CONODONT BIOSTRATIGRAPHY NEAR THE MISSISSIPPIAN\ PENNSYLVANIAN BOUNDARY IN THE NEW WELL PEAK SECTION, BIG HATCHET MOUNTAINS, HIDALGO COUNTY, NEW MEXICO

by

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ABSTRACT

The lower part of the New Well Peak section (Zeller, 1965) in the southern Big Hatchet Mountains, Hidalgo County, New Mexico, was systematically sampled for conodonts, and petrographic and lithologic studies.

Although nearly half of the section is characterized by barren or impoverished intervals, one provisional conodont zone (Idiognathodus delicatus zone), and three previously proposed conodont zones (Adetognathus unicornis zone, Rachistognathus primus zone, and Neognathodus symmetricus zone) were recognized.

The Mississippian\Pennsylvanian boundary was determined to lie within a 20 foot interval which is barren of conodonts. Below this interval are diagnostic late Mississippian (late Chesterian) conodonts: Adetognathus unicornis, Cavusgnathus cf. C. unicornis, Cavusgnathus cf. C. naviculus, and Gnathodus commutatus commutatus. Above are diagnostic early Pennsylvanian (early Morrowan) conodonts: Rachistognathus primus, Adetognathus lautus, and Declinognathodus noduliferus. This barren interval includes, within its upper part, an indistinct regional unconformity representing a hiatus that is believed to be of short duration.

No significant changes in conodont faunas were observed at or near the Morrowan\Derryan boundary as determined by

fusulinids (in this study).

Conodont color alteration data indicate a post-mature thermal maturity for the rocks of the lower New Well Peak section. This degree of heating has probably altered any indigenous hydrocarbons to gas. For any major accumulations of oil to be preserved in strata of similar thermal history in this area, the oil would have had to migrate into reservoirs late in the thermal history of the strata.

Lithologic, paleontologic, and petrographic data gathered in this study indicate a restricted, marginal-marine depositional environment for the lower half of the section studied. This environment was characterized by relatively low biotic diversity, frequent periods of relatively high salinity, and periodic agitation. Distinctive environmental indicators in the upper half of the section are sparse, but the environment is interpreted to have been characterized by relatively unstable, low energy, dominantly restricted, shallow-marine, lagoonal conditions.

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Finally, I wish to thank my parents for their continual encouragement, and material assistance through the completion of this thesis.

INTRODUCTION

The main focus of this report deals with conodont biostratigraphy of uppermost Mississippian and lower Pennsylvanian strata in the lower part of the New Well Peak section (Zeller, 1965), Hidalgo County, New Mexico. Conodonts are carbonate-apatitic microfossils of unknown zoological affinity. They are valuable tools for Cambrian-Triassic biostratigraphy and correlation because of their nearly ubiquitous distribution in marine rocks throughout the world, their wide variety of host lithologies, and their relatively short-ranging species. In addition, conodont elements are useful indicators of thermal alteration. The degree to which host rocks have been heated, as determined by conodont color alteration, enables estimation of the generation and preservation of indigenous hydrocarbons.

Objectives

The main objective of this report was to designate a preliminary conodont zonation for the uppermost Mississippian-Lower Pennsylvanian in this area, as an additional step toward establishing a complete biostratigraphic framework for the upper Paleozoic which could be used in regional and interregional correlations. A secondary objective was to attempt to document both the

Chesterian\Morrowan and the Morrowan\Derryan boundary based on distinct changes in conodont taxa.

In addition, studies of the lithostratigraphic succession and interpretations of the environments of deposition were made with the aid of field descriptions, hand specimens, and thin-section data.

Finally, a preliminary estimate of the thermal maturity of the strata was made. This estimate was based primarily on conodont color alteration data.

Location and Topographic Setting

The Big Hatchet Mountains are located in southern Hidalgo County in extreme southwestern New Mexico. The present topographic setting of the Big Hatchet Mountains features the Little Hatchet Mountains to the north, Hachita Valley to the northeast and east, Alamo Hueco Mountains to the south, and the Playas Valley and Animas Mountains to the west (Figure 1).

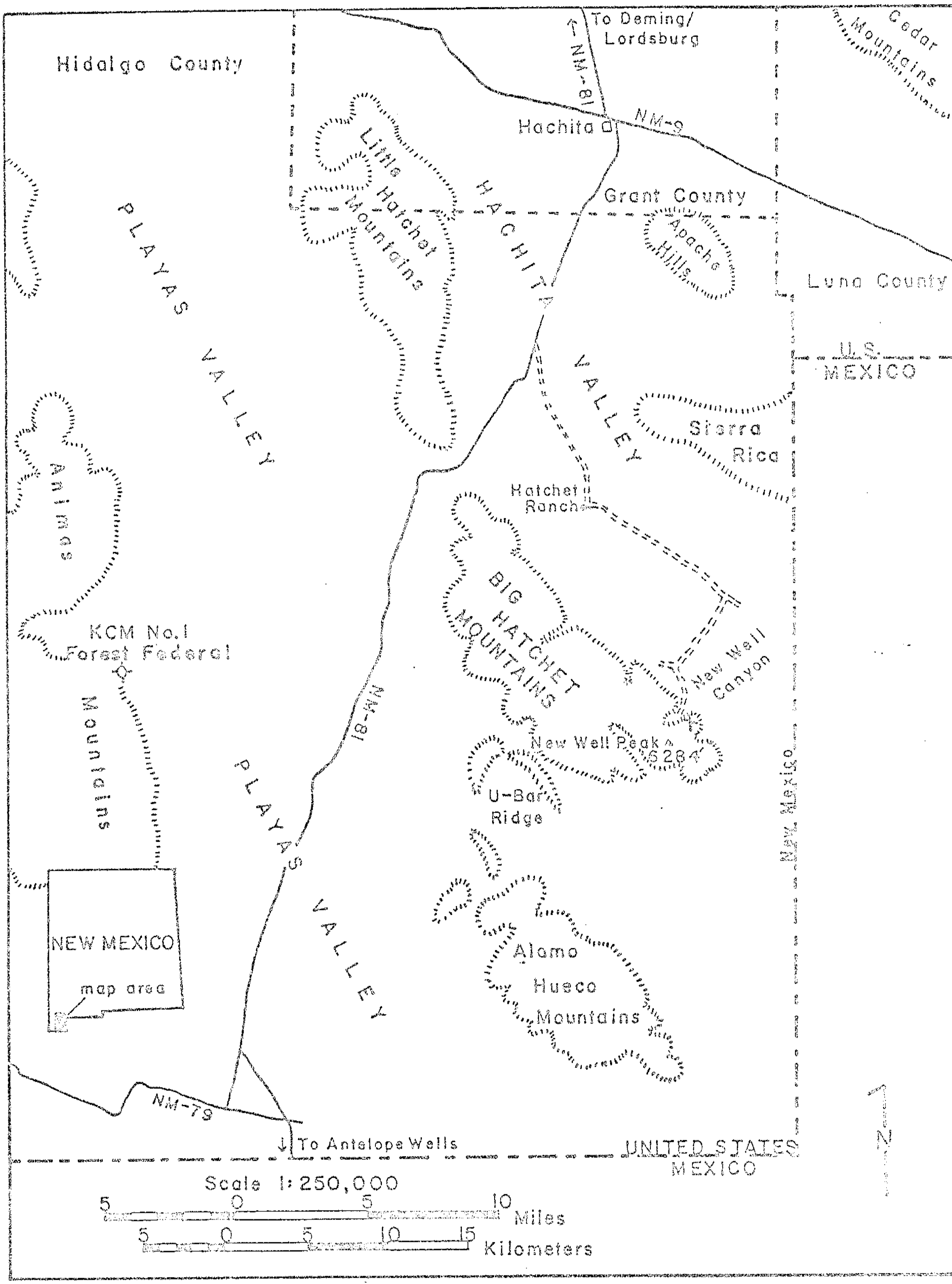
The lower New Well Peak section (Zeller, 1965) is located subcentrally within the NE 1/4 SW 1/4 sec. 28, T. 31 S., R. 14 W.. The base of the section is located in a gully on the northeastern flank of the southern Big Hatchet Mountains, one mile due east of the Deep Well windmill and stocktank in New Well Canyon. The line of section trends southwestwardly, with a few lateral offsets, to the top of the hill.

FIGURE 1

LOCATION MAP
(X = lower New Well Peak section)

FIGURE I

Location Map



According to Zeller (1965) and Thompson and Jacka (1981), the New Well Peak section is perhaps the best exposed, least disturbed, least hazardous, most easily accessible, and most complete section of Pennsylvanian strata in the Big Hatchet Mountains. For these reasons, this section was chosen for this study of upper Mississippian\Lower Pennsylvanian conodont biostratigraphy.

Previous Work

Zeller (1965) measured and described the entire Paleozoic and Mesozoic succession in this mountain range. Three of his sections include uppermost Mississippian-lowermost Pennsylvanian strata: Mescal Canyon section (p. 76-77), New Well Peak section (p. 87-88), and the Bugle Ridge section (p. 93). Thompson and Jacka (1981) measured and described the Big Hatchet Peak section in the northern Big Hatchet Mountains.

Geologic Setting

Carboniferous sedimentation in the Big Hatchet Mountains area was influenced by pronounced subsidence of the northwesterly trending Pedregosa Basin. During Pennsylvanian to Permian (Wolfcampian) time the Pedregosa Basin was bounded by the Graham-Burro- Florida-Moyotes uplifts to the northeast, and the Magdalena Uplift to the southwest (Thompson and Jacka, 1981; Figure 2).

According to Thompson and Jacka (1981, p. 11), sedimentary characteristics of the upper Mississippian, Paradise Formation indicate deposition on a shallow-marine, relatively stable shelf with periodic, moderate energy. Furthermore, Thompson and Jacka (1981, p. 14) interpret the depositional environment of the Lower Pennsylvanian, Horquilla Limestone to have been shallow-marine with open circulation.

Low-angle thrusting, produced during the Laramide Orogeny (late Cretaceous to early Tertiary), is evident in the southwestern part of the Big Hatchet Mountains. The area is believed to have experienced final uplift by northwesterly trending, high-angle normal and reverse faulting during Basin and Range deformation in the middle Tertiary. The reader is referred to Zeller (1975) for further information concerning the structural history of the Big Hatchet Mountains.

Even though the New Well Peak section had been previously reported as being the least disturbed section of Pennsylvanian strata in the Big Hatchet Mountains, numerous fault gouge zones were obvious in the field. One minor fault and numerous scissor faults were encountered in the lower part of the section. Maximum offset of these faults appeared to be only a few meters, or less.

FIGURE 2

REGIONAL GEOLOGIC SETTING OF THE LOWER NEW WELL PEAK SECTION ALONG THE MARGIN OF THE PEDREGOSA BASIN

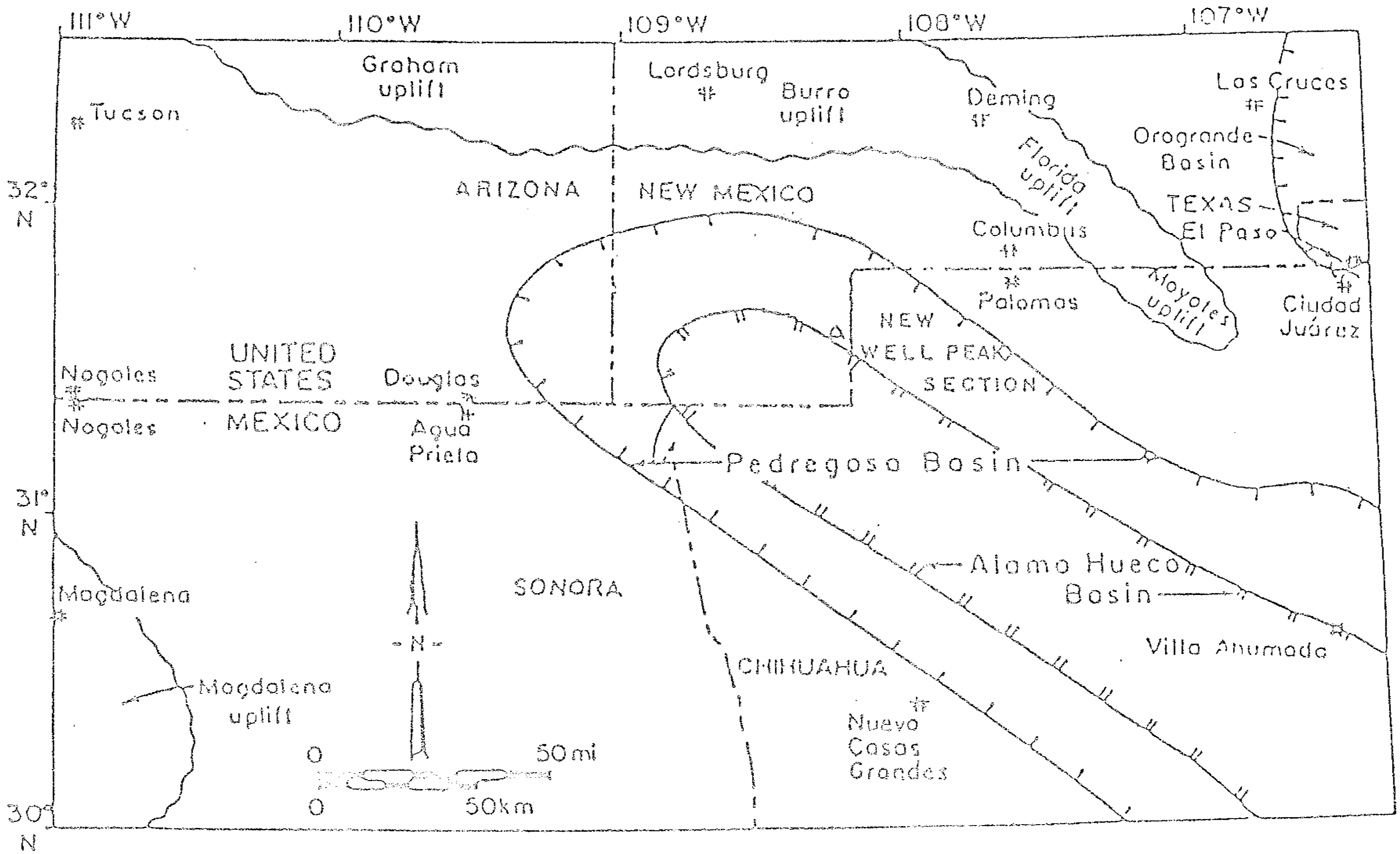


FIGURE 2. Regional geologic setting of the New Well Peak section on the shelf margin of the Pedregosa Basin (modified from Thompson and Jacka, 1981).

Stratigraphy

Zeller (1965) established the base of his New Well Peak section at the base of the Horquilla Limestone (Pennsylvanian-Permian). An unconformity occurs at that boundary, which also is inferred to be the boundary between the Mississippian and Pennsylvanian systems. To establish biostratigraphic trends and distinguish possible changes in the conodont fauna across this boundary, the lower New Well Peak section was extended, below the unconformity, to include 31.7 meters (104 feet) of the uppermost Paradise Formation (Mississippian; Chesterian). Zeller (1965) correlated both the Paradise Formation and the Horquilla Limestone with their type sections in southeastern Arizona to the Big Hatchet Mountains.

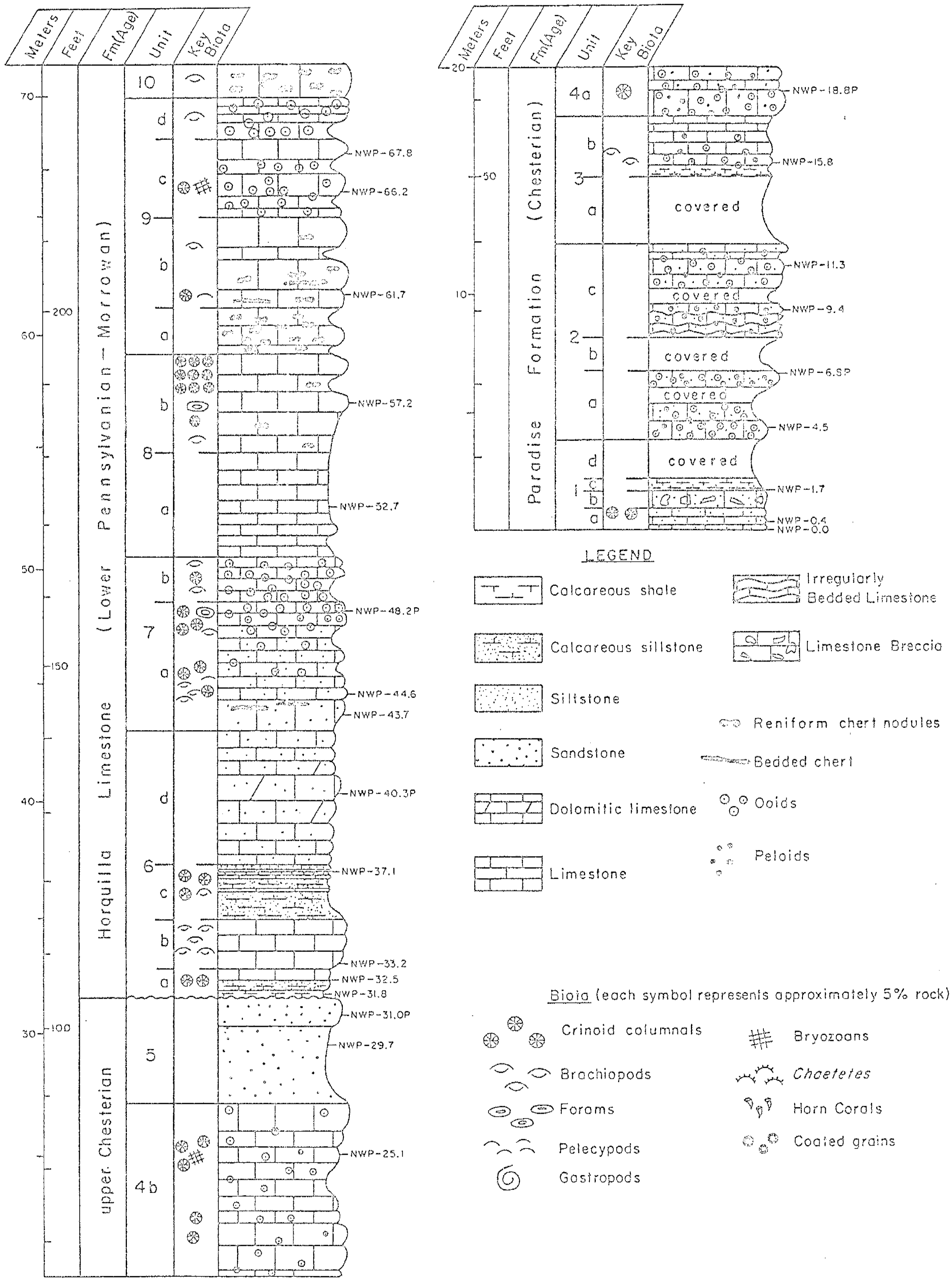
The stratigraphic section studied herein was divided, in the field, into 26 units based on similar characteristics or trends in characteristics of the strata within each unit. At least one petrographic sample was collected within each unit. The unit descriptions are presented in Appendix B. The stratigraphic section is shown in Figure 3.

