low permeability seals. The results obtained are then compared in detail to the observations made on the Anadarko basin. The predictions made by our model are in good agreement with observed petrologic and pressure data.

Reprinted as published in the American Association of Petroleum Geologists *1995 Annual Convention Official Program,* v. 4, p. 62A.

## Stratigraphic Distribution and Interpretation of a Pennsylvanian "Time Slice" (Croweburg Coal to Verdigris Limestone)

*J. M. ELICK,* Dept. of Geology, Kansas State University, Manhattan, KS 66506

The interval of study consists of the Croweburg coal through the Verdigris limestone. It is exposed in southeastern Kansas, Oklahoma, and Missouri and has been correlated within three basins across Kansas: the Cherokee, Sedgwick, and Hugoton Embayment of the Anadarko Basin. These basins are separated by the Nemaha Anticline and the Central Kansas Uplift, two post Mississippian features.

Sections across each basin indicate that changes of facies within and between basins are the result of changes in climate, eustasy, and tectonics. The study interval in the Cherokee Basin was strongly influenced by changes in climate and subsidence. The sequence (up to 7 m thick) consists of a vertic-like paleosol, coal, an intermittent grey mudrock, a carbonaceous black shale, and an argillaceous limestone. In the Sedgwick Basin, the interval contains a variegated shale, a black shale, and a cherty, less argillaceous limestone. There appears to have been very little tectonic activity in the Sedgwick Basin during this time, and the basin was probably similar to a carbonate platform. West of the Central Kansas Uplift, in the Hugoton Embayment, channel deposits, probably cut by streams flowing off the Central Kansas Uplift, occur in this interval. Farther west, a paleosol containing calcareous nodules is overlain by black shale, and the sequence is capped by a "clean," fossiliferous limestone.

Considering the paleolatitude of Kansas during the Late Paleozoic, it appears that climate played a major role in the facies distribution across the state. The vertical and lateral stratigraphic relationships between all of the facies in the interval suggest a pos-

sible climatic spectrum from wetter to drier, combined with eustatic changes. The Cherokee Basin was near the equatorial region with a predominantly wet environment. The Sedgwick Basin and the Hugoton Embayment were at slightly higher latitudes and were subject to drier conditions.

Reprinted as published in the Geological Society of America *1995 Abstracts with Programs*, v. 27, no. 3, p. 47.

## Pressure Regimes, Burial History, and Source Rock Maturation of the Morrow Formation in the Western Anadarko Basin and the Hugoton Embayment, Kansas, Oklahoma, and Texas

*LARS B. HUBERT*, Dept. of Geology and Geophysics, University of Wyoming, Laramie, WY 82071

The western Anadarko Basin and the Hugoton Embayment have been subject to uplift and erosion during the Tertiary. The flanks have been uplifted more than the deep basin: approximately 5,500 feet of sediment have been removed from the deep basin, and 6,500 from the Hugoton Embayment. The deep Morrowan source rocks have generated both oil and gas. The source rocks in the Oklahoma Panhandle and Kansas are marginally mature, and may have generated some oil, but no gas. Hydrocarbon maturation is now dormant due to reduction of temperatures during uplift.

Three pressure regimes are found in the Morrow Formation in the study area. The shallow reservoirs are water saturated, and follow a hydrostatic gradient. This zone is termed the hydrostatic zone. Below this lies the low-pressure gas zone. This zone is gas-saturated and pressures here are low due to depletion of gas as seals breached during uplift. The deepest zone, termed the high-pressure gas zone, is also gas-saturated and coincides with mature source rocks. The high pressures were initiated during source-rock maturation, as hydrocarbons charged reservoirs.

As all rocks below the hydrostatic zone are gas-saturated, any reservoir rock with sufficient porosity and permeability should be a promising exploration target.

Reprinted as published in the American Association of Petroleum Geologists *1995 Annual Convention Official Program*, v. 4, p. 45A.

## Carbonate Diagenesis and Porosity Evolution of the Council Grove Group, (Upper Pennsylvanian–Lower Permian), Hugoton Embayment, Anadarko Basin, Southwest Kansas

*NICHOLAS J. PIERACACOS*, Dept. of Geology, Baylor University, Waco, TX 76798

The Hugoton Embayment of southwestern Kansas is a large, shelf-like extension of the Anadarko Basin of Oklahoma. Shallow-shelf carbonates of the giant Hugoton-Panhandle gas trend form the largest gas producing field in North America. The Council Grove Group is a major reservoir within this trend.

