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GRADUATE COLLEGE

BRACHIOPOD BIOSTRATIGRAPHY AND FAUNAS OF THE MORROW SERIES (LOWER PENNSYLVANIAN) OF NORTHWESTERN ARKANSAS AND NORTHEASTERN OKLAHOMA

A DISSERTATION

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degree of

DOCTOR OF PHILOSOPHY

BY

THOMAS WOOD HENRY

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1973

BRACHIOPOD BIOSTRATIGRAPHY AND FAUNAS OF THE MORROW SERIES (LOWER PENNSYLVANIAN) OF NORTHWESTERN ARKANSAS AND NORTHEASTERN OKLAHOMA

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BRACHIOPOD BIOSTRATIGRAPHY AND FAUNAS OF THE MORROW SERIES

(LOWER PENNSYLVANIAN) OF NORTHWESTERN ARKANSAS

AND NORTHEASTERN OKLAHOMA

by

Thomas Wood Henry

ABSTRACT

The Morrow Group of the southwestern part of the Ozark Mountains region consists of a highly fossiliferous sequence of predominantly marine limestones, shales, and sandstones. The brachiopod fauna is highly varied, and the Morrow Group is subdivided into three brachiopod zones based upon the established ranges of the 45 species recognized in this stratigraphic sequence. These zones are based upon the first occurrence of a number of brachiopod taxa. They are, in ascending order, the *Sandia welleri* Range Zone, the *Plicochonetes*? *arkansanus* Range Zone, and the *Linoproductus nodosus* Range Zone.

The *Sandia welleri* Range Zone corresponds to the Cane Hill and lower half of the Prairie Grove Member of the Hale Formation in northwestern Arkansas and to the lower one third of the grainstone-shale member of the Gore Formation in northeastern Oklahoma. The *Plicochonetes*? *arkansanus* Range Zone occupies the upper part of the Prairie Grove Member and the Brentwood Limestone and the Woolsey Member of the overlying Bloyd Formation. It corresponds to the middle and upper parts of the grainstone-shale member and all of the algal wackestone member of the Lower Morrow Formation in northeastern Oklahoma.

The boundary between the lower two Morrowan brachiopod zones is accordant with the boundary between the *Idiognathoides noduliferus* and the *Neognathodus bassleri symmetricus* conodont zones as defined by Lane (1967), Lane and Straka (1971), and Henry (1970).

The upper boundary of the *Plicochonetes*? *arkansanus* Range Zone marks the uppermost occurrence of nine brachiopod species that commonly occur in the lower strata. Ten brachiopod species are confined to the overlying *Linoproductus nodosus* Range Zone. This boundary marks the most important faunal break in the Morrow Group and is the basis for subdividing the Morrow Series into Lower and Upper Morrow Subseries.

The base of the *Linoproductus nodosus* Range Zone corresponds to the regional unconformity that occurs at the base of the Dye Shale Member in northwestern Arkansas and at the base of the Upper Morrow Formation in northeastern Oklahoma. McCaleb (1968) reported a similar hiatus at this boundary for the goniatite faunas of the Bloyd Formation.

The high degree of similarity between the brachiopod fauna in the basal part of the La Pasada Formation in north-central New Mexico and the fauna of the *Linoproductus nodosus* Range Zone in the Morrow Group affirms Sutherland and Harlow's (*in press*) suggestion that the basal La Pasada is Late Morrowan in age.

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Financial assistance for some of the field work in northeastern Oklahoma was provided by the Oklahoma Geological Survey, and the Arkansas Geological Commission helped support part of the field work in northwestern Arkansas. I extend my appreciation to Dr. Mankin and Mr. Norman F. Williams, directors of the respective surveys, for their generous assistance. Part of the field expenses was also deferred by a grant from the Penrose Foundation of the Geological Society of America (Grant #1386-70). Portions of the cost of photography was absorbed by funds from a Grant-in-Aid-of-Research from The Society of the Sigma Xi.

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A special thanks is extended to Dr. and Mrs. Dwight M. Moore of Fayetteville, Arkansas, with whom I lived while working in the field in northwestern Arkansas.

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Most of the text-figures were drafted by David M. Deering of the Oklahoma Geological Survey, and the final text was typed by Susan Seybert. I am indebted to them for their generous assistance.

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BRACHIOPOD BIOSTRATIGRAPHY AND FAUNAS OF THE MORROW SERIES (LOWER PENNSYLVANIAN) OF NORTHWESTERN ARKANSAS AND NORTHEASTERN OKLAHOMA

INTRODUCTION

Importance of Investigation

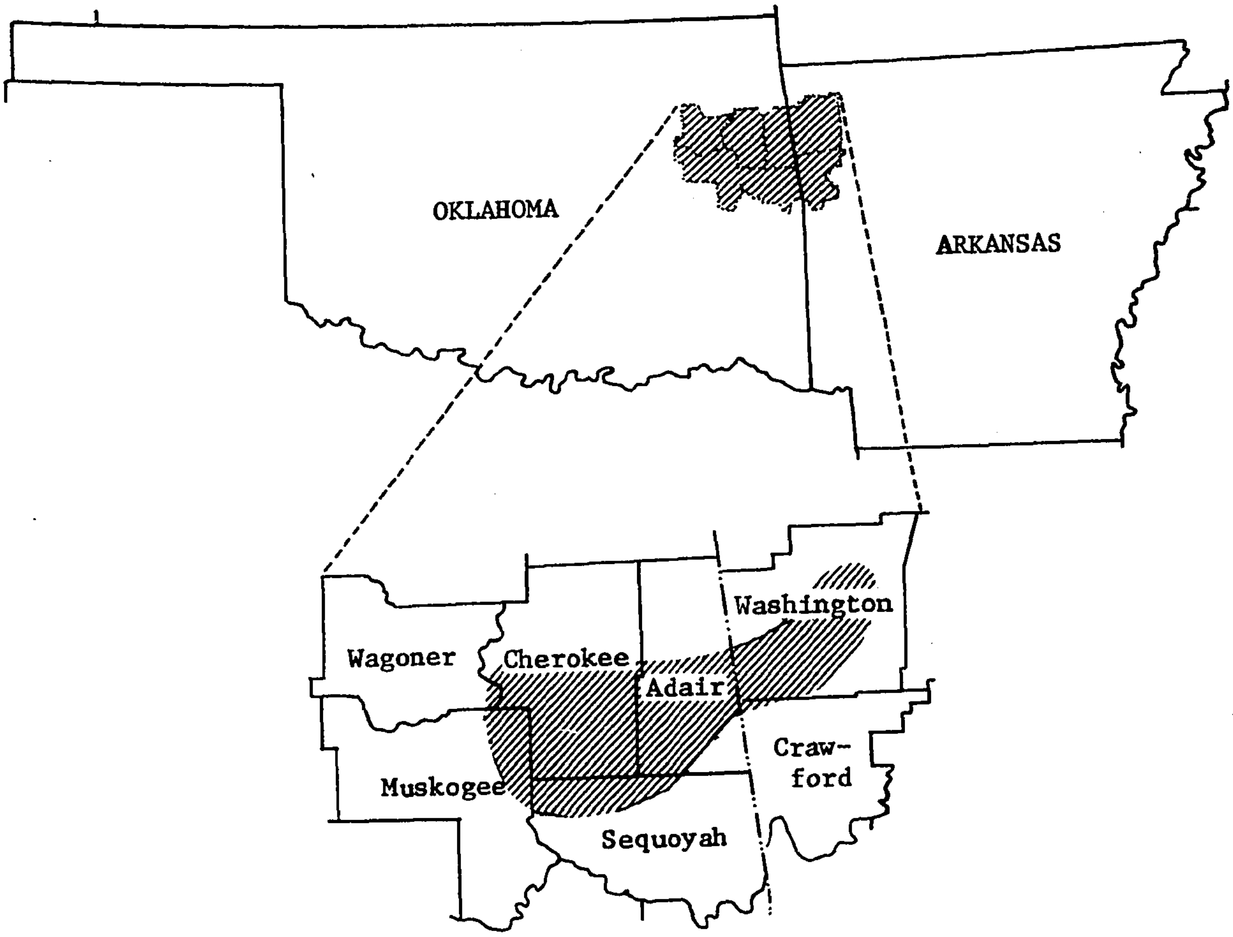
Knowledge about the biota of the Morrow Group is especially important for investigations of Upper Paleozoic stratigraphy and historical geology because this sequence of strata in Washington County, Arkansas, constitutes the type section and standard sequence of reference for the Early Pennsylvanian of the Midcontinent and western North America. This succession is additionally important because it is composed principally of marine limestones, sandstones, and shales containing highly diverse and abundant organic remains. This sequence contains subordinate terrestrial deposits, the Woolsey Member with the Baldwin Coal, which contains a diverse and well known flora. The presence of nonmarine, fossiliferous strata in a dominantly marine sequence has fascilitated integration of Early Pennsylvanian floral and faunal zonations.

In contrast, the Lower Pennsylvanian Pottsville Formation is composed predominantly of thick nonmarine deposits consisting of about 80 percent coarse-grained terrigenous sedimentary rocks interbedded with finer-grained terrigenous sedimentary rocks and coal (Meckel, 1967) in its type locality in the southern anthracite field of eastern Pennsylvania. Although the flora of the Lower Pennsylvanian in this area is well known (Read and Mamay, 1960), a few marine fossils have been reported from this sequence (Dutcher, and others, 1959). Fossiliferous marine strata of the Pottsville Group do occur in the western part of Pennsylvania, but these are restricted to the upper part of the Pottsville Series (Dutcher, and others, 1959; Williams, 1960). The Pottsvillian sequence in Ohio and eastern Kentucky contains a higher proportion of marine strata, but the most abundantly fossiliferous strata occur in the higher parts of the sequence (Morningstar, 1922; Sturgeon and Hoare, 1968). The approximate Morrowan equivalents of the lower Pottsville Group of Ohio and eastern Kentucky contain only scattered, generally rarely fossiliferous marine units (Sturgeon and Hoare, 1968; Furnish and Knapp, 1966).

Location of Area

The area investigated lies on the southwestern flanks of the Ozark Dome in northwestern Arkansas and northeastern Oklahoma. In Arkansas it encompasses portions of central and southwestern Washington and extreme northwestern Crawford Counties, and in Oklahoma portions of southern Adair, southern Cherokee, northern Sequoyah, northeastern Muskogee, and extreme southeastern Wagoner Counties (text-figure 1).

More specifically, the main portion of the area of investigation in Oklahoma lies in parts of townships 13 through 17N. and ranges 19 through 23E., occupying an irregularly shaped area of approximately 350 square miles in Cherokee, Sequoyah, and Muskogee Counties (text-figure 2). In addition, a line of sections extends across the central portion of



Text-figure 1.--Area of investigation in southwestern Ozark Mountains region.

Adair County to southwestern Washington and northwestern Crawford Counties, Arkansas and thence northeastward to the vicinity of Fayetteville in north-central Washington County (text-figure 3). The line of sections across Adair County is in township 15N. and ranges 24 through 26E. and extends from T. 12N., R. 33W. to T 16N., R. 30W. in northwestern Arkansas.

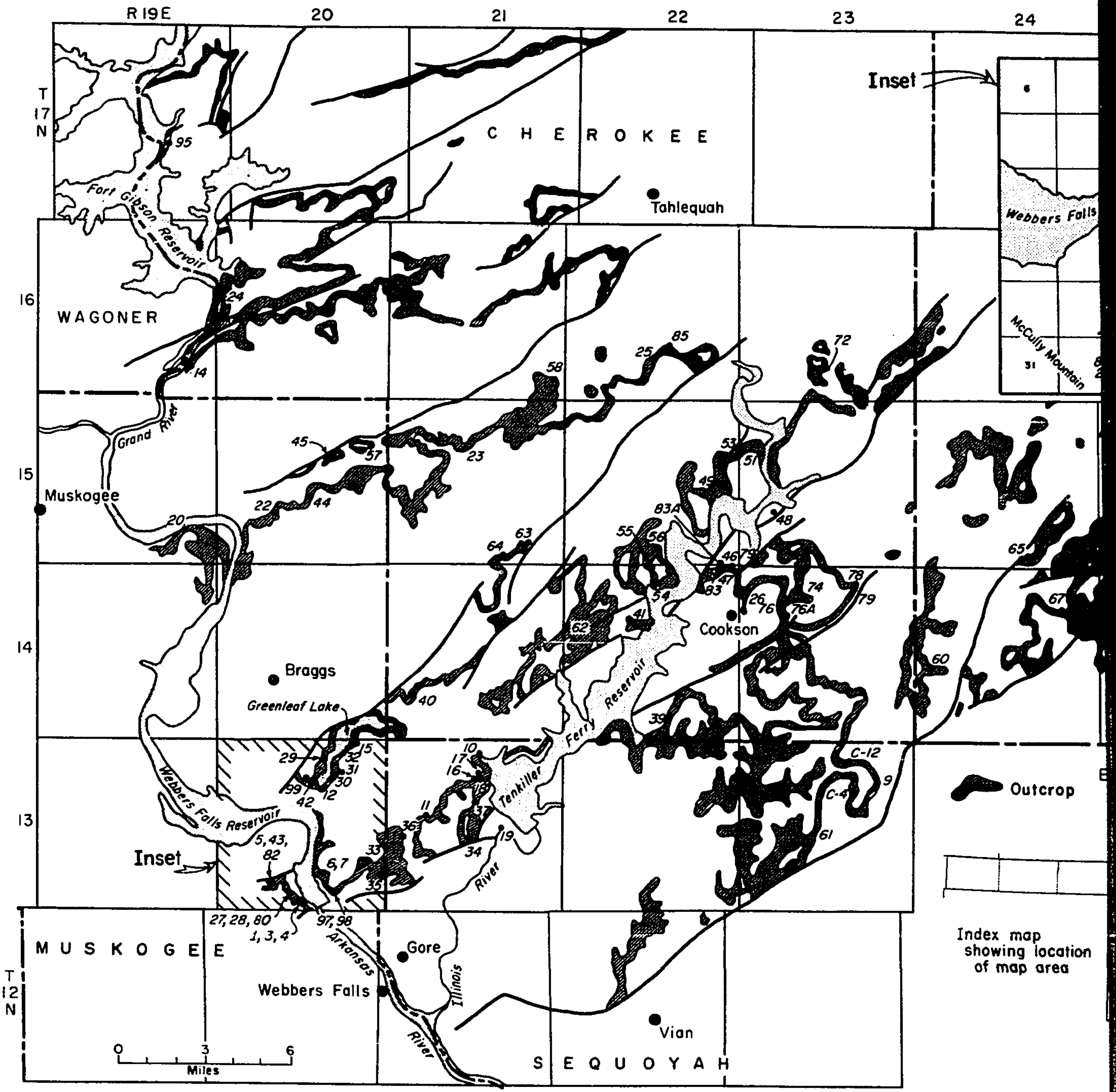
Nature of Outcrops

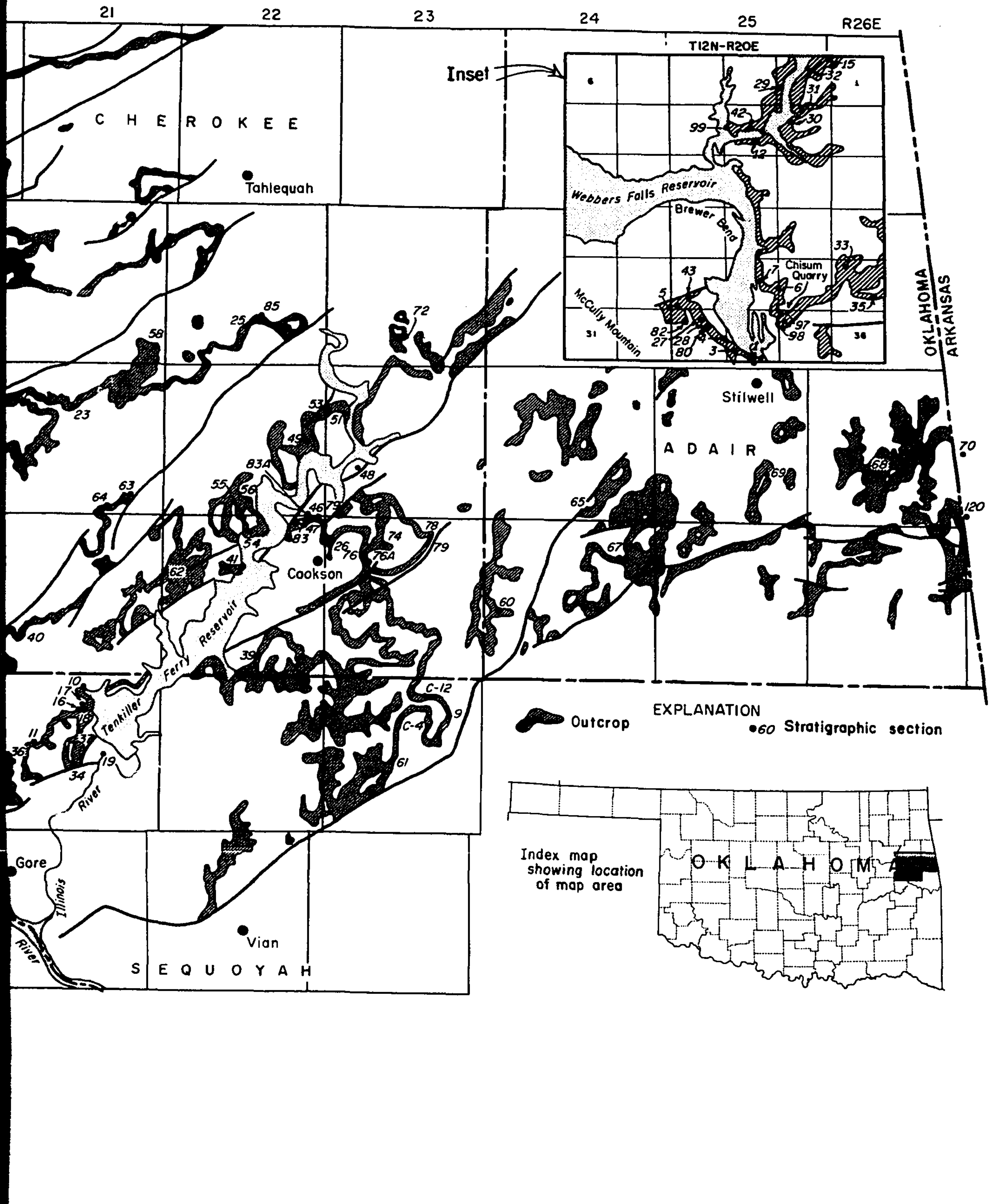
Strata of Morrowan age, which unconformably overlie the Late Mississippian units and are overlain by the Atoka Formation (Atokan), are exposed as a series of bands that are associated with the elongated fault blocks that form a radial pattern around the southwestern part of the Ozark Dome. The principal exposures of the Morrow Group throughout the southwestern flanks of the Ozark Mountains are on bluff escarpments and steep valley sides beneath the relatively resistant sandstones and siltstones of the Atoka Formation that cap the plateaus and mountains.

The strata generally lie flat or dip gently to the south and southwest throughout most of the area of investigation, with the dips exceeding about 3 degrees only near the system of radiating faults mentioned above. Near these structural features, the dips may be accentuated sharply.

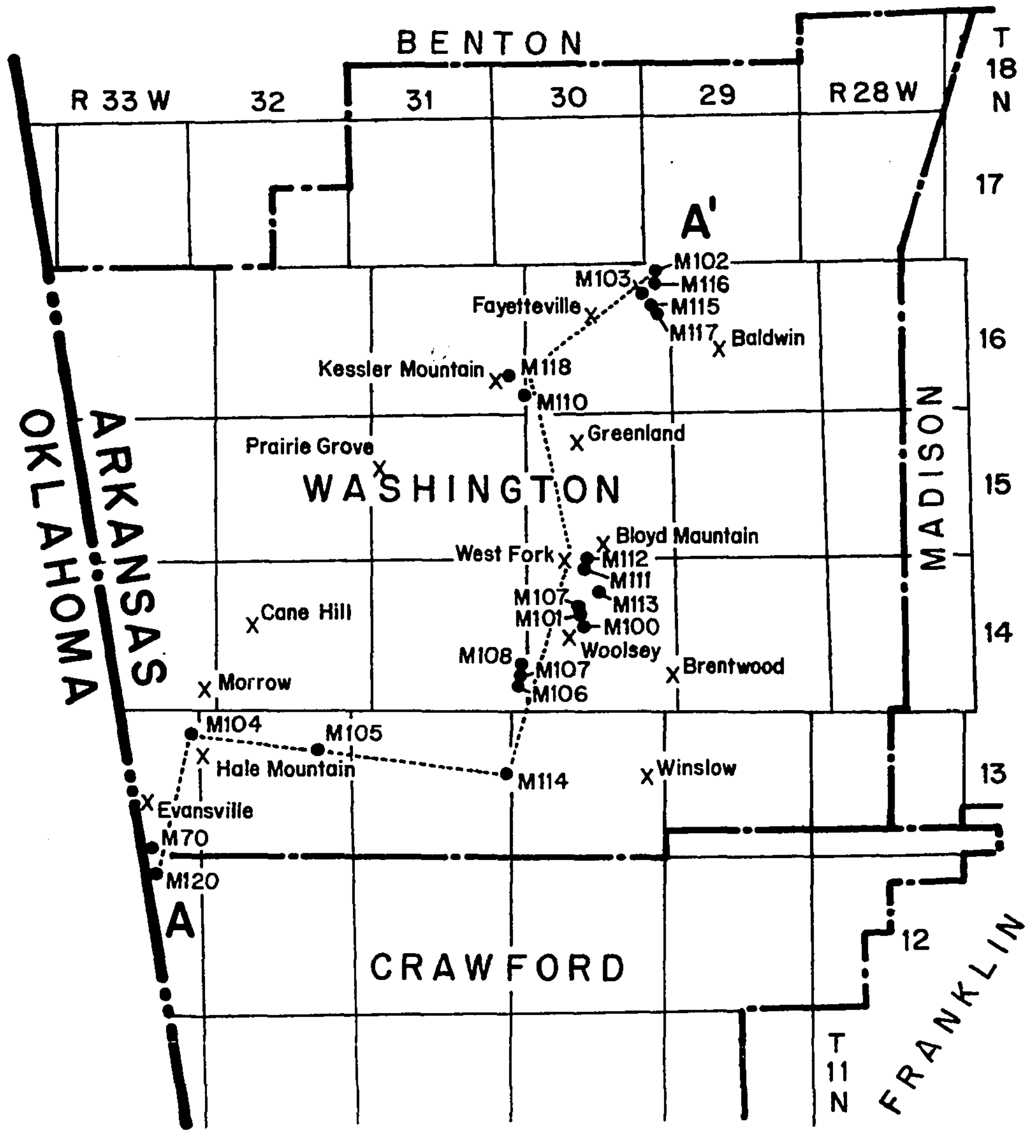
The best exposures of the Morrow Group are found either in artificial cuts or in steep creeks and gullies that cut the sides of the bluffs. Most of the area is heavily wooded, and individual stratigraphic units can rarely be traced laterally from one measured section to another because of the heavy vegetation. The rainfall in the area is generally high, and this factor plus the steepness of the slopes contributes heavily to slump-

Text-figure 2.--Detailed locality and geologic map of area of investigation in northeastern Oklahoma. Dots and numbers refer to measured stratigraphic sections or collecting localities (from Sutherland and Henry, *in press*).


R19E
20
21
22
23
24
T 17 N
16
15
14
13
T 12 N
CHEROKEE
WAGONER
MUSKOGEE
SEQUOYAH
Tahlequah
Muskogee
Braggs
Cookson
Gore
Webbers Falls
Vian
Fort Gibson Reservoir
Grand River
Greenleaf Lake
Tenkiller Ferry Reservoir
Webbers Falls Reservoir
Arkansas River
Illinois River
Inset
Webbers Falls
McCully Mountain
Outcrop
Index map showing location of map area
0 3 6
Miles
95
24
14
58
25
85
72
45
57
23
53
51
49
22
44
20
83A
48
55
56
46
79
64
63
65
54
47
83
26
76
74
78
79
76A
67
62
41
60
40
39
C-12
29
15
32
31
30
12
99
42
10
17
16
18
11
36
37
33
34
19
9
C-4
61
5, 43,
82
6, 7
35
27, 28, 80
1, 3, 4
97, 98



21
22
23
24
25
R26E
T12N-R20E
Inset
CHEROKEE
Tahlequah
Webbers Falls Reservoir
Brewer Bend
Chisum Quarry
McCully Mountain
OKLAHOMA
ARKANSAS
Stilwell
ADAIR
Cookson
Tenkiller Ferry Reservoir
Illinois River
Gore
Vian
SEQUOYAH
EXPLANATION
Outcrop
•60 Stratigraphic section
Index map showing location of map area
OKLAHOMA



Text-figure 3.--Index map showing area of study in Washington and northwestern Crawford Counties, Arkansas. Dots refer to measured sections on cross-section A-A' (in pocket); X's refer to geographic localities mentioned in text.

ing of massive blocks of more resistant strata over the less resistant shales, particularly in the upper parts of the section.

Purpose, Scope, and Methods of Investigation

Approximately 21,000 brachiopods have been collected from known stratigraphic intervals within the Morrow Group in the Ozark Mountains region of northwestern Arkansas and northeastern Oklahoma. These collections are closely integrated with the lithostratigraphic succession and are reposited in the Invertebrate Paleontological Repository of The University of Oklahoma. These have been analyzed in order (1) to describe and/or evaluate each brachiopod species represented in these collections, (2) to ascertain the degree of variability for each taxon, (3) to establish the stratigraphic ranges for these elements, and (4) to construct a biostratigraphic zonation based upon the brachiopods.

This dissertation orginiated as a portion of a much broader study of the lithostratigraphy, biostratigraphy, depositional history, and paleoecology of the Morrow Series in the southwestern Ozark Mountains region. This project is under the supervision of Dr. Patrick K. Sutherland and has been supported by National Science Foundation Grant No. GA-422X. Field work for this investigation was conducted partly with Dr. Sutherland and with Bruce N. Haugh (M. Sc., 1968), David C. Bowlby (M. Sc., 1968), and Tommy L. Rowland (Ph. D., 1970). David A. Kotila (Ph. D., 1973) supplied additional stratigraphic information on the area. The author's own M. Sc. thesis (Henry, 1970) was a part of this project. Several of the sections in the northwestern area were measured jointly with Dr. H. Richard Lane of the Amoco Research Laboratory in Tulsa, Oklahoma. A summary to the overall results is being published by Sutherland and Henry (*in press*).

The studies mentioned above have produced 81 measured stratigraphic sections and 8 cores in northeastern Oklahoma (text-figures 2); sixty-nine of these stratigraphic sections plus six collecting localities are presented in Sutherland and Henry (*in press*).

In addition to the time spent in the field working on his master of science thesis, the author engaged in field work in northeastern Oklahome during a period of a month and a half in the early fall of 1971. The Morrow Group in northwestern Arkansas was investigated by the author during a period of approximately four months in the fall and winter of 1971-1972, and an additional three weeks in the late spring of 1972. During this period of time, 26 additional stratigraphic sections were examined and/or measured by the author. These sections, including most of the type sections for the various members and formations or the Morrow Group in this area, are included in Appendix I of this dissertation. Field methods utilized by the author and a brief discussion of the petrographic terminology used in this dissertation are described in the introduction to this appendix.

Drs. Doy L. Zachry and James H. Quinn of The University of Arkansas took the author to a number of the localities and assisted in some of the reconnoitering. The Garret Hollow sections (M105A, M105C, and M105D) had previously been measured by Zachry and his students but were remeasured by the author. One of the Hale Mountain sections (M104A) was measured by the author and Jerry D. Branch, a graduate student at The University of Arkansas, and Charlotte Glenn, also a graduate student at The University of Arkansas, assisted in collecting the Garrett Hollow sections. Dr. Walter L. Manger provided the information for measured section M110 and showed this section to Sutherland and the author in the spring of 1973.

Cross-section A-A' (in pocket) connects the type Hale area in southwestern Washington County with the type Bloyd area in the north-central part of the county. The lithostratigraphic framework is evaluated in the chapter on lithostratigraphy.

Mather (1915) described the entire megafauna of the Morrow Series. In order to evaluate the brachiopod species that he proposed, it was necessary to reestablish, where possible, the collecting stations from which he described the new species. In the present study, these type localities were integrated with the lithostratigraphic framework where possible and a number of measured stratigraphic sections presented in Appendix I include his collecting stations. Appendix III is a compilation of notes and observations made by the author in attempting to relocate and reestablish Mather's stations.

History of Previous Biotic Investigations

Only a summary of the history of biotic investigations of the Morrow Group is presented here. A more complete and detailed history is given by Sutherland and Henry (in press).

The flora of the terrestrial Woolsey Member is well known and was first described by Lesquereux (1860), who suggested that these strata should be included in the "true coal measures" (p. 298). White (1895, 1898, 1900) presented evidence based upon the flora that this sequence correlates with the lower part of the Pottsville Series in the Appalachian region.

Simonds (1891), Branner (1891), and Drake (1898) all assigned the Morrowan sequence to the Mississippian System based upon the common occurrence of the blastoid *Pentremites* and the reported occurrence of the bryozoan *Archimedes*.[1]

Ulrich (1904) first called attention to the abundant marine fauna contained within these strata and made the first published reference to the Pennsylvanian aspects of this fauna. Girty (1905) discussed briefly the Morrowan fauna, its dominance by Pennsylvanian elements, and its relationships with faunas of similar age in other regions. He noted the virtual absence of marine faunas in the Pottsville Series of the Appalachian region and suggested that the Morrowan strata might be used as a reference sequence with which the faunas of other Midcontinent and western strata might be compared.

Mather (1915) published the only study of the complete Morrowan megafauna.[2] This work resolved most of the lingering controversy over the Early Pennsylvanian age assignment of these strata. This age assign-

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[1]Some doubt still exists whether the bryozoan *Archimedes* is indigenous to the Morrow Group or not. Mather (1915, p. 115, 116) described a species of *Archimedes* from two localities in the Brentwood Limestone. Henbest (1953, p. 1939) stated: "The writer has not yet found a free specimen of *Archimedes* in the Morrow that was not abraded, nor has he found well preserved specimens outside of clearly derived pieces of Mississippian limestone. All of the specimens of *Archimedes* so far seen in the Morrow by this writer showed evidence of redeposition."

[2]Croneis (1930) refigured many of the specimens that Mather illustrated.

ment was followed by all subsequent geologists with the temporary exception of R. C. Moore (1933a, p. 100; 1933b, p. 603), who suggested that the Mississippian boundary should be extended upward to include the Morrow Group because the magnitude of the unconformity at the top of the interval was alleged to be greater than that at the base of the sequence. Although in 1934 Moore (p. 451) retained his proposal of extension of the Mississippian boundary upward, he stated in a footnote (p. 452) that he had changed his mind and accepted an Early Pennsylvanian age for these strata.

A more detailed study of the crinoid fauna of the Morrow Series in Oklahoma, Arkansas, and Texas was published by R. C. Moore and Plummer (1937), and numerous subsequent, more limited papers have followed by a number of authors (Moore, 1940, Moore and Plummer, 1940, Moore and Laudon, 1942; Strimple, 1951; and Moore and Strimple, 1969). Moore and Strimple (1973) revised the entire Morrowan crinoid fauna. All of these studies are descriptive in nature, and the crinoid faunas have much less biostratigraphic utility than might be the case if they were carefully tied to lithostratigraphic successions and did not consist of typologically defined species from isolated collecting localities.

Some elements of the coelenterate faunas were described by R. C. Moore and Jeffords (1945), and this group is currently being investigated by P. K. Sutherland; limited aspects of the coral faunas are treated in Sutherland and Henry (in press).

The goniatite cephalopod faunas are highly diverse but occur scattered throughout the Morrow Group. They have been vigorously studied by a large number of workers, too numerous for complete listing here.

Major papers devoted mostly or entirely to the studies of Morrowan goniatites, include those of Unklesbay (1962), Gordon (1964, 1965, 1968), and McCaleb (1968). Much apparently significant biostratigraphic information has been gained from these studies, although many of these studies, like those of the crinoid workers, do not properly integrate the physical stratigraphic succession with the faunal succession, as pointed out by Manger (1971, p. 4). Nevertheless, these studies have resulted in the first attempts to correlate the type Morrowan sequence with the European and Asian standards (see Quinn and Saunders, 1968; McCaleb, 1968).

LITHOSTRATIGRAPHY

Introduction

The Morrowan rocks of the southwestern flanks of the Ozark Dome unconformably overlie Late Chesterian strata and are in turn overlain by the Atoka Formation (Atokan), earlier referred to as the Winslow Formation. The latter relationship is inadequately understood in Washington County because of the poor quality of exposures near the boundary, but the Atoka Formation unconformably overlies the Morrow Group in northeastern Oklahoma.

Chesterian and Atokan strata were studied only to the extent that they could be differentiated from the Morrowan sequence.

The Pitkin is the youngest Chesterian unit in the study area, although younger Mississippian rocks do occur to the east in northern Arkansas (Gordon, 1965). The Pitkin Formation subcrops beneath the Morrow Group throughout the southern part of the area of investigation and is regionally truncated northward by the pre-Morrowan erosional surface. In the vicinity of Fayetteville, Arkansas, the Pitkin occurs only as isolated outliers beneath the Morrowan sequence, which generally rests in this area of the subjacent Fayetteville Shale. In northeastern Oklahoma, this erosional surface is highly irregular, and the basal part of the Morrow Group locally rests on the Hindsville

Formation in the southeastern part of Cherokee County in T. 15N. (Sutherland and Henry, *in press*).

Pitkin Formation

The term Pitkin Formation was initially used by Ulrich (1904, p. 109) for strata previously referred to by many authors as the "*Archimedes* limestone" and was named for the exposures in the vicinity of the Pitkin Post Office in Washington County, Arkansas. A detailed discussion of this formation and measured stratigraphic sections were presented by Easton (1942). Henbest (1962a, p. 38) designated the extensive exposures in the cliffs along the eastern side of the West Fork of the White River at the base of Bloyd Mountain in central Washington County as the type locality (vicinity of M111 and M112 of this dissertation).

Throughout its outcrop area in the area of investigation, the Pitkin Formation is dominated by oolitic calcarenites (grainstones). Other common lithic types are algal and mixed-skeletal calcilutites (wackestones), skeletal calcarenites (packstones and grainstones), and minor calcareous shales, many of which contain abundant fragments of the bryozoan *Archimedes*. Noteworthy features of the Pitkin Formation at most localities are its low contant of quartz-sand relative to the overlying sequence and its light gray color, contrasting to the bluff and orangish brown colors of the overlying Morrowan.

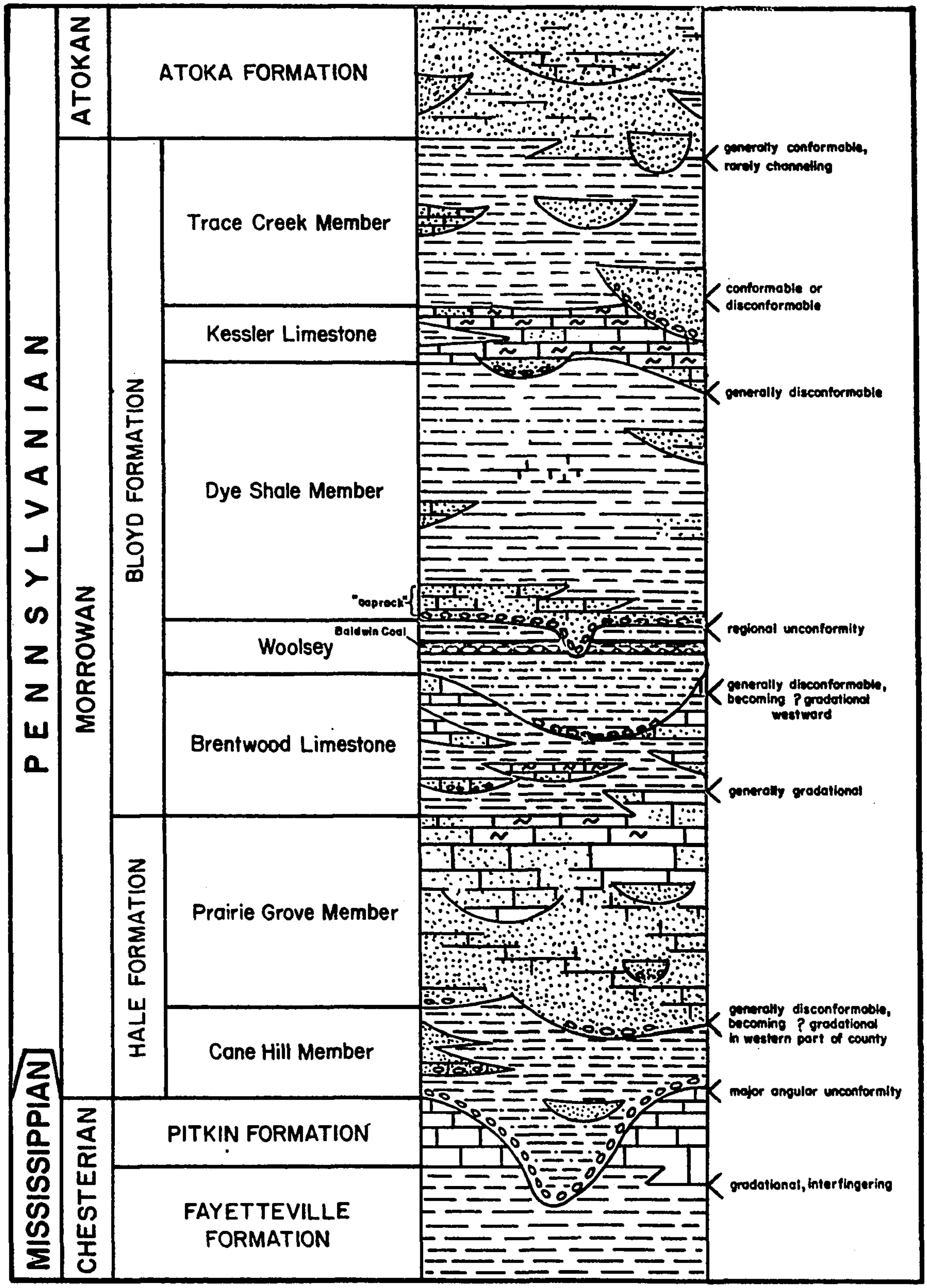
The Pitkin Formation conformably succeeds and intergrades with the dark gray to black shales, nodular calcilutites (wackestones and mudstones), and skeletal calcilutites (wackestones and packstones) of the Fayetteville Formation. It is unconformably overlain by the basal Morrow Group.

Morrow Group (General)

The Morrow Group of Washington County, Arkansas, has been subdivided into two formations, the Hale and the Bloyd, and a number of members based primarily upon reasonably consistant differences in lithic characteristics and secondarily upon mappability. The nomenclature for this sequence has been formalized and reviewed by Henbest (1962a, 1962b), and a composite section is presented in text-figure 4 of this dissertation. The formation names and many of the member names recognized in Washington County are not applicable in most of northeastern Oklahoma because of the rapid facies changes that occur, particularly in the basal and middle portions of this sequence, westward into Oklahoma. Sutherland and Henry (in press) proposed that the Morrow Group in northeastern Oklahoma be subdivided into the Gore and McCully Formations (text-figure 5), for which further subdivisions were recognized.

The following discussion treats in some detail the stratigraphic relationships of the type Morrowan in Washington County because of new information gained during the current investigation. The stratigraphic discussion for the Morrowan of northeastern Oklahoma is summarized from Sutherland and Henry (in press).

Text-figure 4.--Composite section of Morrow Group in type area in Washington County, Arkansas, showing formal subdivisions and unconformities. (Modified from Henbest, 1962b).


PENNSYLVANIAN
MISSISSIPPIAN
ATOKAN
MORROWAN
CHESTERIAN
ATOKA FORMATION
BLOYD FORMATION
HALE FORMATION
Trace Creek Member
Kessler Limestone
Dye Shale Member
"caprock"
Baldwin Coal
Woolsey
Brentwood Limestone
Prairie Grove Member
Cane Hill Member
PITKIN FORMATION
FAYETTEVILLE FORMATION
generally conformable, rarely channeling
conformable or disconformable
generally disconformable
regional unconformity
generally disconformable, becoming ? gradational westward
generally gradational
generally disconformable, becoming ? gradational in western part of county
major angular unconformity
gradational, interfingering

Morrow Group, Northwestern Arkansas

The term Morrow was originally used as a formation name by Adams and Ulrich (1905, p. 4) for the sequence of Pennsylvanian strata lying between the Pitkin Formation and the Winslow (Atoka) Formation. This sequence was defined to include not only the strata that Simonds (1891) had referred to as the "Washington shale and sandstone", the "Pentremital limestone", the coal-bearing shale, and the Kessler limestone, but also to include the shale immediately overlying the Kessler and underlying the base of the first prominent sandstones at the base of the Atoka Formation.

The Morrow was raised to group status to include the Hale and Bloyd Formation (Purdue, 1907), and it was designated the type section and standard of reference for the Early Pennsylvanian in the Midcontinent and western North America by the American Commission on Stratigraphic Nomenclature (R. C. Moore, and others, 1944).

The sequence in the general area of Hale Mountain, approximately 2 miles south of the community of Morrow, was designated the reference area for the Morrowan succession by Adams and Ulrich (1904, p. 4). Giles and Brewster's (1930, p. 141) composite stratigraphic section of the Morrow Group on Hale Mountain is no longer well exposed. Henbest (1953, p. 1950; 1962a, p. 39) designated the exposures in the area of the NE¼, Sec. 12, T. 13N., R. 33W, Washington County, as the best reference section, but he did not present a detailed stratigraphic section. This is the site of measured sections M104A, M104B, and M104C of this dissertation (refer to Appendix I).

Henbest (1953, p. 1935) stated that the Morrow Group varies in thickness from 300 to 400 feet in the type area. The Morrow Group at the type section (M104A, M104B, and M104C, composite) is approximately 379 feet thick, and the same thickness is recorded in the vicinity of Bloyd and Everett Mountains in central Washington County (M100 and M112, composite). Thicknesses of approximately 315 and 325 feet are recorded in the Garrett Hollow area (M105A, M105C, and M105D) in southwestern Washington County and in the Fayetteville area (M116 and M118, composite), respectively. The Morrow Group is 346 feet thick on Evansville Mountain (M70, see Sutherland and Henry, <u>in press</u>) in extreme southwestern Washington County.

Hale Formation

The Hale Formation was initially proposed by Simonds (1891, p. 75-92) as the "Washington shale and sandstone". Taff (1905, p. 4) renamed this stratigraphic sequence the "Hale sandstone lentil" for the outcrops on Hale Mountain, since Simonds' name was preoccupied. The name Hale was quickly adopted (Adams and Ulrich, 1905, p. 4), and Purdue (1907, p. 3) raised this sequence to formational status.

Henbest (1962a, p. 39) defined the type section to be "near the center of the west side, sec. 7, T. 13 N., R. 32 W." on the northern side of Hale Mountain. Henbest presented no measured stratigraphic section. This locality is the site of measured section M104A.

The Hale Formation varies in thickness in the line of cross-sections (A-A', in pocket) from about 140 feet in southwestern Washington County to about 121 feet in the vicinity of Bloyd Mountain (M112) and about 104 feet in the Fayetteville area. Henbest (1953, p. 1936) reported that the Hale Formation in Washington County is between 125 and 200 feet thick.

This formation has been subdivided into the Cane Hill and Prairie Grove Members, both of which are widely distributed and generally easily recognized throughout the area investigated in Washington County.

Cane Hill Member.--The Cane Hill Member was first recognized as a discrete stratigraphic interval by Simonds (1891, p. 75), who referred to it as the lower division of his "Washington shale and sandstone". This sequence was not named until Henbest (1953, p. 1938) formally proposed the subdivisions of the Hale Formation. Henbest stated in this publication that the Cane Hill Member is most typically developed near the community of the same name in southwestern Washington County (text-figure 3), but later (1962a, p. 39) he moved the type section to the base of the Evansville Mountains exposures (M70, cross-section A-A', in pocket).

The bulk of the Cane Hill Member typically consists of dark gray, silty shales interlaminated with thin- to very thin-bedded, fine-grained sandstones and siltstones, producing a distinctive flaggy appearance. The coarser grained material generally bears exceedingly common asymmetrical ripple marks on the upper surfaces and abundant costs of burrows and trails on the lower surfaces. Conostichus is a common trace fossil. The sequence generally also contains some thicker interlaminated sandstones, and a few lenses up to about 9 feet in thickness in the Fayetteville area (M116).

The base of this member is generally marked by a thin basal conglomerate, which locally may attain a thickness of as much as 2 feet (M111, M112). Limestone pebbles are the common coarse-grained constituents, but sandstone-, phosphate-, and siltstone-pebbles are also present along with shale- and claystone-clasts in many of the outcrops. Limestone-pebbles and -cobbles clearly derived from the underlying Pitkin Limestone are present in the Bloyd Mountain area (M111, M112).

Limestones are rare in the Cane Hill Member. The Garrett Hollow section (M105A) contains a conglomeratic, highly quartz-sandy calcarenite (grainstone) (units 3 and 4) that is about 6 feet thick in the middle portion of the member.

Henbest (1953, p. 1938) stated that the Cane Hill Member varies in thickness "from a thin edge" to a maximum of 65 feet in Washington County. The type section for the Cane Hill Member was reported by him to be 65 feet thick (1962a, p. 39). Sutherland and Henry (in press) have recorded a thickness of only 38 feet for this member at the Evansville Mountain section (M70). The maximum thickness of this member recorded in the present study is 66 feet in Garrett Hollow (M105A); the thinnest Cane Hill section is at section M116 in Fayetteville, where

29 feet was measured (cross-section A-A').

The upper boundary of the Cane Hill Member is defined as the change from interbedded shale and sandstone to either quartz-sandy calcarenites (grainstones) or to calcareous sandstones. This contact is generally also marked by a conglomeratic sandstone or conglomeratic limestone at the base of the overlying Prairie Grove Member.

The Cane Hill Member is not recognizable west of the central part of Adair County, Oklahoma (Sutherland and Henry, in press), where it becomes patchy in distribution and pinches out. The Cane Hill Member is widely distributed and easily recognizable in northwestern Arkansas. It extends continuously from central Adair County eastward to the Fayetteville area (cross-section A-A'), and it has been recognized eastward as far as Boone County, Arkansas (Manger, 1971) and southward into Crawford County (Gordon, 1964, p. 39).

The Cane Hill Member was interpreted by Henbest (1953, p. 1939) to represent a mixture of low-lying, near-shore terrestrial and shallow, near-shore marine environments. The shales and sandstones generally contain a very sparse fauna; a few unidentifiable molluscan and brachiopod molds have been observed by the author at a number of localities. The only identifiable brachiopods were obtained from the conglomeratic limestone at Garrett Hollow (M104A), and these are highly abraded and fragmentary. Large goniatite collections have been made by a number of investigators from the conglomerates of the Cane Hill at a number of different localities, and many such conglomerates contain mixtures of both indigenous fossils and reworked fossils. The collection of brachiopods from Garrett Hollow is exclusively Lower Morrowan and includes no reworked specimens.

Prairie Grove Member.--The Prairie Grove Member was named by Henbest (1953, p. 1940) for the exposures in the mountains to the east and south of the community of Prairie Grove in west-central Washington County. Included within this member was the upper sandstone division of Simonds' (1891) "Washington sandstone and shale" and limestone beds previously referred to the Brentwood Member of the overlying Bloyd Formation by a number of authors. Henbest (1962a, p. 40) moved the type locality to the Evansville Mountain section (M70 of this dissertation), where it is easily accessable and excellently exposed above the Cane Hill Member.

The bulk of the Prairie Grove Member, particularly in the western part of Washington County (see cross-section A-A'), consists of a monototonous sequence of irregularly alternating, strongly cross-laminated, fine- to medium-grained, calcareous sandstones and quartz-sandy, skeletal calcarenites (grainstones). Oolitic calcarenites (grainstones) are also common. This particular facies forms massive cliffs throughout most of Washington County and can be recognized by its strong cross-laminations and by the distinctive coarsely pitted weathering surfaces, described by many authors as a "honeycombed" surface. This latter feature is the product of differential weathering of what Henbest (1953, p. 1941) interpreted as numerous _Arthrophycus_-like burrows. This facies is also characterized by highly discontinuous bedding and channeloid, cut-and-fill structures; it contains few abraded, unfragmentary megafossils. Henbest (ibid., p. 1942) suggested that perhaps this facies represents a beach deposit.

Skeletal calcarenites (grainstones and packstones) form a minor part of the total Prairie Grove, and mud-supported limestones (wackestones and mudstones) and shales constitute an extremely small proportion of the total sequence. All of these types are restricted to the upper part of the Prairie Grove Member in western Washington County but become more of a prominent lithic group and more equally dispersed throughout the member toward the Bloyd Mountain and Fayetteville areas. These lithic types are particularly important for this study because they are in places highly fossiliferous, in stark contrast to the dominant lithofacies of this member.

The Prairie Grove is generally separated from the Cane Hill Member by a thin, basal conglomeratic sandstone or limestone. The clasts are generally small pebbles of siltstone, sandstone, shale clasts, or, more rarely limestone and phosphate. Henbest (1953, p. 1941) noted "a pebble of novaculite about 2 cm across and cobbles of quartzitic sandstone" in the basal conglomerate on the southwestern side of Bloyd Mountain. The conglomerates are generally concentrated near the base of the member, although small pebbles of sandstone and limestone are not uncommon scattered widely at the base of beds throughout the dominant sandstone and quartz-sandy limestone facies. These latter, however, are most probably intraclasts rather than extraclasts.

The thickness of the Prairie Grove Member is cross-section A-A' varies irregularly from maxima of 98 and 93 feet at Evansville Mountain (M70) and Hale Mountain (M104A), respectively, to a minimum recorded thickness of about 41 feet at Kessler Mountain (M110). This member is about 75 feet thick in the Fayetteville area (M116).

The nature of the contact between the Prairie Grove Member and the subjacent Cane Hill Member is unquestionably unconformable from the Hale Mountain section (M104A) eastward (see cross-section A-A'), but no physical evidence can be found for an unconformity southwestward and westward from Hale Mountain at either the Evansville Mountain section (M70) where it is exposed only locally (Henbest, 1953, 1962a; Sutherland and Henry, _in press_) or in eastern Adair County (Sutherland and Henry, _in press_).

The upper contact of this member is gradational with the overlying Brentwood Limestone Member of the Bloyd Formation and, according to the definition of Henbest (1962a, p. 40), "is drawn at the base of the first shale bed, 2 feet or more thick, above the upper most massive, honeycombed (arthrophycid) calcareous sandstone of the Prairie Grove Member." This quotation referred only to the boundary at the type locality for the Prairie Grove Member (M70), although presumably Henbest intended a more widespread application of this definition. An upper boundary chosen in this manner is applicable to all the sections investigated by the current author in Washington County (see cross-section A-A'). Manger (1971, p. 64) contends that such criteria cannot be applied eastward into Madison County nor are they applicable westward into Oklahoma (Sutherland and Henry, in press).

The Prairie Grove Member is both widespread and readily recognizable throughout most of Washington County, and it has been recognized in both Madison County to the east and in Crawford County to the south (Gordon, 1965, p. 38). It is a relatively consistant lithostratigraphic unit in Washington County, but rapid facies changes to the west in Adair County exclude its application farther westward than about central Adair County (Sutherland and Henry, in press).

Bloyd Formation

The Bloyd Formation was named and described by Purdue (1907, p. 3) for the exposures on Bloyd Mountain, immediately southwest of Fayetteville. Henbest (1962a, p. 40) defined the type locality to be the section on "the southwest part of Bloyd Mountain extending from the center of the E½ sec. 3 to the center, north side of sec. 4, T. 14 N., R. 30 W." This is the immediate vicinity of measured section M112 of the current dissertation (see Appendix I for additional remarks).

The Bloyd Formation is reported to vary in thickness from 100 feet to 220 feet in Washington County (Gordon, 1965, p. 42). This formation varies irregularly in thickness in cross-section A-A' from a maximum of about 250 feet on Hale Mountain (M104B and M104C) to a minimum of about 200 feet in the Fayetteville area (M118).

The Bloyd Formation is approximately one half to two thirds shale. This formation has been subdivided into the following members, in ascending order: Brentwood Limestone, Woolsey Member, Dye Shale, Kessler Limestone, and Trace Creek Shale (text-figure 4).

Brentwood Limestone Member.--The Brentwood Limestone, originally referred to by Simonds (1891, p. 83) as the "Pentremital limestone", was formally named by Ulrich (1904, p. 109) for the outcrops at Brentwood Station in central Washington County. Purdue and Miser (1916, p. 4) clarified Ulrich's definition and applied the term to strata in the counties to the east of Washington County. Henbest (1953, p. 1943) more precisely defined this member by selecting as type locality the exposures on the eastern side of U. S. Highway 71, approximately 4 miles northwest of the community of Brentwood (M100 and M101 of this dissertation). Henbest did not published a detailed measured section for the type locality of the Brentwood Limestone, and some confusion exists as to where in that sequence he placed the upper boundary of this member. In his description of the Brentwood, Henbest (1953, p. 1943) stated:

> "The Brentwood limestone member ... begins with a dark, slightly fissile bed of shale 18 feet thick in which a few lenses of marine limestone interfinger. This shale is followed above by alternating benches of limestone and shale, which are terminated by the striking disconformity at the base of the terrestrial, coal-bearing sediments of the Woolsey member."

He asserted that when viewed "from across the valley west of Woolsey, the truncation by the Woolsey member of the uppermost beds of the

Brentwood is rather striking." What is actually seen when the exposures are viewed from the now-abandoned Woolsey Station is that the uppermost beds of what are herein referred to as Brentwood limestones cut out some of the lower limestones of this member. The base of the Woolsey lies higher on the bluffside and its contact with the Brentwood is sharp but not truncating.

Henbest pointed out that this unit is so highly variable in lithic character that it is recognized more by its stratigraphic position between the cliff-forming Prairie Grove Member and the overlying terrestrial Woolsey Member than by its own distinctive nature. This sequence is composed predominantly of interbedded layers and interfingering lenses of limestone and shale (text-figure 4) that show marked lateral changes in thickness and character. Many of the limestone beds are cross-bedded and lie within channels in the shale. A whole spectrum of limestone types is represented; the most common types are mixed-skeletal calcarenites (grainstones and packstones), which may or may not have an appreciable content of quartz sand and silt. clay clasts and phosphate pebbles are common in these limestones, particularly those that truncate subjacent strata.

The Brentwood Limestone is the most highly fossiliferous member of the Morrow Group in the type area, and it contains a highly diverse brachiopod fauna at most localities. The shales are generally noncalcareous, however, and only rarely fossiliferous.

Henbest (1953) reported the thickness of the Brentwood to be 40 feet at its type locality. This author has measured 51 feet for

This member at M100 and 48 feet and M101. The Brentwood ranges irregularly in thickness, in the line of cross-sections, from a maximum of 61 feet at Sawnee Hollow (M120) in extreme northwestern Crawford County to a minimum of 25 feet in Garrett Hollow (M105C). The Brentwood is about 48 feet thick in the Fayetteville area (M116).

The top of the Brentwood is chosen as the highest limestone below the terrestrial sediments of the Woolsey Member throughout most of the area investigated in Washington County. However in southwestern Washington County (M104B and M104C), in extreme northwestern Crawford County (M120) and in Adair County (M68 and M69), the overlying Woolsey Member is not present, and the basal part of the Dye Shale Member rests unconformably upon the Brentwood. In these cases, the upper contact is placed at the base of the lowest highly quartz-sandy, conglomeratic limestone or conglomeratic sandstone ("caprock") beneath the thick shales of the Dye Shale proper.

A number of authors have applied the term Brentwood to strata in northeastern Oklahoma (C. A. Moore, 1940; R. C. Moore and Strimple, 1973; among others); however, Sutherland and Henry (_in press_) did not recognize the Brentwood farther west than the central part of Adair County.

Woolsey Member.--The Woolsey Member, which comprises the lower part of what was referred to as the "coal-bearing shale" by many early investigators, was formally named and described by Henbest (1953, p. 1943) for exposures near Woolsey Station in the central part of

Washington County. At the type locality, he described this sequence as consisting of a local basal conglomerate and argillaceous, plant-bearing sandstones, an underclay, the Baldwin Coal, and an overlying terrestrial shale with coal stringers. This sequence terminates with what Henbest describes as an angular unconformity with the overlying "caprock" of the Baldwin Coal (basal Dye Shale Member). A measured section and additional discussion is presented in Appendix I under measured section M112, the type section.

The Woolsey is generally poorly exposed since it consists of relatively nonresistant lithic types. However, artificial exposures are found in many areas of central Washington County where the Baldwin Coal, which locally attains thicknesses of up to 18 inches (Henbest, 1953, p. 1944), was mined. The type locality is in one of these abandoned coal diggings.

The terrestrial origin of most of this sequence of strata is affirmed by the abundance of aerial parts of plants preserved on bedding surfaces, particularly in the fine-grained sandstones and argillaceous siltstones, by the presence of the Baldwin Coal and the underclay with root fragments, and by the recovery of an amphibian from this sequence (Roemer, 1963). However, in Garrett Hollow (M105C and M105D), a sequence of thin, sparsely fossiliferous, marine limestones (wackestones and mudstones) lies conformably and gradationally above the shale that grades downward into the Baldwin Coal; these limestones are unconformably overlain by the "caprock". They are thus genetically related to the Woolsey Member and are herein included within this member.

The Woolsey Member disconformably overlies the Brentwood Limestone throughout much of Washington County. A spectacular conglomerate is present at the base of the Woolsey in the Devil's Den State Park section (M114), where the upper part of the Brentwood is marked by a sharp undulating contact with up to 1.5 feet of local relief on it. The basal Woolsey here contains scattered pebbles of limestone and one small imestone boulder measuring 0.8 foot by 0.4 foot. A basal conglomerate was not observed in the Garrett Hollow sections (M105C and M105D), and that area may represent the westward extent of this disconformity.

The Woolsey Member attains its maximum thickness in its type area, where it is represented by a maximum of about 38 feet in measured sections M100 and M112. It thins northward and is only about 25 feet thick in the Fayetteville area. The sequence thins westward toward the Arkansas-Oklahoma State Line and is not present on Hale Mountain (M104B and M104C). The Woolsey is represented by only 5.5 to 7 feet of quartz-silty shale at Evansville Mountain (M70), where it includes an underclay up to 1-foot thick and a thin, lensing coal layer, which locally reaches a thickness of 3 inches.

Sutherland and Henry (in press) reported that the Woolsey is missing westward. They interpreted the westward thinning and disappearance of the Woolsey to be the result of interfingering between a predominantly shallow water, near shore marine environment, under which conditions the Brentwood strata were deposited, and a low-lying, predominantly nonmarine environment, under which conditions the Woolsey lithic types were laid down. The presence of Lane's (1967, p. 925) *Idiognathodus humerus* conodont fauna in the basal part of the Woolsey Member in its type area (M101) and in the upper parts of the sequence at Evansville Mountain assigned to the Brentwood by Sutherland and Henry also supports the temporal equivalency of at least parts of the Woolsey with portions of the Brentwood. The results of the current study would affirm this contention, because it appears that the disconformity at the base of the Woolsey may disappear westward; in addition, the discovery of the marine beds in the upper Woolsey at Garrett Hollow would strongly suggest that much of this area was at least in near proximity to shoreline during deposition of the upper Woolsey.

The westward thinning and disappearance of the Woolsey may also at least in part be due to truncation by the regional unconformity at the base of the overlying sequence of strata (Sutherland and Henry, *in press*).

Dye Shale Member.--Henbest (1962b, p. 42) applied the name Dye Shale Member to the interval of rocks within the Bloyd Formation lying between the top of the Woolsey Member and the base of the Kessler Limestone. As such, it forms the bulk of what was referred to in the earlier geologic reports as the "coal-bearing shale".

The Dye Shale is dominated by dark gray, quartz-silty shales with a lesser proportion of clay shales and argillaceous siltstones.

Disc-shaped, dark gray, micritic carbonate (?dolomite) nodules or concretions are commonly scattered in zones throughout much of the interval, but limestones are rare. These are generally highly argillaceous. The basal part of this member is characterized by a discontinuous and highly variable unit referred to as the "caprock" of the Baldwin Coal.

The total Dye Shale Member is uniformly thick across the line of cross-sections (A-A'), with an average thickness of around 70 to 75 feet. Henbest (1962b) reported that the Dye Shale varies in thickness from 60 to 110 feet in Washington County.

The Dye Shale is generally poorly exposed throughout most of Washington County, but a few good exposures have been found on the tributaries of the larger streams. The Dye Shale is poorly exposed on the southwestern side of Bloyd Mountain (M112 of this dissertation) in the general area that Henbest (1962b) designated the type locality, but this sequence is continuously exposed approximately 1.75 miles to the southeast in the Mill Creek section (M113).

The "caprock" of the Baldwin Coal is widely distributed in Washington County and is one of the most distinctive "horizons" in the Morrow Group, particularly where the Baldwin Coal crops out a variable but generally short distance beneath it. The base of the "caprock" was chosen as the datum for cross-section A-A' (in pocket) because of its easy recognition, and since it represents the basal part of a marine transgressive sequence on top of an unconformity that is recognizable throughout the Ozark region and that represents a major hiatus in the brachiopod and goniatite faunas (see discussion of biostratigraphy).

The "caprock" is nevertheless locally highly variable in both lithic character and lateral continuity. It is generally a conglomeratic, calcareous sandstone or conglomeratic, highly quartz-sandy limestone that is a few feet thick and that forms small but distinct, cross-bedded benches or ledges. It may be represented, however, by a layer no more than 1 or 2 inches thick consisting of scattered clay clasts and/or pebbles of various lithic types set in a matrix similar to that of the bulk of the Dye Shale, with which it intergrades. Throughout the area investigated by this author, the thickness of this bed ranges from less than 1 foot (M108) to 7 feet (M70), and it is generally less than 4 or 5 feet thick in most of the stratigraphic sections. Rapid variability in both the lateral thickness and lithic character can be readily seen in the three closely spaced sections measured near the headwaters of Lee Creek (see introduction to sections M106, M107, and M108 in Appendix I).

Henbest (1953, p. 1945) stated that "at the old mines on Robinson Mountain ... and near Zion Chapel ... [about 6 miles southeast and about 6 miles northeast of Fayetteville, respectively] the conglomerate is 3-10 feet thick and varies laterally from massive calcareous sandstone to quartz gravel conglomerate like that of the Atoka formation."

The pebbles in the conglomerate are generally well rounded and consist of a wide spectrum of lithic types. The most commonly encountered are clasts of fine-grained sandstones and siltstones, similar to those from the underlying Woolsey Member and limestones of the types found commonly in the Brentwood. Henbest (1962b) reported that quartz pebbles up to 14 mm across have been found locally.

The Dye Shale generally contains few readily recognizable megafossils. The "caprock" has yielded only a very small collection of brachiopods, although it contains numerous gonitatites at a number of localities (Gordon, 1964; McCaleb, 1968). Most of the megafossils are badly worn and abraded, attesting to the turbulence of the environment in which they were deposited. The few scattered limestone lenses and calcareous shales that occur in the Dye Shale above the "caprock" have not yielded identifiable brachiopods; about the most common fossils in these lithic types are bryozoans and pelmatozoan columnals. Molds of bryozoans, pelecypods, gastropods, and rarely other fossil types are rarely encountered in the noncalcareous shales, quartz-silty shales, and fine-grained quartzsiltites that form the bulk of this member.

The upper contact of this member is placed at the base of the first thick limestone of the Kessler Limestone Member.

Kessler Limestone Member.--The Kessler Limestone was first recognized and named by Simonds (1891, p. 103-105) for outcrops on Kessler Mountain near Fayetteville. Henbest (1962a, p. 41) defined the type locality to be "near the center, SE¼ sec. 25, T. 16 N., R. 31 W." but published no stratigraphic section for the type locality.

The type locality is the site of measured section M118 of this dissertation (refer to Appendix I).

The Kessler Limestone in Washington County is dominated by oolitic calcarenites (grainstones), algal oncolith-bearing calcarenites (packstones), and algal and mixed skeletal calcarenites (grainstones to wackestones). Other lithic types include minor calcareous sandstones, shales, and quartz-sandy limestones. Conglomeratic beds are minor and generally occur at the base of highly lensing and channeloid units.

The individual lithic types in the Kessler appear to have little lateral continuity, but the Kessler Limestone has been recognized in all of the areas studied in Washington County where the upper sequence is well exposed. It does not appear to be discontinuous as the earlier applied term "Kessler limestone lentil" would imply. Both the rapid changes in thickness laterally and the marked lateral changes in lithic character are well illustrated in the three closely spaced sections measured near the headwaters of Lee Creek (see introduction to measured sections M106, M107, and M108, Appendix I).

The Kessler is generally only sparsely fossiliferous. However, at Garrett Hollow (M105D), the Kessler contains a diverse and abundant brachiopod fauna.

The Kessler Limestone varies in thickness from about 9 feet in Fayetteville (M115) to maximum thicknesses of 28 and 32 feet at

M108 and M113, respectively. In the latter section, the Kessler is about 50 percent shale with limestones at the base and at the top and a thin calcareous sandstone in the middle.

The lower contact of the Kessler is generally sharp and commonly marked by a thin conglomeratic layer. The clasts, however, are generally exclusively clay and shale clasts, most probably derived from the subjacent Dye Shale. The contact would appear to be generally disconformable, but no evidence exists suggesting that the contact is regionally truncating.

The upper contact is rarely well exposed and is picked at the top of the highest prominent limestone.

The Kessler Limestone Member has been recognized eastward into Madison County (Doy L. Zachry, personal oral communication, November, 1971). Sutherland and Henry (in press) recognized the Kessler Limestone westward into central Adair County, and stated that the Greenleaf Limestone Member, which occurs farther to the west, may represent a westward extension of this member but is interpreted to be stratigraphically slightly lower.

Trace Creek Shale.--The Trace Creek Shale Member was defined by Henbest (1962b, p. 44) for the "rocks that lie between the top of the Kessler Limestone Member of the Bloyd Formation and the base of the Greenland Sandstone Member of the Atoka Formation". Simonds (1891) and Taff (1905) had included this sequence of shales in what was to be later named the Atoka Formation, but most early authors

(Ulrich, 1904; Adams & Ulrich, 1905; Purdue, 1907) included this interval with the Morrowan.

This sequence is generally poorly exposed, but normally consists of dark gray clay shales and quartz-silty shales with lesser amounts of argillaceous siltstones, fine-grained sandstones, and rare, thin lenses and beds of sandstones or quartz-sandy limestones. Dark gray, micritic carbonate (?dolomite) nodules are locally common, particularly near the base of the member.

The Trace Creek Member on Hale Mountain (M104B, M104C) is unusual in that it locally contains a basal limestone-pebble and -cobble conglomerate overlain by a thick, lensing sandstone (see discussion of the Hale Mountain sections for additional remarks) and also contains several thick, lensing sandstone bodies up in the member itself.

The Trace Creek Member is generally poorly fossiliferous, and few identifiable brachiopods have been collected from it.

The Trace Creek is widely distributed in Washington County and generally varies in thickness from about 60 to 70 feet. However, at Kessler Mountain (M118), the Trace Creek Shale is only 38 feet thick, and on Hale Mountain it varies in thickness from 116 to 121 feet (M104C and M104B, respectively).

The lower contact with the Kessler Limestone appears in places to be gradational but is obviously disconformable in others (e.g., M104C). The upper contact of the Trace Creek is defined as the base of the first prominent cliff-forming sandstone. This contact, too, appears in places to be conformable and in others disconformable.

Morrow Group, Northeastern Oklahoma

The Morrow Group changes facies extremely rapidly westward into Oklahoma, particularly in the middle and lower parts of the sequence. In the opinion of Sutherland and Henry (in press) the bases for subdivision proposed by C. A. Moore (1940, 1947) and Huffman, and others (1958) for extending the Hale and Bloyd into Oklahoma are not applicable. The distribution of the quartz-sand in these strata is highly irregular, and the lowest thick shales are developed progressively stratigraphically much lower westward than in Arkansas. Neither criterion can be consistantly utilized as a basis for subdivision of these strata. Sutherland and Henry (in press) do recognize that the Hale and Bloyd can be employed for strata as far west as central Adair County and use this general area as an arbitrary cut-off point for employment of both the Arkansas and Oklahoma formational terms.

The entire Morrowan sequence is predominantly limestone in Muskogee, Cherokee, and Sequoyah Counties and consists of complexly interfingering carbonate facies. Sutherland and Henry (in press) recognized a single distinctive, persistant datum throughout the area of exposure in northeastern Oklahoma. This datum is a regional unconformity and corresponds to the unconformity at the base of the "caprock" of the Baldwin Coal (basal Dye Shale Member) in northwestern Arkansas. The sequence above this unconformity, for which they introduced the term McCully Formation, and the sequence below this datum, the Gore Formation, are quite different lithically. The two formations are also subdivided into a number of members based upon persistant lithic differences.

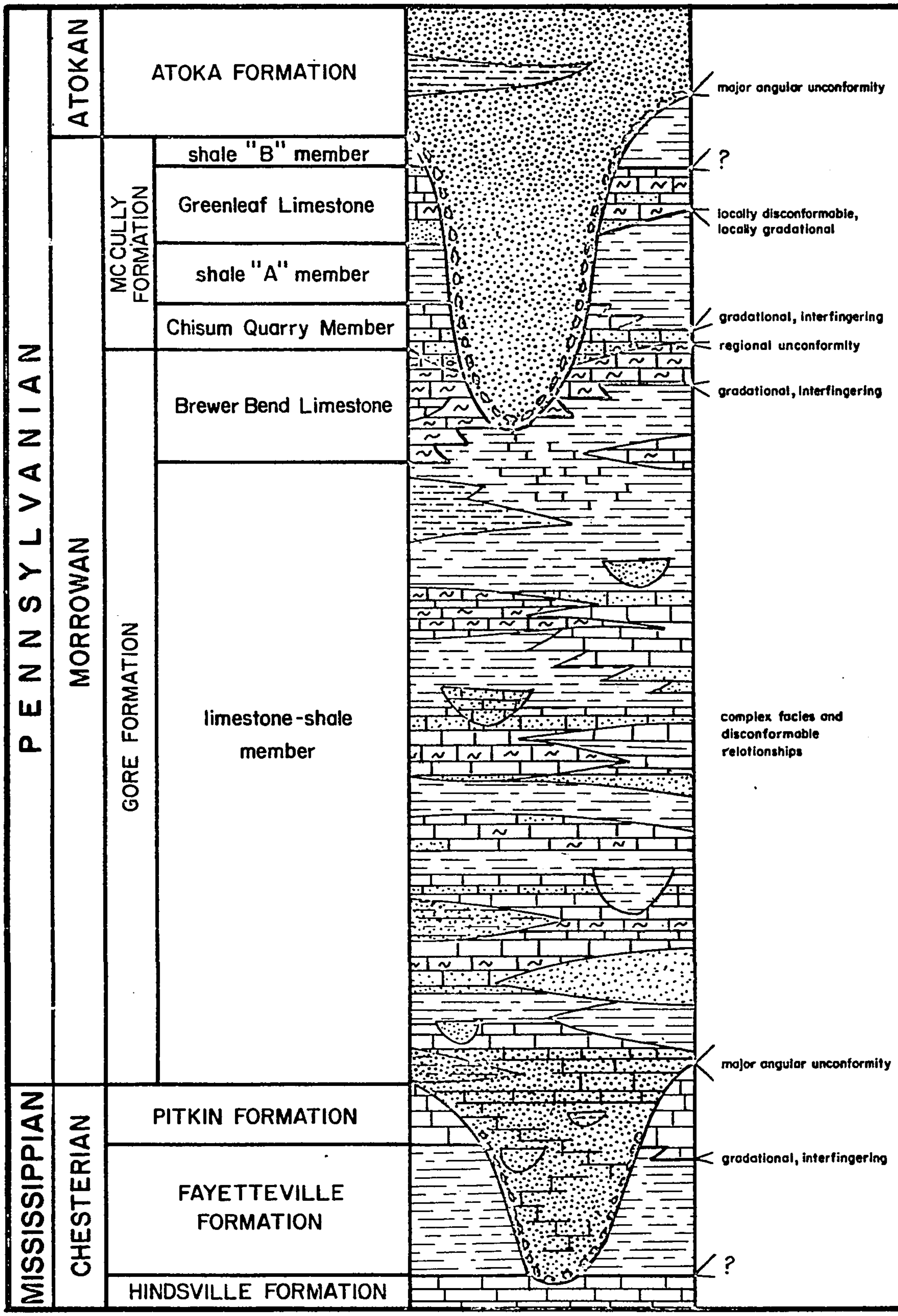
The following discussion is summarized from Sutherland and Henry (in press). This information is presented graphically in text-figure 5.

The Morrow Group thins irregularly westward from Arkansas and is about 200 feet thick in the vicinity of Webbers Falls Reservoir (see text-figure 2 for location). The Morrow Group thins irregularly northward and is truncated by strike-overlap of the Atoka Formation in the vicinity of Pryor in Mayes County (T. 21N., R. 19 E.). The irregular thickness of the Morrowan strata is due primarily to topographic relief developed upon both the post-Chesterian erosional surface and the post-Morrowan, pre-Atokan surface.

Gore Formation

The Gore Formation, named by Sutherland and Henry (in press), consists of limestones with minor percentages of sandstones, siltstones, and shales. A thin, local basal conglomerate is present at a number of localities. The formation is best seen in the exposures on both the western and eastern sides of the Arkansas River near

Text-figure 5.--Composite section of the Morrow Group in the Webbers Falls Reservoir area, northeastern Oklahoma, illustrating the subdivisions proposed by Sutherland and Henry (*in press*).


PENNSYLVANIAN
MISSISSIPPIAN
ATOKAN
MORROWAN
CHESTERIAN
ATOKA FORMATION
MC CULLY FORMATION
shale "B" member
Greenleaf Limestone
shale "A" member
Chisum Quarry Member
GORE FORMATION
Brewer Bend Limestone
limestone-shale member
PITKIN FORMATION
FAYETTEVILLE FORMATION
HINDSVILLE FORMATION
major angular unconformity
?
locally disconformable, locally gradational
gradational, interfingering
regional unconformity
gradational, interfingering
complex facies and disconformable relationships
major angular unconformity
gradational, interfingering
?

Webbers Falls Reservoir in southeastern Muskogee County (text-figure 2), the designated type area for the formation.

The Gore Formation is unconformably overlain by the McCully Formation throughout most of the outcrop area; locally in T. 15N., R. 20E., the Atoka Formation rests directly upon the Gore Formation, the McCully Formation having been removed by pre-Atokan erosion. The formation varies in thickness from 225 feet (M51) to 51 feet (M24) in the area studied by Sutherland and Henry (in press; see text-figure 2 of this dissertation).

This formation is subdivided throughout most of eastern Muskogee, Sequoyah, Cherokee, and southeastern Wagoner County into the limestone-shale member and the overlying Brewer Bend Limestone.

The limestone-shale member forms the bulk of this formation and consists of a highly complex series of interfingering, lensing, and channeling limestones with lesser percentages of sandstones, siltstones, and shales. The limestones represent a complete spectrum of carbonate types, but skeletal grainstones and packstones are the most important. This member is recognized primarily by its stratigraphic position at the base of the Morrow beneath the highly distinctive Brewer Bend Limestone.

The contact between the limestone-shale member and the overlying Brewer Bend is gradational and the two lithic groups interfinger in the area around Webbers Falls Reservoir, where the contact is in places arbitrarily chosen.

The Brewer Bend Limestone is predominantly an algal calcilutite (wackestone) that is thin bedded and nodular and interbedded with thin dark gray shale lamellae. Consequently, this member appears on the outcrop generally as a rubbly surface.

The Brewer Bend Limestone is unconformably overlain by the McCully Formation throughout most of northeastern Oklahoma where it has not been removed by the pre-Atokan erosional surface. The member is about 30 feet thick in the southwestern outcrop area, but less than 10 feet thick in the northern Lake Tenkiller area.

The Gore Formation is highly fossiliferous in most places. The calcareous shales are particularly fossiliferous and large brachiopod and goniatite collections have been made from them at a number of localities. This sequence is particularly important in this regard since highly fossiliferous strata begin much lower in the Morrowan interval here than in strata of the same age in northwestern Arkansas.

McCully Formation

The McCully Formation was proposed by Sutherland and Henry (in press) for McCully Mountain near Webbers Falls Reservoir (text-figure 2) and the type sections are contiguous with those of the Gore Formation. This formation, in marked contrast to the subjacent Gore Formation, consists predominantly of fine-grained terrigenous clastics, of which shale is volumetrically the most abundant lithic type. Limestones are next most abundant, and a few sandstones and siltstones are present. Conglomerates are rare and are generally confined to the basal few inches of the formation.

The formation is between 55 and 80 feet thick in its type area and is truncated to the northwest by the Atoka Formation in southeastern Wagoner and western Cherokee Counties. The McCully Formation is also truncated locally in T. 15N., R. 20E. It is recognized eastward and northeastward as far as the eastern edge of Cherokee County.

This formation has been subdivided into the following members in ascending order: Chisum Quarry Member, the shale "A" member, Greenleaf Limestone Member, and shale "B" member.

The Chisum Quarry Member at the base of the McCully Formation is a distinctive bioclastic limestone (generally a grainstone or a packstone) that commonly contains algal oncoliths. The basal bed generally contains clay clasts and rests with sharp disconformable contact upon the underlying Brewer Bend Limestone. The relatively high content of iron oxides gives the unit a characteristic reddish-brown appearance on the outcrop, in contrast to the light gray weathering color of the underlying unit. This member is between 15 and 25 feet thick in the southwestern outcrops but thins to less than 5 feet thick in the northern Lake Tenkiller area (text-figure 2). It is gradational with and interfingers with the overlying shale "A" member. The limestones of this member are in places highly fossiliferous, and large brachiopod collections have been made.

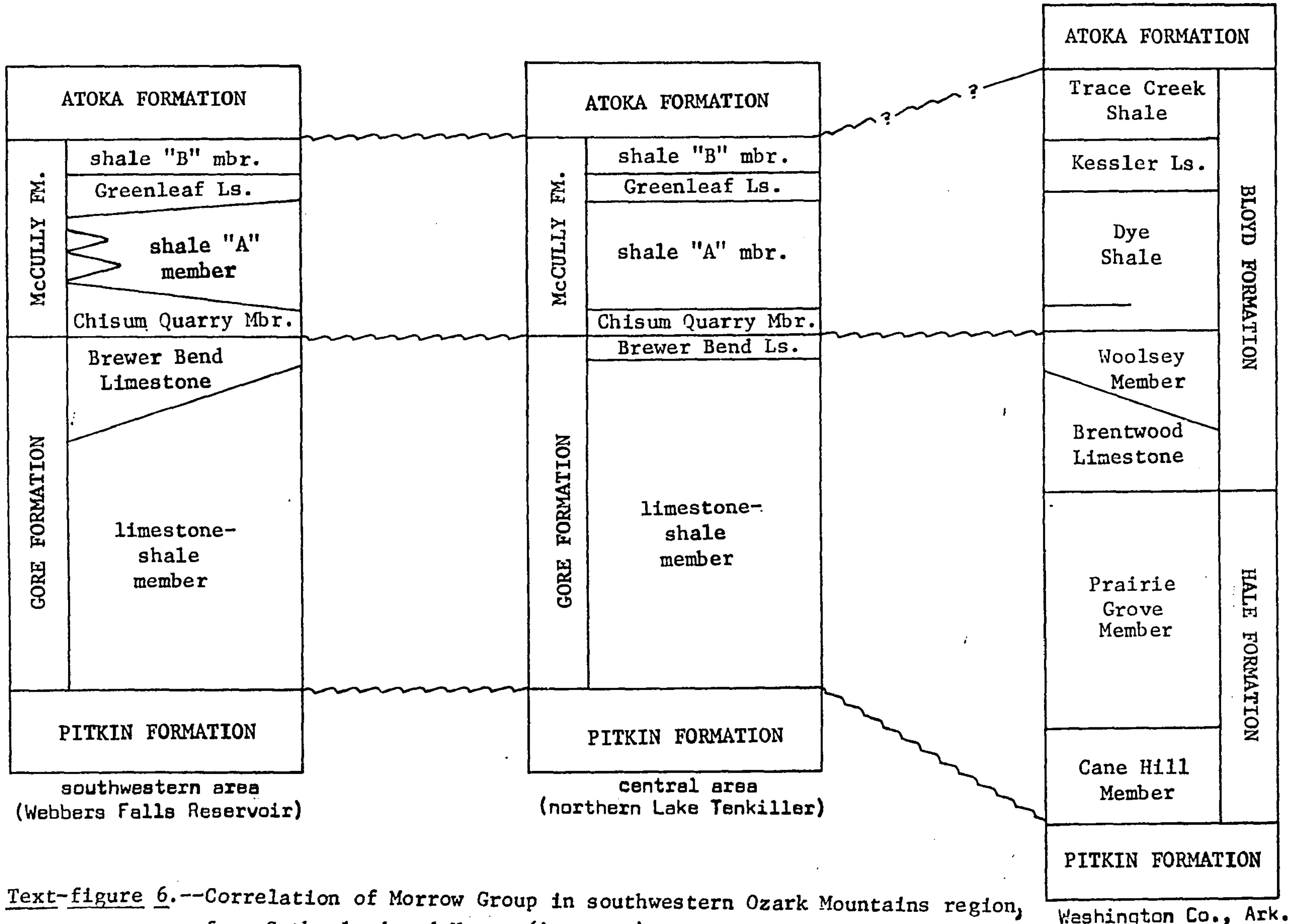
The shale "A" member is the first of the two relatively persistant shale intervals in the McCully Formation. This member varies in thickness generally from about 25 to 30 feet. It consists mostly of dark gray, noncalcareous shales and thin, argillaceous siltstones. Locally in the southwestern area, this member contains numerous thin limestones, some of which are highly fossiliferous.

The Greenleaf Limestone overlies the shale "A" member and consists principally of complexly interbedded micritic, skeletal calcarenites and calcilutites (wackestones and packstones) and a few skeletal calcarenites (grainstones). A few thin, generally calcareous shales are present at a number of localities, and these are highly fossiliferous. Sandstones are rare in this member. The Greenleaf is 19 feet thick in the Greenleaf Lake area. The thickness of this member is highly variable primarily because of the irregular truncation by the unconformity at the base of the overlying Atoka Formation.

The shale "B" member attains a maximum thickness of 40 feet in measured section M78, and it is truncated throughout much of the area in the southwestern outcrops (e.g., M1, M3, M27, etc.) and has been completely removed by pre-Atokan erosion north and northwest of Greenleaf Lake. This unit is generally poorly exposed, and no megafossils have been collected from it.

Correlation of Morrow Group Northwestern Arkansas with Northeastern Oklahoma

Text-figure 6 shows the correlation of the Morrow Group in northeastern Oklahoma with northwestern Arkansas proposed by Sutherland and Henry (in press). Few beds in the lower and middle parts of the



Text-figure 6.--Correlation of Morrow Group in southwestern Ozark Mountains region, from Sutherland and Henry (*in press*).

Morrowan succession can be recognized for any distance laterally into Oklahoma, and the Prairie Grove Member of the Hale Formation is recognized as a lithologic entity only into central Adair County. This part of the section is correlated with that in Oklahoma on the basis of the conodont microfauna (Henry, 1970; Lane and Straka, 1971), which will be discussed in a succeeding section. The Cane Hill Member cannot be recognized farther westward than the central portion of Adair County (M67). Strata at the base of the limestone-shale member of the Gore Formation are interpreted to be younger than the Cane Hill Member and correlate with the lower to middle portions of the Prairie Grove Member. The middle and upper portions of the limestone shale member correlate with the upper parts of the Prairie Grove Member and the lower parts of the Brentwood Limestone. The Brewer Bend Limestone correlates with the upper Brentwood and Woolsey Members.

The regional unconformity at the base of the Dye Shale Member in northwestern Arkansas is recognized in northeastern Oklahoma, and the lower part of the Chisum Quarry Member has been traced across Adair County into the "caprock" of the Baldwin Coal. Goniatite information from the Chisum Quarry Member substantiates this correlation. The upper parts of this member in the southwestern area where the Chisum Quarry Member is thickest probably correlate with the lower to middle parts of the Dye Shale. The Kessler Limestone can be definitely recognized as far westward as central Adair County. The poor quality of outcrops in the upper part of the Morrowan sequence in western Adair make it impossible to determine whether the Greenleaf Limestone Member is the westward extension of this member. Sutherland and Henry (ibid.) believe, however, that the Greenleaf Limestone may be slightly lower stratigraphically than the Kessler Limestone. Nevertheless, the shale "A" member would correlate with the bulk of the Dye Shale, and the shale "B" member may correlate with part of the Kessler Limestone and/or the lower part of the Trace Creek Member.

Atoka Formation and Nature of Morrowan-Atokan Boundary

The sequence of strata overlying the Morrow Group in the Ozark Mountains area was originally called the Winslow Formation by Ulrich (1904, p. 29) for the exposures in the Winslow Quadrangle immediately south of the Fayetteville area. The name Winslow persisted until Croneis (1930, p. 88-91) placed it in synonymy with the Atoka Formation, originally defined in the western part of the Ouachita Mountains of southeastern Oklahoma (Taff and Adams, 1900, p. 273).

The Atoka Formation is more than 900 feet thick on the outcrop in southwestern and southern Washington County (Jackson, 1959, p. 273) and approximately 800 feet thick on the outcrop in eastern Muskogee County (Newell, 1937, p. 24).

The formation consists predominantly of silty shales and sandstones, many of the latter of which form massive bluffs that cap the ridges and plateaus throughout the area of investigation. The erosion of the underlying shales results in extensive slumping of blocks of sandstone, and these commonly cover the upper part of the Morrowan sequence and obscure the Morrowan-Atokan contact. The actual contact is rarely seen except in a few artificial exposures.

The Atoka Formation unconformably overlies the Morrow Group in all areas of outcrop in northeastern Oklahoma with the possible exception of central and eastern Adair County. Sutherland and Henry (*in press*) demonstrated that the upper members of the Morrow Group are systematically truncated by the pre-Atokan erosional surface toward the northwest as the Atoka formation rests on progressively older strata toward the Wagoner and Mayes Counties area. This erosional surface is highly irregular locally and possesses up to about 80 feet of relief with channels of sandstone cutting out the McCully Formation and the upper part of the Gore Formation in T. 15N., R. 20E.

The Morrowan-Atokan contact in Adair County and Washington County is poorly exposed but does not appear to represent an unconformity, at least not one of significant magnitude. Zachry and Haley (1973, p. 289) stated: "Sedimentary evidence supporting an unconformity between the Bloyd Shale and the Atoka Formation is sparse; and paleontologic evidence does not indicate a time break between the two units."

BIOSTRATIGRAPHY

Introductory Statement

Every attempt was made to utilize only those collections of brachiopods that were made from relatively thin stratigraphic intervals and that were closely integrated with the lithostratigraphic succession. However, both the Prairie Grove Member and the limestone-shale member in the lower part of this sequence are thick and neither contains distinctive beds that can be used to subdivide this part of the section. The brachiopod collections made from this part of the sequence were therefore closely related to the base of the *Neognathodus bassleri* Zone, since considerable conodont information is available from the lower part of the section and since the author (Henry, 1970) found the base of this zone to be both a reliable and persistant datum throughout a relatively large geographic area. A brief discussion of the conodont zonation thus preceeds the discussion of the brachiopod zonation proposed herein.

Conodont Biostratigraphy

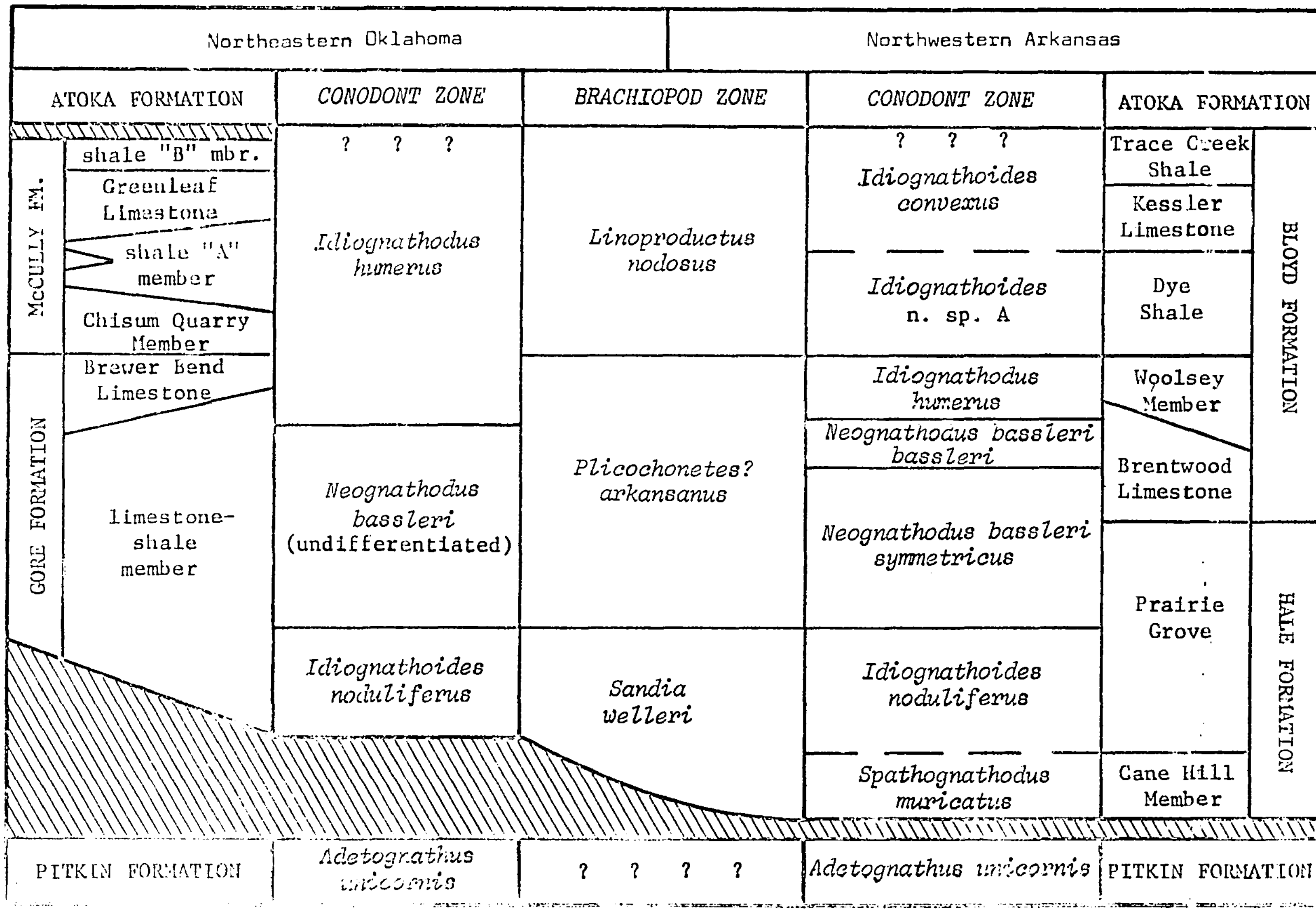
The Morrow Group in Washington County, Arkansas, has been subdivided into seven conodont zones (Lane, 1967; Lane and Straka, 1971). These are, in ascending order, the *Spathognathodus muricatus* Zone, Idiognathoides muricatus Zone, Neognathodus bassleri symmetricus Zone, Neognathodus bassleri bassleri Zone, Idiognathodus humerus Zone, Idiognathodus sp. A (of Lane and Straka, 1971) Zone, and the Idiognathoides convexus Zone (text-figure 7).

The upper six of these zones are range zones constructed on the lowest occurrence of a zonal name-bearer, and most of the zonal markers are long-ranging upward. The top of the highest zone, the I. convexus Zone, is not defined since the Trace Creek Shale has yielded a very limited, identifiable conodont fauna.

The S. muricatus Zone is an assemblage zone. Its lower boundary is defined by the association of the name-bearer and/or S. primus and/or S. transitoria with one or more of the following form-species: Adetognathus lautus, A. gigantus, or I. noduliferus. The top of this zone an the base of the succeeding zone is defined by the highest occurrence of S. muricatus.

Henry (1970) was unable to recognize many of the features of this detailed zonation in northeastern Oklahoma. This inability to recognize many features of Lane and Straka's (1971) zonation was in part due to the paucity of conodont recoveries from the micritic carbonate rocks that are abundant in the Morrow Group of northeastern Oklahoma and to the apparent low diversity of conodont faunas in these same lithic types. Three zones, based on the first occurrence of the zonal name-bearer were recognized: the Idiognathoides noduliferus Zone, Neognathodus bassleri (undifferentiated Zone, and the Idiognathodus humerus Zone (text-figure 7).

Text-figure 7.--Chart showing correlation between strata of Morrow Group of northwestern Arkansas and northeastern Oklahoma. Brachiopod zonation is presented in the central column; conodont zonation for respective areas are given in adjacent columns. Conodont zonation for northwestern Arkansas is modified from Lane (1967) and Lane and Straka (1971); that for northeastern Oklahoma from Henry (1970).


Northeastern Oklahoma
Northwestern Arkansas
ATOKA FORMATION
CONODONT ZONE
BRACHIOPOD ZONE
CONODONT ZONE
ATOKA FORMATION
McCULLY FM.
shale "B" mbr.
Greenleaf Limestone
shale "A" member
Chisum Quarry Member
GORE FORMATION
Brewer Bend Limestone
limestone-shale member
? ? ?
Idiognathodus humerus
Neognathodus bassleri (undifferentiated)
Idiognathoides noduliferus
Linoproductus nodosus
Plicochonetes? arkansanus
Sandia welleri
? ? ?
Idiognathoides convexus
Idiognathoides n. sp. A
Idiognathodus humerus
Neognathodus bassleri bassleri
Neognathodus bassleri symmetricus
Idiognathoides noduliferus
Spathognathodus muricatus
Trace Creek Shale
Kessler Limestone
Dye Shale
Woolsey Member
Brentwood Limestone
BLOYD FORMATION
Prairie Grove
Cane Hill Member
HALE FORMATION
PITKIN FORMATION
Adetognathus unicornis
? ? ? ?
Adetognathus unicornis
PITKIN FORMATION

The base of the Neognathodus bassleri Zone appears to coincide approximately with a change in the constitution of the brachiopod fauna. A number of brachiopod species first appear in the lower part of the N. bassleri Zone (additional discussion to follow).

Brachiopod Biostratigraphy

The Morrow Group is herein subdivided into three brachiopod zones (text-figure 7), based upon the established ranges of the 45 species recognized in this stratigraphic sequence (see Brachiopod Range Chart, in pocket). The zones are a specialized type of range zone, the definition of which is dependent upon the first occurrence of a number of brachiopod taxa. The zones are, in ascending order, the Sandia welleri Range Zone, the Plicochonetes? arkansanus Range Zone, and the Linoproductus nodosus Range Zone.

Seventeen species have been identified from the S. welleri Zone, and 16 of these range into the overlying P.? arkansanus Zone. The largest faunal break in the Morrow Group occurs at the top of the P.? arkansanus Zone; of the 34 species identified from this zone, only 21 range into the highest recognized zone, the Linoproductus nodosus Zone. The latter zone is characterized by 31 species of brachiopods, of which 10 are unique to this interval. This biostratigraphic break corresponds to the geographically widespread erosional unconformity that occurs at the base of the Dye Shale Member ("caprock" of the Baldwin Coal) in northwestern Arkansas and at the base of the Chisum Quarry Member in northeastern Oklahoma. The terms Lower Morrow and Upper Morrow Series are employed in this dissertation based upon this biostratigraphic and lithostratigraphic break.

Sandia welleri Range Zone.--The Sandia welleri Range Zone characterizes the lower part of the Morrow Group (text-figure 7). This zone corresponds to the upper part of the Cane Hill Member of the Hale Formation and to approximately the lower one half of the overlying Prairie Grove Member in northwestern Arkansas. This zone occupies approximately the lower one third of the limestone-shale member in northeastern Oklahoma.

This range zone is characterized by the lowest occurrence of the following brachiopod species: Sandia welleri, Linoproductus n. sp. A, Anthracospirifer matheri, Echinaria n. sp. A, Schizophoria altirostris?, Tesuquea morrowensis, Buxtonia grandis, Derbyia? n. sp. B, and Phricodothyris perplexa (see Brachiopod Range Chart, in pocket). The lowest known occurrence of these taxa is in the middle part of the Cane Hill Member at Garrett Hollow (M105A-3, basal 1.5 feet) in the Spathognathodus muricatus Zone. The actual lower ranges of these species are not adequately known, because the lower part of the Cane Hill Member has not produced collections of identifiable brachiopods.

This zone also contains Pulchratia? n. sp. A, Hustedia miseri, Spiriferellina? campestris, Beecheria n. sp. A, B.? bilobatum, Neochonetes? n. sp. A, Wellerella triangularis, Orbiculoidea sp. A, and O. minuta. The lowest known occurrence of this latter group of species is within the basal parts of both the Prairie Grove Member and the limestone-shale member. Many, if not all, of these species probably also occur in the Cane Hill Member but have not been thus far identified from these strata because of the paucity of brachiopods in this member.

Of the 17 species identified from this zone, only Derbyia? n. sp. B has not been identified in higher intervals. Of the species identified, only S. welleri, T. morrowensis, Linoproductus n. sp. A, P. perplexa, and S. altirostris? occur commonly; of these, S. welleri forms the bulk of the specimens collected from this interval with S. altirostris? representing the second most abundant species collected.

The upper boundary of the S. welleri Zone is delimited by the lowest occurrence of ten brachiopod species (see Brachiopod Range Chart) and is approximately correspondent to the top of the Idiognathoides noduliferus Zone.

Plicochonetes? arkansanus Range Zone.--The P.? arkansanus Zone immediately overlies the S. welleri Zone and corresponds to the upper half of the Prairie Grove Member and all of the Brentwood Limestone in northwestern Arkansas (see text-figure 7) and to the upper two-thirds of the limestone-shale member and the Brewer Bend Limestone in northeastern Oklahoma.

The lower boundary of this zone is based upon the lowest known occurrence of Plicochonetes? arkansanus, Beecheria n. sp. A, Beecheria? bilobatum, Rhynchopora magnicosta, Punctospirifer morrowensis, Schizophoria oklahomae, Krotovia? globosa, Desmoinesia nambeensis, Spirifer goreii, Derbyia n. sp. A, and Orbiculoidea sp. B. (see Brachiopod Range Chart). The lowest occurrences of these species are generally within a thin short stratigraphic interval (generally within about 10 feet) above the first occurrence of Neognathodus bassleri symmetricus. Sufficiently large brachiopod collections have been made from both the lower part of the limestone-shale member and the lower part of the Prairie Grove Member for the author to be reasonably certain that most of the species listed above do not range downward into strata bearing Idiognathoides noduliferus.

In addition to the 11 species named above and the 16 species that range upward into this interval from the subjacent zone, the P.? arkansanus Zone contains the following 7 species that occur rarely: Phricodothyris? transversa, reported only from the upper part of the Prairie Grove Member at a single locality, Lingula cf. L. carbonaria, Rhipidomella trapezoida, Punctospirifer? n. sp. A, Cleiothyridina milleri, Krotovia n. sp. A, and Girtyella? emarginata. Only P.? transversa of these extremely rarely occurring species has been reported from strata older than the Brentwood Limestone or the upper part of the limestone-shale member.

The upper boundary of this zone marks the uppermost occurrence of nine species that occur commonly in the underlying strata and constitutes the most important biostratigraphic break in the entire Morrow Group.[1] The following species are restricted to the Lower Morrowan

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[1] A similar break at this horizon also occurs with the goniatite fauna (McCaleb, 1968).

sequence: Linoproductus n. sp. A, Pulchratia? n. sp. A, Beecheria n. sp. A, H. miseri A. matheri, W. triangularis, B.? bilobatum, Neochonetes? n. sp. A, and Derbyia n. sp. A. Of the seven extremely rare species that are reported in strata no older than the P.? arkansanus Zone, only C. milleri and Krotovia? n sp. A, are reported from the Upper Morrowan.

Linoproductus nodosus Range Zone.--The Linoproductus nodosus Range Zone characterizes all of the McCully Formation (except for the unfossiliferous shale "B" member) and probably most, if not all, of the upper Bloyd Formation (text-figure 7). Only the Kessler Limestone in northwestern Arkansas has produced large collections of brachiopods; a very restricted fauna, consisting of 5 species, has been identified from the "caprock" at the base of the Dye Shale.

Ten brachiopod species in the Linoproductus nodosus Zone do not occur in older strata: L. nodosus, L. pumilus, Neochonetes? platynotus, Pulchratia? picuris, Beecheria stehlii, Hustedia n. sp. A, Anthracospirifer curvilateralis, Meekella n. sp. A, Antiquatonia coloradoensis, and Zia cf. Z. novamexicana. Of these species, only the latter three, which are rarely occurring species, have not been reported from strata older than the Kessler and/or Greenleaf Limestones. The lowest occurrence of the former seven species defines the base of this zone.

The upper ranges of these 10 species and the 20 species that are also present in the Lower Morrowan are not known since only a limited collection of brachiopods is available from the Trace Creek and since the shale "B" member is unfossiliferous.

Comparison with Morrowan Faunas from Northern New Mexico.--Analysis of conodont faunas from the Morrowan sequence in the La Pasada Formation by H. R. Lane and this author (see Sutherland and Harlow, *in press*) indicate (1) that the lowest fossiliferous Pennsylvanian strata in north-central New Mexico correlate with strata no older than the uppermost part of the Brentwood Limestone Member and the lower part of the Woolsey Member (*Idiognathodus humerus* Zone) of northwestern Arkansas and (2) that most of the Morrowan sequence in that area is no older than the basal part of the Dye Shale Member (*Idiognathodus* n. sp. Zone, of Lane and Straka, 1971).

Sutherland and Harlow (*ibid*.) recognized that a high percentage of brachiopod species that occur in the Morrowan of northern New Mexico are also present in the Morrow Group. The present study confirms that an extremely high degree of biotic correspondence exists between the two brachiopod faunas. The current study of the brachiopod faunas also substantiates the correlation of the bulk of the New Mexican strata with the upper part of the Morrow Group as suggested by analysis of the conodonts.

Forty-two[1] species of brachiopods are present in the Morrowan of northern New Mexico. Excluding the inarticulates and the species of *Composita*, the latter of which were not evaluated in the current study, 35 species of brachiopods are recognized for comparison from the

[1]Sutherland and Harlow (*in press*) identified only 41 Morrowan species, but the author has identified undescribed specimens from their collections as *Beecheria*? *emarginata*.

New Mexico sequence (groups A, B, and C of table 1). Twenty-six of these 35 have been collected from the Morrow Group of Arkansas and Oklahoma. Twenty-three of these 35 have been collected from the Morrow Group of Arkansas and Oklahoma. Twenty-three of these (group A of table 1) are among the 28 species identified from the Upper Morrowan Linoproductus nodosus Range Zone (groups A and D) in the Ozark region.

Three additional species present in northern New Mexico (group C) are not reported from the upper Morrowan of the Ozark region but do occur in the lower part of the Morrow Group in strata as high as the upper part of the Plicochonetes? arkansanus Range Zone. Rhipidomella trapezoida is extremely rare in both sets of collections. Both Anthracospirifer matheri and Neochonetes? n. sp. A occur commonly in the Morrow Group, but both species are rare in the New Mexican collections. Both are restricted to the basal part of the Morrowan sequence in that area. Both occur there concurrently with species diagnostic of the Upper Morrowan in the Ozark Region, suggesting perhaps that the lowest part of the Morrowan succession in northern New Mexico may be older than the "caprock" and younger than the uppermost Brentwood, Woolsey, or Brewer Bend Members (i.e., represent strata missing beneath the unconformity separating the Lower and Upper Morrowan in the Ozark area).

Sutherland and Harlow (in press) identified 9 species that are apparently not present in the Morrow Group (group B of table 1). Of these species, only Hustedia gibbosa? occurs commonly; the remainder are rare.

Five species listed as group D are present only in the Morrow Group. Of these, A. curvilateralis is closely related to A. curvilateralis tanoensis in northern New Mexico and Zia cf. Z. novamexicana is closely related to Z. novamexicana. Only Beecheria? bilobatum, Hustedia n. sp. A, and the extremely rare Krotovia? n. sp. A have no closely similar relatives in the Morrowan of northern New Mexico.

SPECIES PRESENT	*LOWER MORROWAN OZARK AREA*	*UPPER MORROWAN OZARK AREA*	*MORROWAN NEW MEXICO*	*ATOKAN NEW MEXICO*
Antiquatonia coloradoensis (Girty)	-	+	+	-
Beecheria stehlii Sutherland & Harlow	-	+	+	-
Buxtonia grandis Sutherland & Harlow	+	+	+	-
Cleiothyridina milleri Sutherland & Harlow	+	+	+	-
Desmoinesia nambeensis Sutherland & Harlow	+	+	+	-
Echinaria n. sp. A (= *Echinaria* n. sp., of Sutherland & Harlow)	+	+	+	-
Girtyella? emarginata Mather	+	+	+	-
Krotovia? globosa (Mather)	+	+	+	-
Linoproductus nodosus (Newberry)	-	+	+	-
Linoproductus pumilus Sutherland & Harlow	-	+	+	-
Meekella n. sp. A (= *Meekella* n. sp. A of			+	-
Sutherland & Harlow)	-	+	+	-
Neochonetes? platynotus (White)	-	+	+	-
Phricodothyris perplexa (McChesney)	+	+	+	+
Plicochonetes? arkansanus (Mather)	+	+	+	-
Pulchratia? picuris Sutherland & Harlow	?	+	+	-
Punctospirifer morrowensis Sutherland & Harlow	+	+	+	-
Rhynchopora magnicosta Mather	+	+	+	-
Sandia welleri (Mather)	+	+	+	-
Schizophoria altirostris? (Mather)	+	+	+	-
Schizophoria oklahomae Dunbar & Condra	+	+	+	-
Spirifer goreii Mather	+	+	+	-
Spiriferellina? campestris (White)	+	+	+	-
Tesuquea morrowensis (Mather) (= ?*T. formosa* Sutherland & Harlow)	+	+	+	-
Anthracospirifer curvilateralis tanoensis Sutherland & Harlow	-	-	+	-
Beecheria gerberi Sutherland & Harlow	-	-	+	-
Derbyia bonita Sutherland & Harlow	-	-	+	-
Desmoinesia sp. A, of Sutherland & Harlow	-	-	+	-
Hustedia gibbosa? B. O. Lane	-	-	+	?
Leptalosia sp., of Sutherland & Harlow	-	-	+	-
Linoproductus devargasi Sutherland & Harlow	-	-	+	-
Pulchratia? pustulosa Sutherland & Harlow	-	-	+	-
Zia novamexicana Sutherland & Harlow	-	-	+	-
Anthracospirifer matheri (Dunbar & Condra)	+	-	+	-
Neochonetes? n. sp. A (= *Neochonetes* n. sp. A, of Sutherland & Harlow)	+	-	+	-
Rhipidomella trapezoida Sutherland & Harlow	+	-	+	-
Anthracospirifer curvilateralis (Easton)	?	+	-	+
Beecheria? bilobatum (Mather)	+	+	-	-
Hustedia n. sp. A	-	+	-	-
Krotovia? n. sp. A	+	+	-	-
Zia cf. *Z. novamexicana* Sutherland & Harlow	-	+	-	-

Table 1.--Chart showing close correspondence of brachiopod faunas occurring in Upper Morrowan Linoproductus nodosus Range Zone of Ozark region (column 2) with Morrowan fauna described by Sutherland and Harlow (in press) from Morrowan portion of La Pasada and Flechado Formations in northern New Mexico (column 3). Pluses indicate presence of taxon; minuses absence. Column 1 depicts which of Upper Morrowan species also occurs in Lower Morrowan of Ozark region; column 4 demonstrates virtual absence of Upper Morrowan brachiopod species in Atokan sequence in northern New Mexico. See text for additional discussion.

SYSTEMATIC PALEONTOLOGY

Introductory Statement

The morphologic terminology follows that presented in the Treatise on Invertebrate Paleontology, Part H, Brachiopoda (R. C. Moore, ed., 1965) with the following exceptions: (1) the terminology for the description of the schizophorids is that of Pocock (1966, 1968), and (2) the term surface length (abbreviated SL) refers to distances measured along the surface of the shell from the beak to some point in the plane of bilateral symmetry (Sutherland and Harlow, 1967).

The classification above the generic level also follows the Treatise except for the classification of the Chonetidina. The grouping of genera of chonetoids into subfamilies by Muir-Wood (1962) and followed by the Treatise is not acceptable (see Sutherland and Harlow, in press).

Lists of localities for each species are presented at the end of the species description and discussion under "Material and Occurrence". Specimens questionably assigned to a given species are so indicated by a questions mark placed in parenthesis after a locality or unit number; M51-15(?) is equivalent, for example, to Sandia welleri? The symbol "cf." placed in parenthesis immediately following a locality or unit number indicates that the specimens from that collection compare generally quite closely with the concept of that species but that these specimens are different from the species in some manner. Hence, M51-15(cf.) is equivalent to Sandia cf. S. welleri.

An estimate of the number of specimens of a given species in a particular collection is indicated either by stating in parenthesis the number of specimens actually present or by indicating the relative number by the use of the terms rare (fewer than 10 specimens), common (from 10 to 49 specimens), and abundant (50 or more specimens).

Specimen measurements are presented in Appendix IV. For species that have previously been adequately described, only measurements of specimens figured herein are given; for species that are redescribed in this dissertation (and inadequately known from previous studies), measurements of all specimens from the type locality are included. Specimen measurements from supplemental localities are presented only if adequate numbers of specimens are not present in the collections from the type locality.

A listing of the species of brachiopods identified from each of the stratigraphic collections studied from the Morrow Group is presented as Appendix II of this dissertation.

Statistical Analysis

Univariant statistical analysis was conducted on a number of samples from different stratigraphic horizons within the Morrow Group to aid in systematic placement of them, following the procedures outlined by Imbrie (1956). Some of the Morrowan samples were also compared with material from other geographic localities in order to determine whether statistically significant differences existed between the samples. Bivariant analysis was not used primarily because of the fragmentary or crushed nature of much of the material. It should be emphasized the taxonomic discrimination as practiced in this dissertation relies on a combination of morphologic and stratigraphic evidence; the biometric analyses, where conducted, are used as a supplemental tool.

The following symbols are used throughout the text: $\bar{x}$ (mean), s (standard deviation), M (mode), and n (sample size).

Status of Collections Examined

Approximately 21,000 brachiopods have been collected over the last 6 years from the Morrow Group in northeastern Oklahoma and northwestern Arkansas by Patrick K. Sutherland, Bruce N. Haugh, David C. Bowlby, David A. Kotila, and the author. These collections were made from narrow intervals within numerous measured stratigraphic sections within the Morrow Group. Talus collections were made only if the interval from which they could have come could be reasonably established; they were still treated as talus samples. This material has been reposited in The University of Oklahoma Invertebrate Paleontological Collections. Material figured from these collections in this dissertation are designated in the descriptions by the prefix OU. Collections of topotypes are also indicated by the same prefix.

Mather (1915) reposited his collections from the Morrow Group with the old Walker Museum of The University of Chicago. These collections are on permanent loan to the Field Museum of Natural History (see Golden and Nitecki, 1972). The author has examined all of the primary and secondary type specimens that are available at this time from the Field Museum; these specimens are herein referred to by the prefix UC-. Unfortunately, about one-third of Mather's figured specimens, including a large percentage of his primary types, cannot at this time be located in the Field Museum (personal written communication from Katherine Kreuger to P. K. Sutherland, March 19, 1973). The missing primary types include the following:

Pustula bullata (UC 16132, holotype)
Pustula sublineata (UC 16131, holotype)
Productus welleri (UC 16095, holotype and allotype)
Productus fayettevillensis (UC 16128, holotype)
Brachythyrina laticosta (UC 16145, holotype)
Hustedia miseri (UC 16152, 1 cotype; UC 16238, 2 cotypes)
Composita ozarkana (UC 16085, holotype; no catalogue record, paratype)

The unavailability of this material has hindered the present study since a number of the type localities for these species cannot be reestablished (see Appendix III for additional discussion) and since several of the species involved are rare in the Morrow Group. Casts of the material successfully borrowed from the Field Museum have been made and are reposited in The University of Oklahoma collections.

The author has examined all of the primary types and many of the secondary specimens reposited in the OU Collections from the Morrowan part of the La Pasada and Flechado Formations in north-central New Mexico

(Sutherland and Harlow, *in press*). The OU collection also includes stratigraphic collections of brachiopods from the Wapanucka Formation (Morrowan) of south-central Oklahoma. Many of these were examined and compared with the Morrowan material from the Ozark region.

Species Recognized by Mather (1915)

Mather (1915) identified 48 species of brachiopods from the Morrow Series of the Ozark Mountains area. He named 25 new species, and one additional species, *Spirifer matheri*, was subsequently named by Dunbar and Condra (1932) for specimens figured by Mather as *S. rockymontanus*. Of the 26 species initially described from these strata, 14 can be recognized with certainty as being valid. Of the remaining 12, *Productus fayettevillensis* and *Hustedia brentwoodensis* are rejected as junior synonyms of other species named by Mather. The 5 species of *Composita* have not been evaluated; and 3 of the remaining 4 species, *Pustula sublineata* (possibly = *Krotovia* n. sp. A of this dissertation), *Pustula bullata*, and *Brachythyris laticosta*, are probably valid species. The types for the latter three species cannot at this time be found in the Field Museum of Natural History, and only a few non-type specimens probably belonging to *P. sublineata* are available to the author. The final species, *Chonetes choteauensis* was possibly collected from the Atoka Formation and not from the Morrow Group.

Most of the 23 species for which Mather used older species names are placed in synonymy with subsequently described species or represent new but unnamed species presented in this dissertation. An exception

MATHER'S IDENTIFICATIONS	MATHER'S FIGURES	IDENTIFICATIONS, THIS DISSERTATION
Orbiculoidea minuta Mather	pl. 8, figs. 2, 2a	*Orbiculoidea minuta* Mather
Orbiculoidea missouriensis (Shumard)?	pl. 8, fig. 1	*Orbiculoidea* sp. A
Rhipidomella altirostris Mather	pl. 8, figs. 5-5c	*Schizophoria altirostris*? (Mather)
Rhipidomella pecosi (Marcou)	pl. 8, figs. 3, 3a	*Rhipidomella trapezoida* Sutherland & Harlow
Schizophoria resupinoides (Cox)	pl. 8, figs. 6-7b	*Schizophoria altirostris*? (Mather)
Schizophoria resupinoides (Cox)	pl. 8, fig. 8	*Schizophoria oklahomae* Dunbar & Condra
Orthotetes robusta (Hall)	pl. 9, figs. 2-3a	*Derbyia*? sp.
Orthotetes? sp.	pl. 9, fig. 8	*Derbyia*? sp.
Meekella striatocostata (Cox)	pl. 10, fig. 10	*Meekella* n. sp. A
Chonetes arkansanus Mather	pl. 8, fig. 4	*Plicochonetes*? *arkansanus* (Mather)
Chonetes choteauensis Mather	pl. 8, figs. 9-10a	*Neochonetes*? *choteauensis* (Mather)
Chonetes laevis Keyes	pl. 8, figs. 13, 14	*Neochonetes*? n. sp. A
Productus morrowensis Mather	pl. 10, figs. 1-4a	*Tesuquea morrowensis* (Mather)
Productus welleri Mather	pl. 9, figs. 10-11a.	*Sandia welleri* (Mather)
Productus nanus Meek & Worthen	pl. 8, figs. 12-12b	*Desmoinesia nambeensis* Sutherland & Harlow
Productus cora d'Orbigny	unfigured	Probably principally *Linoproductus* n. sp. A; also probably includes *L. nodosus*. (Newberry)
Productus gallatinensis Girty	pl. 9, figs. 4-5b	*Sandia welleri* (Mather)
Productus fayettevillensis Mather	pl. 10, figs. 5-5a	?*Tesuquea morrowensis* (Mather)--immature?
Productus fayettevillensis Mather	pl. 10, fig. 6	Too poorly preserved, possibly a buxtonid
Productus sp.	pl. 8, figs. 16-16b	?*Zia* cf. *Z. novamexicana* Sutherland & Harlow
Pustula pertenuis (Meek)	pl. 9, figs. 9, 9a	*Sandia welleri* (Mather)--immature
Pustula globosa Mather	pl. 10, figs. 7-9	*Krotovia*? *globosa* (Mather)
Pustula sublineata Mather	pl. 9, figs 1-1c	Not evaluated; may be *Krotovia*? n. sp. A.
Pustula nebraskensis (Owen)	pl. 9, fig. 6	*Pulchratia*? *picuris* Sutherland & Harlow
Pustula nebraskensis (Owen)	pl. 9, fig. 7	?*Pulchratia* n. sp. A
Pustula punctata (Martin)	pl. 8, fig. 11	*Echinaria* n. sp. A
Pustula bullata Mather	pl. 8, figs. 15-15b	Not evaluated
Pugnoides triangularis Mather	pl. 12, figs. 12-12c	*Wellerella triangularis* (Mather)
Rhynchopora magnicosta Mather	pl. 10, figs. 11-11c	*Rhynchopora magnicosta* Mather
Dielasma subspatulatum Weller	pl. 11, figs. 1-11b	*Beecheria* n. sp. A
Dielasma bilobatum Mather	pl. 11, figs. 14-15b	*Beecheria*? *bilobatum* (Mather)
Dielasma arkansanum Weller	pl. 11, figs. 12-12b	?*Beecheria* n. sp. A
Girtyella? *emarginata* Mather	pl. 11, figs. 13-13b	*Girtyella*? *emarginata* Mather
Spirifer rockymontanus Marcou	pl. 12, figs. 1-6	*Anthracospirifer matheri* (Dunbar & Condra)
Spirifer opimus Hall	pl. 12, figs. 7-7c	?*Anthracospirifer matheri* (Dunbar & Condra)
Spirifer goreii Mather	pl. 12, figs. 10-11a	*Spirifer goreii* Mather
Brachythyris laticosta Mather	pl. 12, figs. 16-16b	Not evaluated
Squamularia perplexa (McChesney)	pl. 12, figs. 13-13b	*Phricodothyris perplexa* (McChesney)
Squamularia transversa Mather	pl. 12, figs. 8-9a	*Phricodothyris*? *perplexa* (Mather)
Spiriferina transversa (McChesney)	pl. 12, figs. 7, 8	*Punctospirifer morrowensis* Sutherland & Harlow
Spiriferina campestris White	pl. 13, figs. 9-10a	*Spiriferellina*? *campestris* (White)
Hustedia brentwoodensis Mather	pl. 13, figs. 1-3c	*Hustedia miseri* Mather
Hustedia miseri Mather	pl. 13, figs. 4-6c	*Hustedia miseri* Mather
Eumetria vera (Hall)	pl. 12, figs. 14-14b	Not evaluated
Composita ozarkana Mather	pl. 13, figs. 11-15c	Not evaluated
Composita wasatchensis (White)	pl. 14, figs. 7-10b	Not evaluated
Composita ovata Mather	pl. 14, figs. 6-6c	Not evaluated
Composita deflecta Mather	pl. 14, figs. 1-3b	Not evaluated
Composita gibbosa Mather	pl. 14, figs. 16-18c	Not evaluated
Composita biplicata Mather	pl. 14, figs. 5-5c	Not evaluated
Composita transversa Mather	pl. 14, figs. 4-4c	Not evaluated

Table 2.--Chart showing Mather's (1915, p. 141-206) systematic identifications and illustrated specimens. Current treatment of species recognized by Mather is presented in column at right.

is the specimen that Mather identified as Eumetrea vera (Hall). This specimen also cannot be found in the Field Museum, but it probably represents a valid but extremely rare new species. No similar specimens have been subsequently collected.

