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THE STRATIGRAPHY OF THE WAPANUCKA FORMATION (LOWER PENNSYLVANIAN)
ALONG THE FRONTAL MARGIN OF THE OUACHITA MOUNTAINS, OKLAHOMA

The University of Oklahoma PH.D. 1980

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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE STRATIGRAPHY OF THE WAPANUCKA FORMATION (LOWER PENNSYLVANIAN) ALONG THE FRONTAL MARGIN OF THE OUACHITA MOUNTAINS, OKLAHOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

ROBERT CALVIN GRAYSON, JR.

Norman, Oklahoma

1980

THE STRATIGRAPHY OF THE WAPANUCKA FORMATION

(LOWER PENNSYLVANIAN) ALONG THE FRONTAL MARGIN

OF THE OUACHITA MOUNTAINS, OKLAHOMA

APPROVED BY

Patrick K. Sutherland

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DISSERTATION COMMITTEE

ABSTRACT

The Wapanucka Formation is exposed in a series of arcuate, thrust fault blocks in the frontal Ouachita Mountains, Oklahoma. The formation is fault repeated as many as five times in a distance of approximately two miles (3.2 kms). These fault blocks exposures range from several miles (4.8 kms) to nearly fifty miles (80 kms) in linear extent. Thirty-three measured sections spaced along this narrow outcrop belt provide control for stratigraphic study and subdivision. The formation is subdivided into four members that contain part or all of four conodont zones.

The four members, where they co-occur, include in ascending order: (1) the Chickachoc Chert Member, (2) the lower limestone member, (3) the middle shale member, and (4) the upper sandstone/limestone member. The lower limestone is a marine shoal water facies. It is a complex lithologic mosaic consisting of varying proportions of oolite and bioclastic calcarenite, micritic and spiculiferous limestone, limestone pebble conglomerate, and shale interbeds. The shoal water lithologies that constitute the lower limestone, based on conodont correlations, are the precise time equivalent to the basinal Chickachoc Chert facies. The Chickachoc Chert Member consists of shale, spiculite, spiculiferous limestone, and rare interbeds of cross-bedded bioclastic calcarenite. The lower limestone and Chickachoc Chert were deposited on a basinward sloping surface. The middle shale is a fine grained clastic wedge that represents a basin fill stage of sedimentation. To a considerable extent, this clastic influx diminished the basinward sloping bathymetric profile that had existed. Subsequently, deposition of carbonate and quartz sand now assigned to the upper member began on a more nearly horizontal substrate. Bioclastic calcarenite and quartz sand accumulated as a system of offshore bars. Interbar facies include micritic and spiculiferous limestone, and shale.

The Wapanucka Formation contains part or all of four conodont zones that are defined on the earliest occurrences of time sensitive platform elements. The oldest zone recognized, the *Idiognathoides convexus* zone, indicates equivalence to the Kessler Limestone Member of the type

Morrowan Series of the Ozark area. The succeeding _Neognathodus kanumai-Idiognathoides ouachitensis_ and _Diplognathodus orphanus_ zones are represented by an erosional gap between the Kessler and overlying Trace Creek Shale, type Morrowan Series. The _Streptognathodus elegantulus_ zone is the youngest biostratigraphic unit present in the Wapanucka. The zone is also present in the Trace Creek Shale,Ozark area. Its occurrence is thoughout to indicate an early Atokan age.

ACKNOWLEDGEMENTS

I am particularly grateful for all the help and encouragement that Patrick Sutherland has provided me through the various stages of this study. He introduced me to the geology of Oklahoma, suggested the dissertation problem, was never to busy to go to the field, aided in the collection of conodont samples from the many important Lower Pennsylvanian localities with which he is familiar, and provided financial support. His willingness to give of his time, his love of field work and dedication to geology has been a source of inspiration.

Bruce Archinal shared the expense of renting an apartment one summer while we were both doing field work in southern Oklahoma. His stratigraphic work on the Atoka Formation on the southwestern margin of the Arkomo Basin made it possible to collect this important sequence for conodonts. We spent many profitable hours discussing geology and the progress that we were making on our thesis problems.

Charles J. Mankin, Director of the Oklahoma Geological Survey, made available equipment and supplies that would not have otherwise been possible to obtain. Also, he gave freely of his time, offered his advice and encouragement, and provided financial support through Oklahoma Geological Survey grants, as well as, by hiring me as a research-laboratory assistant during several summers while I was working on the dissertation.

H. Richard Lane helped arrange a $1500.00 grant from Amoco Oil Company that helped support this study. He also provided support by his willingness to share his experience and knowledge of Carboniferous conodont faunas.

I am grateful to Walter L. Manger of the University of Arkansas, and John Wickham, Burr Silver, and Frank Wantland, all of the University of Oklahoma, who read the dissertation and offered their advice and criticisms.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

Figure		Page

LIST OF PLATES

LIST OF MEASURED STRATIGRAPHIC SECTIONS

INTRODUCTION

Purpose of Study

Lower Pennsylvanian strata are exposed in three general regions in Oklahoma: these are, (1) the southwestern Ozark region in northeastern Oklahoma; (2) the Arbuckle Mountain region of south-central Oklahoma; and (3) the Ouachita Mountains of southeastern Oklahoma. The Lower Pennsylvanian rocks of the Ozark region have been intensively studied (including lithologic and faunal analyses) by Patrick K. Sutherland and graduate students working under his direction at the University of Oklahoma. The Lower Pennsylvanian sequences in and on the margins of the Arbuckle Mountain uplift have also been investigated by P. K. Sutherland and his students. In contrast, very little detailed stratigraphic information has previously existed regarding the equivalent-aged Wapanucka Formation in the Ouachita Mountains. This study was undertaken to determine the stratigraphy and to reconstruct the regional depositional framework of the Wapanucka Formation by interpretion of stratigraphic evidence in the context of a time framework provided by conodonts.

The results of the study are presented in four interrelated chapters; these are, (1) lithostratigraphy, (2) lithofacies description and interpretation, (3) depositional synthesis, and (4) conodont biostratigraphy. The chapter titled lithostratigraphy is primarily concerned with stratigraphic subdivision of the Wapanucka Formation and the nature and relationships of these subdivisions. The following chapter, lithofacies description and interpretation, provides a detailed description and a depositional interpretation of the facies (lithologies) first mentioned in connection with the stratigraphic subdivision of the Wapanucka. The depositional synthesis chapter outlines my interpretation of the regional depositional relationships of the various lithofacies to important environmental parameters. The final chapter deals mainly with the conodont zonation of the Wapanucka and the local and regional correlation of the conodont zones. The time framework utilized in preceding chapters is also fully documented in this last chapter.

Importance of Study

The Wapanucka Formation is the only predominantly shallow marine sequence exposed in the now deformed Ouachita mobile belt. The formation accumulated along the Paleozoic continental margin. Strata of equivalent age, higher on the shelf, now exposed in the southwestern Ozark area in northeastern Oklahoma and northwestern Arkansas, are comparatively incomplete due to the greater frequency and magnitude of regional unconformities. The Wapanucka Formation also contrasts markedly with coeval basinal, or possibly slope, deposits represented by the boulder-bearing Johns Valley Shale and part of the flysch facies of the Atoka Formation. Of additional interest are the marked facies changes present within the Wapanucka Formation. The most striking facies change occur in the lower part of the formation in a basinward direction. A relatively thin but lithologically complex shoal assemblage in the lower Wapanucka grades into a thicker, less lithologically diverse association of deeper water origin. This change is interpreted as having occurred at or near the then existing shelf margin-slope break. An equivalent facies change does not occur in the upper part of the formation but the occurrence of some similar lithologies in both horizons provides significant information for determining the influence of depositional topography and bathymetry on facies genesis.

Conodonts of the Wapanucka Formation provide new evidence for zonation of Lower and Middle Pennsylvanian strata and recognition of a Morrowan-Atokan chronostratigraphic boundary in the southern midcontinent. The conodont faunas suggest correlation of the Wapanucka with the important type Morrowan reference sequence in northwestern Arkansas and northeastern Oklahoma.

Area of Investigation

Location

The study area is in southeastern Oklahoma, along the northern margin of the Ouachita Mountains, immediately south of the Choctaw Fault. It encompasses portions of northern Atoka, southern Pittsburgh and western Latimer Counties (Fig. 1). In addition, the type section of the Wapanucka Formation, located on the northeastern flank of the Arbuckle Mountains, in Atoka County, is included in the study.

The study area lies within Township's 1 South to 5 North and Ranges 12 to 21 East. In this area, the Wapanucka Formation occupies a narrow belt of exposures that extends from about 5 miles north of Atoka to a point about 7 miles south of Redoak. The total length of this belt is about 50 miles but it does not exceed 3 miles in width.

Tectonic Setting

The Ouachita Mountains are thought by most concerned workers to represent part of the Paleozoic continental margin that was deformed by continent-continent collision or perhaps a continent-island are collision (Wickham and others, 1976). In Oklahoma the now deformed Ouachita Mountains are generally subdivided into three tectonic provinces based on structure and age of exposed rocks (for example, Wickham and others, 1976). Two of the provinces

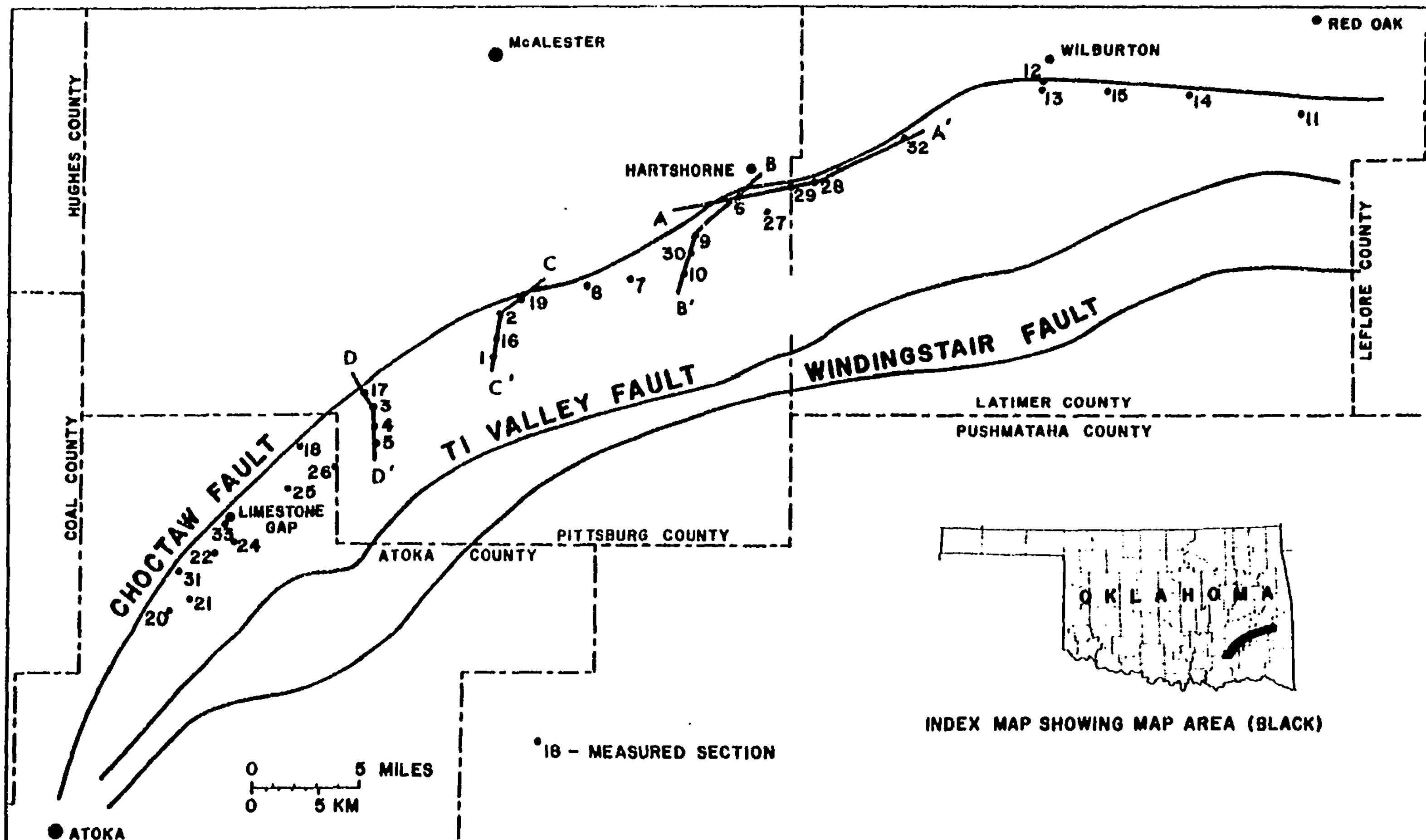


Figure 1. Generalized locality map for measured sections by Robert C. Grayson, Jr., in Wapanucka Formation. Note locations of cross sections A-A', B-B', C-C' and D-D' (figs. 7, 8, 9 and 10, respectively); north-to-south distances between measured sections arbitrarily expanded by a factor of 2 to 3 times.

are dominated by rocks of Carboniferous age, the third includes the so called "core" areas of older rocks such as the Benton-Broken Bow Uplift and the Potato Hills. These areas expose rocks of Ordovician, Silurian and Devonian age. The area south of the Choctaw Fault and north of the Ti Valley Fault is commonly referred to as the "Frontal Ouachita Mountains." This portion of the Ouachitas is characterized by numerous imbricate reverse faults that cut rocks of predominantly Carboniferous age. Three major thrust faults, the Choctaw, Katy Club and Pine Mountain, occur in the frontal belt. All exposures of the Wapanucka Formation in the Ouachita Mountains are present within the Frontal belt, north of the Pine Mountain Fault. The Central Ouachitas include the area from the Ti Valley Fault south to the Benton-Broken Bow uplift. This area is characterized by large recumbent and overturned folds that are cut by comparatively fewer reverse faults.

Stratigraphic Setting

Middle Carboniferous rocks exposed in the Oklahoma Ouachita Mountains exhibit major basinward facies changes particularly between the frontal and central structural regions. These lithologic changes are closely paralleled by changes in names of stratigraphic units at the formation and member level (Table 1). In the blocks south of the Choctaw and Katy Club Faults, the Wapanucka Formation rests, on the "Springer" Shale and is overlain by shales of the

<table>
<tr><th colspan="4">Frontal Ouachita Mountains</th><th colspan="2">Central Ouachita Mountains</th></tr>
<tr><th colspan="2">Block South of Choctaw Fault</th><th colspan="2">Block South of Katy Club Fault</th><th>Block South of Pine Mtn. Fault</th><th>Region South of Ti Valley Fault</th></tr>
<tr><td colspan="2">Atoka Formation</td><td colspan="2">Atoka Formation</td><td rowspan="6">Atoka Formation
— ? — ? — ? —
"Springer" Shale</td><td rowspan="6">Atoka Formation
— ? — ? — ? —
Johns Valley Shale</td></tr>
<tr><td rowspan="4">Wapanucka Fm.</td><td>Upper Sandstone-Limestone</td><td rowspan="4">Wapanucka Fm.</td><td>Upper Sandstone-Limestone</td></tr>
<tr><td>Middle Shale</td><td>Middle Shale</td></tr>
<tr><td>Lower Limestone</td><td rowspan="2">Chickachoc Chert</td></tr>
<tr><td>Chickachoc Chert</td></tr>
<tr><td colspan="2">"Springer" Shale</td><td colspan="2">"Springer" Shale</td></tr>
</table>

Table 1. Stratigraphic setting, diagram also shows basinward changes in stratigraphy (modified from Hendricks and others, 1947).

Atoka Formation. In these areas, dramatic facies changes exist in the Wapanucka Formation, particularly in the lower part of the unit. Significantly greater but more poorly known changes in facies occur in the region south of the Katy Club Fault and extending south of the Ti Valley Fault (Table 1). A facies relationship of the Wapanucka and Johns Valley Shale is supported by correlation of the units by means of goniatites (Gordon and Stone, 1977). The boulder-bearing Johns Valley Shale may represent a continental slope deposit accumulating adjacent to the shelf-margin deposits comprising the Wapanucka Formation. Equivalence of the Wapanucka to the flysch facies of the Atoka Formation cannot be biostratigraphically established. Lithostratigraphic correlations of the Wapanucka with the Atoka in the Central Ouachitas have been based on presence of spiculite and mold faunas in the lower part of the Atoka Formation in the Central Ouachitas (Cline, 1956a, b).

Nature of Exposures

The Wapanucka Formation in the Ouachita Mountains is exposed in a series of fault repeated ridges convex toward the north-northwest. These ridges are separated by broader fault controlled valleys underlain primarily by shale of the "Springer" and Atoka Formations. As many as five fault ridges which repeat the Wapanucka within a lateral distance of less than three miles occur between the Choctaw and Pine Mountain faults. The frontal faulted ridge is known locally as "Limestone Ridge." The frontal fault ridges commonly extend for many miles without significant internal structural complexity but small normal faults occur. The lateral persistence of Limestone Ridge is particularly striking. It extends from sec. 21, T. 1 N., R. 12 E. to sec. 23, T. 4 N., R. 21 E. with only three significant offsets due to faulting. Apparently at either end of the outcrop belt, Limestone Ridge and basinward fault-repeated ridges of the Wapanucka are concealed by overthrust sheets of the Atoka Formation. These thrust sheets also seem to result in local cover of only the upper part of the Wapanucka in the most basinward ridges between sec. 4, T. 1 S., R. 12 E. and sec. 30, T. 3 N, R. 15 E. These incomplete, faulted exposures of the Wapanucka Formation generally conform to those ridges mapped as the Chickachoc Chert Formation by Hendricks and others (1947).

Typically, the best exposures are located on Limestone Ridge but most presumed shale intervals and contacts with shale intervals are generally covered. The most complete exposures are generally located in road cuts, rock quarries, or other man-made features. Good natural exposures, with the exception of a few water or wind gaps, such as that at National Arch (sec. 8) are not common.

Methods of Investigation

Thirty-three (33) measured stratigraphic sections (Appendix 1; Plate 1, in pocket) spaced evenly along the belt of exposures, provide data for the comprehensive stratigraphic analyses herein. In addition the type section located on the southeastern flank of the Arbuckle Mountains is included in the study. The search for suitable sections was aided immensly by the geologic map of the Western Ouachita Mountains (Hendricks and others 1947). Topographic maps, both 7½ and 15 minute, supplemented this map and were used exclusively in the unmapped outcrop area in Latimer County. Aerial photographs were also used to delineate areas to be searched for suitable stratigraphic sections.

The measurement of stratigraphic sections was based on standard techniques (Kottlowski, 1965). Unit boundaries and the unit number in the vertical sequence were marked on resistant beds with yellow highway paint. Hand samples were collected at intervals of 3 to 10 feet to examine lithologic variability within measured units. The hand samples were slabbed, polished with 600 carbonundum grit, and stained with the carbonate dyes alizarin red s and alizarin red s with potassium ferricyanide as described by Dickinson (1965). Rock slabs were subsequently examined with a binocular microscope for lithologic character and sedimentary structures. Examination of acetate peels from carbonate units in most sections permitted a greater accuracy in determining the nature of the matrix and of the secondary constituents although compaction and aggrading neomorphism caused some uncertainty. Thin sections were made of particularly significant units to supplement the peel and hand sample data. These data are presented in Appendix 1.

Bulk samples were collected for conodonts from suitable lithologies, generally lime packstone or lime grainstone units. The stratigraphic location of each conodont sample and the occurrence of important conodonts in each measured section is also recorded in Appendix 1. Laboratory processing and preparation of limestone samples for conodont extraction basically followed the acidization techniques outlined by Collinson (1963). The methods employed in this investigation differ in that formic acid was substituted for acetic acid. Additionally, tetrabromoethane was the heavy liquid used to reduce the volume of insoluble residue prior to microscopic examination. After heavy liquid separation the heavy mineral fractions which contains the conodonts were washed with acetone to recover the tetrabromoethane for future use. Heavy mineral residues with abundant iron bearing minerals were separated magnetically from the conodont bearing fraction by a Frantz Isodynamic Separator.

THE STRATIGRAPHY OF THE WAPANUCKA FORMATION (LOWER PENNSYLVANIAN) ALONG THE FRONTAL MARGIN OF THE OUACHITA MOUNTAINS, OKLAHOMA

CHAPTER I

LITHOSTRATIGRAPHY

General Statement

The Wapanucka Formation in the Ouachita Mountains of Oklahoma is a sequence of various shoal limestones, spiculite, shale and sandstone. Marked facies changes between these lithologies are characteristic. The writers original interest in the formation resulted from a preliminary study with Patrick K. Sutherland of the striking basinward facies changes in the Wapanucka along the Indian Nation Turnpike (Sutherland and Grayson, 1976, 1977). It was apparent that a detailed regional stratigraphic study of the Wapanucka Formation was needed, including lithostratigraphic and biostratigraphic analyses. These studies were undertaken by the writer and they have resulted in the recognition of new subdivisions (Fig. 2) of the Wapanucka Formation

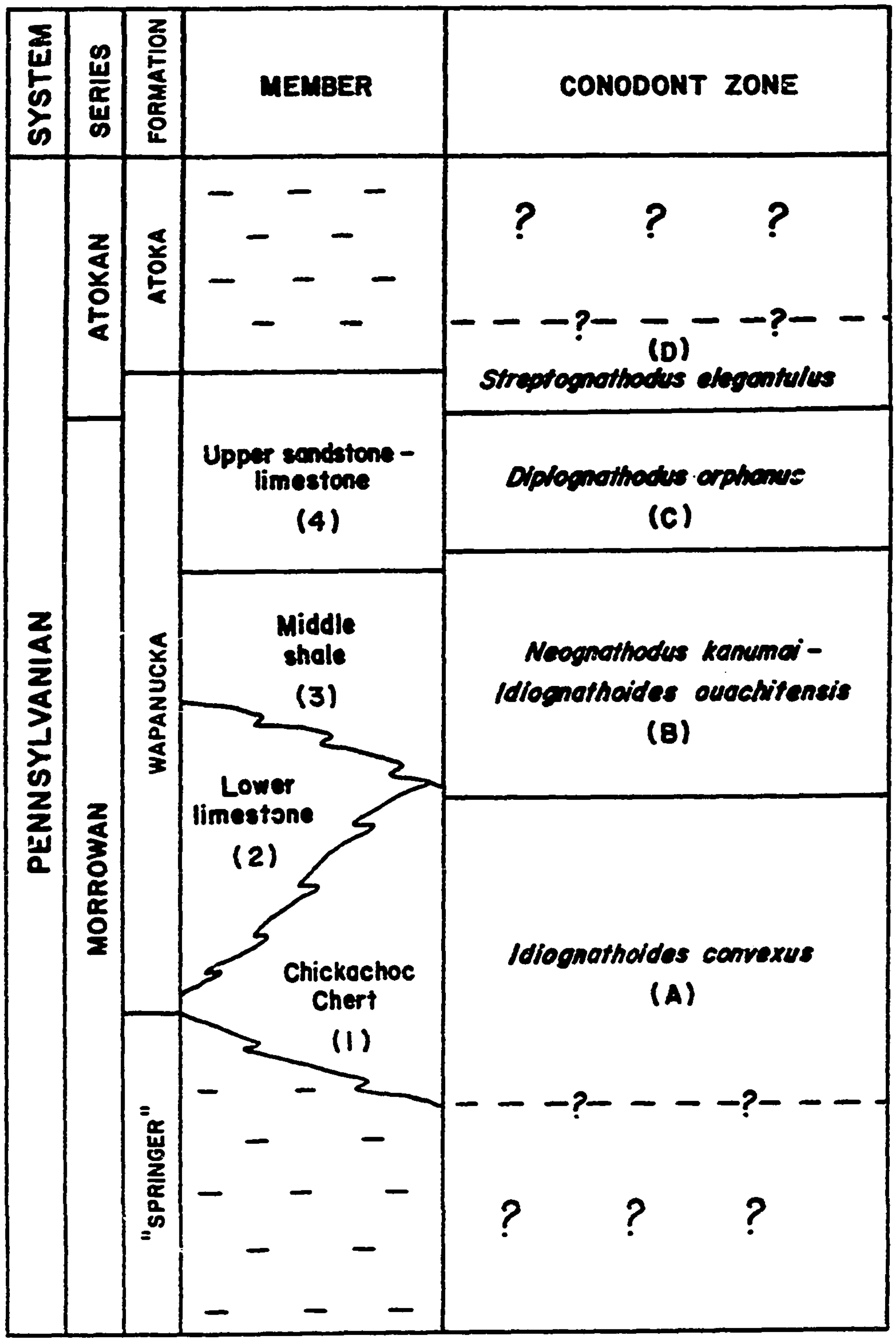


Figure 2. Stratigraphic subdivisions of the Wapanucka Formation in the Ouachita Mountains, Oklahoma,Grayson (1979).

and in the redefinition of previously defined conodont zones.

Previous Lithostratigraphic Studies

Table 2 summarizes the history of formal stratigraphic subdivisions of Carboniferous rocks in the frontal Ouachita Mountains. Taff (1901) named in ascending order the Caney Shale, Wapanucka Limestone, and Atoka Formation. The Atoka Formation was described as containing cherty sandstone lentils in the Katy Club-Pine Mountain fault blocks which he collectively named the Chickachoc Chert. Harlton (1938) subsequently restricted the term Wapanucka to the middle massive portion of Taff's unit. He recognized two additional new formations, the Barnett Hill above and the Limestone Gap Shale below. For beds below his Limestone Gap Shale, Harlton extended the terms Primrose and Union Valley into the Ouachitas, from their type areas in the northeastern Arbuckle Mountains. The stratigraphic subdivisions proposed by Harlton have not been used by more recent workers.

Formational units mapped by Hendricks and others (1947) in the western Ouachita Mountains follow closely the original stratigraphic terminology proposed by Taff (1901). However, they used the term Springer Shale in place of Pennsylvanian "Caney." The term Caney being restricted to underlying lithologically similar but Mississippian age shales. Because the Chickachoc Chert was thought to be a

<table>
<tr><th>Taff
(1901, 1902)</th><th>Harlton
(1938)</th><th colspan="2">Hendricks and Others
(1947)</th><th>Gordon and Stone
(1977)</th></tr>
<tr><th>Northern
Arbuckle Mountains
and
Western
Ouachita Mountains</th><th>Frontal
Ouachita Mountains</th><th>Choctaw-
Katy Club
Fault Block</th><th>Katy Club-
Pine Mountain
Fault Block</th><th>Choctaw-
Ti Valley
Fault Block</th></tr>
<tr><td rowspan="2">Atoka
Formation

Chickachoc
Chert Lentil</td><td>Atoka
Formation</td><td rowspan="2">Atoka
Formation</td><td rowspan="2">Atoka
Formation</td><td rowspan="2">Atoka
Formation</td></tr>
<tr><td>Barnett Hill</td></tr>
<tr><td rowspan="3">Wapanucka
Limestone</td><td>Wapanucka Formation</td><td rowspan="3">Wapanucka
Limestone</td><td rowspan="3">Chickachoc
Chert</td><td rowspan="3">Wapanucka
Limestone

Chickachoc
Chert
facies</td></tr>
<tr><td>Limestone Gap
Shale</td></tr>
<tr><td>Primrose Sandstone</td></tr>
<tr><td>Caney
Shale</td><td>Union Valley
Sandstone</td><td>Springer
Formation</td><td>Springer
Formation</td><td>"Springer"
Formation</td></tr>
</table>

Table 2. History of formal stratigraphic subdivisions of Carboniferous rocks in the frontal Ouachita Mountains, Oklahoma.

basinward equivalent of the Wapanucka, it was raised to formational status by Hendricks and others (1947). The term Chickachoc Chert has been used by Gordon and Stone (1977) in an informal way to indicate a facies of the Wapanucka Formation. The use of the term Springer in the Ouachita Mountains has come under scrutiny (Hart, 1974). Hart uses the Ardmore Basin terminology of the Goodard Shale, instead of Springer.

Wallis (1915), Hendricks and others (1947) and Rowland (1974) have proposed informal subdivisions for the Wapanucka Formation in the frontal Ouachita Mountains. The presumed relationship of units recognized by these authors is compared in Table 3, to the informal stratigraphic subdivisions used in this study. Wallis (1915) observed that the Wapanucka becomes a predominantly sandstone sequence near its eastern-most limits in Latimer County but his beds 1-9 are difficult to recognize. In contrast, the subdivisions recognized by Hendricks and others (1947) and Rowland (1974) seem to conform partially with those established by this investigation. Precise recognition of their units is difficult, however, because they did not provide adequate documentation.

Formations Above and Below Wapanucka

"Springer" Formation

A series of shales, presumably spanning the

Wallis (1915) Limestone Ridge	Hendricks and Others (1947) Western Ouachita Mountains	Rowland (1974) Hartshorne-Wilburton area	Present Investigation Frontal Ouachita Mountains, Ok.
limestone (bed 1)	Unit 4 (80-170') spicular black chert pseudo-brecciated limestone oolitic limestone calcareous sandstone siliceous limestone	Upper Sandstone Member	Upper Sandstone-Limestone Member (20 - 160')
chert (bed 2)			
sandstone (bed 3)			
shale (bed 4)	Unit 3 (60-250') calcareous clay shale	Middle Shale Member	Middle Shale Member (15 - 290')
cherty sandstone and limestone (beds 5, 6, 7, & 8)	Unit 2 (0-120') finely crystalline limestone, medium grained sandstone, spicular and oolitic limestone, and shale	Limestone Member	Lower Limestone Member (0 - 285')
	Unit 1 (60-320) shale, spicular limestone and calcareous sandstone	Lower Shale and Limestone Member	Chickachoc Chert Member (0 - 444')

Table 3. Previous informal stratigraphic subdivisions of the Wapanucka Formation compared with those recognized in the present investigation.

Mississippian and Pennsylvanian boundary, underlies the Wapanucka in the frontal Ouachitas. This sequence is poorly exposed and fossils are generally uncommon. Gordon and Stone (1977) refer local exposures of shales in this interval that have produced Morrowan-aged fossils to the "Springer" Shale. Precise stratigraphic subdivision and definition of this interval is impossible and the term "Springer" is used in this report for shales that immediately underlie the Wapanucka because of the lack of any viable alternative. The original reference to the Springer was to a series of shales and sandstones, thought to be partly Mississippian and partly Pennsylvanian in age in the Ardmore Basin area (Goldston, 1922). Apparently the term was first introduced into the Carboniferous nomenclature of the Ouachita Mountains by Harlton (1938) as a time stratigraphic unit encompassing both Mississippian and Pennsylvanian age rocks. Hendricks and others (1947) restricted the term Springer to Pennsylvanian-aged strata consisting of clay shales and thin sandstone interbeds above the black Mississippian Caney Shale and below the Pennsylvanian Wapanucka Limestone. Most recently Hart (1974) on a generalized geologic map covering the Western Ouachita Mountains, has used the Ardmore Basin term Goddard Shale for the interval here referred to as "Springer." These differences point out the need for further reevaluation of the Ouachita Mountain Carboniferous shale sequences.

Lithologically the "Springer" is indistinguishable from thick shale intervals within the Wapanucka Formation. Consequently its recognition is based on stratigraphic position below exposed Wapanucka Limestone. The "Springer" consists of blue-gray shale that typically weathers to fissile shale and exhibits variagated red, blue, yellow, and orange brown colors. A characteristic feature at some localities is the abundant occurrence of clay-ironstone concretions which locally contain goniatites. According to Hendricks and others (1947) the "Springer" Shale overlies the Caney Shale, but there is apparently no lithologic basis for the separation of the two formations, only the sporadic occurrences of fossils indicating either Mississippian Caney or Pennsylvanian "Springer."

The "Springer" is inferred to be present below the Wapanucka Formation over the whole of the area investigated. A complete section, estimated to be 2,500 feet by Hendricks and others, 1947 was not seen at any locality. In fact questionable exposures of the uppermost 50 to 100 feet of the formation were found only at sections 1, 2, 7 and 23. An undetermined thickness of well exposed "Springer" occurs along the axis of a recumbent anticline, in Bandy Creek, south of Wilburton, Oklahoma (sections 12 and 13, Appendix 1).

Atoka Formation

Taff and Adams (1900) named the Atoka Formation for a sequence of deltaic shale and sandstone in a report on the eastern portion of the Choctaw coal field located in the central Arkoma Basin. A type section was not designated, but most workers regard the deep water flysch facies exposed in the vicinity of Atoka, Oklahoma, as the type section (Branson, 1962). Spivey and Roberts (1946) raised the term Atoka to series rank. They defined the Atoka Series to include all beds from the top of the Wapanucka Limestone (Morrowan) to the base of the Hartshorne Sandstone (Desmoinesean Series).

The basal portion of the Atoka Formation was observed in depositional contact with the Wapanucka at only one locality (sec. 15). There the Atoka Formation consists of gray shale with common lenses and thin beds of sideritic, clay-ironstone concretions. In all other measured sections the lower part of the Atoka Formation is covered. Its topographic expression, however, indicates that the lower part of the formation is probably shale. At section 11 (Redoak South) shale and sandstone interbeds in the Atoka Formation are exposed above a covered interval. This may represent a continuous depositional sequence, but fault juxtaposition cannot be ruled out. In any event, this is the closest observed proximity of shallow water Wapanucka lithologies and deep water Atoka flysch. A more complete discussion of the lithology of Atoka Formation is given by Hendricks and others (1947) for the southwestern Ouachita Mountains.

The Atoka Formation is presumed to rest conformably on the upper sandstone/limestone member of the Wapanucka Formation. At the one section where the contact is exposed (sec. 15, Wilburton southeast), the contact is sharp but apparently conformable. In the southwestern portion of the study area the Atoka Formation is in fault contact with either the middle shale or Chickachoc Chert members.

In the "central" Ouachita Mountains, the base of the Atoka has been regarded as equivalent to the upper part of the Wapanucka Formation and has been presumed to be late Morrowan in age (Cline, 1956a, b). It is possible that the basal Atoka Formation in that area is equivalent to only that part of the upper sandstone/limestone member which is thought to be Atokan age. The age of the Atoka Formation in its type area has not been faunally determined so any correlation of that unit is speculative and can only be based on superposition.

Wapanucka Formation

Definition and Type Section

The name Wapanucka Limestone was proposed by Taff (1901) for a relatively thin predominantly limestone sequence between what Taff termed the Caney Shale and the Atoka Shale. A type section was not designated and the exposures near the town of Wapanucka, in Atoka County, in the eastern Arbuckle Mountains, are regarded as constituting the type section (sec. A16, Appendix 1). The Wapanucka Formation just west of the town of Wapanucka, Oklahoma, totals about 190 feet in thickness (Fig. 3, sec. A16). It consists predominantly of bioclastic and oolitic calcarenite (Table 4), but micritic and spiculiferous limestone, limestone pebble conglomerate, and carbonaceous calcarenitic limestone are also present in significant volumes. Similar carbonate lithologies, occur in the lower and upper members of the Wapanucka Formation in the Ouachita Mcuntains. The occurrence of oolitic calcarenite and the general absence of sandstone in the Wapanucka Formation in its type area and in the lower limestone member in the Ouachita Mountains is consistent with a lithologic correlation of the two. Strata equivalent to the upper part of the Ouachita Wapanucka are seemingly absent in the type area of the Wapanucka Formation. This relationship is possibly due to pre-Atoka Formation erosion. Conodont correlations (Fig. 4) based on data collected by the author, Bruce Archinal and Patrick Sutherland in conjunction with a thesis study of the Atoka Formation by Archinal (1977) in the northeastern Arbuckle Mountains area are thought to support this unconformity. Apparently the unconformity documented by Rowett and Sutherland (1964) between the Wapanucka and overlying Atoka Formation in the Arbuckle Mountain region, represents a period of erosion that is in part the time equivalent of more continuous sedimentation and accumulation of the

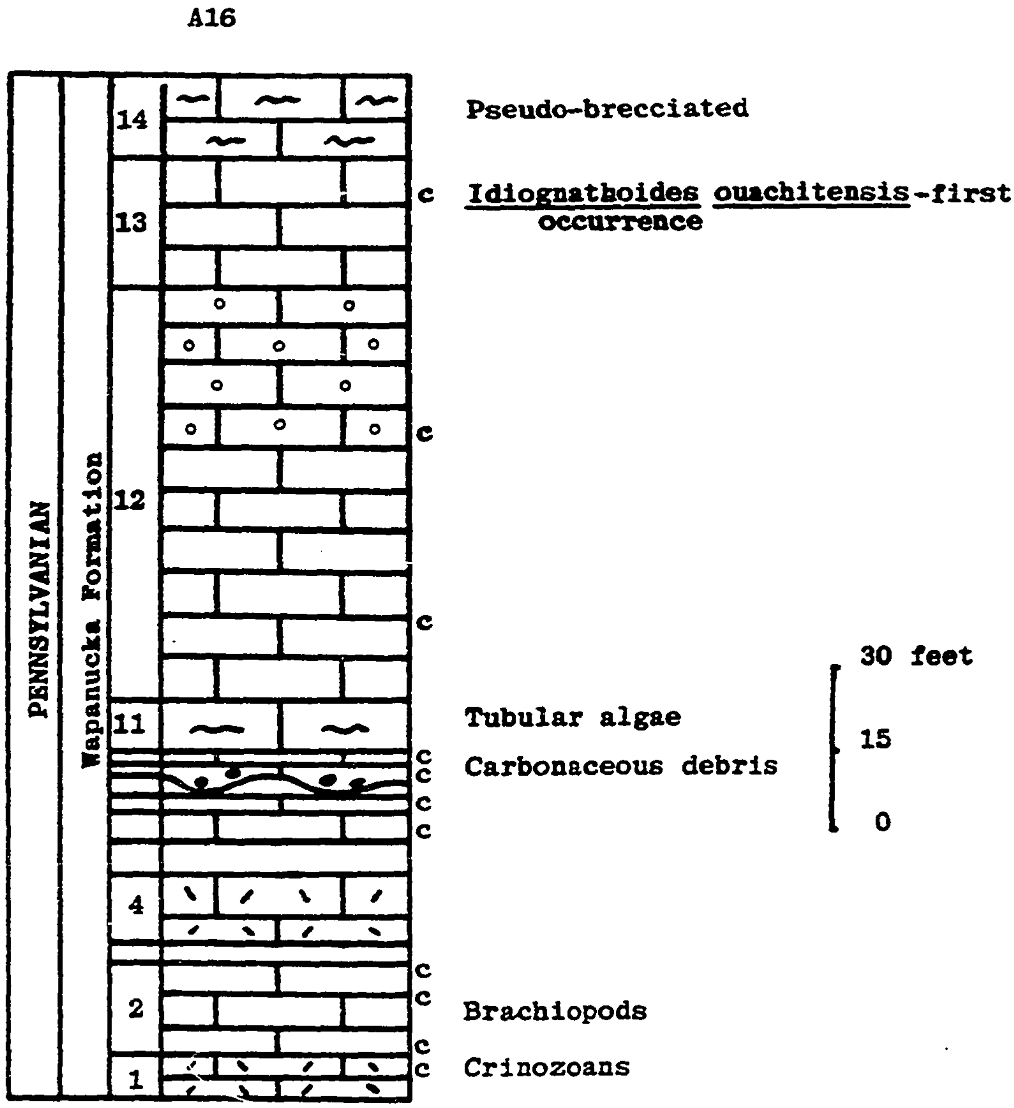


Figure 3. Measured stratigraphic section of the Wapanucka Formation in its type area on the flank of the Arbuckle Mountains, Oklahoma. Symbols are explained in Figure 7. See Appendix 1 for detailed description of measured section and numbered units.

upper Wapanucka Formation in the Ouachita Mountains.

Lithologic Character

Six lithologies comprise the bulk of the Wapanucka Formation in the frontal Ouachitas Mountains. These lithologies include spiculite, spiculiferous limestone, bioclastic and oolitic calcarenite, micritic limestone, shale, and sandstone. Facies changes and repetitive occurrence of lithologies laterally and in vertical sequence are characteristic of the formation (Pl. 1). Consequently, the relative volmetric importance and/or relative persistence of lithologies serves as the basis for internal stratigraphic subdivision.

Stratigraphic Relations

The regional nature of both the upper and lower boundaries of the Wapanucka Formation in the Ouachita Mountains with the underlying "Springer" Shale and the overlying Atoka Formation, is undeterminable since the contacts are almost invariably covered. Hendricks and others (1947),based on map evidence, judged the boundaries to be conformable.

Thickness and Extent

The complete thickness of the Wapanucka cannot be established in most instances in the frontal Ouachitas because of cover and/or faulting at both the top and base of the formation. My measured thickness's in this region

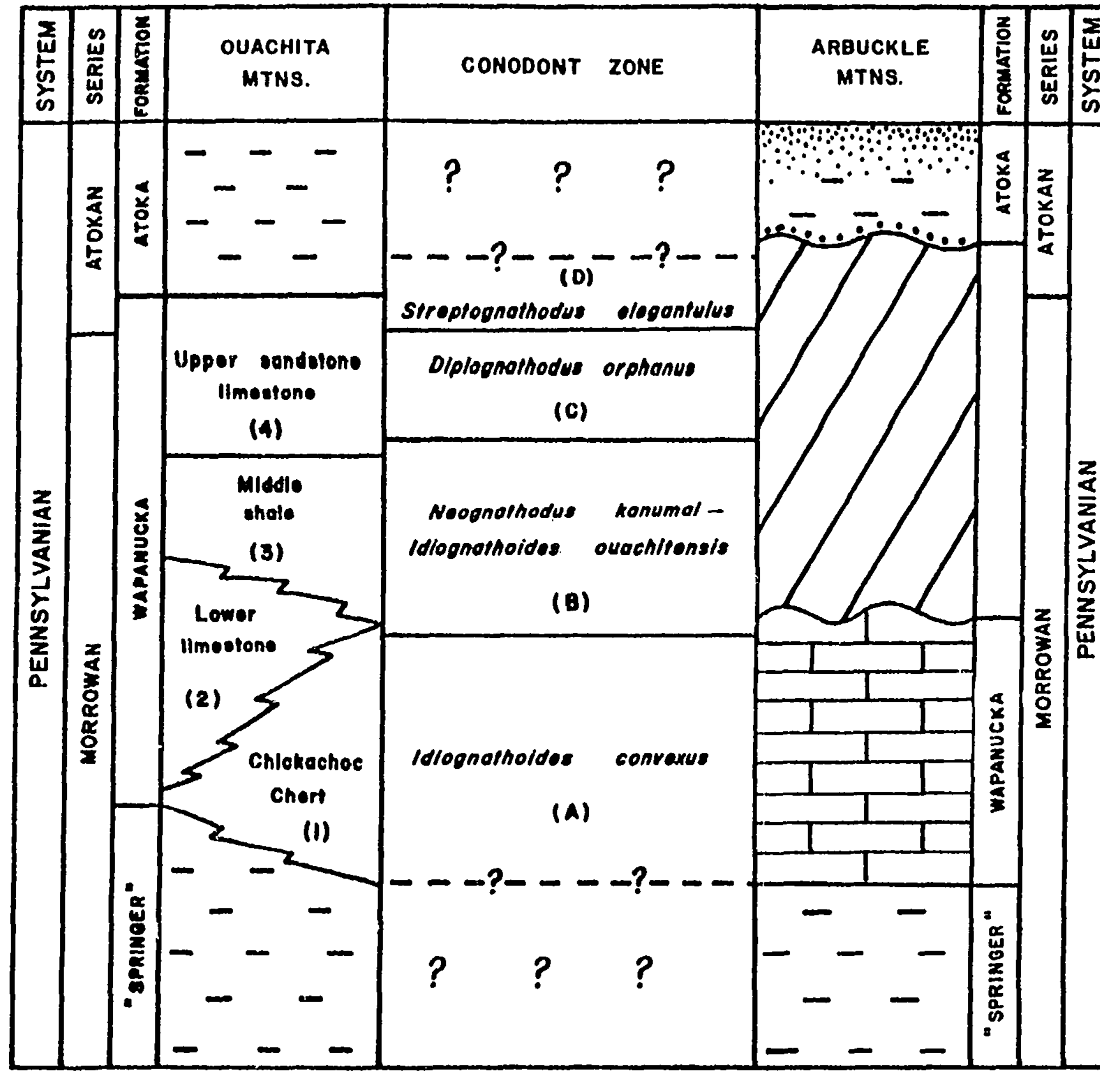


FIGURE 4. CORRELATION OF THE WAPANUCKA FORMATION IN THE OUACHITA MOUNTAINS WITH THE SAME FORMATION IN ITS TYPE AREA ON THE EASTERN FLANK OF THE ARBUCKLE MOUNTAINS.

range from 180 to 720 feet and the formation progressively increases in thickness from north to south (basinward) from Limestone Ridge (Pl. 1). In the Arbuckle Mountain region the formation does not exceed 200 feet in thickness (Rowett and Sutherland, 1964). The Wapanucka is also known to be present in the subsurface of the Arkoma Basin (Lunsden and others, 1971) but no detailed studies have as yet been published.

Subdivision

The Wapanucka Formation is subdivided into four members (Fig. 2). They include, in ascending order, (1) the Chickachoc Chert Member, (2) the lower limestone member, (3) the middle shale member, and (4) the upper sandstone/limestone member. The Chickachoc Chert and lower limestone members are laterally equivalent for the most part, so only three members are recognized at most localities.

Lower Limestone Member

Definition

The lower limestone member represents a shoal facies that is laterally equivalent to the basinward, deeper water facies that comprise the Chickachoc Chert. It is an internally complex sequence that exhibits both rapid lateral and vertical lithologic changes (Pl. 1, in pocket). Typically the lower limestone consists of varying proportions of micritic limestone, spiculiferous limestone, oolitic and bioclastic calcarenite, shale and rare sandstone interbeds. Oolitic calcarenites are particularly characteristic of the member and there is also abundant secondary chert.

The lower limestone is Morrowan in age. It belongs in part to the Idiognathoides convexus and Neognathodus kanumai-Idiognathoides ouachitensis conodont zones (see Pl. 1). The occurrence of these zones indicates that the lower limestone is equivalent in age to the Wapanucka Formation in its type area on the northeastern flank of the Arbuckle Mountains and to the Dye Shale(?) and Kessler Limestone Members of the Bloyd Formation in northwestern Arkansas.

Typical exposures of the lower limestone occur at sections 19 and 6 (Pl. 1). These exposures demonstrate the vertical repetitiveness of carbonate lithologies comprising the lower limestone, as well as, the major facies changes that typify the unit. Individual lithologies generally lack regional, lateral persistence.

Lithologic Character

The lithologic facies present are similar to those encountered in the upper sandstone/limestone member (Table 4), however, oolitic calcarenite and the common occurrence of secondary chert characterize the ridge forming lower limestone member (Pl. 2, Fig. 1). Oolitic calcarenite occurs as medium to very thick beds that range from one to six feet in thickness. These beds may exhibit tabular or more uncommonly trough cross-bedding (Pl. 2, Fig. 2). Secondary chert occurs abundantly in the lower limestone, particularly in the west-central outcrop area. Invariably this chert is most abundant and pervasive in the upper part of the member in either spiculiferous or micritic limestones. It occurs as isolated nodules, as coalescent nodules that form a complex anastomosing pattern, or as pseudo-beds (Pl. 2, Fig. 3).

Shale is volumetrically the most important lithology (Table 4). The greatest majority of presumed shale units are covered and therefore cannot be positively determined to represent shale. Exposed shale beds are generally barren of fossils and typically contain clay-ironstone concretions.

The remainder of the member is composed of subequal amounts of micritic and spiculiferous limestone, and volumetrically less important bioclastic calcarenites and sandstone interbeds. The very thick-bedded micritic limestones characteristically weather into very thick isolated blocks. At one locality a thick layer of this rock type forms a striking natural arch in a small stream (Pl. 2, Fig. 4). Generally these limestones are sparsely fossiliferous. Algae are the most abundant fossil constituent. Particularly distinctive are the abundant tubular algae. Less commonly phylloid algae occur. Solitary rugose corals constitute the most obvious megafossil remains. Ostracodes, gastropods, spicules, and bryozoans are less conspicuous. Many micritic limestone units exhibit pseudo-brecciation (Pl. 2, Fig. 5).

In contrast to micritic limestone, spiculiferous limestone consists almost exclusively of loose sponge spicules in a micritic, organic rich matrix cemented by silica. Preservation of the sponges is rare although a meager fauna has been described (Rigby and others, 1970). Calcareous fossils are rare. They consist of crinozoan columnals, bryozoans, solitary rugose corals, and productid and spiriferid brachiopods. Development of local surfaces of nondeposition are indicated at one section (sec. 19) by occurrences of distinctive bioturbated horizons (Pl. 2, Fig. 6). The ichnogenera characteristic of these surfaces are Nereis, Zoophycos, and Helminthoida. They are assigned to the Zoophycos ichnofacies of Sielacher (1967). A few rare spiculiferous limstone units are laminated but more often if originally present bioturbation has altered their appearance.

Micritic and spiculiferous limestone exhibit an interesting lateral facies relationship. The volumetric importance of these lithologies is generally related in an inverse manner. This relationship is readily apparent by comparing percentage isopleth maps of micritic and spiculiferous limestone abundance (Figs. 5 and 6, respectively). Peak abundances of one of these lithologies coincides with minimal abundances of the other. This inverse relationship can also be seen in basinward cross-sections (Figs. 8, 9 and 10), but it is also obvious that the two lithologies can occur in subequal volumes at some sections. Intertounging gradational change in lithology suggests that the depositional environments of micritic and spiculiferous limestone were closely related but dissimilar regimes that existed adjacent to one another.

Bioclastic calcarenite units are diverse in terms of texture, composition, and sedimentary structures. Most are packstones that consist predominantly of crinozoan bioclasts but grainstones also occur. They generally contain abraded bioclasts with an appreciable admixture of ooliths. A particularly distinctive calcarenite is the limestone pebble conglomerate that occurs only along Limestone Ridge in the upper part of the lower limestone in the Hartshorne area (Pl. 1, in pocket; Fig. 7). This conglomerate (Pl. 3, Fig. 1) contains rounded, pebble to cobble size clasts of spiculiferous, micritic and calcarenitic limestone. Another equally distinctive but even more rarely occurring bioclastic calcarenite is present at section 19, units 22A, B and C. These calcarenites contain the enigmatic fossil Chaetetes (Pl. 3, Fig. 2). Chaetetes is common in Morrowan age rocks in northeastern Oklahoma and Arkansas (Sutherland and Henry, 1977) but is unknown from the Wapanucka with this exception.

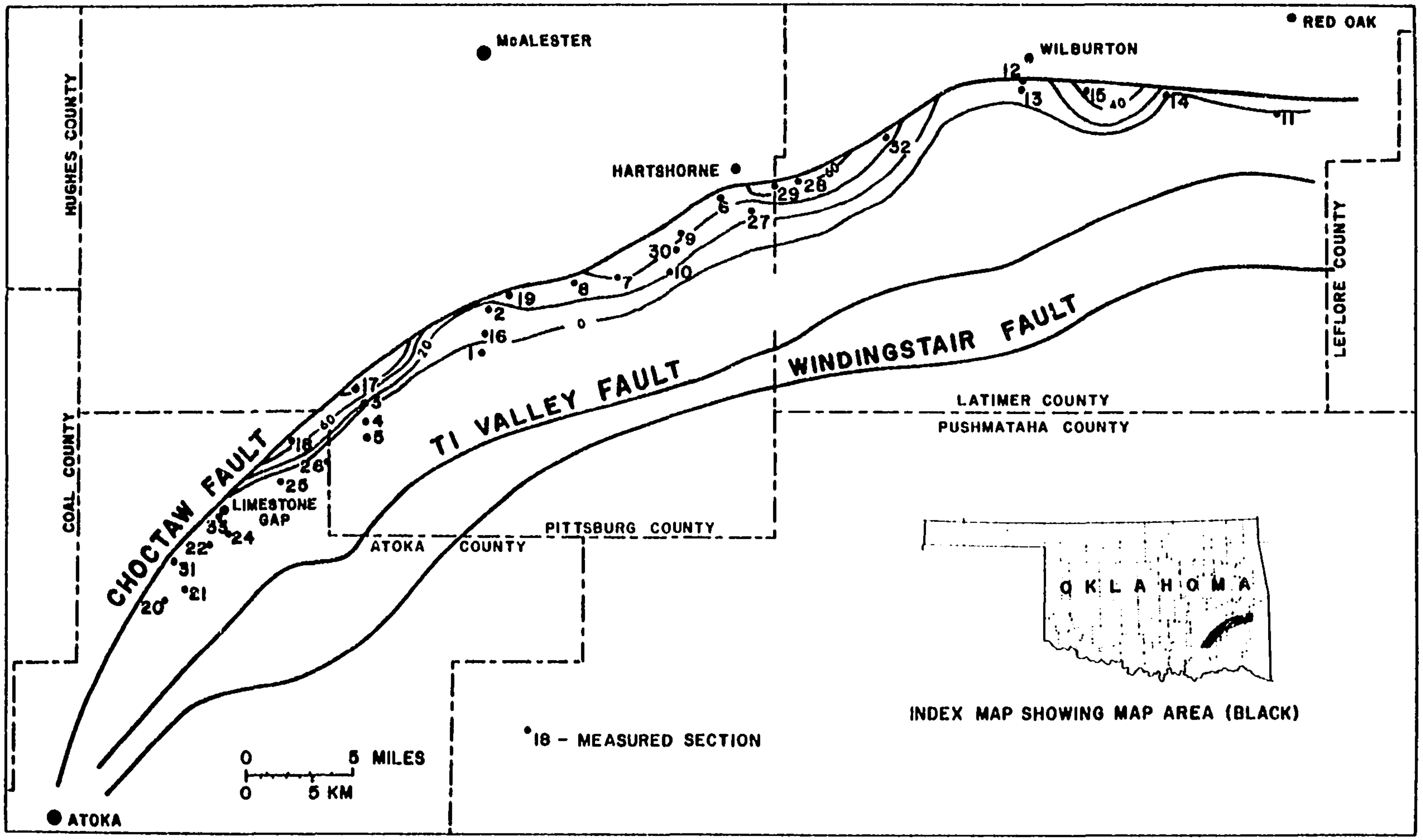


Figure 5. Isopleth map of micritic limestone units in the lower limestone member. Contour interval is 20 percent of total section.

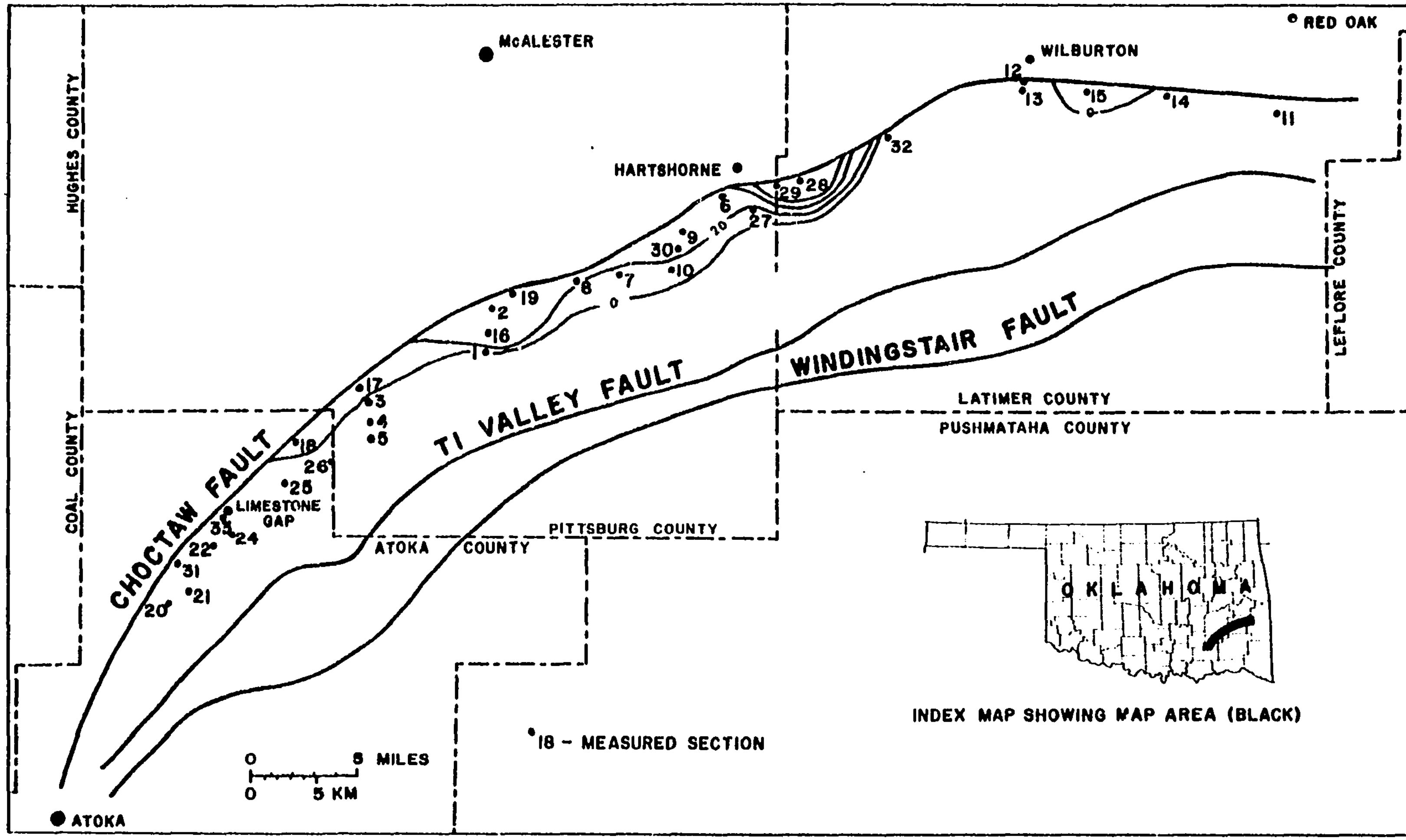


Figure 6. Isopleth map of spiculiferous limestone units in the lower limestone member. Contour interval is 20 percent of total section.

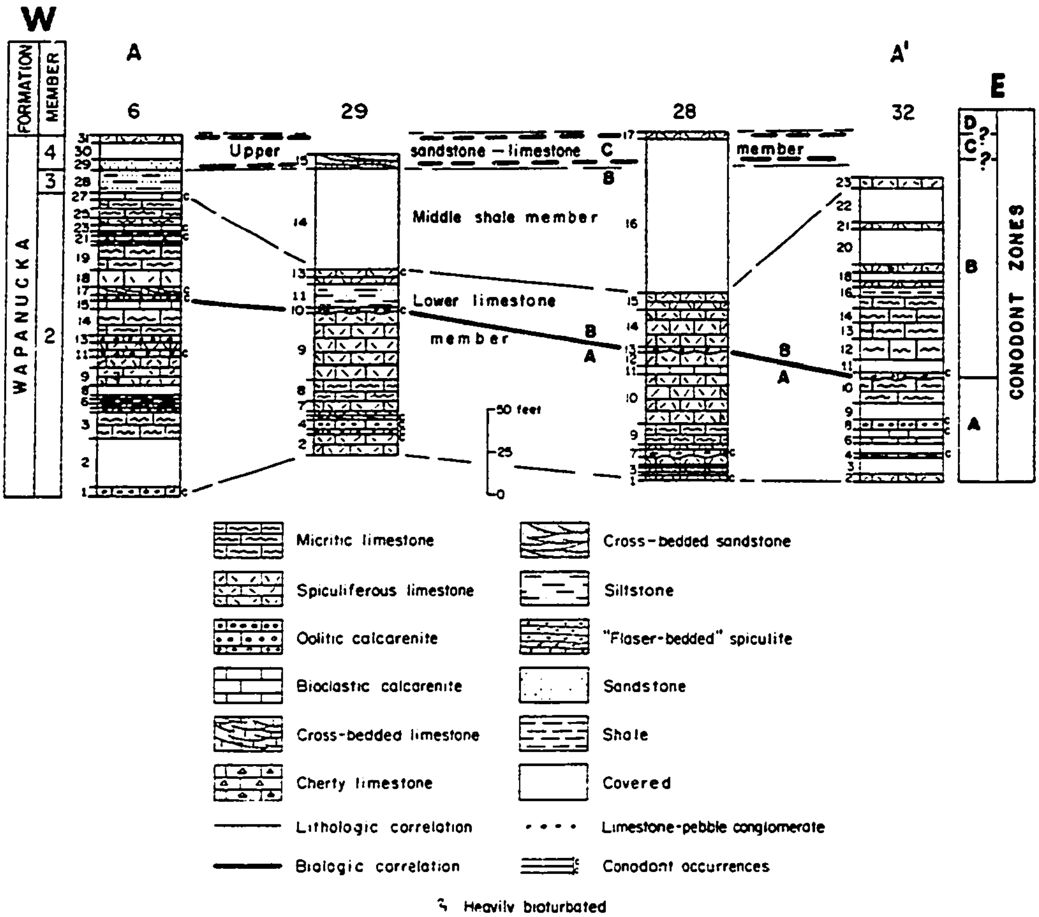


FIGURE 7. STRIKE-PARALLEL CROSS-SECTION OF THE WAPANUCKA FORMATION ALONG LIMESTONE RIDGE IN THE HARTSHORNE, OKLAHOMA, AREA. ALPHA-NEUMERIC SYMBOLS ARE EXPLAINED IN FIGURE 2.

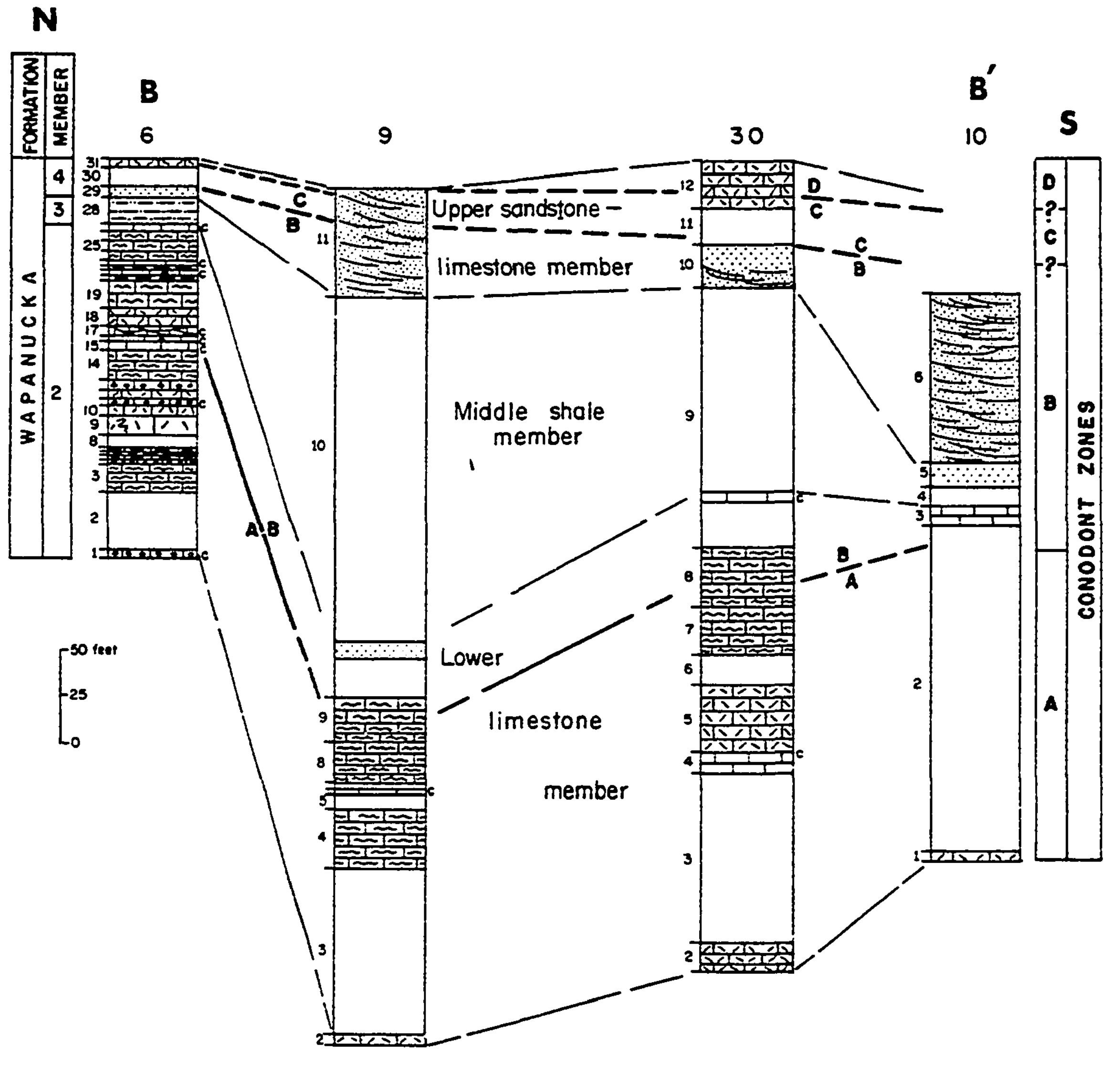


FIGURE 8. BASINWARD CROSS-SECTION OF THE WAPANUCKA FORMATION IN HARTSHORNE, OKLAHOMA, AREA. LITHOLOGIC SYMBOLS ARE EXPLAINED IN FIGURE 6 AND ALPHA-NEUMERIC SYMBOLS ARE EXPLAINED IN FIGURE 2.