The section studied encompasses parts of the Chesterian, Morrowan, and Derryan Series. Thicknesses of the series, as interpreted using conodonts (Chesterian through middle Morrowan) and fusulinids (upper Morrowan and Derryan), include: 31.7 meters (104 feet) of upper Chesterian; 91.5 meters (300 feet) of Morrowan; and 50.6 meters (166 feet) of lower Derryan.

FIGURE 3

STRATIGRAPHIC SECTION

FIGURE 3 (continued)



Paradise Formation (upper Mississippian)

The Paradise Formation in this area of the Big Hatchet Mountains is characterized by reddish and brownish weathered, oolitic, crinoidal, and silt-bearing wackestones and mudstones (all mudstone designations in this study are lime mudstones; limestone classification after Dunham, 1962), with minor calcareous siltstones and rare calcareous shales. The strata are predominantly thin bedded, and generally show little resistance to weathering.

Zeller (1965, p. 29) indicated that the Paradise Formation in the Big Hatchet Mountains area ranges from Meramecian to Chesterian age based on megafossils. The upper part of the Paradise Formation below the New Well Peak section in this study, is dated as upper Chesterian based on conodonts.

Post-Paradise\Pre-Horquilla Unconformity

The unconformity in the New Well Peak section is not clearly marked. Zeller (1965, p. 32) lists four convincing arguments in support of the presence of a regional unconformity between the Paradise Formation and Horquilla Limestone throughout the Big Hatchet Mountains: 1) an abrupt change of lithology at the contact; 2) the upper part of the Paradise Formation contains beds and lenses of inferred terrestrial sandstone, which are relatively thick in some places and missing in others; 3) the Paradise Formation varies considerably in thickness within the Big Hatchet Mountains, and where it is thin, the upper beds are missing; and 4) the detailed sequence of the lowermost Horquilla beds is nearly identical throughout the region in contrast to the varied lithology of the underlying Paradise beds.

The duration of the hiatus at the unconformity is believed to be short based on age determinations of late Chesterian conodonts 6.6 meters (22 feet) below the unconformity and early Morrowan conodonts 1.5 meters (5 feet) above. The 4.5 meters (15 feet) of strata immediately below the unconformity is a silica-cemented quartz sandstone with scarce biota. If conodonts are present in this unit, no effective means is known for their removal, so age determinations based on conodonts, are not possible at this time.

The Mississippian\Pennsylvanian boundary is believed, by workers in the area, to coincide with the unconformity; however, based on collections made in this study, the boundary may lie anywhere within the conodont-barren unit adjacent to the unconformity. Previous studies indicate much of North America experienced a depositional hiatus between the Mississippian and Pennsylvanian systems.

Horquilla Limestone (Pennsylvanian-Permian)

Approximately 142 meters (466 feet) of lowermost Horquilla Limestone in the New Well Peak section were studied in the present investigation. Virtually all of the

Horquilla encountered was represented by gray-weathered, resistant, generally medium- to thick-bedded limestones (terms defined in Appendix A) with rare laminated intervals (Figure 4). The strata are dominated by 1) oolites and barren mudstones in the lower third, 2) wackestones and barren, calcispheric, and pelletal mudstones (Figure 5) in the middle third, and 3) wackestones and packstones in the upper third. Total diversity and abundance of biotic constituents increases upward.

The Horquilla Limestone of the lower New Well Peak section studied in this investigation ranges in age from lower Morrowan (not necessarily earliest) through lower Derryan. Early Morrowan ages were determined using conodonts, while late Morrowan and early Derryan ages were determined using fusulinids.

FIGURE 4

LAMINATED BEDDING (L) AND CROSS-STRATIFIED

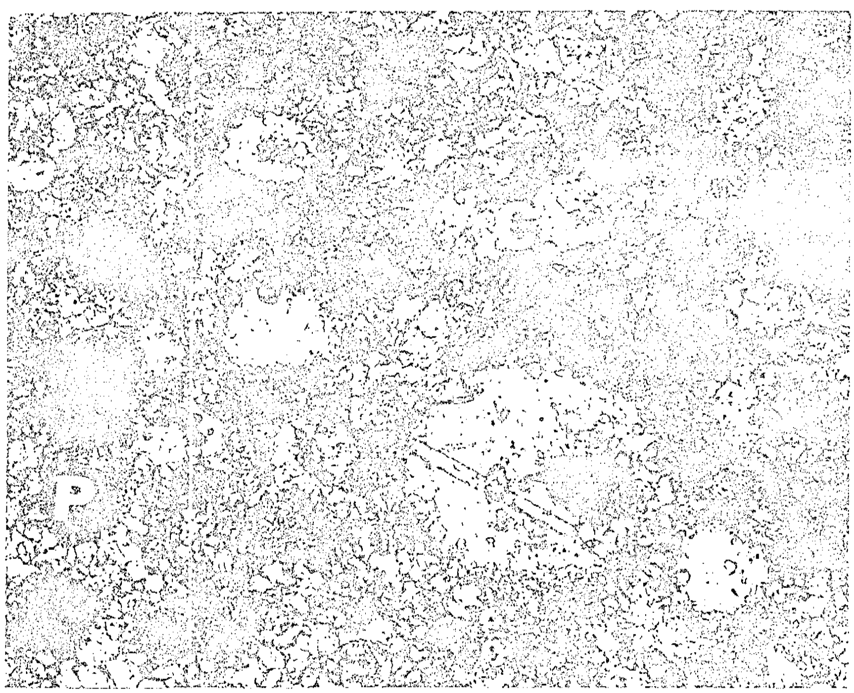
BRACHIOPOD\CRINOID SHELL-HASH ZONE (H)

IN LOWER PART OF UNIT 7, INTERVAL A
[hammerhead for scale is 10 cm (4 inches) long]

Figure 4

FIGURE 5

PHOTOMICROGRAPH OF CALCISPHERES (C) AND PELLETS (P)
(plane-polarized light)



.1 mm

Figure 5

LITHOSTRATIGRAPHY

This section deals with investigative techniques, lithologic descriptions and observations of the upper Chesterian through lower Derryan strata in the New Well Peak section of the southern Big Hatchet Mountains. The descriptions and observations are based on field investigations, hand-specimen study, residue (obtained from dissolved limestones) analysis, and point counts from 55 thin sections.

Investigative Techniques

Field Work

Approximately 31.7 meters (104 feet) of the uppermost Paradise Formation and 141.6 meters (466 feet) of the lowermost Horquilla Limestone were measured, collected, and described in this investigation. A Jacob's staff and Brunton compass were used to measure the section.

During description, special attention was given to the following factors believed to be useful in paleo-environmental interpretations: diversity and volumetric abundance of the biota, presence of non-skeletal constituents (ooids, peloids, intraclasts, terrigenous material, etc.), types of sedimentary structures, amount of interstitial carbonate mud, rock color, and Dunham's (1962) limestone classification. Unit thicknesses and descriptions are combined with results of the residue analysis (described below) and presented in Appendix B.

Residue Analysis

Analysis of insoluble residues, which remained after samples were processed for conodonts, revealed many constituents not recognized in the field and not encountered or recognized in thin section. This analysis enabled: 1) three-dimensional perspective of grains without intervening matrix, 2) specific taxonomic identifications, 3) recognition of relative amounts and kinds of terrigenous material (clay, silt, sand), and 5) tentative identification of opaque constituents (insoluble) encountered in thin section (tentatively identified in as dominantly intergranular, diagenetic hematite).

The main disadvantage of residue analysis, and the reason it should only be used in combination with other data gathering methods, is that treatment of carbonate rocks with formic acid dissolves nearly all of the calcium carbonate constituents; thus the only grains which remain are those which have been selectively silicified or are otherwise not now composed of calcium carbonate.

Petrographic Analysis

Samples for petrographic analysis were taken approximately every five meters (16 feet). This sampling interval was thought to be adequate for description and general environmental interpretations.

Point-count analysis of 55 thin sections was completed in an attempt to quantify the grains and intergranular materials present. Changes in carbonate constituents over time are especially important. Plotting percentages of various parameters versus stratigraphic position enabled recognition of general trends throughout the section.

A minimum of 350 point counts per thin section (an average of 400) were made. With a 95 percent confidence level, a minimum of 350 point counts translates to a precision of $\pm$ 5 percent of the total points counted for the entire thin section (according to van der Plas and Tobi, 1965, fig. 1). As the number of counts of individual constituents decreases, the precision of determining percentages of these constituents also decreases.

The grain-bulk method of Dunham (1962) was used while point counting, to estimate the volume percentage of particles in thin section. This method considers voids within grains, and intragranular void-fill as parts of those grains. This method was useful in determining the relative abundances of skeletal and non-skeletal grains, an important consideration in paleoenvironmental interpretations.

During point-count analysis, micrite, microspar, pseudospar, and unidentifiable matrix material (less than twenty microns is size) were assumed to be original carbonate mud.

To aid in recognition of dolomite, each thin section was stained with Alizarin Red-S. Dolomitized portions (or constituents with less than fifty percent calcium) do not accept the pinkish stain. Point-count percentages are tabulated in Appendix C.

Observations

Observations presented in this section represent a summary of Appendices B, C, and E. General observations of the uppermost Paradise and lower Horquilla in the section studied, reveal a predominance of carbonate mud (dominantly mudstones and wackestones), and an increase in total biotic diversity upwards. The lower half of the section (upper Paradise through lowermost Horquilla) differs distinctly from the upper half. The lower half is characterized by occasional intervals of laminated strata, relatively low biotic diversity, frequent ooid- and pellet-rich intervals (Figure 5 and Figure 10), rare burrowed intervals (Figures 6 and 7), variable percentages of fine-grained terrigenous material (clay, silt, fine sand), infrequent intervals containing coated grains (Figure 8), and the characteristic reddish and brownish color (in the lower third) of relatively thin calcareous siltstones, calcareous shales, and limestone beds.

FIGURE 6

SILICIFIED BURROWS FROM UPPER PART OF UNIT 14
[hammerhead for scale is 10 cm (4 inches) long]

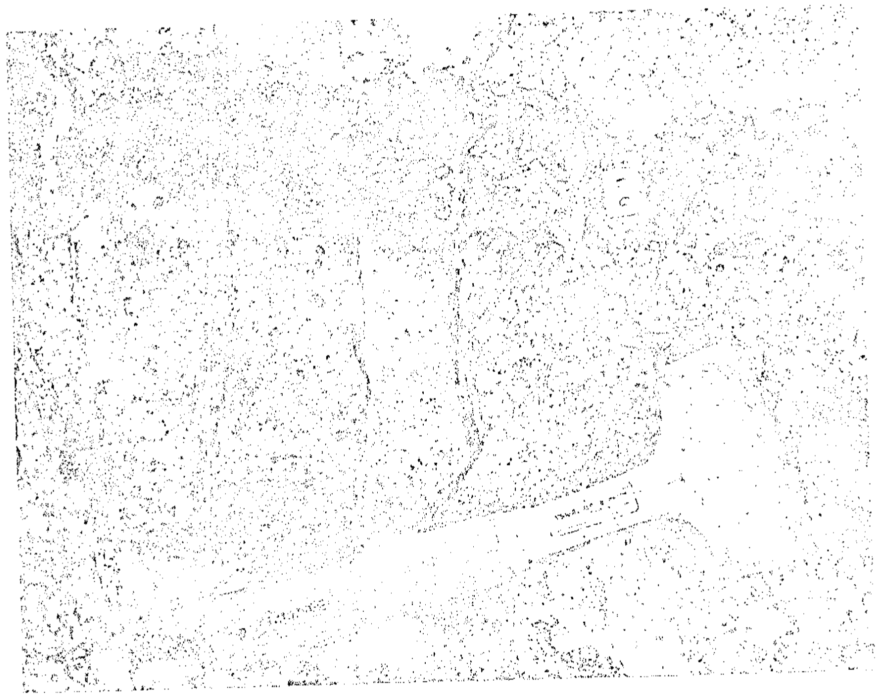
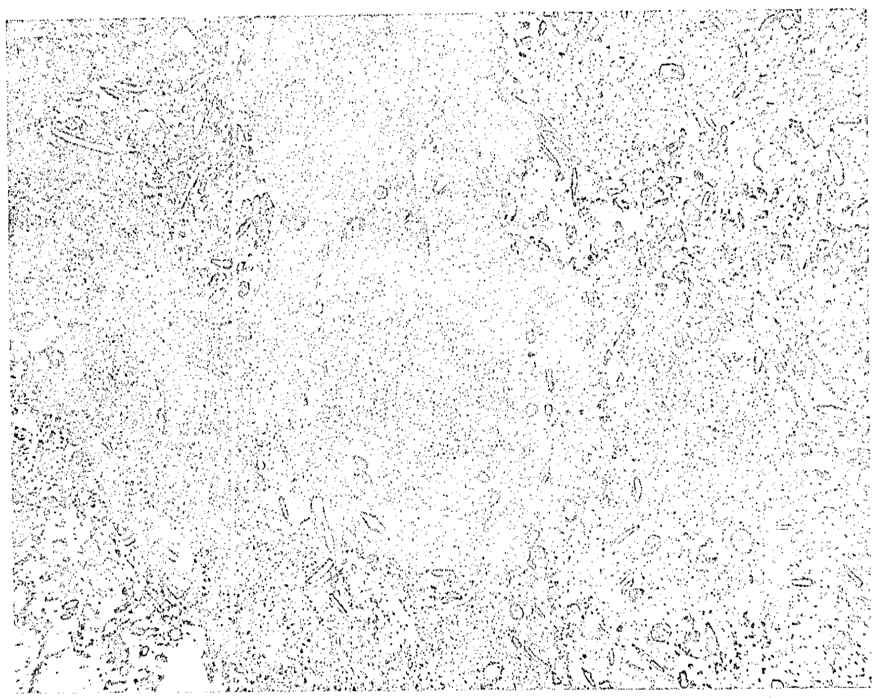


Figure 6

FIGURE 7

CROSS SECTION OF A BURROW (CENTER OF PHOTOGRAPH)

IN THIN SECTION FROM UNIT 6, INTERVAL A
(Note the tangential orientation of fossil grains
around the edge of the subcircular burrow)



5 mm

Figure 7

FIGURE 8

PHOTOMICROGRAPH OF COATED FUSULINID

GRAIN (F) AND OTHER COATED GRAINS
(Crossed-polarized light)

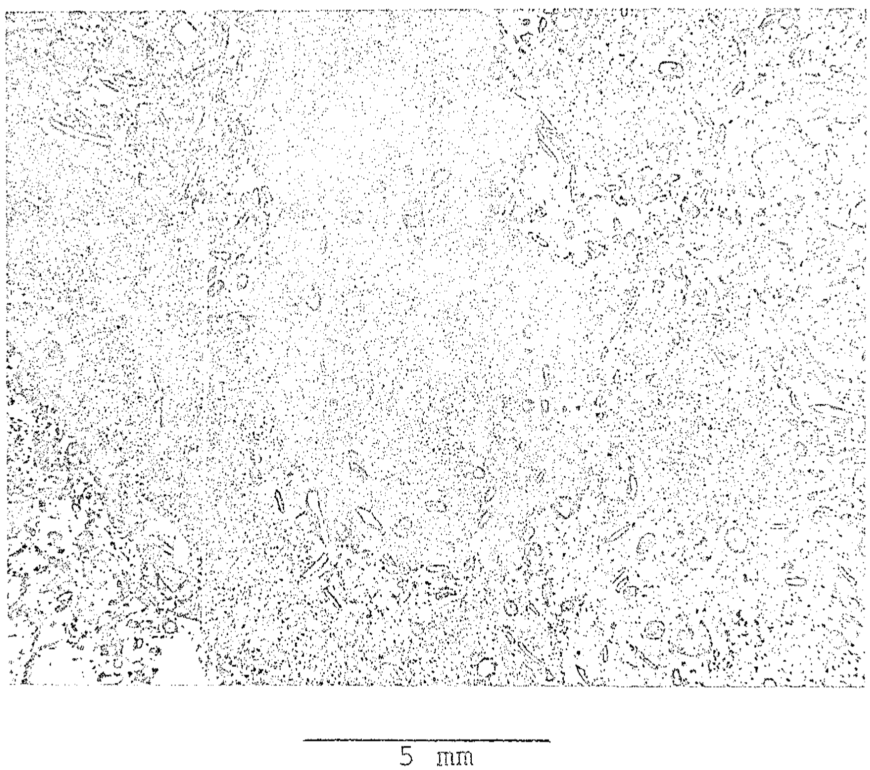
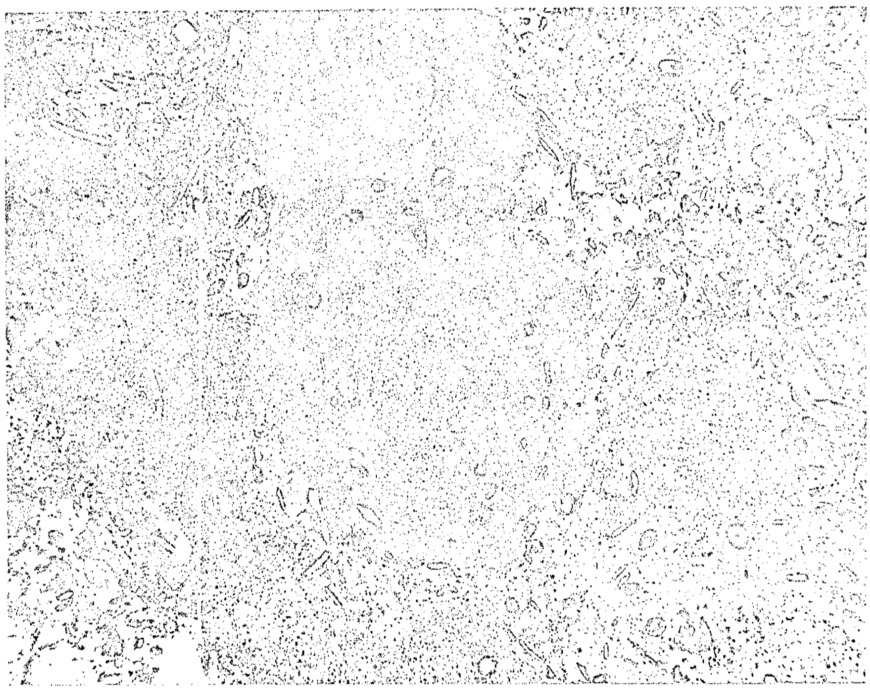