Table 2 provides a list of the species that Mather identified and/or figured and indicates the manner in which each is treated in the current dissertation. The list is presented in the order that these species appear in Mather (1915, p. 141-206).

PHYLUM BRACHIOPODA

CLASS INARTICULATA

ORDER LINGULIDA

SUPERFAMILY LINGULACEA

FAMILY LINGULIDAE

Genus Lingula Bruguiere, 1797

Lingula cf. L. carbonaria Shumard

Pl. 1, fig. 1.

Lingula carbonaria Shumard, 1858, p. 215: Dunbar and Condra, 1932, p. 31, pl. 1, figs. 1, 2.

Discussion.--Linguloid brachiopods are rare in the Morrow Series of the Ozark Mountains region. Two specimens from different localities agree closely with the description of Lingula carbonaria by Dunbar and Condra (1932, p. 31). The one complete specimen (pl. 1, fig. 1) from the Morrow Series has the typical elliptical outline and measures 17.4 mm in length, 10.0 mm in width, and has a thickness of 4.7 mm.

A small specimen, assigned to *Lingula* sp., from the Chisum Quarry Member of the overlying McCully Formation at M63-20, may be an immature representative of this species. This specimen measures 2.1 mm in length and 1.4 mm in width.

Traditionally, the name *Lingula carbonaria* has been applied to all specimens of *Lingula* from the entire Pennsylvanian System in the Midcontinent. The collections from the Morrow Group are too small to ascertain whether they represent a species other than *L. carbonaria*.

Material and Occurrence.--The two specimens from the Morrow Group tentatively assigned to this species occur at the following localities: BLOYD FORMATION--Brentwood Limestone: M70-12. GORE FORMATION--limestone-shale member: M97-5.

Figured Specimen.--OU 7221.

ORDER ACROTRETIDA

SUBORDER ACROTRETIDINA

SUPERFAMILY DISCINACEA

FAMILY DISCINIDAE

SUBFAMILY ORBICULOIDEINAE

Genus *Orbiculoidea* d'Orbigny, 1847

Orbiculoidea minuta Mather

Pl. 1, figs. 2-4.

Orbiculoidea minuta Mather, 1915, p. 141, pl. 8, figs. 2, 2a.

Description (Based upon All Specimens from Morrow Group).--Shell very small for genus, circular to subcircular outline with width commonly slightly greater than length; mature specimen measuring 5.1 mm in length, 5.4 mm in width, about 0.6 mm in height; Mather's holotype (brachial valve) 3.3 mm in length, 3.4 mm in width, about 0.6 mm in height.

Pedicle valve almost planar; pedicle track tear-shaped, partially covered by listrium, with narrow, slot-like foramen.

Brachial valve depressed cone, postion of apex varying in position from centric to position about one-fourth distance to posterior margin; surface from apex to posterior margin planar; slope from apex to anterior margin slightly concave.

Surface of both valves marked with concentric growth lines varying from being only slightly elevated above surface of valve to distinct fila; generally spaced about 0.2 to 0.3 mm apart.

Interiors unknown.

Discussion.--Mather's (1915, p. 141) original description of *Orbiculoidea minuta* is based upon a single complete brachial valve (figured holotype, UC 16133) and a single, incomplete brachial valve (unfigured allotype, UC 16133). Both of these specimens are figured in this dissertation.

The description presented above is based upon all specimens of this species from the Morrow Group. Most are immature or fragmentary

Figured Specimens.--UC 16133 (holotype, allotype), OU 7222.

Orbiculoidea sp. A

Pl. 1, fig. 5

Orbiculoidea missouriensis, Mather (not Shumard), 1915, p. 142, pl. 8, fig. 1.

Description.--Brachial valve flattened, conical, subcircular to suboval base; specimens parabolic in anterior profile, anterior portion of valve convex seen in lateral profile, posterior slope nearly straight; surface with fine concentric growth lines superimposed upon larger, very faint, concentric, undulations in shell; faint striations radiating from umbo. Figured brachial valve measuring 19.2 mm in length by 22.2 mm in width, 9.6 mm high; height to width ratio thus approximately 0.5; most specimens smaller and with height to width ratio as low as approximately 0.3.

Pedicle valve and interiors unknown.

Discussion.--Mather (1915, p. 142, pl. 8, fig. 1) assigned a single somewhat crushed specimen to Orbiculoidea missouriensis (Shumard), and this and several other available Morrowan specimens are similar in size to those illustrated by Dunbar and Condra (1932, pl. 1, figs. 12-17) from the Desmoines Series of Kansas and Nebraska. However, the Morrowan specimens are herein assigned to Orbiculoidea sp. A because of inadequate preservation.

Orbiculoidea sp. A differs from O. minuta Mather, which also specimens retrieved from insoluble residues prepared for conodonts. However, this would appear to be a highly variable species, particularly with respect to the degree of development of the concentric growth lines.

This species is characterized by its minute size and extremely low conical shape of the brachial valve and by the almost planar pedicle valve.

Material and Occurrence.--*Orbiculoidea minuta* ranges from the lower part of the Prairie Grove Member through the Kessler Limestone and throughout the Morrow Group in northeastern Oklahoma. Its lowest occurrence is in strata assigned to the *Idiognathoides noduliferus* Zone. Eighty-seven specimens are assigned to this species, which occurs rarely in the following collections, unless otherwise specified: HALE FORMATION--Prairie Grove Member: sta. 136 and M117-11. BLOYD FORMATION--Brentwood Limestone: sta. 134 (type locality), and M68-12. Kessler Limestone: M69-27. GORE FORMATION--limestone-shale member: M49-10, M49-12, M51-14B, M63-13 (12 specimens), M63-17, M72-4A, M72-4B, M78-18, and M85-4 (20 specimens). McCULLY FORMATION--Chisum Quarry Member: M49-19, M63-22 (11 specimens). Greenleaf Limestone Member: M26-26 (11 specimens) and M51-25 (11 specimens).

Immature specimens tentatively assigned to this species were obtained and identified by the author from the Upper Morrowan and Atokan portions of the La Pasada Formation in north-central New Mexico. These specimens were also picked from insoluble residues processed for conodonts.

occurs in the Morrow Group of the study area, principally by its much larger size and by its less conspicuous growth lines. Specimens intermediate in size between the two species have not been observed.

Material and Occurrence.--Fifteen poorly preserved specimens from the Morrow Group are assigned to *Orbiculoidea* sp. A. The range of this species is from the Brentwood Limestone through the Kessler Limestone in northwestern Arkansas and it has thus far been identified only from the limestone-shale member in northeastern Oklahoma, where its lowest occurrence is in strata assigned to the *Idiognathoides noduliferus* Zone. This species occurs rarely in the following collections: BLOYD FORMATION--Brentwood Limestone: M70-15, M100-11, and M104B-17. GORE FORMATION--limestone-shale member: M51-7 (37 feet above base), M65-3, M65-14, and M97-5. McCULLY FORMATION--Chisum Quarry Member: M29-10 and M29-11. Greenleaf Limestone: M60-22.

Figured Specimen.--OU 7223.

Orbiculoidea? sp. B

Description.--Brachial valve elliptical, longer than wide; apex centric to slightly eccentric; triangular anterior profile, posterior slope planar to slightly convex, anterior slope slightly concave; apical angle steep, measuring 59 to 95 degrees in anterior profile; largest specimen measuring 21.1 mm by 17.1 mm, 11.9 mm high. Surface ornamented with closely spaced, concentric growth lines.

Pedicle valve, interiors unknown.

Discussion.--Orbiculoidea? sp. B is a highly distinctive form characterized by its exceptional height to the apex of the brachial valve compared with its other dimensions. It undoubtedly represents a new species but available material is inadequate for proper definition.

Orbiculoidea? sp. B differs from Orbiculoidea sp. A, which also occurs in the Morrow Group, by having an apex that is centric to slightly eccentric, by being consistantly longer than wide, and be being proportionally much higher.

Material and Occurrence.--This distinctive species occurs rarely in the Morrow Group. Approximately 15 specimens have been identified as belonging to this species. Its lowest occurrence is in strata of the limestone-shale member that also bear Neognathodus bassleri symmetricus; its highest known occurrence is in the Greenleaf Limestone. This species occurs rarely in the following collections: GORE FORMATION--limestone-shale member: M1-5, M34-7, and M51-7 (22 feet above base). Brewer Bend Limestone: M3-12. McCULLY FORMATION--Greenleaf Limestone: M60-21.

CLASS ARTICULATA

ORDER ORTHIDA

SUBORDER ORTHIDINA

SUPERFAMILY ENTELETACEA

FAMILY ENTELETIDAE

SUBFAMILY SCHIZOPHORIINAE

Genus Schizophoria W. King, 1850

Discussion.--An excellent generic summary and discussion of the highly varied morphological attributes of the genus was given by Pocock (1966, 1968), who also presented an inferred phylogeny for a number of European Devonian and Carboniferous species. The best summary of the schizophorids of the Pennsylvanian of North America was given by Dunbar and Condra (1932), who also compared the genus with a number of closely related genera from the Upper Paleozoic.

Species assigned to this genus range in age from Silurian through Permian. Two species from the Morrow Group are assigned to Schizophoria. They are S. oklahomae Dunbar and Condra and S. altirostris? (Mather).

Schizophoria oklahomae Dunbar and Condra

Pl. 1, figs. 6-8c.

Schizophoria resupinoides, Mather (not Cox), 1915, pl. 8, fig. 8 (not 6, 7); Morgan (not Cox), 1924, pl. 45, figs. 2, 2a.

Schizophoria oklahomae Dunbar and Condra, 1932, p. 58, pl. 29, figs. 3-5; Branson, 1965, p. 50, fig. 1; Sutherland and Harlow, in press, pl. 1, figs. 13, 14.

Description (Based upon Specimens from M17-14 base, M35-11A, M39-4, M42-7, and M48-13).--Valves large for genus, dorsibiconvex to plano-convex; subcircular to slightly transversely suboval, maximum width slightly posterior to midlength; largest specimen measuring about

52 mm long, 70 mm wide, and 27 mm thick.

Pedicle valve with rounded posterolateral extremities; lateral, anterior margins evenly rounded; beak low, broad, overhanging hinge slightly, incurved; shells generally almost planar in lateral profile, with slight convexity at umbo, decreasing anteriorly; gerontic shells tending to become somewhat geniculate at anterior, lateral extremities; anterior profile very gently, uniformly convex except on small number of specimens having slightly flattened posterolateral margins away from umbo; anterior commissure rectimarginate on most specimens, few with very broad, gentle uniplicate flexure; hingeline submegathrid almost straight, measuring approximately two-thirds to three-fourths maximum shell width; interarea catacline, slightly curved toward beak, measuring about 7.5 mm high on largest specimens, ornamented with fine growth lines, containing open delthyrium with apical angle measuring about 45 degrees, slightly greater; delthyrium flaring somewhat laterally with growth. Radial ornamentation subequally parvilirate, consisting of very fine rounded lirae, separated by narrower striae; lirae arising by intercalation at irregular intervals, numbering between 18 to 21 per 5 mm in venter at 20 mm SL, maintaining about equal density over entire valve; scattered lirae gradually becoming higher anteriorly, abruptly decreasing to height of adjacent lira; entire surface with extremely fine, concentric growth lines occasionally becoming more prominent, rugate, particularly near anterior, lateral margins on mature specimens. Shell material finely punctate with puncta concentrated externally along lira.

Brachial valve with more strongly incurved beak than pedicle valve, produced slightly posteriorly from hinge line; valve distinctly more convex than pedicle valve, with maximum curvature in lateral profile occurring at broad, flaring, inflated umbo, decreasing only slightly anterior to umbo; shell with narrow, slightly concave area immediately laterally from infalted umbo; posterolateral slopes slightly flattened; specimens generally with uniform convexity in transverse profile anterior to umbo, few having slightly flattened mesial portion, single specimen with extremely low brachial sulcus; largest shells tending to become somewhat gerontic with thickening of anterior, lateral margins. Interarea about half as high as that of pedicle valve, notothyrium open. Surface ornamentation same as on pedicle valve.

Pedicle valve interior with strong hinge teeth, supported by strong dental plates; plates dipping toward mesial portion of valve, forming concave depression immediately beneath teeth, joining flange-like lateral ridge at base; lateral ridges bordering heart-shaped diductor field, continuing anteriorly to about one-third length of valve, forming slight anterior reentrant; median septum low, thin anteriorly, becoming higher, thicker anteriorly, fusing with lateral ridges at anterior reentrant, truncating abruptly; floor of diductor scars smooth, with shallow, broad radial grooves on anterior half of scars on single specimen; delthyrial cavity (seen on single specimen) small, with small triangular plates; anterior half of pedicle interior beyond muscle field with prominent vascular media, highly variable in details (compare pl. 1, figs. 6 and 7), forming highly complex, anastomosing pattern; valve interior with band of fine lirae maximum of about 3 mm wide around lateral, anterior periphery.

Brachial valve interior (known only from single fragment) with blunt, broad cardinal process; simple(?) myophore supported by narrow shaft, bounded by strong brachiphore plates, supporting stubby brachiophores; muscle field suboval, bounded posteriorly by brachiophore plates, laterally by flange-like accessory ridges; anterior margins of field poorly defined; anterior scars pyriform, depressed slightly beneath level of posterior field, separated by median septum; posterior field smooth, separated by median septum only near anterior margin. Remainder of interior unknown.

Discussion.--The description given above is based upon 8 well preserved, generally complete, disarticulated valves with the interiors also well preserved, 1 fragmentary brachial interior, 5 disarticulated brachial exteriors, and numerous fragments.

The specimens from the Morrow Group agree closely in most respects with the description of this species presented by Dunbar and Condra (1932, p. 58) and with the collection of topotypes examined from the Wapanucka Formation. The specimens from the Wapanucka tend to be somewhat smaller, with the largest specimen measuring 42.5 mm in length by 55.8 mm in width (contrast to 52 mm by about 70 mm), and the individual valves are not as thick. None of the specimens from the Wapanucka is gerontic; the thickness of the individual pedicle valve thins regularly from about 3 mm immediately anterior to the muscle field to less than 1 mm at the periphery, thus producing a blade-like appearance when viewed from the anterior margin. The vascular media are only faintly developed. On most of the specimens from the Morrow Group, the vascular media are prominent, and one single pedicle valve has a distinct raised rim about 3.5 mm wide and 6.3 mm high around the anterior margin.

Schizophoria oklahomae is not readily confused with the other Morrowan species, S. altirotris? (Mather), with which it sometimes occurs. S. oklahomae is characterized by its large size, generally completely asulcate valves, unequally biconvex to almost plano-convex lateral outline, and by its transversely slightly suboval to subcircular outline. The largest specimens of Schizophoria altirostris? are only about half as large, are more strongly biconvex, have a distinct ventral sulcus even in the early growth stages, and the diductor scars of the pedicle interior are distinctly more deeply impressed beneath the general level of the shell's interior than those of S. oklahomae.

Material and Occurrence.--Schizophoria oklahomae was initially described from the Wapanucka Formation (Morrowan) "about 15 miles southeast of Ada, Oklahoma" (Dunbar and Condra, 1932, p. 59). The type specimens almost certainly come from the well known Canyon Creek locality in the NE¼, NW¼, SE¼, Sec. 8, T. 1N., R. 7E., Pontotoc County (see Branson, 1965, p. 50). The locality was described by Morgan

(1924, p. 57, loc. 37), and a measured section of these strata was presented by Rowett and Sutherland (1964, p. 78). The specimen figured by Morgan (1924, pl. 45, figs. 2, 2a) as S. resupinoides is a topotype. About 25 topotypes are present in the OU collections.

Approximately 175 largely fragmentary specimens from the Morrow Group are assigned to S. oklahomae. The range of this species is from the middle portions of the limestone-shale member (lower part of Neognathodus bassleri Zone) through the Greenleaf Limestone and from the upper parts of the Prairie Grove Member through the Kessler Limestone. It has not yet been identified from the Idiognathoides noduliferus Zone. This species is rare in the following collections, unless otherwise stated: GORE FORMATION--limestone-shale member: M1-6, M5-13, M12-8, M39-4 (15 specimens), M42-4, M42-6(?), M49-6(?), M51-7(?; 25 feet above base), M51-15, loc. M76A, loc. M77, M85-8, M95-3(?), M97-5, and M97-9. Brewer Bend Limestone: M28-8B(?), M29-9 base, M36-6B, M63-19, and M98-7. McCULLY FORMATION--Chisum Quarry Member: M17-13, M17-14, M26-23, M27-14, M28-12, M35-8, M35-9, M42-15, M42-16, M49-18(?), M61-9, and M62-23. Shale "A" member: M48-13 (17 specimens), and M48-13 to 15, Greenleaf Limestone: M1-19, M1-20, M35-11A talus, M36-10B, M42-21, M51-25 (3 feet above base), and M98-13. HALE FORMATION--Prairie Grove Member: M70-8 and M112-15. BLOYD FORMATION--Brentwood Limestone: M68-25 and M100-11. Kessler Limestone: M68-27, M70-25, M105D-13, M105D-15, M108-20, and M118-18.

Figured Specimens.--OU 7224-7226.

Schizophoria altirostris? (Mather)

Pl. 1, figs. 9a-13.

Rhipidomella altirostris Mather, 1915, p. 143, pl. 8, figs. 5-5c.

Schizophoria resupinoides, Mather (not Cox), 1915, p. 145, pl. 8, figs. 6-7b (not fig. 8); Plummer (not Cox), 1950, pl. 12, figs. 3a-3c.

?Schizophoria texana Girty, 1927, p. 432, pl. 27, figs. 1-8; Murphy, 1954, p. 49, pl. 4, figs. 9a-9f; N. G. Lane, 1963, p. 381, pl. 43, figs. 9-19.

Schizophoria altirostris, Murphy, 1954, p. 50, pl. 4, figs. 10, 10b.

Schizophoria altirostris?, Sutherland and Harlow, in press, pl. 1, fig. 8.

Discussion.--The second and smaller species of Schizophoria in the type Morrow Group is apparently conspecific with the species that Girty (1927, p. 432) defined as Schizophoria texana from the Marble Falls Limestone (Morrowan) of Texas, but considerable uncertainty exists.

Mather (1915, p. 143) described a new species, Rhipidomella altirostris, from the lower part of the Hale Formation at his station 139 near Fayetteville, Arkansas. His description was based on a single, distorted pedicle valve and described as having a shell "below median size, sub-pentagonal in outline, length and breadth sub-equal, the hinge-line about half as long as greatest width, the latter occurring half way between the anterior margin and mid-length of the shell." The dimensions of this specimen were given as "length, 16 mm.; width, 17 mm.; length of hinge line, 8.3 mm.; height of cardinal area, 4 mm.; convexity of pedicle valve, about 6 mm."

Easton (1962, p. 86) makes the following statement about this species:

> "Some new information is available about Schizophoria altirostris (Mather), which was originally described from a single pedicle valve. Girty assembled hundreds of specimens from strata ... of Morrow age in Arkansas which are referable to this species. Specimens at hand from Girty's locality 1998 (mostly topotypes) show features of the brachial valve very well. Length and breadth are both from 15 to 17 mm and height is 5 or 6 mm. Lateral slopes converge at an angle of about 75°. A faint, narrow sulcus is commonly present and may extend near the beak. The anterior edge of the valve is slightly emarginated. Eight lirae occur in 2 mm at 1 cm from the beak; from 1 to 3 weak lirae occur between strong lirae. Concentric wrinkles are common. Brachiophore plates diverge at 60° in specimens from another Morrow locality. Brachial valves have their interareas in plane of commissure. Dental plates in specimens from this latter locality (2848) diverge at 65° to 70° and the median ridge separating muscle scars is low and broad. The anterior margin is folded up noticeably into a near semicircle.
>
> The types of Schizophoria texana Girty are not available for restudy, but the figures and description, augmented by much comparative material of S. altirostris, convince the writer of the identity of the two species. S. altirostris is the prior name."

It should be pointed out that U.S.G.S. locality 1998 is Mather's station 136 at Klyce's Spring and not his station 139, although the two localities are only about 0.6 mile apart; both occur in the same stratigraphic interval near the base of the Prairie Grove Member of the Hale Formation. (For additional discussion refer to Appendix III.)

Easton, as is implied in the quotation given above, probably did not examine the holotype of Rhipidomella altirostris Mather. The author borrowed UC 16635 from the Field Museum. According to Golden and Nitecki (1972, p. 182), "UC 16135 has been sectioned and partially destroyed." The pedicle valve bearing this number has indeed been damaged; the dorsal surface of the valve has been ground away, revealing strong hinge teeth and a strong median septum extending the length of the valve; the ventral surface has been cut into two parts and reveals the strong median septum extending to the floor of the valve interior. This specimen, however, is _not_ the holotype of _Rhipidomella altirostris_ Mather. The surface, or what remains, bears distinct costellae, not unlike that of _Derbyia_. Mather (1915, p. 144) stated that his species is "apparently devoid of radiate markings, although this may be due to the preservation of the available material".

P. K. Sutherland and F. H. Harlow borrowed the holotype of _R. altirostris_ from the Walker Museum (where Mather's specimens were then housed). Sutherland (personal communication) confirmed that the specimen sent to the author by the Field Museum is not Mather's holotype. Sutherland and Harlow (_in press_) made the following remarks about this specimen: It is

> "a single pedicle valve ... which appears to be a gerontic individual and shows strong, abundant growth lines and an apparent thickening of the shell near the anterior margin. Mather gives a good description of this specimen except that he fails to point out that one side of the posterior part of the shell is slightly crushed. His illustration suggests a shell with a shorter hinge than was probably the case."

Sutherland (personal communication) added that the hinge teeth cannot be well seen on the holotype although Mather describes them as being large. A request will be sent to the Field Museum so that a search can be conducted for the correct holotype of _R. altirostris_.

This author questionably and tentatively accepts Easton's recognition of S. altirostris as a valid species and as the senior synonym of S. texana. A final decision cannot be made until the author examines the USGS collections referred to by Easton. However, no individual specimen currently available to this writer from the Morrow Group is closely similar to the specimen figured by Mather as R. altirostris. Mather's holotype is possibly an extreme variant of the species.

The writer has reestablished both Mather's station 139 (the true type locality of R. altirostris; see Appendix III for further remarks) and his station 136 (M103-14; USGS 1998) and has collected a small number of specimens of S. altirostris? from the former. The collection of probable topotypes from M117-2 and M117-3 (OU 7330) agrees in all respects with the description presented by Easton (1962, p. 86) and quoted above. The single pedicle valve has a broad, flaring sulcus that increases in depth somewhat anteriorly; the specimen is about 18 mm long, 21 mm wide, and approximately 6 to 7 mm in height; the largest complete brachial valve is about 17 mm long, 19 mm wide, and approximately 7 mm high.

Girty did not include measurements of his type specimens for S. texana but the larger of the two specimens that he figured (1927, pl. 27, figs. 1-3) measures about 24 mm in length, 27 mm in width, and is about 17 mm thick; the largest specimen from the type Morrow Group that is placed in S. altirostris? is a pedicle valve (pl. 1, fig. 10 of current text), measuring 26.5 mm in length and 25.3 mm in width. The specimens from the large collections from the Morrow Group of northwestern Arkansas and northeastern Oklahoma do tend to be somewhat smaller in the lower part of the stratigraphic succession. However, some of the specimens from the basal part of the succession (i.e., the Idiognathoides noduliferus Zone) are quite large, and a single valve from locality M61-1 measures 19.5 mm by 26.5 mm.

The collections from the type Morrowan sequence have a few individuals that have a more highly arched umbo and more strongly convex brachial valves than those described by Girty but these clearly intergrade with forms typical in shape to S. altirostris?. Such a form was identified and figured by Mather (ibid., pl. 8, fig. 6) as Schizophoria resupinoides (Cox). This writer has examined this single brachial valve (UC 16102) and places it within S. altirostris? (= ?S. texana); it is refigured here as pl. 1, figs 12a-12c. Dunbar and Condra (1932, p. 57) also suggested that it is a form of S. texana. This specimen is 18.0 mm long, 18.4 mm wide, and about 10 mm in height; its greatest width is only slightly posterior to the anterior margin.

Schizophoria altirostris? differs from S. resupinoides (Cox), widely reported from higher Pennsylvanian strata, in bearing a well defined sulcus on the pedicle valve even in the smaller specimens, in having a more deeply impressed muscle field in the pedicle interior, and in being only about half as large. For a comparison with S. oklahomae Dunbar and Condra, see discussion of that spcies.

Material and Occurrence.--Schizophoria texana (= S. altirostris?) was originally described by Girty (1927, p. 433) from the Marble Falls

Limestone (Morrowan) of Texas and was also reported to occur abundantly in the lower (i.e., Morrowan) portion of the Wells Formation at numerous localities in southeastern Idaho. It also occurs in the Rocky Mountains area in the upper Morrowan parts of the La Pasada Formation in north-central New Mexico (Sutherland & Harlow, in press), and N. G. Lane (1963) described this species from the basal part of the Bird Spring Formation (Morrowan) in Nevada.

Schizophoria altirostris? was originally described by Mather (1915, p. 143) from what is now referred to the basal Prairie Grove Member at his station 139 (= M117-2 and M117-3). The author has made a small collection of topotypes from these units. This species ranges throughout the Morrow Group in both northwestern Arkansas and northeastern Oklahoma. Its lowest occurrence is in the Cane Hill Member in strata assigned to the Spathognathodus muricatus Zone. Approximately 400 specimens from the Morrow Group are assigned to this species. It is one of the few species that occurs in the quartz-sandy limestones and calcareous sandstones of the dominant facies of the Prairie Grove and is most abundant throughout the Morrow Group in similar lithic types. The following collections contain S. altirostris? rarely to commonly, unless otherwise indicated: HALE FORMATION--Cane Hill Member: M105A-3, basal 1.5 feet. Prairie Grove Member: M68-7, M70-8, M100-6, M101-3, M104A-10, M105C-4, M111-16, M112-15, M116-16, M117-2 (type locality), M117-3 (type locality), and M117-11. BLOYD FORMATION--Brentwood Limestone: M68-12, M68-18, M69-19, M70-12 (top), M100-11, M101-19, M102-8, M102-9, M104B-17 (talus), M105C-6, M110-20, M116-18 (top 4 feet), M118-11 or 12 (talus), M118-13, M20-4 and M120-5 (base). Kessler Limestone: M69-27B and M100-25. GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8, M3-9, M3-10, M12-8, M23-4, M25-7 (top), M26-7, M28-4, M29-1, M29-9, M31-4, M40-15, M42-6 (base), M49-3, M49-6 (base), M49-8 (basal 1 foot), M51-7 (from throughout unit), M56-3, M61-1, M61-6, M63-9, M64-6, M65-3, M65-6, M65-14, loc. M76A, M78-38, M79-6, and M97-5 (talus). Brewer Bend Limestone: M3-12, M28-8B, and M95-7. McCULLY FORMATION--Chisum Quarry Member: M26-23, M63-23, and M63-20. Greenleaf Limestone: M33-11.

Figured and Numbered Specimens.--UC 16102 (figured), OU 7227-7230 (figured), OU 7330 (topotypes).

FAMILY RHIPIDOMELLIDAE

Genus Rhipidomella Oehlert, 1890

Rhipidomella trapezoida Sutherland and Harlow

Pl. 1, figs. 14a-14e.

Orthis Pecosii, White (not Marcou), 1877, p. 125, pl. 9, figs. 5a-5e.

Rhipidomella pecosi, Mather (not Marcou), 1915, p. 144, pl. 8, figs. 3, 3a.

Rhipidomella carbonaria, Gehrig (not Swallow), 1958, p. 10, pl. 6, figs. 39-41.

Rhipidomella trapezoida Sutherland and Harlow, in press, pl. 1, figs. 10-12.

Discussion.--Sutherland and Harlow (in press) based their description of Rhipidomella trapezoida upon 50 specimens from the Upper

Morrowan portion of the La Pasada Formation in north-central New Mexico. They described the species as being characterized by its small size, subtrapezoidal outline, having its maximum width anterior to midlength, by having a low, subequally biconvex lateral profile, and by a broad, somewhat shallow sulcus on the brachial valve resulting in a gently sulcate anterior commissure. The holotype is 9.6 mm long, 10.7 mm wide, and 4.3 mm thick. The lirae average 19 in 5 mm at 5 mm SL.

A very small number of specimens from the Morrow Group are assigned to this species. Included is a specimen figured by Mather (1915, pl. 8, figs. 3, 3a) as Rhipidomella pecosii (Marcou), and it is refigured here (pl. 1, figs. 3). This specimen, from Mather's station 153, is 5.5 mm long, 5.7 mm wide, and 2.5 mm thick. It is ornamented with fine lirae numbering about 17 per 5 mm in the venter at 5 mm SL. Also included are four specimens from the Gore Formation. The single uncrushed specimen, from loc. M76A, measures about 8.8 mm by 10.2 mm by 4.2 mm. About 16 lirae are present in 5 mm at 5 mm SL; these are low, even, flare slightly anteriorly, and they increase by bifurcation. The largest specimen, also from locality M76A, is crushed and measures 11.1 by 12.0 mm.

Rhipidomella carbonaria (Swallow), occurring in the Atokan through Missourian strata in the Midcontinent, differs from R. trapezoida in having a distinctly subcircular outline, a rectimarginate anterior commissure, no brachial sulcus, and in having a distinctly greater biconvexity.

B. O. Lane (1962, p. 897) described R. elyensis from the upper

Atokan part of the Ely Group in southern Nevada. This species would appear to differ from R. trapezoida only in not having a brachial sulcus and sulcate anterior commisure.

Material and Occurrence.--The type specimens of Rhipidomella trapezoida are from the Upper Morrowan portion of the La Pasada Formation in the Santa Fe, New Mexico, area (Sutherland and Harlow, in press). They suggested that R. trapezoida may also occur in the lower part of the Derry Group (Atokan) in southern New Mexico and tentatively assigned the specimens described by Gehrig (1958, p. 10) to this species. They note, however, that R. trapezoida was not found in the Atokan sequence of the La Pasada Formation.

Mather (1915, p. 83) noted that this species is also present in the Wapanucka Formation (Morrowan) of southern Oklahoma. However, the OU collections have no specimens assignable to this species.

This is one of the rarest species of brachiopods in the Morrow Group of the Ozark region. A total of 8 specimens are available from these strata, 4 of which were collected by Mather. It has not been reported from strata older than the Brentwood Limestone and equivalent parts of the limestone-shale member, nor has it yet been collected from the Upper Morrowan in the Ozark region. BLOYD FORMATION--Brentwood Limestone: sta. 153 and sta. 210. GORE FORMATION--limestone-shale member: sta. 301, loc. M76A, and M97-5 (talus)

Figured Specimen.--UC 16099.

ORDER STROPHOMENIDA

SUBORDER STROPHOMENIDINA

SUPERFAMILY DAVIDSONIACEA

FAMILY MEEKELLIDAE

SUBFAMILY MEEKELLINAE

Genus *Meekella* White and St. John, 1867

Meekella n. sp. A

Meekella striatocostata, Mather (not Cox), 1915, p. 148, pl. 10, fig. 10.

Meekella n. sp. A, of Sutherland and Harlow, *in press*, pl. 1, figs. 16, 17.

Discussion.--Sutherland and Harlow (*in press*) described but did not name a new species of *Meekella* from the upper Morrowan part of the La Pasada Formation from near Santa Fe, New Mexico. They stated that their species differs from the highly variable *Meekella striatocostata* (Cox), which occurs widely in the upper Desmoinesian, Missourian, and Virgilian in the Midcontinent and Rocky Mountain area, in having a wider hinge line compared with the width of the shell, in having finer plications that do not originate near the beak, and in having lirae that are less convergent on the crests of the plications.

The author has examined the figured specimens of *Meekella* n. sp. A from New Mexico, Mather's figured specimen (UC 16155) from the Kessler Limestone, and two poorly preserved specimens in the OU collections from the upper part of the Morrow Group in northeastern Oklahoma, and has concluded that they should not be assigned to *M. striatocostata* and do represent a new species. This species cannot be named because of the inadequate collections.

Mather's solitary specimen, an incomplete, poorly preserved pedicle valve, is the largest specimen in the collections from the type Morrowan sequence, measuring 35.3 mm in length and approximately 47 mm in width. The two other specimens, from northeastern Oklahoma, are much smaller.

Material and Occurrence.--Meekella n. sp. A is rare in the Upper Morrowan portion of the La Pasada Formation in north-central New Mexico. It is exceptionally rare in the Morrow Group, and only 4 specimens have been collected from these latter strata. Included is the specimen described as M. striatocostata (Cox) by Mather from the Kessler Limestone (sta. 144). The remaining 3 specimens come from the following Oklahoma localities: Kessler Limestone: M69-27B. Greenleaf Limestone: M30-8. It is thus reported only from the highest Morrowan strata.

FAMILY SCHUCHERTELLIDAE

SUBFAMILY SCHUCHERTELLINAE

Genus Schuchertella Girty, 1904

Schuchertella? n. sp. A

Discussion.--A small number of planoconvex, impunctate stropheminids are present at a few localities in the limestone-shale member. These specimens are small, the largest of them measuring about 13.5 mm in length and 18 mm in width. They are unequally parvicostellate; the costellae are strong, subangular, and number about 9 to 10 in 5 mm at 5 mm SL and about 7 per 5 mm at 10 mm SL. The costellae flare anteriorly and new costellae are intercalated at irregular intervals; the new costellae thus formed do not attain the height and strength of the adjacent costellae. The valves contain fine growth lamellae that are imbricated every 1 to 3 mm, giving the costellae the appearance of recumbent spines, particularly near the anterior margin.

The brachial interior has a very blunt, high, bilobed cardinal process that is unsupported posteromedianly but is supported laterally by strong crural plates. The larger two of the three interiors have an extremely subdued median septum continuing anteriorly for about one third the distance to the anterior margin and slightly depressed adductor muscle field. The sockets are deep.

One tiny specimen from M51-15, measuring 1.3 by 1.5 mm, was attached by the pedicle valve to the brachial umbo of a larger specimen of the same species.

This species is easily distinguishable from the other Morrowan strophomenoids by its small size, coarse costellation, and spinose exterior appearance due to the imbricated growth lamellae. It is tentatively placed within the genus Schuchertella primarily because of the impunctate shell material.

Material and Occurrence.--Specimens assigned to Schuchertella? n. sp. A have been collected from the following localities in the upper part of the limestone-shale member of the Gore Formation in northeastern Oklahoma: M42-7 (1 brachial valve, good exterior) and M51-15 (1 pedicle interior with good exterior, 3 small brachial interiors, 1 tiny specimen, and 1 incomplete pedicle valve with good exterior, fair interior preservation, interarea broken).

FAMILY ORTHOTETIDAE

SUBFAMILY DERBYIINAE

Genus Derbyia Waagen, 1884

Derbyia n. sp. A

Pl 1, fig. 21.

?Derbyia crassa, Murphy (not Meek and Hayden), 1954, p. 24, pl. 1, figs. 14a-14d.

Description (Based upon Specimens from M49-10, M51-15, M76A, and M83A).—Shell plano-convex to gently concavo-convex(?), transverse subquadrate to suboval, large for genus; largest specimen (slightly crushed) measuring approximately 40 mm long, 55 mm wide; shell pseudopunctate.

Pedicle valve with maximum length slightly anterior to hinge line; posterolateral margins slightly rounded; pedicle valve of uncrushed specimens apparently planar in profile to slightly concave(?). Valve unequally parvilirate, ornamented with radiating rounded to subangular lirae over entire surface, increasing by frequent intercalations; lirae subequally spaced laterally, intercalating ones somewhat lower, narrower, less distinct at points of origin, gradually increasing to same strength as adjacent lira within approximately 5 mm. Faint growth lines subequally spaced, not as conspicuous over entire surface as lirae except near anterior margin on larger specimens. Ventral interarea on few undistorted specimens, nearly planar, weakly apsacline to catacline, set 80 degrees to almost perpendicular to plane of valve; interarea apex measuring approximately 145 degrees on largest specimens; two largest specimens with ventral interarea height 7.8-8.8 mm for maximum interarea width of 46 and 55 mm, respectively; interarea ornamented with fine growth lines; pseudodeltidium covers delthyrium, gently arched posteriorly, apical angle around 35 to 40 degrees, also ornamented with fine growth lines, slightly more conspicuous than on interarea. Individual shells very thin, about 1 mm thick at mid-length, approaching 2 mm toward thickened periphery.

Brachial valve gently convex with maximum curvature about one-third distance to anterior margin on some specimens; others with equally very gentle convexity anteriorly over valve length; postero-lateral slopes gently concave to planar; some specimens possessing broad, gentle sulcus arising in front of beak, flaring anteriorly with poorly defined margins; apparently subequal number asulcate with slightly flattened mesial area not distinctly set off from lateral slopes, grading into gently convex lateral, anterolateral slopes. Interarea very narrow; well developed chilidium present on one specimen. Surface ornamentation identical with that of opposite valve; possessing between 21 and 24 lirae in 10 mm in the venter at 10 mm SL, between 17 and 20 lirae at 20 mm SL, and about 17 lirae at 30 mm SL.

Pedicle valve interior with short, low, thin median septum, less than 1 mm in height, originating within 1 mm of pseudodeltidium, extending to about one third length of valve; dentacles strong, separated from interarea by thin, shallow groove, supported by short flanges joining interior surface of pseudodeltidium; adductor scars narrow, lance-like; diductor scars flabellate, with slight marginal rim separating them from adductor scars; floor of muscle field slightly depressed beneath valve surface; internal ornamentation consisting of faint lirae, scattered papillae.

Brachial interior with low, short, strophomenoid cardinal process with lobes not joined posteromedianally, with oval to slit-like muscle facets on posterior surface of lobes; process joined to crural plates; latter diverging at high angle from median line, remaining near hinge to abrupt terminus at edges of muscle scars; dental sockets deeply impressed; adductor field subcircular, poorly defined, with slightly depressed floor. Valve interior ornamented like that of opposite valve.

Discussion.--The description given above is based upon 14 complete but crushed specimens or individual valves, 3 poorly preserved, crushed pedicle interiors, 4 poorly preserved but almost complete brachial interiors, plus numerous fragments of the posterior part of the interior, and numerous fragments of the exteriors, collected from the upper part of the limestone-shale member of the Gore Formation at closely spaced localities near the northern part of Lake Tenkiller (see text-figure 2).

Dunbar and Condra (1932, p. 81) noted that the shape and form of the cardinal process and supporting structures in the brachial valve of Derbyia crassa (Meek and Hayden) varies considerably with inferred maturity of the specimen. The same is also true for the interiors of Derbyia n. sp. A. In the smaller, presumably less mature shells, the process is low, narrow, blunt, and simply bilobed. The supporting crural plates are note strongly developed and lack the concave posterolateral surface on the plates and the deeply impressed dental sockets. The posterior face of the cardinal process becomes higher and broader and strophomenid with growth, and the muscle scars diverge outward and upward on the process. The posterolateral margins of the crural plates become concave as the plates grow ventrally.

Derbyia n. sp. A differs from Derbyia crassa (Meek and Hayden), widely reported from the Lower Desmoinesian through the Lower Permian strata in the Midcontinent, in being about twice as large (contrast a length of 40 mm and width 55 mm to 25 by 30 mm, reported by Dunbar and Condra, 1932, p. 79, for large specimens of the latter species), in having less rounded posterolateral margins, in having a shallow sulcus on some brachial valves, and internally by having the median septum of the pedicle valve apparently much less strongly developed, by having the muscle field not as deeply depressed or recognizable anteriorly, and by having larger and broader hinge teeth.

The Morrowan species is slightly smaller than Derbyia haesitans Dunbar & Condra, from the Missouri Series of Nebraska and Kansas, but has the same general transversely subquadrate shape. The brachial valve, however, is less convex than D. haesitans, and the latter species tends to be asulcate and to have somewhat coarser, more fasciculate surface ornamentation.

B. O. Lane (1962, p. 899) identified a small number of poorly preserved specimens from the upper Atokan portion of the Ely Group in Nevada as Derbyia aff. D. haesitans. This material may be closely related to Derbyia n. sp. A. The Nevada specimens are larger than the material from northeastern Oklahoma, but appear to be otherwise similar.

For a comparison of Derbyia n. sp. A, from the middle part of the Morrow Group with the specimens herein described as Derbyia? n. sp. B, from the lower part of the Prairie Grove Member and from the Cane Hill Member, see the discussion of the latter species.

The only other species of Derbyia that has been described from the Lower Pennsylvanian is D. bonita (Sutherland and Harlow, in press) from the Upper Morrowan portion of the La Pasada Formation near Santa Fe, New Mexico. That species is described as being comparatively thin with a low convexo-plano profile, as having the greatest width at about midlength, and a large specimen is reported to measure about 17 mm in length and 20 mm in width. Derbyia n sp. A is much larger, tends to have a more highly convex brachial valve, develops a shallow sulcus on some of the specimens, and has posterolateral extremities that meet the hinge line almost perpendicularly. The extremities on D. bonita are rounded, and the species is asulcate.

Material and Occurrence.--Derbyia n. sp. A is common only in the calcareous shales of the upper part of the limestone-shale member of the Gore Formation. Its occurrence in other lithic types is rare indeed. The shells are relatively thin and are almost invariably crushed and fragmentary.

The lowest unquestioned occurrence of this species is in strata of the middle portion of the limestone-shale member near the base of the N. bassleri Zone. Its highest definite occurrence is within the upper part of the Brewer Bend Limestone. Questionable specimens from higher stratigraphic horizons have been assigned to this species. In northwestern Arkansas, Derbyia n. sp. A occurs unquestionably only in the upper part of the Prairie Grove Member and in the Brentwood Limestone. Its presence in this area was apparently limited by the general absence of suitable benthic environments during deposition of the Morrowan sequence.

Approximately 15 complete but crushed specimens are present in the collections from the study area. Thousands of fragments were collected from the Morrowan strata. Derbyia n. sp. A occurs rarely to commonly in the following collections: GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8, M3-9, M5-13, M12-8 Station A, M23-4(?), M24-10(?), M26-7(?), M26-9, M28-5 (talus), M34-3(?), M39-4, M39-10, M40-9, M49-10 (basal 2 feet), M49-10 (middle), M51-15, M64-8(?; top), M64-11(?), M65-14 (base), loc. M76A, M78-38, loc. M83A, loc. M87(?), M95-3(?), M95-5(?), M97-5, M97-9 (talus), M97-10(?), M98-7, and loc. M98D. Brewer Bend Limestone: M5-15, M5-16, M37-9, M39-7, M39-14(?), and M97-11(?). McCULLY FORMATION--Chisum Quarry Member: M33-6C(?).

HALE FORMATION--Prairie Grove Member: M100-5(?), M100-6, M101-1(?), M101-3, M101-5(?), M101-6(?), and M101-7. BLOYD FORMATION--Brentwood Limestone: M68-21(?), M70-15 (base), M100-11, M101-15, M101-16(?), M101-19, and M102-6.

Figured Specimen.--OU 7237.

The following specimens are herein assigned to Derbyia? spp. Many of them could probably be assigned to Derbyia n. sp. A if larger collections and more complete specimens were available for study. GORE FORMATION--limestone-shale member: M39-10, loc. M56, and M60-15. McCULLY FORMATION--Chisum Quarry Member: M17-9, M26-23, M29-10 (top), M34-15, and M62-23. Shale "A" member: M36-10B (top), M42-15, M48-13, and M48-13 to 15. Greenleaf Limestone: M35-11, M53-17 (base), and M98-13. HALE FORMATION--Prairie Grove Member: M69-13 and M100-3. BLOYD FORMATION--Kessler Limestone: M104B-26 (basal 1.5 feet), M108-20, and M118-18.

Derbyia? n. sp. B

Discussion.--A small number of collections from the Cane Hill Member and from the lower part of the Prairie Grove Member have poorly preserved individuals that appear to differ from Derbyia n. sp. A. These specimens are exfoliated and fragmentary. Two relatively complete, uncrushed brachial valves are included. The larger, from M103-14, measures about 35 mm in length and is about twice as wide as long; the smaller is from the Cane Hill Member, M105-3, and is about as long as the former specimen but is only about 50 mm wide. The latter is strongly concave and has a height of about 14 mm. Both bear distinct, rounded sulci. A fragment of a pedicle valve from M103-14 suggests that this valve was planar.

The lirae appear to be finer and somewhat more rounded than those characterizing Derbyia n. sp. A. The more highly convex specimen has 23 lirae per 10 mm in the venter at 10 mm SL, 28 at 20 mm SL, and 21 at 30 mm SL. Contrast this with ranges of 21 to 24, 17 to 20, and about 17 per 10 mm on the venter of the brachial valve of Derbyia n. sp. A at corresponding surface lengths.

It would appear that Derbyia? n. sp. B differs from Derbyia n. sp. A in having a more highly arched, more highly convex brachial valve, in having a more prominent sulcus on the brachial valve, in being slightly more coarsely lirate, and in having slightly less angular and lower lirae. The latter feature may be a function of the differences in preservation.

No interiors of Derbyia? n. sp. B are available, and the generic assignment is tentative. The shells are pseudopunctate.

Material and Occurrence.--A small number of highly fragmentary specimens are provisionally assigned to Derbyia? n. sp. B from the basal part of the Morrow Group in northwestern Arkansas. This species occurs rarely in the following collections: HALE FORMATION--Cane Hill Member: M105A-3. Prairie Grove Member: M103-14, M111-16, M112-10, M116-8 (top 4 feet), M117A-2, and M117A-6. The collections from the Prairie Grove Member occur in the lower portions of this member in strata assigned to the *Idiognathoides noduliferus* Zone.

SUBORDER CHONETIDINA

SUPERFAMILY CHONETACEA

FAMILY CHONETIDAE

Genus *Neochonetes* Muir-Wood, 1962

Discussion.--*Neochonetes dominus* (King) is the type species for the genus *Neochonetes*. It comes from the upper Marble Falls Limestone (Atokan) in central Texas. The range of the genus is reported by Muir-Wood (1962, p. 87) to be from the Upper Carboniferous and Pennsylvanian to Permian. The oldest species included in her list is the type species. Sutherland and Harlow (*in press*) noted the occurrence of two Morrowan species that they assigned to this genus (*N*.? *platynotus* and *Neochonetes* n. sp. A) from the basal part (Morrowan) of the La Pasada Formation in north-central New Mexico. These two species *Neochonetes* n. sp. A of Sutherland and Harlow (= *Neochonetes*? n. sp. A of this dissertation) also occur in the Morrow Group. In addition, it would appear that *Chonetes choteauensis* Mather may be assignable to this genus, but the character and stratigraphic position of this species are not well known.

Neochonetes? *platynotus* (White)

Pl. 1, figs. 15-20.

Chonetes platynota White, 1874, p. 19; 1877, p. 21, pl. 9, figs. 6a-6e.

Neochonetes? platynotus, Sutherland and Harlow, in press, pl. 2, figs. 14-16; pl. 3, figs. 10-14.

Discussion.—Neochonetes? platynotus is one of the more distinctive species in the Morrow Group. It is characterized by its subrectangular shape, small size, having its greatest width at midlength, smooth exteriors, and plano-convex lateral profile.

White (1874, p. 19) described Chonetes platynota as coming from "Strata of the Carboniferous period, near Santa Fe, and near Salt Lake, New Mexico." The specimens that he illustrated, however, are from the Santa Fe area. Sutherland and Harlow (in press) reestablished the type locality as being within the Upper Morrowan portion of the La Pasada Formation, examined White's type specimens, selected a lectotype, and redescribed the species. They noted that the specimen that White incorrectly portrayed as having a mesial lobe, has only a slight flattening of the anterior slope (ibid, pl. 2, figs. 18b, 19b).

Direct comparison of the plastotypes and the topotypes of this species with the material from the Upper Morrowan of northeastern Oklahoma shows that the collections agree closely in most respects, except that the specimens from the Morrow Group tend to have a higher percentage of asulcate forms than those from New Mexico. The specimens from the Greenleaf Limestone tend to be larger than the New Mexico specimens. Sutherland and Harlow's largest specimen measures 9.5 mm in length and 13.1 mm in width; the largest specimen from northeastern Oklahoma measures

11.6 mm by 17.3 mm (pl. 1, fig. 16). All of the brachial valves are unusually thin for the size of the specimens.

Sutherland and Harlow (ibid.) stated that all of the type specimens are decortiated and that it cannot be determined with certainty if they are capillate or not. Unweathered specimens from northeastern Oklahoma are clearly not capillate.

Neochonetes platynotus differs from N. dominus (King), the type species for the genus, primarily in having a smaller size, no capillae, and in generally lacking a sulcus. The two species are similar internally.

Neochonetes? platynotus possesses the internal characteristics of the genus Neochonetes but externally has some of the characteristics of Eolissochonetes, particularly in the overall shape and absence of capillae on the valve exteriors. This species is not assigned to Eolissochonetes because of the presence of the pair of vascular trunks that bound the median septum in the interior of the pedicle valve and because the brachial valve possesses well-developed anderidia. It is possible that this species is the ancestral form to the genus Eolissochonetes rather than Mesolobus messlobus decepiens (Girty) as suggested by Hoare (1960, p. 35).

Neochonetes? platynotus is thought to have evolved from Neochonetes? n. sp. A from the Lower Morrowan of the Ozark region. A small percentage of specimens from the Chisum Quarry Member at M27-14 have the maximum width at the hinge and have slightly extended alae. In overall shape, these specimens are more closely similar to Neochonetes? n. sp. A from the Lower Morrowan strata. For additional remarks and a comparison without species, see the discussion of Neochonetes? n. sp. A.

The small collections of this species from the Wapanucka Formation (Morrowan) of southern Oklahoma in the undescribed OU collections agree closely with the material from the Morrow Group, except that some of the specimens are slightly more highly arched than typical.

N.? platynotus is externally similar to Chonetes chesterensis Weller, from the Chester Series of Illinois except for being acapillate. Muir-Wood (1962, p. 65) placed the latter species in the genus Rugosochonetes, in spite of the fact that its internal characteristics are unknown.

N.? platynotus is externally similar in size and shape to N.? choteauensis (Mather). For additional remakrs, see discussion of that species.

Material and Occurrence.--Neochonetes? platynotus is one of the most distinctive species in the Morrow Series and is restricted to the Upper Morrowan. The type specimens are from the basal part of the La Pasada Formation (Upper Morrowan) of north-central New Mexico (Sutherland and Harlow, in press), and does not occur in younger strata there. This species occurs in the Wapanucka Formation (Morrowan) of southern Oklahoma, although it does not occur abundantly.

This species occurs rarely throughout the McCully Formation in northeastern Oklahoma, where 72 generally complete specimens have been collected. A single specimen was recovered from the Kessler Limestone in northwestern Arkansas. McCULLY FORMATION--Chisum Quarry Member: M27-13 (10 specimens), M27-14 (top; 19 pedicle interiors, 2 brachial interiors, 2 complete specimens), M28-11, M29-10 (top), M29-11 (base), M30-3, and M78-44 (top). Greenleaf Limestone: M1-19, M1-20 (20 pedicle interiors, 7 complete specimens). BLOYD FORMATION--Kessler Limestone: M105D-13.

Figured Specimens.--OU 7231-7236.

Neochonetes? n. sp. A.

Pl. 2, figs. 1-8.

Chonetes laevis Mather (not Keyes), 1915, p. 151, 152, pl. 8, figs. 13, 14.

Neochonetes n. sp. A, of Sutherland and Harlow, _in press_, pl. 3, figs. 15-19.

Description (Based on Specimens from M26-9).--Shells medium-sized for genus, averaging approximately 5.8 mm in length, 10.3 mm in width, and 1.7 mm in height (additional measurements in Appendix IV); shell wider than long, greatest width along hinge line; cardinal extremites extended, forming acute angle with lateral margins; valve with low convexity, almost flat in earlier growth stages; rare specimens with very gentle and broad sulcus anteriorly. Hinge line straight; maximum of eight fragile, hollow spines on each side of beak, increasing in diameter laterally, apparently long; apsaclinal interarea elongated, gently concave, highly convex pseudodeltidium partly covering delthyrium. Shell ornamented with concentric growth lines, generally more numerous, closely spaced near anterior margins; most shells devoid of radial ornamentation, approximately one-third of more mature specimens with finely spaced, almost obsolete capillae near anterior margin, generally about 7 per mm; rare specimens with capillae over most of surface.

Brachial valve gently concave, almost flat, with greatest curvature immediately anterior to hinge line; generally flattened in areas corresponding to lateral socket ridges on interiors, gently cancave elsewhere except for anterior, anterolateral margins, where flattened; interarea hypercline; chilidium or chilidial plates not preserved. Most of valve generally ornamented with fine, almost obsolete capillae, contrasting to pedicle valve; fine concentric growth lines present. Valve thin, generally crushed.

Pedicle valve interior varying with apparent maturity of specimen; mature specimens generally possessing high median septum near posterior margin, rapidly decreasing in height anteriorly within 1 to 2 mm, extending farther anteriorly as low, almost obsolete, thin ridge to about one-fourth to one-half distance to anterior margin; both median septum, vascular trunks generally bearing scattered, unevenly spaced pustules; adductor scars forming oval, raised platform near posterior margin on some diductor scars tear-shaped, slightly depressed on most specimens; some specimens ornamented with irregularly spaced pustules; teeth diverging acutely from hinge line at about 20 degrees, set off from interarea by small, distinct groove; well-preserved specimens with six or seven small grooves on ventral margins of teeth, diverging obliquely from hinge line at approximately 50 degrees. Valve interior variably ornamented with irregularly spaced pustules, becoming finer and more closely spaced in distinct rows outside visceral area on generally slightly flattened anterior, anterolateral margins; alae unornamented.

Brachial valve interior with broad, externally quadrilobate cardinal process, internally bilobate, terminating anteriorly in broad, shallow alveolus, rarely deep; process supported laterally by strong socket ridges; sockets deep, flaring laterally; lateral ridges present in about half of mature specimens, generally joining low median septum, if present, rarely longer than 3 mm on mature specimens; posterior, anterior adductor scars generally well defined in mature specimens, obscure in younger ones; brachial ridge particularly well defined anteriorly with thickening of shell; large endospines present on mature specimens. Valve ornamented variably with pustules, becoming more closely spaced, segregated into rows anteriorly, anterolaterally beyond brachial ridge.

Discussion.--*Neochonetes*? n. sp. A is characterized by its small size, extended hinge line, converging lateral margins, rectimarginate anterior commissure, low convexity, generally acapillate pedicle valves except for the anterior margin, and development of lateral septa in some of the brachial interiors.

The brachial valves on the articulated specimens are invariably crushed. The shape of the brachial valve and character of the brachial interarea was ascertained from disarticulated, uncrushed valves.

Neochonetes? n. sp. A from the Morrow Group compares quite favorably with the specimens from the basal part of the La Pasada Formation in north-central New Mexico described by Sutherland and Harlow (*in press*) also as *Neochonetes* n. sp. A, except that the Morrowan material from New Mexico is distinctly capillate over the entire pedicle valve. The material from the Ozark Mountains region is generally acapillate except for the anterior margin of the pedicle valve, although a few specimens do have capillae over the entire surface. The species from the Ozark Mountain region is placed tentatively in *Neochonetes* because of the general absence of capillae.

Neochonetes? n. sp. A differs from *N*.? *platynotus* (White), from which it is separated stratigraphically, in being smaller, and in having a greater width-length ratio as a consequence of the development of the extended hinge line and pronounced alae, which in some specimens give a distinct subtriangular appearance. In contrast, *N*.? *platynotus* is distinctly subrectangular in all growth stages and has only modestly developed alae. *Neochonetes*? n. sp. A also differs from *N*.? *platynotus* in that approximately one-third of the mature specimens from the type locality have faint capillae developed on the anterior and anterolateral margins; the brachial valves are generally capillate. Both of the valves of *N*.? *platynotus* are devoid of radial ornamentation, at least on the specimens from northeastern Oklahoma. Both species are generally asulcate and are gently concave in transverse profile. Internally, the two species are closely similar except that a number of specimens of *Neochonetes*? n. sp. A develop lateral septa on the brachial valve.

The specimens in the large collection from M51-15, in the upper part of the limestone-shale member, tend to be somewhat larger than those from the stratigraphically lower M26-9. Although the surfaces on these specimens are not as well preserved, it would appear that the ornamentation on the anterior portion of the pedicle valve is even less distinct than on the specimens from M26-9. A few specimens in this collection approach the typical shape of *N.*? *platynotus* in being subrectangular; these variants do not possess the distinctly extended hinge line and converging lateral margins, but they do grade into forms more typical in shape to *Neochonetes*? n. sp. A, and these latter dominate the collection. A relatively large percentage of the brachial interiors of the more mature specimens possess lateral ridges than do the mature brachial interiors from M26-9, but this may be a function of the larger valve sizes. The presence of the transitional specimens and the variants like *N.*? *platynotus* in this collection and the presence of the more conservative variants like *Neochonetes*? n. sp. A in the larger collections of *N.*? *platynotus* (see discussion of that species for additional details) strongly suggests that *Neochonetes*? n. sp. A is the immediate ancestor of the Upper Morrowan form.

Mather (1915, p. 151, 152, pl. 8, figs. 13, 14) illustrated two specimens (UC 16082) from his station 301 near Ft. Gibson, Oklahoma as *Chonetes laevis*, originally described by Keyes (1888, p. 229, pl. 12, figs. 3a, 3b) from the Desmoines Series of Iowa. Hoare (1960, p. 220) designated *C. laevis* Keyes as the type species for the genus *Eolisso-*

chonetes. Muir-Wood (1962, p. 76) noted that C. laevis Keyes (1888) is preoccupied by Chonetes laevis Davidson (1866), and renamed Keyes' species Eolissochonetes keyesi. She included Mather's illustrated specimen in synonymy with E. keyesi. The specimen that Mather figured does not belong to E. keyesi and is herein referred to Neochonetes? n. sp. A.

Neochonetes? n. sp. A differs from Neochonetes? choteauensis (Mather) in typically having no sulcus and in having extended cardinal extremities and converging lateral margins; it appears to differ from that species also in having poorly developed radial ornamentation.

Material and Occurrence.--Neochonetes? n. sp. A is restricted to the Lower Morrowan of the Ozark Mountains region and occurs in strata in the La Pasada Formation that is correlated with the upper part of the Lower Morrowan in the type region.

The range of this species is from the lower to the middle part of the limestone-shale member in northeastern Oklahoma and from the lower part of the Prairie Grove Member through the Brentwood Limestone in northwestern Arkansas. This species occurs rarely in both areas in strata of the Idiognathoides noduliferus Zone, but occurs commonly in the middle and upper parts of the limestone-shale member, particularly in the calcareous shale facies. Approximately 2,000 specimens, including about 200 brachial valve interiors and 100 valve pedicle interiors are present in the OU collections from the Morrow Group. Most of the specimens are crushed but are complete. The specimens from M26-9 in the lower to middle portion of the limestone-shale member (lower Neognathodus bassleri Zone) upon which the description of this species is based, are also well preserved; over 350 complete specimens, 90 pedicle interiors, and 54 brachial interiors are present in this collection. This species occurs rarely to commonly in the following collections unless otherwise mentioned: GORE FORMATION--limestone-shale member: M1-5, M1-6, M5-13, M23-4, M26-6, M26-7 (lower 2 feet), M26-9, M26-14, M26-19, M27-8B (4 feet above base), M39-4, M39-5, M48-0A (117 specimens, 28 pedicle interiors, 9 brachial interiors), M49-10 (middle), M51-15 (262 specimens, 72 pedicle interiors, 35 brachial interiors), M56-8, M64-11, loc. M76A, loc. M83A, M95-5, M97-5, M97-8, and loc. M98D. Brewer Bend Limestone: M24-12 and M33-4C. HALE FORMATION--Prairie Grove Member: M70-8, M100-6, M110-18, M112-16, and M118-8.

Figured Specimens.--OU 7238-7245.

Neochonetes? choteauensis (Mather)

Pl. 2, figs. 9-10b.

Chonetes choteauensis Mather, 1915, p. 150, pl. 8, figs. 9-10a.

Discussion.--Mather (1915, p. 150) based Chonetes choteauensis upon two cotypes (UC 16083) and five fragmentary and badly exfoliated specimens (UC 16321) from his station 295, near Choteau, Mayes County, Oklahoma. This writer has examined these specimens and recommends that the specimen figured by Mather as pl. 8, figs. 10, 10a (refigured here as pl. 2, figs. 9a, 9b) be designated the lectotype.

In addition to the specimens mentioned above, Mather assigned a single specimen (UC 16322) from his station 301 near Ft. Gibson, Oklahoma, to this species. This writer has not examined this specimen, but Sutherland (personal communication) states that it is not a chonetid but rather is a poorly preserved brachial valve of a productid.

Both of Mather's types are badly decorticated, revealing the rows of fine pseudopunctae. Mather's description of these specimens is generally accurate. The mesial portion of the pedicle sulcus of both specimens is flattened, and the specimen suggested by this writer as the lectotype (pl. 2, fig. 9b) has the faintest suggestion of a mesial fold in the sulcus. The posterolateral extremities of both specimens are slightly chipped and broken, but it would appear that both specimens had only slightly extended alae in their earlier growth stages; the lateral margins met the posterior margin at about 90 degrees. Thus, in outline, the shell approached that of _N_.? _platynotus_ (White).

The suggested lectotype measures 6.1 mm in length and slightly more than 11 mm in width; the greatest width may have been slightly anterior to the hinge line. This specimen has 21 "costellae" measured in 5 mm in the venter at 5 mm SL. The remaining cotype measures 6.5 mm in length and was about 10 mm wide. The surface of this specimen is too badly decorticated to count the number of costellae.

The five fragmentary specimens from Mather's type locality (UC 16321) are too poorly preserved to be of any value.

The type locality has not been reestablished, but the specimens may not have been collected from the Morrow Group (see discussion of Mather's station 295 in Appendix III) but rather from the overlying Atoka Formation.

Neochonetes? *platynotus* (White) may be the senior synonym of *Chonetes choteauensis* Mather. Both species are similar in size, shape, and general outline. The specimens of *N.*? *platynotus* from northeastern Oklahoma tend to be more asulcate and unweathered specimens appear to be acapillate. The type specimens and topotypes from north-central New Mexico may be faintly capillate. In their redescription of this species based upon type material, Sutherland and Harlow made the following remarks: "Most specimens are decorticated but the pedicle valve of some has what may be faint capillae, apparently confined to the anterior slope, which number 7 or 8 per millimeter. Some specimens appear to be smooth."

The name *C. choteauensis* Mather has been rather widely used for Morrowan and Atokan(?) specimens from throughout the Midcontinent. The following identifications have been made: Plummer and Moore (1921, p. 45), Marble Falls Limestone, Texas; Morningstar (1921, p. 50; 1922, p. 178), lower part of Pottsville Group, Ohio; and Plummer (1950), Marble Falls Limestone, Texas. These collections should be reexamined in order to determine whether they are assignable to *N. platynotus* (White).

Figured Specimens.--Cotypes, UC 16083.

Genus Plicochonetes Paeckelmann, 1932

Discussion.--The genus Plicochonetes was originally defined by Paeckelmann (1930) and emended by Muir-Wood (1962). The type species is Chonetes buchianus de Koninck from the Lower Carboniferous (Visean) of Belgium. This represents an unfortunate choice for the type species since its internal features are poorly known.

The genus is characterized by species with small to medium sized, concavo-convex, highly arched shells that have a short interarea that may or may not contain a small pseudodeltidium, and characteristic, coarse costae or costellae. Hinge spines and spinules are well developed and intersect the valve at a relatively high angle. Both species that have a median septum in the brachial valve and species that do not have a median septum have been assigned to this genus. The type species apparently has a median septum (Muir-Wood, 1962, p. 83). They are all characterized by short inner socket ridges, cardinal processes that are internally bilobed and externally quadrilobed, and well defined brachial ridges.

Muir-Wood (1962) gives the range for the genus as from Devonian to Carboniferous; it is not reported by her to occur in North America in strata younger than early Mississippian.

One species from the type Morrow Series is herein questionably included within the genus. It is Chonetes arkansanus Mather.

Plicochonetes dotus Sturgeon and Hoare (1968, p. 33), from the lower Desmoinesian strata of Ohio, is the only other Pennsylvanian form that has been previously referred to Plicochonetes. It is closely similar to P.? arkansanus.

Plicochonetes? arkansanus (Mather)

Pl. 2, figs. 11-20.

Chonetes arkansanus Mather, 1915, p. 149, pl. 8, fig. 4.

Plicochonetes? arkansanus, Sutherland and Harlow, in press, pl. 3, figs. 1-9.

Description (Based upon Specimens from Localities M1-5 and M97-5).--Shell small, subelliptical; hingeline extending laterally, alae distinct; posterior margin diverging from plane of symmetry at approximately 80 degrees; large specimen measuring 7.0 mm in length, 9.6 mm in width, 2.4 mm in height (for additional measurements, refer to Appendix IV).

Pedical valve strongly convex in lateral profile, stronger near beak; beak overhanging hinge slightly; umbo inflated, lateral slopes steep, flaring sharply anteriorly; alae thin, flat; most specimens asulcate, few having slight flattening on anterior slope, rarely with very shallow sulcus; interarea orthocline, narrow, slightly concave; narrow, small pseudodeltidium present; maximum of eight spines occurring on each side of beak, becoming larger in diameter away from beak.

Brachial valve gently, uniformly concave in central portion, with more flattened areas near posterolateral margins and alae; valve thin, generally crushed.

Both valves possessing strong, subangular costellae, bifurcating every 2 to 3 mm anteriorly; on pedicle valve number of costellae measured in 5 mm in venter at 5 mm SL ranges from 16 to 24 (M = 20; $\bar{x}$ = 19.67, n = 58, text-figure 8) several prominent growth lines generally present near anterior margin.

Pedicle valve interior with median septum varying in both height, extent of development, generally slightly elevated beneath delthyrium for 1 to 2 mm, extending anteriorly as low ridge about one-fourth to one-sixth distance to margin, occasionally consisting of row of papillae on anterior portion; mature shells possessing low, thickened ventral trunks close to median septum, beginning at anterior margin of small, distinct, oval, elevated adductor scars; trunks extending anteriorly beyond midlength on mature specimens, generally slightly higher than median septum, also ornamented with small, irregularly spaced papillae; diductor scars less distinct than adductors; anterior slopes with rows of fine papillae, becoming progressively finer near anterior margins; hinge teeth oval, well developed.

Features of brachial valve varying with age; cardinal process short, small, internally bilobate, posteriorly quadrilobate on mature specimens; most specimens with poorly developed, papillose median septum beginning immediately anteriorly to alveolus as low ridge, rising slightly anteriorly, becoming abscure by midlength; lateral septa short, longest observed 1.8 mm long; socket ridges well developed, diverging from hinge line at about 20 degrees; sockets narrow, deep; adductor field poorly defined; visceral area set off with weak, papillcse brachial ridge only in largest specimens; interior ornamented with rows of regularly spaced papillae, becoming finer, more closely spaced near anterior margin.

Discussion.--Plicochonetes? arkansanus is a particularly distinctive species and is characterized by its small size, strongly developed radial costellae, extended alae, strongly convex lateral profile, and inflated umbo. This species is questionably referred to Plicochonetes on the basis of its overall size, shape, and surface ornamentation. The type species of the genus is poorly known internally, but P.? arkansanus differs from many species assigned to this genus in having a weakly developed brachial ridge in the mature specimens.

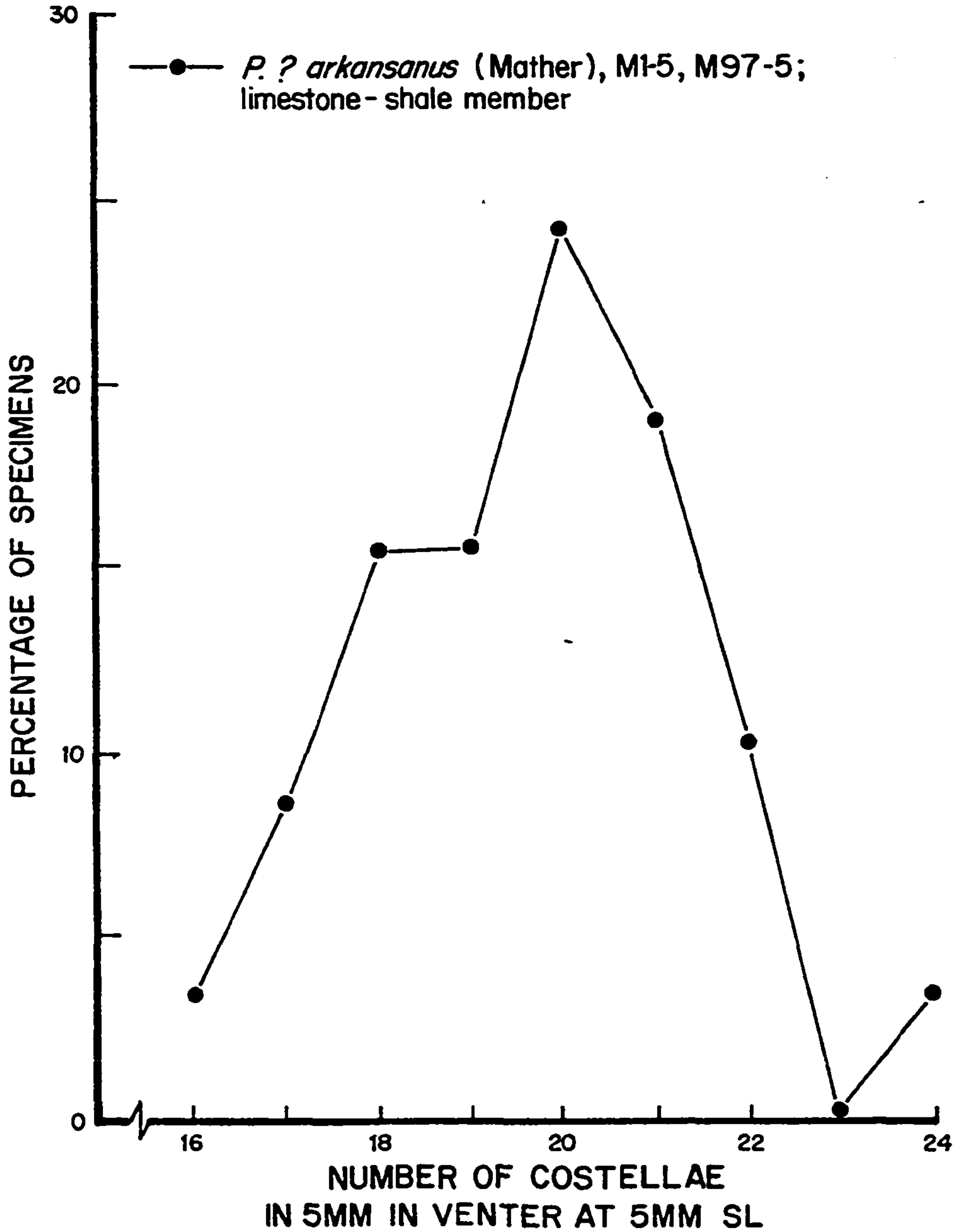
Mather's (1915, p. 149) types of Chonetes arkansanus were collected from the Brentwood Limestone at his station 210 (=M120). Mather collected nine immature specimens (UC 16084), of which only four are complete shells. He figured one of these cotypes (ibid., pl. 8, fig. 4); two additional cotypes are figured here (pl. 2, figs. 11 and 12). The author and P. K. Sutherland unsuccessfully tried to reestablish the type locality for C. arkansanus (see discussion of Mather's station 210 for additional remarks).

The largest collections in northeastern Oklahoma occur in the upper part of the limestone-shale member at two closely spaced localities M1-5 and M97-5. The description presented above is based upon this material, and measurements for these collections and the type material are given in Appendix IV.

It would appear that the specimens from the Greenleaf and Kessler Limestones (Upper Morrowan) possess slightly finer costellae than the material from lower stratigraphic intervals, although the material is insufficient to allow statistical analysis.

The author has examined the collections of _P._? _arkansanus_ described by Sutherland and Harlow (_in press_) from the Upper Morrowan portions of the La Pasada Formation in north-central New Mexico. This material appears to be slightly larger and also more finely costellate than the material described from the upper part of the limestone-shale member. Sutherland and Harlow reported a range in number of costellae from 19 to 27 ($\bar{x}$ = 23.6, M = 23, 24, n = 18) in 5 mm across the venter at 5 mm SL; the material from the limestone-shale member ranges between 16 and 24 ($\bar{x}$ = 19.67, M = 20, n = 58; text-figure 8). Statistically, no significant difference between the two means is calculated, but this is most probably a result of the small sample size for the material from northern New Mexico. It is interesting, however, that the New Mexican collections, which are Upper Morrowan, are more similar to the Upper Morrowan forms from the Ozark Mountains region. Larger collections may indicate that two species of plicochonetoids can be differentiated in the Morrow Series.

Sturgeon and Hoare (1968, p. 33) described _Plicochonetes dotus_ from the Lower Mercer Shale (Lower Desmoinesian) of Ohio. It is said to differ from _P._? _arkansanus_ in having slightly finer costellae. Unfortunately, Sturgeon and Hoare do not present data to allow statistical analysis between the collections of _P._? _arkansanus_ from the



Text-figure 8.--Plot of number of costellae in 5 mm in venter at 5 mm SL for *Plicochonetes*? *arkansanus* (Mather) from limestone-shale member at M1-5 and M97-5. See text for additional discussion.

upper part of the limestone-shale member and from the Lower Mercer Shale. They merely stated (ibid., p. 34) that this species has "5-6 costae and costellae per mm along anterior margin." It would appear that with respect to the fineness of the costellation, the material from the Upper Morrowan strata is closer to _P. dotus_ than to _P.? arkansanus_. The only other difference between the material described as _P. dotus_ and the material from the upper part of the limestone-shale member is that the Lower Desmoinesian species is reported to be consistantly slightly larger.

Girty (1915d, p. 11) described a new variety of _Chonetes ornatus_ Shumard, which he called _C. ornatus_ var. _arkansanus_, from strata of the Boone Limestone immediately overlying the St. Joe Member in northern Arkansas. These strata are lower Osagian (Mississippian). _C. ornatus arkansanus_ is a highly arched, small, and strongly costellate form and probably would be placed by many authors in _Plicochonetes_. Publication dates in 1915 of the Mather and Girty papers have not been determined, but it may be that _Chonetes arkansanus_ Mather is preoccupied.

Material and Occurrence.--_Plicochonetes? arkansanus_ ranges from the middle portion of the limestone-shale member in northeastern Oklahoma (lower part of _Neognathodus bassleri_ Zone) through the McCully Formation. This species ranges from the upper part of the Prairie Grove Member through the Kessler Limestone in northwestern Arkansas. The species was originally described by Mather (1915, p. 149) from the Brentwood Limestone at his station 210 (see discussion of that station in Appendix III for further remarks).

Approximately 350 specimens occur in the collections from the Morrow Group; most of these are well preserved. This species occurs most commonly in the calcareous shales of the upper part of the limestone-shale member. P.? arkansanus occurs rarely in the following collections, unless otherwise stated: GORE FORMATION--limestone-shale member: M1-5 (81 specimens, plus interiors), M1-6, M5-13, M5-15, M12-8, M23-3C, M26-9, M26-14, M27-8B, M31-5 (top), M37-5, M39-4, M48-0A (19 specimens, 3 pedicle interiors, 2 brachial interiors), M48-6, M49-10, M51-7 (22 feet above base, M51-15 (24 specimens, 3 pedicle interiors), M60-16, M61-6, M65-14 (top 1 foot), loc. M76A, loc. M83A, M97-5 (10 specimens), M97-6 or 8, M97-8, and loc. M98D. Brewer Bend Limestone: M31-12C, M37-9, and M39-7. McCULLY FORMATION--Chisum Quarry Member: M26-23, M28-11, M30-3, M40-18A (5 to 6 feet above base), M61-9 (top 6 feet), and M63-20. Shale "A" member: M29-14, and M30-6. Greenleaf Limestone: M1-21(?), M42-21, M51-25 M112-10 and M112-16. BLOYD FORMATION--Brentwood Limestone: M68-25 (23 specimens), M70-15 (6 feet above base), M105C-10, M116-16. Kessler Limestone: M105D-13, M105D-15, M114-28(?).

Plicochonetes? arkansanus occurs in the Upper Morrowan portions of the La Pasada Formation in north-central New Mexico (Sutherland and Harlow, in press) and is present in the OU collections from the Wapanucka Formation (Morrowan) in south-central Oklahoma.

Figured Specimens.--UC 16084, OU 7246-7253.

SUBORDER PRODUCTIDINA

SUPERFAMILY PRODUCTACEA

FAMILY OVERTONIIDAE

SUBFAMILY OVERTONIINAE

Genus *Krotovia* Frederiks, 1928

Discussion.—The internal characters of the type species of the genus *Krotovia* Frederiks, *Productus spinulosus* J. Sowerby, from the Lower Carboniferous of Britain, were unknown for many years. Nevertheless, many Carboniferous and Permian spinose productoids were assigned to this species. Brunton (1966) illustrated the interiors of silicified specimens of the genotype.

Two species from the Morrow Group are tentatively assigned to this genus on the basis of similarity in shape and exterior ornamentation to the genotype. Interiors of both of these species are not present in the collections available to this writer.

Krotovia? *globosa* (Mather)

Pl. 2, figs. 21a-22d.

Pustula globosa Mather, 1915, p. 167, pl. 10, figs. 7-9; Murphy, 1954, 27, pl. 2, figs. 3a-3e.

?*Krotovia maccoyensis* Stevens, 1962, p. 628, pl. 94, figs. 1, 2.

Krotovia globosa, Sutherland and Harlow, *in press*, pl. 5, fig. 16.

Description (Based upon Specimens from M1-5, M1-6, and M97-5).—Shell small for genus, highly concavo-convex, subhemispherical profile with relatively deep body cavity, distinct subcircular outline with maximum width generally greater than length, maximum width at mid-length, hinge width subequal to length; largest specimen measuring 8.1 mm long, 8.7 mm wide, 4.6 mm high, 7.3 mm hinge width, 14 mm SL.

Pedicle valve strongly, uniformly convex longitudinally, transversely; rare specimens with slightly flattened venter; beak small, pointed, incurved, extended beyond hingeline maximum of about 1 mm, with generally obscure, slightly flattened cicatrix of attachment up to 1 mm long; umbo not inflated, not well set off from posterolateral margins; flat alae generally small, only slightly extended; lateral margins meeting posterior margin almost perpendicularly. Surface ornamentation characterized by small, suberect spines, spaced about 3 per mm near umbo, on alae, becoming more widely spaced anteriorly, anterolaterally, becoming larger away from beak, with spine bases up to 1 mm in diameter at anterior margin; spines tapering slightly, bending gently anteriorly, irregularly spaced along growth lines, longest (broken) spine measuring 4.2 mm. Most specimens with very fine, concentric, low, slightly wrinkled growth lines, numbering between 4 to 6 per mm, becoming slightly more prominent near anterior, lateral margins; few specimens characterized by more irregular, slightly wrinkled, concentric rugae over much of surface; radial ornamentation lacking.

Brachial valve deeply concave, uniformly curved in longitudinal profile, in lateral profile anteriorly; posterolateral margins flattened, rarely slightly convex, alae more sharply defined than on pedicle valve.

Surface ornamentation similar to that of opposite exterior except that concentric, wrinkled growth lines slightly more conspicuous; spines consistantly smaller and slightly more densely spaced than those of opposite valve.

Discussion.—Mather (1915, p. 167) based his description of Pustula globosa upon three specimens, which the author has examined. The holotype (UC 16130) is a badly exfoliated pedicle valve with the alae partly broken off (pl. 2, figs. 21a-21d of this dissertation), but scattered, large spine bases can be clearly seen, particularly on the pedicle view. Mather's description of this species is for the most part accurate but is inadequate because of the poor preservation and limited number of specimens that he had available to him. He refers to the allotype (UC 16130, his pl. 10, fig. 8) as a brachial valve; it is in fact a badly exfoliated brachial interior.

The specimens from other localities in the Morrow Group agree with the material upon which the current description is based, except that a number of the specimens do attain a larger size with the development of a trail. The largest of all the specimens is from the middle of the limestone-shale member at M29-4; this specimen has a surface length of 16 mm, a length of 10.2 mm, width of 7.2 mm, and is about 4.1 mm high. Specimens with the trail commonly have a length greater than the width.

Pustula globosa is provisionally placed within the rather widely defined genus Krotovia, following Muir-Wood and Cooper (1960, p. 189), who assigned to this genus Avonia knighti Newell, from the Missouri

Series of Kansas. The placement of _K_.? _globosa_ is questioned because (1) the interiors of this species are unknown, (2) the Morrowan species is much smaller than most species commonly assigned to this genus, (3) the alae of this species are very small and not extended, and (4) the concentric ornamentation of _K_.? _globosa_ varies from very fine, closely spaced growth lines to coarser concentric rugae. Muir-Wood and Cooper (1960, p. 189) stated that the absence of concentric bands of rugae is characteristic of _Krotovia_ and distinguishes it from most other genera of spinose productoids.

Stevens (1962, p. 628) described _Krotovia maccoyensis_ from the upper part of the Atoka Series in the Minturn Formation in northwestern Colorado. This latter species is said to differ from Mather's descriptions of _Pustula globosa_ only in being somewhat larger and more spinose. Stevens' illustrations (_ibid_., pl. 94, figs. 1-2c) do not appear to have more spines than the material used for the revised description of this species, and _K_. _maccoyensis_ should be reexamined and possibly reassigned to _K_.? _globosa_ (Mather). Interiors of _K_. _maccoyensis_ are also unknown.

Krotovia? _globosa_ can be readily distinguished from other small, spinose productoids that occur in the Morrow Group by its very small size, its strongly concavo-convex, subhemispherical profile, its subcircular outline and small alae, and by the absence of radial ornamentation.

For a comparison with _Krotovia_? n. sp. A, see the discussion of that species.

Material and Occurrence.—Mather (1915, p. 167) based this species upon two badly exfoliated specimens (UC 16130, holotype and allotype) from the Brentwood Limestone at his station 210 and upon a single specimen (UC 16237) from the Brentwood at his station 148 near Fayetteville. The type locality has been tentatively reestablished as M120-12, and two badly exfoliated topotypes (OU 7331) have been collected. This unit, however, is in the "caprock" and not in the Brentwood (for additional remarks, see discussion of Mather's station 210 in Appendix III).

The description of the species presented in the previous section is based upon 78 relatively complete exteriors from the uppermost part of the limestone-shale member of the Gore Formation in the Webbers Falls area. These specimens were collected from freshly exposed shale units and have exceptionally well preserved, unweathered, unexfoliated surfaces.

Approximately 285 specimens identified as Krotovia? globosa have been collected from the Morrow Group. This species ranges from strata in the middle part of the limestone-shale member (lower part of Neognathodus bassleri Zone) through the Greenleaf Limestone. Approximately three-fourths of the specimens occur in the middle to upper part of the limestone-shale member. In northwestern Arkansas, this species is reported from the upper part of the Prairie Grove Member through the Kessler Limestone. This species occurs rarely in the following collections, unless otherwise indicated: GORE FORMATION—limestone-shale member: M1-5 (40 excellent specimens), M1-6 (11 excellent specimens), M5-13, M12-8 Station A, M14-9, M26-9, M27-7 (6 to 8 feet below top), M27-8B (4 feet above base), M29-4 (22 specimens), M31-5 top, M35-6, M48-0A, M49-8 basal 1 foot, M49-10 basal 2 feet, M49-10 middle, M51-15, M56-3 top, M65-14 top, M67-12(?), loc. M76A, M78-38, M95-3, M97-5 (27 good specimens plus fragments), M97-8, and loc. M98D. Brewer Bend Limestone: M3-12C, M31-12C, M33-4C, and M36-6B. Chisum Quarry Member: M26-23 (45 specimens), M27-16 top, M28-11, M35-8, M37-10, and M62-23. HALE FORMATION--Prairie Grove Member: M100-3, M100-6, M101-3, M112-15, M112-16, and M117-11. BLOYD FORMATION--Brentwood Limestone: M68-16(?), M68-25 (14 specimens), M70-16 (13 specimens), M100-11, M101-9, and M110-20. Dye Shale Member ("caprock"): M120-12 (type locality, topotypes, 2 specimens). Kessler Limestone: M105D-15.

Sutherland and Harlow (in press) have identified this species from the La Pasada Formation in north-central New Mexico. It is extremely rare in these strata. Murphy (1954) identified a number of specimens of this species from the lower portion (Morrowan) of the Oquirrh Formation in north-central Utah.

Figured and Catalogued Specimens.--UC 16130 (holotype), OU 7254; OU 7331 (2 topotypes, unfigured).

Krotovia? n. sp. A

Discussion.--Several small collections of productoids from the middle to upper part of the Morrow Group are similar in size, shape, and overall surface ornamentation to the typologically defined _Krotovia paucispina_ Sturgeon and Hoare from the Lower Desmoinesian equivalents of the Pottsville Series in Ohio.

The largest of the Morrowan specimens measures 20.1 mm in length, 22.7 mm width, 18 + mm hinge width, 9.8 mm height, 5.0 mm thick, and has a surface length of 33 mm (for additional measurements, refer to Appendix IV). The valves are concavoconvex, have a subcircular shape interrupted by a straight hinge that is apparently about as wide as maximum width, which occurs at midlength; a narrow, small beak overhangs the hinge slightly. The ears are small and not well set off from the venter; they are aspinose, but dense, suberect to oblique spines ornament the remainder of the valve, becoming arranged in roughly concentric rows anteriorly. Additional surface ornamentation consists of very fine growth lines and low, flattened, scattered costae arising at the base of spines only on the short trail. The brachial valve is strongly and uniformly concave, without geniculation, and is similarly ornamented except that the spines are more scattered and smaller. Interiors are lacking.

In many respects, the shells closely resemble _K_.? _globosa_ (Mather), which occurs in the same collections, but they are approximately three times larger than that tiny species, less strongly concavoconvex, and the umbo is proportionally broader.

The OU collections from the Wapanucka Formation (Morrowan) of south-central Oklahoma contain fairly large numbers of this species. These collections also do not contain interiors.

Krotovia? n. sp. A is possibly a junior synonym of *Pustula bullata* Mather, the types of which have been lost by the Field Museum. Mather (1915, p. 174) described this species based upon a very small collection from the Brentwood Limestone at his stations 145 and 152; the former station is the type locality, and it was not reestablished during the current study. Mather's (pl. 8, figs. 15-15b) illustrations of the holotype show a poorly preserved, incomplete specimen, and it is similar to *Krotovia*? n. sp. A. However, the two are tentatively retained as separate species until the type specimens of *Pustula bullata* can be located and until topotypes can be collected.

Material and Occurrence.--A total of 7 specimens assigned to this species are present in the collections from the Morrow Group. Three of these are well preserved. GORE FORMATION--limestone-shale member: M1-6, M1-8, M5-13, and loc. M76A. McCULLY FORMATION--Chisum Quarry Member: M37-10. BLOYD FORMATION--Kessler Limestone: M105D-15.

FAMILY MARGINIFERIDAE

SUBFAMILY COSTISPINIFERINAE

Genus *Desmoinesia* Hoare, 1960

Desmoinesia nambeensis Sutherland and Harlow

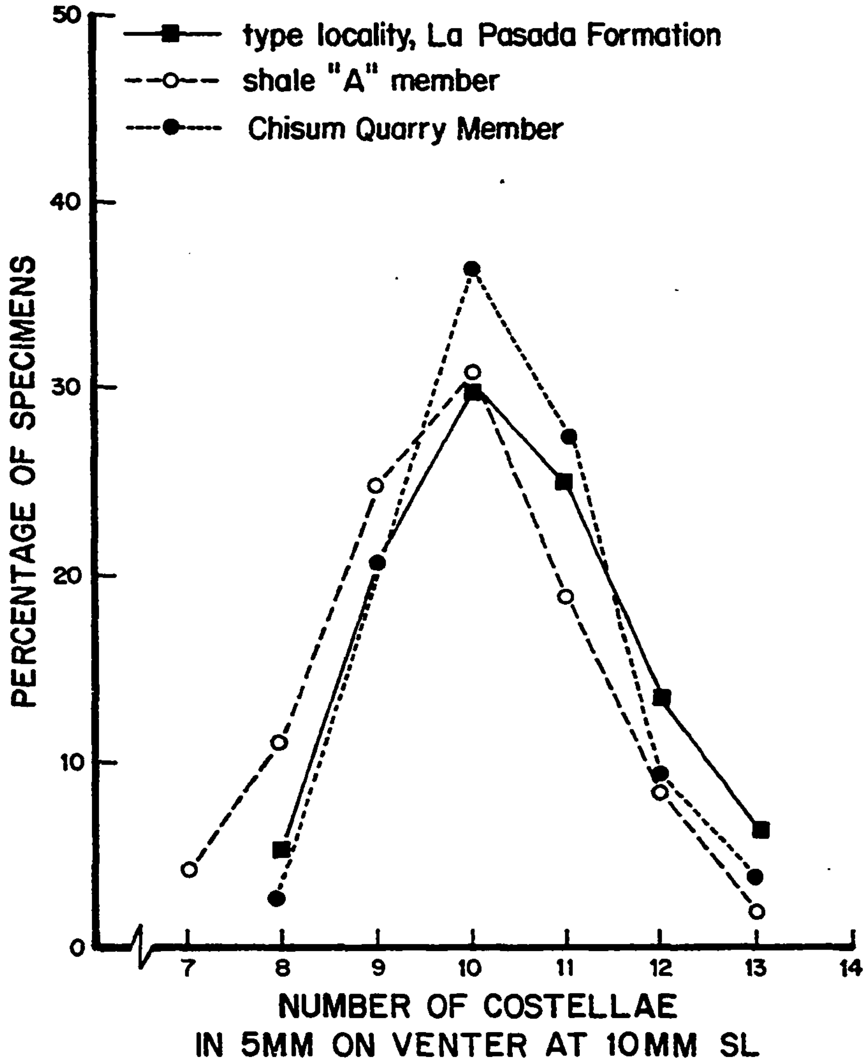
Pl. 3, figs. 1a-1e.

Productus nanus, Mather (not Meek and Worthen), 1915, p. 156, pl. 8, figs. 12-12b.

Desmoinesia nambeensis Sutherland and Harlow, in press, pl. 6, figs. 12-15.

Discussion.--Desmoinesia nambeensis is the smallest, most highly convex, most finely costellate, and oldest species currently assigned to this genus. It was defined by Sutherland and Harlow (in press) from a large number of well preserved specimens from the uppermost Morrowan portion of the La Pasada Formation in north-central New Mexico. The author has examined the type collection.

D. nambeensis is one of the most commonly occurring productid brachiopods in the upper part of the Morrow Group in the Ozark Mountains region. It is most abundant in the McCully Formation in northeastern Oklahoma and in the Kessler Limestone in northwestern Arkansas. Specimens from these units are closely similar to the type material. The number of costellae measured in 5 mm on the venter at 10 mm SL ranges between 8 and 13 ($\bar{x}$ = 10.33, M = 10, n = 44), for material from the Chisum Quarry Member (text-figure 9), between 7 and 13 ($\bar{x}$ = 9.79, M = 10, n = 49) for material from the shale "A" member, and between 8 and 15 for a combined collection from the Greenleaf and Kessler Limestones (units M33-11 and M105D-15, 12 specimens); the mode for the latter also appears to be 10. The type specimens have between 8 and 13 costellae, with a mode of 10 and an average 9.9 (Sutherland and Harlow, in press). No statistically significant differences exist at the 95 percent confidence levels for this feature between the collections from the



Text-figure 9.--Plot of number of costellae in 5 mm on venter at 10 mm SL for specimens of Desmoinesia nambeensis Sutherland and Harlow for combined samples from shale "A" member and Chisum Quarry Member of McCully Formation and for type specimens from Upper Morrowan part of La Pasada Formation in northern New Mexico (data for latter from Sutherland and Harlow, in press).

Chisum Quarry Member and the shale "A" member or between the combined collections from all of these Upper Morrowan collections from the Ozark region and the type material.

The majority of specimens from the upper part of the Morrow Group are slightly smaller than the majority of specimens from the type collection. However, the largest specimens are quite comparable in size with the type specimens from New Mexico. The holotype is the largest specimen in that collection and has a surface length of 31 mm, a length of about 18 mm, is 16.2 mm wide at the hinge, and has a height of about 10 mm. The largest specimens from the Chisum Quarry Member (M37-10) and from the shale "A" member (M29-14) both have the trails broken off but have hinge widths of 18 and 16 mm, respectively. The largest specimen from the Kessler Limestone (M105D-15) too has the trail broken but measures 14.5 mm wide at the hinge. These latter specimens appear more quadrate, since the trail is broken.

The only difference observed between the specimens from the upper part of the Morrow Group and the type material is that the former tend to have a slightly higher percentage of specimens with a broad, shallow, poorly defined sulcus on the venter.

The collections from the Lower Morrowan (i.e., the limestone-shale member, Brewer Bend Limestone, upper part of the Prairie Grove and the Brentwood Limestone) consist of many fewer specimens. About 35 specimens from the upper part of the grainstone-shale member and Brewer Bend Limestone Members are assigned without reservation to this species. An additional 100 specimens are either identified questionably or are assigned to Desmoinesia cf. D. nambeensis. In this case, the specimens appear to possibly be more finely costellate than those from the Upper Morrowan. The modal number of costellae appears to be around 11 or 12, as contrasted to 10, but the collections are too small and too poorly preserved to allow statistical analysis. None of these specimens attains the size noted in the Upper Morrowan material. If more and better preserved material were available, it is probable that the more finely costate material from the Lower Morrow Group could be placed in a separate species.

Sutherland and Harlow (in press) found that the mean number of costellae changes significantly between the Morrowan and Atokan, Atokan and Lower Desmoinesian, and Lower Desmoinesian and higher Desmoinesian species of the genus Desmoinesia in the Pennsylvanian sequence in northern New Mexico. The species become pregressively more coarsely costellate in stratigraphically higher collections. It would therefore appear that this trend toward species that are more coarsely costellate may have begun in the Early Morrowan.

Sutherland and Harlow (in press) had few well preserved brachial valve exteriors and stated that spines are apparently absent on this valve. Several specimens from M1-6 and M97-5 do have small, widely scattered spines, but the extent to which they are developed over the valve cannot be determined, since these specimens are fragmentary and crushed.

Material and Occurrence.--Desmoinesia nambeensis was first described by Sutherland and Harlow (in press) from the uppermost Morrowan portion of the La Pasada and Flechado Formations in northern New Mexico.

D. nambeensis also occurs in the Wapanucka Formation (Morrowan) of southern Oklahoma.

In the Ozark Mountains area, this species occurs abundantly at many localities in the upper part of the Morrow Group. About 1000 specimens from these higher horizons are assigned to this species. Most of these specimens are poorly preserved, "crack out" specimens. An additional 35 specimens from the upper part of the limestone-shale member, the Brewer Bend Limestone, the upper part of the Prairie Grove Member, and the Brentwood Limestone are placed within Desmoinesia cf. D. nambeensis. This species ranges from the upper part of the Prairie Grove Member (N. bassleri symmetricus Zone) through the Kessler Limestone in northwestern Arkansas and from the middle part of the limestone-shale member (N. bassleri Zone) through the Greenleaf Limestone in northeastern Oklahoma. The following collections contain fewer than 10 specimens of this species, unless otherwise stated: GORE FORMATION--limestone-shale member: M1-6, M3-9, M5-13, M12-8 Station A, M12-9, M14-9, M23-4, M31-1(cf.) 2 feet above base, M31-5 top, M35-2 top, M36-6A(cf.), M39-4(?), M39-6(cf.), M40-15, M48-0A(cf.), M51-15(cf.), M61-6(cf.) 10 feet above base, M63-16(cf.) base, M64-8(cf.) top, M64-11, M67-9(cf., 25 specimens), M97-5(cf., 10 specimens), M97-8(cf.), M97-9, and loc. M98D. Brewer Bend Limestone: M3-12C, M5-15, M35-7, M36-6B(cf., 16 specimens), and M95-7(cf.). McCULLY FORMATION--Chisum Quarry Member: M26-23 top, M37-10 (about 90 specimens), M40-18A (5 to 6 feet above base, about 65 specimens), and M61-9(cf., 10 feet above base). Shale "A" member: M29-14 (about 130 specimens), M42-18 (27 specimens), and M48-15 (150 specimens). Greenleaf Limestone: M1-21, M27-16 base, M28-14 base, M28-14 top, M29-15, M33-11 (75 specimens), M35-11, M42-21, M51-25 (3 feet above base), M98-13 (about 25 on slabs). HALE FORMATION--Prairie Grove Member: M100-3(?) and M112-16. Brentwood Limestone: M100-9(cf.), M101-19, M105C-8(?), and M105C-10 (16 specimens on slabs). Kessler Limestone: M105D-15 (about 300 poorly preserved specimens on slabs), M108-20, and M114-28.

Figured Specimen.--OU 7255.

Genus *Sandia* Sutherland and Harlow, *in press*

Discussion.--The genus *Sandia* Sutherland and Harlow (*in press*) is characterized by large prostrate spines that are directed anteriorly near the anterior margin on mature specimens. On some specimens, these spines are deflected ventrally, interrupting the growth of both the brachial and the pedicle valves. This produces the irregularly spaced, coarse radial ridges seen on the pedicle trail of many specimens. This feature, the presence of coarse spines on the ears of the pedicle valve, and the presence of more highly elevated muscle platforms and more highly exaggerated internal features of both valves serve to distinguish *Sandia* from *Desmoinesia*, which it most closely resembles. *Sandia* and the Mississippian genus *Inflatia* are similar, but that genus has no spines on the brachial valve.

Muir-Wood and Cooper (1960, p. 265) questionably placed the Morrowan species *Productus welleri* Mather in *Protoniella*. The internal features of that genus are poorly known, but Muir-Wood and Cooper consider it to be related to *Buxtonia*. Such is not the case with *P. welleri*. Sutherland and Harlow (*in press*) placed *P. welleri* in their new genus *Sandia*, and this assignment is verified by the present study.

Sandia welleri (Mather)

Pl. 3, figs. 2a-7b.

Productus welleri Mather, 1915, p. 155, pl. 9, figs. 10-11a.

Productus gallatinensis, Mather (not Girty), 1915, p. 163, pl. 9, figs. 4-5b.

Pustula pertenuis, Mather (not Meek), 1915, p. 165, pl. 9, figs. 9, 9a.

Sandia welleri, Sutherland and Harlow, *in press*, pl. 8, figs. 13-17.

Sandia welleri variant A, of Sutherland and Harlow, *in press*, pl. 8, figs. 18-22.

Description (Based upon all Specimens from Lower Morrow Group).--Shell strongly biconvex, medium sized for genus, with large, almost complete topotype measuring 35 mm SL, 20 mm length, 21 mm width, estimated 22 mm hinge width, height about 16 mm.

Pedicle valve strongly biconvex, becoming only slightly less convex anteriorly; mature specimens commonly developing short, gently convex trail; small pointed beak strongly incurved, extended beyond hingeline; umbo with steep lateral slopes diverging from about 100 to 110 degrees; sulcus broad, gentle, generally inconspicuous, beginning from 10 to 15 mm SL from beak, commonly extending onto trail; about half of specimens asulcate or with slight flattening of venter; ears large, flattened to slightly concave, well defined, slightly produced, forming angle of about 80 degrees with lateral margin, maximum width of shell at hingeline. Surface with strong concentric wrinkles posteriorly on exfoliated specimens, extending across umbo onto ears, forming reticulate pattern with fine costellae; surface length to end of reticulation ranging between 14 and 23 mm, averaging 18.7 mm for 50 specimens; exfoliated surface ornamentation beyond reticulation consisting of fine, concentric growth lamellae, radiating costellae, numbering between 7 to 11 for 50 specimens, averaging 8.9 costellae per 5 mm on venter at 20 mm SL, tending to broaden, become less conspicuous on trail, anterior slope; few specimens with almost smooth trail except for fine, closely spaced growth lamellae; more mature shells with scattered costellae becoming distinctly enlarged, forming ridges on anterior slope, trail. Unexfoliated shells with irregular, wrinkled, fine growth lamellae over entire surface, becoming somewhat less irregular, less conspicuous anteriorly, particularly on trail, making reticulate pattern with costellae on umbo; subdued wrinkles on ears; spines scattered over entire shell surface, somewhat more closely spaced, smaller, erect on umbo; valve characterized by single, rarely double row of suberect spines on alae, divering from hinge line at about 10 degrees, becoming slightly larger laterally.

Brachial valve concave, distinctly geniculate; mesial portion flattened to gently concave, with sulcate specimens bearing gentle, flaring fold on brachial valve; alae distinctly set off, flaring, slightly convex; row of small, suberect spines set along hinge line on alae; scattered, smaller body spines present on remainder of valve; few, large, irregularly spaced prostrate spines directed anteriorly near anterior margin of mature specimens; spines either paralleling valve surface, or curving ventrally, interupting growth of brachial valve, causing groove where brachial valve grew around spine; this groove corresponding to raised ridge on pedicle valve exterior of some specimens. Surface ornamentation on visceral disc reticulate; alae strongly wrinkled; anterior portion of valve on trail nonreticulate; unexfoliated surfaces similar to that of opposite valve in minute markings.

Pedicle interior with long, narrow adductor platform, diductor scars large, broad, apparently longitudinally striated; latter bounded laterally, anteriorly by broad, low, poorly defined ridge; diductor scars slightly impressed beneath general level of valve.

Brachial valve interior characterized by small, short, sessile trilobed cardinal process; median lobe slightly sulcate ventrally, sloping dorsally posteriorly; lateral lobes excavate posteriorly, curving, converging dorsally; process supported by lateral ridges, paralleling hinge line to extremities, becoming broader, somewhat less elevated laterally, bearing evenly spaced pustules at extremities; median septum low, thin, extending beyond muscle platform generally to about midlength; adductor scars set on elongated, suboval, elevated platforms, apparently faintly dendritically sculptured on more mature specimens, separated from median septum by narrow groove; low, thin median septum arising within groove, extending beyond muscle platform generally to about midlength. Interior ornamentation consisting of fine endospines, becoming progressively finer on trail; trail with irregularly spaced, flaring ridges corresponding to prostrate spines on valve exterior on mature specimens.

Discussion.--Mather (1915, p. 155) based his description of *Productus welleri* upon two specimens from the basal part of the Prairie Grove Member from his station 136 (= M103-14; for additional discussion refer to Mather's station 136 in Appendix III). The holotype, a badly exfoliated pedicle exterior, and the allotype, a partially exfoliated brachial interior, were among the specimens from the Mather collection not located by the Field Museum. However, the author collected 64 topotypes, most of which are partially broken and all of which are badly exfoliated. The description of the size, shape, and exfoliated surface ornamentation of this species is based primarily upon these topotypes and supplemented by approximately 200 "crack out" specimens from the same stratigraphic horizon from near-by measured sections in the Fayetteville - West Fork area. About 30 brachial interiors, mostly partially exfoliated, are also available. One of these (pl. 3, fig. 7b), from M116-8, shows the distinctive ridges on the trail that are characteristic of the genus *Sandia*.

The descriptions of the additional features are based on the collections, mostly from the middle to upper part of the limestone-shale member, in northeastern Oklahoma. About 50 specimens and fragments have superbly preserved surface ornamentation; these are from the sections in the Webbers Falls Reservoir area (e.g., M1, M5, M97, and M98). The description of the brachial valve interior is based upon approximately 30 largely fragmentary specimens from widely spaced localities. The prostrate hinge spines on the brachial valve that are commonly deflected ventrally and cause the grooving of the pedicle trail are rarely preserved and have been observed on about 10 specimens in the collections from the Ozark region.

Most of the collections from the Lower Morrowan agree quite closely with the type material in terms of general size, shape, and surface ornamentation and are identified as Sandia welleri without reservation. However, a number of specimens from the middle part of the Morrow Group (i.e., the upper part of the limestone-shale member, the Brewer Bend Limestone, the Chisum Quarry Member, and the Brentwood Limestone) differ from this material in being consistently somewhat broader, having somewhat more divergent umbonal slopes, and in attaining much larger adult sizes (e.g., pl. 3, figs. 3, 4). The largest complete specimen of this type is from the Brewer Bend Limestone (M18-3) and measures 50 mm SL, 29 mm length, 30 mm width at midlength, 31 mm hinge width, and 17 mm height. Since these collections also generally contain individuals closely resembling the type material and intermediates, they are herein identified as Sandia cf. S. welleri. Such collections come exclusively from calcareous shales or mud-supported limestones (wackestones and mudstones), which occur abundantly in this part of the section. A number of specimens of this type are present in the material from the Upper Morrowan portions of the La Pasada Formation in north-central New Mexico. They too were collected from shales and mud-supported carbonates. Such larger, broader variant possibly represented a response to less competent substrates.

Mather (1915, p. 156) stated that this species is characterized by a single, straight row of spine bases on the ears, but the specimens from northeastern Oklahoma have a rather wide arrangement of spine bases on the ears. A linear arrangement is the most common, but a few specimens have a double row of spines, and a single specimen has a cluster of irregularly spaced spine bases on the ears. The spacing of the spines when they are arranged in rows varies from a minimum of 1.5 mm to a maximum of about 3.5 mm. Similar variation in this feature was noted by Sutherland and Harlow (in press) from the Upper Morrowan collections from north-central New Mexico.

The specimens from the upper part of the Morrow Group also compare favorably with the type material in terms of size, shape, and surface ornamentation. Several of the large collections from the Kessler Limestone contain a rare variant with a trail that is longer than typical. Such specimens tend to approach the shape of some of the smaller specimens of S. santafeensis Sutherland and Harlow, described from the Atokan portion of the La Pasada Formation in north-central New Mexico. One such variant from M105D-13 has a surface length of about 42 mm, length about 24 mm, width about 21 mm, and an estimated hinge width of 20 mm.

Sutherland and Harlow (in press) suggested that S. santafeensis was the immediate descendant of S. welleri and noted a transitional collection from about the Morrowan-Atokan boundary in the La Pasada Formation. The variant, just discussed, from the Upper Morrowan of northwestern Arkansas, would strongly support this contention, *S. welleri* differs from *S. santafeensis* in having a shorter trail, in being less tightly coiled, and by not having as coarse anterior grooves. The latter feature is a function of the degree to which the prostrate spines on the brachial valve are hooked ventrally. They are deflected ventrally on *S. welleri* but do not interfere with the growth of the pedicle valve to the extent found in *S. santafeensis*. Internally, mature specimens of *S. santafeensis* have features on both valves that are similar to those of *S. welleri* but the internal ridges and platforms are far more elevated in *S. santafeensis*, reflecting the increased length of the pedicle valve.

Sandia welleri is possibly also the immediate ancestor of *S. brevis*, also described by Sutherland and Harlow from the Atokan portion of the La Pasada Formation. It differs from that species in being somewhat larger, in having a consistantly longer trail, a greater width to length ratio, and in having less coarse costae on the anterior portion of the valve caused by the hooked spines on the brachial valve. Internal features are similar; the only major difference is that the well defined brachial ridges present on *S. brevis* have not been observed yet on specimens identified as *S. welleri* from the Morrow Group. This is probably a matter of poor preservation, however, because such ridges are present on the specimens of *S. welleri* from New Mexico.

The author examined the specimen described by Mather (1915,

p. 165, pl. 9, figs. 4-5b; UC 16129) as Pustula pertenuis (Meek). Although this specimen is extremely small, measuring only 9 mm SL, it is probably an immature S. welleri. The rows of spines on the alae are characteristic of this species.

Material and Occurrence.--Sandia welleri occurs abundantly throughout most of the Morrow Group and appears to be restricted to the Morrow Series. Its lowest occurrence is in strata of the basal part of the Prairie Grove Member, from whence it was originally defined (Mather's station 136 = M103-14), and its highest occurrence is in the Kessler Limestone Member. This is one of the few species that occurs abundantly in the Kessler. Its first occurrence in northeastern Oklahoma is in the basal part of the limestone-shale member (Idiognathoides noduliferus Zone), and it ranges through the Greenleaf Limestone. An estimated 1000 specimens are included in the collections from the Lower Morrowan of the Ozark Mountains area, and an estimated 750 specimens from the Upper Morrowan. The following collections contain S. welleri rarely to commonly unless otherwise indicated: HALE FORMATION--Cane Hill Member: M105A-3 (basal 1.5 feet). Prairie Grove Member: M70-8, M103-14 (type locality; 64 specimens, mostly poorly preserved, plus 10 exfoliated brachial interiors), M109-5, M110-18, M111-6*, M111-8*, M112-10*, M112-16, M116-7*, M116-8*, M117-2*, M117-3*, M117-9, M117A-6*, and M118-5 (top)*. BLOYD FORMATION--

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* Asterisk depicts localities in the Fayetteville - West Fork area in the basal part of the Prairie Grove Member in strata in the same horizon as the type locality, M103-14.

Brentwood Limestone: M68-17, M68-18, M68-21, M68-25, M69-19, M70-12, M100-11(cf.), M101-19(cf.), M104B-17(cf.), M105C-10(?), M110-20, M116-18, M118-11 or 12(cf.), and M120-4. Dye Shale Member ("caprock"): M104B-19. Kessler Limestone: M68-27, M69-27B, M104C-1 (65 specimens), M105D-13 (about 600 specimens), M105D-15, and M114-28. GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8(cf.), M14-9(cf.), M16-1(?), M22-7, M23-4(cf.), M25-8, M26-3, M26-6(cf.), M26-9(cf.), M26-10(cf.), M26-14(cf.), M26-17, M27-7 (6 to 7 feet below top), M27-8 (4 feet above base), M34-7, M39-2(cf.), M39-4(cf.), M40-15, M42-7(cf.), M48-0A(cf.), M49-3, M49-10 (top), M51-7 (7, 23, and 25 to 27 feet above base), M51-14A (base), M51-15, M53-3, M63-13(cf.; top), M64-6 (base), M64-11, M65-M65-11, M65-14 (top), loc. M83A(cf.), loc. M96(cf.), M97-5(cf.), M97-6 or 8(cf.), M97-8(cf.), M97-9(cf.), and loc. M98D(cf.). Brewer Bend Limestone: M18-3 through 5 (cf.), M18-13(cf.), M23-6(cf.), M31-12C, M35-7(cf.), M39-7(cf.), M39-14(cf.), M47-11, M48-9, M63-18(cf.), M63-19(cf.), M78-43(cf.), M95-7(cf.), M98-6 or 9(cf.), M98B-2(cf.), and M98C-7(cf.). McCULLY FORMATION--Chisum Quarry Member: M17-9, M17-11 (cf.), M17-14 and 15(cf.), M26-23, M28-10, M34-15, M35-8, M37-10, M41-15, M42-15, M49-18 (67 specimens), M62-23 (56 specimens), and M63-20. Shale "A" member: M29-14, M36-10B, and M48-15. Greenleaf Limestone: M1-19, M1-20, M28-14 (base), M35-11A, M51-25 (3 feet above base), M60-21, M60-22, M98-13, and M99-2.

<u>Figured and Catalogued Specimens</u>.--OU 7256-7262; OU 7332 (74 topotypes).

FAMILY ECHINOCONCHIDAE

SUBFAMILY ECHINOCONCHINAE

Genus Echinaria Muir-Wood and Cooper, 1960

Discussion.--Muir-Wood and Cooper (1960, p. 248) defined the genus Echinaria and selected the type species to be Productus semipunctatus Shepard from the La Salle Limestone (Missouri Series) of northern Illinois. A relatively small number of species, all of which are exclusively Pennsylvanian, have been assigned to this genus; a single Morrowan species, Echinaria n. sp. A, represents the oldest known species.

Echinaria n. sp. A

Pl. 4, figs. 1a-3c.

Pustula punctata, Mather (not Martin), 1915, p. 172, pl. 8, fig. 11.

Echinaria n. sp. A, of Sutherland and Harlow, in press, pl. 10, figs. 12, 13.

Description (Based upon Specimens from M109-4 and M112-17).--Shells large; outline elongate subtriangule, profile concavo-convex; length, width subequal, with greatest width near anterior margin, hinge narrow with width less than half width of valve; body cavity large, large complete specimen measuring 105 mm SL, 62 mm long, 64 mm wide, 25 mm hinge width, 30 mm high, 21 mm thick.

Pedicle valve with very strongly incurved, narrow, pointed beak; beak, umbo overhanging hinge line maximum of about 10 mm, flaring slightly anteriorly, with steep lateral margins; valve strongly convex near beak, becoming less strongly convex anteriorly, approximating rapidly expanding spiral, with flattened area on trail near anterior margin, with anterior extremities developing slightly concave lip about 5 mm wide; venter of umbo with very gentle, rounded, rather narrow sulcus originating near beak, extending anteriorly to proximity of lip; anterior commissure generally rectimarginate, rarely slightly uniplicate; hinge line short, straight, meeting straight lateral extremities obtusely at about 130 to 135 degrees; alae small, almost obsolete, slightly concave. Surface ornamentation consisting of numerous concentric bands, irregularly developed about 2 to 4 mm apart over entire surface of valve, decreasing slightly in width toward lateral, anterior margins; posterior part of band with concentric, uniform row of fine, prostrate spines spaced from 0.3 to 0.5 mm apart laterally, bases no larger than 0.3 mm; rarely with two rows of fine spines on each concentric band with anterior row of spines smaller, less regularly spaced; spines tapering slightly; longest observed spine about 6 mm, broken.

Brachial valve with small, concave visceral disc; valve slightly, uniformly concave except for slight flattened area on narrow, small alae, area corresponding to anterior lip on opposite valve; valve slightly more concave in transverse profile than in longitudinal profile; valve with slight, broad fold near anterior margin on some specimens. Surface ornamentation with narrower bands, slightly smaller spines than opposite valve.

Pedicle valve interior unknown.

Brachial valve interior characterized by elongated cardinal process with shaft up 5 mm in length, recurved abruptly dorsally at about 90 degrees, with deep median sulcus forming bilobate process anteriorly; dorsal face not observed; process supported by strong lateral ridges, decreasing in height, strength laterally; slightly depressed groove developed immediately anteriorly to lateral ridges; median septum with massive base supporting process, tapering anteriorly, extending about half valve length as low, thin ridge; median septum bounded laterally by deep, sharp, thin grooves separating small, sharply defined muscle platforms; adductors placed posteriorly, becoming slightly tapered and more elevated anteriorly, extending about one-third valve length; posterior scars dendritic; anterior scars elongated, oval-shaped, smooth, set on long tapering platforms. Interior ornamentation consisting of concentric bands like exterior, with fine, prostrate endospines.

Discussion.--This species was first recognized by Sutherland and Harlow (in press), but they referred to it as *Echinaria* n. sp. A and did not name it because of the limited material available to them. They presented a brief description based upon a small collection from the Upper Morrowan portion of the La Pasada Formation in north-central New Mexico. The author has examined their collection, which is conspecific with the material from the Morrow Group in the Ozark Mountains region. A single brachial interior in their collection reveals the dorsal face of the sharply deflected cardinal process; it is trilobed, a characteristic feature of this genus. The cardinal process on their specimens is deflected dorsally at about 100 to 110 degrees from the valve surface rather than at about 90 degrees, as in the Ozark specimens. The largest New Mexican specimen is about two-thirds the size of the largest specimen from the Morrow Group.

The description presented in the preceeding section is based upon approximately 5 whole, uncrushed specimens, 12 incomplete and/or crushed specimens, and 4 brachial valve interiors from M109-4 and 2 uncrushed, complete specimens, 14 relatively complete specimens, and 1 brachial interior from M112-17. These localities are approximately 0.7 mile apart and occur in the same horizon in the upper part of the Prairie Grove Member in strata bearing Neognathodus bassleri symmetricus. The specimens from both localities are in argillaceous calcilutites (mudstones) and the non-talus specimens were all collected in growth position. The specimens are exfoliated when they are "cracked out" of the matrix. These specimens for the most part have most of the spines intact before they are extracted. The description is supplemented by numerous fragments from both localities. The largest specimen from M11-17, is crushed but was about 85 mm long, had a surface length probably in excess of 120 mm, and was at least 75 mm wide. (For additional measurements, refer to Appendix IV.)

The illustrated brachial interior (pl. 4, fig. 2) has been crushed at the anterior margin, producing the effect of a somewhat exaggerated internal sulcus. The remaining interiors, which are not as well preserved, have only a slight internal sulcus.

A number of superbly preserved brachial interiors of this species are present in the OU collections from the Wapanucka Formation (Morrowan) of southern Oklahoma. They are typical of the material from the Morrow Group except that, as with the New Mexican specimens, they have a cardinal process that is deflected dorsally at about 100 to 110 degrees rather than at about 90 degrees.

The fragmentary specimens from Late Mississippian or Early Pennsylvanian strata in Montana, assigned by Easton (1962, p. 48, pl. 4, fig. 28) to *Echinoconchus* aff. *E. alternatus* (Norwood and Pratten), may represent this species.

Echinaria n. sp. A differs from its closest Pennsylvanian relative, *Echinaria knighti* (Dunbar and Condra), widely reported from Desmoinesian strata of the Midcontinent and western United States, in being subtriangular in shape rather than having an elongate suboval shape, in not having a persistant sulcus extending to the anterior margin, in not having a gentle fold consistantly devloped on the brachial valve on most specimens, by the presence of the slightly concave lip on the anterior and anterolateral margins, and by having a hinge width that is approximately half the width of the valve rather than one that approaches the maximum width of the valve. The concentric bands that bear the spines on the exterior of the pedicle valve tend to be somewhat more closely and irregularly spaced than those commonly described for the Desmoinesian species, and the cardinal process is more strongly deflected dorsally in *Echinaria* n. sp. A.