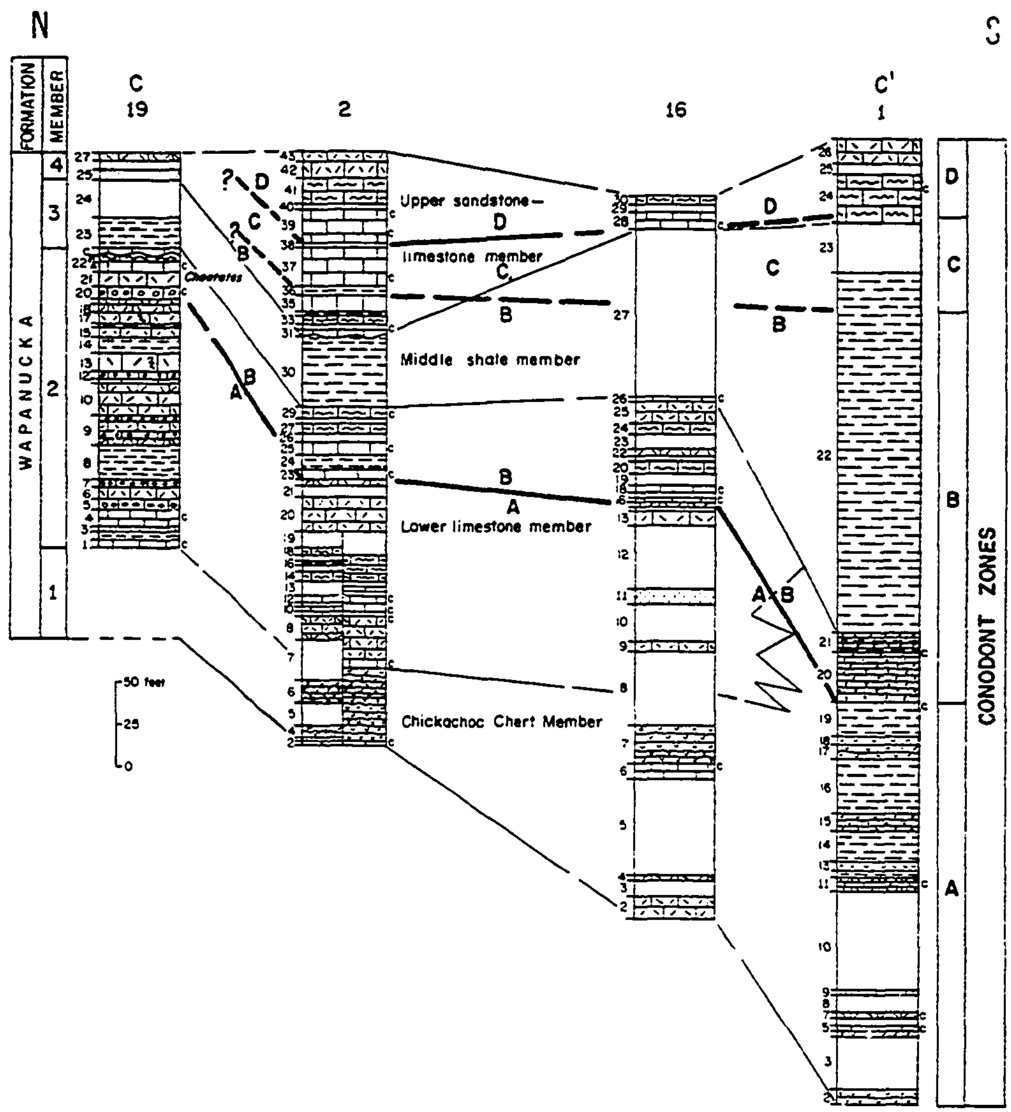


FIGURE 9. BASINWARD CROSS-SECTION OF THE WAPANUCKA FORMATION IN AREA ALONG THE INDIAN NATION TURNPIKE, SOUTH OF MCALESTER, OKLAHOMA. LITHOLOGIC SYMBOLS ARE EXPLAINED IN FIGURE 7 AND ALPH-NEUMERIC SYMBOLS ARE EXPLAINED IN FIGURE 2.

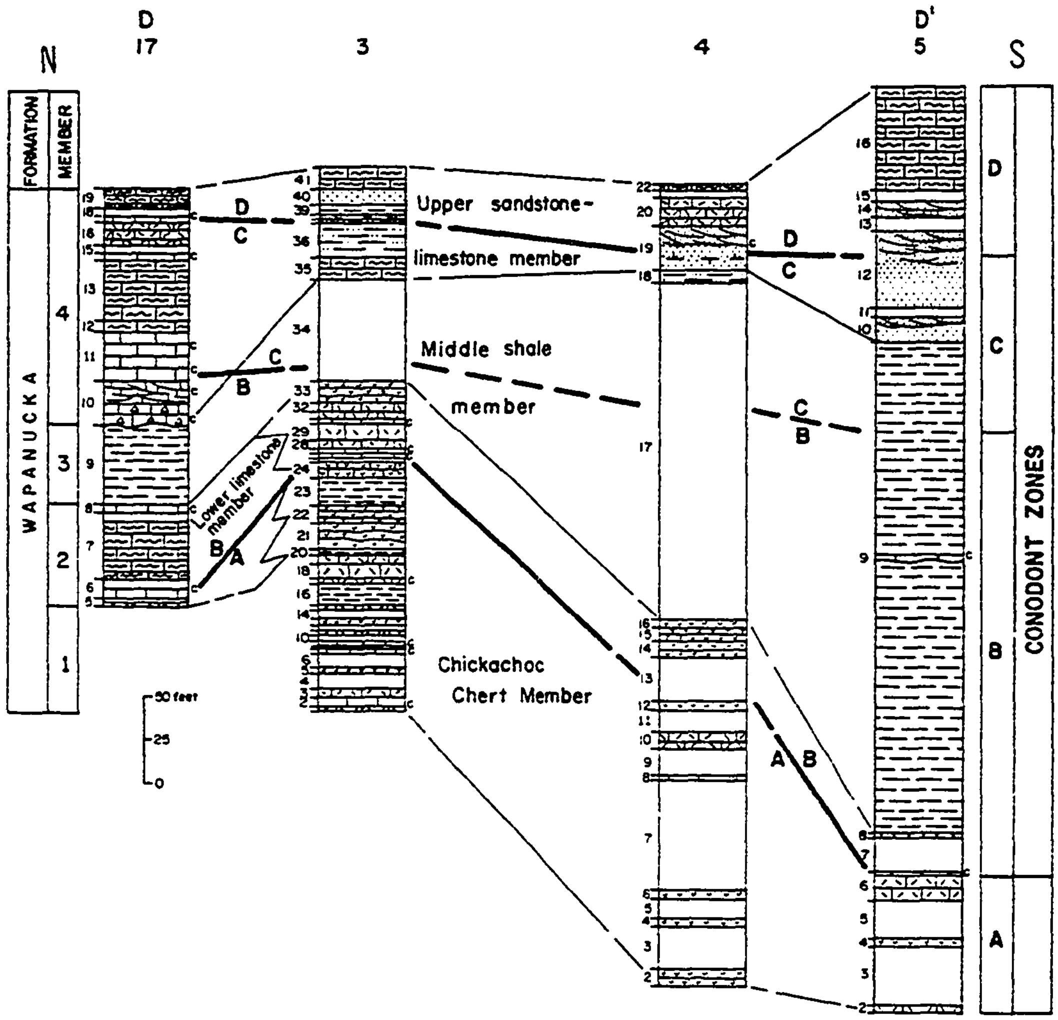


FIGURE 10. BASINWARD CROSS-SECTION OF WAPANUCKA FORMATION NEAR PITTSBURG, OKLAHOMA. LITHOLOGIC SYMBOLS ARE SHOWN IN FIGURE 7 AND ALPHA-NEUMERIC SYMBOLS ARE THOSE SHOWN IN FIGURE 2.

PLATE 2

Character of Lower Limestone

Figure 1. Typical exposure of the lower limestone member (sec. 29). Note thick to very thick bedding of limestone layers.

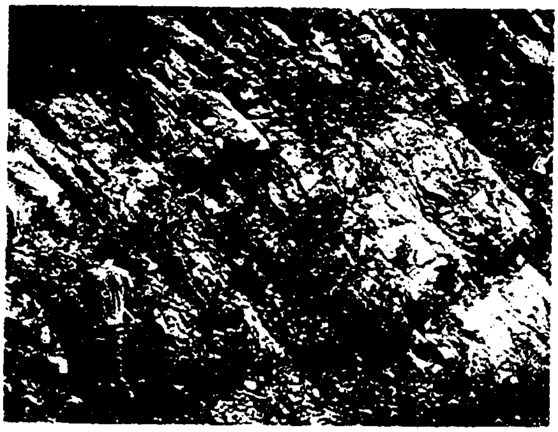
Figure 2. Cross-bedded oolitic calcarenite in the lower limestone member (sec. 8, unit 12). Note predominantly tabular nature of cross-bedding. Hammer head is about 4 inches long.

Figure 3. Pseudo-bedded and anastomosing replacement chert in spiculiferous limestone in the lower limestone member (sec. 19, units 16 and 17). Hammer is 18 inches long.

Figure 4. Natural arch formed by small tributary cutting through very thick bedded micritic limestone in lower limestone member (sec. 8, unit 22). Arch is about 15 feet high.

Figure 5. Pseudo-brecciated micritic limestone in lower limestone member (sec. 6, unit 14). Hammer is 18 inches long.

Figure 6. Bioturbation surface marking a presumed submarine hardground developed on spiculiferous limestone in the lower limestone member (sec. 19, unit 13).



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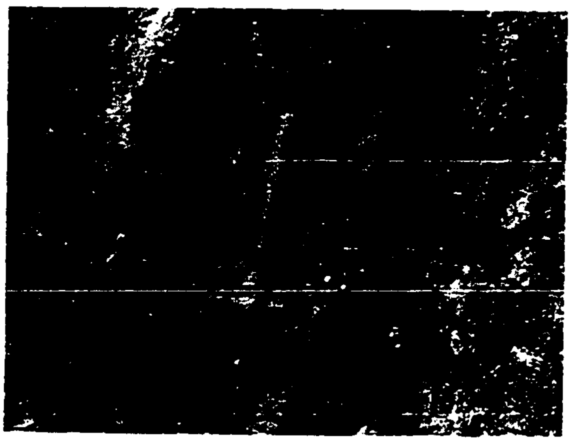

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6

Calcarenites punctuate buildup of micritic and spiculiferous limestone. They record environments ranging from subaerial exposure through intertidal conditions to shallow, agitated subtidal environments.

Stratigraphic Relationships

The lower limestone rests with apparent conformity on the "Springer" Shale or Chickachoc Chert, if present. The lower boundary of the lower limestone, in the few cases where the contact is exposed, is obviously distinguished from the "Springer" by the first occurrence of one of the limestone types that characterize the unit. Where the lower limestone rests on the Chickachoc Chert, its base is defined to coincide with the upward disappearance of spiculite and the first appearance of one of the several limestone types that characterize the unit.

The upper boundary of the lower limestone is marked by a thick, regionally persistent shale unit which is recognized as the middle shale member.

The lower limestone is a sedimentary wedge consisting of limestone, shale and sandstone (Pl. 1). It thins basinward to extinction by facies change with the Chickachoc Chert. This relationship is basically that of a wedge on a wedge (Figs. 9 and 10). In the eastern outcrop area only the lower limestone is exposed (Fig. 8) and it becomes progressively more sandy in that direction (Pl. 1).

Basinward, facies changes occur within the lower limestone that are consistent with an increase in water depth. One of the more obvious changes is the pronounced basinward increase in the volumetric importance of shale. This can be easily seen based on a percentage isopleth of shale abundance (Fig. 11). Equally indicative of increase in water depth is the marked decrease in volumetric importance of oolitic and bioclastic calcarenites (Fig. 12). Their abundant occurrence defines a carbonate sand belt interpreted to have accumulated parallel to a slope break. Similarly micritic limestone and spiculiferous limestone also decrease in importance (Figs. 8, 9 and 10) in a basinward direction.

Thickness and Extent

The complete thickness of the lower limestone is probably not ascertainable in outcrops where the Chickachoc Chert is absent because of the uncertainty regarding location of the contact with the underlying "Springer" Shale. Measured thicknesses range from 0 feet to nearly 300 feet (Fig. 13),and 200 feet is an average thickness for the unit. The greatest measured thicknesses occur in the east-central outcrop area, however, considerable variability in thickness of the member is encountered in this region. This variability is attributed to facies change of carbonate interbeds into shale units assigned to the adjacent "Springer" Shale and middle shale members. Southwestward the lower limestone thins to extinction by facies change into the more

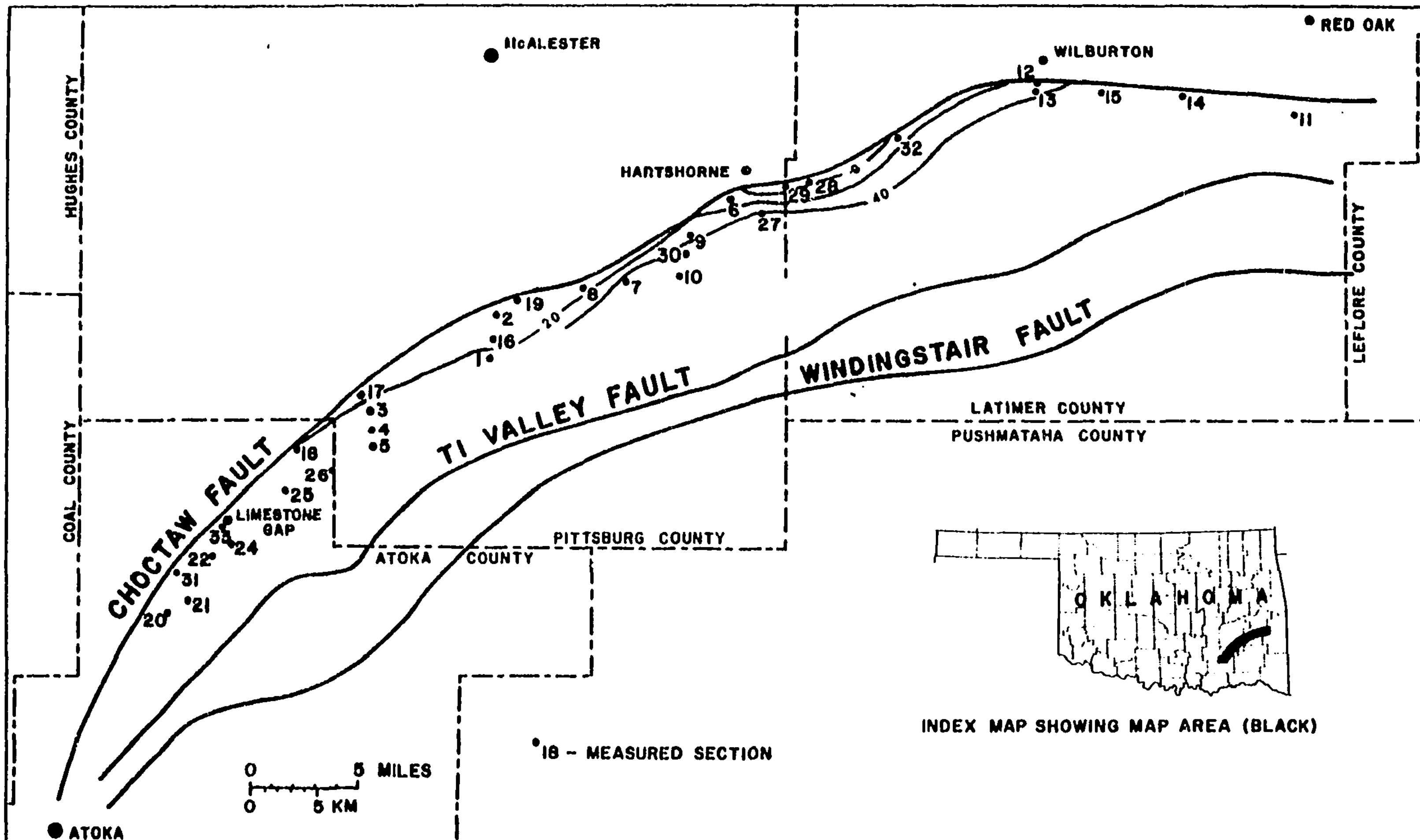

Figure 11. Isopleth map of shale and covered intervals in the lower limestone member. Contour interval is 20 percent of total section.

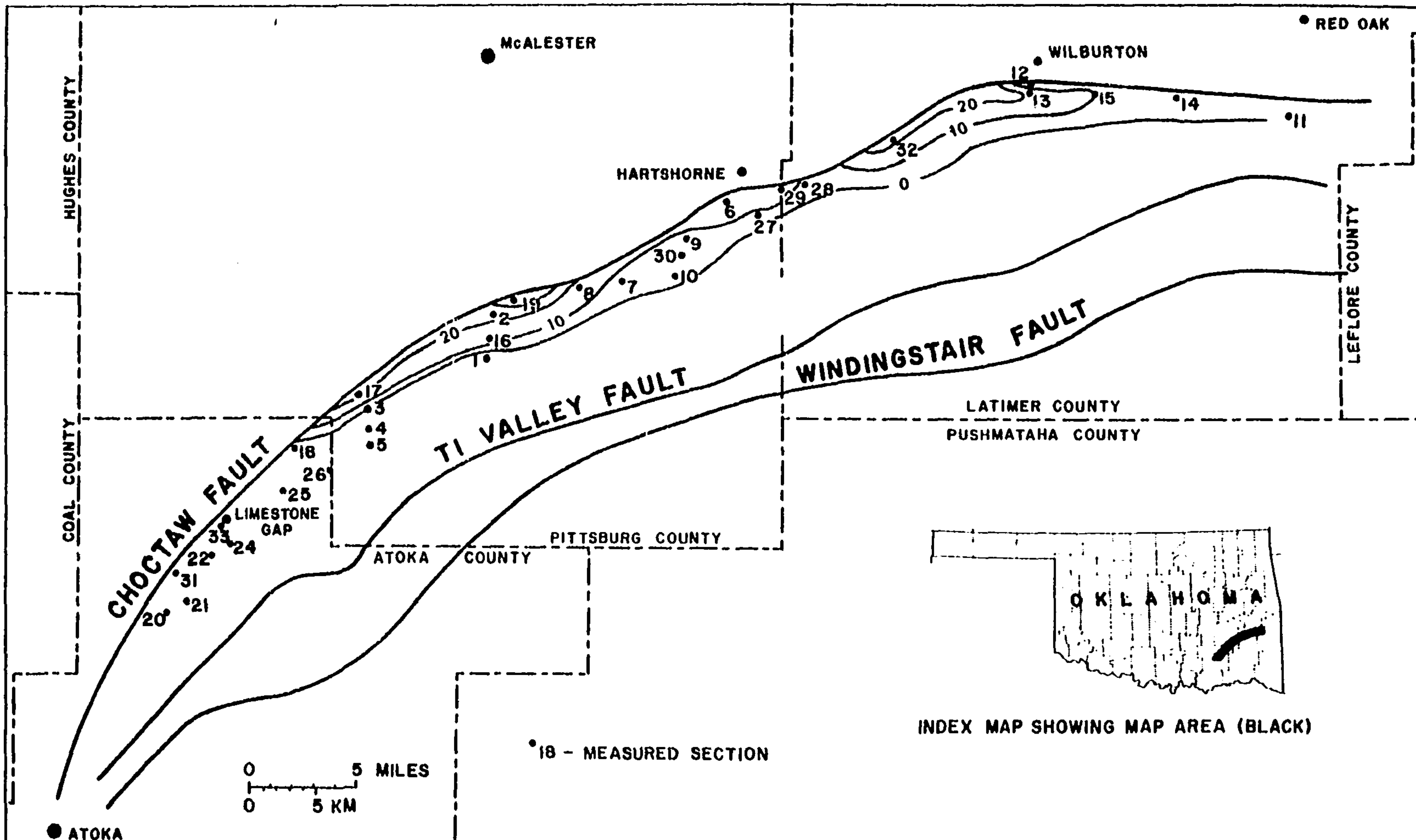

Figure 12. Isolith map of calcarenitic units in the lower limestone member. Contour interval is 10 feet

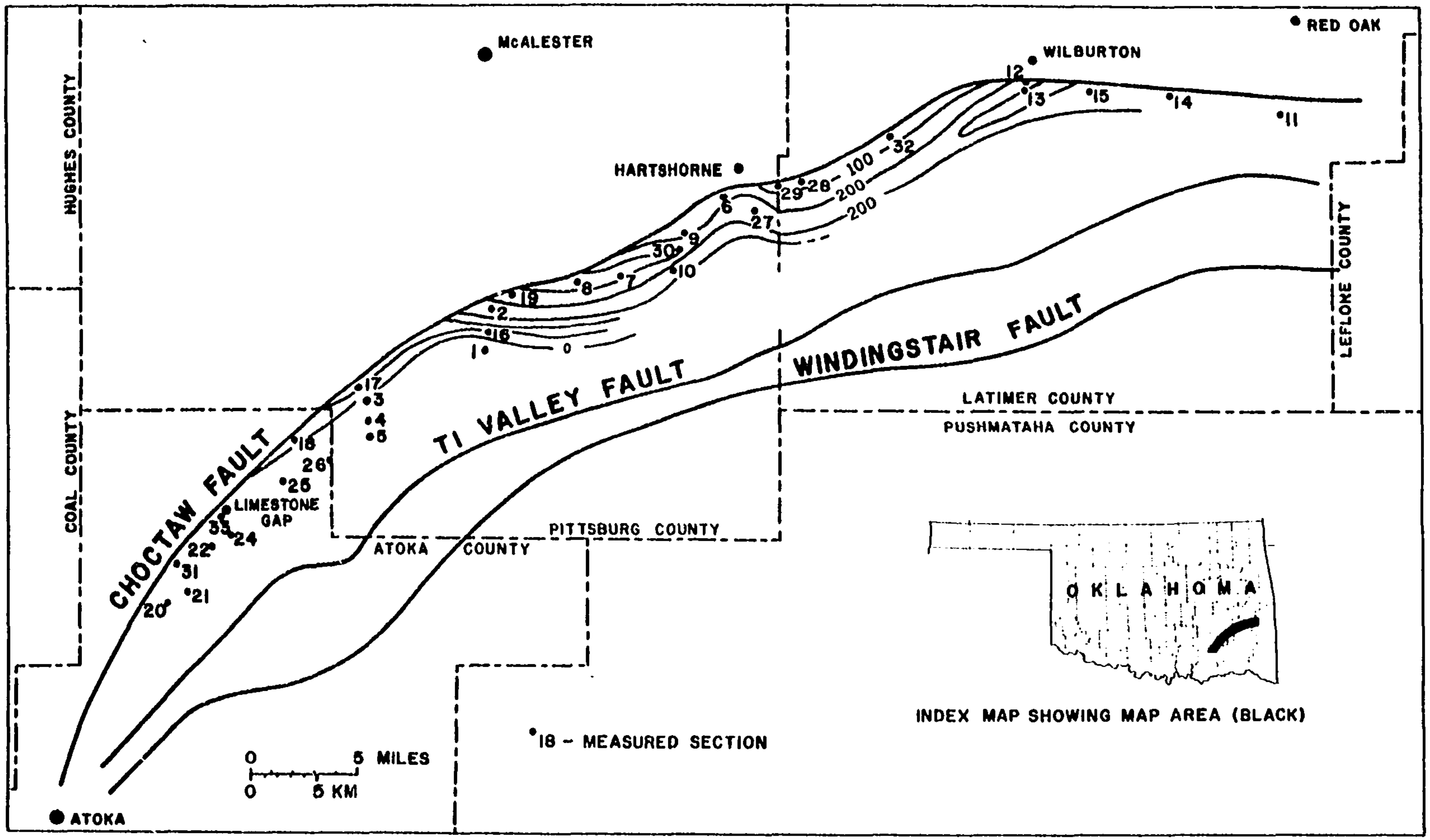

Figure 13. Isopach map of lower limestone. Contour interval is 50 feet.

basinward, deeper water Chickachoc Chert.

Chickachoc Chert Member

Definition

The Chickachoc Chert was named by Taff (1901) for what he thought were cherty sandstone lentils in the lower part of the Atoka Formation in the frontal Ouachita Mountains. A type section was not designated by Taff (1901). The name Chickachoc was apparently derived from a post office that was located in 1901 at or near the former railroad station at Chokie, Oklahoma (U.S.G.S. Lexicon of Geologic Names). Presumably, measured stratigraphic section 23 (Appendix 1) located near the small communities of Burg and Chokie, Oklahoma, represents a typical although incomplete exposure of the chickachoc Chert in its type area.

The Chickachoc has received varying stratigraphic treatment. Harlton (1938) favored abondonment of the term because he thought that his newly proposed units were more applicable. In contrast, Hendricks and others (1947) regarded the Chickachoc Chert as a formation, consisting of interbedded shales and spiculite, that was laterally equivalent to the whole of the Wapanucka Limestone. They noted, however, the similarity of the Chickachoc Chert, as observed in faulted ridges located parallel to and southeast of Limestone Ridge, with the lower part of the Wapanucka. Most recently Gordon and Stone (1977) have used the term

Chickachoc Chert in an informal way, to designate a specific facies of the Wapanucka Formation.

In the present investigation the Chickachoc Chert is regarded as a formal member of the Wapanucka Formation. It represents a basinward, deeper water facies that is equivalent to only the lower limestone member. The area critical to documenting the present interpretation extends westward from the Indian Nation Turnpike, south of Blanco, Oklahoma, to approximately two miles north of Stringtown, Oklahoma. This region contains one to three faulted ridges south of Limestone Ridge that were mapped as the Chickachoc Chert Formation by Hendricks and others (1947). The present interpretation that these Chickachoc Chert ridges are a basinward facies of only the lower limestone member of the Wapanucka Formation follows three lines of evidence. First, some of these ridges thought to consist entirely of Chickachoc Chert by Hendricks and others (1947) have been found to also expose the middle shale and upper sandstone/limestone members (for example, sec. 6 and 26; Pl. 1). Second, measured thicknesses of Chickachoc Chert in this highly faulted belt range from 200 feet to approximately 480 feet. Thus, the maximum thicknesses of Chickachoc Chert in this controversial belt are comparable with the 387 feet of thickness determined for the Chickachoc at section 1 (Pl. 1). This thickness is not comparable to the total thickness of the formation at section 1 which is 719 feet. Finally, the most compelling evidence for the present interpretation is based on the equivalence established by the conodonts. Conodonts have been recovered from the upper part of the Chickachoc Chert at three localities (sec. 20, unit 12; sec. 21, unit 12; and sec. 25, unit 5; Pl. 1) where the member is incomplete. The faunas belong to the Idiognathoides convexus zone, which is characteristic of only the lower two-thirds of the Chickachoc Chert Member in stratigraphically complete sections (e.g. secs. 18, 26, 3, 2, 16 and 1) or the lower part of the lower limestone, where present.

Lithologic Character

The Chickachoc Chert Member consists predominantely of shale, spiculite, spiculiferous limestone and minute percentages of bioclastic calcarentite and quartz sandstone (Table 4). The relative volumetric importance of shale and the initial occurrence of spiculite serve to distinguish the member. Because of the importance of shale the member is characteristically poorly exposed and topographically subdued (Pl. 3, Fig. 3). No persistent lithology or marker bed was found, however, in an unfaulted section the thickness and number of spiculite interbeds generally increases upward.

Fossils are not abundant. Where present they typically occur in the rare calcarenite interbeds or shales. The most abundant faunal elements are sponge spicules, crinozoan columnals, bellerophontid gastropods, goniatites,

LITHOLOGY MEMBER	Micritic Limestone	Spiculiferous Limestone	Bioclastic Limestone	Oolitic Limestone	Shale and Covered	Spiculite	Sandstone
Lower limestone	26.8	20.5	8.6	2.3	40.0	0.0	1.8
Chickachoc Chert	0.0	10.4	0.2	0.0	64.1	21.8	0.2
Upper sandstone/ limestone	13.9	16.5	9.6	0.0	16.4	0.0	46.8
type Wapanucka	12.9	10.5	49.0	22.1	5.5	0.0	0.0

Table 4. Volumetric comparison of members of Wapanucka Formation in the Ouachita Mountains and the Wapanucka Formation in its type area in the eastern Arbuckle Mountains, by percentage composition of selected lithologies.

and conodonts. Rugose corals, brachipods, bryzoans, conularids, and myalinid bivalves are rare.

Stratigraphic Relationships

The Chickachoc Chert Member overlies the "Springer" Shale throughout its extent. This contact cannot be located with certainty at most exposures due to the possible presence of faulting in concealed intervals. Only three sections (1, 2, and 7; Pl. 1) expose what is presumed to be the basal contact. At sections 1 and 7 the base is marked by occurrence of spiculite. These spiculite beds are gradational with the underlying shale. In contrast, thin bioclastic calcarenite with thin shale partings and interbeds marks the basal contact at section 2. This calcarenite rests with a sharp, slightly erosive contact on the underlying shale. These occurrences are insufficient to characterize the nature of the contact.

The upper boundary of the Chickachoc Chert occurs immediately below the base of the middle shale or the lower limestone, if present. In either case the contact is conformable.

The most interesting aspect of the Chickachoc Chert is its facies relationship with the lower limestone, which has been discussed. Where the two units co-occur the Chickachoc Chert is invariably overlain by the lower limestone.

Basinward facies changes occur within the Chickachoc

Chert. The significant changes in facies can be seen in Figs. 9 and 10. Although the possibility of faulting in some exposures precludes certainty, the Chickachoc Chert is thought to be a basinward thickening wedge (Fig. 14). This thickening is due almost entirely to the increased volume of shale (Fig. 15). Calcarenites are essentially absent in the most basinward exposures (Fig. 16). Spiculiferous limestone and spiculite also decrease basinward in volumetric importance (Figs. 17 and 18, respectively). Spiculiferous limestone is most common in the northernly exposures when compared to spiculite. Presumably these facies changes reflect the basinward, progressively deeper water character of the Chickachoc Chert. The basinward increase in importance of shale is consistent with the idea that the member grades basinward into the Johns Valley Shale in the central Ouachitas as suggested by Sutherland and Grayson (1976).

Thickness and Extent

The complete thickness of the Chickachoc Chert cannot be established with certainty due to fault concealment, cover and erosion, but a general basinward thickening is indicated (Pl. 1, Fig. 10). The greatest thickness of the Chickachoc is approximately 484 feet at section 24. This section is dominantly shale and its location in a faulted area precludes placing confidence in this value. The most nearly complete, demonstrably unfaulted exposure occurs at

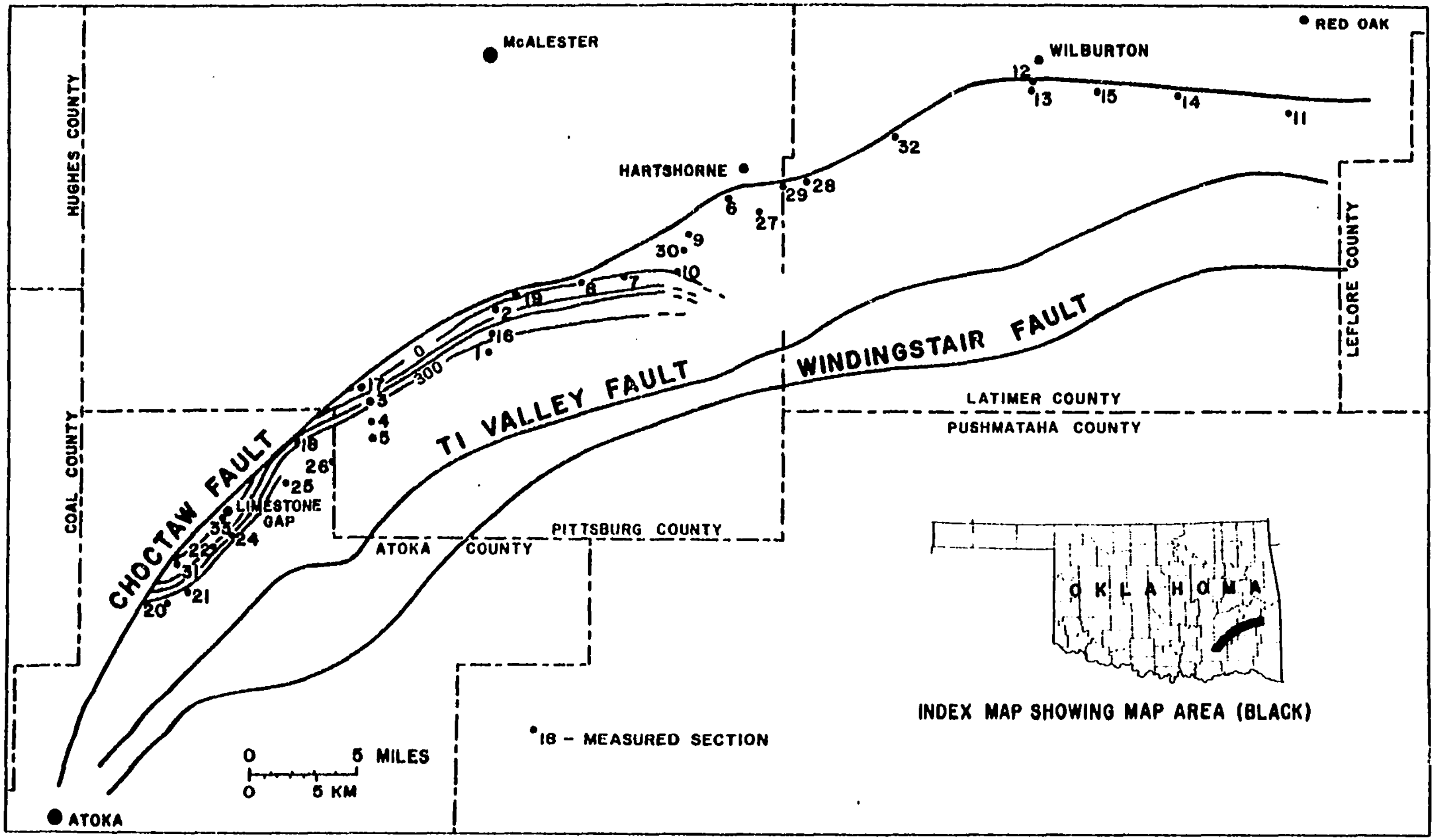

Figure 14. Isopach map of Chickachoc Chert Member. Contour interval is 100 feet.

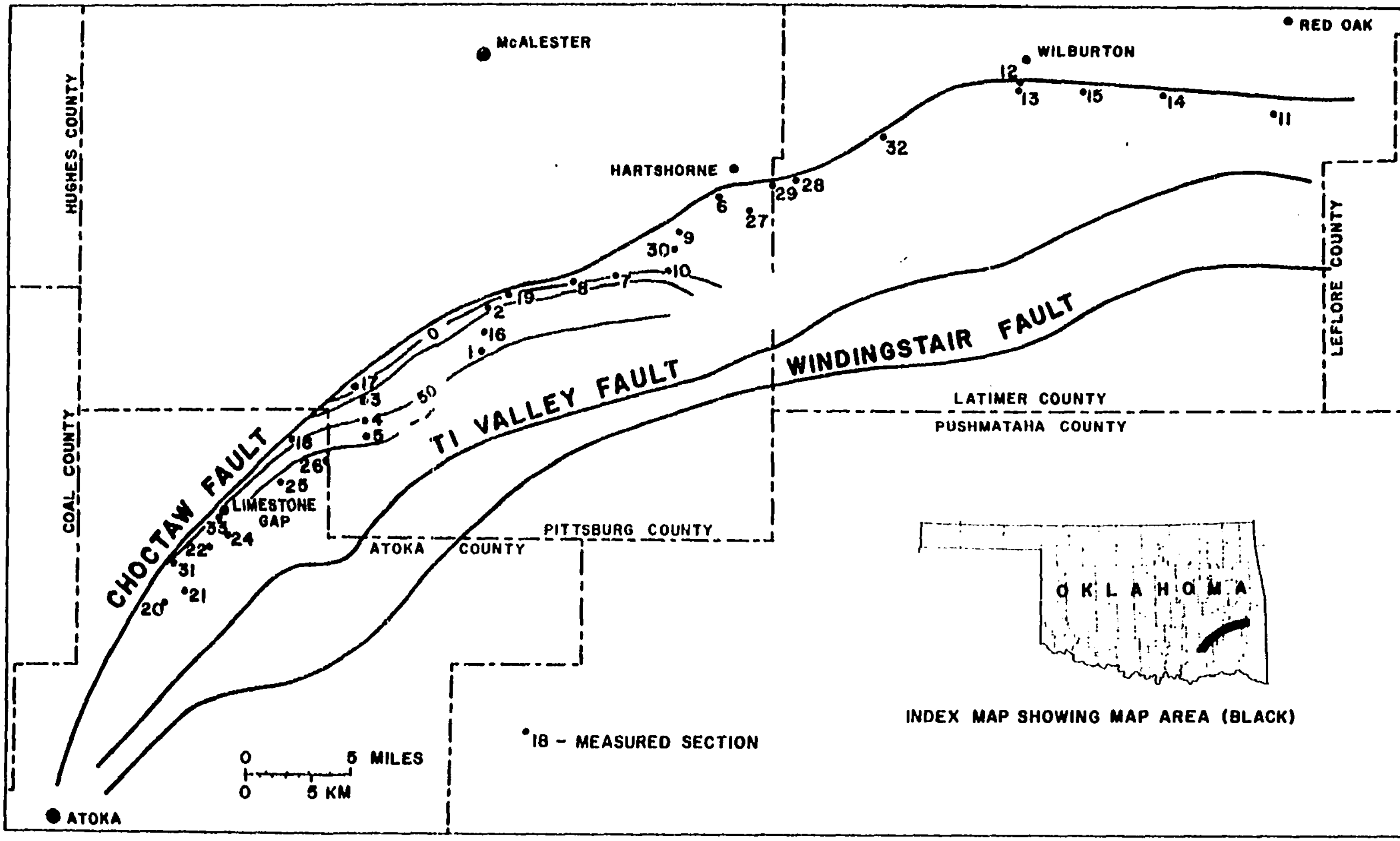

Figure 15. Isopleth map of covered and shale units in the Chickachoc Chert Member. Contour interval is 25 percent of total section.

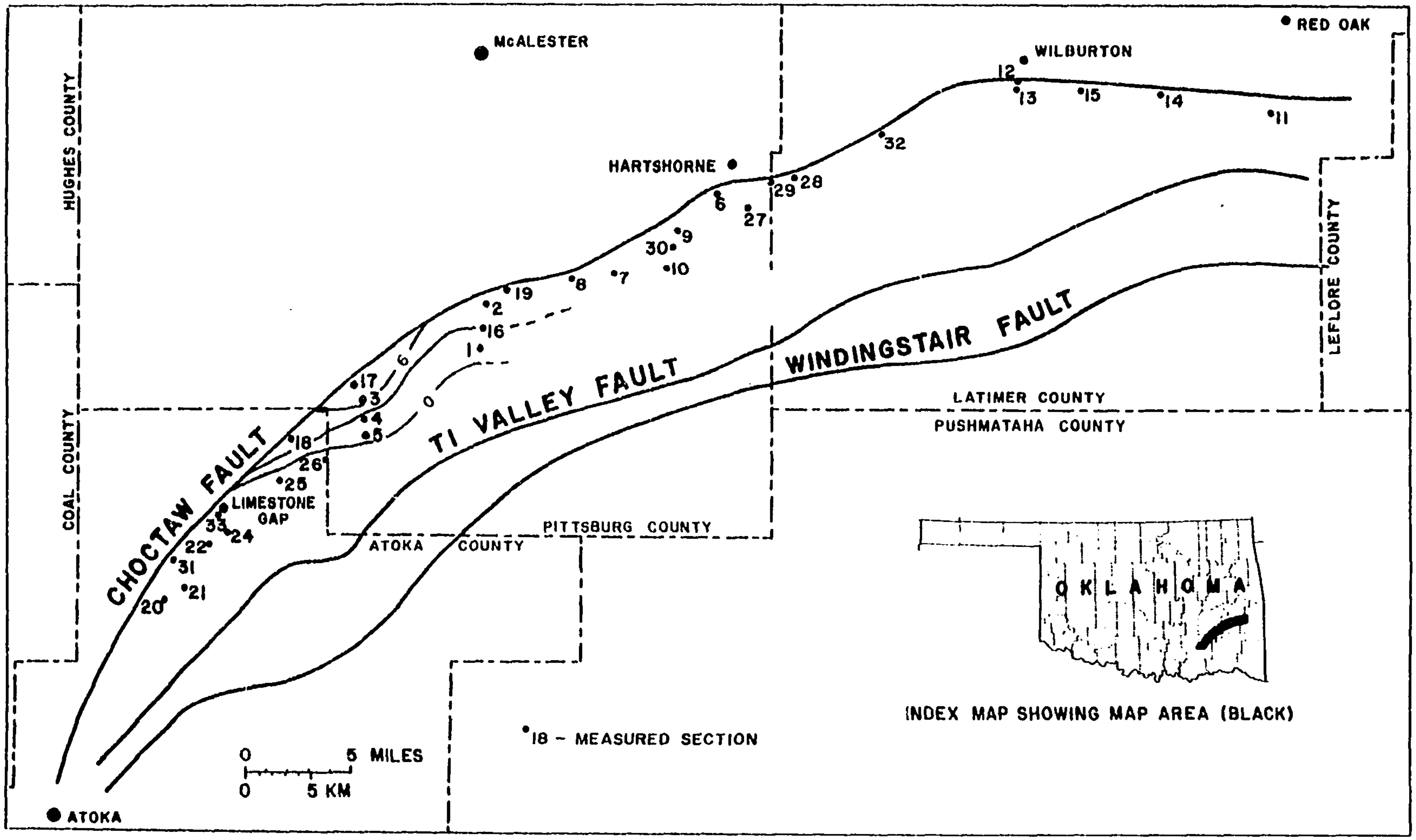

Figure 16. Isopleth map of allocthonous bioclastic calcarenitic limestone units in the Chickachoc Chert Member. Contour interval is 3.0 percent.

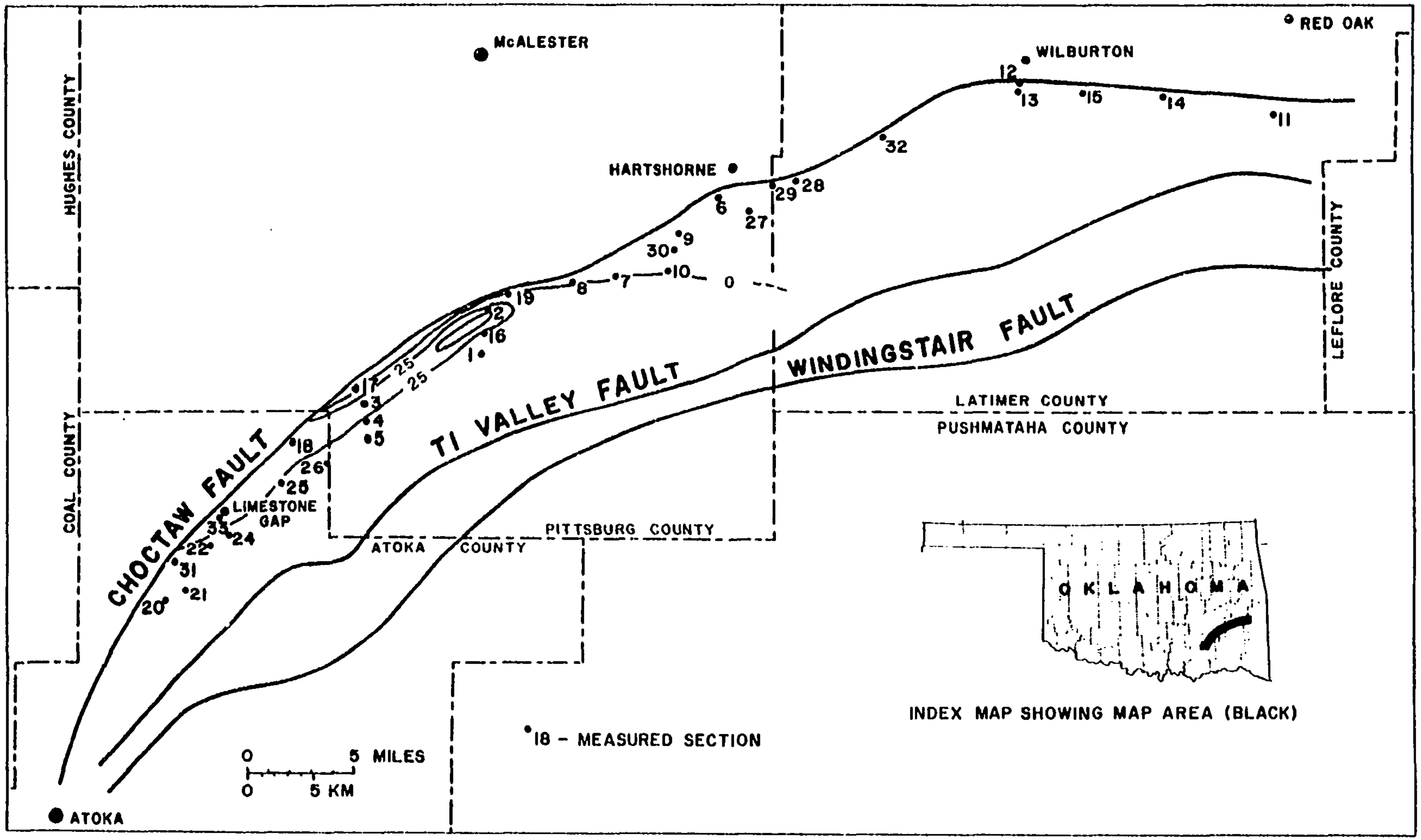

Figure 17. Isopleth map of spiculiferous limestone units in the Chickachoc Chert Member. Contour interval is 25 percent.

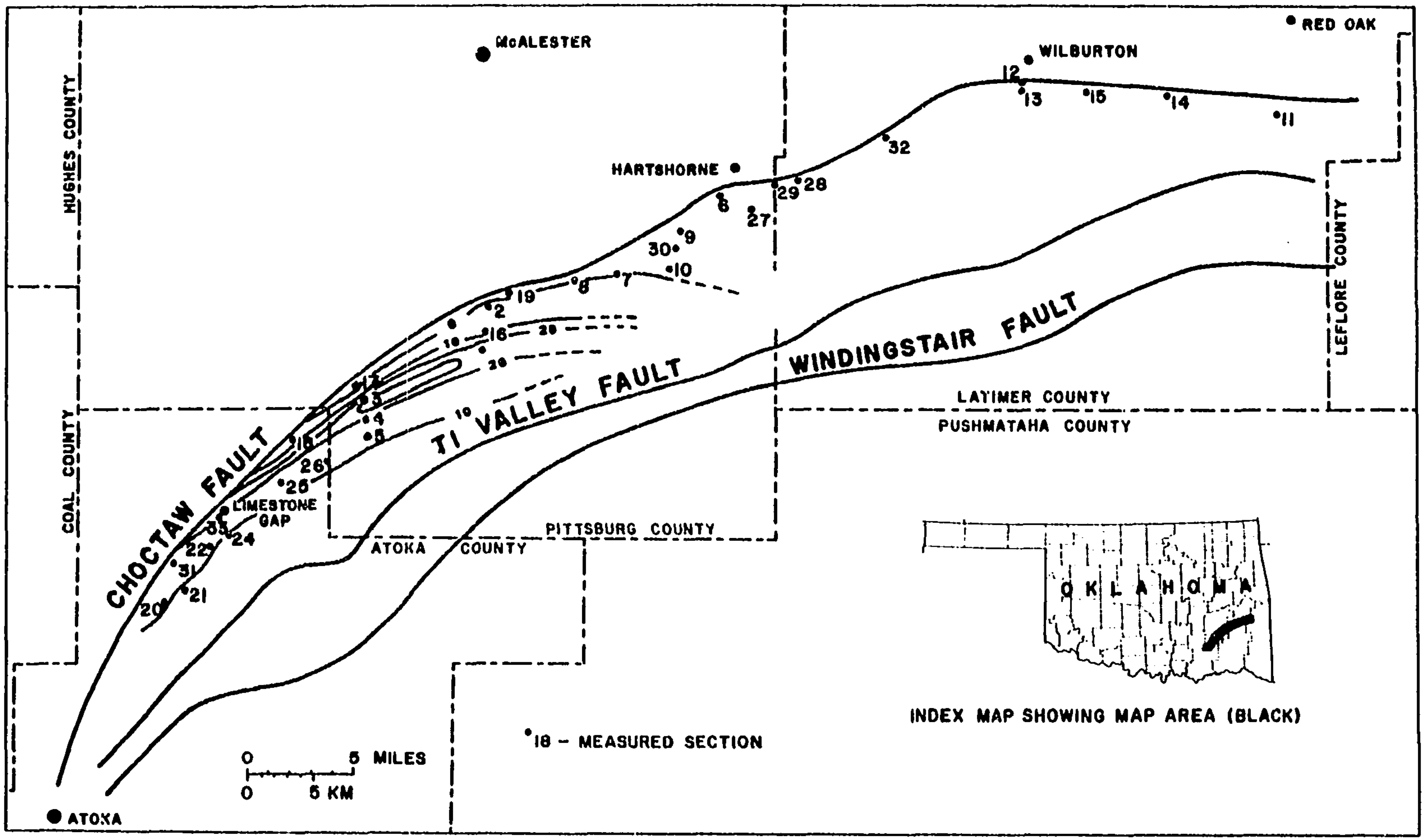

Figure 18. Isopleth map of spiculite units in the Chickachoc Chert Member. Contour interval is 10 percent of total section.

section 1. At this locality the member totals nearly 390 feet in thickness. The thinnest exposure is about 45 feet at section 2.

The member is exposed only in the southwestern one-half of the outcrop belt. From basinward sections in that area, the Chickachoc Chert thins northward and the complete extinction of the member occurs by facies change into strata assigned to the lower limestone member.

Middle Shale Member

Definition

The middle shale member is a persistent terrigenous mudrock unit that overlies the Chickachoc Chert or lower limestone member, if present, and underlies the upper sandstone/limestone member. Good exposures of the middle shale are present at sections 1, 5, 6, 13, 17 and 19. The middle shale represents a major clastic influx that temporarily terminated biogenic sedimentation. The effect of this influx seems to have been to cause a reduction in the previously existing depositional slope.

Lithologic Character and Age

Significant conodonts have not been recovered from the middle shale. Based on its stratigraphic position with regard to conodont-producing beds, the middle shale is presumed to represent part of the erosional interval separating the Kessler Limestone Member of the Bloyd Formation and the overlying Trace Creek Shale Member of the Atoka Formation in the type Morrowan region.

The middle shale member exhibits only minor (megascopic) lithologic variability. Normally, the member consists of blue-gray, clay shale. Thin zones and thin beds of sideritic clay-ironstone concretions are locally present. These concretions are generally unfossileferous, however, concretions in the lower 20 feet of the middle shale member at section 1 contain a depauperate fauna consisting of crinozoan bioclasts and productid brachiopods.

A thin (one foot) ferruginous bioclastic calcarenite bed occurs in the middle part of the member at section 5 (Pl. 1). The calcarenite rests with a sharp erosional contact on underlying shale. Fragments of shale are incorporated in the basal part of the interbed. Fossils are abundant and include crinozoan bioclasts, productid brachiopods, ramose bryozoans, rugose corals, goniatites and conodonts. Ooliths and coated grains are also common.

Spiculiferous limestone and chert are interbedded in the middle shale member at section 32 (Pl. 1).

Generally the middle shale is covered, but where exposed, it generally constitutes a lithologically monotonous mudrock sequence. Lithologically the middle shale is indistinguishable from the "Springer" shale or the basal shale member of the Atoka Formation. A strong possibility exists, however, that these shales can be differentiated by volatile organic components absorbed by the clay particles. A technique using thin layer chromatography for visual characterization of these organic components has been described by Schnitzer (1975). Basically this technique involves concentration of the volatile organic compounds by steam distillation. The concentrated organic molecules are allowed to ascend a glass plate coated with silica gel from an ascending fluid composed of various proportions of N-hexane, benzene, chloroform, and methanol. The resulting chromatogram is treated with iodine and the spots are intensified by pencil. This method results in a visual aid that can be used to portray volatile organics for solving correlation problems.

Two 500 gram samples from two localities (sec. 1 and 2) were collected from freshly exposed "Springer" Shale, and Atoka Shale. Chromatograms were prepared from these samples with the aid of Oklahoma Geological Survey Chemist David Foster. The chromatograms indicated that these shale units have dissimilar organic constituents. The technique appears to be useful for correlation but more detailed study is needed to document the techniques applicability. X-ray analyses might also be a means of differentiating the shales of the "Springer", Wapanucka and Atoka Formations. If these stratigraphic tools could be perfected it would be particularly useful in the structurally complex Ouachita Mountain fold belt where shales comprise much of the record and fossils are rare.

Stratigraphic Relationships

The middle shale member conformably overlies the Chickachoc Chert or lower limestone, if present. It is conformably overlain by the upper sandstone/limestone member. Locally along Limestone Ridge (sec. 2 and 17) the basal contact of the upper sandstone/limestone appears to be a truncating surface, but at other localities where the contact is exposed it is gradational.

Thickness and Extent

At most localities the middle shale is a covered interval that is expressed as a major reentrant between more resistant beds of the Wapanucka Formation. Although imprecise due to cover, measured thicknesses are probably reliable for determining thickness trends. In general, the middle shale can be characterized as a basinward thickening wedge (Fig. 19). The greatest measured thickness is 288 feet at section 5 (Pl. 1), which is one of the most basinward exposures. The thinnest exposures are 11 and 13 feet at sections 10 and 12 (Pl. 1) in the northeastern outcrop area, respectively. Unusually thin exposures occur at sections 9 and 10 due to the lower occurrence of sandstone bodies or possibly structural complexities. Suprisingly thick exposures of middle shale are found along Limestone Ridge just east of Hartshorne, Oklahoma (secs. 29 and 28; Pl. 1). This greater thickness is due to a facies change to shale from carbonate and sandstone in the lower limestone

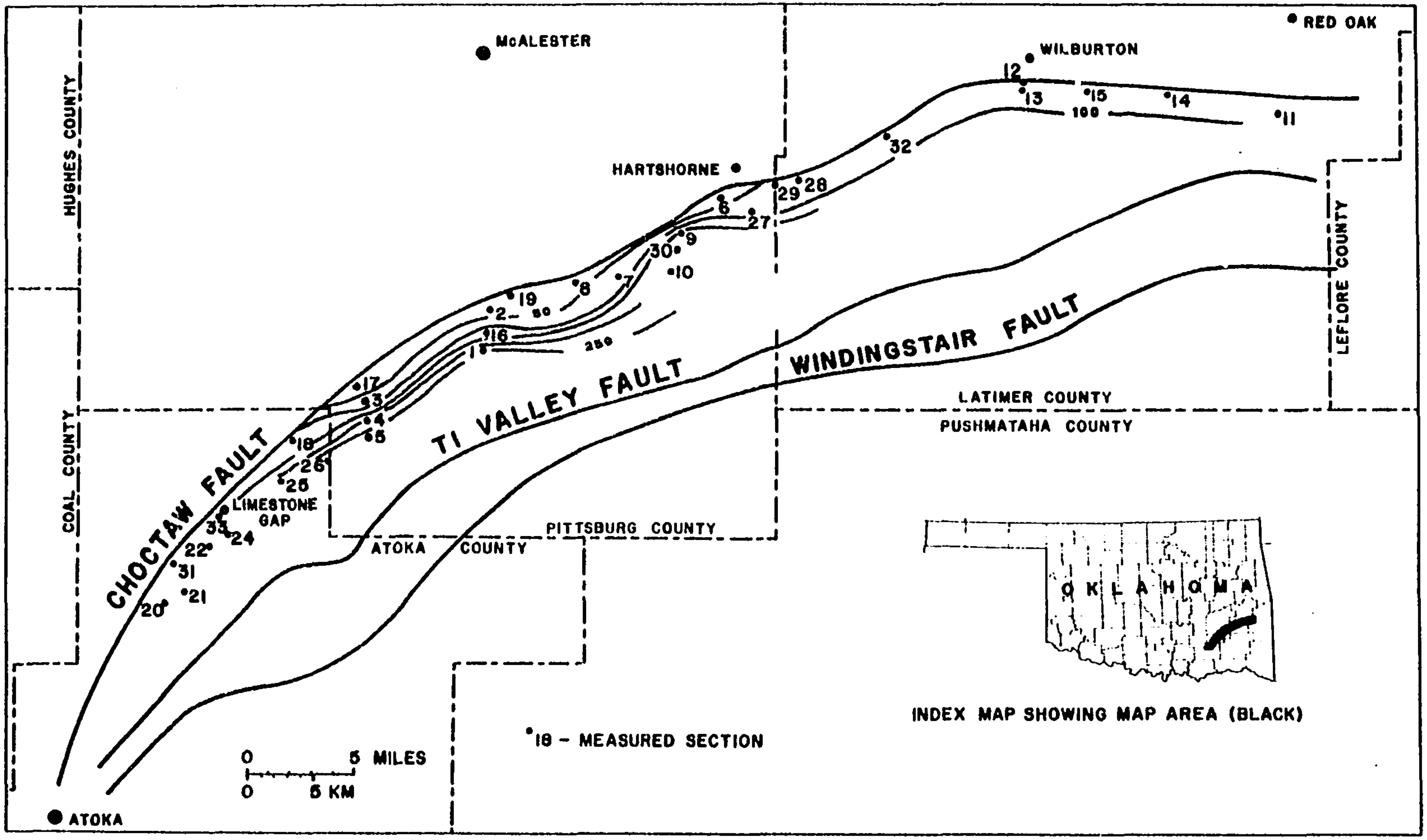

Figure 19. Isopach map of middle shale member. Contour interval is 50 feet.

and upper sandstone/limestone.

The middle shale is present over the whole of the Ouachita Mountain outcrop belt. It extends into the southern part of the McAlester Basin, Oklahoma, where it has been termed the sub-Spiro shale by Lumsden and others (1971). Along the northern margin of the McAlester Basin the sub-Spiro shale (=middle shale member) has been removed by pre-Atokan (Spiro sandstone) erosion (Lumsden and others, 1971). It is also abesent in the Arbuckle Mountain area presumably due to either pre-Atoka Formation erosion or to nondeposition.

Upper Sandstone/Limestone Member

Definition

The upper sandstone/limestone member is a complex intertonguing quartz sandstone and carbonate sequence. Carbonate lithologies predominate in the western area of outcrop. To the east, quartz sandstone becomes increasingly more important. Between these areas the member forms a major topographic ridge that is easily traced. In terms of volumetric importance, quartz sandstone is the most important constituent of the upper member. Carbonate lithologies including spiculiferous and micritic limestone, and bio-clastic calcarenite constitute a volume of less than one-half the member (Table 4).

Exposures that illustrate the typical lithologic character of the upper sandstone/limestone are sections 5 and 17, which are located in the area south of Pittsburg, Oklahoma (Pl. 1). Section 17 consists almost entirely of carbonate rock and section 5 illustrates the intertonguing relationship of carbonate and sandstone units (Fig. 10). Some of the lithologies that occur in these exposures closely resemble those found in the lower limestone member. Exceptions are the differential abundance of quartz sandstone and the virtual absence of oolitic calcarenite in the upper member. Also in contrast to the lower limestone, units in the upper sandstone/limestone exhibit greater lateral persistance and continuity.

Conodonts recovered from the upper sandstone/limestone member belong to either the Diplognathodus orphanus or Streptognathodus elegantulus zones. The former zone indicates equivalence to the erosional gap separating the Kessler Limestone and Trace Creek Shale in the Morrowan Series type area. The latter zone is presumed to indicate an Atokan age. Its occurrence in the Wapanucka suggests the upper part of the upper sandstone/limestone correlates with the Trace Creek Shale in the type area of the Morrowan Series in northeastern Oklahoma and northwestern Arkansas.

Lithologic Character

A gradational but inverse relationship exists between the volumetric importance of bioclastic calcarenite and quartz sandstone. These genetically distinct but depositionally equivalent lithologies do not co-occur except at sections 8 and 7 (Pl. 1). Bioclastic calcarenite is least widespread in occurrence and is volumetrically less important than quartz sandstone (Table 4). The isopleth map for bioclastic calcarenite indicates a distinctly circumscribed, elipsoidal geometry (Fig. 20). Quartz sandstone in contrast, forms basically a basinward thickening wedge (Fig. 21).

Quartz sandstone and bioclastic calcarenite units generally exhibit features indicative of current transport. A characteristic current feature is tabular cross-bedding (Pl. 3, Fig. 4), which occurs commonly in both carbonate and quartz sandstone units, but is best developed in sandstone units. Generally the tabular cross laminations dip 5 to 15 degrees to the south with an occasional slight east or west component; however, at one locality (sec. 18, unit 19) a north-south bipolar dip of tabular cross laminations results in herringbone cross stratification in one bioclastic limestone unit (Pl. 6, Fig. 6). Tabular sets are generally 2.0 to 4.0 feet in thickness but sets no thicker than 0.5 foot have been observed. The lower contract of each set is invariably sharp. Ripple bed forms are preserved on the upper surface of a few thicker sandstone sets (sec. 9, unit 4). Equally uncommon are occurrences of trough cross-bedding and parallel laminations.