Figure 7

FIGURE 7

CROSS SECTION OF A BURROW (CENTER OF PHOTOGRAPH)

IN THIN SECTION FROM UNIT 6, INTERVAL A
(Note the tangential orientation of fossil grains
around the edge of the subcircular burrow)



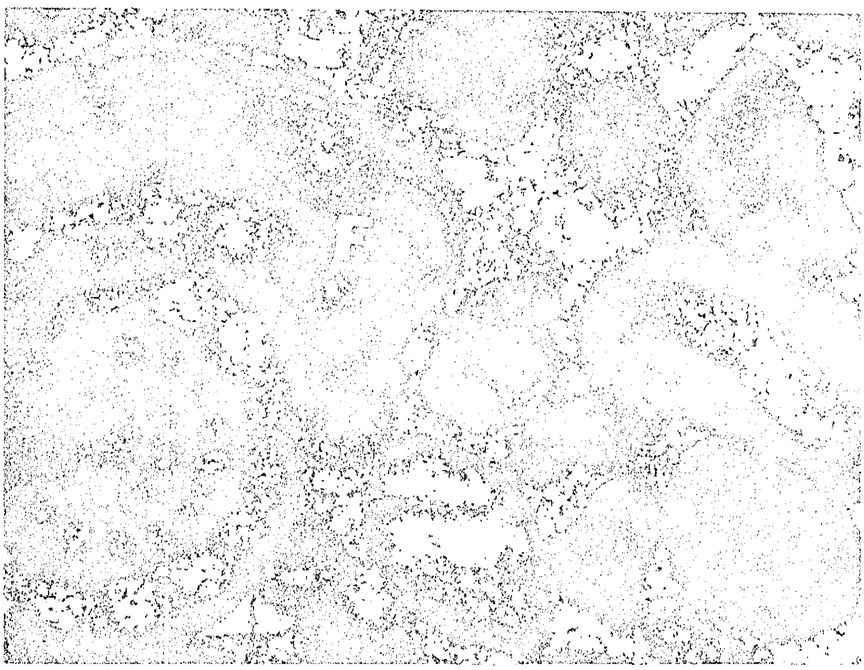
5 mm

Figure 7

FIGURE 8

PHOTOMICROGRAPH OF COATED FUSULINID

GRAIN (F) AND OTHER COATED GRAINS
(Crossed-polarized light)



.5 mm

Figure 8

The upper half of the section is characterized by relatively high total biotic diversity and relatively high diversity of euryhaline organisms; rare burrowed intervals; infrequent laminated strata; virtual absence of ooids, pellets, and terrigenous material; relatively high abundance of carbonate mud; and predominance of medium to thick beds.

DEPOSITIONAL ENVIRONMENTS

Discussion and interpretations of the depositional environments are based on field observations and thin-section data. Concepts and terminology from Heckel (1972, graphically represented in figure 3) will be used in this manuscript.

Discussion

Based on skeletal-grain analyses in modern environments, general relationships among biotic size, diversity, and abundance may be used to interpret paleoenvironmental conditions. Although relationships between such parameters and their depositional environment were probably similar in the past, application of this technique to the fossil record is difficult. One must establish (or assume) that the fossil grains sampled are representative of the depositional environment of the stratigraphic interval in which they occur. Sessile organisms in growth positions are the best indicators of depositional environments. In addition, skeletal grains which show little abrasion or other evidence of transportation may also be useful. In this study, most field sampling was conducted where there was no field evidence of reworking and/or where there was evidence of *in situ* growth.

Maximum attainable size of a particular taxon is largely dependent on the amount and reliability of appropriate food available for that taxon; the greater the relative amount and reliability of appropriate food, the larger the individual. Utilization of size, however, requires a large sample of in situ organisms, ubiquitous distribution of the individual taxon under investigation, selected sampling of only mature individuals, and an assumption that the taxon does not evolve to larger or smaller maximum size (given optimum conditions) with time, among other factors. Comparative analysis of sizes of a particular taxon can only be accomplished in the field. This technique was not attempted in this study.

Problems were also encountered when attempting to utilize quantitatively, the abundances of different taxa to determine paleoenvironmental conditions. Besides requiring samples of in situ organisms, the relatively high amount of carbonate mud present in the lower New Well Peak section generally resulted in low precision when characterizing relative abundances of biotic constituents identified in thin section. Abundances have been used only qualitatively for comparisons of different elements of the biota in this study.

Although still requiring sampling of in situ organisms, use of biotic diversity seems to have the least number of problems in application to the fossil record. In this study, diversities were determined from thin-section analyses.

An increasing total biotic diversity is generally interpreted to indicate more "normal" marine conditions, while decreasing total diversity is interpreted to indicate a more restricted environment, however, it is important to consider which types of organisms are contributing to the total diversity of a particular environment.

Water temperature, salinity, turbidity and circulation, terrigenous input, water depth, light penetration, appropriate food availability and dependability, substrate conditions, and many other factors affect the development and distribution of the biota. Of these factors, salinity may be most important (Heckel, 1972). Some taxa have the ability to tolerate a wide variety of salinities. These taxa are referred to as euryhaline. Taxa with a restricted tolerance to variations in salinity are termed stenohaline.

Strata representing a dominantly restricted environment may contain fossil remains of both euryhaline and stenohaline organisms. In a dominantly restricted environment, normally only inhabited by euryhaline organisms, periodic or seasonal influxes of normal-marine waters, or occasional reductions of salinity (by fresh-water influx) may cause stenohaline organisms to inhabit the same environment. A return to restricted conditions would result in termination of the stenohaline faunas, with the remains of both stenohaline and euryhaline marine faunas preserved in the fossil record. An environment with a relatively high diversity of euryhaline organisms is generally interpreted to have been predominantly restricted (Heckel, 1972).

Stenohaline and euryhaline faunas may also be found together in normal marine environments, however, euryhaline organisms are usually not as competitive and do not survive the greater number of predators in such an environment. Therefore, only a relatively small diversity of euryhaline organisms can usually survive in a stenohaline environment. An environment with a relatively high diversity of stenohaline organisms is generally interpreted to have been characterized by normal or near normal marine conditions (Heckel, 1972).

Heckel (1972) lists brachiopods, bryozoans, cephalopods, most calcareous forams, corals, and echinoderms, among stenohaline organisms; and ostracodes, agglutinated forams, blue-green algae, worm tubes, pelecypods, and gastropods among euryhaline organisms in modern environments. An assumption was made that these modern organisms had similar ecologic associations in Carboniferous time.

To test this assumption, abundances of particular elements of the biota were plotted versus stratigraphic position. These plots were used to determine qualitatively, which taxa increased and decreased in relative abundance, in response to varying environmental conditions.

In this study, relative abundances of brachiopods and pelmatozoans (crinoids) responded similarly to environmental changes. In addition, relative abundances of molluscs (gastropods and pelecypods) and ostracodes also responded similarly to varying environmental conditions, but their responses generally were opposite to those of the brachiopods and pelmatozoans.

It seems unlikely that all of these organisms have drastically changed their environmental preference from Carboniferous time to the present, nevertheless, in this report it is assumed that, as Heckel (1972) found in modern environments, a relatively high diversity of brachiopods and pelmatozoans (stenohaline organisms) indicates normal- (or near normal-) marine conditions. Similarly, a high diversity of molluscs and ostracodes (euryhaline organisms) indicates restricted marine conditions.

Bryozoans and conodonts have been considered to be stenohaline organisms; however, the plots of relative abundances of bryozoans, and relative abundances and diversities of conodonts revealed inconsistencies when compared with both stenohaline and euryhaline organisms of this study, and when compared with each other.

Because of their relatively low density, reworking may have caused the anomalous patterns displayed by the abundance plot of the bryozoans. Since little is known about the "conodont animal" or its predators, post-mortem redistribution may be the cause of the unpredictable distribution of the conodont elements; however, other environmental factors, such as the availability of suitable food, among other unknown environmental factors, may have been controlling influences.

In this report, bryozoans and conodonts have not been included with either stenohaline or euryhaline organisms. Due to their relative ease of transportation and concentration, trilobite carapaces, foraminiferal tests, and calcispheres (Figure 5) also were not employed in environmental interpretation.

A plot of relative diversity of stenohaline organisms (S) and relative diversity of euryhaline organisms (E), versus stratigraphic position, reveals variable diversities throughout the section with no apparent trend (Figure 9). The upward increasing trend of total diversity may reflect an increasing actual diversity of euryhaline organisms (Figure 9). These plots are utilized as an aid in environmental interpretation in this investigation.

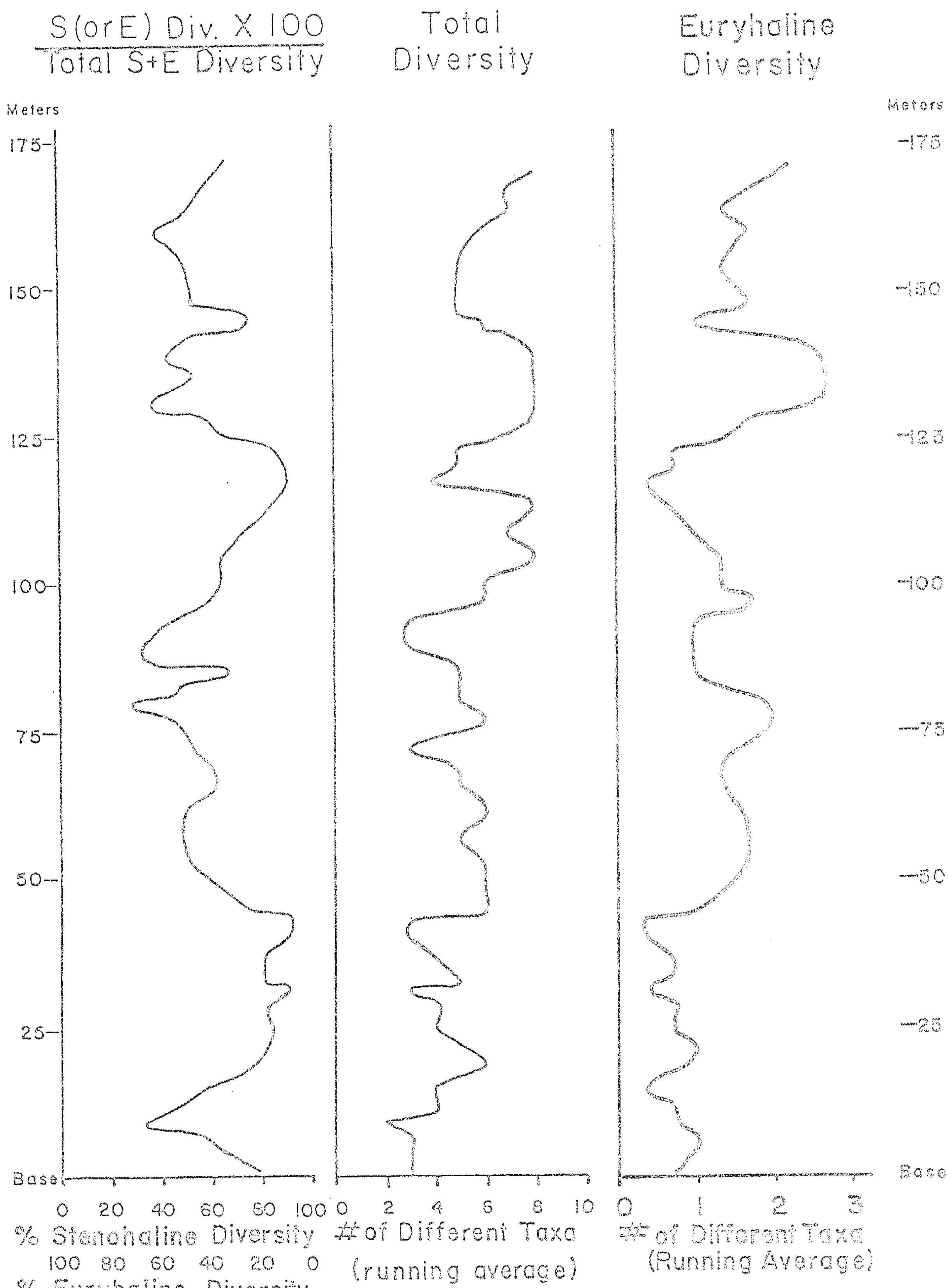
According to Lees (1975), optimum conditions for formation of ooids in modern marine environments are relatively high marine salinity (higher than present normal marine) and sufficient agitation to frequently suspend the ooids. He maintains that most modern ooids form in water less than 5 meters deep.

Similarly, Lees (1975) found that pellets, although formed nearly any place inhabited by marine biota, were preferentially preserved in non-agitated, high water-temperature environments. Absence of ooids and/or pellets should not be used as an environmental indicator, since there are several conditions that are required to form and preserve such non-skeletal grains.

FIGURE 9

RELATIVE DIVERSITIES OF STENOHALINE (S) AND OF EURYHALINE (E) ORGANISMS; TOTAL BIOTIC DIVERSITY; AND ACTUAL DIVERSITY OF EURYHALINE ORGANISMS, VERSUS STRATIGRAPHIC POSITION

FIGURE 9


S(or E) Div. X 100
Total S+E Diversity
Total
Diversity
Euryhaline
Diversity
Meters
175
150
125
100
75
50
25
Base
Meters
175
150
125
100
75
50
25
Base
0 20 40 60 80 100
% Stenohaline Diversity
100 80 60 40 20 0
% Euryhaline Diversity
0 2 4 6 8 10
# of Different Taxa
(running average)
0 1 2 3
# of Different Taxa
(Running Average)

Environmental stability, in this report, refers to the degree of fluctuation between normal marine and restricted marine conditions. Deeper water environments are usually more stable, with respect to most physical factors, for longer periods of time, than most shallower water environments, which, due to a larger surface to volume ratio, are more strongly influenced by atmospheric changes in temperature and precipitation, wind-induced water turbulence, sedimentation rates, changes in relative water depth, and salinity fluctuations, among many other factors (modified from Heckel, 1972).

Interpretations

The following environmental interpretations are based solely on observations and sample collections from one vertical section.

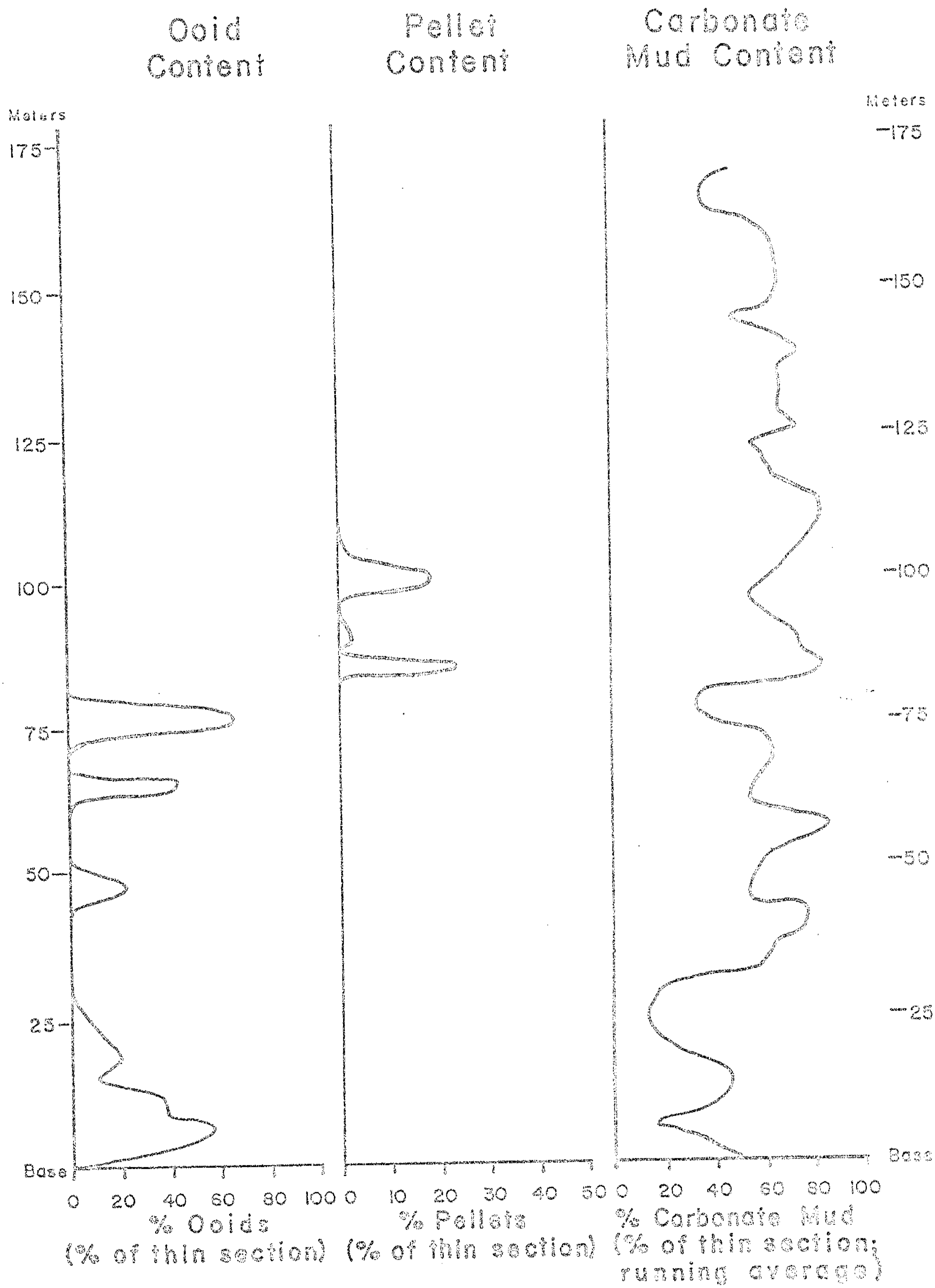
Lower Half of the Section

The lower half of the section extends from the base of the section in the upper Paradise Formation through the lowermost Horquilla Limestone (95 meters above the base). The relatively low amount of carbonate mud (Figure 10); relatively low total biotic diversity, dominated by euryhaline organisms (Figure 9); relatively small excursions (low variation) of the actual euryhaline diversity curve (Figure 9); and the predominance of pellet- and ooid-rich

FIGURE 10

OOID CONTENT; FECAL PELLET CONTENT; AND CARBONATE MUD CONTENT, VERSUS STRATIGRAPHIC POSITION

FIGURE 10


Ooid Content
Pellet Content
Carbonate Mud Content
Meters
175
150
125
100
75
50
25
Base
0 20 40 60 80 100
% Ooids
(% of thin section)
0 10 20 30 40 50
% Pellets
(% of thin section)
0 20 40 60 80 100
% Carbonate Mud
(% of thin section; running average)

intervals (Figure 10) in the lower half of the section, are interpreted to indicate a relatively stable, shallow and periodically agitated, restricted environment of deposition, characterized by frequent periods of relatively high salinity and/or high water-temperature.