Lithologies identified in core include siltstones, dolostones, mudstones, wackestones, and packstones that are developed in somewhat variable repetitive sequences of shallow subtidal shelf to peritidal sabkha depositional environments. A shallowing-upward cycle generally consists of thin transgressive marine limestones overlain by thicker progradational and aggradational subtidal-supratidal limestones, which is succeeded by nearshore siltstones and paleosols.

Petrographic analysis of carbonates from several wells indicates a complex diagenetic pattern, characterized by numerous stages of diagenetic modification and alteration. Most original textures have been destroyed, obliterated, or masked by regional diagenetic processes, which have severely altered the original fabric of most reservoir quality carbonates within the Council Grove Group. Precipitation of evaporates (anhydrite), silicification, dolomitization, secondary calcite cementation, and stylolitization have extensively altered the original depositional fabric.

Diagenetic environments recognized include marine phreatic, freshwater phreatic, mixing zone, and deep burial. Porosity types include: (1) major amounts of late stage dissolution porosity, (2) intercrystalline porosity related to dolomitization, (3) interparticle and intraparticle porosity, and (4) microporosity associated with silicification and dolomitization. Diagenetic modifications appear to be facies selective and are manifested in varying degrees throughout the Council Grove Group. Reservoir quality appears best in the subtidal-supratidal depositional environments which are characterized by wackestones and packstones.

**Reprinted as published in the American Association of Petroleum Geologists *1995 Annual Convention Official Program*, v. 4, p. 76A.**

## Designation and Description of the Principal Reference Section of the Foraker Limestone, Council Grove Group, Osage County, Oklahoma

*CARTER KEAIRNS*, School of Geology, Oklahoma State University, Stillwater, OK 74078; and *JAMES R. CHAPLIN*, Oklahoma Geological Survey, Norman, OK 73019

The Foraker Limestone, (basal formation in the Council Grove Group) is recognized throughout the Midcontinent as an important stratigraphic marker bed, both in the subsurface and at the surface. Heald (1916) named the Foraker for exposures in the vicinity of Foraker (T27N, R7E), in northern Osage County, Oklahoma. A generalized stratigraphic column was presented for exposures in the Foraker Quadrangle, however, no precise type section was designated. Heald stated that the Foraker Limestone forms the rim of Ekler Canyon (sections 15, 16, 17, 21, 22; T29N, R7E) and is prominent along the eastern part of the Foraker Quadrangle. Heald recorded the thickness of the Foraker Limestone in the type area as 74 feet consisting of a basal 6 foot limestone, followed by a 11 feet shale, 7 feet limestone, 10 feet limestone and shale interbeds, 5 feet limestone, 13 feet thin limestone and shale interbeds, and a 22 feet limestone with some thin shale interbeds.

Field examination of the Foraker in the type area demonstrates that the best candidate for the principle reference section in the original type area is a road cut and superjacent hillside exposures in the W½ of section 16, T29N, R7E in Ekler Canyon. At this locality the Foraker Limestone has an actual thickness of 59.5 feet and has an excellent base exposed as well as a nearly complete section. In addition to the principle reference section, two outcrop reference sections (one in central Osage County and one in Cowley County, Kansas) as well as three reference core holes in Osage County provided by the Oklahoma Geological Survey are described.

Analysis of the outcrops and supportive core hole data demonstrate that individual limestone beds within the Foraker Limestone can be easily correlated in northern Oklahoma and southern Kansas. However, the traditional tripartite lithic subdivision of the Foraker Limestone (Americus Limestone, Hughes Creek Shale, and Long Creek Limestone) which is recognized in northern Kansas are not identifiable into the southern outcrop belt.

**Reprinted as published in the Geological Society of America *1995 Abstracts with Programs*, v. 27, no. 3, p. 62.**

## Depositional Cycles in the Subsurface Permian Council Grove Group of the Hugoton Embayment: Evidence of Sea Level Fluctuation

*JIM PUCKETTE, ZUHAIR AL-SHAIEB*, and *DARWIN R. BOARDMAN II*, School of Geology, Oklahoma State University, Stillwater, OK 74078

The upper part of the Council Grove Group in the Hugoton Embayment is represented by a series of sequences composed of shallow-marine limestones and shales and nonmarine red mudstones. The repetitive nature of these units documents Milankovitch forced cyclic sea level oscillations.

The typical upper Council Grove sequence consists of a (1) basal flooding surface, (2) shallow marine limestone that represents the transgressive and highstand systems tracts, (3) weathered upper surface of the limestone, and (4) red caliche-bearing mudstone (paleosols).