The greatest measured thickness of quartz sandstone

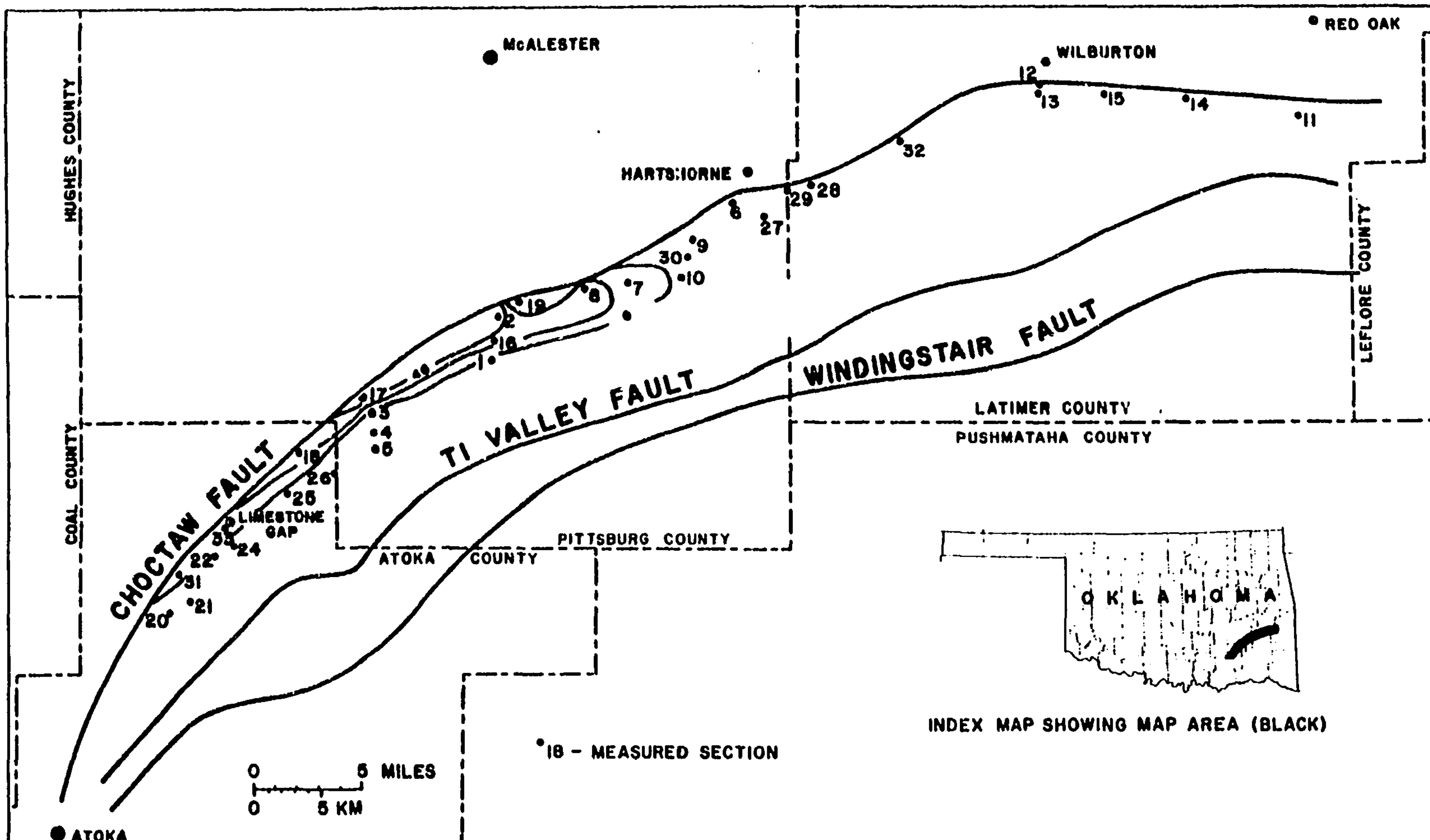

Figure 20. Isopleth map of bioclastic calcarenite units in the upper sandstone - limestone member. Contour interval is 20 percent.

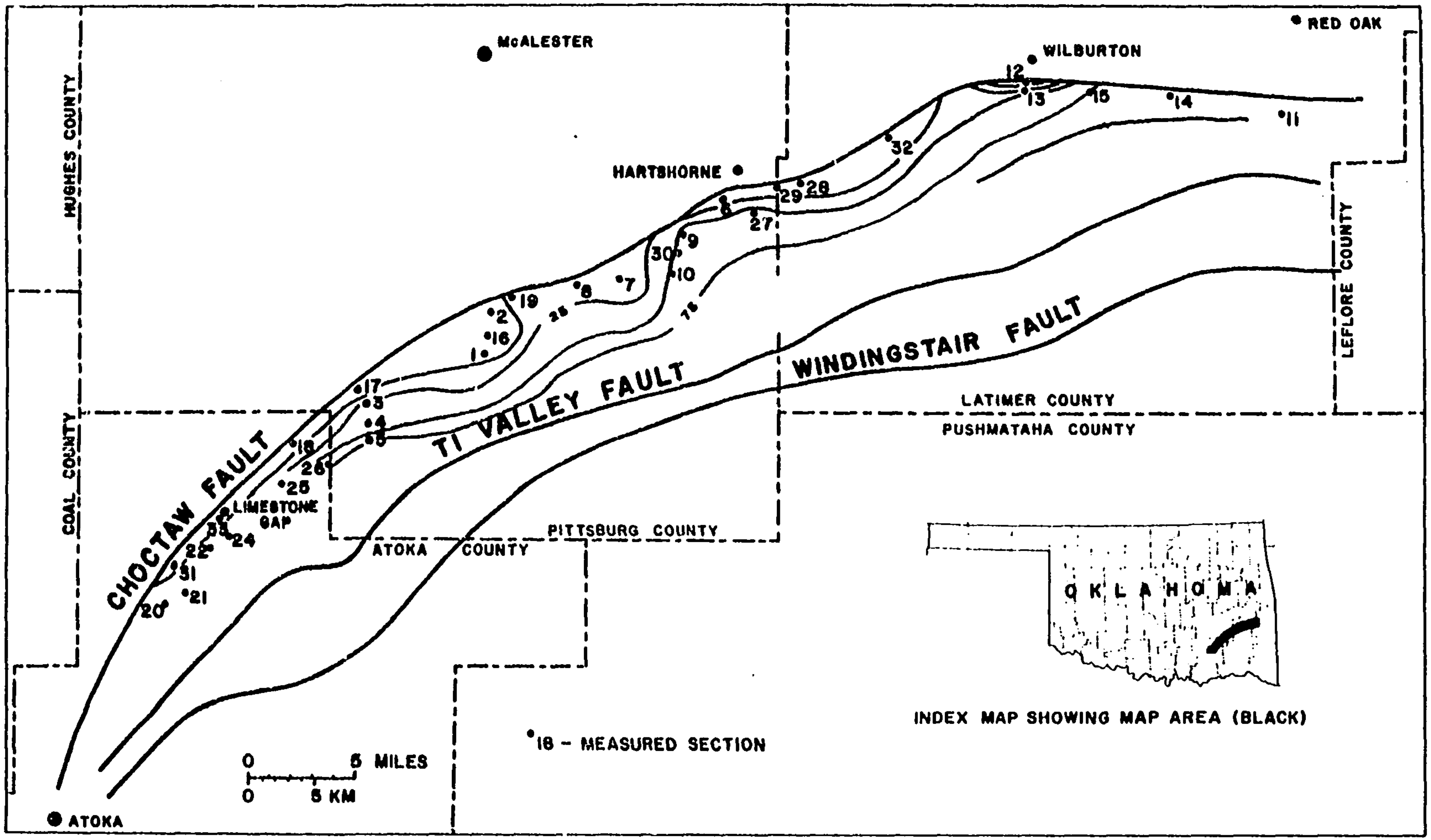

Figure 21. Isolith map of sandstone units in the upper sandstone - limestone member. Contour interval is 25 feet.

units is in the eastern-most outcrop area (Pl. 1). This suggests that the quartz sand source was relatively nearby and that marine processes distributed detritus both basinward and westward. A marine depositional environment for the quartz sandstone wedge is indicated by fossils. Particularly convincing is an in situ mold fauna consisting mostly of productid brachiopods that occurs in a quartz sandstone unit at section 15. Similar mold faunas that consist predominantly of crinozoans are common at other sections.

The isopleth map (Fig. 22) for micritic limestone outlines two major mound-like features both centered in Pittsburg County. In contrast the isopleth map for spiculiferous limestone (Fig. 23) exhibits two maxima that occur adjacent to the maxima for micritic limestone. This relationship is similar to that documented for these lithologies in the lower limestone. Micritic limestone is not as volumerically important as other carbonate lithologies in the upper sandstone/limestone but it does form a distinctive laterally persistent unit. This persistent unit is present in the western part of the outcrop belt at the top of the Wapanucka Formation or just below a higher more sporadically developed spiculiferous limestone (Pl. 1). Micritic limestone also occurs, less abundantly, lower in the member interbedded with other carbonate lithologies or quartz sandstone.

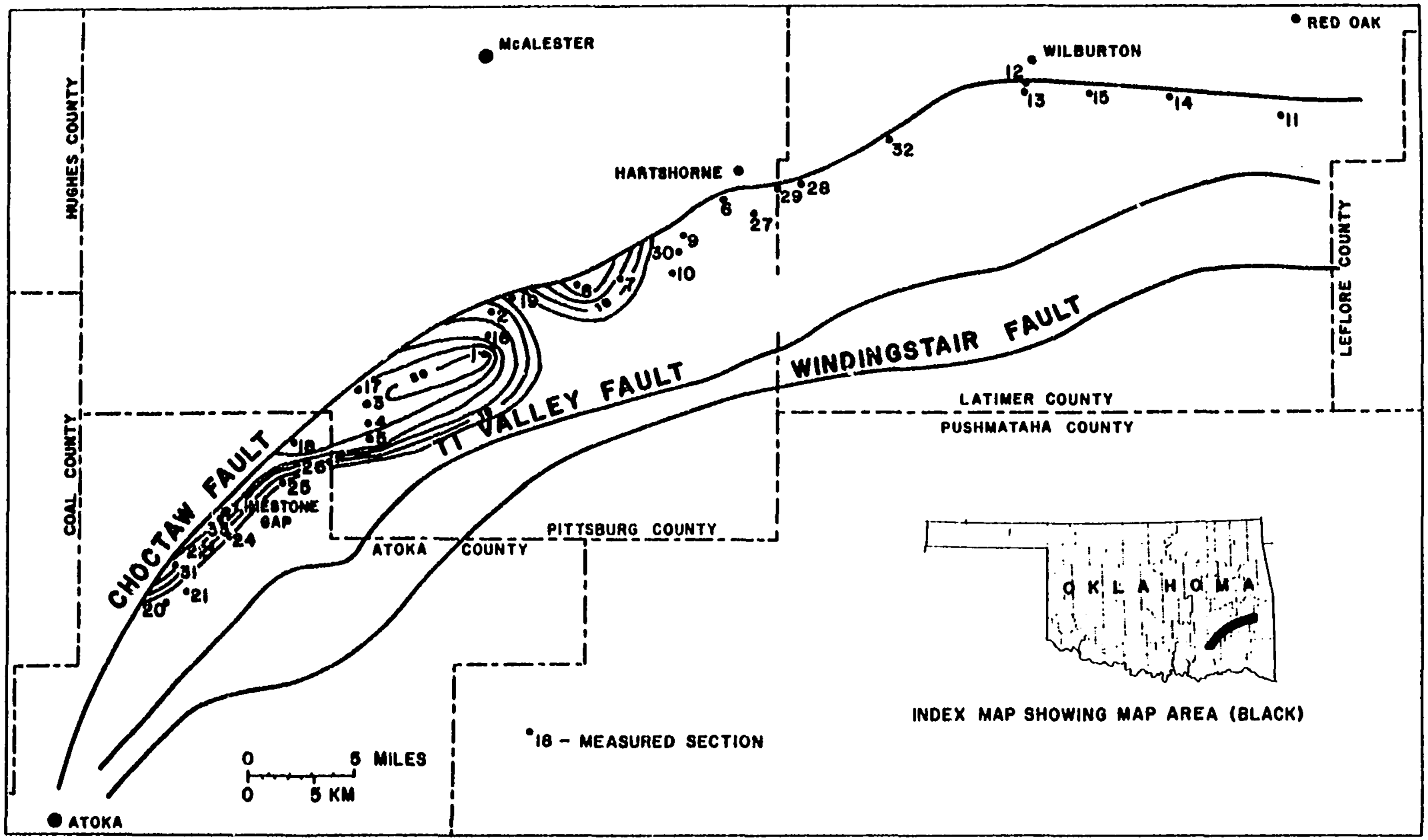

Figure 22. Isopleth map of micritic limestone units in the upper sandstone - limestone member. Contour interval is 10 percent.

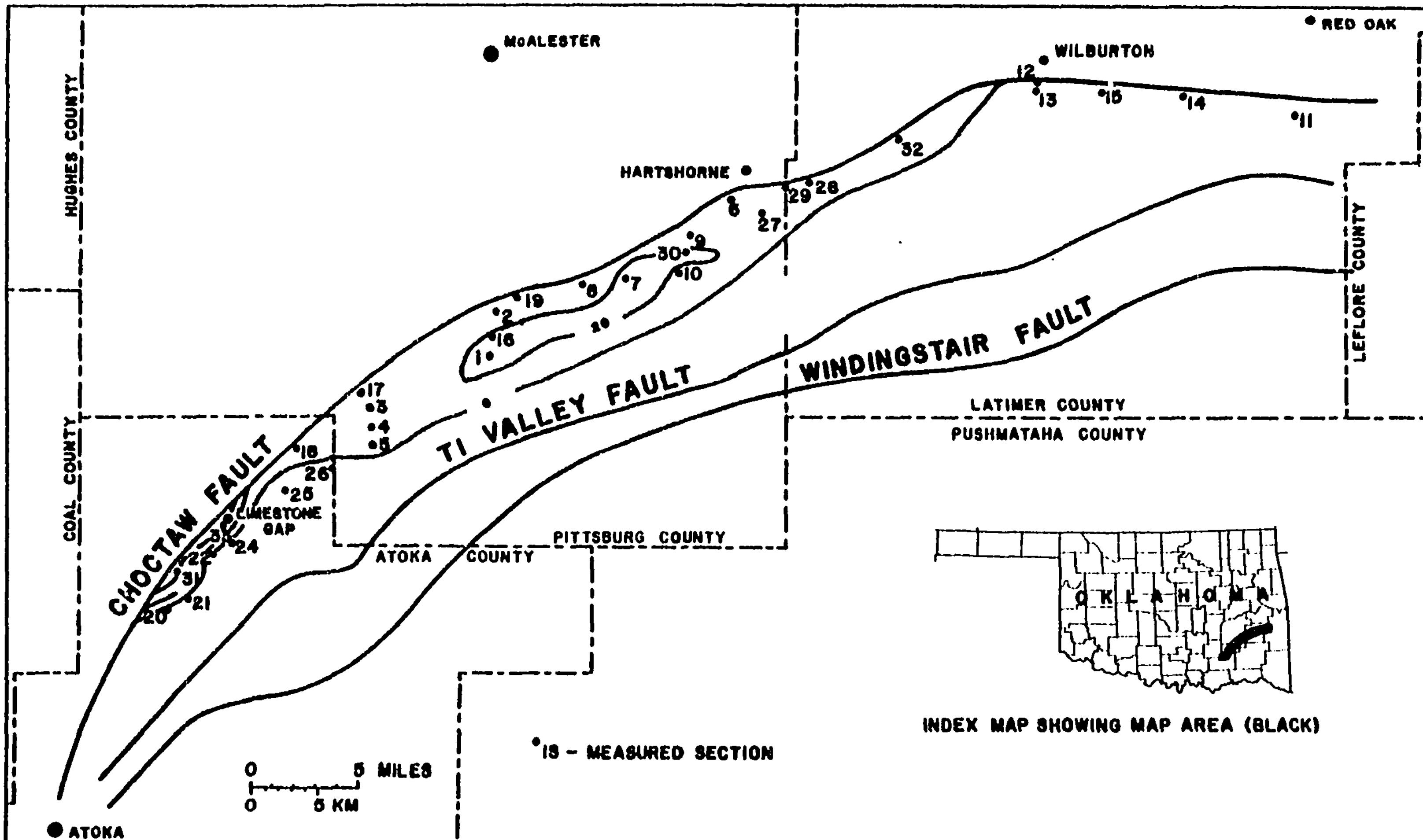

Figure 23. Isopleth map of spiculiferous limestone units in the upper sandstone - limestone member. Contour interval is 20 percent.

Spiculiferous limestone is not volumetrically important in the upper sandstone/limestone. It is comparable to bioclastic calcarenite in volumetric importance (Table 4). The spiculiferous limestone units are invariably cherty and develop a distinctive weathered appearance (Pl. 3, Fig. 6). Spiculiferous limestone forms a discontinuous bed at the top of the Wapanucka Formation over much of the western part of the outcrop belt. In part of this area (secs. 31, 33, 18, 4, and 7, Pl. 1) spiculiferous limestone also occurs interbedded with quartz sandstone, micritic limestone and bioclastic calcarenite.

Limestone pebble conglomerates containing spiculiferous and micritic limestone intraclasts occur in the lower part of the member along Limestone Ridge from the exposure at Limestone Gap (sec. 33) to section 17 (Pl. 1). In the Limestone Gap area (secs. 33 and 18), the conglomeratic horizon occurs within the lower middle part of the upper sandstone/limestone member. Eastward, at section 17 (Pl. 1), a limestone pebble conglomerate occurs at the base of the member. These layers are not precisely time correlative but are thought to have accumulated in a similar environment.

Shale interbeds or covered intervals are comparatively rare in this predominantly quartz sandstone and carbonate sequence (Table 4).

Stratigraphic Relationships

The upper sandstone/limestone member is conformably

PLATE 3

Character of Members of Wapanucka Formation

Figure 1. Limestone pebble conglomerate in lower limestone member (sec. 8, unit 13). Hammer is 18 inches long.

Figure 2. Chaetetes heads in bioclastic limestone in lower limestone member (sec. 19, unit 22a). Hammer head about 4 inches long.

Figure 3. Typical topographically subdued exposure of Chickachoc Chert Member (sec. 1, units 16-19).

Figure 4. Tabular cross-bedded sandstone exposed in unusual elephantine blocks in the upper sandstone/limestone member (sec. 9, unit 10). Hammer is 18 inches long.

Figure 5. Thick sequence of coarse to fine grained, crinozoan grainstone-bioclastic calcarenite in the upper sandstone/limestone member (sec. 17, units 10, 11). Note tabular cross-bedding in lower part of sequence. Hammer is 18 inches long.

Figure 6. Heavily weathered spiculiferous limestone showing characteristic weathering of chert remnants in upper sandstone/limestone member (sec. 17, unit 16). Hammer is 18 inches long.

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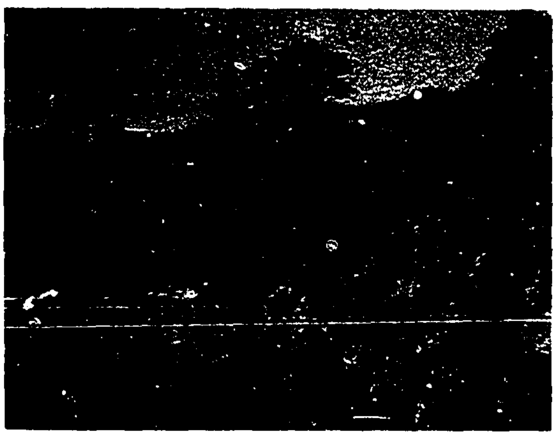

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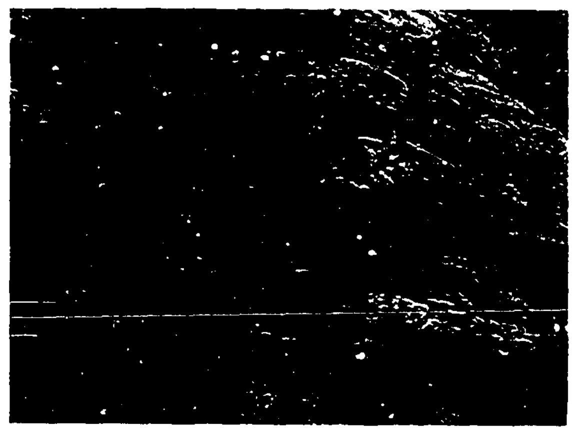

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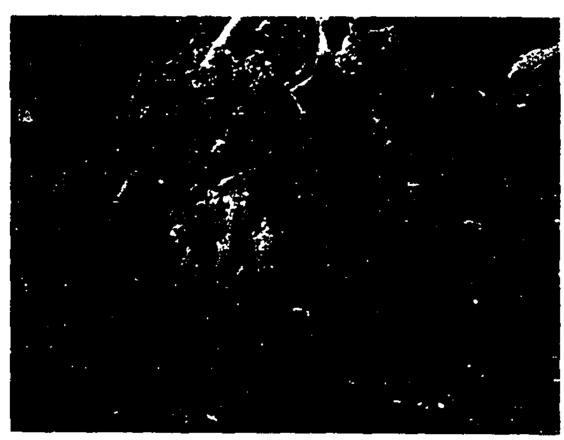

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overlain by the basal shale of the Atoka Formation. It conformably overlies the middle shale except for a limited area in Pittsburg County, Oklahoma. This area is essentially bounded by sections 17, 2, and perhaps 16, Pl. 1). Here the contact of the upper sandstone/limestone with the subjacent middle shale is marked by a sharp erosive boundary or superjàcent bioclastic calcarenites contain shale clasts.

A major basinward change in facies in the upper sandstone/limestone member cannot be demonstrated. Although from section 18 to section 31, along Limestone Ridge, in the extreme southwestern part of the study area, the member seemingly exhibits minor changes consistent with a basinward change in facies (Pl. 1). It is possible that the postulated basinward thickening of quartz sandstone could indicate that the upper sandstone/limestone grades basinward into strata regarded by most stratigraphers as the lower part of the Atoka Formation. The reported occurrence of spiculite (Cline, 1956 a and b) and mold fauna's (Honess, 1924) in the basal part of the Atoka Formation in the central Ouachitas provides some corroboration for this hypothesis.

The upper sandstone/limestone member is known to subsurface geologists concerned withthe McAlester Basin as the Spiro sandstone (Lumsden and others, 1971). In subsurface terminology the Spiro sandstone is the basal member of the Atoka Formation. In the southern part of the basin the Spiro rests conformably on the middle shale (= sub-Spiro shale) but northward this contact becomes a truncating, erosional surface (Lumsden and others, 1971).

Thickness and Extent

The precise thickness of the upper sandstone/limestone member, is difficult to determine due to cover and fault concealment. Measured thicknesses for the interval; however, range from approximately 5 to 160 feet (Fig. 24). The member is a basinward thickening wedge that thickens mostly due to an increased importance of quartz sandstone. An exception to these generalities occurs in the western outcrop where bioclastic calcarenite occurs to the near exclusion of quartz sandstone.

The upper sandstone/limestone member is present over the whole of the outcrop area except for the most basinward ridges in the extreme southwestern outcrop areas, in western Pittsburg and Atoka Counties. These ridges essentially coincide with those mapped as Chickachoc Chert by Hendricks and others (1947). As previously stated, the Wapanucka Formation in these ridges is incomplete due to fault concealment by overthrust sheets of the Atoka Formation. In the McAlester Basin, the equivalent Spiro sandstone, the basal member of the Atoka Formation in that area, has a thicknesses approaching 120 feet (Lumsden and others, 1971).

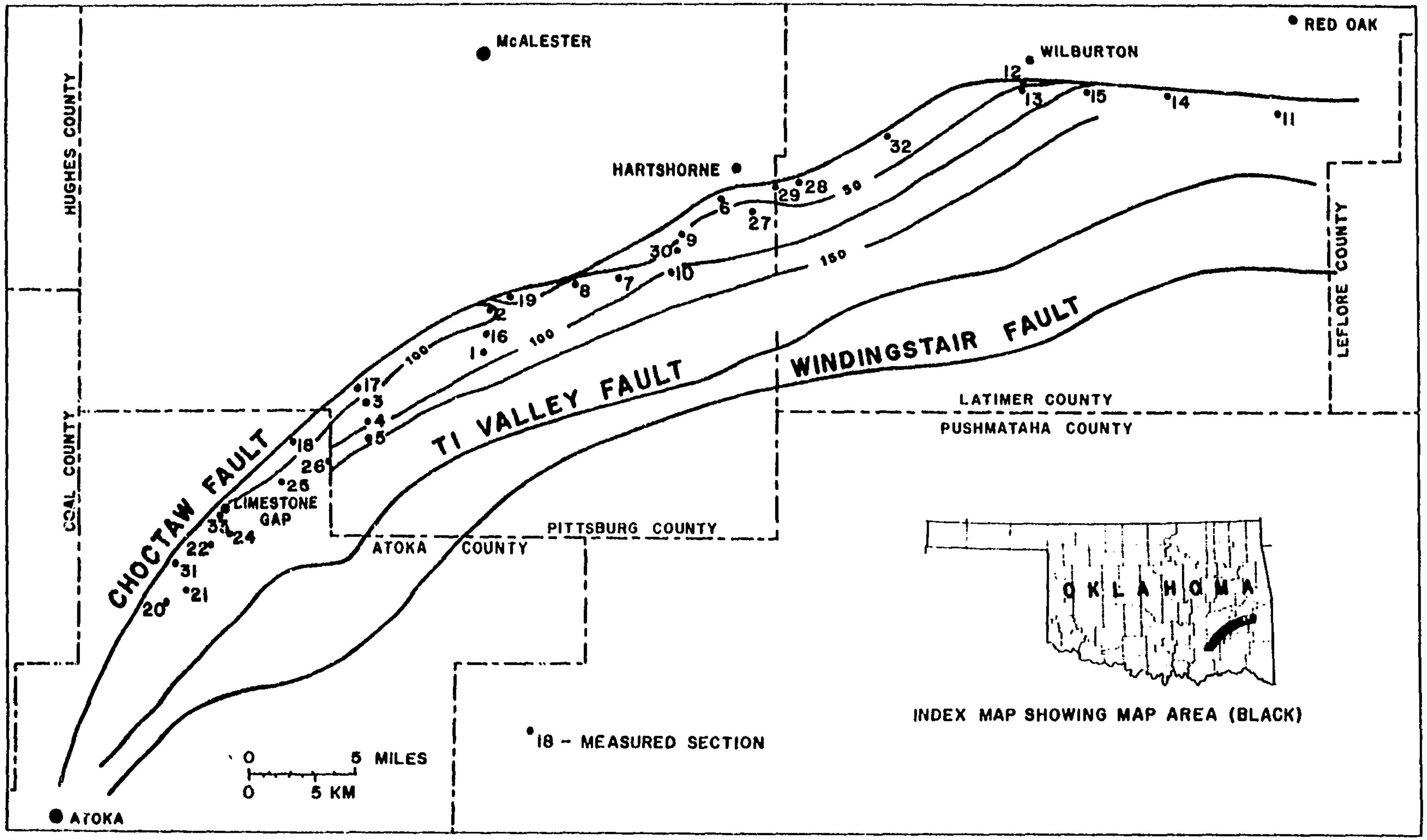

Figure 24. Isopach map of upper sandstone - limestone member. Contour interval is 50 feet.

CHAPTER II

LITHOFACIES DESCRIPTION AND INTERPRETATIONS

General Statement

The Wapanucka Formation consists of diverse lithofacies (Table 4) including terrigenous and chemical lithologies. Chemical lithologies are subdivided into six lithofacies based primarily on the nature of the matrix, percent matrix and allochemical constituents. The distribution of terrigenous and chemical lithofacies is shown diagrammatically in Plate 1 and the lithofacies designations (Table 4) serve as headings for the description of individual measured units in Appendix 1. Some of the lithofacies are subdivided into lithotypes based on sedimentary structures and/or occurrence of distinctive allochems. The facies defined in the present study are thought to have accumulated in mutually distinct and internally heterogenous depositional environments. The lithotypes recognized within a lithofacies represent an initial attempt to identify and characterize the environmental heterogeny within a more specific depositional setting.

The distribution of lithofacies in the Wapanucka Formation shows a recognizable pattern. Occurrences of the spiculite and allocthonous bioclastic calcarenite lithofacies are restricted to the Chickachoc Chert Member, and shale characterizes the middle shale member. The remaining lithofacies occur in varying proportions but exhibit dissimilar geometry in the lower limestone and the upper sandstone/limestone members. The differences in geometry and relative volumetric importance of specific lithofacies in the lower limestone compared to the upper sandstone/limestone result principally from differences in depositional topography, bathymetry, and importance of clastic influx.

Micritic Limestone Lithofacies

Description

The micritic limestone lithofacies includes most limestones that have a predominantly micritic/neomorphic microspar matrix. The essential character of the lithofacies is the subequal occurrence of micrite/neomorphic microspar compared to calcareous allochems particularly those of algal origin. This definition excludes those limestones that have a micritic matrix but are predominantly composed of spicules or exhibit a bioclastic texture.

Rocks belonging to this lithofacies present a distinctive weathered outcrop appearance due to their characteristic color, grain size and bedding. Typically, these limestones are light gray or blue-gray carbonate mudstones. Coarser lithologies occur but are not volumetrically significant. Individual beds are thick to very thick and exhibit sharp but essentially planar contacts. Internal pseudo-brecciation and clotted fabrics are pervasive. These structures result from both depositional and post-depositional factors. Post-depositional "brecciation" results principally from intense styolitization.

The lithofacies is subdivided into four lithotypes based on examination of polished slabs, acetate peels and thin sections. These lithotypes are: (1) carbonate mudstone/wackestone, (2) algal packstone/boundstone, (3) rugose coral wackestone/packstone, and (4) lithotypes 1-3 modified by fenestral and geopetal fabrics. These lithotypes do not exhibit a detectable pattern in terms of geographic or stratigraphic occurrence. Also, they are equally abundant at most localities except for lithotype 3 which is least volumetrically important.

Carbonate Mudstone/Wackestone Lithotype

The carbonate mudstone/wackestone lithotype is distinguished by a paucity of fossils and an abundance of micrite/microspar matrix (Pl. 4, Fig. 1). Megascopically little except rare crinozoan bioclasts, birdseye structures and replacement chert nodules are observable. Petrographically, a somewhat richer assemblage of fossils can be seen.

Bioclasts that occur in low abundance in the micritic limestone lithofacies include forams, gastropods, bryozoans, sponge spicules, brachiopods and nautiloids. Locally, a few thin beds contain scattered ooliths. These fossils are not restricted to this lithotype however, and are actually more abundant in the other micritic limestone lithotypes.

Algal Packstone/Boundstone Lithotype

The algal packstone/boundstone lithotype is distinguised by an abundance of *in situ* algal remains. At least two different types of algae were important in binding and trapping of the now lithified carbonate mud. These are informally classified; based on their morphology, as tubular and phylloid algae. The phylloid algae, possibly *Archeolithophyllum*, is not very important volumetrically. The most abundant and most important sediment binding algal type present is tubular in nature (Pl. 4, Fig. 2). The tubes are about one millimeter in diameter but their length is indeterminate. Dichotomous branching and close intertwining of tubes forms both loose bundles of indeterminate shapes (Pl. 4, Fig. 3) and more tightly packed nodular shapes (Pl. 4, Fig. 4).

Rugose Coral Wackestone/Packstone Lithotype

Rugose coral wackestone/packstone is not a volumetrically important lithotype although it constitutes the most distinctive micritic limestone lithology. The corals mostly belong to the genus Koninckophyllum. Many specimens occur in a presumed near life position but others have obviously been disoriented (Pl. 4, Fig. 5).

Pseudo-Brecciated, Carbonate Mudstone

Pseudo-brecciated, micritic limestone appears as irregular clumps of micrite separated by sharp locally styolitic boundaries. The boundaries are thought mostly to be primary dessication features along which some secondary styolitization has occurred. In hand sample and thin section (Pl. 4, Fig. 6) pseudo-brecciated micritic limestone exhibits abundant irregular fenestrae partially infilled with geopetal mud chips and clasts.

Interpretation

Recent shallow marine environments of carbonate mud accumulation are found in either supratidal mud flats or lagoonal areas. Supratidal mud flats are characterized by laminated algal mats generally referred to as stromatolites. To a lesser degree, mud flats are distinguished by dessication structures that include mud cracks, fenestral fabric and birdseye structures. In areas of intense evaporation proto-dolomite, gypsum and anhydrite may occur (Bathurst, 1975). Wapanucka micritic limestone facies lack most of these distinguishing characteristics. They do, however, possess features indicative of lagoonal sedimentation. The

PLATE 4

Character of Micritic Limestone Lithofacies

Figure 1. Polished slab of carbonate mudstone lithotype from the micritic limestone lithofacies in the upper sandstone/ limestone member (sec. 1, unit 41). Magnification approximately X1.

Figure 2. Photomicrograph of tubular algal lithotype from the micritic limestone lithofacies showing typical pervasive nature of algal tubes. Specimen from the lower limestone member, X1 (sec. 18, unit 16).

Figure 3. Polished slab of tubular algal lithotype from the micritic limestone lithofacies exhibiting indeterminate shapes of algal bundles. Specimen from upper member, X1 (sec. 18).

Figure 4. Polished slab of tubular algal lithotype from the micritic limestone lithofacies showing nodular shape of some tubular algae colonies. Specimen from lower limestone member, X1 (sec. 9, unit 8).

Figure 5. Polished slab of rugose coral lithotype from the micritic limestone lithofacies. Specimen from the lower limestone member, X1 (sec. 29, unit 8). Note tubular algal encrustations on corals.

Figure 6. Photomicrograph of pseudo-brecciated lithotype from the micritic limestone lithofacies. Specimen from the upper sandstone/limestone, X7.5 (sec. 33, unit 25). Note mudcrack with internal geopetal sediment.

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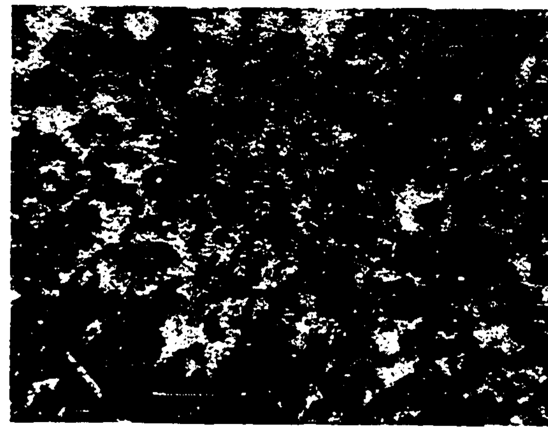

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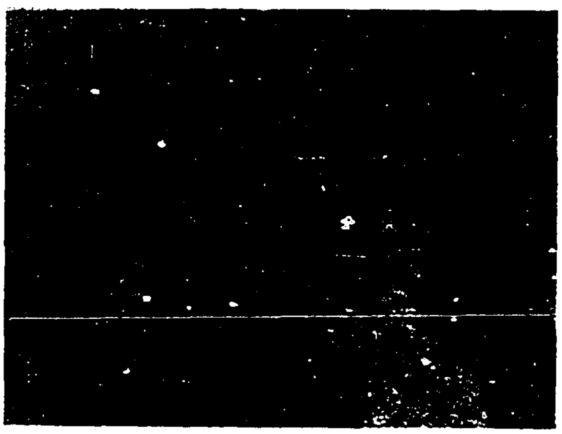

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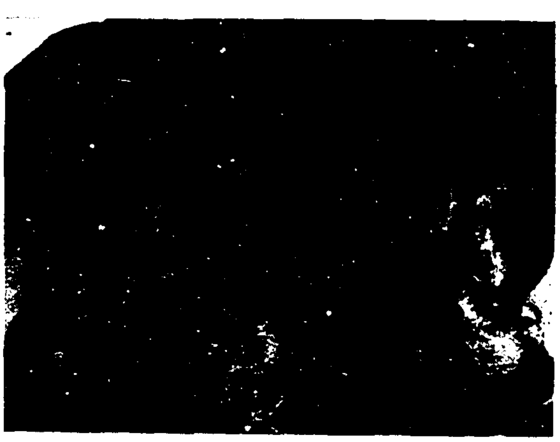

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The best known recent sites of lagoonal, carbonate mud sedimentation are Florida Bay and the Bahamian Shelf Lagoon. Descriptions of these environments based on the work of many authors has been compiled in the form of field trip guides; Florida Bay by Ginsburg (1972) and Multer (1971), and for the Bahamas by Purdy and Imbrie (1964). Although the setting of these areas does differ, the sites of carbonate mud accumulation in both regions exhibits many similar characteristics. Both of these lagoonal environmental settings are broad expanses (850 square miles or greater) of carbonate mud accumulation. They are bounded by supratidal mud flats and marsh environments on one hand, and by shoal environments on the other. Because of the sheltering effect provided by adjacent shoal environments and the dampening of tides and currents resulting from the large area of shallow water, these lagoons are low energy environments characterized by fluctuating salinities. The fauna is meager and consists predominantly of molluscs, foraminifers and algae; although, radiolarians and siliceous sponge spicules occur. These deposits have been recognized by several authors (Scholl , 1966; Purdy and Imbrie, 1964; Bathurst, 1975) as providing an analogy with ancient carbonate mudstones (calcilutites).

In analogy with the previously mentioned recent environments, Wapanucka micritic limestone facies are thought to have accumulated in lagoonal environments. The importance of micrite attests to the low energy environment during deposition and the generally poor circulation of marine water in the lagoon(s). The general absence of algal laminations indicates the micritic limestone facies was mostly subtidal in origin.

In this lagoonal setting deposition and accumulation of the four (4) lithotypes recognized in the micritic limestone facies is thought to have been controlled primarily by water circulation and salinity fluctuations. A simplified model based on analogy with the modern faunal distribution in Florida Bay (Ginsburg, 1972), depicting inferred conditions of circulation and salinity with respect to the lithotypes is shown as Figure 25. Rugose corals and other metazoans flourished in the most nearly normal marine lagoonal environments. In addition, some circulation of normal marine waters into the lagoon was probably necessary to provide food for these sedentary, filter feeding organisms. The algal lithotype could have accumulated in less well circulated environments characterized by greater fluctuations in salinity. Even those simple organisms were excluded from harsher regimes characterized by the poorest circulation and greater, more frequent variations in salinity. The development of pseudo-brecciated carbonate mudstone is thought to have occurred in the most poorly circulated saline lagoonal environments. Presumably the variations in salinity occurred here either due to subaerial exposure

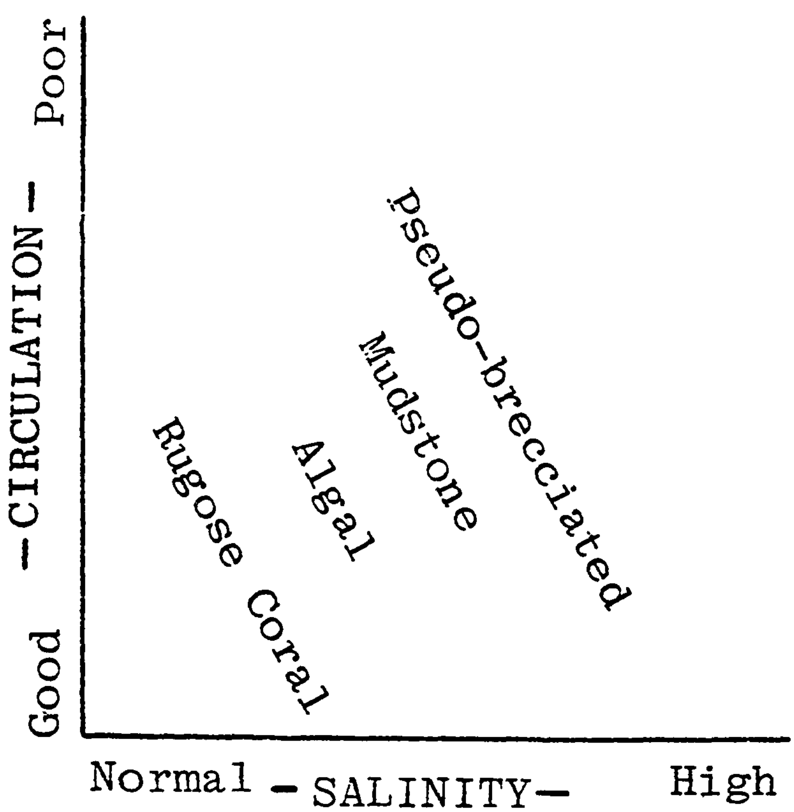


Figure 25. Generalized model depicting environmental relationship of lithotypes in the micritic limestone lithofacies.

and dessication or penecontemporaneous chemical dehydration. In either event, a fenestral and birdseye fabric developed in the poorly cohesive carbonate mud.

Spiculiferous Limestone Lithofacies

Descriptions

The spiculiferous limestone lithofacies is recognized by the greater volumetric importance of siliceous sponge spicules compared to calcareous bioclasts (Pl. 5, Fig. 1). The sponge spicules are mostly monaxon and are closely packed. They typically exhibit random orientations in either a siliceous or micritic/microspar matrix. In rare instances spicules occur in clumps or globules that may represent near-life position of individual sponges.

Two lithotypes can be distinguished based on the abundance of calcareous bioclasts, these are: (1) calcisiltire: spicule lime packstone, and (2) calcisiltite-calcarenite: skeletal, spicule lime packstone. The two lithotypes are closely related since gradations exist between them but spicule lime packstone is volumetrically much more important.

The spiculiferous limestone lithofacies grades into units of the micritic limestone lithofacies at one end of a depositional spectrum and into units belonging to the spiculite lithofacies at the other end. At secs. 19, 8, and 6 (Pl. 1), spiculiferous limestone is interbedded with bioclastic and oolitic calcarenite in the lower limestone and upper sandstone/limestone but more commonly it is interbedded and/or intertongues with micritic limestone in those members.

Calcisiltite: Spicule Lime Packstone

The matrix of this lithotype consists of subequal volumes of micrite/microspar, comminuated plant debris, and very finely divided organic debris; some of which appears asphaltic. Typically, spiculiferous limestone pervasively saturated with organic matter exhibits a dark gray or grayish black color. This color contrasts markedly with the lighter gray color of spiculiferous limestone lacking abundant organic material. Surface weathering phenomena may result in oxidation of organic matter thus inhibiting estimation of original organic content. Although most organic material is comminuated, occurrences of well preserved plant fragments have been observed (sec. 7, unit 30; sec. 28, unit 14).

Bioturbation is a very common sedimentary feature of spiculiferous limestone. Generally bioturbation is indicated by the presence of mottling (Pl. 5, Fig. 2) but distinct, subvertical burrows occur locally. In several cases (sec. 6, unit 9; sec. 11, units 13 and 17) meandering bioturbation traces parallel to bedding are also abundant. In one instance (sec. 29, unit 11) the trace fossil genus <u>Conostichus</u> occurs commonly in a unit consisting of interbedded shale and spiculiferous limestone.

Laminations are locally present in some spicule lime packstones (Pl. 5, Fig. 3). Generally, these laminations are produced by alternation of dark and light layers presumably reflecting primary variation in organic content. Calcareous biotic constituents consist of forams, crinozoan bioclasts, tubular algae (Pl. 5, Fig. 4), productid and spiriferid brachiopods, and indeterminate calcareous allochems.

A pervasive feature of the lithotype is the occurrence of secondary chert. The silicification takes many forms, ranging from isolated to anastomosing nodules (Pl. 2, Fig. 3) that obscure primary depositional features.

Shale interbeds and thin partings are locally present but the common occurrence of shale is limited to the more basinward exposures.

Calcisiltite to Calcarenite: Skeletal, Spicule Lime Packstone

The subequal occurrence of calcareous bioclasts and siliceous sponge spicules is the basis for recognition of this lithotype. These grains occur in a matrix of micrite/microspar and organic debris. The lithotype is not volumetrically important and seems to represent a gradation from spiculiferous limestone to calcarenite. Bioclasts found in this lithotype include crinozoans, bellerophontid gastropods, (Pl. 5, Fig. 5), bryozoans, tubular algae, phylloid algal blades, foraminifers and brachiopods.

Interpretation

Certain Paleozoic skeletal sediments were deposited in depositional environments that represented unique physical and biological interactions. Their interpretation presents special problems because of the difficulties in establishing recent-ancient analogues. Particular uncertainty exist in assuming similar distribution of ancient populations and their presumed modern day counterparts. An example of relevance to understanding Wapanucka depositional history is that of evaluating the environmental significance of accumulations of loose siliceous sponge spicules. In modern marine environments, hyalosponges, the dominant producers of siliceous spicules are most abundantly found in deep water associations. Upper Paleozoic spiculites have traditionally been interpreted as indicating deep water, basinal sedimentation (Newell, 1957; Ham and Rowland, 1971). Ham and Rowland (1971) concluded that spiculiferous limestone in the Wapanucka (frontal ridge) accumulated at water depths exceeding 600 feet. Alternatively, siliceous sponge spicules have been described as occurring in abundance in quiet, shallow, near shore (generally less then ten miles from the assumed strand line), normal marine environments in Pennsylvanian strata in the Appalachian Plateau (Cavoroc and Ferm, 1968).

Wapanucka spiculiferous limestone units are thought to represent *in situ* accumulations of loose spicules. The abundant comminuated and finely divided organic debris and general paucity of calcareous biota are consistent with a mildly to strongly reducing environment. The occurrence of light and dark laminations may indicate seasonal changes in water chemistry or temperature. At one end of an environmental spectrum, spiculiferous limestone in the Wapanucka represents a shallow water, marine environment with normal salinities. At the other end, they represent a deeper water deposit that intertongues with the outer shelf-upper slope accumulations of spiculite and shale. A shallow water interpretation for spiculiferous limestone units on the frontal fault ridge exposures is supported by intertonguing and gradation with micritic limestone (lagoonal deposits) and interbedding with shoal oolite and bioclastic calcarenite (Figs. 7, 8, 9, and 10). The environments of spiculiferous limestone accumulation must have ranged from near shore settings proximal to marshs through relatively deeper, stagnant water, lagoons to deeper water marine conditions. The latter setting is most probable for spiculiferous limestone units occurring on the more basinward fault-repeated Wapanucka ridges; especially those spiculiferous limestone units found co-occurring with the spiculite lithofacies in the absence of micritic limestone. In these settings the accumulation of spiculiferous limestone probably represent an outer shelf setting above a deeper water, more strongly reducing environment at the shelf margin. Water depths cannot be established, but it is suggested that *in situ* spicules in the lower and upper members accumulated in water depths of several feet to 60 feet. A maximum depth for accumulation of *in situ* Wapanucka spicules is conjectured to be several hundred feet. Spiculiferous limestone units that accumulated at this latter depth are mostly found in the Chickachoc Chert Member.

Oolitic Calcarenite Lithofacies

Description

The oolitic calcarenite lithofacies is distinguished by the occurrence of ooliths in volumes exceeding 75 percent. Individual ooliths typically exhibit several oolitic laminations but superficial ooliths also occur. The oolitic nuclei are generally bioclastic in origin but locally oolitic laminations may be developed on quartz sand grains. The effective winnowing of mud size particles is evidenced by the fact that the ooliths and associated bioclastic grains occur in a sparry calcite matrix (Pl. 5, Fig. 6). Typical lithologies include: medium to coarse calcarenite, poorly sorted fossil, oolith lime grainstone and medium calcarenite, sorted, oolith lime grainstone. Transport by traction currents, indicated by occurrence of cross-bedding, is a common feature. The cross-bedding is mostly tabular, but at one locality (sec. 8, unit 19) trough cross-bedding

PLATE 5

Character of Spiculiferous Limestone Lithofacies

Figure 1. Photomicrograph of spicule packstone lithotype from the spiculiferous limestone lithofacies in the lower limestone member, X7.5 (sec. 6, unit 13). Note carbonaceous matrix.

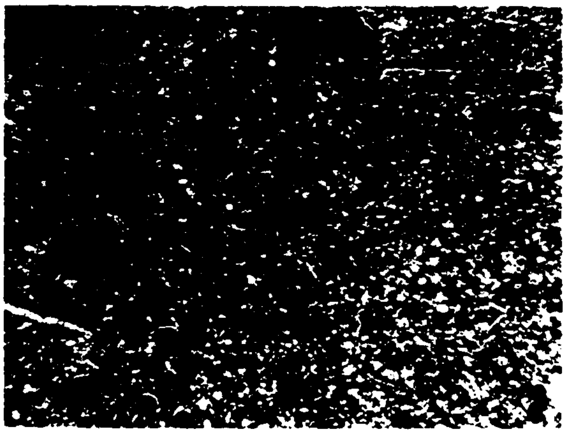
Figure 2. Polished slab of spicule packstone lithotype from spiculiferous limestone lithofacies that exhibits motting due to burrowing. Specimen from the lower limestone, X1.

Figure 3. Polished slab of spicule packstone lithotype from spiculiferous limestone lithofacies, showing laminations of carbonaceous material and spicules. Specimen from the lower limestone member, X1 (sec. 28, unit 10).

Figure 4. Photomicrograph of spicule packstone lithotype from the spiculiferous limestone lithofacies in the lower limestone member, X12 (sec. 6, unit 12). Note algal rich layer near base of sample.

Figure 5. Polished slab of spicule, skeletal packstone lithotype from spiculiferous limestone lithofacies in the lower limestone, X1.

Figure 6. Photomicrograph of oolitic calcarenite from the oolitic calcarenite facies from the lower limestone member, X7 (sec. 6, unit 1).



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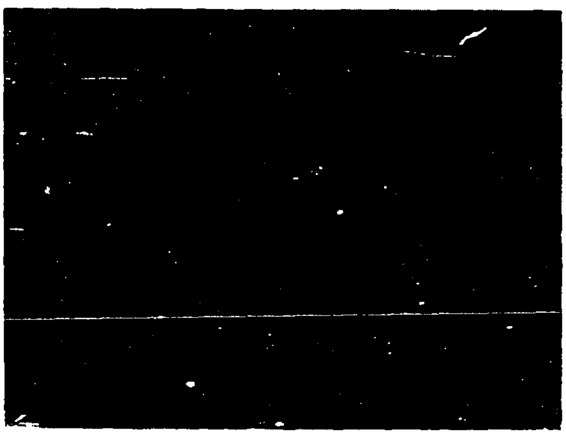

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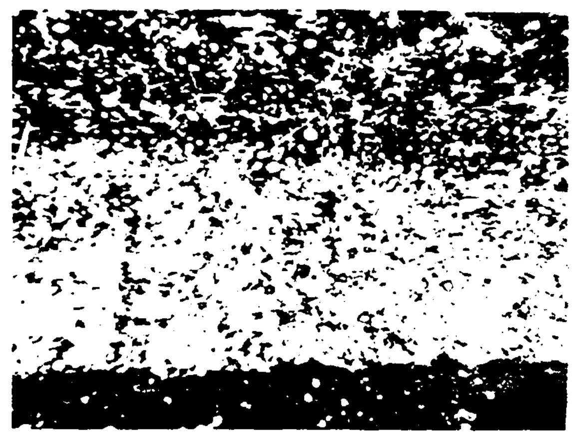

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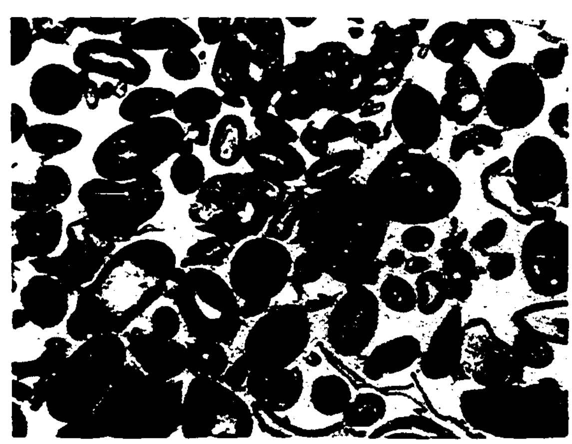

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occurs. Where the transport direction can be estimated either a southernly basinward, or northernly shelfward, direction is invariably deduced. Intermediate directions parallel to the outcrop belt have not been observed. Carbonate grains other than ooliths include fragmental fossils of diverse origin. They are dominated by fragments of crinozoans and ramose bryozoans. Intraclasts composed of spiculiferous, micritic and calcarenitic limestone are other allochems that are present in low volumes (Pl. 6, Fig. 1). Carbonaceous plant debris, consisting principally of macerated trunk segments, is ubiquitous but only locally abundant.

Occurrences of the oolitic calcarenite lithofacies have been identified at only 7 measured sections; all are located along the frontal two fault ridges. At six of these exposures, the lithofacies occurs in the lower limestone (secs. 19, 8, 6, 29, 32 and 13) and only one occurrence of the lithofacies is in the upper sandstone/limestone (sec. 11).

Interpretation

The occurrences of the oolitic calcarenite lithofacies defined a marine sand belt that was deposited in a relatively specific set of environmental conditions. Modern oolith shoals form in calcium carbonate saturated shallow marine waters, generally less than 10 feet in depth, where bottom sediments are kept in constant agitation by currents and waves. Ooliths that form under these conditions are generally referred to as Bahamian ooliths. They are distinguished from "low energy" Bimini or lagoonal ooliths by the relatively greater thickness of individual oolitic laminae and by the greater number of oolitic laminations (Bathurst, 1971). Purdy (1961) provides a detailed description of recent Bahamian oolith shoals which may serve as a analogue for oolitic accumulations in the Wapanucka Formation. Bahamian oolite shoals are characterized by the occurrence of three facies that result from the interplay of bathymetry and "energy." The shoal facies is composed predominantly of ooliths which average 94% in the Bahama's shoals (Purdy, 1961). This facies develops in the most turbulent, agitated waters at either the crest of rock ridges near the platform margin (Purdy, 1961) or proximal to the slope break at the edge of the platform (Ball, 1967). A lagoon generally occurs on the protected landward side of the oolith shoal. Typically, the lagoons are active sites of carbonate mud production and accumulation. An outer platform environment characterized by mixed ooliths and skeletal bioclasts occurs immediately seaward of the oolite shoal. Spill over lobes consisting of ooliths washed in toward the lagoon or out toward open sea are common. The spill-over lobes resemble small deltas at the head of a tidal or storm channel and internally they exhibit cross-bedding that is tabular in nature.

Ball (1967) describes two types of oolite shoals in the Bahama area: (1) an oolite sand belt, and (2) an oolite belt of tidal bars. These two types of oolitic sand bodies differ principally in terms of their geometry, setting and internal structures. Oolite sand belts are discontinuous shoals parallel to a slope break and oolite belts of tidal bars are bars formed at the heads of straits or embayments by tidal currents.

Wapanucka oolite lithofacies probably represent deposition in an oolite sand belt with spill-over lobes being represented by units with tabular cross-bedding.

The Wapanucka oolite sand belt occurred adjacent to the break in slope that separated shallow water deposits now assigned to the lower limestone and deeper water deposits now assigned to the Chickachoc Chert.

Autochthonous Bioclastic Calcarenite Lithofacies

Description

The autochthonous calcarenite lithofacies is distinguished from all but the allocthonous bioclastic calcarenite lithofacies by the greater volumetric importance of calcareous bioclasts compared to that of ooliths and micrite matrix. Stratigraphic occurrences, bedding features and sedimentary structures serve as bases for recognition of the autochthonous bioclastic calcarenite lithofacies which occurs only in the lower limestone and upper sandstone/limestone members. Four lithotypes are recognized in the autochthonous bioclastic calcarenite lithofacies, based on the presence or absence of sedimentary structures, limestone intraclasts, and plant debris: (1) bioclastic calcarenite, (2) intraclast-bearing, bioclastic calcarenite, (3) cross-bedded, bioclastic calcarenite, and (4) carbonaceous, bioclastic calcarenite.

Bioclastic Calcarenite Lithotype

This lithotype includes rocks having a depositional texture of either packstone or grainstone. These lithologies range from unsorted to well sorted, medium calcarenite to medium calcirudite. Fragmental and/or abraded crinozoan columnals are particularly distinctive (Pl. 6, Fig. 2). Sand size grains of ramose bryozoans, millerellid and staffellid foraminifers and fragmental phylloid algae are less important but occur in some calcarenites (Pl. 6, Figs. 3 and 4, respectively). Occurring less commonly are fragments of productid or spiriferid brachiopods, goniatites, and globose and high spired gastropods. In many instances these bioclasts are sufficiently fragmented that original shapes or morphologies cannot be distinguished. Algal coated grains, oncolites, rugose corals, agglutinated foraminifers, and sponge spicules are volumetrically the least significant bioclasts. Typically, bioclasts exhibit partial of nearly complete micritization due to the boring activity of endoliths.

Ooliths and superficial ooliths are common but make up less than 40% of any sample. Intraclasts generally composed of rock types similar to the immediately subjacent lithotypes, occur in volumes less than 10%.

Detrital grains range from traces to nearly 50% of some samples. These grains are mostly subangular to subrounded quartz sand but chert grains have been observed. Shale clasts are locally abundant and glauconite occurs either as a replacement of bioclasts or as a pore filling cement.

Intraclast-Bearing, Bioclastic Calcarenite Lithotype

This lithotype is essentially the same as the bioclastic calcarenite lithotype but is distinguished from it by the occurrence of limestone intraclasts (Pl. 6, Fig. 5) in volumes ranging from 15% to 50%. The intraclasts are well rounded, spherical to sub-discoid in shape. They typically range in diameter from about one-quarter to four inches. A maximum diameter for a single intraclast of one by four feet has been reported by Ham and Rowland (1971) from the working quarry in the lower limestone located south of Hartshorne, Oklahoma. Compositionally, the intraclasts, regardless of occurrence in either the lower or upper member, consists of either micritic, or spiculiferous limestone, bioclastic, or oolitic calcarenite, all derived from units in the Wapanucka. Field observation indicates that micritic and spiculiferous limestone intraclasts are invariably more abundant than those composed of calcarenite. Micritic and spiculiferous limestone intraclasts may occur in subequal volumes, but spiculiferous limestone intraclasts are most important overall.

In contrast to other calcarenites, the geometry of the intraclast bearing, bioclastic calcarenite lithotypes is readily determinable. Several lenticular bodies are recognized. One of these occurs in the lower limestone near Hartshorne, Oklahoma, the others are present in the upper sandstone/limestone in the vicinity of Limestone Gap, Oklahoma. In both instances, the lithotype occurs in exposures located on Limestone Ridge (Pl. 1).

Carbonaceous, Bioclastic Calcarenite Lithotype

Carbonaceous, bioclastic calcarenite is comparatively rare in occurrence. Units that in part are assigned to the lithotype include units 2-37, 6-11, 17-10, and 29-4. Two of these occurrences (6-11 and 29-4) are in the lower limestone and the other two (2-37 and 17-10) are in the upper sandstone/limestone. Although not common, the lithotype is lithologically distinctive due to the abundant occurrences of carbonaceous debris. Generally, the carbonaceous debris consists of one to six inch fragments of plant trunks and stems concentrated on bedding plane surfaces. Foliage and reproductive bodies are extremely rare but a single fossil nut was collected by my wife at locality 17-10.

The lithotype also differs from typical bioclastic calcarenite by the relatively greater importance of either ooliths or algal sand. Intraclasts are present in low volumes and at two sections (17-10 and 29-4) the lithotype exhibits tabular cross-bedding.

Cross-bedded, Bioclastic Calcarenite Lithotype

The occurrence of cross-bedding (Pl. 6, Fig. 6) distinguishes this lithotype from the bioclastic calcarenite lithotype. The general absence of carbonaceous debris and intraclasts permits discrimination of this lithotype from the carbonaceous or intraclast bearing, bioclastic calcarenite lithotypes, respectively.

The cross-bedding includes trough and tabular cross-bedded sets. Trough cross-bedded sets are considerably less volumetrically important than tabular sets. Only three units at three different sections (sec. 6, unit 29, sec. 8, unit 19, and sec. 32, unit 8) exhibit trough cross-bedding only one of these occurrences (sec. 6, unit 29) belongs to this lithotype (the other two are oolitic calcarenites).

Tabular cross-bedded units occur in single or multiple sets that range from four inches to three feet in thickness. The sets have sharp bases. The cross laminations within a set are inclined at angles of 4 or 5 degrees to about 15 degrees relative to the base of the set. Although it is difficult to measure dip direction precisely, most cross laminations appear to exhibit a southeast to southwest dip. Exceptions to the generally basinward dip of

PLATE 6

Character of Calcarenitic Lithofacies

Figure 1. Polished slab of oolitic calcarenite from the oolitic calcarenite lithofacies in the lower limestone member, X1 (sec. 8, unit 12). Note fragmental rugose coral bioclast, and bioclastic calcarenite and spiculiferous limestone intraclasts.

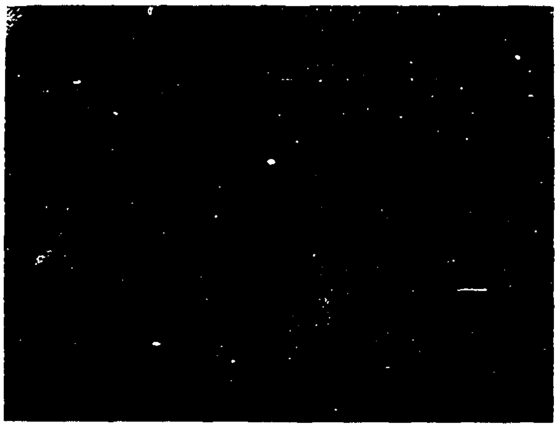
Figure 2. Polished slab of typical crinozoan grainstone from the bioclastic calcarenite lithofacies in the lower limestone member, X1.5 (sec. 17, unit 8).

Figure 3. Photomicrograph of crinozoan, ramose bryozoan packstone from the bioclastic calcarenite lithofacies in the upper sandstone/limestone member, X7 (sec. 2, unit 31).

Figure 4. Photomicrograph of algal calcarenite from the bioclastic calcarenite lithofacies in the lower limestone member, X12 (sec. 6, unit 12).

Figure 5. Polished slab of limestone pebble conglomerate from the bioclastic calcarenite lithofacies in the lower limestone member, X1 (sec. 28, unit 13).

Figure 6. Polished slab of tabular cross-bedded bioclastic calcarenite from the upper sandstone/limestone member, X1 (sec. 18, unit 30).