Although normal-marine salinities may have been different during the Carboniferous, the common association of ooids and pellets, with a relatively high diversity of euryhaline organisms, suggests a restricted environment of deposition with, at least periodically, higher than normal marine salinities and water-temperature, and frequent agitation.

Upper Half of the Section

The upper half of the section (95 to 174 meters above the base) exhibits evidence of a less stable environment. Except for the abundance of carbonate mud, environmental interpretations are based predominantly on the contained biota.

Figure 9 shows the predominance of euryhaline organisms (relative to stenohaline organisms), indicating a dominantly restricted environment, in the upper half of the section. The total diversity and actual euryhaline diversity exhibit continued increasing trends from the lower half of the section (Figure 9). The increased excursions (higher variability) of the actual euryhaline diversity curve in the upper half of the section, may indicate more drastic fluctuations near normal marine conditions to restricted marine conditions, thus greater overall instability of environmental conditions.

The upper part of the section exhibits an abundance of carbonate mud, indicating a low energy environment. While the lower part of the section studied shows little evidence of the presence of an offshore barrier due to relatively agitated environmental conditions, the presence of a seaward barrier in the upper half of the section would result in relatively low energy conditions behind the barrier, and thus account for the high carbonate mud accumulation.

The large fluctuations in environmental conditions in the upper half of the section, may have been caused by frequent partial removal (possibly by violent storms) and subsequent replacement of a barrier, causing temporarily near normal marine conditions followed by restricted marine conditions.

Perhaps a more likely cause of these frequent and drastic environmental changes may be due to relative fluctuations of sea level. Relative lowering of sea level to a position where an offshore barrier would have a significant influence on the environment of deposition may have resulted in restricted environmental conditions shoreward of the barrier. Subsequent relative raising of sea level to a position where the barrier had little influence on environmental conditions may have resulted in near normal marine environmental conditions. In both cases (relatively low and high positions of sea level), the environment may be characterized by relatively low energy, resulting in accumulations of large amounts of carbonate mud.

The strata in the upper half of the section may represent a predominantly restricted, relatively unstable, relatively low energy, lagoonal facies.

Petroleum Source and Reservoir Rocks

Many factors influence the petroleum potential of strata. Some of these are:

1) nearby petroleum source rocks,
2) Sufficient thermal effects for maturation of hydrocarbons,
3) reservoir units with sufficient porosity and permeability,
4) trapping mechanism, and
5) preservation of hydrocarbons.

Most of these factors are related to lithology, environment of deposition, and diagenetic processes.

Because of their relatively oxidized environment of deposition, shelf carbonates normally are not good source rocks for petroleum. Perhaps the best source for hydrocarbons in this area would be the deep, anoxic, organically-rich sediments deposited in the Alamo Hueco Basin, the deep marine basin within the Pedregosa Basin

(Thompson and Jacka, 1981).

Column three in Figure 10 shows the relatively high original carbonate mud content (quantified by point count data) of the strata throughout the lower part of the New Well Peak section. Subsequent micritization has reduced the original high porosity of this carbonate mud. The amount of original pore space is perhaps better illustrated in Figure 13 (column one). This graph plots percent precipitated spar versus stratigraphic position. This plot indicates that much of the original pore space in the section was restricted to oolitic intervals in the lower half of the section. Nearly all of the original pore space has since been filled with precipitated calcite spar. Other than the frequent scissor fault gouge and associated fracture porosity, little secondary pore space was observed in the field or in thin section (Appendix C).

Because transformation from calcite to dolomite causes a reduction in crystal size, dolomitized intervals are normally characterized by increased intercrystalline porosity (and permeability). A few, thin, fine-grained, dolomitized intervals were encountered in this study (Figure 13).

BIOSTRATIGRAPHY

Introduction

One objective of this part of the study was to devise a upper Chesterian through lower Derryan conodont zonation as an additional step toward the goal of establishing a complete biostratigraphic zonation for the Paleozoic of the region. An additional objective was to determine which, if any, conodont taxa might aid in recognition of both a Chesterian\Morrowan and a Morrowan\ Derryan boundary.

Forty-four samples were collected over a stratigraphic interval of approximately 175 meters (575 feet). Over 72 kilograms of limestone, sandstone, calcareous siltstone, and calcareous shale were processed from the samples. More than 1800 whole conodonts and fragments were recovered, representing 10 genera and 20 previously described species. No new species were recognized.

Previous Work

Many previous conodont studies spanning upper Chesterian through lower Derryan strata have been conducted (most within the last two decades) in the United States. Some of these studies include, in the eastern part of the country: Merrill (1967, 1972, 1973, 1974), Merrill *in* Lane et al. (1971); in the Mid-Continent Region: Gunnell (1931, 1933), Harris and Hollingsworth (1933), Branson and Mehl (1940, 1941), Ellison (1941), Ellison and Graves (1941), Youngquist and Miller (1949), Rexroad (1957, 1958), Rexroad and Burton (1961), Collinson et al. (1962, 1971), Rexroad and Furnish (1964), Dunn (1966, 1970b), Lane (1967, 1977), Thompson (1970), Lane et al. (1971), Straka (1972), Lane, Sanderson and Verville (1972), Lane and Straka (1974), Grayson (1979, 1981), Landing and Wardlaw (1981); and in the west and southwest: McLaughlin (1952), Murray and Chronic (1965), Dunn (1965, 1966, 1970a, 1970b, 1976), Webster (1969), Webster in Lane et al. (1971), and Lane, Sanderson, and Verville (1972). Rhodes et al. (1969, p. 5-11) and Higgins and Bouckaert (1968, p. 6) list most of the Carboniferous conodont works up until their time.

Sampling Technique

In order to recognize the Mississippian\Pennsylvanian boundary using conodonts, the stratigraphic ranges of Late Mississippian conodont taxa had to be established. Sampling was initiated 31.7 meters (104 feet) below the base of Zeller's (1965) New Well Peak Section. Early reconnaissance and later detailed sampling resulted in the collection of forty-four samples. Sample collections were concentrated:

1) adjacent to the unconformity (believed to represent the Mississippian\Pennsylvanian boundary) between the Paradise Formation and the Horquilla Limestone;

2) near the upper and lower range limits of diagnostic conodont taxa; and
3) above and below previously collected barren (with respect to conodonts) samples.

The dominantly carbonate rock samples were treated with a 15% formic acid solution to extract the conodonts. Conodonts are composed of calcium phosphate and do not appear to be affected by this concentration of formic acid. The conodonts were retrieved from the remaining residue, and subsequently identified with the aid of a binocular microscope.

Regional Biostratigraphic Correlation of System and Series Boundaries

Mississippian\Pennsylvanian System Boundary

Unconformities present at the top of the type Chesterian in Illinois and at the bottom of the type Morrowan in Arkansas, markedly reduce the utility of these sequences as type sections for chronostratigraphic units. Through the efforts of Dunn (1965, 1966, 1967, 1970a, 1970b, 1976), Webster and Lane (1967), Webster (1969), Collinson et al. (1971), Lane and others (1971, 1972), Lane and Straka (1974), Brenckle et al. (1977), Lane and Baesemann (1982), and many others, most North American conodont workers recognize the base of the Pennsylvanian at the first appearance of *Rachistognathus primus*.

The base of the Pennsylvanian may also be recognized at the first appearances of Adetognathus lautus, Declinognathodus noduliferus, and by the lack of the diagnostic late Chesterian species Adetognathus unicornis. Particularly in the western United States, the Mississippian\Pennsylvanian boundary occurs at the top of the Rhipidomella nevadaensis (Brachiopod) Zone. The reader is referred to the aforementioned authors regarding comments on the intercontinental correlation of the Mississippian\ Pennsylvanian boundary.

Morrowan\Derryan (Atokan) Series Boundary

There are many problems with biostratigraphic determinations of the Morrowan\Derryan and/or Morrowan\ Atokan boundary, as used in North America, due to the inadequacies of the type sections. These inadequacies include:

1) the unconformable nature of the upper boundary of the type Morrowan section in northwest Arkansas;
2) the unconformable nature of the lower boundaries at both the type Atokan Section in Oklahoma and the type Derryan section in New Mexico;
3) the possible time overlap, or time gap, between the aforementioned type sections;
4) the unfavorable lithologies of the type Atokan section, and
5) the rare occurrence of fusulinids in the Mid-Continent

region.

The International Subcommission on Stratigraphic Classification (Hedberg, 1972) lists standards for establishing boundary strato-types for chronostratigraphic units, specifying that such boundaries be placed in "...sequences of continuously deposited strata... ." Applying this criterion, placement of a Morrowan\Atokan chronostratigraphic boundary at the top of the type Morrowan section (Kessler Limestone), an unconformity, is inappropriate. Similarly, in the type Atokan region, the Atoka Formation is separated from the underlying Wapanucka Formation by an unconformity.

In the type Derryan section, the lowermost Derryan Arrey Formation lies unconformably on the Devonian Percha Shale (King, 1973). This evidence, combined with the unconformity at the top of the Kessler Limestone (type Morrowan area), may make biostratigraphic determination of a Morrowan\ Derryan boundary impossible.

Several proposed boundary designations have been submitted by various authors in an attempt to determine the Morrowan\Derryan and/or Morrowan\Atokan boundary. Some of these are included below.

1) Dunn (1976) and Lane (1977), using conodonts, proposed the Morrowan\Derryan boundary to be near the lowest appearance of Diplognathodus coloradoensis (Murray and Chronic, 1965); however, this species appears to occur sporadically and its distribution may be environmentally

controlled. Recognition of D. coloradoensis as representing Derryan strata is based on its association with the fusulinid genera, Pseudostaffella and Eoschubertella. See Dunn (1976) and Lane (1977) for further comments concerning the placement of the Morrowan\Derryan boundary in relation to the appearance of D.coloradoensis. Diplognathodus coloradoensis is present in the current study, but does not appear near the Morrowan\Derryan boundary (as defined by fusulinids). Diplognathodus coloradoensis first appears in sample NWP-154.8--the lower Derryan of this study (Figure 12).

2) Grayson (1979) proposed a conodont-based determination of the Morrowan\Atokan boundary in the frontal Ouachita Mountains of Oklahoma, where deposition across the boundary was apparently continuous. He placed the boundary in the upper part of the Wapanucka Formation based on the lowest appearance of the Streptognathodus elegantulus assemblage. This assemblage was presumed to be equivalent to the zone of Profusulinella (Atokan Series), even though no specimens of Profusulinella have been recovered from the frontal Ouachitas (Sutherland and Manger, 1983). Dunn (1976) reported the occurrence of Diplognathodus coloradoensis, a diagnostic Derryan conodont species, below the lowest appearance of S. elegantulus.

3) Lane and others (1972), and Lane and Straka (1974) proposed an Idiognathoides n. sp. Zone to mark the

lower Derryan strata. Later, Lane (1977) commented that this species has yet to be found outside of the North American Cordillera; thus its limited utility. Neither *Streptognathodus elegantulus* nor *Idiognathoides* n. sp. (Lane and Straka, 1974) were identified in the present study.

4) Merrill (1972) suggested the use of different species of *Neognathodus* in his evolutionary symmetry-morphologic transition series: *N. bassleri* to *N. bothrops* to *N. medadultimus* to *N.* cf. *N. medexultimus*, in acme zonation of the Atokan and Desmoinesian Series of the Appalachian region. Some of these species were identified in the lower Derryan strata in this study (*N. bassleri*, *N. medadultimus*, and *N.* cf. *N. medexultimus*). Zonation based on these species was not attempted because their evolutionary trends have not been established in this area.

5) Mamet and Skipp (1970) proposed that the Derryan be determined by the sequential appearance of *Pseudostaffella*, *Eoschubertella*, and *Profusulinella* (their zone 21). Unfortunately the lowest appearance of these fusulinid genera appears to be stratigraphically inconsistent, possibly reflecting environmental controls (Dunn, 1976).

6) According to Sutherland and Manger (1983):

> Both Derryan and Atokan strata were recognized as containing primitive *Fusulinella*, now referred to as *Profusulinella*..., [however], ...There is no evidence to equate

> the appearance of Profusulinella with the Morrowan-Atokan/Derryan boundary at the type localities, or anywhere else.

Sutherland and Manger (1983) suggest that the Derryan and Atokan be determined by the lowest occurrence of Pseudostaffella-Eoschubertella, to make these boundaries more consistent with the Morrowan, Derryan, and Atokan type sections. This practice would also be consistent with what is known of other faunal groups (Sutherland and Manger, 1983).

It appears that neither the Morrowan\Atokan, nor the Morrowan\Derryan boundary is marked by a pronounced biostratigraphic event (Sutherland and Manger, 1983). Even though most faunal groups seem to occur sporadically and do not exhibit predictable changes through the interval (ibid), there are distinct faunas that are recognized to be indigenous to each series (Morrowan and Derryan, or Atokan) and the Morrowan\Derryan (or Morrowan\Atokan) boundary will lie somewhere in between these distinct faunas.

The inadequacies of the Morrowan, Atokan, and Derryan type sections have been previously presented. Until a fossiliferous boundary-stratotype is proposed and accepted, the Morrowan\Atokan and/or Morrowan\Derryan boundary problem will likely remain unresolved.

For the purposes of this study, the author agrees with Sutherland and Manger's (1983) working definition that the: "boundary reflect a horizon approximating the lowest occurrence of Pseudostaffella-Eoschubertella" [below

Profusulinella]. According to Sutherland and Manger (1983): "This position is compatible with what is known from the type regions at present, and we believe that it reflects more accurately the level at which the change from 'Morrowan' to 'Atokan' occurs in those faunal groups studies thus far."

Unfortunately, the lowest of these three genera (Pseudostaffella, Eoschubertella, and Profusulinella) to occur in the lower New Well Peak section was Profusulinella (@ NWP-123.2). The lowest occurrence of Pseudostaffella was 37 meters (122 feet) above the lowest occurrence of Profusulinella. Specimens of Eoschubertella were not recovered in this study, however, Zeller (1965) recorded the occurrence of this species at a position correlated to approximately 161.3 meters (529 feet) above the base of the current section, or 38 meters (125 feet) above the lowest appearance of Profusulinella of this study.

The reader is referred to Lane, Sanderson, and Verville (1972), Lane and Straka (1974), Shaver and Smith (1974), Dunn (1976), Lane (1977), and Sutherland and Manger (1983), for further comments concerning the Morrowan\Atokan, Morrowan\Derryan boundary placement problem.

The author questions the practice of using the series names, Atokan and Derryan, as equivalents (as many other authors seem to). Although both names were proposed to represent the strata between the uppermost Morrowan and the lowermost Desmoinesian (Derryan by Thompson in 1942; Atokan by Spivey and Roberts in 1946), until evidence is presented that the type Atokan Section in Oklahoma is biostratigraphically equivalent to the type Derryan Section in New Mexico, these series names should not be used interchangeably.

The fusulinids obtained in this study were identified by Donald A. Myers, a Geologist (Branch of Central Regional Geology), with the United States Geological Survey. For age-determination purposes, he employed the use of the series names Morrowan and Atokan. He stated (personal communication, 1984) that he "uses 'Atokan' as essentially biostratigraphically equivalent to 'Derryan'"; however, he also stated that he has no first-hand knowledge of either type section. Interestingly, he noted: "...the similarity of your material from NWP-108.9, -100.1, -84.8, -57.2, and -48.2 [identified as Morrowan by Myers] with King's (1973) described material [from the type Derryan] suggests a faunal correlation with the Derry as discussed by King (1973)." This suggests that there may be some Morrowan age strata within the type Derryan. The results of Myers' findings are presented in Table 1.

TABLE 1

SAMPLE NUMBER	IDENTIFICATIONS AND COMMENTS	AGE DESIGNATION
NWP-172.2P	*Millerella* cf. *M. marblensis* Thompson	
NWP-169.3	Fusulinid indet., probably *Fusulinella* *Millerella* sp.	Atokan
NWP-166.8	*Millerella* sp. Fusulinid indet.	Atokan

TABLE 1 (continued)

NWP-163.5P	*Profusulinella* sp. indet. *Staffella* sp.	Atokan
NWP-160.5	*Millerella* cf. *M. marblensis* Thompson *Profusulinella*? sp. indet. *Pseudostaffella* ? sp.	Atokan
NWP-154.8	*Eostaffella* sp. closest to *E. ovoidea* (Rauser Chernoussova) *Millerella* aff. *M. extensis* King	
NWP-147.3	*Eostaffella* sp.	
NWP-135.6	*Millerella* sp. *Eostaffella* sp. *Profusulinella* sp.	Atokan
NWP-128.1	*Profusulinella* ? sp. *Millerella* aff. *M. extensis* King *Staffella* sp. *Eostaffella* sp.	Atokan
NWP-125.2P	Poorly preserved millerellids; not identifiable	
NWP-123.2	*Eostaffella* aff. *E. carbonica* Grozdilova and Lebedva; *Millerella* aff. *M. extensis* King *Profusulinella* ? sp. (single small poorly preserved specimen; uncertain of identification)	Atokan?
NWP-120.1	Very poorly preserved, possible millerellid	
NWP-117.8P	*Millerella* aff. *M. extensis* King	
NWP-113.1	*Eostaffella* sp.	
NWP-108.9	*Millerella* aff. *M. extensis* King *Staffella* aff. *S. powowensis* Thompson	Morrowan
NWP-100.1P	*Staffella* aff. *S. depressa* Thompson	Morrowan
NWP-84.8	*Millerella* aff. *M. extensis* King	Morrowan
NWP-57.2	*Eostaffella* aff. *E. postmosquensis* var. *acutiformis* Kireeva	Morrowan
NWP-48.2P	*Eostaffella* aff. *E. ovoidea* (Rauser Chernoussova) *Eostaffella* sp.	Morrowan

The lowest appearance of the fusulinid genus Fusulinella is considered to be indicative of upper Derryan (after Thompson, 1948) and is noted at NWP-169.3.