Material and Occurrence.--*Echinaria* n. sp. A ranges in the Morrow Group from strata of the Cane Hill Member through the Kessler Limestone in northwestern Arkansas and from the base of the limestone-shale member (*Idiognathoides noduliferus* Zone) through the Chisum Quarry Member. It has not yet been collected from the upper part of the McCully Formation. This species is not a common species in the Morrow Group and is generally collected from limestones with a high content of fine-grained terrigenous clastics (i.e., quartz-sandy calcarenites). Approximately 200 generally poorly preserved, fragmentary specimens have been collected from the Ozark Mountains region. This species occurs rarely in the following collections unless otherwise indicated: HALE FORMATION--Cane Hill Member: M105A-3 (basal 1.5 feet; 17 specimens). Prairie Grove Member: Mather's Station 137, M70-10A, M101-7, M103-14, M107-9, M109-4 (about 21 specimens), M110-18, M111-6, M112-17 (about 17 specimens plus fragments), loc. M119, and loc. M121. BLOYD FORMATION--Brentwood Limestone: M68-13 and M68-25. Kessler Limestone: M105D-13 and M105D-15. GORE FORMATION--limestone-shale member: M26-7, M26-9, M29-1 (10 specimens), M29-2 (38 specimens), M35-2 (top), M36-5(?), M39-2, M39-4, M49-3, M49-8 (basal 1 foot), M51-7 (29 to 30 feet above base), loc. M56, loc. M56A, M79-6, M85-4 (4 feet below top; 19 specimens), and loc. M87. McCULLY FORMATION--Chisum Quarry Member: M26-23, M27-13 (base), M29-10 (top), and M62-23. Shale "A" member: M48-15(?).

This species also occurs in the upper part of the Morrowan sequence in the La Pasada Formation from north-central New Mexico

(Sutherland and Harlow, *in press*) and from the Wapanucka Formation (Morrowan) in southern Oklahoma.

Figured Specimens.--OU 7267-7269.

Genus *Pulchratia* Muir-Wood and Cooper, 1960

Pulchratia? *picuris* Sutherland and Harlow

Productus Nebrascensis, White (not Owen), 1877, pl. 8, figs. 8c, 8d.

Pustula nebraskensis, Mather (not Owen), 1915, p. 169, pl. 9, fig. 6 (not fig. 7).

Pulchratia? *picuris* Sutherland and Harlow, *in press*, pl. 9, figs. 14-16.

Discussion.--*Pulchratia*? *picuris* was described by Sutherland and Harlow (*in press*) from Upper Morrowan strata in north-central New Mexico. This species differs from *Pulchratia*? *pustulosa* Sutherland and Harlow, which has a more restricted range in the Upper Morrowan sequence in that area, in being distinctly more elongated, in having a more strongly convex pedicle valve, much steeper sides to the umbo, and wider and more distinct concentric bands on the anterior portion of the valve. Both species have body spines that are not arranged in conspicuous concentric bands on the posterior part of the body and regularly spaced concentric bands of spines on the anterior portion of the valve. Hence, posteriorly the surface ornamentation is more like *Buxtonia* or *Juresania*, anteriorly like *Echinaria*.

Specimens from the upper part of the Morrow Group in the Ozark Mountains region compare favorably in most respects with the type material from the La Pasada Formation, except that about one-third of the specimens from the Morrow Group have a broad, gentle sulcus. Most of the specimens from the upper part of the Morrow Group are consistantly smaller than the type material, but one large, almost complete specimen from the Greenleaf Limestone is comparable in size with the larger type specimens. This specimen, from M98-13, is 26 mm in length, 24 mm in width, has a hinge width estimated to be 15 mm, is 16 mm high, and has a surface length of 47 mm.

A small number of specimens from the shale "A" member and the Greenleaf Limestone are proportionally much more elongated and narrower than typical, having surface length to width ratios as high as about 2.7 contrasted to about 2.25 for the type specimens. A small number of such variants also occur in Sutherland and Harlow's New Mexican stratigraphic collections of this species.

The specimen that Mather (1915, pl. 9, fig. 6) illustrated as Pustula nebraskensis (Owen) from the Kessler Limestone (sta. 144) is among the specimens that could not be found by the Field Museum. However, this form is included without reservation in the synonym of Pulchratia? picuris.

For a comparison with Pulchratia? n. sp. A, see discussion of that species.

Material and Occurrence.--Pulchratia? picuris Sutherland and Harlow was first described from the Upper Morrowan part of the La Pasada and Flechado Formations of north-central New Mexico.

Pulchratia? picuris occurs rarely throughout the Upper Morrowan in the Ozark Mountains region, occurring throughout the McCully Formation in northeastern Oklahoma, and its lowest unquestioned occurrence is in the Chisum Quarry Member. It may extend down into the Lower Morrowan, but the collections from these strata are not adequate and this cannot be ascertained at this time. It is recorded from the Kessler Limestone in northwestern Arkansas. This species occurs rarely in the following collections unless otherwise stated. BLOYD FORMATION--Kessler Limestone: M69-27B, M70-24, M104B-23, M104B-24, M104B-26 (basal 1.5 feet), and M114-28. McCULLY FORMATION--Chisum Quarry Member: M17-14, M26-23, M28-10, M28-11 (top), M34-15, M37-10, M42-15 & 16, M42-16, M49-18, M60-19, and M62-23. Shale "A" member: M29-14, M48-13, and M48-15. Greenleaf Limestone: M1-20, M27-16 (base), M28-14, M42-21(?), M51-25, M78-47, and M98-13.

Pulchratia? n. sp. A

Pl. 3, figs. 9a-12b.

?Pustula nebraskensis Mather, (not Owen), 1915, p. 169, pl. 9, fig. 7 (not fig. 6).

Discussion.--Specimens of Pulchratia? from the lower part of the Morrow Group differ in several possibly significant respects from Pulchratia? picuris, a characteristic Upper Morrowan species. These lower collections most probably represent a new species, but description is not presented here because of the lack of adequately preserved specimens. Collections from the lower Morrowan contain a high percentage of morphotypes that differ from typical specimens of P.? picuris in being larger in size and proportionally wider, in having a broader umbo, and in generally possessing a shallow sulcus on at least part of the valve. One such specimen from the Brentwood Limestone (pl. 3, fig. 10) has a surface length of 34 mm, width of 25 mm, and is about 16 mm high. The ratio of surface length to width is about 1.7 for the Lower Morrowan morphotype contrasted to about 2.25 for the type material of P.? picuris. It should be emphasized that some of the lower Morrowan collections also contain specimens that are typical of P.? picuris as well as rare specimens that appear to be intermediate between the two forms. However, the material is inadequate to determine whether two species are present in these stratigraphically lower collections or whether the morphotypes typical of P.? picuris are merely extreme variants of a highly variable species.

A collection of mostly fragmentary and crushed specimens from the Brentwood Limestone (M102-9) contains approximately 45 specimens of the brachial interior assigned to Pulchratia? n. sp. A that have the cardinal process and at least a portion of the muscle area present in varying states of preservation. The brachial interiors of the smaller specimens closely resemble the brachial interiors of the type specimens of P.? picuris, but the larger specimens (pl. 3, figs. 12a, 12b) have thicker cardinal processes, and the antron is filled with shell material.

Material and Occurrence.--Approximately 300 poorly preserved, generally fragmentary or crushed specimens are identified as Pulchratia?

n. sp. A or are questionably identified. They occur in the lower part of the Morrow Group, ranging from the middle part of the limestone-shale member (basal part of Neognathodus bassleri Zone) through the Brewer Bend Limestone. Similar collections in northwestern Arkansas are restricted to the upper part of the Prairie Grove through the Brentwood Limestone. The inadequacies of the collections and the poor preservation is emphasized by the large proportion of these that are questionably identified. It occurs rarely in the following collection unless otherwise indicated: GORE FORMATION--limestone-shale member: M1-8, M5-15, M23-4, M25-7(?), M26-6(?), M26-7, M26-9, M26-10, M27-7(?), M29-4, M34-7, M49-8, M49-10(?), M51-7 (7 feet above base), M51-7(?; 23 feet above base), M51-7 (29-30 feet above base), loc. M56A (12 specimens), M61-7, M63-13(?; top), M64-6 (base), M65-8 (top; 17 specimens), M65-14(?), M79-6, loc. M83A, M97-8 (top), and loc. M98D. Brewer Bend Limestone: M5-17(?), M23-6(?), M24-12, M28-8(?), M31-12C, M42-12(?), M63-19(?), M95-7(?), and M98-6 or 9(?). HALE FORMATION--Prairie Grove Member: M100-5, M101-1 (30 crushed specimens), M107-9, M109-4(?), M114-3(?; base), and M116-8(?). BLOYD FORMATION--Brentwood Limestone: M68-12, M68-17 & 18 (15 specimens), M68-25(?), M70-12, M70-16, M100-9, M100-11 (26 specimens), M101-19, M102-8(?), M102-9 (3 whole crushed, 4 brachial interiors, numerous fragments of interiors), M104B-11(?), M104B-17 (41 highly fragmentary specimens), M110-20, M114-15, and M120-4.

Figured Specimens.--OU 7263-7266.

Genus Pustula I. Thomas, 1914

Pustula? sublineata Mather

Pustula sublineata Mather, 1915, p. 168, pl. 9, figs. 1-1c.

Discussion.--Pustula sublineata was described by Mather (1915, p. 168) from two specimens collected by R. D. Messler from station 152 about 3 miles northeast of Fayetteville. This station can no longer be collected (see discussion of Mather's station 152 in Appendix III for additional remarks); the holotype and the paratype are among the specimens that cannot be located by the Field Museum.

P. K. Sutherland (personal communication), who examined the type specimens at an earlier time, states that the holotype is badly exfoliated but that Mather's description is generally accurate exept that Mather was incorrect in stating that the holotype is characterized by abundant body spines. Mather's illustrations (pl. 9, figs. 1-1c) of the holotype show the shape well.

This species is extremely rare in the Morrow Group. A total of six additional specimens have been identified tentatively as belonging to this species; all of them are poorly preserved. The largest of these is about 21 mm in length, has a width of about 22 mm (at the hinge), and is about 10 mm high; the surface length is about 28 mm. One of the best preserved specimens has 14 costellae per 5 mm on the venter at 10 mm SL, and these costellae are continuous, not discontinuous as stated by Mather (1915, p. 169). Two of the specimens have slightly deeper sulci than on the specimen illustrated by Mather, and the umbos are slightly more highly arched. The better preserved of these specimens does have small spine bases scattered over the alae and body, but they are not dense.

In overall size and general appearance, these poorly preserved specimens could be confused with poorly preserved specimens of Sandia welleri (Mather), but they can be readily differentiated from that species by the large alae that are not distinctly set off from the remainder of the valve, by the absence of a row of spines on the alae, and by the absence of grooves on the trail.

This species is quentionably retained in the genus Pustula. The absence of large collections and interiors make its correct generic assignment impossible at this time.

Material and Occurrence.--Mather's type specimens were collected from the Brentwood Limestone at this station 152. This species is extremely rare in the Morrow Group, and a total of six specimens, in addition to the holotype and paratype, have been collected. These specimens are in older OU thesis collections and all are poorly located both geographically and stratigraphically. (1) SE corner, Sec. 31, T. 14N., R. 23E., Cherokee County, Oklahoma ("Bloyd Formation"; 4 specimens; coll. by Brauer); (2) T. 14N., R. 20-22E ("Bloyd"; 1 specimen; coll. by Mondy); and (3) Greenleaf Lake, Oklahoma ("Morrowan"; 1 specimen; coll. by Siemans; this specimen may have come from the Greenleaf Lake spillway and may have been collected from strata equivalent to M12-8 of this dissertation).

FAMILY BUXTONIIDAE

SUBFAMILY BUXTONIINAE

Genus Buxtonia I. Thomas, 1914

Buxtonia grandis Sutherland and Harlow

Pl. 5, fig. 1.

Buxtonia grandis Sutherland and Harlow, in press, pl. 10, figs. 1-8.

Discussion.--Buxtonia grandis Sutherland and Harlow is an almost planoconvex, broadly and gently sulcate Buxtonia that is readily distinguishable from other species of the genus by its extremely large size and low convexity of the pedicle valve.

This species is rare in the Morrow Group and the specimens are generally poorly preserved and fragmentary. The few relatively complete specimens in these collections compare favorably with the type and supplemental material from New Mexico. The largest complete specimen from the Morrow Group measures 100 mm SL, 72 mm length, 79 mm width, 73 mm hinge width, and about 21 mm height. The largest specimen from northern New Mexico has a surface length of 95 mm, length 65 mm, estimated width 74 mm, estimated hinge width 84 mm, and is 20 mm thick. This specimen from the Morrow Group has a slightly lower convexity of the pedicle valve than the material from northern New Mexico, but the remainder of the specimens from the Ozark Mountains region have about the same convexity as the type material.

A partial interior of a brachial valve from loc. M22 (pl. 5, fig. 1) has conspicuous dendritic ornamentation on the elevated adductor scars and coarser endospines near the anterior and anterolateral margins than on the type interiors. It does not have the finely pustulose costellae present on the remainder of the interior. The differences in internal features suggest that the larger specimen from Oklahoma is probably more mature than those available from New Mexico.

A second nearly complete brachial interior unit M70-12, unlike the other interiors at hand, has a faintly elevated brachial ridge preserved, and a narrow flange, 2 to 3 mm wide, extends completely around the commissure. A similar flange is present on Sutherland and Harlow's unfigured brachial interior from the type locality, but the latter specimen has the anterior margin broken off and it is not seen to continue completely around the commissure. The specimen from M70-12 possesses lateral ridges that become somewhat less elevated toward the posterolateral margin and are deflected anteriorly adjacent to the flange. They broaden slightly become less elevated anteriorly, and disappear at about midlength.

Material and Occurrence.--*Buxtonia grandis* was originally described from the Upper Morrowan strata of the La Pasada Formation in north-central New Mexico (Sutherland and Harlow, *in press*). This species is also present in the OU collections from the Wapanucka Formation (Morrowan) of southern Oklahoma.

This species is rare in the Morrow Group but appears to be relatively more common in the upper part of the sequence. Approximately 70 largely fragmentary, poorly preserved specimens, including three poorly preserved brachial interiors, were collected. This species occurs rarely in the following collections unless otherwise indicated: HALE FORMATION--Cane Hill Member: M105A-3 (basal 1.5 feet). Prairie Grove Member: M112-10. Brentwood Limestone: M70-12 (base; 12 fragments and 1 brachial interior , M104B-15, and M114-15 (talus; 10 fragments). Kessler Limestone: M68-27 (base), M104B-23, M105D-13, M108-17, and M108-20. GORE FORMATION--limestone-shale member: M1-6, M12-8, loc. M22*, and M49-8 (basal 1 foot). McCULLY FORMATION--shale "A" member: M29-14 and M30-6. Greenleaf Limestone: M51-25 (3 feet above base), M60-21, M98-13, and M99-2. In addition, the large specimen mentioned in the preceeding discussion comes from the grainstone-shale member from somewhere in the Marble City area in Adair County, Oklahoma.

Figured Specimen.--OU 7270.

FAMILY DICTYOCLOSTIDAE

SUBFAMILY DICTYOCLOSTINAE

Genus *Antiquatonia* Miloradovich, 1945

Antiquatonia coloradoensis (Girty)

Pl. 5, fig. 2.

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* The brachial valve interior figured as pl. 5, fig. 1 was collected by C. G. Beckweth, Jr. (1950, M. Sc. Thesis, University of Oklahoma) from his station 5, described as "Sec. along roadcut Hy. 10 over Braggs Mt., Sec. 21, T. 15N., R. 20E." (*ibid*., p. 56). This is the site of measured section 22 of Sutherland and Henry (*in press*), and the only unit from Beckwith's measured section for which he mentions brachiopods (*ibid*., p. 42) is in the upper part of the limestone-shale member.

Productus inflatus, Girty (not McChesney), 1903, p. 359, pl. 3, figs. 1-3.

Productus inflatus var. coloradoensis Girty, 1910, p. 216 (not Girty, 1915a, pl. 8, figs. 1, 2).

Antiquatonia coloradoensis, Hoare (1961, p. 57, pl. 7, figs. 6-9) Sutherland and Harlow, in press, pl. 11, figs. 1-5.

Discussion.--Several small collections of large, semireticulate productoids from the Kessler Limestone are herein identified as Antiquatonia coloradoensis (Girty). These specimens are exfoliated, disarticulated exteriors and are externally similar in all observable respects to the forms identified by Sutherland and Harlow (in press) as A. coloradoensis from the La Pasada Formation of north-central New Mexico, where this species occurs in Upper Morrowan and Atokan strata.

This species is easily distinguished from A. hermosana (Girty), from the Lower Desmoinesian of that area, by being more strongly convex, more finely costellate, and smaller. Specimens intermediate between the two species were reported by Sutherland and Harlow (ibid.) from the lowermost Desmoinesian strata in the La Pasada Formation.

The only other productoid with which A. coloradoensis can be confused in the Morrow Group is Tesequea cf. T. morrowensis (Mather) from the Chisum Quarry Member; both are about the same size, have the same general shape, and both possess a row of spines along the flanks of the pedicle valve. The exteriors identified as A. coloradoensis can be differentiated from this material in that they have a deeper and more consistantly developed sulcus, a somewhat broader umbo, lower and more uniform convexity, and distinctly coarser costellae. A.

coloradoensis has between 17 and 20 costellae ($\bar{x}$ = 18.6, n = 8) on the venter in 10 mm at 20 mm SL; the specimens of *Tesequea* cf. *T. morrowensis* from the Chisum Quarry Member have between 19 and 26 ($\bar{x}$ = 23.0 for 12 specimens). The larger body cavity of *A. coloradoensis* is reflected by the greater distance to the end of reticulation (contrast a range of from 26 to 31 mm SL, $\bar{x}$ = 30.4, to between 18 to 28, $\bar{x}$ = 22.6.

Considerable confusion exists in the literature as to the nature of *Productus inflatus* var. *coloradoensis* Girty and its exact stratigraphic range, because Girty used this name to refer to at least two different productoid brachiopods that represent different species and probably different genera. The lower Pennsylvanian species, which includes the type specimens, is an *Antiquatonia*. The generic placement of the second, a Mississippian species, is uncertain (see illustrations by Girty, 1911, 1915b, 1915c, 1915d). Girty (1910, p. 216) proposed the name *Productus inflatus* var. *coloradoensis* for specimens that he had in 1903 (p. 359, pl. 3, figs. 1-3) referred to *Productus inflatus* McChesney from the lower part of the Weber Formation (Morrowan?) in the Leadville, Colorado, area and from the basal portion of the Hermosa Formation (Atokan?) of southwestern Colorado. His figured specimens in the 1903 paper are from the "Weber formation(?)" near Leadville. He reiterated this proposal in a later paper (1915a, p. 65), but the specimens that he referred to this species from the Wewoka Formation (Upper Desmoinesian) of eastern Oklahoma in the latter paper probably belong to *A. hermosanus*.

The precise stratigraphic range of this species has not been determined in Colorado, and the species needs to be redefined based upon the type specimens and additional material from that region.

Material and Occurrence.—It appears likely that this species is restricted to the Upper Morrowan and Atokan Series in that it has been collected only in strata of these ages in northern New Mexico (Sutherland and Harlow, *in press*). It occurs in the Wapanucka Formation (Morrowan) of southern Oklahoma, and in the Bergner Formation (Atokan, at least in part) from southwestern Missouri (Hoare, 1961).

It has been collected from the Morrow Group only from the Kessler Limestone and Greenleaf Limestone. Approximately 20 exfoliated, disarticulated specimens are present in the following collections: BLOYD FORMATION—Kessler Limestone: M69-27B(?), M105D-13 (13 specimens plus fragments), and M105D-15. McCULLY FORMATION—Greenleaf Limestone: M60-21.

Figured Specimen.—OU 7271.

Genus *Tesuquea* Sutherland and Harlow, *in press*

Discussion.—The genus *Tesuquea* was defined by Sutherland and Harlow (*in press*) for specimens externally similar to the smaller species of *Antiquatonia*, such as *A. coloradoensis* (Girty), but characterized by a circum-visceral ridge or flange on the interior of the brachial valve. A corresponding thickened ridge is present opposite the flange on the trail of the pedicle valve. *Tesuquea* and *Antiquatonia* are both characterized by a lateral row or rows of spines that flank each side of the umbo and extend onto the trail, but these rows are most commonly not related to a supporting ridge in _Tesuquea_.

Sutherland and Harlow (_in press_) chose as the type species _T. formosa_, from the Upper Morrowan part of the La Pasada Formation in north-central New Mexico. That species is probably a junior synonym of _T. morrowensis_, originally described from the Morrow Group by Mather (1915).

Tesuquea morrowensis (Mather)

Pl. 5, figs. 3a-8b.

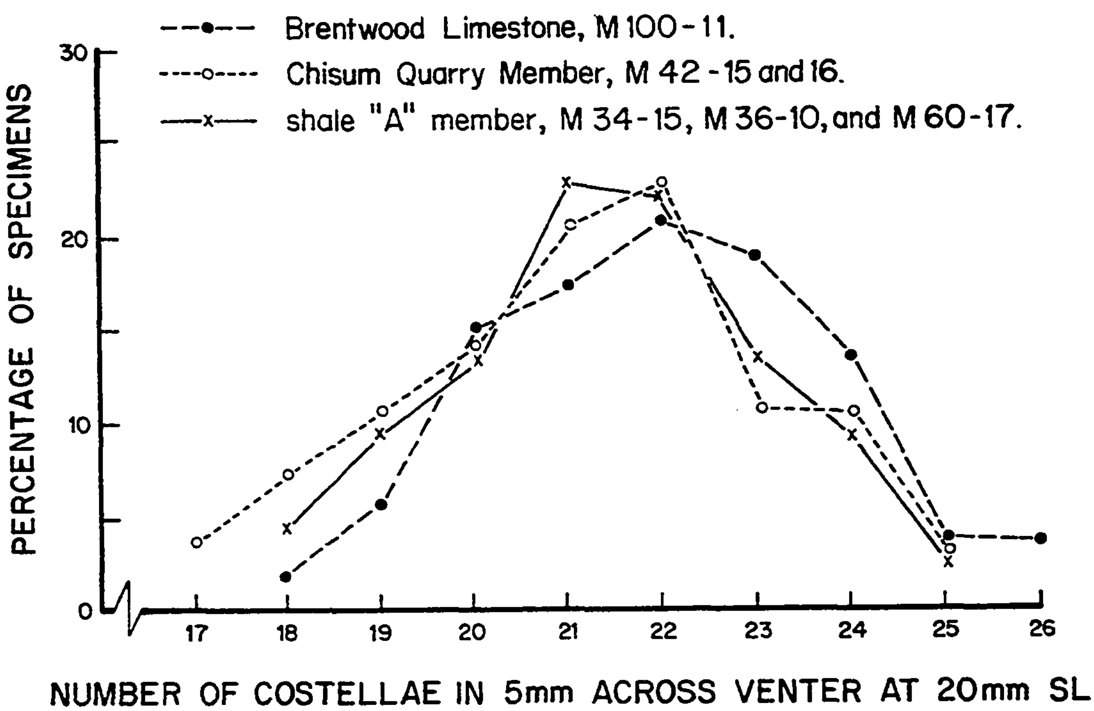
Productus morrowensis Mather, 1915, p. 152, pl. 10, figs. 1-4a; Croneis, 1930, p. 86, pl. 22, figs. 1, 2.

Productus fayettevillensis Mather, p. 163, pl. 10, figs. 5, 5a (not fig. 6).

?_Tesuquea formosa_ Sutherland and Harlow, _in press_, pl. 6, figs. 1-11, 17, 18.

Description (Based upon All Specimens from Lower Morrow Group).--Valves small to medium sized, concavo-convex, with maximum width either on trail, at hinge; nearly complete, large specimen from M100-5 measuring 66 mm SL, about 40 mm length, 45 mm restored width, hinge width about same, height (slightly crushed) estimated 22 mm (for additional measurements refer to Appendix III).

Pedicle valve somewhat gibbous, strongly convex posteriorly, becoming preogressively slightly less convex anteriorly without distinct geniculation; trail slightly convex to flattened in lateral profile with slight concave flaring at anterolateral margins on some large specimens; beak arched slightly over cardinal area; beak, umbo extended posteriorly beyond hinge line commonly about 5 mm, rarely as much as about 8 mm; umbo broad, inflated, with steep, well defined lateral slopes diverging generally at about 100 degrees; shallow, rounded, poorly defined sulcus generally arising on umbo short distance from beak, continuing anteriorly onto trail, to anterior margin, generally not increasing in depth, width; sulcus generally narrow, measuring about 4 to 5 mm wide, rarely wider; small percentage of specimens asulcate with mesial flattening of venter; medium sized alae distinctly set off from umbo by subangular to subrounded depressions, alae gently arched transversely with slightly rounded lateral margins joining posterior margins at almost right angles. Surface ornamentation (based upon material from M100-11, see text-figure 10) consisting of fine, rounded costellae, numbering between 18 and 26 ($M = 22$, $\bar{x} = 21.9$, $n = 53$) within 10 mm across venter at 20 mm SL, becoming broader, generally increasing total number of costellae on shell by intercalation, bifurcation anteriorly; costellae numbering 18 to 24 ($M = 20$, $\bar{x} = 20.7$, $n = 44$) in 10 mm at 30 mm SL: costellae characteristically of about equal height, spacing at given surface lengths across umbo, posterior part of trail; two, three costellae on trail commonly uniting at base of body spines, forming coarser costa; latter becoming broader, flaring toward anterior margin, rarely again bifurcating; most of trail thus characterized by presence of both costellae, costa, numbering between 10 to 13 in 10 mm on trail of most



Text-figure 10.--Percentage polygon for number of costellae in 10 mm across venter at 20 mm SL for 53 specimens of *Tesuquea morrowensis* (Mather) from the Brentwood Limestone, for 28 specimens from the Chisum Quarry Member, and for 22 specimens from the shale "A" member. See text for discussion.

larger, more complete specimens; umbonal region reticulate with from 16 to 21 concentric rugae extending across umbo, onto ears; surface length to end of reticulation (based on specimens from M100-11) ranging between 17 to 24 mm (M = 20, $\bar{x}$ = 20.3, n = 43); beyond reticulation, concentric ornamentation consisting of very fine, irregular, subequally spaced growth lines; valves characterized by single row of erect spines originating on either side of umbo near beak, extending anteriorly, commonly becoming irregular double row with spines alternating, rarely triple row, commonly extending onto trail, to anterior margin; spines quite small, spaced about 0.7 mm apart near posterior margin, becoming larger, more widely spaced anteriorly, averaging about 1.5 to 2.0 mm apart about 20 mm SL from beak; spine row unsupported by ridge, but bordered posteriorly on some specimens by faint, irregular ridge subparallel to spine row; when present, ridge originating obscurely on flank of umbo at point lateral to early spines; ridge extending onto trail, intersecting spine row in few cases; body with erect spines irregularly spaced across most of remainder of vlave, averaging between 2 to 4 mm apart on umbo, becoming larger, spaced commonly 5 to 10 mm apart on trail, commonly absent near anterior margin of trail; hinge spines not common, not forming distinct row.

Brachial valve slightly concave on visceral disc, becoming strongly geniculate anteriorly, following trail of pedicle valve; surface finely costellate, reticulate on visceral disc; ears distinctly set off from rest of shell, ornamented only with concentric wrinkles; spines absent; scattered pits present.

Pedicle valve interior with elongated, faintly dendritically sculptured adductor scars set on elevated platform anteriorly; larger specimens with adductor scars impressed into thickened part of shell posteriorly; diductor scars broad, suboval to subcircular, extending beyond adductor scars, longitudinally faintly striated; trail with thickened band from 2 to 3 mm wide, approximately 0.75 to 1 mm thick, extending across central portion of valve, beginning near flanks; this ridge ornamented with irregularly spaced, fine, radiating grooves and minute spines.

Brachial valve interior characterized by sessile, short, trilobed cardinal process, with dorsally sloping posterior face, median shaft grooved longitudinally, lateral lobes curving dorsally around prominent pits flanking median lobe, not joining dorsally; process supported by lateral ridges, paralleling hinge, abruptly deflecting from hinge line from 30 to 35 degrees at inner margins of ears, thus setting off ears from remainder of valve, continuing as faint, low ridge arching around anterolateral margin, thickening, widening, continuing across trail, forming raised flange; ridge up to 3.2 mm wide, located about 6 to 9 mm anterior to geniculation; flange corresponding to ridge on pedicle interior; broad, extremely low median septum joined to cardinal process posteriorly, thinning markedly anteriorly within short distance to central portion of muscle field, extending anteriorly to point from two-thirds length of visceral cavity to near edge of same, generally becoming slightly more elevated anteriorly, attaining maximum height of 1 mm on one specimen; adductor muscle scars borne upon small, tear-shaped, elevated platforms, sloping posteriorly, separated from each other by narrow grooves flanking median septum; brachial impressions low, faint, not generally well preserved. Visceral disc, trail ornamented with fine radiating costellae; scattered, medium sized, almost recumbent spines situated on costellae beyond geniculation, posterior to flange; flange ornamented with fine, irregular radiating grooves, minute, recumbent endospines.

Discussion.--Mather (1915, p. 152) designated his station 136 (= M103-14), in the lower Prairie Grove Member, to be the type locality He had only the holotype (UC 16125), which is herein refigured (pl. 5, figs. 3a-3d), and an allotype (UC 16126), a mold of a brachial valve. The holotype is a medium-sized specimen for the species, exposing the pedicle valve and is well preserved except for being partly exfoliated. It has the double row of alternately spaced spine bases on each of the flanks, and it shows the obscure ridge, as described by Mather, that lies posterior to the spine row. The author has recollected the type locality extensively (see discussion of Mather's station 135 in Appendix III for additional remarks), but a topotype collection of only 8 badly exfoliated, crushed specimens resulted.

The primary types, the small collection of topotypes, and the other poorly preserved specimens of this species from the basal part of the Prairie Grove Member from the Fayetteville area are comparable in essential features with the large collection of approximately 200 specimens of this species from the Brentwood Limestone at unit M100-11.

This latter material consists of exfoliated, somewhat fragmentary, disarticulated exteriors but is the largest available collection of this species from the Morrow Group; it was used as the primary base for the description of the external features of the species described above. The external description is supplemented by observations of approximately 100 fragmentary, generally slightly crushed specimens from the upper part of the Prairie Grove Member from units M100-5 and M101-6. The description of the pedicle interiors is based primarily upon about ten fragments from units M1-5 and M97-5 or 6 in the upper part of the limestone-shale member and upon two molds of the anterior portion of the valve from the Chisum Quarry Member at units M42-15 & 16. Approximately 13 reasonably well preserved brachial interiors from units M1-5, M32-4, M26-7, M39-10, M53-3, M63-13, loc. M83A, M97-9, and loc. M98D in the limestone-shale member and from units M33-4 and M39-7 of the Brewer Bend Limestone form the nucleus for the description of the internal characters of this valve.

The specimens from units M100-5 and M101-6 in the upper part of the Prairie Grove Member have, in some instances, remarkably well preserved exteriors. Many of these specimens were collected in life position, and a number of them had long, slender spines preserved on the pedicle valve. These specimens occur in an argillaceous calcilutite (wackestone), and they cannot be separated from the matrix without breaking the remainder of the spines. An incomplete spine, 27 mm long, was observed on the spine row on the flanks of a pedicle valve. A number of these specimens also have the slightly flaring, fragile trail and ears preserved, although these tend to be somewhat crushed. The anterior portion of the trail on a few specimens seem to form a slightly concave rim but this may be the result of crushing.

Mather's (1915, p. 152) description of the external characters of this species is accurate in most respects. He is incorrect, however, in stating (p. 153) that "there is always a double row of spines" on the flanks. A double row is the most common arrangement (pl. 5, fig. 3d), but almost as many specimens have a single row (pl. 5, fig. 5b), and rare specimens have 3 irregular rows (pl. 5, fig. 4c). One of Mather's figured specimens (his pl. 10, fig. 4; UC 16412) from northeastern Oklahoma has only a single row of spines.

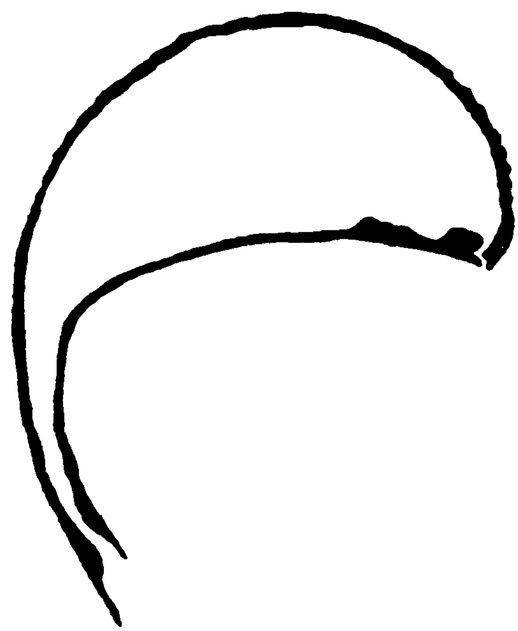
Mather had a single exfoliated brachial interior (UC 16127) from the Brentwood Limestone at his station 210. This specimen has the cardinal process and part of the lateral ridges preserved; it also has the highly distinctive flange on the trail about 4 to 5 mm beyond the geniculation. This flange can be clearly seen on Mather's (pl. 10, fig. 3) figure of this specimen.

The flange or ridge on the anterior part of the interior of the brachial valve can be seen clearly on approximately 30 of the roughly 100 brachial interiors at hand, representing most stratigraphic horizons in the Morrow Group. This flange is easily broken off (pl. 5, figs. 7b, 8b) commonly leaving little trace of its existance. It commonly occurs from 5 to 10 mm beyond the geniculation of the brachial valve. On some specimens, a mere thickening of the shell material is present, but on others an actual lip developed forming a true flange like that described by Sutherland and Harlow (_in press_) for _T. formosa_. This ridge or flange is normally regularly developed across the entire anterior surface and on a small number of specimens arches slightly posteriorly across the slight internal sulcus on the interior of the brachial trail.

A number of specimens that have most of the shell material deeply exfoliated on the anterior part of the pedicle valve reveal a distinct groove across the anterior portion of the valve. These grooves occur at surface lengths of from 28 to 42 mm, and they represent raised bands on the pedicle interior. This correspondence can be most clearly seen on the sections made through the plane of symmetry of the valve (text-figure 11). The pedicle band occurred directly opposite the brachial flange when the valves were closed on some specimens and immediately posterior to the flange on others (text-figure 11), thus effectively limiting the entrance of foreign material into the valve. Both the flange and the band are ornamented with fine, closely spaced, grooves and minute recumbent endospines, enhancing the screening function.

On most of the interiors studied, the geniculation of the brachial valve is such that the trail is set from about 90 degrees to about 105 degrees to the flattened, visceral portion of the valve. However, a range of from 73 to 118 degrees has been recorded.

This species is highly variable with respect to the coarseness of the costellae. As is shown in text-figure 10, the number of costellae for T. morrowensis in 10 mm across the venter at 20 mm SL ranges between 17 and 26. The specimens from the Brentwood Limestone at unit M100-11 have a mode of 22 costellae ($\bar{x}$ = 21.9, n = 53); those from the Chisum



Text-figure 11.--Longitudinal section through specimen of *Tesuquea morrowensis* (Mather) from top of limestone-shale member of Gore Formation at M97-9. Figure taken from thin-section; magnification X3; see text for additional discussion.

Quarry Member (units M42-15 & 16) have a mode of 23 also ($\bar{x}$ = 21.1, n = 28); and those from the shale "A" member (units M34-15, M36-10, and M60-17) have a mode of 22 ($\bar{x}$ = 21.5, n = 22). Statistically, the means are not significantly different at 98 percent confidence limits. The small collection of material from the Cane Hill Member (M105A-3) has between 18 and 28 costellae, and material from the upper part of the Prairie Grove at units M100-5 and M100-6 between 17 and 26. The material from the lower part of the Morrow Group is generally too poorly preserved and/or the collections to small to allow meaningful statistical comparisons of this feature.

Tesuquea formosa, described by Sutherland and Harlow (*in press*) from the Upper Morrowan portion of the La Pasada Formation in north-central New Mexico, was selected as the type species for their genus *Tesuquea*, to which they questionably assigned *Productus morrowensis*, because the internal features of the latter species were unknown at the time of their study. Sutherland and Harlow noted that both species appeared to be present in the collections from the Morrow Group of northeastern Oklahoma and that their stratigraphic distributions in this area had not been determined. *T. formosa* was said to differ from Mather's species in being smaller, more sharply convex, and in having slightly finer costellae.

Tesuquea morrowensis is one of the most common brachiopods in the Morrow Group, and considerable morphological variability both in terms of size and shape and external ornamentation can be observed in any large collection from any stratigraphic horizon in the Morrow Group.

In most such collections, variants quite similar to the "typical" _T. formosa_ can be found. In a large percentage of these, a complete range in morphologic characteristics from those specimens that are smaller and more highly convex to specimens with the slightly less convex shape and larger size. Some of these collections are composed exclusively of one or the other of these variants, but ecologic control does not seem to have been a factor since collections of exclusively (or almost exclusively) one or the other variant have been made from grain-supported limestones, mud-supported limestones, and calcareous shales. The problem here, however, is that most of these collections were taken from death assemblages, rarely from remains of "life assemblages". No stratigraphic change in the relative proportions of these variants is apparent in the collections at hand. Mather (1915, p. 154) stated that "the specimens from the Kessler limestone are below the average size of the species...". The collections available to this writer from both the Kessler and the approximately equivalent Greenleaf Limestone are extremely small, but the larger variant is nevertheless present in the latter member. The collections from the subjacent shale "A" member contain both variants and intermediates as well. It is therefore concluded that _T. formosa_ may be a junior synonym of _T. morrowensis_.

A collection of about 280 specimens from M17-9 through M17-17 in the Chisum Quarry Member are herein referred to as _Tesuquea_ cf. _T. morrowensis_. These individuals tend to be much larger, have broader umbos, and are less convex than typical for the species. One of the largest specimens in this collection has the trail and alae broken off but has a preserved surface length of 58 mm, length of 41+ mm, width 42+ mm, and height 22+ mm. The umbos on these specimens commonly diverge at around 110 to 115 degrees rather than about 100 degrees for more typical specimens. The surface length to the end of reticulation tends to be greater than typical also, reflecting the greater size and lesser convexity of the valves. It ranges from about 18 to 33 with an average of around 25 mm, contrasted with a range of from 17 to 24 with an average of about 19 mm for the more typical specimens. A number of brachial interiors are present in these collections, and the anterior flange is well developed on many of these.

P. K. Sutherland (personal communication) has examined the holotype of _Productus fayettevillensis_ Mather (1915, p. 163, pl. 10, fig. 5) and concluded that this specimen is either an immature specimen of _T. morrowensis_ or is a fragment of the posterior portion of the pedicle valve of that species. This specimen is not included in the list of type specimens in the Field Museum of Natural History (Golden and Nitecki, 1972), although one of Mather's referred specimens of _P. fayettevillensis_ is included in this list (p. 156). The holotype cannot be located by the Field Museum at this time.

Tesuquea morrowensis differs from _T. planocosta_ (Easton), from the lower Pennsylvanian Cameron Creek Formation of Montana, in having more densely spaced and more numerous spines on the spine row on the umbonal flank of the pedicle valve, in having generally a double row of alternating spines, in being slightly larger, in having somewhat finer costellae, in having fewer hinge spines, and in having a better developed flange on the interior of the brachial valve.

<u>Material and Occurrence</u>.--<u>Tesuquea morrowensis</u> is one of the most frequently encountered brachiopods in the Morrow Group. Approximately 2700 specimens have been collected; most of these specimens are exfoliated, fragmentary, and/or crushed. Included in these collections are approximately 100 brachial valve interiors of varying states of preservation, and approximately 20 highly fragmentary pedicle valve interiors and molds. Approximately one-third of the specimens were collected in the limestone-shale member although this species has been collected from all fossiliferous intervals within the Morrow Group. This species occurs rarely to commonly in the following collections unless otherwise noted: HALE FORMATION--Cane Hill Member: M105A-3. Prairie Grove Member: M100-3, M100-5, M100-6, M101-3, M101-6 (approximately 100 specimens), M101-7, M103-14 (8 fragmentary specimens--type locality), M104B-5, M105C-4, M107-9, M109-4, M110-18, M111-6, M111-8, M111-15(?), M112-15, M112-17, M116-7, M117-8, M117-9, M117A-6, M118-5 (top 2 feet), and M118-8. BLOYD FORMATION--Brentwood Limestone: M68-12, M68-17, M68-18, M68-21, M68-25, M69-19, M70-10B, M70-12 (top), M70-13, M70-16, (top 1 foot), M100-9, M100-10, M100-11 (estimated 200 specimens), M101-15, M101-16, M102-11, M104B-11, M104B-17, M104C-B, M110-20, M112-24, M114-12, and M116-20. Woolsey Member: M105C-14. Dye Shale Member ("caprock"): M70-20, M100-18 and M104B-19. Kessler Limestone: M68-27 and

M100-25. GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8 (65 specimens), M5-13, M5-15, M14-8 & 9, M22-7, M22-11, M23-3C, M23-4, M25-5, M25-11, M26-5 (1 foot above base), M26-6, M26-7, M26-9, M26-10, M27-7 (6 to 8 feet below top), M26-8A (basal 4 feet), M29-1, M29-2, M29-4, M31-1 (2 feet above base), M31-4 (top), M31-5 (top), M31-8 (4 feet above base), M34-7, M34-8, M35-2 (top), M36-6A, M37-8, M39-4, M39-10, M42-7, M48-0A, M49-3, M49-6, M49-8 (basal 1 foot), M49-10 (basal 2 feet), M49-10 (middle), M49-10 (top; 60 specimens), M51-7 (7 feet above base, 25 to 27 feet above base, 29 to 30 feet above base), M51-15, M53-3, M60-15, M60-17, M61-6, M63-13 (top; 75 specimens), M63-15, M63-17, M64-8 (top), M64-11 (55 specimens), M65-14 (top), M67-11, M67-14, M67-17, M72A-2D, M72-4A, M78-38, M78-39 (base), loc. M83A (73 specimens), M85-4, M85-8 (3 feet above base), loc. M87, M97-5, M97-6, M97-8, M97-9, and loc. M98D (75 specimens). Brewer Bend Limestone: M3-12A, M5-17, M18-3, M28-8, M33-4C, M34-11, M35-7, M39-7, M39-14, M40-17, M42-12, M51-20, M60-15, M63-19, M64-13 (middle), M78-43, M98A-7, and M98C-7. McCULLY FORMATION--Chisum Quarry Member: M17-9(cf.), M17-11 & 12(cf.), M17-13(cf.), M17-14(cf.; 146 specimens, 12 brachial interiors, 2 pedicle interiors), M17-14 & 15(cf.), M17-15 & 16(cf.), M17-17 & 18(cf.), M24-14, M26-23, M27-14 (base; cf.), M28-10 (top), M28-12, M29-10 (top), M31-17, M33-6, M34-15, M35-8, M36-7, M37-10, M37-11 (top), M40-18 (5 to 6 feet above base), M41-15, M42-15 (72 specimens), M42-15 & 16, M42-16 (126 specimens), M42-18, M49-18, M61-9, M62-23, M63-20, M67-19, and M97-13. Shale "A" member: M29-14, M30-6, M36-10B (top), and M48-13 to 15. Greenleaf Limestone: M1-20, M27-16 (base), M27-16 (top), M28-14(?), M33-11, M35-11, M51-25

(3 feet above base), M98-13, and M99-2.

Figured and Catalogued Specimens.--UC 16125 (holotype), OU 7272-7276; OU 7333 (8 fragmentary topotypes).

FAMILY LINOPRODUCTIDAE

SUBFAMILY LINOPRODUCTINAE

Genus *Linoproductus* Chao, 1927

Discussion.--The name *Linoproductus* has been applied to a relatively large number of Mississippian through Permian productoids from geographically widespread areas. Three species from the Morrow Group are herein assigned to this genus; these are *Linoproductus* n. sp. A, which occurs in the Lower Morrowan, *L. nodosus*, and *L. pumilus*, both from the Upper Morrowan. A fourth Morrowan species, *L. devargasi* was described by Sutherland and Harlow (*in press*) from the Upper Morrowan strata of the La Pasada Formation in north-central New Mexico, but has not been identified in the Morrow Group.

Linoproductus n. sp. A

Pl. 5, figs. 10a-10c.

Description (Based upon Specimens from M100-11).--Shell medium sized for genus, strongly concavo-convex, maximum width on flaring trail, large, almost complete specimen measuring 70 mm SL, 44 mm long, 53 mm wide, 34 mm hinge width, about 20 mm high.

Pedicle valve strongly convex in posterior portion, becoming progressively less convex anteriorly, almost planar on trail, approximating rapidly expanding spiral; blunt beak, umbo overhanging straight hinge line maximum of from 10 to 12 mm; umbo flaring, inflated, with well defined lateral slopes, with ventral surface uniformly convex in transverse profile posteriorly, becoming less strongly convex anteriorly onto broad, flaring trail; latter with slightly concave anterolateral surfaces; anterior commissure gently, broadly sulcate; alae blunt, well defined, bearing single row of from four to eight hinge spine bases, each set on strong wrinkles. Radial ornamentation consisting of fine, flattened, sinuous costellae, flaring slightly anteriorly on venter, increasing number by intercalation, commonly bending, converging around pathogenic areas, body spines; costellae numbering between 8 to 13 on venter, averaging about 10.9 in 5 mm on venter at 10 mm SL, about 9.3 at 20 mm, 8.7 at 30 mm, 8.4 at 40 mm for 11 specimens counted; concentric ornamentation consisting of very fine growth lines ranging between 3 to 6 per mm on venter; valve characterized by broad, flaring band row of body spines set at acute angle to surface; spines alternately set on either side of median line in flaring, generally regular, zig-zag double row commonly measuring as much as 10 mm wide on trail; number, spacing of body spines highly variable, generally becoming farther apart, larger anteriorly, with maximum of 12 spines present on large specimen; remainder of valve aspinose.

Brachial valve with small, concave visceral disc, well defined alae, gently geniculate anteriorly; surface marked by fine costellae, strong concentric wrinkles on alae, becoming less well defined toward median portion of valve; with fine growth lamellae; valve apparently aspinose.

Pedicle interior unknown.

Brachial interior with sessile, blunt, trilobed cardinal process, median lobe broadly sulcate, with two lateral lobes curing dorsally, uniting with median lobe; shallow alveolus separating process from thin, low median breviseptum; latter extending anteriorly about 10 mm to almost end of visceral disc, becoming progressively thinner, lower anteriorly; muscle field obscure; lateral ridges diverging from hinge margin away from process, curving posteriorly slightly toward alae, not extending around alae. Internal ornamentation of fine radial costellae, broad wrinkles, particularly near alae; wrinkles becoming less well defined, extending across venter.

Discussion.--Linoproductus n. sp. A is characterized by the general absence of body spines except for an expanding double row of generally regularly alternating spines down the ventral portion of the valve, by the presence of a single row of hinge spines, by a rounded umbo, and by the flaring trail and gently sulcate commissure.

Linoproductus nodosus (Newberry), reestablished by Sutherland and Harlow (in press) from the upper part of the Morrow Series in the La Pasada Formation near Santa Fe, New Mexico, differs only in having a single instead of an alternating double row of spines down the venter. The author has examined the neotype (OU 7770) and the approximately 75 topotypes of this species in the OU collection. On the majority of specimens the median row of spines is almost straight; only a few specimens have a narrow zig-zag pattern with the spines offset only about 1 to 2 mm from the median line. The largest specimens of L. nodosus from the type collections are comparable in size to the largest specimens of Linoproductus n. sp. A and also have the broad, flaring trail. It is also characterized by the single row of hinge spines.

Linoproductus n. sp. A gave rise to L. nodosus during the earliest Late Morrowan. The following trend has been observed: (A). Specimens of Linoproductus n. sp. A in the lowest Morrowan strata (e.g., the Cane Hill Member, lower Prairie Grove Member, and lower limestone-shale member) are generally characterized by a band of irregularly alternating body spines down the venter and additional body spines scattered over the pedicle valve. (B). Collections from the upper part of the Lower Morrowan (e.g., the upper Prairie Grove and lower Brentwood Members and the upper limestone-shale member and Brewer Bend Limestone) are characterized by a row of regularly alternating body spines on the ventral band and rarely have other body spines. (C). Truly transitional collections between Linoproductus n. sp. A and L. nodosus occur in the lower part of the Chisum Quarry Member. Most of the specimens have an alternating spine pattern, but the spines are offset rarely more than 2 to 3 mm from the plane of symmetry. A few collections contain specimens with a straight, single row of spines down the venter. (D). Specimens from the shale "A" member and the Greenleaf and Kessler Limestones are identified as L. nodosus and are characterized by the single, straight row of spines; rare variants with a narrow zig-zag pattern occur in these strata.

Linoproductus n. sp. A is similar in size and shape to *L. platyumbonus* Hoare, originally described from the Lower Desmoinesian Krebs Group in Missouri. The latter species is characterized by having a flattened ventral region or a broad, shallow sulcus on the pedicle valve, in having a double row of hinge spines, and by having few irregularly spaced spines scattered over the entire body.

Material and Occurrence.—The description of *Linoproductus* n. sp. A, presented in the preceeding section, is based upon approximately 50 generally incomplete, "crack out" specimens, about three brachial valves, a single brachial interior, and about 100 fragments from the upper part of the Brentwood Limestone Member at unit M100-11. Most of the specimens from this unit are badly exfoliated and only the spine bases can be observed.

Linoproductus n. sp. A ranges from the Cane Hill Member through the Brentwood Limestone in northwestern Arkansas and throughout the Gore Formation in northeastern Oklahoma. This species was most commonly collected from limestones; it did not prefer an environment in which there was a large influx of fine-grained terrigenous clastics. A total of approximately 300 largely fragmentary, exfoliated specimens were collected from these strata; approximately 65 additional specimens identified as *Linoproductus* cf. *L.* n. sp. A are from the Chisum Quarry Member. *Linoproductus* n. sp. A occurs rarely in the following collections unless otherwise indicated: HALE FORMATION—Cane Hill Member: M105A-3 (basal 1.5 feet, 25 specimens). Prairie Grove Member: M101-1, M101-7, M103-14, M105C-4, M107-9, M109-5, M111-16, M112-15, M116-7 (4 to 5 feet above base), M117-11, and M118-8. BLOYD FORMATION--Brentwood Limestone Member: M68-17 & 18(cf.), M68-18 (talus), M69-17(cf.), M69-18, M70-16, M100-11 (about 50 specimens plus about 100 fragments), M101-19, M104B-17 (12 specimens), and M118-11 or 12 talus. GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8, M5-13, M5-15, M26-5 (14 crushed specimens), M27-7 (6 to 8 feet below top; 58 fragmentary specimens), M31-1 (2 feet above base), M31-4, M31-5 (top), M34-7, M35-2 (top), M39-2, M39-4, M49-3, M49-6 (basal 1 foot), M49-8, M49-10 (basal 2 feet), M49-10 (top), M51-7 (23 feet above base), M51-7 (29 to 30 feet above base), M51-15, loc. M56A, M61-6 (10 feet above base), M62-21, M63-9, M63-13 (top), M64-8 (top), M64-11, M72-4A, M78-38, loc. M83A, M85-4 (5 feet below top, 10 specimens), loc. M87, M97-8, and M97-9. Brewer Bend Limestone: M5-17, M28-8A, M34-11, M36-6B, M39-14, M42-12, M48-9 (top), and M60-15. McCully Formation--Chisum Quarry Member: M17-11 and 12(cf.), M28-11(cf., top), M29-10(cf.), M36-7(cf.), M40-18A(cf.), M63-20(cf.), and M67-19(cf.).

Figured Specimen.--OU 7278.

Linoproductus nodosus (Newberry)

Pl. 5, figs. 11, 12.

Productus nodosus Newberry, 1861, p. 124, pl. 1, figs. 7-7b; 1876b, p. 140, pl. 3, figs. 3-3c; Price, 1916, p. 699, pl. 30, figs. 9-11.

Productus gallowayi Morgan, 1924, p. 184, pl. 44, figs. 1, 1a.

Linoproductus nodosus, Dunbar and Condra, 1932, p. 246, pl. 32, fig. 6; Plummer, 1950, pl. 11, fig. 13; Sutherland and Harlow, in press, pl. 12, figs. 1-6.

Discussion.--Linoproductus nodosus is one of the most easily recognizable large productoids in the Morrow Series. It is characterized by the single row of suberect to obtuse body spines located along the median line of the pedicle valve, by the single row of hinge spines on the strongly wrinkled, medium-sized alae, by the narrow, rounded to slightly flattened umbo, and by a pedicle valve with a broad, somewhat flaring trail with the maximum width near the anterior margin.

This species appears to be restricted to the Upper Morrowan. It was originally described by Newberry (1861, p. 124) from the "Carboniferous strata near Santa Fe, New Mexico"; he listed its occurrence (1876, p. 43-45) in two stratigraphic sections measured in the area, and this enabled Sutherland and Harlow (in press) to collect topotypes and reestablish the species. They have dtermined that it occurs in that area only in the lower portion (Upper Morrowan) of the La Pasada Formation.

Typical examples of this species are also restricted to the upper part of the Morrow Group in the Ozark region. It is interpreted that L. nodosus is the direct descendant of Linoproductus n. sp. A, from the Lower Morrow Group in the Ozark Mountains region. For a comparison with this species and a more detailed commentary on this lineage, see discussion of Linoproductus n. sp. A.

The author has examined the collection of approximately 75 topotypes and the neotype from the La Pasada Formation, and the material from the upper part of the Morrow Group agrees closely in all observable respects with the type material. As in the material from New Mexico, the spacing of the spines is highly variable (compare pl. 5, fig. 11 with fig. 12).

Material and Occurrence.--Linoproductus nodosus is widely distributed geographically in strata of the Morrow Series, and it is known only from the Upper Morrowan. The type material is from the lower part of the La Pasada Formation in north-central New Mexico (Sutherland and Harlow, in press), and L. nodosus has been reported by Plummer (1950) from the Marble Falls Limestone in north-central Texas, by Price (1916) from the Pottsvillian Dingess Limestone in West Virginia, and by Morgan (1924) in the Wapanucka Formation of southern Oklahoma.

This species is restricted to the upper part of the Morrow Group in the Ozark Mountains region. It is one of the few species that is reasonably widespread in its occurrence in the Kessler Limestone. Approximately 160 specimens of this species have been "cracked out" of limestones. Its occurrence in the following collections is rare unless otherwise indicated: BLOYD FORMATION--Kessler Limestone Member: M68-27 (base), M69-27B, M70-24, M104B-23, M104B-24, M104C-1, M105D-13 (21 specimens), M105D-15, and M108-20. McCULLY FORMATION--Chisum Quarry Member: M17-14 through 17(cf.; 14 specimens), M33-6C(cf.), and M34-15(cf.). Shale "A" member: M30-4 (17 specimens), M30-6 (48 specimens), M34-15, M37-10, and M95-10. Greenleaf Limestone: M27-16(?; top), M29-15, M51-25 (3 feet above base; 26 specimens), and M60-21.

Figured Specimens.--OU 7279, 7280.

Linoproductus pumilus Sutherland and Harlow

Pl. 5, figs. 9a, 9b.

Linoproductus pumilus Sutherland and Harlow, *in press*, pl. 13, figs. 7-14.

Discussion.--*Linoproductus pumilus* was defined by Sutherland and Harlow (*in press*) from the uppermost Morrowan or lowermost Atokan portion of the La Pasada Formation in north-central New Mexico. It is characterized by its very small size, relatively narrow beak and inflated umbo, by its highly concavo-convex, subglobular profile, and finely capillate surface ornamentation. It has small spines scattered over its surface.

L. pumilus is most similar to *L.*? *duodenarius* Easton from the Cameron Creek, Alaska Bench, Otter, and Heath Formations (Upper Mississippian through Lower Pennsylvanian) in Montana. It differs from this species in being more highly arched, slightly smaller, and in having finer capillae.

The author has examined the material from New Mexico and has assigned about 100 specimens of small linoproductoids from the upper part of the Morrow Group to it. The material from northeastern Oklahoma and northwestern Arkansas resembles the type material in all respects except that it appears to be slightly more coarsely capillate. L. pumilus from New Mexico has between 16 and 21 capillae in the venter per 5 mm at 10 mm SL ($\bar{x} = 19.7$); the same species from the Morrow Group ranges between 14 and 20 per 5 mm at the same surface length.

A single specimen assigned to Linoproductus cf. L. pumilus occurs in the upper part of the limestone-shale member at M12-8. This specimen has a much broader, less inflated umbo than typical for this species.

Material and Occurrence.--Linoproductus pumilus was defined by Sutherland and Harlow (in press) from the La Pasada Formation in north-central New Mexico, where it occurs in the highest Morrowan or lowest Atokan strata.

This species is restricted to the upper part of the Morrow Group in northwestern Arkansas and northeastern Oklahoma. Approximately 120, largely exfoliated and fragmentary specimens of this species have been identified from the Ozark Mountains area. Of these, all but two occur in northeastern Oklahoma, and this species generally occurs associated with Desmoinesia nambeensis Sutherland and Harlow. L. pumilus occurs rarely in the following collections unless otherwise indicated: GORE FORMATION--limestone-shale member: M12-8 Station A (cf.). McCULLY FORMATION--Chisum Quarry Member: M26-23, M29-10 top, M31-19 (30 specimens), and M37-10. Shale "A" member: M29-14 (64 specimens), M30-6 (20 specimens), and M48-15. Greenleaf Limestone: M27-16 top, M33-11 (10 specimens), M51-25, and M98-13. BLOYD FORMATION--Kessler Limestone:

M105D-13, M105D-15, and M108-20.

Figured Specimen.--OU 7277.

Genus Zia Sutherland and Harlow, in press

Discussion.--Sutherland and Harlow (in press) based their genus Zia upon a previously undescribed species, Z. novamexicana, from a restricted stratigraphic interval within the Upper Morrowan part of the La Pasada Formation in north-central New Mexico. The genus was tentatively placed in the Linoproductidae because of the general character of the brachial interior, particularly the linoproductid type of cardinal process. It differs from most memebers of this family by having a pedicle valve that has extremely low convexity, is moderately geniculate, and has a reticulate ornamentation over the visceral disc.

Zia is similar to the MIssissippian genus Marginirugus in general shape and outline but the latter genus has a large trilobed cardinal process, obscure reticulation, and much smaller spines.

Zia novamexicana is the only species currently assigned to this genus. Small collections from the upper part of the Morrow Group are herein identified as Zia cf. Z. novamexicana, thus extending the geographic range of this genus into the Ozark Mountains area.

Zia cf. Z. novamexicana Sutherland and Harlow

Pl. 6, figs. 1a-1d.

?*Productus* sp., of Mather, 1915, p. 165, pl. 8, figs. 16-16b.

Zia novamexicana Sutherland and Harlow, *in press*, pl. 13, figs. 1-6.

Discussion.--*Zia novamexicana* Sutherland and Harlow is a highly distinctive Upper Morrowan species that is not closely similar to any previously described Pennsylvanian brachiopod. Externally, this species is distinguished by the low degree of convexity of the pedicle valve over the visceral disc and by the anterior geniculation. Surface ornamentation is also distinctive, consisting of a strong reticulate pattern only on the umbonal region, a row of laterally oblique spines along the hinge line, a single larger spine on each ear, and numerous body spines. These are oblique, nearly recumbant on the reticulated portion of the valve, arising from the costellae and having about the same width as the latter. Beyond the reticulation, the spine bases become larger, are slightly more widely spaced, and become suberect to erect.

The small collections of material identified as *Zia* cf. *Z. novamexicana* from the Kessler and Greenleaf Limestones are closely similar to the type material in general outline, shape, and particularly in the distinctive surface ornamentation and pattern of spines. The single, almost complete pedicle exterior (pl. 6, figs. 1a-1d), however, differs in being much larger, in having a much broader umbo, in being more distinctly flattened over the visceral disc, in being more sharply geniculate, in having a more of a subrectangular shape, and in having a broad, shallow sulcus developed on the anterior part of the valve.

This specimen measures about 53 mm SL, is about 34 mm long, has a hinge width of approximately 45 mm, and is about 20 mm high. The specimen becomes distinctly geniculate at about 35 mm SL. The holotype, one of the largest specimens in the New Mexican collections, by contrast, measures about 50 mm SL, is about 30 mm long, and has a restored hinge width of only about 38 mm.

The specimen figured by Mather (1915, p. 165, pl. 8, figs. 16-16b) as *Productus* sp. has not been examined by the author but is probably also assignable to this species. The general outline of the specimen is more similar to that of the type material, does not appear to have a sulcus, but is more comparable in size to the specimen herein figured from the Kessler rather than to the type specimens.

Material and Occurrence.--*Zia* cf. *Z. novamexicana* has been collected only from the Kessler Limestone at M104B-26 (1 almost complete pedicle valve, 2 fragmental pedicle valves, 1 pedicle mold, and about 7 brachial molds) and from the Greenleaf Limestone at M98-13 (1 brachial mold). The specimen identified by Mather (1915, p. 165, pl. 8, figs. 16-16b) as *Productus* sp. and herein tentatively assigned to *Zia* cf. *Z. novamexicana* is also from the Kessler Limestone at his station 209 (= M115-2).

Figured Specimen.--OU 7283

ORDER RHYNCHONELLIDA

SUPERFAMILY RHYNCHONELLACEA

FAMILY WELLERELLIDA

SUBFAMILY WELLERELLINAE

Genus Wellerella Dunbar and Condra, 1932

Wellerella triangularis (Mather)

Pl. 5, figs. 13a-16.

Pugnoides triangularis Mather, 1915, p. 175, pl. 12, figs. 12-12c; Murphy, 1954, p. 33, pl. 3, figs. 2a-23.

Wellerella osagensis, Murphy (not Swallow), 1954, p. 34, pl. 3, figs. 4a-4e.

Discussion.--Mather (1915, p. 175) based his description of Pugnoides triangularis on a small number of specimens. His 3 cotypes (UC 16136) come from the Hale Formation at his locality 137; he figured 1 of these (his pl. 12, figs. 12-12c; pl. 5, figs. 13a-13e of this dissertation), and it should be selected as the lectotype. One of his remaining cotypes is herein figured for the first time (pl. 5, fig. 14).

Serial sections through a single specimen of this species from M24-10 in the upper part of the limestone-shale member reveal that the pedicle valve possesses dental plates and that the rostral portion of the brachial valve has a strong median septum. This species is confidently placed in the genus Wellerella based on these serial sections.

Mather (p. 176) stated that the surface of the pedicle valve bears approximately nine simple, angular plications, originating in front of the umbo and rapidly increasing in strength to the margins, and that the three mesial plications are depressed below the ones bordering the sulcus. The plications themselves generally arise from 2.2 to 4.0 mm anteriorly from the beak, and not all initiate at the same point (see pl. 5, fig. 14). Of the 14 specimens on which these features can be observed, including the 3 type specimens, 2 have 2 plications in the sulcus, while the remainder, including the type specimens, have 3. The suggested lectotype has 3 plications per flank. Only 1 additional specimen has 3 per flank, and a solitary specimen has only 1 plication on each side of the sulcus. Hence, 11 of the 14 specimens have only 2 plications on each side of the sulcus, including the remaining cotype. The total number of plications on the brachial valve thus ranges from 5 to 9.

The sulcus on the majority of specimens is rather shallow and the plications in the sulcus are generally depressed dorsally approximately 1 mm or less below those bordering the sulcus (pl. 5, fig. 13e). Only on 2 specimens are they depressed more deeply.

Mather (p. 176) noted that the surface markings of both valve consist of fine, closely spaced growth lines that are about as conspicuous in the posterior part of the valve as in the anterior portion. The growth lines are more conspicuous near the anterior margins than on the umbonal region on a few specimens (pl. 5, figs. 14, 16).

Mather suggested that _Pugnoides triangularis_ is probably the immediate ancestor of _Pugnoides uta_ (Marcou). The Pennsylvanian forms to which Mather alluded are now generally placed within _Wellerella_ osagensis (Swallow), widely described from the lower part of the Virgil Series in the Midcontinent. *W. triangularis* differs from *W. osagensis* in being smaller, proportionally much thinner, and in having a much shallower, almost obsolete sulcus.

W. triangularis is approximately the same size as *W. immatura* Dunbar and Condra. It differs from that species in having a distinctly more triangular outline, a much lower convexity, by being much thinner, and in having a less deeply depressed sulcus. The latter species occurs throughout the Missouri Series and possibly as low as the Desmoines Series in the Midcontinent (Dunbar and Condra, 1932) and may range as high as the lower part of the Virgil Series in New Mexico (Sutherland and Harlow, *in press*).

Material and Occurrence.--*Wellerella triangularis* is known from the Morrow Group in strata ranging from the lower part of the Prairie Grove Member (*Idiognathoides noduliferus* Zone), including the type locality, through the Brentwood Limestone in northwestern Arkansas and from the middle part of the limestone-shale member (base of *Neognathodus bassleri* Zone) through the Brewer Bend Limestone in northeastern Oklahoma.

Twenty specimens of *W. triangularis* are available for study in addition to Mather's three cotypes. This species is rare in the following collections: HALE FORMATION--Prairie Grove Member: Mather's station 137 (type locality, 3 specimens), M70-8, and M103-14. BLOYD FORMATION--Brentwood Limestone: Mather's 134 and 135 and M116-18. GORE FORMATION--limestone-shale member: M24-10, and M26-1. Brewer

Bend Limestone: M3-12C and M24-12.

Wellerella triangularis is also reported from the basal portion of the Oquirrh Formation (Morrowan) in north-central Utah (Murphy, 1954).

Figured Specimens.--UC 16136 (2 cotypes), OU 7281, 7282.

SUPERFAMILY RHYNCHOPORACEA

FAMILY RHYNCHOPORIDAE

Genus *Rhynchopora* W. King, 1865

Rhynchopora magnicosta Mather

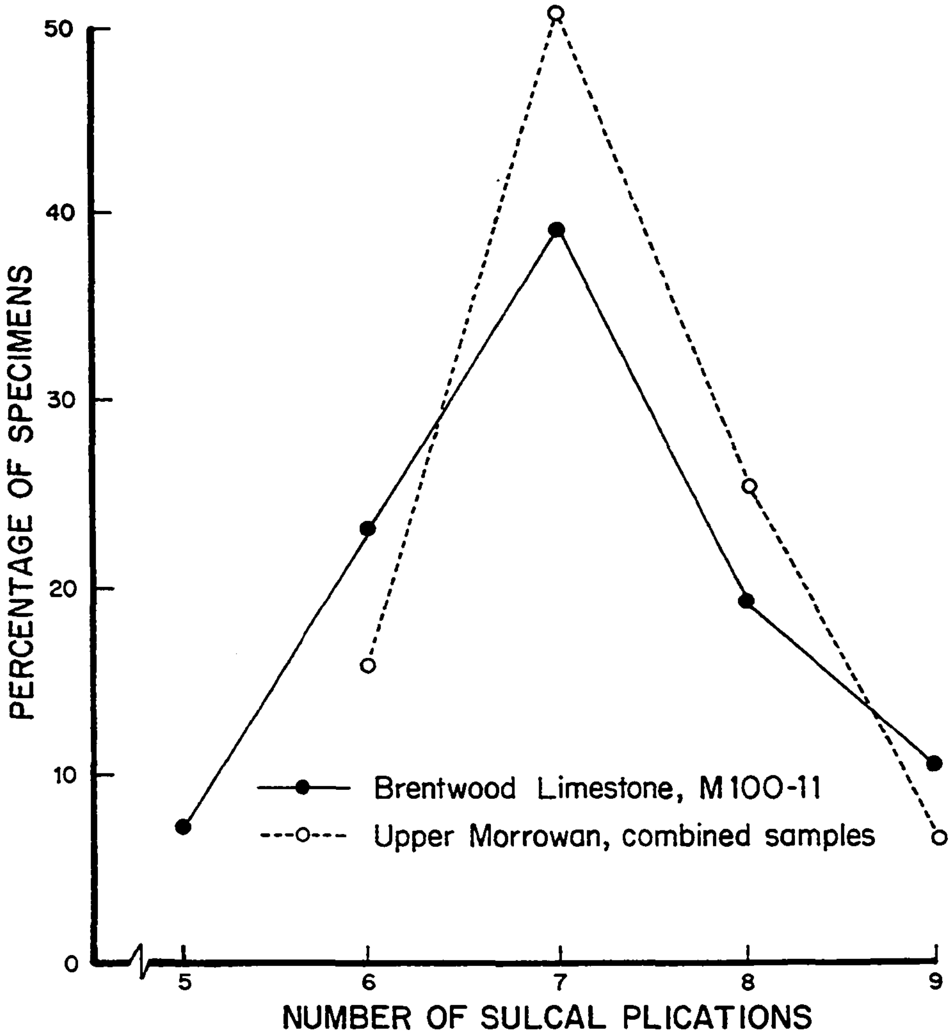
Pl. 5, figs. 2a-9.

Rhynchopora magnicosta Mather, 1915, p. 176, pl. 10, figs. 11-11c; Morgan 1924, pl. 44, fig. 14; Croneis, 1930, p. 84, pl. 21, figs. 8-10, Dunbar and Condra, 1932, p. 301, pl. 37, figs. 35-40; Sutherland and Harlow, *in press*, pl. 13, figs. 22, 23.

Description (Based upon Specimens from M100-11).--Shell small to medium sized for genus, subtriangular outline, subpyramidal form; posterolateral margins straight, meeting at beak at obtuse angle of approximately 102 to 105 degrees (range, 97 to 111 degrees); anterolateral margins rounded, anterolateral margin straight to very gently convex in anterior direction; shells generally slightly wider than long with maximum thickness typically two thirds to three fourths distance to anterior margin; shells coarsely punctate. Largest specimens measuring 14.1 mm long, 12.8 mm wide, 10.8 mm thick; 13.4 mm long, 15.5 mm wide, 11.6 mm thick; width of respective sulci 9.6, 8.9 mm (additional measurements in Appendix IV).

Pedicle valve shallow, depressed convex in posterior portion, with ventral surface flattened, becoming deflected dorsally near posterolateral, lateral margins, strongly deflected at anterolateral, anterior margins; beak broad, closely incurved over than of brachial valve; possessing small, suboval pedicle opening; broad delthyrium present; mesial sulcus originating near midlength to slightly anterior to midlength, becoming gradually deeper anteriorly; sulcus abruptly curved dorsally, forming flat, broad, lingual extension, the surface of which lies from 80 to 90 degrees to plane of valve; commissure deeply serrate with apices of plications forming acute angle of about 20 to 25 degrees. Plications rounded to subangular, simple, originating near beak, flaring rapidly, increasing in size anteriorly, extending to anterior margin; between 9 and 13 plications occurring in 5 mm in mesial portion of valve at 5 mm SL, flaring to number approximately half in mesial portion at 10 mm SL; sulcus containing between 5 and 9 plications ($\bar{x}$ = 7.03, M = 7, n = 56, text-fig. 12); between 5 to 6 plications generally visible on each lateral margin, numbering as many as 9, including plications bounding sulcus; plications more poorly developed laterally than in mesial portion of valve.

Brachial valve much deeper, more convex than pedicle, becoming somewhat gibbous anteriorly with maximum thickness almost at anterior margin; valve flattened in umbonal region, generally with very slight longitudinal sulcus in mesial portion, sloping anteriorly, becoming obsolete beyond midlength; gentle, flattened mesial fold corresponding to sulcus on pedicle valve occurring anteriorly to valve margin. Beak



Text-figure 12.--Plot of number of sulcal plications versus percentage of specimens for *Rhynchopora magnicosta* Mather from Brentwood Limestone (M100-11) and from combined sample from Chisum Quarry Member and shale "A" member of McCully Formation. See text for additional discussion.

strongly incurved beneath pedicle beak; lateral margins of valve strongly convex in transverse profile with rather abrupt curvature anterolaterally; anterior margin sharply truncated. Plications similar in form, number to those of opposite valve.

Pedicle valve interior with hinge teeth supported by dental lamellae, extending anteriorly approximately one fourth to one third length of valve. Brachial valve with undivided hinge plate; crural plate supporting hinge plate posteriorly, converging into median septum, enclosing triangular crural cavity in rostral portion, opening anteriorly; median septum continuing anteriorly about same distance as dental lamellae of pedicle valve.

Discussion.--Mather (1915, p. 176) based the original description of *Rhynochopora magnicosta* upon two specimens from the area around Fayetteville, Arkansas. The holotype (UC 16137), herein refigured as pl. 6, figs. 2a-2d, is a badly distorted specimen from the Brentwood Limestone at his station 150 (= ?M117-14). This specimen measures approximately 11 mm by 17.4 mm by 13 mm, and the width of the sulcus at the anterior margin is approximately 11.5 mm. Mather did not figure the second specimen (UC 16576), which was collected from his station 135 (= M102-9). The holotype was refigured by Croneis (1930, pl. 21, figs. 8-10), who reported (p. 84) the species to occur principally in the Brentwood Limestone.

The type locality has not been definitely reestablished but is probably equivalent to M117-14 of this dissertation (see discussion of

Mather's station 150 in Appendix III). The description presented above is based upon 28 exfoliated but largely complete specimens and 34 incomplete specimens from M100-11 near the top of the Brentwood Limestone at its type locality. This collection is the largest available to the author from the Morrow Group. Three of these specimens were serially sectioned, and the description of the internal characters is based upon these.

Several crushed specimens from a fossiliferous shale at M51-15 in the upper part of the limestone-shale member have well preserved surfaces, and ornamentation consists of inconspicuous, finely spaced growth lamellae, noticable only near the anterior margins of the shell. The specimens from other localities are exfoliated and reveal only the coarsely punctate nature of the shells.

One specimen from M51-15 is an almost complete pedicle interior and allows verification of the characters of the pedicle interior described from the serial sections.

Dunbar and Condra (1932, p. 301) redescribed *R. magnicosta*, utilizing material from the Schuchert Collection from the Morrow Group of the Ozark Mountains area and from strata of Morrowan age (Marble Falls Limestone) near San Saba, Texas. They also unfortunately used Schuchert's collections from "near the top of the Strawn of the basal Canyon 3 miles west of Strawn, Texas". These latter strata are upper Desmoinesian or lower Missourian and not Morrowan.

The average specimen in their collections is reported to measure about 15 mm in length by 18 mm in width and to have a thickness of approximately 14 mm. The largest available specimen from the Ozark region is comparable in size to this. It is from the upper part of the limestone shale member (M97-5); the specimen is crushed but was about 15.5 mm long, at least 20 mm in width, and probably 15 to 16 mm in thickness. This is somewhat larger than the typical specimens from the Morrow Group.

Mather (1915) did not describe the internal features of this species. Dunbar and Condra's (1932, p. 301, text-figure 18) illustrations of serial sections through the rostral region were based upon a specimen that they assigned to this species from near the base of the Canyon Group (Missouri Series) near Strawn, Texas, and not from Morrowan material. This author has sectioned several specimens from M100-11 and they are consistant with the internal characters described by Dunbar and Condra.

Dunbar and Condra also stated that the sulcus generally bears between 5 and 7 plications. The specimens from the Brentwood Limestone (M100-11) bear between 5 and 9 plications ($\bar{x}$ = 7.03, M = 7, n = 56); the combined sample from the Chisum Quarry Member and shale "A" member (text-fig. 12) has between 6 and 9 plications in the sulcus ($\bar{x}$ = 7.23, M = 7, n = 31). Statistically, there is no significant difference in the means between the two sets of samples at 95 percent confidence limits. The specimens with more plications in the sulcus tend to be slightly more finely plicate and appear to have a proportionally slightly broader sulcus.

The specimens described as belonging to _R. magnicosta_ from the Atokan equivalents of the Ely Group in Nevada by B. O. Lane (1962, p. 899) may belong to this species, but his illustrations are inadequate.

The only species in the Morrowan strata with which R. magnicosta could be confused is Rhipidomella trapezoida Sutherland and Harlow. Immature specimens of R. magnicosta, before they become geniculate, have the same general subtriangular outline and flattened lateral profile (compare pl. 1, figs. 14a, 14e with pl. 6, figs. 3a, 3b). Both species, in addition, have a somewhat similar radial surface ornamentation, but the costellae of the early growth stages in R. magnicosta increase in size with growth to become plications and do not bifurcate; those on R. trapezoida remain costellae and bifurcate at irregular intervals. In addition, R. magnicosta is coarsely punctate; R. trapezoida has a very finely punctate shell structure.

Rhynchopora magnicosta differs from Rhynchopora illinoisensis (Worthen), widely reported from the Desmoinesian and Missourian strata of the Midcontinent, in being larger, in having coarser plications even in the earlier growth stages, and in the crests of the plications at the anterior margin and commissure forming a more acute angle.

Material and Occurrence.--Rhynchopora magnicosta is one of the most easily recognizable of the Morrowan brachiopod species. The type specimens were collected by Mather from the Brentwood Limestone at his station 150 near Fayetteville (see discussion of this station in Appendix III for additional remarks). The definite range of this species in northwestern Arkansas is from the upper part of the Prairie

Grove Member through the Brentwood Limestone; it has been questionably identified from a single small fragment of an immature specimen at unit M116-7 in the lower Prairie Grove from strata that should correlate with the Idiognathoides noduliferus Zone. R. magnicosta ranges from the lower to middle part of the limestone-shale member through the equivalents of the shale "A" member in northeastern Oklahoma. Its lowest occurrence is at unit M34-1, which is about 5 feet above the base of the Gore Formation. These strata may be equivalent to the Idiognathoides noduliferus Zone, or they may be in the lower part of the Neognathodus bassleri Zone; it is in this geographic area where the lower part of the Gore Formation rests on a pre-Morrowan topographic high and the former conodont zone is locally missing by onlap (see Henry, 1970). This species rarely occurs in strata bearing N. bassleri symmetricus, and its acme was reached during deposition of the strata of the upper part of the limestone-shale member. It occurs rarely in the following collections unless otherwise indicated: HALE FORMATION--Prairie Grove Member: M100-6, M100-7, M116-7(?). BLOYD FORMATION--Brentwood Limestone Member: Mather's Stations 135 and 150 (type locality, 1 specimen), M68-21, M68-25, M70-12 top, M100-11 (62 specimens), M101-19, M105C-10, and M114-12. GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8, M5-13, M5-15, M12-8 Station A, M14-8(?), M14-8 and 9, M22-7, M22-11, M29-4, M31-4, M31-5 top, M33-1, M34-1, M35-4, M36-6A (12 specimens), M37-5, M37-8, M39-6, M48-0A, M49-10 basal 2 feet (11 specimens), M49-10 top, M51-15 (43 specimens, mostly crushed, 1 pedicle interior), M53-3, M64-6, M64-8, M67-17 (?), loc. M76A, M78-38, M78-39, loc. M83A, Loc. M87 (27 specimens plus fragments), M97-5, M97-5 or 6 talus, M97-9, and Loc. M98D. Brewer Bend Member: M60-15 and M98C-7. McCULLY FORMATION--Chisum Quarry Member: M17-15 and 16, M24-14, M26-23 top, M27-13, M28-12, M29-11 base, M33-6 (16 specimens), M34-15 (28 specimens), M37-10, M40-18, M41-15, M42-16 (10 specimens), M42-18, and M61-9.

R. magnicosta occurs rarely in the upper most Morrowan and perhaps the lowest Atokan strata in north-central New Mexico (Sutherland and Harlow, <u>in press</u>); it occurs commonly to abundantly in the Wapanucka Limestone (Morrowan) of southern Oklahoma; and is reported in the Marble Falls Limestone (Morrowan) of Texas. Its reported occurrence in the Atokan strata by B. O. Lane (1962) needs to be confirmed, and the material identified by Dunbar and Condra (1932, from the upper Strawn or lower Canyon Groups in north-central Texas should be examined before extending the range of this species into the lower part of the Missouri Series.

<u>Figured Specimens</u>.--UC 16137(H), OU 7284-7290.

ORDER SPIRIFERIDA

SUBORDER RETZIIDINA

SUPERFAMILY RETZIACEA

FAMILY RETZIIDAE

Genus <u>Hustedia</u> Hall and Clarke, 1893

<u>Hustedia miseri</u> Mather

Pl. 6, figs. 10a-15.

Hustedia miseri Mather, 1915, p. 196, pl. 13, figs. 4-6c.

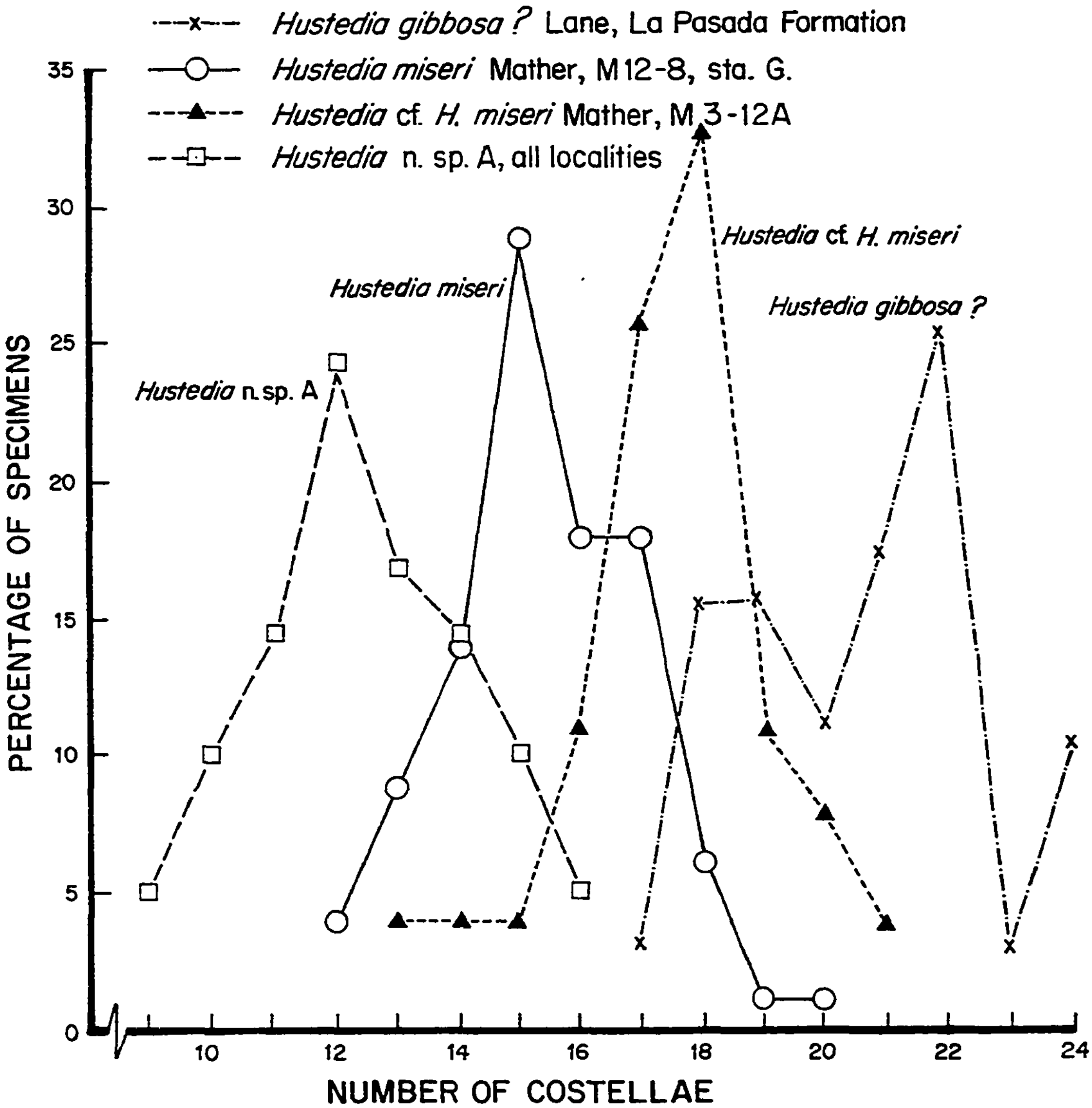
?Hustedia miseri, Plummer and Moore, 1921, p. 45, pl. 6, figs. 19, 20; Morgan, 1924, pl. 43, figs. 2, 2a; Murphy, 1954, p. 26, pl. 2, figs. 1a-1e.

Hustedia brentwoodensis Mather, 1915, p. 195, pl. 13, figs. 1-3c.

Description (Based upon Specimens from M12-8, Station G).--Valves small for genus, subequally, strongly biconvex, suboval, rarely subtriangular shape, with width generally greater than thickness, maximum width slightly anterior to midlength; few specimens slightly gibbous; largest specimen 11.0 mm long, 7.9 mm wide, 8.0 mm thick (see Appendix III for measurements); shell densely punctate.

Pedicle valve gently, almost uniformly convex in longitudinal profile, with almost vertical posterolateral slopes, generally flattened mesially, rarely with broad, extremely gentle, poorly defined sulcus; narrow beak erect to suberect, overhanging hinge generally 1 to 2 mm, with circular foramen up to 1.0 mm in diameter on largest shells; hinge line short; interarea orthocline, crescentic, slightly concave, bearing small symphytium below foramen. Surface characterized by from 12 to 21 strong angular, evenly spaced costellae ($\bar{x}$ = 15.31, M = 15, n = 100, text-figure 13); costellae arising at foramen, extending anteriorly, anterolaterally to margins, tending to flare slightly; concentric ornamentation consisting of fine growth lines, becoming somewhat more prominent near anterior margin.

Brachial valve subtriangular, decreasing slightly in convexity anteriorly, generally more strongly convex than opposite valve; valve



Text-figure 13.--Plot of total number of costellae versus percentage of specimens for Hustedia miseri Mather from upper part of limestone-shale member (M12-8, Sta. G), for specimens of Hustedia cf. H. miseri from Brewer Bend Limestone (M3-12), for Hustedia n. sp. A from McCully Formation, and for H. gibbosa? B. O. Lane from Upper Morrowan part of La Pasada Formation in northern New Mexico (data for latter from Sutherland and Harlow, in press).

generally slightly flattened mesially with steeper lateral slopes; interarea small. Surface ornamentation same as opposite valve.

Pedicle interior bearing stout, flattened teeth; dental lamellae absent. Brachial interior with short, broad median septum; cardinal process bilobate posteriorly, curving slightly ventrally, extending anteriorly for about 1 mm; crura bounding sockets, extending anteriorly as elongated tapering processes, bending slightly ventrally; spiralium with about seven volutions in mature specimens.

Discussion.--Both Hustedia miseri and H. brentwoodensis were typologically defined by Mather (1915, p. 195, 196), and his cotypes for both "species" were collected from the Brentwood Limestone at his station 135 (= M102-9; see discussion of that station in Appendix III for additional remarks). A collection of approximately 150 topotypes was made by this writer; all but five of these are crushed. Four of the five uncrushed specimens are poorly preserved, but they appear to be more like H. miseri; the fifth is like H. brentwoodensis.

The extremely large collections of Hustedia from a thin stratigraphic interval in the upper part of the limestone-shale member (M12-8) reveal an extremely wide range of variation in most morphological attributes (see pl. 6, figs. 10-15), but most of the specimens are similar to Mather's (1915, p. 196, pl. 13, figs. 4-6c) H. miseri. Morphological types closely resembling H. brentwoodensis, in being relatively narrow, in being subtriangular in shape, in having the thickness greater than width, and in bearing fewer and coarser costellae, are present in these larger collections as rarer variants. Complete intergradation between the two morphotypes exists in these collections. The horizon represented is equivalent to the lower part of the Brentwood Limestone and represents is approximately the same horizon as the type locality of H. miseri. Since H. miseri is more typical of these large collections, this name is utilized for this neontologic species in spite of the fact the description of H. brentwoodensis was given first by Mather. It is assumed that a similar gradation would be found at the type locality if large numbers of uncrushed topotypes could be collected.

The 4 cotypes of H. miseri (UC 16152, UC 16238) cannot be found at this time by the Field Museum, but the three cotypes of H. brentwoodensis (UC 16153) have been examined by the author. P. K. Sutherland (personal communication) borrowed the cotypes of H. miseri in 1958 from the Walker Museum, and the following discussion is taken from the notes that he made at the time. Of the 4 cotypes collected by Mather at his station 135, only UC 16152 (Mather's pl. 13, figs. 4-4c) is mature, and it should be designated the lectotype. However, this specimen possesses only 16 costellae (or at most 18), not 20 as stated by Mather (p. 196). Mather's illustrations give a good idea of the size, shape, and surface ornamentation of this specimen, although the costellae do flare slightly at the anterior margin. Two of the remaining cotypes (UC 16238) were figured by Mather. Both (pl. 13, figs. 5 and 6) are slightly enlarged on his plate without being so designated. The former specimen is illustrated at X1.5, the latter at X1.2. Both are immature specimens.

Specimens of the morphological variants represented by the type specimens of both H. miseri and H. brentwoodensis occour throughout the Morrow Group and specimens and at all horizons appear to show much variation. A shift occurs from a predominance of the H. miseri morphotype in the Lower Morrowan to a greater percentage of the H. brentwoodensis type in the Upper Morrowan. A stratigraphic separation into two species appears reasonable based on a shift in the mean of variation as represented by the change in the relative percentages of the two morphotypes in the collections; this separation is approximately correspondant with the Gore-McCully boundary in Oklahoma. Mather's species name H. miseri is available for the Lower Morrowan species, but, regretfully, the name H. brentwoodensis is not available for the Upper Morrowan species, since Mather's type specimens for that form are from the same locality in the Lower Morrowan as H. miseri. In this dissertation, the Upper Morrowan species is described as Hustedia n. sp. A.

A single collection from the Brewer Bend Limestone (M3-12) and two collections from the Brentwood Limestone (M100-9 and M101-17) are identified as Hustedia cf. H. miseri since they are composed of individuals tending to be more finely costellate than those from the upper part of the limestone-shale member, which were used in the description for this species. These specimens are generally slightly more elongated than H. miseri and tend to be slightly more gibbous; this collection is characterized by a predominance of individuals like the variant figured as pl. 5, fig. 15. The collection of Hustedia cf. H. miseri from M3-12 has a range in number of costellae from 13 to 22

(M = 18, $\bar{x}$ = 17.78); H. miseri from M12-8 from 12 to 20 (text-figure 13; M = 15, $\bar{x}$ = 15.31). Statistically, a significant difference exists between the collections from M12-8 and M3-12 for the number of costellae at 98 percent confidence limits.

The material identified as Hustedia cf. H. miseri from M3-12, M100-9, and M101-16 is immediate between H. miseri and the collections tentatively identified by Sutherland and Harlow (in press) from the Upper Morrowan part of the La Pasada Formation in north-central New Mexico. The New Mexican collections (text-figure 13) have a range between 17 and 24 costellae (M = 22, $\bar{x}$ = 20.6), and a statistically significant difference exists between these two sets of collections at 95 percent confidence limits.

The collections from the Chisum Quarry Member are generally more coarsely costellate than those described for M12-8 in the upper part of the limestone-shale member. The "average" specimen from the Chisum Quarry Member is generally intermediate between the typical H. miseri (as described from unit M12-8) and Hustedia n. sp. A, but somewhat closer to H. miseri. In the few larger collections from this interval, a wide range of variability is evident. These collections are referred to as Hustedia cf. H. miseri.

Hustedia n. sp. A from the Upper Morrow Group has a range in number of costellae between 9 and 16 (text-figure 13; M = 12, $\bar{x}$ = 12.10), and a statistically significant difference at 98 percent confidence limits is calculated between the mean number of costellae for this species and for H. miseri from M12-8.

The specimens that Sturgeon and Hoare (1963, p. 45, pl. 10, fig. 13) identified as *H. miseri* from the lower Mercer unit (Lower Desmoinesian equivalents of the Pottsville Series) should be reexamined before this species is extended upward into the Lower Desmoinesian. The current investigation suggests strongly that *H. miseri* is restricted to the Lower Morrowan.

H. miseri has been reported from the Wapanucka Formation of southern Oklahoma (Morgan, 1924). Variants typical of both *H. miseri* and *Hustedia* n. sp. A appear to occur in the OU collections from the Wapanucka, but the collections have not been evaluated in detail. The specimens figured by Plummer and Moore (1921) from the Marble Falls Limestone of Texas appear to be similar to *H. miseri* but collections from that formation have not been examined; the same is true for the specimens identified as *H. miseri* by Murphy (1954) from the lower part of the Oquirrh (Morrowan) of north-central Utah.

Material and Occurrence.--*Hustedia miseri*, as redefined above, is one of the most widely distributed and commonly occurring species in the lower part of the Morrow Group. An estimated 5000 specimens are present in the collections at hand. It is particularly common in the calcareous shales of the upper part of the limestone-shale member in northeastern Oklahoma.

Mather (1915) reported the typologically defined species to occur in the Hale Formation (throughout strata now assigned to the Prairie Grove Member), the Brentwood Limestone, and the Kessler

Limestone. However, consistant with the discussion in the preceeding section, H. miseri is restricted in this study to strata no higher than the upper part of the Brentwood Limestone and to the Gore Formation in northeastern Oklahoma. The forms that Mather reported from the Kessler Limestone may be referrable to Hustedia n. sp. A.

Hustedia miseri occurs rarely to commonly in the following collections, unless otherwise indicated: GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8, M3-9, M3-10, M5-13, M12-8 Stations A, B, C, G, and I (approximately 4000 specimens), M22-11, M23-4, M24-10, M26-1, M26-9, M29-1, M29-4, M31-4, M36-6A, M37-5, M39-6, M40-12, M40-15, M42-6, M42-7, M48-0A, M49-10 middle, M51-7 (25 to 26 feet above base), M51-15, M53-3, M61-1 base, M64-8, M64-11, M67-9, loc. M76A, M78-38, M79-6 (basal 1 foot), loc. M83A, M95-3, M95-5, M97-5 (154 specimens), M97-8, M97-9, and loc. M98D. Brewer Bend Limestone: M3-12A (cf.; 53 specimens), M3-12B, M3-12C, M5-15, M24-12, M33-4C, M39-7, M39-14 (top), M40-17, M95-7, M97-11, and M98C-7. McCULLY FORMATION--Chisum Quarry Member: M17-13(cf.), M26-23(cf.), M27-14(cf.; top), M28-11(cf.), and M40-18A(cf.). HALE FORMATION--Prairie Grove Member: M69-13, M100-6, M107-15, M116-8, M116-16, M117-2, M117-3, M117-11, and M118-8. BLOYD FORMATION--Brentwood Limestone Member: M68-17, M68-21, M69-19, M70-12, M70-13, M100-9(cf.), M101-16(cf.), M102-9 (type locality), M105C-6, M113-4(?), and M114-12.

Figured and Catalogued Specimens.--OU 7291-7296; OU 7334 (topotypes, 150 specimens).

Hustedia n. sp. A

Pl. 6, figs. 16a-20.

?*Hustedia brentwoodensis*, Morgan (not Mather), 1924, pl. 43, figs. 1, 1a.

Hustedia miseri, Croneis (not Mather), 1930, p. 86, pl. 22, figs. 18-20.

Description (Based upon All Specimens from Upper Morrow Group).--Valves small for genus, almost equally biconvex, distinctly elongated, subtriangular to subspatulate shape, with almost straight anterior margin, with maximum width from midlength to anterior margin, thickness greater than width, maximum thickness approximately at midlength, largest specimen measuring 10.7 mm long, 6.5 mm wide, 7.1 mm thick (for additional measurements, see Appendix IV). Shell structure densely punctate.

Pedicle valve almost uniformly convex in longitudinal profile, generally flattened mesially, rarely with broad, gentle, poorly defined sulcus; lateral slopes steep, generally breaking sharply from mesial portion of valve, almost vertical on some specimens; beak narrow, tapering, suberect to almost straight, slightly overhanging hinge with small, circular foramen; hinge line short, straight, with slightly crescentic, orthocline interarea. Radial ornamentation consisting of from 9 to 16 strong, angular costellae ($\bar{x}$ = 12.10, M = 12, n = 41; text-figure 13), arising at foramen, flaring very slightly anteriorly, anterolaterally, becoming more pronounced; intercostal grooves flattened; generally with only from 4 to 6 costellae on flattened to gently sulcate venter; concentric ornamentation of fine, faint growth lines.

Brachial valve subtriangular, almost as convex as pedicle valve, lateral slopes not as steep, mesial portion tending to be gently convex in transverse profile; beak very small, incurved beneath that of opposite valve; interarea very small, short. Surface ornamentation like that of opposite valve.

Interiors unknown.

Discussion.--The narrow, subtriangular, elongated forms typified by *Hustedia brentwoodensis*, as typologically defined by Mather (1915, p. 195) become progressively more prominent in collections from the Upper Morrowan in the Ozark Mountains region, as mentioned in the discussion of *H. miseri*. Collections from the higher units in the McCully Formation and from the Kessler Limestone also contain rare variants reminescent of *H. miseri*. Mather's name *H. brentwoodensis* is not available for the species from the Upper Morrowan, herein referred to as *Hustedia* n. sp. A, since its type specimens come from the same locality in the lower Brentwood Limestone as the types of *H. miseri*, in the lower part of the Brentwood Limestone (see discussion of *H. miseri*). The collection of 14 specimens from unit M30-6 in the shale "A" member forms the reference collection for *Hustedia* n. sp. A. Material from M42-16 in the upper part of the underlying Chisum Quarry Member serves as supplemental material.

Hustedia n. sp. A is characterized by a mode of 12 costellae ($\bar{x}$ = 12.10) with a range from 9 to 16 costellae (text-figure 13); *H.*

miseri, as redefined, by a mode of 15 costellae ($\bar{x}$ = 15.31, r = 12 to 21). A statistically significant difference between the means of costellae for the two species is calculated at 98 percent confidence limits. Hustedia n. sp. A also tends to be distinctly more elongate, subtriangular in shape, has a thickness greater than maximum width, is much narrower, and has a suberect to nearly straight beak. The beak of H. miseri is typically suberect to erect.

The specimen figured by Croneis (1930, pl. 22, figs. 18-20) as H. miseri and reported to come from the Kessler Limestone is tentatively assigned to Hustedia n. sp. A as is the specimen figured by Morgan (1924, pl. 43, figs. 1, 1a) as H. brentwoodensis from the upper part of the Wapanucka Formation (Morrowan) of southern Oklahoma. The OU collections from the Wapanucka have both morphological types present in them, but the majority of the specimens are of the elongated types typical of Hustedia n. sp. A.

The specimens identified as H. gibbosa? B. O. Lane by Sutherland and Harlow (in press) from the Upper Morrowan portion of the La Pasada Formation in north-central New Mexico differ from Hustedia n. sp. A in being broader, less elongate, suboval in shape, and by having more numerous, weaker costellae. The beaks of these specimens are suberect to erect, and this species is morphologically more similar to H. miseri.

Material and Occurrence.--Eighty-eight specimens of Hustedia n. sp. A have been collected from the upper part of the Morrow Group. This species occurs rarely in the following collections, unless otherwise noted: McCULLY FORMATION—Chisum Quarry Member: M24-14, M42-15, and M42-16 (10 specimens). Shale "A" member: M30-6 (15 specimens), M36-10B (15 feet above base), and M48-13 (13 specimens). Greenleaf Limestone: M1-20 (10 specimens), M27-16 (top), M51-25 (3 feet above base, 11 specimens), M60-21(?), and M98-13(?). BLOYD FORMATION--Dye Shale Member ("caprock"): M104B-19. Kessler Limestone: M69-27B, M105D-13, M105D-15, M108-20, and M118-20.

Figured Specimens.--OU 7297-7301.

SUBORDER ATHYRIDIDINA

SUPERFAMILY ATHYRIDACEA

FAMILY ATHYRIDIDAE

SUBFAMILY ATHYRIDINAE

Genus *Composita* Brown, 1849

Discussion.--The genus *Composita* is one of the most long-ranging, most commonly occurring, and geographically most widespread of the Upper Paleozoic brachiopods. It has been reported from strata of the Lower Mississippian (Kinderhookian) through the upper Permian (Guadalupian) in North America. Morphologically, it has a simple external from, the only surface ornamentation being fine growth lines; interiors are rarely available since the hinge teeth are strong and the valves rarely disarticulated. Consequently, most of the species that have been described have been typologically defined with little regard for morphologic variation inherent in any large collection from a single locality.

Mather (1915, p. 198-206) described seven species of Composita from the Morrow Group: C. ozarkana, C. ovata, C. deflecta, C. gibbosa, C. biplicata, C. transversa, and C. wasatchensis. Of these seven species, only the latter had been previously described (White, 1874). Sutherland and Harlow (in press) recognized three of these (C. gibbosa, C. deflecta, and C. "ovata") as distinct, neontological species in their studies of the Upper Morrowan portion of the La Pasada Formation in north-central New Mexico.

Mather's (1915, p. 198-206) typological descriptions of each species is in no instance based upon more than four specimens. Several of the primary types are among the specimens that cannot be found by the Field Museum at this time. This writer was able to reestablish only one type locality, that of C. ozarkana, but only a small collection of potential topotypes (OU 7335) was made in spite of extensive collecting. Consequently, an analysis of Mather's species is not attempted in this dissertation. As a preliminary note based upon a cursory examination of collections from the Ozark Mountains region, it would appear that the three species distinguished by Sutherland and Harlow (in press) are also distinguishable in the Morrow Group. It also appears probable that C. ozarkana and C. biplicata are valid species. The former appears to be more characteristic of the Lower Morrowan, and C. biplicata may be restricted stratigraphically to the upper part of the limestone-shale member and to the Brentwood Limestone.

Several of the species of Composita may be restricted to the

Morrow Series. Grinnell and Andrews (1962, p. 234) stated that of the seven species described by Mather, only C. ovata occurs in younger strata, and only C. wasatchensis has been identified from strata older than Morrowan. Sutherland and Harlow (in press) confirmed that only C. ovata occurs both in the Morrowan and Atokan Series of northern New Mexico.

Genus Cleiothyridina Buckman, 1906

Cleiothyridina milleri Sutherland and Harlow

Pl. 6, figs. 21a-21d.

Spirigera planosulcata, White (not Phillips), 1877, p. 143, pl. 10, figs. 5a-5d.

Cleiothyridina orbicularis, Murphy (not McChesney), 1954, p. 41, pl. 4, figs. 1a-1d.

Cleiothyridina milleri Sutherland and Harlow, in press, pl. 14, figs. 28-30.

Discussion.--Cleiothyridina milleri was initially described by Sutherland and Harlow (in press) from the Upper Morrowan portion of the La Pasada Formation in north-central New Mexico. It is characterized by a transversely subelliptical outline, equally convex valves, and relative thinness. Surface ornamentation is distinctive and consists of concentric lamellae, averaging 2 to 3 per millimeter, and flattened, prostrate spines set along these raised lamellae.

The author has examined Sutherland and Harlow's collections of this species. The specimens from the Morrow Group in the Ozark Mountains region are generally somewhat smaller than those from New Mexico, and the few uncrushed specimens assigned to this species from the former area have a slight suggestion of a sulcus. The largest specimen from the Morrow group is from M51-15; it is crushed and measures 11.2 mm in length by 14.0 mm in width. The figured specimen (pl. 6, figs. 21a-21d) measures 7.8 mm long, 9.6 mm wide, and 5.5 mm thick. This specimen is proportionally somewhat thicker than typical for the species. Two other complete and uncrushed specimens measure 9.0 mm by 9.6 mm by 4.8 mm and 8.4 mm by 9.0 mm b6 4.7 mm, respectively.

Composita transversa Mather superficially resembles C. milleri and Mather's (1915, pl. 14, figs. 4-4c) figures of the former species do not make a clear distinction possible. The author has, however, examined the holotype of C. transversa Mather (UC 16151), and this specimen is definately a Composita. It lacks the somewhat elevated growth lamellae reported by Mather (p. 206) and is more gibbous than Cl. milleri.

Cleiothyridina milleri differs from Cleiothyridina pecosii (Marcou) [= Cl. orbicularis (McChesney)], a geographically widespread species from the middle and upper parts of the Pennsylvanian System in the Midcontinent, in being more transverse and comparatively thinner, and by having more widely spaced growth lamellae. Sutherland and Harlow (in press) noted the presence of specimens transitional between the two species in the Atokan portion of the La Pasada Formation.

Material and Occurrence.--The type specimens are from the Upper Morrowan portions of the La Pasada Formation of northern New Mexico

(Sutherland and Harlow, *in press*). This species has also been identified from the lower portion of the Oquirrh Formation (Morrowan) in north-central Utah (Murphy, 1954).

Cleiothyridina milleri occurs rarely in the Morrow Group; approximately 35 specimens are present in the collections from the Ozark region. It is recorded in northwestern Arkansas only from the Brentwood Limestone at M114-12, and it ranges in northeastern Oklahoma from the lower part of the limestone-shale member (*Neognathodus bassleri* Zone) through the Chisum Quarry Member. It occurs rarely in the following collections, unless otherwise indicated: GORE FORMATION--limestone-shale member: M1-6, M26-9, M39-4, M51-15 (14 specimens), loc. M76A, M95-5, and M97-5. McCULLY FORMATION--Chisum Quarry Member: M26-23.

Figured Specimen.--OU 7302.

SUBORDER SPIRIFERIDINA

SUPERFAMILY SPIRIFERACEA

FAMILY SPIRIFERIDAE

Genus *Spirifer* Sowerby, 1816

Discussion.--Sutherland and Harlow (*in press*) have discussed the recent practice of restricting the usage of the name *Spirifer* to large, transverse Spiriferidae characterized by numerous bifurcating costae in both the sulcus and on the flanks of the valve. Such forms, presumably similar to those of the type species of *S. striatus* (Martin) from Great Britain, are common in Lower Carboniferous and Mississippian strata.

Neospirifer differs from Spirifer (s.s.) primarily in being rather strongly fasciculate. Spirifer goreii Mather, from the Morrow Series, forms the youngest North American species assigned to the genus Spirifer. It is most probably the immediate ancestor of Neospirifer cameratus (Morton) from the Atoka and Lower Desmoines Series (see Sutherland and Harlow, in press).

Anthracospirifer differs from Spirifer (s.s.) by having many fewer, stronger, simple lateral costae and by being generally smaller in size.

Spirifer goreii Mather

Pl. 7, figs. 4-11.

Spirifer goreii Mather, 1915, p. 186, pl. 12, figs. 10-11a; Morgan, 1924, pl. 45, figs. 4, 4a; Sutherland and Harlow, in press, pl. 15, figs. 1-4.

Neospirifer goreii, Dunbar and Condra, 1932, p. 341, pl. 39, fig. 3 (? figs. 1, 2); Plummer, 1950, pl. 12, figs. 4a, 4b.

Description (Based upon Specimens from All Localities in Lower Morrowan Group).--Shell large, subequally biconvex, strongly transverse, with mature specimens having maximum length about two-thirds maximum width; greatest width at hinge line; large specimen, in part restored, measuring 30 mm long, 56 mm wide, about 25 mm thickness (for additional measurements, see Appendix IV).

Pedicle valve characterized by moderate to low, uniform convexity; beak comparatively small, narrow, slightly incurved over delthyrium; umbo weakly inflated; posterolateral portion of valve not distinctly set off from umbo, generally with only slightly extended alae on most mature specimens; lateral margins meeting slightly curved posterior margin commonly from 80 to 85 degrees; lateral, anterior margins smooth, uniformly subelliptical; subrounded sulcus originating near beak, bounded laterally by well defined, subangular to subrounded P-costae, diverging from beak commonly at about 20 to 25 degrees, flaring somewhat anteriorly, continuing to anterior margin, deepening slightly; interarea well defined, moderate to low apsacline, gently concave transversely, vertically striated, about one-ninth to one-tenth as high as wide; apex of delthyrium approaching 60 degrees, bearing scars for deltidial plates. Surface ornamentation consisting of fine radial capillae, radial costae; capillae equally spaced, numbering about 11 to 14 per costa near anterior past of valve; sulcus bearing between 6 to 13 ($\bar{x}$ = 9.8, M = 10) subrounded to flattened costae on mature specimens; most specimens bearing between 7 to 10; M-costa originating within 10 mm of beak, bifurcating on 15 to 30 specimens studied at surface lengths varying from 18 to 25 mm; A-costae invariably arising from P-costae bounding sulcus within 8 mm SL; most common sulcal pattern (see table 3; text-figure 14) PCBAa,mm,aABCP on 6 of 30 valves studied; 18 of 30 specimens with symmetrical sulcal pattern; no specimen with costal pattern same on both lateral slopes; each slope commonly with from 17 to 23 subrounded costae becoming progressively fainter laterally, becoming obsolete on lateral extremitites; P-costa bounding sulcus

	Sulcal formula	Total specimens
Symmetrical:	PBAa,M,aABP	3 specimens
	PBAa,mm,aABP	1 specimen
	PCBA,M,ABCP	1 specimen
	PCBAa,M,aABCP	3 specimens
	PCBAa,mm,aABCP	6 specimens, text-figure 14A.
	PDCBAa,M,aABCDP	1 specimen
	PDCBAa,mm,aABCDP	2 specimens
	PEDCBAa,M,aABCDEP	1 specimen
Asymmetrical:	PBAa,M,ABP	1 specimen
	PBAa,M,aABCP	1 specimen
	PCBAa,M,ABCP	1 specimen
	PCBAa,mm,aA,aBCDP	1 specimen
	PCBa,Aa,M,aABCP	2 specimens
	PCBa,Aa,mm,aA,ABCDP	1 specimen
	PDCBA,M,ABCP	1 specimen
	PDCBA,mm,aABCDP	1 specimen
	PDCBAa,mm,aABCP	1 specimen
	PDCBAa,mm,aA,aBCDP	1 specimen
	PDCBa,Aa,mm,aA,aBCP	1 specimen, text-figure 14B.

Table 3.--Sulcal bifurcation formulae for 30 mature specimens of *Spirifer goreii* Mather from type locality (units M97-5, M97-9, and loc. M98A) and from units M1-5, M1-6, M5-13, M19-5, M27-13, M36-6B, M42-15 & 16, M42-18, M48-15, M85-8, M98-13, M99-2, and M120-12. The notational system is that of Sutherland and Harlow (1967, p. 1081).

generally bifurcating once or twice; first secondary costa thus produced rarely rebifurcating; several of next 3 to 5 primary lateral costae bifurcating at irregular surface lengths from beak once or twise; next 1 to 2 primary lateral costae bifurcating generally only once; remainder of lateral primary costae simple; genetic groups of costae evenly developed with respect to height, strength, characteristically non-fasciculate.

Brachial valve less convex than pedicle; posterolateral portion generally slightly concave to flattened; beak inconspicuous, only slightly extended, slightly incurved beneath that of opposite valve; interarea slightly concave, apparently anacline; characterized by low mesial fold originating on umbo, extending to anterior margin, distinctly set off from extremities by grooves corresponding to P-costae bounding sulcus on opposite valve, becoming slightly higher, more arched, smoothly rounded at margin.

Pedicle valve interior with generally deeply impressed muscle scars; latter highly variable in size, shape, generally slightly elongate suboval, rarely elongate suboval, subcircular, tear-shaped, subtriangular; posterior part of muscle scars more deeply impressed, with floor rising anteriorly; adductor scars forming narrow, linear mesial region separated from each other on small percentage of specimens by narrow, shallow groove, separated laterally from diductor scars by narrow ridges, not enclosed anteriorly by diductor scars; latter generally longitudinal striae; short, stout teeth supported by short dental plates, generally extending to posterolateral margin of muscle scars as curving supports, forming concave area on lateral sides of plates; few loops of spiralia preserved on small number of specimens. Interior ornamentation generally of weak, radial grooves, seemingly unrelated to external ornamentation near muscle field, other specimens with numerous, densely spaced pits particularly concentrated near posterior portion of valve; margins reflecting external costae.

Brachial valve interior with subtriangular cardinal process, consisting of anterodorsally sloping, grooved plate; dental sockets well developed, rather shallow, unsupported dorsally; posterior diductor scars gently impressed, separated by weak, very low median septum; anterior diductor scars elongated, diverging, slightly depressed, poorly defined; ornamentation consisting of faint costae, grooves related to external ornamentation.

Discussion.--*Spirifer goreii* was initially described by Mather (1915, p. 186, pl. 12, figs. 10-11a) from the Morrow Group in northeastern Oklahoma at his station 304 (see discussion of that station in Appendix III for additional remarks). Specimens herein considered to be topotypes have been collected from units M97-5 through M97-9 and from loc. M98D in the upper part of the limestone-shale member of the Gore Formation in the large quarry approximately 0.75 mile southeast of the approximate location of Mather's station 304. This collection contains 11 almost complete, crushed specimens, about 18 fragments of pedicle interiors, about 12 poor fragmentary brachial interiors, and numerous fragments.

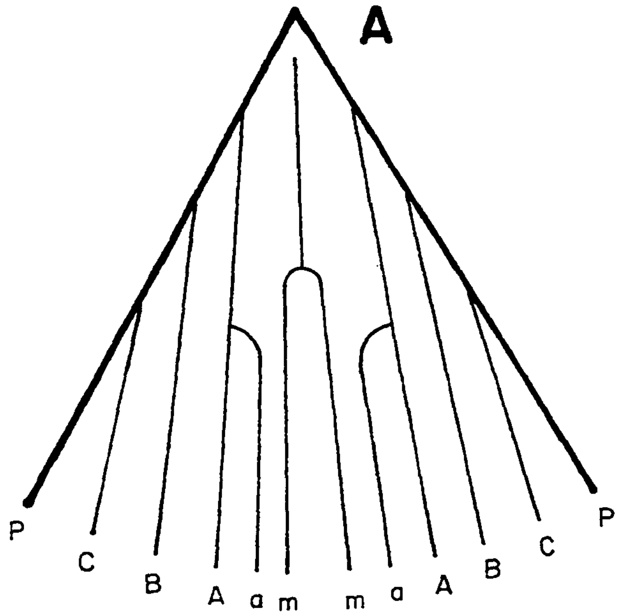
The holotype and the allotype (UC 16144) of *S. goreii* are refigured as pl. 7, fig. 4 and fig. 5, respectively); the former is a badly exfoliated incomplete pedicle valve, the latter an incomplete, also badly exfoliated brachial valve. The bifurcation pattern on the left side of the sulcus is PCBAa,mm---; the remainder of the sulcus is too poorly preserved to determine the bifurcation pattern.

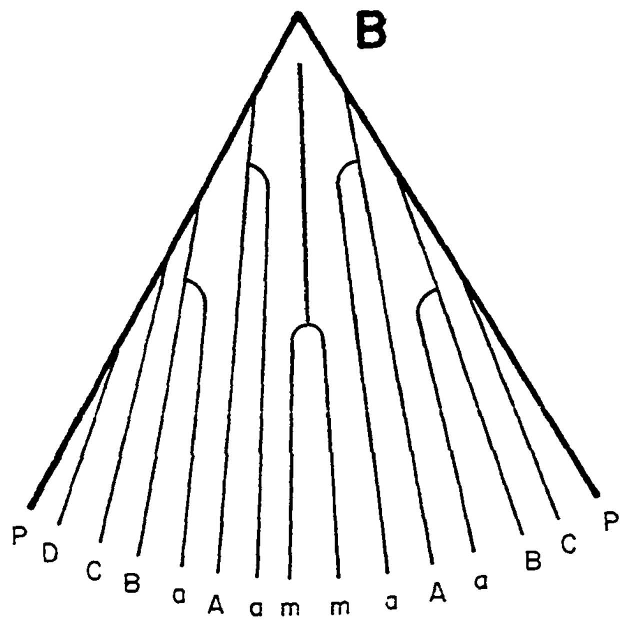
Considerable variation has been observed in the pattern of costal bifurcation in the sulcus. The basic pattern (table 3, text-figure 14A) is symmetrical and is PCBAa,mm,aABCP; this is also the most common sulcal bifurcation pattern for collections of this species from the La Pasada Formation in north-central New Mexico (Sutherland and Harlow, *in press*) and from the Wapanucka collections from south-central Oklahoma. One of the more complicated patterns is depicted as text-figure 14B. No two lateral flanks studied on *S. goreii* are alike; one pattern of lateral bifurcation is shown in text-figure 15.

The material from northern New Mexico and collections of this species from the Wapanucka Formation (Morrowan) of south-central Oklahoma are closely similar to that in the Morrow Group.

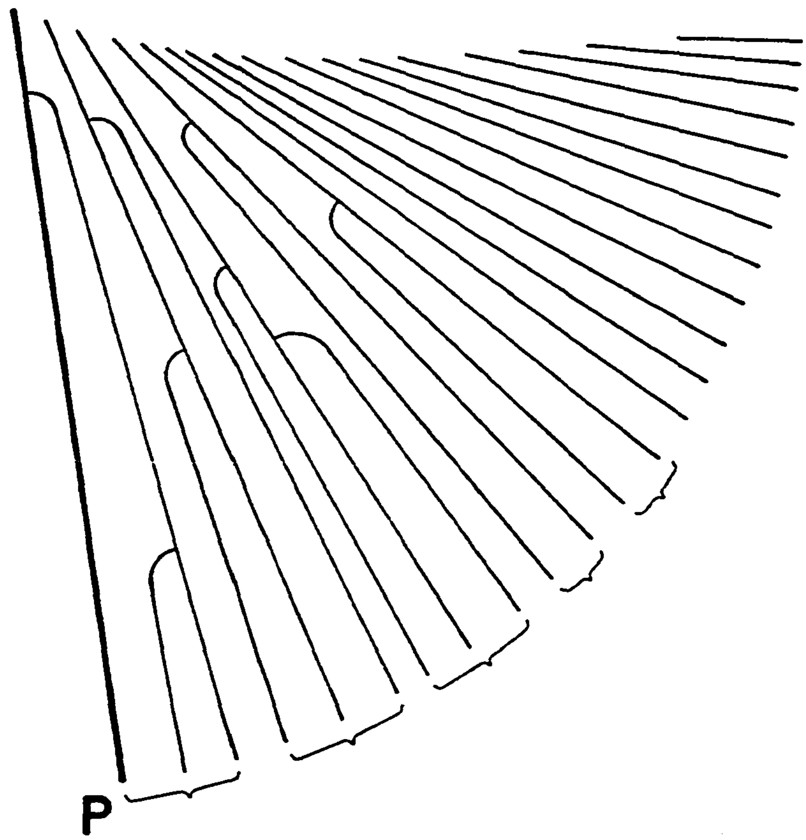
Spirifer goreii differs from *Neospirifer cameratus* (Morton), which occurs in the Atoka and Lower Desmoines Series, primarily in the almost complete absence of fasciculation and in having a much more irregular pattern of bifurcation on the lateral flanks (see Sutherland and Harlow, *in press*). Only rarely is a specimen of *S. goreii* slightly fasciculate on the flanks of the umbo; such specimens are restricted to the higher Morrowan strata. None of these specimens become as coarsely fasciculate as *N. cameratus*.