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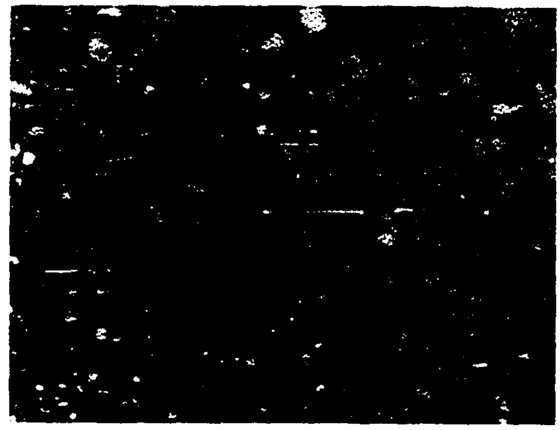

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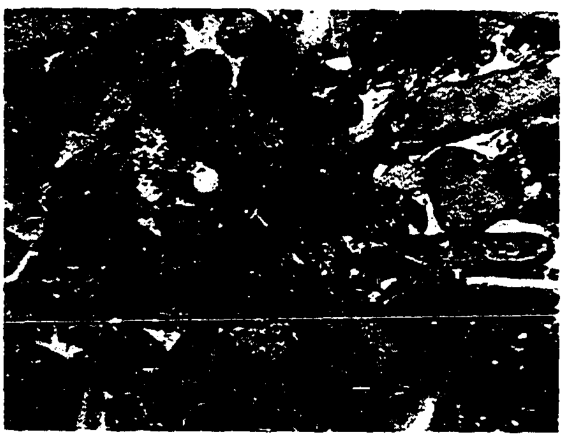

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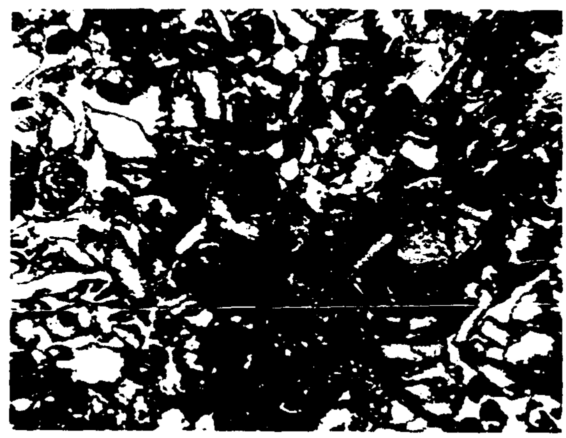

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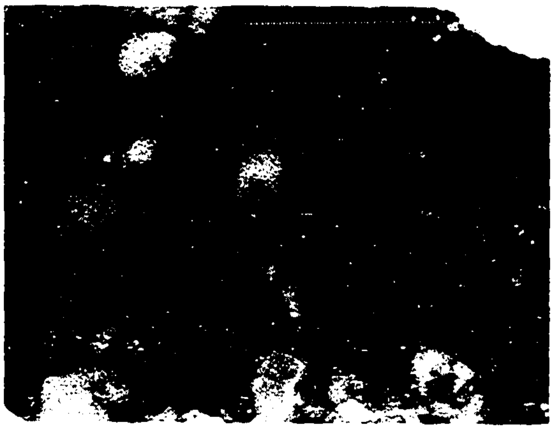

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cross-beds have been noted at sections 18 (sec. 18, unit 30) and 28 (sec. 28, unit 5). At these localities, cross laminations are present that dip in a northeasterly direction, approximately at an angle of 180 degrees to the more prevalent southernly dip direction.

Interpretation

Interpretation of Wapanucka carbonate sand depositional environments is hampered because precise recent alalogues either do not exist or have not been described. Meaningful interpretations of water "energy" can be deduced from spar/micrite ratios but particular uncertainties exist in assessing some environmental parameters, for example, salinity, temperature, nutrient availability, and turbidity. In modern carbonate depositional environments it is possible to examine each of these factors and to determine their influence on the fossilizable biota. Fossil biota can then be used to interpret near recent carbonate rocks, that is, rocks that contain an essentially modern fauna. The farther back in the geologic past that a particular carbonate rock accumulated the less reliable are interpretations of depositional environments based on fossils. Laporte (1968) has outlined some general depositional principles based on studies of recent carbonates. Some of these principles appear to be particularly useful for reconstruction of ancient carbonate sand environments. The fundamental principle applied to Wapanucka calcarenites is that they accumulated in close proximity to where the constituent grains were produced. Were this not the case normal day to day marine processes of sediment transport would have resulted in rapid grain size reduction of sand size particles to silt (Laporte, 1968). Another principle useful in interpreting indigenous carbonate sands is best described as lateral/vertical facies studies and these provide significant data regarding boundary conditions of carbonate sand accumulations (Laporte, 1968). Basin configuration (bathymetry) and water energy are the most significant factors in carbonate facies genesis (Laporte, 1968). Ball (1967) has convincingly demonstrated this principle in his study of modern carbonate sand bodies of Florida and the Bahamas. He recognizes four basic types of carbonate sand bodies: (1) marine sand belts, (2) belts of tidal bars, (3) eolian ridges, and (4) platform interior sand blankets. Each type of sand body is distinguished by special relationships of setting, geometry, internal structure, composition, and texture. The principal control is the bottom topography's influence on the current regimen. Waves generated by tides or wind, if constricted by bottom topographic features produce currents that are instrumental in concentrating carbonate sands into characteristic geometric bodies.

The marine sand belts and belts of tidal bars described by Ball (1967) appear to have analogues with some Wapanucka calcarenites.

Tidal bar belts form in settings that promote strong tidal currents. Embayments and straits are two examples where amplification of tidal flow occurs. Ball (1967) discusses the tidal bar belt in the Schooner Cay area at the north end of Exuma Sound. The sand belt is subdivided into approximately equally spaced and sized bars that curve across it. Individual bars average 5 miles in length and are ¼ to ½ mile in width. The bars are convex toward the east and are assymmetrical in cross-section with their crests adjacent to their steeper west edges. Internally, the bars contain (accretion?) tabular cross-bedding that dips toward the west. Similar but larger tidal bars composed of quartz sand have been described by Off (1963) in the North Sea. These tidal bars are thought to be analogues for the occurrences of quartz sand and bioclastic calcarenite now assigned to the upper sandstone/limestone.

Marine sand belts accumulate parallel to a slope break that is sufficiently pronounced to constrict waves to the point where currents are produced. Two types are described that represent opposite ends of a spectrum. One of these, the Cat Cay oolitic sand belt in the Bahamas, is located along a narrow zone parallel to the major slope break separating the Great Bahama Bank from the deep water of Florida Straits. The other example (Ball, 1967) at the western margin of the carbonate mud accumulation in Florida Bay illustrates the occurrence of a marine sand belt well within the interior of the Florida Shelf, nearly 100 miles from the shelf edge where currents enter. The bottom topography rises gently from west to east. The edge of carbonate mud accumulation in Florida Bay forms a small but sufficiently pronounced break in slope to cause a concentration of carbonate sands. In both examples of marine sand belts, the predominant dip direction of cross-beds is toward shallow water and away from deeper or more open water (Ball, 1967).

Wapanucka autochthonous calcarenites assigned to the lower limestone are thought to constitute a marine carbonate sand belt that formed in a shllow, relatively high energy regime at the (northern) margin of a basinward sloping shelf-shelf margin. In contrast to modern carbonate sand belts which typically develop due to currents generated as waves approach the shoal from deeper water, this ancient example has directional indicators that indicate a current regimen dominated by basinward (southern) transport of carbonate sand. Autochthonous bioclastic calcarenites of the lower limestone represent specific depositional environments ranging from intertidal conditions adjacent to subaerially exposed limestone islands to subtidal fully marine conditions. The bulk of lower limestone calcarenite deposits accumulated in subtidal environments. Tidal channel deposits and spillover lobes that crossed the marine sand belt are thought to be indicated by tabular accretion-bedding. Other subtidal bioclastic calcarenite deposits not distinguished by cross-bedding are not as readily interpreted. A more complete petrographic study of these calcarenite bodies should make possible a more detailed interpretation. Calcarenite accumulations marginal to limestone islands include rocky shore carbonate sands and marshy shore carbonate sand. Rocky island shoreline deposits are marked by occurrences of intraclast-bearing, bioclastic calcarenite. In contrast marshy island shoreline conditions are indicated by occurrences of carbonaceous, bioclastic calcarenite.

Autochthonous calcarenite deposits of the upper sandstone/limestone contrast depositionally with those in the lower limestone. Although lithologically similar, geometric considerations and vertical sequence suggest that calcarenite accumulations in the upper sandstone/limestone represent a belt of tidal bars. An isopleth map (Fig. 20) of these calcarenites suggest a bar-like geometry. The occurrence of intraclast-bearing and carbonaceous bioclastic calcarenite deposits located centrally in the bar-like geometry suggest that the carbonate sand bars initially began to accumulate in an area of subaerially exposed limestone probably near low lying islands with rocky shores. The development of subtidal conditions are marked by deposits of bioclastic calcarenite. Shoaling conditions at the crests of the subsequently developed offshore, tidal bars are indicated by occurrences of tabular cross-bedded, bioclastic calcarenite.

Quartzarenite Lithofacies

The quartzarenite lithofacies consists of two genetically related lithotypes, tabular cross-bedded quartzarenite and quartzarenite.

Tabular Cross-bedded Quartzarenite Lithotype

This lithotype is distinguished by the occurrence of tabular cross-bedding (Pl. 3, Fig. 4). Cross-bedded sets range in thickness from one to four feet. The sets have sharp bases that generally truncate portions of underlying sets, but ripple bed forms may mark the top of some sets. The nature of exposures generally precludes precise measurement of dip direction, but where seen they invariably have a strong basinward (southward) component. These cross-laminae are inclined as much as fifteen degrees.

Tabular cross-bedded sandstone is a fine to medium grained, subangular to subrounded, sorted to very well sorted, mature quartzarenite. These quartzarenites are cemented by siliceous, ferruginous or calcareous cement. In the latter case it is quite common to find abundant molds of crinozoan bioclasts and fragmental brachiopods.

Interpretation

Recent marine, quartz sand, tidal bars, which are thought to provide an analogy for interpreting Wapanucka quartz sand depsoits, have not been described in as great a detail as that for genetically similar carbonate sand bodies. Off (1963), Kenyon (1970), and Deraaf and Boersma (1971) have contributed to our understanding and knowledge of recent quartz sand, tidal bars. Kenyon (1970) discussed the geometry of sand bars in European tidal seas. Deraaf and Boersma (1971) distinguish between offshore tidal deposits and onshore tidal flat deposits, as well as, providing some information concerning sedimentary structures found in tidal deposits. The linear quartz sand bars described by Off (1963) from the North Sea provide the most useful information for the present study. Off (1963) recognized two types of quartz sand bars caused by tidal currents: (1) tidal current ridges, and (2) sand waves. Both of these are found near coastlines characterized by large vertical tidal ranges (greater than 10 feet) and strong tidal currents (1 to 5 knots). The tidal current ridges and sand waves both exhibit wave-like profiles but tidal current ridges are oriented parallel with the direction of tidal currents; whereas, sand waves are oriented perpendicular to the direction of the tidal currents.

Wapanucka quartz sand deposits, by analogy, are interpreted as having accumulated as sand wave, quartz sand bars in a tidally dominated regime. The linear sand waves were oriented east to west perpendicular to the tidal currents.

Exum and Harris (1968) in a study dealing with ancient marine bar deposits in subsurface Cretaceous rocks in Nebraska distinguish three bar facies: (1) a central bar facies, (2) a bar margin facies, and (3) a interbar facies. Their central bar facies is predominantly quartz sand that exhibits low angle, planar cross-bedding in sets about one foot thick and some ripple cross-bedding. The bar margin facies consists of burrow mottled sandstone and interbedded shale and the interbar facies consists of shale with rare sandstone beds.

Wapanucka tabular cross-bedded quartzarenite lithofacies probably accumulated as the central bar facies at the crests of a linear (east to west) system of offshore bars. The tabular cross-bedding was presumably produced by basinward (southward) migration of sand wave(s) at the crest of these offshore bars, possibly due to ebb tidal currents.

Quartzarenite Lithotype

The quartzarenite lithotype is a siltstone and fine grained, submature to mature, quartzarenite that occurs in thin to thick beds. Fossils may be abundant and consist of siliceous sponge spicules, molds of crinozoan bioclasts, bryozoans, and productid brachiopods. At one locality (sec. 15, unit 21) abundant productid brachiopods occur in near life positions. Trace fossils are also common. They consist most commonly of vertical tube-shaped burrows and fucoids. *Conostichus* also occurs.

Interpretation

This lithotype is thought to have accumulated in an interbar or bar margin environment. Fine grained sandstone probably represents sand accumulation proximal to the bar crest, whereas siltstone may have accumulated in deeper water perhaps in interbar and/or open marine shelf environments.

Spiculite Lithofacies

Description

The term spiculite as used in this dissertation excludes both spiculiferous limestone and its silicified equivalent. Wapanucka spiculites are composed of subequal volumes of interbedded laminae of siliceous sponge spicules and terrigenous clay cemented by silica (Pl. 7, Fig. 1). Typically, the spicules exhibit some degree of alignment that is presumed to be due to current activity. The current oriented spicule laminae are draped by shale laminae resulting in a complex pattern of lenticular, flaser and wavey bedding (Pl. 7, Fig. 2).

Spiculite units in outcrop are dominantly thin to medium bedded. On fresh surfaces the rock is black or dark blue-gray but the thin spicule-rich laminae or beds may be light gray. The spiculites are commonly silicified. As the rock weathers to tripoli, it looses its dense, black appearance and turns orange-brown, buff and tan in color and commonly becomes porous.

Typically, spiculite units exhibit gradational contact with adjacent shale and/or spiculiferous limestone units. In contrast, the basal contact of the associated rare thin bioclastic calcarenite units are invariably sharp.

Calcareous allochems are generally rare. Ooliths, coated grains and crinozoan bioclasts do occur but are not thought to be indigenous (Pl. 7, Fig. 3). These allochems, as well as the volumetrically more important spicules and rare occurrences of wood fragments, exhibit evidence of transport. Presumed indigenous fossils are rare and consist of a low diversity assemblage of fossils composed predominantly of molluscs. These include goniatites, nautiloids, bellerophontid gastropods, and mytilid bivalves. In thin section conodonts are locally abundant. Mottling due to burrowing is very commonly observed in rock slabs (Pl. 7, Fig. 4) but is more difficult to see on outcrop surfaces. Trace fossils, where seen, have invariably been characteristic of the *Zoophycus* ichnofacies of Sielacher (1967).

Interpretation

The spiculite lithofacies accumulated in an outer shelf setting in an environment that was slightly reducing to anoxic. Depths of water in this setting cannot be precisely determined but were possibly on the order of magnitude of several hundred feet. Presumably, the spicules were transported basinward from environments of accumulation of spiculiferous limestone higher on the shelf. The occurrence of laminations, flaser, wavey and lenticular bedding suggest periodic transport of spicules punctuated by episodes of pelagic clay deposition. A deeper water, current dominated regime may have existed. In this setting periods of current activity would be marked by layers of spicules that were transported from higher on the shelf whereas, normal pelagic deposition is indicated by shale laminations.

Allocthonous Bioclastic Calcarenite Lithofacies

Description

The calcarenites assigned to this lithofacies occur only in the Chickachoc Chert Member. They are thin (several inches to two feet in thickness), tabular cross-bedded, medium to coarse grained, crinozoan lime packstone or lime grainstone lithologies. These calcarenites rest with sharp, possibly erosive, contacts on underlying spiculite or shale beds (Pl. 7, Fig. 5). The direction of transport indicated by the cross-bedding (where determinable) is toward the basin (southward).

Excluding spicules, allochems are dominantly fragmental calcareous bioclasts of biologically diverse, presumably shoal derived origin. Other less common shoal derived allochems, including ooliths and coated grains, also occur (Pl. 7, Fig. 6). Intraclasts derived from scouring

PLATE 7

Character of Lithofacies Found in the Chickachoc Cheıt

Figure 1. Photomicrograph of typical spiculite from the spiculite lithofacies in the Chickachoc Chert Member, X15 (sec. 33, unit 7). Note character of carbonaceous shale laminae.

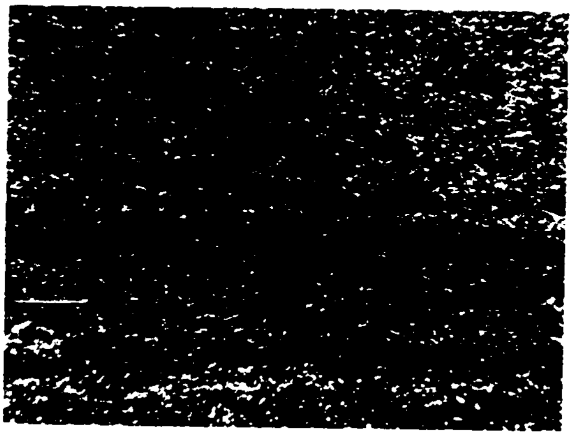
Figure 2. Polished slab of spiculite from the spiculite lithofacies in the Chickachoc Chert Member, X1 (sec. 21, unit 3). Note presence of flaser, wavey and lenticular bedding.

Figure 3. Photomicrograph of spiculite from the spiculite lithofacies in the Chickachoc Chert Member, X15 (sec. 1, unit 18). Note presence of shoal allochems.

Figure 4. Polished slab of spiculite from the spiculite lithofacies in the Chickachoc Chert Member, X1.5 (sec. 1, unit 2). Note destruction of laminations due to subvertical Zoophycus bioturbation traces.

Figure 5. Polished slab of crinozoan, oolitic packstone from the allocthonous bioclastic calcarenite lithofacies in the Chickachoc Chert Member, X1.5 (sec. 1, unit 5). Note abrupt contact of calcarenite with thin spiculite layer near base of photo.

Figure 6. Photomicrograph of allocthonous bioclastic calcarenite from the Chickachoc Chert Member, X15 (sec. 1, unit 5).



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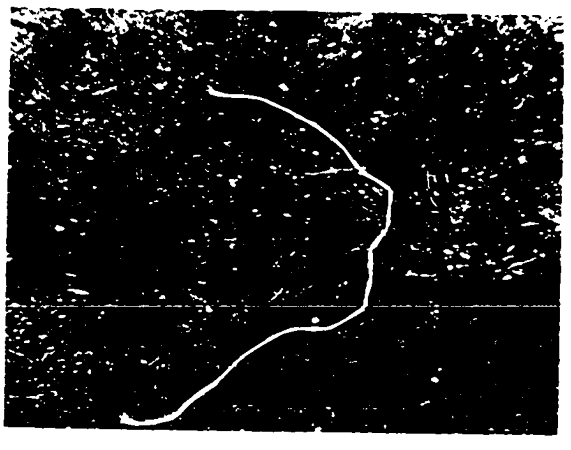

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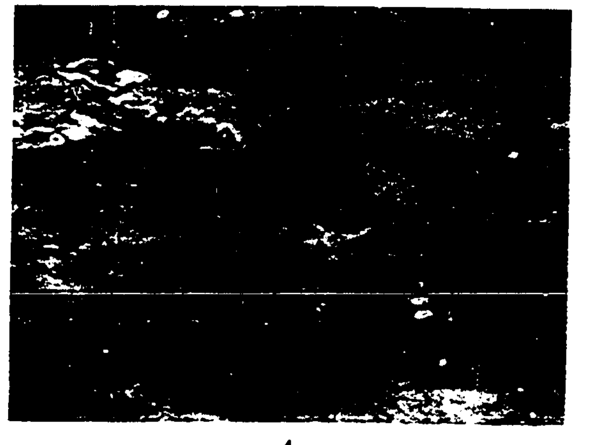

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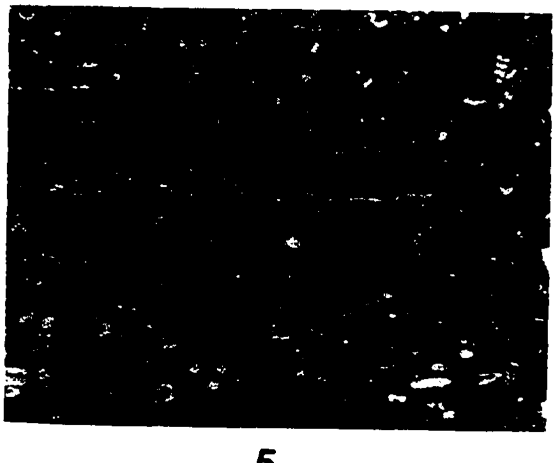

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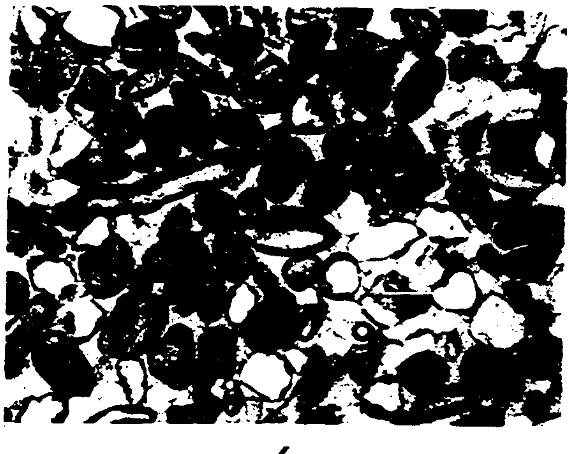

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of pre-existing spiculite or shale surfaces are commonly incorporated in the base of these calcarenites.

Interpretation

The allocthonous, bioclastic calcarenite lithofacies was deposited by a catastropic event that introduced carbonate sand into the outer shelf or upper slope environments where spicules and mud were accumulating. These calcarenites represent basinward transport of shoal allochems by high energy current system. The allochems were swept basinward in megaripple or sand wave bed forms that migrated basinward in response to undirectional currents. A major storm is presumed to have been responsible for producing this current regime.

CHAPTER III

DEPOSITIONAL SYNTHESIS

General Statement

The Wapanucka Formation accumulated in three stages or episodes of sedimentation, these are: (1) current influenced deposition on a basinward sloping shelf and shelf margin which corresponds to accumulation of the lower limestone and Chickochoc Chert; (2) infilling and reduction of depositional slope by a major influx of clastic, terrigenous mud now recognized as the middle shale; and (3) current dominated sedimentation across the whole belt on a more nearly horizontal substrate, as evidenced by the upper sandstone/limestone.

Stage 1

A generalized diagram depicting lithofacies distribution and the principal depositional controls for Stage 1 is presented as Figure 26. This interval of sedimentation is marked by the accumulation of shoal lithologies now known as the lower limestone and its basinward equivalent, the

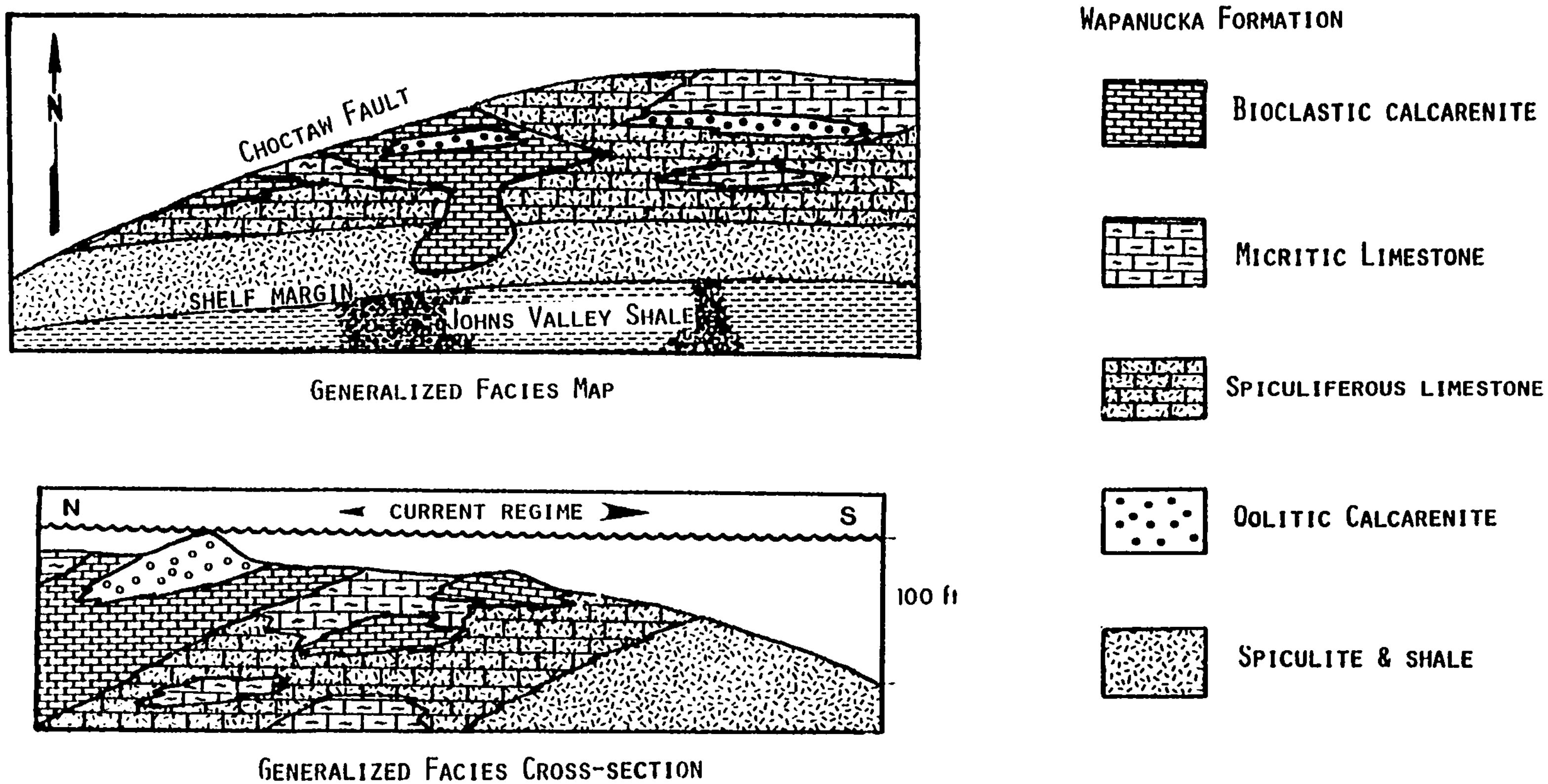


FIGURE 26. STAGE 1 - ACCUMULATION OF WAPANUCKA FORMATION ON A BASINWARD SLOPING SUBSTRATE WITH PROGRADATION OF SHOAL ENVIRONMENTS.

deeper water deposits now assigned to the Chickachoc Chert Member. Deposition began on a basinward sloping substrate consisting of shales of the "Springer" Shale. Once initiated, shoal environments subsequently prograded seaward over deeper water spiculite and shale environments producing the wedge on wedge relationship previously documented for the lower limestone and Chickachoc Chert.

The shoal facies developed in shallow, clear marine water on the shelf margin in response to energy variations resulting from the interplay between currents and bathymetry. Several environmental regimes existed on the shelf including marine carbonate oolitic and bioclastic sand belts, lagoons and rocky or marshy shorelines. A carbonate sand belt characterized by discontinuous accumulations of lithologies of the oolitic and bioclastic calcarenite lithofacies formed in a zone parallel tothe shelf margin-slope break where strong currents affected bottom sediments.

Spiculiferous and micritic limestone lithofacies accumulated in lagoonal environments or other quiet water protected regimes adjacent to the marine sand belt. High on the shelf, minor falls in sea level resulted in occasional subaerial exposure of lithified limestone as islands. Along their shorelines, carbonaceous and intraclastic lithologies of the bioclastic calcarenite lithofacies accumulated.

Spiculite, shale, spiculiferous limestone and allocthonous bioclastic calcarenite lithofacies (now assigned to the Chickachoc Chert Member) were accumulating in deeper water environments along the shelf margin and perhaps out onto the upper slope. These environments ranged from quiet water conditions marked by accumulation of pelagic mud or spiculiferous limestone to deeper water regimes that lacked a fossilizable benthos. The lithologies of the spiculite lithofacies and shale accumulated in this anoxic, reducing environment. This generally monotonous deep water regime was disturbed by periodic influx of shoal allochems during major storm events. Deeper in the basin, beyond the slope break, the Johns Valley Shale, which contains exotic masses of slope derived boulders of varying Paleozoic ages, was accumulating during this stage of sedimentation. A general deepening due to transgression or subsidence ended this stage of sedimentation.

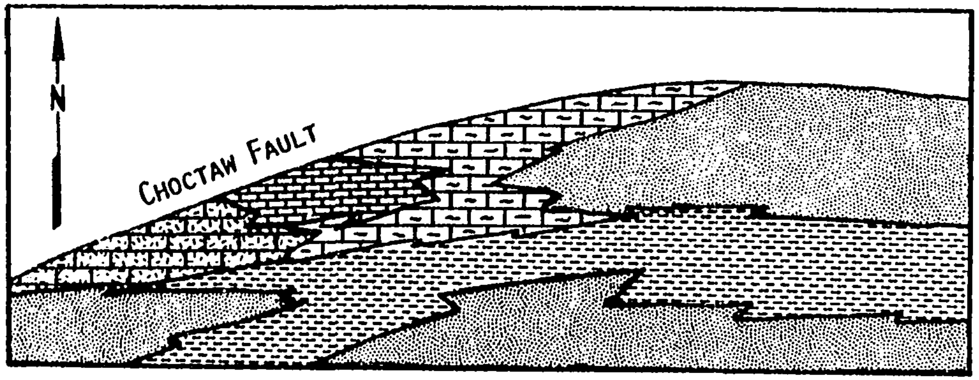
Stage 2

The middle shale is a basinward thickening wedge that represents a period of generally quiet water, pelagic sedimentation. This accumulation of terrigenous mud resulted in a significant decrease in the previously existing depositional slope. Shoaling conditions due to vertical accumulations of terrigenous mud and a major influx of quartz sand initiated the final stage of Wapanucka sedimentation.

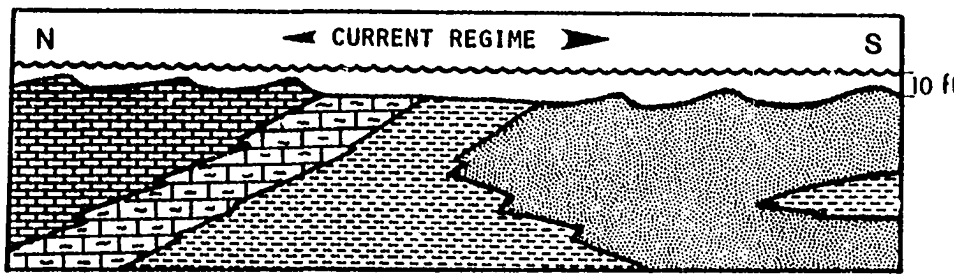
Stage 3

A generalized diagram depicting lithofacies distribution and the principal depositional controls for Stage 3 is shown in Figure 27. This episode of sedimentation correponds to the accumulation of shoal lithologies now recognized as the upper sandstone/limestone. The accumulation of shoal lithologies began on an essentially horizontal substrate as vertical accretion of shale resulted in shoaling conditions. The distribution of shoal lithologies consisting of sandstone, bioclastic calcarenite, and micritic and spiculiferous limestone lithofacies were largely determined by energy variations on the tidally dominated shelf.

Quartz sand from an eastern source was transported westward where it accumulated in a series of tidal bars analogous to those described by Off (1963) from the North Sea. In similar regimes bypassed by terrigenous influx, equivalent deposits of tabular cross-bedded bioclastic calcarenite also accumulated as tidal bars. These carbonate sand bars incised pre-existing lithified limestone producing the distinctive intraclastic and carbonaceous bioclastic calcarenites. In inter-bar environments or protected sites, micritic or spiculiferous limestone or shale was deposited. Shallow, very quiet water conditions prevailed at the close of Wapanucka deposition as evidenced by the distinctive micritic or spiculiferous limestone at the top of the sequence. Deepening subsequently initiated deposition of Atoka shale and sandstone which had been accumulating earlier further into the basin.



GENERALIZED FACIES MAP



GENERALIZED FACIES CROSS-SECTION

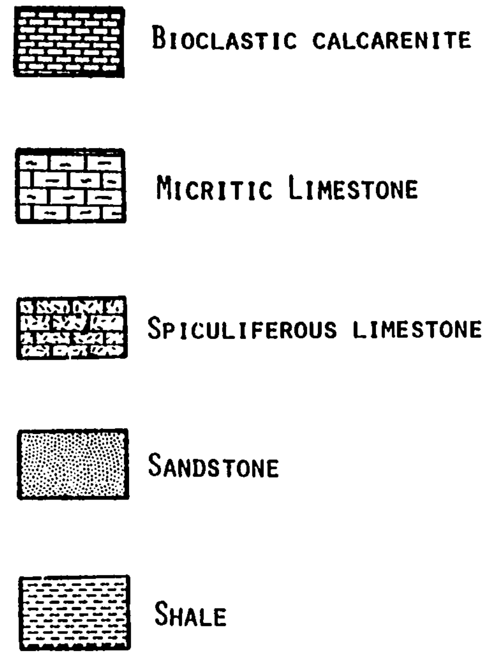


FIGURE 27. STAGE 3 - ACCUMULATION OF THE WAPANUCKA FORMATION ON AN ESSENTIALLY PLANAR SUBSTRATE.

CHAPTER IV

BIOSTRATIGRAPHY

General Statement

The conodonts have been useful in the stratigraphic interpretation of the Wapnaucka Formation and have made possible the local correlation of stratigraphic units that exhibit rapid internal facies changes. Equally important are the more precise correlations that can now be made with the Lower Pennsylvanian type Morrowan Series in northwestern Arkansas and northeastern Oklahoma, and with the Wapanucka Formation in its type area on the northeastern margin of the Arbuckle Mountains in southern Oklahoma (see previous discussion).

The Wapanucka Formation contains part or all of four conodont zones (Fig. 28; Grayson, 1979). The *Idiognathoides convexus* zone (Lane, 1977) indicates equivalence to the Kessler Limestone Member of the type Morrowan Series. The succeeding *Neognathodus kanumai-Idiognathoides ouachitensis* and *Diplognathodus orphanus* zones are new or are redefined zones that are correlative with an erosional gap between

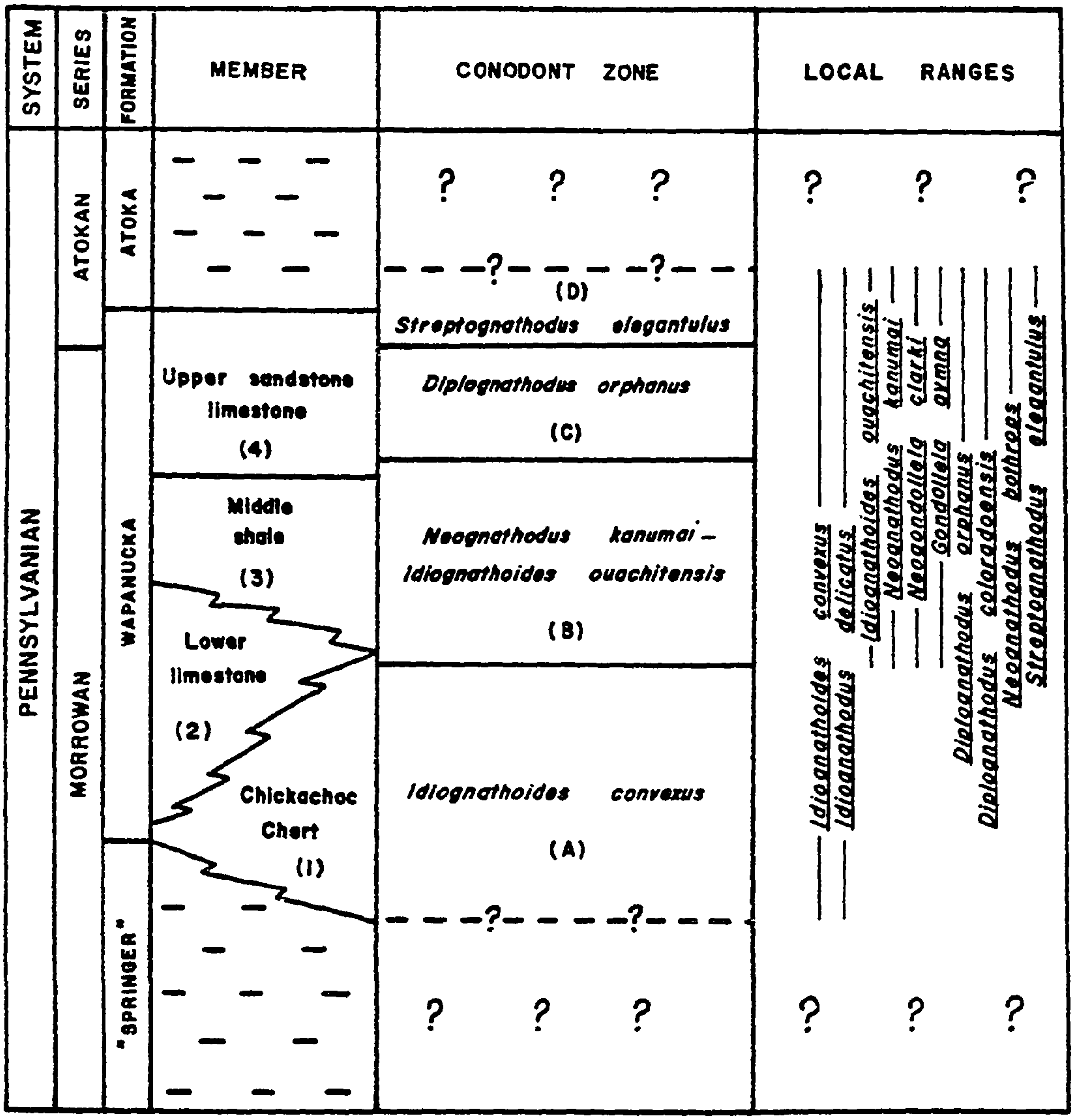


Figure 28. Conodont zones and local ranges of selected platform elements in the Wapanucka Formation, Ouachita Mountains, Oklahoma.

the Kessler Limestone and overlying Trace Creek Shale (Grayson and Sutherland, 1977; Grayson, 1978, 1979) in the type Morrowan Series in northwestern Arkansas and northeastern Oklahoma. The chronostratigraphic significance of these zones in relation to the Morrowan-Atokan boundary is currently a major problem. A problem exists because the zones are missing in the type Morrowan area presumably due to an unconformity, and because of the lack of a well defined faunal sequence in the Atokan Series. The new *Streptognathodus elegantulus* zone occurs in the upper part of the Wapanucka and is also present in the Trace Creek Shale Member of the redefined Atoka Formation (Sutherland, Grayson and Zimbrick, 1978) in northwestern Arkansas and northeastern Oklahoma. Its occurrence is thought to indicate an early Atokan age.

Previous Investigations

An early Pennsyvlanian age for the Wapanucka Formation in the Ouachita Mountains has been indicated by the study of many fossil groups, including the ostracodes (Harlton, 1931; Knox, 1977), conodonts (Harlton, 1933) and rugose corals (Rowett and Sutherland, 1964). Detailed correlations and age assignments with regard to the midcontinent reference sequences have been made based only on ammonoids and conodonts. Gordon and Stone (1977) report the occurrence of two zonal ammonoid indices from the

Wapanucka in the Ouachitas. The older of these, *Axinolobus modulus*, was collected from the lower and middle part of the Wapanucka. Its occurrence in the Wapanucka indicates equivalence of the ammonoid bearing interval to the Dye Shale and Kessler Limestone members of the middle Bloyd Formation, type Morrowan Series. The younger ammonoid index, *Diaboloceras neumeieri*, reported to come from the upper part of the Wapanucka was suggested to indicate a correlation with the Trace Creek Shale Member of the Bloyd Formation (Gordon and Sutherland, 1975; Gordon and Stone, 1977). The latter correlation was based on the ammonoid fauna first reported from the Wapanucka by Gordon and Sutherland (1975). That fauna comes from the upper part of the Chickachoc Chert Member at section 1. This apparently is an older occurrence then that of *D. neumeieri* in the Trace Creek Shale based on conodont correlations. Grayson (1978, 1979) suggested the following correlations of the Wapanucka Formation with the type Morrowan, based on analysis of the conodont faunas (Fig. 29): the lower Wapanucka Formation with the Dye Shale (?) and Kessler Limestone Members of the Bloyd Formation (type Morrowan) based on occurrences of *Idiognathoides convexus*; an erosional gap between the Kessler Limestone and the overlying Trace Creek Shale based on non-occurrence of the *Neognathodus kanumai* -*Idiognathoides ouachitensis* and the *Diplognathodus orphanus* zones; and the Trace Creek Shale

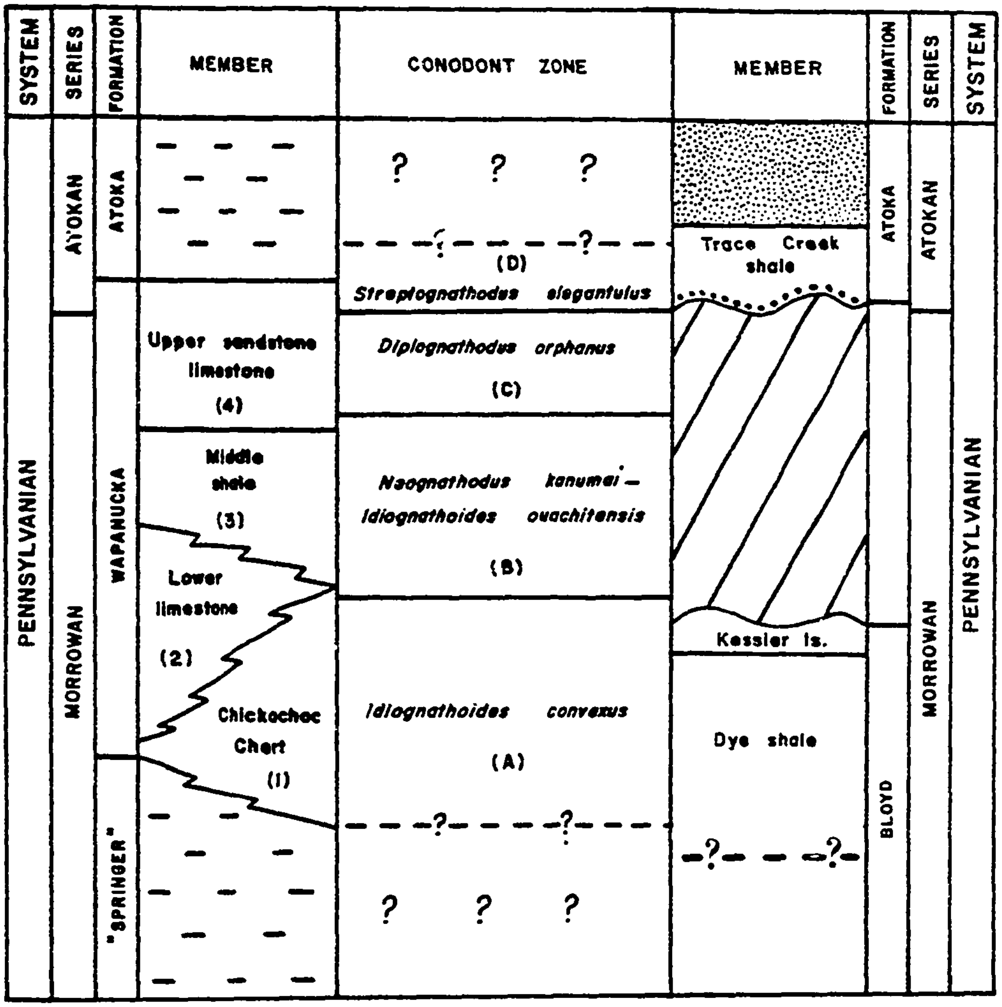


Figure 29. Correlation of the Wapanucka Formation with the Bloyd and Atoka formations based on conodonts.

with the upper part of the Wapanucka Formation based on occurrences of Streptognathodus elegantulus. These correlations are the same as those presented in the present investigation (Fig. 29).

Lowett and Sutherland (1964) correlated the upper part of the Wapanucka Formation in the Arbuckle Mountains with the top of the formation in the Ouachita Mountains. This correlation was based on occurrence of the coral genus Koninckoplyllum. However, dissimilar species were present in the Ouachita region compared to the Arbuckle area. Evidence from the conodonts suggests that these occurrences of Koninckoplyllum are diachronous. The youngest part of the Wapanucka Formation sampled in the Arbuckle Mountains belongs to the Neognathodus kanumai-Idiognathoides ouachitensis zone which indicates a shorter duration of carbonate deposition in the Arbuckles compared with the formation in the Ouachita Mountains. Strimple and Nassichuk (1965) reported an ammonoid fauna containing Axinolobus quinni from the Arbuckle Wapanucka. They suggested that the fauna indicated equivalence of the Arbuckle Wapanucka to the Dye Shale and Kessler Limestone Members of the Bloyd Formation. This correlation is basically in agreement with that indicated by conodonts (Fig. 4); however, conodont evidence suggests that the Arbuckle Wapanucka may also include strata slightly younger than the Kessler.

Present Investigation

General Statement

The major contribution of the present study is an increased precision in correlation of Lower Pennsylvanian aged rocks, particularly those adjacent to the Morrowan-Atokan chronostratigraphic boundary.

The following conodont platform species are recognized from the Wapanucka Formation in the Ouachita Mountains and/or Arbuckle Mountains:

Adetognathus lautus (Gunnell, 1933)
*Diplognathodus orphanus (Merrill, 1973)
*Diplognathodus coloradoensis (Murray and Chronic, 1965)
Gnathodus commutatus (Branson and Mehl, 1941)
Gondolella gymna (Merrill and King, 1971)
*Idiognathoides convexus (Ellison and Graves, 1941)
*Idiognathoides ouachitensis (Harlton, 1933)
Idiognathodus sinuosis (Gunnell, 1931)
*Neogondolella clarki (Koike, 1967)
*Neognathodus bassleri (Harris and Hollingsworth, 1933)
*Neognathodus bothrops (Merrill, 1972)
*Neognathodus kanumai
Polygnathus sp.
Spathognathodus minutus (Ellison, 1941)
*Streptognathodus elegantulus (Stauffer and Plummer, 1964)
*Streptognathodus expansus (Igo and Koike, 1964)

Platform species identified by an asterisk are treated systematically in Appendix 2. These elements are important for zonation and correlation. The stratigraphic distribution of the important conodonts is shown in Figure 28. A systematic treatment of the remaining platform and unlisted non-platform elements was not undertaken because they provide little information useful for correlation in the present study.

Occurrence of Conodont Faunas

Some difficulty exists in precisely locating zonal boundaries within the Wapanucka Formation because of the paucity of suitable carbonate rock types for acid recovery techniques. The generally rare bioclastic packstone and grainstone units produce the greatest abundance and diversity of conodonts. Intervening micritic and spiculiferous limestone when sampled produced low conodont diversity and typically nondiagnostic faunas of low abundance. In addition, the occurrence of unsuitable lithologies, such as spiculites, sandstones and shales, further complicate precise location of zonal boundaries.

Nature of Conodont Faunas

The conodont faunas are numerically dominated by platform elements. This distribution is characteristic of many of the Lower and Middle Carboniferous sequences that have been described in the literature (see Von Bitter, 1972). A satisfactory explanation for this phenomena has not been proposed. The suggestion that these occurrences indicate abundance of a conodont animal that possessed only platform elements is possible but most elements have been shown to belong to multielement species. The postulation that selective sorting and destruction has removed many of the non-platform elements is unlikely since the preserved platform elements commonly show no abrasion and have many delicate morphologic features preserved. Hopefully, additional study of conodont faunas from various paleoenvironmental settings will help solve this biological mystery.

The color of most conodont elements ranges from pale yellow to dark brown. Based on Epstein's (1977) conodont color alteration index it is unlikely that the Wapanucka Formation has been heated to temperatures exceeding 140°C.

Almost all of the conodont faunas recovered from the Wapanucka Formation in the Ouachita Mountains appear to be idigenous. However, two platform elements, *Gnathodus commutatus* (Mississippian) and *Polygnathus* sp. (Upper Devonian-Lower Mississippian) were recovered from the upper sandstone/limestone member. Their significance is uncertain. Possibly these reworked conodonts may have been introduced into the basin at sites of terrigenous influx and subsequently redistributed by marine processes.

Zonation of the Wapanucka Formation

The Wapanucka Formation in the Ouachita Mountains is subdivided into four zones (Fig. 4) based on the earliest occurrence of selected platform conodont elements. Published and unpublished information collected by the author indicates that these zones have differing utility for local, regional and inter-regional correlation. The description and characteristics of the zones are described below, in ascending order.

Idiognathoides convexus Zone

This zone occurs in approximately the lower one-third of the Wapanucka Formation in the Ouachitas, and it includes up to three-quarters of the Chickachoc Chert and/or lower limestone members. In the Arbuckle Mountains the zone comprises the whole of the formation at most localities. In the type area (section 16 of Rowett and Sutherland, 1964; section 16A in the present study), however, the highest part of the formation contains conodonts characteristic of the succeeding zone.

Limits. The basal boundary coincides with the initial appearance of the zonal name-bearer, above the last occurrence of *Idiognathodus klapperi* as defined originally by Lane (1972). The latter species has not been recognized in faunas from the Wapanucka Formation. The upper limit of the zone was defined by Lane as occurring immediately below the initial occurrence of *Neognathodus kanumai* (= *Neognathodus* n.sp. of Lane, 1977). The upper limit of the zone has subsequently been emended by Grayson (1978) to also occur at the initial occurrence of *Idiognathoides ouachitensis*.

Associated Species. *Idiognathoides convexus* and

Idiognathodus sinuosis.

Remarks. The concept of the I. convexus zone as originally proposed by Lane (1972) has been criticized by Dunn. Dunn (1976) extended the limits of the zone downward in the Western United States compared to its occurrence in the type Morrowan because of the co-occurrence of Strepthognathodus expansus, a supposed Middle Morrowan index, with Idiognathoides convexus. My interpretation is that this occurrence of S. expansus is in the Idiognathoides convexus zone and is younger than its occurrences in the type Morrowan region. Consequently, the range of S. expansus must be extended upward. This interpretation is supported by my collections which contain S. expansus in obviously younger horizons (Appendix 2) than its occurrences in the type Morrowan region. However, the limits of Idiognathoides convexus zone in the type Morrowan area are currently not precisely located. The lower limit of the zone, defined by Lane (1972) to coincide with the initial occurrence of Idiognathoides convexus, is shown by Lane as occurring in the Kessler Limestone. This may not be the earliest occurrence because a thick (50 feet plus) barren shale interval in the Dye Shale separates the conodont-bearing conglomeratic packstone at the base of the Dye Shale from the overlying conodont-bearing Kessler Limestone. Tentatively, the author suggests that the zone is unlikely to extend as low as the base of the Dye Shale Member or much higher than the top of the Kessler Limestone Member of the Bloyd Formation (type Morrowan). However, the upper limit of the zone is not preserved in the type Morrowan type area because of erosion at the base of the overlying Trace Creek Shale Member which is now included in the Atoka Formation by Sutherland, Grayson and Zimbrick (1978).

Neognathodus kanumai-*Idiognathoides ouachitensis* zone

This zone occurs in approximately the middle one-third of the Wapanucka Formation in the Ouachita Mountains. This includes the uppermost part of the Chickachoc Chert Member, the upper part of the lower limestone member, all of the middle shale; and possibly the lowermost portion of the upper sandstone/limestone at some localities.

In the Arbuckle Mountains region the zone occurs locally in the highest part of the type Wapanucka Formation.

Limits. The basal boundary is defined as coincident with the earliest occurrence of *Neognathodus kanumai* and/or *Idiognathoides ouachitensis*. The upper limit is modified to occur immediately below the initial appearance of *Diplognathodus orphanus* and/or *D. coloradoensis*.

Associated Species. *Neognathodus kanumi*, *Idiognathoides ouachitensis*, *Idignathodus sinuosis*, *Idiognathoides convexus*, *Neogondolella clarki* and *Gondolella gymna*.

Remarks. The zone as defined by Lane (1972) did not include *I. ouachitensis* as a zonal index. With this emendation the *Neognathodus kanumai-Idiognathoides ouachitensis* zone constitutes the most widespread and distinctive zone recognized in the Wapanucka Formation. *I. ouachitensis* evolved phylogenetically from *I. convexus*. The initiation of this evolutionary event almost invariably coincides with the first occurrence of *N. kanumai*, if present. Because *I. ouachitensis* is more widespread and more commonly occurring that *Neognathodus kanumai*, the utility of the zone is increased by including *I. ouachitensis* as an index.

The *N. kanumai* zone as recognized by Lane (1977) was shown to have its lowest occurrence in northwestern Arkansas in the Trace Creek Shale; however, the Trace Creek Shale contains *Streptognathodus elegantulus* which means that this occurrence in the Trace Creek is not the earliest occurrence of *Neognathodus kanumai* but a younger occurrence in the *Streptognathodus elegantulus* zone. Lane (1977) shows his *Neognathodus kanumai* zone (a larger range zone which encompases a greater stratigraphic interval than the *Neognathodus kanumai-Idiognathoides ouachitensis* zone of this study as spanning the Morrowan-Atokan (Derryan) chronostratigraphic boundary. Lane and others (1972) and Lane (1977) use the initial occurrence of the fusulinids *Eoschubertella* and *Pseudostaffella* in the upper part of Mamet and Skipp's (1970) foraminifer zone 21 (zone of

Millerella) as coinciding with the Morrowan-Atokan (Derryan) chronostratigraphic boundary. This usage is not followed herein because it would place many stratigraphic units traditionally assigned to the Morrowan Series in the Atokan (Derryan) Series.

The top of the type Morrowan Group in northwestern Arkansas and northeastern Oklahoma has been redefined by Sutherland, Grayson and Zimbrick (1978) to coincide with the unconformable base of the Trace Creek Shale Member, now assigned to the Atoka Formation. The underlying Kessler Limestone contains *Idiognathoides convexus* zone conodonts. The next higher *Neognathodus kanumai-Idiognathoides ouachitensis* and *Diplognathodus orphanus* zone are missing due to pre-Trace Creek erosion. The conglomerate unit commonly developed at the base of the Trace Creek has now yielded *Streptognathodus elegantulus* zone conodonts.at two localities in Arkansas described by Henry (1973); these are, Kessler Mountain West (section 11B) and Lee Creek North (section 10B). The two conodont zones underlying the earliest Atokan-aged *Streptognathodus elegantulus* zone are assigned to the Morrowan Series; an arbitrary solution until a more formal treatment of this problem is completed.

Diplognathodus orphanus Zone

This zone occurs in the upper Wapanucka Formation, and includes most of the lower part of the upper sandstone/

limestone member.

The zone is not recognized in the Arbuckle Mountain area due presumably to non-deposition or removal by pre-Atoka Formation erosion.

Limits. The basal boundary is defined to coincide with the earliest occurrence of Diplognathodus orphanus or D. coloradoensis. The upper limit is defined herein as occurring immediately below the lowest occurrence of Streptognathodus elegantulus.

Associated Species. Diplognathodus orphanus, Diplognathodus coloradoensis, Idiognathodus sinuosis, Idiognathoides convexus, Idiognathoides ouachitensis, Neognathodus kanumai, Neognathodus bothrops, Neogondolella clarki, and Gondolella gymna.

Remarks. This zone can only be recognized at two localities (sections 17 and 18) in the upper sandstone/ limestone member. Consequently, the zone has very little applicability for local correlation. Were it not for the fact that the species also occurs in the Ardmore Basin and Mill Creek Syncline of the Arbuckle Mountains, the author would not have regarded occurrences of D. orphanus or D. coloradoensis in the Wapanucka as worthy of being named as zonal indices.

Some conodont workers (Lane, 1977; Dunn, 1976) have suggested that the earliest occurrence of diplognathodids conforms to the Morrowan-Atokan (Derryan) chronostratigraphic boundary. The age of the zone is herein arbitrarily assigned to the Morrowan Series although it is absent in the type Morrowan area due to pre-Trace Creek (Atokan) erosion.

Merrill (1975) recognized a *Diplognathodus orphanus* zone succeeded by a *Diplognathodus coloradoensis* zone in the Kewanee Group (Desmoinesian) northwestern Illinois and the Pottsville Group of the Appalachian region. These zones were regarded by him as supplemental zones to the generally more useful zonation based on the phylogeny of *Neognathodus*. The neognathodid species and associated fusulinid fauna in Illinois and the Appalachians indicate that Merrill's (1975) two diplognathodid zones are younger than the single diplognathodid zone recognized in the present study.

Streptognathodus elegantulus Zone

This zone occurs in approximately the upper one-eighth of the Wapanucka Formation. This includes only the upper-most portion of the upper sandstone/limestone member.

The zone has not been recognized in the Arbuckle Mountain area. It may be represented by the generally barren shale interval present at many localities at or near the base of the Atoka Formation below occurrences of *Idiognathoides noduliferus*.

Limits. The base of the zone coincides with the lowest occurrence of *Streptognathodus elegantulus*. The upper limit is not recognizable in the Wapanucka Formation.

The upper limit is known to be present in the Bostwick Limestone of the Ardmore Basin, and in the Atoka Formation of the Ozark Dome and Arbuckle Mountain regions and in the Lower Pennsylvanian limestone sequence in the Mill Creek Syncline of the Arbuckle Mountains based on the authors unpublished data. The upper limit occurs immediately below the lowest occurrence of Idiognathoides noduliferus (Ellison and Graves).

Associated Species. Streptognathodus elegantulus, Idiognathodus sinuosis, Idiognathoides convexus, Idiognathoides ouachitensis, Neognathodus bothrops, Neognathodus kanumai, Neogondolella clarki, Gondolella gymna, Diplognathodus coloradoensis, and Diplognathodus orphanus.

Remarks. Streptognathodus elegantulus bears a distinctive platform which evolved phyletically from Idiognathodus sinuosis by development of a pronounced oral trough. The species is geographically widespread but morphologically variable; however, the zone is a regionally recognizable, persistent biostratigraphic horizon.

An early Atokan age for the zone is indicated by occurrences of S. elegantulus (based on the author's collections) in: (1) the basal Atoka Formation of the Ozark Dome region of northeastern Oklahoma and northwestern Arkansas and the northeastern flank of the Arbuckle Mountains, (2) the middle portion of the Bostwick Member, Lake

Murray Formation, Ardmore Basin, southern Oklahoma, and (3) the middle part of the unnamed Lower Pennsylvanian sequence in the Mill Creek Syncline in the Arbuckle Mountains of southern Oklahoma. The species has previously been regarded as indicating a Desmoinsean to Virgilian age but now it can be shown to occur in older Atokan aged rocks.

Age and Correlation

General Statement

Conodonts serve as a basis for correlation of the Wapanucka Formation with the midcontinent type Morrowan Series in northwestern Arkansas and northeastern Oklahoma. The conodont zonation recognized in the Wapanucka Formation can also be used for comparison and correlation with other important sequences of similar age where the conodont faunas have been described. These sequences include the Bird Spring Formation in Nevada, U.S.A.; the Seville Member of the Spoon Formation in northwestern Illinois, U.S.A.; the Pottsville Group of the central Appalachians, U.S.A.; and the Kodani Formation in southwestern Japan.

Type Morrowan Sequence

The Morrowan Series, the basal unit of the Pennsylvanian System in the midcontinent region consists of two formations (1) the Hale Formation below, and (2) the Bloyd Formation. The type area for the Morrowan Series is northwestern Arkansas but recently it has been extended westward to include fossiliferous strata of equivalent age in northeastern Oklahoma (Sutherland and Henry, 1977). A Conodont zonation defined by the local ranges of conodont platform taxa was first proposed by Lane (1967)and Lane and others (1972) for the Morrowan Series in northwestern Arkansas. Subsequently, the zonation was emended to include new information from the Ardmore Basin and northeastern Oklahoma (Lane and Straka, 1975). Some more recent emendations and revisions have been presented by Lane (1977) in a study dealing primarily with intercontinental correlation. These studies as well as the author's unpublished information provide a basis for the age determination of the Wapanucka Formation and its correlation with the type Morrowan sequence.

A correlation of the Wapanucka Formation based on conodonts with the type Morrowan section is shown in Figure 29. The *Idiognathoides convexus* zone of the Wapanucka Formation indicates a correlation with at least the Kessler Limestone Member of the Bloyd Formation (Arkansas) and the Greenleaf Lake Limestone Member of the McCully Formation (Oklahoma). Because the range of *I. convexus* may be incomplete at its base in the type Morrowan region compared to its range elsewhere, the correlation shown also includes rock units older than the Kessler Limestone and Greenleaf Lake Limestone, but younger than the base of the Dye Shale.

The base of the *Neognathodus kanumai-Idiognathoides ouachitensis* Zone is shown by Lane (1977 = *Neognathodus* n. sp. Zone) to coincide with the base of the Trace Creek Shale Member of the Bloyd Formation. Occurrences of *Neognathodus kanumai* in the Trace Creek Shale are not the oldest occurrences of that species. This occurrence in the Trace Creek is younger than the initial appearance of *N. kanumai* in the Wapanucka Formation. Grayson and Sutherland (1977) have shown that the Trace Creek Shale actually bears conodonts belonging to the higher (younger) *Streptognathodus elegantulus* Zone. They presented evidence to document a two zone gap in the conodont faunas between the Kessler Limestone and the overlying Trace Creek Shale. This erosional gap corresponds to the uppermost portion of the *Idiognathoides convexus* Zone, all of the *Neognathodus kanumai-Idiognathoides ouachitensis* (as here redefined)and *Diplognathodus orphanus* Zones, and possibly the lower part of the *Streptognathodus elegantulus* Zone. The *Streptognathodus elegantulus* Zone of the Wapanucka Formation indicates a correlation of this interval with the Trace Creek Shale Member of the redefined Atoka Formation in the type Morrowan region.

Other Important Sequences

The Wapanucka Formation is correlative with part or all of the Bird Spring Formation in Nevada and the

Kodani Formation in Japan (Fig. 30). Bird Spring conodonts have been described by Dunn (1970a), Lane and others (1972) and Webster (1969). The Lee Creek section (Locality 6 of Dunn, 1970a) and the Arrow Canyon section studied by Lane and others (1972) and Webster (1969) are the critical sections for the present correlation. A composite section based on their data, is shown in Figure 30. At the Lee Creek section, conodonts thought to represent the Idiognathoides convexus Zone occur in the Bird Spring from about 150 to 250 feet above its base (SN 37-47, Dunn 1970a). The limits of the zone at the Arrow Canyon section cannot be recognized based on Webster's (1969) or Lane and others (1972) data. The base of the Neognathodus kanumai-Idiognathoides ouachitensis zone based on the earliest occurrence of Neognathodus kanumai (= N. roundyi of Dunn, 1970a) is placed at or about 250 feet (SN 47) above the base of the Bird Spring Formation at the Lee Creek section. The top of the zone is not recognizable at Lee Creek but can be recognized at Arrow Canyon. At the latter locality D. coloradoensis (an index for the next younger zone) has its lowest occurrence at 850 feet above the base of the Bird Spring. The next two higher conodont zones cannot be recognized at that section based on Lane and others published data.