In agreement with Myers (personal communication, 1984), I would place the Morrowan\Derryan boundary below NWP-123.2 and above NWP-108.9. These findings narrow the control on the Morrowan\Derryan boundary to 14.3 meters (47 feet) from the 63.1 meters (201 feet) determined by Zeller (1965). Zeller's units in the lower New Well Peak section were reconstructed and correlated with the section collected in the present investigation. His sample numbers in the New Well Peak Section, correlated meterages above the base of the current section, and fusulinid determinations are given in Table 2.

TABLE 2

Zeller Collection	Meters above base of current section	Fusulinid Determinations
56i	165.8m	Profusulinella apodacensis? P. decora (Derryan)
56h	161.3m	Millerella sp. Paramillerella sp. Eoschubertella sp. Ozawainella plummeri Profusulinella copiosa (Derryan)
56g	98.2m	Millerella (large form) Paramillerella sp. (Morrowan)

The reader is referred to Higgins (1981), Brenckle et al. (1977), and Lane and Baesemann (1982), for international correlation of Carboniferous conodonts and other taxa.

Conodont Zonation

Lane (1967) first proposed a preliminary conodont zonation for the lower and middle Morrowan based on his collections in the type Morrowan region of Arkansas. Conodont zonation of the Upper Mississippian was first established by Collinson and others (1962) for the Upper Mississippi Valley. Since their proposal, these zonations have undergone multiple modifications by many authors working in different localities (Figure 11). Numerous conodont zonations have been proposed for the upper Chesterian through lower Derryan, but to date, no zonations have been proposed for the entire Derryan or Atokan Series. Several authors have attempted to document a distinctive conodont fauna which might distinguish Derryan or Atokan strata from Morrowan strata and enable establishment of a boundary based on conodonts. Some of these have been presented previously. Unfortunately, few of these "diagnostic" Derryan conodont taxa were recognized in this investigation. Those that were recognized did not have their first occurrence anywhere near the Morrowan\Derryan boundary as defined by fusulinids.

The lowest appearance of Idiognathodus delicatus in this study appears to approximate the Morrowan\Derryan boundary and thus conforms with Lane, Sanderson, and Verville's (1972) findings in the Arrow Canyon Section in

FIGURE 11

SUGGESTED COMPARISON OF UPPER MISSISSIPPIAN-
LOWER PENNSYLVANIAN CONODONT ZONATIONS

SYSTEM	Series	CONODONT ZONES (THIS REPORT)	WESTERN U.S. DUNN (1976)	PRELIMINARY TYPE MORROWAN NW ARKANSAS LANE (1967)	REVISED TYPE MORROWAN NW ARK, NE OKLA LANE (1977, 1982)	TYPE CHESTERIAN U. MISSISSIPPI VALLEY COLLINSON et al. (1962)	NEVADA WEBSTER (1969)
PENNSYLVANIAN (part)	Derryan	*Idiognathodus delicatus*			*Neognathodus n. sp.* (= *N. kanumai*)		*Streptognathodus noduliferus*—*Idiognathoides convexus*
	Morrowan	Barren Interval	? *Streptognathodus parvus* — *Adetognathus spathus*	*Idiognathodus* appears in upper Morrowan	*Idiognathoides convexus*		
			Idiognathodus humerus — *Idiognathodus sinuosis*		*Idiognathodus klapperi*		
			S. expansus — *S. suberectus*		*Idiognathodus sinuosis*		
		Impoverished Zone	*Neognathodus bassleri bassleri*	*Gnathodus bassleri bassleri*	*Neognathodus bassleri*		
		Neognathodus symmetricus	*Neognathodus bassleri symmetricus*	*Gnathodus bassleri symmetricus*	*Neognathodus symmetricus*		
		Impoverished Zone	*Declinognathodus noduliferus*	*Idiognathoides aff. I. nodulifera*	*I. sinuatus* — *R. minutus*		
		Rachistognathus primus	*Rachistognathus primus*		*Rachistognathus primus*		
MISSISSIPPIAN	Chesterian (part)	Barren Interval	*Rachistognathus muricatus*	Barren	U. / L. *Rachistognathus muricatus*		*Gnathodus girtyi simplex*
		? *Adetognathus unicornis*	*G. girtyi simplex* — *Adetognathus unicornis*	*Adetognathus unicornis*	*Adetognathus unicornis*	*Streptognathodus unicornis*	
						Kladognathus — *Cavusgnathus naviculus*	

Figure 11. Suggested comparison of U. Miss.—L. Penn. conodont zonations.

southern Nevada (also corresponding to the lowest appearance of Eoschubertella-Pseudostaffella in southern Nevada); however, this species is known to range into the upper Morrowan in west Texas (Lane and others, 1972).

The lowest appearance of Neognathodus bassleri, is coincident with the appearance of Idiognathodus delicatus in this study. Nearly all previous reports indicate a lowest appearance of N. bassleri immediately above the highest occurrence of the short ranging N. symmetricus in the middle Morrowan.

Although there are unequivocally diagnostic conodont taxa of the Morrowan Series (Neognathodus symmetricus) and Derryan Series (Diplognathodus coloradoensis) in the present section, neither occur near the Morrowan\Derryan boundary as defined by fusulinids. Many long ranging species span the boundary. It is clear, from this and previous studies, that there are no conclusive conodont taxa that may be used to determine consistently, a Morrowan\ Derryan or Morrowan\Atokan boundary at horizons equivalent to the boundaries determined by fusulinids.

In this investigation, an attempt was made to conform, as closely as possible, to previously proposed zonations. One provisional and three established conodont zones, in most cases separated by barren or impoverished intervals, were recognized as representing the upper Mississippian and the Lower Pennsylvanian strata in the lower New Well Peak section of the Big Hatchet Mountains. Three of the zones, the Adetognathus unicornis Zone, the Rachistognathus primus Zone, and the Neognathodus symmetricus Zone) appear to be stratigraphically equivalent to the zonations of Dunn (1976), Lane (1967, 1977, 1982), and others (see Figure 11). The remaining Idiognathodus delicatus Zone, is newly proposed in this report and apparently represents early to at least late Derryan time in this part of New Mexico. Figure 12 shows the ranges of individual conodont species, and Figure 11 shows the comparison of the present zonation with zonations of previous authors.

Zonation becomes difficult toward the top of the Morrowan strata due to the presence of many long ranging species and few biostratigraphically significant, short-ranging taxa. This trend continues into the overlying Derryan strata.

The succession of zones recognized in this study is presented in ascending order below:

Adetognathus unicornis Zone

This geographically widespread and widely accepted upper Mississippian zone is present in the uppermost Paradise Formation.

Limits.-- The Adetognathus unicornis Zone has been defined as the range of the name-bearer below the lowest appearance of Rachistognathus muricatus. In this study, the lower range of Adetognathus unicornis may extend below the base of the described section. The placement of

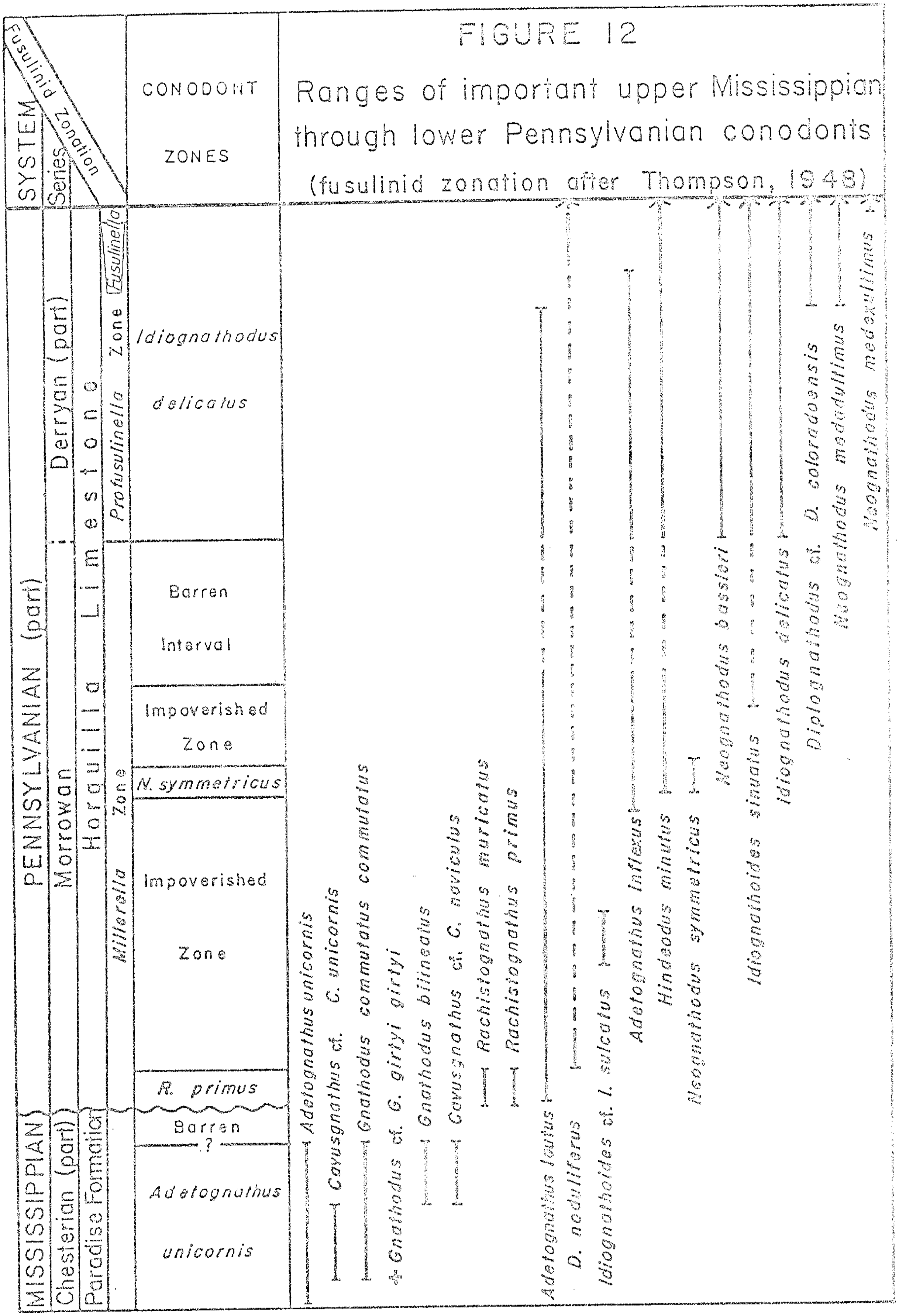
FIGURE 12

RANGES OF IMPORTANT UPPER MISSISSIPPIAN THROUGH

LOWER PENNSYLVANIAN CONODONTS (THIS REPORT)

FIGURE 12

Ranges of important upper Mississippian through lower Pennsylvanian conodonts (fusulinid zonation after Thompson, 1948)



the upper boundary remains in question due to the presence of an overlying barren zone and unconformity.

Characteristic Species.-- Species typical of this zone include: *Adetognathus unicornis*, *Cavusgnathus* cf. *C. unicornis*, *C.* cf. *C. naviculus*, *Gnathodus bilineatus*, *G.* cf. *G. girtyi girtyi*, and *G. commutatus commutatus*.

Remarks.-- The uppermost zone in the Paradise Formation (upper Chesterian) appears to be stratigraphically equivalent to the zone by the same name below the type Morrowan in northwestern Arkansas (described by Lane, 1967). In addition, the *Adetognathus unicornis* zone of this area of New Mexico appears to be, at least in part, stratigraphically equivalent with the *Adetognathus unicornis* Zone as recognized by Dunn (1976), in Arrow Canyon, Nevada (Figure 11).

Webster (1969) proposed recognition of a *Gnathodus girtyi simplex* Zone immediately overlying his *Adetognathus unicornis* Zone; however, Dunn (1976) notes that this zone may be hard to recognize due to the homeomorphy of *G. girtyi simplex* with its predecessor *G. girtyi girtyi*, and with its ancestor *Declinognathodus noduliferus*.

Immediately overlying the *Adetognathus unicornis* Zone, most authors recognize a *Rachistognathus muricatus* Zone. Defined as the range of the name-bearer below the lowest occurrence of *R. primus*, it is the youngest recognized zone in the Mississippian System.

Neither specimens of Gnathodus girtyi simplex nor specimens of Rachistognathus muricatus (without R. primus) were recovered in this study; however the absence of these two species may be attributed to the barren nature of the strata overlying the Adetognathus unicornis Zone, or its included unconformity.

Barren Interval

Immediately overlying the Adetognathus unicornis Zone in the present section is an interval approximately eight meters (26 feet) thick that is barren of conodonts. In its upper part, this interval includes an erosional unconformity representing erosion and/or lack of deposition of unknown duration. The 4.5 meters (15 feet) of strata immediately below the unconformity is represented by a silica-cemented sandstone, for which no effective method is known for removal of conodonts (if any are present).

The lowest conodont zone in the Pennsylvanian System, the Rachistognathus primus Zone, normally overlies the uppermost Mississippian R. muricatus Zone. The boundary between these two zones is considered by most conodont workers, at least in North America, to represent the boundary between the Mississippian and Pennsylvanian systems.

Approximately 1.5 meters (5 feet) of barren strata are present between the unconformity and the lowest representatives of Rachistognathus primus (R. primus

Zone) in the lowermost Horquilla Limestone. In addition, as mentioned previously, approximately 6.5 meters (22 feet) of barren strata lie below the unconformity. Any remaining part of the Adetognathus unicornis Zone, the normally relatively thin "Rachistognathus muricatus Zone", and possibly the lowermost part of the Rachistognathus primus Zone are apparently absent from the lower New Well Peak section.

Rachistognathus primus Zone

This widely recognized (North American) conodont zone represents lowest Pennsylvanian (lower Morrowan).

Limits.-- This range zone is defined as the total range of Rachistognathus primus. The placement of the lowermost boundary is uncertain due to the underlying barren zone and unconformity.

Characteristic Species.-- Platform species diagnostic of this zone include: Rachistognathus primus, R. muricatus, Adetognathus lautus, and Declinognathodus noduliferus.

Remarks.-- This lowest Pennsylvanian conodont zone also represents the lowest conodont zone in the Horquilla Limestone. It has also been recognized in the Cane Hill and Prairie Grove Members of the Hale Formation in northwest Arkansas and the Target Limestone Lentil in southern Oklahoma (Lane and Straka, 1974), the lower Bird Spring Formation of the Arrow Canyon area in southern Nevada (Dunn, 1970a, b, 1976; Lane et al., 1971) and the lower La Tuna

Limestone in west Texas (Dunn, 1966; Lane et al., 1971); however, this zone is apparently absent in the type Morrowan region. This absence may be due to the unconformity at the base of the type Morrowan sequence.

Impoverished Zone

The Rachistognathus primus Zone is overlain by a 43 meter (141 foot) thick impoverished zone which contains three long ranging species (Adetognathus lautus, A. inflexus, and Declinognathodus noduliferus) and one apparently short ranging species, Idiognathoides sulcatus. The latter species has been known to be relatively long ranging in other areas of North America.

This impoverished zone is apparently stratigraphically equivalent to the Idiognathoides noduliferus Zone of Lane (1967), Lane et al. (1971, 1972), Straka (1972), Lane and Straka (1974); Streptognathodus noduliferus Zone, in part, of Webster (1969); Idiognathoides sinuatus-Rachistognathus minutus Zone of Lane (1977, 1982); and the Declinognathodus noduliferus Zone of Dunn (1970b, 1976).

No specimens of Declinognathodus noduliferus were recovered within this impoverished zone. Declinognathodus noduliferus is relatively abundant at its lowest occurrence, but this occurrence is immediately below the lower boundary of the impoverished zone, where this species occurs in association with Rachistognathus primus. The next occurrence of *D. noduliferus* is in lower Derryan strata of the Horquilla Limestone.

Neognathodus symmetricus Zone

This geographically widespread and stratigraphically narrow range zone is recognized by most North American conodont workers. The name-bearer is a well known Morrowan index species.

Limits.-- This zone is defined as the range of the name-bearer below the lowest occurrence of *Neognathodus bassleri*.

Characteristic Species.-- Conodonts typical of this zone in the New Well Peak section are: *Neognathodus symmetricus*, *Hindeodus minutus*, *Adetognathus lautus*, and *A. inflexus*.

Remarks.-- The *Neognathodus symmetricus* Zone of this study is considered to be stratigraphically equivalent to reported occurrences of this zone from the Bird Spring Formation (Webster, 1969; Dunn, 1970b, 1976; Lane, 1977), the La Tuna Limestone (Lane et al., 1972), and in the basal part of the Primrose Member of the Golf Course Formation in southern Oklahoma (Lane and Straka, 1974). In addition, Lane (1967) reported an impoverished interval comprised dominantly of *Neognathodus symmetricus* in the upper Prairie Groove Member of the Hale Formation and in the lower Brentwood Member of the Bloyd Formation in the type Morrowan area of northwest Arkansas.

Impoverished Zone

Immediately above the _Neognathodus symmetricus_ Zone is a 12.4 meter (41 foot) thick impoverished zone characterized by the long ranging species: _Idiognathoides sinuatus_, _Hindeodus minutus_, _Adetognathus lautus_, and _A. inflexus_.

Since this zone occurs immediately above the highest occurrence of _Neognathodus symmetricus_ (below _N. bassleri_), it apparently correlates with the lower part of the _Neognathodus bassleri_ Zone of Dunn (1970), Lane (1977), Lane and Baesemann (1982); _Neognathodus bassleri bassleri_ Zone of Lane et al. (1972), Merrill (1972), Lane and Straka (1974), Dunn (1976); and the _Gnathodus bassleri bassleri_ Zone of Lane (1967), Lane and Straka _in_ Lane et al. (1971), and Merrill _in_ Lane et al. (1971).

The lowest appearance of _Neognathodus bassleri_ in this study occurs approximately 35 meters (116 feet) above the highest occurrence of _N. symmetricus_. Its lowest appearance is coincident with the lowest occurrence of members of the genus _Idiognathodus_ (_Ius. delicatus_). The appearance of this latter genus is normally considered by most conodont workers, to mark the top of the _Neognathodus bassleri_ Zone (and equivalent zones).

Barren Interval

A thick, 23 meter (75 foot), barren interval which yielded essentially no conodonts, overlies the aforementioned impoverished zone. Large volumes of rock were processed in this interval in an unsuccessful attempt to either extend the lower boundary of *Neognathodus bassleri*, the upper boundary of *N. symmetricus*, or to recover other stratigraphically significant conodonts.