The lower sequence boundaries are characterized by thin (<1 ft) transgressive lag deposits which separate the limestones from the underlying nonmarine mudstones. The transgressive systems tracts consist of upward deepening carbonate from the transgressive lag to the maximum flooding carbonate marine condensed section which contains abundant glauconite, skeletal phosphate and conodonts. The highstand systems tracts are represented by shoaling upward carbonates punctuated by flooding surfaces that delineate parasequences. The upper surfaces of the carbonate units and overlying nonmarine mudstones exhibit evidence of subaerial exposure. The limestones developed weathered zones consisting of carbonate regolith in a red-green matrix. The succeeding mudstones are red in color and contain nodular calcrete. These features are indicative of subaerially exposed rocks and paleosols. Also, a variety of karstic features such as vugs and solution channels are common in the limestones. Some of these vugs and cavities were infilled with red mud.

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## Sequence Stratigraphy of Uppermost Carboniferous and Lowermost Permian Strata (Admire, Council Grove and Lower Chase Group) from the Midcontinent, USA

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Outcropping Admire, Council Grove, and Chase strata of northernmost Oklahoma to southern Nebraska consist of numerous alternations of shallow marine carbonate, marginal marine shale, and terrestrial red to variegated mudstone (paleosol). Several orders of cyclicity are recognized in these strata. Third order sequences (Wabaunsee Group–Admire Group Sequence, Council Grove Group Sequence, and the Chase Group Sequence) are recognized based on the patterns of inferred magnitudes of sequential fourth order sea-level rises and falls. Each fourth order sequence represents a carbonate dominated cyclothem coupled with a clastic dominated cyclothem as used by Elias (1937). Fourth order sequence boundaries are recognized by the surface separating the overlying transgressive lag from the underlying highest subaerial exposure surface. The transgressive lags are succeeded by a thin deepening upwards carbonates that represent the transgressive systems tract. Maximum flooding is represented by thin carbonate marine condensed sections which typically contain highly fossiliferous, glauconitic, skeletal phosphatic wackestone to packstone with large numbers of the relatively offshore conodont *Streptognathodus*. Black, phosphatic shales that represent marine condensed sections (core shales) in Middle and Late Pennsylvanian (Desmoinesian–middle Virgilian) sequences are noticeably rare in Permian and are restricted to the lower Council Grove Group. The highstand systems tracts consist of thicker shoaling upwards carbonate, punctuated with minor flooding surfaces that mark meter-scale parasequence boundaries. The upwards shoaling carbonate is overlain by thin to relatively thick red to variegated mudstone that contains paleosol indicators such as columnar peds, caliche, blocky peds, root casts, and slickensides.

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## Upper Pennsylvanian and Lower Permian Conodont Biostratigraphy of Kansas and Oklahoma

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Outcropping uppermost Carboniferous (Gzhelian) and lower Permian (Asselian–lower Artinskian) rocks of the Admire, Council Grove, and lower Chase Groups are composed of a series of major and minor order cyclothems in a high shelfal marine setting distinguished by the interplay of terrestrial and normal marine environments. *Streptognathodus* species are common to abundant and define the maximum flooding surfaces within most cycles. The conodont introductions through this interval provide glimpses of the evolution of three clades of the genus *Streptognathodus* and two clades of the sweetognathids "*Wardlawella*" (of Kozur) and *Sweetognathus*. The *Streptognathodus* clades are recognized through a succession of minor variations on three basic architectural plans of the platform (Pa) element. The other five elements of these apparatuses are very similar, especially within a clade, and are only subtly different between clades. The clades are (1) elongate forms typified by and beginning with *S. elongatus*; (2) nodose forms (containing common accessory denticles), which can be subdivided into a root stock that has a slitlike furrow, typified by *S. wabaunsensis*, and the common stock that defines the Carboniferous–Permian boundary, which has a troughlike furrow anteriorly typified by *S. farmeri*; and (3) robust forms typified by *S. barskovi*. Two of the three *Streptognathodus* clades gradually drop out through the upper Council Grove and lower Chase Group leaving a single clade (that typified by *S. farmeri*) in the Florence Limestone Member of the Barneston Limestone. In the Florence Member, the species of the *S. farmeri* clade co-occurs with *Sweetognathus whitei*, marking the base of the Artinskian.

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## Carboniferous Gnathodontid and Neognathodontid Conodont Taxa: Application to Understanding Unusual Platinum-Group Geochemistries

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Reconstruction of apparatuses of Carboniferous gnathodontid and neognathodontid conodont taxa provides a basis for revising their phylogeny. Within the two distinct clades, a number of genera and species have been recognized. Some revision of these now seems necessary. At the generic level, any taxonomic revision should reflect the new understanding of phylogenetic relationships. Utilizing a species concept that takes into consideration the mode of evolution within each clade results in an improved and more precise biostratigraphy. This biostratigraphic philosophy has been useful in interpreting the origin and significance of mudrocks that show unusual geochemistry similar to those that have been found in association with the K/T boundary.