The Neognathodus kanumai-Idiognathoides ouachitensis zone seemingly contains the first occurrence of the fusulinids

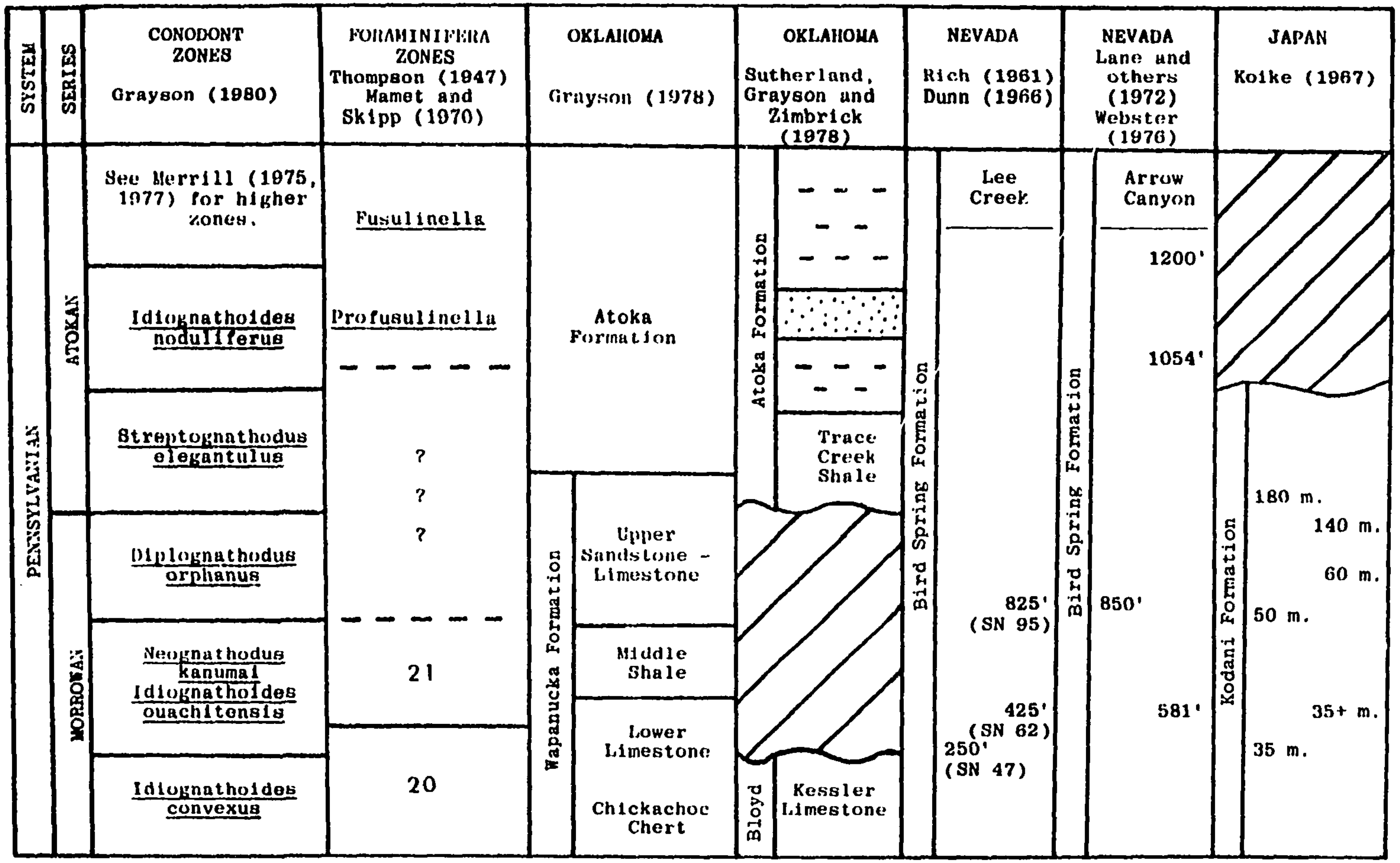


FIGURE 30. CORRELATION OF SOME IMPORTANT PENNSYLVANIAN SEQUENCES AND RELATIONSHIPS OF FUSULINID AND CONODONT ZONES. FOR THE BIRD SPRING AND KODANI FORMATIONS THE FOOTAGE ABOVE THE BASE OF THE LOWEST OCCURRENCE OF IMPORTANT CONODONTS AND FUSULINIDS IS SHOWN FOR EACH FORMATION. CONODONT FOOTAGES ABOVE THE BASE OF THE FORMATIONS ARE PLOTTED ON THE LEFT SIDE OF THE COLUMNS AND FUSULINID OCCURRENCES ARE PLOTTED ON THE RIGHT. SEE TEXT FOR A DISCUSSION OF THESE IMPORTANT INDEX FOSSILS.

Eoschubertella and Pseudostaffella foraminifer zone about 425 feet above the base of the Bird Spring at Lee Creek (see Rich, 1961) and at 581 feet above the base of the formation at Arrow Canyon (see Lane and others, 1972).

The Kodani Formation contains a particularly complete conodont succession that contains all of the zones recognized in the Wapanucka. Based on Koike's (1967) generalized columnar section the Idiognathoides convexus zone is present in the interval of about 10 to 35 meters above the base of the Kodani. The base of the Neognathodus kanumai-I. ouachitensis zone occurs at about 35 meters above the base of the Kodani; the base of this zone is essentially coincident with the initial appearance of the fusulinids Eoschubertella and Pseudostaffella. The base of the succeeding Diplognathodus orphanus zone occurs at about 50 meters above the base of the Kodani based on the appearance of the zonal name bearer (= D. coloradoensis of Koike, 1967). This zone in Japan contains the earliest occurrence of the fusuiform fusulinids Profusulinella at 60 meters and Fusulinella at 140 meters. The top of the Diplognathodus orphanus zone occurs at about 180 meters above the base of the Kodani. This is coincident with the lowest occurrence of Streptognathodus elegantulus; however, the base of this latter zone in Japan may represent a younger horizon then its occurrence in the Wapanucka. Younger Pennsylvanian conodont zones are missing and the Permian rests unconformably on the Middle Pennsylvanian in Japan.

Relationship of Fusulinid and Conodont Zones

More work is needed to integrate fusulinid and conodont zones but a clearer picture of their relationship is beginning to emerge. The initial appearance of *Eoschubertella* and *Pseudostaffella* is at (e.g. Kodani Formation) or slightly above the base (e.g. Bird Spring) of the *Neognathodus kanumai*-*Idiognathoides ouachitensis* conodont zone. Unfortunately, the relationship of conodont zones to occurrences of *Profusulinella* and *Fusulinella* are less certain. In Nevada, Lane and others (1972) have found *D. coloradoensis* to occur significantly below the lowest occurrence of *Profusulinella* in the Bird Spring Formation at the Arrow Canyon Section. When the Arrow Canyon section is compared with the Lee Creek Section based on interval thickness of selected faunal occurrences above the base of the formation, the earliest occurence of diplognathodids and *Profusulinella* is essentially the same. *Profusulinella* first occurs slightly higher (10 meters) than the first occurence of *D. orphanus* in the Kodani Formation in Japan (see Koike, 1967); and at one locality in the Lower Pennsylvanian of the Mill Creek Syncline in the Arbuckle Mountains the first occurrence of *D. orphanus* coincides with the initial appearance of fusiform fusulinids. In most areas in Oklahoma fusiform fusulinids are extremely uncommon and the earliest occurrences are species of

Fusulinella in the *Idiognathoides noduliferous* conodont zone.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study is primarily a stratigraphic analysis of the Wapanucka Formation in the Ouachita Mountains of southern Oklahoma. The investigation includes both litho-stratigraphic and conodont biostratigraphic analyses. Lithostratigraphically, the Wapanucka is subdivided into four members. These are: the lower limestone and Chickachoc Chert, the middle shale, and the upper sandstone/limestone. In the study area, typically, only 3 of these members are recognized at most localities because of the facies, wedge on wedge, relationship of the lower limestone and Chickachoc Chert Members. The lower limestone is characterized by repetitious occurrence of various shoal lithologies including oolitic and bioclastic calcarenite, and spiculiferous and micritic limestone. The basinward equivalent, the Chickachoc Chert, is a deeper water litho-logic association principally composed of shale and spiculite. The middle shale is a basinward thickening wedge of megascopically monotonous mudrock. The upper sandstone limestone member is present at the top of the formation. This member is lithologically similar to the lower limestone. It is distinguished from the lower limestone by absence of oolitic calcarenite and abundance of quartz sandstone. Typically, lithologic facies in the upper member exhibit greater lateral persistance which further distinguishes the two members.

Strata comprising the lower limestone, Chickachoc Chert and upper sandstone/limestone members have been subdivided into lithofacies based on matrix constituents, allochems and sedimentary structures, these lithofacies are: micritic limestone, spiculiferous limestone, oolitic calcarenite, autocthonous bioclastic calcarenite, quartz arenite, spiculite and allocthonous bioclastic calcarenite. The micritic limestone lithofacies is distinguished by the abundant occurrence of micrite and the general paucity of fossils. It is subdivided into four (4) lithotypes. These are: rugose coral wackestone/packstone, algal packstone/boundstone, carbonate wackestone/mudstone and pseudobrecciated carbonate mudstone. These lithotypes in the order mentioned, are interpreted to represent increasing salinity, decreasing circulation and possible subaerial exposure of subtidal, lagoonal carbonate mud. Spiculiferous limestone lithofacies is recognized by its organic rich micritic matrix and abundance of siliceous sponge spicules which provide grain support. The lithofacies is subdivided into two lithotypes based on presence or absence of calcareous bioclasts. The lithofacies cannot be interpreted by analogy with recent sedimentary environments. It interfingers with micritic limestone; however, suggesting that their respective environments of deposition were laterally adjacent. These spiculiferous limestone units are interpreted to represent shallow water, reducing conditions. Spiculiferous limestone changes facies basinward into deeper water siliceous spiculite. This aspect is an area that needs additional research particularly detailed petrographic analysis. The oolitic calcarenite lithofacies is distinguished by an abundance of ooliths in a sparry calcite matrix. It is interpreted to indicate deposition in a shoal regimen including shoal crest and spillover deposits.

The autochthonous bioclastic calcarenite lithofacies comprises the most diverse lithologic association recognized in the current study. It is preliminarily subdivided into four lithotypes based on texture, and presence or absence of cross-bedding, carbonaceous debris and limestone intraclasts. An absence of cross-bedding, carbonaceous debris and limestone intraclasts and the presence of bioclastic texture distinguishes the volumetrically predominant bioclastic calcarenite lithotype. It generally represents shallow water, low to high energy conditions. A more detailed petrographic analysis should permit a more refined environmental interpretation. The occurrence of carbonaceous debris in the absence of cross-bedding or limestone intraclasts distinguishes the carbonaceous bioclastic calcarenite lithofacies. This lithofacies is thought to represent accumulation of skeletal grains adjacent to a swampy or marshy island. Intraclasts in volumes exceeding 15% composed of limestone types derived from within the Wapanucka are diagnostic of the intraclast-bearing bioclastic calcarenite lithotype. This lithotype represents deposition in a high energy zone near a shoreline of small islands. The cross-bedded limestone lithofacies is recognized by the occurrence of tabular cross-bedding. For the most part the lithotype is thought to indicate deposition at the crest of offshore bars. The quartzarenite lithofacies consists predominantly of fine grained, sorted quartz sand. It is subdivided into two lithotypes: (a) quartzarenite, and (2) tabular cross-bedded quartzarenite. The quartzarenite lithofacies is interpreted to have accumulated as a series of linear offshore bars constructed by ebb tidal currents. The tabular cross-bedded lithotype indicates shoaling at the crest of the bar; whereas, the quartzarenite lithotype indicates deposition in an inter-bar or bar margin setting.

The spiculite lithofacies consists of current laminated spicules with shale drapes and thicker shale interbeds. The source of the spicules is thought to have been higher on the shelf above the shelf margin setting inferred for deposition of spiculite. Allocthonous bioclastic calcarenite characterized by erosive basal contacts and basinward directed cross-bedding is a rare but closely associated lithofacies.

The accumulation of the diverse facies comprising the Wapanucka Formation occurred in three stages. Wapanucka deposition initiated on a basinward sloping shelf-shelf margin. Tidal currents and other marine currents with a strong basinward component controlled facies genesis in this shlef margin setting. In shallow water on the shelf, lithofacies characteristic of the lower limestone were deposited. In the highest energy environments, oolitic and bioclastic calcarenite accumulated. Lower energy but adjacent environments were sites of accumulation of micritic and spiculiferous limestone. In deeper water near the shelf margin spiculite, shale and allocthonous bioclastic calcarenite assigned to the Chickachoc Chert accumulated. Presumably further toward the basin, at or below the slope break the Johns Valley Shale was being deposited.

A major influx of clay recognized as the middle shale is the second stage in accumulation of the Wapanucka Formation. This influx of shale resulted in a reduction of the previously existing basinward sloping bathymetry.

Carbonate and quartz sand accumulation (now known as the upper sandstone/limestone) occurred on a relatively horizontal substrate after termination of shale influx due to shoaling conditions. Quartz sand introduced from an eastern source was deposited as offshore bars constructed by sand waves migrating basinward due to current activity. In areas free from terrigenous influence, mostly in the west, carbonate deposition occurred. Deposition of tabular cross-bedded bioclastic calcarenite probably occurred in a bar type environment with micritic and spiculiferous limestone accumulating laterally in low energy environments. Wapanucka deposition closed with deposition of a widespread, distinctive carbonate mudstone and spicular black chert prior to a major influx of shale assigned to the Atoka Formation.

Conodonts recovered from the Wapanucka Formation are subdivided into four zones that can be correlated locally and regionally. The four zones in ascending order are: the *Idiognathoides convexus* zone, the *Neognathodus kanumai-Idiognathoides ouachitensis* zone, the *Diplognathodus orphanus* zone, and the *Streptognathodus elegantulus* zone. The *Idiognathoides convexus* zone and lower part of the *Neognathodus kanumai-Idiognathoides ouachitensis* zones occur in the lower limestone and/or Chickachoc Chert. This indicates equivalence of these members to the whole of the Wapanucka Formation in the Arbuckle Mountains of Oklahoma. The *Idiognathoides convexus* zone indicates correlation of part of the two members with the Dye Shale and Kessler

Limestone in Arkansas. The *Neognathodus kanumai-Idiognathoides ouachitensis* and *Diplognathodus orphanus* zones are represented by an erosional gap in the type Morrowan succession of Arkansas. The *Streptognathodus elegantulus* whch occurs in the upper part of the upper sandstone/limestone member indicates equivalence to the Trace Creek Shale Member of the Atoka Formation in Arkansas. The zone is thought to be earliest Atokan age. A satisfactory faunal definition of the Morrowan-Atokan boundary has yet to be proposed. Additional study involving other faunal groups is needed to satisfactorily resolve this problem.

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APPENDIX 1

MEASURED STRATIGRAPHIC SECTIONS

A total of 34 stratigraphic sections were measured, described, and systematically collected for lithologic and conodont biostratigraphic analyses. The description for each unit in the stratigraphic sections were based principally on field observations that followed this format: (1) descriptive rock name; (2) visual estimate of color of rock on fresh and weathered surfaces; (3) texture (grain size, sorting and roundness); (4) composition of allochem, cement and detrital grains; (5) significant fossils; (6) sedimentary structures and bedding features; (7) miscellaneous characters including degree of induration, weathering and topographic expression; (8) nature of the basal contact (abrupt, sharp, gradational or erosional). For detrital grains, the grain sizes are those of Wentworth (1922). For carbonate grains, grain size classes follow those used by Dunham (1962) in his classification of carbonate rocks. Bedding terminology is that presented by Ingram (1953). Fossils were described as: rare-less then 1% of volume; common - 1 to 5% of volume; abundant - over 5% of volume.

In most instances the field descriptions are followed by descriptions of samples from the measured units that were examined in the lab. The samples were slabbed, stained, thin sectioned or replicated by acetate peel and examined by binocular and petrographic microscopes. This description of the slabbed samples is in parentheses and includes; (1) location of the sample within the measured unit; (2) a clastic descriptive name or carbonate classification (Dunham's,1962); (3) miscellaneous characters. The occurrence of important conodont species, where recovered, is also given in parentheses.

SECTION 1

Indian Nation Turnpike 3

This section was described by Sutherland and Grayson (1977) as their locality 2. The exposure can be reached by following the instructions for section 2. Section 1 is located on the third faulted Wapanucka Ridge 1.0 mile south of section 2 on the Indian Nation Turnpike in the NW¼, NE¼, sec. 2, T. 3 N., R. 15 E. Pittsburg Quadrangle, Pittsburg County, Oklahoma. This section in conjunction with sections 19, 2 and 16 constitute the most important basinward reference sequence for the Wapanucka. However, the section has been partially covered by recent efforts to grass over the exposure by the Turnpike Authority. This effort has resulted in cover of a stratigraphically important goniatite locality reported by Gordon and Sutherland (1975). The goniatite fauna was collected by P. K. Sutherland and his students from units 17-19.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	713.9
	upper sandstone/limestone member	65.0
26	Spiculiferous limestone, dark blue gray fresh, weathers yellowish brown; calcisiltite; rare crinozoan bioclasts; very cherty; thin to medium bedded, base covered	22.6
25	Covered	7.0

Unit	Lithology	Thickness (feet)
24	Micritic limestone light gray fresh and weathered, calcilutite, rare crinozoan bioclasts; pseudo-brecciated; common algal debris; 22 feet above base abundant crinozoans; thick to very thick bedded; base covered	35.4
	(22.0 feet above base--fine calcirudite: crinozoan, lime packstone)	
	(base-calcilutite: algal, lime mudstone/wackestone)	
	(conodont sample 22.0 feet above base - <u>Streptognathodus</u> sp. and <u>I. sinuosis</u>)	
	middle shale member	261.7
23	Covered	30.4
22	Shale dark gray fresh and weathered, mostly poorly exposed; rare concretions, concretions in lower 30-50 feet contain productid brachiopods; basal contact gradational	231.3
	Chickachoc Chert Member	387.2
21	Spiculite, dark blue-gray fresh weathers yellowish-brown; very fine grained; wavy, lenticular and flaser bedded, interbed of shale in middle part of unit and 4 feet of shale at base, shale, as above; medium to thick bedded; basal contact gradational	6.8
20B	Spiculiferous limestone, dark gray fresh and weathered; very fine calcarenite; common crinozoan bioclasts, vertical burrows, burrows appear segmented; single bed; basal contact gradational	1.5
	(top - very fine calcarenite: argillaceous, crinozoan, spicule, lime packstone)	

Unit	Lithology	Thickness (feet)
	(conodont sample top 0.5 feet- *I. ouachitensis*, *I. sinuosis*, *N. kanumai* and *N. clarki*)	
20A	Spiculite, as above, except thin to medium bedded; basal contact gradational	31.1
19	Shale, as above, except abundant clay-ironstone concretions; this interval produces an important goniatite fauna; calcareous at top; basal contact gradational	30.0
	(conodont sample top 0.5 foot- *I. sinuosis* and *N. kanumai*)	
18	Spiculite, dark gray, weathers buff, very fine grained; rare to common very thin laminae containing shoal bioclasts and ooliths; wavy, lenticular and flaser bedding; thin to medium bedded; basal contact gradational	6.6
17	Spiculite, very heavily weathered; reddish-brown; thin bedded; basal contact gradational	7.8
16	Shale, as above, concretions indistinct layers; basal contact gradational	33.1
15	Spiculite, dark blue-gray fresh, weathers buff to reddish-brown, otherwise as above; basal contact gradational	10.2
14	Shale, as above, but fewer concretions; basal contact gradational	19.3
13	Spiculite, as above; base covered	6.5
12	Covered, scattered shale	4.5
11	Spiculite, weathers yellowish-orange; very argillaceous, abundant thin shale partings; bioturbated; thin bioclastic calcarenite near top; thin to medium bedded; unit poorly exposed; base covered	14.5

Unit	Litholo gy	Thickness (feet)
	(12.0 feet above base - coarse calcarenite: sandy, oolith, crinozoan lime packstone)	
	(12.0 feet above base - _I._ _convexus_ and _I._ _sinuosis_)	
10	Shale medium gray, weathers light brown; abundant clay-ironstone concretions; base gradational	64.7
9	Sandstone, light olive brown, fresh, weathers pale yellowish-brown; very fine-grained; argillaceous particularly in center of unit; single bed, base gradational	3.3
8	Shale, as above, except rare concretions	11.5
7	Spiculite, black fresh, gray weathered; very poorly exposed; argillaceous; 4 inches of calcarenite in center of unit; thin to medium bedded; basal contact gradational	5.0
	(2.5 feet above base - medium calcarenite: sandy, crinozoan lime packstone)	
	(conodont sample - _I._ _convexus_ and _I._ _ouachitensis_)	
6	Shale as above	
5	Bioclastic limestone, medium gray fresh and weathered; coarse calcarenite; abundant crinozoan bioclasts, rare trilobite and brachiopod fragments; bed varies in thickness, basal contact sharp	0.1-0.5
	(coarse calcarenite: sandy, oolith, crinozoan lime packstone)	
	(_I._ _convexus_ and _I._ _sinuosis_)	
4	Spiculite, dark gray to black fresh, yellowish orange weathered; single bed, base sharp	1.0
3	Shale, dark blue-gray fresh, tan or brown weathered; abundant clay-ironstone concretions; basal contact	

Unit	Lithology	Thickness (feet)
	sharp	108.3
2	Spiculite, dark gray to black fresh buff weathered, laminated light spicule and dark shale layers; thin to medium bedded; base sharp	14.1
	Springer Formation	
1	Shale	10+

SECTION 2 and 2W

Indian Nation Turnpike 1, and Offset Partial Section

The section is located on the Indian Nation Turnpike 10.1 miles south of the tollgate at the intersection of the turnpike with U. S. 69, south of McAlester, Oklahoma. The section is located in the SE¼ SE¼, sec. 18, T. 3 N., R. 15 E., Pittsburgh Quadrangle, Pittsburg County, Oklahoma.

The section was described and collected for lithologic and conodont samples by Patrick K. Sutherland and Robert C. Grayson, Jr. The lower part of the exposure was subsequently recollected and redescribed by Robert C. Grayson, Jr. At that time the lowest exposed beds on the west side of the road cut were measured and described (see section 2 W following description of section 2). This exposure is locality 1 of Sutherland and Grayson (1977). Section 2 in conjunction with sections 19, 16, and 1 constitute the most important basinward reference sequence for the Wapanucka. Recent efforts by the Trunpike Authority to grass over this exposure, however, has destroyed some of the usefullness of the sequence.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	356.0
	upper sandstone limestone member	104.0
43	Chert, dark blue-gray fresh, black	

Unit	Lithology	Thickness (feet)
	and iron stained weathered, argillaceous, thin bedded, basal contact obscured but appears to sharp	6.0
42	Spiculite, dark blue-gray or black fresh, brown weathered, argillaceous, thin bedded, lenticular and flaser bedded, rare crinozoan columnals only lower three (3) feet of unit is exposed on the east side of road, basal contact gradational	11.0
41	Micritic limestone, light gray fresh and weathered; calcilutite; common phylloid algal blades and "Ortonellid" algal fragments; rare crinozoan columnals, calcareous forams, gastropods and ostracods; thick to very thick bedded, styolitic; base covered	17.4
	(10 feet above base-calcilutite: algal lime mudstone)	
40	Covered	2.6
39	Bioclastic limestone, medium gray fresh and weathered; fine calcarehite; well sorted, abundant crinozoan detritus; sparry calcite matrix; quartz sandy, glauconitic; very thick bedded; basal contact covered	19.4
	(5 feet above base, fine calcarenite: sandy, well sorted, fossil, lime grainstone; crinozoan debris is the dominant bioclast, brachiopod fragments, molluscan (gastropods) and millerellid forams are relatively common, ramose bryozoans and indeterminate skeletal grains occur, nonbioclastic allochems include rare ooliths and intraclasts. Bioclasts are rounded and generally exhibit some micritization, they are very thightly packed).	
	(conodont sample basal 2 feet - _S. elegantulus_ and _D. coloradoensis_	

Unit	Lithology	Thickness (feet)
38	Covered	1.9
37	Bioclastic limestone, medium to dark gray fresh, buff weathered, weathered surface "punky"; fine calcarenite; origin of bioclasts mostly indeterminate; argillaceous, very sandy, locally a calcareous sandstone; basal contact covered by talus	23.5
35	Bioclastic limestone, light to dark gray fresh, dark gray and buff or brown weathered; fine to medium calcarenite; very sandy and sorted in basal ½ of unit becoming argillaceous in upper part; abundant ooliths and crinozoan detritus; common calcite veins; thick bedded; basal contact sharp	9.4
	(conodont sample from upper-most 2 feet - I. sinuosis)	
	(2 feet above base - medium calcarenite: sandy, well sorted, oolith, crinozoan, lime grainstone; common brachiopod valves, fenestellid and ramose bryozoans, rare gastropods and indeterminate mulluscan fragments, rare millerellid forams, indeterminate cross bedding, sand grains typically are oolitically coated)	
	(7.5 feet above base-medium calcarenite: sandy-argillaceous, oolith, crinozoan, lime packstone)	
34	Shale, as above	4.0
33	Micritic limestone and shale interbeds, dark gray fresh, medium or light gray to tan or buff weathered; calcilutite; fossil constituents consist predominantly of crinozoan columnals, brachiopods, and algal fragments; rugose corals, millerellid forams and ostracods are uncommon; shale interbeds at base become partings and drapes in irregular micrite surfaces in upper part of unit; basal 4 inches of unit contains abundant crinozoan and brachio-	

Unit	Lithology	Thickness (feet)
	pod bioclasts; siliceous; thin to medium bedded, basal contact gradational	4.0
	(2 feet above base-calcilutite; argillaceous, crinozoan, algal Wackestone; dominant algal type is cellular branching tubes, phylloid algae and frondose red (?) algae are less abundant)	
32	Shale: as above	3.5
31	Bioclastic limestone, medium gray fresh and weathered; coarse calcarenite; abundant crinozoan and brachiopod detritus (_Schiziphoria oklahomea_); less abundant bioclasts include ramose bryozoans, millerelid forams, michelinid corals, gastropods, and indeterminate molluscan grains; most bioclasts have micrite coatings or are even more pervasively micritized; argillaceous; common flat clay clasts; chert and calcilutite clasts near base, single bed, basal contact sharp and very irregular	1.0-4.0
	(conodont sample from top 1 foot - _I. ouachitenis_, _N. clarki_, _I. sinuosis_)	
	(1.0 feet above base - coarse calcarenite: argillaceous, ramose bryozoan, crinozoan, lime packstone with grainstone laminae)	
	middle shale member	43.0
30	Shale: as above, basal contact sharp and slightly irregular	43.0
	lower limestone member	170.4
29	Micritic limestone: medium gray fresh, medium gray and buff weathered; calcilutite; bioclasts dominated by rudite-size crinozoan stem fragments; very siliceous	

Unit	Lithology	Thickness (feet)
	particularly in upper part, common chert nodules; upper surface of unit brecciated and bioturbated; argillaceous with shale partings on irregular micrite surfaces; thick-very thick bedded; base covered	5.8
	(conodont sample from uppermost 1 foot - A. lautus)	
	(1.5 feet above base-calculutite: argillaceous, fossil lime mudstone; crinozoan bioclasts dominant allochem, benthonic crustose bryozoans, brachiopods, and ostracods are less common bioclasts)	
	(5.5 feet above base-calcilutite: algal lime mudstone; cellular algal tubes appear to have bound sediment, silicification so intense most depositional textures and features have been obscured, spiculiferous, rare gastropods)	
28	Covered	1.3
27	Micritic limestone, dark blue-gray fresh; medium gray, buff, tan or light brown weathered; calcilutite; rare crinozoan columnals, ostracods, bryozoans and brachiopod valves; argillaceous, shale partings, shale drapes; clotted, irregular micrite surfaces; thick to thin bedded; base covered	7.1
	(3.0 feet above base-calcilutite: argillaceous, crinozoan, ostracod, lime mudstone with fine calcarenite: crinozoan, lime packstone laminae)	
26	Covered	4.5
25	Bioclastic limestone, medium gray fresh; brick-red weathered; medium calcarenite; abundant crinozoan detritus, ramose and fenestellid bryozoans, and brachiopods; common bivalves, gastropods; comminuated mulluscan	

Unit	Lithology	Thickness (feet)
	debris, and trilobite pygidiums; rare rugose corals and goniatites; common sideritic nodules and/or clasts; rare micritic intraclasts; quartz silty; shale partings common; ferruginous, thin to thick bedded; basal contact sharp	8.1
	(conodont sample 6.0 to 7.0 feet above base - I. ouachitensis and I. sinuosis)	
	(2.0 feet above base - coarse calcarenite: silty, coated grain, crinozoan, lime packstone; "poorly washed," most bioclasts are micritized)	
24	Shale, dark blue-gray fresh; blue-green, tan or orange-brown weathered; fissile; common red-brown clay ironstone concretions; basal contact gradational	10.3
23	Bioclastic limestone, brown-gray fresh and weathered; fine calcarenite to fine calcirudite; abundant crinozoan detritus, ramose bryozoans, and brachiopods; common "turitellid" and trochoid gastropods, and comminuated molluscan debris; argillaceous; sparry calcite matriz; glauconitic; thick bedded, basal contact gradational	4.5
	(conodont sample from top 1.0 foot - N. clarki and I. ouachitensis	
	(3.0 feet above base - fine calcirudite: ramose bryozoan, crinozoan, lime packstone with wackestone laminae; bioclasts commonly micritized; grain contacts styolitic and pressure welded)	
22	Spiculiferous limestone, dark blue-gray fesh, buff weathered; fine calcarenite; origin of most grains	

Unit	Lithology	Thickness (feet)
	indeterminate due to pervasive silicification, but crinozoan columnals and sponge spicules occur; shale partings, flaser and lenticular sedimentary structures; argillaceous, glauconitic; thin to medium bedded; base covered	1.9
	(0.5 feet above base - fine calcarenite: quartz silty, argillaceous, crinozoan, spicule, packstone)	
21	Covered:	9.0
20	Spiculiferous limestone, dark gray fresh, light to medium gray weathered; calcisiltite; abundant siliceous sponge spicules; rare to common crinozoan columnals; siliceous micrite matrix, abundant blue-black chert nodules that weather buff; medium to thick bedded; base covered	20.0
	(9.0 feet above base - calcisiltite: crinozoan, spicule, lime packstone; burrow mottled)	
19	Covered	12.6
18	Micritic limestone, medium and dark gray fresh and weathered; calcilutite; abundant algal colonies including branching, cellular tubes (ortonellid) to pavements of algal branches in sub-spherical masses or chip-like encrustations, and phylloid algal blades; rare crinozoan detritus; burrow mottles; argillaceous partings; common chert nodules; medium to thick bedded; base covered	5.5
	(2.0 feet above base - calcilutite: burrow mottled, algal boundstone with shale laminae or partings encrusted by algae)	
17	Covered:	5.8

Unit	Lithology	Thickness (feet)
16	Micritic limestone, light gray fresh, light to medium gray weathered; calcilutite; abundant algal remains; rare crinozoan detritus and sponge spicules; abundant chert nodules; single bed; base covered	3.2
	(1.5 feet above base - calcilutite algal boundstone; algae dominated by cellular tube-like branches which form anastomosing colonies with indeterminate shapes to sub-spherical colonies of loosely or tightly packed branches; less common algal types include ovate colonies of pavement-like branches, and phylloid algal blades; disrupted, clotted and fenestrate fabric due to dessication and bioturbution intimately associated with algal branches and colonies, these disrupted zones typically contain biserial agglutinate forams, gastropods, bivalves, worm tubes and crinozoan colomnals)	
15	Covered:	5.2
14	Micritic limestone, medium to dark gray fresh and weathered; calcilutite; rare algal fragments, crinozoan columnals, sponge spicules, ostracods, mollusc shell debris and benthonic agglutinate forams; abundant dark gray chert nodules, common shale partings and laminae; styolitic thin to thick bedded; forms rubbly surface; base covered	7.1
13	Covered	8.0
12	Bioclastic limestone, dark gray fresh, medium gray weathered; coarse calcarenite to fine calcitudite; abundant bimodally distributed crinozoan columnals and stem fragments, ramose bryozoans, brachiopods, coated grains and ooliths; less common allochems include millerellid and agglutinate forams; quartz sandy and argillaceous; unit consists of cyclical laminae and thin (2-3 inches)	

Unit	Lithology	Thickness (feet)
	beds that exhibit fining upward due to loss of crinozoan detritus and more abundant occurrence of ooliths; thick bedded, base covered	3.2
	(1.0 foot above base - coarse calcarenite: sandy-argillaceous, crinozoan, oolith, lime packstone with oolith grainstone laminae; bioclasts typically micritized superficially or completely)	
	(conodont sample - I. convexus and I. sinuosis)	
11	Covered:	1.3
10	Bioclastic limestone, dark gray fresh, tan or light gray weathered, weathered sufrace has punky sandstone appearance; fine calcirudite; abundant bimodal crinozoan detritus, and brachiopods which exhibit geopetal structure; common ramose bryozoans, molluscan debris, sponge spicules, and millerellis forams; rare algal coated grains; quartz sandy and argillaceous, sand commonly most abundant in thin laminae; glauconitic; medium to thick bedded; basal contact gradational	4.5
	(3.0 feet above - fine calcirudite: quartz silty-argillaceous, brachiopod, crinozoan, lime packstone)	
9	Bioclastic limestone, dark gray fresh; medium gray or rust-brown weathered; medium to coarse calcarenite; abundant crinozoan detritus, ramose bryozoans, and molluscan debris; rare michelinid corals and fenestellid bryozoans; most grains are coated or micritized, sandy and argillaceous; bimodal grain size produces crude graded laminae that is repeated several times within a bed; thick bedded; basal contact obscured by talus	3.5

Unit	Lithology	Thickness (feet)
	(1.5 feet above base - coarse calcarenite: sandy argillaceous, ramose bryozoan, crinozoan, lime packstone)	
8	Spiculiferous limestone, dark gray fresh, tan weathered; fine calcarenite; abundant sponge spicules and phylloid algal, common crinozoan columnals and brachiopod valves particularly in upper part; argillaceous, shaly partings; thin to thick bedded; basal contact covered	15.2
	(12.0 feet above base - calcisiltite: silty, argillaceous, crinozoan, algal spicule, lime packstone; common ramose bryozoans and molluscan fragments)	
7	Covered:	28.4
	Chickachoc Chert Member	44.7
6	Spiculite, gray-black fresh, tan or light gray weathered; calcisiltite; abundant sponge spicules, rare to common crinozoan columnals, crinozoan debris occurs in distinct layers; argillaceous: abundant blue black chert nodules; wavey, flaser and lenticular sedimentary structures; color banded, lighter layers are nearly pure sponge spicules; thin to medium bedded; base covered	16.8
5	Covered:	14.8
4	Spiculite: as above; base covered	9.7
3	Covered:	2.3
2	Bioclastic limestone, medium gray fresh, medium gray and red-brown weathered; coarse calcarenite; abundant crinozoan debris, productid and spiriferid brachiopods, molluscan grains including immature goniatites and gastropods; rare to common millerellid forams,	

Unit	Lithology	Thickness (feet)
	benthonic agglutinate forams, oncolites, ooliths, and intraclasts; most skeletal grains have micrite coats; intraclasts composed of shale, micrite, and spiculiferous micrite; quartz silty, glauconitic, 1 or 2 thin shale partings or interbeds occur within unit; medium bedded; basal contact sharp	1.1
	(conodont sample from entire bed - _I._ _convexus_ and _I._ _sinuosis_)	
	(1.0 feet above base - coarse calcarenite: silty, bryozoan, crinozoan, lime packstone)	
	"Springer" Shale	50 +
1	Shale, dark blue-gray fresh and weathered, common sideritic concretions, base covered	50 +

SECTION 2W

Indian Nation Turnpike 1, Offset

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	
	lower limestone member	
17	Shale, blue-gray fresh and weathered; fissile; common clay-ironstone concretions; base sharp; thickness estimated	3.0
16	Micritic limestone, medium gray fresh, light to medium gray weathered; calcilutite; rare crinozoan debris rugose corals, ostracods, and bryozoans; common tubular algae; argillaceous, shale partings on lumpy irregular micrite surfaces; medium to thick bedded, base not seen in direct contact with unit 15	16.0
	(12.0 feet above base - calcilutite: argillaceous, algal, lime mudstone)	
15	Micritic limestone, light to medium gray fresh and weathered; burrow (?) mottled; abundant tubular algae, commonly in life position; rare crinozoan and bryozoan bioclasts; thick to very thick bedded; basal contact covered	9.0
	(4.0 feet above base - calcilutite: burrow mottled, algal lime wackestone)	
14	Covered	1.3
13	Spiculiferous limestone, dark gray fresh and weathered; fine calcarenite; abundant sponge spicules; common crinozoan bioclasts; rare fenestellid bryozoans and brachiopod valves;	

Unit	Lithology	Thickness (feet)
	burrow (?) mottled; agrillaceous, thin interbeds of silty shale which commonly exhibit flaser bedding; thin to medium bedded; basal contact gradational	2.3
	(1.0 feet above base - fine calcarenite: argillaceous, crinozoan, spicule, lime packstone)	
12	Shale, blue-gray fresh and weathered; fissile; silty; flaser bedded in 0 upper 1.0 foot; common crinozoan columnals particularly in upper part; basal contact sharp	5.1
11	Bioclastic limestone medium gray fresh and weathered; coarse calcarenite at base grading upward into calcilutite; abundant crinozoan columnals, bryozoans, and brachiopod valves; common rugose corals and molluscan bioclasts; argillaceous; thick to thin bedded; basal contact covered	9.0
	(conodont sample 0.5-2.0 feet above base *I. convexus* and *I. sinuosis*)	
	(1.5 feet above base - coarse calcarenite: quartz sandy, argillaceous, crinozoan, lime packstone; bioclasts generally micritized, grain contacts styolitic)	
	(8.5 feet above base - calcilutite: fossil wackestone; fossils consist of encrusting and ramose bryozoans, phylloid algae, rugose corals, and benthonic agglutinate forams; matrix exhibits disrupted fabric possibly birdseye and/or fenestrae)	
10	Covered:	1.6
9	Spiculiferous limestone, dark gray fresh, medium gray or tan weathered; fine to medium calcarenite; abundant sponge spicules, crinozoan bioclasts, spiriferid and productid brachiopods, and ramose bryozoans; glauconitic,	

Unit	Lithology	Thickness (feet)
	quartz sandy, very argillaceous; thick bedded; mature of basal contact obscured by talus	4.8
	(0.5 feet above base - fine calcarenite: argillaceous, sandy, crinozoan, spicule, lime packstone; sand grains present in laminae; chertification of both fossils and matrix common, sponge spicules filled with sparry calcite)	
8	Bioclastic limestone, dark gray fresh, dark gray or tan weathered; fine calcarenite; abundant sponge spicules; common crinozoan bioclasts; quartz sandy, very argillaceous; thin interbeds of flaser bedded, spiculitic shale; medium bedded; nature of basal contact obscured by talus	3.9
7	Spiculiferous limestone, medium to dark gray fresh, medium gray, tan or white weathered; abundant siliceous monaxon sponge spicules, common phylloid algae and crinozoan bioclasts, rare bryozoans; argillaceous; medium to thin bedded; base covered. This unit is equivalent to unit 8 (sec. 2) on the other side of the turnpike.	5.8
6	Bioclastic limestone, medium to dark gray fresh and weathered; coarse calcarenite to fine calcirudite; abundant rudite size crinozoan bioclasts, common ramose bryozoans gastropods and molluscan debris; very argillaceous, glauconitic; single bed, base obscured by talus	3.9
	(*I. convexus* and *I. sinuosis*)	
	(1.0 foot above base - fine calcirudite: argillaceous, ramose bryozoan, crinozoan lime packstone)	
	Chickachoc Chert	61.1
5	Spiculite, dark blue-gray fresh, weathers dark gray; calcisiltite to fine	

Unit	Lithology	Thickness (feet)
	calcarenite; rare crinozoan and ramose bryozoans; very argillaceous, common shale partings; thick bedded; basal contact gradational	10.3
	(3.0 feet above base - fine calcarenite: argillaceous, crinozoan, spicule lime packstone)	
4	Spiculiferous limestone, dark gray fresh and weathered; fine calcarenite to coarse calcirudite; abundant spicules and crinozoan bioclasts, common ramose bryozoans and brachiopod valves; silty, abundant shale partings; thin bedded to thick bedded at top; basal contact gradational	18.7
	(17.0 feet above base - Coarse calcarenite: argillaceous, crinozoan, spicule lime packstone)	
	(Top 1.0 foot - _I._ _sinuosis_)	
3	Spiculite, medium to dark gray, tan or brown weathered; calcisiltite; common crinozoan bioclasts; argillaceous with common partings; flaser, wavey and leticular bedding; medium to thick bedded; basal contact gradational	31.0
2	Limestone with a few thin shale interbeds, medium gray fresh, weathers gray with iron stains; coarse calcarenite; abundant crinozoan bioclasts, common productid and spiriferid brachiopods, rare to common molluscs including immature goniatites and ramose bryozoans; common shale intraclasts and oolites thin to medium bedded; basal contact sharp	1.1
	(0.5 feet above base - Coarse calcarenite: oolitic, bioclastic lime packstone)	
	"Springer" Shale	
1	Shale, see description of unit 1, section 2	

SECTION 3

Pleasant Valley I

This section can be reached by taking state highway 63 east from Kiowa, Oklahoma, 2.4 miles to the second section line road. Turn south, drive 1.8 miles to the point where the road cuts the first fault exposure of the Wapanucka south of Limestone Ridge.

Three members are present at this section. These are: the Chickachoc Chert, middle shale, and upper sandstone/ limestone. The Chickachoc Chert is anamolous because of the unusal abundance of spiculiferous limestone and bioclastic calcarenite. This is interpreted to indicate a somewhat shallower water depositional environment compared to the Chickachoc in more basinward exposures. The upper sandstone/ limestone is predominantly sandstone but a distinctive carbonate mudstone marks the top of the section.

Section 3 in conjunction with sections 17, 4, and 5 constitute an important basinward reference sequence for the Wapanucka.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	349.5
	upper sandstone/limestone	52.7
41	Limestone, light gray fresh and weathered; calcilutite; rare crinozoan columnals and rugose corals; rare chert nodules;	

Unit	Lithology	Thickness (feet)
	thick to very thick bedded; basal contact sharp	12.0
	(top - calcilutite: lime mudstone)	
40	Spiculiferous limestone, medium gray fresh, tan weathered; very fine calcarenite; rare crinozoan bioclasts; quartz sandy; abundant black organic wisps; thick bedded; base gradational	15.0
39	Shale and siltstone interbeds, reddish brown heavily iron stained; rare chert beds; basal contact gradational	5.6
38	Sandstone, quartzarenite; reddish brown; medium grained, subangular, sorted quartz sand; common crinozoan molds, rare bivalves; tabular cross bedded, inclined to the south; thick bedded; basal contact sharp	5.2
37	Sandstone, tan; fine grained, sorted, quartz sand; rare thin clay ironstone concretions and black wispy streaks; medium to thick bedded; basal contact gradational	2.0
36	Shale and siltstone, brown-red; rare brachiopod fragments; unit mostly covered; base obscure	19.3
35	Micritic limestone, light gray fresh and weathered; calcilutite; spiculiferous, rare crinozoan columnals and gastropods; on some surfaces the micrite appears "clotted;" common chert nodules; thick bedded; basal contact covered	11.8
	(base and top - Calcilutite: crinozoan lime mudstone)	
	middle shale member	85.6
34	Covered	85.6
	Chickachoc Chert Member	190.9

Unit	Lithology	Thickness (feet)
33	Spiculite, dark blue gray fresh, reddish-brown weathered; rare crinozoan columnals; flaser, wavey and lenticular laminations; thin to medium bedded; basal contact sharp	11.8
32	Spiculiferous limestone, medium to dark gray fresh tan weathered; calcilutite; rare crinozoan columnals and rugose corals; common shale partings, rare chert nodules; thin to medium bedded; basal contact gradational	7.3
	(base and top - calcisiltite: spiculiferous lime packstone)	
31	Spiculiferous limestone, dark blue gray fresh, tan weathered, calcisiltite; abundant siliceous sponge spicules, rare crinozoan columnals; thick to very thick bedded; basal contact sharp	5.0
30	Bioclastic limestone, medium gray fresh, tan weathered; coarse to medium calcarenite; abundant crinozoan bioclasts, common spicules particularly in lower part; abundant coated grains and ooliths; cross-bedded; nodular bedding; basal contact sharp and slightly irregular	2.1
	(conodont channel sample - _I. sinuosis_)	
	(base-medium calcarenite: sandy, fossil lime packstone; top-medium calcarenite: oolith, crinozoan lime grainstone)	
29	Spiculiferous limestone, medium gray fresh, tan weathered, calcisiltite; current laminated, same scouring; middle portions of unit covered by talus and soil; basal contact sharp	9.5
	(Top-calcisiltite: spiculiferous, lime packstone)	

Unit	Lithology	Thickness (feet)
28	Interbedded spiculiferous limestone and shale; Spiculiferous limestone, dark blue-gray fresh, tan weathered; calcisiltite; common crinozoan bioclasts and bellerophontid gastropods; fossils most abundant in upper part, rare fossil wood; medium bedded; basal contact gradational	5.9
	(conodont channel sample - _I. ouachitensis_, _I. sinuosis_)	
27	Bioclastic limestone, dark blue-gray fresh, medium gray weathered; fine calcarenite; common crinozoan bioclasts, rare bellerophontid gastropods and mollusc shell fragments, spiculiferous, rare algal blades; single bed; basal contact sharp	0.9
	(Top - very fine calcarenite: fossil, spicule lime packstone)	
	(conodont channel sample - _I. ouachitensis_, _I. sinuosis_)	
26	Bioclastic limestone, medium to dark gray fresh tan weathered; fine calcarenite with thin coarse calcarenite lenses; abundant crinozoan bioclasts, common brachiopod fragments, ramose bryozoans and millerellid forams; small scale trough cross-bedded; thick bedded, base covered	1.6
	(base - medium calcarenite: sorted, oolith, crinozoan lime grainstone)	
	(conodont channel sample - _I. ouachitensis_, _I. sinuosis_, _N._ cf. _clarki_)	
25	Covered	2.9
24	Spiculiferous limestone, dark blue-gray fresh, tan or red-brown weathered; calcisiltite; rare crinozoan columnals; abundant, anastomosing	

Unit	Lithology	Thickness (feet)
	chert nodules; thin to thick bedded; basal contact sharp	9.0
	(Top - calcisiltite: spicule packstone)	
23	Shale, blue-gray fresh, olive and gray weathered, very slightly silty; basal contact obscure but appears gradational	16.4
22	Shale and spiculite; shale, as above; spiculite, flaser, wavey and lenticular laminations; argillaceous; thin bedded; basal contact gradational	14.0
21	Spiculite, dark blue-gray fresh, tan weathered; abundant shale partings and interbeds, common flaser, lenticular, and wavey laminations; thin to thick bedded; basal contact gradational	13.1
20	Shale, blue gray fresh, gray and olive weathered; rare clay-ironstone concretions; basal contact gradational	1.9
19	Spiculite, dark blue-gray fresh, tan or brown and punky weathered; abundant chert nodules and stringers; wispy; vague laminations; medium to thick bedded; base gradational	6.0
18	Spiculiferous limestone, blue-gray fresh, white-gray weathered; calcisiltite; rare crinozoan bioclasts, brachiopods, and bryozoans, abundant algal blades and spicules; common dark gray shale interbeds; medium to thick bedded, irregular beds; basal contact gradational	9.1
	(very fine calcarenite; argillaceous, spicule, algal lime packstone)	
17	Spiculiferous limestone, medium to dark gray fresh; fine calcarenite; abundant algal blades, common spicules, crinozoan bioclasts,	

Unit	Lithology	Thickness (feet)
	brachiopods, and rugose corals; abundant shale partings and interbeds; thin to medium bedded; basal contact gradational	2.2
	(conodont channel sample - _I. convexus_)	
16	Shale, dark blue-gray fresh; rare gastropods, crinozoan bioclasts; brachiopods, and bivalves; rare clay-ironstone concretions; thin spiculite interbeds near base, base gradational	14.5
15	Spiculite, dark blue-gray fresh, tan or brown weathered; calcisiltite: bioturbated; flaser, wavey and lenticular bedding; thin bedded; base covered	1.5
14	Covered	4.0
13	Spiculite, as above; base gradational	6.4
12	Shale, blue-gray fresh, olive drab weathered; mostly covered; basal contact sharp	1.3
11	Spiculite, as above, except thin to medium bedded; base covered	1.5
10	Covered	5.3
9	Bioclastic limestone, medium gray fresh, tan with iron staining weathered; coarse calcarenite; horizontal laminations produced by alternating coarse calcarenite and fine calcirudite crinozoan bioclasts; common brachiopod valves and ramose bryozoans, most grains micritized; common ooliths; single bed; base covered	0.9
	(fine calcirudite: sandy, oolith, crinozoan lime packstone)	
	(conodont channel sample - _I. convexus_, _I. sinuosis_)	

Unit	Lithology	Thickness (feet)
8	Covered	1.7
7	Bioclastic limestone, medium gray fresh, brown weathered; medium calcarenite; abundant crinozoan bioclasts, ooliths and coated grains; quartz sandy; low angle tabular cross-bedded; thin to medium bedded; base covered	2.5
	(conodont channel sample - _I. convexus_, _I. sinuosis_)	
6	Covered	8.2
5	Spiculite, as above, except heavily weathered; base covered	3.0
4	Covered	11.2
3	Spiculite, as above	4.3
2	Bioclastic limestone, medium gray fresh, tan weathered; coarse calcarenite to fine calcirudite; abundant crinozoan bioclasts; rare fenestellid bryozoans and productid brachiopods; horizontally laminated; medium bedded, beds lensoidal; base covered	3.5-4.0
	(fine calcirudite: ramose bryozoan, brachiopod, crinozoan lime packstone)	
	(conodont channel sample - _I. convexus_, _I. sinuosis_)	
1	Spiculite, as above, base covered	1.9

SECTION 4

Pleasant Valley 2

This section can be reached by traveling south 0.2 miles on the section line road from section 3. The section is located on the second fault ridge south of Limestone Ridge on the section line between the SE¼, sec. 31 and SW¼ sec. 32, T. 3 N. 14 E. Section measured in drainage ditch mostly on east side of road.

This section in conjunction with sections 17, 3, and 5 constitute an important basinward reference sequence.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	475.1
	upper sandstone limestone	56.5
22	Micritic limestone, blue-gray fresh, light gray weathered; calcilutite; rare to common crinozoan bioclasts and sponge spicules, rare rugose corals and gastropods; clotted texture common; medium to thick bedded; base covered	2.2+
21	Covered	10.4
20	Sandstone, red brown; medium grained, sorted quartzarenite; siliceous ferruginous cement; common crinozoan bioclasts, rare gastropods; common ripple bed-forms; thin calcareous lense about 4.5 feet above base; grades upward into several feet of spiculiferous limestone; thin to thick bedded; basal contact sharp	22.2

Unit	Lithology	Thickness (feet)
	(4.5 feet above base - _I. ouachitensis_, _I. sinuosis_ reworked _Polygnathus_ sp.)	
19	Sandstone, reddish brown; fine to medium grained, sorted subangular quartz arenite; common organic wisps; tabular cross stratified; thick to very thick bedded; basal contact sharp	16.3
18	Sandstone and siltstone interbeds, rusty brown and tan; very fine grained quartz sandstone, argillaceous; thin to thick bedded; basal contact covered	5.4
	middle shale	203.8
17	Covered, scattered exposures of shale soil	203.8
	Chickachoc Chert	214.8
16,15, 14	Spiculite, dark blue-gray fresh, tan weathered; very fine grained; flaser, wavey and lenticular bedding; bioturbated; medium to thick bedded; when first described unit 15 was a covered interval; basal contact covered	21.5
13	Covered	20.5
12	Spiculite, as above, base covered	9.9
11	Covered	13.3
10	Spiculite, as above except common black chert nodules	9.6
9	Shale and covered; shale, dark blue-gray fresh, olive green or gray weathered; common clay-ironstone concretions; thin spiculite interbeds near base; basal contact gradational	15.6
8	Spiculite, as above	2.1
7	Covered with scattered shale soil	64.9

Unit	Lithology	Thickness (feet)
6	Spiculite, as above but less abundant chert	7.1
5	Shale, as above	12.1
4	Spiculite, dark blue-gray fresh, brown and black weathered; very fine grained; abundant shale partings; wispy structures; thin bedded; base covered	3.0
3	Covered	26.7
2	Spiculite, as above	8.5
	Springer Shale (?)	10.+
1	Shale, as above	10.+

SECTION 5

Pleasant Valley 3

This section is located 0.3 miles south of section 4 and on the same section line road as section 4. The section was measured on the east side of the road in the NW¼, NW¼, NW¼, sec. 32, T. 3 N., R. the E., Pittsburg Quadrangle, Pittsburgh County, Oklahoma.

Three members are exposed; in ascending order, these are: (1) Chickachoc Chert, (2) middle shale, and (3) upper sandstone limestone. Conodonts were recovered from only one thin calcarenite at the top of unit 6 (Chickachoc Chert). The unit produces a conodont fauna belonging to the N. kanumai I. ouachitensis zones. This section in conjunction with sections 17, 3, and 4 constitute an important basinward reference sequence. This locality is stop 40 in the Oklahoma Geological Society Guidebook 19.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	549.3
	upper sandstone/limestone member	158.90
16	Micritic limestone, light gray fresh, medium gray weathered; calcilutite; abundant rugose corals in upper one-third of unit, occur mostly on bedding plane surpaces, many appear in near life position; abundant tabular algae in basal bed; some nodular chert; medium to thick bedded; base covered	60.0

Unit	Lithology	Thickness (feet)
	(top-calcilutite: algal lime mudstone)	
	(base-coarse calcarenite: fossil, algal lime packstone)	
	(conodont sample basal 1.0 foot- A. lautus)	
15	Covered	7.2
14	Sandstone, rusty brown or tan; medium to fine grained, well to poorly sorted, subangular quartzarenite; abundant crinozoan molds; plane laminations in lower part; thin to medium bedded; abundant iron staining; base covered	8.6
13	Covered	9.1
12	Sandstone, rusty brown to red; to medium grained, well sorted, subangular quartzarenite; upper one half of unit tabular cross bedded; abundant crinozoan molds; very thick to thin bedded; base covered	45.6
11	Covered	4.4
10	Sandstone, rusty brown, tan or brown; fine to medium grained, well sorted, subangular quartzarenite; rare crinozoan molds; slightly argillareous and common organic wisps near base; thin to very thick bedded; base covered	24.0
	middle shale member	288.0
9	Mostly covered, thin scattered exposures of shale and a 1.0 foot ferruginous calcaremite about 200 feet above the base of the unit; basal contact covered	288.0
	Chickachoc Chert Member	102.4
8	Spiculite, dark blue-gray fresh, tan weathered; very fine grained; wavey, lenticular and flaser bedding; burrow mottling; thin to medium bedded; base covered	3.0
7	Covered	19.8
6	Spiculiferous limestone, dark blue-gray or medium gray fresh, tan weathered;	

Unit	Lithology	Thickness (feet)
	thin (4 inch) crinozoan calcarenite at top of unit; abundant blue-black chert nodules particularly in upper part; medium to thick bedded; base covered	15.6
	(base - calcisiltite: spicule lime packstone)	
	(conodont sample top 4 inches - *I. sinuosis*, *I. ouachitensis*, *N. clarki*, *N. kanumai*)	
5	Covered	24.8
4	Spiculite, dark blue-gray fresh, tan weathered; very fine grained; wispy structures; very thin to thick bedded; base covered	2.3
3	Covered, spiculite rubble in lower 20-25 feet	35.2
2	Spiculite, pervasively weathered; tan; thin bedded; base covered	1.7
1	Covered	-

SECTION 6

Hartshorne Quarry

This section located in the NW¼ NW¼, sec. 18, T. 4 N, R. 17 E, Hartshorne Quadrangle, Pittsburg County, Oklahoma, was measured on the Western Wall of an abandoned cement quarry cut into Limestone Ridge. The quarry is most easily reached by driving south on 7th Street from Hartshorne, Oklahoma, about 1.5 miles to the park area just north of the spillway on Hartshorne Lake. Walk east-northeast from this area across a small pasture and then ascend Limestone Ridge, about a quarter of a mile, to the quarry floor. Proceed to the prominent quarry wall along the western margin of the cut.

The Wapanucka is exceptionally well exposed at this locality. The lower limestone, middle shale and upper sandstone/limestone members are present. Only the Idiognathoides convexus and Neognathodus N. kanumai - Idiognathoides ouachitensis zones occur.

Section 6, in conjunction with sections 9, 30 and 10 which are located on basinward fault blocks, comprises the basinward reference sequence for the Hartshorne area.

Published descriptions of this section can be found in Harlton (1938) and Rowett and Sutherland (1964), their descriptions differ considerably from that presented in this study. An unpublished section prepared by Ham and Rowland in 1964 is basically the same as that found by the author although the present day exposure is less complete at its base.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	
	upper sandstone/limestone member	25.0
31	Spiculiferous chert rubble exposed at crest of ridge just north of quarry	1+
30	Covered	15.0+
29	Sandstone, rusty red weathered; fine grained, well sorted quartz sand; unit caps crest of ridge; thin even beds; basal contact gradational	6.0
	middle shale member	15.0
28	Silty shale and thin sandstone interbeds, base of unit not soon in direct juxta-position with underlying unit	15.0
	lower limestone member	209.2
27	Bioclastic limestone, light gray fresh, medium gray and rusty red weathered; medium calcarenite; trough cross-bedded in upper sandy part of unit, trough axis oriented perpendicular to strike of ridge; abundant crinozoan bioclasts, rate to common ramose bryozoans and rugose corals, fossils decrease in abundance upward; thick bedded, basal contact sharp	3.0
	(N. kanumai and I. ouachitensis)	
26	Micritic limestone, blue-gray fresh, weathers medium gray or tan; calcilutite with thin interbeds of argillaceous algal limestone; rare crinozoans, brachiopods and rugose corals; medium to thick bedded; basal contact gradational	5.5
25	Micritic limestone, medium gray fresh and	

	weathered; calcilutite; rare to common algal flakes, crinozoan bioclasts and rugose corals; single bed with gradational basal contact	8.5
24	Micritic limestone, blue-gray fresh, weathers buff; calcilutite; abundant algal flakes, rare crinozoan bioclasts and rugose corals; argillaceous; medium bedded; basal contact gradational	3.8
23	Bioclastic limestone, blue-gray fresh, brown or buff weathered; fine to medium calcarenite; well sorted, sandy abundant crinozoan bioclasts and ooliths; current laminated; thick bedded; basal contact sharp	3.0
22	Shale, greenish gray; fissile, forms re-entrant due to differential weathering; basal contact gradational	1.0
21	Ferruginous limestone, brick red; coarse calcarenite; abundant crinozoan bioclasts, common ramose bryozoans, michelinid and rugose corals, and brachiopods; common clay clasts near base; current laminated, single bed with sharp erosive basal contact	3.5
20	Shale, as above	0.4
19	Micritic limestone, light gray fresh and weathered; pseudo-brecciated calcilutite, rare rudite crinozoan bioclasts, common medium interbeds of medium calcarenite; crinozoan lime packstone in upper part of unit; medium to very thick bedded; basal contact sharp and irregular, and marked by bioturbation	21.5
18	Spiculiferous limestone, light gray fresh, mottled gray and tan weathered; calcilutite to very fine calcarenite, common spiculos, rare crinozoans and brachiopods, thin irregular to nodular beds; basal contact sharp and uneven	10.5
17	Bioclastic limestone, medium gray fresh, weathers gray-brown; very coarse calcarenite; abundant crinozoan bioclasts, common small productid brachiopods; sandy, current laminated possibly tabular cross-bedding; very thick bedded; basal	

Unit	Lithology	Thickness (feet)
	contact sharp and irregular	7.0
	(top 1.0 foot - _I_. _ouachitensis_)	
16	Bioclastic limestone with thin irregular calcareous sandstone interbeds; medium gray fresh, mottled gray and red-brown weathered; abundant crinozoan bioclasts; sandy and glauconitic; tabular cross bedded; thin to medium bedded; basal contact sharp	3.4
15	Bioclastic limestone, light gray fresh and weathered; coarse calcarenite; abundant algal sand and crinozoan bioclasts in a micritic matriz; rare chert nodules; single bed with abruptly gradational contact	6.0
14	Micritic limestone, light gray fresh and weathered; calcilutite; pseudo-brecciated; rare crinozoan bioclasts; rare chert nodules; very thick bedded; basal contact sharp	19.0
13	Oolitic limestone, light gray fresh and weathered; medium to coarse calcarenite; abundant ooliths, crinozoan bioclasts and coated grains; thick bedded; basal contact sharp	5.0
	(top 1.0 foot - _I_. _convexus_)	
12	Limestone, medium gray fresh and weathered; calcilutite to very fine calcarenite; spiculiferous, common crinozoan bioclasts; common chert nodules distributed parallel to bedding; massive to thick bedded; basal contact sharp	5.0
11	Carbonaceous limestone, medium gray fresh and weathered; coarse calcarenite; abundant ooliths and crinozoan bioclasts, common trachospiral gastropods, abundant carbonized plant debris; common thin argillaceous partings; thick bedded; sharp slightly irregular basal contact	2.6
10	Spiculiferous limestone, light green-gray fresh, weathers buff; very fine calcarenite; rare crinozoan bioclasts;	

Unit	Lithology	Thickness (feet)
	abundnat chert nodules; beds exhibit distinctive ropey appearance; medium bedded; basal contact gradational	5.5
9	Spiculiferous chert, blue-gray fresh, weathers buff; calcisiltite; laminated; very thin to medium bedded; basal contact covered	14.5
8	Covered	9.0
7	Micritic limestone, medium gray fresh and weathered; calcilutite; rare crinozoan bioclasts and shale infilled burrows; single bed with sharp basal contact	1.7
6	Shale, blue-gray, fissile clay shale with sharp basal contact	0.5
5	Micritic limestone, medium gray fresh and weathered; pseudo-brecciated calcilutite; rare crinozoan bioclasts; abundant black chert nodules along bedding; upper-most surface of unit bioturbated; thick to very thick bedded; basal contact gradational	6.0
4	Limestone, red-brown fresh, light gray weathered; medium to coarse calcarenite; grades upward from crinozoan calcarenite to oolite; single bed with sharp irregular basal contact	1.3-1.5
3	Micritic limestone, blue-gray fresh, weathers medium gray; calcilutite; common rudite-size crinozoan bioclasts; argillaceous, common thin shale partings or interbeds; very thick bedded; base covered	21.0
2	Covered	38.0
1	Oolitic limestone, gray-brown fresh and weathered; medium calcarenite; abundant ooliths, common crinozoan bioclasts in a sparry calcite matrix; thick bedded; base covered	2.8

SECTION 7

Powerline Cut

This section was measured in a powerline cut that bisects the second Wapanucka ridge. Access, to the exposure, is best attained by driving 2.4 miles to the northeast on the gravel road that also provides access to section 8 (Natural Arch). The Powerline Cut is located on the south-east side of the gravel road in the NW¼ NE¼, sec. 6, T. 3 N, R. 16 E., Hartshorne SW Quadrangle, Pittsburg County, Oklahoma.

Three conodont zones can be recognized at this section: they are, in ascending order: the *Idiognathoides convexus* zone, the *Neognathodus N. kanumai* - *Idiognathoides quachitensis* zone, and the *Streptognathodus elegantulus* zone. The *Diplognathodus orphanus* zone is not recognized because of the non-occurrence of the zonal name bearer.