Idiognathodus delicatus Zone

This assemblage zone is newly proposed in this report and should be treated as provisional for this area. Many other zones have been proposed for this stratigraphic interval. The reasons for proposal of this zone are as follows:

1) Diagnostic species of previously proposed zones for this stratigraphic interval were not recognized. These include: *Idiognathodus sinuosis* (Note: *Idiognathodus* will herein be abbreviated "*Ius.*"), *Ius. humerus*, *Ius. klapperi*, *Neognathodus kanumai*, *N. bothrops*, *Adetognathus spathus*, *Idiognathoides convexus*, *Streptognathodus expansus*, and *S. suberectus*.
2) This species represents the lowest occurrence of members of the genus *Idiognathodus* in the Pennsylvanian.
3) Numbers of specimens of *Ius. delicatus* dominate all other conodont taxa in this interval.
4) This species has been reported throughout much of the western United States (including Nevada, Colorado, and west Texas).

A complete ontogenetic development, from juvenile to gerontic stage, can be demonstrated for this species. Once the growth trends are recognized, the various growth stages of this species can be easily identified in future studies. For further comments concerning the ontogenetic development of *Idiognathodus delicatus*, refer to "Remarks" for *Idiognathodus delicatus* in "Systematic Paleontology".

Limits.-- The lower boundary is marked by the lowest appearance of *Ius. delicatus* above the highest occurrence of *Neognathodus symmetricus*. The lower boundary of this zone is tentative in this report due to the barren nature of the underlying strata. The upper boundary remains undefined since this species extends beyond the top of the current section, and little is known about the ranges of some of the conodont taxa which first appear near the top of the section (for example, *Neognathodus medadultimus*, *N.* cf. *N. medexultimus*, and *Diplognathodus* cf. *D. coloradoensis*). The lowest appearance of any of these taxa or of other taxa may be chosen, by future authors, to define an upper boundary for this zone.

Characteristic Species.-- Platform species typical of this zone in the stratigraphic section studied herein are: *Ius. delicatus*, *Neognathodus bassleri*, *N. medadultimus*, *N.* cf. *N. medexultimus*, *Idiognathoides sinuatus*, *Hindeodus minutus*, *Adetognathus lautus*, *A. inflexus*, and *Diplognathodus* cf. *D. coloradoensis*.

Remarks.-- As discussed previously, the appearance of

Ius. delicatus, and coincidently Neognathodus bassleri, appear to approximate the Morrowan\Derryan boundary (as defined by fusulinids); however, future recovery from the underlying barren interval may result in extension of the ranges of these two species and the lower boundary of this zone. If the lowest appearance is found at a lower stratigraphic position in other sections, placement of the lower zonal boundary should be revised.

The lowest appearance of Idiognathodus delicatus in the Arrow Canyon Section in southern Nevada (Lane et al., 1972) occurs just above the Morrowan\Derryan boundary; however, in west Texas, it appears in the uppermost Morrowan of the La Tuna Limestone (Lane et al., 1972). Ius. delicatus is present at the unconformable base of the type Derryan Section in south-central New Mexico (Lane et al., 1972).

All available data indicate that the lower boundary of the Idiognathodus delicatus Zone of this study approximates the Morrowan\Derryan boundary and that the zone itself represents at least lower Derryan.

CONODONT COLOR ALTERATION

Introduction

In addition to their biostratigraphic value, conodonts can be used to estimate the degree of thermal maturation of the rocks that contain them, much in the same way palynomorphs and coal particles are. Once the thermal alteration of the strata has been determined, using changes in conodont color, a preliminary estimate of the petroleum potential can be made.

Organic matter within laminated layers of conodonts irreversibly changes color between 50 degrees C and 500 degrees C (Epstein et al., 1977). Conodonts range in color from pale yellow (unaltered conodonts) to dark grayish brown to black (chlorite-grade metamorphic stage), with an apparent increase in the fixation of their contained carbon (with increasing temperature). Further heating and suspected volatilization of the fixed carbon causes lightening of the conodont elements from black to gray to opaque white. Simultaneously, this increased heating apparently causes the originally shiny and vitreous surface of the conodonts to become grainy and pockmarked. The final change in color from opaque white to crystal clear (garnet-grade metamorphic stage) is believed to be due to the release of water of crystalization (Epstein et al., 1977). The color change of conodont elements is time and temperature dependent and apparently independent of pressure

(Epstein et al., 1977).

Conodonts recovered in this study exhibit a gray to grayish-black color. The surfaces of the conodont elements are generally shiny and vitreous. Little or none of the original amber (now brown) color remains. Comparison of these conodont elements with the conodont Color Alteration Index (CAI) charts of Epstein et al. (1977), as well as with standards developed by Kevin Cook (personal communication, 1984) who is completing a masters thesis on conodont color alteration, reveals a CAI value of approximately four.

The Ahrrenius Plot developed by Epstein et al. (1977) is used to estimate the temperature range responsible for the thermal alteration of the conodonts recovered in this study. The maximum estimated duration of burial (sediment loading) of the Lower Pennsylvanian strata in the Big Hatchet Mountains area, from deposition to uplift in the middle Tertiary, is approximately 270 $\pm$ 30 my. The minimum duration of burial, taking into account the unconformities (periods of constant or decreasing burial temperature due to unloading of sediments) between the Permian and Lower Cretaceous strata, and between the Lower Cretaceous strata and overlying Tertiary fanglomerates (determined by Zeller, 1965) is approximately 170 $\pm$ 50 my.

When these durations were plotted on the Ahrrenius Plot (Epstein et al. 1977), the temperature range that produced the color of the conodonts of this study was determined to be approximately 185 degrees C to 230 degrees C.

Based on the present thickness of the overlying rocks, approximately 5030 meters (16,500 feet) (compiled data from thicknesses measured by Zeller, 1965; and Thompson and Jacka, 1981), and assuming an average geothermal gradient of 1 degree C/100 feet, the present known overburden can account for a temperature of approximately 180 degrees C [making the assumption that the mean surface temperature at the time of maximum overburden was 15 degrees C]. Thus the missing section may easily account for the difference of 5 degrees between this estimate and the 185 degrees C at the bottom of the temperature range determined by the Ahrrenius Plot.

Tertiary intrusions are sporadic in the region (Thompson and Jacka, 1981) and few intrusions have been reported in the Big Hatchet Mountains. In the present investigation, a small dike was observed in a gully approximately 40 meters (130 feet) south of the lower part of the section. This minor intrusion appears to have had no thermal influence on the upper Mississippian and Lower Pennsylvanian strata. Further to the northwest, however, in the KCM No. 1 Forest Federal Well in the eastern Animas Mountains, the Lower Pennsylvanian (Desmoinesian?) has been intruded by a quartz-monzonite pluton (and associated dikes) of middle Tertiary age (Thompson, 1977). Although conodont-color alteration studies were attempted in this well by Behnken (1977) his results were inconclusive. There were no shows of oil or gas reported and the well was plugged and abandoned.

Application to Petroleum Exploration

Conodont color alteration may be a useful method for petroleum exploration. Conodont color alteration indices, which may be used to estimate the thermal maturity of the rocks that contain the conodonts, may be useful to determine if the responsible temperature range was optimal for generation and preservation of indigenous oil and gas.

Thermal Maturation

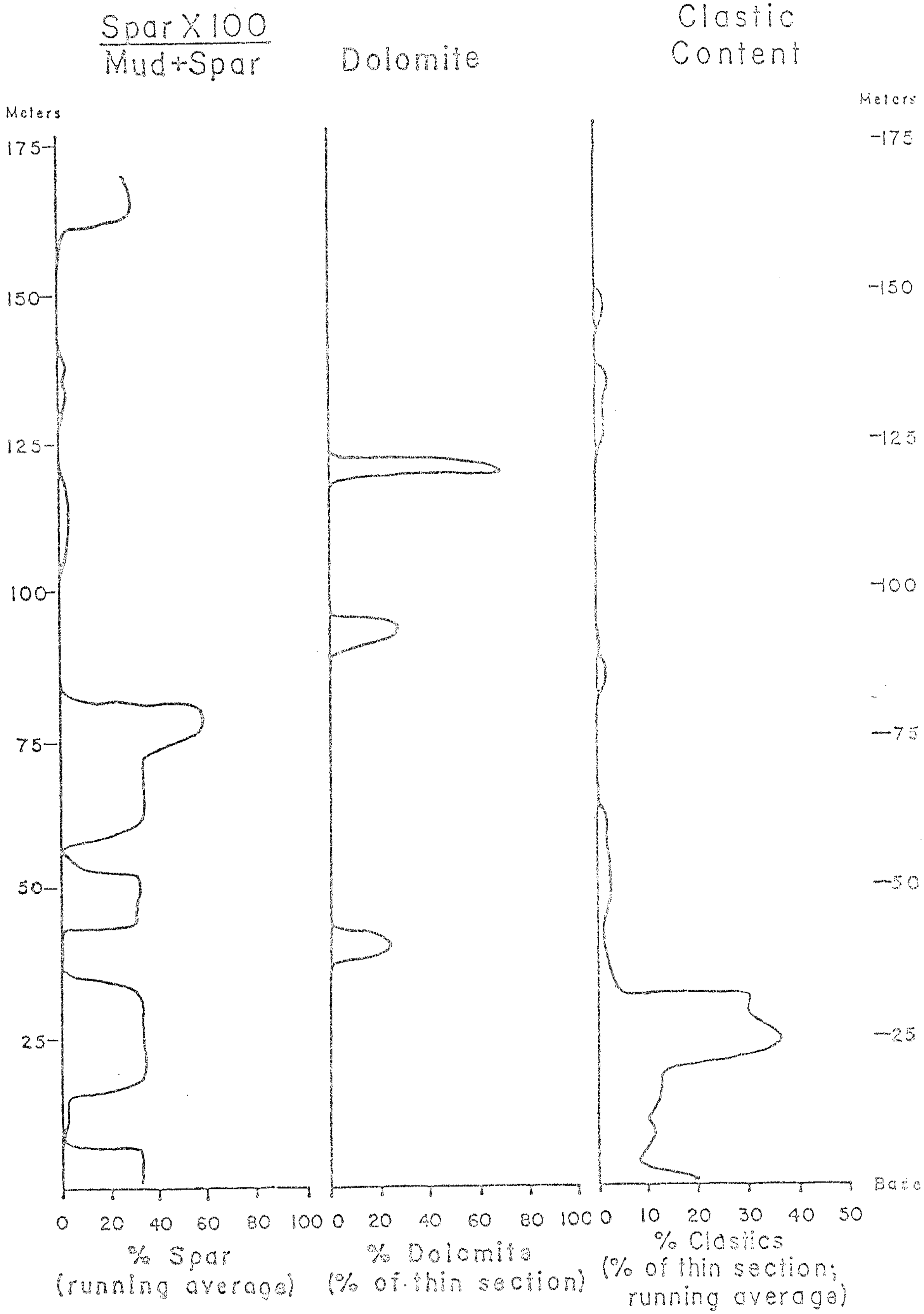
A conodont color alteration index (CAI) value of approximately four was determined for the conodonts of this study. According to Perry (1983), a CAI value of 4.0 (= Thermal Alteration Index of 3.5 to 4+) represents early post-mature to late post-mature thermal maturity of hydrocarbons. Generally, this degree of thermal maturation would only result in production of wet gas and condensate (early post-mature) or dry gas (late post-mature). Perry (1983) states that the "oil-generation window" corresponds to CAI values of from 1.5 to less Qdeo 2 % -?N ueWcnX WnXX than 1.0 (pre-matcwn| rw vwneQnw Qdeo 3%0 @yrXQUieQcwn| indicate little, if any, native oil or gas will be encountered.

Excessive post-depositional heating (post-mature state for oil) is detrimental to the preservation of not only the

FIGURE 13

PRECIPITATED SPAR/PRECIPITATED SPAR + CARBONATE MUD X 100; DOLOMITE (%); AND AMOUNT OF TERRIGENOUS MATERIAL (CLASTICS), VERSUS STRATIGRAPHIC POSITION

FIGURE 13


Spar X 100 / Mud+Spar
Dolomite
Clastic Content
Meters
175
150
125
100
75
50
25
Meters
175
150
125
100
75
50
25
Base
0 20 40 60 80 100
% Spar (running average)
0 20 40 60 80 100
% Dolomite (% of thin section)
0 10 20 30 40 50
% Clastics (% of thin section; running average)

hydrocarbons, but also the reservoir. According to Harris (1979), generally, once CAI values reach four or more, the indicated high temperature causes "mineral metamorphism", which reduces porosity and permeability.

Based on evaluations of data collected in this report, the strata in the lower New Well Peak section have been heated beyond optimum temperature for generation and preservation of oil, to a post-mature level, where any organic materials originally present would have been thermally altered to gas. Any commercial accumulations of oil in rocks of similar thermal history in this area will have had to migrate into reservoirs in the area late in the thermal history of the strata.

To date, there have been no commercial shows of oil or gas reported in strata of this age intercepted by exploration wells in the Hidalgo County area.

CONCLUSIONS

One provisional (Idiognathodus delicatus zone) and three previously proposed conodont zones (Adetognathus unicornis zone, Rachistognathus primus zone, and Neognathodus symmetricus zone) are recognized in the lower New Well Peak section of the Big Hatchet Mountains. However, nearly half of the section is represented by barren (with respect to conodonts) or impoverished intervals with few distinctive, short-ranging conodont species (thus reduced conodont control).

Based on conodont evidence, a Mississippian\Pennsylvanian boundary is recognized at the unconformity, or within the adjacent barren strata. Although distinctive Morrowan conodont species and distinctive Derryan conodont species were recovered in this study, the control was not close enough to determine the Morrowan\Derryan boundary.

Petrographic, lithologic, and paleontologic evidence suggests a restricted marginal-marine (lower half of the section) to predominantly restricted lagoonal facies (upper half of section) interpretation of the depositional environments of the lower New Well Peak section of this report.

Conodont color-alteration data from this investigation indicates that any indigenous accumulations of oil in rocks of similar age and thermal history in the Big Hatchet Mountains area, have been altered to gas. Any oil present would have to have migrated into reservoirs in the area late in the thermal history of the strata.

RECOMMENDED FUTURE WORK

The entire Paleozoic section in the Big Hatchet Mountains should be biostratigraphically subdivided using conodonts and other diagnostic biota. Similar studies should be conducted in surrounding areas of southern New Mexico, southeastern Arizona, and possibly northern Mexico, to establish a regional biostratigraphic framework. Such extensive (but regional) collections may result in a more complete conodont zonation not only for the Carboniferous, but also for other parts of the Paleozoic. A more complete Carboniferous conodont zonation may enable better resolution of a Morrowan\Derryan boundary based on conodonts.

Once a complete biostratigraphic zonation, encompassing many elements of the biota, has been established for the upper Paleozoic of the region, it will be very useful for regional and interregional biostratigraphic correlations and thus be a valuable tool in exploration. Conodont color alteration is another exploration tool which provides a relatively easy, rapid, inexpensive method of estimating thermal maturation (therefore maturation and preservation of indigenous oil and gas). Similar conodont color alteration studies could be achieved in other areas, and with caution, in exploration wells.

Petroleum source and reservoir evaluations are needed to determine the resource potential of the Paleozoic strata in the Big Hatchet Mountains area of southwestern New Mexico.

Some work has already been completed (Thompson 1977, 1980; Thompson et al. 1977, 1978; Thompson and Jacka, 1981; and others). Thompson (personal communication, 1984) is continuing his stratigraphic studies and petroleum-resource evaluations of the Paleozoic in the Big Hatchet Mountains.

SYSTEMATIC PALEONTOLOGY

Introduction

Because of their rapid evolution and relative ease of preservation and identification, generally only platform elements have been considered in this study. Conodont element morphologies are discussed by Sweet in Robison (ed.; 1981, p. W5-W20). Most of the genera and species discussed below have been thoroughly described in recent publications; therefore complete descriptions have been omitted. In most cases, a diagnosis has been provided to allow the reader to make comparisons to similar genera and species. Synonomies are limited to the original reference and available publications.

More than 1800 conodont elements and fragments were recovered from the strata of the lower New Well Peak section studied in this report. Because of a large number of broken specimens (mostly from the bottom half of the section), only about 40 percent of the elements were confidently identifiable to the species level. Twenty previously described species representing ten genera were identified. No new species were encountered.

Age determinations for the upper Chesterian were made with the help of diagnostic late Chesterian and early Morrowan conodonts. Morrowan age determinations were ascertained with the aid of diagnostic early and middle Morrowan conodonts and with the aid of fusulinids.

Morrowan\Derryan boundary resolution and age determination of Derryan strata were based on fusulinids and diagnostic Derryan conodonts.

Terminology

The symmetry classification presented by Lane (1968) is utilized in this study. When considering the pairing of asymmetrical conodont elements which have equal ranges and similar abundances, the author agrees with Lane and Straka's (1974, p. 53-54) concept of synonomizing the element-pair. This concept serves to make the literature less cumbersome when both lefts and rights of an element-pair are given different specific names, and may more nearly reflect the original association of the specific conodont elements. According to Lane and Straka (1974), "In such a system, conodont species nomenclature is affected only where both lefts and rights of a Class IIIb symmetry pair have been given different names." The aforementioned concept slightly modifies the traditional form-species concept in which a single lectotype or holotype was erected as a reference for the species.

Left-sided elements are defined as those which, when oriented orally with the anterior (blade) at the top, possess a distinguishing feature (usually the blade attachment to the platform, lobe or node development, etc.) located on the element's left side, regardless of curvature (similarly for right-sided elements).

Curvature of elements serves to distinguish "lefts" from "rights". Elements (oriented properly) with their dominant curvature convex to the left, are considered "lefts". Those with their dominant curvature convex to the right, are considered "rights". It is possible for either left- or right-sided elements to possess both lefts and rights (based on curvature). Conodont distribution, including "lefts", "rights", and "indeterminates", for each sample location, are listed in Appendix D.

Repository

All specimens are reposited in the collections of the New Mexico Institute of Mining and Technology in Socorro, New Mexico (NMBMMR-LW-).

ORDER CONODONTOPHORIDA Eichenberg, 1930

Genus Adetognathus Lane, 1967

Type species: Cavusgnathus lautus Gunnell, 1933, p. 286, pl. 31, figs. 67, 68; pl. 33, fig. 9 (sinistral element). In agreement with Lane and Straka (1974), Cavusgnathus gigantus Gunnell, 1933, p.286, pl. 33, figs. 7, 8 (holotype) =UMC515-5.

Diagnosis

Species belonging to the genus Adetognathus display Class II, Class IIIb, or Class IV symmetry. The platform is characterized by possessing a deep, median, longitudnal trough throughout its length, with no carina developed. The fixed blade, if present, is much shorter than the long free blade. The blade rises in height anteriorly. Members of this genus display a narrow, elongate, lachrymiform basal cavity.

Description

For a complete description, see Lane (1967, p. 63-64).