Material and Occurrence.--Collections of this species rarely





Text-figure 14.--Selected sulcal bifurcation patterns for *Spirifer goreii* Mather. (A). One of the more common symmetrical sulcal patterns. (B). One of the asymmetrical patterns with 13 costae in sulcus.



Text-figure 15.--One example of lateral bifurcation of costae for *Spirifer goreii* Mather; specimen from Greenleaf Limestone Member at unit M98-13.

contain complete or uncrushed specimens because of the extremely thin shell for the size of the specimens and because the mode of articulation allows easy separation of the valves upon death. No complete, uncrushed, mature specimen is present in these collections. Approximately one-third of the specimens are posterior parts of the pedicle valve, revealing the interior of that valve; only about 15 fragmentary brachial interiors are present. Of the 1100 specimens in the collections at hand, approximately 800 are from the Gore Formation (particularly from the upper part of the limestone-shale member), and about 275 are from the McCully Formation. This species is extremely rare in the collections from northwestern Arkansas, reflecting the dirth of mud-supported carbonates and calcareous shales in that area.

The range of _S. goreii_ in northeastern Oklahoma is from the lower to middle part of the Gore Formation (lower part of the _Neognathodus bassleri_ Zone) through the Greenleaf Limestone. This species definitely occurs in strata ranging from the Brentwood Limestone through the Kessler Limestone in northwestern Arkansas. Mather's (1915, p. 187) report of this species occurring at his station 136 (= M103-14) in the lower part of the Prairie Grove Member (_Idiognathoides noduliferus_ Zone) is highly questionable because this writer has extensively recollected this station and equivalent strata in the area and has not recovered _S. goreii_. A fragment of an _Anthracospirifer matheri_ (Dunbar and Condra) could be misidentified as _S. goreii_.

This species occurs rarely to commonly in the following collections unless otherwise indicated: GORE FORMATION--limestone-shale member: M1-2 (base), M1-5 (65 specimens), M1-6 (148 specimens), M3-9, M5-13 (90 specimens), M5-15, M22-7, M22-11, M23-4, M25-11, M26-9, M26-17, M35-4, M40-10 (top), M48-0A, M49-10 (middle), M49-10 (top), M51-7 (top), M51-15 (103 specimens), M51-16, M60-16, M64-8 (top), loc. M83A, M97-5 through 9 (type locality, 105 specimens), and loc. M98D (type locality, 31 specimens). Brewer Bend Limestone: M36-6B, M98B-2, and M98C-7. McCULLY FORMATION--Chisum Quarry Member: M19-5, M26-23, M27-13 (base), M27-14 (top), M28-10, M28-11 (top), M33-6 (about 100 specimens), M35-8, M42-15 & 16, M42-18, M61-9, and M98-11. Shale "A" Member: M29-14, M48-13, and M48-15. Greenleaf Limestone Member: M1-18, M1-19, M1-20, M27-16 (base), M27-16 (top), M28-14 (base), M28-14 (top), M30-8, M33-11, M35-11, M98-13, and M99-2. BLOYD FORMATION--Brentwood Limestone: M68-21, M68-25, M70-15 (basal 1 foot), M105C-10, M114-12, M120-4. Dye Shale Member ("caprock"): M120-12. Kessler Limestone Member: M104B-23 and M118-18. Trace Creek Shale: M69-31. Mather also reported this species from the Kessler Limestone at his Station 209 (= M115-2).

Spirifer goreii occurs commonly in the Wapanucka Limestone (Morrowan) of southern Oklahoma and in the lower part of the La Pasada Formation (Upper Morrowan) of north-central New Mexico. It is also reported from the Marble Falls Limestone (Morrowan) of north-central Texas. It would appear that this species is restricted to the Morrow Series, contrary to opinions expressed by a number of writers (Dunbar and Condra, 1932; Hoare, 1961; Spencer, 1967; Sturgeon and Hoare, 1968).

Figured and Catalogued Specimens.--UC 16144 (holotype and allotype), OU 7307-7312; OU 7336 (105 topotypes, M97-5 through 9), OU 7337 (31 topotypes, loc. M98D).

Genus *Anthracospirifer* N. G. Lane, 1963

Discussion.--N. G. Lane (1963, p. 347) proposed the genus *Anthracospirifer* for small to medium sized, nonmucronate Spiriferidae characterized by a small number of strong, mostly simple lateral and sulcal plicae and internally by well developed dental plates. Lane's species, *A. birdspringensis*, described from the Morrowan portion of the Bird Spring Formation in southern Nevada, was selected as the type species.

Brachythyrina Fredricks (1929), *Unispirifer* Campbell (1957), and *Sergospirifer* Ivanova (1952) are closely similar to *Anthracospirifer*. Lane's genus differs from *Brachythyrina* only in lacking dental plates that descend to the floor of the pedicle valve, and *Unispirifer* is said to be larger, more distinctly transverse, and to have more lateral plicae than *Anthracospirifer*. *Anthracospirifer* may be a junior synonym of *Sergospirifer*, originally described from the Upper Carboniferous of the Soviet Union.

A relatively large number of Mississippian and Pennsylvanian spriferids from North America have been assigned to *Anthracospirifer* (see Sutherland and Harlow, *in press*). Two species from the Morrow Group are placed in this genus. They are *A. curvilateralis* (Easton) and *A. matheri* (Dunbar and Condra). Additional study may demonstrate that *A. birdspringensis* is a junior synonym of *A. matheri*.

Anthracospirifer matheri (Dunbar and Condra)

Pl. 6, figs. 22a-22d; pl. 7, figs. 1a-1c.

Spirifer rockymontanus, Mather (not Marcou), 1915, p. 181, pl. 12, figs. 1-6.

?*Spirifer opimus*, Mather (not Hall), 1915, p. 185, pl. 12, figs. 7-7c; Croneis (not Hall), 1930, pl. 21, figs. 11-13.

Spirifer matheri Dunbar and Condra, 1932, p. 322; Sadlick, 1960, p. 1212.

?*Anthracospirifer birdspringensis* N. G. Lane, 1963, p. 388, pl. 44, figs. 4, 7, 10-18, pl. 45, fig. 3.

Anthracospirifer matheri, Sutherland and Harlow, *in press*, pl. 17, fig. 13.

Description (Based upon Specimens from Selected Localities in Brentwood Limestone).--Shell highly variable, strongly to moderately biconvex, medium size for genus, longitudinal curvature generally greater than maximum width, with maximum width generally at hinge line, less commonly slightly anterior to hinge line; large specimen measuring about 26 mm long, 35 mm wide, estimated 17 mm thick, with surface length of 38 mm (for additional measurements, refer to Appendix IV).

Pedicle valve moderately to strongly convex; beak strongly incurved, suberect to erect, narrow; sulcus generally quite well defined, originating on beak as simple depression between two strong, subangular P-plicae, diverging anteriorly at about 25 to 30 degrees, flaring only slightly generally deepening gradually, rarely sharply;

sulcal floor generally subangular, particularly at commissure, forming angle ranging between about 45 to 70 degrees on mature specimens, with mean angle around 60 degrees; flanks convex with slight flattening, concavity at posterolateral margins; anterior, lateral margins subelliptical to subtriangular; alae very small, only slightly extended; apsaclinal interarea slightly concave, about one-eighth as high as wide, with strong vertical striations, weak horizontal growth lines; delthyrium generally higher than wide, bounded by grooves. Surface ornamentation of strong, subangular, radiating plicae, fine radial capillae on both plicae, interplical grooves, with concentric ornamentation of fine growth lines, forming minute reticulation on better preserved specimens; from 5 to 10 plicae in sulcus ($\bar{x}$ = 5.70, M = 5, n = 23; see table 4 for bifurcation formulae), with A-plicae, M-plicae

Sulcal formula	Total specimens
Symmetrical:	
PBA,M,ABP	15 specimens
PBA,mm,ABP	1 specimen
PBAa,M,aABP	1 specimen
PDCBa,A,A,aBCDP	1 specimen (UC 16139)
Asymmetrical:	
PBAa,M,ABP	1 specimen
PBA,M,ABCP	1 specimen
PBAa,M,ABCP	2 specimens
PCBA,mm,ABP	1 specimen (UC 16140)

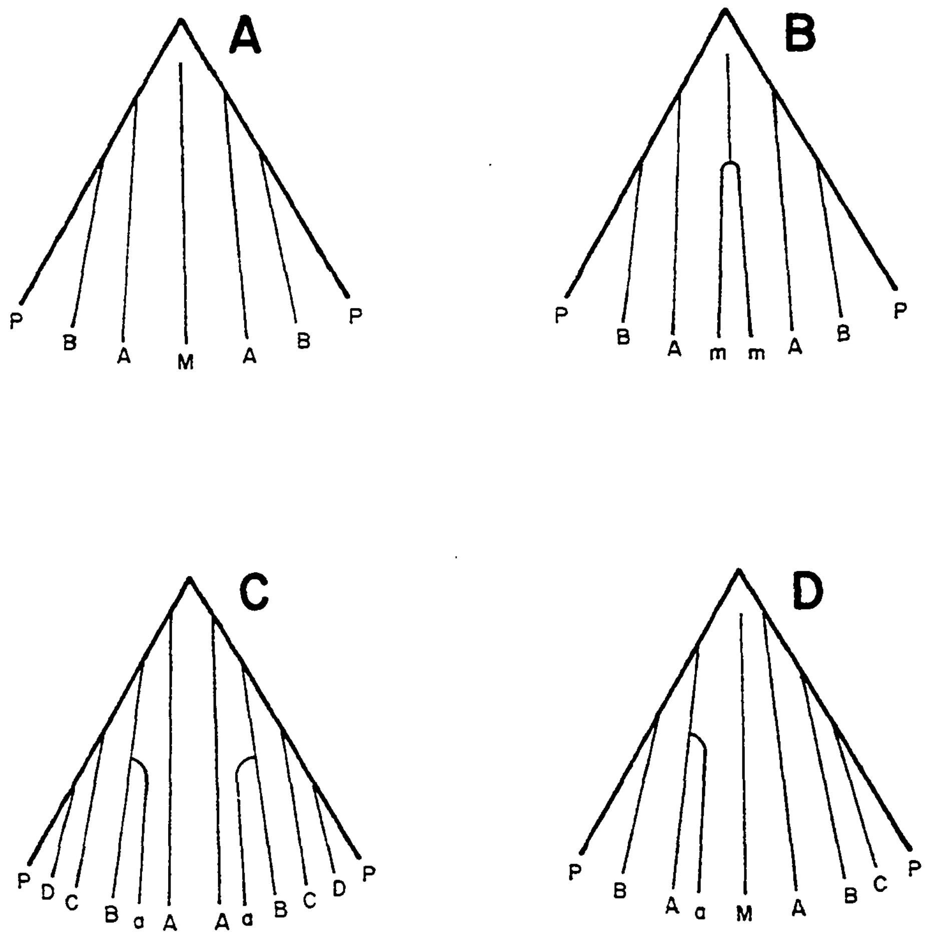
Table 4.--Formulae for bifurcation patterns of plicae in sulcus for 23 specimens of *A. matheri* (Dunbar and Condra) from selected localities in the Brentwood Limestone.

commonly bifurcating (text-figure 16); P-plicae bounding sulcus bifurcating once laterally after formation of A-plicae in sulcus; slopes with lateral bifurcations of at least first lateral primary plicae (text-figure 17) on slightly less than half of specimens studied, 3 of 40 sides studied with bifurcation of both first, second primary lateral plicae; single side with only second primary lateral plica bifurcating; remainder of plicae simple; specimens rarely with symmetrical lateral bifurcation patterns; single specimen with completely simple lateral plicae on one side, bifurcation on other; total number of lateral plicae ranging from 9 to 13 ($\bar{x}$ = 11.23, M = 11, n = 39 sides).

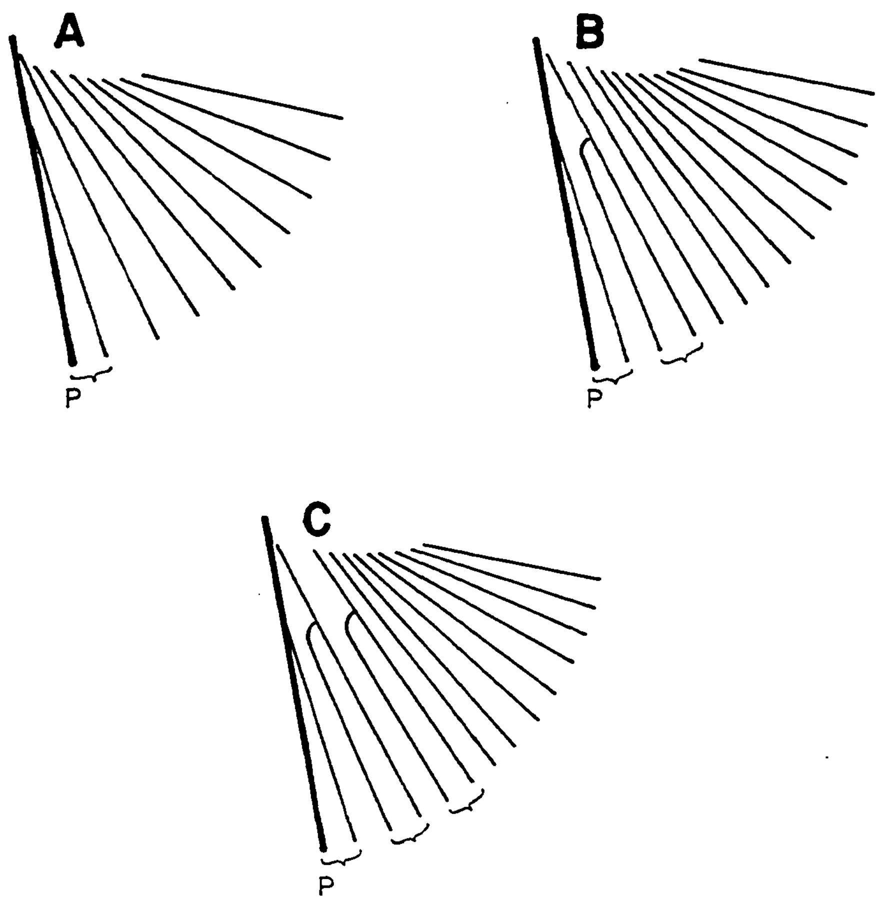
Brachial valve generally slightly less convex than pedicle, with smaller, more closely incurved beak; interarea quite small, apparently almost orthocline; mesial fold generally sharply defined in all growth stages, generally subangular, becoming generally keelate toward anterior margin, bounded by grooves corresponding to P-plicae bounding sulcus on opposite valve; lateral slopes gently convex, becoming gently concave near posterolateral extremities.

Interiors unknown.

Discussion.--Dunbar and Condra (1932, p. 322) proposed the name *Spirifer matheri* for the specimens that Mather (1915, p. 181, pl. 12, figs. 1-6) had identified as *S. rockymontanus* Marcou from the Morrow Group. Sadlick (1960, p. 1212) chose as lectotype the specimen illustrated by Mather as figs. 4-4c on plate 12. Unfortunately, both this specimen and the paratype from the same station (figs. 3-3c) are



Text-figure 16.--Most common sulcal bifurcation patterns for *Anthraco-spirifer matheri* (Dunbar and Condra) from the Brentwood Limestone. See table 3 for relative abundances of each pattern.



Text-figure 17.--Common lateral bifurcation patterns for *Anthracospirifer matheri* (Dunbar and Condra) from the Brentwood Limestone. See text for explanation.

immature specimens and are among those that cannot at this time be found in the Field Museum (UC 16138).

Mather (1915, pl. 12, figs. 1-4c, figured four complete but immature specimens as a part of an ontogentic series, a single large pedicle valve (fig. 5), and a single large brachial valve (fig. 6). In this explanation to plate 12, Mather stated that all of the figured specimens were collected from the "Brentwood limestone, Stations 134 and 135". Golden and Nitecki (1972, p. 227, 228) indicated that Mather's statement is apparently in error; they gave the following summary (the figure references are to Mather's plate 12):

UC 16141, fig. 1, Station 210, Brentwood
UC 16142, fig. 2, Station 136, Prairie Grove
UC 16138, fig. 3, Station 140, Brentwood
UC 16138, fig. 4, Station 140, Brentwood
UC 16139, fig. 5, Station 134, Brentwood
UC 16140, fig. 6, Station 135, Brentwood

Thus, the lectotype and the paratype, both immature specimens, are from Mather's Station 140, which is approximately equivalent to M117-1 of this dissertation. No topotypes were collected by this author (for additional remarks, see discussion of Mather's station 140, Appendix III).

Mather's single mature figured pedicle valve (UC 16139) was examined by the writer. This specimen is disarticulated but has a deep, angular sulcus, and has strong angular plications. On the right flank, the P-plica bounding the sulcus and the first and second primary plications bifurcate; these are succeeded laterally by 5 simple plicae, making a total of 11 lateral plicae. On the left flank, the P-plica and the first and second plicae also bifurcate, but 7 simple plicae are present laterally, making a total of 12 lateral plicae. This specimen tends to be slightly fasciculate, a rare condition. However, the sulcal formula is atypical for the species (PDCBa,A,A,aBCP); it is clear that no M-plica is present; both the median plicae (A-plicae) bifurcate from the P-plicae at about 7 mm SL, immediately anterior to a strong growth line, perhaps marking the site of an early injury.

The large brachial valve that Mather figured (UC 16140, pl. 12, fig. 6) is more typical of the species. The derived sulcal bifurcation formula for this specimen is PCBA,mm,ABP; on the right flank, the P-plica bifurcates as do both the first and second primary lateral plicae; these are followed by 5 simple primary plicae, for a total of 10 lateral plicae. The P-plica on the left flank bifurcates, followed by 11 simple primary lateral plicae, making a total of 12 on the left flank.

The description of this species presented in the preceeding section is based upon these specimens plus specimens from the Brentwood Limestone in the Fayetteville area (M102-9, M110-20, and M116-18) and from the type sections of the Brentwood (M100-11 and M101-19). The latter collections are the largest, but only approximately 100 largely fragmentary, exfoliated specimens are available. It is clear from observation of the collection from M100-11 that this is a highly variable species and seems to be characterized by a high percentage of specimens with lateral plical bifurcations, strong, subangular plicae, a generally strong, rather deep, subangular sulcus, typically a V-shaped commissure, and a strong, somewhat keelate brachial fold. Variants are present in this collection, however, that tend to approach A. curvilateralis in having simple, less angular plicae, a simpler, more regular sulcal bifurcation pattern, a more gentle, more widely divergent, more subrounded sulcus and a less strongly developed, non-keelate fold.

Some of the specimens from the uppermost Prairie Grove (M100-5 and M101-6) are somewhat more transverse than observed from the Brentwood collections. These specimens have slightly extended alae, and one specimen has PBA,mmm,ABP as a sulcal bifurcation pattern. Specimens from units M111-14 and M112-15, also in the upper Prairie Grove, are large and generally strongly keelate. A brachial valve, representing the largest specimen in the entire collections, measures about 27 mm in length and at least 31 mm in width. These latter collections have a high proportion of specimens with bifurcating lateral plicae. One specimen from M111-14 has lateral bifurcation of the first three primary lateral plicae on both flanks.

Although the full range of variability of A. matheri has not been established, it is clear that this species does not extend into the Upper Morrowan in the study area. It is interesting to note that the small collection of specimens that Sutherland and Harlow (in press) have identified as A. matheri from the Morrowan part of the La Pasada Formation in northern New Mexico occur in the lowest parts of the sequence in strata that most probably correlate with the Brentwood Limestone or the Woolsey Members of the Bloyd Formation.

Most of the collections, even the smaller ones, in the Hale Formation and the Brentwood Limestone have been confidently identified as A. matheri. However, many specimens of Anthracospirifer from the collections from the Gore Formation more closely resemble A. curvilateralis (Easton). In this paper, these specimens are treated as variants of A. matheri. It is possible, however, that both species are present in Lower Morrowan strata but the available collections are too fragmentary and too poorly preserved to allow precise evaluation and possible separation.

A. birdspringensis, described by N. G. Lane (1963, p. 388, pl. 44, figs. 4, 7, 10-18, pl. 45, fig. 3) from the Morrowan portion of the Bird Spring Formation in southern Nevada, is the type species for the genus Anthracospirifer. This species is similar to A. matheri in general shape, outline, and in having some plicae on the flanks that bifurcate; it may be a junior synonym of A. matheri. A. birdspringensis would appear to differ only by having fewer lateral plicae. It is not possible to clarify this questions at this time since the complete range of variability of A. matheri has not been established.

Material and Occurrence.--Approximately 450 specimens have been identified as Anthracospirifer matheri from the Morrow Group. Of these specimens, approximately 120 occur in collections from the Hale Formation, 120 from the Brentwood Limestone, with the remaining specimens from the Gore Formation. This species ranges from the Cane Hill Member through the Brentwood Limestone in northwestern Arkansas and throughout the Gore Formation in northeastern Oklahoma. The following collections contain rare specimens of A. matheri, unless otherwise indicated: HALE FORMATION--Cane Hill Member: M105A-3 (basal 1.5 feet; 44 specimens). Prairie Grove Member: M100-5, M100-6(?), M101-3, M101-6 (10 specimens), M101-7, M104-14 (10 specimens), M105C-4 (17 specimens), M107-9, M109-4, M109-5(?), M111-8(?), M111-14 (12 specimens), M111-15, M112-7, M112-10, M112-15 (10 specimens), M116-8 (top 4 feet), M116-16, M117-3, M117-9(?), M117A-6, and M118-5 (top 2 feet). BLOYD FORMATION--Brentwood Limestone: M68-12, M68-16, M100-9, M100-11 (75 specimens), M101-15, M101-19 (21 specimens), M110-20(?), M116-18, M116-20, and M118-13. GORE FORMATION--limestone-shale member: M1-5(?), M26-5(?), M26-7, M26-8, M29-1, M29-2, M29-4, M29-6(?), M31-1 (2 feet above base), M31-7(?), M31-8(?; 4 feet above base), M37-5(?), M40-15 (top), M49-6(?; basal 1 foot), M49-8 (44 specimens), M51-7 (7 feet above base), M51-7 (22 to 23 feet above base, 29 to 30 feet above base), M51-15(?), M61-1, M64-6, M64-8(?), M64-11 (24 specimens), M65-12(?), M65-14 (top), and M97-6 or 8. Brewer Bend Limestone: M1-10(?), M23-6, M33-4C(?), M39-7, M40-17(?), and M42-14(?).

Figured Specimens.--OU 7303, 7304.

Approximately 200 generally highly fragmentary and/or immature specimens are herein identified as Anthracospirifer sp. from the Lower Morrowan. These specimens occur rarely in the following collections unless otherwise stated: HALE FORMATION--Prairie Grove Member: M68-7, M69-13, M70-8, M111-6, M112-16, M114-13 (base), M116-7 (4 to 5 feet above base), and M118-8. BLOYD FORMATION--Brentwood Limestone: M68-17, M68-18, M68-21, M68-25, M69-18, M70-10B, M70-12, M70-16, M102-9, M104B-11, M104B-17, M105C-10, and M114-12 (20 specimens). GORE FORMATION--limestone-shale member: M1-6, M1-8, M5-13, M5-15 (41 specimens), M5-16, M12-8 Station B, M23-4 (10 specimens), M25-7 (top), M25-8, M26-1, M26-3, M26-9, M28-5 (middle), M29-A, M31-5 (top), M34-7, M35-2, M39-6, M49-5(?), M49-10 (basal 2 feet), M61-6, M61-7, M63-12, M63-13, M65-3, M65-6, M72-4A, loc. M87, and M95-3. Brewer Bend Limestone: M24-12, M28-8, M31-12C, M35-7, M39-14 (top), M39-15, M63-18, M78-43, M95-7, and M98C-7.

Anthracospirifer curvilateralis (Easton)

Pl. 7, figs. 2a-3c.

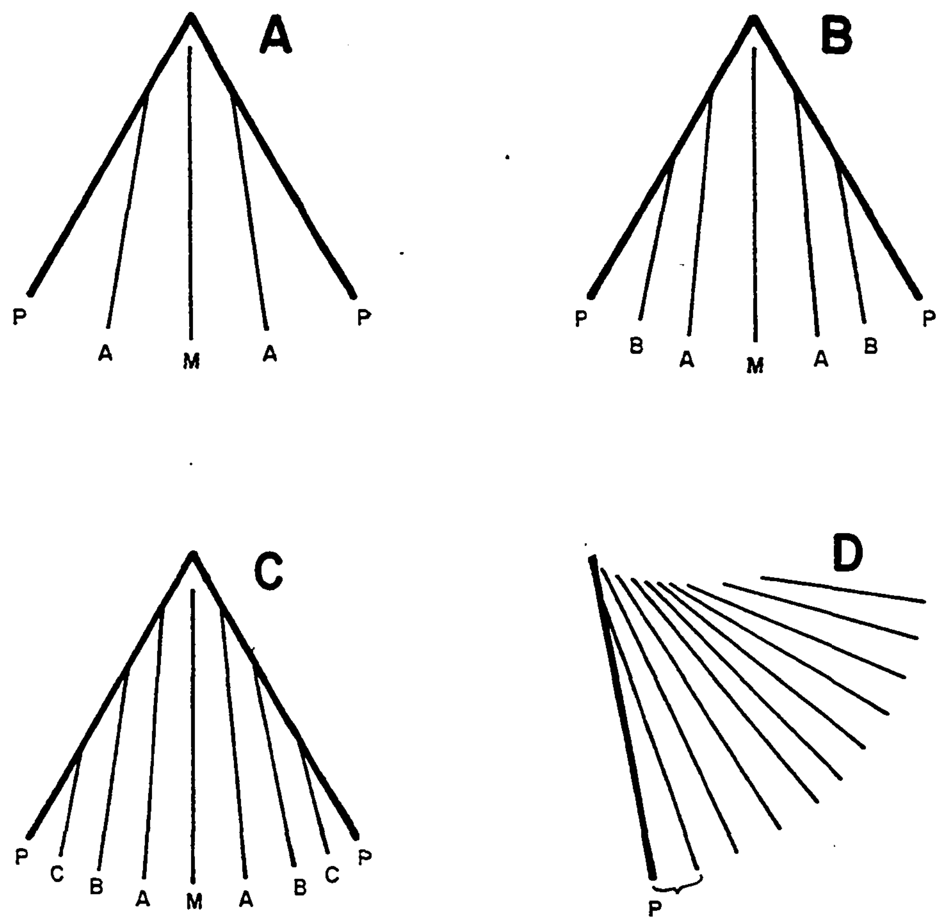
Spirifer rockymontanus, Croneis (not Marcou), 1930, pl. 22, figs. 10-13.

Spirifer curvilateralis Easton, 1962, p. 68, pl. 9, figs. 14-19.

Anthracospirifer curvilateralis, McGugan and May, 1965, p. 31, pls. 11-13, all figs.

Description (Based upon All Specimens from Upper Morrow Group).--Valve subequally biconvex, medium size, moderately extended, nonmucronate, with maximum width generally slightly anterior to hinge line, rarely at hinge line, with larger specimens measuring about 16 mm long, 20 mm wide, 10 mm thick (for measurements, see Appendix IV).

Pedicle valve with low to moderate convexity; umbo not inflated; suberect to erect beak overhanging hinge only slightly; valve characterized by well defined, broad sulcus, with sides diverging from about 27 to 31 degrees, rarely flaring; sulcus with subrounded floor, becoming moderately deep at anterior margin, with slight tongue-like dorsal extension on majority of mature specimens; valve genetly convex laterally; anterior, lateral margins subelliptical, with gently rounded cardinal extremities; interarëa slightly concave, about one-eighth as high as long, with distinct vertical striations, very weak horizontal growth lines; delthyrium higher than wide, bounded by grooved margins. Surface ornamentation consisting of very weak growth lines, becoming slightly less obscure anteriorly; radial ornamentation consisting of strong, subrounded plicae, fine capillae concentrated in interplical grooves; sulcus bounded by P-plications, giving rise to A-plicae in sulcus within 7 to 8 mm SL, generally B-plicae, rarely C-plicae; M-plication arising within 5 mm SL; all sulcal plicae continuing to anterior margin without bifurcation; sulcus thus characterized by between 3 and 7 plicae ($\bar{x}$ = 4.83, M = 5, n = 70 specimens; text-figure 18), with most common sulcal formula PBC,M,ABP (text-figure 18B); between 8 and 16 plicae occurring on either side of sulcus ($\bar{x}$ = 10.0, M = 10, n = 100 sides); P-plicae on either side of sulcus giving rise to single, simple secondary plica; remainder of lateral P-plicae generally simple (text-figure 18D) becoming slightly fainter near posterolateral extremities; bifurcation of lateral primary plicae rare, with only 4 sides of 102 studied with any lateral bifurcation; 2 of 4 sides with first P-plicae bifurcating (pl. 7, fig. 3a); fine radial capillae observed on crests of plicae, in grooves of better preserved specimens,



Text-figure 18.--Most common sulcal and lateral bifurcation patterns for *Anthracospirifer curvilateralis* (Easton) from the upper part of Morrow Group. (A). Sulcal bifurcation pattern, 14 percent of specimens studied. (B). Sulcal bifurcation pattern, 66 percent. (C). Sulcal bifurcation pattern, 9 percent. (D). Lateral bifurcation pattern, 40 percent.

forming minute reticulation.

Brachial valve with about same convexity as opposite valve; umbo low; beak inconspicuous; lateral flanks nearly planar, with slightly concave area near posterolateral margins; subrounded fold extending from beak to anterior margin, becoming only slightly elevated anteriorly, bounded by grooves corresponding to P-plicae on opposite valve; brachial interarea narrow, almost orthocline.

Interiors unknown.

Discussion.--*Anthracospirifer curvilateralis* was defined by Easton (1962, p. 68, pl. 9, figs. 14-19) from the Heath Formation of central Montana, and he reported this species from the Cameron Creek Formation and Alaska Bench Limestone. He reported these strata to be Late Mississippian and questionably Lower Pennsylvanian in age. Maughan and Roberts (1967, p. B6) have assigned the Heath Formation to the upper Chester Series, the Cameron Creek to the Morrow Series, and the Alaska Bench Limestone to the upper Morrow and Atoka Series.

Easton (1962, p. 69) stated that *A. curvilateralis* "usually has 5 ribs in the sulcus and from 12 to 16 ribs on each lateral slope, although the ranges are from 3 to 7 in the sulcus and from 10 to 18 on each lateral slope." The mode for Easton's type material (p. 70) is 12 within an average of 13.2 on the flanks. The material from the current study area compares favorably with Easton's description and figures except that the observed range of lateral plications is from 8 to 16 plicae on each lateral slope, with a mode of 10 and an average of 10.0 plicae per side (n = 102 sides). McGugan and May (1965, p. 32) recorded from 11 to 13 simple, subrounded plicae on the flanks and only 3 to 5 plicae in the sulcus, in their biometric analysis of a collection of silicified specimens of _A_. _curvilateralis_ from the Tunnel Mountain Formation (Upper Mississippian-Lower Pennsylvanian) in British Columbia. Sutherland and Harlow (_in press_) recorded from 9 to 14 for their two subspecies of _A_. _curvilateralis_ from the Upper Morrowan through Desmoinesian of north-central New Mexico, with modes of 10 lateral plicae for the Upper Morrowan through lower Atokan subspecies.

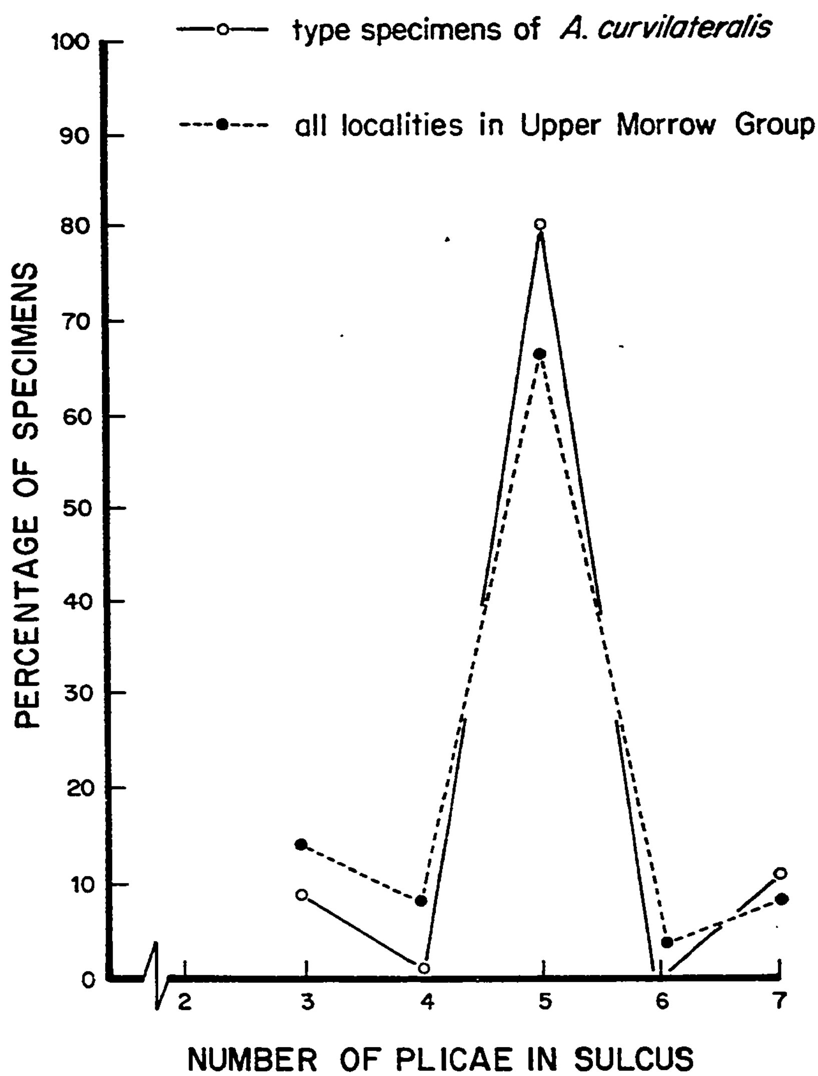
The collections from the packstone and shale "A" members in northeastern Oklahoma are closely similar to the material from the stratigraphically higher Greenleaf and Kessler Limestones. Only one out of 69 specimens studied in the Chisum Quarry Member and shale "A" member had any bifurcation of primary lateral plicae; on it, only the first primary lateral plica on one side bifurcated (pl. 7, fig. 3a). No statistically significant difference in the mean number of plicae in the sulcus can be detected between the collections from the Chisum Quarry Member and those from the Greenleaf and Kessler Limestones at 98 percent confidence limits. The sulcal formulae for the combined collections from all localities in the Upper Morrowan in the Ozark region is presented in table 5 below; the most commonly sulcal pattern is shown in text-figure 18B.

Sulcal formula	Total specimens	
Symmetrical:		
PA,M,AP	10 specimens	
PBA,M,ABP	46 specimens	
PCBA,M,ABCP	6 specimens	
Asymmetrical:		
PA,M,ABP	3 specimens	pl. 7, fig. 2a
PBA,MABCP	1 specimen	pl. 7, fig. 3a
PBA,M,AP	3 specimens	
PCBA,M,ABP	1 specimen	

Table 5.--Formulae for bifurcation patterns of plicae in sulcus for 70 specimens of *A. curvilateralis* (Easton) from all localities in the Upper Morrowan of the study area.

No significant statistical difference is calculated between the number of sulcal plicae for the combined material from the Upper Morrowan in the study area and the mean number of sulcal plicae for the type specimens of *A. curvilateralis* at 90 percent confidence limits; however, a significant difference exists at 95 percent confidence limits. Text-figure 19 is a frequency polygon comparing the number of sulcal plicae for this material.

Sutherland and Harlow (*in press*) recognized two distinct but closely related subspecies of *A. curvilateralis* in the Lower and Middle Pennsylvanian of northern New Mexico. They noted a progressive shift in the number of sulcal plicae from the Upper Morrowan to the Lower Desmoinesian. The Upper Morrowan forms of *A. curvilateralis tanoensis* are characterized by a mode of 3 plicae ($\bar{x}$ = 3.48, range 3 to 5) and



Text-figure 19.--Plot of percentage of specimens versus number of sulcal plicae for specimens of Anthracospirifer curvilateralis (Easton) from all localities of upper part of Morrow Group and for type specimens for A. curvilateralis from U.S.G.S. locality 13395, Heath Formation, central Montana (data for latter from Easton, 1962, p. 70).

the lower Atokan forms of the same subspecies by a mode of 3 plicae ($\bar{x}$ = 4.00, range 3 to 5); the upper Atokan collections of A. curvilateralis chavazae has a mode of 5 ($\bar{x}$ = 5.09, range 3 to 7). Statistically, the Lower Desmoinesian material compares most closely with the Upper Morrowan collections from the current study area in terms of the number of sulcal plicae. However, in terms of general shape, size, and number of lateral plicae, the Upper Morrowan collections from the current study area compare most favorably with the Upper Morrowan collections of A. curvilateralis tanoensis.

The specimen figured by Croneis (1930, pl. 22, figs. 10-13) as Spirifer rockymontanus (Marcou) from the Kessler Limestone has not been examined, but it is unquestionably placed in synonymy. It appears to have five plicae in the sulcus, and the lateral plicae are simple.

For a comparison of A. curvilateralis with A. matheri (Dunbar and Condra), see discussion of the latter species.

Material and Occurrence.—Anthracospirifer curvilateralis is a widely occurring species having been identified from New Mexico, Montana, northwestern Arkansas, northeastern Oklahoma, and British Columbia. Its known range is from Upper Mississippian (Chesterian) through Lower Desmoinesian.

This species has been identified in the Upper Morrowan strata of the Ozark Mountains area. The range of this species possibly also extends into the Lower Morrowan strata, at least in northeastern Oklahoma, but the collections are inadequate to allow confident separation from

A. matheri (for additional remarks, see discussion of that species). Approximately 350 generally fragmentary, exfoliated specimens occur in the following collections; their occurrence is rare unless otherwise noted: BLOYD FORMATION—Dye Shale Member ("caprock"): M104B-19. Kessler Limestone Member: M69-27B, M104B-23 (3 specimens), M104B-24, M104B-26, M104C-1, M105D-13 (about 100 specimens); M105D-15, M108-17, M108-20 (basal 0.5 foot), M108-20 (2 feet above base), and M114-31. Trace Creek Shale: M69-31. McCULLY FORMATION—Chisum Quarry Member: M17-9, M17-11 & 12, M17-14, M17-14 & 15, M17-15 & 16, M26-23 (27 specimens), M28-10 (top), M28-11, M29-10 (top; 11 specimens), M35-8, M35-9, M40-18, M42-15, M42-16, M49-18, M60-15, and M62-23 (16 specimens). Shale "A" member: M29-15, M30-6, M34-15 (13 specimens) M42-18, M48-15 (11 molds), and M95-10. Greenleaf Limestone: M27-16 (base), M28-14 (base), M33-11, M35-11, M42-21, M51-25 (15 specimens), M60-21 (40 specimens), M60-22, and M98-13.

Figured Specimens.--OU 7305, 7306.

Genus Spiriferellina Frederiks, 1919

Spiriferellina? campestris (White)

Pl. 7, figs. 14a-15.

Spiriferina spinosa var. *campestris* White, 1874, p. 21.

Spiriferina octoplicata White, 1877, p. 139, pl. 10, fig. 8a (not figs. 8b, 8c).

Spiriferina campestris, Mather, 1915, p. 193, pl. 13, figs. 9, 10; Morgan, 1924, pl. 45, figs. 7, 7a.

Spiriferina transversa, Morgan (not McChesney), 1924, pl. 45, fig. 8.

Spiriferellina campestris, Sutherland and Harlow, *in press*, pl. 18, figs. 1-4.

Description (Based upon Specimens from M1-5, M1-6, M1-8, M3-12, loc. M77, and M95-5).--Shells medium-sized for genus, equally biconvex, moderately transverse with maximum width at, slightly anterior to hinge line; characterized by strong plications, aplicate sulcus, dense surface spinules; shell material finely punctate; dimensions two largest specimens; length, 16.0 mm, 12.0 mm; width 22.5 mm, 17.2 mm; thickness 12.8 mm, 11.5 mm (for specimens from M1-8, M16-1, respectively).

Pedicle valve with slightly rounded to slightly extended posterolateral margins, lateral margins gently curved; beak narrow, slightly incurved, overhanging hinge line as much as 3 mm, shell uniformly convex in lateral profile, sloping uniformly away from sulcus laterally; interarea apsacline, almost catacline; ratio of height to width of interarea about 0.6; delthyrium with apical angle varying from about 35 to 40 degrees; deltidial plates partly covering opening, projecting posteriorly outward from delthyrium at about 120 degrees from plane of interarea; shell bearing distinct, simple, angular to subangular, deep sulcus, bounded by strong lateral plications; sulcus stronger than lateral grooves, originating at beak, making angle of about 25 to 30 degrees posteriorly, flaring somewhat anteriorly; each flank of shell bearing between 4 to 8, most commonly 6, simple, angular to subangular plications, becoming progressively stronger anteriorly, flaring slightly; lateral plications becoming smaller away from sulcus. Surface ornamentation consisting of small, erect spinules arranged in rows parallel to growth lamellae; spinules largest near apex of crests, becoming progressively finer, more closely spaced toward troughs; spinules becoming progressively finer, more closely spaced along crests posteriorly; spinule density highly variable, ranging between 5 per mm to 10 per mm on crests of plications of different valves at same distance from beak; shells also possessing fine growth lamellae, becoming slightly more conspicuous, coarser anteriorly; few shells characterized by geronitic coarsening of growth lines at anterior margins.

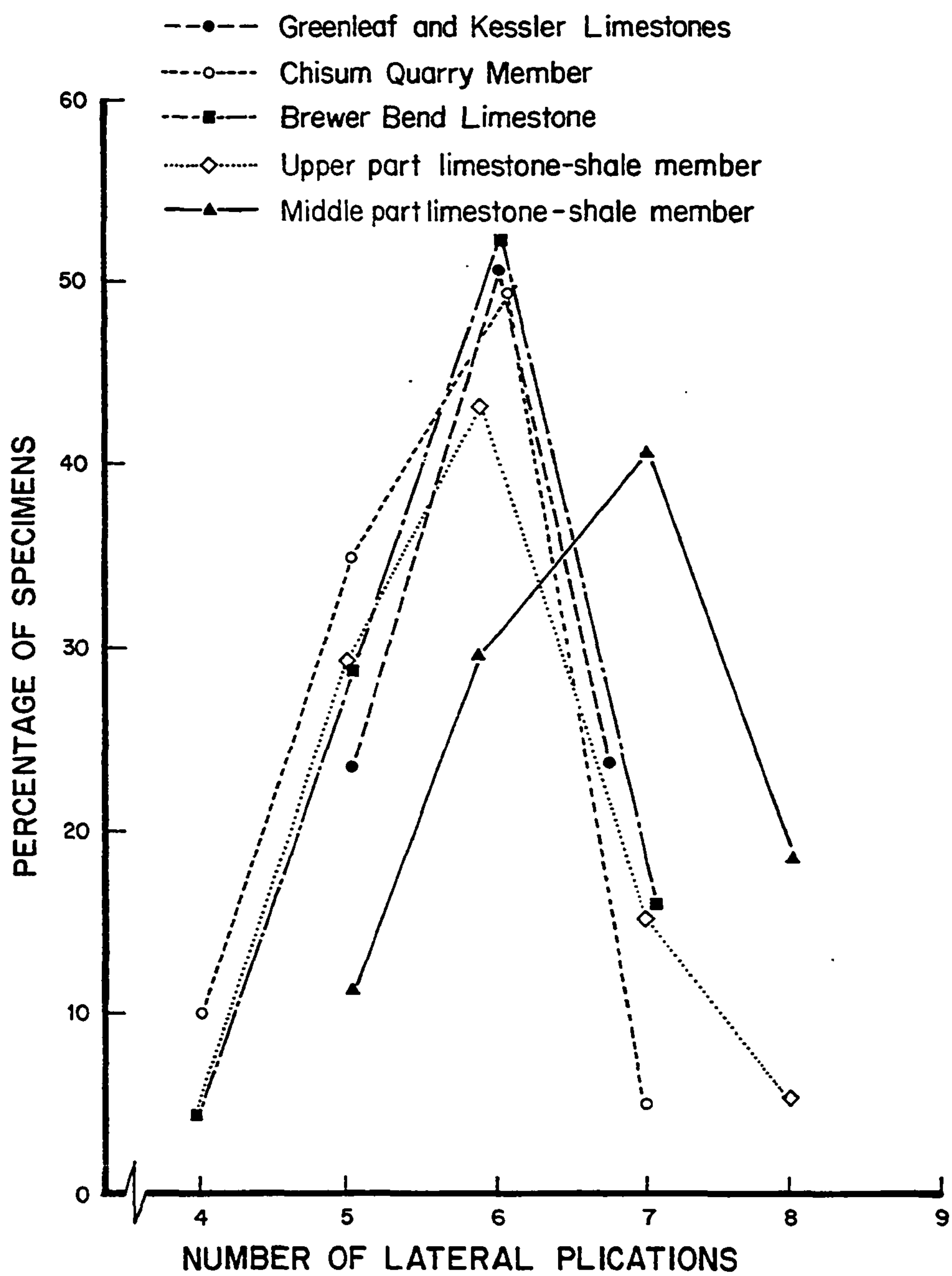
Brachial valve variable in longitudinal profile; umbo slightly inflated on most specimens; small, slightly incurved beak overhanging hinge maximum of about 1 mm ; interarea orthocline, extremely narrow. Surface ornamentation like that of opposite valve.

Pedicle interior (based upon two specimens) characterized by well developed, high, narrow median septum, extending from beak to midlength on one specimen, to two-thirds valve length on second, terminating abruptly; elongated teeth (preserved on single specimen) supported by strong dental plates; dental plates fused with median septum posteriorly, supporting small muscle platform in beak (pl. 7, fig. 15). Interior with plications corresponding to grooves on valve exterior; finely spaced puncta conspicuous over entire interior.

Brachial valve interior (known from single specimen) with strong dental sockets, strong socket plates; cardinal process short, low, fused to crural plates; muscle scars elongate, bounded by low lateral ridges, separated by thin median septum. Interior covered with fine puncta over entire surface.

Discussion.--This highly distinctive Morrowan species was originally defined by White (1874, p. 21) as *Spiriferina spinosa* var. *campestris* from Carboniferous strata "near Santa Fe, New Mexico" and "Camp Cottonwood, Lincoln County, Nevada". In 1877, White referred these species to *S. octoplicata* Sowerby, but Girty (1903, p. 396) utilized *S. campestris* as the specific name and stated that one of White's figured specimens (1877, pl. 10, fig. 8a) was collected from the Santa Fe area. Sutherland and Harlow (in press) reestablished the type locality of *S. campestris* in the Upper Morrowan portion of the La Pasada Formation at Santa Fe, selected White's figured specimen as the lectotype, and redescribed this species based upon a collection of 17 topotypes. They placed this species in the genus *Spiriferellina*. The type material includes no interiors. The author has examined the material from New Mexico.

Considerable morphological variation is observed in both the material from the type locality in north-central New Mexico and within the collections from northeastern Oklahoma. Most of the material from northeastern Oklahoma compares favorably with the type material. The highest degree of disparity between collections is with respect to the number of lateral plications on the pedicle valve. Sutherland and Harlow (in press) stated that the topotype material bears between 4 and 6 lateral plications on each side of the sulcus. Material from the middle part of the limestone-shale member (basal part of *Neognathodus bassleri* Zone) bears between 5 to 8 lateral plications per side ($\bar{x}$ = 6.73, M = 7, n = 71; text-figure 20); material from the upper part of this member has between 4 and 8 plications ($\bar{x}$ = 5.88, M = 6, n = 62); and the material from the Brewer Bend Limestone between 4 and 7 ($\bar{x}$ = 5.87, M = 6, n = 44). Material from the Chisum Quarry and higher strata is limited, but it would appear that the number of lateral plications is about the same as in the Brewer Bend Limestone (see text-figure 20). Statistically, the material from the Brewer Bend Limestone and from the upper part of the limestone-shale member does not differ significantly with respect to the number of lateral plications at 98 percent confidence limits. However, there is a statistically significant difference at 95 percent confidence limits for this feature between the sets of collections from the lower and upper parts of the limestone-shale member. The decrease in number of lateral plications would seem to be accompanied by the shells becoming proportionally somewhat less transverse and slightly more gibbous. This contention cannot be documented, however, because most of the material utilized for this plication counts from the lower part of the limestone-shale member is crushed. With larger collections of better preserved material from the lower part of the limestone-shale member, it might be possible to recognize a second species of *Spiriferellina*?.



Text-figure 20.--Plot of percentage of specimens versus number of lateral plications for selected samples of *Spiriferellina*? *campestris* (White) from various stratigraphic horizons in Morrow Group. See text for discussion.

The surface ornamentation is generally poorly preserved on most of the specimens examined. A single specimen from the Chisum Quarry Member at M17-14 has portions of the surface that are exceptionally well preserved. The spines are suberect and gradually taper away from the shell; the ends are rounded rather than pointed, and the longest spinules are about 0.75 mm long. They are typically largest at and near the crests of the plications and increase in density and decrease in size and diameter toward the troughs.

S.? campestris can be readily distinguished from other spiriferids of the Morrow Group even from immature specimens or tiny fragments. It differs from Punctospirifer morrowensis Sutherland and Harlow, with which it commonly occurs, in possessing surface spines, in having nonimbricated and less conspicuous growth lamellae, by the much coarser and fewer lateral plications, and by having no plications in the sulcus. Even the early growth forms of P. morrowensis are more transverse.

S.? campestris is externally similar to Reticulariina spinosa (Norwood and Pratten), the genotype of Reticulariina, which is widely described from the Chester Series throughout the Midcontinent. It differs from that species primarily in having extremely small, densely spaced spines, rather than the larger tubercles characterizing the reticulariinids. The internal features of S.? campestris are poorly known.

The material identified by Easton (1962, pl. 10, figs. 12-16) as R. spinosa from the Heath, Cameron Creek, and Alaska Bench Formations (Upper Mississippian and Early Pennsylvanian; see discussion by Easton, p. 15 and Maughan and Roberts, 1967, p. 3 for controversy over age assignments of these formations) should be reexamined for possible inclusion in S.? campestris. Easton (p. 84) stated that no spines were observed on his specimens, and if his material is exfoliated, it may be impossible to assign the collections to either species.

Material and Occurrence.--Sutherland and Harlow (in press) have reestablished the type locality for S.? campestris in the Upper Morrowan portion of the La Pasada Formation in north-central New Mexico, and stated that it is restricted to the upper part of the Morrow Series in that area. Girty (1903, p. 400) identified but did not figure specimens from the Weber Formation (upper Morrowan? through Desmoinesian) in Colorado as S. campestris. He did not state from which part of the Weber these specimens were collected. This species occurs commonly in the Wapanucka Formation (Morrowan) of southern Oklahoma.

Spiriferellina? campestris is one of the more common species in the Morrow Group, particularly in northeastern Oklahoma. The description presented above is based upon approximately 160 specimens, about two thirds of which are crushed or are fragmentary, from M1-5 through 8, M3-12, loc. M77, and M95-5. All of these units occur within the upper part of the limestone shale member. About 10 imperfect interiors are present in these collections; two well preserved pedicle interiors are present, plus one poor brachial interior.

This species has been definitely identified from the middle part of the limestone-shale member (lower Neognathodus bassleri Zone) and ranges through the Greenleaf Limestone. Approximately 600 specimens have been collected from these strata. Its lowest unquestioned occurrence in northwestern Arkansas is in the middle part of the Prairie Grove Member (N. bassleri symmetricus Zone), and it occurs in strata as high as the Kessler Limestone. Only 40 specimens have been identified from northwestern Arkansas. S.? campestris occurs rarely in the following collections, unless otherwise indicated: GORE FORMATION--limestone-shale member: M1-5, M1-6, M1-8 (11 specimens), M3-9, M3-10, M3-11, M12-8 Station A, M12-8 Station B, M12-8 Station C (31 specimens), M12-8 Station G (33 specimens), M16-1, M22-11, M23-4 (34 specimens), M26-6(?), M26-7(?), M26-9 (80 specimens, mostly crushed), M31-1(?) 2 feet above base, M31-5 top, M40-15 top, M42-6, M42-7, M49-10(?) base, M49-10 middle, M51-7 (25 to 26 feet above base; 8 silicified interiors), M51-15 (30 crushed specimens), M60-17, M61-6 upper 10 feet, M64-8, M64-11, M67-11, loc. M76A, loc. M77, M78-38, loc. M83A, loc. M87, M95-3, M95-5 (40 specimens and interiors, mostly crushed), M97-5, M97-8, M97-9, loc. M98D, and loc. M121 (25 specimens). Brewer Bend Limestone: M1-10, M3-12A, M3-12C (33 specimens), M24-12, M33-4C, M34-11, M39-7, M40-17, M47-11(?), M95-7, and M97-11. McCULLY FORMATION--Chisum Quarry Member: M17-9 (cf.), M17-13, M17-14 (16 specimens), M17-15 and 16, M26-23 top (10 specimens), M33-6C base, and M42-16. Shale "A" member: M30-6, M36-10B (top), and M48-15. Greenleaf Limestone: M3-21, M28-14, and M51-25 (basal 3 feet). HALE FORMATION--Prairie Grove Member:

M101-1, M101-4, M103-14(?), M112-10, and M117-2(?). BLOYD FORMATION—Brentwood Limestone: M68-21, M69-19, M102-9 (19 specimens), and M114-12(?). Dye Shale Member ("caprock"): M104B-19. Kessler Limestone: M105D-15.

Genus *Punctospirifer* North, 1920

Punctospirifer morrowensis Sutherland and Harlow

Pl. 7, figs. 12a-13.

Spiriferina Kentuckensis, White (not Shumard), 1877, p. 138, pl. 10, figs. 4a-4c.

Spiriferina transversa, Mather (not McChesney), 1915, p. 192, pl. 13, figs. 7, 8.

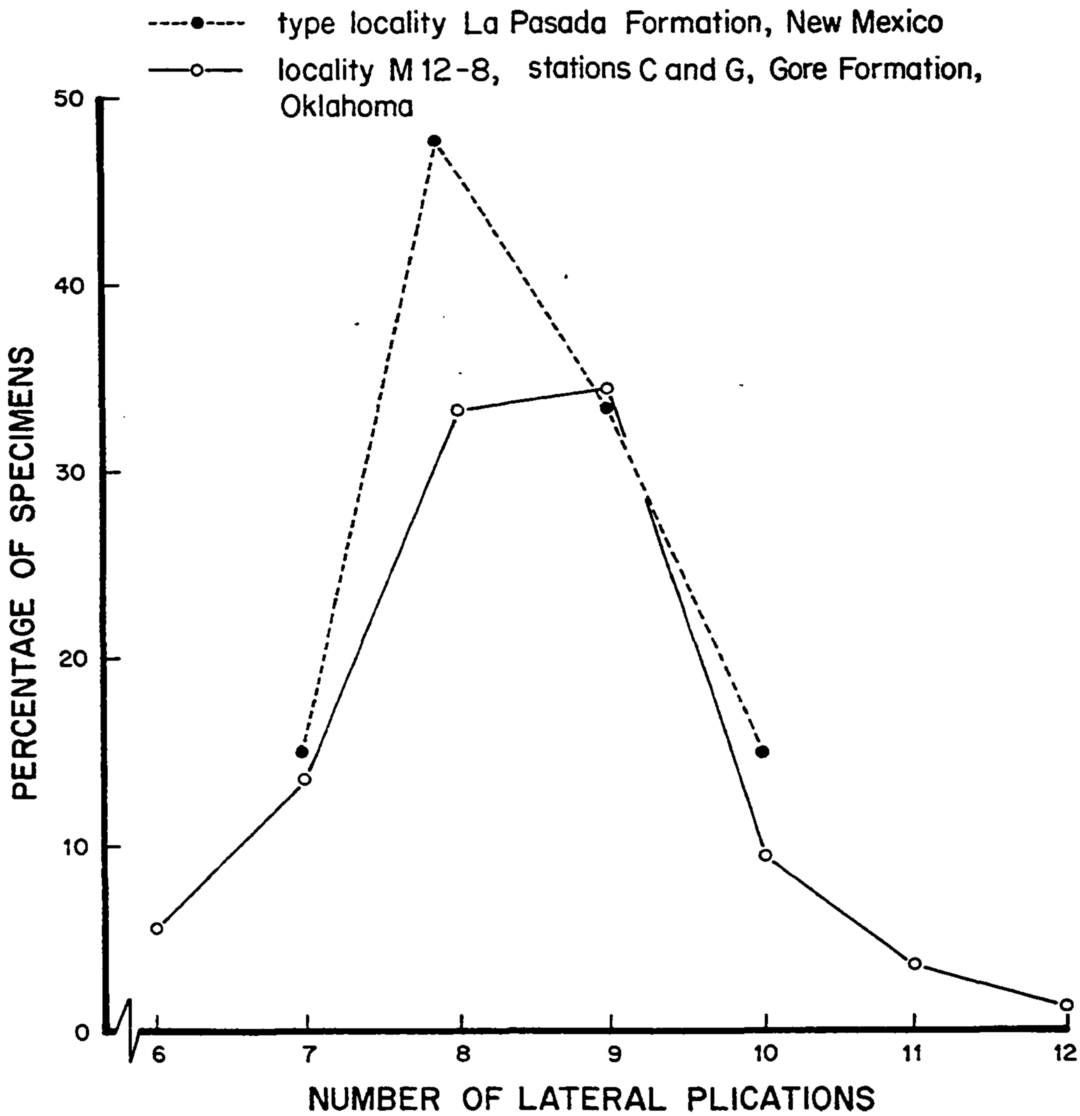
Punctospirifer morrowensis Sutherland and Harlow, *in press*, pl. 18, figs. 5, 6.

Discussion.--*Punctospirifer morrowensis* was initially described from strata of Late Morrowan age from the La Pasada Formation of north-central New Mexico by Sutherland and Harlow (*in press*). This species was based upon 25 type specimens and about the same number of specimens from other localities in northern New Mexico. The author has examined this material.

This species occurs commonly in the Morrow Group in northeastern Oklahoma. A large collection of specimens from the Lower Morrowan unit M12-8, Stations C and G, from the upper part of the limestone-shale member, has been used as a basis of comparison with the type material. The Oklahoma collection includes 168 specimens, most of which are uncrushed and are well preserved. The smallest specimen is 3.2 mm long, 5.0 mm wide, and 2.9 mm thick; the largest 8.0 mm long, 11.2 mm wide, and 7.7 mm thick. Most mature specimens tend to be somewhat less than twice as long as wide (pl. 7, fig. 12a), and the immature specimens tend to be slightly more transverse with the width commonly slightly greater than twice the maximum length. The length and thickness are generally subequal, with the thickness being slightly greater than length in mature specimens, slightly less in immature ones. The material from New Mexico does not contain smaller representatives, but the adult specimens from both collections are similar in the overall size and shape.

Most of the specimens from locality M12-8 have slightly extended alae, even in the immature specimens, setting off the posterior margin from the lateral margins. Rare specimens possess rounded posterolateral margins; a single specimen has an extended ala on one side and a rounded posterolateral margin on the other. The alae tend to be bent slightly dorsally on most of the specimen (pl. 7, fig. 13b), a condition also observed in the type material.

The material from M12-8 bears between 6 and 12 simple lateral plications are on each lateral slope ($\overline{x}$ = 8.79, M = 9, n = 87), including the one bounding the sulcus (text-figure 21). Sutherland and Harlow stated that the number of plications for the type material is generally "8 or 9 on each flank". The author has counted the number of plications on each lateral slope, and the range for the type material is between 7 and 10 ($\overline{x}$ = 8.09, M = 8, n = 24; text-figure 21). Statistically, a significant difference is calculated between the mean number



Text-figure 21.--Plot of percentage of specimens versus number of lateral plications for *Punctospirifer morrowensis* Sutherland and Harlow from type locality in La Pasada Formation in north-central New Mexico and from upper part of limestone-shale member of Gore Formation. See text for discussion.

of lateral plications on each lateral slope for the two collections. Since the specimens are similar to the type specimens in all other respects, however, the difference in number of lateral plications is not interpreted as indicating that the material from the limestone-shale member should be placed in a separate species.

Several specimens from M12-8 that have both slopes well preserved showed that the number of lateral plications may not be the same on both sides of the sulcus. The greatest discrepancy was one specimen with 7 on the left slope and 10 on the right. Such asymmetrical specimens also tend to have the side with the greater number of plications being more extended laterally.

A number of small collections from the Brewer Bend Limestone and from the Chisum Quarry Member tend to be somewhat larger than those from M12-8 and have more numerous lateral plications on the pedicle valve. The largest of these specimens measures 10.6 mm in length, 19.5 mm in width, and about 9 mm in thickness; a second specimen is 9.6 mm long, about 23 mm wide, and 9.6 mm thick. The number of lateral plications of these specimens ranges between 10 and 15 for 10 specimens. These collections are herein referred to as *Punctospirifer* cf. *P*. *morrowensis*.

Punctospirifer *morrowensis* differs from *P*. *transversa* (McChesney), widely reported from the upper part of the Mississippian System in North America, primarily in being consistantly smaller and in having significantly fewer lateral plications on either side of the sulcus. Weller (1914, p. 298) stated that the Chesterian material is characterized by from 10 to 12 simple, rounded plications on each slope; P. morrowensis from M12-8 has between 6 and 12 (text-figure 21), and the type material from 7 to 10. P. morrowensis is apparently less transverse than P. transversa, but McChesney's species needs to be redescribed and the range of variation established. It is interesting to note that the material from the lower and middle parts of the Lower Morrowan includes collections that are possibly transitional between the two species. The fact that the mean for the number of lateral plications for the material from M12-8 (Lower Morrowan) is greater than the mean number of lateral plications for the type material (Upper Morrowan) also suggests that a close phylogenetic relationship exists between the two species. The collections from the basal and lower parts of the Lower Morrowan and from the Upper Morrowan in the Ozark Mountains region are not adequate to document this apparent transition. The material that Easton (1962, p. 80) described as P. transversa from the Upper Mississippian and Lower Pennsylvanian Heath, Cameron Creek, and Alaska Bench Formations in Montana should be examined for possible differentiation between the Chesterian and Morrowan species.

Punctospirifer kentuckyensis (Shumard) was originally described from the Pennsylvanian strata around Weston, Missouri (see Dunbar and Condra, 1932, p. 353, 354). This species has been widely described from Desmoinesian and higher strata in the Midcontinent. Punctospirifer morrowensis differs from this species in having a greater number of lateral plications. P. kentuckyensis was described (Dunbar and Condra,

p. 352) as having "usually five or six plications on each lateral slope" but they noted that "in large specimens, or those with extended ears, as many as eight or nine plications may be present on each lateral slope." Again, considerable morphological overlap is indicated between the two species. Dunbar and Condra (p. 153) stated that "commonly the very young shells have rounded cardinal extremities but some are acute at an early stage." The opposite would appear to hold for the Morrowan specimens from M12-8, with most of the younger specimens being strongly transverse and with extended alae.

Material and Occurrence.--Sutherland and Harlow (in press) described Punctospirifer morrowensis from the Upper Morrowan portion of the La Pasada Formation near Santa Fe, New Mexico. This species is restricted to the Upper Morrowan in northern New Mexico.

Approximately 400 generally crushed specimens of Punctospirifer morrowensis Sutherland and Harlow were collected from the Morrow Group in northeastern Oklahoma. About 160 of these are from M12-8, Stations C and G, in the upper part of the limestone-shale member. Only 15 specimens were collected from the Morrow Group in northwestern Arkansas. This species ranges from the upper part of the limestone-shale member of the Gore Formation (middle to upper part of the Neognathodus bassleri Zone) through the Chisum Quarry Member. Its established range in northwestern Arkansas is from the uppermost part of the Prairie Grove Member (middle to upper part of N. bassleri symmetricus Zone) through the Kessler Limestone Member. Specimens tentatively identified as

Punctospirifer cf. *P. morrowensis* occur in lower strata in both areas. This species occurs rarely in the following collections unless otherwise indicated: GORE FORMATION--limestone-shale member: M1-5, M1-8, M3-9, M12-8 Station B, M12-8 Station C (74 mostly uncrushed specimens), M12-8 Station G (94 good specimens), M14-8 & 9(cf.), M16-1(?), M23-3C, M23-4 (12 specimens), M29-2(cf.), M31-4(cf.), M40-15 top, M42-7, M49-8, M51-7(?) 25 to 26 feet above base (9 poor, silicified interiors), M51-15, loc. M76A, M78-38 (31 mostly crushed), M78-39, loc. M83A, loc. M94, M95-3, M95-5 (17 good specimens), M97-5 (15 crushed specimens), M97-8, M97-9, and loc. M98D. Brewer Bend Limestone: M3-12C(cf.), M18-5(cf.), M24-12, M39-13 top, M39-14(cf.) top, M40-17, M97-11, M98A-7(cf.), M98C-7. McCULLY FORMATION--Chisum Quarry Member: M17-14 through 17 (cf.), M26-23 (top), M27-14, M28-11, M31-17, M42-15, and M42-16. HALE FORMATION: Mather's sta. 149, M105C-4, and M117-3(cf.). BLOYD FORMATION--Brentwood Limestone: M70-12 (top), M100-11, M102-9, M114-9 (talus), and M114-12; Mather's sta. 134, 135, and 140. Dye Shale Member ("caprock"): M104B-19. Kessler Limestone: M105D-13; Mather's sta. 144 and 209.

Figured Material.--OU 7313, 7314.

Punctospirifer? n. sp. A

Description.--Shell medium sized, distinctly triangular in shape, strongly transverse, widest at hinge, strongly, subequally biconvex; largest specimen (M78-38) measuring approximately 14.2 mm in length, 24.8 mm wide, about 11 mm thick; much more alate, single pedicle valve (M59-5) 10.4 mm long by about 27 mm wide. Shell with large, densely spaced punctae.

Pedicle valve strongly extended laterally, with lateral margins meeting posterior margin acutely at from 10 to 35 degrees; characterized by strong, subrounded sulcus, expanding uniformly anteriorly at about 30 degrees, not flaring; sulcus somewhat deeper than lateral grooves; valve with 3 or 4 subangular to subrounded, simple lateral plications (small, immature specimens with 2 plications); plication bounding sulcus slightly broader, hgiher than lateral plications, becoming progressively broader anteriorly; lateral extremities without plications, flat, smooth. Poorly preserved surface ornamentation of irregularly spaced growth lamellae with intervening smooth surfaces with very fine growth striae only; lamellae groups becoming somewhat imbricated at irregular intervals, producing knobby appearance on plications; spines apparently lacking.

Brachial valve more strongly arched in lateral profile, characterized by highly arched, keelate fold; fold much more strongly developed, more angular than corresponding pedicle sulcus; valve with 3, 4 lateral plications. Ornamentation same as that on pedicle valve.

Pedicale valve interior with strong hinge teeth, median septum; remainder of characters of both valve interiors unknown.

<u>Discussion</u>.--<u>Punctospirifer</u>? n. sp. A is characterized by having a strongly transverse, triangular shape, a few coarse, simple lateral

plications that do not extend onto the lateral extremities, irregularly spaced growth lamellae that produce a knobby appearance on the plications, the apparent lack of spines, and a coarsely punctate shell surface. It differs from typical examples of the genus Punctospirifer in the lack of closely spaced, imbricate growth lamellae, in shape, size, and spacing of plications, and in the character of the growth lamellae. It is similar to the Permian genus Altiplecus Stehli in overall size, shape, and in having few, strong lateral plications, but differs in lacking the widely spaced, concentric rows of coarse spines. It is radically different from any described Lower Pennsylvanian spiriferid and unquestionably represents a new species.

It is apparent from observation of the largest specimen of Punctospirifer? n. sp. A that the individuals were much more strongly transverse in their earlier than in their later growth stages.

Material and Occurrence.--Punctospirifer? n. sp. A is extremely rare in the Morrow Group of northeastern Oklahoma and has been identified only from strata in the upper part of the limestone-shale member (upper part of Neognathodus bassleri Zone) at units M12-8 Station G (1 immature specimen), M16-1 (1 immature specimen), M51-15 (1 brachial valve), M78-38 (1 large specimen, 1 fragment), loc. M94 (1 specimen), and M95-5 (1 complete specimen, 1 poor brachial valve).

This species is extremely rare in the OU collections from the Wapanucka Formation (Morrowan) from southern Oklahoma.

SUPERFAMILY RETICULARIACEA

FAMILY ELYTHIDAE

Genus *Phricodothyris* George, 1932

Phricodothyris perplexa (McChesney)

Pl. 7, figs. 16a-17.

Squamularia perplexa, Mather, 1915, p. 188, pl. 12, figs. 13-13b; Plummer and Moore, 1921, p. 46, pl. 7, fig. 4; pl. 21, figs. 6, 7; Murphy, 1954, p. 43, pl. 4, figs. 3a-3d.

Phricodothyris perplexa, Sutherland and Harlow, in press, pl. 17, figs. 18-20.

Discussion.--McChesney (1859, p. 43) presented a brief description of *Spirifer perplexa* but did not illustrate his species or present specific locality information for his collections. Dunbar and Condra (1932, p. 316) concluded that McChesney's types probably were collected from Desmoinesian strata near Springfield, Illinois, but they did not arbitrarily specify a type locality. To the author's knowledge, the original types of this species have never been illustrated.

Partly as a result of this and partly because of the morphological conservatism of the Pennsylvanian forms, the name *P. perplexa* has been applied to all but a single occurrence of this genus in the Pennsylvanian; that exception is *Phricodothyris*? *transversa* (Mather) from the Morrow Group near Fayetteville, Arkansas.

The material herein identified as *P. perplexa* from northwestern Arkansas and northeastern Oklahoma is highly variable in morphological character but cannot be differentiated from collections of material from higher in the Pennsylvanian. It is generally characterized by a transversely oval outline interrupted by a prominent, high, narrow, strongly incurved beak on the pedicle valve. The relative lengths and widths vary from shells approximately one-tenth wider than long to those that are slightly longer than wide, but the transverse forms are predominant. The valves are subequally biconvex with the pedicle valve generally being slightly more curved and possessing the larger, strongly incurved beak. The spiralia are shown on a weathered specimen from Ml-5.

The specimen figured by Mather (1915, pl. 12, figs. 13-13b; UC 16093) from the Brentwood Limestone is the largest specimen that has been observed from the Morrow Group, measuring 13.2 mm by 13.5 mm by 9.9 mm.

Specimens of Phricodothyris perplexa (McChesney) from the Morrow Group differs from Phricodothyris? transversa (Mather), from the Hale Formation near Fayetteville, Arkansas, in being approximately one-fourth as large, in having a more strongly arched pedicle beak, and in being proportionally far less transverse.

P. perplexa, from the Morrow Group can be confused only with some species of Composita. It is differentiated by the strongly incurved, overhanging, narrow beak and high pedicle interarea, by the strong concentric ("squamose") growth lines, and by the "striated" appearance of the exfoliated shells due to the double-barreled spines having been broken off.

The material from the Hale Formation in northwestern Arkansas tends to be somewhat smaller than stratigraphically higher collections in the Morrowan of the Ozark region.

Material and Occurrence.--Mather (1915, p. 190, 191) stated that this species is one of the more common ones in the Morrowan fauna and noted its occurrence in strata ranging in age from the lower part of what is now termed the Prairie Grove Member through the Kessler Limestone in northwestern Arkansas. It also occurs in strata of the Cane Hill Member and throughout the Morrow Group in northeastern Oklahoma. It is one of the few brachiopod species that occur in abundance in the quartz-sandy calcarenites (grainstones) typical of the Prairie Grove Member, but it is most abundant in the Brentwood Limestone. Approximately 300 specimens have been collected from the Morrow Group; most of these specimens are fragmentary. P. perplexa occurs rarely to abundantly in the following collections unless otherwise noted: HALE FORMATION--Cane Hill Member: M105A-3. Prairie Grove Member: M70-8, M100-6, M101-3, M101-6, M101-7, M103-14, M104A-10, M105C-4, M112-15, M116-8 (top 4 feet), M116-16, M117-3, and M117-11. BLOYD FORMATION--Brentwood Limestone: M70-12, M101-16, M101-19, M102-8, M105C-6, M110-20, M116-18, M116-20, and M118-11 or 12 (talus), Kessler Limestone: M105D-13, and M105D-15. GORE FORMATION--limestone-shale member: M1-5, M26-1, M26-6 (basal 2 feet), M26-7, M26-9 (1 to 2 feet above base), M26-17, M39-4, M51-7 (22 to 23 feet and 25 to 27 feet above base), M51-15, and M62-21. McCULLY FORMATION--Chisum Quarry Member: M26-23 (top), M61-9, and M67-20. Greenleaf Limestone: M1-20 and M60-21.

Other Morrowan occurrences of P. perplexa are in the La Pasada

Formation in northern New Mexico (Sutherland and Harlow, in press), in the lower part of the Oquirrh Formation in northern Utah (Murphy, 1954), the Marble Falls Limestone of northern Texas (Moore and Plummer, 1921), and in the Wapanucka Formation of southern Oklahoma.

Figured Specimens.--OU 7317, 7318.

Phricodothyris? transversa (Mather)

Pl. 8, figs. 1a-2c.

Squamularia transversa Mather, 1915, p. 191, pl. 12, figs. 8-9a; Croneis, 1930, p. 80, pl. 20, fig. 1.

Discussion.--Mather's (1915, p. 191) description of Squamularia transversa was based upon 4 specimens from a single locality in the upper part of the Hale Formation. His cotypes (UC 16094) consist of one almost complete, disarticulated pedicle valve and three disarticulated brachial valves, one of which is fragmentary. He figured the pedicle valve (pl. 12, figs. 9, 9a; herein refigured as pl. 8, figs. 1a-1c) and the complete brachial valve (pl. 12, figs. 8, 8a; herein refigured as pl. 8, figs. 2a-2c). The latter was refigured by Croneis (1930, pl. 20, fig. 1). Mather's figured pedicle valve should be selected as the lectotype. Mather's description of these specimens is accurate and needs no further comments.

The nature of the interior of this species is not known, but the present writer has questionably transferred this species to the genus Phricodothyris because of its similarity to P. perplexa (McChesney).

For a comparison of P. perplexa with P.? transversa, refer to the discussion of P. perplexa.

Material and Occurrence.--A. H. Purdue collected the 4 cotypes of P.? transversa from a locality probably equivalent to M117-7 in the upper part of the Prairie Grove Member. No topotype material was collected from this locality (for additional remarks refer to the discussion of Mather's Station 149 in Appendix III). The cotypes remain the only specimens of the species that are known to have been collected.

Figured Specimens.--UC 16094 (2 cotypes).

ORDER TEREBRATULIDA

SUBORDER TEREBRATULIDINA

SUPERFAMILY DIELASMATACEA

FAMILY CRANAENIDAE

SUBFAMILY GIRTYELLINAE

Genus Girtyella Weller, 1914

Pl. 8, figs. 3-7d.

Girtyella? emarginata Mather, 1915, p. 180, pl. 11, figs. 13-13b; Croneis, 1930, p. 86, pl. 22, figs. 14-16.

Description (Based upon All Specimens in Morrow Group).--Shells small, terebratuliform, biconvex, length approximately 1.5 times width, maximum width occurring at midlength or slightly beyond, maximum thickness occurring about one-third distance to anteriormargin; anterior commissure ligate. Dimensions of two complete specimens: length 8.3

and 6.9 mm, width 6.1 and 4.9 mm, thickness 4.5 and 2.9 mm. Valves finely punctate.

Pedicle valve uniformly convex in lateral profile in mesial portion; slope from middle of valve to anterior margin slightly flattened transversely; posterolateral margins of valve deflected, forming false cardinal area; lateral margins uniformly rounded from ventral view, truncated abruptly at anterior margin; latter deflected posteriorly slightly by low, flattened to slightly sulcate mesial portion of valve; umbo broadly convex; beak narrow, projecting posteriorly to that of brachial valve.

Brachial valve tending to be less strongly convex than pedicle valve; umbo broad, low; area anterior to umbo distinctly flattened laterally from mesial portion of valve except near margins where strongly curved ventrally; mesial sulcus originating at approximately midlength, beocming slightly deeper, broader anteriorly, having about same to slightly greater degree of development as that of pedicle valve; sulcus possessing rounded, broadly transverse outline; beak small, inconspicuous, incurved beneath pedicle beak.

Surface of both valves smooth except for exceptionally faint, rounded growth lines noticable only near anterior margin.

Interior of pedicle valve with well developed dental lamellae; brachial interior possessing short median septum.

Discussion.--Mather (1915, p. 181) had only three nearly complete internal molds upon which to base his description of this species.

Of the three cotypes (UC 16079), Mather figured the most nearly complete specimen (pl. 11, figs. 13-13b; pl. 22, figs. 14-16 of Croneis, 1930; pl. 8, figs. 4a, 4b of this dissertation). The anterior margin of this specimen has been partially broken, but the posterior portion of the valve is intact; it should be selected as the lectotype. The two remaining cotypes, herein figured as pl. 8, figs. 3, 5a, 5b, show the details of the posterior margin.

This species is extremely rare in the Morrow Group, and of the 9 specimens available in addition to the cotypes, four have damaged posterior margins. One of the remaining specimens was sectioned in order to ascertain the nature of the interior, but it is poorly preserved. Some of the internal features are shown on the coptypes. Mather (1915, p. 181) noted that this species "is probably not a Girtyella as it lacks the well developed median septum of that genus." The median septum of the brachial valve would indeed appear to be short for Girtyella, which has not been described from strata younger than Upper Mississippian (Chesterian). If this species does prove to belong to this genus, it will represent the youngest reported species and will extend the range of the subfamily into the Lower Pennsylvanian.

Girtyella? emarginata is characterized by its truncated anterior margin, the presence of a slight sulcus on both valves, its ligate anterior commissure, and its small size. The only species with which it may be confused in the Morrow Group is Beecheria? bilobatum (Mather) and then only with immature specimens. It differs from the immature specimens of B. bilobatum in being proportionally much thinner and narrower, in having a sulcus on both valves, and by having a sharply truncated anterolateral margin.

The Mississippian species externally most closely resembling G.? emarginata is G. brevilobata (Swallow), reported from the Chester Group of the northern Midcontinent (Weller, 1914, p. 278). It differs externally from this species in lacking the bilobation characteristic of that species, in being somewhat less elongated and less gibbous, and in having the alteral margins slightly more evenly rounded.

A collection of approximately 17 specimens tentatively identified as Girtyella? emarginata Mather comes from Sutherland and Harlow's (in press) locality 22-41 in the uppermost Morrowan or lowermost Atokan portion of the La Pasada Formation in north-central New Mexico. These specimens resemble the specimens of G.? emarginata from northeastern Oklahoma and northwestern Arkansas very closely externally. The largest of the New Mexico specimens is slightly larger than the largest specimen from northeastern Oklahoma, measuring 11.2 mm by 7.8 mm by 5.1 mm.

Material and Occurrence.--This species is extremely rare in the Morrow Group, and a total of only 9 specimens in addition to the three cotypes have been collected. Mather described this species from internal molds from the Kessler Limestone at his station 209 (= M115-2); the author did not recover topotypes when this station was recollected (see discussion of Mather's station 209 in Appendix III for additional remarks). The known range of this species in northeastern Oklahoma is from the upper part of the limestone-shale member (M12-8 and M27-8) of the Gore Formation (upper part of Neognathodus bassleri Zone) through the shale "A" member (M30-6). It has thus far been collected in northwestern Arkansas from the Kessler Limestone at Mather's station 209 (= M115-2) and from M105D-15.

As stated in the preceeding section, this species is tentatively identified by this author from Sutherland and Harlow's (in press) collections from the uppermost Morrowan or lowermost Atokan strata of the La Pasada Formation in northern New Mexico.

Figured Specimens.--UC 16079 (3 cotypes); OU 7319, 7320.

FAMILY HETERELASMINIDAE

Genus Beecheria Hall and Clarke, 1893

Beecheria n. sp. A

Pl. 8, figs. 8a-11b.

Dielasma subspatulatum, Mather (not Weller), 1915, p. 178, pl. 11, figs. 1-11b, text-fig. 4.

?Dielasma arkansanum, Mather (not Weller), 1915, p. 180, figs. 12-12b; Croneis, 1930, p. 84, pl. 21, figs. 23-25.

Description (Based upon Specimens from M116-18).--Shell slightly less than medium size for genus, subspatulate to subtriangular in in outline, with almost straight, diverging lateral margins curving progressively more strongly anteriorly; width much greater than thickness; maximum width generally occurring slightly anterior to three-fourths distance to anterior margin; valves subequally biconvex, with maximum thickness occurring about one-third distance from beak.

Pedicle valve moderately convex, slightly greater convexity in lateral profile near beak, becoming only slightly less convex anteriorly; gently convex posteriorly in transverse profile, becoming abruptly curved dorsally, inflected toward cardinal extremities near posterolateral margins; beak erect to suberect, slightly overhanging brachial valve, with large foramen encroaching upon umbonal region; mesial sulcus developed gradually, generally as narrow gentle groove from about one-fourth to half distance to anterior margin, flaring, deepening uniformly anteriorly beyond midlength; sulcus not well defined laterally, subrounded; some specimens with slight dorsal deflection of sulcus near anterior margin, producing somewhat bilobed appearance of anterolateral surfaces.

Brachial valve less convex than pedicle, greatest convexity near umbo, becoming almost planar anteriorly; valve characterized by gentle, low, narrow, poorly defined fold anteriorly; anterolateral portion flattened to slightly concave in transverse profile; lateral margins not as sharply deflected ventrally near cardinal extremities as on other valve; beak low, gently incurved.

Valve surfaces ornamented with obscure growth lines, about equally inconspicuous near umbo as near anterior margins; shell material finely, densely punctate.

Valve interiors not observed.

Discussion.--The description of Beecheria n. sp. A presented above is based upon 22 complete specimens and three fragments from the lower part of the Brentwood Limestone Member at M116-18. The specimens in this collection exhibit little morphological variability.

A second relatively large collection of this species also occurs in the lower part of the Brentwood Limestone from unit M110-20. This collection has a large range of morphological variability, and the outlines range from subspatulate individuals with low, almost obsolete sulci, characteristic of Beecheria subspatulatum (Weller), to specimens that closely approach B. stehlii Sutherland and Harlow. Some of the suboval forms in this collection approach those forms described by Mather (1915, p. 180, pl. 11, figs. 12-12b) as B. arkansanum (Weller). The typical specimen, however, is like that described above for Beecheria n. sp. A from M116-18.

The collections identified as Beecheria n. sp. A from northeastern Oklahoma fall within the range of variation observed in both large Brentwood collections.

The author has examined the specimens figured as Dielasma subspatulatum Weller by Mather (1915), and these specimens are herein assigned to Beecheria n. sp. A. Most of the specimens figured by Mather are less sulcate than the forms characteristic of the collection from unit M116-18, particularly the collection from his station 150 (= M117-14) from the lower part of the Brentwood. These specimens (his pl. 11, figs. 7-8a, UC 16075) approach the form of B. stehlii Sutherland and Harlow quite closely, except that they are proportionally somewhat thinner. The smaller of these specimens measures 25.5 mm by 16.8 mm by about 9.7 mm; the larger 31.0 mm by 19.7 mm by about 13.6 mm. This two specimens are identified as *Beecheria* cf. *B.* n. sp. A.

It would appear that *Beecheria* n. sp. A, from the lower and middle part of the Morrow Group is the immediate ancestor of *B. stehlii*, restricted to the upper part of the Morrow Series. For additional comparison with *B. stehlii*, see discussion of that species.

Weller (1914, p. 270, pl. 33, figs. 6-11) described both *Dielasma subspatulatum* and *D. arkansanum* (*ibid*., p. 269, pl. 31, figs. 41-44) on the basis of a small number of specimens collected by A. H. Purdue from an unknown locality in Washington County, Arkansas; (Golden and Nitecki, 1972, p. 71, p. 76). Mather (1915, p. 180) stated that *D. arkansanum* "is abundant ... in the Fayetteville shale and the type material was probably derived from that formation." It would seem reasonable to assume that the types of *B. subspatulatum* may have also been collected from this Late Mississippian (Chesterian) formation. The character and distribution of both species needs to be established in the Upper Mississippian before a comparison can be made with *Beecheria* n. sp. A.

It would seem from Weller's (1914, p. 270, pl. 33, figs. 6-11) description and illustrations of *B. subspatulatum* that it and *Beecheria* n. sp. A are similar in size, in having a subspatulate outline, and in having about the same degree of convexity of both valves. The primary difference is that collections of *Beecheria* n. sp. A have a majority of specimens with at least a faint sulcus on the pedicle valve and corresponding fold on the brachial valve, and most collections have these features strongly developed. A few morphologic variants in the collections from the Morrow Group are similar to *B. subspatulatum* in being asulcate. This is cited as evidence that *Beecheria* n. sp. A may be descendant of the Chesterian *B. subspatulatum*.

Upper Mississippian specimens of what are apparently *B. arkansanum* are apparently distinctly suboval in outline and more gibbous than *Beecheria* n. sp. A, although again morphologic types approaching *B. arkansanum* persist into the Lower Pennsylvanian as apparently extremely rare morphologic variants of *Beecheria* n. sp. A.

For a comparison with *B.? bilobatum* (Mather), which also occurs in the Morrow Group, see the discussion of that species.

Material and Occurrence.--Approximately 150 specimens of this species are present in the collections from the Morrow Group. *Beecheria* n. sp. A is restricted to the Lower Morrowan in the Ozark Mountains region. This species ranges from the basal part of the Prairie Grove Member through the Brentwood Limestone in northwestern Arkansas and throughout the Gore Formation in northeastern Oklahoma. This species is rare in the following collections, except where otherwise noted: HALE FORMATION--Prairie Grove Member: M101-3, M111-15 (top), M112-10(cf.), M116-7, and M117-2(cf.). Brentwood Limestone: M68-12, M68-18, M100-11 (10 specimens) M101-14(?), M110-20 (50 specimens), M114-12(cf.; talus), M116-18 (25 specimens), and M118-11 or 12 (talus).

GORE FORMATION--limestone-shale member: M5-15(?), M14-6 or 7, M25-7(?; top), M28-5 (middle), M31-1 (2 feet above base), M37-8 (top), M49-3, M49-10(?; basal 2 feet), M51-7 (23 feet, 25 to 26 feet above base), M67-9(?), loc. M83A(cf.), and M97-5(cf.). Brewer Bend Limestone: M31-12C and M39-13 (13 specimens).

Figured Specimens.--OU 7319-7324.

Beecheria stehlii Sutherland and Harlow

Pl. 8, figs. 12a-14c.

Beecheria stehlii Sutherland and Harlow (in press), pl. 18, figs. 19-22.

Discussion.--Beecheria stehlii was originally described from the lower part of the La Pasada Formation (Upper Morrowan) in the vicinity of Santa Fe, New Mexico, by Sutherland and Harlow (in press). The original description was based upon 32 specimens from the type locality and supplemented by 29 specimens from nearby localities. The author has examined these collections.

Beecheria stehlii is medium sized, subequally biconvex, characterized by generally having a broad flattening of the mesial portion of the pedicle valve beyond midlength and rarely by having a broad, almost obsolete sulcus beyond midlength. The pedicle valve is slightly more convex than the brachial valve. The species is narrow posteriorly with almost straight, divergent lateral slopes. The shell thus has the shape of a tear-drop, with the maximum width occurring at about three-fourths the distance to the anterior margin.

One group of beecherids from the upper part of the Morrowan sequence in the Ozark region agrees quite closely with the material from north-central New Mexico, and is herein assigned to _Beecheria stehlli_.

Mather (1915, p. 178) identified a number of specimens from the Morrowan sequence in northwestern Arkansas and northeastern Oklahoma as _Dielasma subspatulatum_ Weller. The specimens that Mather figured from the upper part of the Prairie Grove Member and the Brentwood Limestone Member have been examined and are herein assigned to _Beecheria_ n. sp. A and not to _B. subspatulatum_ (for additional remarks, see the discussion of _Beecheria_ n. sp. A), and the specimens that Mather referred to _B. subspatulatum_ from the Kessler Limestone possibly belong to _B. stehlii_. These latter specimens cannot at this time be found in the Field Museum.

Collections of _B. stehlii_ differ from those of _Beecheria_ n. sp. A, from the Lower Morrowan, in having the majority of specimens with either a mesial flattening or an obscure sulcus developed anteriorly to midlength rather than having a shallow to strongly developed sulcus, in having the shape of a tear-drop rather than being subspatulate, in having the maximum width about three-fourths the distance to the anterior margin rather than near the anterior margin, in having a more convex pedicle valve, and in having a more sharply incurved pedicle beak. Morphologic overlap does occur between the two species. About 10 percent of the specimens from the Kessler Limestone (M105D-13 and

M105D-15) have an outline that is subspatulate and similar to Beecheria n. sp. A, but these specimens are asulcate to very gently sulcate. A number of small collections from the Brewer Bend Limestone in northeastern Oklahoma cannot clearly be assigned to either species. This material is morphologically intermediate between the two species.

Material and Occurrence.--Beecheria stehlii appears to be restricted to Upper Morrowan strata. The type material is from the upper part of the Morrow Series in the lower La Pasada Formation in north-central New Mexico (Sutherland and Harlow, in press). It occurs rarely in the OU collections from the Wapanucak Formation in southern Oklahoma.

B. stehlii ranges throughout the McCully Formation in northeastern Oklahoma and specimens assigned to Beecheria cf. B. stehlii occur in strata as low as the subjacent Brewer Bend Limestone. This species has been identified from the Kessler Limestone in northwestern Arkansas. Approximately 65 specimens are in the OU collections from northeastern Oklahoma; about 75 occur in these collections from northwestern Arkansas. B. stehlii occurs rarely in the following collections, unless otherwise mentioned: GORE FORMATION--Brewer Bend Limestone: M63-19(cf.). McCULLY FORMATION--Chisum Quarry Member: M17-9, M26-21 (top; 15 specimens), M28-10, M42-15(cf.), M49-18, and M62-23. Shale "A" member: M30-6(cf.), M34-15, and M42-18(cf.). Greenleaf Limestone: M51-23 (basal 3 feet), and M78-47B. BLOYD FORMATION--Kessler Limestone: M60-21, M104B-23, M104B-24, M105D-13 (45 specimens), and M105D-15 (19 specimens).

Figured Specimens.--OU 7324-7327.

Beecheria? bilobatum (Mather)

Pl. 8, figs. 15a-18c.

Dielasma bilobatum Mather, 1915, p. 179, pl. 11, figs. 14-15b; Croneis, 1930, p. 84, pl. 21, figs. 14-16.

Description (Based upon Specimens from M110-20).--Shell small for genus, subequally biconvex, terebratuliform, greatest width generally at midlength, rarely to about three-fourths distance to anterior margin; maximum thickness near midlength; larger specimens somewhat gibbous (for measurements, see Appendix IV); anterior commissure strongly uniplicate.

Pedicle valve with maximum convexity posteriorly, becoming only slightly less convex anteriorly, moderately convex in transverse profile near beak; beak narrow, suberect to slightly incurved, with small, circular foramen slightly encroached upon umbo; valve characterized by subangular median sulcus, arising rather abruptly from about 5 to 6 mm SL from beak, deepening rapidly anteriorly, lateral margins diverging generally at about 25 degrees; sulcus floor becoming increasingly more strongly convex anteriorly, with anterior portion commonly produced byond margin, meeting place of commissure almost perpendicularly, producing strongly emarginated commisure, imparting distinct bilobed appearance to anterolateral part of ventral surface.

Brachial valve characterized with about same convexity in lateral profile as pedicle valve; beak narrow, pointed, slightly incurved beneath that of opposite valve; with mesial fold generally originating about three-fourths distance to anterior margin as narrow, rounded ridge, continuing to margin with slight increase in elevation, width; generally with flattened, rarely with slightly cancave area laterally to fold; fold rarely obsolete.

Surface ornamentation consisting of few, irregularly spaced, faint growth lines, slightly more conspicuous anteriorly; shell material finely, densely punctate.

Discussion.--Considerable variation in the degree of divergence of the lateral margins of the sulcus is observed in the collection from the Brentwood Limestone described above. The angle of divergence of the sulcus of most specimens is around 25 degrees; rarely it is as high as about 30 degrees, and a single specimen has a slot-like sulcus that diverges first at about 10 degrees and then the sulcal margins bend mesially slightly and continue anteriorly almost parallel to one another.

The material from the Kessler Limestone Member, identified as *Beecheria*? cf. *B*.? *bilobatum*, consists of specimens with a slightly shallower, subrounded sulcus, generally arising between 8 and 9 mm (SL) anteriorly. A number of these specimens are somewhat more gibbous than the Brentwood material, and a single specimen is distinctly gerontic.

The largest specimen in the collection from the Brentwood

Limestone measures 8.2 mm by 7. 1 mm by 4.6 mm; Mather's larger cotype is broken at the beak (pl. 8, figs. 16a-16e of this dissertation) but was about 9 mm in length, 7.8 mm in width, and 5.9 mm in thickness. This specimen (Mather, 1915, pl. 11, figs. 15-15b) should be selected from the two cotypes (UC 16077) as the lectotype. The second type specimen is herein figured as pl. 8, figs. 15a-15c. The largest specimen from approximately equivalent strata in the grainstone-shale member of the Gore Formation is 10.5 mm long, 8.5 mm wide, and has thickness of 6.2 mm.

Mather's cotypes are from the Brentwood Limestone at his station 134, which is no longer accessible (see discussion of Mather's station 134 in Appendix III). He also made a small collection of this species reportedly from the Brentwood Limestone at his station 135 (M102), which is approximately 1 mile northeast of station 134 and should be considered an alternative type locality for this species. Mather's specimens from station 135, however, are among the specimens that cannot at this time be found in the Field Museum. A possible second alternative reference locality would be M110-20.

Beecheria? bilobatum also occurs with Beecheria n. sp. A in the large collection from the Brentwood Limestone at M110-20. Mature specimens of the latter species are about two to three times as large as mature specimens of B.? bilobatum, have a proportionally much shallower and subrounded sulcus, do not have the distinct bilobed appearance of the anterolateral surfaces, and have pedicle beaks that are more strongly incurved. Morphological intermediates between the two species are not observed in this collection or in any of the other collections from northeastern Oklahoma where the two species are present, and they are therefore considered to be valid, separate taxa. Immature specimens of Beecheria n. sp. A differ from B.? bilobatum in having no sulcus or merely a very shallow, subrounded sulcus that does not increase markedly in depth anteriorly. B.? bilobatum tends to be somewhat more gibbous at corresponding lengths than the other species. The smallest specimens of both species cannot be differentiated.

Beecheria? bilobatum is very closely related to Beecheria? gerberi Sutherland and Harlow from the upper Morrowan portion of the La Pasada Formation in north-central New Mexico. The author has examined the type material for the latter species, and B.? gerberi differs from B.? bilobatum only in being parasulcate as opposed to uniplicate.

Material and Occurrence.--Mather based his species upon two cotypes from his station 134 and a small collection of specimens from his station 135 (= M102), both in the Brentwood Limestone. The specimens figured by Croneis (1930, pl. 21, figs. 14-16) are also from the Brentwood. This species ranges from the upper part of the Prairie Grove Member through the Brentwood Limestone in northwestern Arkansas and is reported only from the lower to upper part of the limestone-shale member in northeastern Oklahoma. Its lowest known occurrence is in the upper part cf the Idiognathoides noduliferus Zone in the latter area. Approximately 50 specimens are present in the following collections; the species is rare unless otherwise stated: HALE FORMATION--Prairie Grove Member: M105C-4 and M111-15 (top). BLOYD FORMATION--Brentwood Limestone: M110-20 (35 specimens), sta. 134, sta. 135. Kessler Limestone: M105D-15(cf.). GORE FORMATION--limestone-shale member: M27-8, M49-3, loc. M76, and loc. M94.

Figured and Catalogued Specimens.--UC 16077(C), OU 7328, 7329.

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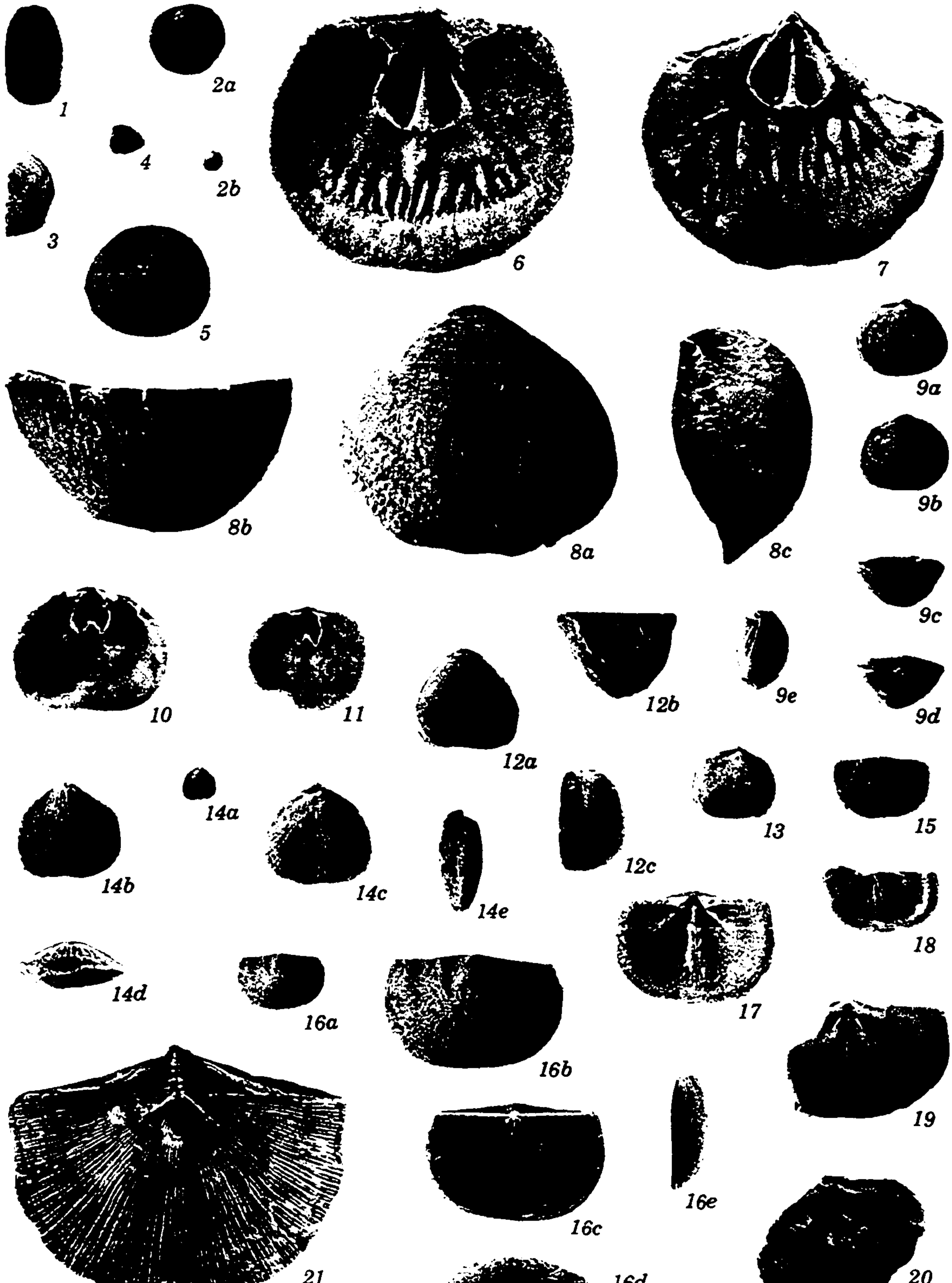
Plate 1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6. OU 7243, M26-9, X2, brachial interior.
7. OU 7244, M26-9, X2, brachial interior.
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10. UC 16083, sta. 295, X3: a, pedicle; b, anterior; figured cotype (Mather, 1915, pl. 8, figs. 10, 10a).

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11. UC 16084, sta. 210, X3, pedicle; immature specimen, unfigured cotype.
12. UC 16084, sta. 210, X3, pedicle; immature specimen, unfigured cotype.
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14. OU 7247, M97-5, X3: a, pedicle; b, anterior; typical mature specimen.
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Plate 2

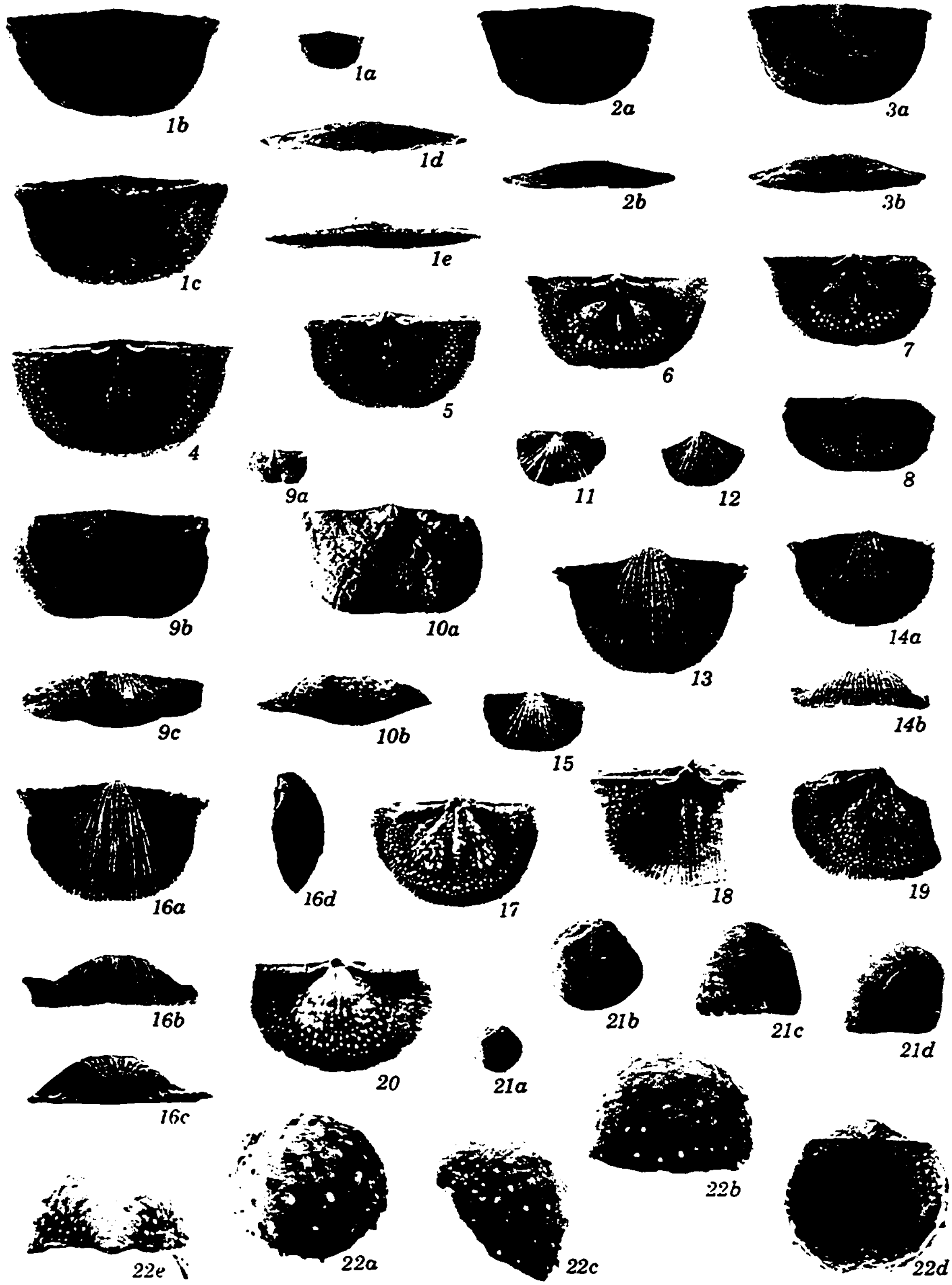
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Plate 3

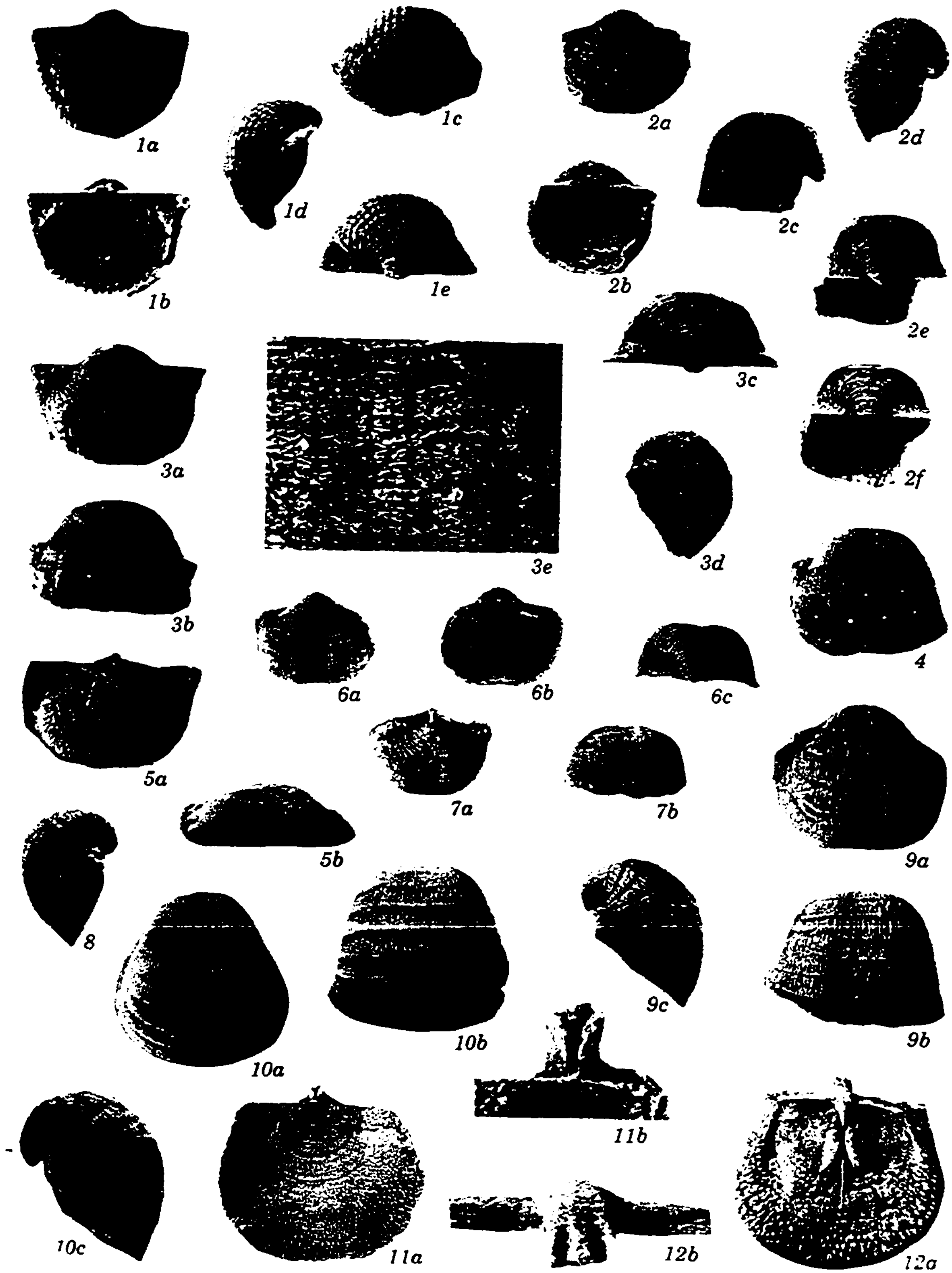
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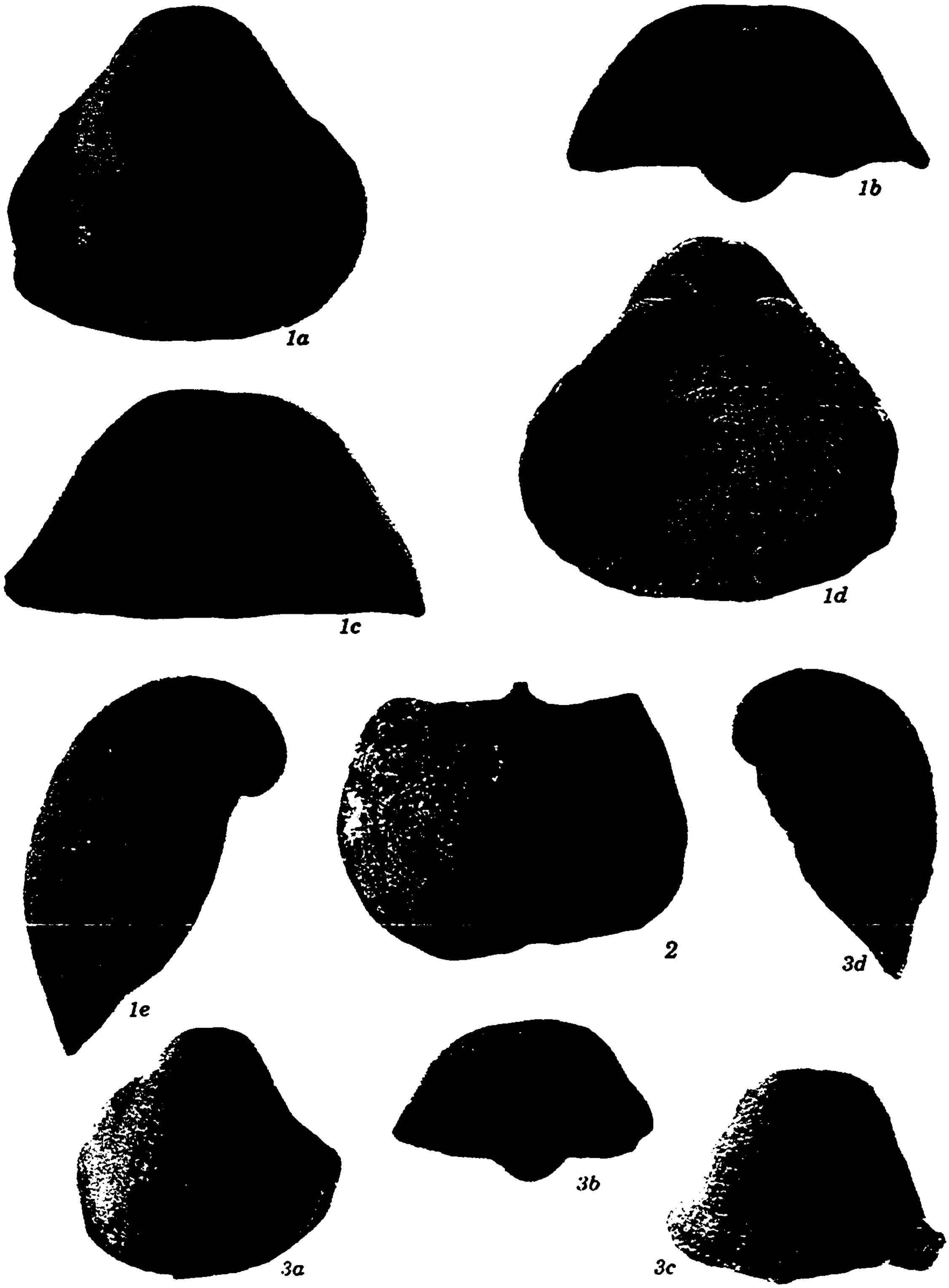
Plate 4



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14. UC 16136, sta. 137, X2, pedicle; unfigured cotype.

15. OU 7281, M116-18, X2: a, pedicle; b, anterior; c, brachial; specimen broader than typical.

16. OU 7282, M24-10, X2, pedicle.

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Plate 6

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13. OU 7314, M12-8, sta. G, X2: a, pedicle; b, brachial; specimen more transverse than typical.

14-15. *Spiriferellina? campestris* (White) 252

14. OU 7315, M17-14: a, pedicle, X1; b, pedicle, X2; c, brachial, X2; d, anterior, X2; e, posterior, X2; f, right lateral, X2; note pustules over surface.

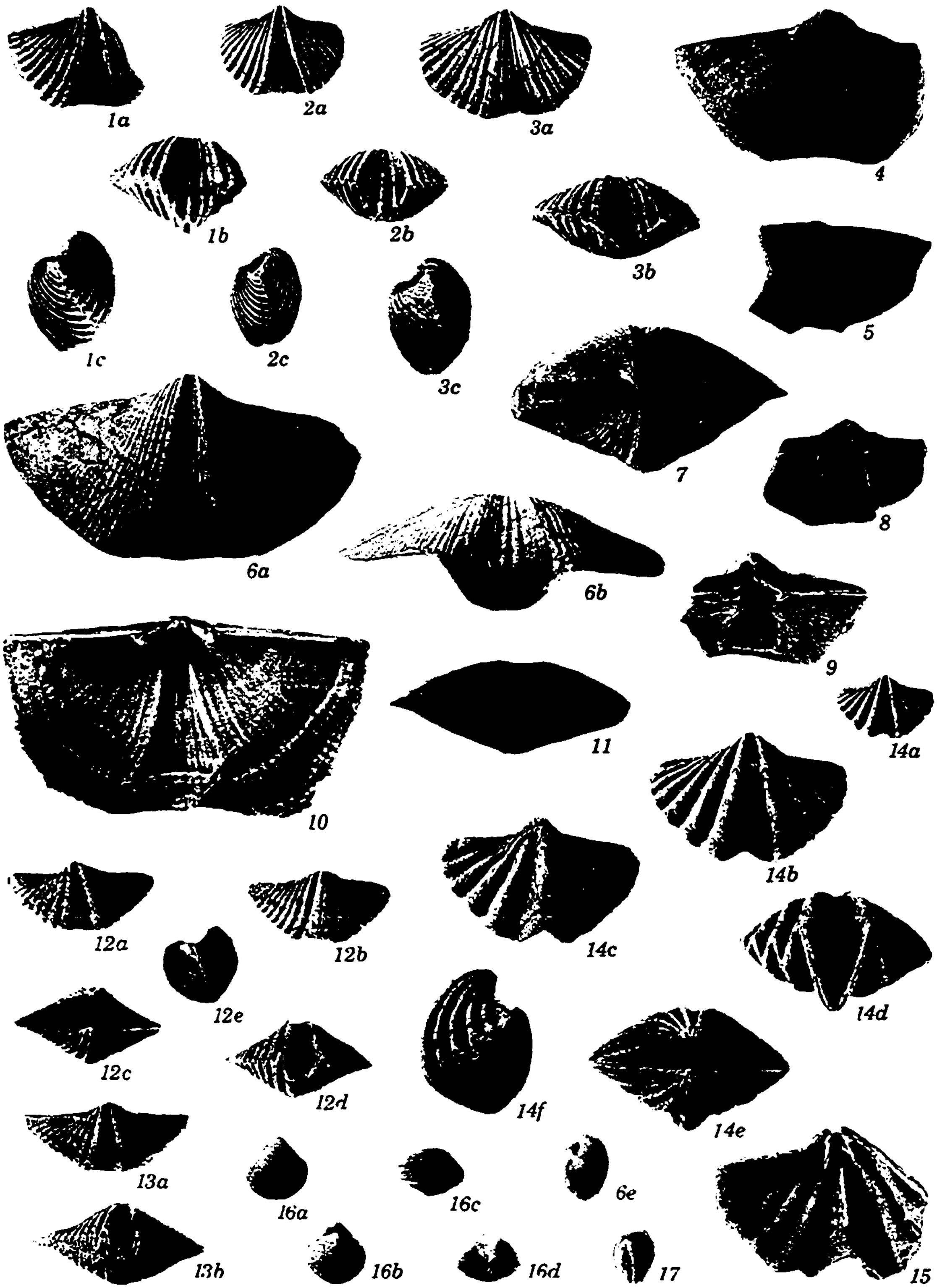
15. OU 7316, M12-8, sta. A, X2; pedicle interior; dental plates broken off; note platform, dental supports.

16-17. *Phricodothyris perplexa* (McChesney) 270

16. OU 7317, M116-8 top 4 feet, X1; a, pedicle; b, brachial; c, anterior; d, posterior; e, left lateral.

17. OU 7318, M116-18, X1; left lateral.

Plate 7



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13. OU 7314, M12-8, sta. G, X2: a, pedicle; b, brachial; specimen more transverse than typical.

14-15. Spiriferellina? campestris (White) — 252

14. OU 7315, M17-14: a, pedicle, X1; b, pedicle, X2; c, brachial, X2; d, anterior, X2; e, posterior, X2; f, right lateral, X2; note pustules over surface.

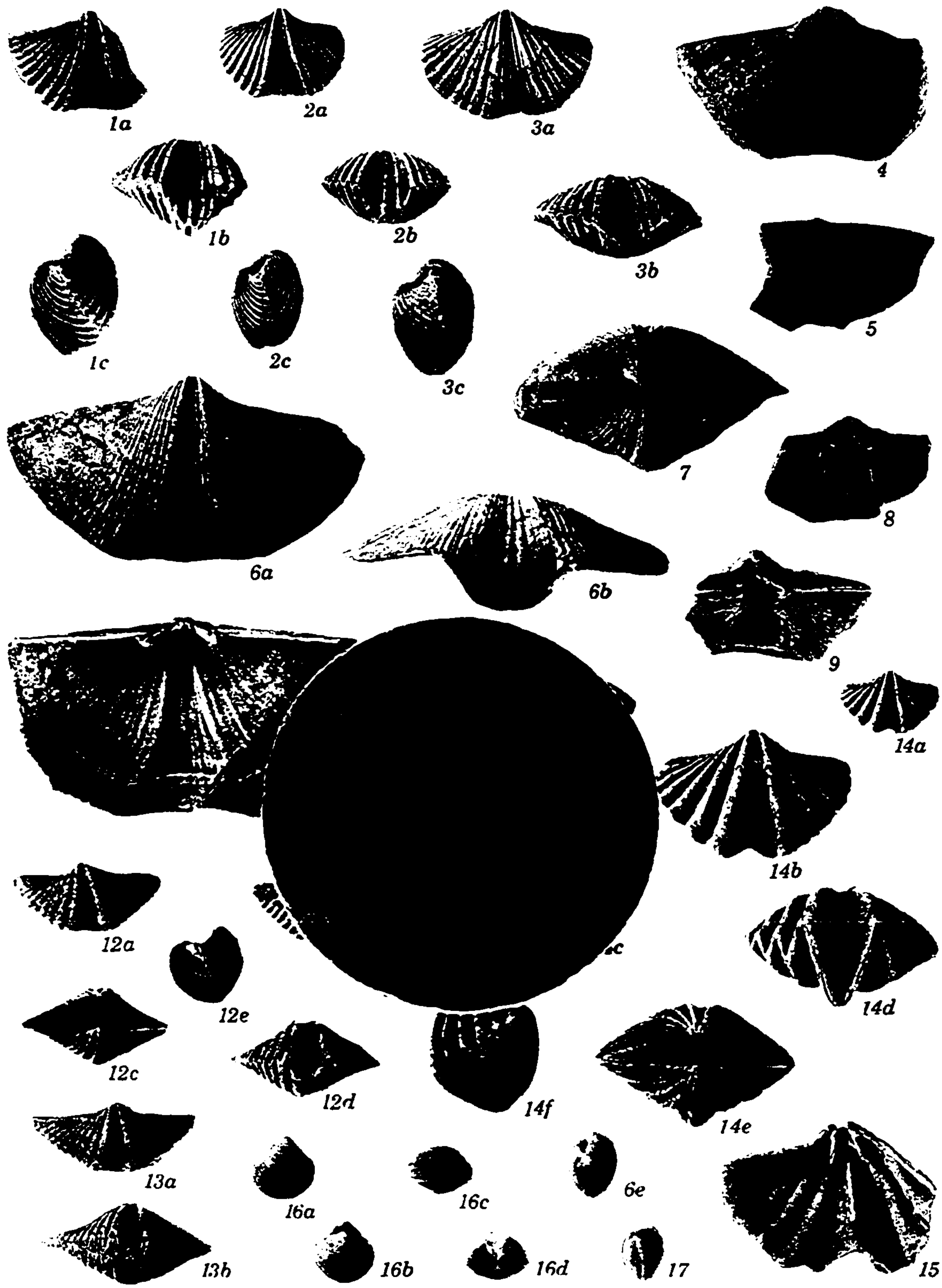
15. OU 7316, M12-8, sta. A, X2; pedicle interior; dental plates broken off; note platform, dental supports.