Section 7 and section 8 located to the northeast on Limestone Ridge, comprise a basinward reference sequence for the Arch area.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	558.0
	upper sandstone/limestone member	61.7
31	Micritic limestone, light gray fresh, weathers medium gray; calcilutite;	

Unit	Lithology	Thickness (feet)
	common crinozoan bioclasts and small birdseye structures and algal debris; thick to very thick bedded; basal contact sharp	10.3
	(top- calcilutite: crinozoan lime mudstone)	
30	Spiculiferous limestone and chert nodules, medium gray fresh, weathers tan or black; calcisiltite; abundant well preserved plant debris scattered on bedding plane surfaces; thick bedded; basal contact sharp	9.4
	(top - calcisiltite: spicule packstone)	
29	Limestone, light gray fresh, weathers medium to dark gray; fine calcirudite; abundant crinozoan bioclasts with sparry calcite overgrowths and ramose bryozoans; vaguely current laminated; thin to medium bedded; basal contact obscurred by talus	3.9
	(top - fine calcirudite: ramose bryozoan-crinozoan lime packstone)	
	(conodont sample top 1.0 foot - S. elegantulus and I. sinuosis)	
28	Spiculiferous chert, blue gray fresh, weathers rust red, gray or black; rare fossil molds; weathers to pinky sandstone appearance; thick bedded; nature of basal contact uncertain	11.3
27	Bioclastic limestone, dark gray fresh and weathered; fine calcirudite; abundant crinozoan bioclasts and forams; silty and common chert nodules parallel to bedding; vaguely current laminated; single bed, base covered	2.2
	(top - medium calcarenite: foram - crinozoan lime packstone)	
	(conodont channel sample - S. elegantulus, N. kanumai, I. ouachitensis and I. sinuosis	
26	Covered and thin chert beds	11.3

Unit	Lithology	Thickness (feet)
25	Bioclastic limestone, medium gray fresh weathers dark gray; coarse calcarenite to fine calcirudite; abundant crinozoan bioclasts and oolites, common ramose bryozoans; very sandy in lower part; shale clasts near base; thin to very thin bedded; basal contact gradational	6.1
	(base - medium calcarenite: sandy sorted, crinozoan lime grainstone)	
	(top - medium calcarenite: sandy, poorly sorted, oolith. bryozoan, crinozoan lime grainstone)	
	(conodont sample top 1.0 foot - _I. ouachitensis_ and _I. sinuosis_)	
24	Sandstone, tan, rusty-brown or gray; fine to medium grained, sorted quartz sand; ferruginous cement; horizontal laminations; medium to thick bedded; basal contact covered	12.0
	(base - fine grained, sorted quartzarenite)	
	(top - medium grained, well sorted, quartzarenite	
	middle shale member	85.0
23	Covered	85.0
	lower limestone member	385.5
22	Bioclastic limestone, medium gray fresh and weathered; coarse calcarenite; abundant crinozoan bioclasts, common bryozoan and molluscan shell fragments including gastropods, rare brachiopods, spiculiferous in lower part; current laminated; medium bedded; basal contact sharp and slightly irregular	10.3
	(top - coarse calcarenite: crinozoan lime grainstone)	
	(conodont sample - _I. ouachitensis_ and _I. sinuosis_)	

Unit	Lithology	Thickness (feet)
21	Spiculiferous limestone, dark blue gray fresh, weathers brown or tan and becomes porous; calcisiltite; abundant chert nodules and stringers; very thin to medium bedded; basal contact obscurred by soil	18.3
	(base - calcisiltite: spicule packstone)	
20	Micritic limestone, light gray fresh, weathers dark gray; calcilutite; rare crinozoan detritus, spicules become common in upper part; thin to thick bedded; nature of basal contact not clearly evident	15.5
	(base - calcilutite: lime mudstone)	
19	Micritic limestone and subequal covered intervals, blue gray fresh, weathers medium gray; calcilutite; rare to common algal and crinozoan bioclasts; common chert nodules; medium to thick bedded; basal contact covered	49.8
	(base - calcilutite: spiculiferous, fossil lime wacketstone)	
	(top - calcilutite: fossil lime mudstone)	
18	Micritic limestone, light gray fresh, weathers medium gray; calcilutite; abundant phylloid algae, rare crinozoan bioclasts; abundant chert nodules; medium to very thick bedded; base covered	12.2
	(top - calcilutite: algal lime mudstone)	
17	Micritic limestone, light gray fresh, weathers white; calcilutite; abundant phylloid algae; medium to thick bedded; basal contact covered	5.2
	(top - calcilutite: algal lime mudstone)	
16	Covered	13.2

Unit	Lithology	Thickness (feet)
15	Bioclastic limestone, blue grey fresh, weathers medium gray; medium calcarenite to calcilutite; abundant crinozoan bioclasts in lower part of unit; common ramose bryozoans and brachiopod debris; very thin to thick bedded; basal contact sharp	10.8
	(base - fine calcarenite: spicule-crinozoan lime packstone)	
	(top - calcilutite: tubular algae lime boundstone)	
	(6.0 feet above base - A. lautus, I. sinuosis, and I. convexus)	
	(basal 1.0 foot - A. lautus)	
14	Micritic limestone, dark blue gray fresh, weathers light gray,; calcilutite; common crinozoan bioclasts, ramose and encrusting bryozoans; abundant chert nodules generally disposed along bedding; medium to very thick bedded; basal contact sharp	5.3
	(base and top - calcilutite: bryozoan-crinozoan lime wackestone)	
13	Micritic limestone, medium gray fresh, weathers light gray; calcilutite; common crinozoan bioclasts and tubular algae, rare gastropods and brachiopods; medium to very thick bedded, beds, slightly irregular in thickness; basal contact covered	14.3
	(base - calcilutite: fossil lime wackestone)	
12	Covered	3.3
11	Bioclastic limestone, blue gray fresh, light gray weathered; calcilutite; common crinozoan bioclasts, brachiopods and bryozoans; argillaceous; irregular bedding with shale partings; thick beds; basal contact covered	1.7
	(top - calcilutite: bryozoan, crinozoan	

Unit	Lithology	Thickness (feet)
	lime wackestone)	
	(conodont sample barren)	
10	Covered	110.0
9	Calcareous sandstone, medium grey fresh, rusty brown weathered; very fine to fine grained quartz sand; poorly sorted, argillaceous; glauconitic, common crinozoan bioclasts; thin bedded; basal contact covered	2.6
8	Covered	0.6
7	Bioclastic limestone, medium gray fresh, weathers brownish-gray, medium calcarenite; abundant crinozoan bioclasts, ooliths and ramose bryozoans, rare brachiopods; thin to medium bedded; basal contact covered	4.9
	(top - coarse calcarenite: oolith, crinozoan lime packstone)	
	(top 1.0 foot - *I. convexus* and *I. sinuosis*)	
6	Covered	11.5
5	Bioclastic limestone, dark gray fresh, weathers brown; medium calcarenite; abundant crinozoan bioclasts, common bryozoans and brachiopod fragments, common subvertical burrows in upper part of bed; unit contains siliceous sandstone clasts similar to underlying unit; single bed, sharp slightly erosive basal contact	0.5
	(medium calcarenite; bryozoan, crinozoan lime packstone)	
	(*I. convexus* and *I. sinuosis*)	
4	Siliceous siltstone, dark blue-gray fresh, weathers tan; very fine grained; common spicules; single bed, base covered	2.0
3	Covered	8.6

Unit	Lithology	Thickness (feet)
2	Spiculite, dark blue-gray fresh, weathers brown; calcisiltite; very thin beds some of which appear rippled; weak flaser and lenticular bedding; basal contact gradational	0.9
	"Springer" Shale	
1	Shale, blue gray, platy-fissile shale with rare siderite concretions	10+

SECTION 8

Natural Arch

This section was measured on the west wall of the natural arch cut by a tributary of Brushy Creek in the NW ¼, sec. 11, T. 3 N., R. 15 E., Hartshorne SW Quadrangle, Pittsubrgh County, Oklahoma. The Natural Arch is on the property of Raymond Goddard, his ranch can be reached from Oklahoma 63 in Blanco, Oklahoma. Take the second gravel road, at the northeast edge of Blanco, to the southeast frc a distance of 3.8 miles. Turn to the north on the gravel road that parallels Limestone Ridge. Travel along this road 1.4 miles to the gravel driveway from the north that descends Limestone Ridge to the home of Raymond Goddard. The section was measured on the southwest side of a small creek that forms a natural arch in Limestone Ridge. Section 8 which is located on Limestone Ridge and section 7 to the northeast constitute the basinward reference sequence for the Arch area.

Three conodont zones are recognized at this section; they are in ascending order: Idiognathoides convexus zone, Idiognathoides ouachitensis - Neognathodus n. kanumai zone and the Streptognathodus elegantulus zone. The Diplognathodus orphanus zone is not recognized because of the non-occurrence of the zonal name-bearer.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	383.1
	upper sandstone/limestone member	64.4
32	Micritic limestone, light gray weathers medium gray; calcilutite; common algal blades, crinozoan columnals, forams and ostracods; "birdseyes" rare chert nodules in lower part; medium to very thick bedded; basal contact sharp	24.5
	(base and top - calcilutite; lime mudstone)	
31	Interbedded calcareous sandstone and sandy limestone; light to medium gray fresh; weathered medium gray; tan and brown; sandstone, at top of unit; fine to medium grained; limestone at base of unit medium calcarenite, abundant crinozoan bioclasts and some ooliths; unit contains brachiopod, rugose corals, forams, and spired gastropods; rare plant fragments; tabular cross-bedded in lower part; rare chert nodules; tabular cross-bedded in lower and upper part; thick to very thick bedded; base gradational	14.2
	(base - medium to coarse calcarenite: sandy poorly sorted, oolith, crinozoan lime grainstone)	
	(10.0 feet above base - _D. orphanus_ and _S. elegantulus_)	
30	Sandstone, light to medium gray, weathers to rust red; fine grained quartz sand, poorly sorted quartzarenite; calcareous, abundant crinozoan bioclasts and coated grains; common spiriferid brachiopods siliceous spicules; tabular cross-bedded in lower part; rare chert nodules; thin to thick bedded; base covered	12.7
29	Covered	6.1
28	Sandstone, light gray, weathers brown, black and brick-red; fine to medium grained, sorted quartzarenite; common crinozoan bioclasts and fenestellid	

Unit	Lithology	Thickness (feet)
	bryozoans; ferruginous cement; thick bedded; base covered	7.0
	middle shale member	35.2
27	Covered	35.2
	lower limestone member	248.3
26	Micritic limestone, light gray fresh, weathers medium gray; calcilutite; common spar blebs and infilled algal blades; severely altered diagenetically to pseudopeloidal texture in upper part; medium to thick bedded; base covered	12.3
	(base and top - calcilutite; crinozoan lime mudstone)	
25	Covered	16.0
24	Bioclastic limestone, medium gray fresh, weathers light gray; coarse calcarenite to fine calcirudite; sandy; abundant crinozoan, brachiopod and ramose bryozoan bioclasts, many grains micritized; medium to thick bedded; basal contact sharp	7.8
	(base and top - coarse calcarenite; ramose bryozoan crinozoan lime packstone)	
	(top 1.0 foot - _I._ _sinuosis_ and _I. ouachitensis_)	
23	Micritic limestone, light to medium gray fresh and weathered; calcilutite except medium calcarenite near base; rare to common crinozoan columnals and brachiopods; abundant anastomosing chert; medium to very thick bedded; basal contact gradational	10.2
	(base - fine calcarenite; crinozoan, peloid packstone)	
	(top - calcilutite: crinozoan mudstone)	
22	Spiculiferous limestone, medium gray weathers	

Unit	Lithology	Thickness (feet)
	dark gray; calcisiltite; abundant sponge spicules, rare crinozoan bioclasts; anastomosing chert; partly covered may represent slab interbeds; thin to medium bedded; basal contact gradational	11.2
21	Micritic limestone, medium gray weathers white; calcilutite; common crinozoan detritus and rare gastropods; considerable part of unit covered which may represent shale interbeds; common chert nodules; medium to thick bedded; basal contact sharp	11.3
20	Bioclastic limestone, light gray fresh weathers medium gray; coarse calcarenite; abundant crinozoan bioclasts, rare poorly preserved brachiopods; rare spiculiferous limestone intraclasts; very thick bedded; basal contact sharp	5.7
	(top - coarse calcarenite; ramose bryozoan, crinozoan grainstone)	
	(conodont sample top 2.0 feet - <u>I. sinuosis</u>)	
19	Siliceous spiculiferous limestone; blue-gray weathers medium gray; calcisiltite; abundant spinge spicule; abundant chert nodules; thin to medium bedded; basal contact sharp	2.7
	(top - calcisiltite: spicule packstone)	
18	Siliceous spiculiferous limestone, dark blue-gray fresh weathers gray and becomes porous (tripoli); abundant siliceous sponge spicules, common crinozoan detritus, brachs, and gastropods; very thin to medium bedded; abundant chert; part of unit that is covered may be shale interbeds; basal contact covered	2.7
17	Siliceous spiculiferous limestone, blue-gray fresh weathers medium gray and buff; calcisiltite, abundant sponge	

Unit	Lithology	Thickness (feet)
	spicules and rare crinozoan bioclasts; thin to medium bedded; basal contact covered	12.0
	(top - fine calcarenite; argillaceous, spicule packstone)	
16	Covered	8.2
15	Micritic limestone, dark blue-gray fresh, weathers medium gray common spicules and crinozoan bioclasts; abundant chert replacement; medium to very thick bedded; basal contact gradational	8.2
	(base - calcilutite: fossil mudstone)	
14	Limestone, light gray weathers medium gray; calcilutite; rare to abundant crinozoans and algal blades; single bed; base sharp	1.3
	(base - calcilutite:lime mudstone)	
	(conodont channel sample - *A. lautus*)	
13	Oolitic limestone, medium gray fresh and weathered; fine calcarenite; abundant ooliths and coated grains; sorted bioclastic debris at base; rare chert nodules; tabular cross-bedded (accretion); thick to medium bedded; basal contact gradational	
	(base and top - medium calcarenite: well sorted, oolith grainstone)	
	(conodont basal 1.0 foot - *I. convexus*, *I. sinuosis*)	
12	Oolitic limestone, light gray weathers medium gray, coarse to medium calcarenite; well sorted; abundant ooliths and coated grains, common thin lenses with abundant crinozoan bioclasts; rare limestone intraclasts; trough and tabular cross-bedded; rare chert nodules; medium to very thick bedded; basal contact sharp	7.9

Unit	Lithology	Thickness (feet)
	(top - medium calcarenite: well sorted, bioclastic, oolite grainstone)	
	(conodont top 1.0 foot - _I. convexus_, _I. sinuosis_)	
11	Bioclastic limestone medium gray fresh and weathered; medium calcarenite; well sorted crinozoan bioclasts and oolites; thick-bedded weathers thin-bedded with noticeable current-bedding; basal contact sharp	3.3
	(top - medium calcarenite: crinozoan packstone)	
	(conodont channel sample - _I. convexus_, _I. sinuosis_)	
10, 9	Siliceous spiculiferous limestone, dark blue-gray weathers light gray; calcisiltite; common crinozoan bioclasts particularly in upper part; common chert nodules; thin to medium bedded; some thin covered intervals may represent shale interbeds; basal contact covered	21.3
	(base - calcisiltite: spiculiferous packstone)	
	(top - medium calcarenite: crinozoan, spiculiferous packstone)	
8	Covered	13.1
7	Oolitic limestone, medium gray fresh and weathered; coarse to medium calcarenite, fines upward; abundant oolites and crinozoan bioclasts; tabular cross-beds in lower part; thick to very thick bedded; base slumped but contact appears sharp	6.5
	(base - coarse calcarenite: oolith grainstone)	
	(top - coarse calcarenite: crinozoan, oolith packstone)	
	(conodont sample basal 1.5 feet - _I. convexus_)	

Unit	Lithology	Thickness (feet)
6	Siliceous spiculiferous limestone, blue gray fresh weathers light gray and tan with thin insoluable rind; common crinozoan bioclasts; very thin to medium bedded; basal contact covered	9.4
	(base - medium calcarenite; crinozoan, spiculiferous packstone)	
5	Covered	53.2
4	Bioclastic limestone, light gray weathers medium gray, coarse calcarenite; abundant crinozoan bioclasts in a micritic matrix; rare chert nodules; thick bedded; basal contact gradational	3.1
	(top - fine calcarenite: bryozoan, crinozoan packstone)	
	(conodont channel sample - _I. convexus_, _I. sinuosis_)	
3	Siliceous spiculiferous limestone; dark blue-gray weathers tan and with distinct rind; common crinozoan bioclasts; thin to thick bedded; abundant chert nodules; basal contact sharp	10.2
2	Siliceous limestone, dark gray weathers buff; coarse calcarenite; abundant crinozoan bioclasts, common ramose and encrusting bryozoans, rare brachiopods and pectenid bivalves; thin bedded; basal contact covered	4.3
	(conodont sample - _I. convexus_, _I. sinuosis_)	
1	Covered	4.3

SECTION 9

Blue Creek

This section begins in the SW¼ SW¼ SW¼, sec. 23 and ends in the NW¼ NW¼ NW¼, sec. 26, T. 4 N., R. 16 E., Hartshorne Quadrangle, Pittsburg County, Oklahoma. It is located on the property of Mr. Blanchard. The section was measured adjacent to the country road and west of the Blanchard's fence line; it begins to the north of the house near the country road, passes well in front of the house and ends in the valley of Blue Creek. The Blanchard's residence can be reached by driving south on 7th Street from Hartshorne, Oklahoma, a distance of 4.9 miles.

The lower limestone, middle shale and upper sandstone/limestone are exposed. Conodonts (belonging to the *I. convexus* zone) were recovered from only one sample in the lower limestone.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	410.0
	upper sandstone/limestone member	61.2
11	Sandstone, white fresh, weathers tan, black or red-brown; very fine to fine, well sorted subangular quartz sand; common covered intervals in lower part, upper more massive part contains tabular cross-bedding that apparently dips to southeast; thick to very thick bedded; basal contact covered	61.2

Unit	Lithology	Thickness (feet)
	middle shale member	137.0
10C	Covered	137.0
	lower limestone member	211.8
10B	Siltstone, poorly exposed in Blanchard's driveway near access road	5.0+
10A	Covered	15.0
9	Micritic limestone, light gray fresh, weathers medium gray; calcilutite; rare to common tabular algae, rare crinozoan bioclasts and rugose corals; abundant chert nodules; medium to thick bedded, common covered intervals in upper part; basal contact gradational	26.7
	(15.0 feet above base - calcilutite: crypt algal lime mudstone)	
	(top - calcilutite: tubular algae lime boundstone)	
8	Micritic limestone, light gray fresh, weathers medium gray; calcilutite, pseudo-brecciated; rare crinozoan bioclasts, brachiopod valves and gastropods; medium to very thick bedded; base covered	22.0
	(base - calcilutite argillaceous, crypt algal lime mudstone)	
	(11.0 feet above base - calcilutite: crypt algal lime mudstone)	
	(top - calcilutite: spicule, algal lime mudstone)	
7	Covered	2.4
6	Spiculiferous limestone, blue gray fresh, weathers to tan or brown with prominent rind on surface, conchoidal fracture; abundant fossils include sponge spicules,	

Unit	Lithology	Thickness (feet)
	crinozoan bioclasts, rugose and michelenid corals, gastropods, benthonic forams and algal encrusted grains; single bed, base covered	0.7
	(calcisiltite: spicule lime packstone laminae interbedded with medium calcarenite: spicule, fossil lime packstone)	
5	Covered	10.2
4	Micritic limestone, blue-gray fresh, weathers medium gray, calcilutite with prominent pseudo-brecciation in middle of unit; thin fossiliferous calcarenite at base; common chert nodules; medium to thick beds, basal contact covered	32.2
	(top - calcilutite cryptalgal lime mudstone)	
	(14.0 feet above base - calcilutite: crinozoan, cryptalgal lime wackestone)	
	(base - medium calcarenite: sandy, oolite, crinozoan lime packstone)	
	(basal 1.0 foot - *I. convexus* and *I. sinuosis*)	
3	Covered	91.4
2	Spiculiferous chert, rusty red or brown; common crinozoan molds, leaching of carbonate has resulted in anastomosing caverns; medium bedded, base covered	4.7

SECTION 10

New State Mountain

This section is located in the NE¼ SW¼, sec. 34, T. 4 N., R. 16 E., Hartshorne Quadrangle, Pittsburg County, Oklahoma. This area is part of the Blue Valley Road. Instructions for access to the ranch are provided in the discussion of section 9. The section begins in pasture immediately below main ranch house on hilltop and continues up the ridge to unit 3 and then is offset about 500 feet to the east.

The lower limestone, middle shale and upper sandstone/limestone members are thought to be present. Units 5 and 6 have been interpreted to be the upper sandstone/limestone but may in fact be sandstone in the upper part of the lower limestone. Additional work is needed to solve this problem. This section is stop 37 in Field Trip 11 of the Ninth International Congress of Carboniferous Stratigraphy and Geology (Sutherland and Manger, 1979).

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	247.7
	upper sandstone/limestone	58+
6	Sandstone, tan or rusty brown, fine grained, sorted subangular quartz sand; unit consists of tabular cross-bedded sets 2 to 4 feet in thickness that dip to the southwest and exhibit little dispersion,	

Unit	Lithology	Thickness (feet)
	most tabular sets are accretion types; rare crinozoan and brachiopod molds; thick to very thick bedded	50+
5	Sandstone, reddish-brown and tan; fine grained, sorted subangular quartz sand; medium bedded, base covered	7.9
	middle shale member	11.4
4	Covered	11.4
	lower limestone member	186.3
3	Micritic limestone, blue-gray fresh, weathers medium gray; calcilutite; rare crinozoan bioclasts; medium to very thick bedded; base covered	14.2
2	Covered	168.1
1	Spiculiferous chert, rusty brown, tan brick red or black; leaching of carbonate has resulted in a porous somewhat cavernous rock; unit forms axis of small anticline; medium bedded, base covered	4.0

SECTION 11

Red Oak South

This section is located in the SW¼ SW¼ SW¼, sec. 23, T. 5 N., R. 21 E., Red Oak Quadrangle, Latimer County, Oklahoma. The section was measured on the west side of the blacktop road. To reach this locality, turn south at the east edge of Red Oak from U.S. 270 onto a blacktop road. Drive 4.3 miles to a T intersection, turn east and drive an additional 1.7 miles to the highest exposed beds.

This outcrop represents the eastern most Wapanucka exposure. It is unusual in two respects: (1) the flysch facies of the Atoka Formation closely overlies the Wapanucka, and (2) the Wapanucka Formation is overturned to the north. This locality is stop 34A in the Oklahoma Geological Society Guidebook 19 (Sutherland and Manger, 1979).

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	276.3
	upper sandstone/limestone member (?)	276.3
10	Sandstone, red-brown; fine grained, calcareous, sorted quartz sand; abundant crinozoan molds; flaggy, cross-bedded; basal contact covered	9.8
9	Covered	4.9
8	Micritic limestone, light to medium gray fresh and weathered; calcilutite;	

Unit	Lithology	Thickness (feet)
	common crinozoans including basal cups, small brachiopods, algal strips and ostracods; thick to very thick bedded, base covered	13.7
7	Covered	1.0
6	Oolitic limestone, medium gray fresh, light gray weathered; fine calcarenite; abundant coated grains and ooliths, most have quartz sand nuclei, rare fossils; single bed, base covered	2.0
	(top - medium calcarenite: sandy, well sorted, oolite lime grain stone)	
	(Streptognathodus elegantulus)	
5	Covered	3.4
4	Sandstone, blue gray, tan or buff, siltstone to fine grained, sorted quartzarenite, siltstone with fucoids and Conostichus at base, common crinozoan molds; 18 feet above base abundant red weathering clay chips, medium to very thick bedded, basal contact gradational	64.4
3	Siltstone and shale interbeds	75.0
2	Shale and siltstone interbeds	100.0

SECTIONS 12 and 13

Bandy Creek North and Bandy Creek South

These sections were measured on a recumbent anticline exposed in Bandy Creek in the NE¼, sec. 20, T. 5 N., R. 19 E., Wilburton Quadrangle, Latimer County, Oklahoma. To reach these sections, take Highway 2 south 1.0 mile from its intersection with U.S. Highway 270 in Wilburton. Turn east (left) on a section line road and drive 0.3 miles to the small bridge that spans Bandy Creek. Walk south about 300 to 500 feet down Bandy Creek to the prominent sandstone ledge which marks the top of section 12. Section 12 (Bandy Creek North) represents the north, overturned limb of the recumbent anticline. Section 13 is the southern limb of the recumbent anticline.

The sections at this locality were measured by Cline (1968). His section is similar to that presented here but differs significantly in terms of total measured thickness. The thickness across the anticline determined is about 300 feet less than that reported by Cline (Bowsher and Johnson, 1968).

SECTION 12

Bandy Creek North

The present interpretation is that the lower limestone, middle shale and upper sandstone/limestone members occur. A possiblity exists, however, that measured units regarded as the middle shale (unit 2) and the upper sandstone/ limestone (unit 1) are really part of the lower limestone. Additional field study will shed light on this problem.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	242.8
	upper sandstone/limestone member	11.1
1	Sandstone, tan and reddish brown, medium grained, sorted quartzarenite; abundant fossil molds; common clay ironstone concretions; abundant shale clasts; a greater thickness of this unit is exposed to the east on the nearby Golf Course; thick to very thick bedded, base covered	11.1
	middle shale member	9.6
2	Covered	9.6
	lower limestone member	222.1
3	Micritic limestone, medium gray fresh, weather light gray, tan or orange-brown; calcilutite to calcisiltite; abundant spicules and tubular algae, calcilutite layers are pseudo-brecciated and contain tubular algae, calcisiltite layers contain mostly sponge spicules; abundant chert nodules; medium to very thick bedded, base covered	16.3
4	Covered	18.5
5	Calcareous sandstone and sandy limestone, sandstone at base; fine grained sandstone grades upward into fine calcarenite, both poorly sorted; sandstone contains abundant gastropods, brachiopods, crinozoans, rugose corals and oolites occur in limestone; thin to medium bedded, base covered	4.1
	(top - coarse calcarenite: sandy, molluscan, crinozoan lime packstone)	

Unit	Lithology	Thickness (feet)
	(top 1.0 foot - *I. convexus*)	
6	Covered	11.1
7	Spiculiferous limestone, dark gray fresh, weathers buff or medium gray; fine calcarenite; abundant sponge spicules and crinozoans, common ramose bryozoans; abundant shale partings and interbeds in lower part; common chert nodules; common euhedral pyrite, thin to medium bedded, base covered	9.3
	(top - fine calcarenite: argillaceous, crinozoan, spicule lime packstone, common shale filled subvertical burrows)	
8	Covered	159.0
9	Bioclastic limestone, dark gray fresh, weathers light gray and stained red or brown; coarse calcarenite to fine calcirudite; abundant crinozoan bioclasts, common ramose bryozoans, brachiopods, gastropods and oolites; sandy, argillaceous with thin reddish shale partings; common flat clay clasts that are heavily stained by limonite and siderite; abundant burrows in top 6 inches; medium bedded; this unit is unit F of Cline (1968); base covered	

Approximately, 400 feet of shale and cover between unit 9 and lowest exposed beds in section 13.

SECTION 13

Bandy Creek South

The lower limestone, middle shale and upper sandstone-limestone members are exposed in this limb. The lower limestone was measured in and along Bandy Creek. The middle shale and upper sandstone/limestone members were measured along Highway 2, to the west of the exposures in the creek.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	385.3
	upper sandstone/limestone member	74.8
25	Sandstone, tan and brown-red, medium grained, well sorted quartzarenite, ferruginous and siliceous cement; abundant crinozoan and brachiopod molds; tabular cross-bedded, dip to south, basal contact gradational	53.7
24	Siltstone and shale interbeds; abundant vertical plug shaped burrows and fucoids; basal contact gradational	21.1
	middle shale member	50.2
23	Shale, blue-gray fresh and weathered; common clay-ironstone concretions; much of unit is covered, base covered	50.2
	Offset on unit 22 to east into Bandy Creek	
	lower limestone member	260.3
22	Micritic limestone, blue-gray fresh, weathers tan and medium gray; calcilutite, pseudo-brecciated; common algal debris, rare crinozoans and rugose corals; medium to very thick bedded, base covered	9.7
	(top - calcilutite: algal lime mudstone)	
21	Covered	10.2
20	Oolite limestone and covered, medium gray fresh, weathers brown or rusty brown; medium calcarenite; sandy; abundant ooliths and coated grains in lower limestone beds,	

Unit	Lithology	Thickness (feet)
	becomes argillaceous and contains crinozoans and brachiopods in highest bed; base covered	15.8
	(top - coarse calcarenite; sandy, crinozoan lime packstone)	
	(7.8 feet up - medium calcarenite: sorted, fossil, oolith lime grainstone)	
	(7.0 to 8.0 feet up - I. convexus)	
19	Covered	3.9
18	Spiculiferous limestone, dark blue-gray fresh, weathers medium gray; calcisiltite; abundant chert nodules, medium bedded, base covered	3.9
	(top - calcisiltite; argillaceous, spicule limes packstone)	
17	Covered	7.4
16	Spiculiferous limestone, medium gray, weathers brown; fine calcarenite; abundant spicules; crinozoan debris and brachiopods, laminated, shale partings; common vertical burrows infilled with shale; single bed, base covered	1.5
	(top - fine calcarenite: argillaceous, fossil, spicule lime packstone)	
15	Covered	5.5
14	Bioclastic limestone, light gray fresh, weathers medium gray, fine calcirudite to coarse calcarenite; abundant fossils and skeletal bioclasts grade upward into oolite; fossils include crinozoans, brachiopods, rugose corals, ramose bryozoans, oncolites and other algal coated grains; thick to very thick bedded, base covered	18.2
	(base - fine calcirudite: argillaceous,	

Unit	Lithology	Thickness (feet)
	oncolitic, crinozoan lime packstone)	
	(8.0 feet up - coarse calcarenite: ramose bryozoan, crinozoan lime packstone)	
	(top - coarse calcarenite: sorted, fossil, oolitic lime grainstone)	
	(8.0 to 9.0 feet up - I. convexus)	
13	Covered	22.6
12	Bioclastic limestone, medium gray fresh, weathers iron stained colors; medium to coarse calcarenite; basal lithology is medium calcarenite with abundant coated grains and ooliths in a sparry calcite matrix; tabular cross-bedded; this grades upward into a coarse calcarenite with abundant crinozoans, brachiopods, and rugose corals in a micritic matrix, bioturbated; medium bedded, base covered	5.4
11	Covered	8.8
10	Sandstone, light to medium gray fresh, weathers buff and orange brown; very fine grained, argillaceous, unsorted quartz sand; thin to thick beds with thin shale partings and abundant bioturbation markings particularly Conostichus; hint of remenant cross-bedding; base gradational	3.5
9	Shale, blue-gray fresh and weathered; calcareous; fissile; common thin siliceous, silty layers; basal contact obscured by talus	37.1
8	Bioclastic limestone, dark gray or brown; coarse calcarenite; abundant crinozoans, heavily bioturbated, burrows infilled with shale; base sharp	2.1
	(top - coarse calcarenite: sandy,	

Unit	Lithology	Thickness (feet)
	crinozoan lime packstone)	
	(top 1.0 foot - _I._ _convexus_)	
7	Bioclastic limestone, dark gray fresh, medium gray and orange-brown weathered; coarse calcarenite, abundant fossils, oncolites, crinozoans, spiriferid and productid brachiopods, and ramose and fenestellid bryozoans; base covered	4.1
6	Covered	15.0
5	Sandstone, medium gray fresh, reddish brown weathered; medium grained, sorted quartzarenite; calcareous; tabular cross-bedded, dip to southeast; rare crinozoans and spicules; common intraclasts, composed of shale, clay ironstone and spiculiferous limestone; common oolitic coats on sand grains; medium to thick bedded, base covered	4.7
4		46.4
3	Bioclastic limestone, dark gray fresh, weathers medium gray; medium to coarse grained calcarenite; abundant crinozoans, ramose bryozoans and brachiopods, common molluscan debris including gastropods, rare oolites; argillaceus, sandy; abundant burrows which are mostly filled by shale; abundant chert nodules and clay-ironstone concretions; medium to very thick bedded, base covered	1.8
	(top - fine calcirudite: sandy, fossil lime packstone)	
	(top 1.0 foot - _I._ _convexus_)	
2	Covered	23.8
1	Sandstone, calcareous; dark gray fresh, brown with red stringers weathered; fine to medium grained, poorly sorted	

Unit	Lithology	Thickness (feet)
	quartz sand and fossils including crinozoans, ramose bryozoans, tabulate corals, brachiopods and gastropods; common shale partings; thin to medium bedded, base covered	8.9

Approximately, 400 feet of shale and cover to base of section 12.

SECTION 14

Spring Creek Gap

This section is located in the center of the west ½ of sec. 23, T. 5 N., R. 20 E., Red Oak Quadrangle, Latimer County, Oklahoma. The section is located on the new road across Limestone Ridge about 0.3 miles west of Spring Creek Gap. To get to this section, drive south from U.S. Highway 270 in Wilburton on Highway 2, one mile. Turn east on the section line road and drive 9.0 miles to Cravens School. Turn south and drive 0.3 mile to the lowest exposures on Limestone Ridge.

Units 1-7 (not reported) represent the north overturned limb of a recumbent anticline. Their stratigraphic assignment is uncertain. Units 8-14 represent the south limb of the anticline and include the lower limestone, middle shale and upper sandstone/limestone members. At this locality the lower limestone is predominantly a terrigenous clastic facies.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	294.8
	upper sandstone/limestone member	31.5
14	Sandstone, tan, brown or black; fine grained at base becoming medium grained at top; well sorted quartz sand abundant southward dipping tabular cross-beds in upper part; base marked by clay clasts, common clay	

Unit	Lithology	Thickness (feet)
	ironstone concretions; medium to very thick bedded, base covered	31.5
	middle shale member	64.7
13	Covered	64.7
	lower limestone member	294.8(?)
12	Sandstone, red-brown, medium to coarse grained; abundant crinozoan molds; ferruginous cement; tabular cross-bedded, dip to south; thick to very thick bedded, basal contact sharp and slightly irregular, marked by small clay dikes	19.9
11	Shale, rusty red streaked with light gray; slightly silty and with some interbedded sandstone; basal contact gradational	17.3
10	Sandstone, multicolored including tan, brown, rusty red, orange-brown and purple; fine grained, sorted quartzarenite; a few thin siltstone interbeds; basal part of unit contains tabular cross-bedding, abundant fossils at 45-50 feet above base, at 80 feet above base common clay clasts occur, medium to thick bedded, base covered	94.6
9	Covered	158.0(?)
8	Micritic limestone, light gray fresh, medium gray weathered, calcilutite; common algal blades, crinozoans and ostracods; pseudobrecciated; single bed, base covered	4.6

SECTION 15

Wilburton Southeast

This section is located in the S½ NW¼, sec. 23, T. 5 N., R. 19 E., Wilburton Quadrangle, Latimer County, Oklahoma. To reach this locality travel south on Highway 2, one mile from its intersection with U.S. Highway 270 in Wilburton, Oklahoma. Turn east on the section line road and drive 2.1 miles. Turn south on the small gravel road and travel 1.0 mile to a point near a recently bulldozed area on Limestone Ridge just past the small lake. The section begins on the north side of the road and in the woods slightly east of the bulldozed field. The section was measured here up to unit 16 and then was offset to the east 0.2 miles. The upper part of the section was measured due north of road at the southeasterly flexure in the road beginning from the presumed base of unit 16.

The lower limestone, middle shale and upper sandstone/ limestone members occur at this locality. The lower limestone contains a thick sand unit (16) in its upper part which apparently becomes more prominent to the east. A micritic limestone similar to that found at the top of the formation in most of Atoka and Pittsburg Counties is present at the top of this section. Conodonts from the lower part of the lower limestone belonging to the _I. convexus_ zone were the only conodonts recovered.

Unit	Lithology	Thickness (feet)
	Atoka Formation	
24	Shale, olive gray; common sideritic clay-ironstone concretions; base not seen directly in contact with Wapanucka.	100+
	Wapanucka Formation	447.2
	upper sandstone/limestone member	121.4
23	Limestone, medium gray fresh and weathered; pseudo-brecciated calcilutite; rare crinozoans, fenestrate bryozoans and algae; abundant spar blebs, and iron-oxide blebs; some minor silicification; very thick bedded, basal contact gradational	15.8
	(top - calcilutite: bryozoan, crinozoan lime wackestone)	
22	Shale with some minor siltstone, light gray, basal contact gradational	7.9
21	Sandstone, rust brown, red and white; very fine to fine grained, poorly sorted, argillaceous quartz sand; abundant fossils, crinozoans, brachiopods and bryozoans, exceptionally well preserved, in place productids in upper 6 to 8 feet; top 30 feet contains shale interbeds; thin to thick bedded, basal contact gradational	27.7
20	Sandstone, orange-brown and rusty red; medium grained, well sorted quartzarenite; ferruginous and siliceous cement; common crinozoan molds; thin to medium at base, no apparent bedding in upper part; basal contact gradational	34.6
19	Silty shale and argillaceous sandstone interbeds, light gray, orange and red stains, basal contact gradational	8.4

Unit	Lithology	Thickness (feet)
18	Sandstone, rusty red; fine to medium grained, well sorted quartzarenite; abundant crinozoan molds; plane beds or south dipping tabular cross-beds in upper part; thin to very thick bedded, basal contact covered	27.0
	middle shale member	65.2
17	Covered	65.2
	lower limestone member	238.2
16	Sandstone, white, light gray, orange-brown or purple; fine to medium grained, sorted quartzarenite; ferruginous cement; tabular cross-bedded, dip to south or southeast; medium to very thick bedded, basal contact covered	33.0
15	Covered	60.1
14	Micritic limestone, blue-gray fresh, medium gray weathered; common crinozoans and brachiopods; abundant spar blebs; thick to very thick bedded; basal contact gradational	38.0
	(top - calcilutite: fossil lime mudstone)	
13	Bioclastic limestone, dark gray fresh, medium gray or light brown weathered; coarse calcarenite; abundant crinozoans, brachiopod valves, ramose and encrusting bryozoans, molluscans and oolites in a micritic matrix; thick to very thick bedded, base covered	
	(base - coarse calcarenite: oolitic, crinozoan lime packstone)	
	(basal 1.0 foot - *I. convexus*)	
12	Covered	57.6
11	Oolitic limestone, dark gray fresh,	

Unit	Lithology	Thickness (feet)
	medium gray or orange-brown weathered; coarse calcarenite; abundant ooliths and crinozoan bioclasts, common fistuliporid bryozoans and brachiopods; siliceous matriz, abundant iron-oxide blebs; moldic porosity; single bed, base covered	5.7
	(base - medium calcarenite; sandy, poorly sorted, oolite lime grainstone)	
	(basal 1.0 foot - I. convexus)	
10	Covered, scattered exposures of shale	13.7
9	Bioclastic limestone, blue-gray fresh, medium gray and tan weathered; coarse calcarenite, abundant crinozoans bioclasts and ramose bryozoans; sandy, moderate surface silicification; unit thickens and thins; single bed with load casts at base, base sharp	2.3
	(top - coarse calcarenite: bryozoan, crinozoan lime packstone)	
	(I. convexus)	
8	Spiculiferous chert with minor shale interbeds, very pervasively tripolized; orange-brown; abundant molds of crinozoan stems and columnals; medium bedded, base covered	14.7
7	Bioclastic limestone, medium gray fresh, weathers light gray or white, calcilutite to fine calcirudite; rare to common fistuliporid bryozoans, crinozoans, algal fragments and spicules; thick bedded; basal contact gradational	2.5
	(top - fine calcirudite: bryozoan lime wackestone)	

Unit	Lithology	Thickness (feet)
6	Spiculiferous chert, dark gray fresh, weathers brown and porous; calcisiltite, common crinozoans columnals and molds; appears flaser bedded; thin to medium bedded, base covered	5.8
5	Covered	10.4
4	Spiculiferous chert, as above	2.5
3	Covered	7.5
2	Spiculiferous chert, as above	2.0

Units 2 and 4 might represent slump blocks, nature of exposure precludes satisfactory determination of their stratigraphic significance.

SECTION 16

Indian Nation Turnpike 2

This section is located on the Indian Nation Turnpike 0.5 miles south of section 2 (see section 2 for detailed discussion regarding access). The section was measured on the east side of the turnpike except for the highest beds; the section is located in the S½, NW¼, sec. 19, T. 3 N., R. 15 E., Pittsburg Quadrangle, Pittsburg County, Oklahoma.

This exposure is located on the first fault repeated ridge south of Limestone Ridge. The lower limestone and Chickachoc Chert are present, from this section the Lower Limestone pinches out southward and the Chickachoc thins northward. Together sections 16, 19, 2 and 1 constitute the most important basinward reference sequence of Wapanucka zections.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	441.5
	upper sandstone/limestone member	19.2
30	Micritic limestone, medium gray fresh and weathered; calcilutite; common crinozoan bioclast, rare rugose corals; pseudo-brecciated; thick bedded; base covered	4.9
	(top - calcilutite: ostracod lime mudstone)	
29	Covered	6.0

Unit	Lithology	Thickness (feet)
28	Bioclastic limestone, medium gray fresh, brown or buff weathered; fine calcarenite, well sorted crinozoan bioclasts and ooliths; thick to very thick bedded; base covered	8.3
	(top - medium calcarenite: sandy, well sorted crinozoan, coated grain, lime grainstone)	
	(conodont sample basal 1.0 foot - *I. ouachitensis*, *I. sinuosis* and *Streptognathodus sp.*)	
	middle shale member	105.0
27	Covered, scattered exposures of shale	105.0
	lower limestone member	61.3
26	Bioclastic limestone, medium gray fresh and weathered; coarse calcarenite; abundant crinozoan bioclasts common ramose bryozoans and rugose corals; single bed; base sharp	3.0
	(top - coarse calcarenite: argillaceous, crinozoan, brachiopod, lime packstone)	
	(conodont channel sample - *I. ouachitensis* and *I. sinuosis*)	
25	Spiculiferous limestone, dark blue gray and very cherty, weathers tan or buff; abundant nodular chert; thick bedded; base gradational	14.6
24	Micritic limestone, medium gray fresh, light gray weathered; calcilutite; slightly siliceous, conchoidal fracture; argillaceous partings; thick to very thick bedded; base covered	6.0
	(top - calcilutite: crinozoan, lime mudstone)	
23	Covered	9.0

Unit	Lithology	Thickness (feet)
22	Spiculiferous limestone, dark blue-gray fresh tan or buff weathered; abundant nodular and bedded chert; thick bedded; base covered	3.4
21	Covered	1.5
20	Micritic limestone, dark gray fresh, blue-gray weathered; calcilutite; very cherty; medium to thick bedded; base covered	10.1
19	Covered	6.8
18	Bioclastic limestone, dark gray fresh, medium gray weathered; medium calcarenite with thin lenses of coarse calcarenite; abundant crinozoan bioclasts and ooliths; sandy; thick bedded; base covered	5.3
	(top - medium calcarenite: sandy, sorted crinozoan, oolith, lime grainstone)	
	(conodont sample top 1.0 feet - *I. ouachitensis*, *I. sinuosis* and *N. kanumai*)	
17	Covered	1.1
16	Bioclastic limestone, medium gray fresh, light gray weathered, course calcarenite at base which fines upward; abundant crinozoan bioclasts, common brach fragments, argillaceous concentrations marks bioturbation; common spiculiferous limestone intraclasts; single bed, sharp basal contact	0.5
	(base - coarse calcarenite: sandy, sorted, crinozoan, lime grainstone)	
	(conodont channel sample - *I. ouachitensis*, *I. sinuosis*, *N. kanumai* and *N. clarki*)	
15	Spiculiferous limestone, dark blue-gray fresh, light gray or buff weathered; calcisiltite; rare crinozoan columnals; argillaceous	

Unit	Lithology	Thickness (feet)
	partings; medium bedded; base covered	3.4
	(top - calcisiltite: crinozoan, spicule, lime packstone)	
14	Covered	2.6
13	Spiculiferous limestone, very cherty, anastomosing chert nodules, dark blue-gray fresh, tan or buff weathered; calcisiltite; thick to very thick bedded; base covered	9.8
12	Covered	38.3
	Chickachoc Chert	256.0
11	Sandy spiculite, dark blue-gray fresh, buff weathered; fine grained; abundant horizontal feeding traces; common crinozoan bioclasts; medium to thick bedded; base covered	11.3
10	Covered	21.0
9	Spiculiferous limestone, dark blue-gray fresh, tan weathered; calcisiltite; abundant chert nodules common crinozoan bioclasts; medium to thick bedded; base covered	8.3
	(top - very fine calcarenite; fossil, spicule, lime packstone)	
8	Covered	43.5
7	Spiculite, dark blue-gray fresh, buff or light brown weathered; wispy structures, abundant siliceous shale partings; thin interbeds of coarse calcarenite at base; medium to very thick bedded; basal contact sharp	24.0
6	Bioclastic limestone, medium gray fresh, tan or red-brown weathered; medium to coarse calcarenite that fines upward, abundant crinozoan bioclasts, brachiopod valves and ramose bryozoans; abundant clay ironstone	

Unit	Lithology	Thickness (feet)
	concretions and clay galls; very sandy especially near top; thick to very thick bedded; base covered	8.3
	(top - medium calcarenite: sandy, well sorted, crinozoan, lime grainstone)	
	(base - coarse calcarenite: sandy, crinozoan lime packstone)	
	(top 1.0 feet - I. convexus and I. ouachitensis)	
5	Covered	60.0
4	Spiculiferous limestone, dark blue-gray fresh, buff weathered; very cherty; thin to medium bedded; base covered	3.0
3	Covered	9.5
2	Spiculiferous limestone; dark blue-gray fresh, medium gray or buff weathered; calcisiltite; rare to common crinozoan bioclasts; very cherty especially near top; medium to very thick bedded; base covered	13.0
1	Covered	

SECTION 16A

Type Wapanucka

This section in the type area of the Wapanucka is located in the NE¼, NW¼, sec. 22, T. 2 S., R. 8 E., Johnston County, Oklahoma. The section was measured, described and collected for conodonts by R. C. Grayson, Jr., and P. K. Sutherland along the bluffs adjacent to the reservoir on Sulphur Creek about 1.4 miles west of Wapanucka, Oklahoma.

This primary reference section of the Wapanucka constitutes for practical purposes the type section. It is lithologically and biostratigraphically correlative with the lower limestone member of the Wapanucka in the Ouachita Mountain outcrop belt.

The exposure at this locality was measured by Rowett (1962), his section differs substantially from that reported in the present study.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	190.5
14	Micritic limestone, blue-gray fresh, weathers medium gray; pseudo-brecciated calcilutite; abundant phylloid algae, peloidal; single hummocky weathering bed, base sharp	15.0
	(top - calcilutite: algal lime packstone)	

Unit	Lithology	Thickness (feet)
13	Bioclastic limestone, buff brown, coarse calcarenite; abundant crinozoan and ramose bryozoan bioclasts, common forams; thick bedded, base sharp	24.0
	(18.0 feet up - coarse calcarenite: crinozoan lime grainstone)	
	(18.0 feet up - *I. ouachitensis*)	
12	Oolitic limestone, light gray fresh and weathered; fine to medium calcarenite; unit grades from fossil packstone at base to oolitic, grainstone; abundant crinozoans and oolites, common forams and gastropods; medium to very thick bedded with some covered intervals, basal contact gradational	74.0
	(8.0 feet up - fine grained calcarenite: fossil lime packstone)	
	(36.0 feet up - medium calcarenite: sorted, oolitic, fossil lime grainstone)	
	(60.0 feet up - fine calcarenite: sorted, oolite lime grainstone)	
	(17.0 and 60.0 feet up - *I. convexus*)	
11	Micritic limestone, blue-gray fresh, weathers medium gray, pseudo-brecciated calcilutite; abundant tabular algae, common phylloid algae, rare brachiopods, ostracods and forams; thick to very thick bedded, basal contact gradational	
	(base and top - calcilutite: tubular algae lime boundstone)	
10	Carbonaceous limestone, light gray to white fresh and weathered, medium calcarenite, abundant carbonaceous debris and crinozoan bioclasts; common bryozoans, brachiopods and molluscan debris, rare forams and tabulate corals, many grains micritized	

Unit	Lithology	Thickness (feet)
	or coated; common intraclasts composed of tubular algae packstone and spiculiferous limestone; single bed, sharp basal contact	2.5
	(top - medium calcarenite: fossil lime packstone)	
	(Adetognathus lautus)	
9	Carbonaceous limestone, medium gray fresh, weathers light gray; coarse calcarenite; abundant plant debris and crinozoan bioclasts, common brachiopod, bryozoans and fine grained fossil debris; rare intraclasts of spiculiferous limestone; single bed that channels slightly into underlying unit	2.2
	(top - medium calcarenite: crinozoan lime packstone)	
	(A. lautus)	
8	Conglomeratic limestone, medium gray fresh and weathered; coarse calcirudite; abundant pebble to cobble size intraclasts composed of micritic and spiculiferous limestone; abundant crinozoans; single bed that channels into underlying units	4.0-8.0
7	Bioclastic limestone, light gray fresh, weathers medium gray; fine calcarenite; abundant crinozoans, common bryozoans and brachiopods; common intraclasts composed of spiculiferous limestone; thick bedded, basal contact sharp	3.0
	(top - fine calcarenite: crinozoan lime grainstone)	
6	Bioclastic limestone, medium gray fresh and weathered; medium calcarenite; abundant crinozoans and tubular algae; very cherty; medium to thick bedded, base covered	4.5
	(base - medium calcarenite: tubular	

Unit	Lithology	Thickness (feet)
	algae, crinozoan lime packstone)	
	(basal 1.0 foot - I. convexus)	
5	Covered	6.5
4	Spiculiferous limestone, partly covered may indicate presence of shale interbeds, blue-gray fresh, weathers buff; calcisiltite; rare organic stains and fossils; cherty; medium to thick bedded, base covered	13.0
	(base and top - calcisiltite: spicule packstone)	
3	Covered	4.0
2	Bioclastic limestone,medium gray fresh and weathered; coarse calcarenite to fine calcirudite; abundant fossils and dead oil, fossils include crinozoans, brachiopods, bryozoans, michelenid corals and molluscs, many grains coated, algal coated or micritized, rare oolites; thick bedded, basal contact sharp	16.5
	(base - coarse calcarenite: sandy, fossil lime packstone)	
	(2.5 feet up - fine calcirudite: fossil lime packstone)	
	(top - coarse calcarenite: fossil, coated-grain lime grainstone)	
	(base, 2.5 and top - I. convexus)	
1	Spiculiferous limestone and shale interbeds; limestone, medium gray fresh, buff weathered; abundant spicules and crinozoans, common ramose bryozoans and forams; fine calcarenite with lenses of fine calcirudite; nodular beds, very cherty; base covered	11.5
	(5.0 feet up - fine calcirudite: crinozoan, spicule lime packstone)	
	(top - very fine calcarenite: spicule lime packstone)	

Unit	Lithology	Thickness (feet)
	(5.0 above base and top - *I. convexus*)	

SECTION 17

Kiowa East

A nearly complete successsion of conodont faunas has been obtained from this exposure. Faunas ranging from the Neognathodus kanumai-Idiognathoides ouachitensis to the Streptognathodus elegantulus zones have been recovered, the Idiognathoides convexus zone fauna does not occur because the lowest (oldest) beds are not exposed.

A prolific goniatite fauna dominated by Pseudoparalogoceras kesslerense occurs in unit 10.

The section was originally measured with the intent to include four lithologic units to the east of the measured section. However, a small cross fault offsets the ridge across that area preventing a reliable stratigraphic offset. The section was measured across Limestone Ridge through a rock quarry, mostly in units 10-13. The exposure is located in the NE¼, NE¼, sec. 36, T. 3 N., R. 13 E, Kiowa Quadrangle, Pittsburgh County, Oklahoma. One can reach this exposure from Kiowa, Oklahoma. Follow Oklahoma Highway 63 eastward from U.S. 69 a distance of one mile to the first section line road which intersects Oklahoma Highway 63. Travel south about 1.6 miles on this road until it crosses Limestone Ridge. Walk about 500 feet westward along the strike of Limestone Ridge to a point just south of the abandoned rock quarry to the lowest exposed bed, a distinctive cherty Limestone (unit 5).

Section 17 combined with sections 3, 4, and 5 constitute an important basinward reference sequence. This locality is stop 39 in Oklahoma Geological Survey Guidebook 19.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	295.1
	upper sandstone/limestone member	132.6
19	Micritic limestone, light to medium gray fresh and weathered; calcilutite; rare crinozoan detritus; medium to very thick bedded; slightly cherty, nodular-brecciated appearance; forms crest of Limestone Ridge; basal contact covered	13.0
	(2.5 feet above base-calcilutite: fossil lime mudstone)	
18	Covered	5.2
17	Bioclastic limestone, tan-gray fresh, medium gray weathered; fine to medium calcarenite; well sorted, abundant crinozoan detritus and ooliths in sparry calcite matrix; cherty; single bed, base sharp	0.5-0.8
	(fine calcarenite: sandy, well sorted, oolith-crinozoan lime grainstone; abundant fauna consisting principally of bryozoans, brachiopods, and forams; some dead oil)	
	(conodont channel sample - _D. coloradoensis_, _N. kanumai_, _N. clarki_, _S. elegantulus_)	
16	Spiculiferous chert, buff, red-brown and orange-brown; very fine grained; punky, anastomosing chert nodules, poorly replaced carbonate typically dissolved leaving large cavities	

Unit	Lithology	Thickness (feet)
	and micro-caves; thin to thick bedded; base covered	12.0
15	Covered	5.3
14	Bioclastic limestone, light gray fresh, medium gray and gray-brown weathered; coarse calcarenite, poorly sorted abundant crinozoan detritus; very quartz sandy; abundant shale and organic partings; upper part vaguely current bedded; medium to thick bedded; basal contact sharp	3.5
	(0.5 and 3.0 feet above base - coarse calcarenite: sandy, sorted, crinozoan grainstone)	
	(conodont channel sample - I. sinuosis)	
13	Micritic limestone, light gray fresh, medium gray weathered; calcilutite to medium calcarenite, abundant birdseye and fenestrae filled with sparrry calcite, common crinozoan columnals; thick to very thick bedded; upper one-half of unit mostly covered; basal contact sharp	46.0
	(6.0 feet above base-calcilutite: fossil lime wackestone; common fossils include phylloid algae, crinozoan debris, forams, ostracods and brachiopods)	
12	Micritic limestone, light gray fresh, medium gray weathered; calcilutite, abundant spar filled blebs and stringers; common crinozoan columnals; abundant blue-gray chert nodules; medium bedded, base sharp	4.0
	(calcilutite: fossil lime mudstone)	
11	Bioclastic limestone, light to medium gray fresh becoming brownish gray weathered; fine to coarse calcarenite, coarsens upward; sorted, abundant abraded fossil grains particularly crinozoans; abundant shale partings and coalified plant debris particularly in lower part; cross-bedded	

Unit	Lithology	Thickness (feet)
	mostly tabular; medium to very thick bedded; loosely cemented; basal contact gradational	23.6
	(1.0 foot above base - fine calcarenite: sandy, well sorted, crinozoan lime grainstone)	
	(11.0 feet above base - medium calcarenite: sorted, bryozoan, crinozoan lime grainstone)	
	(22.0 feet above base - coarse calcarenite: poorly sorted, bryozoan, crinozoan lime grainstone)	
	(conodont sample 2.0 to 4.0 feet above base - I. ouachitensis, D. coloradoensis, N. bothrops)	
10	Conglomeratic and carbonaceous limestone, medium gray fresh, medium gray or orange brown weathered; fine calcirudite to fine calcarenite near top, poorly sorted to well sorted near top; abundant crinozoan detritus and ramose bryozoans, common ooliths, abundant wood fragments, rare fossil nuts, abundant goniatites (Pseudoparalogoceras kesslerense); upper part tabular cross-bedded, cross beds inclined toward the southeast; common to abundant flat, disc-shaped spiculiferous and micritic intraclasts; thick to very thick bedded; basal contact sharp and slightly erosive	29.0
	middle shale member	48.1
9	Shale, blue-gray fresh, brown and blue-gray weathered; clay-shale; slightly silty; abundant clay-ironstone concretions; rare bivalves and gastropods; base obscure due to weathering and cover	48.1
	middle limestone member	62.0
8	Bioclastic limestone, medium to dark gray fresh, medium gray weathered; coarse calcarenite to fine calcirudite;	

Unit	Lithology	Thickness (feet)
	abundant bimodally distributed crinozoan bioclasts, rare calcilutite intraclasts argillaceous, sparry calcite matrix; single bed, thickens and thins, base covered	1.6-5.7
	(4.5 feet above base - coarse calcarenite: sorted, ramose bryozoan-crinozoan, lime grainstone)	
	(top 1.0 foot - _I. ouachitensis_, _N. kanumai_, _N. clarki_)	
7C	Covered	5.0
7B	Micritic limestone and covered intervals; limestone, blue-gray fresh, light gray weathered; calcilutite; common chert nodules and thin beds; rare crinozoan bioclasts; thick to very thick bedded; base covered	27.0
	(20.0 feet above base - calcilutite: lime mudstone)	
7A	Covered	8.0
6B	Bioclastic limestone, medium gray fresh, brownish-gray weathered; coarse calcarenite; poorly sorted, abundant crinozoan bioclasts; sparry calcite matrix; glauconitic; medium bedded; basal contact covered	2.6
	(base-coarse calcarenite: poorly sorted, ramose bryozoan, crinozoan lime grainstone)	
	(conodont channel sample - _I. ouachitensis_, _I. sinuosis_)	
6A	Covered	11.0
5	Chert, orange, white and blue-gray; chert replacement occurs in an anastomosing pattern; medium to thick bedded; base covered	3.3

SECTION 18

Reynolds Lake

This section is located in the SE$\frac{1}{4}$, SE$\frac{1}{4}$, and SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 10, T. 2 N., R. 13 E., Kiowa Quadrangle, Atoka County, Oklahoma. The section can be reached by driving north on U.S. Highway 69 from Limestone Gap 3.7 miles to a blacktop road that exits to the northeast. Follow the blacktop road 1.0 mile, then exit to the east on a gravel road. Continue on the curvy road about 0.8 miles to where the road cuts Limestone Ridge. All but the highest two units were examined only on the northern side of the water gap.

A complete section of the Wapanucka, all four members, is exposed at this locality. The first occurrence of the lower limestone is found at this section in relation to move southwesterly exposures. The complete sequence of conodont zones is also represented here. Together, this exposure and section 26 show the nature and character of basinward facies changes in this area.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	434.6
	upper sandstone/limestone member	106.2
34	Spiculiferous chert, dark blue-gray fresh, orange-brown, buff and black weathered; very fine grained; common shale partings; medium to thick	

Unit	Lithology	Thickness (feet)
	bedded, basal contact sharp	2.9
33	Spiculiferous limestone and calcarenite interbeds, dark blue-gray fresh, weathers tan or brown; very fine to medium calcarenite; spiculiferous limestone contains rare crinozoan bioclasts; calcarenite contains abundant crinozoans, productid brachiopods, and oolites, common spiculiferous limestone and shale intraclasts; bioturbated, single bed, sharp basal contact	2.0
	(base - very fine calcarenite: argillaceous, algal, crinozoan lime packstone)	
	(top - medium calcarenite: argillaceous, intraclastic, crinozoan lime packstone)	
	(conodont channel sample - *I. ouachitensis* and *I. sinuosis*)	
32	Micritic limestone, blue-gray fresh, weathers white and light gray; pseudo-brecciated calcilutite; rare crinozoans, rugose corals, ostracods and biserial agglutinate forams; birdseye and fenestral fabric with geopetal; very thick bedded, basal contact sharp	19.2
	(base and top - calcilutite: fossil lime wackestone)	
31	Bioclastic limestone, medium gray fresh and weathered; fine calcirudite to medium calcarenite; abundant crinozoans, ramose and encrusting bryozoans, common brachiopods and algal fragments, most bioclasts are micritized and stained with organic matter; common well rounded micritic and spiculiferous intraclasts; sandy, common chert nodules; tabular cross-bedded; very thick bedded, basal contact sharp	6.0
	(1.5 feet up - fine calcarenite:	

Unit	Lithology	Thickness (feet)
	sandy, poorly sorted, intraclastic, crinozoan lime grainstone)	
	(3.0 feet up - medium calcarenite: sandy, sorted, crinozoan lime grainstone)	
	(2.0 to 3.0 feet up - _S. elegantulus_ and _G. gymna_)	
30	Bioclastic limestone, light gray fresh, weathers medium gray; fine to coarse calcarenite; abundant crinozoan bioclasts and ooliths, common bryozoans, mollusc shells and micritic intraclasts; tabular cross-bedded, bidirectional possibly bipolar northward and southward; sandy; very thick to thick bedded, basal contact sharp	19.5
	(2.0 feet up - medium calcarenite: sandy, sorted crinozoan lime grainstone)	
	(10.0 feet up - coarse calcarenite: sandy, oolitic, crinozoan lime packstone)	
	(15.0 feet up - medium calcirudite: sandy, intraclastic, crinozoan lime packstone)	
	(18.0 feet up - medium calcarenite: sandy, well sorted, crinozoan lime grainstone)	
	(2.0 to 5.0 feet up - _S. elegantulus_, _N. clarki_ and _I. ouachitensis_)	
29	Bioclastic limestone, medium gray fresh and weathered; fine calcirudite to coarse calcarenite, abundant crinozoan bioclasts, common bryozoans, brachiopods, oolites and spiculiferous limestone intraclasts; current bedded; few chert nodules, thick to very thick bedded; basal contact sharp and erosional	7.6
	(base - fine calcirudite: sandy, intraclastic, crinozoan lime packstone)	

Unit	Lithology	Thickness (feet)
	(top - coarse calcarenite: sandy, sorted, crinozoan lime grainstone)	
	(top 2.0 feet - D. orphanus)	
28	Spiculiferous limestone, medium gray fresh, weathers brown and black; very fine calcarenite with thin oolitic layers at base, grade, upward into calcisiltite; abundant chert nodules that exhibit a box-work appearance; very thick bedded, basal contact sharp	4.0
	(base - very fine calcarenite: oolitic, spicule lime packstone)	
	(top - calcisiltite: spicule lime packstone)	
	(basal 1.0 foot - N. kanumai, I. ouachitensis and I. sinuosis)	
27	Bioclastic limestone, medium gray fresh and weathered; fine calcirudite; abundant crinozoan bioclasts and bryozoans, rare brachiopods and gastropods, rare ooliths; sandy, abundant iron-oxide blebs; tabular cross-bedded; thick bedded, base covered	3.2
	(1.0 foot up - coarse calcarenite: sandy, bryozoan, crinozoan lime packstone)	
	(basal 1.0 foot - I. ouachitensis)	
26	Covered	11.2
25	Micritic limestone, blue-gray fresh, weathers medium gray and brown; calcilutite; abundant tubular algae, rare crinozoans, bryozoans and agglutinate forams; common thin cherty zones, common shale partings; medium to very thick bedded, base covered	23.0
	(base and 10.0 feet up - calcilutite: tubular algae lime boundstone)	

Unit	Lithology	Thickness (feet)
24	Covered	6.5
23	Spiculiferous limestone, dark blue-gray fresh, weathers buff; calcisiltite; single bed, base covered	1.1
	middle shale member	115.0
22	Covered	115.0
	lower limestone member	43.3
21	Spiculiferous limestone, dark blue-gray fresh, buff and brown weathered; calcisiltite to medium calcarenite, changes upward from spicules only to calcarenite with clay clasts; argillaceous; medium to thick bedded, base covered	3.1
20	Covered	19.3
19	Micritic limestone, medium gray fresh weathered; calcilutite, abundant tubular and phylloid algae, rare crinozoan bioclasts, surfaces of beds bioturbated; argillaceous, common shale partings; medium to thick bedded, base covered	5.0
	(3.5 feet up - calcilutite: tubular algae lime boundstone)	
18	Covered	2.8
17	Micritic limestone, light gray fresh, medium gray weathered; calcilutite; abundant phylloid and tubular algae, rare crinozoans, gastropods and paleotextularids; slightly cherty; thick to very thick bedded, base sharp	4.5
	(base - calcilutite: algal lime boundstone)	
16	Micritic limestone, dark gray fresh, weathers light gray; calcilutite; abundant tubular and phylloid algae, common crinozoan bioclasts and bryozoans, rare brachiopods;	

Unit	Lithology	Thickness (feet)
	common birdseye and fenestral fabric floored with geopetal mud; medium to thick bedded, base covered	8.6
	(base - calcilutite: algal lime boundstone)	
15	Covered	1.6
	Chickachoc Chert Member	170.7
14	Spiculite, dark blue-gray fresh, weathers brown; very fine grained, rare crinozoan bioclasts, bioturbated; some flaser, lenticular and wavey bedding; single bed, base covered	0.9
13	Covered	5.7
12	Spiculite, dark blue-gray fresh, brown or buff weathered; very fine grained; rare crinozoans and gastropods; vaguely flaser, wavey and lenticular bedded; medium to thick bedded, base covered	13.1
11	Covered	0.5
10	Bioclastic limestone, gray-brown fresh and weathered; coarse calcarenite, abundant crinozoan bioclasts in a micritic matrix; sandy, single bed, base covered	0.5
9	Covered	18.3
8	Spiculite, as above but with shale partings and thin bedded, base covered	3.0
7	Covered	27.2
6	Spiculite, blue-gray fresh, brown or black weathered; very fine grained; abundant chert nodules; medium to thick bedded, base covered	15.8
5	Covered	45.1
4	Spiculite and covered	30.7

Unit	Lithology	Thickness (feet)
3	Bioclastic limestone, medium gray fresh and weathered; coarse calcarenite; abundant crinozoans and ramose bryozoans; rare intraclasts composed of spiculite; thin shale partings common; single bed with basal contact	0.6
	(coarse calcarenite: argillaceous, bryozoan, crinozoan lime packstone)	
	(*I. convexus* and *I. sinuosis*)	
2	Spiculite, dark blue-gray fresh, brown weathered; very fine grained; abundant chert nodules; argillaceous wispy structures; medium to thick bedded, base covered	7.7

SECTION 19

Blanco East

Section measured along eastern side of quarry in small fault block north of Limestone Ridge. The quarry is located on the south side of the section line that intersects Oklahoma 63, 2.8 miles to the northwest, in Blanco, Oklahoma, SW¼, SW¼, SW¼, sec. 19, T. 3 N., R. 15 E., Pittsburgh County, Oklahoma.