Remarks

Adetognathus differs from the genus Cavusgnathus by:

1) consisting of both left and right blade attachments (cavusgnathids have only right-sided forms),

2) the absence of a fixed blade, or if present, the fixed blade is less than half the length of the long free blade, and

3) having the apex of its usually discreet, closely spaced, denticulate, long free blade, excepting an abnormally large posteriormost denticle, in the anterior half (cavusgnathids have the highest point of their usually fused, denticulate blade in the posterior half).

The above characteristics (for Adetognathus) had developed in the cavusgnathid-adetognathid lineage, for the most part, by Latest Mississippian time. As a result, all Pennsylvanian forms previously designated as cavusgnathids, were considered by Lane (1967, p. 930) to belong to the genus Adetognathus. This designation restricts species belonging to the genus Cavusgnathus to the Mississippian.

Range

Uppermost Mississippian (upper Chesterian) through Lower Permian.

Adetognathus inflexus Dunn, 1970a

(Pl. 2, Figs. 14, 16, 19, 20)

Adetognathus sp. Lane, 1967, p. 31, pl. 122, figs. 3, 8.

Adetognathus inflexus Dunn, 1970a, p. 327, pl. 61, figs. 8-10, 15, 16; text-fig 10D.

Diagnosis

This species displays Class IV symmetry and is exclusively right-sided. Adetognathus inflexus closely resembles the the right element of Adetognathus lautus, but is best distinguished by the sinuous or flexed nature of the platform. In addition, the blade of A. inflexus decreases in height anterior of the abnormally large posteriormost denticle. The blade of the dextral element of A. lautus rises in height anterior of its posteriormost abnormally large denticle. The basal cavity of A. lautus is deeper than that of A. inflexus.

Description

For description, see Dunn (1970a, p. 327).

Remarks

Adetognathus inflexus displays many of the features characteristic of the genus Cavusgnathus including having a blade that decreases in height anteriorly and possessing exclusively right-sided forms. However, this species is perhaps better placed in the genus Adetognathus due to its possession of a short fixed blade (less than half the total blade length), and its apparent homeomorphy with the dextral element of A. lautus, which possesses all of the characteristics of the genus Adetognathus.

Adetognathus inflexus is present in most samples which also contain A. lautus. Since elements of A.

inflexus seem to intergrade with the dextral elements of A. lautus and are sometimes hard to distinguish from the latter, the former species may be considered a morphologic variant of A. lautus. For the purposes of this study, however, the author will conform to previous designations of A. inflexus as a separate species.

Range

This species ranges from middle Morrowan through lower Derryan in this part of southwest New Mexico. The previous range of this species had been reported from the lower to middle Morrowan.

Material

Rights: 21.

Figured Specimens

NMBMMR-LW-0034, -0036.

Adetognathus lautus (Gunnell, 1933)
(Pl. 2, Figs. 1, 7, 8, 12, 13, 15, 17, 18)

Sinistral Platform Elements
(Pl. 2, Figs. 1, 7, 15, 17, 18)

Cavusgnathus lautus Gunnell, 1933, p. 286, pl. 31, figs. 67, 68; pl. 33, fig. 9; Webster, 1969, p. 28, pl.4, figs. 9a, 9b.

Cavusgnathus lauta Gunnell. Ellison, 1941, p. 126, pl.

21, figs. 47, 48.

Cavusgnathus regularis Youngquist and Miller. Stibane, 1967, p. 333, taf. 35, figs. 8, 9, 14-16.

Adetognathus lautus (Gunnell). Dunn, 1970a, p. 327, pl. 61, figs. 1, 4; Thompson, 1970, p. 1044-1045, pl. 139, figs. 21-23; Lane and Straka in Lane and others, 1971, pl. 1, fig. 5; Baesemann, 1973, p. 697, pl. 2, figs. 29, 30, 36, 39, 40.

Dextral Platform Elements

(Pl. 2, Figs. 8, 12, 13)

Cavusgnathus gigantus Gunnell, 1933, p. 286, pl. 33, figs. 7, 8; Webster, 1969, pl. 4, figs. 6a, 6b.

Cavusgnathus missouriensis Gunnell, 1933, p. 286, pl.33, figs. 10, 11.

Cavusgnathus giganta Gunnell. Ellison, 1941, p. 126, pl. 21, figs. 44, 45, 49; Ellison and Graves, 1941, pl. 3, fig. 3; McLaughlin, 1952, p. 620, pl. 83, figs. 3, 4, 6, 7.

Cavusgnathus flexa Ellison, 1941, p. 126, pl. 21, figs. 42, 43, 46.

Cavusgnathus unicornis Youngquist and Miller. Stibane, 1967, p. 333, taf. 35, figs. 1-3, 5.

Adetognathus giganta (Gunnell). Lane, 1967, p. 931, pl. 120, figs. 16, 18, 19; pl. 121, figs. 8, 12, 13, 16.

Adetognathus gigantus (Gunnell). Dunn, 1970a, p. 326, pl. 61, figs. 2, 3; Thompson, 1970, p. 1044, pl. 139, figs. 9, 10, 14, 26; Lane and Straka in Lane and others, 1971, pl. 1, fig. 6; Baesemann, 1973, p. 696, pl. 2, figs. 38, 41.

Both Sinistral and Dextral Elements
Considered as One Species

Cavusgnathus lautus Gunnell. von Bitter, 1972, p. 61-63, pl. 4, figs. 3a-h.

Adetognathus lautus (Gunnell). Lane and Straka, 1974, p. 64-65, fig. 36: 17, 21, 22, 25-31; fig. 38: 1-4, 6-8, 10-15, 20 [mismarked as 1-3, 7-14]; Bender, 1980, p. 8-9, pl. 4, figs. 26-33.

Diagnosis

This element-pair displays Class IIIb symmetry. Left element: The sinistral element of Adetognathus lautus exhibits characteristics of the species A. lauta diagnosed by Lane (1967, p. 933) below:

> This species of Adetognathus is exclusively left-sided and the marginal blade, which has no fixed portion, rises in height anteriorly from its attachment to the platform.

The inner margin of this element may be flared and raised slightly above the left outer margin (Pl. 2, Fig. 7). See Lane (1967, p.933) for additional description.

The dextral element of Adetognathus exhibits characteristics of the species Adetognathus giganta diagnosed by Lane (1967, p. 931) as follows:

> Adetognathus giganta, an exclusively right-sided form, has a fixed blade that is less than half the total blade length. The posterior end of the blade has an abnormally large denticle.

See Lane (1967, p. 932) for extensive description.

The right element of *Adetognathus lautus* is distinguished from *Cavusgnathus unicornis* by a distinctly different blade morphology and having less than half the blade fixed to the platform. It differs from *A. unicornis* by having a portion of the blade fixed, by the unbowed nature of both the blade and the parapet-like outer margin, and by possessing a deeper and broader median longitudnal trough (Lane, 1967).

The left element of *Adetognathus lautus* differs from *A. unicornis* by the lack of an abnormally large denticle on the posterior end of the free blade, and the free blade is invariably attached to the left margin (Lane, 1967). The right element of this element-pair differs from *Adetognathus inflexus* by the sinuous or flexed nature of the platform of the latter species.

Remarks

The author agrees with the observations ("Remarks") of Lane and Straka (1974, p. 64-65) and the reader is referred to this paper for further comments. This element-pair is long ranging and generally not considered singly useful for conodont zonation.

Range

This long ranging species spans the lowermost Morrowan through the Lower Derryan in this study and has been reported by other authors to range from its lowest appearance in the basal Morrowan through the basal Permian. The lowest appearance of this species (along with the lowest appearance of Rachistognathus primus and Declinognathodus noduliferus is considered, by most conodont workers, to represent lowermost Morrowan.

Material

Lefts: 56; rights: 41; indeterminate: 8.

Figured Specimens

NMBMMR-LW-0023, -0028, -0029, -0032, -0033, -0035, 0037.

Adetognathus unicornis (Rexroad and Burton, 1961)
(Pl. 2, Figs. 6, 11)

Streptognathodus unicornis Rexroad and Burton, 1961, p. 1157, pl. 138, figs. 1-9; Dunn, 1965, p. 1149, pl. 140, figs. 5, 6, 13, 14; Webster, 1969, p. 49, pl. 4, figs. 13a, 13b.

Adetognathus unicornis (Rexroad and Burton). Lane, 1967, p. 930, pl. 119, figs.16-21; Dunn, 1970a, p. 327, pl. 61, figs. 20-22; Lane and Straka, 1974, p. 66, fig. 33: 14-18.

Diagnosis

The original diagnosis is given by Lane (1967, p. 930). This was subsequently updated by Lane and Straka (1974) below:

Left element: The free blade attaches to the left margin of the platform, and the blade-margin upper profile is gently convex outwardly. The posteriormost denticle of the free blade is abnormally large, and its right side may occupy a mid-platform position at the blade-platform junction. No fixed blade is developed.

Right element: Right-sided specimens in our collections assigned to *Adetognathus unicornis* closely compare as mirror-image representatives of the left element. The free blade attaches to the right margin of the platform; however, the posteriormost denticle is generally larger in right-sided forms.

This species displays Class II symmetry. This species differs from *Cavusgnathus unicornis* by its possession of both right and left elements. Cavusgnathids are exclusively right-sided. In addition, *Adetognathus unicornis* possesses a fixed blade less than half the total blade length, or has a complete absence of a fixed blade.

Description

For description, see Lane and Straka (1974, p. 66).

Range

Previous authors restrict the range of this species to lower through upper Chesterian. The common association of this species with other diagnostic Late Mississippian conodonts (*Cavusgnathus naviculus* and *C. unicornis*) allows an upper Chesterian age to be assigned to strata bearing *Adetognathus unicornis*.

Material

Lefts: 0; rights: 1; indeterminate: 4.

Figured Specimens

NMBMMR-LW-0027.

Genus Cavusgnathus Harris and Hollingsworth, 1933

Type species: Cavusgnathus altus Harris and Hollingsworth, 1933, p. 201, pl. 1, figs. 10a, 10b.

Diagnosis

Members of this genus display Class IV symmetry. Elements possess a long fixed blade, about three-quarters of the blade length, by way of the anterior extension of the left platform margin. The free blade constitutes about one-quarter of the total blade length. In general, the blade rises in height posteriorly (Lane and Straka, 1974, p. 68). All elements are right-sided and exhibit a narrow, deep, lachrymiform basal cavity.

The longer fixed blade than free blade in members of Cavusgnathus, as well as its possession of exclusively right-sided forms, distinguishes this genus from Adetognathus. Further differences between Cavusgnathus and Adetognathus are presented under "Remarks" for Adetognathus.

Description

Harris and Hollingsworth's original description (1933, p. 200-201) follows:

> This genus is erected to include those lanceolate plated conodonts with no semblance of a median crest in the oral channel. Outline of plate lanceolate to claviform; oral face of plate with complete, deep, median, longitudnal channel without crest and bordered by marginal rims ornamented with denticles, nodes, corrugations or combinations of the same; posterior [now considered anterior] bar denticulate.

Further description is provided by Thompson and Goebel (1968, p. 21).

Range

Upper Mississippian (upper Meramec through upper Chesterian). This genus is found in the upper Chesterian of this study.

Cavusgnathus cf. C. naviculus (Hinde, 1900)

(Pl. 2, Figs. 10, 21)

Polygnathus navicula Hinde, 1900, p. 342, pl. 9, fig. 5.

Cavusgnathus navicula (Hinde). Rexroad and Burton, 1961, p. 1151, pl. 139, figs. 4-13; Rexroad and Nicoll, 1965, p. 17, pl. 1, figs. 24, 25.

Cavusgnathus naviculus (Hinde). Dunn, 1965, p. 1147, pl. 140, figs. 10, 11; Webster, 1969, p. 28, pl. 4, fig. 3; Dunn, 1970a, p. 329, pl. 61, figs. 24, 25 (? fig. 23); Lane and Straka, 1974, p. 69, fig. 32: 6, 8, 10, 14-18.

Diagnosis

The diagnosis given by Lane and Straka (1974) is as follows:

> The broad massive platform is flat across the upper surface, with only a very narrow, slit-like trough which is generally restricted to the anterior half of the platform.

Description

For description, see Hinde (1900, p. 342). Also see Lane and Straka (1974, p. 69).

Remarks

From Rexroad and Burton (1961, p. 1151):

> In ontogenetic development, the trough is of moderate depth in juvenile specimens, becomes shallow in adults, and is commonly filled-in, except at the extreme anterior, in gerontic individuals. On each parapet there is a change from single row of nodes to a double row, and in some individuals the nodes unite to form subparallel transverse ridges which may extend irregularly across the filled-in trough of the gerontic stage.

All six specimens studied in this report are fragmentary and range from mature to gerontic individuals.

Range

<u>Cavusgnathus</u> cf. <u>C</u>. <u>naviculus</u> has been previously reported as representing Chesterian strata. It maintains a short range in the upper Chesterian of this study.

Material

Lefts: 1; Rights: 2; 3 with indeterminate curvature. All specimens are right-sided.

Figured Specimens

NMBMMR-LW-0031, -0038.

Cavusgnathus cf. *C. unicornis* Youngquist and Miller, 1949
(Pl. 2, Fig. 5)

Cavusgnathus unicornis Youngquist and Miller, 1949, p. 619, pl. 101, figs. 18-23; Rexroad, 1957, p. 17, pl. 1, fig. 7; Rexroad, 1958, p. 17, pl. 1, figs. 6-11; Rexroad and Burton, 1961, p. 1152, pl. 138, figs. 10-12; Rexroad and Collinson, 1963, p. 9, pl. 1, figs. 26, 27; Rexroad and Furnish, 1964, p. 670, pl. 111, fig. 6; Rexroad and Nicoll, 1965, p. 18, pl. 1, figs. 18-20; Globensky, 1967, p. 439, pl. 57, figs. 5, 14; Thompson and Goebel, 1968, p. 23, pl. 1, figs. 2, 5, 6, 8; Dunn, 1970a, p. 329, pl. 61, fig. 29; Lane and Straka, 1974, p. 70.

[Non] *Cavusgnathus unicornis* Youngquist and Miller. Stibane, 1967, p. 333, pl. 35, figs. 1-5 (=*Adetognathus gigantus*).

Diagnosis

According to youngquist and Miller (1949):

> The horn-like appearance of the posteriormost denticle is the most distinctive feature of our species and serves to distinguish it from *C.*

> *cristata* Branson and Mehl in the holotype of which there is no gradational series of denticles in the blade and one of the median, rather than the posteriormost, denticle is most prominent. Of all the described representatives of *Cavusgnathus*, *C. arca* Sturgeon and Youngquist (1949, pl. 75, figs. 11, 12) from the Allegheny of Ohio appears superficially, at least, to be the closest to our late Mississippian form for it also has a large posterior denticle. However, the Allegheny species is considerably smaller, has a relatively longer blade, and a relatively wider groove in the oral surface of the platform, and is much more arched than is *C. unicornis*.

The differences between *Cavusgnathus unicornis* and *Adetognathus unicornis* are discussed under the diagnosis of the latter (this study). Lane (1967, p. 932) discusses the morphologic distinctions between *C. unicornis* and its homeomorph, the dextral element of *A. lautus* (*A. giganta* Gunnell). Further diagnosis is given in the remarks by Thompson and Goebel (1968, p. 23).

Description

The original description is given by Youngquist and Miller (1949, p. 619).

Remarks

The variation and ontogenetic development of this species is described by Rexroad (1958) below:

> Except for changes during ontogeny, the species shows little variation. The young specimens tend to be narrow with parapets nearly straight or slightly concave toward the inner side. With growth the platform broadens without a proportional increase in length, there develops a pronounced convexity of the inner parapet near the posterior as viewed orally, an increase in the flare of the inner lip of the navel, and an increase in the number of small denticles on the

blade anterior to the prominent posterior denticle.

Range

Cavusgnathus unicornis has been reported as a diagnostic late Chesterian form by previous authors; therefore the few specimens studied in this report are considered representative of upper Chesterian strata.

Material

Five right-sided specimens were recovered.

Figured Specimens

NMBMMR-LW-0026.

Genus Declinognathodus Dunn, 1966

Type species: Cavusgnathus nodulifera Ellison and Graves, 1941, p. 4, pl. 3, figs. 4, 6.

Diagnosis

This genus displays Class II symmetry. For further diagnosis see Lane and Straka (1974, p. 83).

Description

For description see Dunn (1966, p. 1299).

Remarks

The medial junction of the blade with the plate, combined with the declination of the carina to an outer position and the presence of one to three nodes, anterior to the declined carina, are characteristics significantly different from those of _Cavusgnathus_, _Streptognathodus_, _Idiognathodus_, and _Idiognathoides_ to justify establishment of the genus _Declinognathodus_ (modified from Dunn, 1966). In addition, the gnathoidal basal cavity possessed by _Declinognathodus_, precludes any relationship of members of this genus to the genera _Adetognathus_ and _Cavusgnathus_ which have a narrow, lachrymiform basal cavity (after Dunn, 1966). See Dunn (1966, p. 1299) for further discussion.

Range

This genus ranges from lowermost Morrowan to middle Derryan.

Declinognathodus noduliferus (Ellison and Graves, 1941)
(Pl. 3, Figs. 3, 10, 11, 18, 25)

Cavusgnathus nodulifera Ellison and Graves, 1941, p. 4, pl. 3, figs. 4, 6.

Streptognathodus parallelus Clarke, 1960, p. 29, pl. V, figs. 6-8, 14, 15.

Streptognathodus japonicus Igo and Koike, 1964, p. 188, pl. 28, figs. 5-10.

Declinognathodus nevadaensis Dunn, 1966, p. 1300, pl. 158, figs. 4a-4c, 8.

Streptognathodus noduliferus (Ellison and Graves). Webster, 1969, p. 48, pl. 4, figs. 7, 8.

Declinognathodus nodulifera (Ellison and Graves). Dunn, 1970a, p. 330, figs. 1, 2.

Declinognathodus lateralis (Higgins and Bouckaert). Dunn, 1970a, p. 330, pl. 62, figs. 5-7.

Declinognathodus-Neognathodus Dunn, 1970a, p. 330, pl. 62, fig. 8.

Idiognathoides noduliferus (Ellison and Graves). Straka and Lane, 1970, fig. 1A; Thompson, 1970, p. 1046, pl. 139, figs. 2, 3, 5, 6, 8, 16, 20; Lane and Straka, 1974, p. 85, fig. 35: 1-15; fig. 41: 15-17; Bender, 1980, p. 12, pl. 1, figs. 3, 8-16.

Declinognathodus noduliferus (Ellison and Graves). Sweet in Ziegler, 1975, p. 63, Neognathodus pl. 1, fig. 6.