16-17. Phricodothyris perplexa (McChesney) — 270

16. OU 7317, M116-8 top 4 feet, X1; a, pedicle; b, brachial; c, anterior; d, posterior; e, left lateral.

17. OU 7318, M116-18, X1; left lateral.

Plate 7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1-2. Phricodothyris? transversa (Mather) 273

1. UC 16094, sta. 149, X1: a, pedicle; b, posterior; c, right lateral; figured cotype (Mather, 1915, pl. 12, figs. 9, 9a); suggested lectotype.

2. UC 16094, sta. 149, X1: a, brachial; b, right lateral; c, posterior; figured cotype (Mather, 1915, pl. 12, figs. 8, 8a; Croneis, 1930, pl. 20, fig. 1).

3-7. Girtyella? emarginata Mather 274

3. UC 16079, sta. 209, X3; pedicle valve; internal cast; unfigured cotype.

4. UC 16079, sta. 209, X3: a, pedicle; b, brachial; internal cast; figured cotype (Mather, 1915, pl. 11, figs. 13-13b; Croneis, 1930, pl. 22, figs. 14-16); suggested lectotype.

5. UC 16079, sta. 209, X3: a, pedicle; b, brachial; internal cast; unfigured cotype.

6. OU 7319, M27-8: a, pedicle, X1; b, pedicle, X2; c, brachial, X2; d, left lateral, X2; e, anterior, X2.

7. OU 7320, M12-8, X2: a, pedicle; b, brachial; c, anterior; d, right lateral.

8-11. Beecheria n. sp. A 278

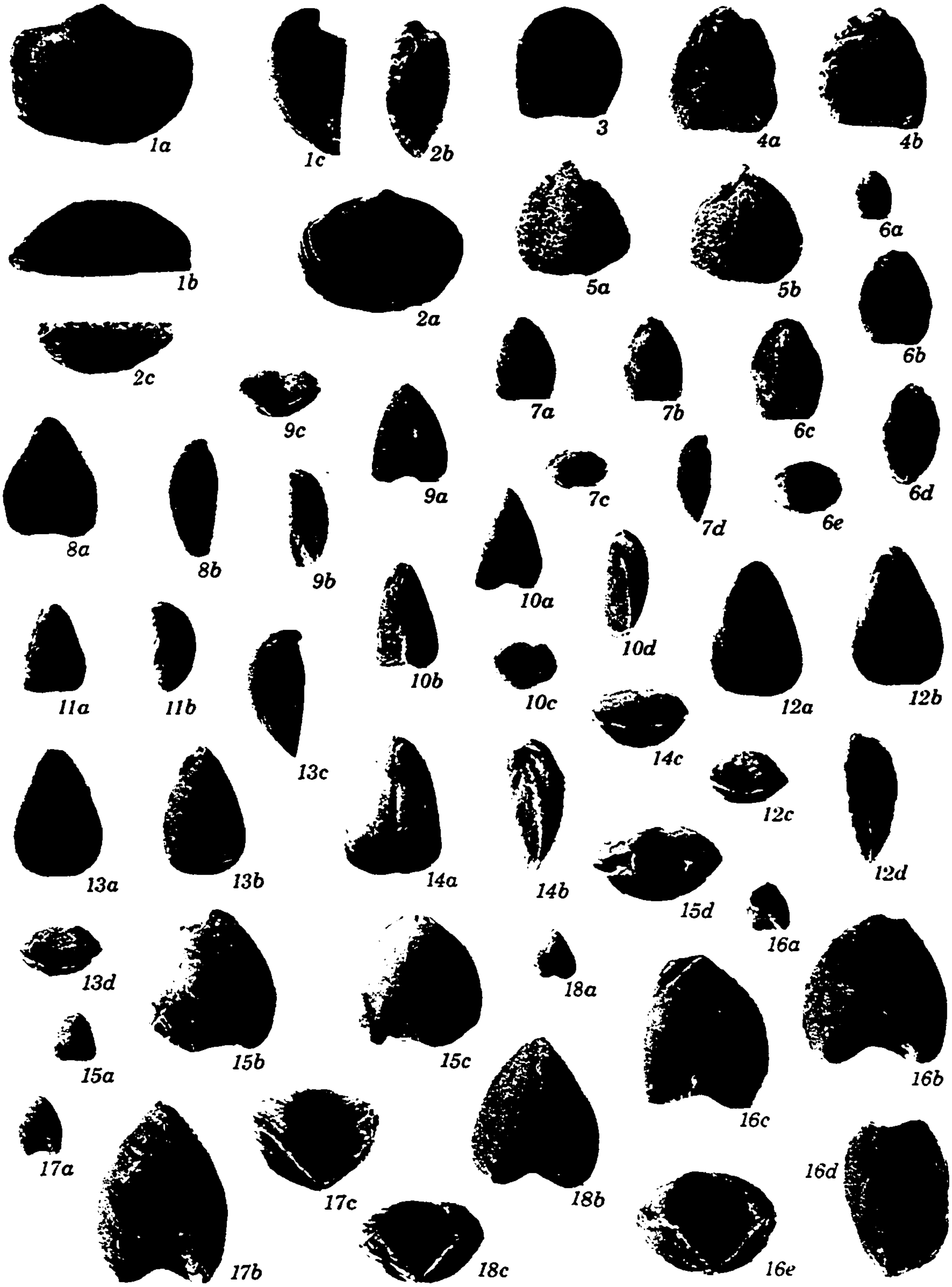
8. OU 7321, M116-18, X1: a, pedicle; b, brachial; typical specimen.

9. OU 7322, M116-18, X1: a, pedicle; b, brachial; c, anterior; typical specimen.

10. OU 7323, M110-20, X1: a, pedicle; b, brachial; c, anterior; d, left lateral; sulcus deeper than typical.

11. OU 7324, M110-20, X1: a, pedicle; b, left lateral; specimen thicker than typical.

Plate 8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APPENDIX I: MEASURED STRATIGRAPHIC SECTIONS AND COLLECTING LOCALITIES

INTRODUCTION

Field Methods

All stratigraphic sections were measured using the field methods described by Kottlowski (1965, p. 59-91). The most common technique was the Abney level held on top of a five-foot Jacob's staff, graduated into feet and tenths of feet. Occasionally, steel tape and eyeheight measurements were employed.

Horizontal distances and locations were determined from aerial photographs, 7.5 minute topographic maps (where available), county highway maps, and the geologic maps of Huffman and others (1958) in northeastern Oklahoma.

Field descriptions were compiled at the outcrop, and a record was made of the rock type, color, bedding thickness and regularity, sedimentary structures, hardness, weathering characteristics, topographic expression, relationship to other units, types of fossils, attitude of the strata, and unit thickness. The descriptions are presented in this appendix in this order. The brachiopod faunal lists are presented as Appendix II.

A standard numbering system has been used for all stratigraphic sections measured during the study of the Morrow Group in northeastern

Oklahoma by a number of students working under the direction of Dr. P. K. Sutherland and has been extended into northwestern Arkansas by the author. Stratigraphic sections are designated by the prefix "M" followed by a number that stands for a unique stratigraphic sections; individual units are also designated by a number than is preceeded by a hyphen ("-"). For example, the symbol M105-8 indicates Morrowan stratigraphic section M105, unit 8. Occasionally after a section was measured, it became convenient to subdivide a given unit into two or more units (i.e., M105-8A and M105-8B). The symbol M105D represents a different stratigraphic sections than M105, M105A, or M105C. Localities are depicted by a capital "M" succeeded by a number (e.g., M123).

Each unit was painted in the field with yellow traffic grade paint to facilitate collecting and reexamination.

A number of the stratigrahic sections used in this study have been included in Sutherland and Henry (in preparation) and/or in recent theses by Haugh (1968), Bowlby (1968), Henry (1970), and in dissertations by Rowland (1970) and Kotila (1973), all of which have employed the standardized numbering system mentioned above. These sections are not repeated in this appendix. Only the sections that have not been described in one of these sources are included in Appendix I.

Terminology

In this appendix, irregularly bedded refers to beds that pinch or swell or are broken into a nodular appearance and may tongue out between bedding planes within a short distance or even coalesce with the beds above and below as the intervening bedding plane disappears (Dunbar and Rodgers, 1957, p. 98). Regularly bedded refers to those beds present-ing an even appearance and that generally can be traced for long distances, and between which the beds do not coalesce.

The quantitative description of bedding, which was proposed by McKee and Weir (1953, p. 381-390) and modified by Ingram (1954, p. 937, 938), is adopted in this appendix as follows:

very thickly bedded.	greater than 3 feet
thickly bedded	1 to 3 feet
medium bedded.	4 inches to 1 foot
thinly bedded.	1 to 4 inches
very thinly bedded	0.4 to 1 inch
thickly laminated.	0.1 to 0.4 inches
thinly laminated	less than 0.1 inch

A "unit", as used in this appendix, generally imples a distinct lithic division that is recognizable in the field and which can be distinguished from overlying and underlying units. In this sense, a unit can be of any thickness. Occasionally, however, a single lithic entity has been divided into two "units" on the basis of a distinct change in bedding character.

The terrigenous sedimentary rocks were described in the field using the Wentworth (1922) grade-scale and following the pattern suggested by Folk (1968, p. 144) of: grain-size, prominent cements, textural maturity, notable or unusual transported constituents, and main rock name.

The field description of the carbonate rocks is the field classification of Grabau (1904, 1913), modified by Folk (1959, p. 16). Thin-section or polished and etched slab descriptions utilized the same terminology and in addition employ the classification of Dunham (1962, p. 117) as a supplementary term.

MEASURED STRATIGRAPHIC SECTIONS

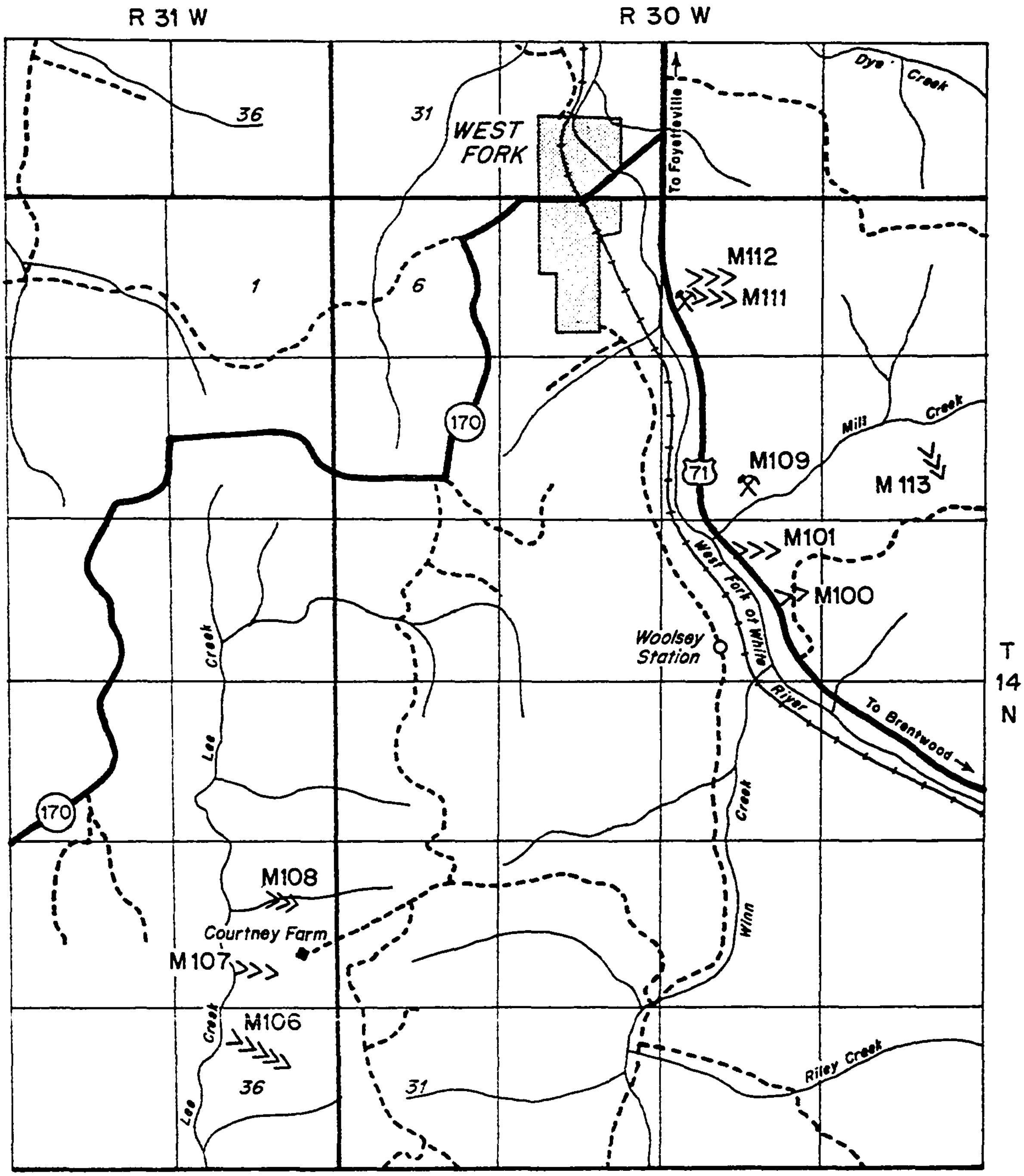
Introduction to Woolsey Station Sections, M100 and M101

Location.--Two closely spaced stratigraphic sections, M100 and M101, were measured near Woolsey Station in Sec. 16, T. 14N., R. 30 W., Washington County, Arkansas.

Description of Outcrops.--One of the best and most complete exposures of the Bloyd Formation in central Washington County occurs along the eastern side of U. S. Highway 71 on the western side of Everett Mountain, beginning immediately south of the highway bridge over Mill Creek at its confluence with the West Fork of the White River.

The two stratigraphic sections, M100 and M101, are measured in these exposures (text-figure 22). The roadcuts themselves expose the entire Brentwood Limestone Member and extend approximately 1.5 miles to the south.

The main (northern) roadcut exposes the upper part of the Prairie Grove Member, the entire Brentwood Limestone, and the lower part of the Woolsey Member. Beginning at a point about 50 to 60 feet above the highway, much of the higher portion of the Bloyd is covered with soil and talus and is heavily wooded. The best outcrops of the middle and upper parts of the Bloyd occur in a small ravine, trending eastward up Everett Mountain and located about 0.3 mile south of the Mill Creek bridge and 100 yards north of a small fault. It is within this ravine that measured section M101 was measured. Measured section M100 was measured near the northern end of the outcrop.



Text-figure 22.--Map showing location of Woolsey Station sections (M100, M101), sections on headwaters of Lee Creek (M106, M107, M108), Skelton's Quarry section (M109), West Fork sections (M111, M112) and Mill Creek section (M113). Base taken from Washington County General Highway Map (1963); scale: 1 inche = 1 mile.

Previous Investigations.--The earliest recorded reference to the Woolsey outcrops is by Simonds (1891, p. 88), who referred the strata in the lower part of the section to what he termed the "Pentremital limestone". He (ibid., p. 104, 105) also noted the presence of the Kessler Limestone on the hillside above the bluffs, and presented a measured stratigraphic section (ibid., p. 137, Section VIII).

L. G. Henbest and F. R. Henbest visited the Woolsey outcrops in 1933 and assigned U.S.G.S. localities 8178 and 8179 to the Brentwood exposures in the vicinity of measured section M100. Locality 8179 is near the C, W½, SW½, NE¼, Sec. 16 and is within the upper part of the Brentwood Limestone Member (Gordon, 1965, p. 57). It is in the same location as measured section M100 of this dissertation. U.S.G.S. locality 8178 is near the C, NW¼, SE¼, Sec. 16 and is reported to be within the same horizon. This locality is slightly south of measured section M100.

In 1936, G. H. Girty and L. G. Henbest collected fossils from the upper portion of the Brentwood Limestone Member near the C, east side, NE¼, NE¼, NW¼, Sec. 16 and assigned to this site U.S.G.S. locality 8203 (Gordon, 1965, p. 58). This coincides with the approximate location of measured section M101.

A measured section of the outcrops at this general site was made by Oglesby (1952) as a part of the master of science thesis at the University of Arkansas.

Henbest (1953, p. 1942) mentioned the superb exposures at Woolsey Station, and in his discussion of his locality 8 (ibid., p. 1950, 1951) made the following remarks about these outcrops: "The stratigraphic section from the Prairie Grove member of the Hale formation up to and including the base of the Woolsey member of the Bloyd shale is better displayed here than perhaps at any other place. This is unquestionably true of the Brentwood limestone member of the Bloyd shale." In Henbest's later publication (1962a, p. 40) he reassigned the type locality of the Brentwood Limestone Member to be the exposures in the immediate vicinity of sections M100 and M101. He stated: "the Brentwood at this locality is 40 to 45 feet thick, contains an 18-foot dark shale at the base, and terminates above in a marine limestone unit. The top of the Brentwood is truncated by an unconformity beneath the basal conglomerates and plant-bearing shaly sandstone of the Woolsey Member."

U.S.G.S. locality 14384 was assigned to the outcrops at the top of the Prairie Grove Member in the NW¼, NE¼, Sec. 16 by M. Gordon and R. A. Lewandowski in 1953 (Gordon, 1965, p. 63). This locality is most probably equivalent to unit M101-7.

Gordon (1965, p. 42) also mentioned these outcrops, described the details of the U.S.G.S. localities in this immediate area, and presented a list of the goniatites collected from them.

Conodont samples were collected from the upper Prairie Grove Member, the Brentwood Limestone Member, and the basal portion of the Woolsey member at locality M101 by H. R. Lane (1966) and the conodont fauna from these samples was published by him in 1967. Lane's sample numbers have been incorporated in the unit numbers of the current dissertation.

Detailed measured sections of the Bloyd Formation were made by Ewald (1971) for his study of the paleoecology of the Bloyd in this area.

Measured section M100 is located in the same ravine as Ewald's "main section".

Manger (1971) presented a measured section of the upper part of the Prairie Grove Member and part of the Brentwood Limestone Member at the site of M101 as a part of his Ph.D. dissertation at The University of Iowa.

<u>Section M100: Woolsey Station -- Everett Mountain</u>

<u>Location</u>.--E½, Sec. 16, T. 14N., R. 30W., Washington County, Arkansas. The section begins with the lowest outcrops in the upper part of the Hale Formation in the culvert on the east side of U. S. Highway 71 at a point approximately 0.5 mile southeast of the bridge over Mill Creek (text-figure 22). The section begins in the NE¼, NW¼, SE¼, Sec. 16 and is measured eastward up the ravine and steep wash up the west side of Everett Mountain and terminates in the lower part of the Atoka Formation in the SW¼, SE¼, NE¼, Sec. 16 at a point approximately 50 yards east of the gravel road leading up the western side of Everett Mountain.

<u>Stratigraphy</u>.--The section begins in the upper part of the Prairie Grove Member and terminates in the lower part of the Atoka Formation. Unit assignment of units to members and thicknesses of these members are as follows:

- Morrow Group (partial section, 277 feet)
  - Bloyd Formation (261 feet)
    - Trace Creek Shale (units 27 and 28, 83 feet)
    - Kessler Limestone (units 25 and 26, 3.4 feet)
    - Dye Shale Member (units 18 through 24, 85 feet)
    - Woolsey Member (units 12 through 17, 39 feet)
    - Brentwood Limestone (units 7 through 11, 51 feet)
  - Hale Formation (partial section, 16 feet)
    - Prairie Grove Member (partial section, units 1 through 6, 16 feet)

The section up through the basal part of the Woolsey Member is continuously exposed in the roadcuts. The Woolsey Member itself is largely covered, except for the basal few feet and the upper contact with the "caprock" (units 18 and 19, 2.4 feet thick). The Dye Shale above the "caprock" is poorly exposed in the ravine, and it is probable that only the lower part of the Kessler Limestone Member actually crops out on the hillside above. The Kessler is poorly exposed, and only the lower part of the Trace Creek Shale is exposed. The lower part of the Atoka Formation forms good exposures all along the mountainside above the road.

A total Morrowan exposure of 290 feet can be calculated from Simond's (1891, p. 137) Section VIII, but he recorded 107 feet for the interval corresponding to the Dye Shale and only 60 feet for the interval now assigned to the Trace Creek Member.

Remarks.--The current section was measured by T. W. Henry on October 18 and 19, 1971. For additional remarks see "Introduction to Woolsey Station Sections".

Unit No.	Description	Thickness
ATOKA FORMATION		
29	Sandstone; fine-grained, immature, clay-bonded, micaceous quartzarenite; light brownish yellow, weathers moderate yellowish brown. Thin- to medium-bedded, regularly bedded; oscillation ripple marks common. Forms distinct cliff on hillside above road and 50 to 60 yards east of road. Thickness not measured.	

MORROW GROUP

BLOYD FORMATION

28	Covered. No indicative talus; road crosses at 35 to 40 feet above base; measured at point 35 to 50 yards north of house and perpendicular to hillside. Thickness, estimated	75'
27	Covered and shale: shale; clay shale; dark olive gray, weathers light olive gray. Poorly exposed on banks of wash above ledges formed by units 25 and 26; slope becomes much less steep and unit forms bench approximately 35 yards west of gravel road; house located on this bench 35 to 50 yards to south. Thickness approximately	8'
26	Limestone; fine- to coarse-grained, conglomeratic, highly quartz-sandy, pelmatozoan calcarenite (grainstone); pebbles and granules of quartzarenite, calcilutite, and claystone scattered in basal portion; medium dark gray, weathers moderate brownish gray. Thin- to medium-bedded, irregularly bedded. Weathers with clasts and pebbles in relief; forms slightly slumped ledge above unit 25. Contains scattered algal oncoliths. Thickness, direct measurement	1.2'
25	Limestone; medium- to coarse-grained, pelmatozoan calcarenite (grainstone) at base, becoming fine- to medium-grained, micritic, pelmatozoan, intraclast-bearing calcarenite (packstone to grainstone) in upper 0.5 foot; medium light gray, weathers light yellowish gray. Medium-bedded, irregularly bedded. Forms ledge in wash. Upper contact obscure. Contains scattered algal oncoliths in upper 0.5 foot. Thickness direct measurement, maximum thickness	2.2'
24	Shale; quartz-silty at base, becoming nonsilty upward; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated at base, becoming thinly laminated upward. Exposed in steep wash below bluff of Kessler Limestone; particularly well-exposed on north bank of wash; upper 1 foot covered. Thickness, estimated	19'
23	Covered. Thickness estimated	17.5'

22 Shale and covered: shale, non-quartz-silty; olive gray, weathers light olive gray. Poorly exposed in gully on north bank of creek beneath fallen log approximately 50 feet west of barbed wire fence. Thickness approximately 10'

21 Covered. Estimated thickness measured with Abney level through open woods 30'

20 Shale, non-quartz-silty; contains clay-ironstone concretions; dark olive gray, weathers light olive gray; concretions weather moderate yellowish orange. Thinly laminated. Lower part well-exposed 15 feet north of creek; upper 1 foot poorly exposed. Thickness 6'

19 Sandstone; fine-grained, calcite-cemented and clay-bonded, carbonaceous, submature quartzarenite; medium dark gray, weathers olive brown. Thin-bedded, cross-bedded, irregularly bedded. Forms receeding upper part of bench, well-exposed 15 to 25 feet north of creek. Upper contact obscure. Thickness, direct measurement, maximum exposure 1.2'

18 Limestone; fine- to coarse-grained, quartz-sandy, pelmatozoan, mixed-skeletal calcarenite (grainstone); moderate olive gray, weathers moderate olive brown. Medium-bedded, cross-bedded, irregularly bedded. Unit forms distinct bench north of creek; bench can be traced northward for several hundred yards; poorly exposed south of creek. Upper contact gradational. Thickness, direct measurement, maximum exposure 1.2'

17 Shale, highly quartz-silty; moderate brownish gray, weathers light yellowish gray and moderate yellowish brown. Thickly laminated, irregularly laminated. Exposed as recess beneath unit 18. Upper contact sharp. Contains carbonized wood and plant fragments throughout. Maximum exposure, direct measurement 3.3'

16 Covered. Thickness approximately 5'

Note: Measured 9 foot-interval from top of unit 15 in creek to top of unit 18 in north bank of creek; offset northward on top of unit 19 and measured thickness of units 17, 18, and 19 at this point. Subtracted thickness of these units from 9 foot-interval to obtain thickness of unit 16.

15 Shale, quartz-silty; medium dark gray, weathers moderate grayish brown. Thickly laminated to very thin-bedded. Lower part well-exposed in north bank of creek; upper part poorly exposed north of creek. Thickness approximately 14'

14 Covered. Thickness measured eastward up creek, approximately 6.5'

13 Shale and siltstone: shale, highly quart-silty, grading into argillaceous siltstone; medium dark gray, weathers moderate brownish gray. Thickly laminated to very thin-bedded, irregularly laminated. Poorly exposed and slightly slumped in north bank of creek above cliff; basal few feet intermittently exposed at top of bluff along where section offset southward. Thickness, approximately 9.5'

Note: Offset section southward approximately 75 yards to creek above culvert where powerline cut intersects upper bluff at top of unit 12.

12 Sandstone; fine- to medium-grained, clay-bonded and limonite-cemented, immature, slightly calcareous quartzarenite; light grayish brown, weathers moderate grayish brown. Hard and porous. Thin-bedded, single bed, cross-laminated; regularly bedded, but thins southward slightly. Forms ledge at top of bluff below trees and barbed wire fence. Hard and porous weathers pitted. Upper contact sharp. Thickness, direct measurements, varies from 0.8 to 1.1 feet, averages 0.9'

11 Limestone; medium- to coarse-grained, pelmatozoan calcarenite (grainstone) becoming quartz-sandy in upper 2 feet and grading into calcareous sandstone in upper 0.3 foot; moderate brownish gray, weathers moderate yellowish gray. Medium- to thick-bedded, cross-bedded, irregularly bedded. Forms cliff at top of roadcut; lower part weathers cavernous; upper part weathers with quartz-sandy layers in relief emphasizing cross-bedding. Upper contact sharp, gently undulating. Measured above cane thicket (best approached from top); thickness varies from 5.0 feet in creek to south to 6.5 feet on bluff above where units 7 through 10 were measured, direct measurements, averages 5.8'

10 Siltstone and limestone: limestone; fine- to medium-grained, mixed-skeletal calcarenite (grainstone) with quartz-silty lenses and irregularly interbedded highly quartz-silty shale and argillaceous, calcareous

quartzsiltites; medium gray, weathers moderate yellowish brown. Limestone lenses, thin- to medium-bedded in lowerpart; siltstone, thickly laminated, irregularly laminated, ?ripple-marked. Unit forms highly distinctive recessed middle portion of cliff in roadcut, top of which can be traced northward fro several hundred yards; locally recessed as much as 6 feet; limestones weather platy. Thickness varies from 7.4 feet at north end of exposures to 12.0 feet at creek, averages 9.7'

9 Limestone, conglomeratic; medium-grained, pelmatozoan, mixed-skeletal calcarenite to fine-grained calcirudite (grainstone); contains abraded whole fossils, shale clasts, and scattered phosphate pebbles; light olive gray, weathers moderate yellowish brown. Medium-bedded, single bed, irregularly bedded, lensing. Upper contact sharp, undulating. Thickness varies from 0.0 to 1.0 feet, averages 0.5'

8 Limestone; medium- to coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone); contains shale clasts sparsely in base; moderate brownish gray, weathers dark brownish gray. Medium- to thick-bedded, irregularly bedded; cross-bedding apparent on weathered surfaces; locally contains 0.2 foot calcareous shale at top. Forms basal portion of high cliff in roadcuts; weathers crumbly; top can be walked for 30 to 50 feet northward and southward from cane thicket. Upper contact sharp, undulating. Thickness varies because of irregularity of upper surface, varies from 4.5 to 5.1 feet, averages 4.8'

7 Shale, noncalcareous, nonsilty; contains scattered, flattened clay-ironstone concretions throughout; lower 2 feet calcareous and fossiliferous; dark gray, weathers olive gray. Thickly laminated, regularly laminated. Well-exposed in cutbanks of highway. Upper contact sharp, undulating. Thickness approximately 30'

HALE FORMATION (partial)

Note: Offset section approximately 100 feet northward on top of unit 6 to good shale exposures in cutbank of highway; unit 6 is poorly exposed with talus of unit 7 covering most of unit.

6 Limestone; medium-grained, oolitic, mixed-skeletal calcarenite at base with zones of micrite (grainstone and packstone) becoming medium- to coarse-grained, quartz-sandy, mixed-skeletal, oolitic calcarenite at top (grainstone); medium gray, weathers light brownish gray. Medium-bedded, irregularly bedded. Forms upper part of ledge for 25 feet north of culvert and approximately 100 feet south of culvert. Contains large, scattered Michelinia colonies in upper portion. Thickness varies from 3.0 to 3.2 feet, averages 3.1'

5 Limestone; medium- to coarse-grained, mixed-skeletal calcilutite (wackestone to mudstone), with basal portion medium- to very coarse-grained, pelmatozoan, bryozoan, micritic calcarenite (packstone); dark gray, weathers medium orangish gray. Basal two beds medium-bedded; upper portion thin-bedded, regularly bedded, interbedded with thin calcareous and sparsely fossiliferous shale. Forms lower part of upper bluff by small sycamore tree above concrete culvert. Lower beds weather with cavernous solution surfaces, upper beds blocky. Contains sparse Michelinia. Thickness, direct measurement 5.0'

4 Shale, calcareous at base, becoming noncalcareous upward; medium gray, weathers moderate brownish gray. Thickly laminated, irregularly laminated, interlaminated with lenses of quartz-silty shale. Slightly recessed beneath overlying unit. Upper contact sharp. Thickness, direct measurement 1.7'

3 Limestone; medium- to very coarse-grained, pelmatozoan, bryozoan, mixed-skeletal, micritic calcarenite (packstone to grainstone) with scattered quartz-sand and coated grains; medium gray, weathers moderate grayish brown. Medium-bedded, becoming thin-bedded at top; irregularly bedded. Upper contact gradational. Thickness, direct measurement 1.6'

2 Limestone; medium- to very coarse-grained pelmatozoan, slightly quartz-sandy, partially silicified carcarenite (grainstone); contains scattered clay clasts at base; medium dark gray, weathers brownish orange and moderate grayish brown. Thin-bedded, irregularly bedded. Forms middle portion of lower ledge immediately east of culvert. Upper contact sharp, undulating, welded. Contains Michelinia, solitary rugose corals. Thickness, direct measurements, varies from 1.7 to 2.0 feet at expense of underlying unit, averages 1.9'

1 Limestone; fine- to medium-grained, quartz-sandy, mixed-skeletal, oolitic calcarenite (grainstone) with scattered lenses and zones of micrite; medium dark gray, weathers moderate brownish gray. Medium-bedded, irregularly bedded. Exposed at level of culvert. Upper contact sharp. Thickness, direct measurement, maximum exposure 2.8'

Section M101: Woolsey Station — Mill Creek, U. S. Highway 71 Bridge

Location.—N½, Sec. 16, T. 14N., R. 30W., Washington County, Arkansas. The section is exposed in the road cuts and bluffs along the east side of U. S. Highway 71 overlooking the West Fork of the White River on the west side of Everett Mountain (text-figure 22). The section begins in the upper part of the Hale Formation at a point 0.5 mile northeast of the townsite of Woolsey, Arkansas, and 0.4 mile south of the junction of Mill Creek and the West Fork of the White River.

The lowest exposures are located 10 yards south of the access to the house at the south end of the Mill Creek bridge and 100 yards south of the bridge in the SE¼, NE¼, NW¼, Sec. 16. It is offset southward on the top of the Hale Formation for a distance of 200 yards, and the remainder of the section is measured eastward up the bluffs to the highest exposures at the top of the ridge in the SW¼, NW¼, NE¼, Sec. 16.

Stratigraphy.—Measured section M101 begins in the upper part of the Prairie Grove Member and ends in the upper part of the Woolsey Member. Thicknesses of members and assignment of units to members are as follows:

Morrow Group (partial section, 105 feet)
  Bloyd Formation (partial section, 83.9 feet)
    Woolsey Member (partial, units 21 through 25, 36 feet)
    Brentwood Limestone (units 8 through 20, 48 feet)
  Hale Formation (partial section, 21 feet)
    Prairie Grove Member (units 1 through 7, 21 feet)

The upper part of the Prairie Grove Member is quite well exposed; the middle part of the Woolsey Member is completely covered, and only the basal portion and upper part of this member are exposed.

Considerable confusion has arisen as to what Henbest (1953, 1962a) considered the base of the Woolsey Member here. Both H. R. Lane (1967) and Henry agree on the placement of the base of the Woolsey Member at the top of the last prominent, cliff forming limestone (M101-20). Lane's Idiognathodus humerus fauna first occurs in this section in the thin argillaceous, quartz-silty limestones in the lower part of M101-22.

Remarks.—The section was described on October 26, 1971, by T. W. Henry and was visited on December 12, 1971, by H. R. Lane and T. W. Henry. Lane's (1967, p. 926, 1969, p. 30, p. 58, table 3) conodont samples were fitted into the measured sequence. The conodont fauna is listed herein at the end of the appropriate units.

Unit No.	Description	Thickness
	MORROW GROUP	
	BLOYD FORMATION (partial)	
25	Sandstone; very fine grained, clay-bonded, immature quartzarenite; light brownish gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded. Exposed as slightly slumped blocks immediately west of powerline cuts. Covered above. Thickness, maximum exposure	2.5'

24 Covered. Heavily wooded slope with scattered pieces of calcilutite (mudstone) talus approximately 5 feet above base. Thickness estimated 20'

23 Siltstone; coarse-grained, clay-bonded, immature, micaceous quartzsiltite; moderate yellowish brown, weathers light yellowish gray. Thickly laminated, irregularly laminated. Slightly slumped at top of nonvegetated area below woods and fence. Thickness, maximum exposure 5'

22 Shale, nonsilty; medium dark gray, weathers same. Thicly laminated. Exposed by digging; found in receeding part of upper bluff. May contain clay-ironstone concretions. Thickness, approximately 5'

21 Siltstone and sandstone: sandstone; fine-grained, clay-bonded, immature quartzarenite interbedded with coarse-grained, clay-bonded, immature quartz-siltite; moderate orangish brown, weathers light brownish gray. Thickly laminated to thin-bedded, cross-laminated, irregularly laminated. Forms receeding part of upper cliff; locally forms over-hanging, slabby-weathering ledges where block of underlying unit has slumped down hillside. Note: unit contains thin lenses of fine-grained, quartz-silty, argillaceous, mixed-skeletal, pelmatozoan calcarenite (packstone) in basal 1 foot from which Lane's condont sample #25 was collected. Conodonts: Adetognathus lautus, Idiognathoides sinuatus, Neognathodus bassleri bassleri, Idiognathodus humerus, Neoprioniodus sp. Thickness, direct measurement 3.2'

20 Limestone; medium- to coarse-grained, pelmatozoan, bryozoan calcarenite (grainstone) with scattered coated-grains and quartz-sand; moderate brownish gray, weathers light brownish gray. Thick-bedded, single bed, regularly bedded. Forms upper part of highest cliff. Upper contact sharp. Lane's conodont sample #24: Adetognathus gigantus, A. lautus. Thickness, direct measurement 3.6'

19 Limestone; fine-grained, brachiopodal, mixed-skeletal calcilutite to coarse-grained, micritic, mixed-skeletal calcarenite (wackestone to pack-stone); medium dark gray, weathers moderate brownish gray. Lower bed medium-bedded, upper bed thin-bedded, separated by shale parting, regularly bedded. Weathers smoothly, forms middle part of highest cliff. Upper contact sharp. Lane's conodont samples #22 and 23: Adetognathus lautus, A.

gigantus, Idiognathoides inalienatus, I. sinuatus, I. corrugatus, Neognathodus bassleri bassleri, Ozarkodina delicatula, Spathognathodus minutus, Neoprioniodus sp. Thickness, direct measurement 2.0'

18 Limestone; fine- to medium-grained, slightly quartz-sandy, pelmatozoan, mixed-skeletal, partially silicified calcarenite (? grainstone); medium dark gray, weathers moderate brownish gray. Medium-bedded, regularly bedded, single bed. Forms lower part of distinct upper bluff; weathers with fossils slightly in relief, tends to weather platy. Lane's conodont sample #21: Adetognathus lautus, A. gigantus, Idiognathoides inalienatus, I. sinuatus, I. corrugatus, Neognathodus bassleri symmetricus, Ozarkodina sp. Thickness, direct measurement 1.7'

Note: Offset section 50 feet southward on top of unit 17.

17 Shale, calcareous; medium gray, weathers light olive gray. Thickly laminated, irregularly laminated with scattered limestone concretions. Recessed slightly on bluff face. Upper contact sharp, undulating. Contains Michelinia. Thickness, direct measurement, varies from 0.5 to 1.0 foot, averages 0.8'

16 Limestone; medium- to coarse-grained, pelmatozoan, bryozoan, mixed-skeletal calcarenite to fine-grained calcirudite; contains scattered coated-grains; argillaceous in lower part; medium gray, weathers light brownish gray. Thickly laminated in lower part, becoming thin-bedded in upper part. Forms lower half of cliff, locally slightly recessed. Upper contact sharp. Contains Michelinia, solitary rugose corals, Branneroceras branneri; Lane's conodont sample #20: Adetognathus lautus, A. gigantus, Idiognathoides inalienatus, I. sinuatus, I. corrugatus, Neognathodus bassleri bassleri, Synprioniodina sp., Hibbardella sp., Neoprioniodus sp. Thickness, direct measurements, varies from 0.5 to 2.0 feet, averages 1.5'

15 Shale and limestone: shale, noncalcareous; dark gray; and calcareous; moderate yellowish brown. Limestone; lenses of argillaceous mixed-skeletal calcarenite. Unit forms second break in cliff, generally recessed beneath highest cliff. Upper contact sharp, truncating. Contains Michelinia; Lane's conodont sample #19: Adetognathus lautus, A. gigantus, Idiognathoides inalienatus, I. sinuatus,

I. corrugatus, Neognathodus bassleri symmetricus, Synprioniodus sp., Ozarkodina delicatula, Hibbardella sp., Neoprioniodus sp. Thickness, direct measurements, varies from 3.5 to 4.5 feet, averages 4.0'

Note: Offset 50 to 75 feet southward on top of unit 14.

14 Limestone; medium- to coarse-grained, pelmatozoan calcarenite (grainstone); medium dark gray, weathers light brownish gray. Thin- to medium-bedded, regularly bedded, cross-bedding minor. Forms middle cliff; weathers slightly fluted. Lane's conodont samples #17 and #18: Adetognathus lautus, A. gigantus, Idiognathoides sinuatus, I. corrugatus. Thickness, direct measurement 5.5'

13 Shale and limestone: shale; medium dark gray, weathers light gray. Limestone; fine- to medium-grained, quartz-sandy, pelmatozoan calcarenite (grainstone). Shale; thickly laminated with limestone lens 0.5 to 1.0 feet thick in middle. Unit forms first break on bench in exposure above roadcut. Upper contact sharp. Thickness, direct measurement 5.0'

Note: Offset section 25 feet to the south on top of unit 12.

12 Limestone; medium-grained, well-sorted, pelmatozoan, quartz-sandy calcarenite (grainstone); dark brownish gray, weathers moderate brownish gray. Thick-bedded, irregularly bedded, strongly cross-laminated. Unit forms distinctive lower bluff above road cut; weathers with quartz-sandy lamillae in relief, accentuating cross-lamination. Upper contact sharp. Lane's conodont samples #13, #14, and #15: Adetognathus lautus, A. gigantus, Neognathodus bassleri symmetricus, Idiognathoides sinuatus, I. corrugatus, Ozarkodina sp. Thickness varies from 3.5 to 4.0 feet, averages 3.8'

11 Shale, non-quartz-silty; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Blocky and splintery. Thickness, direct measurement 1.6'

Note: The units were initially misnumbered; the omission of the use of #10 was discovered only after the section was measured, described, painted, and collected. There is no unit 10.

9 Limestone; fine- to medium-grained, pelmatozoan, slightly quartz-sandy, conglomeratic calcarenite (grainstone) with pebbles of phosphate and shale clasts; medium dark gray, weathers light yellowish brown. Thin-bedded, irregularly bedded. Exposed as small ledge under overhanging cliff. Upper contact sharp. Contains Michelinia, small solitary rugose corals. Thickness, direct measurement 0.7'

8 Shale; non-quartz-silty; calcareous only in basal 0.5 feet; dark olive gray, weathers light olive gray. Thinly laminated. Mostly covered where measured thickness but well-exposed laterally; forms receeding bench, mostly weed- and grass-covered approximately 200 yards south of highway bridge over Mill Creek. Contains clay-ironstone concretions up to 0.5 foot long and thin limestone lenses near top. Lane's conodont samples #10 and #11: Adetognathus gigantus, Neognathodus bassleri symmetricus. Thickness approximately 18'

Note: Section offset southward to point 200 yards south of bridge on top of unit 7.

HALE FORMATION (partial)

7 Limestone; medium- to coarse-grained, pelmatozoan-brachiopodal calcarenite to fine-grained calcirudite (grainstone); basal portion contains scattered quartz-sand; zones of micritic limestones (packstones) within upper part of unit; moderate brownish gray, weathers moderate yellowish brown. Medium-bedded, irregularly bedded, slightly cross-bedded. Forms upper part of cliff approximately 75 feet south of access road to house. Upper contact gradational. Contains Michelinia. Thickness 3.4'

6 Limestone; fine-grained, mixed-skeletal calcilutite (wackestone); medium dark gray, weathers moderate yellowish brown. Medium-bedded at base, becoming thin-bedded at top and interbedded with thin calcareous shale, irregularly bedded. Forms receeding upper part of bluff approximately 75 feet south of access road to house; also exposed as bench in ditch of highway approximately 75 yards south of bridge. Upper contact sharp, welded, undulating. Thickness, direct measurement 2.2'

5 Limestone; coarse-grained, highly quartz-sandy, pelmatozoan, mixed-skeletal calcarenite (grainstone) at base, becoming medium-grained, quartz-sandy, micritic,

mixed-skeletal calcarenite (grainstone to packstone) in middle and medium- to fine-grained, micritic, mixed-skeletal calcarenite (packstone) at top; medium dark gray, weathers moderate yellowish brown. Lower 4 feet thick-bedded, cross-bedded, irregularly bedded, becoming thin-bedded and interbedded with thin shale in upper part. Unit forms distinctive middle part of cliff south of first highway sign south of Mill Creek bridge; weathers slightly fluted in lower part with quartz-sandier layers in relief. Upper contact gradational and picked at first micrite-supported limestone bed. Thickness, direct measurement 7.9'

4 Shale and limestone: shale, quartz-sandy, calcareous. Sandstone; medium-grained, calcite-cemented and clay-bonded, submature quartzarenite; medium dark gray, weathers moderate brownish gray. Thickly laminated to thin-bedded, irregularly bedded. Unit forms distinct break in cliff. Upper contact sharp, undulating. Contains solitary rugose corals, Michelinia. Thickness, direct measurements, varies from 0.5 to 1.2 feet, averages 0.9'

3 Limestone; fine-grained, highly quartz-sandy, mixed-skeletal calcarenite (grainstone) to fine-grained, calcite-cemented, glauconite-bearing, skeletal quartzarenite; medium gray, weathers moderate orangish brown. Thick-bedded, irregularly bedded, cross-bedded; single bed. Forms middle part of cliff immediately east of highway sign and lower part of cliff 20 feet south of sign; weathers with pitted surfaces. Upper contact sharp. Thickness, direct measurements, varies from 2.5 to 2.8 feet, averages 2.7'

2 Limestone; recrystallized, mixed-skeletal calcilutite to fine-grained, micritic, mixed-skeletal calcarenite (packstone to wackestone); medium gray, weathers moderate yellowish gray. Medium-bedded, irregularly bedded. Forms lower part of small cliff at northernmost part of road cut. Upper contact obscure. Thickness, direct measurement 3.1'

1 Shale and limestone: shale, calcareous; dark gray, weathers moderate brownish gray. Thickly laminated, irregularly laminated, interbedded with thin, nodular limestone. Limestone; fine- to medium-grained, micritic, bryozoan, mixed-skeletal calcarenite (packstone); medium dark gray, weathers moderate yellowish brown. Unit poorly exposed immediately above highway ditch on east side of road sign and

below small limestone cliff. Thickness, direct measurement, maximum exposure | 1.0'

Note: Lane's conodont samples #0 through #6 were collected from the upper part of the Prairie Grove Member here; the lowest strata contains _Adetognathus lautus_, _A. gigantus_, and _Neognathodus bassleri symmetricus_.

Section M102: Dillon's Supermarket

Location.—$NE\frac{1}{4}$, $SE\frac{1}{4}$, $SW\frac{1}{4}$, Sec. 2, T. 16N., R. 30W., Washington County, Arkansas. This section is located in an abandoned quarry, now mostly filled by Dillon's Supermarket, at the intersection of Greenview Drive and Arkansas State Highway 45 (Mission Boulevard) in the northeastern part of the city of Fayetteville. The section is immediately southeast of the supermarket.

Stratigraphy.—The section begins in the uppermost part of the Prairie Grove Member and terminates in the lower part of the Brentwood Limestone Member. Thicknesses of and units assigned to these members are as follows:

Morrow Group (partial section 37 feet)
  Bloyd Formation (partial section)
    Brentwood Limestone (partial, units 3 through 11, 29 feet)
  Hale Formation (partial section)
    Prairie Grove Member (partial, units 1 and 2, 8 feet)

Remarks.—The current section was measured and described by T. W. Henry on November 1, 1971, at which time the store manager stated that the supermarket will be expanding in the near future and the remains of the quarry will be filled for the construction. The section was reexamined on March 4, 1973, by T. W. Henry and P. K. Sutherland.

A previous section was measured at this site by Manger (1971, p. 177, 178). This is probably the site of Mather's (1915, p. 247) Station 135 and U.S.G.S. locality 1999. For additional remarks, see discussion of Mather's Station 135 in Appendix III.

Unit No.	Description	Thickness
MORROW GROUP		
BLOYD FORMATION (partial)		
11	Limestone and shale: limestone; highly argillaceous, bryozoan calcarenite (packstone) to bryozoan biolithite (boundstone); medium dark gray, weathers moderate orangish brown. Thin-bedded, irregularly bedded, interbedded with calcareous shale. Exposed in wash north of quarry at point approximately 10 to 20 feet west of fence. Thickness, maximum exposure	4'
10	Limestone; medium- to coarse-grained, slightly micritic, bryozoan-pelmatozoan calcarenite (packstone to grainstone); medium gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded, single bed. Exposed as small ledge about two-thirds of way up slope at top (northeastern corner) of old quarry proper. Upper contact obscure. Thickness, direct measurement	0.9'
9	Shale, calcareous, and shale, noncalcareous, with latter one-third way up unit and approximately 2 feet thick; former light olive gray, weathers moderate yellowish gray; latter dark olive gray, weathers light olive gray. Thickly laminated, irregularly laminated with thin limestone nodules and discontinuous layers in lower part. Well exposed on southeastern side of old quarry where unit forms barren slope at point approximately 35 yards south of supermarket. Upper contact sharp, undulating. Unit highly fossiliferous; topotypes of *Hustedia brentwoodensis* come from this unit. Thickness approximately	7'

8	Limestone; coarse-grained, quartz-sandy, pelmatozoan, poorly sorted calcarenite (grainstone) becoming fine-grained, quartz-sandy, pelmatozoan, intraclast-bearing calcirudite (grainstone) at top; dark gray, weathers moderate yellowish brown. Medium-bedded, distinctly cross-bedded, irregularly bedded. Forms distinct ledge approximately 100 feet south of southeastern corner of building; weathers with rough surface with quartz-sandier layers in relief accentuating cross-bedding. Offset on top of bed southward into old quarry proper. Upper contact exposed in north side of quarry, gradational. Thickness, direct measurements, varies from 1.3 to 1.8 feet, averages	1.5'
7	Limestone; fine-grained, oolitic, highly quartz-sandy, recrystallized micritic calcarenite (recrystallized packstone) to quartzarenite; moderate orangish gray, weathers moderate yellowish brown. Thickly laminated to very thin-bedded, cross-laminated, irregularly laminated; irregularly interlaminated with thin quartz-silty shale. Unit generally recessed beneath unit 8; weathers rubbly. Upper contact sharp, undulating, locally welded. Thickness, direct measurements, varies from 0.9 to 1.2 feet, averages	1.0'
6	Limestone; fine-grained, pelmatozoan, bryozoan, coated-grained, recrystallized micritic calcarenite (recrystallized packstone); medium dark gray, weathers brownish yellow. Medium-bedded, irregularly bedded. Exposed as recessed ledge underneath unit 8 approximately 100 feet south of southeastern corner of building. Upper contact sharp, locally welded. Thickness, direct measurements, varies from 1.3 to 1.5 feet, averages	1.4'
5	Shale, quartz-silty, noncalcareous; medium dark gray, weathers moderate yellowish gray. Thickly laminated, regularly laminated. Forms second bench approximately 100 feet due south of southeast corner of building; upper part slightly recessed. Upper contact sharp, undulating. Thickness, approximately	8'
4	Limestone; fine- to medium-grained, micritic, intraclast-bearing, pelmatozoan calcarenite (packstone); medium dark gray, weathers yellowish brown. Thin-bedded, irregularly bedded; upper surface contains burrow casts and sparse trails. Exposed as slightly overhanging ledge approximately 35 feet south of edge of parking lot; can be traced southward into floor of old quarry proper. Upper contact obscure but apparently sharp. Contains *Michelinia*. Thickness, direct measurements, varies from 1.0 to 1.2 feet, averages	1.1'

3 Shale, quartz-silty, noncalcareous; dark olive gray, weathers moderate yellowish gray. Thickly laminated, regularly laminated. Forms recess beneath overlying limestone approximately 35 feet south of south edge of parking lot; also exposed on east side of store. Upper contact sharp, irregular. Thickness, approximately 4.5'

HALE FORMATION (partial)

2 Limestone; coarse-grained, recrystallized, mixed-skeletal calcilutite? to fine-grained, micritic calcarenite? (recrystallized ?wackestone to ?packstone); dark brownish gray, weathers light yellowish gray. Medium- to thick-bedded, irregularly bedded, single bed; upper surface distinctively pitted and containing numerous burrow fills. Forms upper part of vertical face at south edge of parking lot; can trace upper surface southward for 25 feet into edge of old quarry; poorly exposed on east side of parking lot. Upper contact obscure. Thickness, direct measurements, varies from 0.8 to 1.5 feet, thinning eastward, averages 1.0'

Note: The quarry itself has some minor structure in it, but the small anticline, affecting units 1 and 2, does not appear to influence the higher units.

1 Limestone; medium- to coarse-grained, bryozoan-pelmatozoan, slightly quartz-sandy calcarenite (grainstone); moderate brownish gray, weathers moderate grayish brown. Thick- to very thick-bedded, irregularly bedded, cross-laminated. Forms blasted face immediately south of parking lot at back of Dillon's Supermarket. Upper contact sharp, undulating, locally welded. (J. H. Quinn has reestablished this unit as the type locality of <u>Pygmaeoceras pygmaeum</u> Mather and states that it is U.S.G.S. locality 1999.) Thickness, maximum exposure measured directly at crest of small anticline 6.8'

<u>Section M103: Klyce's Spring (Big Spring)</u>

<u>Location</u>.—NW¼, Sec. 15, T. 16N., R. 30W., Washington County, Arkansas. The measured section begins near the top of the Fayetteville

Formation in the NW¼, SE¼, SW¼, NW¼, Sec. 15 in the creek immediately west of the house at 105 Willow Street, Fayetteville. The section is measured northward up the creek across Spring and East Dickson Street and terminates in the upper part of the Prairie Grove Member in the S½, SW¼, NE¼, NW¼, Sec. 15 in the back yard of the house at 404 East Dickson Street.

Stratigraphy.—The Fayetteville Formation (unit 1) is unconformably overlain by a limestone-pebble and -cobble conglomerate in the basal part of the Cane Hill Member. The Cane Hill Member is excellently exposed in the creek; the Prairie Grove Member is also characterized by a basal conglomeratic quartzarenite with scattered pebbles. The Prairie Grove is not well exposed, but the section probably terminates near the top of this member. The units in this section are assigned to the following members:

Morrow Group (partial)
 Hale Formation (almost complete, 84 feet)
  Prairie Grove Member (units 7 through 15, 42 feet)
  Cane Hill Member (units 2 through 6, 42 feet)

Henbest (1953, p. 1953) referred to this area as his locality 24 and noted the good exposures of the Cane Hill Member and the cross-bedded, calcareous quartzarenites of the Prairie Grove Member, the lower part of which forms the aquifer at Klyce's Spring.

Remarks.—This locality is Mather's (1915, p. 247) Station 136 and is the site of U.S.G.S. localities 1998 and 8193. For additional remarks, see discussion of Mather's Station 136 in Appendix III.

This section was measured and described on November 4 and 5, 1971, by T. W. Henry and was examined on March 4, 1973, by P. K. Sutherland and T. W. Henry.

Unit No.	Description	Thickness
MORROW GROUP		
HALE FORMATION (almost complete)		
15	Sandstone; medium-grained, calcite- and quartz-overgrowth-cemented, submature, sparsely skeletal, glauconite-bearing quartzarenite at base, becoming medium-grained, quartz-overgrowth-cemented, submature quartzarenite higher in unit; medium light gray, weathers moderate brownish gray. Thick- to thin-bedded, irregularly bedded, cross-bedded. Lower 8 feet forms small cliff on northern bank of creek below rock wall in back yard of 356 East Dickson Street; upper part exposed in both branches of creek; weathers pitted in places and cavernous in others. Lower contact gradational. Thickness measured to highest ledges in east bank of creek in back yard at 404 East Dickson Street, estimated	20-25'
	Note: Immediately northeast of wire storm gate across creek between property of Mrs. Englehart (318 East Dickson) and the property at 356 East Dickson, a small anticline brings unit 14 back to surface in creek. What is interpreted to be same unit is also exposed in creek 35 to 50 feet northeast of storm gate. Small sandstone bluff (unit 15) is exposed on northwestern bank of creek below rock wall at this point, and beds appear to be dipping 2 to 3 degrees eastward again.	
14	Limestone; medium- to coarse-grained, micritic, pelmatozoan-mixed-skeletal calcarenite (packstone); light gray, weathers medium light gray. Medium-bedded, becoming thin-bedded at top, irregularly bedded. Unit exposed immediately southeast of foot bridge where it makes small waterfall; top also exposed in creek north of small building on property of Mrs. E. J. Englehart	

	(318 East Dickson). Unit moderately fossiliferous; reestablished type locality of Tesuquea morrowensis (Mather) and Sandia welleri (Mather); Mather's locality 136. Thickness measured on northwest side of creek south of bridge, approximately	2.7'
13	Covered. Thickness approximately	2'
12	Limestone; medium-grained, bryozoan-brachiopodal, pelmatozoan calcarenite (packstone) at base, becoming medium- to coarse-grained, pelmatozoan, bryozoan-brachiopodal calcarenite (grainstone) at top; medium light gray, weathers medium gray. Bedding obscure but apparently medium-bedded. Lowest exposure immediately north of East Dickson Street bridge over creek; top bed exposed in creek bed approximately 50 feet northeast of bridge; unit worn smoothly by stream. Strike N80°E, dip approximately 2°SE. Thickness approximately	2.5'
11	Covered. Rock- and concrete-bridge of East Dickson Street crosses creek at this point. Thickness approximately	2'
10	Covered and sandstone: sandstone; medium-grained, glauconite-bearing, quartz-cemented quartzarenite; medium gray, weathers moderate yellowish brown and brownish gray. Thin- to medium-bedded, irregularly bedded, cross-bedded. Upper 2 feet well-exposed immediately south of bridge; also poorly exposed in banks of creek, especially on west side. Thickness, estimated	5'
9	Sandstone; fine-grained, clay-bonded and quartz-overgrowth cemented, immature, limonitic, glauconite-bearing quartzarenite; moderate brownish gray, weathers same. Thin-bedded, irregularly bedded, slightly cross-bedded. Forms ledge in creek and small waterfall; upper bed forms last well defined ledge in creek south of East Dickson Street bridge. Strike N80°E, dip approximately 2°N. Thickness, measured on east bank of creek	2.0'
8	Shale and siltstone: shale, quartz-silty, noncalcareous; dark gray, weathers moderate brownish gray. Thinly to thickly laminated, irregularly laminated, interbedded with siltstone. Siltstone; fine- to coarse-grained, clay-bonded, immature quartzsiltite; dark gray, weathers moderate brownish gray. Thickly laminated to very thin-bedded, regularly bedded. Forms recess under	

overlying unit at small pool in creek. Upper contact gradational. Thickness, direct measurement, maximum exposure 1.8'

7 Covered. Thickness approximately 1'

6 Sandstone; at base, very fine-grained, clay-bonded, immature, sparsely skeletal quartzarenite; middle, fine-grained, conglomeratic, calcite- and quartz-cemented quartzarenite with granules and rounded small pebbles of quartzarenite, quartzsiltite, and clay clasts; top, medium-grained, quartz overgrowth-cemented, submature quartzarenite; medium gray, weathers light olive gray. Thickly laminated in lower part, becoming thin-bedded, irregularly bedded in upper part. Well-exposed at point midway between Spring and East Dickson Streets where waterpipe crosses creek; forms upper, receeding part of waterfall. Upper contact covered. Thickness approximately 3.5'

5 Shale and siltstone: shale, quartz-silty; dark gray, weathers moderate brownish gray. Thinly to thickly laminated, irregularly laminated, interlaminated with siltstone. Siltstone; fine- to coarse-grained, clay-bonded, immature quartzsiltite; colors same as shale. Thickly laminated to very thin-bedded, irregularly bedded. Siltstones more prominent in upper 10 to 12 feet and shales in upper part also more quartz-silty. Upper part well-exposed on both banks of creek; lower portion poorly exposed; upper 8 feet makes waterfall in creek at point where waterpipe crosses creek. Beds at this point are flat. Thickness measured northward up creek, estimated 21'

4 Covered. Minor material like found in unit 2 approximately 3 feet above base below small artificial waterfall near manhole south of culvert under East Spring Street; section crosses street in upper part of interval. Thickness approximately 8'

3 Siltstone, sandstone, and shale: siltstone; coarse-grained, clay-bonded, immature, quartzsiltite to very fine-grained quartzarenite; moderate brownish gray, weathers light brownish gray. Thin-bedded to thickly laminated, irregularly bedded; well-developed current ripple marks on upper surfaces; interbedded with shale. Shale, quartz-silty, micaceous; colors same as siltstone. Thickly laminated, irregularly laminated. Basal 3 feet poorly exposed in creek to northeast where section measured but well-exposed on east bank of creek

between houses at 127 Willow Street and 207 East Spring Street; upper 5 feet well-exposed in creek bed where it forms series of small ledges on east side of house at 207 East Spring Street. Attitude measured on bed near top; strike N55°E, dip 2°N. Lower 5 feet measured with 0° in Abney level, upper 3 feet with 2° in level, maximum exposure, approximately 8'

2 Conglomerate; pebbles of calcilutite, oolitic calcarenite, phosphate and quartzarenite and shale clasts set in matrix of fine- to coarse-grained quartzsiltite and skeletal debris; contains sparse, abraded and broken Mississippian fossils; color highly variable. Thin- to medium-bedded, irregularly bedded. Forms overhanging ledge on east side of creek between houses at 105 Willow and 127 Willow Street; also forms large slump blocks in creek, and in creek immediately west of home at 127 Willow and beneath foot bridge where unit forms waterfall. Apparent dip of unit on average base is 3 to 4° northward between houses; at waterfall in creek, unit appears to be flat but has highly irregular, jointed surface. Thickness, direct measurements, varies from 0.5 to 1.7 feet, averages 1.0'

FAYETTEVILLE FORMATION

1 Shale with limestone nodules: shale, slightly quartz-silty; dark gray, weathers medium dark gray and moderate brownish gray. Thickly laminated, regularly laminated. Contains flat, plate-like limestone concretions dispersed throughout unit, ranging in size from 1 inch to 18 inches in length; coarse-grained calcilutite (mudstone); medium dark gray, weathers moderate yellowish gray. Unit exposed on eastern creek bank between abandoned house at 105 Willow and brown frame house at 127 Willow Street; best exposed on east side of creek. Upper contact sharp, undulating, unconformable, truncating layer of nodules at top. Thickness, maximum exposure, taken parallel to presumed strike, approximately 8'

<u>Section M103A</u>: <u>Klyce's Spring, Offset</u>

<u>Location</u>.—S½, NE¼, SW¼, NW¼, Sec. 15, T. 16N., R. 30W., Washington County, Arkansas. The section begins at a point 15 feet above

the base of unit 5 in measured section 103 at a point in the creek behind the home of Dr. George Moore (308 East Spring Street, Fayetteville). The section is measured eastward behind the Moore home to Klyce's Spring (Mather's Station 136) and eastward to the highest exposures in the Moore's yard. The section was then offset southward to Spring Street, and the remaining section was measured eastward up Spring Street to the highest exposures on the north side of the street in the SE¼, NE¼, SW¼, NW¼, Sec. 15.

Stratigraphy.—The measured strata are included within the Prairie Grove Member and a partial thickness of 43 feet of this member is included. The lowest strata (unit 2) are situated near the Cane Hill-Prairie Grove boundary at a point 32 feet above the Cane Hill-Fayetteville boundary.

Remarks.—The section, which includes Mather's (1915, p. 247) original Station 136, was measured on November 3, 1971, by T. W. Henry to supplement the stratigraphic information presented in measured section M103.

Unit No.	Description	Thickness
	MORROW GROUP	
	HALE FORMATION (almost complete)	
6	Sandstone; basal 1.5 feet is medium- to coarse-grained, highly quartz-sandy, bryozoan-pelmatozoan calcarenite (grainstone), grading upward into	

medium-grained, quartz-cemented, submature quartz-arenite; weathers moderate grayish brown. Medium- to thin-bedded, irregularly bedded, cross-bedded. Exposed in ditch on north side of Spring Street. Strike N45°E, dip 2°SW measured on top of bed 14 feet above base. Thickness measured to highest exposures, estimated 30'

Note: Offset section 25 to 30 feet southward on top of unit 5.

5 Limestone; medium- to coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone); upper part becomes quartz-sandy; weathers moderate brownish gray. Thick-bedded, irregularly bedded. Forms upper part of bluff above Klyce's Spring; weathers with rounded surfaces. Many old surfaces look like they have been worked upon with a hammer and chisel; may represent Mather's collecting. Thickness, direct measurement 5.2'

4 Limestone; medium-grained, quartz-sandy, mixed-skeletal calcarenite (packstone); weathers moderate brownish gray. Medium bedded, irregularly bedded, cross-bedded. Forms basal part of small bluff with Klyce's Spring at base. Upper contact sharp, welded. Contains *Composita* sp., *Anthracospirifer* sp., *Tesuquea morrowensis*, and *Sandia welleris*; this is Mather's old locality 136 and the type locality for the latter two species. Thickness, direct measurements, varies from 0.9 to 2.0 feet, thinning northward, averages 1.5'

3 Shale; nonsilty clay shale; dark olive gray, weathers light olive gray. Thickly laminated. Exposed below spring only in creek. Thickness, direct measurement 3.6'

2 Limestone; medium- to coarse-grained, pelmatozoan, mixed-skeletal, slightly quartz-sandy calcarenite (grainstone); medium gray, weathers moderate yellowish gray. Thick-bedded. Bed forms back wall of fish pond 3 feet below and 15 feet west of Klyce's Spring. Upper contact sharp. Thickness, maximum exposure, direct measurement 3.0'

1 Covered. Measured unit behind home of Dr. Moore, starting from point 15 feet above base of unit 103-5 in creek; measured eastward to top of unit 2 and subtracted thickness of unit 2 from interval to get thickness of unit 1; measured with 0° dip in Abney level, assuming strike of N45°E as measured within unit 6. Thickness, estimated 20'

Introduction to Hale Mountain Sections, M104A, M104B, and M104C

Location.—Three closely spaced stratigraphic sections, M104A, M104B, and M104C, were measured on the northern side of Hale Mountain in the NE¼, Sec. 12, T. 13N., R. 33W., Washington County, Arkansas.

History of Previous Investigations.—Adams and Ulrich (1904, p. 4) were the earliest to refer to the Morrowan sequence on Hale Mountain and designated this general area as the reference area for the Morrowan sequence. It is approximately 2 miles south of the village of Morrow.

Giles and Brewster (1930, p. 141) published a composite stratigraphic section of the Morrow Group measured mainly in the cut banks and ditch of the paved county road leading from the community of Morrow southward to the top of Hale Mountain. This section extended southeastward from the SE¼, Sec. 25 through the eastern part of Sec. 6, the northwestern part of Sec. 8, and then westward to the central part of Sec. 7. This area is between 1.0 and 1.5 miles northeast of the current sections. This section is no longer well exposed and consequently does not make a good reference section.

The exposures in the area of the NE¼, Sec. 12 were designated the type Hale section by Henbest (1953, p. 1950, locality 3; 1962a, p. 39), but he did not present a detailed stratigraphic section of these exposures.

Manger (1971, p. 155) measured the Hale Formation at the site of measured section M104A of the current report.

Composite Stratigraphy.--Measured sections M104A, M104B, and M104C constitute a composite type section for the Morrow Group. The Morrow Group as defined herein is a maximum of 379 feet thick and a minimum of 270 feet thick (to the top of what is herein defined as the Kessler Limestone Member). Giles and Brewster (1930) recorded a maximum of 348 feet for the Morrow Group in their section, with a thickness of Morrowan strata to the top of the Kessler Limestone Member of 284 feet.

The Hale Formation is 139 feet thick (units M104A-1 through 16), with the Cane Hill Member quite well exposed and measuring 43 feet in thickness (units 1 through 5) and contains a basal conglomerate. The basal part of the Prairie Grove also contains a pebble conglomerate, and this member is 91 feet thick.

The Bloyd Formation is a maximum of about 240 feet thick, depending on how the Trace Creek Shale Member is treated. The Brentwood Limestone is about 43 feet thick (M104B-6 through 18) and consists of limestones and shales. It is directly overlain by the "caprock" (basal Dye Shale Member) in both Bloyd sections (M104B-19 and M104C-G). The Woolsey Member is not present in this area, an observation also made by Henbest (1953, p. 1950).

The Dye Shale Member in both sections is approximately 70 feet thick; Giles and Brewster (1930) measured a total thickness of about 89 feet for this interval in their section. The Dye Shale is in turn overlain by the Kessler Limestone Member (units M104B-22 through 26 and M104C-1 through 5). This member is quite well exposed and forms a small bench that is traceable laterally for some distance. The Kessler is 15 and 17 feet thick in the respective sections.

The Kessler Limestone is directly overlain by 36 feet of moderately well exposed black shale in measured section M104 (units 27 and 28), and this shale is unquestionably assigned to the Trace Creek Shale Member. This unit is succeeded stratigraphically by a calcareous, skeletal quartzarenite and fine-grained quartzarenites, comprising an interval (unit 29) that is approximately 8 feet thick. Unit 29 locally forms a small ledge that can be traced to the east and west-northwest only approximately 50 to 75 yards before it disappears. It is overlain by a 45-foot thick covered interval that has some black shale talus in the lower portion. Resting on top of this interval is another thin, fine-grained quartzarenite (unit 32) that is in turn overlain by 22 feet that is covered. The coarse-grained, quartz granule-bearing quartzarenites characteristic of the basal part of the Atoka Formation on Hale Mountain are found at the top of the section (unit M104B-34). Units 29 and 32 are interpreted to be lenses of coarser terrigenous materials within the Trace Creek Shale. The total Trace Creek interval, according to this interpretation, would be approximately 120 feet thick in measured section M104B.

The Kessler Limestone is directly overlain by a coarse limestone pebble and limestone cobble conglomerate in section M104C (unit 5, 1.5 feet thick). This rests unconformably upon the Kessler and truncates locally the upper 1 foot of this member; it is succeeded in turn by about 20 feet of immature, fine-grained quartzarenites that make a distinct cliff above the Kessler. The bench formed by these latter units can be traced eastward for approximately 0.1 mile into the main tributary of the north-flowing creek that heads at the old Hale Mountain

School, where the same unconformable relationship and basal limestone cobble conglomerate can be seen directly on top of the Kessler Limestone. The author traced this bench toward the northeast for approximately 0.25 mile where it disappears. The same bench can be traced to the northwest from M104C toward measured section M104B for only about 100 yards before it disappears and only the small bench formed by the Kessler Limestone Member can be traced into section M104B. The interpretation of the sequence formed by units 5 through 8 is that it represents a channel of coarser-grained terrigenous clastics developed in the lower part of the Trace Creek Shale Member; it is overlain by a black shale characteristic of the Trace Creek Member.

The coarse-grained quartzarenites of the basal portion of the Atoka Formation (unit M104C-13) form a distinct cliff near the crest of Hale Mountain. Unit M104C-13 can be walked to the west-northwest into unit M104B-34 and to the northeast for approximately 1.5 miles to the section on the road leading to the top of Hale Mountain from Morrow in SE¼, SE¼, SE¼, Sec. 6, T. 13N., R. 32W., where the top of the section measured by Giles and Brewster (1930) is exposed. This unit is the same as the one that they designated the basal part of the Atoka (their Winslow) Formation at the latter locality. In the Giles and Brewster section, the Trace Creek Member consists of black shale with scattered, thin, quartz-sandy limestones and calcareous quartzarenites, and the Kessler is not as well developed.

Section M104A: Hale Mountain, Western Offset

Location.—S½, NW¼, NE¼, Sec. 12, T. 13N., R. 33W., Washington County, Arkansas. The section begins with the upper part of the Pitkin Formation in the creek bed in the SE¼, NW¼, NE¼, Sec. 12 and is measured westward up a steep ravine which intersects the creek at the Pitkin-Hale contact.

To reach the beginning of the section, drive 3.5 miles southward on the paved county road from the town of Morrow, Arkansas, to the Hale Mountain Church (formerly a school house). Immediately north of the church, turn westward on the gravel driveway leading to the brick home of Mr. Thomas E. Abshier. Park and walk northward past the chick barn and down and into the ravine which heads at the barn for approximately 0.4 mile to the point where the Pitkin Formation crops out on the banks of the creek. The section is measured westward up a steep wash from this point to the top of the receeding cliffs.

Stratigraphy.--This section begins with the outcrops of the Pitkin Formation in the creek. The Pitkin (unit 0) is unconformably overlain by the Cane Hill Member of the Hale Formation, the basal part of which contains a pebble conglomerate. This member is quite well exposed intermittently in the main creek to the south and on its banks and is unconformably overlain by the Prairie Grove Member, which forms the precipituous cliffs above the creek and the waterfalls in the main creek and its tribitaries. The section terminates in the basal part of the Bloyd Formation. The units in the type Hale section are assigned to the following members:

- Morrow Group (partial section, 142 feet)
  - Bloyd Formation (partial section)
    - Brentwood Limestone Member (partial section, unit 17, 2.5 feet)
  - Hale Formation (complete section, 139 feet)
    - Prairie Grove Member (units 6 through 16, 91 feet)
    - Cane Hill Member (units 1 through 5, 48 feet)

Remarks.—This area and exposures were designated the type Hale section by Henbest (1953, 1962a).

The current section was measured and described on November 6 and 11, 1971, by Jerry Branch and T. W. Henry. It was examined on December 2 by D. L. Zachry, Jerry Branch, and T. W. Henry, and was collected for conodonts on December 11, 1972, by H. R. Lane and T. W. Henry. P. K. Sutherland and T. W. Henry revisited this site on March 29, 1973.

For additional comments, refer to "Introduction to Hale Mountain Sections M104A, M104B, and M104C".

Unit No.	Description	Thickness
MORROW GROUP		
BLOYD FORMATION (partial)		
17	Shale; dark olive gray, weathers light olive gray. Poorly exposed to north of wash. Section covered above. Thickness, maximum exposure	2.5'
HALE FORMATION		
16	Limestone; medium- to coarse-grained, pelmatozoan calcarenite with scattered quartz sand (grainstone), interbedded with medium- to coarse-grained, pelmatozoan-bryozoan, brachiopodal, slightly micritic calcarenite (packstone); medium light gray, weathers same. Thin- to medium-bedded, irregularly bedded. Exposed as series of receeding ledges in wash; top forms ill-defined bench in woods. Contains <u>Michelinia</u>. Thickness, approximately	12'
15	Covered. Thickness	1.3'

14	Sandstone; very fine-grained, quartz-cemented, submature quartzarenite at base, becoming fine-grained, calcite-cemented, submature, glauconite-bearing, skeletal quartzarenite at top; medium dark gray, weathers moderate brownish gray. Thin-bedded, regularly bedded, cross-laminated in lower part with carbonaceous material on lamellae; interbedded with thin shales; upper surfaces contain current ripple marks; burrows scattered on bottoms of beds. Forms series of ledges in wash, particularly well-exposed on south side of wash. Thickness	3.6'
13	Limestone; fine-grained calcilutite (mudstone); some beds contain *Cuniephycus*; medium dark gray, weathers light gray. Thin-bedded, irregularly bedded, interbedded with thin shales. Forms distinctive series of ledges approximately 20 feet east of top of main cliff with thin shales recessed; unit poorly exposed in middle portion but ample material in slump blocks immediately north of wash. Upper contact sharp. Thickness approximately	5.0'
12	Covered but shale exposed laterally to southeast. Thickness	1.7'
11	Sandstone; fine- to medium-grained, calcite-cemented, submature to mature quartzarenite, grading upward into fine- to medium-grained, quartz-sandy, mixed-skeletal calcarenite (grainstone); medium light gray, weathers same. Medium-bedded, irregularly bedded. Forms top of receeding cliff in wash. Thickness	3.2'
10	Limestone; medium- to very coarse-grained, pelmatozoan-bryozoan, brachiopodal calcarenite (grainstone); medium light gray, weathers same. Thick-bedded, irregularly bedded. Forms upper part of receeding upper cliff; weathers rounded in wash. Upper contact sharp. Thickness, direct measurement	3.4'
9	Limestone; medium-grained, quartz-sandy, oolitic calcarenite (grainstone) at base, becoming medium- to coarse-grained, quartz-sandy, oolitic, pelmatozoan calcarenite (grainstone) at top; medium light gray, weathers moderate brownish gray. Thin- to medium-bedded, cross-bedded. Weathers with quartz-sandier lamellae in relief. Forms receeding upper part of main cliff. Upper contact gradational. Thickness	2.5'

8 Sandstone and limestone: sandstone; medium-grained, calcite-cemented, mature quartzarenite, interlaminated with medium- to coarse-grained, highly quartz-sandy, pelmatozoan, mixed-skeletal calcarenite (grainstone); unit becomes more of a quartzarenite upward; moderate brownish gray, weathers same. Thin-bedded, irregularly bedded, cross-laminated. Forms massive upper part of first cliff above creek; weathers pitted and "honeycombed", with calcarenitic layers receeding and quartzarenitic layers in relief; weathers mainly by exfoliation. Upper contact gradational. Thickness, approximately 30'

7 Limestone and sandstone: limestone; fine- to medium-grained, oolitic calcarenite with quartz-sand nuclei (grainstone) to medium-grained, pelmatozoan, oolitic, quartz-calcarenite (grainstone); interbedded and gradational with sandstone; medium- to fine-grained, ooid-bearing, calcite-cemented, mature quartzarenite; medium gray, weathers moderate brownish gray. Medium-bedded, irregularly bedded; small-scale cross-laminations. Forms lower half of steep bluff on west side above creek; weathers with quartz-sandier layers in relief emphasizing cross-lamination. Upper contact sharp. Thickness measured in wash due eastward with strike, thickness, approximately 26'

6 Sandstone, conglomeratic; medium-grained, clay-bonded, immature, conglomeratic quartzarenite with pebbles of siltstone and shale clasts; medium reddish brown, weathers moderate brown; pebbles of pinkish white. Medium-bedded, irregularly bedded, single bed. Forms lower part of bluff. Upper contact gradational, picked at highest occurrence of pebbles. Thickness, direct measurement 1.8'

5 Sandstone; fine- to medium-grained, clay-bonded, immature quartzarenite; medium reddish brown, weathers moderate brown. Thick-bedded, irregularly bedded, single bed. Exposed at base of cliff on southside of wash leading eastward from main creek. Upper contact sharp, truncating. Thickness, direct measurement 1.7'

4 Siltstone; coarse-grained, clay-bonded, immature quartzsiltite; contains lamellae of carbonaceous material; medium brownish gray, weathers moderate grayish brown. Thin- to very thin-bedded, irregularly bedded. Well exposed in wash as slope and series of small ledges. Upper contact sharp, undulating. Thickness approximately 9'

3 Covered; toward intersection of creeks to south interval consists of siltstone and shale, probably more than enough to fill in unit 3. Thickness approximately 24'

Note: Offset section to west side of main creek at point approximately 100 feet northward (downstream) on top of unit 0. Thickness of covered interval ascertained by subtracting thickness of units 1 and 2 from interval measured with strike to base of unit 4. Measured up west slope of hill to base of cliff in wash.

2 Shale, sandstone, with minor conglomerate: shale, quartz-silty at base becoming less quartz-silty near top of exposure; olive gray. Thickly laminated, regularly laminated. Sandstone; very fine-grained, clay-bonded, immature quartzarenite to coarse-grained quartzsiltite; few lenses contain granules and small pebbles of siltstone and clasts of shale; moderate brownish gray, weathers same. Very thin-bedded, irregularly bedded; upper surfaces with current ripple marks. Unit contains more sandstone at base and progressively more shale higher. Unit well-exposed on east bank of creek and above creek. Thickness measured with strike, approximately 8.5'

1 Sandstone, shale, and conglomerate: sandstone; fine- to very fine-grained, clay-bonded and quartz-cemented, immature quartzarenite; moderate brownish gray, weathers brownish gray. Thin- to medium-bedded, regularly bedded, small scale cross-bedding; upper surface contains well-developed current ripple marks. Shale, quartz-silty; dark gray, weathers moderate brownish gray. Thickly laminated. Conglomerate; pebbles of shale, sandstone, and phosphate, elongated and imbricated, set in matrix of fine- to medium-grained quartzarenite. Thin-bedded. Unit consists of basal conglomerate 0.2 to 0.3 feet thick, overlain by 0.6 foot of shale, overlain by sandstone. Unit forms small ledges on east side of creek above where Pitkin is measured. Upper contact gradational, picked at first shale bed. Thickness, direct measurement 2.5'

PITKIN FORMATION

0 Limestone; fine- to coarse-grained, oolitic, pelmatozoan clacarenite (grainstone), becoming fine- to

medium-grained, oolitic calcarenite (grainstone) in higher beds; medium light gray, weathers light yellowish gray. Thin- to medium-bedded, irregularly bedded. Forms small bluff on east side of creek, approximately 100 yards north (downstream) from intersection of main creek branches; also exposed on west side of creek approximately 100 feet northward; weathers with smooth surfaces. Upper contact sharp, unconformable, locally welded. Strike N90°E, dip 2 to 3°N. Thickness measured on east side of creek, direct measurement 7.0'

Section M104B: Hale Mountain, Central Offset

Location.—W½, SW¼, NE¼, Sec. 12, T. 13N., R. 33W., Washington County, Arkansas. The section begins with the upper protion of the Prairie Grove Member of the Hale Formation on the northwestern bank of a ravine in the NW¼, SW¼, NE¼, Sec. 12. The section is offset to the southeastern banks of the creek and is measured up the steep hillside in a small wash to the top of the bluffs in the SW¼, SW¼, NE¼, Sec. 12. The section terminates in the Atoka Formation.

To reach the beginning of the section, drive to the home of T. E. Abshier (see discussion under section M104A), park, and walk northward into the (middle) ravine heading at the stock pond west of the chicken barn. Walk down the ravine below the first cliff formed by the massive sandstones of the Atoka (Winslow) Formation and onto the first bench below. Follow this bench westward for 0.3 mile above the eastern branch of the creek, and descend to the top of the Hale Formation in the creek.

Stratigraphy.—The section includes a complete and well-exposed Bloyd section, and combined with measured sections M104A and M104C constitutes the type Morrowan as designated by Adams and Ulrich (1904). The section begins in the upper part of the Prairie Grove Member and terminates in the lower part of the Atoka Formation. The stratigraphic breakdown is as follows:

Morrow Group (partial section, 270 feet)
  Bloyd Formation (complete section, 246 feet)
    Trace Creek Shale (units 27 through 33, 121 feet)
    Kessler Limestone (units 22 through 26, 15 feet)
    Dye Shale Member (units 19 through 21, 70 feet)
    Brentwood Limestone (units 6 through 18, 42 feet)
  Hale Formation (partial section)
    Prairie Grove Member (partial, units 0 through 5, 23 feet)

Remarks.--The basal part of the section was measured and described by T. W. Henry and Jerry Branch on November 11, 1971, and the remainder of the section on November 12 by T. W. Henry. The section was field checked on December 2, 1971, by D. L. Zachry, Jerry Branch, and T. W. Henry. The section was collected for conodonts on December 11, 1972, by H. R. Lane and T. W. Henry, and P. K. Sutherland and T. W. Henry reexamined the section on March 2, 1973.

Unit No.	Description	Thickness
ATOKA FORMATION (partial)		
34	Sandstone; very coarse-grained, quartz-overgrowth cemented, quartz granule bearing quartzarenite; dusky yellow, weathers dark grayish brown. Thick- to very thick-bedded, cross-bedded. Forms prominent bluff below top of Hale Mountain; weathers with Liesegang rings, highly contorted. Thickness, estimated	15'

MORROW GROUP

BLOYD FORMATION

33	Covered. Thickness approximately	28'
32	Sandstone; very fine-grained, limonite-cemented, immature quartzarenite; moderate orangish brown, weathers moderate grayish brown. Thick-bedded, irregularly bedded. Forms upper cliff. Thickness, direct measurement, maximum exposure	4.5'
31	Covered. Used 2^{o} dip in Abney level, estimated	40'
30	Shale, slightly quartz-silty; contains scattered clay-ironstone concretions; very dark gray, weathers moderate brownish gray. Thinly laminated. Exposed mainly as talus approximately 10 yards northeast of barbed wire fence; fresh shale found by digging. Thickness approximately	4'
29	Sandstone; very fine-grained, calcite-cemented and clay-bonded, skeletal, immature quartzarenite interbedded with thin dark gray shales in lower 3 feet, grading upward into fine-grained, limonite-cemented and clay-bonded, immature quartzarenite; light brownish gray, weathers moderate yellowish brown. Thin-bedded in lower part, interbedded with thin shale; becoming medium-bedded, regularly bedded in upper part. Forms highly distinctive ledge which can be walked southeastward into next creek; upper part of unit overhanging lower beds by as much as 6 feet where measured approximately 50 to 75 yards southwest of wash and 15 to 20 yards northeast of barbed wire fence. Upper contact sharp. Strike 70^{o}E, dip 2^{o}S. Thickness, approximately	8'
28	Shale, quartz-silty; very dark gray, weathers moderate brownish gray. Thinly laminated; contains ?dolomite nodules (6 inches x 6 inches x 1 inch). Well-exposed beneath overhanging ledge. Upper contact sharp, even. Thickness, maximum exposure	1.5'
27	Covered with dark gray shale talus exposed in interval 30 to 50 yards to southeast. Thickness measured perpendicular to strike with 2^{o} in Abney level, approximately	35'

26 Limestone; medium- to coarse-grained, bryozoan, pelmatozoan calcarenite (grainstone); contains clay clasts in lower part; moderate brownish gray, weathers same; contains patches of black where petroleum has solidified. Thick-bedded, single bed. Well-exposed only in wash; few blocks present as talus to southwest; forms small ledge in wash. Upper contact obscure. Current attitude is N80°E, dip 18°S; may be slightly slumped even though unit dips back into hillside. Thickness, direct measurement 1.5'

25 Shale; contains sparse, dark gray, ?dolomite nodules near top; quartz-silty; dark olive gray, weathers moderate brownish gray. Thinly to thickly laminated, regularly laminated. Unit well exposed above cliff formed by unit 24 in wash. Upper contact sharp. Unit measured by using 14° in Abney level, approximately 3.8'

Note: Offset section northeastward to wash on top of unit 24. Units 25 and 26 are measured after offset; then went back to point where measured units 22 through 24 and measured perpendicular to strike up hillside. To obtain thickness of unit 27, subtracted thickness of units 25 and 26 from interval to base of unit 28. The top of unit 24 was used for both offsets.

24 Limestone; medium- to coarse-grained, bryozoan, pelmatozoan calcarenite (mainly grainstones with few packstones); lower beds contain scattered ooids, coated-grains, clasts of calcilutite, and phosphate; medium dark gray, weathers moderate brownish gray. In wash to northeast, upper bed contains pebble-sized, flattened, *Osagia* oncoliths. Thin- to thick-bedded, irregularly bedded; lower beds contain thin shale interbeds. Forms distinct small cliff all along north-facing hillside; can trace unit southeastward into next creek. Upper contact exposed in wash, sharp. Attitude in wash strike N80°E, dip 10°S; where measured 50 to 75 yards southeast of wash, strike N 70°E, dip 2°S. Thickness measured directly approximately 50 to 75 yards southwest of wash 5.2'

23 Siltstone; fine-grained, calcite-cemented and clay-bonded quartzsiltite; more of a quartz-silty shale in lower part with flattened concretions or ?algal oncoliths; unit becomes more of a quartz-silty calcarenite toward northeast in wash; medium dark

gray, weathers moderate brownish gray. Thickly laminated to very thin-bedded, irregularly bedded. Splintery; forms slightly recessed vertical face 50 to 75 yards southwest of wash. Upper contact sharp, even. Thickness, direct measurement 3.6'

22 Limestone; medium- to coarse-grained, recrystallized micritic, pelmatozoan-bryozoan calcarenite (recrystallized ?packstone to grainstone); moderate brownish gray, weathers same. Medium-bedded, single bed. Poorly exposed at base of cliff, approximately 50 to 75 yards southeast of wash and 30 yards northeast of fenceline; highly weathered. Upper contact sharp, lower contact covered. Thickness, direct measurement 1.0'

21 Covered and shale: shale; weathers light olive gray. Exposed only as sparse talus. Thickness measured with 6° in Abney level, estimated 60'

20 Shale, slightly quartz-silty; dark olive gray, weathers light olive gray. Thinly laminated. Exposed on both sides of wash. Thickness, maximum exposure 5'

Note: Unit 19 also crops out approximately 10 yards west of wash where it forms small bench beneath group of twisted, storm damaged trees; unit does not crop out in wash. Section offset 40 yards westward on top of unit 19 to point 10 yards west of creek or wash. Section measured directly up hill to top of unit 24, and then offset westward 50 to 75 yards along top of unit to point where units 22, 23, and 24 are well-exposed. Thicknesses of units 20 and 21 are measured with 6° in Abney level, compromising between dip of unit 19 (2°S) and unit 24 (10°S).

19 Limestone; medium- to coarse-grained, pelmatozoan-bryozoan calcarenite (grainstone), with scattered clasts of limestone and scattered quartz-sand; medium gray, weathers moderate yellowish gray. Medium-bedded, irregularly bedded; basal bed with burrow casts. Forms upper part of small cliff east of wash approximately 30 yards; top bed poorly exposed. Attitude measured on bottom of lower bed, strike N80°E, dip 2°S. Thickness, direct measurement 4.8'

18 Shale, noncalcareous quartz-silty, with clay-ironstone concretions in basal portion; basal portion

weathers moderate yellowish brown; upper half dark gray, weathers moderate grayish brown. Thickly laminated, irregularly laminated. Forms recess beneath overlying unit, exposed only 30 yards east of wash. Upper contact sharp, uneven. Thickness, direct measurement 1.4'

17 Limestone; medium-grained, micritic, bryozoan, pelmatozoan, algal calcarenite (packstone); medium light gray, weathers moderate brownish gray. Thick-bedded, single bed. Exposed only at base of small bluff approximately 30 yards east of wash; weathers smoothly. Upper contact sharp, undulating. Thickness, direct measurement, maximum exposure 1.8'

16 Covered; abundant shale float but may not be from unit. Measured perpendicular to strike with 2° in Abney level, approximately 7.5'

Note: Offset section approximately 30 yards eastward on top of unit 15.

15 Limestone; medium- to coarse-grained, micritic, bryozoan, pelmatozoan, mixed-skeletal calcarenite (packstone); medium dark gray, weathers moderate brownish gray. Thin- to medium-bedded, irregularly bedded, interbedded with thin shale in middle portion. Unit forms distinct overhanging ledge in wash; top can be traced westward for 30 yards. Attitude measured on base of bed in middle of unit, strike N80°E, dip 4°S. Thickness, direct measurement 4.6'

14 Limestone; fine-grained, mixed-skeletal calcilutite (wackestone) in lower part, becoming Ottonosia?, micritic boundstone in upper bed; medium dark gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded, nodular, in lower part with single medium bed at top. Recessed beneath unit 15 in wash only; forms small ledge. Upper contact sharp, undulating. Thickness, direct measurement 1.6'

13 Shale, slightly quartz-silty; dark olive gray, weathers light olive gray. Thickly laminated. Exposed as recess beneath units 14 and 15 and in wash. Upper contact sharp, undulating. Thickness, approximately 2.5'

12 Covered; no diagnostic float. Measured perpendicular to strike with 4° in Abney level, approximately 7.5'

11 Limestone; fine- to medium-grained, micritic, bryozoan, mixed-skeletal calcarenite (packstone); medium light gray, weathers moderate grayish brown. Thick-bedded, irregularly bedded. Exposed only in wash and 5 feet on either side; makes small ledge. Thickness, direct measurement 1.6'

10 Covered and shale: shale, calcareous; light olive gray, weathers same. Poorly exposed in wash only. Thickness, Abney level, approximately 3'

9 Limestone; medium-grained, micritic, coated-grain to oolitic, intraclast-bearing, mixed-skeletal calcarenite (packstone) in basal bed; medium- to coarse-grained, pelmatozoan calcarenite (packstone), in top bed, separated by thin, calcareous shale. Medium-bedded, irregularly bedded. Exposed as slight ledge to east and west of wash. Upper contact obscure. Thickness, direct measurement 2.3'

8 Shale and limestone: shale, slightly quartz-silty; dark olive gray, weathers light olive gray. Thickly laminated. Limestone; fine-grained, algal (*Archaeolithophyllum*), gastropodal calcilutite (wackstone); medium dark gray, weathers medium light gray. Limestones form discontinuous nodules in lower part of unit with large colonies of *Chaetetes* in growth position. Poorly exposed on hillside but dug out immediately east of wash. Thickness, Abney level 3.8'

7 Limestone; coarse-grained, recrystallized calcilutite (mudstone); medium dark gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded, single bed. Forms ledge in small wash. Thickness, direct measurement 0.6'

6 Shale, quartz-silty; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Weathers blocky; poorly exposed but found by digging. Upper contact sharp, undulating. Thickness 3.6'

Note: Units 0 through 5 are measured on the north side of the creek; the section is offset to south side of creek in small wash; remainder of section measured southward up this wash.

HALE FORMATION

5 Limestone; fine- to very coarse-grained, slightly quartz-sandy, pelmatozoan calcarenite (grainstone),

becoming micritic and slightly finer grained upward (packstone); medium dark gray, weathers moderate brownish gray. Medium-bedded, irregularly bedded; small-scale cross-bedding. Thickness measured with 4.5^{o} in Abney level, approximately 7'

4 Sandstone; fine-grained,ccalcite-cemented, submature, glauconite-bearing quartzarenite in upper part, medium dark gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded in lower 5 feet with prominent current ripple marks and burrow and trail casts on lower surfaces, interbedded with thin shale; upper beds medium-bedded. Well-exposed on north side of creek above waterfall. Contains carbonaceous lamellae in lower beds. Attitude measured on 3 beds averages N55°E, dip 4 to 5°SE. Thickness, direct measurement 7.2'

Note: Unit 4 is equivalent to unit 14 in section 104A.

3 Limestone; fine-grained, algal (Cuniephycus) calcilutite (mudstone); medium gray, weathers light gray. Thin-bedded at base, interbedded with thin shale, irregularly bedded, nodular; becomes medium-bedded at top. Best exposed on north side of tributary above waterfall; also crops out on west bank above waterfall. Upper contact sharp, undulating, with small knobs protruding up into overlying unit. Thickness, direct measurement 2.2'

Note: Unit 3 is equivalent to unit 13 of measured section M104A.

2 Limestone; medium- to coarse-grained, quart-sandy, mixed-skeletal calcarenite (grainstone) at base, becoming medium-grained, highly quartz-sandy, mixed-skeletal calcarenite upward; medium light gray, weathers same. Thin- to medium-bedded, irregularly bedded, small-scale cross-bedding. Forms top of massive cliff on south side of tributary above waterfall. Upper contact sharp, undulating. Thickness, direct measurement 5.8'

1 Shale, highly quartz-silty; very dark gray, weathers moderate brownish gray. Thickly laminated, irregularly laminated. Forms recess under overlying unit; highly distinctive and can be traced around hillside and bluffside for long distance. Upper contact sharp, undulating. Thickness varies as underlying and overlying units undulate, varies from 0.8 to 1.2 feet, averages 1.0'

0 Limestone; medium- to coarse-grained, oolitic, quartz-sandy, pelmatozoan calcarenite (grainstone); medium light gray, weathers same. Thin- to medium-bedded, irregularly bedded, cross-laminated. Forms upper part of massive Hale cliff on hillside and on both sides of tributary. Upper contact sharp, undulating. Thickness not measured.

Section M104C: Hale Mountain, Eastern Offset

Location.--W½, SE¼, NE¼, Sec. 12, T. 13N., R. 33W., Washington County, Arkansas. The section begins in the NW¼, SE¼, NE¼, Sec. 12 immediately south of the point where the tributary joins the main creek, which heads at the Hale Mountain Church. The section is measured southward up the tributary on the north side of Hale Mountain and ends in the lower part of the Atoka Formation near the top of Hale Mountain in the SW¼, SE¼, NE¼, Sec. 12, at a point immediately northwest of the chicken barn northwest of the home of T. E. Abshier.

Stratigraphy.--This section contains a superbly exposed middle and upper Bloyd, beginning in the upper part of the Brentwood Limestone Member and terminating with the massive-cliff-forming quartzarenites of the Atoka Formation that cap the top of Hale Mountain. The stratigraphic breakdown is as follows:

- Morrow Group (partial section, 248 feet)
  - Bloyd Formation (partial section)
    - Trace Creek Shale (units 6 through 12, 116 feet)
    - Kessler Limestone (units 1 through 5, 17 feet)
    - Dye Shale (units G and H, 67 feet)
    - Brentwood Limestone (partial section, units A-F, 24 feet)

The Dye Shale Member, with the well developed "caprock" at the base, directly overlies the Brentwood limestones and is continuously exposed in the steep ravine. The Kessler Limestone contains an exceptionally fossiliferous bed in the lower part, and it is overlain by an unusual cobble-bearing conglomerate and quartzarenite in the lower part of the Trace Creek Member. The shales of the Trace Creek are poorly exposed above in the ravine.

Remarks.--Units 1 through 8 were measured and described on December 2, 1971, by T. W. Henry; units A through H and units 9 through 13 were measured on January 3, 1972, by T. W. Henry and Jerry Branch. The Kessler Limestone Member was collected for conodonts by H. R. Lane and T. W. Henry on December 11, 1972. The section was field checked by D. L. Zachry, Jerry Branch, and T. W. Henry on December 2, 1972, and by P. K. Sutherland and T. W. Henry on March 2, 1973.

Unit No.	Description	Thickness
ATOKA FORMATION		
13	Sandstone; coarse- to very coarse-grained, granule-bearing quartzarenite; dusky yellow, weathers dark grayish brown. Thick- to very thick-bedded, cross-bedded. Forms prominent bluff below chicken barn and on creek side north of barn; weathers with highly distinctive Liesegang surfaces, highly contorted; forms caprock on top of Hale Mountain. Thickness, direct measurement	14'
MORROW GROUP		
BLOYD FORMATION		
12	Covered. Measured with 0^{o} in Abney level along strike, estimated	18'

11	Shale; dark gray, weathers moderate brownish gray. Poorly exposed on north bank of creek above unit 10. Thickness measured to highest shale talus, approximately	12'
10	Sandstone; medium-grained, clay-bonded, immature quartzarenite; very light gray, weathers moderate grayish brown. Thin-bedded; basal beds ripple-marked, cross-bedded. Exposed in creek approximately 100 yards north of chicken barn; forms series of small ledges; top exposed approximately 50 feet upstream from base. Attitude measured on lower bed, strike N80°W, dip 2°S; on top of unit, strike N70°W, dip 5°N (forms small, local anticline). Thickness, direct measurement, approximately 1.5 to 2.0 feet, averages	1.7'
9	Covered. Shale in talus in lower 3 feet. Thickness estimated	58'
8	Sandstone; fine-grained, clay-bonded, immature quartzarenite; medium dark gray, weathers moderate brownish gray. Thin-bedded, regularly bedded; ripple marks. Exposed as top of cliff on both sides of creek; top exposed in creek. Thickness, direct measurement	6.0'
7	Sandstone with shale: sandstone; fine-grained, clay-bonded quartzarenite; dark gray, weathers moderate brownish gray. Medium- to thin-bedded, interbedded with thin quartz-silty shales; regularly bedded; lower surfaces contain sparse burrow casts. Unit forms top of cliff at waterfall; set off from overlying and underlying units by distinct bedding planes. Unit contains sparse plant fragments. Attitude measured on top bed, strike N85°W, dip 3°S. Thickness measured in creek at waterfall, direct measurement	3.0'
6	Sandstone; very fine-grained to fine-grained, clay-bonded; immature quartzarenite; dark gray, weathers light olive gray. Very thin-bedded to thin-bedded, regularly bedded, unevenly bedded; upper surfaces with current ripple marks; lower surfaces with numerous burrow casts, Conostichus. Forms vertical cliff immediately east and west of waterfall. Upper contact sharp, even. Thickness measured on east side of waterfall with steel tape, direct measurement	15.5'
	Note: The bench formed by units 6, 7, and 8 can be followed laterally northward for approximately 100 yards and then it disappears; the bench can be followed southward into main stream that heads at Hale Mountain Church.	

5 Conglomerate; pebbles of claystone and limestone set in matrix of fine- to medium-grained,quartz-sandy and skeletal debris cemented with calcite, hematite; clay-bonded; isolated small rounded cobbles of oolitic calcarenite; moderate reddish brown, weathers moderate grayish brown. Thin- to medium-bedded, irregularly bedded; distinctly cross-bedded. Unit forms vertical face slightly recessed beneath overlying unit; particularly well-exposed approximately 25 feet northeast of waterfall. Thickness, direct measurement, varies at expense of underlying units from 0.2 to 2.1 feet, averages 1.5'

4 Limestone; fine-grained, oolitic calcarenite (grainstone); medium gray, weathers moderate grayish brown. Medium- to thick-bedded, irregularly bedded, cross-laminated. Weathers with solution surfaces. Upper contact sharp, unconformable; possesses from 0.5 to 1.0 feet of local relief; thins as overlying unit thickens. Thickness varies from 1.2 to 1.8 feet, averages 1.5'

3 Covered and shale: shale, quartz-silty; dark gray, weathers moderate brownish gray. Upper 1.0 foot is exposed slightly recessed beneath overlying unit; remainder of unit covered. Upper contact sharp, undulating. Thickness, approximately 4'

2 Shale and limestone: shale; highly quartz-silty; medium dark gray, weathers olive gray. Thickly laminated. Limestone; coarse-grained, pelmatozoan calcarenite (packstone); medium dark gray, weathers moderate brownish gray. Thin-bedded, regularly bedded. Unit exposed on east side of creek east of large sandstone slump blocks. Upper contact covered. Thickness approximately 2'

Note: Offset section approximately 75 feet eastward into creek on top of unit 1. Remaining units of Morrow Group measured immediately east of creek below and on sides of waterfall.

1 Limestone; basal 3 feet is fine- to medium-grained, oolitic, mixed-skeletal calcarenite, grading upward into fine- to coarse-grained, mixed-skeletal calcarenite (grainstone); top 2 feet is coarse-grained, micritic, bryozoan-brachiopodal, oolitic calcarenite (packstone); medium light gray, weathers medium gray. Thick- to medium-bedded, irregularly bedded; upper portion cross-bedded. Forms vertical cliff approximately 75 feet west of creek; upper portion exposed also in creek. Upper contact sharp, undulating. Thickness, direct measurement 9.5'

H	Shale and covered: shale, quartz-silty; contains scattered clay-ironstone concretions; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Lower 30 feet well-exposed in creek and on banks; abundant shale talus to 45 feet; dug shale from top beneath Kessler Limestone. Thickness measured by dip and strike offset method, using 2^{o} in Abney level, approximately	64'
G	Limestone and siltstone: limestone; fine- to very coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone); contains local pebbles of siltstone and limestone in lower part of bed; medium gray, weathers moderate grayish brown. Thin-bedded, irregularly bedded, interbedded with quartz-sandy shale in upper 2.6 feet. Lower 1.0 foot of unit consists of quartz-sandy shale and siltstone with lenses of conglomeratic limestone and sandstone at base. Thickness, direct measurement, varies from 3.2 to 3.8 feet, averages	3.6'
F	Shale, quartz-silty; moderate olive gray, weathers moderate brownish gray. Thickly laminated. Well exposed in creek at small plunge pool, recessed locally with base of unit G beneath more resistant beds in unit G. Upper contact sharp, undulating, locally truncating. Thickness, direct measurement, varies from 0.3 to 0.9 feet, averages	0.6'
E	Limestone; fine-grained, bryozoan, brachiopodal calcilutite (wackestone) with scattered ooids; medium light gray, weathers moderate brownish gray. Thin-bedded, single bed. Exposed as small ledge in creek. Upper contact obscure. Thickness, direct measurement	1.0'
D	Shale, clay shale, becoming slightly quartz-silty at top; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Well exposed on west bank of creek. Upper contact gradational. Thickness measured with strike, approximately	7'
C	Covered. Thickness measured with strike, approximately	7'
B	Limestone and shale: limestone; at base, recrystallized, bryozoan, brachiopodal calcilutite (recrystallized wackestone) with scattered pebbles; at top, recrystallized skeletal calcilutite (recrystallized mudstone); medium gray, weathers moderate grayish brown. Thin-bedded, irregularly bedded, interbedded with shale. Weathers smoothly. Shale, calcareous; olive gray, weathers light olive gray. Unit exposed near creek junction beneath large slump block of sandstone; forms sequence of small ledge in creek. Attitude	

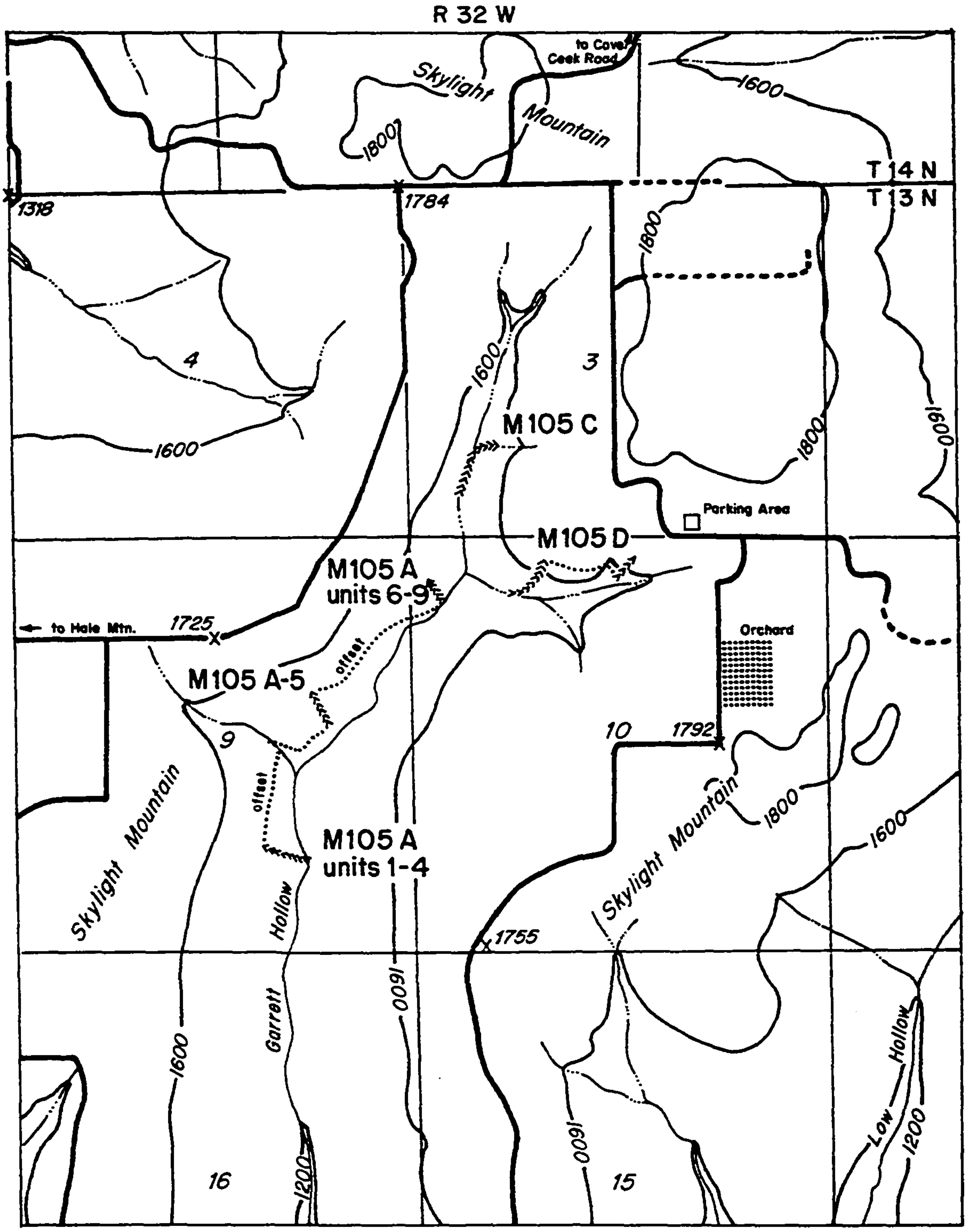
measured on top bed, strike N70°E, dip 6°S. Thickness measured with strike, approximately 3.5'

A Shale, nonsilty clay shale; contains scattered clay-ironstone concretions; dark olive gray, weathers light olive gray. Thickly laminated, irregularly laminated. Exposed at creek junction. Upper contact gradational. Thickness measured with strike, maximum exposure 4.5'

Introduction to Garrett Hollow Sections, M105A, M105C, and M105D

Location.--The three Garrett Hollow Sections are located approximately three miles southeast of the community of Morrow, Arkansas, in Secs. 9 and 10, T. 13N., R. 33W., Washington County, Arkansas. They are measured in the creek forming the upper part of Garrett Hollow and in the northern and northeastern tributaries of that creek heading up the saddle of U-shaped Skylight Mountain (text-figure 23).

To reach the Garrett Hollow Sections, drive northward 0.6 mile from the Arkansas State Highway 265 bridge over Fall Creek at the community of Strickler. Turn westward on the gravel road and drive 1.8 miles to the ford over Cove Creek and the intersection with the Cove Creek road. Turn northward on the Cove Creek road and drive 0.5 mile to the intersection with a dirt road from the west. Drive northward for approximately 1.7 miles on the rough, winding road to the first intersection with a road trending southwest-northeast. Turn left (southwestward) on this road and drive for approximately 2.0 miles, where the road meets an east-west road. Turn eastward on this road and drive 0.1 mile, at which point the road turns due south. Proceed southward for 0.75 mile to a point where the road turns abruptly eastward once more. Park at this point.



Text-figure 23.--Map showing location of Garrett Hollow sections (M105A, M105C, M105D). Base taken from Evansville (1970) and Strickler (1970) 7.5 minute quadrangle maps; scale: 1 = 24,000.

Composite Stratigraphy.--The Garrett Hollow Sections constitute a composite section of the entire Morrow Group near the community of Morrow. This composite section is approximately 315 feet thick.

The Hale Formation is about 135 feet thick in this area (units M105A-2 through M105C-4); the Cane Hill Member is unusually thick and a total of 66 feet (units M105A-2 through 5), and it includes a highly fossiliferous limestone (units M105A-3 and 4) in the middle of it. The Prairie Grove Member is correspondingly thin, measuring only about 69 feet in thickness (units M105A-6 through M105C-4). The base of the Prairie Grove Member is marked by a thin pebble conglomerate (unit M105A-6).

The Bloyd Formation is exceptionally well exposed in both sections M105 and M105C and is approximately 180 feet thick. The Brentwood Limestone Member is only 27 feet thick in section M105C (units 5 through 10) and 25 feet thick in section M105D (units 2 through 6). The Woolsey Member is quite well exposed in both sections, measuring only 11 feet in thickness in M105C (units 11 through 14) and 15 feet thick in M105D (units 7 through 9). The Baldwin Coal is exposed in both sections. The "caprock" of the Baldwin Coal (basal Dye Shale Member) is present in both M105C and M105D, and in both sections unconformably overlies dark gray micritic limestones (mudstones) that contain sparse fossils and that are gradational with the underlying Woolsey terrestrial sediments. These limestones (units M105C-14 and M105D-9) are interbedded with dark gray, calcareous shales and are interpreted to represent a marine unit genetically related to the Woolsey Member. The Dye Shale Member is quite well exposed in measured section M105D (units 10 and 11) and measures 65 feet in thickness. The Kessler Limestone Member is exceptionally well exposed (M105D units 12 through 15, 12 feet thick) and is quite fossiliferous, particularly in the lower part of the member. The overlying Trace Creek Shale Member is 66 feet thick (units 16 through 21), and includes a calcareous, sparsely skeletal sandstone in the lower portion.

Remarks.--These sections, and measured section M105B (not included in the present study), were initially measured and roughly described in the spring of 1971 by Doy L. Zachry, Charlotte Glenn, and John Glenn of the University of Arkansas. Those sections are presented in C. Glenn (1972), a Master of Science Thesis at the University, who also describes the conodont biostratigraphy of this section.

The sections were examined by Doy Zachry and T. W. Henry on November 3, 1971. The lower part of measured section M104A was redescribed and remeasured on November 14 and 15, 1971, by Charlotte Glenn and T. W. Henry, and the upper portion (Prairie Grove Member) was redescribed and remeasured on March 30, 1973, by T. W. Henry and P. K. Sutherland. Measured section M105C was redescribed and remeasured on November 19 and 20, 1971, by T. W. Henry and field checked on March 30, 1973, by P. K. Sutherland and the author. And measured section M105D was remeasured, redescribed, and collected on November 14, 15, and 16, 1971 by T. W. Henry and Charlotte Glenn.

Section M105A: Garrett Hollow, Lower

Location.--SE¼, Sec. 9, to NW¼, Sec. 10, T. 13N., R. 33W., Washington County, Arkansas. Measured section M105A begins in the upper part of the Pitkin Formation (unit 1) in the N½, SW¼, SE¼, Sec. 9 at a point approximately 1.3 miles southwestward from the place where the car is parked (text-figure 23); the beginning of the section is approximately 0.7 mile downstream from the confluence of the two tributaries making the northern and northeastern extensions of Garrett Hollow. The section is measured up the western side of Garrett Hollow onto the western branch of Skylight Mountain to the base of the limestone bed (units 3 and 4) in the Cane Hill Member of the Hale Formation. The section is offset approximately 0.4 to 0.5 mile northeastward on the top of unit 4 to the SW¼, SE¼, NE¼, Sec. 9, where the limestones are exposed in the creek. The section is then measured up the west side of Garrett Hollow to the base of the Prairie Grove Member in the W½, SE¼, NW¼, Sec. 9. The section was then offset an additional 0.5 mile northeastward on the base of the Prairie Grove Member (unit 6) into the creek in the SW¼, NW¼, NW¼, Sec. 10. The bulk of the Prairie Grove Member was measured again up the west wall of Garrett Hollow to the top of the exposures near the top of the Prairie Grove Member (unit 10) in the NW¼, NW¼, NW¼, Sec. 10.

Stratigraphy.--This section begins in the upper part of the Pitkin Formation and terminates in the upper part of the Prairie Grove Member. The Cane Hill and Prairie Grove Members are both continuously exposed, and the former contains a fossiliferous limestone in the middle. The following is the stratigraphic breakdown:

Hale Formation (partial section, 109 feet)
  Prairie Grove Member (partial units 6 through 9, 42 feet)
  Cane Hill Member (units 2 through 5, 67 feet)

The top of unit 9, which is the top of the massive portion of the cliffs formed by the Prairie Grove, can be walked into unit 0 of measured section M105C, approximately 0.25 mile to the north-northeast.

Unit No.	Description	Thickness
	MORROW GROUP	
	HALE FORMATION (partial)	
9	Sandstone; medium-grained, calcite-cemented, submature, skeletal quartzarenite; light brownish gray, weathers moderate brownish gray. Thin- to medium-bedded, irregularly bedded. Exposed as series of receeding ledges at top of bluffs on west side creek. Thickness approximately	5'
8	Sandstone and limestone: sandstone; fine- to medium-grained, calcite-cemented, submature, skeletal, ooid-bearing quartzarenite grading laterally and vertically into medium- to coarse-grained, highly quartz-sandy, oolitic, skeletal calcarenite (grainstone); several beds nonoolitic and with glauconite; medium light gray, weathers moderate grayish brown and moderate reddish brown. Medium- to thick-bedded, irregularly bedded, distinctly cross-bedded. Exposed as bluffs on hillside; weathers pitted and honeycombed. Thickness approximately	21'
7	Sandstone; medium-grained, calcite-cemented, submature, skeletal quartzarenite, with several beds containing scattered ooids; medium gray, weathers moderate brownish gray. Thin- to thick-bedded, irregularly bedded, cross-laminated. Forms series of ledges on steep hillside; weathers mainly by exfoliation. Thickness approximately	15.5'
6	Limestone; fine- to coarse-grained, highly quartz-sandy, mixed-skeletal calcarenite (grainstone); lower bed contains scattered siltstone clasts; medium light gray, weathers moderate grayish brown. Thin-bedded, irregularly bedded. Forms lower part of steep bluff. Thickness approximately	2.0'
5	Shale with siltstone: shale, highly quartz-silty; medium gray to medium dark gray, weathers medium gray. Thinly laminated, regularly laminated, interlaminated with siltstone. Siltstone; fine-grained, highly argillaceous quartzsiltite; color same. Very thin-bedded to thickly laminated. Exposed poorly mainly as talus on hillside above unit 4 on	

west side of creek; intermittently exposed northward on banks of creek. Thickness measured up west bank of creek above unit 4, estimated 34'

4 Limestone to sandstone: medium-grained, pelmatozoan, highly quartz-sandy calcarenite (grainstone) to medium-grained, calcite-cemented and clay-bonded; immature to submature, skeletal quartzarenite; moderate brownish gray, weathers same. Thin-bedded, irregularly bedded, cross-bedded. Forms small ledges on hillside before offset and as small bluff on west side of creek after offset; weathers platy by exfoiliation. Thickness 3'

3 Limestone; fine- to medium-grained, argillaceous, quartz-sandy, pelmatozoan, conglomeratic calcarenite (grainstone) with pebbles of siltstone; moderate brownish gray, weathers same. Medium-bedded, irregularly bedded. Best exposed in creek at base of small cliff 0.4 mile upstream from Pitkin outcrops. Highly fossiliferous with goniatites, brachiopods. Lower contact exposed on west bank of creek, sharp, truncating. Thickness 3'

2 Siltstone with shale and minor sandstone: siltstone; fine- to coarse-grained, clay-bonded, immature quartz-siltite; dark gray, weathers moderate brownish gray. Thickly laminated, regularly laminated; current ripple marks and burrow casts common; interlaminated with shale. Shale; highly quartz-silty; medium dark gray to very dark gray, weathers moderate brownish gray. Occasional sandstone; very fine-grained, clay-bonded, immature quartzarenite; colors same. Unit poorly exposed on west side of creek above creek; basal 5 to 10 feet mostly covered; abundant talus on hillside and occasional outcrops to north on creek banks. Thickness, estimated 27'

PITKIN FORMATION

1 Limestone with scattered chert nodules: limestone; fine-grained, skeletal calcilutite (mudstone); light brownish gray, weathers light gray. Medium- to thick-bedded, irregularly bedded; contains stringers and isolated chert nodules. Weathers smoothly; forms small bluff in creek. Upper contact covered. Thickness 4'

Section M105C: Garrett Hollow, Middle

Location.--W½, SW¼, Sec. 3, T. 13N., R. 33W., Washington County, Arkansas. Measured section M105C begins in strata equivalent to the upper part of measured section M105A. The lower part of this section can be reached by walking due west 0.3 to 0.4 mile from the point where the car is parked down into the northern extension of Garrett Hollow (text-figure 23). The beginning of the section is located in the SW¼, SW¼, SW¼, Sec. 3 about 0.25 mile upstream from the confluence of the tributaries marking the northern and northeastern extensions of Garrett Hollow. The upper part of the Prairie Grove Member (units 0 through 4) and the lower part of the Brentwood Limestone are measured northward in the creek bed and on the western bank of the tributary to the first small tributary from the east. The upper part of the Brentwood, the Woolsey Member, and the "caprock" are measured to a point approximately 50 to 100 feet upstream in the small tributary in the NE¼, NW¼, SW¼, Sec. 3.