Six stratigraphically different platinum-group enrichments have been discovered: four of these are within the Carboniferous succession of central Texas and southern Oklahoma, and two are within the Ordovician of southern Oklahoma. At present, our data for the mid-Carboniferous platinum-group enrichment is the most complete. Coincident conodont samples demonstrate that the enrichment mechanism was neither synchronous nor equal in its effects across the basin. We are as of now unsure of the exact cause of enrichment. Whatever the process may be, it is clearly associated with the accumulation of muddy sediments containing organic material, phosphate and glauconite. Our findings lead us to conclude that similar geochemistries at the K/T boundary should be reexamined for the possibility that some or all of the iridium might be of sedimentary origin.

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## Morphotypic Variation in Pa Elements of Lower and Lower–Middle Pennsylvanian Idiognathodontid Conodonts

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Multiple species of *Idiognathodus* and *Streptognathodus* are recognizable from the Wapanucka Limestone, Spiro Sandstone, and Bostwick Member of the Golf Course Formation using conventional taxonomic criteria. Some of the most widely cited morphologic criteria of the Pa elements used to taxonomically subdivide species of the plexus include: (1) the presence or absence of a groove or trough; (2) the presence or absence of an inner accessory lobe; (3) the presence or absence of an outer accessory lobe; (4) the nature of the carina; (5) the nature of the transverse ridges; (6) platform shape or outline; and (7) the nature of the adcarinal ridges. A minimum of forty varying states of these seven characters exists in the present material. Accounting for the morphologic variability that directly relates to ontogeny reduces the spectrum of variation to more manageable proportions. Most of these variants are interpretable as morphotypic variation across an ecological cline. The character state of the adcarinal ridges provides the only criterion that is reliable for biostratigraphic correlation based on comparison with fusulinid biostratigraphy. Conservative application of this criterion reduces the number of genera to one and the number of species drastically, a conclusion that many Late Paleozoic conodont workers appear unable to accept.

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## Color Patterns on Upper Pennsylvanian (Missourian) Rugose Corals

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Several rugose corals with color patterns were recovered from the Quivira Shale (Dewey Fm.; Upper Carboniferous: Missourian) in northeastern Oklahoma. These solitary corals occur in the lower 2 meters of the dark gray clay shale facies of the Quivira Shale member. Abundant limonitized juvenile ammonoids and limonitized *Paragassizocrinus* occur in the lower coral-bearing horizon. The upper part of the coral-bearing horizon contains small gastropods, bivalves, tabulate corals (*Michelinia*), larger ammonoids and *Paragassizocrinus* preserved as calcite. Unaltered fish remains preserved in phosphate nodules occur below the coral-bearing horizon.

The rugose coral's epitheca displays distinct red and white color bands alternating between each major growth line development. This color banding may represent the preservation of the original color patterns of the once living corals or the diagenetically altered skeletal remains. The presence of color patterns on several bivalves and gastropods species recovered from the same location indicates that the color patterns found on the corals is most likely the original color ornamentation. Alternatively, the color patterns on the corals may be the result of seasonal variations in skeletal composition that were later modified by diagenesis and weathering.

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## Crinoid Assemblage from the Barnsdall Formation, Late Pennsylvanian (Missourian) Washington County, Oklahoma

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A large assemblage of crinoids collected from the Late Pennsylvanian Barnsdall Formation, Missouri Series, exposed in Washington County, Oklahoma, has yielded 36 genera in 15 families of cladid inadunates. Disparids are represented by two genera in two families; camerates include two genera in two families, and flexibles consist of four genera in three families. Many of the crinoids are preserved as more or less complete crowns, many having intact anal sacs; some parasitized. Rather complete growth sequences can be made for *Stenopecrinus planus* (Strimple) and *Stellacrocrinus* cf. *virgilensis* Strimple. The former shows a progressive deepening of basal concavity, widening of PBr1 plates, and development of branching on arms. The latter shows a flat base becoming deeper and variability in the attitude of the radial articular facets. The sample also includes a new genus of Stellarocrinidae having flattened, patelliform arms attached to a nearly flat cup, and a new genus of Pachylocrinidae having a slightly upflare base and plate sculpture showing a strong stellate pattern crossing BB and RR plates. The exquisite preservation of the crinoids and the presence of more or less complete growth series of several species and the diversity of the fauna suggest we are dealing with a life assemblage with forms that occupied niches ranging from the substrate to over a meter above it.