The lower limestone, middle shale and upper sandstone/limestone members of the Wapanucka are exposed in this Quarry. A non-diagnostic suite of conodonts was obtained from the mostly high energy oolite and bioclastic calcarenites. The important features of this section are the interbedding of oolite and spiculiferous limestone; and the occurrence of Chaetetes in unit 22. This section in conjunction with sections 2, 16, and 1 constitute the most important basinward reference sequence of Wapanucka sections. This locality is stop 38 in Oklahoma Geological Society Guidebook 19.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	273.3
	upper sandstone limestone	15.5
27	Spicular chert, buff; medium bedded; base covered	4.5

Unit	Lithology	Thickness (feet)
26	Covered	6.0
25	Sandstone, red-brown; fine grained, sorted, subangular quartzarenite: silica cemented, common crinozoan molds; medium bedded; base covered	5.0
	middle shale	55.0
24	Covered	35.0
23	Shale, dark blue-gray fresh, olive weathered; rare spicules, basal contact sharp	20.0
	lower limestone member	204.6
22C	Bioclastic limestone, medium gray fresh, red brown weathered; medium calcarenite; abundant crinozoan bioclasts, rare *Chaetetes*; micrite matrix; single bed, thickens and thins; basal contact sharp	0.6-1.0
22B	Micritic limestone, light gray fresh and weathered; calcilutite; rare *Chaetetes*, pseudo-brecciated; thickens and thins; thick-very thick bedded; basal contact gradational	3.0-3.4
22A	Bioclastic limestone, light gray fresh and weathered; coarse calcirudite; abundant *Chaetetes* heads and crinozoan bioclasts; spiculiferous; common interbeds of calcilutite and coarse calcarenite layers; rare rugose corals; medium to thick bedded; basal contact sharp	9.5
21	Spiculiferous limestone, medium gray fresh and weathered; very fine calcarenite; spicules occur in buttons that may represent collapsed sponges; common crinozoan detritus; micritic matrix; abundant chert nodules; medium to thick bedded; basal contact gradational	11.0
20	Oolitic limestone, light gray fresh and	

Unit	Lithology	Thickness (feet)
	weathered; medium to coarse calcarenite; poorly sorted; abundant ooliths and fragmental crinozoan and ramose bryozoan bioclasts, common spicules; tabular cross-bedded, minor trough cross-bedding; very thick to thick bedded; basal contact sharp	10.5
19	Spiculiferous limestone, medium gray fresh and weathered; very fine to fine calcarenite; laminated; rare calcareous bioclasts; thick to very thick bedded; basal contact gradational	3.5
18	Spiculiferous limestone, medium gray fresh and weathered; abundant coalescing chert nodules that weather red-brown; common lenses of crinozoan bioclasts; laminated in part; thick to very thick bedded; basal contact gradational	5.5
17	Spiculiferous limestone, dark gray fresh, red-brown weathered; very cherty; very fine calcarenite; abundant meandering feeding trails on bedding surfaces; rare calcareous bioclasts; thin to medium bedded; basal contact gradational	9.0
16	Shale, dark blue-gray fresh; rare productid and spiriferid brachiopods; basal contact sharp	0.5
15	Spiculiferous limestone, medium gray fresh, red brown and buff weathered; very fine to fine calcarenite; common crinozoan bioclasts rare productid and spiriferid brachiopods; very cherty; laminated; common meandering feeding traces; medium to thick bedded; basal contact sharp and slightly irregular	7.0
14	Shale, dark blue-gray fresh, olive weathered; sparsely fossiliferous, rare spicules; basal contact sharp	11.0
13	Spiculiferous limestone, medium gray	

Unit	Lithology	Thickness (feet)
	fresh and weathered; calcisiltite; common crinozoan bioclasts; common thin black organic-rich shale partings; very abundant black chert nodules, nodules fist-size or smaller, concentrated at bedding plane surfaces; near top of unit two bioturbated surfaces occur, bioturbation types include meandering grazing traces, Zoophycus feeding structure, and subvertical tube shaped burrows, common small bivalves on these surfaces; very thick to thick bedded; basal contact sharp	15.0
12	Oolitic limestone, light gray fresh, medium gray weathered; fine calcarenite; abundant ooliths; current lineation structures oriented N. 10 W., separated by black layers; single bed; basal contact obscured by talus and weathering	3.0
11	Spiculiferous limestone, medium to dark gray fresh, light gray weathered; medium calcarenite; abundant crinozoan and ramose bryozoan bioclasts, common algal chips; micritic and slightly cherty; single bed; basal contact gradational	1.2
10	Spiculiferous limestone; medium gray fresh and weathered; calcisiltite; common crinozoan bioclasts, rare ramose bryozoans, brachiopods and lacy bryozoans, fossils concentrated on bedding surfaces; cherty and argillaceous; medium to thick bedded; basal contact sharp and irregular	28.0
9	Oolitic calcarenite and spiculiferous limestone, unit forms high point at edge of quarry preventing detailed examination, unit consists of four subunits evenly divided between the above lithologies: oolitic calcarenite, light gray fresh medium gray weathered; medium calcarenite to fine calcirudite; poorly sorted; common fragmental crinozoan bioclasts, rare ramose bryozoans; cross-bedded; spiculiferous limestone, dark gray	

Unit	Lithology	Thickness (feet)
	fresh, medium gray weathered; fine calcarenite; rare crinozoan bioclasts; argillaceous, common shale partings; thickness estimated	24.0
8	Covered and shale	23.0
7	Oolitic limestone, medium gray fresh, medium gray or brown or buff weathered; medium calcarenite to fine calcirudite; poorly sorted; abundant ooliths, some have spiculiferous limestone nuclei, abundant crinozoan bioclasts; cross-bedded; common pyrite blebs and iron staining; thin beds of spiculiferous limestone in lower six inches; thick to very thick bedded	5.9
	(4.0 feet above base - coarse calcarenite: sorted, fragmental fossil, oolith lime grainstone; top - coarse calcarenite: poorly sorted, crinozoan, oolith lime grainstone)	
6	Spiculiferous limestone, dark gray fresh, blue gray to buff weathered; in basal three inches common coated grains, crinozoan bioclasts, gastropods, and calcareous forams; abundant carbonaceous debris and wood fragments; argillaceous; thick bedded; basal contact gradational	12.0
	(top and 5.0 feet above base - calcisiltite: argillaceous spicule lime packstone; base - medium calcarenite: fossil lime packstone)	
5	Oolitic limestone, medium gray fresh, gray-brown or buff weathered; medium calcarenite; sorted, abundant ooliths, common crinozoan bioclasts; tabular cross-bedded; very thick bedded; basal contact gradational	7.0
	(base - coarse calcarenite: sorted, crinozoan, oolith, lime grainstone)	
	(4.0 feet above base - medium calcarenite: sandy, well sorted, oolith lime grainstone)	

Unit	Lithology	Thickness (feet)
	(top - medium calcarenite: sorted, crinozoan oolith, lime grainstone)	
3	Sandstone, blue-gray fresh, red-brown weathered; fine grained, poorly sorted, subangular quartz sand; argillaceous; abundant shale laminae and partings; pervasively bioturbated; common crinozoan and ramose bryozoan bioclasts; single bed; basal contact gradational	0.4
2	Shale, blue-gray fresh, olive weathered; thin sand and spiculitic interbeds; common siderite nodules and concretions; base sharp	7.0
1	Bioclastic limestone, medium gray fresh, red-brown weathered; coarse calcarenite; abundant crinozoan and ramose bryozoan bioclasts; tabular cross-bedded; single bed at northeast wall of Quarry; base covered	1.0+
	(top - coarse calcarenite: argillaceous, crinozoan, lime packstone)	

SECTION 20

Chilly Creek Tributary

The fault ridges on which this section and sections 21, 22, 23, 24, 25, 26, and 5 are located were mapped by Hendricks (1947) as Chickachoc Chert. The Chickachoc is the only member of the Wapanucka exposed at sections 20 through 25, but at sections 26 and 5 the middle shale and upper sandstone/limestone are also exposed. Field evidence suggests that the top of the Wapanucka at this locality, and sections 20 through 25 is incomplete due to faulting.

The section is located on the first fault block southeast of Limestone Ridge. The exposure is on the south bank of a tributary of Chilly Creek in the NW¼, NW¼, NW¼, SE¼, sec. 22, T. I N., R. 12 E., Coalgate SE Quadrangle, Atoka County, Oklahoma. Access to this locality can be gained by foot from Chilly Creek where it crosses U.S. Highway 43. Proceed east along Chilly Creek, follow the first tributary to the south about 700 feet. The base of the exposure is just south (100 feet) of the creek and east (50 feet) of the railroad tracks.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	402.4
	Chickachoc Chert Member	402.4

Unit	Lithology	Thickness (feet)
23	Spiculite: black fresh, medium gray or red-brown weathered, wavy, lenticular and flaser bedding; thin to thick bedded; top faulted (?), base covered	5.2
22	Covered	18.0
21	Spiculite and Cherty Spiculite: Spiculite, as above, grades upward from base into cherty spiculite; cherty spiculite light gray fresh, rusty brown and tan weathered; thin to thick bedded, base covered	12.5
20	Covered	34.0
19	Spiculite, as above, except thin to medium bedded; base covered	2.5
18	Covered	5.5
17	Spiculite, as above	1.2
16	Spiculiferous limestone, medium gray fresh, tan and brown weathered, calcisiltite, spiculiferous, micritic matrix; medium bedded; base sharp	5.0
15	Covered	12.6
14	Spiculite: black fresh, gray-brown weathered; rare goniatites, nautiloids, and brachiopods, argillaceous; vaguely laminated; thin to medium bedded; base covered	1.3
13	Covered	31.0
12	Spiculite: black fresh, rusty brown weathered, wavy bedded; medium bedded; base covered	2.0
11	Covered	54.0
10	Spiculite: black to blue-gray fresh, gray-brown weathered, argillaceous, glauconitic, rare iron oxide blebs, vaguely current laminated; medium bedded; base covered	11.0

Unit	Lithology	Thickness (feet)
9	Covered	24.0
8	Spiculite; blue-gray fresh, orange-brown weathered, vertical to sub-vertical bioturbation, argillaceous; lenticular and flaser bedding; medium bedded; base covered	5.3
7	Covered	3.0
6	Spiculite: dark blue-gray fresh, rusty-brown weathered, argillaceous; wavy, lenticular and flaser bedding; thin to medium bedded; base covered	2.3
5	Covered	6.3
4	Spiculite: as above	19.0
3	Covered	138.0
2	Spiculite: as above	8.7
1	Covered	not measured

SECTION 21

Chilly Creek

The Chilly Creek section is located about 0.6 mile northeast of section 20 on the third fault ridge southeast of Limestone Ridge. The exposure is in the NE¼, NE¼, sec. 23, T. I N., R. 12 E., Coalgate SE Quadrangle, Atoka County, Oklahoma. This section may be found by continuing up Chilly Creek from the tributary leading to section 20 about 0.5 mile. From that point proceed due east along intermittent tributary about 800 feet to base of section. Only the Chickachoc Chert is present, the upper part of the formation is faulted out.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	439.8
	Chickachoc Chert Member	439.8
14	Spiculiferous chert: buff; very fine grained; rare crinozoan molds; thin to thick bedded; base covered	4.3
13	Covered	2.3
12	Bioclastic limestone; medium gray fresh, medium gray and buff weathered; coarse calcarenite; abundant crinozoan bioclasts, common coated and micritized grains, rare ooliths; cherty, glauconitic; common subvertical burrows infilled with shale;	

Unit	Lithology	Thickness (feet)
	common shale rip up clasts; single bed; base covered	0.7
	(coarse calcarenite: sandy, crinozoan-ramose bryozoan, lime packstone)	
	(conodonts - *Idiognathoides convexus* and *Idiognathodus sinuosis*)	
11	Covered	1.1
10	Spiculiferous limestone: light gray fresh, brown weathered; calcisiltite; spiculiferous, common crinozoan bioclasts in lower part of unit; siliceous micritic matrix; cherty; horizontal bioturbation features on bedding plane surfaces; very thick to thin bedded; base covered	23.5
9	Covered	40.0
8	Spiculiferous chert, buff to orange-brown; fine grained, horizontal bioturbation (*Zoophycos*) on bedding plane surfaces; single bed; base covered	2.8
7	Covered	135.0
6	Spiculite: black fresh, brown or orange-brown weathered; wavy, lenticular, and flaser bedding; thin to thick bedded; base covered	1.9
5	Covered	135.0
4	Spiculite: as above, base gradational	2.2
3	Covered	156.0
2	Spiculite: as above, base gradational	4.8
1	Spiculite and shale: spiculite, as above; shale, olive fresh and weathered, thin limonite stringers; thin to medium bedded; base covered	5.2

SECTION 22

Burg, Oklahoma

This section is incomplete but is important because it is located in the type area of the Chickachoc Chert. The section is located 200 to 300 feet south of the McIntyre Ranch house which constitutes the entire community of Burg, Oklahoma. Burg is 0.1 mile southeast of Chockie on a small farm road which proceeds eastward from U.S. Highway 69, 8.6 miles north of Stringtown, Oklahoma. The measured section is in SW¼, SW¼, SE¼, sec. 1, T. 1 N., R. 12 E., Limestone Gap Quadrangle, Atoka County, Oklahoma.

The Chickachoc Chert is the only member exposed at this locality.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	238.1
	Chickachoc Chert Member	238.1
10	Spiculite: black fresh, black and orange-brown weathered; wavey, flaser, and lenticular bedding; medium bedded; base covered	0.7
9	Covered	4.2
8	Spiculite: as above	1.5
7	Covered	128.0
6	Spiculite: as above	1.5
5	Covered	30.0

Unit	Lithology	Thickness (feet)
4	Spiculite: as above	20.5
3	Covered	170.0
2	Spiculite: as above	1.7
1	Covered: not measured	not measured

SECTION 24

Limestone Creek Tributary

This section is located on the first fault ridge southeast of Limestone Ridge in the NW¼, SW¼, sec. 32, T 2 N., R. 13 E.,Coalgate SE Quadrangle, Atoka County, Oklahoma. The measured section lies along the northeast bank of a tributary of Limestone Creek. This tributary is the first one encountered going north on Limetone Creek from Limestone Gap. The section can be found by following the tributary to the southwest approximately 0.3 miles. At dirt road paralleling the tributary may be used in dry weather.

Only the Chickachoc Chert Member is exposed at this locality.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	483.6
	Chickachoc Chert Member	483.6
10	Spiculite, dark gray to black fresh, light gray weathered, wavey, lenticular and flaser bedding; thin to thick bedded; basal contact covered	8.0
9	Covered	16.0
8	Spiculiferous chert, gray, brown and orange brown, heavily weathered, minor shale partings; medium to thick bedded; base covered	6.8

Unit	Lithology	Thickness (feet)
7	Covered	208.0
6	Spiculite, as above	5.8
5	Covered	162.0
4	Spiculite, as above	2.0
3	Covered	70.0
2	Spiculite, black fresh, orange, brown and tan weathered; common wood fragments, rare compressed goniatites, rare gastropods; wavy, flaser and lenticular bedded; thin to very thick bedded; base covered	4.0
1	Covered	not measured

SECTION 25

Hungry Cows Section

This section exposes only the Chickachoc Chert. The other members have presumably been concealed by faulting. The section is located on the north bank of a tributary to Buck Creek in C. sec. 15, T. 2 N., R. 13 E., Kiowa Quadrangle, Atoka County, Oklahoma. To get to this exposure follow the truck trail along the southeastern side of Limestone Ridge from the Reynolds Lake Section (18) for about 0.7 miles. From that point angle southwestward for about 0.3 miles to the lowest exposures in the tributary where it angles sharply eastward. This tributary is the second tributary entering a larger creek that flows into Buck Creek at the Reynolds Lake Section.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	205.3
	Chickachoc Chert Member	205.3
9	Spiculiferous chert, rusty brown, orange brown and black; heavily weathered; porous; medium to thick bedded; basal contact covered	7.9
8	Covered	9.0
7	Spiculiferous chert, as above	1.9
6	Covered	4.2

Unit	Lithology	Thickness (feet)
5	Spiculite, black fresh and weathered; calcareous; flaser, lenticular, and wavey bedded; thin to medium bedded; base gradational	5.0
4	Spiculite, black fresh, orange-brown or gray weathered; flaser, lenticular, and wavey bedded; thin to thick bedded; base covered	17.0
3	Covered	150.0
2	Spiculite, as above, forms small ridge	9.8
1	Covered	not measured

SECTION 26

Country Club Lake

This measured section is significant because it represents the southwestern-most extent of the upper sandstone/limestone member on basinward fault ridges from Limestone Ridge. Hendricks (1947) mapped the fault block on which this exposure is found as consisting entirely of Chickachoc Chert. In as little as one mile in a southwesterly direction the upper sandstone/limestone cannot be found on this ridge presumably due to fault removal.

The section is located in the NW¼, NW¼, sec. 12, T. 2 N., R. 13 E. Kiowa Quadrangle, Atoka County, Oklahoma. Access to the section is best obtained by following the gravel road eastward from the Reynolds Lake Section (18) about one mile. At that point take the section line road to the east to Country Club Lake, about 0.5 miles. Walk along the old log road to the southeast and south of the lake about 0.25 miles until the first very small intermittent creek is reached. Follow this creek 1000 feet southward to the lowest exposed beds in the Chickachoc Chert.

In conjunction with the Reynolds Lake Section (18), this exposure provides the basis for evaluating basinward changes in the Wapanucka in this area.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	562.4
	upper sandstone/limestone member	62.4
16	Sandstone, quartzarenite; buff fresh and weathered; fine grained; spiculiferous, subangular grains, poorly sorted, siliceous cement; wispy structures; thin to medium bedded; basal contact covered	4.0
15	Sandstone, quartzarenite; orange-brown fresh and weathered; fine grained; spiculiferous; subangular to subround grains, sorted; ferruginous and siliceous cement; medium to thick bedded, weathers to nodular appearance; basal contact obscure due to weathering	19.0
14	Sandstone, quartzarenite; orange-brown, light gray or red weathered, fresh surface not seen; medium grained, subangular grains, sorted; ferruginous and siliceous cement, medium to thick bedded; basal contact indistinct due to weathering	7.1
13	Sandstone, quartzarenite; light gray or orange-brown to buff; fine to very fine grained, subangular grains, argillaceous, poorly sorted; spiculiferous, common crinozoan molds; medium to thin irregular beds, basal contact indistinct due to weathering	10.8
12	Sandstone, quartzarenite; light gray, buff or red-brown; fine grained, subangular to subround grains, well sorted; ferruginous cement, silica case hardened; common chert nodules; very thick bedded; basal contact covered	21.5
	middle shale member	270.0
11	Covered	270.0
	Chickachoc Chert Member	230.0
10	Spiculite, black fresh, rusty brown or dark gray weathered; argillaceous;	

Unit	Lithology	Thickness (feet)
	wavy, lenticular and flaser bedding; medium to thick bedded; base covered	8.3
9	Covered	46.0
8	Spiculiferous chert, medium gray fresh, brown or buff weathered; calcareous to non-calcareous and porous where heavily weathered; upper one half of unit characterized by sinuous, smooth walled cavities, about one inch diameter; spiculiferous calcisiltite lense in uppermost 0.5 to 1.0 foot, rare crinozoan debris and molds; unit supports ridge base covered	9.5
7	Covered	11.0
6	Spiculite, black fresh, gray or buff weathered; argillaceous; thin bedded, base covered	0.5-1.0
5	Covered	131.0
4	Spiculite, dark gray to black fresh, brown to tan or medium gray weathered; wavy, lenticular, and flaser bedding; thin to medium bedded, base covered	6.2
3	Covered	5.0
2	Spiculite, as above, base covered	12.0
1	"Springer" Shale (?), covered	——

SECTION 27

Hugle Ranch

This section is located on the second Wapanucka ridge exposure on Pet Hugle's ranch in the NW¼, sec. 20, T. 4 N., R. 17 E., Hartshorne Quadrangle, Pittsburg County, Oklahoma. The section can be reached by taking 7th Street to the south from Hartshorne about 1.6 miles to the Y intersection at Hartshorne Lake. At this intersection take the road on the east, continue on this road which souths in a half mile a total distance of about 3.5 miles to Pete Hugle's Ranch. The section was measured behind and just east of the stock barn.

At this locality, the lower limestone, middle shale and upper sandstone/limestone members are present. Conodonts belonging to the I. convexus Zone occur in the lower part of the lower limestone. No other units produced conodonts.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	420.9
	upper sandstone/limestone member	114.5
18	Spiculiferous limestone, medium gray fresh, red-brown and black weathered; calcisiltite; pervasive silica replacement, anastomosing chert, when leached results in cavernous appearance; unit measured on back side of ridge; medium bedded, base covered	9.5

Unit	Lithology	Thickness (feet)
17	Covered	40.0
16	Sandstone, multicolored, rust-red or brown, lavender and black; fine to medium grained, subangular, well sorted quartz sand; ferruginous and siliceous cement; abundant crinozoan molds and tabular cross-bedding in upper part; medium to very thick bedded, base covered	65.0
	middle shale member	92.0
15	Covered	92.0
	lower limestone member	214.4
14	Micritic limestone, medium gray fresh and weathered; pseudo-brecciated calcilutite; thin (1-2 feet) calcarenite layer about 15 feet above base that contains crinozoans, brachiopods and ostracods; thick to very thick bedded; basal contact covered	32.5
	(base - coarse calcarenite: tubular algae lime boundstone)	
	(15.0 feet up - medium calcarenite: sandy, peloid lime packstone)	
	(top - calcilutite: algal lime Wackestone)	
	(15.0 - 16.0 feet up - non-diagnostic conodonts)	
13	Covered	22.5
12	Micritic limestone, medium gray fresh and weathered; calcilutite; rare crinozoans, brachiopods and bryozoans except in shaly zones and partings where they are more common; thin to very thick bedded; base covered	8.5
	(base - calcilutite: algal lime packstone)	
11	Covered	8.4

Unit	Lithology	Thickness (feet)
10	Micritic limestone, medium gray fresh and weathered; pseudo-brecciated calcilutite; common tubular algae, rare crinozoans; very thick bedded, base covered	21.0
	(16.0 feet up - calcilutite:algal, fenestral lime mudstone)	
9	Covered	30.5
8	Micritic limestone, medium gray fresh weathered; pseudo-brecciated calcilutite; rare to common tubular algae, crinozoans and twiggy bryozoans; thick to very thick bedded, base covered	16.0
	(base - calcilutite: phylloid algae lime mudstone)	
	(7.0 feet up - calcilutite: tubular algae lime boundstone)	
	(top - calcilutite: tubular algae lime boundstone)	
7	Covered	15.0
6	Bioclastic limestone, medium gray fresh and weathered; coarse calcarenite; abundant crinozoans, ramose bryozoans and brachiopods; common clay clasts; single bed, base covered but contact probably irregular	1.8-2.2
	(top - coarse calcarenite: oolith, bryozoan, crinozoan lime packstone)	
	(top 1.0 foot - *I. convexus*)	
5	Covered	9.8
4	Limestone, as above	0.4-0.6
	(*I. convexus*)	
3	Covered	43.0
2	Spiculiferous chert, dark gray fresh, weathers red-brown; common crinozoan molds; thin to medium bedded; base covered	3.4

SECTION 28

Latimer-Pittsburg County Line

This section is located in roadcut formed by Highway 1 where it crosses Limestone Ridge in the SE¼, SW¼, sec. 10, T. 4 N., R. 17 E., Hartshorne Quadrangle, Latimer County, Oklahoma. The section was measured on the north side of Oklahoma Highway 1 about 1.9 miles southeastward from Hartshorne. This section and general locality is reported by Grayson (1979) as stop 36 in Oklahoma Geological Survey Guidebook 19 (Sutherland and Manger, 1979).

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	211.4
	upper sandstone/limestone member	1.8
17	Spiculiferous chert, orange-brown; thick bedded, unit measured in field about 400 feet east of highway; base covered	1.8
	middle shale member	99.0
16	Covered interval may include part of upper sandstone/limestone member	99.0
	lower limestone member	110.8
15	Spiculiferous limestone, dark blue-gray fresh, buff weathered; calcisiltite; spicules most abundant in lower part, rare crinozoans and brachiopods, common carbonaceous matter and plant debris; very thick bedded, basal contact sharp	10.0

Unit	Lithology	Thickness (feet)
	(top - calcisiltite: peloid, spicule lime packstone)	
14	Spiculiferous limestone, dark blue-gray fresh, buff weathered; calcisiltite; spicules most abundant in lower half, rare gastropods, crinozoan bioclasts rugose corals and spiriferid brachiopods, common plant material on bedding surfaces; cherty layers along bedding; thick bedded, basal contact sharp	22.0
	(base - calcisiltite: spicule lime packstone)	
	(17.0 feet above base - calcisiltite: argillaceous, spicule lime packstone)	
13	Conglomeratic limestone, gray-brown fresh, orange-brown weathered; very coarse calcirudite; rudite size crinozoan columnals; pebble to boulder size limestone intraclasts in micritic matrix, clasts mostly similar to underlying unit; single bed with sharp erosive basal contact	1.2-1.5
	(very coarse calcirudite: crinozoan, intraclast lime packstone)	
	(*I. ouachitensis*)	
12	Spiculiferous limestone, dark blue-gray fresh, buff weathered; calcisiltite; abundant carbonaceous debris on bedding surfaces; abundant chert replacement, particularly in upper part; highly fractured, fractures healed by calcite; thick bedded, base gradational	10.5
	(3.5 feet above base - calcisiltite: spicule lime packstone)	
11	Shale, blue-gray to black fresh, brown weathered; silty with thin siliceous shale interbeds, spiculitic in upper part; common carbonaceous debris; unit forms notch; basal contact obscured by talus	5.0

Unit	Lithology	Thickness (feet)
10	Spiculiferous limestone, dark blue-gray fresh, weathers light to medium gray; calcisiltite; rare crinozoan bioclasts and brachiopod debris; abundant chert nodules; laminated; thick bedded, sharp basal contact	30.5
	(1.2 and 15.0 feet above base - calcisiltite: argillaceous, spicule lime packstone)	
9	Micritic limestone, medium gray fresh and weathered; calcilutite; abundant algal debris, rare crinozoan and brachiopod fragments and rugose corals; thin to thick beds with hummocky surfaces, base gradational	12.0
	(calcilutite: crypt algal lime mudstone)	
8	Spiculiferous limestone, light to medium gray fresh and weathered; calcilutite; thin zones with common crinozoan bioclasts; slightly cherty, nodular thin to medium beds, basal contact gradational	2.8
7	Conglomeratic limestone, dark gray fresh, weathers brown; medium calcarenite with thin interbeds of calcilutite; abundant crinozoan bioclasts; common chert nodules; thick to very thick bedded, basal contact gradational	4.2
	(base - medium calcarenite: argillaceous, intraclastic, crinozoan lime packstone)	
	(basal 1.0 foot - _I. convexus_)	
6	Micritic limestone, dark gray fresh and weathered; calcilutite to calcisiltite; abundant tubular algae and spicules, common crinozoan debris; argillaceous partings impart nodular appearance to weathered surfaces; common chert nodules; medium to thick bedded, basal contact gradational	4.9

Unit	Lithology	Thickness (feet)
5	Bioclastic limestone, medium gray fresh and weathered; fine to medium calcarenite; abundant crinozoan bioclasts and oolites in a micritic matrix, rare rugose corals; single bed with a gradational basal contact	1.4
4	micritic limestone, dark gray fresh, weathers medium gray; calcilutite to calcisiltite; abundant tubular algae, common spicules and crinozoan bioclasts, rare rugose corals; argillaceous partings produce nodular bedding, medium to thick beds; nature of basal contact obscured by weathering	3.5
	(1.8 feet above base - specimen consists of three distinct layers symmetrically disposed in the bed: layer 1 - calcisiltite: argillaceous, crinozoan, spicule lime packstone; layer 2 - calcisiltite: spicule, tubular algae lime boundstone; layer 3 - calcilutite: tubular algae lime boundstone)	
3	Bioclastic limestone, dark gray fresh, weathers orange-brown; coarse calcarenite; abundant crinozoan bioclasts, brachiopod valves including strophomenids and fenestrate bryozoans in a micritic matrix; laminated; abundant chert nodules; medium bedded, base gradational	1.0
	(conodont channel sample - <u>I. convexus</u>)	
2	Spiculiferous limestone, medium gray fresh and weathered; very fine calcarenite; abundant sponge spicules and fine skeletal debris in micritic matrix, common wood debris, vaguely laminated; rate chert nodules; medium to thick bedded, base covered	1.5
	(top - very fine calcarenite: peloid, spicule lime packstone)	
	(<u>I. convexus</u>)	

SECTION 29

Carlton's Quarry

This section is located in the SW¼, SW¼, sec. 9., T. 4 N., R. 17 E., Hartshorne Quadrangle, Pittsburg County, Oklahoma. The section was measured on the east wall of a rock quarry that is intermittently quarried for crushed stone. The quarry is owned by Mr. Carlton, who lives on the south side of Oklahoma Highway 1 about 5 miles southeast of Hartshorne, Oklahoma. The quarry can be reached from Hartshorne by taking Highway 1, southeastward from Hartshorne, a distance of 1.8 miles to the quarry access road which intersects the highway from the south. Follow this access road about one-half mile to the east wall of the quarry.

The lower limestone, middle shale and upper sandstone/limestone members are exposed. The *Idiognathoides convexus* and the *Neognathodus kanumai* - *Idiognathoides ouachitensis* zones are found in the lower limestone but higher zones were not recognized because of lack of suitable lithologies for standard conodont recovery techniques. This section and section 27 provide additional information concerning basinward facies changes in the Hartshorne area. Section 29, 6, 28, and 32, all located on Limestone Ridge demonstrate the rapid facies changes seen along strike.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	183.6
	upper sandstone/limestone member	7.3
15	Sandstone, red-brown or tan; fine grained, well sorted subangular quartz sand; ferruginous; tabular cross-bedded in upper 1.0 foot, cross-beds dip to southwest; medium to thick bedded; unit located at crest of ridge above quarry; base covered	7.3
	middle shale member	65.0
14	Covered	65.0
	lower limestone member	111.3
13	Bioclastic limestone, light gray fresh, weathers brown with iron stains; medium calcarenite; abundant crinozoan bioclasts, coated grains and oolites, common brachiopod valves, bryozoans and molluscs; sandy; medium to thick bedded, basal contact gradational	5.4
	(2.7 feet above base - medium calcarenite: sandy, sorted, brachiopod, crinozoan lime grainstone)	
	(top two feet - *I. ouachitensis* and *G. gymna*)	
12	Spiculiferous, sandy limestone, medium to dark gray fresh, red-brown and brown weathered; abundant spicules and crinozoan bioclasts, common ramose bryozoans, brachiopods and mollusc fragments, abundant vertical plug shaped burrows; medium to thick bedded; basal contact gradational	2.8
	(base - fine grained: sandy, spicule, fossil lime packstone)	
11	Shale, dark blue-gray fresh, weathers to rusty brown; common crinozoan bioclasts, vertical burrows and *conostichus*, rare goniatites; thin spiculiferous limestone interbeds	

Unit	Lithology	Thickness (feet)
	in upper part; basal contact gradational	16.0
10	Conglomeratic limestone, medium gray fresh and weathered, iron stained; coarse calcarenite; abundant crinozoan bioclasts, coated grains and oolites, common bryozoans, molluscan debris and rugose corals, abundant limestone intraclasts, mostly composed of spiculiferous limestone; layer thickens and thins, basal contact sharp and erosive	2.5
	(1.5 feet above base - coarse calcarenite: intraclast bearing, oolitic crinozoan lime packstone)	
	(top 1.0 foot - *I. ouachitensis*)	
9	Spiculiferous limestone, dark blue-gray fresh, light gray and tan weathered; calcisiltite; rare to common crinozoan stem fragments some nearly an inch in diameter, rugose corals and brachiopods, fossils most abundant in top 10.0 or 15.0 feet; laminated; abundant chert nodules; common shale partings; thin to very thick bedded, basal contact gradational	40.0
	(base - calcisiltite: argillaceous, spicule lime packstone)	
	(top - calcisiltite: argillaceous, crinozoan, spicule lime packstone)	
8	Micritic limestone, medium gray fresh and weathered; pseudo-brecciated calcilutite with thin red-brown crumbly calcarenite interbeds near base; abundant rugose corals encrusted by tubular algae 2.5 to 3.5 feet above base, in general fossils are rare, these include crinozoan bioclasts, brachiopods and gastropods; thick to very thick bedded, basal contact gradational	16.0
	(3.0 feet above base - medium calcirudite: rugose coral lime packstone)	

Unit	Lithology	Thickness (feet)
7	Spiculiferous limestone, medium gray fresh and weathered, iron stained; calcisiltite; abundant spicules, spiculiferous zones tend to be replaced by chert, rare crinozoan columnals; thick to very thick bedded; basal contact covered by talus	4.7
	(base - calcisiltite: spicule lime packstone)	
6	Spiculiferous limestone, dark blue-gray fresh, blue-gray or tan weathered; fine calcarenite, abundant spicules, common crinozoan bioclasts, abundant vertical to subvertical shale infilled burrows; thick bedded, basal contact sharp	1.5
	(top - fine calcarenite: argillaceous, crinozoan, spicule, lime packstone)	
5	Bioclastic limestone, medium to dark gray fresh, dark gray or orange-brown; medium calcarenite to fine calcirudite; abundant crinozoan bioclasts and oolites, common micritized grains, bryozoans, molluscan fragments, brachiopods and rugose corals; tabular cross-bedded, tabular cross-beds dip to north or northwest; single bed that thickens	0.5-1.0
	(top - medium calcarenite: sandy, sorted, oolith, crinozoan lime grainstone)	
	(conodont channel sample - *I. convexus*)	
4	Carbonaceous limestone, medium gray fresh, orange-brown weathered; fine to very fine calcarenite; abundant ooliths, coated grains and crinozoan bioclasts, abundant carbonaceous debris on bedding plane surfaces; cross-bedded; very thick bedded, sharp basal contact	7.0-7.5
	(base - medium calcarenite: well sorted, peloid, oolitic lime grainstone)	
	(1.4 feet above base - coarse calcarenite: sorted, crinozoan, oolitic lime grainstone)	

Unit	Lithology	Thickness (feet)
	(basal one foot - _I_. _convexus_)	
3	Oolitic limestone, gray-brown fresh, light gray weathered, coarse to fine calcarenite; abundant coated grains and ooliths, common crinozoan and brachiopod debris; common rounded limestone intraclasts similar to underlying unit, basal contact sharp and irregular	1.0-1.4
	(top - medium calcarenite: well sorted, peloid oolitic lime grainstone)	
	(top 4 inches - _I_. _convexus_)	
2	Spiculiferous limestone, blue-gray fresh, medium gray or buff weathered; calcilutite to very fine calcarenite; common medium interbeds that contain crinozoans, brachiopods, massive bryozoans and oncolites; thin shale interbed in upper part of unit; abundant chert nodules; medium to thick bedded, base covered	12.5
	(3.4 feet above base - calcisiltite: fossil, spicule lime packstone)	

SECTION 30

Blue Valley Ranch

This section is located in the NE¼, NW¼, sec. 34, T. 4 N., R. 16 E., Hartshorne Quadrangle, Pittsburg County, Oklahoma. The section is on the Blue Valley Ranch which can be reached by driving south from section 9 a distance of about 1.5 miles. At that point the ranch road intersects the country road from the west, drive about a half a mile to the foreman's house in the valley between ridge exposures of the Wapanucka. The section was measured in a powerline cut almost due north of the main ranch house and about a 1000 feet northeastward from the secondary ranch house.

The lower limestone, middle shale and upper sandstone/limestone members are exposed in the powerline cut. Conodonts were recovered from two units (4 and 9b), the lower fauna is characteristic of the *I. convexus* zone, the upper fauna is non-diagnostic.

Unit	Lithlogy	Thickness (feet)
	Wapanucka Formation	445.4
	upper sandstone/limestone member	66.5
12	Spiculiferous chert, orange-brown; abundant crinozoan molds, common spiriferid brachiopod molds; leaching of carbonate has resulted in anastomosing caverns; medium bedded, base covered	25.0+

Unit	Lithology	Thickness (feet)
11	Covered	18.0
10	Sandstone, pale yellow, white or orange-brown; fine grained, sub-angular, well sorted quartz sand; ferruginous; tabular cross-bedded, cross-beds dip to south or south-east; thick bedded; only 8.0 feet exposed in power line cut but 25 feet exposed in offset to east where upper part is more completely exposed; base covered	25.0
	middle shale member	118.0
9C	Covered	118.0
	lower limestone member	261.3
9B	Bioclastic limestone, medium gray fresh and weathered; coarse calcarenite; abundant crinozoan bioclasts and ramose bryozoans; current laminated; medium bedded; unit measured in offset section to east of power line cut, base covered	2.4
	(top - medium calcarenite: sandy, crinozoan lime packstone)	
	(non-diagnostic conodonts)	
9A	Covered	25.0
8	Micritic limestone, blue-gray fresh, weathers medium gray; calcilutite; rare crinozoan bioclasts, spiculiferrous; abundant chert nodules in lower 25 feet; unit mostly covered, medium to thick beds, base marked by 1st occurrence of abundant chert	36.5
	(base - calcilutite: tabular algae lime boundstone)	
	(top - calcilutite: cryptalgal lime mudstone)	
7	Micritic limestone, light gray fresh, medium gray and white weathered;	

Unit	Lithology	Thickness (feet)
	pseudo-brecciated calcilutite; abundant tabular algae, rare crinozoans and rugose corals; very thick beds that weather spheroidally, base covered	22.0
	(top - fine calcarenite: tabular algae lime boundstone)	
6	Covered	17.0
5	Spiculiferous limestone, dark blue-gray fresh, weathers medium gray; calcisiltite, rare thin calcarenite beds; abundant tabular algae and spicules, common crinozoans, ramose bryozoans, forams and molluscan debris; abundant chert nodules; medium to thick bedded; nature of basal contact uncertain	38.5
	(base - medium calcarenite: argillaceous, spicule, crinozoan lime packstone)	
	(10.0 feet above base - medium calcarenite: spicule, tabular algae lime packstone)	
	(top - fine calcarenite: argillaceous, spicule, tubular algae lime packstone)	
4	Bioclastic limestone, medium gray freh, weathers tan; medium to coarse calcarenite; abundant crinozoan bioclasts, common oolites and ramose bryozoans; current bedded; thin to very thick bedded, base covered	11.4
	(base - medium calcarenite: sandy, poorly sorted, oolith, crinozoan lime grainstone)	
	(basal 1.0 foot - _I. convexus_)	
3	Covered	92.0
2	Spiculiferous chert and spiculiferous	

Unit	Lithology	Thickness (feet)
	limestone, dark blue-gray fresh, orange-brown or buff weathered; calcisiltite, abundant chert nodules, loss of carbonate results in anastomosing caverns; thin to thick bedded, base covered	16.5
	(1.5 feet above base - calcisiltite: spicule lime packstone)	

SECTION 31

Penitentiary Quarry

This section is located on property belonging to the Oklahoma State Prison System. Permission to enter may be obtained from the warden at the minimum security prison facility at Flora, Oklahoma. The section was measured adjacent to a small logging trail which cuts Limestone Ridge in the NW¼, SE¼, sec. 15, T. 1 N/, R. 12 E., Coalgate SE Quadrangle, Atoka County, Oklahoma. The logging trail can be reached by U.S. Highway 69, the trail intersects this highway from the west about 1.4 miles north of the intersection of U.S. Highway 69 with Oklahoma State Highway 43 west, 14.3 miles north of Atoka.

This section represents the western-most exposure of the Wapanucka on Limestone Ridge. Immediately to the southwest, about 1.0 mile, Limestone Ridge is terminated by a major fault. The Wapanucka is next exposed to the east along the eastern flank of the Arbuckles, west of Atoka. The section at this locality includes the Chickachoc Chert, middle shale, and upper sandstone/limestone members. Only the upper member is well exposed.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	310.0

Unit	Lithology	Thickness (feet)
	upper sandstone/limestone member	310.0
24	Micritic limestone, light gray fresh, weathers medium gray; pseudo-brecciated calcilutite; common phylloid algae, rare crinozoans, rugose corals and bryozoans, fossils occur most abundantly in thin layers parallel to bedding; slightly cherty; thick bedded, sharp basal contact	4.7
	(base - calcilutite: fossil lime wackestone)	
23	Bioclastic limestone, medium gray fresh and weathered; medium calcarenite, abundant micritized crinozoan bioclasts and ooliths, common spicules particularly in lower part, rare bryozoans, brachiopods, gastropods and forams; abundant black anastomosing chert nodules; medium to thick bedded, basal contact sharp	3.0
	(base - fine calcarenite: sandy, crinozoan, spicule lime packstone)	
	(top - medium calcarenite: oolitic, crinozoan lime packstone)	
	(S. elegantulus)	
22	Micritic limestone, light gray fresh, weathers medium gray; calcilutite; common tubular and phylloid algae and rugose corals; thin argillite partings, pseudo-brecciated; medium to thick bedded, basal contact sharp	8.3
	(3.2 feet up - calcilutite: algal lime mudstone)	
21	Bioclastic limestone, light gray fresh, medium gray, brown or black weathered; very fine to fine cal-carenite; abundant crinozoan bio-clasts, spicules, ooliths and coated grains; cherty; single bed, sharp basal contact	1.6
	(base - fine calcarenite: sandy,	

Unit	Lithology	Thickness (feet)
	crinozoan, spicule lime packstone)	
	(S. elegantulus, D. coloradoensis, N. clarki)	
20	Micritic limestone, light gray fresh and weathered; calcilutite; common phylloid and tubular algae, rare crinozoans and rugose corals; cherty; very thick bedded sharp basal contact	9.0
	(5.0 feet up - calcilutite algal lime mudstone)	
19	Spiculiferous limestone, dark blue-gray fresh, tan weathered; calcisiltite; rare crinozoans and rugose corals; common shale partings; very cherty particularly in top 5.0 feet; medium to thick bedded, sharp basal contact	15.0
	(4.0 feet up - calcisiltite: argillaceous, spicule lime packstone)	
18	Bioclastic limestone, medium gray fresh and weathered; fine calcarenite; abundant crinozoans, ooliths and coated grains, common spicules, most calcareous grains black due to micritization; single bed, sharp basal contact	4.4
	(3.0 feet up - medium calcarenite: oolitic, crinozoan lime packstone)	
	(top 1.0 foot - I. sinuosis)	
17	Spiculiferous limestone, dark blue-gray fresh, buff weathered; calcisiltite: as much as 50% of unit replaced by black anastomosing chert; thick bedded, sharp basal contact	22.0
	(2.3 feet up - calcisiltite: argillaceous, spicule lime packstone)	

Unit	Lithology	Thickness (feet)
16	Bioclastic limestone, medium gray fresh and weathered; medium to coarse calcarenite: abundant crinozoan bioclasts, common brachiopod valves, bryozoans and molluscan fragments; sandy, current laminated; thin interbeds of cherty spicule packstone; medium to thick bedded, sharp basal contact	1.0
	(base - medium calcarenite: sandy, crinozoan lime packstone)	
	(_I. sinuosis_)	
15	Spiculiferous limestone, light gray fresh, brown weathered; very fine calcarenite; common crinozoan bioclasts; abundant chert nodules; thick bedded, sharp basal contact	4.4
	(base - very fine calcarenite: peloid, spicule lime packstone)	
14	Bioclastic limestone, blue-gray fresh, red-brown weathered; fine calcirudite; abundant crinozoans, rare brachiopod fragments; sandy, current bedded; medium to thick bedded, basal contact sharp	2.4
	(base - coarse calcarenite: crinozoan lime packstone)	
	(_I. sinuosis_, _I. ouachitensis_, _N. kanumai_ and _N. clarki_)	
13	Spiculiferous limestone, blue-gray fresh, brown weathered; calcisiltite; common crinozoans and bryozoans; irregular beds with shale drapes; very cherty, base covered	4.1
12	Spiculiferous limestone, as above, and covered	11.5
	middle shale member	130.0
11	Covered, thickness estimated	130.0

Unit	Lithology	Thickness (feet)
	Chickachoc Chert Member	91.2
10	Spiculite, dark blue-gray to black fresh, orange-brown weathered; calcisiltite; argillaceous, flaser, wavy and lenticular bedding; thick bedded, base covered	3.0
9	Covered	21.3
8	Bioclastic and spiculiferous limestone, medium gray fresh, orange-brown and buff weathered; unit consists of 1 to 2 feet of spiculiferous limestone overlain by calcarenite: abundant crinozoans, common brachiopod valves, bryozoans, ostracods, and ooliths; single bed, base covered	4.3
	(base - calcisiltite: spicule lime packstone)	
	(2.5 feet up - medium calcarenite: spicule, crinozoan lime packstone)	
	(2.5-3.5 feet up - N. kanumai -I. ouachitensis and G. gymna)	
7	Covered	9.5
6	Spiculite, as above, base covered	15.0
5	Covered	21.3
4	Spiculiferous limestone, medium gray fresh, weathers gray-brown, calcisiltite; cherty; thick to very thick bedded; base covered	9.8
	(base - calcisiltite: argillaceous, spicule lime packstone)	
3	Covered	14.5
2	Spiculiferous limestone, as above, base covered	6.0

SECTION 32

Gravel Pit

This section was measured on the northeast wall of an abandoned rock quarry located in the NW¼, SE¼, NE¼, sec. 33, T. 5 N., R. 18 E., Higgins Quadrangle, Latimer County, Oklahoma. The route to this locality is somewhat circuitous, take Highway 1 southeastward from Hartshorne to Higgins, Oklahoma. At Higgins, turn north on the small black top road that quickly passes into a gravel road. Travel north on this road about five miles to the large ranch located to the north of the point where the road is tangential with the subdued Limestone Ridge. Turn north into the driveway and proceed to either the main house or hired hands house, there permission and detailed instructions for finding the quarry can be obtained.

Only the middle shale and lower limestone members are exposed. The middle shale contains several chert interbeds which is unusual. Two conodont zones, *I. convexus* and *N. kanumai* - *I. ouachitensis*, occur in the lower limestone. This locality was stop 12 in the South-Central Section, Geological Society of America fieldtrip prepared by Shelton and Rowland (1974).

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	201.2
	middle shale member	90.4
23	Spiculiferous chert, orange, brown; medium bedded; cavernous, poorly exposed below crest of ridge outside quarry; base covered	4.0
22	Covered	22.0
21	Spiculiferous chert, orange-brown very porous and heavily weathered; thin to medium bedded, base covered	4.0
20	Covered	21.0
19	Spiculiferous chert, orange-brown to black, very argillaceous; thin bedded, base covered	4.0
18	Covered, laterally covered interval filled by lithology similar to units above and below	8.2
17	Spiculiferous limestone which weathers to spiculiferous chert; dark blue-gray fresh, weathers buff; medium to thin bedded, basal contact gradational	1.0
16	Shale, tan and light olive green; thin spiculiferous interbeds; nature of basal contact indeterminate	6.0
	lower limestone member	110.8
15	Micritic limestone, light gray fresh and weathered; calcilutite, sparse biomicrite; rare rudite size crinozoan stem fragments mostly at bedding surfaces; mottled texture, cherty; very thick bedded, basal contact sharp	5.9
	(1.4 above base - calcilutite: cryptalgal lime mudstone)	

Unit	Lithology	Thickness (feet)
16	Shale, tan and light olive green; thin spiculiferous interbeds; nature of basal contact indeterminate	6.0
	lower limestone member	110.8
15	Micritic limestone, light gray fresh and weathered; calcilutite, sparse biomicrite; rare rudite size crinozoan stem fragments mostly at bedding surfaces; mottled texture, cherty; very thick bedded, basal contact sharp	5.9
	(1.4 above base - calcilutite: cryptalgal lime mudstone)	
14	Micritic limestone, dark blue-gray fresh, weathers light gray; calcilutite; abundant tubular algae, rare crinozoans; abundant poorly silicified chert nodules; thick bedded, sharp basal contact marked by load casts	9.0
	(1.5 feet up - calcilutite: tubular algae lime boundstone)	
13	Micritic limestone with thin shale interbeds and partings, medium gray fresh and weathered; calcilutite; abundant tubular algae, rare crinozoans; medium to thick bedded, gradational basal contact	6.5
	(2.5 feet up - calcilutite: argillaceous, tubular algae lime boundstone)	
12	Micritic limestone, medium gray fresh and weathered; calcilutite; abundant tubular algae; slightly argillaceous; clotted texture, slightly cherty; medium to thick bedded, base covered	15.0
	(15.0 feet up - very fine calcarenite (recrystillized calcilutite): tubular algae lime mudstone)	

Unit	Lithology	Thickness (feet)
	(base - calcilutite: tubular algae lime boundstone)	
11	Covered, probably shale	8.8
10	Micritic limestone, medium gray fresh and weathered; calcilutite with thin calcarenite interbeds in upper part; abundant tubular algae, twiggy bryozoans and rare rugose corals; top of unit marked by thin (1 inch) calcarenite that contains chert clasts; abundant shale interbeds and partings surfaces; medium to thick bedded, base covered	18.0
	(3.0 feet up - calcilutite: tubular algae lime boundstone)	
	13.5 feet up - calcilutite: crinozoan, tubular algae lime boundstone)	
	(top - medium calcarenite: sandy, intrclast-bearing, crinozoan lime packstone; overlies bioturbated tubular algae micritic limestone)	
	(top - _I. ouachitensis_)	
9	Covered	6.8
8	Oolitic limestone, light gray fresh and weathered; coarse calcarenite; sorted oolites, coated grains and crinozoan bioclasts; small scale trough, cross-bedded; very thick bedded, gradational basal contact	10.0
	(4.0 feet up - medium calcarenite: sorted, oolitic lime grainstone)	
	(3.5-4.0 feet up - _I. convexus_)	
7	Bioclastic limestone, medium gray fresh, red-brown weathered; medium to coarse calcarenite; abundant coated grains and crinozoans, common ramose bryozoans and molluscs, rare rugose corals; common red-brown fossiliferous	

Unit	Lithology	Thickness (feet)
	argillaceous partings; thick bedded, gradational base	2.8
	(1.5 feet up - medium calcarenite: argillaceous, crinozoan, coated grain lime packstone)	
	(top 1.0 foot - _I_. _convexus_)	
6	Bioclastic limestone and shale interbeds, medium gray fresh, gray-brown weathered; coarse calcarenite; abundant crinozoan debris and oolites, common rugose corals, fistuliporid and ramose bryozoans, molluscs and red algae; thick bedded, base covered	4.0
	(3.0 feet up - medium calcarenite: argillaceous, oolitic crinozoan lime packstone)	
5	Covered	6.5
4	Bioclastic limestone, medium gray fresh, weathers orange-brown; medium calcarenite to fine calcirudite; abundantly fossiliferous, crinozoans, brachiopods, ramose and fenestellid bryozoans, rugose and tabulate corals, platycerid gastropods, crushed goniatites, many skeletal grains blackened due to micritization; tabular cross-bedded that dip to northwest; medium to thick bedded,base covered	2.0
	(base - coarse calcarenite: oolitic crinozoan lime packstone)	
3	Covered	11.0
2	Biolcastic limestone, blue-gray fresh, orange-brown weathered; coarse calcarenite; abundant crinozoan, common ramose bryozoans, molluscs and brechiopods; many black due to micritization; common flat shale clasts; silicification of unit results in development of weathering rind; medium to thick bedded, base covered	3.5

Unit	Lithology	Thickness (feet)
	(top - coarse calcarenite: argillaceous, crinozoan lime packstone)	

SECTION 33

Limestone Gap

This section is located in the S½, NE¼, sec. 31, T. 2 N., R. 13 E., Limestone Gap Quadrangle, Atoka County, Oklahoma. This section has been measured in detail by Rowett (1959) his section has been slightly modified based on a re-examination of the locality but thicknesses are the same. Rowett's description of the locality, from Rowett and Sutherland (1964) is:

At this locality the ridge is cut by Limestone Creek, which forms a prominent water gap. The Kansas, Missouri, and Texas Railroad also crosses the ridge obliquely here. The lower part of the section (units 1-1B) was measured in a cut northeast of the railroad bridge, and the upper part (units 14-21) was measured in the larger cut to the southwest of this bridge. Unit 22 is exposed only in the bed of Limestone Creek. All beds strike N54°E and dip from 35° to 45° S.

This is a key exposure of the Wapanucka Formation in the frontal belt of the Ouachita Mountains. The section here was measured and described by Wallis (1915, p. 59); fossils were collected from the lower part of the section by Hollingsworth (1933, loc. 7), but the section was not measured at that time; Harlton (1938, p. 904) measured and described the section here in some detail. The top of the Wapanucka Formation is covered but apparently is in fault contact with the overlying Atoka Formation. The section was measured and sampled by Rowett (1959) as the basis of a petrographic study of the Wapanucka Formation. Measurements made at that time are recorded here.

The Chickachoc Chert, middle shale and upper sandstone/ limestone are exposed at this locality.

Unit	Lithology	Thickness (feet)
	Wapanucka Formation	356.0
	upper sandstone/limestone member	107.0
22	Spiculiferous chert, black fresh and weathered; very fine grained; thin, regular beds; basal contact gradational	5.0
21	Limestone, blue-gray, weathers light gray: calcilutite to fine calcirudite, unit consists of at least 4 distinct lithologies: basal 4 to 5 feet consists of spiculiferous limestone with abundant chert nodules; from about 6 to 20 feet above base with grades from fine calcirudite: crinozoan packstone to a medium calcarenite: sandy, sorted, oolitic grainstone; upper part of unit consists of pseudo-brecciated calcilutite; medium to very thick bedded, basal contact gradational	58.5
	(1.0 foot up - calcisiltite: spicule lime packstone)	
	(8.0 feet up - fine calcirudite: crinozoan lime packstone)	
	(15.0 feet up - medium calcarenite: oolite lime packstone)	

Unit	Lithology	Thickness (feet)
	(34.0, 53.0 and 58.0 feet up - calcilutite: algal lime mudstone)	
20	Spiculiferous limestone, dark blue-gray fresh, weathers brown; calcisiltite; abundant vertical to subvertical burrows that extend into underlying units; very argillaceous, abundant chert nodules; thin lumpy beds, base marked by extensive surface of bioturbation	3.0
	(1.0, 2.0 and 3.0 feet - calcisiltite: spicule lime packstone)	
19	Bioclastic limestone, light gray fresh, weathers medium gray; medium to coarse calcarenite; abundant oolites, crinozoan bioclasts and intraclasts, intraclasts are composed of spiculiferous and micritic limestone; single bed with sharp, ercsive basal contact	2.5
	(1.0 foot up - coarse calcarenite: poorly sorted, crinozoan, oolite lime grainstone)	
	(top - medium calcarenite: intraclastic, fossil lime packstone)	
18	Spiculiferous limestone, dark blue-gray fresh, weathers buff and black; calcisiltite; abundant horizontal feeding traces, mostly Zoophycus; argillaceous, cherty; thin to medium even, regular beds that became platy with weathering, basal contact gradational	32.0
	(24.0 feet up - calcisiltite: spicule lime packstone)	
17	Bioclastic limestone, medium gray fresh and weathered, fine calcirudite; abundant crinozoans and ramose bryozoans, rare brachiopods and tabulate corals; single bed, with sharp basal contact	1.5

Unit	Lithology	Thickness (feet)
	(base - fine calcirudite: sandy, ramose bryozoan, crinozoan lime packstone)	
16	Spiculiferous limestone, dark blue-gray fresh; buff and black weathered; calcisiltite, thin regular beds that become irregular and platy; abundant horizontal feeding traces; basal contact gradational	4.5
15	Bioclastic limestone, medium gray fresh and weathered; medium calcirudite; abundant crinozoans and ramose bryozoans; single bed, base covered	1.5
	(base - medium calcirudite: ramose bryozoan, crinozoan lime packstone)	
	middle shale member	149.0
14	Covered	149.0
13	Spiculite, dark blue-gray fresh, brown or buff weathered; very fine grained; abundant horizontal feeding traces which produce wispy appearance; some flaser, wavey and lenticular bedding; thin to medium regular beds, basal contact gradational	7.0
12	Shale, blue-gray fresh, weathers dark gray; slightly siliceous, rare spicules, basal contact gradational	6.5
11	Spiculite, as above	11.0
10	Shale, and thin spiculite, as above	10.5
9	Spiculite, as above	15.0
8	Shale, as above	6.5
7	Spiculite, as above	5.0
6	Shale, as above	8.5

Unit	Lithology	Thickness (feet)
5	Spiculite, as above	8.0
4	Shale, as above	3.5
3	Spiculite, as above except rare transported rugose corals	10.0
2	Shale, as above	4.5
1	Spiculite, as above	2.5
	"Springer" Formation	
	Shale	50-100+

APPENDIX 2

SYSTEMATIC PALEONTOLOGY

Genus <u>Diplognathodus</u> Kozur and Merrill, in Kozur, 1975

Type Species.--<u>Spathognathodus</u> <u>coloradoensis</u> Murray and Chronic, 1965.

Diagnosis.--A comparitively small platform element with a gnathodid basal cavity; the oral surface of which is typically ornamented by a carina that is subsivided into anterior and posterior portions by a distinctive notch or denticle depression.

Remarks.--Species differentiation is based on the nature and fusion of denticles on the carina and the presence or absence of a denticle depression. Platform elements constitute the only known elements associated in the apparatus of species of this genus.

DIPLOGNATHODUS COLORADOENSIS (Murray and Chronic, 1965)

Pl. 8, fig. 15

<u>Spathognathodus</u> <u>coloradoensis</u> Murray and Chronic, 1965, p. 606-607, pl. 72, figs. 11-13; Webster, 1969, p. 44, pl. 7; Webster, 1971, p. 406, pl. 1, fig. 23; Merrill, 1973, p. 304, pl. 3, figs. 20-42.

Non <u>Spathognathodus</u> <u>coloradoensis</u> Murray and Chronic. Koike, 1967, p. 310, pl. 3, fig. 23, 24 (= juveniles of <u>S</u>. <u>minutus</u>).

<u>Gnathodus</u> <u>coloradoensis</u> (Murray and Chronic). Thompson, 1970, p. 1043.

<u>Anchignathodus</u> <u>coloradoensis</u> (Murray and Chronic). Sweet, 1970, p. 222.

Diplognathodus coloradoensis (Murray and Chronic). Merrill, 1975, fig. 16:40, 17:16.

Diagnosis.--A diplognathodid chracterized by a spatulate (completely fused carina).

Description.-- See Murray and Chronic, 1965 and Merrill, 1973.

Remarks.--*D. coloradoensis* is readily distinguished from *D. orphanus* morphologically but there is no apparent difference in age of the two species.

Material and distribution.--For this study a total of 5 specimens were available, all from the upper sandstone/limestone member of the Wapanucka Formation (31-21, 17-11, 17-17, 2-13).

DIPLOGNATHODUS ORPHANUS (Merrill, 1973)

pl. 8, fig. 11

Spathognathodus orphanus Merrill, 1973, p. 309, pl. 3, figs. 45-56.

Diagnosis.--A diplognathidid characterized by a coarsely denticulate posterior carina that is basically convex in lateral view.

Description.--See Merrill, 1973.

Remarks.--This species is very rare in its occurrence in the Wapanucka, however, based on unpublished material of the author the species is extremely widespread and is consequently a useful biostratigraphic index.

The stratigraphic significance of the first occurrence of *D. orphanus* is equivocable. Its first occurrence indicates either a latest Morrowan or earliest Atokan age and is essentially coincident with the first occurrence of *D. coloradoensis*.

Material and distribution.--Two specimens both from the upper sandstone/limestone member of the Wapanucka Formation (18-29, 8-31).

Genus GONDOLELLA Stauffer and Plummer, 1932

Type Species.--*Gondolella elegantula* Stauffer and Plummer, 1932.

Diagnosis.--A gondolla-shaped element; typically, a platform with a central row of nodes on oral surface and an unbroken flaring loop surrounding basal cavity on aboral side.

GONDOLELLA GYMNA Merrill and King, 1971

Platform Element

pl. 8, figs. 8, 10

Gondolella ? sp. A Koike, 1967, p. 302, pl. 1, figs. 29-32.

Lonchodina sp. A Koike, 1967, p. 306, pl. 1, figs. 26-20.

Gondolella gymna Merrill and King, 1971, p. 658, pl. 75, figs. 7-14.

Lonchodina transitans Merrill and King, 1971, p. 658, pl. 75, figs. 15-18.

Diagnosis.--An early and middle Pennsylvanian gondolellid that lacks a platform.

Remarks.--This is the earliest known Pennsylvanian species to have developed an unbroken flaring loop around the basal cavity which is the main character suggested by Merrill and King (1971) to define the genus *Gondolella*. They suggest *G. gymna* evolved from a lonchodinid ancestor based on their material from the Seville Limestone of Desmoinesan age in northwestern Illinois.

Material and distribution.--One specimen from the upper sandstone/limestone member (18-31) was examined for this study.

Genus IDIOGNATHOIDES Harris and Hollingsworth, 1933

Type Species.--*Idiognathoides sinuatus* Harris and

Hollingsworth, 1933.

Diagnosis.--A platform conodont genus commonly consisting of asymmetrically paired polymorphic left and right elements. In oral view these elements exhibit a median trough of variable length. Prominent transverse ridges cross this trough in most right-sided elements but are not always present in left-sided elements but may be developed into a parapet; the outer margin passes anteriorly into a short carina and then into a free blade. Aborally a large, asymmetrical gnathodid basal cavity is developed.

Remarks.--The genus is highly polymorphic both between species and within left and right sided elements of a species. This has resulted in erection of many intergradational species that have little or no phylogenetic significance. A critical study through the range of the genus is sorely needed to clarify the present taxonomic confusion.

Speciation for this study is based on nature of oral ornamentation and the presence or lack of a well developed oral trough. Identification of species of *Idiognathoides* requires sufficient numbers of individuals to access morphologic variability. A species of *Idiognathoides*, for example *I. ouachitensis*, typically contains morphologic variants characteristic of older precursor faunas, in this case *I. convexus*. Consequently, speciation of the genus based on depauperate faunas can lead to erroneous conclusions. The degree to which occurrence of morphologic variants of species of *Idiognathoides* is controlled by environment is uncertain. This control does exist but more study is needed.