Stratigraphy.--Measured section M105C begins in the upper part of the Prairie Grove and ends in the basal part of the Dye Shale Member. The stratigraphic breakdown is as follows:

- Morrow Group (partial section, 73 feet)
  - Bloyd Formation (partial section, 44 feet)
    - Dye Shale Member (basal part, units 15 and 16, 5.5 feet)
    - Woolsey Member (units 11 through 14, 11 feet)
    - Brentwood Limestone (units 5 through 10, 27 feet)
  - Hale Formation (partial)
    - Prairie Grove Member (partial section, units 0-4, 29 feet)

The base of unit 1 contains a bryozoan-caninid coral biolithite (boundstone) with large numbers of corals up to 0.8 foot in length were collected at this locality.

Unit No.	Description	Thickness
MORROW GROUP		
BLOYD FORMATION (partial)		
	Note: Section is covered above; Kessler is exposed poorly higher in tributary.	
16	Shale, quartz-silty; very dark gray, weathers light olive gray. Thickly laminated, reguarly laminated. Exposed above "caprock" on north side of tributary. Thickness, direct measurement	3.5'
15	Limestone with shale: limestone; fine- to medium-grained, highly quartz-sandy, pelmatozoan-bryozoan calcarenite; dark gray, weathers moderate grayish brown. Thin-bedded, irregularly bedded; interbedded with thin shale. Shale, quartz-silty. Exposed as slight overhanging ledge on north side of creek above coal. Upper contact gradational. Thickness, direct measurement	2.0'
14	Shale and limestone: shale, clay shale; very dark gray, weathers moderate grayish brown. Thickly laminated, regularly laminated. Limestone; fine-grained calcilutite (mudstone) with scattered brachiopods; very dark gray, weathers moderate dark gray. Thin-bedded, nodular, up to 0.4 foot thick and set in shale. Block in stream with calcilutite welded to unit 15, sharp contact; unit genetically belongs to Woolsey Member and not to overlying "caprock". Exposed in vertical face on north side of tributary above coal. Thickness, direct measurement	2.1'
13	Shale, non-quartz silty; very dark gray, weathers moderate grayish brown. Thickly laminated, regularly laminated. Exposed on north side of creek above coal. Lower 1 foot bituminous with layer of marcasite and siltstone nodules in lower 0.5 foot. Upper contact gradational. Thickness, direct measurement	5.2'

12 Coal; grayish black. Thin-bedded, regularly bedded. Well-exposed in tributary where it makes small waterfall; weathers blocky. Upper contact blocky. Maximum thickness, direct measurement 0.4'

11 Siltstone and shale: siltstone; fine-grained, clay-bonded, immature quartzsiltite; moderate greenish gray, weathers moderate gray to moderate grayish brown. Thin-bedded to very thin-bedded, regularly bedded; upper surfaces with current ripple marks. Well-exposed in tributary 35 feet east of top of unit 10. Interbedded with very thin highly quartz-silty shale; upper 0.5 foot becomes carbonaceous and contains less quartz-silt. Contains scattered plant impressions on upper surface. Thickness, Abney level 3'

10 Limestone; fine- to coarse-grained, recrystallized, micritic, pelmatozoan-bryozoan calcarenite (packstone); medium dark gray, weathers brownish gray. Medium-bedded, single bed, irregularly bedded. Forms ledge above unit 9 on north bank of tributary, slightly slumped and locally overhanging lower unit up to 6 feet; upper part exposed in creek. Thickness, direct measurement 1.7'

9 Shale, quartz-silty; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Exposed as vertical face above unit 8 and below unit 9 on north bank of tributary. Thickness, direct measurement 3.6'

8 Limestone; fine-grained, micritic, bryozoan, mixed-skeletal calcarenite (packstone to wackstone); medium light gray, weathers moderate yellowish gray. Medium-bedded, irregularly bedded; lower part thin-bedded, discontinuous. Well-exposed on north side of tributary approximately 50 feet of unit 6; makes small ledge. Thickness, direct measurement 1.2'

7 Covered and shale: shale, noncalcareous, quartz-silty; olive gray, weathers light olive gray. Thinly laminated. Possible bed of calcilutite 3 feet below top. Lower 3 feet well-exposed on north creek bank; upper 0.5 foot exposed. Thickness, approximately 12'

6 Limestone; coarse-grained, pelmatozoan, bryozoan, brachiopodal calcarenite (grainstone); light gray, weathers light brownish gray. Thin- to medium-bedded, irregularly bedded, cross-bedding poorly developed. Exposed as series of ledges in tributary approximately at and 25 east of junction with main

stream. Upper contact covered. Thickness, direct measurement 3.8'

Note: Remainder of section measured up tributary to east.

5 Covered, shale, and limestone: approximately 3 feet of shale poorly exposed above unit 4; upper 1 foot of unit calcareous shale with thin calcilutite nodules. Upper contact sharp, poorly exposed beneath ledge formed by unit 6 at junction of stream with tributary to east. Thickness approximately 5'

HALE FORMATION (partial)

4 Limestone with shale: limestone; coarse- to medium-grained, bryozoan, pelmatozoan calcarenite (grainstone) at base, becoming medium-grained, ?micritic, bryozoan, pelmatozoan calcarenite (packstone) in upper part; contains scattered ooids at base; light gray, weathers brownish gray. Thin-bedded, highly irregularly bedded, nodular, discontinuous beds interbedded with thin calcareous shale. Forms rubbly ledges above good exposure of unit 3. Contains Michelinia. Thickness, direct measurement 4.2'

3 Limestone; fine-grained, pelmatozoan calcirudite (grainstone); light gray, weathers moderate brownish gray. Thick-bedded, irregularly bedded. Forms ledge above northwestern side of creek on bank; upper portion measured upstream on northwestern bank of creek where it forms ledges. Upper contact sharp, undulating. Thickness, direct measurement, approximately 10'

2 Limestone; medium-grained, oolitic, glauconite-bearing calcarenite (grainstone); medium gray, weathers moderate brownish gray. Medium- to thick-bedded, irregularly bedded, minor cross-bedding. Forms distinct ledge above northwestern side of creek. Thickness, direct measurement 5.5'

1 Limestone; fine-grained calcilutite (mudstone); contains bed of micritic, fistuloporid bryozoan-caninid coral biolithite (boundstone) in lower 1 to 1.5 feet; medium-grained, oolitic calcarenite (grainstone) present locally 0.5 to 1.0 foot from top; then algal calcilutite (mudstone) in upper 0.5 foot; medium dark gray, weathers light gray. Thin-bedded, highly irregularly bedded, undulating

	and nodular; interlaminated with thin very dark gray shale; abundant burrow fills between nodules. Forms recess beneath unit 2 on west bank of creek. Upper contact sharp, undulating. Contains large caninid corals near base. Thickness, direct measurement	6.0'
0	Sandstone; fine- to medium-grained, calcite-cemented, mature, coated-grain quartzarenite; moderate beige, weathers moderate brownish gray. Medium-bedded, irregularly bedded, cross-laminated. Exposed in creek and on west bank of south-flowing creek. Upper contact sharp, undulating. Thickness, maximum exposure	3.5'

Note: Unit 0 is equivalent to the upper part of unit 9 in section 105A.

Section M105D: Garrett Hollow, Upper

Location.—N½, Sec. 10, T. 13N., R. 33W., Washington County, Arkansas. Measured section M105D begins with the upper part of the Prairie Grove Member in the northeastern extension of the head of Garrett Hollow in the SW¼, NE¼, NW¼, Sec. 10 (text-figure 23). The beginning of the section is located about 0.25 mile south of the parking place in the northeastern extension of Garrett Hollow. The section is measured up the northern wall of the creek to the base of the Kessler Limestone Member in the NW¼, NE¼, NW¼, Sec. 10. The section is offset eastward approximately 0.2 mile to the NW¼, NW¼, NE¼, Sec. 10, where the Kessler crops out in the creek. The remainder of the section to the base of the Atoka Formation is measured up the north side of the valley.

Stratigraphy.—The section begins in the upper part of the Prairie Grove Member and terminates in the lower part of the Atoka Formation. The stratigraphic breakdown is as follows:

Morrow Group (partial section, 189 feet)
  Bloyd Formation (183 feet)
  Trace Creek Shale (units 16 through 21, 66 feet)
  Kessler Limestone (units 12 through 15, 12 feet)
  Dye Shale Member (units 10 and 11, 65 feet)
  Woolsey Member (units 7 through 9, 15 feet)
  Brentwood Limestone (units 2 through 6, 25 feet)
Hale Formation (partial section)
  Prairie Grove Member (units 0 and 1, 5.5 feet)

The Kessler Limestone Member forms a vertical cliff on the northern side of the creek; the Kessler is exceptionally fossiliferous; goniatites were observed but not collected. The overlying Trace Creek Shale contains a calcareous sandstone bed near the base.

Unit No.	Description	Thickness
ATOKA FORMATION		
24	Sandstone; fine-grained, quartz overgrowth-cemented, submature quartzarenite; medium dark gray, weathers light yellowish brown. Thin- to very thin-bedded, regularly bedded, unevenly bedded; upper surfaces with current ripple marks; lower surfaces with tracks and burrow fills. Contains minor argillaceous layers. Forms massive, vertical cliff and escarpment on both sides of creek. Thickness not measured.	
23	Sandstone and shale: sandstone; fine- to very fine-grained, clay-bonded, immature quartzarenite; medium gray, weathers moderate yellowish brown. Thin-bedded, regularly bedded, inter bedded with thin shale. Shale, quartz-silty; grayish black, weathers medium dark gray. Thinly laminated, regularly laminated. Forms slightly recessed area under massive cliff. Upper contact gradational. Thickness, direct measurement	5'
22	Sandstone; fine-grained, quartz-overgrowth-cemented, submature quartzarenite; medium gray, weathers dusky	

yellow. Medium-bedded, regularly bedded, partly cross-bedded; interbedded with thin shale. Forms basal part of bluff on north side of creek. Thickness, direct measurement, maximum exposure on south side of creek 5.0'

MORROW GROUP

BLOYD FORMATION

Note: Measured unit 21 northward up steep hillside between two large slump blocks of Atoka sandstone; measured to prominent bedding plant in unit 23 and offset northward 25 to 40 yards to exposures of unit 22.

21	Covered. Minor very dark gray talus. Thickness estimated	45'
20	Shale, clay shale; very dark gray, weathers light olive gray. Thinly laminated; highly fissile, breaks into paper-thin pieces. Poorly exposed above sandstone bench on north side of creek. Thickness approximately	5'
19	Sandstone; fine- to very fine-grained, clay-bonded and quartz-overgrowth-cemented quartzarenite; moderate grayish brown, weathers moderate brownish gray. Thin-bedded, slightly cross-bedded, irregularly bedded; upper surfaces with current ripple marks. Unit forms bench above Kessler on north side of creek; measured at east end of exposure directly up hillside. Thickness	3.5'
18	Sandstone; fine-grained, calcite-cemented, submature, skeletal quartzarenite; moderate brownish gray, weathers moderate reddish brown. Thin-bedded, irregularly bedded, well-defined cross-beds. Forms lower part of first bench above Kessler Limestone on north side of creek. Upper contact gradational but well-defined. Thickness, direct measurement	3.0'
17	Siltstone; coarse-grained, clay-bonded, immature quartzarenite. Thickly laminated, irregularly laminated. Exposed locally recessed beneath overlying unit on north side of creek. Upper contact sharp. Thickness, direct measurement	1.0'

16 Shale, quartz-silty; becomes highly quartz-silty in upper 1 foot; olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Forms slope above vertical cliff. Upper contact gradational. Thickness, approximately 8.5'

15 Limestone; fine- to medium-grained, micritic, pelmatozoan, mixed-skeletal calcarenite (packstone) at base, becoming fine- to coarse-grained, micritic, mixed-skeletal, brachiopodal calcarenite (packstone to grainstone) at top; medium brownish gray, weathers moderate brownish gray. Medium-bedded, regularly bedded, interbedded and gradational with calcareous shale partings. Forms receeding part of upper cliff. Upper contact gradational. Highly fossiliferous locally. Thickness, direct measurement 3.5'

14 Shale and limestone: shale, calcareous; contains Osagia oncoliths; medium light gray, weathers light olive gray. Thickly laminated, irregularly laminated. Limestone; fine- to coarse-grained, argillaceous, pelmatozoan calcarenite (grainstone to packstone); medium gray, weathers medium yellowish gray. Upper contact gradational. Thickness 3.6'

13 Limestone; medium-grained, micritic, brachiopodal calcirudite (packstone), separated from underlying unit by thin shale; medium gray, weather light brownish gray to moderate grayish brown. Medium-bedded, irregularly bedded. Forms ledge at western end of bluffs on north side of creek. Highly fossiliferous. Unit thins to east as underlying unit thickens, direct measurements, varies from 2.5 to 0.0 feet, averages 1.2'

12 Limestone; medium-grained, micritic, pelmatozoan-bryozoan calcarenite (packstone), grading with and alternating with highly micritic calcarenite (wackestone), slightly quartz-sandy; base contains scattered siltstone pebbles and shale clasts; medium gray, weathers light gray. Medium- to thick-bedded, irregularly bedded, cross-laminated. Forms lower part of Kessler cliff; measured on west side of cliff above creek. Contains Chaetetes near top, goniatites, Composita. Thickness varies from 3.2 to 4.5 feet, direct measurements, averages 3.9'

Note: Measured northward up steep slope parallel to strike to base of Kessler Limestone. Offset section approximately 100 yards eastward to point immediately east of tributary from north on top of unit 11. Units

12 through 19 make cliff at top of shale cuts in upper part of unit 11 at this point.

11	Shale, quartz-silty; olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Almost continuously exposed up north wall of creek; upper 20 feet exposed in vertical cut beneath Kessler Limestone approximately 25 yards east of tributary to main creek from north. Contains bed of coarse-grained, argillaceous pelmatozoan calcarenite 7 to 8 feet below top; makes light ledge in otherwise vertical face. Upper contact sharp, gently undulating. Thickness, estimated	63'
10	Sandstone; medium- to coarse-grained, calcite-cemented, submature, pelmatozoan, mixed-skeletal quartzarenite; upper bed conglomeratic with pebbles of siltstone and shale clasts; moderate brownish gray, weathers dark grayish brown. Basal bed thick-bedded, slightly cross-bedded; upper 0.5 foot with quartz-sandy shale and thin-bedded sandstone. Unit well exposed as ledge in creek; overhangs lower units on north side of creek. Upper contact gradational. Attitude: strike N33°E, dip 3°SE. Contains abraded <u>Michelinia</u>, solitary rugose corals. Thickness, direct measurement	1.9'
9	Limestone and shale: limestone; medium- to fine-grained, micritic, slightly quartz-sandy, bryozoan calcarenite (packstone); medium dark gray, weathers moderate light gray. Thin-bedded, irregularly bedded, interbedded with shale. Shale, calcareous; dark gray, weathers same. Thickly laminated, irregularly laminated. Exposed as recess beneath "caprock" in stream. Upper contact sharp, undulating. Note: unit may genetically belong to depositional cycle of underlying unit. Thickness, direct measurement	3.0'
8	Shale and coal: shale, quartz-silty; weathers greenish gray. Coal, weathers grayish black. Thin-bedded, irregularly bedded, 0.3 foot thick 3 feet above base. Weathers blocky. Contains very thin under-clay. Unit poorly exposed on north bank of creek; coal dug out of bank. Upper contact obscure. Thickness, approximately	6'
7	Siltstone; coarse-grained, clay-bonded, immature quartzsiltite; medium light gray, weathers light brownish gray. Very thin-bedded to thickly laminated, regularly laminated; current ripple marks on upper surfaces, small-scale squamiform load casts on lower surfaces; interbedded with thin, quartz-	

silty shale. Well exposed on north bank of stream. Upper contact obscure. Thickness, direct measurement, approximately 6'

6 Limestone and shale: limestone; medium-grained, micritic, bryozoan, pelmatozoan calcarenite (packstone), becoming coarse-grained, recrystallized, mixed-skeletal calcilutite (recrystallized wackestone?) at top; medium dark gray, weathers moderate brownish gray. Thin- to medium-bedded, interbedded with thin shale; unit grades laterally eastward into calcareous, skeletal shale. Upper contact sharp, undulating. Thickness, direct measurements, varies from 3.0 to 4.0 feet, averages 3.5'

5 Limestone; medium-grained, oolitic, bryozoan, micritic, pelmatozoan calcarenite (packstone); medium dark gray, weathers moderate brownish gray. Medium-bedded, irregularly bedded, cross-laminated. Exposed as ledge above creek on north side; top exposed in creek 50 feet east of base. Upper contact obscure. Thickness, direct measurement 3.2'

4 Limestone and shale: limestone; fine-grained, pelmatozoan calcarenite to fine-grained calcirudite (grainstone); medium gray, weathers moderate brownish gray. Thin-bedded, becoming thickly laminated at top, interbedded with shale. Shale, calcareous, fossiliferous; weathers moderate brownish gray. Thickly laminated, irregularly laminated. Exposed on north side of creek as recess above unit 3. Upper contact gradational. Thickness, direct measurement 2.2'

3 Limestone; fine-grained, slightly quartz-sandy, mixed-skeletal calcarenite (grainstone) at base, becoming fine- to medium-grained, pelmatozoan calcarenite (grainstone) at top; medium dark gray, weathers moderate brownish gray. Thick-bedded, irregularly bedded, single bed. Exposed as ledge above creek on north side. Upper contact gradational. Thickness, direct measurement 3.0'

2 Shale, quartz-silty; calcareous only at base; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Well-exposed on south side of creek above where unit 1 is measured. Upper contact sharp. Thickness, direct measurement 13'

HALE FORMATION

1	Limestone; medium- to coarse-grained, pelmatozoan, bryozoan calcarenite (grainstone) with isolated calcilutite pebbles in lower 0.5 foot; medium gray, weathers moderate brownish gray. Thin- to medium-bedded, irregularly bedded, inter bedded with thin shale in upper 0.5 foot. Well exposed on south bank of creek in small bend and in creek approximately 50 feet to east. Upper contact gradational. Thickness, direct measurement	3.5'
0	Limestone; fine-grained, algal calcilutite (wackestone); medium dark gray, weathers light gray. Thin-bedded, irregularly bedded, interbedded with thin shale in upper part. Exposed on south side of creek under ledge formed by overlying unit, recessed 3 to 4 feet. Upper contact obscure. Thickness direct measurement, maximum exposure	2.0'
	Note: The section is poorly exposed below to west in creek for a long distance.	

Introduction to Sections on Headwaters of Lee Creek, M106, M107, and M108

Location.--Three closely spaced stratigraphic sections were measured on the eastern side of Lee Creek and in the tributaries on the eastern side of Lee Creek near its headwaters in the N½, Sec. 36, T. 14N., R. 31W., Washington County, Arkansas, and in the adjacent Sec. 25. These sections are located approximately 4 miles southwest of the community of West Fork and 3 miles east of the site of the abandoned Woolsey Station.

The sections can be most easily reached from the farm of C. Russell Courtney. To reach the Courtney farm (text-figure 22), drive southward and southwestward from the western city limits of West Fork on Arkansas State Highway 170 for a distance of 2.0 miles. The paved highway at this point reaches the top of the mountain and makes a sharp bend due westward. Continue past this bend for 0.1 mile and turn southward on the gravel country road. Drive southward on the winding road for approximately 3.1 miles to an intersection with a second county road running east and west. Turn westward and then shortly southwestward and drive past the first white frame house on the northwestern side of the road. At a point 0.2 mile from the intersection, turn westward on the farm road that intersects the county road at an acute angle and immediately crosses a cattle guard. The mail boxes of C. R. Courtney and M. Remy will be seen at this intersection. Continue 0.8 mile southwestward on the farm road to the brick and white frame house owned by Mr. Courtney.

Remarks.—The sequence of sections was measured primarily to show the high degree of lateral variation within the Kessler Limestone Member and, to a lesser degree, of the "caprock" of the Baldwin Coal. The three sections are spaced at one-half mile intervals.

In measured section M106, the Kessler Limestone Member is only 9 feet thick (units 11 and 12); in M107, it has thickened to about 14 feet (units 25 and 26); and in M108, the Kessler is 28 feet thick (units 16 to 25). The Kessler Limestone in the latter section is moderately fossiliferous.

The "caprock" likewise exhibits great lateral variability. In measured section M106, the "caprock" is a highly resistant, cross-bedded quartzarenite about 3 feet thick. Farther to the north in M107, this bed is about 4 feet thick. And in M108, the "caprock" is variable in thickness, less than 0.5 foot thick, and contains sparse pebbles.

A complete section of the Bloyd Formation is exposed only in section M107, where this formation is about 245 feet thick.

Section M106: Lee Creek, South

Location.—N½, NE¼, NW¼, Sec. 36, T. 14N., R. 31W., Washington County, Arkansas. The section begins in the NW¼, NE¼, NW¼, Sec. 36 at a point approximately 0.1 mile east (upstream) from the confluence of a small tributary with Lee Creek. It is measured from this point on the small west-flowing tributary upstream to the base of the high bluffs, formed by the basal Atoka (Winslow) sandstones in the NE¼, NE¼, NW¼, Sec. 36.

To reach the beginning of the section, drive behind the home of Mr. C. Russell Courtney and continue southward for approximately 0.7 mile on a small field road. On this stretch of winding road through the woods, one crosses one wire gate and one tributary of Lee Creek (down which section 107 is located). At the point approximately 0.6 mile from the Courtney home, the trail will enter a meadow; drive 0.1 mile to the southwest edge of the meadow and park. Walk southward approximately 75 yards into the second tributary of Lee Creek; walk down this tributary 200 to 300 yards to a point approximately 0.1 mile east of its confluence with Lee Creek and where the Woolsey Member is exposed in the creek. Here, the section begins.

Stratigraphy.—This section begins below the Baldwin Coal in the Woolsey Member of the Bloyd Formation and terminates in the lower part of the Atoka Formation. The following is the stratigraphic breakdown:

Bloyd Formation (partial section, 154 feet)
- Trace Creek Shale (units 13 and 14, 65 feet)
- Kessler Limestone (units 11 and 12, 9 feet)
- Dye Shale (units 6 through 10, 72 feet)
- Woolsey Member (partial, units 1 through 5, 8 feet)

Remarks.--This section was reconnoitered on December 1, 1971, and described on December 2, 1971, by T. W. Henry. H. Richard Lane and the author visited the section on December 12, 1971, and Doy L. Zachry, Walter L. Manger, Patrick K. Sutherland, and T. W. Henry examined the section on March 5, 1973.

Unit No.	Description	Thickness
ATOKA FORMATION		
15	Sandstone and shale: sandstone; fine-grained, glauconite-bearing quartzarenite; medium light gray, weathers moderate grayish brown. Thin- to very thin-bedded, regularly bedded, unevenly bedded; upper surfaces with current ripple-marks; lower surfaces with numerous burrow casts, Conostichus; interbedded with shale. Shale, quartz-silty; very dark gray, weathers same. Unit forms lowest of series of cliffs in Atoka (Winslow) Formation; large cliff. Attitude measured on number of beds and in number of places, approximately horizontal. Thickness not measured but estimated 25 to 35 feet at waterfall.	
MORROW GROUP		
BLOYD FORMATION (partial)		
14	Covered with minor shale talus. Measured from top of unit 13 southward to first prominent cliff in Atoka Formation; offset northeastward into creek on prominent bedding plane for distance of approximately 75 yards where 8 feet of strata lower than the bedding plane are exposed. Thickness estimated	20'
13	Shale, clay-shale; grayish black, weathers same. Thinly laminated, highly fissile. Almost continuously exposed above top of unit 12 in creek and on steep slope to south of creek; unit approximately	

10% covered. Thickness measured due south up slope to highest abundant talus with 0° in Abney level, estimated 45'

12 Limestone and ?shale: limestone; coarse-grained, micritic, brachiopodal, pelmatozoan, molluscan, Osagia oncolith-bearing calcarenite (packstone); medium light gray, weathers light orangish gray. Thin-bedded, apparently interbedded with thin shale. Poorly exposed on south side of creek above approximate top of unit 11, which is slightly slumped in creek. Thickness, approximately 1.5'

Note: Offset section approximately 50 yards northeastward into creek on approximate top of unit 11.

11 Limestone; medium- to coarse-grained, well-washed, oolitic calcarenite (grainstone) with some zones containing uncoated pelmatozoan grains; light gray, weathers same. Very thick-bedded, single bed. Forms bench above stream to south; entire unit does not crop out there, only the upper 2 to 3 feet; upper part well-exposed up wash to south which joins tributary at point where large Kessler block is in stream. Thickness measured directly on same slump block 7.5'

10 Shale and siltstone: lower 8 feet coarse-grained, clay-bonded, calcareous quartzsiltite, grading upward into slightly quartz-silty shale; medium dark gray, weathers same. Lower 8 feet thin-bedded, regularly bedded. Exposed as vertical top of shale bluff above unit 9; does not crop out above unit 9 after offset into creek where Kessler block is located. Upper part of unit largely covered where measured but abundant shale talus in washes on south side of creek. Thickness estimated 35'

Note: Shale bluff south of creek is oriented with strike. Went directly up shale slope perpendicular to strike with 2° in Abney level. Section offset along top of unit 9 into creek at point where large slump block of Kessler is in creek; then measured 48-foot interval from top of unit 9 to top of Kessler Limestone Member and subtracted thickness of unit 11 to get thickness of unit 10.

9 Siltstone and limestone: coarse-grained, calcareous, skeletal quartzsiltite to coarse-grained, argillaceous, highly quartz-silty calcisiltite; dark brownish gray, weathers moderate grayish brown. Thin- to medium-bedded, regularly bedded. Forms slightly overhanging

ledge at top of steep shale slope south of small creek. Upper contact gradational. Thickness, direct measurement 1.1'

8 Shale and siltstone: shale, slightly quartz-silty in lower part, becoming highly quartz-silty in upper part; medium dark gray, weathers light olive gray. Thinly laminated in lower part, becoming thickly laminated to very thin-bedded in upper 2 feet; interbedded with siltstone. Siltstone; coarse-grained, clay-bonded, immature, calcareous quartzsiltite; medium dark gray, weathers moderate brownish gray. Thin-bedded, regularly bedded. Contains, scattered dolomite nodules to northeast immediately above creek bed where Kessler block is in stream. Unit exposed on very steep face south of stream; siltstone beds protrude from face slightly. Upper contact gradational, even. Thickness, direct measurement 8.5'

7 Shale, slightly quartz-silty; contains plate-like dolomite nodules in lower 12 feet and scattered small dolomite nodules in upper part of unit; medium dark gray, weathers same. Thickly laminated, regularly laminated. Forms very steep bluff on south side of intermittent stream. Upper contact gradational, even. Thickness measured with 2° in Abney level perpendicular to strike on southwestern side of steep bluff, estimated 25'

6 Sandstone and limestone: limestone; basal 1.0 foot consists of medium- to coarse-grained, highly quartz-sandy, pelmatozoan calcarenite (grainstone); medium dark gray, weathers dark grayish brown. Medium-bedded, regularly bedded, single bed, cross-laminated. Sandstone; upper part, fine- to medium-grained, calcite-cemented?, limonitic quartzarenite; weathers dark orangish brown. Medium-bedded, regularly bedded, cross-laminated. Unit highly friable; deeply weathered; forms ledge in creek. Upper contact obscure. Attitude measured on top bed, averages N60°E, dip 2°SE. Thickness, direct measurement 2.7'

5 Shale, slightly quartz-silty; medium dark gray, weathers same; contains scattered clay-ironstone concretions. Thinly laminated. Exposed underneath unit 6 in creek. Upper contact sharp, undualting. Thickness, direct measurement, maximum exposure 0.2'

4 Covered. Thickness approximately 2'

3	Shale and claystone: claystone; has features of underclay; light orangish gray, weathers grayish orange. Forms basal 0.4 foot of unit. Shale, slightly quartz-silty, bituminous; dark gray, weathers moderate orangish brown. Overlies claystone and is 0.2 foot thick. Upper part of unit consists of blocky-weathering clay shale; medium dark gray, weathers moderate brownish gray. Thickly laminated, regularly laminated. Contains clay-ironstone concretions. Upper contact covered. Exposed under slump block of caprock in creek. Thickness, direct measurement, maximum exposure	2.7'
2	Coal; grayish black, weathers same. Thin-bedded, regularly bedded, single bed. Exposed beneath slump block of caprock in tributary; weathers blocky. Upper contact gradational. Thickness, direct measurement	0.4'
1	Shale; highly quartz-silty; moderate brownish gray, weathers moderate brown; upper surface stained reddish orange. Contains scattered flattened clay-ironstone concretions up to 3 inches in length. Thickly laminated, irregularly laminated. Exposed in tributary beneath "caprock" and Baldwin Coal. Lower contact covered, upper contact gradational. Contains scattered plant impressions throughout. Thickness, measured with Abney level with 2° dip compensation	2.6'

Section M107: Lee Creek, Central

Location.--S½, Sec. 25, T. 14N., R. 31W., Washington County, Arkansas. The section begins in the SE¼, NE¼, SW¼, Sec. 25, on Lee Creek approximately 35 to 50 yards north of the intersection of a tributary from the east with Lee Creek. Units 1 through 16 are measured here and northward along the bluff on the north side of Lee Creek. Units 17 through 21 are measured eastward up the bluff to the top of the Kessler Limestone Member in the W½, NW¼, SE¼, Sec. 25 and offset southward into the tributary in the SW¼, NW¼, SE¼, Sec. 25, where the upper part of the Dye Shale Member, Kessler Limestone, and the basal Trace Creek Member are measured (units 23 through 27). The section was again offset southeastward approximately 50 to 75 yards on the top of the Kessler to the SW¼, NW¼, SE¼, Sec. 25 where the upper part of the Trace Creek Member (unit 28) and the basal portion of the Atoka (Winslow) Formation are measured southward up the hill to the base of the sequence of high bluffs. The section terminates in the NW¼, SW¼, SE¼, Sec. 25.

Follow the instructions given in the introduction to the sections on the headwaters of Lee Creek to reach the C. R. Courtney home. From the Courtney farm house, drive southward behind the farm house on a winding farm road (the same road leading to section M106) for a distance of 0.4 mile to the wire gate at the southern edge of the Courtney property. Drive through the gate and continue 0.2 mile southward on the trail through the woods to the first tributary south of the gate. Park and walk westward downstream for approximately 0.4 mile to the confluence of this tributary with Lee Creek. The lowest strata in the section are located 35 to 50 yards north of this intersection on the bluffs on the east side of Lee Creek.

Stratigraphy.--The section begins in the upper part of the Hale Formation and terminates in the lower part of the Atoka Formation, the lower units of which form precipitous cliffs on the hillside above Lee Creek. The stratigraphic breakdown is as follows:

- Bloyd Formation (245 feet)
  - Trace Creek Shale (units 27 and 28, 70 feet)
  - Kessler Limestone (units 25 and 26, 14 feet)
  - Dye Shale Member (units 21 through 24, 82 feet)
  - Woolsey Member (unit 20?, 35 feet)
  - Brentwood Limestone (units 16 through 19, 44 feet)
- Hale Formation (partial section)
  - Prairie Grove Member (partial, units 0-15, 48 feet)

Remarks.—The section was described on December 7 and 8, 1971, by T. W. Henry. The section was collected for conodonts by H. Richard Lane and T. W. Henry on December 12, 1971. It was examined by P. K. Sutherland, Doy Zachry, W. L. Manger, and T. W. Henry on March 5, 1973.

Unit No.	Description	Thickness
ATOKA FORMATION		
29	Sandstone; fine-grained, quartz-overgrowth-cemented, submature quartzarenite, medium gray, weathers moderate brownish gray. Thin-bedded, regularly bedded; upper surfaces contain oscillation ripple marks; lower surfaces contain burrow casts and trails; interbedded with thin, dark gray shale. Forms lower part of distinctive bluff along hillside, approximately 35 to 40 feet high. Attitude measured on base of lower bed, strike N83°E, dip 3.5°S. Thickness not measured.	
MORROW GROUP (partial)		
BLOYD FORMATION		
28	Covered with minor dark gray shale in talus. Thickness measured down dip with 3° in Abney level, estimated	60'
	Note: Offset section approximately 100 yards to south side of creek on top of unit 26, and measured interval from top of Kessler to base of unit 29; thickness of unit 28 calculated by subtracting thickness of unit 27 from interval. Measured southward up steep bluff.	
27	Shale, clay shale, becoming slightly quartz-silty higher. Poorly exposed on northwest bank of creek above Kessler Limestone. Thickness estimated	10'
26	Limestone; coarse-grained, micritic?, pelmatozoan calcarenite (packstone) with isolated shale clasts,	

becoming coarse-grained, slightly quartz-sandy, pelmatozoan calcarenite (grainstone) at top; contains few beds of fine-grained, pelmatozoan calcirudite (packstone to grainstone); medium dark gray, weathers moderate brownish gray. Thick-bedded, irregularly bedded. Forms massive cliff 35 yards northwest of creek. Attitude measured on base of lower bed, strike N70°W, dip 5 to 6°NE. Thickness, direct measurement 10.0'

25 Limestone and sandstone: sandstone; at base of unit, fine-grained, calcite-cemented, submature, skeletal quartzarenite grading upward to fine- to medium-grained, quartz-silty, recrystallized ?micritic, pelmatozoan calcarenite (recrystallized packstone?); medium gray, weathers moderate pinkish gray. Thin-bedded, irregularly bedded, with large lenses (nodules) of fine-grained quartzarenite at base, 2 feet thick and 3 feet long at northwestern end of exposure; thin shale breaks near top. Recessed beneath overlying unit from 8 to 12 feet at point 25 yards northwest of Kessler on north bank of creek. Upper contact gradational, undulating. Contains isolated plant fragments. Thickness, difficult to measure, varies from 3.0 to 4.0 feet at expense of underlying unit, averages 3.5'

24 Shale and sandstone: sandstone; very fine-grained, clay-bonded, immature quartzarenite; medium gray, weathers moderate brownish gray. Thin-bedded, regularly bedded, single bed at base of unit. Shale, quartz-silty; contains scattered flattened dolomite nodules; dark olive gray, weathers medium gray. Thickly laminated to very thin-bedded. Well exposed in creek and on north creek bank. Upper contact gradational, exposed underneath overlying unit which forms small shelter approximately 25 yards to northwest. Attitude measured on basal sandstone bed in creek, strike N55°W, dip 3°NE. Thickness measured with 3° in Abney level, approximately 13'

23 Shale with dolomite nodules: shale, quartz-silty; medium olive gray, weathers light olive gray. Thickly laminated, regularly laminated, except near nodules. Well-exposed on north side of creek in bank beneath Kessler Limestone. Upper contact gradational, regular. Thickness, direct measurement, maximum exposure 5'

22 Covered. Thickness estimated 60'

Note: Measured covered interval with 0° dip in Abney level to top of Kessler Limestone, poorly exposed in woods, at point east of unit 21 from top of unit 21. Offset southward for distance of approximately 50 yards, where Kessler bench drops 25 to 30 feet topographically. Followed top of Kessler into creek to southwest, where units 23 through 27 are exposed. The thickness of unit 22 was calculated by subtracting thicknesses of units 23 through 26 from interval measured before offset. -- To the northeast of the exposures in the creek, the Kessler again outcrops but is approximately 35 feet higher topographically, indicating that the outcrops in the creek of the upper Dye Shale and the Kessler Limestone are in a small graben.

21 Sandstone and limestone: sandstone; top 1 foot generally medium-grained, poorly sorted, calcareous quartzarenite with sparse skeletal fragments; dark brownish gray, weathers moderate grayish brown. Limestone; basal portion varies from coarse-grained, highly quartz-sandy, pelmatozoan calcarenite (grainstone) with lenses of skeletal quartzarenite, to medium-grained, quartz-sandy, pelmatozoan, mixed-skeletal calcarenite to fine-grained calcirudite; color highly variable, generally weathers moderate grayish brown. Thin-bedded, irregularly bedded; lower part cross-bedded; upper 0.5 to 1.0 foot generally more regularly bedded, slightly cross-bedded. Forms distinct ledge in woods; can be traced northward from wash where units 16 through 20 are measured for distance of approximately 50 yards; cannot be traced southward. Note: Same unit may crop out in tributary of Lee Creek to southeast below where units 23 through 26 are measured; however, it is only approximately 30 to 35 feet below base of Kessler Limestone (unit 25) and is interpreted to be on south side of graben. Maximum exposure located approximately 25 yards north of wash, direct measurement 4.0'

20 Covered. Shale with clay-ironstone concretions dug out of wash at 13 feet. Thickness measured with 0° dip in Abney level, estimated 35'

19 Limestone; coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone); moderate reddish brown, weathers moderate grayish brown. Thick-bedded. Unit poorly exposed except in washes, but

forms topographic bench on wooded hillside which can be followed for 50 yards in both directions. To north in second wash, unit slightly micritic. Upper contact covered. Thickness, approximately 3.5'

18 Limestone and siltstone: limestone; fine- to medium-grained, highly quartz-silty, pelmatozoan, mixed-skeletal calcarenite (grainstone) interbedded with calcareous quartzsiltites; limestones locally contain clay clasts; moderate brownish gray, weathers moderate yellowish brown. Thin-bedded, irregularly bedded. Forms rounded, poorly exposed bench in woods near wash; weathers by exfoliation. Thickness approximately 3.5'

17 Covered. Thickness, measured eastward up wash with 0° in Abney level, estimated 34'

16 Shale; dark olive gray, weathers light olive gray. Poorly exposed along top of bluff overlooking Lee Creek. Thickness approximately 3'

Note: Offset section 35 yards northward on top of unit 15 to small wash. Measured units 17 through 21 eastward up this small wash.

HALE FORMATION (partial)

15 Sandstone; fine- to medium-grained, calcite-cemented, submature, sparsely skeletal quartzarenite; becomes highly skeletal locally; moderate brownish gray, weathers same. Thin-bedded in lower part, becoming thickly laminated in upper portion, irregularly laminated; upper part locally medium-bedded. Forms distinct overhanging ledge at top of bluff; weathers pitted and honeycombed locally. Thickness, direct measurement, varies from 3.0 to 3.5 feet, averages 3.3'

14 Shale, clay shale; medium dark gray, weathers moderate brownish gray. Thinly laminated, regularly laminated; may become interbedded with thin sandstone northward. Deeply recessed between units 13 and 15; highly fissile, splitting into paper-thin pieces. Upper contact sharp, regular. Thickness, approximately 1'

Note: Section shifted northward on top of unit 13 approximately 25 yards to point where unit 15 overhangs cliff by 8 feet; units 14 and 15 are measured due east of rapids in Lee Creek, approximately 50 feet below.

13 Sandstone; fine-grained, calcite- and quartz-overgrowth-cemented quartzarenite; moderate brownish gray, weathers moderate olive gray. Thick-bedded, regularly bedded. Forms distinct overhanging ledge south of southern fault; weathers slabby locally. Upper contact obscure. Thickness, direct measurements, varies from 2.7 to 3.2 feet, averages 3.0'

12 Limestone and shale: limestone; fine- to medium-grained, bryozoan, pelmatozoan, brachiopodal, micritic calcarenite (packstone to wackestone); medium dark gray, weathers moderate yellowish gray. Thin-bedded, irregularly bedded, becoming nodular in upper part and interbedded with thin shale. Shale, calcareous; dark gray, weathers moderate yellowish gray. Forms recessed ledge beneath overhanging unit 11; shales recessed up to 4 feet with limestones protruding slightly. Upper contact gradational, regular. Thickness, measured immediately south of southern fault (3.0 feet) and north of fault (2.5 feet), averages 2.3'

11 Limestone; coarse-grained, slightly quartz-sandy, pelmatozoan calcarenite to fine-grained calcirudite (grainstone); medium gray, weathers moderate brownish gray. Thick- to medium-bedded, slightly cross-bedded, irregularly bedded. Forms vertical faces. Upper contact gradational, undulating. Contains sparse, large, branching *Michelinia* colonies. Thickness measured 5 feet south of southern fault, direct measurement 4.7'

10 Limestone; basal bed is fine- to medium-grained, micritic, oolitic, mixed-skeletal calcarenite (packstone); middle is fine-grained, oolitic calcarenite (grainstone), becoming locally skeletal calcarenite (grainstone and packstone); medium dark gray, weathers moderate brownish gray. Thin- to medium-bedded, irregularly bedded, nodular. Well exposed in middle to upper part of cliff south of southern fault. Upper contact sharp. Thickness, direct measurements, varies from 1.3 to 1.7 feet, averages 1.5'

Note: Offset section approximately 50 feet southward on base of unit 10 to point 5 feet south of southern fault.

9 Limestone with shale: limestone; fine-grained, partly recrystallized calcilutite (mudstone); medium dark gray, weathers light brownish gray. Thin-bedded, regularly bedded, nodular; interbedded with shale.

Shale, calcareous; dark gray, weathers moderate dark gray. Unit forms middle part of bluff immediately north of northern fault; fractures blocky. Upper contact gradational. Contains Chaetetes colonies. Thickness, direct measurement 5.0'

8 Sandstone; fine-grained, calcite-cemented, submature, skeletal quartzarenite; medium light gray, weathers light brownish gray. Medium-bedded, irregularly bedded. Forms basal part of upper cliff, overhanging lower unit by as much as 8 feet immediately north of northern fault. Upper contact gradational, undulating. Thickness, direct measurement, varies from 1.5 to 2.5 feet, averages 2.0'

7 Shale; medium gray, weathers medium light gray. Thickly laminated. Forms recess impressed as much as 8 feet beneath unit 8 immediately north of northern fault in lower part of cliff; highly fissile, splintery. Upper contact sharp, undulating. Thickness, direct measurement 3.0'

6 Limestone and shale: limestone; medium-grained, mixed-skeletal calcarenite (packstone); medium dark gray, weathers light yellowish gray. Medium-bedded; forms single bed 1 foot thick in upper part of unit; thin limestone in lower part interbedded with shale. Shale, calcareous; dark gray, weathers medium dark gray. Poorly exposed at base of break in bluffs. Upper contact obscure. Thickness 2.2'

5 Limestone; coarse-grained, pelmatozoan, quartz-sandy calcarenite (grainstone) at base, becoming fine-grained, micritic, pelmatozoan-bryozoan calcarenite (packstone) at top; medium dark gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded, cross-bedded. Forms base of cliff approximately 50 yards north of intersection of Lee Creek with tributary; weathers by exfoliation. Upper contact obscure. Thickness, direct measurement varies from 8.5 to 9.0 feet, averages 8.8'

4 Mudstone, quartz-sandy, slightly calcareous; light olive gray, weathers dusky yellow. Thickly laminated. Exposed as recessed area immediately north of small faults; weathers blocky. Thickness, direct measurement 2.0'

3 Sandstone; medium- to coarse-grained, calcite- and limonite-cemented, submature, skeletal quartzarenite; moderate orangish brown, weathers light orangish brown.

Thin- to medium-bedded, irregularly bedded; upper surfaces with scattered burrows and trails. Forms first bench below cliff north of small faults. Upper contact sharp, undulating. Thickness, direct measurements, varies from 0.7 to 1.0 feet, averages 1.9'

Note: Offset section northward 50 feet to point 10 feet north of northern fault using top of unit 2. Two small normal faults, separated by approximately 30 feet horizontally and each having about 2 feet of vertical displacement, can clearly be seen in the bluff.

2 Limestone; coarse-grained, bryozoan, glauconitic, micritic calcarenite (packstone to grainstone) at base, becoming coarse- to very coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone) with scattered quartz-sand at top; medium light gray, weathers medium gray. Thick-bedded, single bed, irregularly bedded. Weathers rounded, smooth. Upper contact sharp, undulating. Thickness approximately 3'

Note: Offset section 25 feet northward on top of unit 1.

1 Sandstone; fine- to medium-grained, calcite-cemented, mature, highly skeletal, glauconitic quartzarenite; medium light gray, weathers medium gray. Medium-bedded, irregularly bedded. Forms ledge above creek on east side below cliffs; weathers smoothly with top pitted. Upper contact sharp, undulating. Thickness measured in axis of small anticline on east side of Lee Creek immediately south of northern fault, direct measurement 2.4'

0 Limestone; highly recrystallized, burrowed, quartz-sandy calcilutite (recrystallized mudstone); medium gray, weathers same. Thin-bedded, irregularly bedded; upper surface knobby with burrows filled with more recrystallized material. Exposed on east side of creek 35 to 50 yards north of confluence of tributary with Lee Creek and at base of cliff; also exposed on west side of creek at point where creek and tributary meet in creek, in creek bed at axis of small anticline, and upstream on west side of Lee Creek approximately 100 yards. Upper contact sharp, undulating. Thickness measured on east side of creek south of southern fault, maximum exposure, approximately 2'

Section M108: Lee Creek, North

Location.--N½, NE¼, Sec. 25, T. 14N., R. 31 W., Washington County, Arkansas. To reach the farm of C. R. Courtney, follow the instructions given in the introduction to the sections on headwaters of Lee Creek (text-figure 22). The beginning of the section may be reached by walking northward down the steep ravine on which the cow pond is situated immediately below the road leading to the Courtney home and 0.1 mile east of the Courtney home. Walk down this ravine for 0.3 mile to the major, westward-flowing tributary of Lee Creek. The Kessler Limestone is located approximately 30 yards upstream (eastward) from the confluence of this wash with the large tributary. The lowest units in the section are located 0.3 mile downstream on the south side of the tributary at a bend. This point is approximately 0.3 mile upstream from the intersection of this tributary with Lee Creek and is located in the SE¼, NW¼, Sec. 25.

Units 1 through 7 are measured on the south bank of the tributary approximately 35 yards east of a large sycamore tree. The upper part of the Woolsey Member, including the Baldwin Coal, and the lower part of the Dye Shale Member are exposed here. Units 9 through 11 are measured approximately 0.1 mile upstream (eastward) on the north bank of the tributary (these include the middle to upper parts of the Dye Shale); and the remainder of the section occurs in the creek approximately 35 to 50 yards east of the confluence of the steep ravine, which was walked down to reach the section, and the tributary in the bed of the stream and eastward 0.1 mile from there to the base of the Atoka (Winslow) Formation on the south side of the creek in the SE¼, NE¼, NE¼, Sec. 25.

Stratigraphy.--The Lee Creek (North) section contains an exceptionally well exposed middle and upper Bloyd section, beginning with the upper part of the Woolsey Member and continuing through the lower part of the Trace Creek Member. The section terminates with the lowest exposures of the cliff-forming basal Atoka Formation. The following is the stratigraphic breakdown:

Bloyd Formation (partial section, 174 feet)
- Trace Creek Shale (units 26 and 27, 60 feet)
- Kessler Limestone Member (units 16 through 25, 28 feet)
- Dye Shale Member (units 3 through 15, 82 feet)
- Woolsey Member (partial section, units 1 & 2, 4 feet)

Remarks.--The section was described on January 2, 1972, by T. W. Henry; units 26 through 28 were measured and described on January 6, at which time bulk samples were collected from the Kessler for conodonts. The section was examined by P. K. Sutherland, Doy Zachry, Walt Manger, and T. W. Henry on March 5, 1973.

Unit No.	Description	Thickness
ATOKA FORMATION		
28	Sandstone; fine- to very fine-grained, clay-bonded, immature quartzarenite; moderate brownish gray, weathers moderate grayish brown. Thin-bedded, regularly bedded, unevenly bedded; interbedded with thin lamellae of grayish black, quartz-silty shale; upper surfaces prominently current ripple marked, lower surfaces with *Conostichus* and other burrow casts. Forms cliff on hillside south of creek and on north hillside. Thickness not measured but estimated to be 20 to 30 feet thick.	
	Note: Lower Atoka sandstones are involved in gentle	

anticline on north side of creek, with east and west limbs dipping 1 to 2 degrees.

MORROW GROUP

BLOYD FORMATION (partial)

27	Covered. Thickness, estimated	50'
26	Shale; clay shale; dark grayish black, weathers moderate grayish brown. Thinly laminated. Poorly exposed above Kessler on creek banks. Thickness taken to highest shale talus, approximately	10'
	Note: Offset section approximately 50 yards upstream to east on top of unit 25 to point approximately 25 yards east of waterfall over unit 25 and at small bend in creek. Measured units 26 and 27 on south side of creek up to base of Atoka (Winslow) cliffs on valley wall, using 0^{o} in Abney level.	
25	Limestone; medium- to coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone); upper part highly quartz-sandy. Moderate reddish brown, weathers moderate brownish gray. Lower part medium-bedded; upper part thick-bedded, cross-laminated with steep foresets, irregularly bedded. Lower part generally poorly exposed, but upper part well exposed on north side of creek; forms upper rapids and waterfall in creek; exposed at top of bench on south side of creek. Thickness, direct measurement, measured on north side of creek	8.5'
24	Sandstone with basal conglomerate: sandstone; fine-grained, calcite-cemented, submature quartzarenite with pebbles locally at base; grades upward into quartz-sandy shale in upper 0.5 foot; medium gray, weathers moderate brownish gray. Thick-bedded, forms slight ledge on north side of creek. Upper contact obscure. Thickness approximately	1.5'
	Note: Offset 10 to 25 feet eastward on base of unit 24.	
23	Shale and limestone: shale, quartz-silty; dark olive gray, weathers medium gray. Thickly laminated, regularly laminated. Contains lens of medium-grained, oolitic calcarenite (grainstone) near top up to 1.7 feet thick. Thin-bedded, cross-laminated, irregularly bedded. Generally recessed beneath unit 24 in upper	

part; exposed best and measured on north side of creek; upper part exposed on south side of creek above and west of lower rapids. Thickness, approximately 4.5'

22 Limestone; fine-grained, slightly quartz-sandy, pelmatozoan mixed-skeletal calcarenite to fine-grained calcirudite (grainstone); moderate reddish brown, weathers moderate brownish gray. Medium-bedded, regularly bedded, single bed. Generally forms slumped blocks on north side of creek downstream from lower rapids; locally in place. Thickness, direct measurement 1.4'

21 Shale and limestone: shale, calcareous, fossiliferous; medium gray, weathers light brownish gray. Thickly laminated; interbedded with highly argillaceous limestone. Limestone, fine- to medium-grained, argillaceous, skeletal calcarenite (packstone); color same as shale. Thin- to very thin-bedded, irregularly bedded, nodular. Unit best seen on north side of creek approximately 15 yards west of base of lower rapids where it is deeply recessed beneath overlying unit; poorly exposed elsewhere because of slumping of unit 22. Upper contact sharp, even. Thickness, direct measurement 1.6'

20 Limestone; medium- to very coarse-grained, micritic, gastropodal, brachiopodal, bryozoan calcarenite (packstone) to fine-grained, mixed-skeletal (gastropodal) calcilutite (wackestone); medium light gray, weathers moderate brownish gray. Medium- to thin-bedded, irregularly bedded. Well exposed in basal part of overhanging cliff on north side of creek; exposed as upper part of lower rapids in creek; poorly exposed on south side of creek; unit weathers smoothly in creek. Thickness measured on north side of creek, direct measurement 5'

19 Limestone conglomerate; matrix of medium- to coarse-grained, quartz-sandy, skeletal calcarenite with small, rounded pebbles of several kinds of limestone, some of which are Osagia-coated; sparse pebbles of phosphate and claystone clasts; moderate reddish brown, weathers moderate brownish gray. Thin- to medium-bedded, regularly bedded, with local shale partings at top. Unit well exposed in creek where it is recessed beneath unit 20 and also on north side of creek where measured. Thickness, direct measurements, varies from 1.0 to 1.5 feet, averages 1.2'

18 Shale and sandstone: shale, quartz-silty; medium dark gray, weathers moderate brownish gray. Thickly laminated, regularly laminated; interbedded with sandstone. Sandstone; fine-grained, clay-bonded and calcite-cemented, immature quartzarenite; medium dark gray, weathers moderate grayish brown. Very thin-bedded, irregularly bedded. Platy. Unit recessed beneath overlying unit; exposed on north creek bank, recessed beneath overlying units. Upper contact sharp, undulating; unit truncated southeastward in creek by unit 19. Thickness, direct measurements, varies from 0.0 to 1.0 feet, averages 0.5'

17 Sandstone; medium- to coarse-grained, calcite-cemented, submature, coated-grain, glauconitic quartzarenite; medium gray, weathers moderate reddish brown to moderate brownish gray. Thin-bedded, regularly bedded, distinctly cross-laminated. Unit forms top of exposure before offset in tributary on south side of creek; makes distinctive bed in lower part of sluiceway after offset; well exposed on both banks of creek. Upper contact gradational. Thickness, direct measurement, measured on north side of creek 1.0'

16 Sandstone; fine-grained, calcite-cemented, submature quartzarenite; medium dark gray, weathers medium gray. Very thin-bedded, irregularly bedded, cross-laminated. Well exposed both in tributary on south side of creek where it overhangs unit 15 and in main creek 35 yards to east where it forms lowest part of lower rapids. Thickness measured on north side of creek, direct measurement 3.0'

Note: Offset section 35 yards eastward on top of unit 15 to waterfall in main creek.

15 Shale; quartz-silty; contains sparse flattened dolomite nodules; dark olive gray, weathers moderate grayish brown. Thickly laminated, regularly laminated. Well exposed on south side of creek up small ravine; upper part recessed beneath unit 16 as much as 3 feet at waterfall in small tributary. Thickness, Abney level 12'

14 Limestone and shale: limestone; at base, fine- to very coarse-grained, pelmatozoan, bryozoan, intraclast-bearing, Osagia oncolith-bearing calcarenite (grainstone) with scattered shale clasts; middle, coarse-grained, pelmatozoan calcarenite (grainstone); top: medium- to coarse-grained, bryozoan, pelmatozoan, mixed-skeletal, micritic, calcarenite (packstone),

with scattered small gastropods; medium dark gray, weathers brownish gray. Thin-bedded, irregularly bedded, cross-bedded, interbedded with shale. Shale, noncalcareous; dark olive gray, weathers light olive gray. Lower beds of unit make small waterfall in small tributary approximately 5 yards south of main creek; shales recessed; upper part also makes small ledge. Upper contact sharp, undulating. Thickness, Abney level and direct measurements, 4.2'

13 Shale, quartz-silty; contains flattened dolomite and clay-ironstone concretions; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Well exposed on south side of creek where small tributary intersects. Upper contact sharp, undulating. Thickness, direct measurement, maximum exposure 1.5'

Note: Section offset eastward (upstream) approximately 50 to 75 yards to point where small wash enters creek from south; units 13 through 15 measured on south side of main creek in wash.

12 Covered. Measured interval from top of unit 10 to top of Kessler Limestone Member (unit 25), which crops out 50 yards northeast of outcrops of units 9 through 11, by dip and strike offset method, using 3°W dip in Abney level. Thickness of unit 12 calculated by subtracting thicknesses of units 13 through 25 from this interval. Thickness, estimated 5'

11 Shale with siltstone at base: shale, quartz-silty; contains discontinuous zone of thin dolomite nodules; dark olive gray, weathers medium gray. Thickly laminated, regularly laminated. Exposed at top of cut in creek bank on north side of creek. Thickness, approximately 10'

Note: Offset section 5 yards westward on top of unit 10; measured unit 11 directly up slope to highest shale talus, with presumed strike.

10 Sandstone, shale, with dolomite nodules: sandstone; fine- to very fine-grained, clay-bonded, immature quartzarenite; medium dark gray, weathers moderate grayish brown. Thin-bedded, regularly bedded; some of beds have cross-laminations with carbonaceous lamellae. Shale, quartz-silty; dark olive gray, weathers moderate brownish gray. Thickly laminated, regularly laminated. Dolomite nodules, sparsely skeletal, quartz-silty; dark gray, weather moderate

reddish brown to moderate yellowish brown. Found sparsely throughout unit, but none of closely spaced nodules 0.8 feet thick present 4 feet below top. Unit well exposed on north side of creek in lower to middle part of deep cut; sandstone protrudes from shale. Upper contact of unit gradational, even. Thickness, direct measurement, approximately 10'

Note: Offset section 10 yards northward on top of unit 9.

9 Shale with siltstone: shale, quartz-silty; dark olive gray, weathers moderate grayish brown. Thickly laminated, regularly laminated; interbedded with siltstone at top of unit. Siltstone; coarse-grained, clay-bonded, immature quartzsiltite; dark olive gray, weathers moderate grayish brown. Very thin-bedded, irregularly bedded, lensing. Unit exposed on north side of creek in steep shale cuts. Upper contact of unit gradational, placed at base of first well-developed sandstone. Attitude measured on bed near top; strike N13°E, dip 3°W. Thickness, direct measurement, maximum exposure 6'

Note: Units 9 through 11 are located on north side of creek in steep cut in shale at point approximately 150 to 175 yards east (upstream) from outcrop of Baldwin Coal.

8 Covered. Measured up south valley side to top of Kessler Limestone (unit 25), going with strike as measured on unit 4. Thickness of unit 8 calculated by subtracting thicknesses of units 9 through 25 from interval measured. Thickness, estimated 12'

7 Shale, slightly quartz-silty; dark olive gray, weathers light olive gray. Thinly laminated, regularly laminated. Poorly exposed beneath oak tree. Thickness approximately 5'

Note: Offset section to point 10 feet south of large oak tree above unit 6, on top of unit 6.

6 Limestone; ?recrystallized, quartz-sandy, mixed-skeletal, conglomeratic calcilutite? (recrystallized ?wackestone); with small, round bryozoan colonies; scattered pebbles of rounded phosphate? and calcilutite; grayish black, weathers moderate grayish brown. Thin-bedded, irregularly bedded, single bed. Unit forms poorly exposed small ledge on south side of creek near top of shale cut; best exposed beneath

large oak tree which leans out over creek bank. Thickness, direct measurements, varies from 0.3 to 0.8 feet, averages 0.5'

5 Shale with scattered zones of dolomite nodules; shale, quartz-silty at base, becoming less quartz-silty higher; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Thin, platy dolomite nodules near base with smaller, more scattered zones higher. Unit well exposed as steep shale cut. Measured up steep shale slope with approximate strike. Thickness, approximately 15'

Note: Offset section 10 yards westward on top of unit 4 to point below overhanging oak on bluff on south side of creek.

4 Sandstone; fine-grained, clay-bonded, immature conglomeratic quartzarenite with rounded, scattered pebbles of ?calcilutite, phosphate, and quartzsiltite; dark gray, weathers dark grayish brown. Thin-bedded, irregularly bedded, lensing, single bed. Forms small ledge above sluiceway on south side of creek. Upper contact gradational. Attitude measured on top of bed, approximately N17^{o}E, dip 3^{o}W. Thickness, varies at expense of underlying unit, direct measurements vary from 0.3 to 0.9 feet, averages 0.5'

3 Shale, quartz-silty; contains scattered plant impressions; medium gray, weathers moderate grayish brown to moderate brownish orange. Thinly laminated, irregularly laminated. Upper contact sharp, undulating. Exposed on south bank of creek at sluiceway, locally recessed beneath unit 4 up to 0.4 foot. Thickness varies from 0.0 to 0.5 foot, averages 0.3'

2 Coal; grayish black. Thin-bedded, regularly bedded. Well exposed on south side of creek at sluiceway and for 20 yards downstream; weathers blocky. Upper contact gradational where unit 3 rests upon it, sharp where unit 4 rests upon it. Note: There is no underclay. Thickness, direct measurement 0.4'

1 Silstone; fine-grained, clay-bonded, immature quartzsiltite; weathers moderate brownish gray with patches of moderate brownish orange. Thickly laminated, irregularly laminated. Unit exposed as sluiceway in creek and on south bank of creek. Upper contact gradational, even. Contains numerous plant impressions on bedding surfaces. Thickness, maximum exposure 3.5'

Section M109: Skelton's Quarry

Location.—E½, SE¼, SW¼, Sec. 9, T. 14N., R. 30W., Washington County, Arkansas. The section begins on the northwestern working face of the quarry (text-figure 22) approximately 2 feet above water level (as of December, 1971) near the east end of the quarry located in the E½, SE¼, SW¼, Sec. 9 on the property of Mr. M. A. Skelton and Mr. J. W. Skelton.

The quarry may be reached from the home of J. W. and M. A. Skelton, which is located on the northeastern side of U. S. Highway 71 0.1 mile northwest of the bridge over Mill Creek. The quarry, which can be seen from the house, is located 0.2 mile northeast of the Skelton home and can be reached on a road leading behind the barn.

Stratigraphy.—A partial section of 64 feet of Morrowan rocks is measured at this locality. The section begins in the upper part of the Prairie Grove Member (units 1 through 5), and an exposed thickness of 34 feet is recorded for this member. The upper part of the member contains large numbers of well preserved *Echinaria* n. sp. A.

Approximately 20 feet of shale (unit 6) of the basal part of the Brentwood Limestone Member overlies the Prairie Grove and is also well exposed by the quarrying operations. The section is covered above this shale. The Hale-Bloyd contact is sharp but not truncating.

Remarks.—The section was described by T. W. Henry on December 4, 1971. The strata at the quarry were previously measured by Manger (1971, p. 160, 161). The section was visited and photographed on March 4, 1973, by P. K. Sutherland and T. W. Henry.

Unit No.	Description	Thickness
MORROW GROUP		
BLOYD FORMATION (partial)		
6	Shale, quartz-silty; medium dark gray, weathers light olive gray. Thickly laminated, regularly laminated. Base well exposed on northwest working face of quarry, becoming progressively more poorly exposed higher. Thickness measured to highest shale talus, estimated	20'
HALE FORMATION (partial)		
5	Limestone; fine- to coarse-grained, slightly quartz-sandy, pelmatozoan-bryozoan, mixed-skeletal calcarenite (grainstone), with areas of scattered ooids and minor areas of micrite (wackestone); medium dark gray, weathers moderate orangish brown. Thin- to medium-bedded, irregularly bedded, lensing. Unit is well-exposed on limestone surface immediately east and southeast of quarry, and is generally present all of way around quarry. Upper surface hummocky, undulating, gradational. Contains isolated, large branching colonies of _Michelinia_. Thickness, direct measurement varies from 0.0 to 1.7 feet, averages	0.8'
4	Limestone; fine-grained, recrystallized calcilutite (mudstone), with scattered large whole productid brachiopods; dark gray, weathers medium dark gray. Thin-bedded, irregularly bedded, interbedded with thin dark gray shale; contains distinctive burrow casts. Exposed halfway up working face on east side of quarry. Upper contact sharp where unit 5 is in contact with it, gradational where unit 6 is overlying. Thickness, direct measurement, approximately	12'
3	Sandstone and limestone: sandstone; at base, fine- to medium-grained, calcite-cemented, mature, glauconitic quartzarenite; grading upward into fine- to very coarse-grained, highly quartz-sandy, pelmatozoan mixed-skeletal calcarenite (grainstone); several beds contain scattered ooids. Medium- to thick-bedded, regularly bedded, cross-bedded. Unit exposed as lower part of working face along northwestern part	

of quarry. Upper contact sharp, undulating. Thickness, direct measurement, approximately 12'

Note: Section offset eastward on top of unit 2 for approximately 25 feet to shale talus pile. Basal 5 feet of unit 3 measured at talus pile; section offset eastward 25 yards on prominent bedding plane, and upper portion of unit 3 measured after offset.

2 Limestone, sandstone, and shale: basal portion generally consists of channels of fine-grained, calcite-cemented quartzarenite; moderate greenish gray, weathers same; and shale, quartz-silty and -sandy; medium dark gray, weathers same. Limestone; medium- to very coarse-grained, recrystallized, pelmatozoan calcarenite (grainstone), with moderate quartz-sand, grading upward into recrystallized, ?micritic, mixed-skeletal calcarenite (recrystallized ?packstone), with shale partings. Thin- to medium-bedded, irregularly bedded; channeloid in basal portion, becoming regularly and unevenly bedded in upper part. Upper contact sharp, even. Thickness, direct measurements, varies at expense of underlying unit from 3.2 to 5.0 feet, averages 4.1'

1 Limestone; medium- to coarse-grained, recrystallized, bryozoan, pelmatozoan calcarenite (grainstone); medium light gray, weathers light brownish gray. Medium-bedded,iirregularly bedded. Forms lowest part of working face on northwestern side of quarry, approximately 50 yards west of east end. Upper contact sharp, truncating with up to 2.5 feet of relief upon it. Thickness, direct measurements, varies from 4.2 to 6.7 feet, averages 5.5'

Section M110: Kessler Mountain, East

Location.--SW¼, NW¼, Sec. 31, T. 16N., R. 30W., and SE¼, NE¼, Sec. 36, T. 16N., R. 31W., Washington County, Arkansas. The section is exposed in the walls and bed of a southeast-flowing tributary of Cato Springs Branch on the eastern side of Kessler Mountain, approximately 4 miles southwest of downtown Fayetteville. The section begins with the lowest exposures of the Cane Hill Member in the NE¼, SW¼, NW¼, Sec. 31 at a point approximately 10 feet above the junction of the main tributary with a smaller tributary joining from the south. The section is measured westward up the main tributary; the top of the Hale Formation is located in the wash in the NW¼, SW¼, NW¼, Sec. 31, and the Bloyd section is measured westward up the same wash to the top of the "caprock" in the NE¼, SE¼, NE¼, Sec. 36.

To reach the section, drive southwestward on Arkansas State Highway 265 (Cato Springs Road) a distance of 1.5 miles from its intersection with U. S. Highway 71 (bypass) in southwestern Fayetteville. Turn westward on the gravel road, drive 0.7 mile, and park. The beginning of the section is located approximately 2000 feet north of the gravel road.

Stratigraphy.--The section begins in the middle part of the Cane Hill Member and continues into the basal part of the Dye Shale Member. The upper part of the Cane Hill and entire Prairie Grove Member are well exposed, but the Brentwood Limestone is quite poorly exposed, except for the basal portion. The Woolsey Member is also poorly exposed. The section terminates in the "caprock", which is quite well exposed and forms a prominent bench in the wash. The following is the stratigraphic breakdown:

- Morrow Group (partial section, 99 feet)
  - Bloyd Formation (partial section, 33 feet)
    - Brentwood Limestone (partial section, units 19 through 23, 33 feet)
  - Hale Formation (almost complete, 66 feet)
    - Prairie Grove Member (units 2 through 18, 18, 47 feet)
    - Cane Hill Member (almost complete, unit 1, 19 feet)

Remarks.--This section was measured by W. L. Manger (1971, p. 167-170), who kindly gave the author permission to use this section.

The section was visited by W. L. Manger, Doy Zachry, P. K. Sutherland and T. W. Henry on March 4, 1973.

Introduction to West Fork Sections, M111 and M112

Location.--Two closely spaced sections, M111 and M112, are located on the southwestern side of Bloyd Mountain, approximately 1 mile southeast of the central part of the community of West Fork in the W½, Sec. 4, T. 14N., R. 30W., Washington County, Arkansas (text-figure 22).

History of Previous Investigations.--Simonds (1891, p. 76, 77) was the first to mention the excellent exposures of the lower part of the Morrowan sequence in this general vicinity. He also noted the presence of the Baldwin Coal in Robinson's Coal Bank (*ibid*., p. 99).

The Bloyd Formation was first defined and named as a subdivision of the Morrow Group by Purdue (1907) from its development in the vicinity of Bloyd Mountain along the West Fork of the White River near the village of West Fork, and Henbest (1953, p. 1951; 1962) discussed the details of the type Bloyd sequence on the western side of Bloyd Mountain. This is the general location for his localities 12 through 15 of the former paper.

Section M111: West Fork -- Abandoned Pitkin Quarry

Location.--NE¼, NW¼, SW¼, Sec. 4, T. 14N., R. 30W., Washington County, Arkansas. The section begins at the top of the Pitkin Formation at the type locality for that formation in an abandoned quarry on the southwestern side of Bloyd Mountain, 1.1 miles south of the junction of U. S. Highway 71 and Arkansas State Highway 170 at West Fork. The quarry is located 0.1 mile east of Highway 71 on the steep bluffs overlooking the West Fork of the White Rive (text-figure 22). The section begins near the south end of the working face of the quarry and is measured due eastward, up the small wash that enters the quarry at this point, to the top of the Prairie Grove bluffs.

Stratigraphy.--The unconformity separating the Pitkin from the overlying Cane Hill Member is superbly exposed near the top of the working face of the quarry. The basal limestone pebble- and cobble-conglomerate (unit 2) can be clearly seen. The Cane Hill is unconformably overlain by the Prairie Grove Member, which also contains a basal conglomerate (unit 5). Only the lower half of the Prairie Grove is well exposed and forms bluffs above the quarry. The stratigraphic breakdown is as follows:

Hale Formation (partial section, 93 feet)
  Prairie Grove Member (partial, units 5 through 15, 36 feet)
  Cane Hill Member (units 2 through 4, 57 feet)

Remarks.--Henbest (1953, p. 1951) also noted the excellent exposures of the Pitkin-Hale contact at this locality.

This section was described by T. W. Henry on December 14, 1971.

Unit No.	Description	Thickness
	MORROW GROUP	
	HALE FORMATION (partial)	
15	Limestone; coarse-grained, micritic, pelmatozoan calcarenite (packstone) at base, becoming fine-grained, mixed-skeletal, micritic calcarenite (packstone) at top; medium gray, weathers medium light gray. Medium-bedded, regularly bedded. Forms distinct bench in woods. Covered above. Thickness, direct measurement	1.5'
14	Limestone; medium- to coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone) with local bryozoan fragments; light orangish gray, weathers moderate brownish gray. Medium-bedded, regularly bedded. Forms middle part of highest bench on hillside, slightly recessed beneath overlying unit. Upper contact gradational but placed at bedding plane. Thickness, direct measurement	1.4'
13	Limestone; fine- to coarse-grained, burrowed, mixed-skeletal calcilutite (wackestone); medium gray, weathers moderate orangish gray. Thin-bedded, irregularly bedded. Well-exposed 25 feet northwest of small tributary, recessed 3 to 4 feet beneath slump block of unit 15; weathers rubbly. Upper contact sharp, undulating. Thickness, direct measurement	4.0'
12	Covered. Thickness	1.0'
11	Sandstone; fine- to medium-grained, calcareous?, limonitic quartzarenite; dusky yellow, weathers moderate grayish brown. Thin-bedded, highly contorted bedding. Poorly exposed along base of bench. Thickness varies at expense of underlying unit from 1.5 to 2.5 feet, direct measurement, averages	2.0'
10	Limestone; fine- to coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone); medium gray, weathers moderate brownish gray. Medium-bedded, single bed. Poorly exposed at base of bench 25 yards north of intersection of creek tributaries. Upper	

contact sharp, undulating. Maximum exposure, direct measurement 1.6'

9 Covered. Measured updip with 1° in Abney level, approximately 6'

8 Limestone; at base, coarse-grained, micritic, bryozoan, brachiopodal calcarenite (packstone), grading upward into medium-grained, recrystallized micritic, mixed-skeletal calcarenite (packstone) with scattered quartz-sand; medium gray, weathers medium dark gray. Forms mostly slumped bench at top of small cliff, but in place to east where tributaries intersect. Upper contact covered. Thickness measured with 1.5° in Abney level, maximum exposure 5.5'

Note: Offset section 10 yards eastward on top of unit 7 to point where creek tributaries intersect bench.

7 Sandstone; medium-grained, calcite-cemented, submature, glauconite-bearing, limonitic quartzarenite with skeletal material in top and at base; dusky yellow to moderate grayish brown, weathers moderate brownish gray. Thick-bedded, irregularly bedded, cross-bedded. Forms top of small bluff 10 yards north of creek. Upper contact obscure. Thickness, direct measurement, maximum exposure 9.2'

6 Limestone; medium- to very coarse-grained, quartz-sandy, glauconite-bearing, brachiopodal, mixed-skeletal calcarenite (grainstone); medium gray weathers moderate brownish gray. Thin-bedded, irregularly bedded. Recessed slightly beneath overlying unit at site of large fallen tree; weathers rubbly. Upper contact sharp, undulating. Contains Michelinia. Thickness, direct measurements, varies from 0.0 to 1.0 feet, averages 0.5'

5 Sandstone to limestone and conglomerate: sandstone; medium-grained, calcite-cemented, submature, ooid-bearing, skeletal quartzarenite to highly quartz-sandy, skeletal calcarenite; contains lenses of scattered, rounded pebbles of siltstone, sandstone, and phosphate; moderate grayish brown, weathers moderate brownish gray. Thick-bedded, single bed. Exposed as basal part of bluff 15 yards north of and above small creek leading to south end of quarry; weathers by exfoliation. Upper contact sharp. Thickness, maximum expsoure, approximately 3.5'

Note: Measured interval from top of unit 2 up creek with strike to 40 feet; then measured northward up dip using 1.5° in Abney level to large fallen tree at lowest exposure of Prairie Grove Member. Total interval measured is 55 feet. To check, went to center of east face of quarry and measured 57 foot-interval from top of unit 2 to base of unit 5.

4 Covered, siltstone, and shale: abundant siltstone talus on hillside above quarry north of creek; silty shales and burrows near base of large fallen tree within 3 feet of base of unit 5. Thickness estimated 35'

3 Siltstone; fine-grained, clay-bonded, immature quartzarenite; medium gray, weathers moderate grayish brown. Thickly laminated to very thin-bedded, regularly bedded; upper surfaces with current ripple marks; lower surfaces with poorly developed flute casts. Basal 15 feet exposed in creek to east; steep bluff near south end of quarry is formed by unit north of small stream. Thickness measured with strike up creek and bluff, maximum exposure, approximately 20'

2 Limestone, limestone conglomerate, and siltstone: limestone; medium- to coarse-grained, hematitie, pelmatozoan calcarenite (grainstone); moderate reddish brown, weathers same. Conglomerate, rounded pebbles and cobbles of oolitic calcarenite and calcilutite, set in matrix like described above; also contains clay-ironstone concretions. Thin-bedded, lensing; with conglomerate at base and limestone at top. Siltstone; fine- to coarse-grained, clay-bonded, immature quartzsiltite; medium gray, weathers moderate yellowish brown. Thickly laminated, irregularly laminated. Generally occurs between conglomerate and limestone. Unit well-exposed above limestone working face of quarry and 20 feet east of waterfall at south end of quarry. Thickness, direct measurements, varies from 1.5 to 2.5 feet, averages 2.0'

PITKIN FORMATION (partial)

1 Limestone and shale: limestone; medium- to coarse-grained, pelmatozoan, recrystallized calcarenite (grainstone); medium light gray, weathers moderate yellowish brown to moderate brownish gray. Thin-

bedded, irregularly bedded, lensing; interbedded with shale. Shale; clay shale; light greenish gray, weathers moderate brownish orange. Lamination obscure. Unit exposed approximately 20 feet east (upstream) from waterfall near south end of quarry and to north along top of quarry face. Upper contact sharp, undulating, unconformable, and locally welded, with upper surface containing numerous borings. Contains Archimedes. Thickness, direct measurements, varies from 2.5 to 1.0 feet, averages 1.8'

0 Limestone; fine- to coarse-grained, oolitic, pelmatozoan calcarenite (grainstone); light gray, weathers medium light gray. Thin- to medium-bedded, irregularly bedded. Forms upper part of working face of quarry at south end. Contains sparse Archimedes. Strike N80°E, dip 1.5°S. Thickness not measured.

Section M112: West Fork — Robinson's Coal Bank

Location.—S½, NW¼, Sec. 4, T. 14N., R. 30W., Washington County, Arkansas. The measured section is located on the southwestern side of Bloyd Mountain approximately 150 to 200 yards north of measured section M111 in the next stream to the north (text-figure 22). The section is measured from the top of the prominent bluff formed by the Pitkin Formation in the C, SW¼, NW¼, Sec. 4 eastward up the mountainside to the top of the abandoned coal dumps in the NW¼, SE¼, NW¼, Sec. 4.

Stratigraphy.—The Hale Formation crops out on the bluff side overlooking the West Fork of the White River. The basal conglomerate of the Cane Hill Member and the shales and interbedded sandstones of this member are well exposed in the wash above the waterfall formed by the Pitkin Limestone. The Cane Hill is separated from the overlying Prairie Grove Member, a distinctive bluff-forming sequence in this area, by a thin pebble conglomerate.

Henbest (1962a, p. 40) designated as the type section for the Bloyd Formation the exposures on "the southwest part of Bloyd Mountain extending from the center of the E½ sec. 3, to the center, north side of sec. 4, T. 14 N., R. 30 W.". The same area was also designated the reference section for the Woolsey Member.

Unfortunately, these are not the best exposures of the Bloyd Formation in the vicinity of West Fork but are the best exposures on Bloyd Mountain. In measured section M112, most of the Bloyd is poorly exposed. The Brentwood is about 50 percent covered, but the overlying Woolsey is excellently exposed in the old coal dumps. This member is 27 feet thick here and contains the Baldwin Coal (unit 26B), once extensively mined here, plus a thin, second coal poorly developed 10 feet higher in the section. The Woolsey is succeeded by a poorly developed "caprock" (unit 29). The remainder of the Dye Shale Member is poorly exposed on the heavily wooded hillside above the coal bank, and only scattered slump blocks of Kessler Limestone can be seen. The Trace Creek Member does not crop out, but the lower part of the Atoka Formation forms persistant bluffs along the mountainside.

The current section terminates in the lower part of the Dye Shale Member; the following is the stratigraphic breakdown:

- Morrow Group (partial section, 206 feet)
  - Bloyd Formation (partial section, 85 feet)
    - Dye Shale Member (basal part, 0.5 foot)
    - Woolsey Member (units 26 through 28, 27 feet)
    - Brentwood Limestone (units 18 through 25, 57 feet)
  - Hale Formation (complete, 121 feet)
    - Prairie Grove Member (units 6 through 17, 65 feet)
    - Cane Hill Member (units 3 through 5, 56 feet)

Simonds (1891, p. 137, Section IX) records 105 feet for the interval between the Baldwin Coal and the Kessler Limestone; hence, the Dye Shale would be about 90 feet thick in this immediate area. For the same stratigraphic section, he notes that the Kessler is only 4 feet thick. The thickness of the overlying Trace Creek Shale cannot be ascertained from Simonds' data, because he included this interval with the overlying "Millstone grit".

Interestingly, Simonds (ibid., p. 99) made the following statement about what is now referred to as the Woolsey Member: "The coal is 11 inches thick, and lies 20 feet above the Pentremital limestone. Above and below the coal bed is gray shale, in which, 10 feet above the main bed, there is a thin carbonaceous layer underlain by fire-clay." Henbest (1953, p. 1951) also noted this relationship of the two coals in his discussion of the type section for the Woolsey Member.

Remarks.--The section was described on December 16, 1971, and January 1, 1972. The section was examined by P. K. Sutherland and T. W. Henry on March 6, 1973.

Unit No.	Description	Thickness
	MORROW GROUP	
	BLOYD FORMATION (partial)	
29	Sandstone; fine- to medium-grained, limonitic, clay-bonded, immature quartzarenite, with scattered pebbles of siltstone; weathers moderate yellowish brown. Thin-bedded, irregularly bedded, cross-bedded, single bed. Exposed above diggings. Thickness, direct measurement, varies from 0.3 to 0.6 feet, averages	0.5'

28 Siltstone; fine-grained, limonitic, clay-bonded, immature quartzsiltite; light olive gray, weathers moderate orangish brown. Thin- to very thin-bedded, irregularly bedded. Exposed as vertical face in cut above coal. Thickness, direct measurement 1.4'

27 Coal and underclay: coal; grayish black. Thin-bedded, 0.3 foot thick, regularly bedded. Underclay, poorly developed; contains clay-ironstone concretions. Exposed near top of diggings. Upper contact gradational. Thickness, direct measurement 1.0'

26C Shale, highly quartz-silty; weathers light olive gray. Exposed on steep working face of dump above Baldwin coal. Upper contact gradational. Thickness, approximately 10'

26B Coal and underclay: coal, very dark gray. Blocky. Coal is 1.1 feet thick, underlain by 0.2 to 0.3 foot of underclay. Unit exposed by digging. Thickness, direct measurement 1.4'

26A Covered and siltstone: siltstone; fine- to coarse-grained, clay-bonded, immature quartzsiltite; light olive gray, weathers moderate yellowish brown. Basal few feet exposed in creek #2; abundant talus on hillside. Contains plant fragments and clay-ironstone concretions. Thickness estimated 16'

Note: Units 26 through 30 are measured up northern most branch (creek #1) of creek, which flows S20°W.

25 Limestone; medium- to very coarse-grained, pelmatozoan, coated-grain, quartz-sandy calcarenite (grainstone); medium gray, weathers light brownish gray. Thick-bedded. Forms sluiceway in creek branches #1 and #2 (northernmost branch and next-to-northernmost branch), but better-exposed in branch #1 where measured; does not outcrop between creek branches. Thickness, approximately 9'

Note: Measured 17 foot-interval from top of unit 23 to top of unit 25 in next-to-northernmost (branch #2) creek branch. Offset on top of unit 25 into creek branch to north (branch #1) where measured thickness of unit 25. Subtracted thickness of unit 25 from interval to obtain thickness of unit 24.

24 Covered and limestone: limestone; slump blocks above unit 23 in creek #2, coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone). Thickness approximately 8'

23 Limestone and sandstone: fine- to medium-grained, calcite-cemented, submature, skeletal, glauconite-bearing quartzarenite, interbedded with fine- to medium-grained, highly quartz-sandy, pelmatozoan, glauconite-bearing calcarenite (grainstone); moderate yellowish brown, weathers moderate brownish gray. Thin- to very thin-bedded; lower part irregularly bedded, cross-bedded; upper part more regularly bedded. Unit weathers with distinct pitted appearance in upper 3 feet; forms vertical cliff in creek immediately north of branch #2; slumped elsewhere along hillside. Thickness, direct measurement 5.0'

22 Shale, quartz-silty; olive gray, weathers light orangish brown. Thickly laminated, irregularly laminated. Exposed as recess under overlying ledge in branch #2. Upper contact sharp, undulating. Thickness, maximum exposure, direct measurement 1.0'

Note: In branch #1, ledges crop out 8 feet above top of unit 20, but they are badly slumped. Offset section on top of unit 17 into creek branch #2 and measured 34 foot-interval at base of unit 22. Calculated thickness for unit 21 by subtracting thicknesses of units 18 through 20 from interval.

21 Covered. Thickness estimated 2'

20 Limestone and covered: limestone; fine-grained, mixed-skeletal calcilutite (wackestone), with scattered brachiopods, algal blades and goniatites; locally lamellar stromatolites (boundstone) occur in basal part; medium light gray, weathers light orangish gray. Medium- to thin-bedded. Basal bed is in place only in creek branch #1; remainder of unit slumped. Thickness estimated to highest limestone talus, approximately 8'

19 Covered. Thickness, approximately 20.5'

Note: Offset section northward on top of unit 17 into creek branch #1; measured interval to base of unit 20 and subtracted thickness of unit 18 from interval to get thickness of unit 19.

18 Shale, slightly quartz-silty; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Exposed in creek branch #2 approximately 10 feet west (downstream) from small rock dam. Thickness, approximately 3.5'

HALE FORMATION

Note: Offset approximately 35 yards eastward into creek branch #2 on top of unit 17.

17 Limestone; basal bed is fine-grained, mixed-skeletal calcilutite (wackestone); remainder of unit fine-grained calcilutite (mudstone); medium dark gray, weathers light brownish gray. Top and basal bed medium-bedded, remainder thin-bedded, irregularly bedded; probably interbedded with thin shale. Top bed forms distinct bench on north side of creek; unit well exposed on north side of creek; forms mixed juniper and grass-covered bench; lower part forms topographically highest well developed, dense juniper stands; unit weathers smooth and slabby. Thickness, Abney level, approximately 10'

16 Limestone; medium- to coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone), with bed of coarse-grained, quartz-sandy, brachiopodal calcarenite (grainstone) in middle; moderate brownish gray, weathers same. Medium-bedded, irregularly bedded. Forms series of rounded benches in juniper-covered woods, receeding uphill north of creek. Upper contact sharp, undulating. Thickness, approximately 12.5'

Note: Offset section 15 yards eastward on top of unit 15 and measured perpendicularly up slope to top of unit 16.

15 Limestone; at base, medium- to coarse-grained, ?micritic, glauconite-bearing, quartz-sandy, pelmatozoan, mixed-skeletal clacarenite (recrystallized packstone?), grading upward into fine- to medium-grained, quartz-sandy, glauconite-bearing, pelmatozoan calcarenite (grainstone to packstone), grading into fine-grained, burrowed, gastropodal calcilutite (wackestone) in upper 3 feet; medium gray, weathers light brownish gray. Thick-bedded, irregularly bedded. Unit well exposed, forming rounded outcrops; weathers smooth and by exfoliation. Upper contact sharp, undulating. Thickness, approximately 6'

14 Limestone; fine-grained, mixed-skeletal calcilutite (wackestone to mudstone); medium light gray, weathers moderate brownish gray. Medium- to thin-bedded, irregularly bedded. Locally contains discontinuous shale partings. Forms series of receeding benches up densely covered juniper hillside. Upper contact

sharp, undulating. Thickness 4.8'

13 Covered. Thickness 1.7'

12 Limestone; coarse-grained, pelmatozoan, quartz-sandy, glauconite-bearing calcarenite to fine-grained calcirudite (grainstone) at base, grading upward into medium- to coarse-grained, pelmatozoan calcarenite (grainstone) with scattered quartz-sand; medium gray, weathers moderate grayish brown. Medium- to thick-bedded, irregularly bedded. Forms series of receeding benches up north side of creek; weathers by exfoliation; densely juniper covered benches. Upper contact obscure. Thickness, approximately 10'

11 Sandstone; medium-grained, calcite-cemented, submature, glauconite-bearing, quartzarenite; moderate grayish brown, weathers moderate brownish gray. Medium- to thick-bedded, irregularly bedded. Forms top of vertical cliff; strata above receed back from bluff face. Upper contact obscure. Measured northward up slope perpendicular to creek. Thickness, direct measurement 7.3'

10 Limestone; medium- to coarse-grained, quartz-sandy, highly micritic, bryozoan, intraclast-bearing calcarenite (packstone to wackestone), grading laterally into medium- to coarse-grained, brachiopodal, bryozoan, micritic calcarenite (packstone to grainstone); contains scattered granules and limestone clasts at base; medium light gray, weathers moderate brownish gray. Medium-bedded, regularly bedded; lower part cross-laminated locally. Unit forms slight recess underneath unit 11; can be followed laterally for some distance. Upper contact sharp, contains small-scale scours, sharp. Thickness, direct measurement, varies from 0.9 to 1.2 feet, averages 1.1'

9 Sandstone, conglomerate, and shale: shale, quartz-silty; medium gray, weathers moderate greenish gray. Thickly laminated. Forms basal 0.5 foot of unit. Sandstone; medium-grained, calcite-cemented, submature, skeletal, coated-grain, glauconitic quartzarenite; contains lenses with rounded sandstone pebbles; moderate yellowish brown, weathers light brownish gray. Thin- to medium-bedded, irregularly bedded, lensing at expense of shale; contains numerous burrow and trail casts on base of few beds; contains claystone partings in upper part. Weathers slightly pitted. Unit forms small ledges, well exposed above unit 8. Upper contact sharp, gently undulating. Thickness, direct measurement 2.0'

8 Sandstone; fine- to medium-grained, limonite-cemented and clay-bonded, immature quartzarenite; moderate brownish orange, weathers moderate grayish brown. Medium- to thin-bedded, irregularly bedded. Forms small, vertical cliff on north side of creek above same. Thickness, direct measurement 4.0'

Note: Offset section 10 yards eastward on top of unit 7.

7 Sandstone with shale: sandstone; fine- to very fine-grained, clay-bonded, immature quartzarenite; moderate brownish orange, weathers moderate grayish brown. Very thin-bedded, irregularly bedded; upper surface ripple-marked; lower surfaces with numerous distinctive burrow casts. Forms vertical, recessed face on north side of creek. Upper contact sharp, even. Measured on north side of creek about 35 yards of waterfall over Pitkin, thickness, direct measurement 3.5'

6 Sandstone; fine-grained, clay-bonded, immature quartzarenite; light brownish gray, weathers moderate yellowish brown. Thin-bedded, regularly bedded; lower beds with groove casts. Forms lower part of vertical bluff on north side of stream. Upper contact gradational. Thickness, direct measurement 2.2'

5 Siltstone and shale: coarse-grained, clay-bonded, immature, micaceous quartzsiltite at base, grading upward into quartz-silty shale; medium dark gray, weathers moderate grayish brown. Very thin-bedded, irregularly bedded; becomes thickly laminated at top; lower part ripple-marked with small-scale load casts and burrow casts. Forms ledges at top of steep slope, particularly well exposed on north side of stream. Upper contact sharp, even. Thickness, approximately 4'

4 Siltstone and covered: siltstone; fine-grained, clay-bonded, immature quartzsiltite; medium dark gray, weathers moderate olive brown to light brownish gray. Thickly laminated to very thin-bedded, irregularly laminated; ripple-marked, numerous small-scale load casts. Unit exposed up creek and on creek banks; 30% covered. Thickness measured to point 35 yards east of waterfall over Pitkin and then northward up slope, estimated 50'

3 Limestone, conglomerate, and siltstone: conglomerate; rounded pebbles of calcilutite, oolitic calcarenite, and phosphate set in matrix of fine- to coarse-grained,

quartz-sandy, pelmatozoan calcarenite (grainstone); contains abraded and reworked fossils and clay-ironstone concretions; few layers nonconglomeratic; medium gray, weathers moderate reddish brown. Thin-bedded, irregularly bedded, with siltstone in middle. Siltstone; fine-grained, clay-bonded, immature, calcareous quartzsiltite; medium gray, weathers light brownish gray. Thin- to very thin-bedded; ?current ripple-marks. Unit poorly exposed in creek; blocks of conglomerate exposed north of creek. Upper contact sharp. Thickness, direct measurement 2.0'

PITKIN FORMATION (partial)

2 Limestone and shale: limestone; medium- to coarse-grained, recrystallized micritic, pelmatozoan, mixed-skeletal calcarenite (recrystallized packstone); medium light gray, weathers light yellowish gray. Thin-bedded, irregularly bedded, interbedded with shale. Shale, clay shale; light gray, weathers moderate brownish orange. Poorly exposed in bed of creek. Upper contact obscure. Thickness 1.5'

1 Covered. Thickness approximately 3'

0 Limestone; fine-grained, burrowed calcilutite (mudstone); very light gray, weathers light gray. Thin- to medium-bedded, irregularly bedded. Upper contact covered. Forms upper part of steep bluff; exposed also in creek bed 10 yards east of waterfall. Contains Archimedes. Thickness not measured.

Section M113: Mill Creek

Location.--SW¼, SW¼, Sec. 10, T. 14N., R. 30W., Washington County, Arkansas. The basal units in the measured section begin in the upper part of the Brentwood Limestone in a generally northwest-flowing tributary of Mill Creek approximately 250 to 300 yards upstream from its confluence with Mill Creek. The beginning of the section is on the north side of Everett Mountain in the NW¼, SW¼, SW¼, Sec. 10, and the section is measured eastward up the tributary to a point in the SE¼, SW¼, SW¼, Sec. 10

where the basal part of the Atoka Formation form precipituous sandstone bluffs. This point is about 0.4 miles upstream from the confluence of this tributary with Mill Creek (text-figure 22).

To reach the beginning of the section, drive 2.1 miles southward on U. S. Highway 71 from West Fork to the southeastern side of the Mill Creek bridge. Park and walk northeastward upstream approximately 0.6 mile to the point where the main tributary enters Mill Creek. Walk southeastward up this tributary for approximately 0.25 mile to the exposures of the Brentwood Limestone.

Stratigraphy.—This section begins in the middle part of the Brentwood Limestone and terminates in the lower part of the Atoka Formation. The entire middle and upper Bloyd Formation is exceptionally well exposed. The stratigraphic breakdown is as follows:

Bloyd Formation (partial section, 232 feet)
- Trace Creek Shale (units 20 and 21, 67 feet)
- Kessler Limestone (units 14 through 19, 32 feet)
- Dye Shale Member (units 10 through 13, 73 feet)
- Woolsey Member (units 5 through 9, 40 feet)
- Brentwood Limestone (partial, units 1 through 4, 23 feet)

The Woolsey Member forms resistant ledges and a sluiceway in the northwest-flowing tributary. It contains the Baldwin Coal (unit 8) and a poorly developed underclay and is overlain by an additional 12 feet of quartz-silty shales. The "caprock" is quite well developed and is about 2.4 feet thick. The overlying Dye Shale is about 80 percent exposed on the banks and steep ravines leading into the main tributary.

Remarks.—This section was described by T. W. Henry on January 7, 1972. The section was examined by P. K. Sutherland and T. W. Henry on

March 6, 1973.

Unit No.	Description	Thickness
ATOKA FORMATION		
22	Sandstone; fine-grained, clay-bonded, immature quartzarenite; dusky yellow, weathers moderate yellowish gray. Thickly laminated to very thin-bedded, generally regularly laminated; current ripple marks on upper surface and burrow casts on bases; few beds at base of exposure are highly contorted ("flow rolls") and medium-bedded. Forms series of cliffs on hillside. Attitude measured on base of bed: strike N10°E, dip 5°E. Thickness not measured.	
BLOYD FORMATION (partial)		
21	Covered. Scattered black shale talus in basal 10 to 15 feet observed up creek. Measured directly up hillside with 5° dip in Abney level, estimated	65'
20	Shale, clay shale; grayish black, weathers very dark gray. Thickly laminated, regularly laminated. Highly fissile, breaking into paper-thin pieces. Poorly exposed above unit 19 to southeast of creek. Thickness approximately	2'
19	Limestone; medium-grained, quartz-sandy, pelmatozoan, coated-grain calcarenite (grainstone) at base, becoming almost a quartzarenite at top; medium grayish brown, weathers moderate grayish brown. Thin- to medium-bedded, regularly bedded, slightly cross-bedded. Unit forms small ledges in creek; well exposed southeast of unit 14 approximately 10 yards on hillside where measured; weathers by exfoliation. Upper contact obscure. Thickness, direct measurement	9.0'
18	Covered and shale: shale, quartz-silty in basal 0.1 foot, grades upward into clay shale; grayish black,	

weathers very dark gray. Thickly laminated, regularly laminated. Measured on northeast side of creek; unit 75% covered. Thickness approximately 6'

17 Sandstone; fine-grained, calcite-cemented and clay-bonded, immature to submature, carbonaceous, skeletal quartzarenite; medium dark gray, weathers moderate grayish brown. Medium-bedded, regularly bedded, cross-laminated; lower surfaces with trail casts. Exposed on northeast bank of creek and in creek as ledges. Upper contact gradational, even. Thickness, direct measurement 1.8'

16 Shale, clay shale; grayish black, weathers very dark gray. Thickly laminated, regularly laminated. Breaks into paper-thin pieces, highly fissile. Well exposed 10 yards upstream from unit 14 in vertical face recessed underneath unit 16 a couple of feet. Upper contact sharp, regular. Thickness direct measurement, maximum exposure 3.2'

15 Covered. Measured downdip in creek with 1° in Abney level. Thickness, approximately 7.5'

14 Limestone and conglomerate: at base, fine- to coarse-grained, pelmatozoan, quartz-sandy, mixed-skeletal calcarenite (grainstone) with Osagia-oncoliths and scattered uncoated pebbles; becoming medium- to coarse-grained, quartz-sandy, mixed-skeletal, conglomeratic calcarenite (grainstone) at top; locally find beds with cobble-sized, dolomite? concretions; medium dark gray, weathers moderate brownish gray. Thin- to medium-bedded, irregularly bedded; interbedded with thin shale in lower part. Forms ledge and waterfall in main creek southward from outcrops in tributary. Measured attitude on base of bed before offset (strike N10°W, dip 8°E) and on top of unit after offset (strike N45°W, dip 1°E). Thickness, direct measurements, varies from 3.5 to 5.5 feet, averages 4.0'

Note: Offset southward on top of unit 13 to main creek, a distance of 35 to 40 yards.

13 Shale, slightly quartz-silty, particularly in lower 8 feet; contains beds of argillaceous, fine-grained sandstone from 5 to 8 feet above base; olive gray, weathers moderate brownish gray. Thickly laminated, regularly laminated. Contains clay-ironstone concretions, particularly in lower part. Unit well exposed in wash located 50 to 75 yards southeast of caprock

leading up hillside to east where measured; upper 5 feet exposed in wash 40 yards to southeast of wash; beds of quartz-sandy material also exposed northward on hillside northeast of creek. Upper contact sharp, undulating. Thickness, estimated 30'

12 Covered; minor shale talus on hillside. Thickness measured upstream 75 yards to first tributary from east and then directly up small tributary or wash to base of unit 13. Thickness, estimated 30'

Note: An attitude of N55°E, dip 7°NW is measured on top of unit 10 at the east end of the outcrop of that unit, and N10°W, dip 8°E is recorded upstream on base of unit 14. Measured unit 12 with 0° dip in Abney level up creek to first tributary and then up the first tributary to base of unit 13 with 8° downdip. Thickness of unit 12 probably accurate to within 5 feet.

11 Shale, slightly quartz-silty; contains scattered, flattened clay-ironstone concretions up to 0.5 foot long; dark olive gray, weathers light olive gray. Thinly laminated. Poorly exposed on north side of creek at bend above caprock. Measured downdip on north bank of creek at point where creek bends and flows a short distance westward; used 7° in Abney level; measured to highest shale talus, approximately 11'

10 Conglomerate, limestone, and shale: base contains conglomerate with rounded siltstone pebbles (up to 1.5 cm. long) set in matrix of fine- to coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone); medium dark gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded, lensing. Forms basal 0.1 to 0.3 foot of unit. Shale, slightly quartz-silty; dark olive gray, weathers light olive gray. Thinly lamainted. Occurs in middle part of unit as recessed area, thinning westward. Limestone; fine- to coarse-grained, pelmatozoan, quartz-sandy calcarenite (grainstone) with scattered siltstone pebbles and coarse granules throughout; medium dark gray, weathers moderate grayish brown. Medium- to thick-bedded, thickens westward. Unit well exposed above sluiceway in creek formed by unit 7 eastward on north side of creek at point where coal crops out in stream. Attitude, measured at west end of outcrop (strike N80°E, dip 5°N), in middle of outcrop (strike N85°E, dip 6°N), and at east end of outcrop (strike N55°E, dip 7°NW); used former dip in compensating for lower units, latter in compensating

for higher units. Thickness, direct measurements, varies from 2.2 to 2.5 feet, averages 2.4'

9 Siltstone; fine-grained, clay-bonded, immature quartzsiltite; medium dark gray, weathers moderate brownish gray. Thinly to thickly laminated, irregularly laminated. Well exposed on north bank of creek where creek flows westward a short distance above coal. Upper contact sharp, undulating. Contains locally plant impressions on bedding planes, particularly immediately above base. Thickness, approximately 12.4'

8 Coal and underclay: coal, bituminous; black, weathers grayish black. Thin-bedded, regularly bedded. Well exposed in stream where it forms a small ledge and on north bank of stream; weathers blocky; coal is 0.4 foot thick. Underclay, weathers light gray. Developed only above where unit 7 is measured, not present in creek. Thickness averages 0.5'

Note: Offset section 25 yards eastward on top of unit 7 into stream bed.

7 Siltstone; coarse-grained, micaceous quartzsiltite to very fine-grained quartzarenite; medium gray, weathers moderate yellowish brown. Thickly laminated, cross-laminated. Forms cliff on north side of creek with upper part receeding; crops out in creek 25 yards to east as sluiceway. Upper contact gradational. Thickness, direct measurement 5.0'

Note: Offset section eastward (upstream) on top of unit 6.

6 Siltstone; fine-grained, clay-bonded quartzsiltite; medium gray, weathers light olive gray to moderate brownish gray. Thickly laminated, irregularly laminated. Well exposed in north bank of creek on vertical recessed face beneath unit 7 and for 20 yards upstream in creek; weathers blocky. Contains numerous plant impressions on bedding surfaces. Upper contact sharp, gently undulating. Thickness, direct measurement, maximum exposure 9.0'

Note: Measured 20 foot-interval with strike from top of unit 4 exposed on west side of creek up small washes to base of unit 7 offset southward on base of unit 7 to point 30 to 35 yards upstream from outcrops of unit 4 in wash. Thickness of unit 5 calculated by subtracting thickness of unit 6 from interval measured.

5 Covered. Minor quartz-silty shale in creek. Thickness estimated 11'

4 Limestone, covered, and shale: limestone; at base, medium- to coarse-grained, pelmatozoan calcarenite (grainstone); upper bed (3.5 feet), medium- to coarse-grained, mixed-skeletal calcarenite (grainstone); medium gray to medium dark gray, weathers moderate grayish brown. Lower beds thin-bedded, irregularly bedded, interbedded with thin, dark gray shales; upper bed thick-bedded, irregularly bedded. Middle of unit contains covered and shale with thin-bedded, lensing calcarenites. Poorly exposed upstream from top of unit 1 for 10 to 15 yards in creek and in gulley leading up southwestern walls of creek; upper 3.5 feet exposed only in gulley. Measured with strike up western valley wall to highest limestone, thickness estimated 14'

3 Covered. Thickness approximately 4'

2 Limestone and covered: limestone; recrystallized calcilutite (recrystallized wackestone); medium dark gray, weathers moderate brownish gray. Thin- to very thin-bedded, irregularly bedded; contains thin shale partings. Upper part exposed in creek 15 yards south of forked sycamore. Thickness measured up dip with 5^{o} compensation, approximately 2'

Note: It is obvious that the strata in the lower part of the measured section are dipping downstream at a low angle; however, it is impossible to measure the attitude because of solution surfaces. In measuring units to caprock (unit 10), need attitude of caprock (N80^{o}E, dip 5^{o}N) measured at western end of exposures of that unit in compensation.

1 Limestone; fine- to medium-grained, micritic, bryozoan, mixed-skeletal calcarenite (packstone) in lower part, becoming fine- to medium-grained, micritic, oolitic, bryozoan calcarenite (packstone) in upper bed; medium light gray, weathers light brownish gray. Thin- to medium-bedded, irregularly bedded. Weathers with smooth solution surfaces in creek; poorly exposed as ledges in creek; exposed approximately 200 to 250 yards upstream from confluence of tributary with Mill Creek, at point 10 to 15 yards north of large forked sycamore in creek. Thickness, direct measurement 2.5'

Note: The upper part of the Prairie Grove Member is exposed on the east creek banks of Mill Creek and in the first few yards of the lower part of the tributary at its confluence with Mill Creek. However, these units are not included within the measured section because of the long offsets which would be involved and the uncertainty of the exact structural attitude.

Section M114: Devil's Den State Park, North

Location.--N½, SE¼, SW¼, Sec. 13, T. 13N., R. 31W., Washington County, Arkansas. The lowest exposures are within the upper part of the Hale Formation in the NW¼, SE¼, SW¼, Sec. 13 in the stream bed of Lee Creek at a point where the creek is flowing S40°W, approximately 85 to 100 yards downstream (southwest) from the first sharp bend of Lee Creek north of Devil's Den State Park. The lowest exposures are located in a small anticline at a point 25 yards north of the confluence of a small tributary from the east with Lee Creek. The section is measured up the point to the northwest of the tributary with a series of short offsets to the top of the Kessler Limestone Member on a bluff on the east side of Lee Creek. The section is offset eastward and southeastward on the Kessler Limestone 0.2 mile to the NE¼, SE¼, SW¼, Sec. 13 where the Kessler Limestone crops out in the tributary. The Trace Creek Member and the lowest part of the Atoka (Winslow) Formation are measured up the southeastern sides of the tributary to the steep, prominent bluffs.

To reach the base of the section, drive eastward and northward 0.3 mile on the northwest side of Lee Creek on the paved park road from the bridge of Arkansas State Highway 74 over Lee Creek. At this point, the paved road makes a circle in a campground in the northern part of Devil's Den State Park. A small dirt road or jeep trail leads northward from the park boundary on the west side of Lee Creek. Ford the small tributary of Lee Creek at the northern park boundary and walk or drive northward on this winding trail for a distance of approximately 1.3 miles. At this point, the jeep trail branches; turn eastward at the intersection and proceed through the heavily wooded (cedar) creek terrace for approximately 0.2 mile to the point where the trail turns northward and makes its closest approach to Lee Creek. Park and walk eastward for approximately 100 yards and ford Lee Creek. The beginning of the section is on the small anticline on the east side of Lee Creek approximately 25 yards north of the confluence of a tributary from the east with Lee Creek, 5 yards north of the small spring, and approximately 85 to 100 yards downstream (southeast) from the big bend in Lee Creek.

Stratigraphy.--The Devil's Den Section is a well exposed section beginning in the middle part of the Prairie Grove Member and continuing into the basal Atoka Formation. The stratigraphic breakdown is as follows:

Morrow Group (partial section, 283 feet)
- Bloyd Formation (complete, 263 feet)
  - Trace Creek Shale (units 32 through 34, 81 feet)
  - Kessler Limestone (units 28 through 31, 20 feet)
  - Dye Shale (units 22 through 27, 80 feet)
  - Woolsey Member (units 16 through 21, 26 feet)
  - Brentwood Limestone (units 5 through 15, 56 feet)
- Hale Formation (partial section)
  - Prairie Grove Member (units 0 through 4, 20 feet)

The Brentwood Limestone contains bryozoan-algal mounds in the upper part (unit 12). Some of the ones in place are up to about 1.5 feet in height. One mound, slumped into the creek, measures about 2.5 feet thick by 10 feet by 5 feet. These mounds are highly fossiliferous.

The Brentwood-Woolsey contact is well exposed and is one of the few places that the author has seen this contact. The upper part of the Brentwood is marked by a sharp, undulating contact with locally up to 1.5 feet of relief on the limestone surfaces; the basal few feet of the Woolsey Member contains pebbles of limestone scattered in a quartzsiltite matrix. One disoriented block, of the underlying limestone, measuring about 0.8 foot by 0.4 foot, was found in the basal 1 foot of the Woolsey.

The Woolsey Member contains the Baldwin Coal and a well developed underclay at this locality. The coal (unit 20) is 1.0 foot thick and is underlain by 0.5 foot of underclay with root fragments. The coal, in turn, is overlain by 11 feet of shale, and the latter is succeeded by the "cap-rock", which is a conglomeratic limestone with rounded pebbles of quartz-siltite and claystone.

The Atoka Formation forms massive cliffs above Lee Creek. The Trace Creek-Atoka contact is sharp but not truncating.

Remarks.--The Devil's Den Section is the best exposed Bloyd section discovered in the study area and marks the southernmost measured section in which the Baldwin Coal has been recorded.

The section was reconnoitered by D. L. Zachry and T. W. Henry on December 11, 1971, and was measured on January 8 and 9, 1972, and on March 20, 1972 by T. W. Henry. P. K. Sutherland and T. W. Henry examined the section on March 5, 1973.

Unit No.	Description	Thickness
ATOKA FORMATION		
39	Sandstone; fine- to medium-grained, clay-bonded and quartz-overgrowth cemented, submature to immature quartzarenite; very light gray, weathers light brownish gray. Thin- to medium bedded, generally regularly bedded; cross-laminated in lower part; bed 1 foot above base is highly burrowed and reworked; upper surfaces with current ripple marks; lower surfaces with sparse trails. Lower part friable, better indurated higher; forms massive Atoka cliff. Thickness not measured.	
38	Shale; contains clay-ironstone and dolomite nodules; dark gray, weathers moderate brownish gray. Thickly laminated, regularly laminated. Exposed as steep slope above lower cliff but below massive main cliff. Lower contact sharp and truncates 2 feet of underlying unit northward within 35 to 50 feet. Upper contact sharp, even. Thickness varies from 12 to 14 feet, averages	13'
	Note: Offset eastward on top of unit 37 distance of approximately 50 feet.	
37	Sandstone with shale: sandstone; fine-grained, clay-bonded, immature quartzarenite; light brownish gray, weathers same. Thickly laminated, irregularly laminated, cross-laminated; upper surfaces ripple marked; interbedded with thin shale streaks. Forms base of cliff. Upper contact sharp, channeloid to north. Thickness, direct measurement varies from 13 to 15 feet, averages	14'
36	Sandstone and shale: sandstone; fine-grained, clay-bonded, immature quartzarenite; light brownish gray, weathers same. Thin-bedded, regularly bedded; contains ripple-marks on upper surface and modest number of burrow casts on lower surfaces; interbedded with quartz-sandy shales. Recessed beneath unit 37. Upper contact sharp, even. Thickness, direct measurement	1.5'
35	Sandstone; fine-grained, clay-bonded, immature, sparsely skeletal (pelmatozoan) quartzarenite;	

contains clay clasts and sparse subrounded quartz granules; moderate brownish gray, weathers dark grayish brown. Thin-bedded, irregularly bedded, lensing; cross-laminated, carbonaceous streaks. Exposed as recessed area; weathers slightly pitted. Upper contact sharp, regular. Thickness varies from 0.3 to 1.0 foot, averages 0.7'

BLOYD FORMATION

34 Shale; contains dolomite nodules; very dark gray, weathers dark gray. Thinly laminated, regularly laminated. Exposed recessed beneath overlying bluff as much as 10 feet locally. Upper contact sharp, even. Thickness, maximum exposure 1.0'

33 Covered. Thickness estimated 40'

32 Covered and shale: shale, clay shale; dark gray, weathers moderate brownish gray. Unit covered with scattered black shale talus to 30 feet, then shale and covered to 40 feet. Thickness, maximum exposure estimated 40'

Note: Offset section southeastward approximately 0.2 mile on top of Kessler Limestone into tributary immediately below massive Atoka slump block in tributary. Here, the Kessler has attitude of approximately N68°E, dip 2°N. Units 32 and 33 are measured updip up the steep southern side of the tributary to the base of unit 37 and then offset westward 50-75 feet to lowest exposures. The thickness of unit 33 is calculated by subtracting the thickness of units 34 through 36 from interval measured.

Note: After offset into tributary from bluff overlying Lee Creek, measured attitude on Kessler: strike N60°E, dip 2°N.

31 Limestone; medium- to coarse-grained, pelmatozoan, brachiopodal calcarenite (grainstone) with scattered quartz-sand; medium light gray, weathers light brownish gray. Thin-bedded, irregularly bedded, cross-laminated. Upper contact sharp. Forms receeding upper part of cliff. Thickness, direct measurement 1.5'

30 Limestone; fine- to medium-grained, oolitic, bryozoan calcarenite (grainstone), grading upward into fine- to medium-grained, mixed-skeletal, oolitic calcarenite (grainstone); medium light gray, weathers light brownish gray. Forms upper part of cliff near point; breaks with conchoidal fracture. Upper contact sharp. Thickness, direct measurement 1.8'

29 Limestone; medium- to coarse-grained, pelmatozoan, slightly quartz-sandy calcarenite (grainstone), grading upward into fine-grained, mixed-skeletal, oolitic, micritic calcarenite (packstone) in upper 0.5 foot; medium light gray, weathers light brownish gray. Thick- to very thick-bedded, regularly bedded. Forms massive vertical cliff high above Lee Creek; weathers smoothly; upper 1 foot rough, weathers recessed. Upper contact gradational. Thickness, direct measurement 11.0'

Note: Units 29-31 are measured 10 to 25 yards north of end of point.

28 Limestone and shale: limestone; fine-grained, micritic, skeletal calcarenite (packstone) with few beds of coated-grains; medium dark gray, weathers light brownish gray. Thin- to medium-bedded, irregularly bedded; becomes interbedded with shale in upper half with progressively more shale higher. Unit well exposed only on north bank of tributary 0.2 mile to southeast. Upper contact sharp, even. Thickness, direct measurement 6.0'

Note: From the top of unit 26 on bluff side north of high point overlooking Lee Creek, originally measured a 10 foot-shale overlain by 30 feet of covered (original units 27 and 28) to the base of unit 29. After the Kessler (units 29 through 31) was measured and the section was offset approximately 0.2 mile to the southeast into the tributary, a massive limestone, petrographically very similar to unit 29 and approximately the same thickness was found to be underlain by 6 feet of limestone and shale; this in turn is underlain by 36 feet of shale; below which is a unit which is most probably the equivalent of unit 26. Hence, the covered interval measured on the point is more than filled in by strata outcropping laterally. The unit numbers were changed accordingly, assuming that the base of unit 29 is the same in both locations.

27 Shale, slightly quartz-silty; contains sparse, cigar-shaped dolomite nodules in upper part; dark olive gray, weathers olive gray. Thickly laminated, regularly laminated. Lower 10 feet exposed on point overlooking Lee Creek; upper part exposed on north bank of tributary 0.2 mile to the southeast; upper 12 feet well exposed. Upper contact sharp, even. Thickness varies from 34 to 36 feet, averages 35'

26 Limestone; fine- to medium-grained, micritic?, pelmatozoan, quartz-sandy and -silty calcarenite (?packstone); lower beds argillaceous, contain claystone clasts; medium dark gray, weathers moderate grayish brown. Thin- to medium-bedded, regularly bedded. Well exposed near point and northward for 25 to 35 yards; unit also exposed in tributary 0.2 mile to southeast. Attitude measured on top of bed: strike N80°W, dip 2°N. Upper contact sharp, even. Offset section northward 30 yards on top of unit. Thickness, direct measurement 1.3'

25 Shale, quartz-silty; medium dark gray, weathers moderate brownish gray. Contains clay-ironstone and sparse dolomite nodules in lower 5 feet. Thickly laminated, irregularly laminated. Well exposed on steep hillside overlooking Lee Creek in basal 10 feet and upper 10 feet with middle less well exposed. Upper contact sharp, even. Thickness, approximately 36'

Note: Offset section northward 35 yards on top of unit 24. Measured unit 25 directly up hillside with strike.

24 Sandstone and siltstone: at base; coarse-grained, clay-bonded, immature quartzsiltite grading upward into fine-grained, clay-bonded, immature quartzarenite at top; medium dark gray, weathers moderate grayish brown. Thickly laminated at base, irregularly laminated; becoming thin-bedded, regularly bedded. Unit well exposed on point and 25 yards to east; also well exposed intermittently for 40 to 50 yards to north above Lee Creek. Attitude measured on top bed near point; strike N5°W, dip 1°E. Thickness, direct measurement, maximum exposure 4.5'

23 Covered. Talus of quartz-silty shale. Thickness measured northwestward up point to top of unit 24 by dip- and strike-offset method. Thickness of unit obtained by subtracting thickness of unit 24 from interval, approximately 1.5'

22 Conglomeratic limestone; rounded pebbles of siltstone and claystone set in matrix of medium- to coarse-grained, clay-bearing, quartz-sandy calcarenite (grainstone); dark reddish brown, weathers moderate reddish brown. Thick-bedded, irregularly bedded, cross-bedded. Unit slumped north of point and northeast of point; top approximately in place on point. Contacts obscure. Thickness, direct measurement, measured on slump block 2.0'

21 Shale, slightly quartz-silty; contains clay-ironstone concretions in talus; medium gray, weathers light olive gray. Poorly exposed above coal on point. Upper few feet covered. Thickness estimated by dip- and strike-offset method 11'

20 Coal, black; weathers very dark gray. Thin- to medium-bedded. Crops out poorly mostly as talus only on point; better exposed by digging; weathers blocky. Upper contact gradational. Thickness, direct measurement 1.0'

19 Underclay; weathers light yellowish gray. Contains sparse plant fragments. Exposed by digging. Upper contact gradational. Thickness, direct measurement 0.5'

18 Shale, highly quartz-silty; weathers medium gray. Uncovered by digging on point beneath coal and underclay. Upper contact gradational. Contains spare plant fragment. Maximum exposure, direct measurement 0.1'

Note: Units 18 through 21 are measured approximately 20 yards north of the top of unit 15 on the point, and 25 yards south of unit 24 on point.

17 Covered. On point to south, north of tributary, siltstone talus and clay-ironstone concretions are found above unit 16 and below coal. Thickness, approximately 3'

Note: Above place where units 10 through 15 are measured, a 35-foot interval was measured to the base of unit 24 using 1° downdip. Offset southward on top of unit 15 and, using dip- and strike-offset method, measured 33-foot interval to top of same bed. Calculated thickness of unit 17 by subtracting thicknesses of units 16 and 18 through 24 from 34-foot interval.

16 Siltstone with basal conglomerate: siltstone; fine-grained, clay-bonded, immature quartzsiltite to highly

quartz-silty shale; medium dark gray, weathers light olive gray. Thickly laminated, irregularly laminated. Conglomerate; basal 2 feet of unit contains irregularly shaped, sparse, disoriented limestone cobbles up to 0.8 foot long and 0.4 foot high exposed where lower part of unit crops out in 20 yard lateral distance; cobbles set in matrix of fine-grained, clay-bonded, immature quartzarenite. Unit becomes more argillaceous higher. Unit moderately well exposed on steep hillside above where units 10 through 15 are described. Thickness measured with 1^{o} downdip, measured to highest good outcrops, estimated 10'

15 Limestone; at base, fine- to coarse-grained, micritic, mixed-skeletal calcarenite (packstone), becoming recrystallized, mixed-skeletal calcilutite (recrystallized wackestone) at top; southward at point, unit becomes more of medium- to coarse-grained calcarenite (packstone); medium dark gray, weathers moderate grayish brown. Medium-bedded, irregularly bedded. Upper contact sharp, undulating. Forms ledge on hillside which can be traced with difficulty 75 yards to south to point. Attitude at point N10^{o}E, dip 3.5^{o}E. Thickness, direct measurements, varies from 1.8 to 2.2 feet, averages 2.0'

14 Shale, quartz-silty, slightly calcareous; olive gray, weathers light olive gray. Thickly laminated. Poorly exposed recessed beneath unit 15. To south near point, unit contains highly fossiliferous small fiolithites (boundstones) in the lower part of the shale; these are mainly bryozoan boundstones. Thickness, direct measurement 1.7'

13 Limestone; at base, fine- to coarse-grained, ?recrystallized micritic, mixed-skeletal calcarenite (recrystallized ?packstone) with scattered shale clasts; grades upward into medium-grained, algal, mixed-skeletal calcarenite (grainstone); medium gray, weathers moderate brownish gray. Medium-bedded, irregularly bedded, single bed. Upper contact sharp. Forms poorly exposed ledge on hillside. Thickness, direct measurements, varies from 1.4 to 2.1 feet, averages 1.3'

12 Shale and limestone: shale, calcareous, highly fossiliferous; medium dark gray, weathers light brownish gray. Thickly laminated, regularly laminated. Limestone; micritic, ?bryozoan, mixed-skeletal biolithite (boundstone); medium light gray, weathers moderate brownish gray. Forms bioherms on

top of unit 11 locally 2 to 2.5 feet in diameter and 1.2 feet high with shale draped between and over structures. Upper contact sharp, undulating. Unit poorly exposed on bluff. Thickness, direct measurement 2.2'

11 Limestone; fine- to very coarse-grained, micritic, pelmatozoan, mixed-skeletal calcarenite (packstone) with rounded shale clasts at base; medium gray, weathers moderate grayish brown. Thick-bedded, irregularly bedded; probable channel. Unit forms vertical cliff on hillside; lateral extent of good exposures is about 30 feet. Upper contact sharp, locally welded where boundstones rest on unit. Thickness, direct measurements, varies from 1.2 to 2.3, averages on outcrop approximately 2.0'

10 Shale and limestone: shale, calcareous, skeletal, with large crinoid stems; dark olive gray, weathers moderate grayish brown. Thickly laminated, irregularly laminated. Gradational with limestone. Limestone; coarse-grained, micritic, argillaceous, pelmatozoan calcarenite to fine-grained calcirudite; moderate brownish gray, weathers moderate grayish brown. Thin-bedded to thickly laminated, irregularly laminated, lensing. Unit exposed at top of covered slope and recessed beneath unit 11; lateral extent of exposure approximately 20 feet. Upper contact sharp, undulating. Thickness, direct measurement, maximum exposure 2.6'

Note: Offset section approximately 25 to 30 yards northward on top of unit 8 and measured interval to top of highest Brentwood (unit 15) cropping out at end of point. Measured this interval downdip, using 3^{o} in Abney level up steep covered slope. From top of unit 15 on point, offset section northward an additional 50 to 75 yards; then dropped down bluff side to point where units 11 through 15 are exposed. The units are dipping northward here on the north limb of the anticline; cannot measure: attitude here due to quality of expsoures, but they are estimated to be dipping northward 2 to 3^{o}. Thickness of unit 9B calculated by subtracting thicknesses of units 9A and 11 through 15 from interval measured.