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## Bryozoan Nodules in the Bromide Formation (Middle Ordovician) of South-Central Oklahoma

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Little studied so far, bryozoan nodules are significant because they represent constructional activity analogous to bryozoan reefs except for being unattached and passively mobile. The Mountain Lake Member (lower Blackriveran) of the Bromide Formation yields spectacular bryozoan nodules at Rock Crossing and KX-Arbuckle Ranch 10 km SSW and 25 km NW of Ardmore, respectively. The nodules are rounded masses, with zooecial apertures opening on the external surfaces all the way around. Regional studies suggest deposition on a sloping ramp at 20–30 m depths, shallow enough for infrequent but repeated overturning of the growing nodules, perhaps by deep-running storm waves or currents. The nodules range from small flattened disks 5 cm across, to large ovoids almost spherical and as much as 26 cm in maximum dimension. Cross-sections show bryozoans as the principal frame-builders; the nodules internally are mostly concentric cruststones and some bindstones, though a few are closely intertwined branchstones. Multiple peel-sections reveal 1–7 species per nodule. Voluminous and in the majority of the nodules are large-zooecia *Dianulites petropolitana* and small-zooecia *Monticulipora grandis* (which includes *M. "compacta"*). Also important are *Batostoma chazvensis* (incl. *B. "campensis"*) and *Lunaferamita bassleri.* Additional species are rare and in few nodules: *Orbipora solida*; *Diplotrypa schucherti*; *Parvohallopora pachymura*; *Hemiphragma ottawaense*; *Mesotrypa tubulifera*; *Monticulipora arborea*, *M. intersita*; *Homotrypa subramosa*; *Anolotichia spinulifera*; *Stomatopora* sp. Comparing and contrasting these Bromide nodules with the recently discovered Chickasaw bryozoan reef of the same age near Sulphur will further elucidate the constructional and sedimentologic potential of their phylum.

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## Clarendonian and Hemphillian Vertebrate Faunas from the Ogallala Formation of Texas and Oklahoma and Their Paleoecological Significance

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For over a century, museums and universities have collected late Tertiary vertebrates, mainly large mammals, from the Ogallala Formation. The Texas Panhandle and western Oklahoma provide an excellent sequence of late Tertiary and Quaternary vertebrate faunas that document significant changes in faunal composition, environment, and climate of the Southern High Plains during the last 12 million years.

Two North American Land Mammal Ages, the Clarendonian and the Hemphillian, are based on late Miocene to early Pliocene faunas from the Ogallala Formation in Texas. Fossils are found most frequently in fluvial deposits, especially paleo-channel sands, but also in lacustrine facies and, locally, in deposits filling ancient sinkholes formed by dissolution of salt in the underlying Permian bedrock.

Clarendonian faunas (~12 to ~9 Ma) are characterized by a great diversity and abundance of grazers, a few browsers or mixed feeders, and carnivores. Significant taxa include horses (*Pseudhipparion, Cormohipparion, Neohipparion, Hipparion, Pliohippus,* and *Calippus*); camels (*Procamelus* and *Aepycamelus*); deer-like mammals; short-legged rhinoceros (*Teleoceras*); gomphotheres; and carnivores. Mild, subhumid climate and grassland savannas with scattered woodland prevailed.

Early Hemphillian faunas (~9 to ~6 Ma) contain advanced species of typical Clarendonian genera plus new immigrant taxa such as ground sloths and several carnivores. Late Hemphillian faunas (~6 to ~4.5 Ma) post-date a mid-Hemphillian extinction event and show a lower diversity of taxa. Decimation of most browsers and many grazers coupled with the development of calcic soil horizons document a progressive trend toward aridity and the replacement of savannas by grassland prairie and steppe.

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## USGS Increases Topographic Quadrangle Map Prices

The U.S. Geological Survey has increased its price for topographic quadrangle maps from $2.50 to $4.00, beginning August 12, 1995.

The Oklahoma Geological Survey stocks USGS topographic maps of Oklahoma quadrangles as a service to our customers. While it will be necessary to increase our price for these maps, we will charge less than the USGS price. We intend to make them available for $3.25, plus postage and handling, effective September 1, 1995. Thus, we will be passing on most of our bulk-purchase discount to our customers.

A copy of the index to topographic mapping is available on request from the OGS Publication Sales Office, 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031 *or* (800) 330-3996; fax 405-325-7069.