IDIOGNATHOIDES CONVEXUS (Ellison and Graves, 1941)

Platform Element

pl. 9, figs. 8, 9, 12-15

Polygnathodella convexa Ellison and Graves, 1941, p. 9, pl. 3, figs. 10, 12, 16.

Polygnathodella c.f. *convexa* Ellison and Graves, Koike, 1967, p. 308, pl. 3, figs. 1, 2.

Idiognathoides _convexus_ (Ellison and Graves) Webster, 1969, p. 37. pl. 5, figs. 17(?), 18; Dunn, 1970, p. 334, pl. 63, fig. 20(?), text-fig. 11F; Higgins and Bouckaert, 1968, p. 39, non pl. 4, fig. 3 (= right element of _I._ _sinuatus_); Lane, et.al., 1971, pl. 1, figs. 18, 19.

Diagnosis.--The non-platform elements, if any, in the apparatus of _I._ _convexus_ are not known. The platform elements are asymmetrically paired, as pointed out by Lane and Straka (1974). The right-sided element is narrow and convex in lateral view. The oral surface is ornamented by prominent acurate, transverse ridges which are convex anteriorly. The left-sided element is similar to the left platform element of _Idiognathoides_ _sinuatus_.

Remarks.--_Idiognathoides_ _convexus_ is the zonal name bearer for a conodont zone reported by Lane (Lane and others, 1972) from the Kessler Limestone (type Morrowan) in northwestern Arkansas. The range of the species in other areas of the contiguous United States may, however, include strata older than that encompassed by its local range in northwestern Arkansas (Dunn, 1977). In the author's collections, the species as presently defined occurs only in late Morrowan age rocks, but this particular morphologic variant persists into early Atoken age strata.

Idiognathoides _convexus_ is a polymorphic species that includes asymmetrically paired left and right platform elements. The right-sided elements in populations of _I._ _convexus_ contain some elements that could be assigned to _I._ _sinuatus_, as emended by Lane and Straka (1974) or _I._ _attenuata_. Generally, these are not abundant but in certain environmental regimes they may numerically dominate populations of _I._ _convexus_.

Material and distribution.--612 platform elements, 304 left-sided and 308 right-sided, were examined for this study. They were recovered from the lower limestone (8-2, 4, 7, 12, 13; 7-5, 7; 30-1; 29-4, 5; 32-4, 8; 27-4, 6; 28-13; 12-5; 13-3, 8; 15-11, 13; A16-2) and Chickachoc Chert (3-2, 7, 9; 2-2, 6W, 11W, 12W; 1-5, 7, 11; 20-6; 25-5; 26-8) members of the Wapanucka Formation in the Ouachita Mountains and the lower 3/4's of the Wapanucka Formation in the Arbuckle Mountain outcrop area. This species also occurs in the Kessler Limestone Member of the Bloyd Formation in northern Arkansas and Oklahoma.

IDIOGNATHOIDES QUACHITENSIS (Harlton, 1933)

Platform Element

pl. 9, figs. 1-7, 10, 11

Polygnathodella ouachitensis Harlton, 1933, p. 15, pl. 4, figs. 14 a-c; Ellison and Graves, 1941, pl. 3, fig. 8, 9; non-Koike, 1967, p. 309, pl. 3, figs. 3-5 (= I. corrugatus (?)).

Idiognathoides corrugatus (Harris and Hollingsworth) Dunn, 1970, p. 335, pl. 63, figs. 18, 25 only, non figs. 16, 17 (= I. corrugatus).

Diagnosis.--A idiognathodid distinguished by an oral surface bearing a prominent trough on right-sided elements that typically is transversed by ridges. These ridges may be partly interrupted by the trough on the anterior portion of the platform.

Remarks.--I. ouachitensis is a member of a phylogenetic sequence that involves several species of Idiognathoides. The phylogeny is characterized by the development of an oral trough that eventually extends the full length of the platform. The oldest (early Morrowan) respresentatives of this phylogeny (I. attenuata) lacks a trough in mature specimens. Middle Morrowan representatives (I. corrugatus) of Idiognathoides possess a trough that extends about 3/4 the length of the platform. This progressive increase in length of the oral trough culminates in a trough that extends the full length of the platform in I. ouachitensis by latest Morrowan time.

Material and distribution.--1,434 specimens (689 left-sided and 745 right-sided) platform elements were examined for this study. The species ranges from the top of the lower limestone (17-6, 8; 2-23, 25; 16-16, 18, 26; 8-24; 7-22; 29-10, 13; 32-10; 12-9; A16-13) and/or Chickachoc Chert (31-8; 18-3; 3-25, 26, 27, 28; 5-6; 16-6; 1-20) through the upper sandstone/limestone (31-14, 21; 18-28, 30, 31; 17-10, 11, 17; 4-20; 2-31; 7-25, 27; 11-6) members of the Wapanucka Formation in the Ouachita Mountains. It also occurs in the highest part of the Wapanucka in the Arbuckle Mountain area. *I. ouachitensis* is also present in my collections from the Trace Creek Shale.

Genus NEOGNATHODUS Dunn, 1970

Type Species.--*Polygnathus bassleri* Harris and Hollingsworth, 1933.

Diagnosis.--See Merrill and King (1971, p. 658).

NEOGNATHODUS BASSLERI (Harris and Hollingsworth, 1933)

Platform Element

pl. 8, figs. 5

Polygnathus bassleri Harris and Hollingsworth, 1933, p. 198, pl. 1, figs. 13a-e.

See Merrill, (1972, p. 822-823) and Merrill and King (1971, p. 659) for additional synonymy.

Diagnosis.--A neognathodid distinguished by a carina that terminates short of the posterior end of the platform's nodose margin.

Remarks.--*N. bassleri* ranges in age from middle Morrowan to early Atokan. It evolves from *N. symmetricus* by gradual shortening of the carina and it evolves into *N. bothrops* by gradual lengthening of the carina (Merrill and King, 1971; Merrill, 1975).

Material.--Two specimens from the highest measured unit of the type Wapanucka Formation (A16-13) on the flank of the Arbuckles were studied.

NEOGNATHODUS BOTHROPS Merrill, 1972

Platform Element

pl. 8, fig. 1, 3

For detailed synonomy see Merrill and King (1971) and Merrill (1972.

Diagnosis.--A neognathodid distinguished by a carina that merges with the posterior end of the platform. It is suggested by Merrill to be a precise homemorph of *N. symmetricus*, its ancestor, but can be separated from that species phylogenetically. *N. bothrops* evolved from *N. bassleri* by gradual lengthening of the carina.

Remarks.--In the author's material from the Ardmore Basin there does not appear to be a phylogenetic distinction between *N. symmetricus* and *N. bothrops*. Further study is needed to determine the relationship of *N. symmetricus* to younger elements referred by Merrill (1972) to *N. bothrops*.

Material and distribution.--Four specimens from two samples (17-10B and 17-11) from one section in the upper sandstone/limestone.

NEOGNATHODUS kanumai Koike

Platform Element

pl. 2, figs. 4, 6, and 7

Gnathodus cf. *roundyi* Gunnell, Koike, 1967, p. 43-44, pl. 1, figs. 27, 28.

Neognathodus roundyi (Gunnell) Dunn, 1970, p. 336-337, pl. 64, figs. 22-24.

Neognathodus n. sp. Lane and others, 1972, p. 553.

Neognathodus bothrops Merrill, Merrill, 1975, fig. 17: 65, only.

Neognathodus kanumai Koike, in press.

Diagnosis.--A neognathodid characterized by rounded platform margins that bear prominent transverse ridges.

Remarks.--As noted by Koike (1967) this species exhibits marked variation during its ontogeny.

Material and distribution.--65 specimens were examined for this study. They were recovered from the top of the lower limestone (17-8; 16-16) and/or Chickachoc Chert (31-8; 5-6; 1-19, 20) and the upper sandstone/ limestone (31-14, 21; 18-28; 17-10, 17; 7-27) member. The species also occurs in the Trace Creek Shale Member of the Atoka Formation in northwestern Arkansas and northeastern Oklahoma.

Genus NEOGONDOLELLA Bender and Stoppel, 1956.

Type Species.--*Gondolella mombergensis* Tatge, 1956.

Diagnosis.--Sweet's (1970) diagnosis is: *Neogondolella* includes conodont species in which the skeletal apparatus included elements of a single morphologic type. These elements, which are elongate, paired,and individually asymmetrical, have a terminal or subterminal posterior cusp; a median nodose or denticulate carina; and finely to coarsely pitted, largely unornamented, platform-like lateral extension, which are joined posteriorly in most species by a more or less well-developed brim that encloses the posterior end of the carina. Underside of elements marked by a longitudinally grooved keel that widens posteriorly to enclose a pit beneath the cusp.

Remarks.--von Bitter and Merrill (1977) have recently discussed neogondolelliform conodonts. They concluded that Pennsylvanian neogondolelliform conodonts are species of *Neogondolella*, sensu stricto, which previously were thought by most workers to be Permian or Triassic in age.

The genus is distinguished from gondolellids by the distinctive pitting on the margins of the oral surface and by an apparent absence of non-platform elements in its apparatus.

NEOGONDOLELLA CLARKI (Koike)

pl. 8, fig. 9

Gondolella clarki Koike, 1967, p. 301, pl. 2, figs. 1-3, and 6, only (non-figs. 4 and 5).

Neogondollella clarki (Koike) von Bitter and Merrill, 1977, fig. 1.

Diagnosis.--A neogondolellid with oral ornamentation consisting of minute pits on the margins of the platform element and a simple carina composed of isolated node-like denticles.

Remarks.--von Bitter and Merrill (1977) regarded early Pennsylvanian neogondolelliform conodonts as being properly assigned to the genus Neogondolella. This latter genus was previously thought of by most workers as indicating a Permian or Triassic age. von Bitter and Merrill argue that it is unlikely that such precise homeomorphy could exist between neogondolelliform conodonts of early and middle Pennsylvanian age and those of Permian and Triassic age. They suggest strong ecological or even provincial controls to account for absence of Neogondolella in studied intermediate age strata (late Pennsylvanian). This contrasts with the suggestion by Sweet (1970) that the genus is polyphyletic. More study is needed to determine which of these hypotheses is correct. The authors collections of Pennsylvanian conodonts suggests that ecological control of the diachronous occurrences of neogondolellid conodonts is possible.

Material and distribution.--16 specimens were available for study. They came from the upper part of the Chickachoc Chert (3-26; 5-6; 1-20) or lower limestone (17-8; 2-23; 16-16, 18; 29-13) members and from the upper sandstone/limestone (31-14, 21; 18-30; 17-10, 14, 17; 2-31) member.

Genus STREPTOGNATHODUS Stauffer and Plummer

Type Species.--Streptognathodus elegantulus Stauffer and Plummer, 1933.

Diagnosis.--A multielement species consisting of platform, ozarkodinid, neoprioniodid, hindeodellid, and trichonedellid elements (von Bitter, 1972; Baesemann, 1973). The platform element is distinguished by a deep median trough that separates the prominent transverse ridges on the flank of the platform.

Remarks.--Baesemann (1973) placed Streptognathodus in synonomy with Idiognathodus because of intergradation between the two. This intergradation is evident in the present study but the two genera are retained because of their distinct and marked difference in their platform elements. This usage stresses morphological differences and minimizes phyletic considerations in classification.

Speciation has been based on presence of accessory lobes; platform shape, and length or posterior extension of the carina.

STREPTOGNATHODUS ELEGANTULUS Stauffer and Plummer

Platform Element

pl. 8, figs. 13, 14, 16-21

Streptognathodus elegantulus Stauffer and Plummer, 1932, p. 47, pl. 4, figs. 6, 7, 22, 27; Ellison, 1941, p. 127-128, pl. 22, Figs. 1-6, 10; Koike, 1967, p. 55-56, pl. 3, figs. 13-15; non-Higgins and Bouckaert, p. 46, pl. 5, figs. 8, 10 (= Neognathodus).

Streptognathodus excelsus Stauffer and Plummer, 1932, p. 48, pl. 4, figs. 4, 5; Ellison, 1941, p. 130, pl. 22, figs. 15, 17, 20.

Streptognathodus gracilis Stauffer and Plummer, 1932, p. 48, pl. 4, figs. 12, 23; Ellison, 1941, p/ 128-129, pl. 22, figs. 7, 11.

Streptognathodus increbescens Stauffer and Plummer, 1932, pl. 4, figs. 9, 15, 16.

Streptognathodus sulcatus Gunnell, 1933, p. 281, pl. 32, Fig. 10; Ellison, 1941, p. 130, pl. 22, figs. 8, 12.

Polygnathus pawhuskaensis Harris and Hollingsworth, 1933, p. 199, pl. 1, figs. 12a, b.

Diagnosis.--Streptognathodid with deep, prominent trough; steep platform flanks, and accessory lobes typically on inner side but in some mature and gerontic specimens on outer side, as well.

Remarks.--Platform elements of S. elegantulus exhibits striking ontogenetic variations. Immature forms may have a carina that extends nearly or completely to the posterior tip of the platform. The carina receeds anteriorly during growth and nodes are added on the inner side of the anterior portion of the platform resulting in the formation of an accessory lobe. In some mature and most gereontic specimens a nodose accessory lobe maybe present on the outer side of the anterior portion of the platform.

Material and occurrence.--A total of 348 elements nearly equally divided between lefts and rights were examined from the upper sandstone/limestone member (31-14, 18, 21, 23; 18-30, 31; 2-31; 1-26; 8-31; 7-27, 29; 11-6) of the Wapanucka Formation. The species is also present in the Trace Creek Shale Member of the Atoka Formation in northeastern Oklahoma and northwestern Arkansas, the Bostwick Member of the Dornick Hills Group in southern Oklahoma.

STREPTOGNATHODUS EXPANSUS Igo and Koike

Platform Element

pl. 9, fig. 12

Streptognathodus expansus Igo and Koike, 1964, p. 188, pl. 128, figs. 1-4; See Lane and Straka, 1974 for additional synonomy.

Diagnosis.--Platform element with broad, flared basal cavity and simple row-like series of nodes on anterior oral surface at platform.

Remarks.--S. expansus has been suggested by Dunn (1970, 1977) to be an excellent short ranged index fossil that indicates a Middle Morrowan age. Occurrences of the species in the Wapanucka Formation are latest Morrowan and earliest Atokan age. This may extend the range into younger rocks then previously reported.

Material and occurrence.--A total of 5 specimens from the top of the Wapanucka Formation in the Arbuckle Mountain area (Locality 3 of Rowett and Sutherland, 1964) and the top of the upper sandstone/limestone member (2-39) of the Wapanucka Formation in the Ouachita Mountains.

PLATE 8

Important Platform Conodonts

(All figures are X20 except where noted)

Fig. 1, 3. Neognathodus bothrops Merrill, oral view of specimen from the upper sandstone/limestone member (sec. 17, unit 11), X50 and oral view of specimen from uppermost part of the type Wapanucka (section A16, unit 13).

Figs. 2, 4, 6, 7. Neognathodus kanumai, 2 and 6 are aboral and oral views of specimens from the Chickachoc Chert Member (sec. 1, unit 21); 4 and 7 are oral views of specimens from the lower limestone member.

Fig. 5. Neognathodus bassleri (Harris and Hollingsworth), oral view of specimen from uppermost part of the type Wapanucka (section A16, unit 13).

Figs. 8, 10. Gondolella gymna Merrill and King, 8 is inner lateral view of specimen from the upper sandstone/limestone member (sec. 31, unit 21) X50; 10 is aboral view of same specimen.

Fig. 9. Neogondolella clarki Koike, oral view of specimen from the upper sandstone/limestone member (sec. 31, unit 21).

Fig. 11. Diplognathodus orphanus Merrill, inner lateral view of specimen from the upper sandstone/limestone member (sec. 18, unit 29) X40.

Fig. 12. Streptognathodus expansus Igo and Koike, oral view of specimen from the Wapanucka type section (sec. A16, unit 13).

Figs. 13, 14, 16-21. Streptognathodus elegantulus Stauffer and Plummer; 13, 14, 17, and 18 are oral views of specimens from the upper sandstone/limestone member (sec. 18, unit 30); 16, 19-21 are one aboral and three oral views of specimens from the Trace Creek Shale at Sawnee Hollow in northeastern Oklahoma.

Fig. 15. Diplognathodus coloradoensis (Murray and Chronic) inner lateral view of specimen from the upper sandstone/limestone member (sec. 17, unit 17) X40.

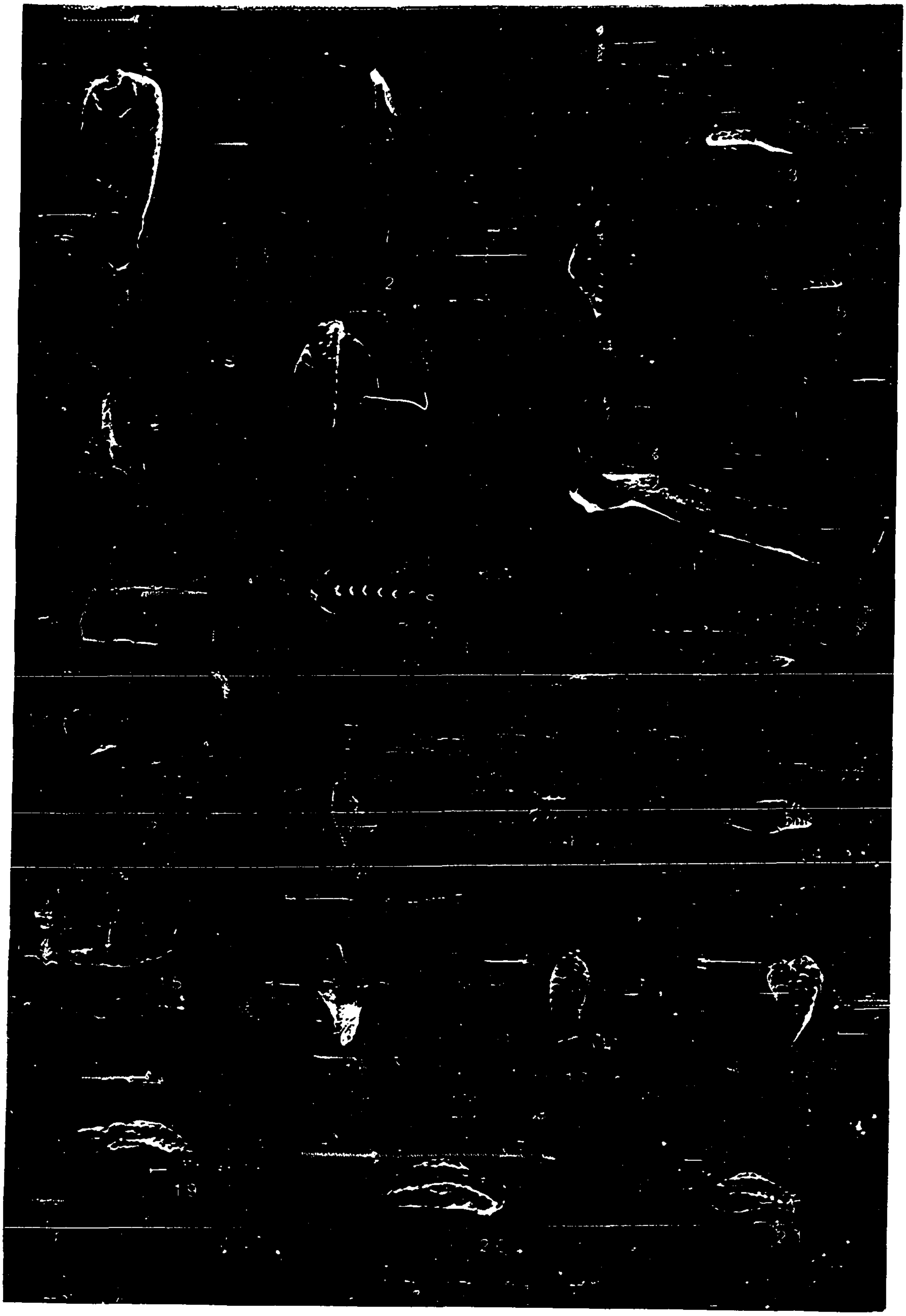


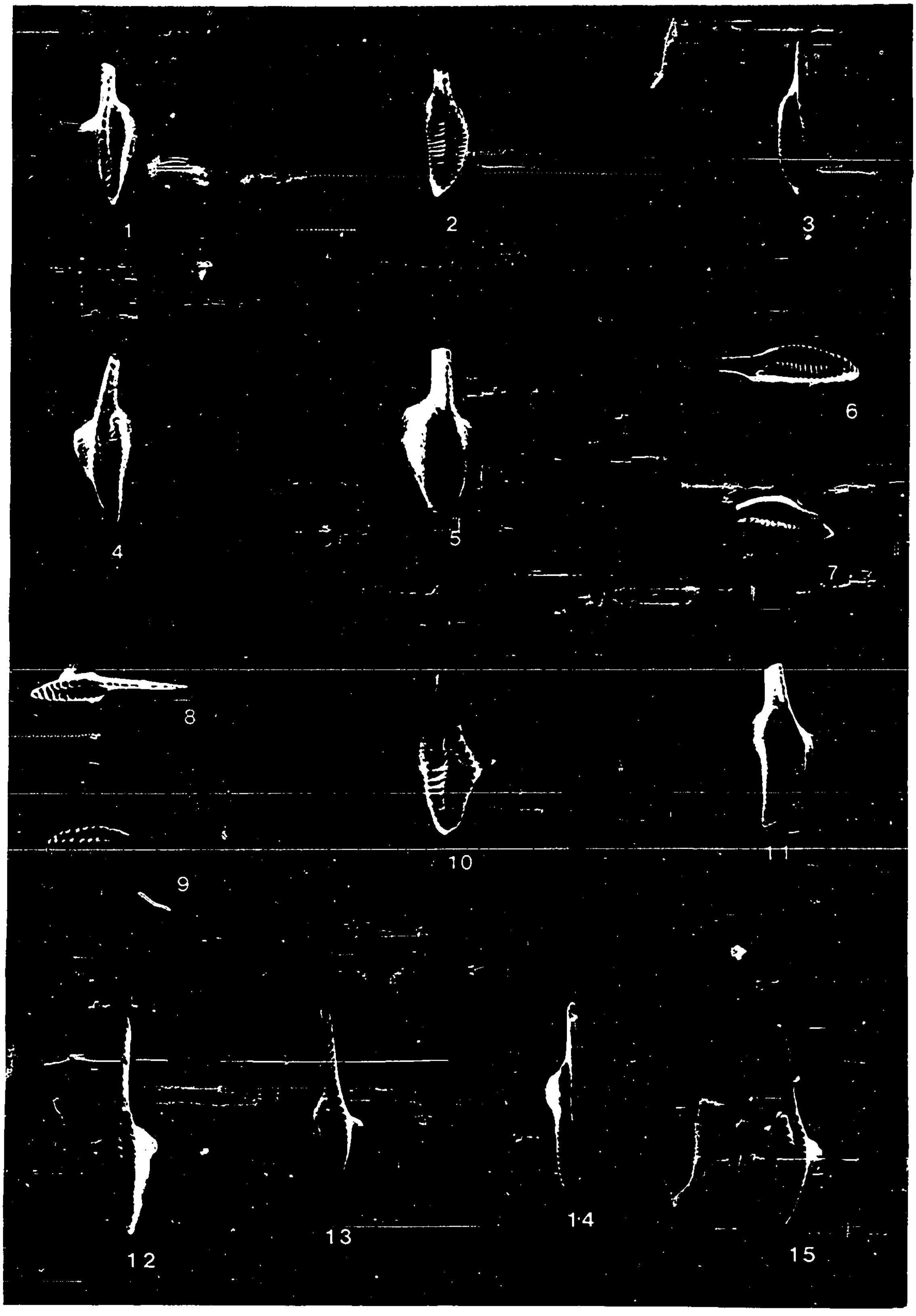
PLATE 9

Important Platform Conodonts

(All figures are X20)

Figs. 1-7. Idiognathoides ouachitensis (Harlton), 1 and 5 oral view of left and right-sided specimens from upper sandstone/limestone member (sec. 17, unit 8); 6 and 7 oral views of right-sided specimens from type section of the Wapanucka Formation (sec. A16, unit 13).

Figs. 8-15. Idiognathoides convexus (Ellison and Graves), 8, 12, 13, 14, and 15 one oral, one inner lateral, three oral and three oblique views of two left-and three right-sided specimens from the lower limestone member (sec. 32, unit 4); 9, 10 and 11 oral view of right-sided specimens from the lower limestone member (sec. 17, unit 11).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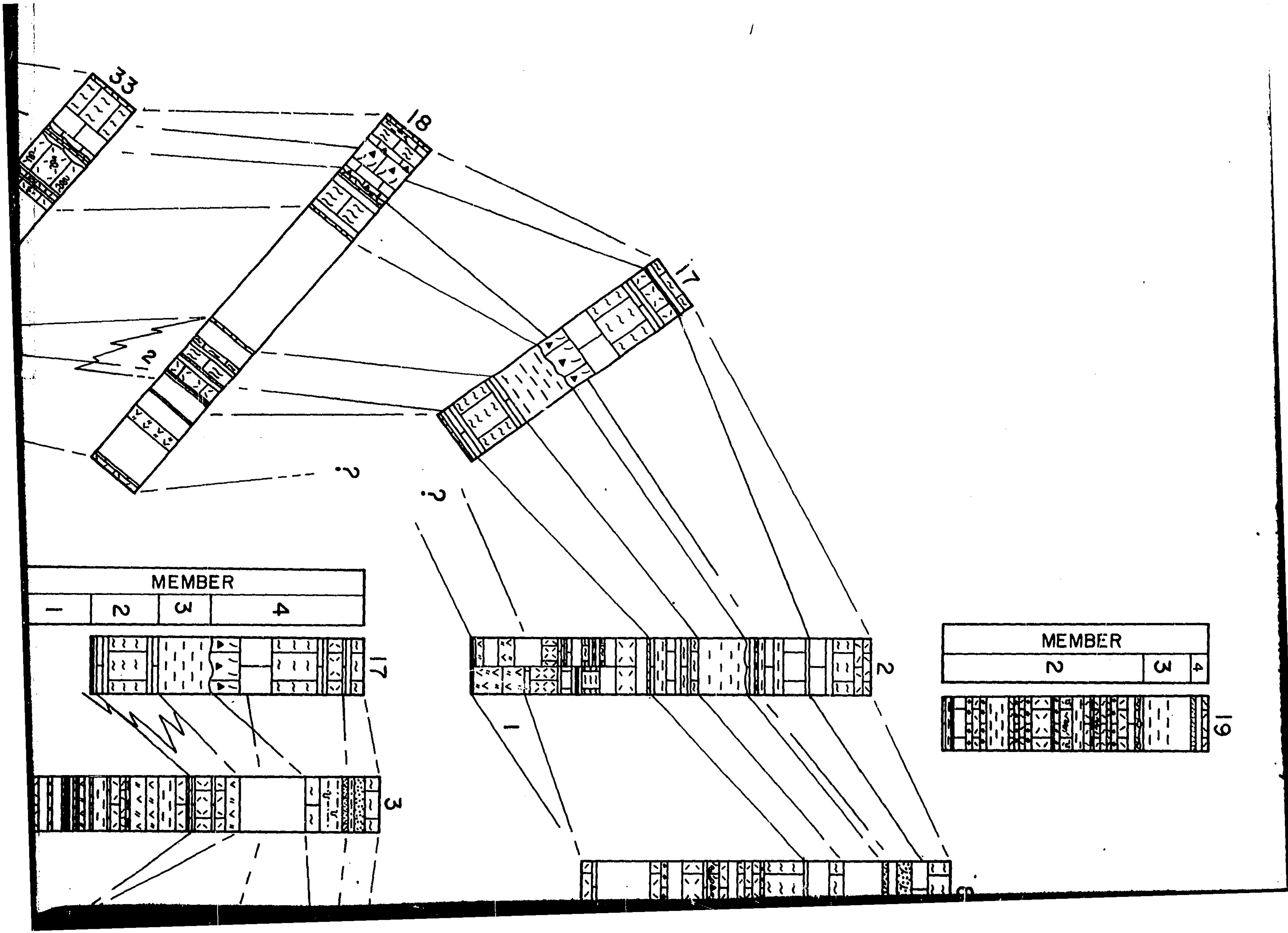
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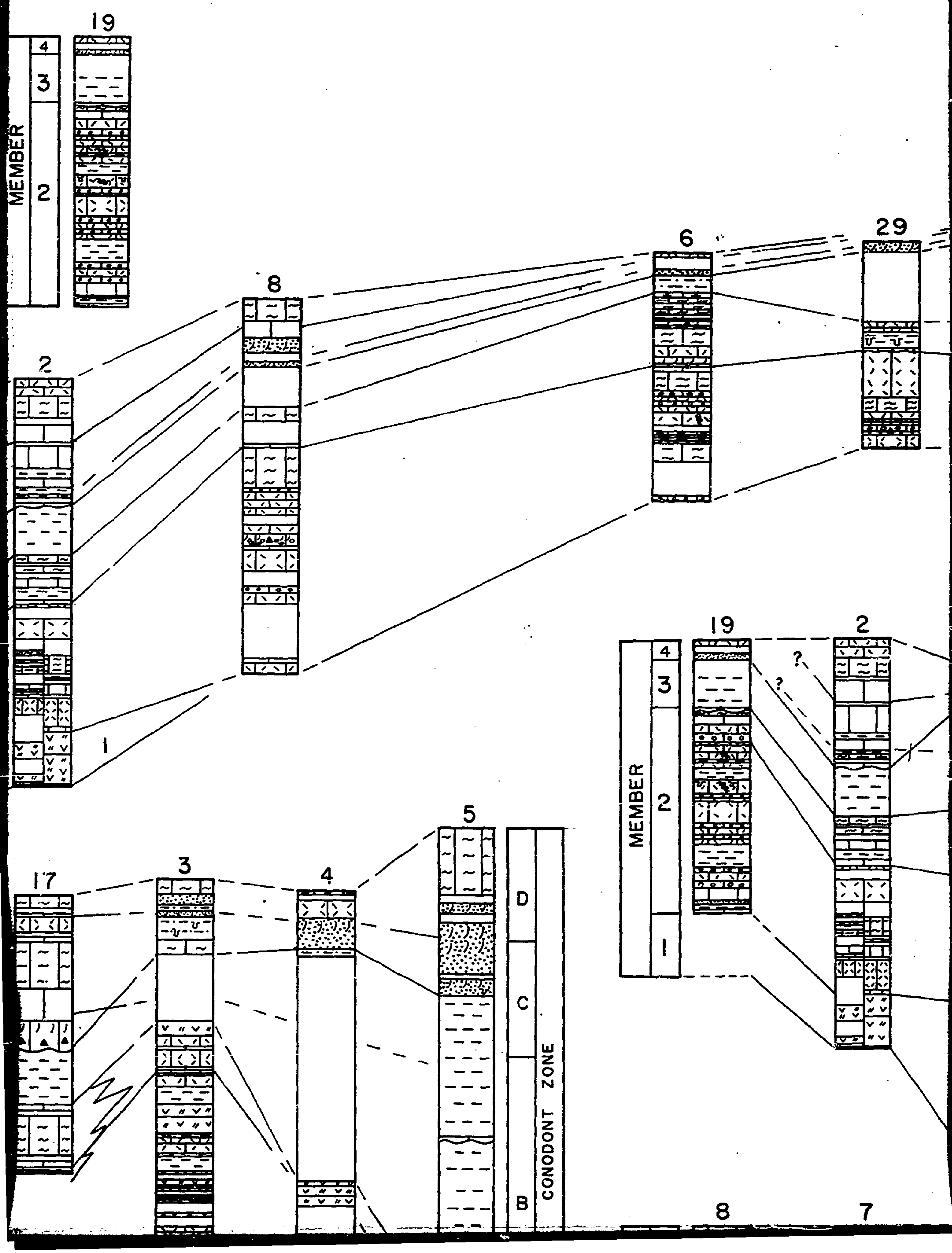
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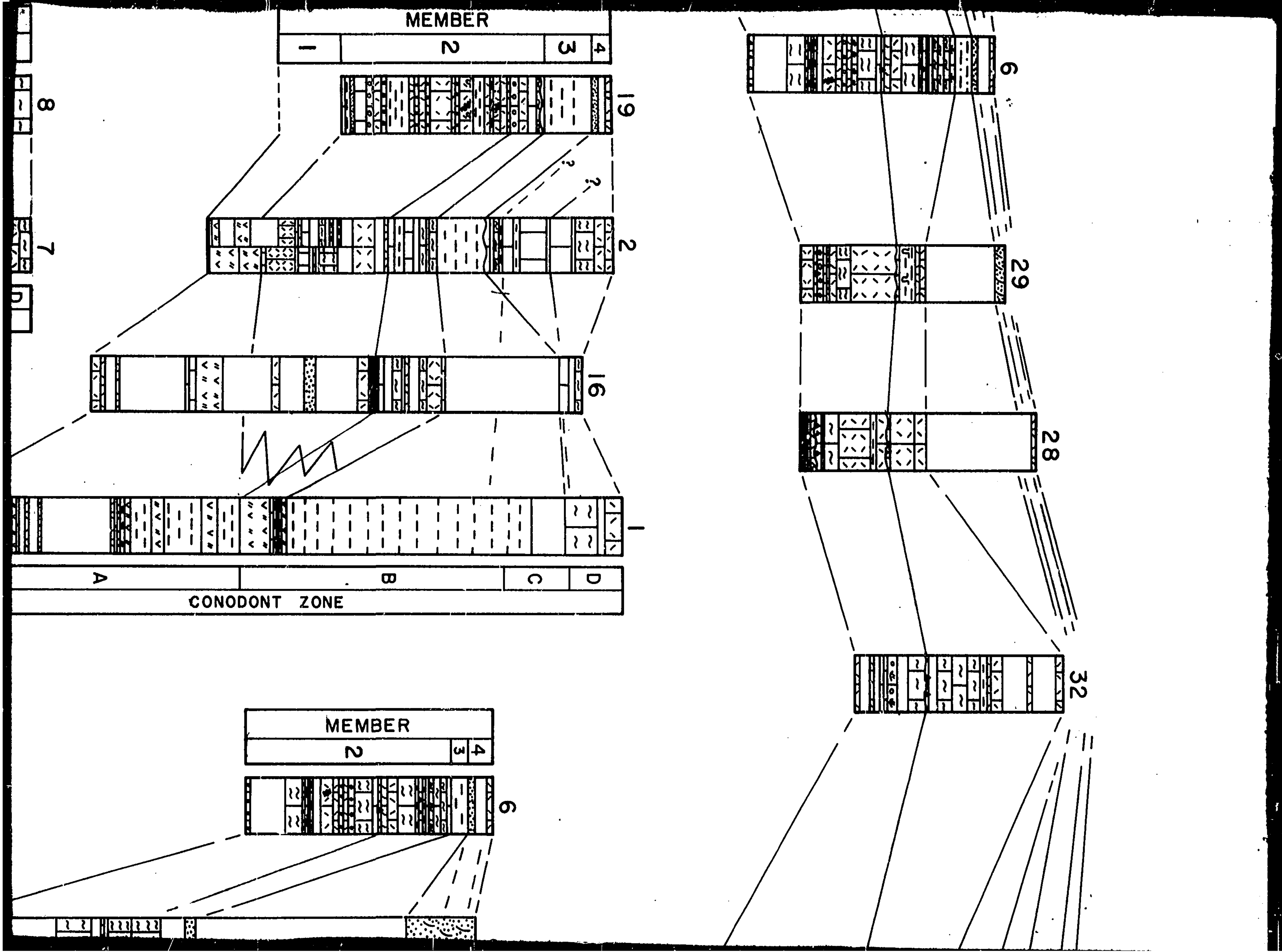

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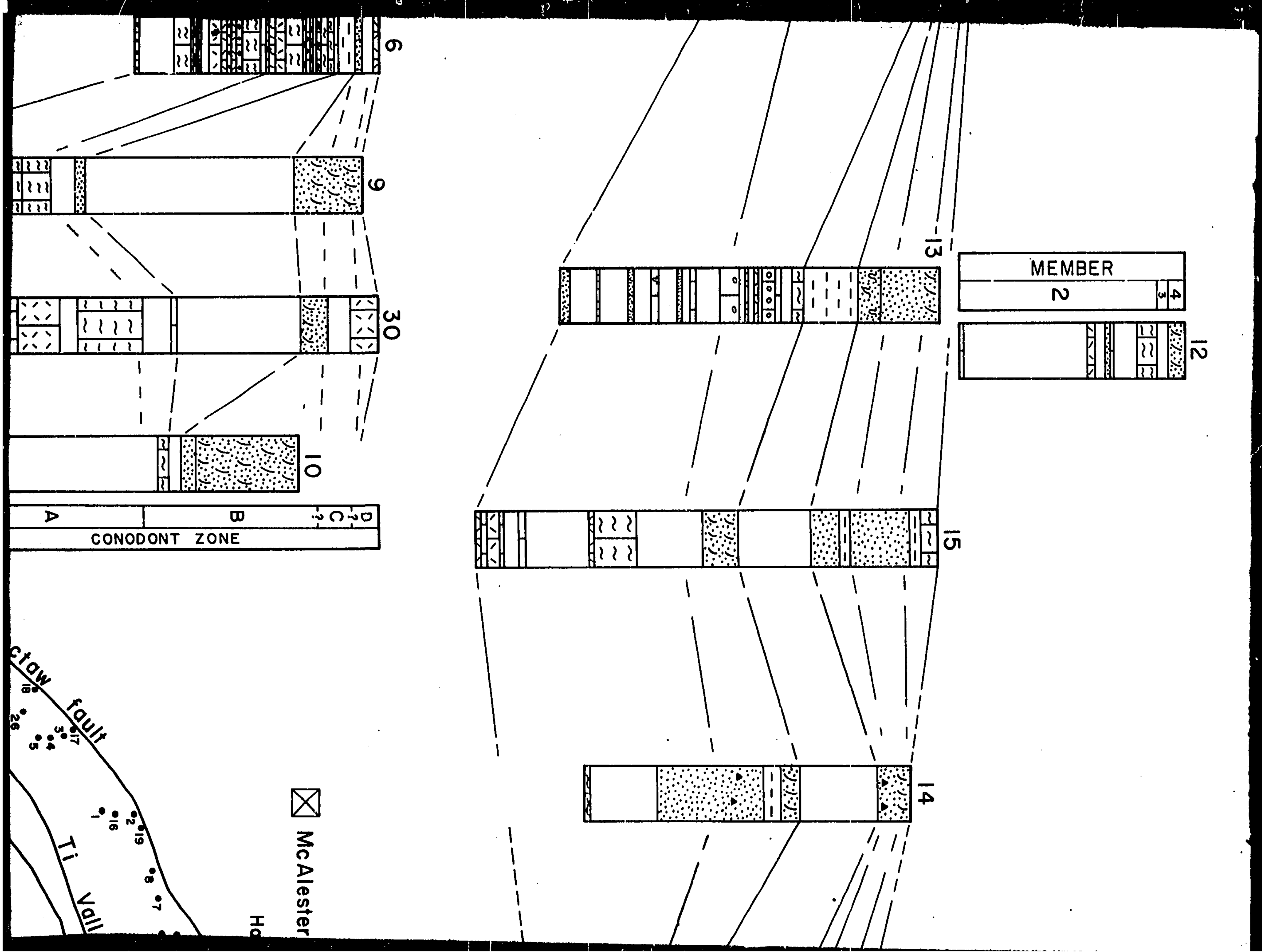
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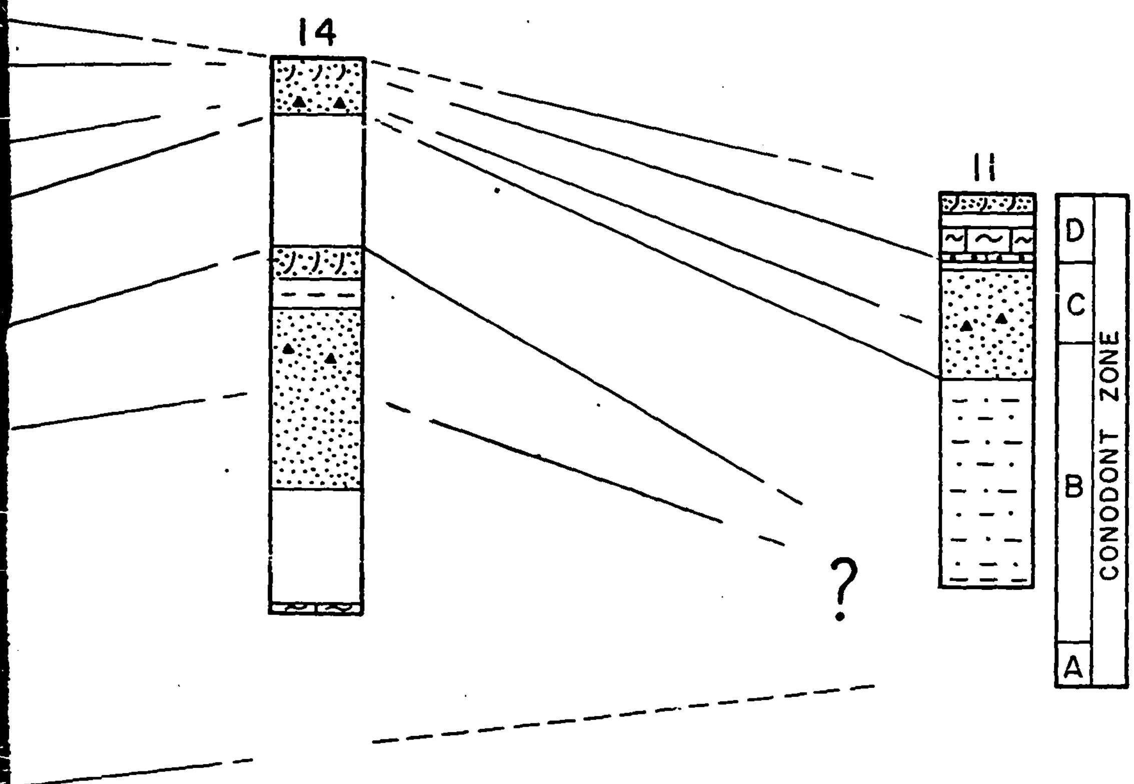
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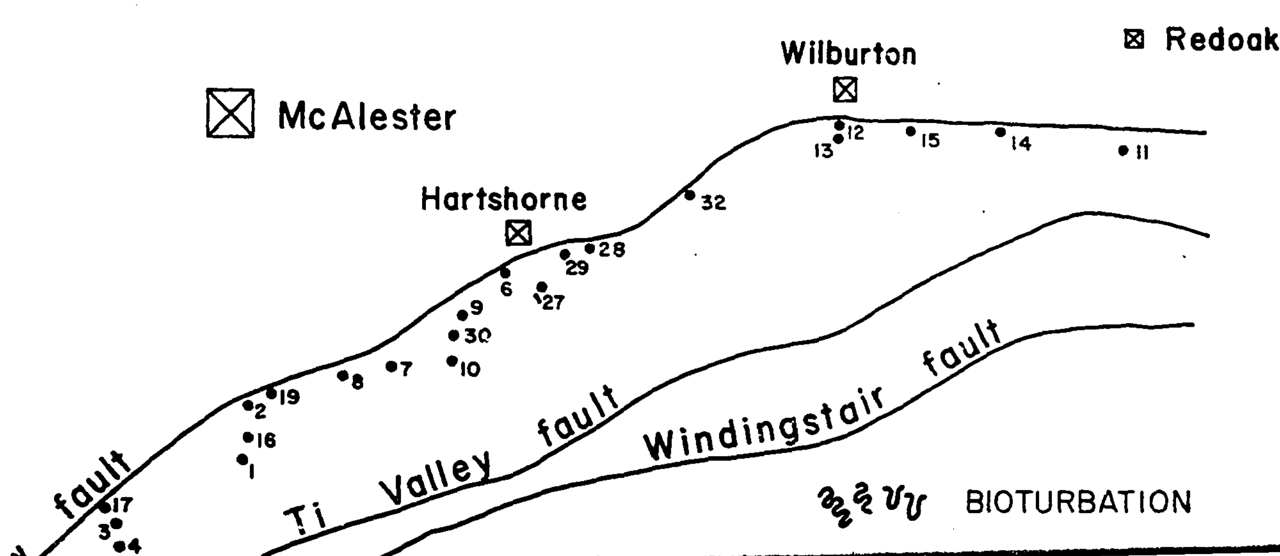
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Wilburton
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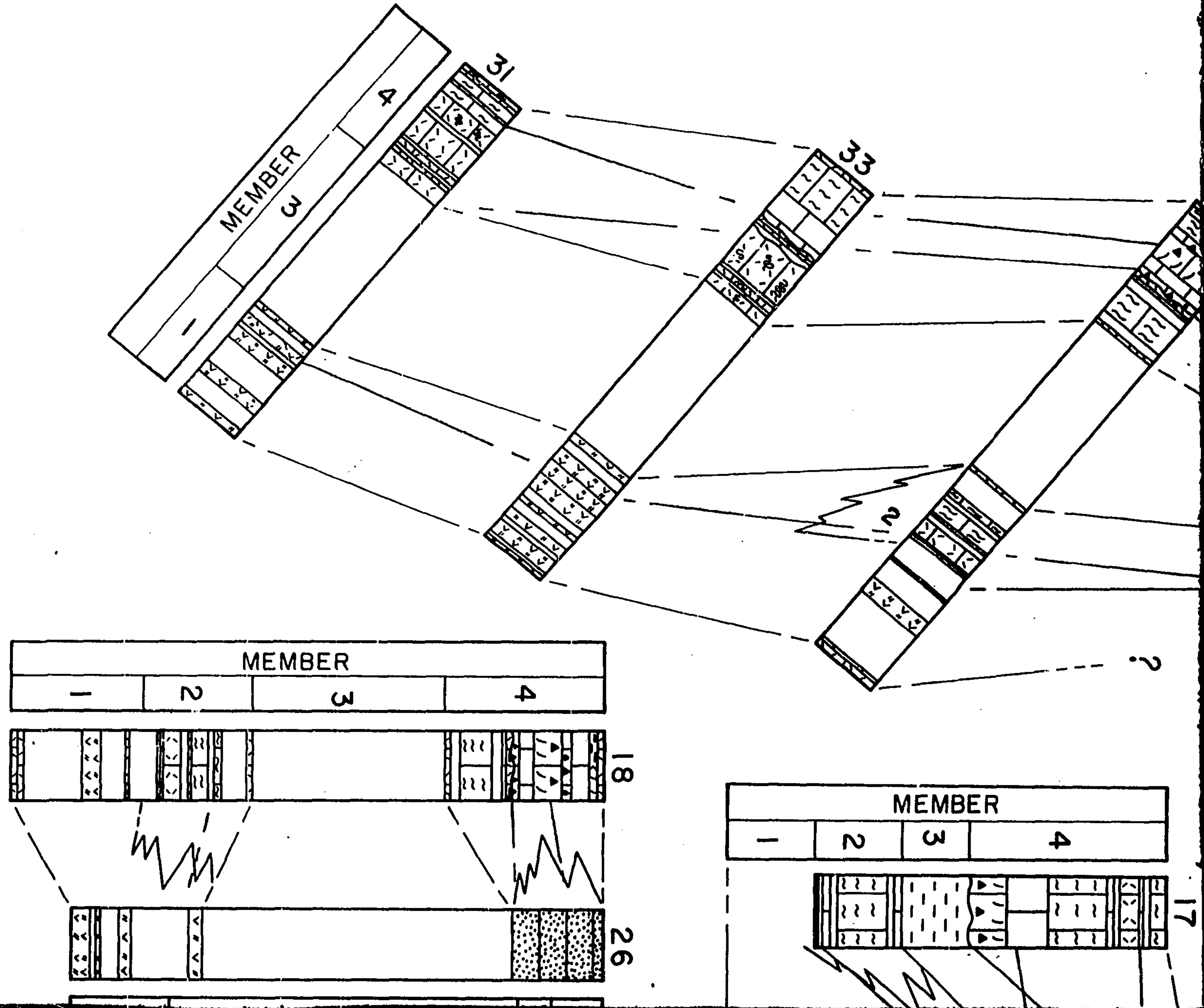
Ti Valley fault
Windingstair fault
BIOTURBATION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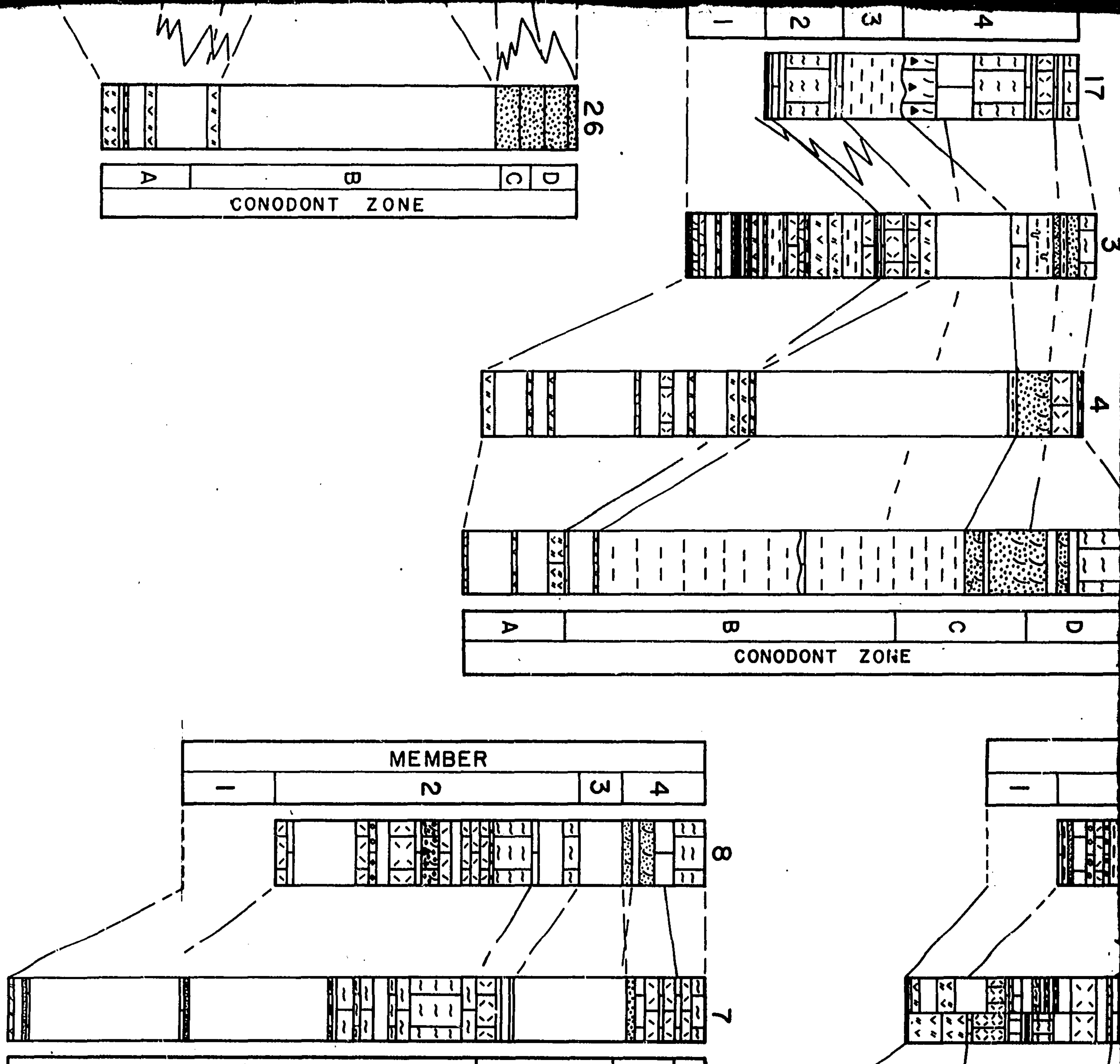

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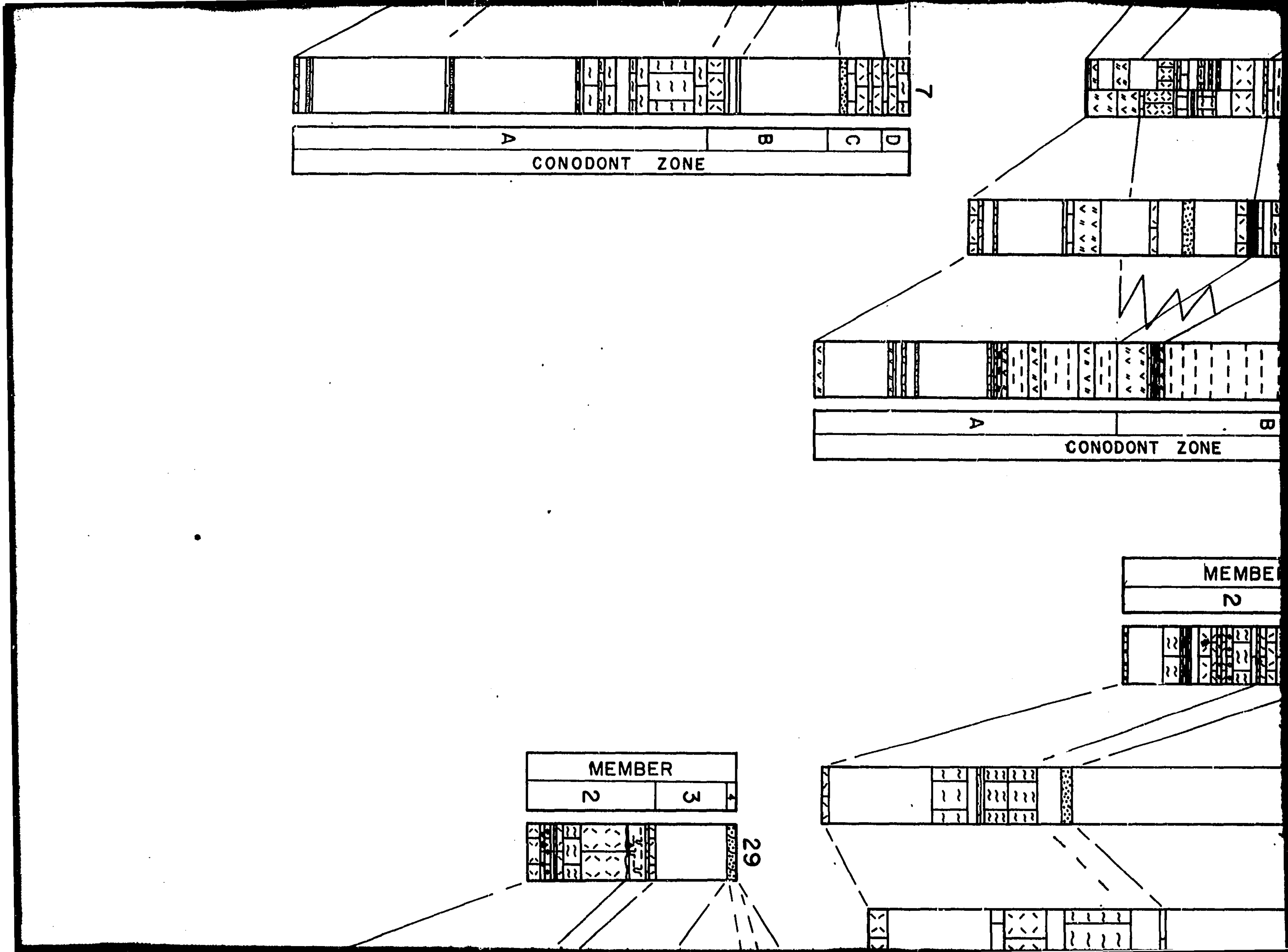
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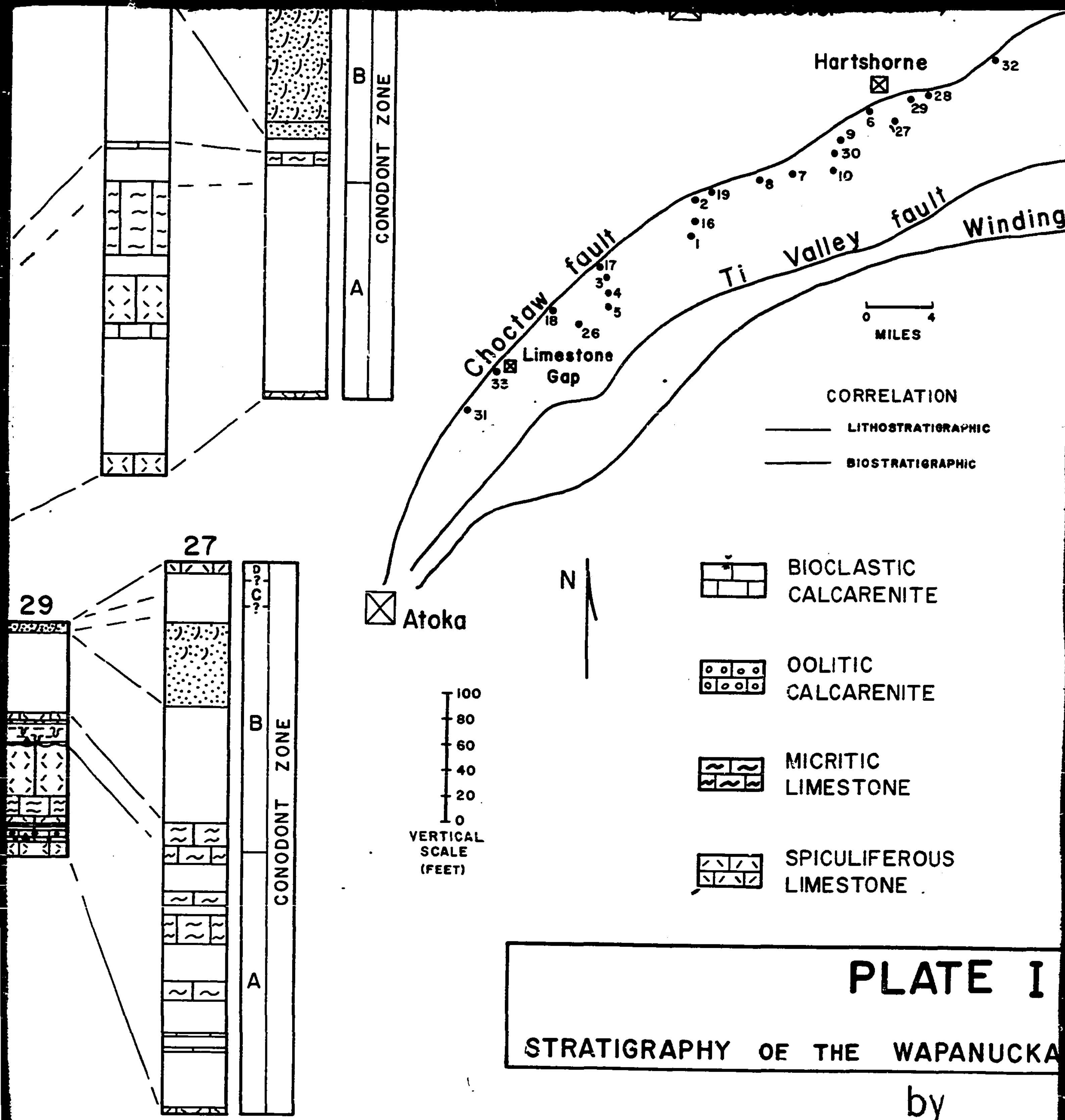

PLATE I

STRATIGRAPHY OF THE WAPANUCKA

by

ROBERT C. GRAYS

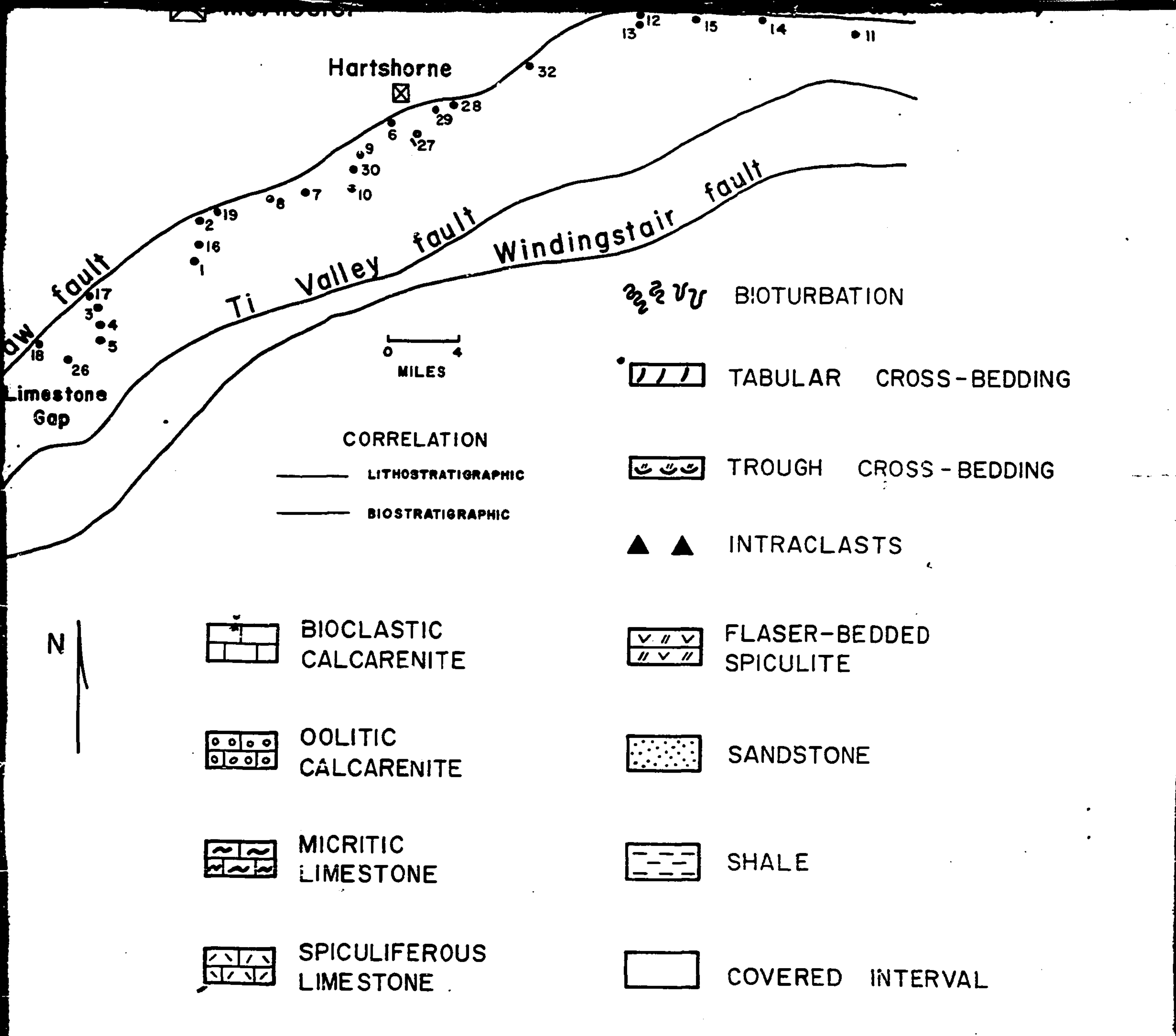

PLATE I

STRATIGRAPHY OF THE WAPANUCKA FORMATION, OK.

by

ROBERT C. GRAYSON, JR.