9B Covered. Thickness estimated 22'

9A Shale, clay shale; dark olive gray, weathers light olive gray. Thinly laminated, regularly laminated. Contains sparse clay-ironstone and dolomite concretions. Exposed mainly as fresh talus 10 yards north of where unit 10 was measured. Thickness measured to highest point where fresh shale can be dug out of slope, approximately 5'

8 Limestone; fine- to coarse-grained, quartz-sandy, pelmatozoan calcarenite (grainstone), becoming highly quartz-sandy in upper 0.3 foot; medium dark gray, weathers moderate grayish brown. Medium- to thick-bedded, regularly bedded, cross-laminated. Forms ledge at point 10 to 25 yards north of tributary on bluff above Lee Creek; also exposed northward above Lee Creek; upper 0.3 foot characteristically overhangs lower part a few inches. Upper contact obscure. Attitude measured on top bed: strike N5°E, dip 2°E. Thickness, direct measurements, varies from 2.2 to 2.4 feet, averages 2.3'

7 Shale, highly calcareous, fossiliferous; medium gray, weathers moderate brownish gray. Thickly laminated, irregularly laminated, cross-laminated; fills in low places between mounds in lower unit. Recessed beneath overlying unit up to 3 feet, 25 feet north of tributary. Upper contact sharp, even. Thickness varies from 1.4 to 1.7 feet, averages 1.6'

6 Limestone; medium-grained, micritic, algal, bryozoan-brachiopodal calcarenite (packstone) at base with micritic, bryozoan biolithite (boundstone) at top; medium dark gray, weathers moderate yellowish gray. Bottom three-fourths of unit thin- to medium-bedded with shale partings, irregularly bedded; upper part with bryozoan mounds up to 1 foot in diameter and 0.5 foot high. Well exposed only approximately 25 yards north of tributary where unit 8 forms the point. Upper contact sharp. Thickness varies from 1.6 to 2.2 feet, averages 1.9'

5 Shale; highly quartz-silty; olive gray, weathers moderate yellowish gray to moderate greenish gray. Thickly laminated, regularly laminated. Contains sparse clay-ironstone concretions near top. Forms steep slope; well exposed 25 yards north of intersection of tributary with Lee Creek. Upper contact sharp, undulating. Thickness measured downdip along axis of anticline with 2° in Abney level, approximately 11.5'

Note: Section offset northward 15 yards on top of unit 4.

HALE FORMATION (partial)

4 Limestone; medium- to very coarse-grained, pelmatozoan, quartz-sandy calcarenite (grainstone) at base, becoming medium- to coarse-grained, micritic, skeletal calcarenite (packstone) in upper 1 foot; medium light gray, weathers light brownish gray. Medium-bedded, irregularly bedded. Forms top of lower cliff above east side of Lee Creek for 75 yards north of tributary; forms sluiceway in tributary. Thickness measured immediately north of cedar tree at junction of Lee Creek with tributary, direct measurement 4.5'

3 Limestone; fine-grained, mixed-skeletal calcilutite (wackestone) and medium-grained, micritic, oolitic, mixed-skeletal calcarenite (packstone); grade into one another laterally and vertically; medium dark gray, weathers light brownish gray. Medium- to thin-bedded, irregularly bedded. Well exposed as lower part of bluff north of tributary for 50 to 75 yards; upper part well exposed 15 yards east of Lee Creek in tributary. Upper contact gradational but placed at bedding plane. Upper beds contain large Chaetetes colonies at tributary. Thickness measured at cedar tree at intersection of creek and tributary, direct measurement 6.3'

2 Shale and limestone: shale, slightly calcareous, quartz-silty, carbonaceous; blackish gray, weathers moderate brownish gray. Thinly laminated, irregularly laminated. Grades upward into thin limestone, interbedded with shale. Limestone; fine- to coarse-grained, argillaceous quartzsiltite to fine-grained, micritic calcarenite (wackestone); dark gray, weathers moderate yellowish gray. Thin-bedded, irregularly bedded; interbedded with thin shale. Unit recessed as much as 5 feet beneath unit 3; best exposed 25 yards north of tributary on Lee Creek at spring; weathers splintery in contrast to lower unit. Upper contact gradational, placed at highest shale parting. Thickness, direct measurement 1.0'

1 Shales, quartz-silty; dark olive gray, weathers light olive gray. Thickly laminated, regularly laminated. Recessed with unit 2 under unit 3, best exposed northward from tributary for 40 yards; weathers blocky. Upper contact sharp, undulating. Thickness, direct measurements, varies from 2.2 to 2.7 feet, averages 2.5'

0 Limestone; medium- to coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone) becoming fine-grained, pelmatozoan, micritic calcarenite (packstone) in upper bed; lowest beds quartz-sandy. Medium- to thick-bedded, irregularly bedded. Forms bed of creek on east side, well exposed for 50 to 75 yards upstream on Lee Creek from intersection with tributary; upper bed has joint set widened by solution. Upper contact sharp. Contains large, branching Michelinia colonies scattered throughout lower beds; large Chaetetes colonies observed at confluence. Maximum exposure measured in core of small anticline 10 yards upstream from creek junction with 2^{o} in Abney level down east-plunging axis, approximately 5'

Section M115: City of Fayetteville Water Filtration Plant

Location.--SW¼, SW¼, SW¼, NE¼, Sec. 15, T. 16N., R. 30W., Washington County, Arkansas. Measured section 115 is located immediately east of the City of Fayetteville water filtration plant at the junction of Oklahoma Way and Leighton Drive on the southwestern side of Mt. Sequoyah (East Mountain). The section begins approximately 50 yards east of the intersection of Oklahoma Way and Leighton Drive in the northern street ditch of the latter near the culvert southwest of a blue frame house owned by J. Palmer Boggs. The section is measured eastward up the road ditch to the Kessler Limestone Member and then northeastward across the eastern part of Mr. Boggs' yard to the basal exposures of the Atoka Formation in the north road ditch of Texas Way. The entire section is measured in the SW¼, SW¼, SW¼, NE¼, Sec. 15.

Stratigraphy.--The section begins in the upper part of the Dye Shale Member and continues through the basal portion of the Atoka Formation, which caps Mount Sequoyah. The stratigraphic breakdown is as follows:

Bloyd Formation (partial section, 72 feet)
Trace Creek Shale (unit 3, 40 feet)
Kessler Limestone Member (unit 2, 7 feet)
Dye Shale Member (partial section, unit 1, 25 feet)

History of Previous Investigations.—The outcrops of the Kessler Limestone and the upper part of the underlying shale in this area was first mentioned by Simonds (1891, p. 103). This is the site of Mather's (1915, p. 248) Station 209 (for additional remarks, see Appendix III), and for U. S. G. S. localities 2803, 2854, 2863, and 2863A. Gordon (1965, p. 44) gives a list of goniatites recovered from the Kessler Limestone here.

Remarks.—The current section was described on January 5, 1972, by T. W. Henry and was visited on March 7, 1973, by T. W. Henry and P. K. Sutherland.

Unit No.	Description	Thickness
ATOKA FORMATION		
5	Sandstone; fine- to medium-grained, quartz-overgrowth-cemented, submature quartzarenite; light brown, weathers moderate grayish brown. Thin-bedded, irregularly bedded; minor cross-bedding. Well exposed ledge above Texas Way and in ditch. Thickness, direct measurement	3.2'
4	Sandstone with shale: sandstone; very fine-grained, clay-bonded, immature, micaceous quartzarenite; moderate dusky yellow, weathers moderate yellowish brown. Very thin-bedded to thickly laminated, regularly laminated; upper surfaces ripple-marked; interbedded with dark gray shale. Poorly exposed on north ditch of Texas Way approximately 75 yards	

east of junction with Oklahoma Way and immediately north of intersection of small gravel road connecting Texas Way with Leighton Trail. Lower contact covered. Thickness measured eastward up ditch of Texas Way to lowest exposures of sandstone of unit 5; upper 5 feet well exposed in ditch. Upper contact sharp. 12'

MORROW GROUP

BLOYD FORMATION (partial)

3 Covered with shale: shale, clay shale; very dark gray, weathers same. Exposed in talus of ditch of Leighton Trail in lower 18 feet of unit. Measured with 0° in Abney level from top of Kessler in ditch of Leighton Trail to base of Atoka (Winslow) on Texas Way across eastern part of Mr. J. Palmer Boggs' yard. Thickness estimated 40'

2 Limestone; medium- to coarse-grained, pelmatozoan, slightly quartz-sandy calcarenite (grainstone); moderate grayish brown, weathers moderate brownish gray. Thin- to medium-bedded, cross-bedded; interbedded with thin shale in lower part. Forms ledge immediately east of gravel road which runs behind (east of) City of Fayetteville water filtration plant at point 25 yards north of Leighton Trail and Oklahoma Way; also outcrops in southwestern part of Mr. Boggs' yard (25 yards north of junction of Leighton Trail and Oklahoma Way on latter street; and in ditch on north side of Leighton Trail approximately 25 yards to the east. Thickness measured behind filtration plant, maximum exposure, direct measurement 7.0'

1 Shale and covered: shale, highly quartz-silty; olive gray, weathers moderate brown. Thickly laminated. Poorly exposed in road ditch of Leighton Trail at intersection of that street with Oklahoma Way; measured eastward with 0° dip in Abney level, maximum exposure, approximately 25'

Section M116: Mount Sequoyah, East

Location.--NW¼, Sec. 14 and SW¼, Sec. 11, T. 16N., R. 30W., Washington County, Arkansas. The section is measured in a north-south trending ravine on the eastern slope of Mount Sequoyah (East Mountain), beginning with what may be the upper part of a remnant of the Pitkin Formation, in the NE¼, NW¼, NW¼, Sec. 14, and ending in the Baldwin Coal in the SW¼, SW¼, SW¼, Sec. 11. To reach the beginning of the section, drive southeastward on Ruth Avenue in Fayetteville to its terminus on the east side of Mount Sequoyah. Turn southwestward on the paved but unnamed street located 1 block south of Anson Drive and continue for approximately 35 yards to a small clearing between two small ravines on the south side of the street. The Baldwin Coal can be dug out in this small clearing; the lowest units can be reached by walking southeastward down either of the ravines for a distance of approximately 200 to 250 yards to the lowest outcrops at a well-defined bench.

Stratigraphy.--The section begins in the upper part of what is apparently a remnant of the Pitkin Formation (unit 0), which is unconformably overlain by a basal conglomerate in the Cane Hill Member. The Cane Hill contains a thick quartzarenite lens (unit 2) in the lower portion. The lower part of the Prairie Grove is quite well exposed and is separated from the Cane Hill by a thin pebble conglomerate. The Brentwood Limestone is poorly exposed above the bluffs of Prairie Grove, and the Woolsey is also poorly exposed. The section terminated in the upper part of the Woolsey immediately above the Baldwin Coal (unit 28). The stratigraphic breakdown is as follows:

- Morrow Group (partial section, 171 feet)
  - Bloyd Formation (partial section, 67 feet)
    - Woolsey Member (almost complete, units 25-29, 19 feet)
    - Brentwood Limestone (units 17 through 24, 48 feet)
  - Hale Formation (complete ?, 104 feet)

Prairie Grove Member (units 7 through 16, 75 feet)
Cane Hill Member (units 2 through 6, 29 feet)

History of Previous Investigations.--Simonds (1891, p. 79, Section XVIII, p. 140), mentioned the thick, ledge-forming quartzarenite and basal conglomerate in this immediate area and referred the limestone at the base of the section (unit M116-0) to the "Archimedes limestone" (Pitkin Formation) and recorded 5 feet for its thickness.

Measured section M116 is within the general area given by Mather (1915, p. 248) for his Station 138. This station is probably equivalent to unit M116-18, which is University of Arkansas Locality L278 (for additional remarks, see Appendix III).

Henbest (1953, p. 1953) referred to these exposures as his locality 25, and assigned the cliff-forming lower sandstone to the Cane Hill Member.

Remarks.--The section was reconnoitered on the morning of January 11, 1972, by T. W. Henry and J. H. Quinn. The section was described on January 12th by T. W. Henry.

Unit 18, University of Arkansas Locality L278, is referred to the lower part of the Brentwood Limestone and not to the Hale Formation.

Unit No.	Description	Thickness
	MORROW GROUP	
	BLOYD FORMATION (partial)	
29	Shale, clay shale; weathers medium light gray. Exposed	

only in hole where dug out coal. Covered above. Maximum thickness, direct measurement 0.2'

28 Coal and underclay: underclay; weathers medium light gray. Thin-bedded, irregularly bedded. Contains scattered plant fragments. Upper contact gradational. Underclay 0.4 foot thick. Coal; blackish gray. Thin-bedded, regularly bedded. Upper contact gradational. Thickness of coal 0.6 foot. Dug out coal and underclay at point in clearing halfway between creek branches, approximately 20 yards south of unnamed, paved street, at point 35 yards west of the junction of Ruth Street and the unnamed street. Thickness, direct measurement 1.0'

27 Covered with siltstone talus. Measured with 3° dip in Abney level up cleared knoll approximately halfway between creek branches. Thickness, approximately 5'

26 Siltstone; fine-grained, clay-bonded, immature quartzsiltite; medium gray, weathers moderate yellowish gray. Thickly laminated to very thin-bedded, irregularly bedded. Exposed in both creek branches; talus abundant to 10 feet, lower 5 feet poorly exposed; weathers slabby. Thickness, approximately 10'

25 Covered with siltstone talus. Thickness approximately 3'

24 Limestone; medium- to very coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone); medium gray, weathers moderate grayish brown. Thin-bedded. Exposed in western tributary as slump blocks approximately in place; weathers slabby. Thickness, direct measurement, maximum exposure 1.8'

23 Covered. Measured up western branch of creek at top of unit 24 and subtracted thickness of that unit from interval; used 3° downdip in Abney level. Thickness estimated 18'

22 Limestone; fine-grained, micritic, mixed-skeletal calcarenite (packstone); medium gray, weathers moderate brownish gray. Medium-bedded. Poorly exposed and slightly slumped in both creek branches; weathers smoothly. Thickness, maximum exposure 1.5'

21 Covered. Measured up western branch using 3° downdip in Abney level; thickness approximately 1.5'

20	Limestone; coarse-grained, mixed-skeletal calcilutite (wackestone) at base, grading upward to fine-grained, micritic, mixed-skeletal calcarenite (packstone) at top; light gray, weathers light brownish gray. Thin-bedded, irregularly bedded. Forms ledge at point where tributaries meet; well exposed in both tributaries approximately 10 yards south of large fallen trees in western branch. Thickness, direct measurement in eastern branch	3.2'
19	Covered with abundant limestone talus. Thickness measured with 3° downdip in Abney level, estimated	10'
18	Limestone; medium- to coarse-grained, mixed-skeletal, brachiopodal calcarenite (grainstone); medium light gray, weathers light brownish gray. Medium-bedded, irregularly bedded. Forms ledge in creek; weathers smoothly on upper beds, exfoliates slabby on lower beds. Note: University of Arkansas Locality 278; Mather's locality 138. Thickness, approximately	4'
17	Covered. Measured with Abney level, using 3° downdip	8'
16	Limestone; fine- to medium-grained, well-sorted, mixed-skeletal, glauconite-bearing, slightly quartz-sandy calcarenite (grainstone) at base, grading upward into medium-grained, well sorted, slightly quartz-sandy, algal, bryozoan calcarenite (grainstone) at top; light gray, weathers medium light gray. Thick-bedded, irregularly bedded. Forms ledges and small waterfall in creek; poorly exposed on hillside to east as slump blocks; also exposed 30 yards to east in gas-line cuts in small wash. Weathers smooth and rounded in creek. Thickness, maximum exposure, approximately	4.5'
15	Covered. Measured with 3° downdip in Abney level, approximately	4'
14	Limestone; fine-grained, quartz-sandy, glauconite-bearing, mixed-skeletal calcarenite; very light gray, weathers light brownish gray. Medium-bedded. Poorly exposed in creek; may be slightly slumped. Thickness, maximum exposure	1.5'
13	Covered. Measured northward with 3° downdip in Abney level, approximately	8.5'
12	Sandstone; fine-grained, quartz-overgrowth-cemented, glauconite-bearing, submature quartzarenite; very	

light gray and light grayish yellow, weathers moderate brownish gray. Thin-bedded, irregularly bedded; upper beds with poorly preserved current? ripple marks. Forms ledge in western creek branch, well exposed; weathers smoothly. Thickness, direct measurement, maximum exposure 2.5'

11 Covered. Thickness, estimated 5.5'

Note: Offset westward for distance of approximately 40 yards into westward branch of creek at barbed wire fence (same fence that crosses unit 9) at section line on approximate top of bed 9; measured unit 11 with 3° downdip.

10 Limestone and sandstone: limestone; quartz-sandy, pelmatozoan calcarenite (grainstone), becoming finer upward; some beds highly quartz-sandy; gradational upward with medium-grained, calcite-cemented, submature, skeletal quartzarenite; medium gray, weathers light brownish gray. Thick-bedded, irregularly bedded, cross-laminated. Forms distinctive rounded bluff in east branch of creek approximately 25 yards west of gas line cut, and forms slumped benches and bluff on hillside to west almost to western branch of creek at barbed wire fence. Weathers smoothly, rounded, with quartz-sandy layers in slight relief. Thickness, approximately 16.5'

9 Covered. Measured up eastern branch of creek to base of unit 10 at point 10 feet south of woven wire and barbed wire section line fence. Thickness measured using 3° downdip, approximately 20'

8 Limestone; medium- to coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone), contains highly scattered clay clasts in base; becomes medium-to coarse-grained, brachiopodal-bryozoan calcarenite (packstone) in top 1 foot; medium light gray, weathers light brownish gray. Thick-bedded, irregularly bedded. Forms upper part of waterfall and exposed as receeding cliffs on either side; particularly well exposed on east side; weathers smoothly; branches of creek intersect at waterfall. Highly fossiliferous in upper 2 feet. Thickness approximately 6'

Note: Used attitude of N85°E, dip 3°N in measuring lower covered intervals; there is no bedding plane on which attitude can be measured on either unit 6, 7, or 8. The top of unit 7 is well defined; stood in creek and with Abney level set at 0° sighted along presumed strike to east and west from same point to top of unit 6; the strike is consistant with that measured on lower units and the dip is still northward into hillside. Thus used N85^{o}E, dip 3^{o}N in compensating for thicknesses of upper covered intervals.

7	Sandstone; at base, fine- to coarse-grained, calcite-cemented, immature, pelmatozoan, mixed-skeletal, quartzarenite with scattered fine-rudite sized pelmatozoan fragments, and scattered pebbles; grades upward into more of a highly quartz-sandy calcarenite (grainstone) and then back into mixed-skeletal quartzarenite; medium gray, weathers moderate brownish gray. Thick-bedded, irregularly bedded, minor cross-bedding. Forms waterfall in creek; lower part of cliff on either side of creek. Upper contact sharp, even. Thickness, direct measurement	6.1'
6	Siltstone with sandstone lens: siltstone; coarse-grained, clay-bonded, immature, quartzsiltite; medium dark gray, weathers medium gray. Thickly laminated, irregularly laminated. Sandstone lens; fine-grained quartzarenite; medium dark gray, weathers moderate brownish gray. Thin-bedded, lensing, located 0.5 foot from top. Unit exposed in slightly recessed area at base of waterfall below where wash divides again. Upper contact sharp, with gentle, large-scale undulations. Thickness, direct measurement, maximum exposure	1.7'
5	Covered. Thickness estimated	5'
	Note: Sighted from top of unit 4 on west bank of stream where measured upstream downdip to top of sandstone outcrops on west bank of stream approximately 35 yards upstream beneath large oak tree; the tops coincide stratigraphically within 0.5 foot. Offset on top of unit 4 to large oak and then downdip upstream 20 to 25 yards to base of waterfall.	
4	Sandstone; fine- to medium-grained, submature quartzarenite with scattered shale clasts and sandstone pebbles on bases of several beds; medium gray and light brownish red; weathers moderate yellowish brown. Thin-bedded, irregularly bedded, lensing, cross-bedded; upper surfaces with current ripple marks. Exposed as small cliff only on west side of creek where measured; also exposed on west side of creek beneath large oak 35 yards upstream. Thickness, direct measurement, maximum exposure	7.0'

3 Covered. Thickness probably accurate to within 2 feet; measured twice, getting 12 and 15 feet. Thickness estimated 13.5'

Note: From top of unit 2 on northeast side of creek, went with strike approximately 75 yards westward to base of unit 4 on west bank of west fork of creek; in so doing crossed gas-line cuts.

2 Sandstone; fine- to medium-grained, well-sorted, quartz-overgrowth-cemented, submature, glauconite-bearing quartzarenite, light brownish gray, weathers light yellowish gray to moderate yellowish brown. Thick- to very thick-bedded, slightly cross-bedded, single bed. Forms distinctive cliff, particularly well exposed on northeast side of wash, and also exposed west side of wash; upper contacts poorly exposed in eastern bank of wash; weathers rounded, smooth with upper part overhanging lower part of unit as much as 12 feet locally; weathers by exfoliation. Thickness, direct measurement 9.1'

1 Conglomerate; fine-grained, clay-bonded, immature quartzarenite matrix with rounded and some elongated pebbles of siltstone reddish calcareous material, and phosphate; pebbles rarely up to 3 inches in length and 0.8 inches wide; matrix moderate brownish gray, weathers light olive gray; pebbles bright orange, dark reddish brown, and moderate dark gray. Bedding not well developed, single bed. Exposed recessed beneath unit 2 at base of cliff. Upper contact sharp, even. Attitude measured on top surface exposed near fence 35 yards southeast of point where units 0 through 2 are described and measured: strike N85°E, dip 3°N. Thickness, direct measurements, varies from 1.5 to 1.8 feet, averages 1.6'

PITKIN FORMATION (?)

0 Limestone; coarse-grained, quartz-sandy, pelmatozoan, intraclast-bearing calcarenite (grainstone); light reddish gray, weathers moderate reddish brown. Medium-bedded, bedding obscure. Exposed intermittently at base of cliff on east side of creek at points 25 to 35 yards northeast of where gas line crosses creek junction. Upper contact sharp, even. Thickness, direct measurement, maximum exposure 1.0'

Section M117: Judge Walker's Farm

Location.—SE¼, NW¼, SE¼, Sec. 15, T. 16N., R. 30W., Washington County; Arkansas. The section is measured in a north-northeast, south-southwest trending ravine and on the hillside on the southern side of Mount Sequoyah 0.2 mile east of the brick, Georgian home built by Judge Walker in 1871 and currently owned by Professor and Mrs. Franklin Williams. To reach the beginning of the section, drive southeastward on Rock Street past the Confederate Cemetary and Walker Cemetary in the southeastern part of Fayetteville for a distance of 0.3 mile to the old Georgian Mansion Park and walk eastward on the winding path starting at the northern side of the Walker home for a distance of approximately 0.2 mile into the first ravine. The offset section, M117A, is measured below the distinct footpath, and the main section begins in the next ravine, 0.1 mile farther east at the lowest exposures 35 yards below the path. The first few units are measured in the ravine, and the section is offset westward to the exposures above the path and near the large slump block of Prairie Grove upon which numerous signatures have been carved and campfires built. The remainder of the section is measured up the bluffs in a small wash immediately north of the "signature rock". The entire section is measured within the SE¼, NW¼, SE¼, Sec. 15.

Stratigraphy.—The section begins in the Cane Hill Member and terminates in the lower part of the Brentwood Limestone, which is quite poorly exposed here. The Prairie Grove forms a distinct bluff on the hill-side in the woods below the pasture. The stratigraphic breakdown is as follows:

Morrow Group (partial section, 109 feet)
Bloyd Formation (partial section)
Brentwood Limestone (partial section, units 12 & 13, 14 feet)
Hale Formation (partial section, 95 feet)
Prairie Grove Member (units 1 through 11, 86 feet)*
Cane Hill Member (unit 0, 9 feet)*

*Note: The Prairie Grove--Cane Hill contact is probably within unit 1 of the measured section.

History of Previous Investigations.--This section, and the offset section, M117A, were measured because this is the general locality of four of Mather's (1915, p. 248) Stations. Station 139 is probably the same strata as constitute unit 2 of the main section and unit 6 of M117A. Station 149 is probably within unit M117-7, near the top of the Prairie Grove Member, and Mather's Station 150 probably is equivalent to unit M117-13, in the lower part of the Brentwood Limestone Member. Mather's Stations 140 and 150 are probably the same locality. (For additional remarks, see Appendix III).

U. S. G. S. locality 2811A (R. D. Messler, 1903) is almost certainly the same as Mather's 139, and U. S. G. S. localities 2853 and 2853A are unit M117A-6. Gordon (ibid., p. 39) described the goniatites from these collections.

A section was also measured here by Manger (1971, p. 170-172).

Remarks.--The current section was described on January 13 and 21, 1972, by T. W. Henry and was visited on March 7, 1973, by T. W. Henry and P. K. Sutherland.

Unit No.	Description	Thickness
MORROW GROUP		
BLOYD FORMATION (partial)		
13	Limestone; fine- to coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone); medium gray, weathers moderate yellowish gray. Medium bedded, single bed, ?irregularly bedded. Exposed as scattered slump blocks near large cedar tree in pasture above bluff in woods formed by Prairie Grove Member and 20 yards north of fence. Thickness, direct measurement, maximum	2.0'
12	Covered with minor shale. Olive gray shale occurring in ditch and bank of small wash, very poorly exposed. Unit measured with no dip in Abney level, approximately	12'
HALE FORMATION (partial)		
11	Limestone; medium- to very coarse-grained, quartz-sandy, pelmatozoan, mixed-skeletal calcarenite (grainstone); moderate brownish gray, weathers moderate grayish brown. Medium-bedded, irregularly bedded. Forms series of ledges only in wash with top of unit 5 feet south of fence and 20 yards south of large cedar tree in pasture. Thickness, maximum exposure, approximately	2'
10	Covered. Thickness approximately	1'
9	Limestone; fine-grained, partly recrystallized, mixed-skeletal calcilutite (wackestone); medium dark gray. Thin-bedded, single bed; upper surface with scattered burrows and trails. Exposed only in wash in woods approximately 20 feet south of fence and southern part of.pasture; weathers somewhat pitted. Thickness	0.5'
8	Covered. Thickness approximately	1'

7 Limestone; fine- to medium-grained, quartz-sandy, oolitic calcarenite (grainstone); with scattered zones of skeletal debris; upper bed medium-grained, well-sorted, oolitic calcarenite; medium light gray, weathers moderate brownish gray. Medium-bedded, cross-laminated, irregularly bedded. Forms series of small benches in wash; upper part of bed exposed 10 yards south of fence and southern edge of pasture; middle part weathers smooth; upper and lower part weather with quartz-sandy lamellae in relief. Thickness measured with 0^{o} in Abney level with strike, approximately 5'

6 Sandstone; fine- to medium-grained, calcite-cemented, submature quartzarenite with scattered coated grains at base and glauconite throughout; dusky yellow, weathers moderate yellowish brown. Thin-bedded, irregularly bedded, marked cross-bedded, with forsets near top of unit with following attitude: strike N25°E, dip 17°W. Well exposed in wash and as ledges laterally; weathers friable, pitted ("honeycombed"). Upper contact gradational, exposed in wash. Measured with 0^{o} in Abney level, approximately 21'

5 Limestone; medium- to coarse-grained, quartz-sandy, oolitic, mixed-skeletal calcarenite (grainstone) at base, grading upward into fine-grained, oolitic, quartz-sandy, calcarenite (grainstone) ; medium light gray, weathers light brownish gray and moderate grayish brown. Thick-bedded, irregularly bedded, cross-laminated. Forms bench on hillside beneath cedars; weathers with quartz-sandy lamellae in relief. Upper contact gradational. Thickness, approximately 4.8'

4 Sandstone; fine- to medium-grained calcite-cemented, submature, skeletal quartzarenite; several beds contain scattered ooids; medium light gray, weathers dark grayish brown. Thick-bedded, irregularly bedded, cross-bedded. Basal 10 feet forms vertical cliffs in woods between creeks; upper part forms sequence of receeding benches up steep hillside; weathers pitted ("honeycombed") and cavernous. Upper contact gradational. Attitude estimated on a lower bed: strike N10°E, dip 3 to 4°W. Thickness, measured by a combination of direct measurements and Abney level measurements with strike, estimated 21'

3 Covered. Thickness approximately 7'

2 Limestone; medium- to coarse-grained, micritic, pelmatozoan calcarenite (grainstone) at base, becoming coarse-grained, pelmatozoan calcarenite (grainstone) in middle and medium- to coarse-grained, pelmatozoan, brachiopodal, bryozoan, micritic calcarenite (packstone) at top; medium light gray, weathers moderate brownish gray. Medium-bedded, irregularly bedded. Poorly exposed for 10 yards east of "signature rock" (large slump block of sandstone); poorly exposed west of block. Weathers rounded with rough surface texture. Highly fossiliferous. Thickness, maximum exposure, direct measurement 3.2'

Note: Measured 22 foot-thick interval up eastern ravine with strike to base of unit 4 from the top of unit 1 near cave. Offset section approximately 30 yards westward to outcrop of unit 2 in woods, where the latter unit was measured. Subtracted thickness of unit 4 from interval to get thickness of unit 1.

1 Covered. Trail for old Walker Home to west crosses unit 5 feet above base. Calculated approximately 19'

0 Sandstone and limestone: sandstone; medium- to fine-grained, calcite-cemented, submature, skeletal quartzarenite; medium light gray, weathers moderate grayish brown. Bed of limestone 4 feet above base; limestone; fine- to medium-grained, oolitic, quartz-sandy, calcarenite (grainstone); medium light gray, weathers moderate grayish brown. Thin- to medium-bedded, irregularly bedded; upper part distinctly cross-laminated. Poorly exposed in eastern creek bed approximately 10 to 30 feet south of trail from west and west of large hackberry tree; weathers slabby, exfoliates; covered with algal scum. Thickness measured along strike, approximately 8.5'

Section M117A: Judge Walker's Farm, Offset

Location.—SE¼, NW¼, SE¼, Sec. 15, T. 16N., R. 30W., Washington County, Arkansas. To get to the beginning of the offset section, walk eastward on the foot path into the first ravine approximately 0.2 mile east of the old Judge Walker home. The lowest exposures in the section are located approximately 30 yards downstream from the point where the trail crosses the ravine.

Stratigraphy.—40.5 feet of lower Prairie Grove Member are recorded at this locality which is approximately 0.1 mile west of measured section M117. The section was measured because of the better exposures of the lower part of the Prairie Grove Member which is partially covered in section M117.

Remarks.—The section was described on January 13, 1972, by T. W. Henry, and was visited on March 7, 1973, by P. K. Sutherland and T. W. Henry.

Unit No.	Description	Thickness
	HALE FORMATION (partial)	
7	Sandstone; fine- to medium-grained, calcite-cemented, submature, skeletal quartzarenite; medium dark gray, weathers dark grayish brown. Thick-bedded, irregularly bedded, cross-bedded. Forms bench and cliff on hillside; weathers "honeycombed". Lower part correlates with lower part of unit 4 in section M117; can walk beds between section. Attitude: strike N5°E, dip 3°W. Thickness not measured.	
6	Covered and limestone: limestone; fine- to coarse-grained, recrystallized, bryozoan, brachiopodal, mixed-skeletal calcarenite (grainstone?); light gray, weathers light brownish gray. Medium-bedded, irregularly bedded. Exposed as large slump blocks only in creek, probably from within the lower 8 feet of unit 6; blocks occur immediately beneath trail from Walker home. Thickness of blocks is 6 feet. Measured unit northward up hillside with strike to base of unit 7. Thickness, approximately	20'

5	Limestone; fine- to very coarse-grained, slightly quartz-sandy, pelmatozoan, brachiopodal, mixed-skeletal calcarenite (grainstone); medium light gray, weathers moderate grayish brown. Thick-bedded. Exposed on east bank of ravine a few feet south of large sandstone slump blocks; weathers by exfoliation. Thickness, approximately	6.5'
4	Covered. Thickness, approximately	2.5'
3	Limestone; fine-grained, recrystallized mixed-skeletal calcarenite (recrystallized packstone?); medium gray, weathers moderate grayish brown. Thin-bedded, single bed. Poorly exposed on east bank of ravine 5 feet south of slump block of sandstone. Thickness, direct measurement, maximum exposure	0.4'
2	Limestone; medium- to coarse-grained, pelmatozoan, slightly quartz-sandy calcarenite (grainstone); basal 0.5 foot contains pebbles of sandstones; medium gray, weathers moderate yellowish brown. Thick-bedded, irregularly bedded. Lower part crops out on east side of ravine; upper part crops out 10 yards upstream on east bank. Upper contact obscure. Thickness, direct measurement	3.6'
1	Sandstone and basal conglomerate: at base, granules and small, rounded pebbles of quartzsiltite and fine-grained calcareous material set in fine- to medium-grained, calcite-cemented and clay-bonded, immature skeletal quartzarenite; moderate brownish gray, weathers moderate grayish brown. Very thin-bedded, irregularly bedded. Weathers slabby. Conglomerate occupies basal 1.7 feet of unit, grades upward into sandstone; medium-grained, slightly calcareous quartzarenite; medium light gray, weathers grayish brown. Thin-bedded, irregularly bedded. Poorly exposed on east bank of ravine; upper part crops out in ravine as small waterfall. Upper contact sharp. Thickness approximately	4.5'
0	Sandstone; medium-grained, well-sorted, calcite-cemented, submature quartzarenite; moderate brown, weathers dark brownish gray. Lower beds very thin-bedded, cross-bedded, irregularly bedded; upper bed thin-bedded, regularly bedded. Forms ledges on east bank of ravine, beneath large slump block at point approximately 30 yards downstream from place where trail crosses ravine; slump blocks of unit occur to east on hillside for few yards. Upper contact	

obscure. Attitude measured on top of upper bed: strike N2°W, dip 2°W. Thickness, direct measurement, maximum exposure 3.0'

Section M118: Kessler Mountain, West

Location.--S½, SE¼, Sec. 25, T. 16N., R. 31W., Washington County, Arkansas. The section is measured up a northwest-southeast trending ravine on the west side of Kessler Mountain, starting with the lowest Morrowan outcrops in the NE¼, SW¼, SE¼, Sec. 25 and terminating with the base of the Atoka (Winslow) Formation immediately north of the saddle on the top of Kessler Mountain in the NW¼, SE¼, SE¼, Sec. 25.

To reach the section, start at the junction of U. S. Highway 71 bypass and Arkansas State Highway 265 (Cato Springs Road) in the southwestern part of Fayetteville and drive southwestward on the latter highway for a distance of 1.5 miles. Turn westward on the gravel road and drive for 1.0 mile to the top of Kessler Mountain. Park in the cleared area near the northernmost set of radio towers, cross the fence to the north, and walk 0.75 mile northward through the woods on the narrow crest of Kessler Mountain. At this point, a small saddle and the cattle pond will be reached. The Kessler Limestone Member and the lower part of the Trace Creek Shale form the saddle at this point. Drop down the steep wash to the west for a distance of approximately 0.2 mile to the exposures of the Cane Hill Member of the Hale Formation which forms the lowest outcrops in the ravine.

Stratigraphy.--The section on the western side of Kessler Mountain affords one of the most complete sections of the Morrow Group in the Fayetteville area. Only the lower part of the Cane Hill Member does not crop out, but it would appear that the Cane Hill rests directly upon the Fayetteville Formation here. The Prairie Grove Member forms very prominent bluffs along the western side of Kessler Mountain, and the Brentwood Limestone Member and the Woolsey Member are not well exposed. The "caprock" (unit 16) is 6 feet thick and is quite well developed, and higher parts of the Bloyd are well exposed. The section terminates in the lower part of the Atoka Formation which forms a cap on the mountainside. The stratigraphic breakdown is as follows:

- Morrow Group (almost complete, 294 feet)
  - Bloyd Formation (196 feet)
    - Trace Creek Shale (units 21 through 23, 38 feet)
    - Kessler Limestone (units 18 through 20, 10.5 feet)
    - Dye Shale Member (units 16 and 17, 76 feet)
    - Woolsey Member (unit 15, 35 feet)
    - Brentwood Limestone (units 9 through 14, 36 feet)
  - Hale Formation (almost complete, 98 feet)
    - Prairie Grove Member (units 4 through 8, 52 feet)
    - Cane Hill Member (almost complete, units 0 through 3, 46 feet)

History of Previous Investigations.--Simonds (1891, p. 104) defined the Kessler Limestone as a discrete lithostratigraphic unit and merely stated that it "appears high up on the slope of Kessler Mountain, in 16 N., 30 W.", where it is reported to be approximately 15 feet thick; he also noted that the upper part bears a large amount of quartz sand and that the "upper layers pass into sandstone". The stratigraphic section (Simonds' Section XV, p. 139) that he presented for Kessler Mountain is located on the southern side of Kessler Mountain, not on the western side.

Henbest (1953, p. 1945; 1951, 1952) discussed the nature of the Kessler outcrops in the locality of current measured section M118, and later (1962a, p. 41) designated "the section of the Kessler on the west side of a shallow saddle near the north end of the highest part of Kessler Mountain ridge, where erosion has removed the caprock (Greenland Sandstone Member of the Atoka Formation)" as the type locality for this member. This is near the C, SE¼, Sec. 25.

Remarks.--The section was described on March 23, 1972, by T. W. Henry. It was visited on March 4, 1973, by P. K. Sutherland, W. L. Manger, D. L. Zachry, and T. W. Henry.

Unit No.	Description	Thickness
ATOKA FORMATION		
24	Sandstone; fine-grained, clay-bonded, immature quartzarenite; light brownish gray, weathers moderate grayish brown. Thin-bedded, regularly bedded. Forms ledge in woods to north of saddle; slightly slumped. Thickness not measured.	
MORROW GROUP		
BLOYD FORMATION		
23	Covered. Measured northward from saddle area with 0° dip. Thickness approximately	15'
22	Shale, clay shale; very dark gray, weathers dark gray. Thinly laminated, regularly laminated. Well exposed at north end of saddle in non-vegetated area; also as talus at cow pond in center of saddle. Thickness measured by dip and strike offset method to highest shale talus at north end of open area at saddle, approximately	18'
21	Covered. Measured with 2° downdip, approximately	5'

20 Sandstone; medium- to fine-grained, calcite-cemented, submature, ooid-bearing, skeletal quartzarenite; light grayish brown, weathers moderate yellowish brown. Medium-bedded, irregularly bedded. Forms series of slump blocks in saddle 25 yards northwest of cow pond and all along west edge of saddle; top in place approximately 25 yards northwest of pond and at north end of saddle; generally deeply leached, lichen covered. Thickness, direct measurement, maximum exposure 2.0'

19 Covered. Possible shale and thin limestone observed to north. Measured to top of unit 20 and subtracted thickness of that unit from interval to get thickness of unit 19. Thickness, approximately 2.5'

Note: Offset southward approximately 35 to 50 yards on top of unit 18.

18 Limestone; highly variable; base contains clay clasts and sparse rounded phosphate pebbles where exposed; generally fine- to medium-grained, mixed-skeletal, quartz-sandy calcarenite (grainstone) but locally contains some micrite (packstone); at northern part of exposures in saddle, unit is thinnest and contains *Osagia*-oncoliths throughout, the nuclei of some of which are fossils, others intraclasts; unit generally light gray, weathers moderate brownish gray. Thin- to medium-bedded, irregularly bedded, cross-bedded in part. Forms distinct bench and small cliff on west side of saddle of Kessler Mountain; weathers platy; partially slumped in all but a few places. Thickness, direct measurements, varies from 3.5 feet at north end to 8.0 feet on large slump block approximately 25 yards northwest of cow pond, averages on the outcrop 6'

17 Covered and shale: lower 15 feet and top 2 feet is quartz-silty shale with sparse shale talus in middle; unit contains scattered clay-ironstone concretions in lower part; weathers light olive gray. Upper contact sharp, undulating. Thickness measured down-dip with 2^{o} in Abney level, estimated 70'

16 Limestone; medium-grained, highly quartz-sandy, pelmatozoan calcarenite; moderate brownish gray, weathers same. Thin-bedded, irregularly bedded, cross-bedded. Forms distinct, well exposed bench north of creek on hillside, poorly exposed in creek, and very poorly exposed south of creek. Offset section on top of unit 35 yards eastward; described and measured on

	north side of ravine. Upper contact obscure. Attitude represents average of four readings on top of bed: strike N5°W, dip 2°E. Thickness	6'
15	Covered with minor quartz-silty shale talus in upper 5 feet in creek and minor siltstone talus 15 feet above base. Thickness measured north of creek using dip and strike offset method, using 3° dip, estimated	35'
14	Limestone; fine- to coarse-grained, pelmatozoan-bryozoan calcarenite (grainstone); medium gray, weathers moderate brownish gray. Thin-bedded, irregularly bedded, cross-bedded. Forms coal bench at barbed wire fence north of creek; weathers slabby, platy. Contacts covered. Attitude measured on top of bed: strike N15°W, dip 4°E. Approximate thickness	4.5'
	Note: Offset southward 30 feet on top of unit 13 to barbed wire fence north of creek.	
13	Limestone; coarse-grained, argillaceous calcilutite (wackestone); medium dark gray, weathers light grayish brown. Thin-bedded, irregularly bedded; nodular, interbedded with lamellae of shale. Poorly exposed north of creek and barbed wire fence; weathers smooth, forms rubbly slope. Thickness measured with 4° downdip, approximately	3.5'
12	Covered. Thickness measured by dip and strike-offset method to base of unit 13, using 4° in Abney level, approximately	12.5'
11	Limestone; fine- to medium-grained, pelmatozoan, bryozoan, micritic calcarenite (packstone); medium gray, weathers light brownish gray. Medium-bedded, irregularly bedded. Poorly exposed as small bench approximately 20 feet north of barbed wire fence on north side of creek. Thickness, direct measurement, maximum exposure	1.5'
10	Covered with possible shale and micritic limestones as indicated by talus. Thickness approximately	7'
9	Covered and shale: shale, highly quartz-silty; olive gray, weathers light olive gray. Thickly laminated, blocky. Unit exposed on hillside north of creek; shale exposed mostly as slump. Thickness measured downdip with 2.5° in Abney level, maximum exposure to top of shale talus	7'

HALE FORMATION

8 Limestone; medium-grained, quartz-sandy, pelmatozoan calcarenite (grainstone) with local patches of micrite (packstone); medium gray, weathers moderate grayish brown. Thick-bedded, irregularly bedded. Forms rounded bluff on hillside, usually badly slumped; best exposed on north side of creek approximately 20 to 30 yards; unit weathers by exfoliation, platy. Upper contact covered. Attitude measured on upper bed: strike N3°E, dip 2.5°E. Thickness, maximum exposure, approximately 9.5'

7 Covered and limestone: limestone; fine-grained, pelmatozoan, argillaceous calcilutite (wackestone to packstone); medium gray, weathers light brownish gray. Thin-bedded, irregularly bedded, nodular; interbedded with thin shale partings. Unit forms mostly covered bench on hillside with minor talus of quartz-silty shale; limestone mentioned above at base of large slump blocks of unit 8 exposed north of creek; sparse limestone itself is found slumped along hillside, but in blocks it occurs at base, and no more than 2 feet is exposed; may form upper 2 feet of unit. Thickness approximately 6.5'

Note: Offset north of creek 30 feet on top of unit 6.

6 Limestone and sandstone: limestone; medium-grained, micritic, quartz-sandy, mixed-skeletal calcarenite (packstone) at base, grading upward into medium-grained, calcite-cemented, submature, glauconite-bearing skeletal quartzarenite at top; medium gray, weathers light gray at base, weathers light brownish gray at top. Medium- to thin-bedded, irregularly bedded, minor cross-bedding at top. Exposed as waterfall in lower part, upper part poorly exposed in creek, but well exposed on south bank and north bank of creek. Thickness approximately 10'

5 Limestone; at base, medium-grained, highly quartz-sandy, oolitic calcarenite (grainstone), grading upward in middle into medium- to coarse-grained, quartz-sandy, pelmatozoan, mixed-skeletal, oolitic calcarenite (grainstone), and medium-grained, brachiopodal, micritic, mixed-skeletal calcirudite (packstone) at top; medium dark gray, weathers moderate brownish gray. Thin- to thick-bedded, irregularly bedded; basal 5 feet cross-laminated. Basal 5 feet and upper 4 feet

well exposed in creek; middle poorly exposed on north side of creek on hillside; basal portion weathers with quartz-sandy layers in relief, pitted; upper portion weathers smoothly. Upper contact exposed beneath waterfall in creek, and on hillside to north, sharp, undulating. Upper part highly fossiliferous. Thickness measured downdip with 2° in Abney level in creek, approximately 16'

Note: Offsect section 30 yards east-northeastward on top of unit 4 into ravine.

4 Limestone and sandstone: limestone; medium-grained, highly quartz-sandy, oolitic calcarenite (grainstone) to medium-grained, calcite-cemented, mature, oolitic, quartzarenite; light brownish gray, weathers same. Thin-bedded, irregularly bedded, cross-laminated. Forms massive bluff on hillside; weathers mainly by exfoliation; more quartz-sandy layers weather in relief. Upper contact sharp, even, distinctive and commonly recessed; can be traced 50 yards north and south around hillside on either side of creek. Thickness, direct measurement, measured on south side of creek, 10.0'

3 Covered. Measured on south side of creek with 2° downdip in Abney level, parallel to creek. Thickness approximately 13'

2 Shale and siltstone: shale, quartz-silty; medium dark gray, weathers moderate brownish gray. Thinly laminated, irregularly laminated; interlaminated with siltstone. Siltstone; fine-grained, clay-bonded, immature quartzsiltite; medium dark gray, weathers light grayish brown. Thickly laminated, regularly laminated, uneven; upper surfaces ripple-marked. Unit exposed mainly as talus above small bench formed by unit 1 immediately north of barbed wire fence south of creek. Thickness measured with strike to highest talus 2.5'

1 Siltstone; fine-grained, clay-bonded, immature quartzsiltite; dark grayish brown, weathers light grayish brown. Thin-bedded, irregularly bedded; upper surfaces ripple-marked, lower surfaces with casts of burrows and trails. Forms small, local bench on south side of creek on hillside. Upper contact covered. Attitude measured on lower surfaces of beds: N3°W, dip 2°E. Thickness, direct measurement 2.5'

0 Shale and siltstone: shale, quartz-silty; medium dark gray, weathers moderate brownish gray. Thinly

laminated, irregularly laminated; interlaminated with siltstone. Siltstone; fine-grained, clay-bonded, immature quartzsiltite; medium dark gray, weathers light grayish brown. Thickly laminated, regularly laminated, uneven; ripple marked. Unit well exposed on south side of wash, where it crops out in steep bank. Lower contact covered; upper contact obscure. Measured due southward up steep bank with 0° dip in Abney level. Thickness approximately 28'

Note: The black shales of the Fayetteville Formation are poorly exposed 50 to 75 yards downstream. The Pitkin Formation are poorly exposed 50 to 75 yards downstream. The Pitkin Formation is apparently not present, having probably been removed by pre-Morrowan erosion.

Locality M119: Evelyn Hills Shopping Center

Location.--NW¼, SW¼, NW¼, Sec. 10, T. 16N., R. 30W., Washington County, Arkansas. This collecting locality is exposed at the southern end of the Evelyn Hills Shopping Center at the intersection of U. S. Highway 71 (College Avenue) and Absher Road in the northern part of Fayetteville.

Stratigraphy.--This section was described by Quinn (1970, p. 186), who referred these strata to his unnamed middle Hale member. These strata should be assigned to the Prairie Grove Member of the Hale Formation. The Cane Hill Member is exposed in the lower part of the outcrops above the paved parking lot behind the IGA Grocery Store, and the calcilutites (mudstones) from which the brachiopods were collected occur in the lower part of the overlying member.

Remarks.--For additional discussion, see Quinn (1970, p. 186). Manger (1971, p. 175, 176) measured a stratigraphic section here.

Locality M121: Fayetteville Railroad Cut

Location.--NW¼, NW¼, NE¼, Sec. 16 and SW¼, SW¼, SE¼, Sec. 9, T. 16N., R. 30W., Washington County, Arkansas. The section is exposed in the eastern cut banks of the St. Louis and Southwestern Railroad between Maple and Lafayette Streets near the eastern edge of the University of Arkansas Campus, Fayetteville.

Stratigraphy.--The collection is from the basal part of the Prairie Grove Member of the Hale Formation. For a measured section, refer to Manger (1971, p. 172).

Remarks.--A collection of corals and brachiopods from this locality was given to P. K. Sutherland and the author by J. H. Quinn. This is the site of University of Arkansas L14 and L117 and U. S. G. S. localities 1603 and 8213.

APPENDIX II: LISTS OF BRACHIOPODS FROM STRATIGRAPHIC SECTIONS AND COLLECTING LOCALITIES

M1

LIMESTONE-SHALE MEMBER: *5*; *Orbiculoidea*? sp. B, *S. altirostris*, *Derbyia* n. sp. A, *Neochonetes*? n. sp. A, *Plicochonetes*? *arkansanus*, *K.*? *globosa*, *S. welleri*, *T. morrowensis*, *Linoproductus* n. sp. A, *R. magnicosta*, *H. miseri*, *S. goreii*, *A. matheri* (?), *S.*? *campestris*, *P. morrowensis*, *P. perplexa*. *6*; *S. oklahomae*, *S. altirostris*?, *Derbyia* n. sp. A, *Neochonetes*? n. sp. A, *P.*? *arkansanus*, *K.*? *globosa*, *Krotovia*? n. sp. A, *D. nambeensis*, *S. welleri*, *B. grandis*, *T. morrowensis*, *Linoproductus* n. sp. A, *R. magnicosta*, *H. miseri*, *C. milleri*, *S. goreii*, *Anthracospirifer* sp., *S.*? *campestris*. *8*; *S. altirostris*?, *Derbyia* n. sp. A, *Krotovia*? n. sp. A, *Sandia* cf. *S. welleri*, *Pulchratia*? n. sp. A, *T. morrowensis*, *Linoproductus* n. sp. A, *R. magnicosta*, *H. miseri*, *Anthracospirifer* sp., *S.*? *campestris*, *P. morrowensis*. BREWER BEND LIMESTONE: *10*; *A. matheri* (?), *S.*? *campestris*. GREENLEAF LIMESTONE: *18*; *S. goreii*. *19*; *S. oklahomae*, *N.*? *platynotus*, *S. welleri*, *S. goreii*. *20*; *S. oklahomae*, *N.*? *platynotus*, *S. welleri*, *P.*? *picuris*, *T. morrowensis*, *Hustedia* n. sp. A, *S. goreii*, *P. perplexa*. *21*; *P.*? *arkansanus*, *D. nambeensis*.

M3

LIMESTONE-SHALE MEMBER: *9*; *S. altirostris*?, *Derbyia* n. sp. A, *D. nambeensis*, *H. miseri*, *S. goreii*, *S.*? *campestris*, *P. morrowensis*. *10*; *S. altirostris*?, *H. miseri*, *S.*? *campestris*. *11*; *S.*, *campestris*. BREWER BEND LIMESTONE: *12*; *Orbiculoidea*? sp. B, *S. altirostria*?. *12*A; *T. morrowensis*, *H. miseri*, *S.*? *campestris*. *12*B; *H. miseri*. *12*C; *K.*? *globosa*, *D. nambeensis*, *W. triangularis*, *H. miseri*, *S.*? *campestris*, *Punctospirifer* cf. *P. morrowensis*. GREENLEAF LIMESTONE: *21*; *S.*? *campestris*.

M5

LIMESTONE-SHALE MEMBER: *13*; *S. oklahomae*, *Derbyia* n. sp. A, *Neochonetes*? n. sp. A, *P.*? *arkansanus*, *K.*? *globosa*, *Krotovia* n. sp. A, *D. nambeensis*, *T. morrowensis*, *Linoproductus* n. sp. A, *R. magnicosta*, *H. miseri*, *S. goreii*, *Anthracospirifer* sp. *15*; *Derbyia* n. sp. A, *P.*? *arkansanus*, *D.*

nambeensis, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, H. miseri, S. goreii, Anthracospirifer sp., Beecheria n. sp. A (?). *16*; Derbyia n. sp. A, Anthracospirifer sp. BREWER BEND LIMESTONE: *17*; Pulchratia? n. sp. A (?), T. morrowensis, Linoproductus n. sp. A.

M12

LIMESTONE-SHALE MEMBER: *8*; S. oklahomae, S. altirostris?, Derbyia n. sp. A, Plicochonetes? arkansanus, K.? globosa, D. nambeensis, B. grandis, Linoproductus cf. L. pumilus, R. magnicosta, H. miseri, Anthracospirifer sp., S.? campestris, P. morrowensis, Punctospirifer? n. sp. A. *9*; D. nambeensis.

M14

LIMESTONE-SHALE MEMBER: *6* or *7*; Beecheria n. sp. A. *8* & *9*; T. morrowensis, R. magnicosta (?), P. morrowensis. *9*; K.? globosa, D. nambeensis, Sandia cf. S. welleri.

M16

LIMESTONE-SHALE MEMBER: *1*; S. welleri (?), S.? campestris, P. morrowensis (?), Punctospirifer? sp.

M17

CHISUM QUARRY MEMBER: *9*; Derbyia sp., S. welleri, Tesuquea cf. T. morrowensis, A. curvilateralis, Spiriferellina? cf. S.? campestris, B. stehlii. *11*; Sandia cf. S. welleri. *11* & *12*; Tesuquea cf. T. morrowensis, Linoproductus cf. L. n. sp. A, A. curvilateralis. *13*; S. oklahomae, Tesuquea cf. T. morrowensis, Hustedia cf. H. miseri, S.? campestris. *14*; S. oklahomae, P.? picuris, Tesuquea cf. T. morrowensis, A. curvilateralis, S.? campestris. *14* & *15*; Sandia cf. S. welleri, Tesuquea cf. T. morrowensis, A. curvilateralis. *14* through *17*; Linoproductus cf. L. nodosus, Punctospirifer cf. P. morrowensis. *15* & *16*; Tesuquea cf. T. morrowensis, R. magnicosta, A. curvilateralis, S.? campestris. *17* & *18*; Tesuquea cf. T. morrowensis.

M18

BREWER BEND LIMESTONE: *3*; T. morrowensis. *3* through *5*; Sandia cf. S. welleri. *5*; Punctospirifer cf. P. morrowensis. *13*; Sandia cf. S. welleri.

M19

CHISUM QUARRY MEMBER: *5*; S. goreii.

M22

LIMESTONE-SHALE MEMBER: *7*; S. welleri, T. morrowensis, R. magnicosta, S. goreii. *11*; T. morrowensis, R. magnicosta, H. miseri, S. goreii, S.? campestris.

M23

LIMESTONE-SHALE MEMBER: *3C*; P. arkansanus, T. morrowensis, P. morrowensis. *4*; S. altirostris?, Derbyia n. sp. A (?), D. nambeensis, Neochonetes n. sp. A, Sandia cf. S. welleri, Pulchratia? n. sp. A, T. morrowensis, H. miseri, S. goreii, Anthracospirifer sp., S.? campestris, P. morrowensis. BREWER BEND LIMESTONE: *6*; Sandia cf. S. welleri, Pulchratia? n. sp. A, A. matheri.

M24

LIMESTONE-SHALE MEMBER: *10*; Derbyia n. sp. A (?), W. triangularis, H. miseri. BREWER BEND LIMESTONE: *12*; Neochonetes? n. sp. A, Pulchratia? n. sp. A, W. triangularis, H. miseri, Anthracospirifer sp., S.? campestris, P. morrowensis. CHISUM QUARRY MEMBER: *14*; T. morrowensis, R. magnicosta, Hustedia n. sp. A.

M25

LIMESTONE-SHALE MEMBER: *5*; T. morrowensis. *7*; Beecheria n. sp. A (?). *8*; S. welleri. *7*; S. altirostris?, Pulchratia? n. sp. A (?), Anthracospirifer sp. *8*; Anthracospirifer sp. *11*; T. morrowensis, S. goreii.

M26

LIMESTONE-SHALE MEMBER: *1*; W. triangularis, H. miseri, Anthracospirifer sp., P. perplexa. *3*; S. welleri, Anthracospirifer sp. *5*; T. morrowensis, Linoproductus n. sp. A, A. matheri (?). *6*; Neochonetes? n. sp. A, Sandia cf. S. welleri, T. morrowensis, S.? campestris (?), P. perplexa. *7*; S. altirostris?, Derbyia n. sp. A (?), Neochonetes? n. sp. A, Echinaria n. sp. A, Pulchratia? n. sp. A, T. morrowensis, A. matheri, S.? campestris (?), P. perplexa. *8*; A. matheri. *9*; Derbyia n. sp. A, Neochonetes n. sp. A, P.? arkansanus, K.? globosa, Sandia cf. S. welleri, Echinaria n. sp. A, Pulchratia? n. sp. A, T. morrowensis, H. miseri, C. milleri,

S. goreii, Anthracospirifer sp., S.? campestris, P. perplexa. *10*; Sandia cf. S. welleri, Pulchratia? n. sp. A, T. morrowensis. *14*; Neochonetes? n. sp. A, P.? arkansanus, Sandia cf. S. welleri. *17*; S. welleri, S. goreii, P. perplexa. BREWER BEND LIMESTONE: *19*; Neochonetes? n. sp. A. CHISUM QUARRY MEMBER: *23*; S. oklahomae, S. altirostris?, Derbyia sp., P.? arkansanus, K.? globosa, D. nambeensis, S. welleri, Echinaria n. sp. A, P.? picuris, T. morrowensis, L. pumilus, R. magnicosta, Hustedia cf. H. miseri, C. milleri, S. goreii, A. curvilateralis, S.? campestris, P. morrowensis, P. perplexa, B. stehlii. GREENLEAF LIMESTONE: *26*; O. minuta.

M27

LIMESTONE-SHALE MEMBER: *7*; K.? globosa, S. welleri, Pulchratia? n. sp. A (?), T. morrowensis, Linoproductus n. sp. A. *8*; S. welleri, B.? bilobatum. *8A*; T. morrowensis. *8B*; Neochonetes? n. sp. A, P.? arkansanus, K.? globosa. CHISUM QUARRY MEMBER: *13*; N.? platynotus, Echinaria n. sp. A, R. magnicosta, S. goreii. *14*; S. oklahomae, N.? platynotus, Tesuquea cf. T. morrowensis, Hustedia cf. H. miseri, S. goreii, P. morrowensis. GREENLEAF LIMESTONE: *16*; K.? globosa, D. nambeensis, P.? picuris, T. morrowensis, L. nodosus (?), L. pumilus, Hustedia n. sp. A, S. goreii, A. curvilateralis.

M28

LIMESTONE-SHALE MEMBER: *4*; S. altirostris?. *5*; Derbyia n. sp. A, Anthracospirifer sp., Beecheria n. sp. A. BREWER BEND LIMESTONE: *8*; Pulchratia? n. sp. A, T. morrowensis, Anthracospirifer sp. *8A*; Linoproductus n. sp. A. *8B*; S. oklahomae, S. altirostris?. CHISUM QUARRY MEMBER: *10*; S. welleri, P.? picuris, T. morrowensis, S. goreii, B. stehlii. *11*; N.? platynotus, P.? arkansanus, K.? globosa, P.? picuris, Linoproductus cf. L. n. sp. A, Hustedia cf. H. miseri, S. goreii, A. curvilateralis, P. morrowensis. *12*; S. oklahomae, T. morrowensis, R. magnicosta. GREENLEAF LIMESTONE: *14*; D. nambeensis, S. welleri, P.? picuris, T. morrowensis, S. goreii, A. curvilateralis, S.? campestris.

M29

LIMESTONE-SHALE MEMBER: *A*; Anthracospirifer sp. *1*; S. altirostris?, Echinaria n. sp. A, T. morrowensis, H. miseri, A. matheri. *2*; Echinaria n. sp. A, T. morrowensis, A. matheri, Punctospirifer cf. P. morrowensis. *4*; K.? globosa, Pulchratia? n. sp. A, T. morrowensis, R. magnicosta, H. miseri, A. matheri. *6*; A. matheri (?). BREWER BEND LIMESTONE: *9*; S. oklahomae, S. altirostris?. CHISUM QUARRY MEMBER: *10*; Orbiculoidea sp. A, Derbyia? sp., N.? platynotus, Echinaria n. sp. A, T. morrowensis, Linoproductus cf. L. n. sp. A, L. pumilus. *11*; Orbiculoidea sp. A, N.? platynotus, R. magnicosta. SHALE "A" MEMBER: *14*; P.? arkansanus, D. nambeensis, S. welleri, P.? picuris, B. grandis, T. morrowensis, L. pumilus, S. goreii. GREENLEAF LIMESTONE: *15*; D. nambeensis, L. nodosus.

M31

LIMESTONE-SHALE MEMBER: *1*; Desmoinesia cf. D. nambeensis, T. morrowensis, Linoproductus n. sp. A, A. matheri, S.? campestris (?), Beecheria n. sp. A. *4*; S. altirostris?, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, H. miseri, Punctospirifer cf. P. morrowensis. *5*; P.? arkansanus, K.? globosa, D. nambeensis, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, Anthracospirifer sp., S.? campestris. *7*; A. matheri(?). *8*; T. morrowensis, A. matheri. BREWER BEND LIMESTONE: *12C*; P.? arkansanus, K.? globosa, S. welleri, Pulchratia? n. sp. A, Anthracospirifer sp., Beecheria n. sp. A. CHISUM QUARRY MEMBER: *17*; T. morrowensis, P. morrowensis. *19*; L. pumilus.

M33

LIMESTONE-SHALE MEMBER: *1*; R. magnicosta. BREWER BEND LIMESTONE: *4C*; Neochonetes? n. sp. A, K.? globosa, T. morrowensis, H. miseri, A. matheri (?), S.? campestris. CHISUM QUARRY MEMBER: *6*; T. morrowensis, R. magnicosta, S. goreii. *6C*; Derbyia n. sp. A (?), Linoproductus cf. L. nodosus, S.? campestris. GREENLEAF LIMESTONE: *11*; S. altirostris?, D. nambeensis, T. morrowensis, L. pumilus, S. goreii, A. curvilateralis.

M34

LIMESTONE SHALE MEMBER: *1*; R. magnicosta. *3*; Derbyia n. sp. A (?). *7*; Orbiculoidea? sp. B, S. welleri, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp. *8*; T. morrowensis. BREWER BEND LIMESTONE: *11*; T. morrowensis, Linoproductus n. sp. A, S.? campestris. campestris. CHISUM QUARRY MEMBER: *15*; Derbyia? sp., S. welleri, P.? picuris, T. morrowensis, Linoproductus cf. L. nodosus, R. magnicosta, A. curvilateralis, B. stehlii.

M35

LIMESTONE SHALE MEMBER: *2*; D. nambeensis, Echinaria n. sp. A, T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp. *4*; Rimagnicosta, S. goreii. *6*; K.? globosa. BREWER BEND LIMESTONE: *7*; D. nambeensis, T. morrowensis, Anthracospirifer sp. CHISUM QUARRY MEMBER: *8*; S. oklahomae, K.? globosa, S. welleri, T. morrowensis, S. goreii. *9*; S. oklahomae. GREENLEAF LIMESTONE: *11*; Derbyia sp., D. nambeensis, T.

morrowensis, S. goreii, A. curvilateralis. *11*A talus; S. oklahomae, S. welleri.

M36

LIMESTONE-SHALE MEMBER: *5*; Echinaria n. sp. A (?). *6*A; Desmoinesia cf. D. nambeensis, T. morrowensis, R. magnicosta, H. miseri. BREWER BEND LIMESTONE: *6*B; S. oklahomae, K.? globosa, Desmoinesia cf. D. nambeensis, Linoproductus n. sp. A, S. goreii. CHISUM QUARRY MEMBER: *7*; T. morrowensis, Linoproductus cf. L. n. sp. A. SHALE "A" MEMBER: *10*B; Derbyia sp., S. oklahomae, S. welleri, T. morrowensis, Hustedia n. sp. A, S.? campestris.

M37

LIMESTONE-SHALE MEMBER: *5*; P. arkansanus, Sandia cf. S. welleri, R. magnicosta, H. miseri, A. matheri (?). *8*; T. morrowensis, R. magnicosta, Beecheria n. sp. A. BREWER BEND LIMESTONE: *9*; Derbyia n. sp. A, P.? arkansanus. CHISUM QUARRY MEMBER: *10*; K.? globosa, Krotovia? n. sp. A, D. nambeensis, S. welleri, P.? picuris, T. morrowensis, Linoproductus cf. L. nodosus, L. pumilus, R. magnicosta. *11*; T. morrowensis.

M39

LIMESTONE-SHALE MEMBER: *2*; Sandia cf. S. welleri, Echinaria n. sp. A, Linoproductus n. sp. A. *4*; S. oklahomae, Derbyia? n. sp. A, Neochonetes n. sp. A, P.? arkansanus, D. nambeensis (?), Sandia cf. S. welleri, Echinaria n. sp. A, T. morrowensis, Linoproductus n. sp. A, C. milleri, P. perplexa. *5*; Neochonetes? n. sp. A. *6*; Desmoinesia cf. D. nambeensis, R. magnicosta, H. miseri, Anthracospirifer sp. BREWER BEND LIMESTONE: *7*; P.? arkansanus, Sandia cf. S. welleri, T. morrowensis, H. miseri, A. matheri, S.? campestris. LIMESTONE-SHALE MEMBER; *10*; Derbyia n. sp. A, Derbyia? sp., T. morrowensis. BREWER BEND LIMESTONE: *13*; P. morrowensis, Beecheria n. sp. A. *14*; Derbyia n. sp. A (?), Sandia cf. S. welleri, T. morrowensis, Linoproductus n. sp. A, H. miseri, Anthracospirifer sp., Punctospirifer cf. P. morrowensis. *15*; Anthracospirifer sp.

M40

LIMESTONE-SHALE MEMBER: *9*; Derbyia n. sp. A. *10*; S. goreii. *12*; H. miseri. *15*; S. altirostris?, D. nambeensis, S. welleri, H. miseri, A. matheri, S.? campestris, P. morrowensis. BREWER BEND LIMESTONE: *17*; T. morrowensis, H. miseri, A. matheri (?), S.? campestris, P. morrowensis. CHISUM QUARRY MEMBER: *18*; T. morrowensis, R. magnicosta. *18*A; P.?

arkansanus, D. nambeensis, Linoproductus cf. L. n. sp. A, Hustedia cf. H. miseri.

M42

CHISUM QUARRY MEMBER: *15*; S. welleri, T. morrowensis, R. magnicosta.

M43

LIMESTONE-SHALE MEMBER: *4*; S. oklahomae. *6*; S. oklahomae, S. altirostris?, H. miseri, S.? campestris. *7*; Schuchertella? n. sp. A, Sandia cf. S. welleri, T. morrowensis, H. miseri, S.? campestris, P. morrowensis. BREWER BEND LIMESTONE: *12*; Pulchratia? n. sp. A (?), T. morrowensis, Linoproductus n. sp. A. CHISUM QUARRY MEMBER: *15*; S. oklahomae, Derbyia sp., S. welleri, T. morrowensis, R. magnicosta, Hustedia n. sp. A, P. morrowensis, Beecheria cf. B. stehlii. *15* & *16*; P.? picuris, T. morrowensis, S. goreii. *16*; S. oklahomae, P.? picuris, T. morrowensis, R. magnicosta, Hustedia n. sp. A, S.? campestris, P. morrowensis. *18*; D. nambeensis, T. morrowensis, R. magnicosta, S. goreii, A. curvilateralis, Beecheria cf. B. stehlii. GREENLEAF LIMESTONE: *21*; S. oklahomae, P.? arkansanus, D. nambeensis, P.? picuris (?), A. curvilateralis.

M47

BREWER BEND LIMESTONE: *11*; S. welleri, S.? campestris (?).

M48

LIMESTONE SHALE MEMBER: *0*A; Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, Desmoinesia cf. D. nambeensis, Sandia cf. S. welleri, T. morrowensis, R. magnicosta, H. miseri, S. goreii. *6*; P.? arkansanus. BREWER BEND LIMESTONE: *9*; S. welleri, Linoproductus n. sp. A. SHALE "A" MEMBER: *13*; S. oklahomae, Derbyia sp., P.? picuris, Hustedia n. sp. A, S. goreii. *13* to *15*; S. oklahomae, Derbyia sp., T. morrowensis. *15*; D. nambeensis, S. welleri, Echinaria n. sp. A (?), P.? picuris, L. pumilus, S. goreii, A. curvilateralis, S.? campestris.

M49

LIMESTONE SHALE MEMBER: *3*; S. altirostris?, S. welleri, Echinaria n. sp. A, T. morrowensis, Linoproductus n. sp. A, Beecheria n. sp. A, B.? bilobatum. *5*; Anthracospirifer sp. (?). *6*; S. oklahomae, S. altirostris?, T. morrowensis, Linoproductus n. sp. A, A. matheri (?). ; S. altirostris?, K.? globosa, Echinaria n. sp. A, Pulchratia? n. sp. A, B. grandis, T.

morrowensis, Linoproductus n. sp. A, A. matheri, P. morrowensis. *10*; O. minuta, Derbyia n. sp. A, Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, S. welleri, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, H. miseri, S. goreii, Anthracospirifer sp., S.? campestris, Beecheria n. sp. A (?). *12*; O. minuta. CHISUM QUARRY MEMBER: *18*; S. oklahomae, S. welleri, P.? picuris, T. morrowensis, B. stehlii. *19*; O. minuta.

M51

LIMESTONE SHALE MEMBER: *7* (7 feet above base); S. altirostris?, S. welleri, Pulchratia? n. sp. A, T. morrowensis, A. matheri. *7* (23 feet above base); Orbiculoidea? sp. B, S. altirostris?, P.? arkansanus, S. welleri, Pulchratia? n. sp. A, Linoproductus n. sp. A, A. matheri, P. perplexa, Beecheria n. sp. A. *7* (25 to 26 feet above base); S. oklahomae (?), S. altirostris?, S. welleri, T. morrowensis, H. miseri, S.? campestris, P. morrowensis (?), P. perplexa, Beecheria n. sp. A. *7* (29 to 30 feet above base); S. altirostris?, Echinaria n. sp. A, Pulchratia? n. sp. A, T. morrowensis, A. matheri. *7* (37 feet above base); Orbiculoidea sp. A, S. altirostris?. *7* (top); S. altirostris?, S. goreii. *14*A; S. welleri. *14*B; O. minuta. *15*; S. oklahomae, Schuchertella? n. sp. A, Derbyia n. sp. A, Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, Desmoinesia cf. D. nambeensis, S. welleri, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, H. miseri, C. milleri, S. goreii, A. matheri (?), S.? campestris, P. morrowensis, Punctospirifer? n. sp. A, P. perplexa. *16*; S. goreii. BREWER BEND LIMESTONE: *20*; T. morrowensis. GREENLEAF LIMESTONE: *25*; O. minuta, S. oklahomae, P.? arkansanus, D. nambeensis, S. welleri, P.? picuris, B. grandis, T. morrowensis, L. nodosus, L. pumilus, Hustedia n. sp. A, A. curvilateralis, S.? campestris, B. stehlii.

M53

LIMESTONE SHALE MEMBER: *3*; S. welleri, T. morrowensis, R. magnicosta, H. miseri. GREENLEAF LIMESTONE: *17*; Derbyia? sp.

Loc. M56

LIMESTONE-SHALE MEMBER: S. altirostris?, Derbyia sp., K.? globosa, Echinaria n. sp. A.

Loc. M56A

LIMESTONE-SHALE MEMBER: Neochonetes? n. sp. A, Echinaria n. sp. A, Pulchratia? n. sp. A, Linoproductus n. sp. A.

M60

LIMESTONE-SHALE MEMBER: *15*; Derbyia? sp., T. morrowensis, Linoproductus n. sp. A, R. magnicosta. *16*; Derbyia sp., P.? arkansanus, S. goreii. *17*; T. morrowensis, S.? campestris. CHISUM QUARRY MEMBER: *19*; P.? picuris. GREENLEAF LIMESTONE: *21*; Orbiculoidea? sp. B, P.? arkansanus, S. welleri, B. grandis, A. coloradoensis, L. nodosus, Hustedia,n. sp. A, A. curvilateralis, P. perplexa, B. stehlii. *22*; S. welleri, A. curvilateralis.

M61

LIMESTONE-SHALE MEMBER: *1*; S. altirostris?, H. miseri, A. matheri. *6*; S. altirostris?, P.? arkansanus, Desmoinesia cf. D. nambeensis, T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp., S.? campestris. *7*; Pulchratia? n. sp. A, Anthracospirifer sp. CHISUM QUARRY MEMBER: *9*; S. oklahomae, P.? arkansanus, Desmoinesia cf. D. nambeensis, T. morrowensis, R. magnicosta, S. goreii, P. perplexa.

M62

LIMESTONE-SHALE MEMBER: *21*; Linoproductus n. sp. A, P. perplexa. CHISUM QUARRY MEMBER: *23*; S. oklahomae, S. altirostris?, Derbyia sp., K.? globosa, S. welleri, Echinaria n. sp. A, P.? picuris, T. morrowensis, A. curvilateralis, B. stehlii.

M63

LIMESTONE-SHALE MEMBER: *9*; S. altirostris?, Linoproductus n. sp. A. *12*; Anthracospirifer sp. *13*; O. minuta, Sandia cf. S. welleri, Pulchratia? n. sp. A (?), T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp. *15*; T. morrowensis. *16*; Desmoinesia cf. D. nambeensis. *17*; O. minuta, T. morrowensis. BREWER BEND LIMESTONE: *18*; Sandia cf. S. welleri, Anthracospirifer sp. *19*; S. oklahomae, Sandia cf. S. welleri, Pulchratia? n. sp. A (?), T. morrowensis. CHISUM QUARRY MEMBER: *20*; S. altirostris?, P.? arkansanus, S. welleri, T. morrowensis, Linoproductus cf. L. n. sp. A. *22*; O. minuta.

M64

LIMESTONE SHALE MEMBER: *6*; S. altirostris, S. welleri, Pulchratia? n. sp. A, R. magnicosta, A. matheri. *8*; Derbyia n. sp. A (?), Desmoinesia cf. D. nambeensis, Pulchratia n. sp. A (?), T. morrowensis, Linoproductus n. sp. A, R. magnicosta, H. miseri, S. goreii, A. matheri (?), S.? campestris. *11*; Derbyia n. sp. A (?), Neochonetes? n. sp. A, D.

nambeensis, S. welleri, T. morrowensis, Linoproductus n. sp. A, H. miseri, A. matheri, S.? campestris. BREWER BEND LIMESTONE: *13*; T. morrowensis.

M65

LIMESTONE-SHALE MEMBER: *3*; Orbiculoidea sp. A, S. altirostris?, Anthracospirifer sp. *6*; S. altirostris?, Anthracospirifer sp. *8*; Pulchratia? n. sp. A. *11*; S. welleri. *12*; A. matheri (?). *14*; Orbiculoidea S. altirostris?, Derbyia n. sp. A, P.? arkansanus, K.? globosa, S. welleri, T. morrowensis, A. matheri.

M68

PRAIRIE GROVE MEMBER: *7*; S. altirostris?, Anthracospirifer sp. BRENTWOOD LIMESTONE: *12*; O. minuta, S. altirostris?, Pulchratia? n. sp. A, T. morrowensis, A. matheri, Beecheria n. sp. A. *13*; Echinaria n. sp. A. *16*; K.? globosa (?), A. matheri. *17*; S. welleri, T. morrowensis, H. miseri, Anthracospirifer sp. *17* & *18*; Pulchratia? n. sp. A, Linoproductus n. sp. A. *18*; S. altirostris?, S. welleri, T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp. Beecheri n. sp. A. *21*; Derbyia n. sp. A (?), S. welleri, T. morrowensis, R. magnicosta, H. miseri, S. goreii, Anthracospirifer sp., S.? campestris. *25*; S. oklahomae, P.? arkansanus, K.? globosa, S. welleri, Echinaria n. sp. A, Pulchratia? n. sp. A, T. morrowensis, R. magnicosta, S. goreii, Anthracospirifer sp. KESSLER LIMESTONE: *27*; S. oklahomae, S. welleri, B. grandis, T. morrowensis, L. nodosus.

M69

PRAIRIE GROVE MEMBER (equivalents): *13*; Derbyia? sp., H. miseri, Anthracospirifer sp. BRENTWOOD LIMESTONE (equivalents): *17*; Linoproductus cf. L. n. sp. A. *18*; Linoproductus n. sp. A, Anthracospirifer sp. *19*; S. altirostris?, S. welleri, T. morrowensis, H. miseri, S.? campestris. KESSLER LIMESTONE: *27*B; O. minuta, S. altirostris?, Meekella n. sp. A, S. welleri, P.? picuris, A. coloradoensis (?), L. nodosus, Hustedia n. sp. A, A. curvilateralis. TRACE CREEK SHALE: *31*; S. goreii, A. curvilateralis.

M70

PRAIRIE GROVE MEMBER: *8*; S. oklahomae, S. altirostris?, Neochonetes? n. sp. A, S. welleri, W. triangularis, Anthracospirifer sp., P. perplexa. *10*A; Echinaria n. sp. A. BRENTWOOD LIMESTONE: *10*B; T. morrowensis, Anthracospirifer sp. *12*; L. carbonaria, S. altirostris?, S. welleri, Pulchratia? n. sp. A, B. grandis, T. morrowensis, R. magnicosta, H. miseri, Anthracospirifer sp., P. morrowensis, P. perplexa. *13*; T.

morrowensis, H. miseri. *15*; Orbiculoidea sp. A, Derbyia n. sp. A, P.? arkansanus, S. goreii. *16*; K.? globosa, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp. DYE SHALE MEMBER ("caprock"): *20*; T. morrowensis. KESSLER LIMESTONE: *24*; P.? picuris, L. nodosus. *25*; S. oklahomae.

M72

LIMESTONE-SHALE MEMBER: *2D*; T. morrowensis. *4A*; O. minuta, T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp. *4B*; O. minuta.

Loc. M76

LIMESTONE-SHALE MEMBER: B.? bilobatum.

Loc. M76A

LIMESTONE-SHALE MEMBER: S. oklahomae, S. altirostris?, R. trapezoida, Derbyia n. sp. A, Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, Krotovia? n. sp. A, R. magnicosta, H. miseri, C. milleri, S.? campestris, P. morrowensis.

Loc. M77

LIMESTONE-SHALE MEMBER: S. oklahomae, S.? campestris.

M78

LIMESTONE-SHALE MEMBER: *18*; O. minuta. *38*; S. altirostris?, Derbyia n. sp. A, K.? globosa, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, H. miseri, S.? campestris, P. morrowensis. *39*; T. morrowensis, R. magnicosta, P. morrowensis. BREWER BEND LIMESTONE: *43*; Sandia cf. S. welleri, T. morrowensis, Anthracospirifer sp. CHISUM QUARRY MEMBER: *44*; N.? platynotus. GREENLEAF LIMESTONE: *47*; P.? picuris, B. stehlii.

M79

LIMESTONE-SHALE MEMBER: *6*; S. altirostris?, Echinaria n. sp. A, Pulchratia? n. sp. A, H. miseri.

Loc. M83A

LIMESTONE-SHALE MEMBER: Derbyia n. sp. A, Neochonetes? n. sp. A, P.? arkansanus, Sandia cf. S. welleri, Pulchratia? n. sp. A, Linoproductus n. sp. A, R. magnicosta, H. miseri, S. goreii, S.? campestris, P. morrowensis, Beecheria cf. B. n. sp. A.

M85

LIMESTONE-SHALE MEMBER: *4*; O. minuta, Echinaria n. sp. A, T. morrowensis, Linoproductus n. sp. A. *8*; S. oklahomae, T. morrowensis.

Loc. M87

LIMESTONE-SHALE MEMBER: Derbyia n. sp. A (?), Echinaria n. sp. A, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, Anthracospirifer sp., S.? campestris.

Loc. M94

LIMESTONE-SHALE MEMBER (?): P. morrowensis, Punctospirifer? n. sp. A, B.? bilobatum.

M95

LIMESTONE-SHALE MEMBER: *3*; S. oklahomae (?), Derbyia? n. sp. A, K.? globosa, H. miseri, Anthracospirifer sp., S.? campestris, P. morrowensis. *5*; Derbyia n. sp. A (?), Neochonetes? n. sp. A, H. miseri, C. milleri, S.? campestris, P. morrowensis, Punctospirifer? n. sp. A. BREWER BEND LIMESTONE: *7*; S. altirostris?, Desmoinesia cf. D. nambeensis, Sandia cf. S. welleri, Pulchratia? n. sp. A (?), H. miseri, Anthracospirifer sp., S.? campestris. CHISUM QUARRY MEMBER: *10*; L. nodosus, A. curvilateralis.

Loc. M96

LIMESTONE-SHALE MEMBER: Sandia cf. S. welleri.

M97

LIMESTONE-SHALE MEMBER: *5*; L. carbonaria, Orbiculoidea sp. A, S. oklahomae, S. altirostris?, R. trapezoida, Derbyia n. sp. A, Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, D. nambeensis, Sandia cf. S.

welleri, T. morrowensis, R. magnicosta, C. milleri, S. goreii, S.? campestris, P. morrowensis, Beecheria cf. B. n. sp. A. *5* or *6*; R. magnicosta. *6* or *8*; P.? arkansanus, Sandia cf. S. welleri, A. matheri. *8*; Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, Desmoinesia cf. D. nambeensis, Sandia cf. S. welleri, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, H. miseri, S. goreii, S.? campestris, P. morrowensis. *9*; S. oklahomae, Derbyia n. sp. A, D. nambeensis, Sandia cf. S. welleri, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, H. miseri, S. goreii, S.? campestris, P. morrowensis. *10*; Derbyia n. sp. A (?). BREWER BEND LIMESTONE: *11*; Derbyia n. sp. A (?), H. miseri, S.? campestris, P. morrowensis. CHISUM QUARRY MEMBER: *13*; T. morrowensis.

M98

BREWER BEND LIMESTONE: *6* or *9*; Sandia cf. S. welleri, Pulchratia? n. sp. A (?). *7*; S. oklahomae, Derbyia n. sp. A. CHISUM QUARRY MEMBER: *11*; S. goreii. GREENLEAF LIMESTONE: *13*; S. oklahomae, Derbyia sp., D. nambeensis, S. welleri, P.? picuris, B. grandis, T. morrowensis, L. pumilus, Zia cf. Z. novamexicana, Hustedia n. sp. A, S. goreii, A. curvilateralis.

M98A

BREWER BEND LIMESTONE: *7*; T. morrowensis, Punctospirifer cf. P. morrowensis.

M98B

BREWER BEND LIMESTONE: *2*; Sandia cf. S. welleri, S. goreii.

M98C

BREWER BEND LIMESTONE: *7*; Sandia cf. S. welleri, R. magnicosta, H. miseri, S. goreii, Anthracospirifer sp., P. morrowensis.

Loc. M98D

LIMESTONE SHALE MEMBER: Derbyia n. sp. A, Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, D. nambeensis, Sandia cf. S. welleri, Pulchratia? n. sp. A, T. morrowensis, R. magnicosta, H. miseri, S. goreii, S.? campestris, P. morrowensis.

M99

GREENLEAF LIMESTONE: *2*; S. welleri, B. grandis, T. morrowensis, S. goreii.

M100

PRAIRIE GROVE MEMBER: *3*; Derbyia(?) sp., K.? globosa, D. nambeensis (?), T. morrowensis. *5*; Derbyia n. sp. A (?), Pulchratia? n. sp. A, T. morrowensis, A. matheri. *6*; S. altirostris?, Derbyia n. sp. A, Neochonetes? n. sp. A, K.? globosa, T. morrowensis, R. magnicosta, H. miseri, A. matheri (?), P. perplexa. *7* (base); R. magnicosta.—BRENTWOOD LIMESTONE: *9*; Desmoinesia cf. D. nambeensis, Pulchratia? n. sp. A, T. morrowensis, Hustedia cf. H. miseri, A. matheri. *10*; T. morrowensis. *11*; Orbiculoidea sp. A. S. oklahomae, S. altirostris?, Derbyia n. sp. A, K.? globosa, Sandia cf. S. welleri, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, R. magnicosta, A. matheri, P. morrowensis, Beecheria n. sp. A. DYE SHALE MEMBER ("caprock"): *18*; T. morrowensis. KESSLER LIMESTONE: *25*; S. altirostris?, T. morrowensis.

M101

PRAIRIE GROVE MEMBER: *1*; Derbyia n. sp. A (?), Pulchratia? n. sp. A, Linoproductus n. sp. A, S.? campestris. *3*; S. altirostris?, Derbyia n. sp. A, K.? globosa, T. morrowensis, A. matheri, P. perplexa, Beecheria n. sp. A. *4*; S.? campestris. *5*; Derbyia n. sp. A (?). *6*; Derbyia n. sp. A (?), T. morrowensis, A. matheri, P. perplexa. *7*; Derbyia n. sp. A, Echinaria n. sp. A, T. morrowensis, Linoproductus n. sp. A, A. matheri, P. perplexa. BRENTWOOD LIMESTONE: *9*; K.? globosa. *14*; Beecheria n. sp. A (?). *15*; Derbyia n. sp. A, T. morrowensis, A. matheri. *16*; Derbyia n. sp. A (?), T. morrowensis, Hustedia cf. H. miseri, P. perplexa. *19*; S. altirostris?, Derbyia n. sp. A, D. nambeensis, Sandia cf. S. welleri, Pulchratia? n. sp. A, Linoproductus n. sp. A, R. magnicosta, A. matheri, P. perplexa.

M102

BRENTWOOD LIMESTONE: *6*; Derbyia n. sp. A. *8*; S. altirostris?, Pulchratia? n. sp. A (?), P. perplexa. *9*; S. altirostris?, Pulchratia? n. sp. A, Hustedia cf. H. miseri, Anthracospirifer sp., S.? campestris, P. morrowensis. *11*; T. morrowensis.

M103

PRAIRIE GROVE MEMBER: *14*; Derbyia? n. sp. B., S. welleri, Echinaria n. sp. A, T. morrowensis, Linoproductus n. sp. A, W. triangularis, A. matheri, S.? campestris (?), P. perplexa.

M104A

PRAIRIE GROVE MEMBER: *10*; S. altirostris?, P. perplexa.

M104B

PRAIRIE GROVE MEMBER: *5*; T. morrowensis. BRENTWOOD LIMESTONE: *11*; Pulchratia? n. sp. A (?), T. morrowensis, Anthracospirifer sp. *15*; B. grandis. *17*; Orbiculoidea sp. A, S. altirostris?, Sandia cf. S. welleri, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, Anthracospirifer sp. DYE SHALE MEMBER ("caprock"): *19*; S. welleri, T. morrowensis, Hustedia n. sp. A, A. curvilateralis, S.? campestris, P. morrowensis. KESSLER LIMESTONE: *23*; P.? picuris, B. grandis, L. nodosus, S. goreii, A. curvilateralis, B. stehlii. *24*; P.? picuris, L. nodosus, A. curvilateralis, B. stehlii. *26*; Derbyia? sp., P.? picuris, Zia cf. Z. novamexicana, A. curvilateralis.

M104C

BRENTWOOD LIMESTONE: B; T. morrowensis. KESSLER LIMESTONE: *1*; S. welleri, L. nodosus, A. curvilateralis.

M105A

CANE HILL MEMBER: *3*; S. altirostris?, Derbyia? n. sp. B, S. welleri, Echinaria n. sp. A, B. grandis, T. morrowensis, Linoproductus n. sp. A, A. matheri, P. perplexa.

M105C

PRAIRIE GROVE MEMBER: *4*; S. altirostris?, T. morrowensis, Linoproductus n. sp. A, A. matheri, P. morrowensis, P. perplexa, B.? bilobatum. BRENTWOOD LIMESTONE: *6*; S. altirostris?, H. miseri, P. perplexa. *8*; D. nambeensis (?). *10*; P.? arkansanus, D. nambeensis, S. welleri (?), R. magnicosta, S. goreii, Anthracospirifer sp. WOOLSEY MEMBER: *14*; T. morrowensis.

M105D

KESSLER LIMESTONE: *13*; S. oklahomae, N.? platynotus, P.? arkansanus, S. welleri, Echinaria n. sp. A, B. grandis, A. coloradoensis, L. nodosus, L. pumilus, Hustedia n. sp. A, A. curvilateralis, P. morrowensis, P. perplexa. *15*; S. oklahomae, P.? arkansanus, K.? globosa, Krotovia? n. sp. A, D. nambeensis, S. welleri, Echinaria n. sp. A, A. coloradoensis, L. nodosus, L. pumilus, Hustedia n. sp. A, A. curvilateralis, S.? campestris, P. perplexa, B. stehlii, Beecheria? cf. B.? bilobatum.

M107

PRAIRIE GROVE MEMBER: *9*; Echinaria n. sp. A, Pulchratia? n. sp. A, T. morrowensis, Linoproductus n. sp. A, A. matheri. *15*; H. miseri.

M108

KESSLER LIMESTONE: *17*; B. grandis, A. curvilateralis. *20*; S. oklahomae, Derbyia? sp., D. nambeensis, B. grandis, L. nodosus, L. pumilus, Hustedia n. sp. A, A. curvilateralis.

M109

PRAIRIE GROVE MEMBER: *4*; Pulchratia? n. sp. A (?), T. morrowensis, A. matheri. *5*; S. welleri, Linoproductus n. sp. A, A. matheri (?).

M110

PRAIRIE GROVE MEMBER: *18*; Neochonetes? n. sp. A, S. welleri, Echinaria n. sp. A, T. morrowensis. BRENTWOOD LIMESTONE: *20*; S. altirostris?, K.? globosa, S. welleri, Pulchratia? n. sp. A, T. morrowensis, A. matheri (?), P. perplexa, Beecheria n. sp. A. B.? bilobatum.

M111

PRAIRIE GROVE MEMBER: *6*; Anthracospirifer sp. *8*; S. welleri, T. morrowensis, A. matheri. *6*; S. welleri, Echinaria n. sp. A, T. morrowensis. *14*; A. matheri. *15*; T. morrowensis (?), A. matheri, Beecheria n. sp. A, B.? bilobatum. *16*; S. altirostris?, Derbyia? n. sp. B, Linoproductus n. sp. A.

M112

PRAIRIE GROVE MEMBER: *7*; A. matheri. *10*; Derbyia? n. sp. B, P.? arkansanus, S. welleri, B. grandis, A. matheri, S.? campestris, Beecheria cf. B. n. sp. A. *15*; S. oklahomae, S. altirostris?, K.? globosa, T. morrowensis, Linoproductus n. sp. A, A. matheri, P. perplexa. *16*; Neochonetes? n. sp. A, P.? arkansanus, K.? globosa, D. nambeensis, S. welleri, Anthracospirifer sp. *17*; Echinaria n. sp. A, T. morrowensis. BRENTWOOD LIMESTONE: *24*; T. morrowensis.

M113

BRENTWOOD LIMESTONE: *4*; H. miseri (?).

M114

PRAIRIE GROVE MEMBER: *3*; Pulchratia? n. sp. A (?). BRENTWOOD LIMESTONE: *9*; P. morrowensis. *12*; T. morrowensis, R. magnicosta, H. miseri, S. goreii, Anthracospirifer sp., S.? campestris, P. morrowensis, Beecheria cf. B. n. sp. A. *13*; Anthracospirifer sp. *15*; Pulchratia? n. sp. A, B. grandis. KESSLER LIMESTONE: *28*; P.? arkansanus, D. nambeensis, S. welleri, P.? picuris. *31*; A. curvilateralis.

M115

KESSLER LIMESTONE: *2*; G.? emarginata.

M116

PRAIRIE GROVE MEMBER: *7*; S. welleri, T. morrowensis, Linoproductus n. sp. A, R. magnicosta (?), Anthracospirifer sp., Beecheria n. sp. A. *8*; Derbyia? n. sp. B, S. welleri, Pulchratia? n. sp. A (?), H. miseri, A. matheri, P. perplexa. *16*; S. altirostris?, P.? arkansanus, H. miseri, A. matheri, P. perplexa. BRENTWOOD LIMESTONE: *18*; S. altirostris?, S. welleri, W. triangularis, A. matheri, P. perplexa, Beecheria n. sp. A. *20*; T. morrowensis, A. matheri, P. perplexa.

M117

PRAIRIE GROVE MEMBER: *2*; S. altirostris?, S. welleri, H. miseri, S.? campestris (?), Beecheria cf. B. n. sp. A. *3*; S. altirostris?, S. welleri, H. miseri, A. matheri, Punctospirifer cf. P. morrowensis, P. perplexa. *8*; T. morrowensis. *9*; S. welleri, T. morrowensis, A. matheri

(?). *11*; S. altirostris?, K.? globosa, Linoproductus n. sp. A, H. miseri, P. perplexa.

M117A

PRAIRIE GROVE MEMBER: *2*; Derbyia? n. sp. B. *6*; Derbyia? n. sp. B, S. welleri, T. morrowensis, A. matheri.

M118

PRAIRIE GROVE MEMBER: *5*; S. welleri, T. morrowensis, A. matheri. *8*; Neochonetes? n. sp. A, T. morrowensis, Linoproductus n. sp. A, H. miseri, Anthracospirifer sp. BRENTWOOD LIMESTONE: *11* or *12*; S. altirostris?, Sandia cf. S. welleri, Linoproductus n. sp. A, P. perplexa, Beecheria n. sp. A. *13*; S. altirostris?, A. matheri. KESSLER LIMESTONE: *18*; Derbyia? sp., S. goreii. *20*; S. oklahomae, Hustedia n. sp. A.

M119

PRAIRIE GROVE MEMBER: Echinaria n. sp. A.

M120

BRENTWOOD LIMESTONE: *4*; S. altirostris?, S. welleri, Pulchratia? n. sp. A, S. goreii. *5*; S. altirostris?. DYE SHALE MEMBER ("caprock"): *12*: K.? globosa, S. goreii.

Loc. M

PRAIRIE GROVE MEMBER: Echinaria n. sp. A, S.? campestris.

APPENDIX III: MATHER'S (1915) TYPE LOCALITIES

Introduction

Mather (1915, p. 247-249) listed 33 collecting stations from the Morrowan sequence in northwestern Arkansas and northeastern Oklahoma. He identified brachiopods from all of these stations and he described 25 new brachiopod species with type specimens coming from 17 of his stations. A 26th species was named from Mather's material by Dunbar and Condra (1932). This appendix is a compilation of observations made by this author in attempting to reestablish these type localities and to collect topotypes from them.

The bulk of Mather's collections from Arkansas were made by him personally during the period of 1911 through 1914 (p. 59), while he was a member of the faculty of the University of Arkansas. Smaller collections from Arkansas were given to him by A. H. Purdue and R. D. Messler and were used in his study. It is not surprising that most of his 17 collecting stations in northwestern Arkansas are near Fayetteville, nor is it surprising that most of them are in the Brentwood Limestone, which is highly fossiliferous. Expansion of the city of Fayetteville has unfortunately eliminated the possibility of collecting topotypes from most of the type localities in that area.

The Morrowan collections from northeastern Oklahoma that were included in Mather's study were given to him by L. C. Snider, who at the time was studying the stratigraphy and biostratigraphy of the Chester Series of that area (1915a, 1915b). These collections were apparently made by Snider alone or by Snider together with J. B. Newby or Stuart Weller or D. W. Ohern, between 1911 and 1914. Mather, in exchange, gave his Chesterian collections from northwestern Arkansas to Snider (1915a, p. 9). No evidence suggests that Mather visited the northeastern Oklahoma outcrops.

Dr. Stuart Weller of The University of Chicago directed the faunal aspects of both studies (Mather, 1915, p. 60; Snider, 1915a, p. 9). Both sets of collections were reposited at The University of Chicago.

In this appendix, the location and stratigraphic information as presented by Mather (1915, p. 247-249) is placed in quotation marks under the heading Location. Under the heading Type Locality, a list of brachiopod species for which the particular station is the type locality is presented. Remarks follow.

Station 134

Location.--"Fayetteville quadrangle: Brentwood limestone lentil. One and a half miles northeast of Fayetteville, Ark. Outcrop near road. Center, sec. 10, T. 16 N., R. 30 W." A more accurate location for this station is the SE¼, SE¼, NW¼, Sec. 10.

Type Locality.--*Orbiculoidea minuta*, *Productus fayettevillensis*, *Composita deflecta*.

Remarks.--Mather identified 25 additional species of brachiopods from this station. The specimens collected by Mather and examined by the author appear to have been "cracked out" of a limestone; matrix adhering to the pedicle valve of *S. rockymontanus* (UC 16139) is a fine-grained pelmatozoan, mixed-skeletal calcilutite (wackestone).

Little doubt exists that Mather's collection were from the Brentwood Limestone, but the locality cannot be recollected. It is now the site of Lake Lucille, a small man-made lake in a housing development of the same name in urban Fayetteville. Quinn (1963, p. 209) published a sketch map of the geology of the area around Lake Lucille; this map shows the Brentwood cropping out on the southeastern (upper) side of the small lake and dipping to the northwest at approximately 8 degrees. The Baldwin Coal is shown cropping out immediately to the west and the Kessler Limestone, dipping to the northwest at about 12 degrees, is located approximately 35 yards farther west. Quinn (personal communication, January 11, 1972) stated that the upper part of the Prairie Grove Member (not shown on the map) cropped out in the small creek upon which the lake is formed at a point about 75 yards southeast of the former Brentwood outcrops (this area is not shown on Quinn's map), and that these strata were unfossiliferous.

The area of former outcrop of the Brentwood is currently covered with a veneer of soil and has been sodded with Bermuda grass.

Station 135

Location.--"Fayetteville quadrangle: Brentwood limestone lentil.

Three and a half miles northeast of Fayetteville, Ark. Abandoned quarry. S. ½, sec. 2, T. 16 N., R. 30 W." A more accurate probable location of this station is the NE¼, SE¼, SW¼, Sec. 2.

Type Locality.—Hustedia brentwoodensis, H. miseri.

Remarks.—Three abandoned quarries are located in the S½, Sec. 2, and all three include strata of the highest portion of the Prairie Grove Member. Only the quarry in the NE¼, SE¼, SW¼ exposes strata of the lower part of the Brentwood Limestone, and it is the most likely choice for Mather's station 135 (see Gordon, 1965, p. 57 and discussion of USGS locality 1999; Manger, 1971, p. 178).

This quarry was by far the largest of the three quarries, and the primary working faces were in the Prairie Grove Member. Dillon's Supermarket has been built on the site of the quarry, covering much of the area, and only the highest Prairie Grove and lower Brentwood strata are currently exposed (November, 1971). The manager of the supermarket informed this writer at this time that the market will soon expand southward and that the remainder of the quarry will be filled.

Mather (1915, p. 247) stated that his collections came from the Brentwood Limestone, but Girty and Henbest (see Gordon's, 1965, p. 57, discussion of USGS 1999) believed that Mather's specimens were collected from the upper part of the Prairie Grove (this is the type locality for the goniatite Pygmaeoceras pygmaeum). This writer is convinced that Mather collected from several different stratigraphic levels within the quarry. P. pygmaeum (Quinn, oral communication) comes from unit M102-1 in the Prairie Grove Member. Mather's specimens of Spirifer rockymontanus (= Anthracospirifer matheri of this report; UC 16140) probably were also collected from this unit. Matrix adhering to this specimen is a fine- to medium-grained, extensively recrystallized, quartz-sandy, glauconitic, bryozoan, mixed-skeletal calcarenite (recrystallized grainstone). The other specimens that this writer has examined were probably collected from the Brentwood Limestone. Mather's referred specimen of Rhynchopora magnicosta (UC 16576) from this locality was collected from a lithic type similar to unit 8, and Mather's referred specimen of Schizophoria resupinoides (UC 16102) is on a small chip of rock like M102-10. Mather's specimen of S. resupinoides (= S. altirostris? of this report; UC 16100) is a well-preserved, uncrushed pedicle interior and was undoubtedly collected from a calcareous shale. Interiors of the same species occur only in M102-9 along with numerous crushed (and a few uncrushed) topotypes of Hustedia miseri.

Station 136

Location.--"Fayetteville quadrangle: limestone lense in Hale formation. Western slope of East Mountain [Mount Sequoyah], Fayetteville, Ark. Outcrop near Klyce Spring. NW. ¼, sec. 15, T. 16 N., R. 30 W." A more accurate description of Mather's original locality (= M103A-4) is the SE¼, NE¼, SW¼, NW¼, Sec. 15; the collections herein treated as topotypes (M103-14) come from approximately 200 yards north of Mather's original station from the same stratigraphic horizon in the

SE¼, SE¼, NW¼, NW¼, Sec. 15.

Type Locality.--Productus morrowensis, P. welleri.

Remarks.--The strata that form the aquifer at Klyce's Spring and from which Mather collected occur in the lower part of the Prairie Grove Member of the Hale Formation and probably correlate with the Idiognathoides noduliferus Zone.

The original locality is part of the beautifully landscaped yard of Dr. and Mrs. George Moore, 308 East Spring Street, and can no longer be collected. Topotypes were collected in the creek behind the house of Mrs. E. J. Englehart, 318 East Dickson Street.

This is the site of USGS localities 1998 and 8193.

Station 137

Location.--"Fayetteville quadrangle: limestone lense in Hale formation. Southwestern slope of East Mountain [Mount Sequoyah], Fayetteville, Ark. Outcrop near Confederate cemetary. SW. ¼, sec. 15, T. 16 N., R. 30 W."

Type Locality.--Pugnoides triangularis, Composita transversa.

Remarks.--Lower Morrowan strata around the old Confederate and Walker Cemetaries are no longer exposed and cannot be recollected. Mather's original collections probably came from the lower part of the Prairie Grove Member in strata equivalent to those at Klyce's Spring (M103-14).

Station 138

Location.—"Fayetteville quadrangle: Brentwood limestone lentil. Eastern slope of East Mountain [Mount Sequoyah], Fayetteville, Ark. SW. ¼, sec. 22, T. 26 N., R. 30 W." A more accurate location is the SW¼, SW¼, SW¼, Sec. 11.

Type Locality.—*Composita ozarkana*.

Remarks.—Mather's station 138 is most probably M116-18, which is in the basal part of the Brentwood Limestone Member.

Station 139

Location.—"Fayetteville quadrangle: limestone lense in Hale formation. Ravine on southern slope of East Mountain [Mount Sequoyah], Fayetteville, Ark." A more accurate location is the SE¼, SE¼, NW¼, SE¼, Sec. 15.

Type Locality.—*Rhipidomella altirostris*.

Remarks.—The strata in the lower part of the Prairie Grove Member of the Hale Formation that constitute M117-2 and 3 and M117A-6 are Mather's station 139. The lithic type is a fine- to coarse-grained, pelmatozoan, mixed-skeletal calcarenite (grainstone).

Station 140

Location.—"Fayetteville quadrangle: Brentwood lentil. Same locality as 139."

Type Locality.--Spirifer matheri.

Remarks.--The specimens that Mather identified as Spirifer rockymontanus were designated the type specimens for Spirifer matheri by Dunbar and Condra (1932).

This station is probably the same as the one designated by Mather as station 150, collected earlier by A. H. Purdue; the latter station is the type locality for Rhynchopora magnicosta. Unfortunately the Brentwood Limestone Member is very poorly exposed in this vicinity, and the only outcrop was a single, slumped block of limestone near a large cedar tree in a heavily grassed pasture. This limestone block (M117-13) was completely broken up by the author, but no specimens of either S. matheri or R. magnicosta were collected.

Station 145

Location.--"Winslow quadrangle: Brentwood limestone lentil. Railroad cut, "Acorn Cut," two miles northwest of Brentwood, Ark. S. ½, sec. 23, T. 14 N., R. 30 W."

Type Locality.--Pustula bullata.

Remarks.--Mather's station 145 was not reestablished by this writer. USGS localities 1995, 1996, 1996a, 1996b, 1996c, and 1996d are near this station.

Station 149

Location.--"Fayetteville quadrangle: limestone lense near top of Hale formation. Southern slope of East Mountain [Mt. Sequoyah], Fayetteville, Ark. A. H. Purdue." A more accurate location is the SE¼, SE¼, NW¼, SE¼, Sec. 15.

Type Locality.--*Squamularia transversa*.

Remarks.--This station is most probably equivalent to units M117-6 or 7. The cotypes of *Squamularia transversa* (UC 16094) are set in a matrix of fine- to medium-grained, pelmatozoan, mixed-skeletal, quartz-sandy calcarenite (grainstone) with scattered ooids and glauconite. Lithically, the matrix is more compatable with unit 7 of this section, and these strata are in the upper part of the Prairie Grove Member of the Hale Formation.

Station 150

Location.--"Fayetteville quadrangle: Brentwood limestone lentil. Same locality as last, horizon 15 feet higher. A. H. Purdue."

Type Locality.--*Rhynchopora magnicosta*.

Remarks.--This is most probably equivalent to M117-13 and the same as Mather's station 140. For additional remarks, see that station.

Station 152

Location.—"Fayetteville quadrangle: Brentwood limestone lentil. NE. ¼, sec. 20, T. 17 N., R. 29 E. R. D. Messler." This must be a typographical error; the correct range would have to be R. 29W.

Type Locality.—*Pustula sublineata*, *Composita gibbosa*.

Remarks.—The exposures of the Morrow Group in the area around Zion School are extremely poor, and much of the land has been cut over and is now in pasture. It is impossible to collect type materials of these species or to determine with certainty the stratigraphic position of Mather's station 152.

Station 209

Location.—"Fayetteville quadrangle: Kessler limestone lentil. West slope of East Mountain, Fayetteville, Ark. Outcrop near city water reservoir." A more accurate location is the SW¼, SW¼, SW¼, NE¼, Sec. 15.

Type Locality.—*Girtyella*? *emarginata*.

Remarks.—This station is equivalent to M117-3 and is in the lower part of the Kessler Limestone Member. The type specimens for *Girtyella*? *emarginata* (UC 16079) are limonitic internal molds. No topotypes were collected by this author, although sparse molds of brachiopods, bryozoans, and gastropods were noted in the unit. This station is the same as USGS localities 2803, 2854, 2863, and 2863A.

Station 210

Location.--"Winslow quadrangle: Brentwood limestone lentil. Sawney Hollow, head of Indian Creek, in Oklahoma, three and a half miles south of Evansville, Ark."

Type Locality.--*Chonetes arkansanus*, *Pustula globosa*.

Remarks.--What are herein considered to be topotypes of *Krotovia*? *globosa* were collected from the "caprock" of the Baldwin Coal (basal Dye Shale Member), unit M120-13, in the approximate C, N½, Sec. 10, T. 12N., R. 33W, Crawford Co., Arkansas. The Woolsey Member is missing at this locality, and the "caprock" rests directly upon the Brentwood Limestone. Topotypes of *P*.? *arkansanus* were not collected from this section, although a number of the strata in the Brentwood are highly fossiliferous. *Amplexus corrugatus* Mather was collected by P. K. Sutherland and T. W. Henry from unit M120-3, in the basal part of the Brentwood Limestone in the SE¼, SE¼, NW¼, Sec. 10; this is the type locality for this species of rugose coral.

The section at the head of Indian Creek is poorly exposed, but the strata in the eastern tributary near the head of Indian Creek (the tributary in which the Brentwood interval of section M120 was measured) are continuously exposed. It is possible that Mather's collections come from the eastern tributary, which heads in Arkansas, rather than on the actual head of the main creek. Mather presumably had only the Winslow (1898) Quadrangle map (30 minute) upon which to locate himself, and this map does not show the eastern tributary extending into Arkansas.

Station 295

Location.--"Pryor quadrangle: limestone in Morrow formation. 7 miles south of Choteau, Oklahoma. SW. ¼, sec. 30, T. 19 N., R. 19 E. L. C. Snider."

Type Locality.--*Chonetes choteauensis*.

Remarks.--M. K. Elias (personal communication) contended that the original type locality for this species cannot be reestablished. Outcrops of calcareous shale in this quarter section, according to Elias, contain Atokan fusulinids, suggesting to him that the species was not collected by Snider from the Morrow Group but from the Atoka Formation. This information would agree with C. C. Branson's (personal communication to P. K. Sutherland) contention that a portion of the State Map of Oklahoma is incorrectly mapped in this area where the Atoka Formation contains calcareous shales and thin limestones.

Station 297

Location.--"Pryor quadrangle: limestone in Morrow formation. 10 miles east-southeast of Choteau, Oklahoma. W. ½, sec. 4, T. 19 N., R. 20 E. L. C. Snider."

Type Locality.—*Brachythyris laticosta*.

Remarks.—This locality was not reestablished. MacKenzie Gordon (personal oral communication) contended that *B. laticosta* is a Late Mississippian form. No specimens of this species have been collected by the author from the Morrow Group.

Station 301

Location.—"Muskogee quadrangle: Morrow formation; shaly member above heavy limestone. 1½ miles north of Fort Gibson, Oklahoma. Sec. 35, T. 16 N., R. 19 E. Stuart Weller and L. C. Snider."

Type Locality.—*Composita ovata*, *C. biplicata*.

Remarks.—This locality was not reestablished. The Morrow Group is not well exposed in section 35, but it seems highly likely that the original collections came from the upper part of the limestone-shale member of the Gore Formation, which is highly fossiliferous in this area.

Station 304

Location.—"Muskogee quadrangle: limestone in upper portion of Morrow formation. Hill east of railroad, 3 miles northwest of Gore, Oklahoma (Campbell on topographic sheet). L. C. Snider." The location is approximately in Sec. 35, T. 14N., R. 20E., Muskogee County, Oklahoma.

Type Locality.--_Spirifer goreii_.

Remarks.--This locality is in the approximate location of measured section M7 and near measured sections M97 and M98. _Spirifer goreii_ occurs throughout the Morrow Group in northeastern Oklahoma, but it is most abundant in the fossiliferous, calcareous shales of the upper part of the limestone-shale member of the Gore Formation. Large collections of this species from units M97-5 through M97-9 and from loc. M98D, approximately 0.75 mile southeast of the approximate location of station 304, are considered to be topotypes.

APPENDIX IV: TABLES OF MEASUREMENTS OF ILLUSTRATED MORROWAN BRACHIOPODS

Introduction.--Appendix IV presents the measurements of the figured specimens of species treated in this dissertation, except for figured specimens whose measurements are included in the systematic descriptions.

Symbols.--The following set of symbols are utilized throughout this appendix:

Loc.	Locality of unit collected
No.	Catalogue number
OU	University of Oklahoma
UC	University of Chicago, Walker Museum (now reposited with the Field Museum of Natural History
USNM	United States Museum of Natural History
	The number may be succeeded by (H), (P), (L), (C), (A), or (T) for holotype, paratype, lectotype, cotype, allotype, or topotype, respectively.
L	Length
W	Width
HW	Hinge width.
H	Height
T	Thickness
SL	Surface length.
NC, NP, etc.	Number of costellae, costae, plicae, etc. in specified length at specified surface length.

SLR	Surface length to end of reticulation
NCS, NCR, NCL	Number of costae in sulcus, on right flank, or on left flank, respectively.
NPS, NPR, NPL	Number of plicae in sulcus, on right flank, or on left flank, repectively.

Schizophoria oklahomae Dunbar & Condra

Loc.	L	W	H	No
M17-14	43.1	50.7	----	OU 7224
	43.2	49.5	----	OU 7255
M39-4	40.9	14.5	22.9	OU 7226

Neochonetes? platynotus (White)

Loc.	L	W	H	No
M1-20	8.7	7.8	----	OU 7233
M27-14	5.0	7.9	1.3	OU 7231
M29-10 or 11	9.5	14.5	2.8	OU 7232

Neochonetes? n. sp. A

Loc.	L	W	H	No
M26-9	5.4	9.5	1.5	OU 7239
	5.7	10.0	1.8	OU 7240
	5.9	11.5	1.7	OU 7238

Plicochonetes? arkansanus (Mather)

Loc.	L	W	H	No
97-5	3.3	5.6	1.0	OU 7248
	5.4	8.2	2.0	OU 7247
	5.7	9.0ca.	2.0	OU 7246
	6.5	10.4	2.3	OU 7249

Krotovia? globosa (Mather)

Loc.	L	W	H	HW	SL	No
Sta. 210	9.0	8.1	6.7ca.	6.7	17	UC 16130(H)
Sta. 138	9.6	9.3	5.1ca.	---	18	UC 16237
M1-6	7.7	7.8	4.9	5.7	14	OU 7254

Desmoinesia nambeensis Sutherland & Harlow

Loc.	L	HW	H	SL	NC*	No
M37-10	11+	12.7	6+	18+	9	OU 7255

*Number of costellae in 5 mm at 10 mm SL.

Sandia welleri (Mather)

Loc.	L	W	HW	H	WL	No
M1-6	22.6	25est.	----	14.1	41	OU 7256
M97-5	22.6	27.4	30.3	15.0	40	OU 7257
	23est.	30est.	30est.	14.3	40	OU 7258
M105D-13	15+	----	18.5ca.	----	24+	OU 7260
	21.2	20.7	19.5ca.	14.0	40	OU 7262

Echinaria n. sp. A

Loc.	L	W	HW	H	T	SL	No
M109-4	62	64	25	30	21	105	OU 7267
M114-17	63ca.	64	32ca.	----	----	105	OU 7269

Pulchratia? n. sp. A

Loc.	L	W	AW	H	SL	No
M68-13	29+	31+	24est.	17+	48+	OU 7263
	34	35	27est.	21	56	OU 7264

Antiquatonia coloradoensis (Girty)

Loc.	L	W	H	SLR	NC*	NC**	SL	No
M105D-13	31+	36+	23+	28	17	18	56+	OU 7271

*Number of costellae in 10 mm at 10 mm SL; **Number of costellae in 10 mm at 20 mm SL.

Tesuquea morrowensis (Mather)

Loc.	SL	L	W	H	HW	SLR	NC*	NC**	No
M100-11	40+	24+	33+	15+	----	20	12	18	OU 7273
	45	25	27	14	----	19	12	22	OU 7272
M103-14	47	26	30	15	30	22	10	17	UC 16125(H)

Linoproductus n. sp. A

Loc.	SL	L	W	HW	H	No
M100-11	70	44	53	34	20	OU 7278

Linoproductus nodosus (Newberry)

Loc.	SL	L	W	H	No
M105D-13	60+	42+	40+	20+	OU 7279

Wellerella triangularis (Mather)

Loc.	L	W	T	NCS	NCL	NCR	A	No
Sta. 137	6.2	6.4	3.5	3	2	2	----	UC 16136(C)
	7.9	8.2	4.0	3	3	3	81°	UC 16136(C)
M24-10	6.2ca.	7.8	5.8	3	2	2	76°	OU 7282
	6.9	6.6	4.0	3	3	3	76°	OU 7281

Rhynchopora magnicosta Mather

Loc.	L	W	T	SW	NPS		NPR	No
Sta. 150	11.3ca.	17.4ca.	13.0ca.	13.5	6	5	5	UC 16137(H)
M12-8	12.5	14.9	11.8	9.0	7	6	7	OU 7290
M36-6A	5.0	5.7	2.1	----	-	-	-	OU 7284
	8.3	9.5	5.2	6.5	6	6	6	OU 7285
	8.9	10.4	9.5	6.3	6	6	6	OU 7286
	12.4	14.0	10.6	8.2	8	7	8	OU 7287
M42-16	12.7	16.0	11.6	10.2	6	7	6	OU 7289
M100-11	12.4	14.5	11.6	9.5	9	9	8	OU 7288

Hustedia miseri Mather

Loc.	L	W	T	NC	No
M12-8	9.2	7.3	5.5	13	OU 7294
	9.3	7.1	6.8	18	OU 7295
	10.2	9.0	6.5	16	OU 7292
	10.4	8.0	7.4	15	OU 7291

Hustedia n. sp. A

Loc.	L	W	T	NC	No
M30-6	7.0	4.7	4.5	11	OU 7301
	9.1	5.1	5.8	13	OU 7300
	10.7	6.5	6.8	15	OU 7297
M42-15	10.2	6.4	6.9	13	OU 7299
M48-13	8.0	4.2	4.9	14	OU 7298

Spirifer goreii Mather

Loc.	L	W	T	SL	No
Sta. 304	35est.	54est.	----	----	UC 16144(H)
	20.0	40est.	----	----	UC 16144(A)
M42-15 & 16	31.5	56	----	41	OU 7307
M99-2	35	54.5	----	----	OU 7311

Anthracospirifer matheri (Dunbar & Condra)

Loc.	L	W	T	SL	No.
M49-8	22.1	23.0ca.	15.6	32	OU 7303
M100-5	22.4	43est.	16.3	36	OU 7304

Anthracospirifer curirlateralis (Easton)

Loc.	L	W	T	SL	No.
M105D-13	17.7	21.5	12.0	27	OU 7305
	20.1	29.2ca.	14.2ca.	30	OU 7306

Punctospirifer morrowensis Sutherland & Harlow

Loc.	L	W	T	No.
M12-8	5.7	12.0	6.3	OU 7313
	6.7	14.0	6.3	OU 7314

Girtyella? emarginata Mather

Loc.	L	W	T	No.
Sta. 209	6.0+	6.0+	——	UC 16079(C)
	6.8+	6.2	4.1	UC 16079(C)
	6.5+	6.1	4.4	UC 16069(C)
M12-8	6.9	4.9	2.9	OU 7320
M27-8	8.3	6.1	4.5	OU 7319

Beecheria n. sp. A

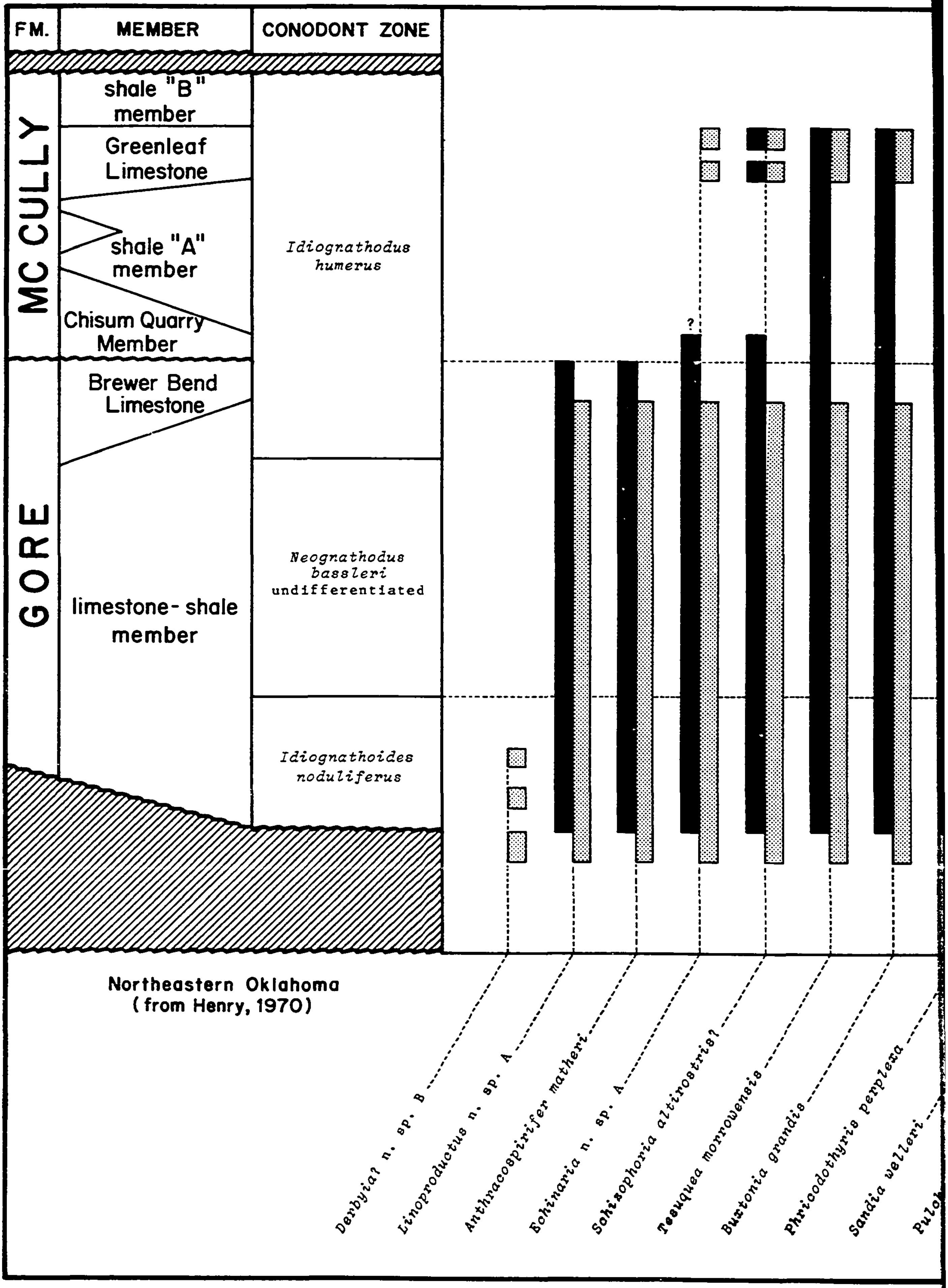
Loc.	L	W	T	No.
M116-18	15.8	13.3	7.0	OU 7322
	19.8	15.2	8.5	OU 7321
M110-20	17.4	11.8	7.9	OU 7323

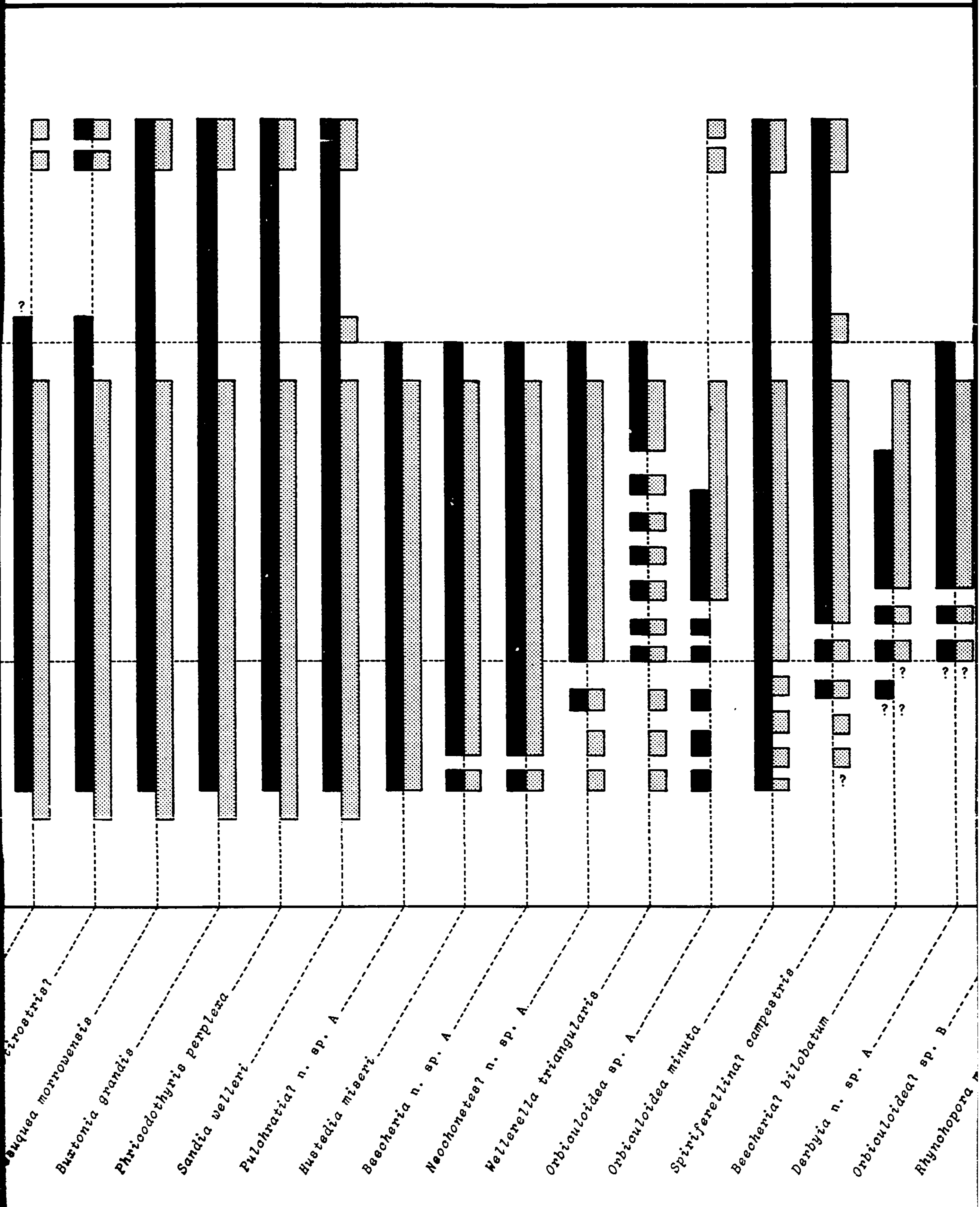
Beecheria stehlii Sutherland & Harlow

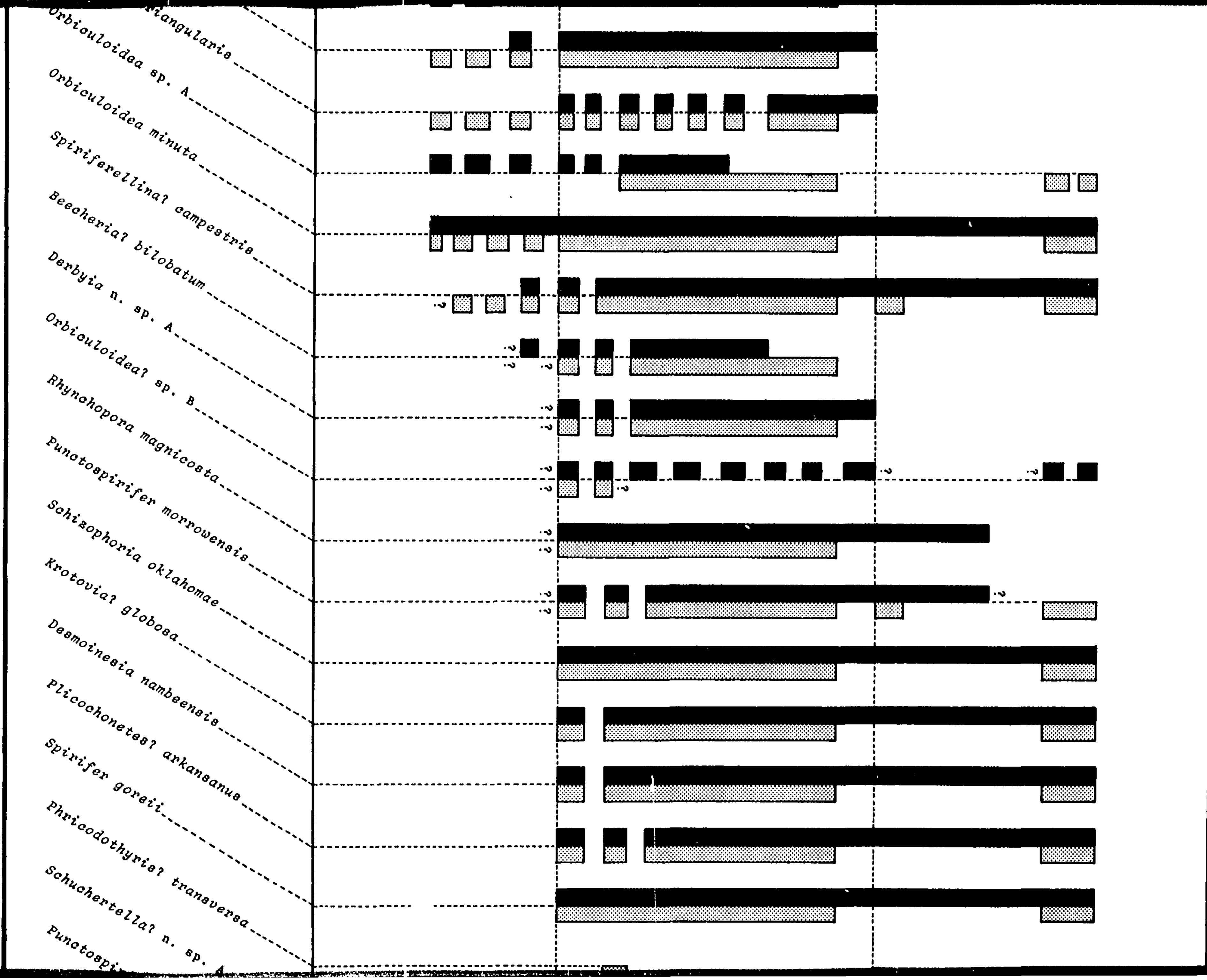
Loc.	L	W	T	No.
M105D-13	22.1	14.6	9.6	OU 7326
	23.0	15.2	9.2	OU 7325
	25.5ca.	17.1	10.5	OU 7327

Beecheria? bilobatum (Mather)

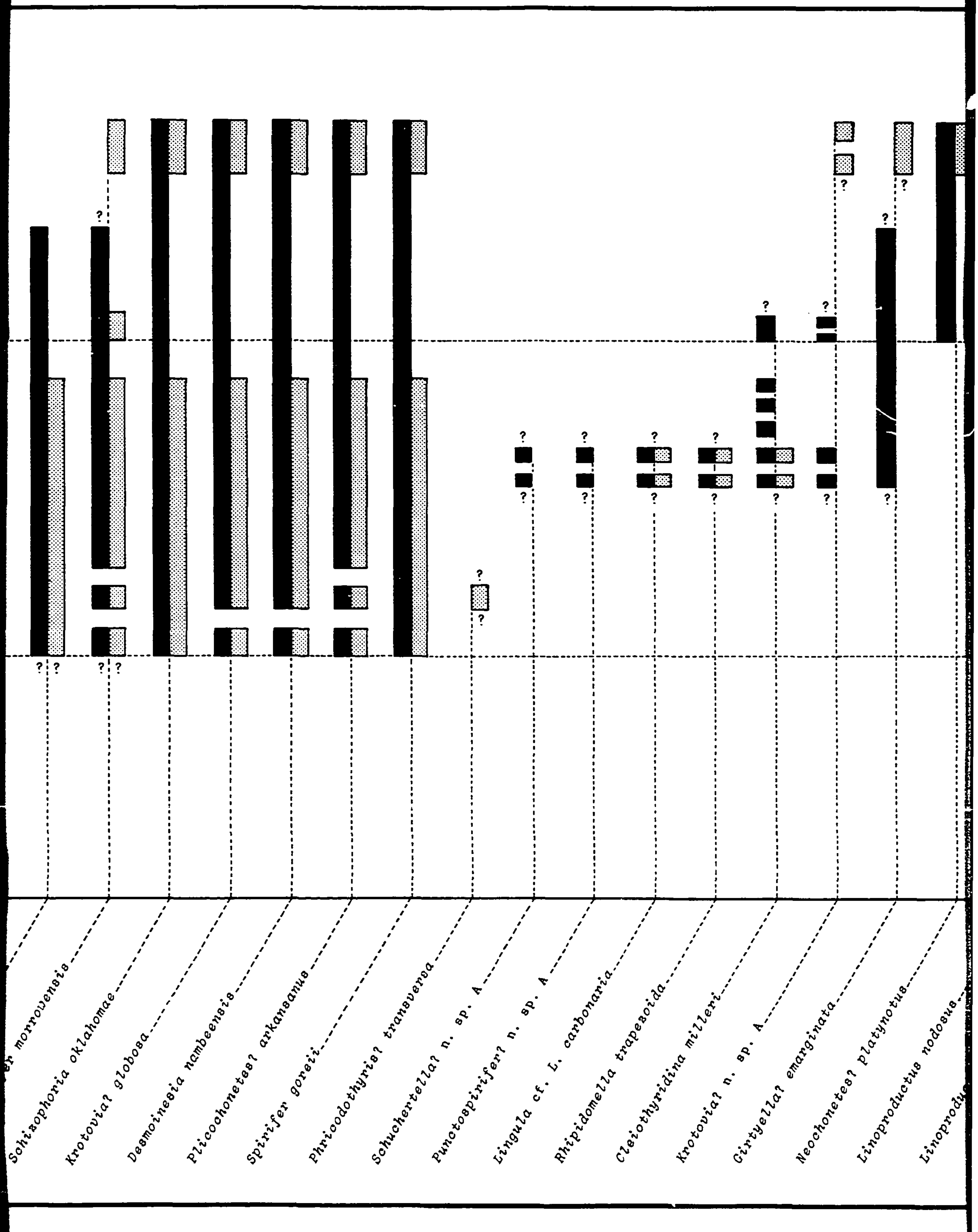
Loc.	L	W	T	No.
Sta. 134	9+	7.2	4.2	UC 16077(C)
	9+	7.8	5.9	UC 16077(C)
M49-3	9.5	7.5	5.9	OU 7328
M110-20	8.0	7.2	4.6	OU 6329

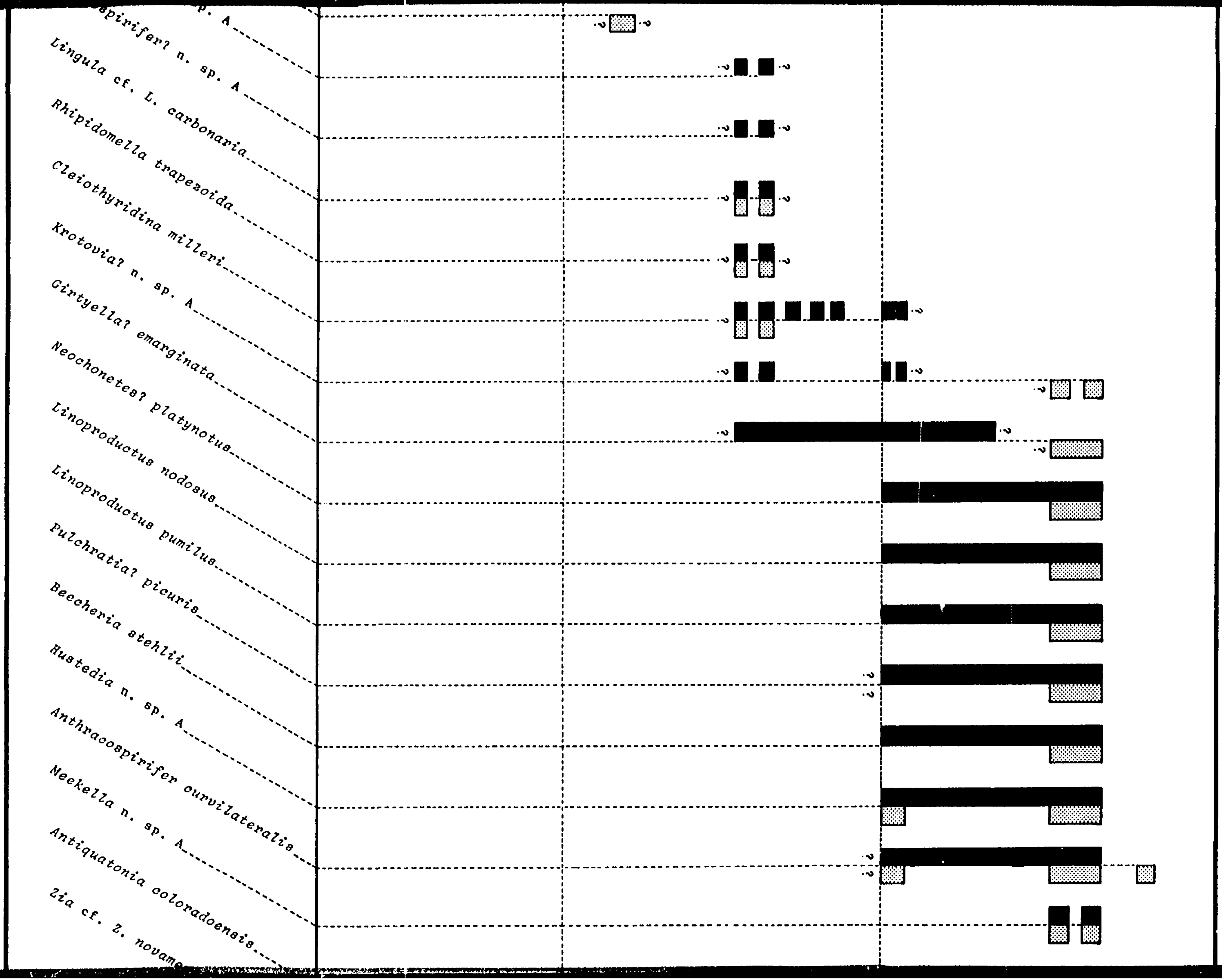

FM.
MEMBER
CONODONT ZONE
MC CULLY
shale "B" member
Greenleaf Limestone
shale "A" member
Chisum Quarry Member
GORE
Brewer Bend Limestone
limestone-shale member
Idiognathodus humerus
Neognathodus bassleri undifferentiated
Idiognathoides noduliferus
?
Derbyia? n. sp. B
Linoproductus n. sp. A
Anthracospirifer matheri
Echinaria n. sp. A
Schizophoria altirostris?
Tesuquea morrowensis
Buxtonia grandis
Phricodothyris perplexa
Sandia welleri
Northeastern Oklahoma
(from Henry, 1970)


irostris?
uquea morrowensis
Buxtonia grandis
Phricodothyris perplexa
Sandia welleri
Pulchratia? n. sp. A
Hustedia miseri
Beecheria n. sp. A
Neochonetes? n. sp. A
Wellerella triangularis
Orbiculoidea sp. A
Orbiculoidea minuta
Spiriferellina? campestris
Beecheria? bilobatum
Derbyia n. sp. A
Orbiculoidea? sp. B
Rhynchopora

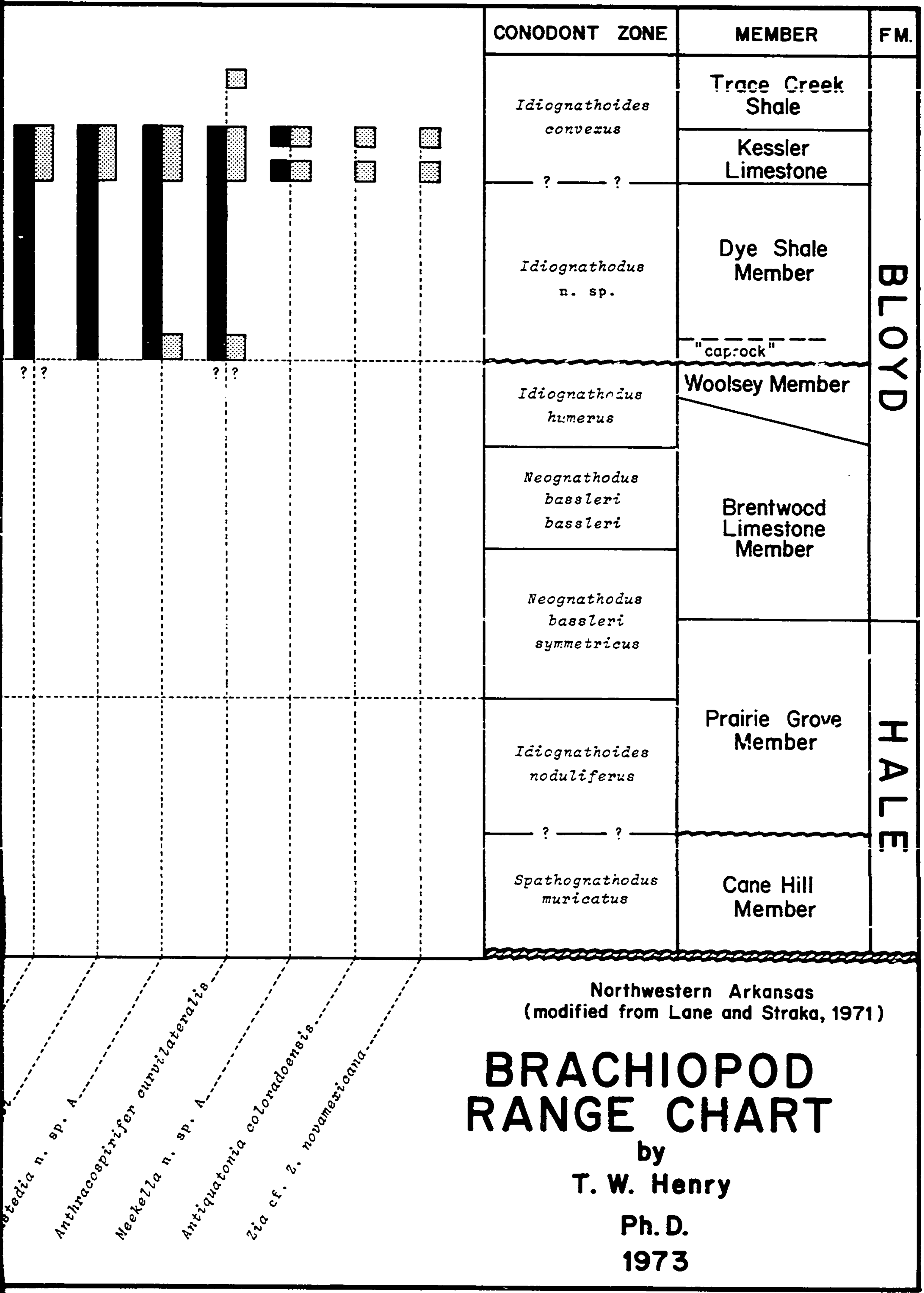


...iangularis
Orbiculoidea sp. A
Orbiculoidea minuta
Spiriferellina? campestris
Beecheria? bilobatum
Derbyia n. sp. A
Orbiculoidea? sp. B
Rhynchopora magnicosta
Punctospirifer morrowensis
Schizophoria oklahomae
Krotovia? globosa
Desmoinesia nambeensis
Plicochonetes? arkansanus
Spirifer goreii
Phricodothyris? transversa
Schuchertella? n. sp. A
Punctospi...
?

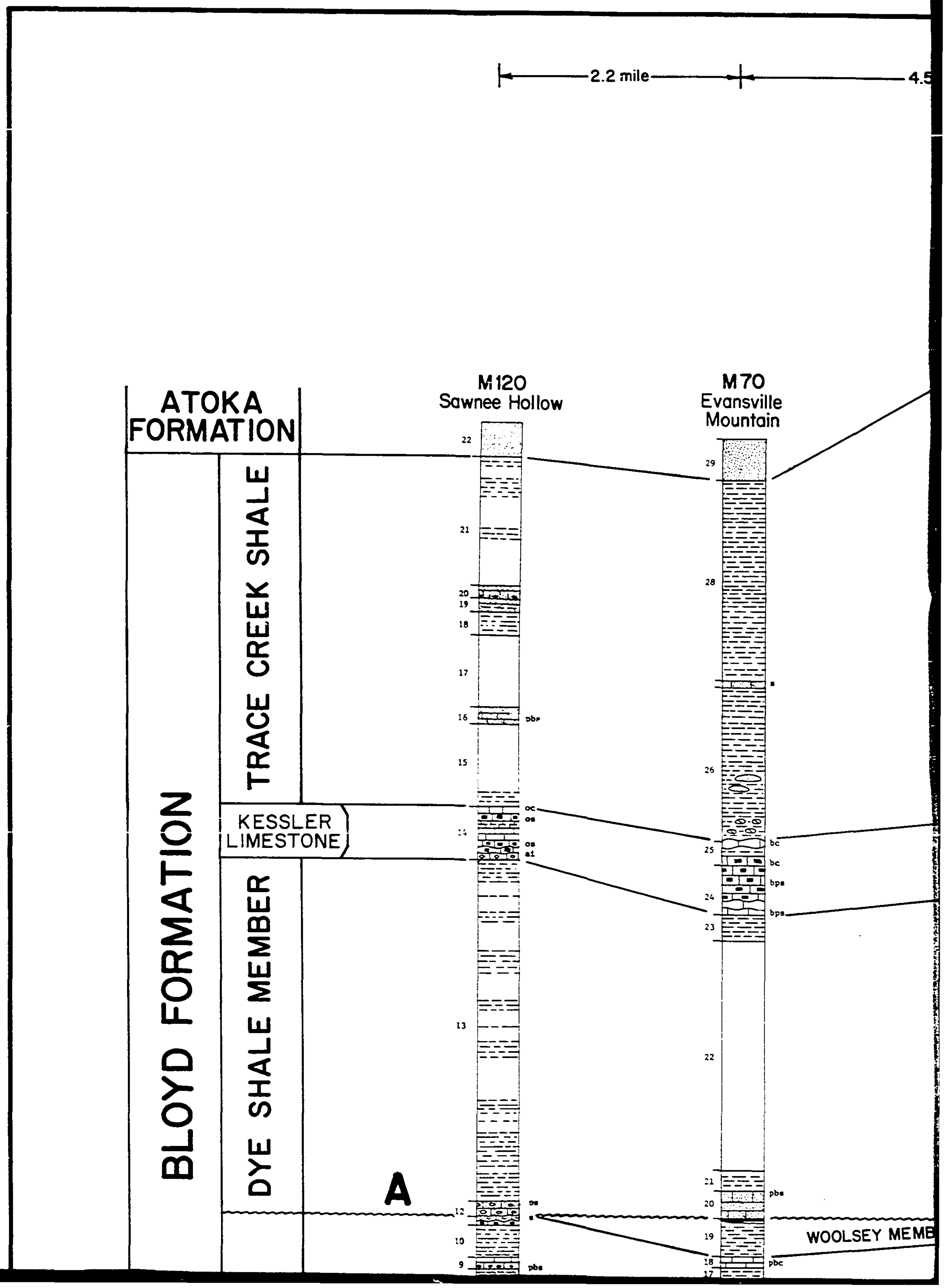

Schizophoria oklahomae
Krotovia? globosa
Desmoinesia nambeensis
Plicochonetes? arkansanus
Spirifer goreii
Phricodothyris? transversa
Schuchertella? n. sp. A
Punctospirifer? n. sp. A
Lingula cf. L. carbonaria
Rhipidomella trapezoida
Cleiothyridina milleri
Krotovia? n. sp. A
Girtyella? emarginata
Neochonetes? platynotus
Linoproductus nodosus

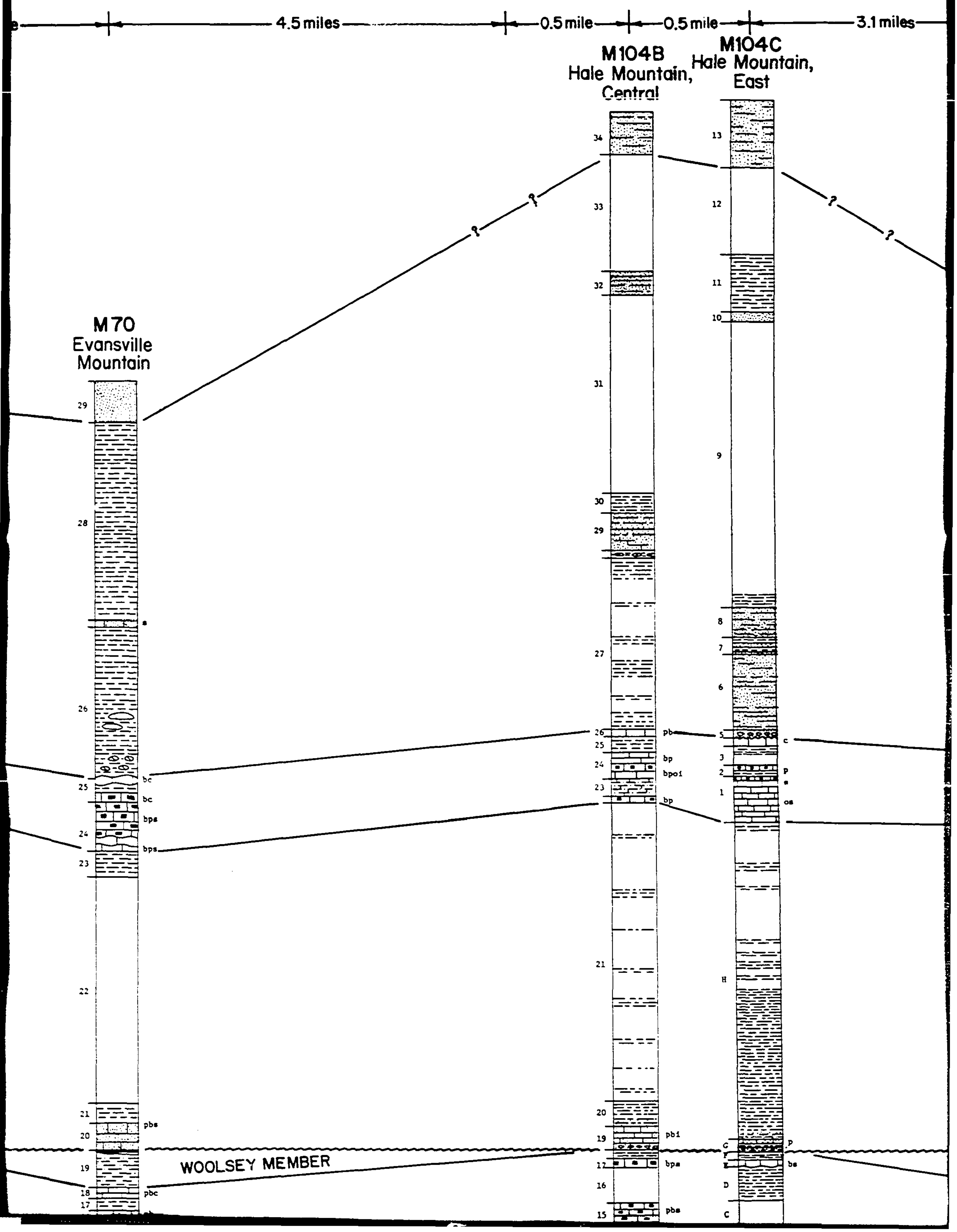


Lingula cf. L. carbonaria
Rhipidomella trapezoida
Cleiothyridina milleri
Krotovia? n. sp. A
Girtyella? emarginata
Neochonetes? platynotus
Linoproductus nodosus
Linoproductus pumilus
Pulchratia? picuris
Beecheria stehlii
Hustedia n. sp. A
Anthracospirifer curvilateralis
Meekella n. sp. A
Antiquatonia coloradoensis

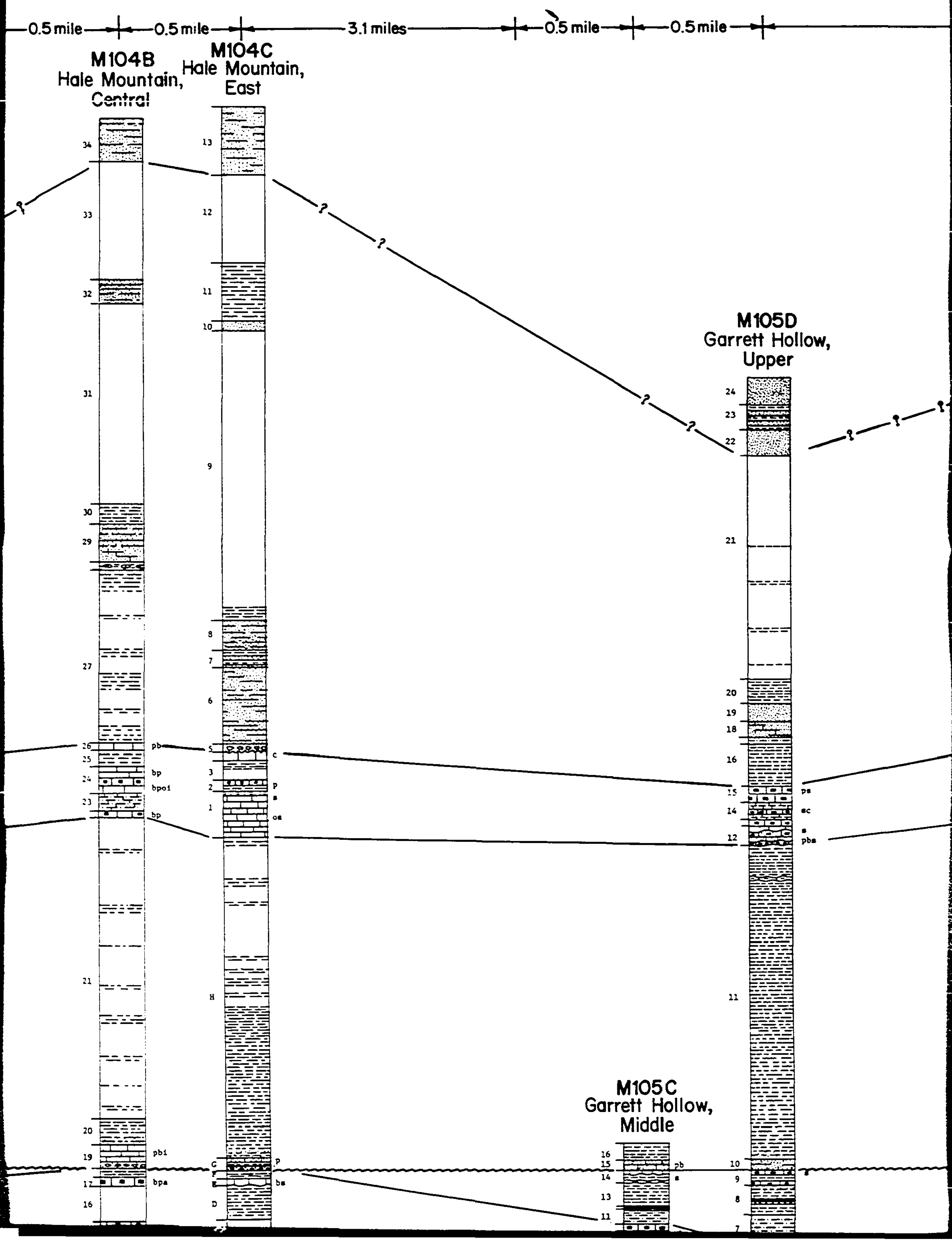


CONODONT ZONE
MEMBER
FM.
Idiognathoides convexus
Idiognathodus n. sp.
Idiognathodus humerus
Neognathodus bassleri bassleri
Neognathodus bassleri symmetricus
Idiognathoides noduliferus
Spathognathodus muricatus
Trace Creek Shale
Kessler Limestone
Dye Shale Member
"caprock"
Woolsey Member
Brentwood Limestone Member
Prairie Grove Member
Cane Hill Member
BLOYD
HALE
tedia n. sp. A
Anthracospirifer curvilateralis
Meekella n. sp. A
Antiquatonia coloradoensis
Zia cf. Z. novamexicana
Northwestern Arkansas
(modified from Lane and Straka, 1971)
BRACHIOPOD RANGE CHART
by
T. W. Henry
Ph. D.
1973

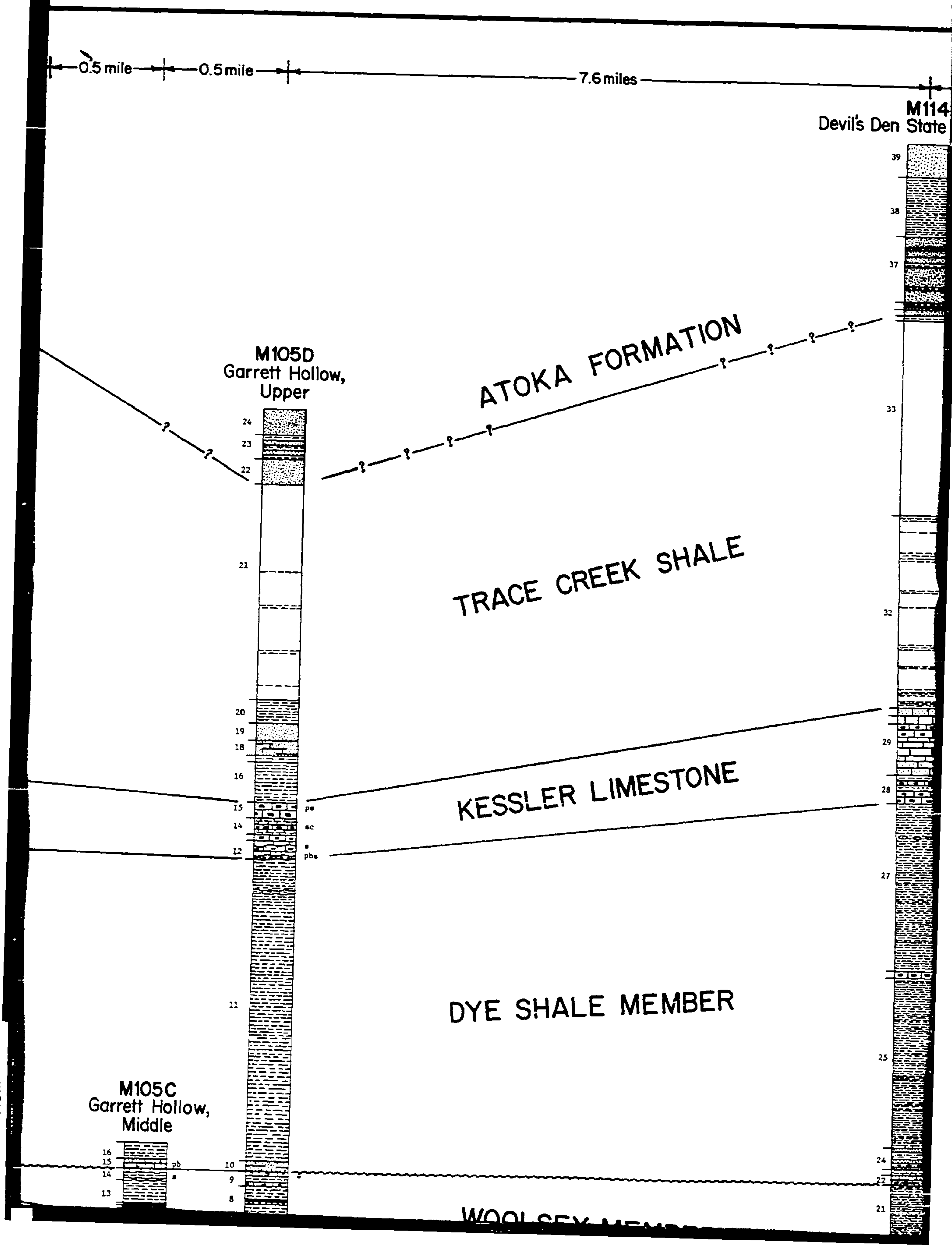

2.2 mile
4.5
ATOKA FORMATION
BLOYD FORMATION
TRACE CREEK SHALE
KESSLER LIMESTONE
DYE SHALE MEMBER
WOOLSEY MEMB
M120
Sawnee Hollow
M70
Evansville Mountain
A



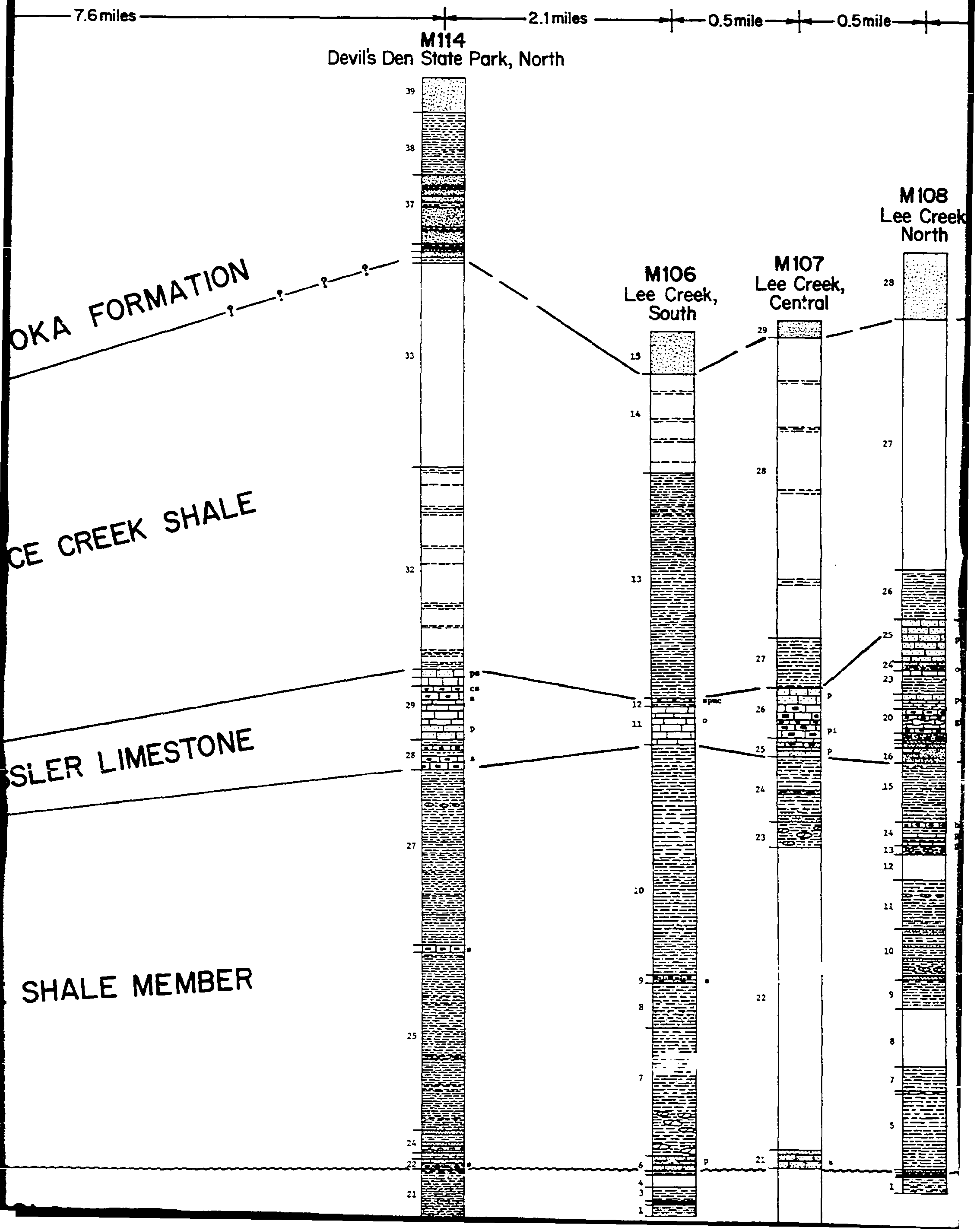
4.5 miles
0.5 mile
0.5 mile
3.1 miles
M70
Evansville Mountain
M104B
Hale Mountain, Central
M104C
Hale Mountain, East
WOOLSEY MEMBER

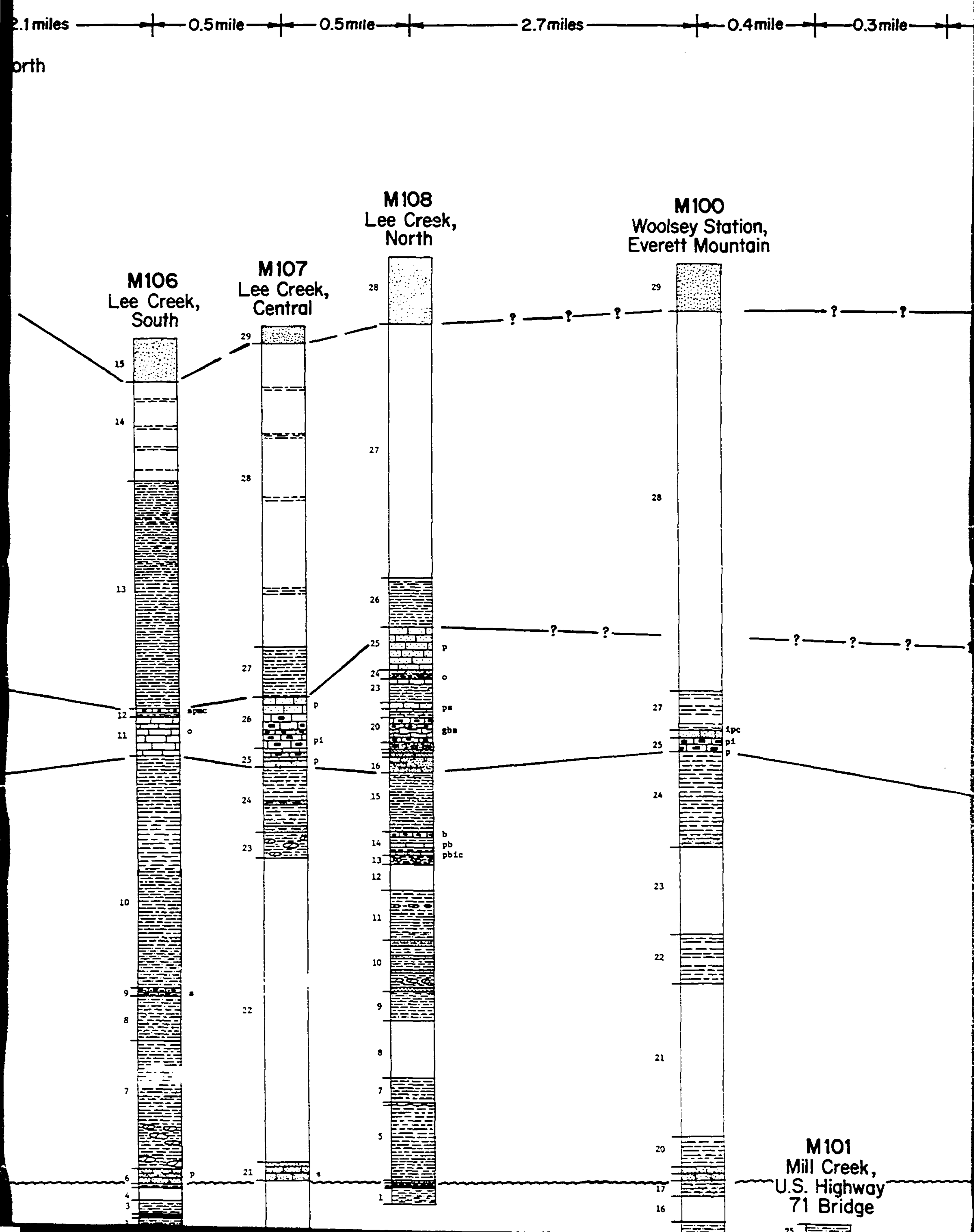


0.5 mile
0.5 mile
3.1 miles
0.5 mile
0.5 mile
M104B
Hale Mountain, Central
M104C
Hale Mountain, East
M105D
Garrett Hollow, Upper
M105C
Garrett Hollow, Middle

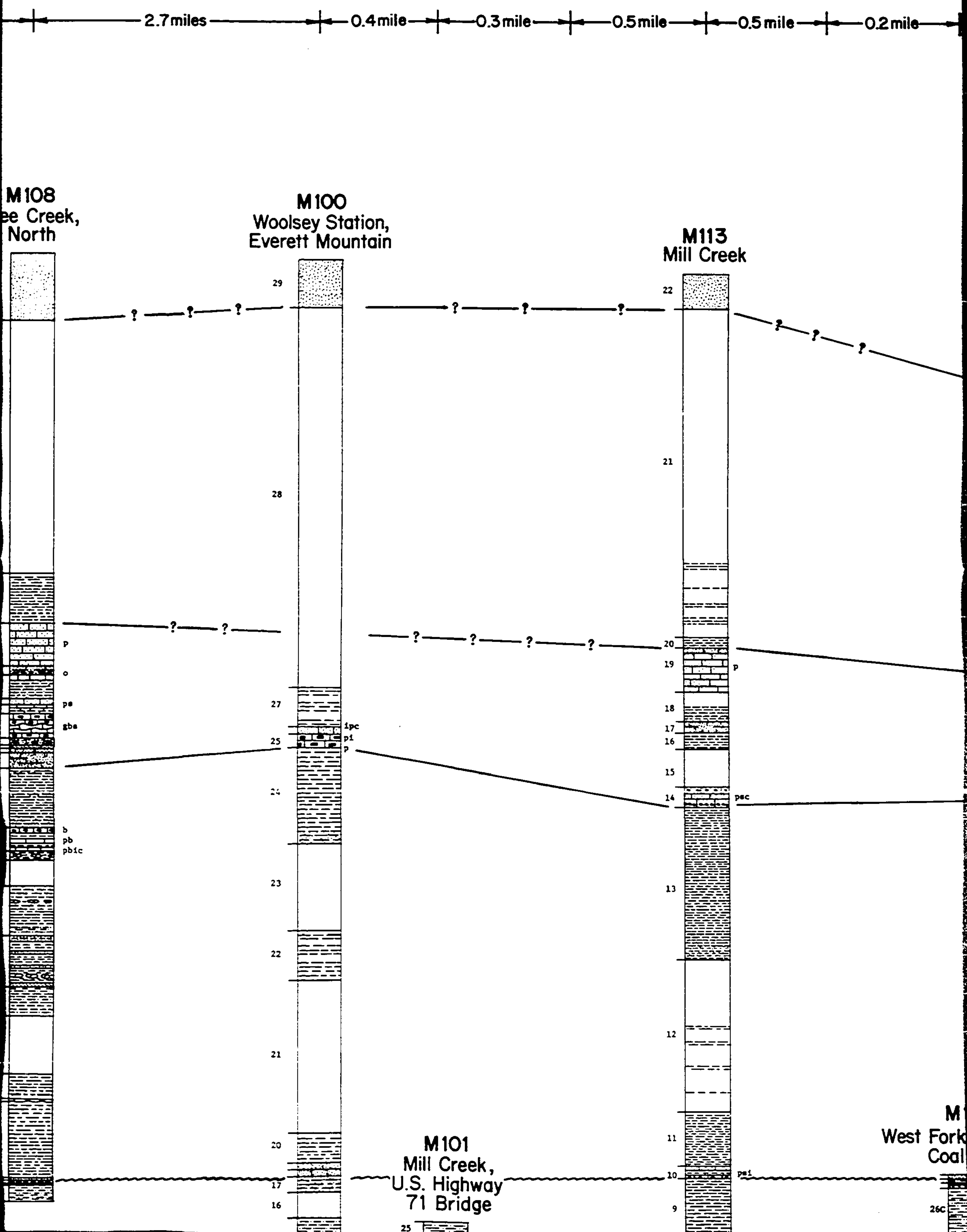


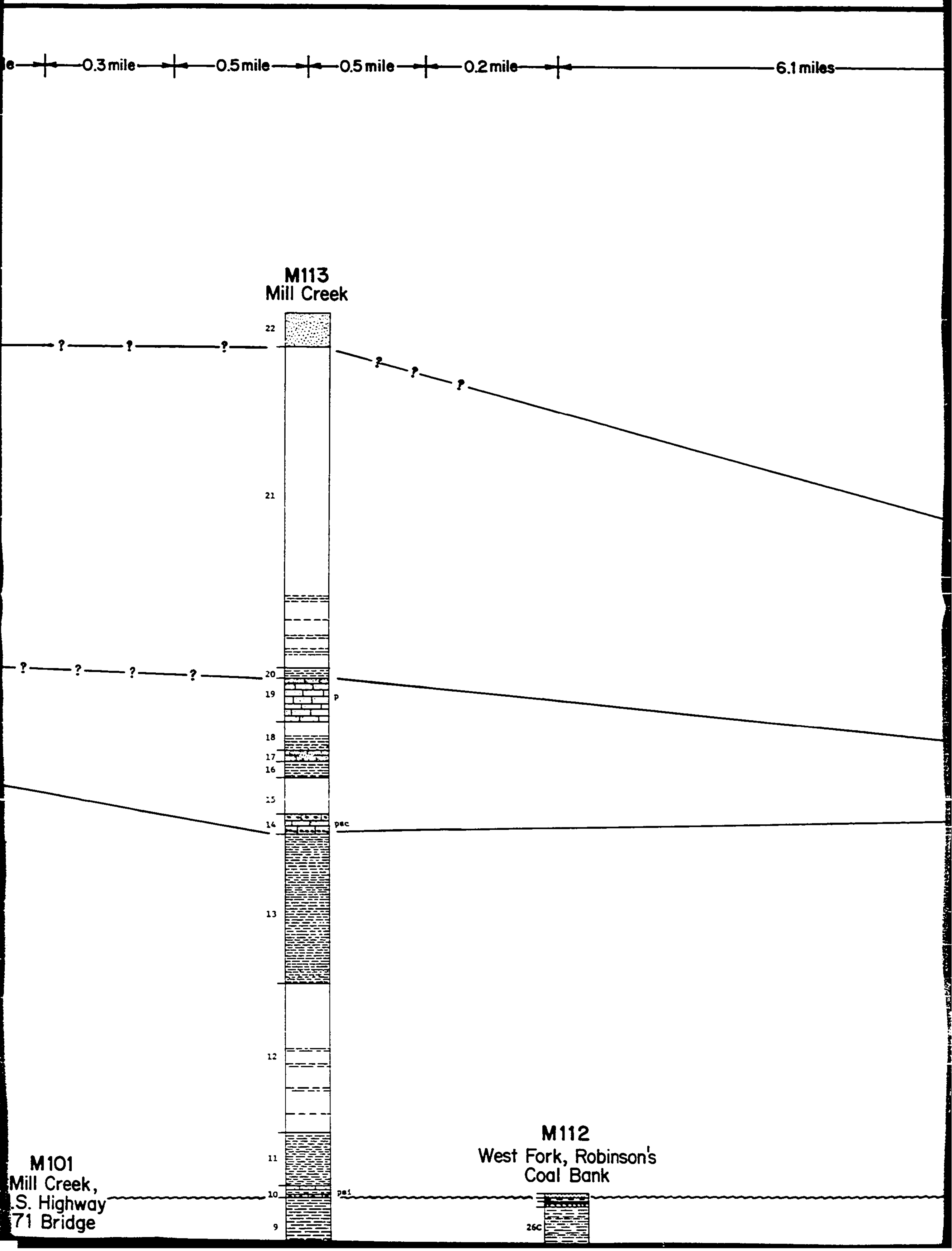
0.5 mile
0.5 mile
7.6 miles
M114
Devil's Den State
M105D
Garrett Hollow,
Upper
M105C
Garrett Hollow,
Middle
ATOKA FORMATION
TRACE CREEK SHALE
KESSLER LIMESTONE
DYE SHALE MEMBER

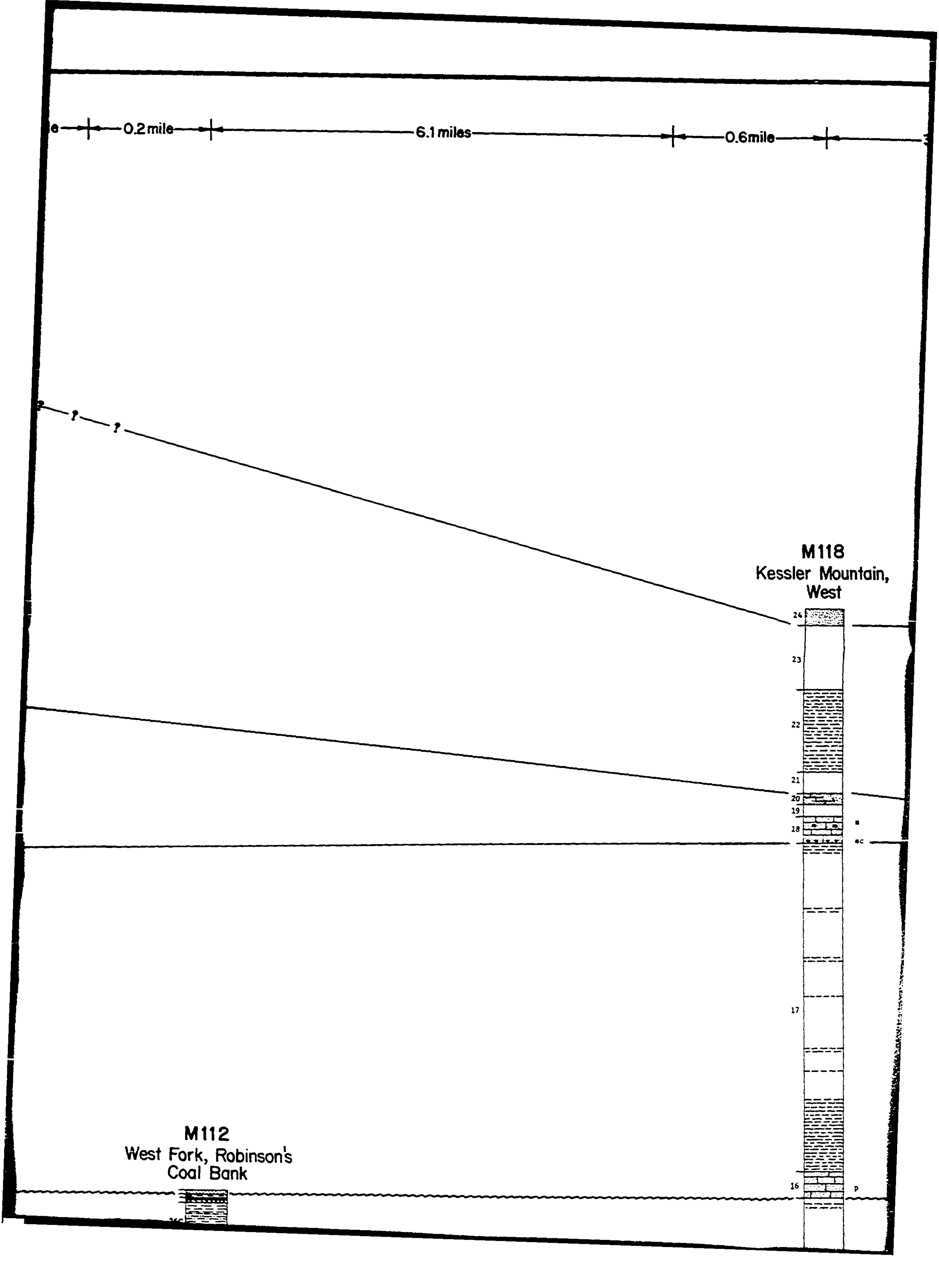

7.6 miles
2.1 miles
0.5 mile
0.5 mile
M114
Devil's Den State Park, North
M106
Lee Creek, South
M107
Lee Creek, Central
M108
Lee Creek North
OKA FORMATION
CE CREEK SHALE
SLER LIMESTONE
SHALE MEMBER

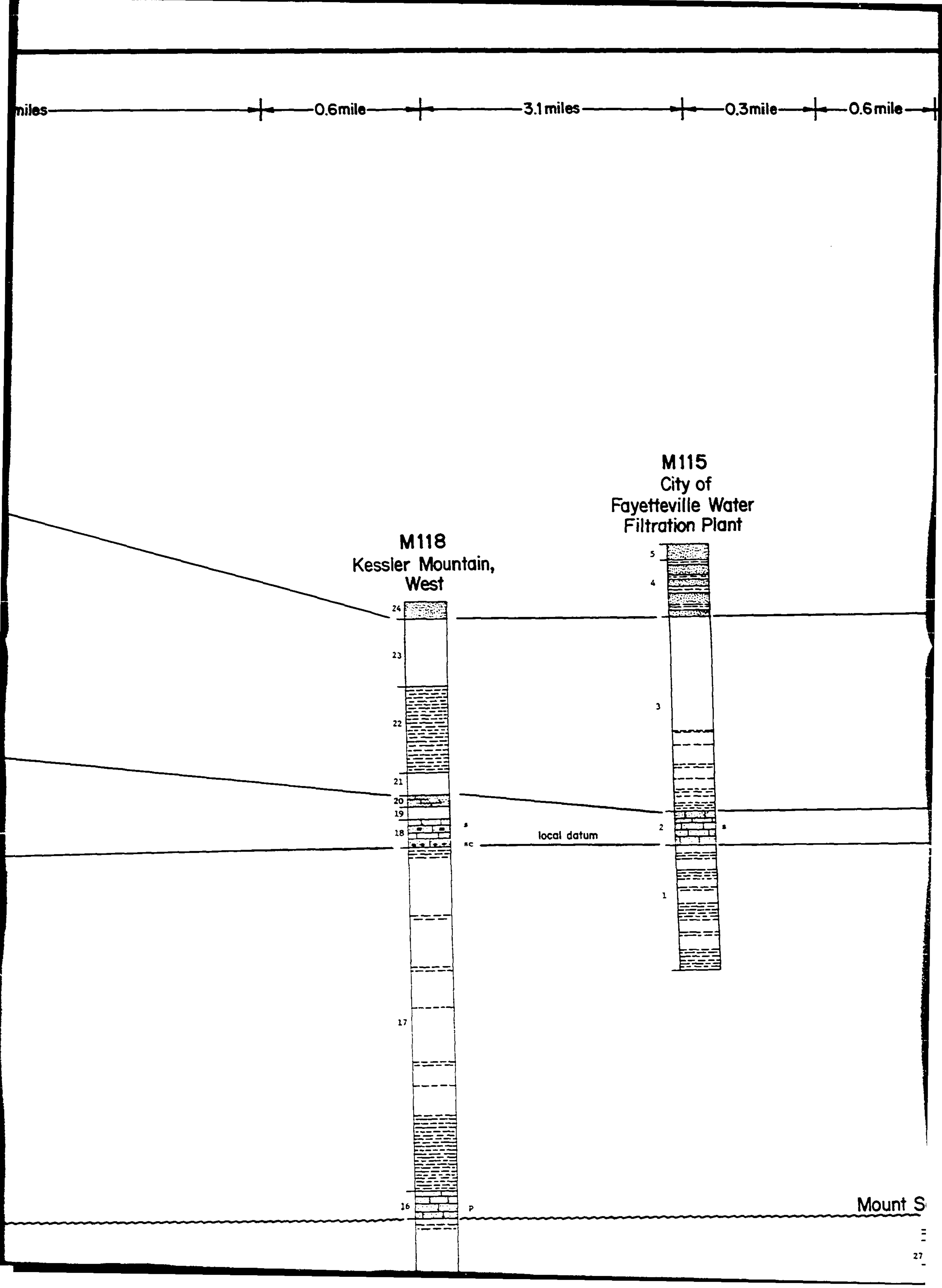


2.1 miles
0.5 mile
0.5 mile
2.7 miles
0.4 mile
0.3 mile
orth
M106
Lee Creek,
South
M107
Lee Creek,
Central
M108
Lee Creek,
North
M100
Woolsey Station,
Everett Mountain
M101
Mill Creek,
U.S. Highway
71 Bridge

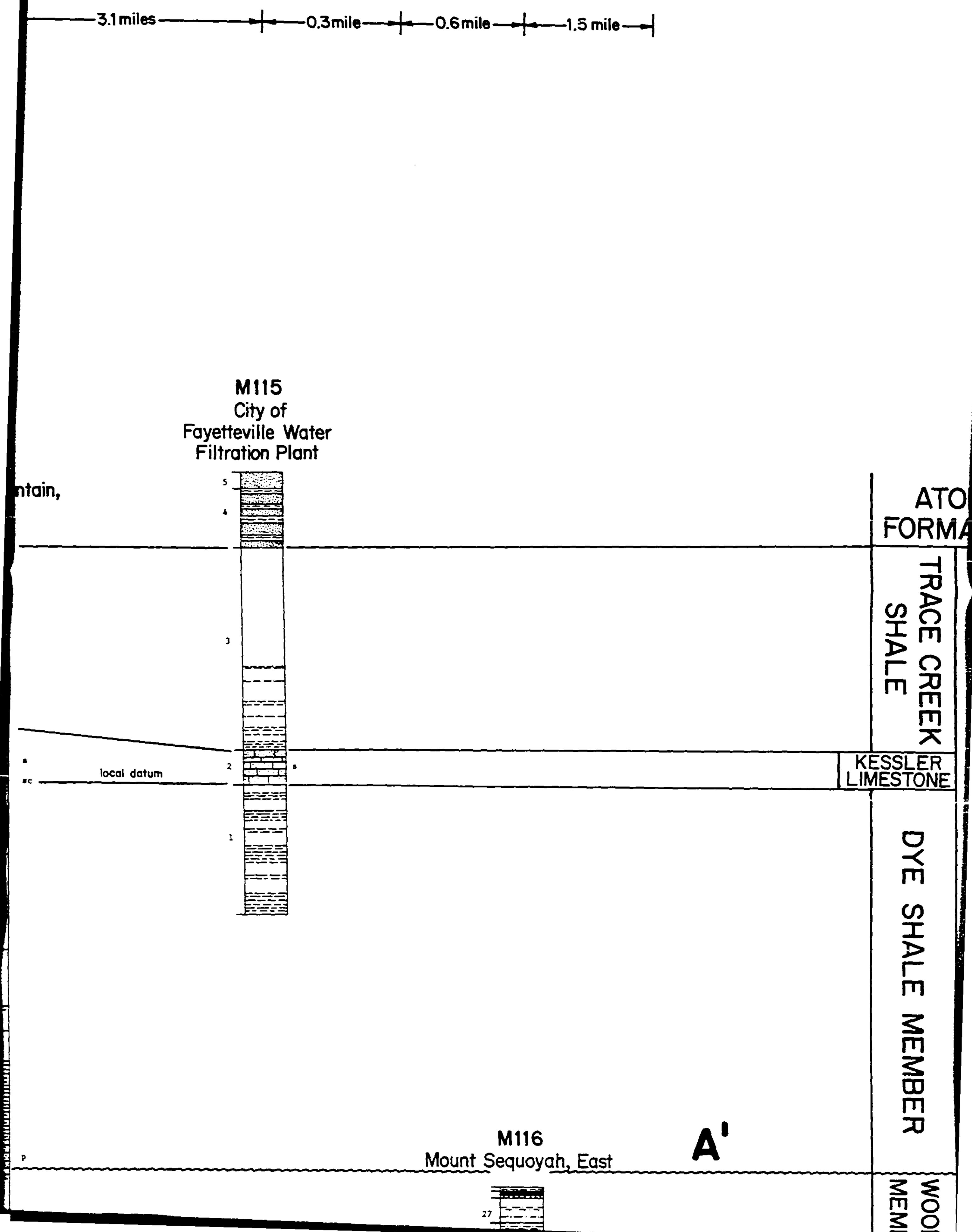

2.7 miles
0.4 mile
0.3 mile
0.5 mile
0.5 mile
0.2 mile
M108
ee Creek,
North
M100
Woolsey Station,
Everett Mountain
M113
Mill Creek
M101
Mill Creek,
U.S. Highway
71 Bridge
West Fork
Coal
29
28
27
25
24
23
22
21
20
17
16
ipc
pi
p
22
21
20
19
18
17
16
15
14
13
12
11
10
9
psc
psi
p
o
ps
gbs
b
pb
pbic
25
26C


e
0.3 mile
0.5 mile
0.5 mile
0.2 mile
6.1 miles
M113
Mill Creek
22
21
20
19
p
18
17
16
15
14
psc
13
12
11
10
psi
9
M101
Mill Creek,
S. Highway
71 Bridge
M112
West Fork, Robinson's
Coal Bank
26C

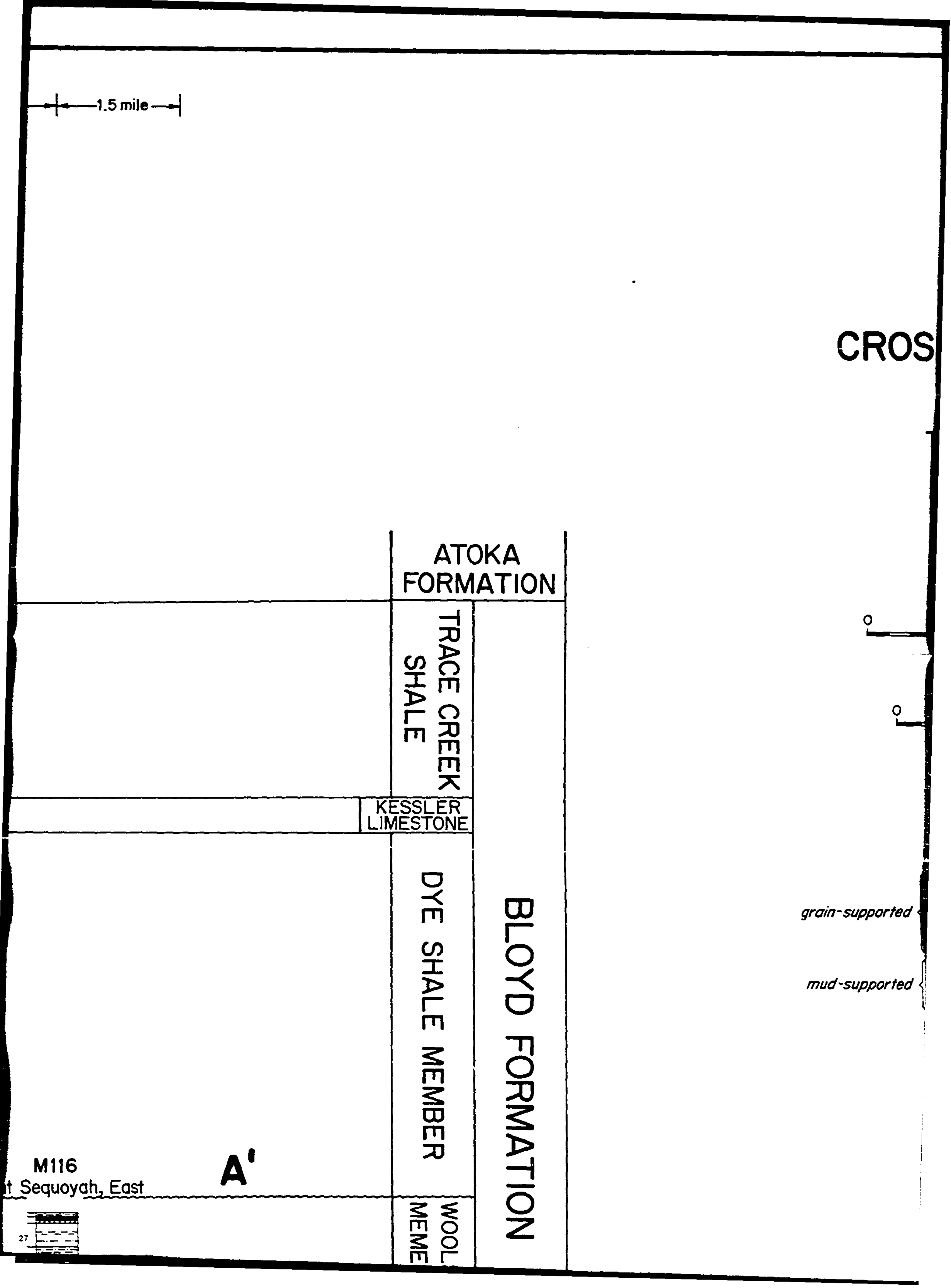

0.2 mile
6.1 miles
0.6 mile
M118
Kessler Mountain,
West
24
23
22
21
20
19
18
17
16
M112
West Fork, Robinson's
Coal Bank



miles
0.6 mile
3.1 miles
0.3 mile
0.6 mile
M115
City of
Fayetteville Water
Filtration Plant
M118
Kessler Mountain,
West
24
23
22
21
20
19
18
17
16
5
4
3
2
1
local datum
Mount S
27



3.1 miles
0.3 mile
0.6 mile
1.5 mile
M115
City of
Fayetteville Water
Filtration Plant
ntain,
5
4
3
2
1
local datum
ATO
FORMA
TRACE CREEK
SHALE
KESSLER
LIMESTONE
DYE SHALE MEMBER
M116
Mount Sequoyah, East
A'
27
WOOL
MEME


1.5 mile
CROS
ATOKA FORMATION
TRACE CREEK SHALE
KESSLER LIMESTONE
DYE SHALE MEMBER
BLOYD FORMATION
WOOL
MEME
grain-supported
mud-supported
M116
A'
t Sequoyah, East
27

CROSS SECTION A-A'

by

THOMAS W. HENRY

Ph. D. Dissertation

1973

N

0 1 2 3 4

Horizontal scale in miles

0 20 40 60

Vertical scale in feet

LEGEND

grain-supported: *grainstone*, *packstone*, *wackestone*

mud-supported: *mudstone*, *boundstone*

limestone (grainstone, packstone, wackestone, mudstone, boundstone)

quartz-sandy limestone

calcareous sandstone

sandstone

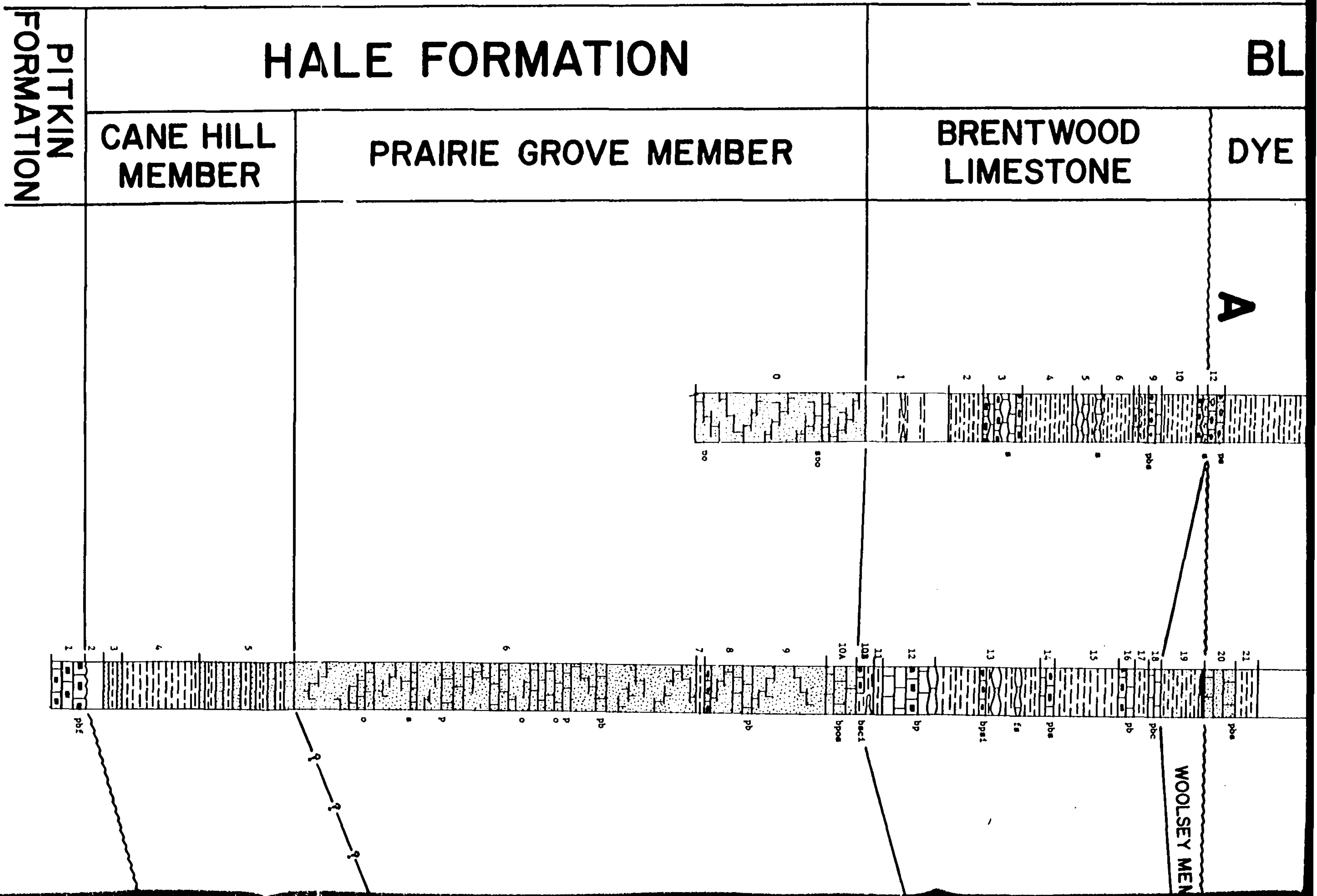
siltstone

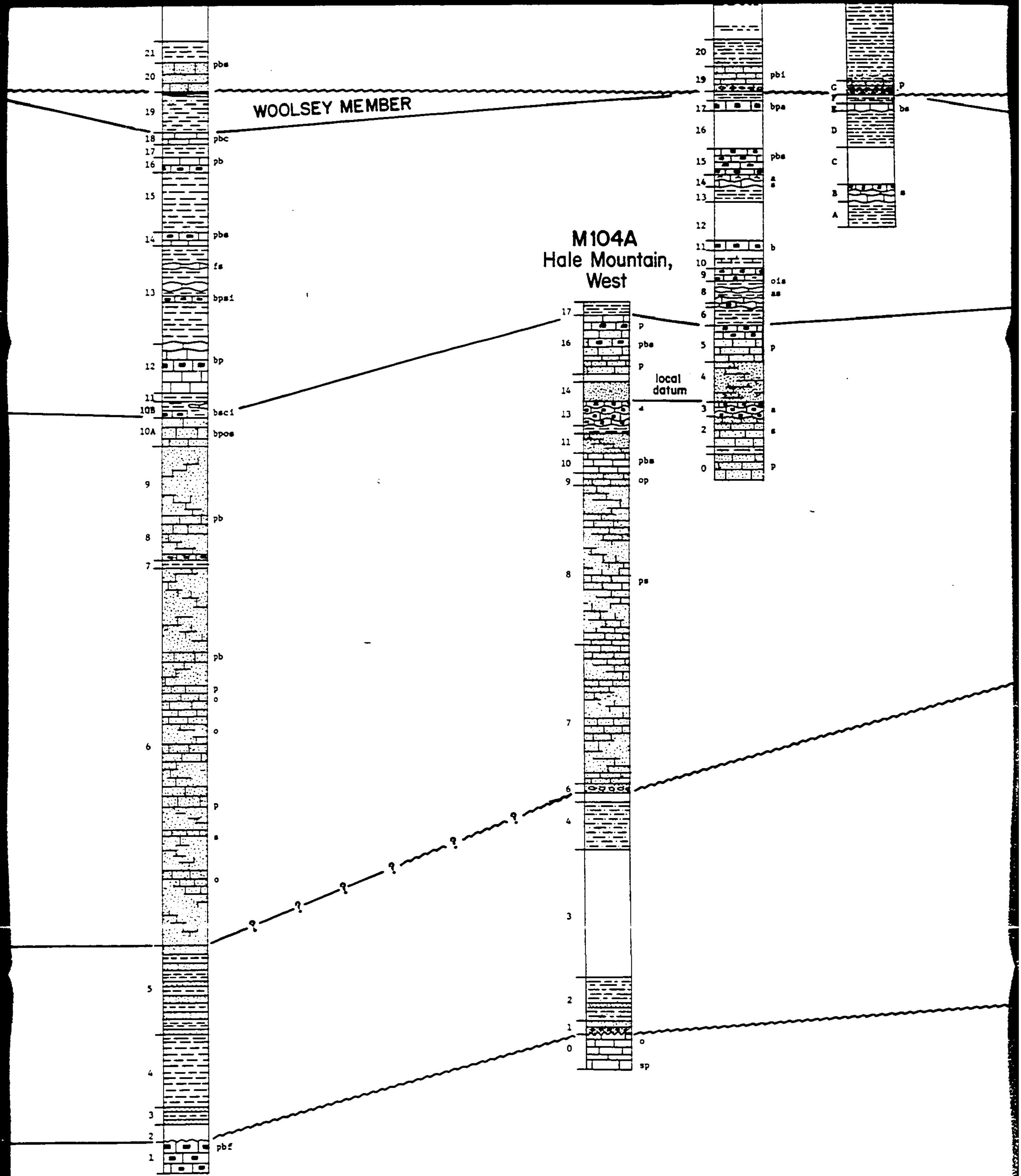
quartz-silty shale

shale

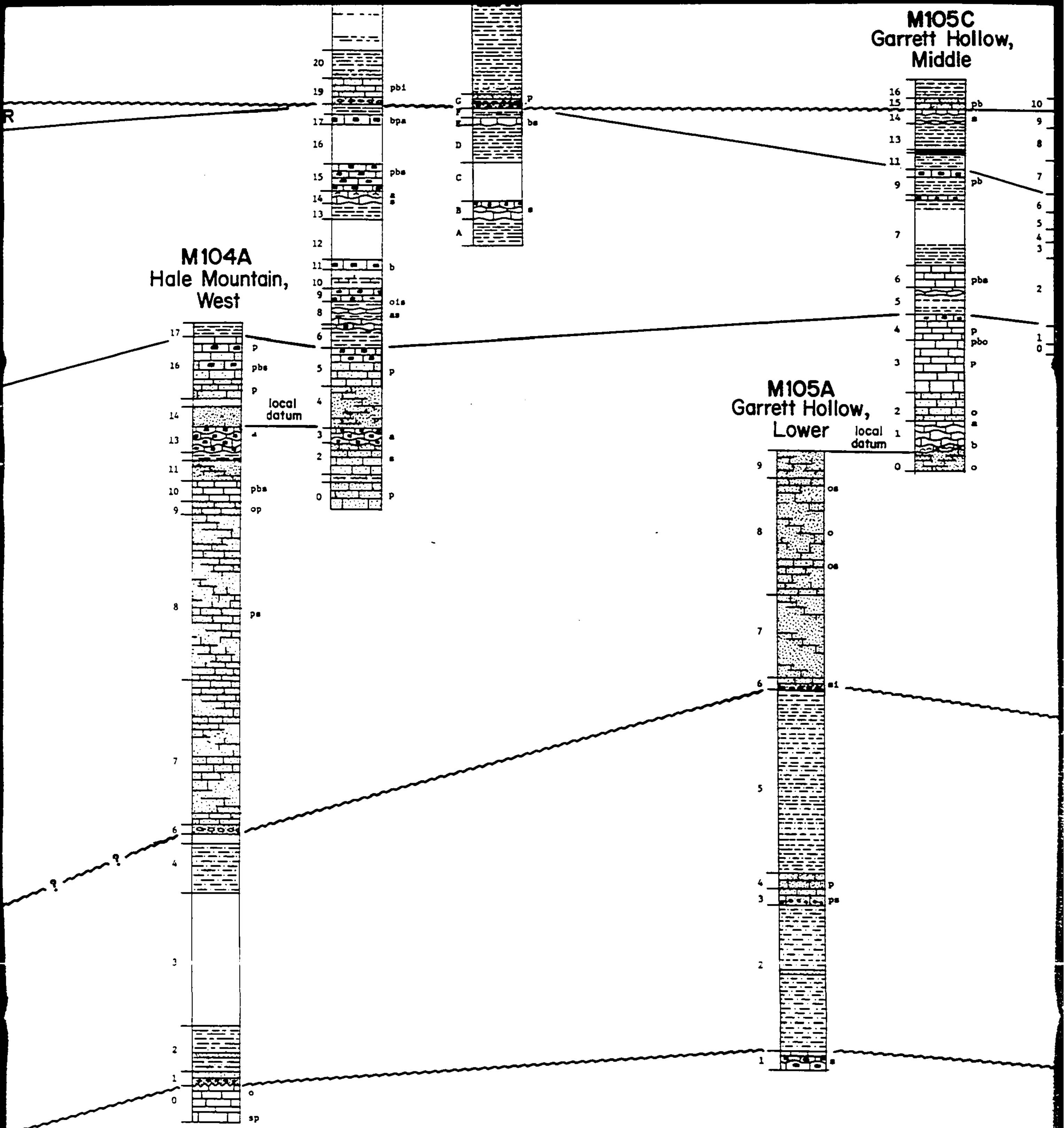
calcareous shale

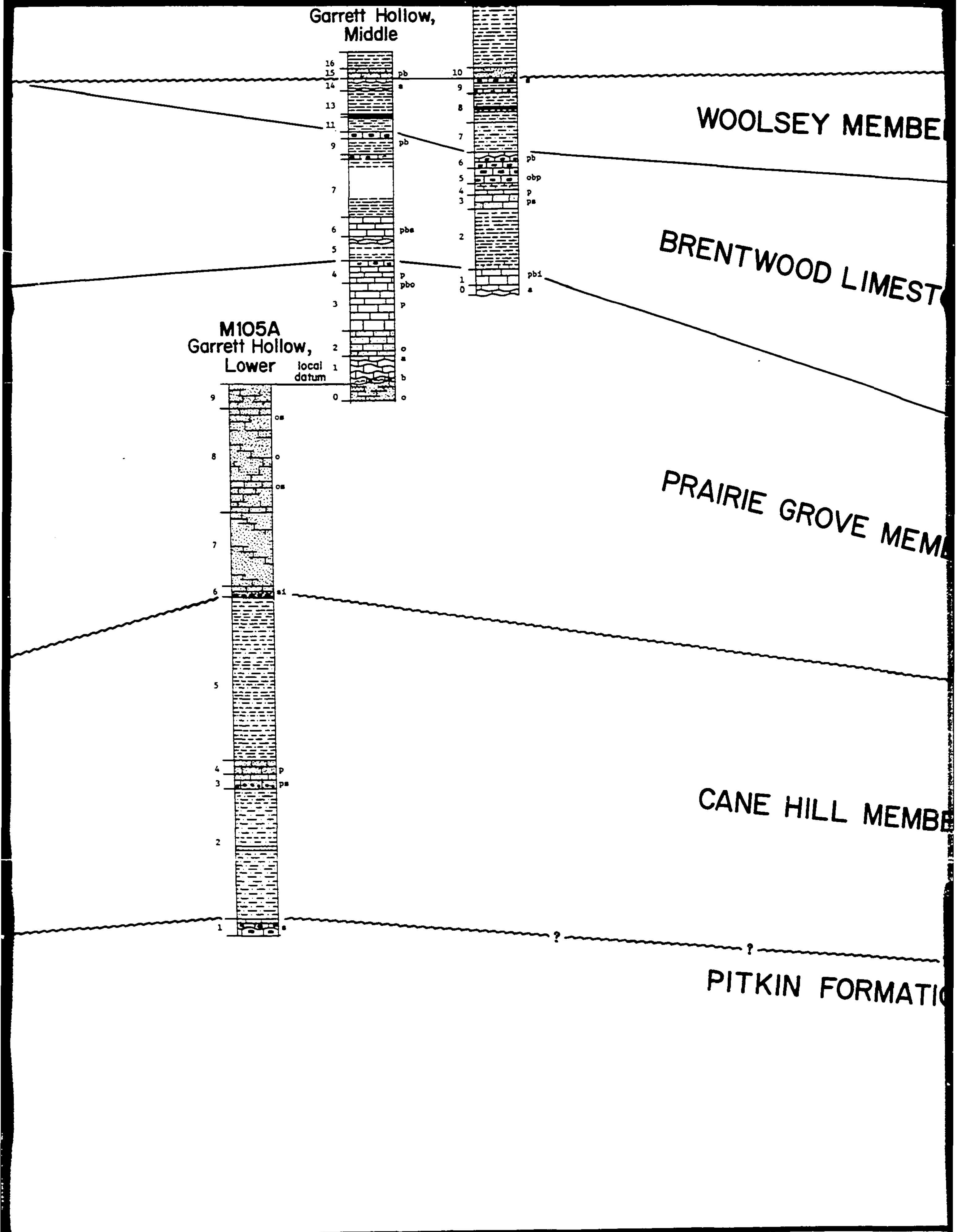
coal and underclay

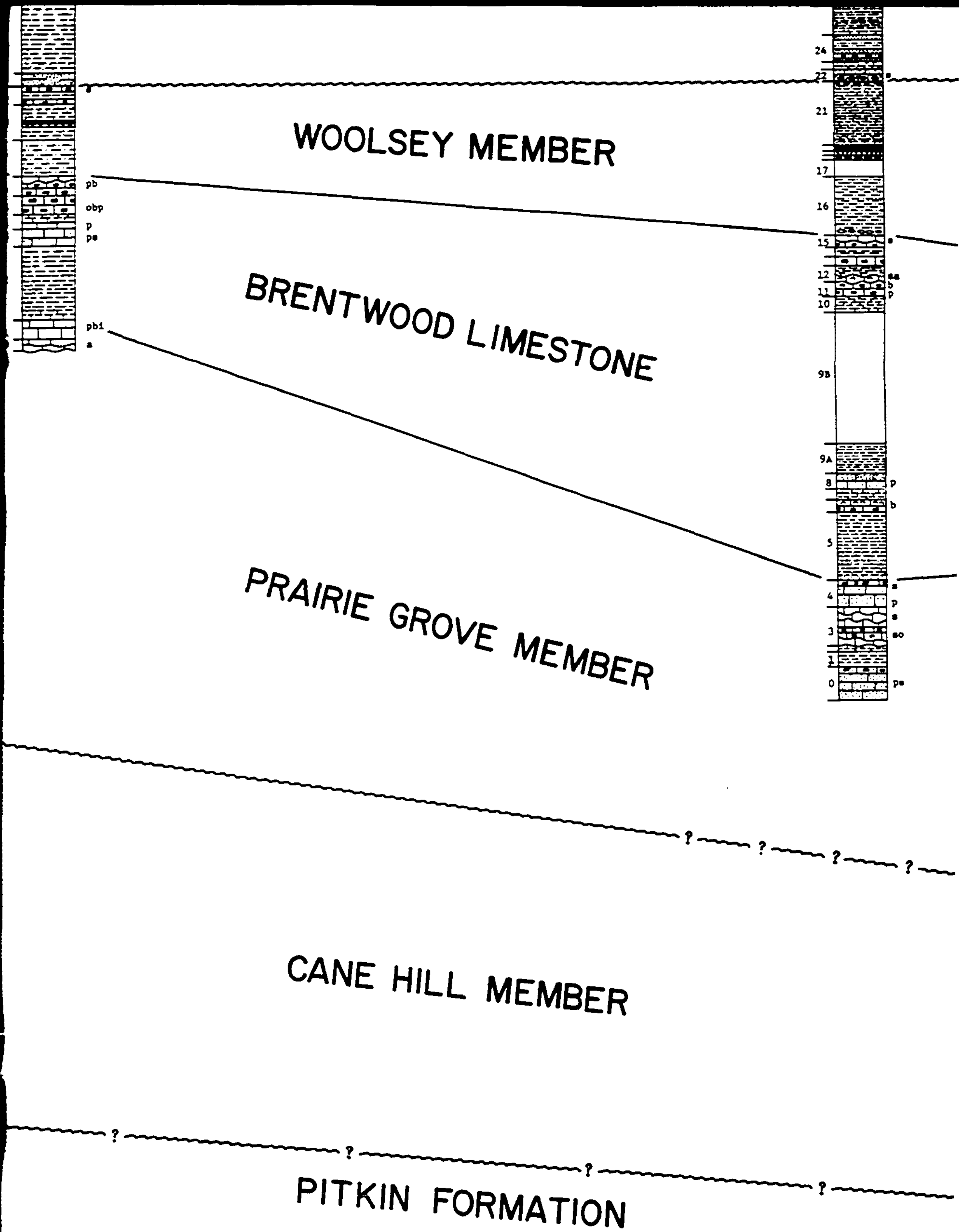

PITKIN FORMATION
HALE FORMATION
BL
CANE HILL MEMBER
PRAIRIE GROVE MEMBER
BRENTWOOD LIMESTONE
DYE
A
WOOLSEY ME

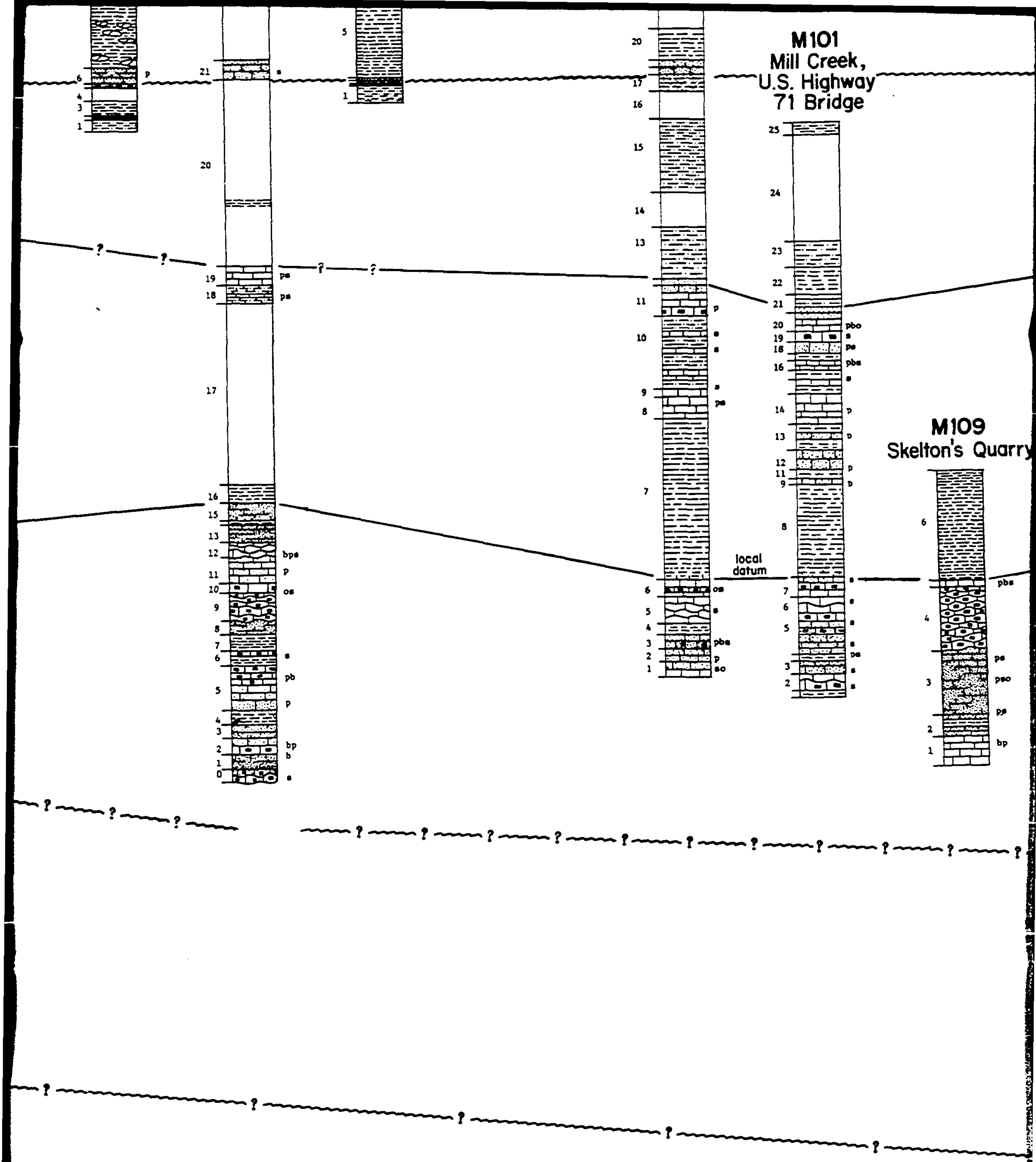


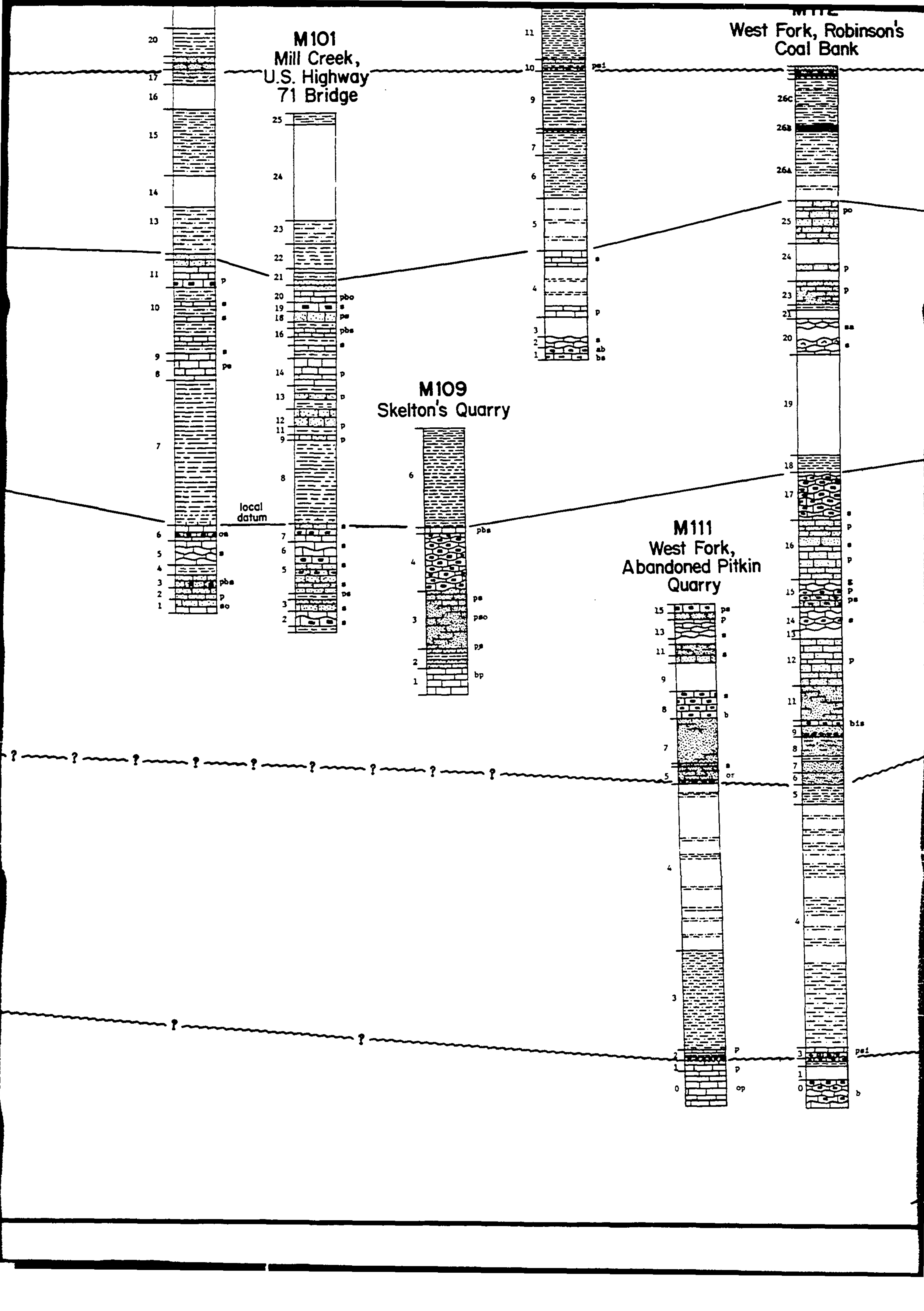
WOOLSEY MEMBER
M104A
Hale Mountain,
West
local
datum

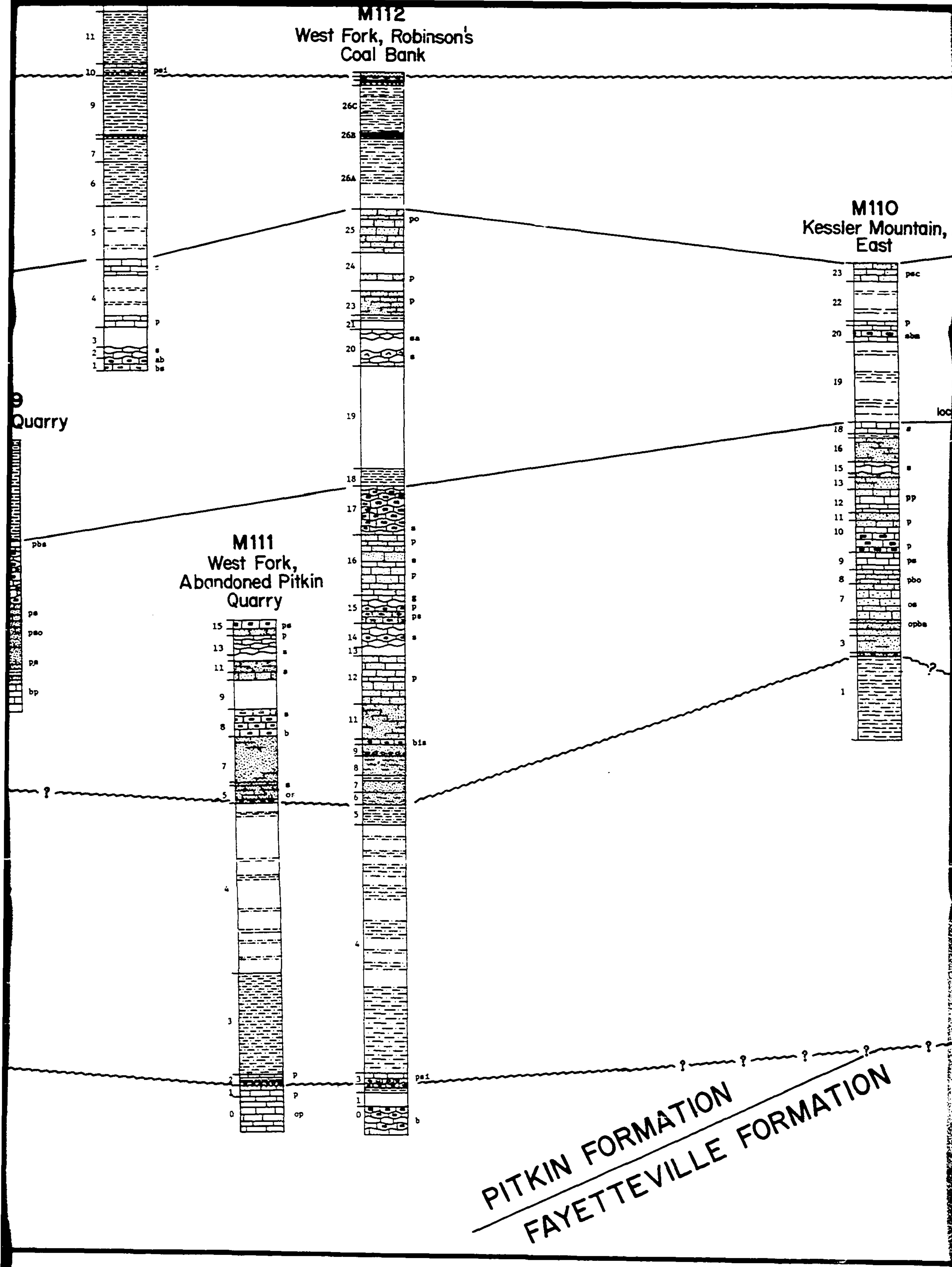

M105C
Garrett Hollow,
Middle
M104A
Hale Mountain,
West
M105A
Garrett Hollow,
Lower
local
datum
local
datum

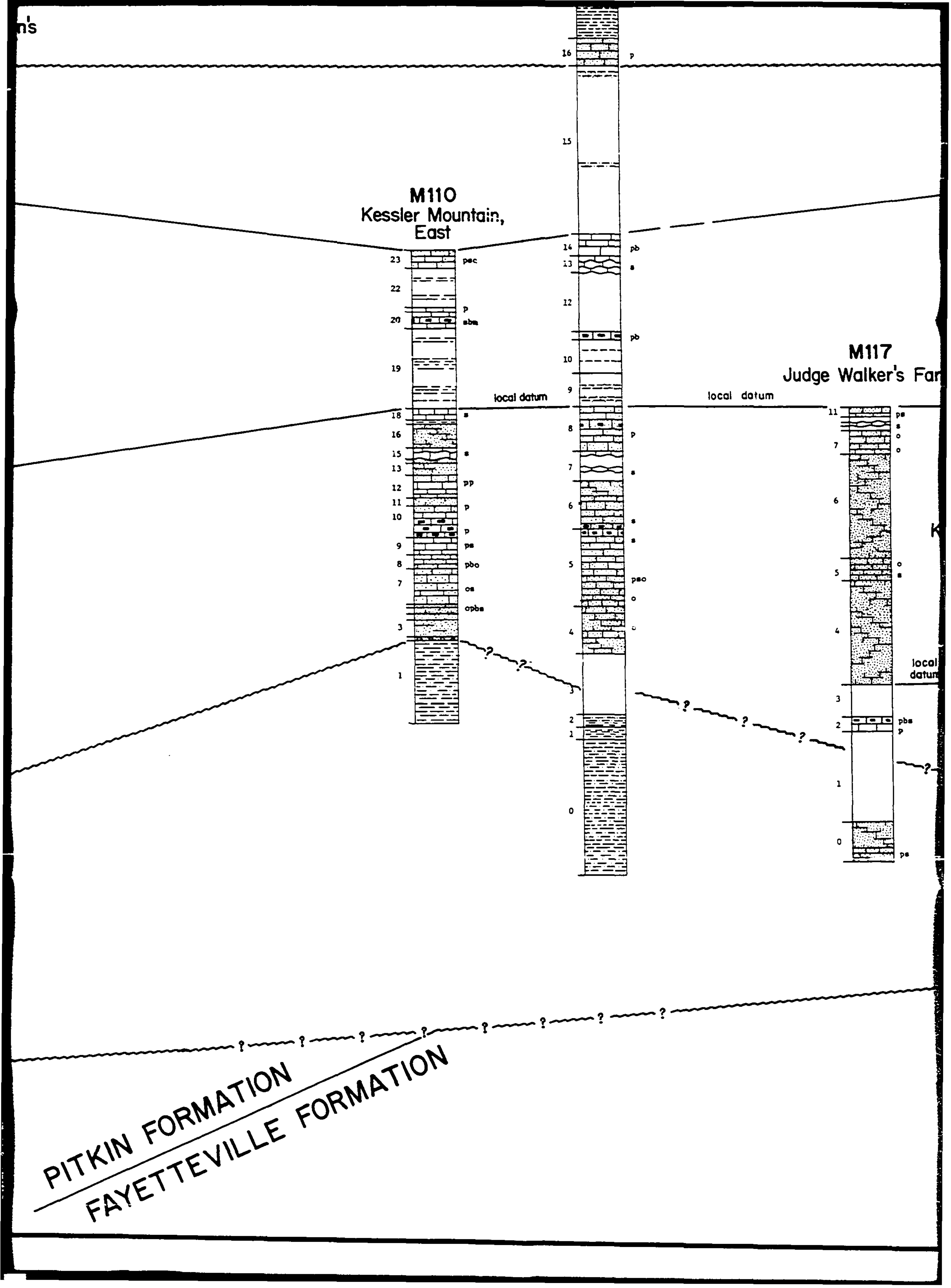

Garrett Hollow,
Middle
M105A
Garrett Hollow,
Lower
local
datum
WOOLSEY MEMBE
BRENTWOOD LIMEST
PRAIRIE GROVE MEM
CANE HILL MEMBE
PITKIN FORMATI

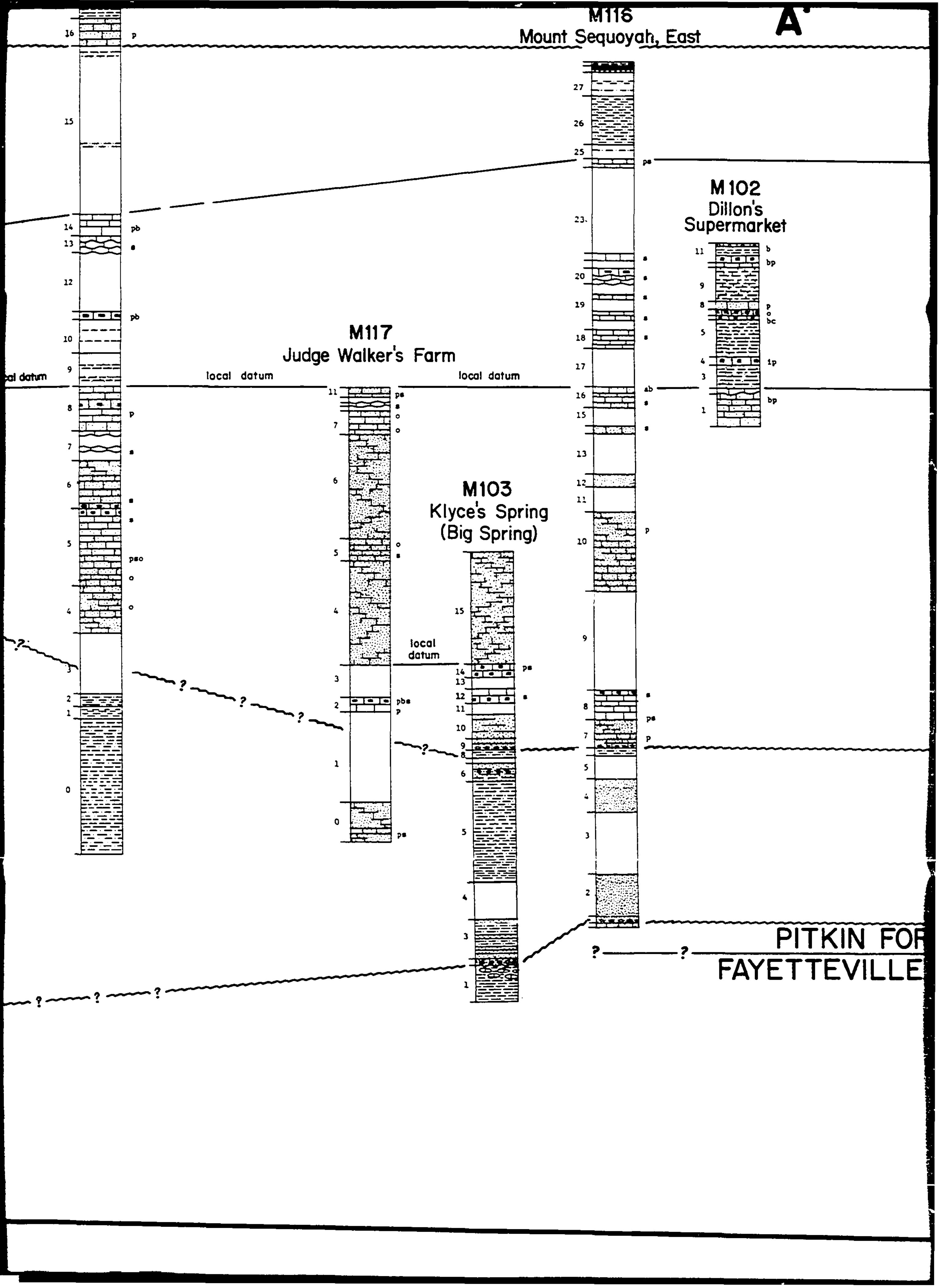

WOOLSEY MEMBER
BRENTWOOD LIMESTONE
PRAIRIE GROVE MEMBER
CANE HILL MEMBER
PITKIN FORMATION


M101
Mill Creek,
U.S. Highway
71 Bridge
M109
Skelton's Quarry
local
datum

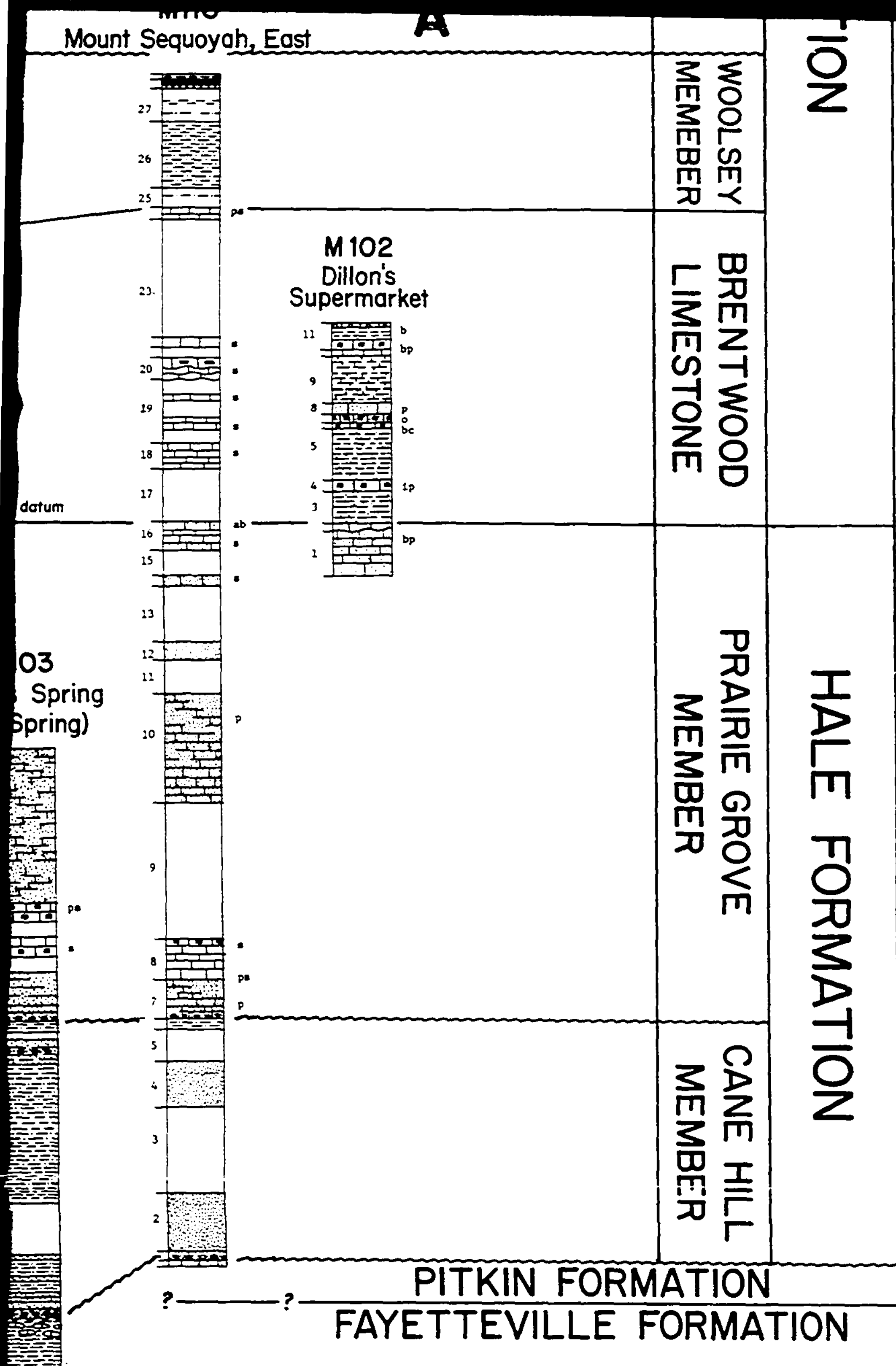

M101
Mill Creek,
U.S. Highway
71 Bridge
M109
Skelton's Quarry
West Fork, Robinson's
Coal Bank
M111
West Fork,
Abandoned Pitkin
Quarry
local
datum


M112
West Fork, Robinson's
Coal Bank
M110
Kessler Mountain,
East
Quarry
M111
West Fork,
Abandoned Pitkin
Quarry
PITKIN FORMATION
FAYETTEVILLE FORMATION


n's
M110
Kessler Mountain,
East
M117
Judge Walker's Far
local datum
local datum
local
datum
PITKIN FORMATION
FAYETTEVILLE FORMATION



M116
Mount Sequoyah, East
A'
M102
Dillon's
Supermarket
M117
Judge Walker's Farm
local datum
local datum
local datum
M103
Klyce's Spring
(Big Spring)
local
datum
PITKIN FOR
FAYETTEVILLE



A
Mount Sequoyah, East
M 102
Dillon's
Supermarket
03
Spring
Spring)
datum
WOOLSEY
MEMEBER
BRENTWOOD
LIMESTONE
PRAIRIE GROVE
MEMBER
CANE HILL
MEMBER
ION
HALE FORMATION
PITKIN FORMATION
FAYETTEVILLE FORMATION

calcareous shale

coal and underclay

conglomerate

dolomite nodules

covered

unconformity

correlation

—?— correlation uncertain

17 unit number

SYMBOLS FOR PRIMARY GRAIN CONSTITUENTS OF LIMESTONES

p pelmatozoan

b bryozoan

mixed skeletal

o oolitic

i intraclasts

c algal oncoliths

algal

f foraminiferal