Diagnosis

Distinguishing characteristics of Declinognathodus noduliferus include a blade which joins the platform in a medial position, then declines to meet the outer margin. One to three nodes, which may be fused into a ridge, are located on the anterior, outer shoulder of the platform, immediately anterior to the declination of the carina to the outer margin.

The reasoning behind the placement of the above synonomized genera and species is discussed in "Remarks" under the genus *Declinognathodus*.

Specimens from the Derryan occurrence of this species are similar in appearance to *Neognathodus medadultimus* Merrill but differ by possessing a consistently narrow platform, a carina which curves to meet the outer margin, and a stronger flared basal cavity which is more commonly preserved than the delicate flare on the gnathoidal basal cavity of *N. medadultimus*.

Neognathodus medadultimus exhibits a straight or slightly bowed (concave inwardly) carina on a slightly broader platform. The outer parapet curves to intersect the carina on the posterior half of the platform. In addition, the ornamentation on the oral surface of *N. medadultimus* exhibit higher relief than those on the oral surface of *Declinognathodus noduliferus*.

Description

For description, see Sweet *in* Ziegler (1975, p. 63).

Remarks

These easily recognizable elements are relatively abundant in the sample where they first appear in the lower Morrowan, then are completely absent from all samples until they recur in moderate abundance, in the lower Derryan. The two occurrences are separated by approximately 130 meters

425 feet) of section. Lane and Straka (1974) discuss three separate occurrences (two in the Morrowan and one in the Derryan) of Declinognathodus noduliferus in their sections in Oklahoma. Dunn (1970a, p. 330) suggests that D. noduliferus is a widely occurring Morrowan index species that exhibits provincial variability. This provincial variability or environmental preference may be the reason behind the widely spaced occurrences of D. noduliferus.

Most specimens from the Derryan occurrence (NWP-166.8) are generally much smaller than those from the lower Morrowan occurrence (NWP-37.1). Other morphologic changes between those specimens which first appear in the lower Morrowan and those which do not reappear until the lower Derryan, are as follows:

1) Besides being generally smaller in size, the Derryan specimens seem to have a deeper, median oral trough;
2) The parapets of the Derryan forms tend to be more nodose, or at least have less well developed transverse ridges;
3) There appears to be no less than two fused nodes anterior to the juncture of the carina with the outer parapet, in the Derryan forms of this study. The Morrowan forms display from one to three nodes which may or may not be fused;
4) In the left elements of the Derryan forms, two or more fused nodes form a ridge which may appear to be

continuous with the outer parapet. At the same time, some specimens exhibit a very small depression (and/or separation) between the carina and the outer parapet, where the carina curves to attach to the latter.

Lane and Straka (1974) report that specimens of Idiognathodus noduliferus [Declinognathodus noduliferus of this study] have been recovered from the lower part of the type Derryan in New Mexico; however this claim appears, as yet, to be undocumented.

Range

Two isolated occurrences of this species are reported in this study, lower Morrowan and lower Derryan. As previously mentioned, Lane and Straka (1974, p. 35) discussed three isolated occurrences of Idiognathoides noduliferus [Declinognathodus noduliferus herein]. The sporadic occurrences of this species may be due to an environmental preference. See also the section on "Conodont Phylogeny" in Lane and Straka (1974, p. 35). In summary, D. noduliferus sporadically ranges from lower Morrowan through lower Derryan.

Material

Lefts: 30; Rights: 59.

Figured Specimens

NMBMMR-LW-0041, -0048, 0053.

Genus *Diplognathodus* Kozur and Merrill, 1975

Type species: *Spathognathodus coloradoensis* Murray and Chronic, 1965, p. 606, pl. 72, figs. 11-13.

Diagnosis

Members of this genus most nearly resemble those of the genus *Hindeodus*, but are distinguished from the latter by the lack of a distinct cusp in the anterior portion of the platform, the possession of a large gnathodid-type basal cavity and, according to Sweet (*in* Ziegler, 1977, p. 85), in the distinct division of the denticle series into a higher anterior segment with apically discreet denticles and a lower posterior segment that is either adenticulate (a "spatula") or bears only low, node-like denticles.

Description

The original description is reprinted by Sweet *in* Ziegler, 1977, p. 85.

Range

Lower Pennsylvanian (Derryan) through Lower Permian (lower Wolfcampian).

Diplognathodus cf. *D. coloradoensis* (Murray and Chronic, 1965)

(Pl. 2, Figs. 2, 3)

Spathognathodus coloradoensis Murray and Chronic, 1965,

p. 605, pl. 72, figs. 11-13; Webster, 1969, p. 44, pl. 7, fig. 7; Webster in Lane and others, 1971, p. 405-406, pl. 1, fig. 23; Merrill, 1973b, p. 304, pl. 3, figs. 20-42.

"Spathognathodus" coloradoensis Murray and Chronic. Merrill, 1974, p. 6-7, 22, pl. 1, figs. 23, 24; pl. 2, figs. 38, 39.

Gnathodus coloradoensis (Murray and Chronic). Thompson, 1970, p. 1043.

Anchignathodus coloradoensis (Murray and Chronic). Sweet, 1970, p. 222.

Diplognathodus coloradoensis (Murray and Chronic). Kozur and Merrill, 1975, p. 9; Merrill, 1975, p. 48, figs. 16(40), 17(16); Sweet in Ziegler, 1977, p. 87-89, Diplognathodus pl. 1, figs. 1a-1c; Bender, 1980, p. 9, pl. 4, figs. 8-10, 12-14; Landing and Wardlaw, 1981, p. 1257, pl. 1, figs. 1-10.

Diagnosis

For diagnosis, see diagnosis for the genus Diplognathodus.

Description

Oral view: Element is spathognathodidoform. The carina is divided into two distinct segments. The posterior segment is low in height and is mostly fused to a ridge forming a "spatula". A couple of low, laterally compressed denticles are present anterior of the "spatula". The anterior segment rises above the posterior segment and exhibits laterally compressed denticles which are not fused at the tips.

Lateral view: The platform is only slightly arched. The oral expression of the spatula extends three-forths the length of the basal cavity and is nearly centered over the latter.

Aboral view: In aboral view, the platform possesses a broadly flaring gnathodid-type basal cavity which extends, posteriorly, somewhat beyond the posterior terminus of the spatula.

Remarks

Only five specimens of this species were recovered in this study. The features these specimens exhibit best compare to those of *Diplognathodus coloradoensis* but the lack of sufficient specimens necessitates the designation as *Diplognathodus* cf. *D. coloradoensis*.

Range

Sweet *in* Ziegler (1975) reports this species to range from Derryan through Desmoinesian. The specimens recovered in this study represent early Derryan.

Material

Five specimens of indeterminate curvature.

Figured Specimens

NMBMMR-LW-0024.

Genus *Gnathodus* Pander, 1856

Type species: *Gnathodus mosquensis* Pander, 1856, pl. 2A, figs. 10a, b, c. The types are irretrievably lost and thus Lane and Ziegler (1979) proposed *Gnathodus texanus* Roundy (1926, pl. 2, fig. 8), reillustrated by Hass (1953, pl. 14, fig. 15), to become the type species. This proposal was still before the International Commission on Zoological Nomenclature, pending a decision, at the time of this writing.

Diagnosis

After Lane (1967):

> A platform genus which in upper view, possesses a carina that extends posteriorly to a position at or near the posterior tip. The free blade meets the platform centrally or subcentrally.

Amended Diagnosis (after Lane, 1980):

> A genus based on a protognathodiform-derived P-element displaying Class II symmetry, but having an asymmetrical posterior cup. The inner side of the cup is narrower, bears a parapet, and meets the blade farther anteriorly than the more expanded outer cup [i.e. expanded outer portion of the cup].

Description

The original description is reprinted by Ziegler (1981,

p. 119, "Original Diagnosis"). A revised description is given by Rexroad (1957, p. 30), and Lane and Straka (1974, p. 71).

Remarks

Gnathodids can be distinguished from spathognathodids by the posterior positioning and great expansion of the basal cavity in the former, as well as the high variability of the ornate platform, including the ornamentation on the oral surface of the flared basal cavity of the gnathodids.

According to Lane and Straka (1974, p. 71-72):

> Species belonging to Gnathodus can be differentiated from those belonging to the genus Neognathodus by possession of an uninterrupted median carina that joins the posterior tip of the platform, and weak, unequally developed adcarinal troughs. Also, except for the youngest forms, Neognathodus has a polygnathid appearance in upper view.

For further remarks, see Ziegler (1981, p. 120).

Range

Few Pennsylvanian species of Gnathodus exist. Members of Gnathodus have been reported from uppermost Devonian to Lower Pennsylvanian (lower Morrowan). All species of Gnathodus recovered in this study are restricted to Upper Mississippian (upper Chesterian) strata.

Gnathodus bilineatus (Roundy, 1926)

(Pl. 2, Figs. 4, 9)

Polygnathus bilineatus Roundy, 1926, p. 13, pl. III, figs. 10a-10c.

Gnathodus pustulosus Branson and Mehl, 1941a, p. 172, pl. V, figs. 32-39.

Gnathodus liratus Youngquist and Miller, 1949, p. 619, pl. 101, figs. 15-17.

Gnathodus bilineatus (Roundy). Hass, 1953, p. 78, pl. 14, figs. 25-29; Globensky, 1967, p. 440, pl. 58, figs. 9, 10; Dunn, 1970a, p. 330, pl. 62, figs. 13, 14; Lane and Straka, 1974, p. 72-77, fig. 32: 1-5, 7, 9, 11-13; fig. 33: 11-13, 19-23, 25, 28-32; fig. 34: 13-26; fig. 40: 27.

Gnathodus modocensis Rexroad, 1957, p. 30, pl. 1, figs. 15, 16, 17a, 17b; Rexroad, 1958, p. 17, pl. 1, figs. 1-2.

Gnathodus bilineatus bilineatus (Roundy). Bischoff, 1957, p. 21, pl. 3, figs. 11, 15-24; pl. 4, fig. 1; Wirth, 1967, p. 205, pl. 19, figs. 6, 7a, 7b, 8, 9.

Gnathodus smithi Clarke, 1960, p. 26, pl. 4, figs. 13, 14; pl. 5, figs. 9, 10.

Gnathodus bilineatus modocensis Rexroad and Furnish, 1964, p. 670, pl. 111, figs. 4, 5.

Diagnosis

Specimens of this species demonstrate a wide variation in size and outer lobal ornamentation. For further diagnosis, see Lane and Straka (1974, p. 72).

Description

The original description is given by Roundy (1926, p. 13). Further description is given by Hass (1953, p. 78-80).

Remarks

Lane and Straka (1974) report that the pattern of ornamentation developed on the outer oral flange of the basal cavity, is first developed in the smallest specimens ("juveniles") and the same pattern is maintained through the largest ("gerontic") specimens. Based on the pattern of ornamentation developed, Lane and Straka divided their specimens into four morphotypes: alpha, beta, gamma, and delta. They reported that the morphotypes show some intergradation and are not of significant stratigraphic importance. For the purposes of documentation and synonomy in this study, Gnathodus bilineatus is not broken down into morphotypes herein, however, the proposed morphotypes are indicated for the specimens of this study (see Material).

Range

All previous work indicates that Gnathodus bilineatus ranges from Chesterian through lowermost Morrowan. The specimens recovered in this study are from the uppermost Paradise Formation (upper Chesterian).

Material

MORPHOTYPE		LEFTS	RIGHTS
Alpha		3	-
Beta		2	1
Gamma		-	1
Delta		-	-
Indeterminate		2	4
	TOTAL:	7	6

Figured Specimens

NMBMMR-LW-0025, -0030.

Gnathodus commutatus commutatus (Branson and Mehl, 1941a)

(Pl. 3, Figs. 16, 19)

Spathognathodus commutatus Branson and Mehl, 1941a, p. 98, pl. 19, figs. 1-4; Branson and Mehl, 1941b, p. 172, pl. V, figs. 19-22; Ellison and Graves, 1941, p. 3, pl. 2, figs. 4, 6.

Gnathodus inornatus Hass, 1953, p. 80, pl. 14, figs. 9-11.

Gnathodus commutatus commutatus (Branson and Mehl). Bischoff, 1957, p. 23, pl. 4, figs. 2-6, 15; Dunn, 1970a, p. 331, pl. 62, figs. 11, 12; Lane and Straka, 1974, p. 77, fig. 37: 1-9; fig. 40: 15-18, 23-26.

Spathognathodus cf. S. commutatus Branson and Mehl. Rexroad, 1957, p. 38, pl. 3, figs. 33, 24.

Gnathodus commutatus (Branson and Mehl). Rexroad and Burton, 1961, p. 1153, pl. 139, figs. 1-3; Thompson and Goebel, 1968, p. 23, pl. 4, figs. 4, 6, 7; Webster, 1969, p. 31, pl. 5, fig. 13.

Diagnosis

Branson and Mehl (1941a) discuss the similarity of G. commutatus [G. commutatus commutatus herein] and the simpler gnathodids, differing mainly in the absence of nodes or ridges on the oral surface of the cup. For further diagnosis, the reader is referred to Bischoff (1957, p. 23).

Description

See Branson and Mehl (1941a, p. 98).

Remarks

In general, the remarks concerning Lane and Straka's specimens of Gnathodus commutatus commutatus conform to the specimens recovered herein. See Lane and Straka (1974, p. 77).

Range

This species was recovered from the uppermost Paradise Formation (Chesterian) in this study. It has been previously reported as ranging throughout the Chesterian.

Material

Lefts: 0; Rights: 4; plus 5 with indeterminate curvature.

Figured Specimens

NMBMMR-LW-0052, -0054.

Gnathodus cf. *G. girtyi girtyi* Hass, 1953

Gnathodus girtyi Hass, 1953, p. 80, pl. 14, figs. 22-24.

Gnathodus clavatus Clarke, 1960, p. 25, pl. 4, figs. 4-9.

Gnathodus girtyi girtyi Hass. Dunn, 1970a, p. 331, text-fig. 9A.

Diagnosis

Dunn (1970, p. 331) characterizes this subspecies as follows:

> Oral surface of platform has a larger inner parapet and a smaller outer parapet that are positioned on either side of a median carina; small outer parapet contains at least four or five nodes or lateral ridges and does not extend as far posteriorly as inner parapet.

He continues in his remarks:

> *Gnathodus girtyi girtyi* is distinguished from *G. girtyi simplex* by the greater development of the outer platform in the former. The outer platform of the latter subspecies consists of one or two nodes.

Description

See Hass (1953, p. 80).

Remarks

Only one specimen of this subspecies was recovered; therefore exact designation of subspecies was not attempted, even though that specimen contains all the features characteristic of the nominate subspecies.

Range

The specimen obtained in this study was recovered from upper Chesterian strata (Paradise Formation). Previous reports also indicate a middle to upper Chesterian range.

Material

Lefts: 1.

Genus *Hindeodus* Rexroad and Furnish, 1964

Hindeodus Rexroad and Furnish, 1964, p. 671; Sweet *in* Ziegler, 1977, p. 203.

Anchignathodus Sweet, 1970a, p. 7; Sweet *in* Ziegler, 1973, p. 9.

Type species: *Spathognathodus cristula* Youngquist and Miller, 1949 s. f..

Diagnosis

See Sweet *in* Ziegler (1977, p. 203).

Range

Upper Mississippian through lowermost Triassic.

Hindeodus minutus (Ellison), 1941

(Pl. 3, Figs. 4, 27, 29)

Spathodus minutus Ellison, 1941, p. 120, pl. 20, figs. 50-52.

?Spathognathodus minutus (Ellison). Ellison and Graves, 1941, p. 3 [minutus], pl. 2, figs. 1, 3, 5.

Spathognathodus minutus (Ellison). Youngquist and Downs, 1949, p. 169-170, pl. 30, fig. 4; Sturgeon and Youngquist, 1949, p. 385, pl. 74, figs. 9-11; Rexroad and Burton, 1961, p. 1156-1157, pl. 141, figs. 10, 11; Dunn, 1965, p. 1149, pl. 140, figs. 15, 21; Murray and Chronic, 1965, p. 606, pl. 72, figs. 29, 30; Igo and Koike, 1965, p. 88-89, pl. 9, figs. 16-18; Webster, 1969, p. 44, pl.7, fig. 4; Dunn, 1970, p. 339, pl. 61, figs. 27, 30; Merrill, 1973b, p. 305-308, pl. 1, figs. 1-14; pl. 2, figs. 1-28; Lane and Straka, 1974, p. 101, fig. 44: 7, 12.

Spathognathodus echigoensis Igo and Koike, 1964, p. 187-188, pl. 28, fig. 24.

Spathognathodus cristula Youngquist and Miller. Stibane, 1967, p. 335, taf. 35, figs. 21-25.

Spathognathodus rexroadi Webster, 1969, p. 45, pl. 7, figs. 2, 3 only.

Anchignathodus minutus (Ellison). Sweet, 1970a, p. 7; Sweet, 1970b, p. 222; von Bitter, 1972, p. 65-66, pl. 6, figs. 2a-i; Sweet in Ziegler, 1973, p. 15,

Ozarkodina minuta (Ellison). Baesemann, 1973, p. 704-705, pl. 2, figs. 14, 15, 19, 20.

Hindeodus minutus (Ellison). Merrill and Powell, 1980, pl. 1, figs. 39, 40; Landing and Wardlaw, 1981, p. 1259-1260, pl. 1, figs. 11, 12.

Hindeodus ex. gr. Hindeodus minutus (Ellison, 1941).

Bender, 1980, p. 10, pl. 4, fig. 22.

Diagnosis

According to Merrill (1973):

> The absence of denticles on the anterior edge of the cusp is not a valid descriminator for separating Spathognathodus cristulus from S. minutus [Hindeodus minutus herein]. Many specimens of S. minutus [H. minutus] lack any sign of such denticles. Their presence does have value, however, for they have not been observed in unquestioned representatives of S. cristulus.

Merrill (1973, p. 295-303) discusses the biometric change from Spathognathodus minutus [Hindeodus minutus] to S. ellisoni which resulted from the "crowded insertion of additional, narrower, more elongate, more erect denticles in the area just posterior to the cusp, with 'concomitant pushing' of the more posterior denticles forward, toward the cusp."

Description

The original description is reprinted and a revised description is given in Merrill (1973, p. 306-307).

Remarks

Although some ramiform elements were recovered, only the Pa element of this species is used for identification purposes. The synonomy thus only covers these Pa elements.

Range

This species ranges from the lower Morrowan to the middle Derryan of the Horquilla Limestone in the Big Hatchet Mountains Area of southwest New Mexico. This species has been reported from the uppermost Mississippian through Lower Permian (Wolfcampian).

Material

Lefts: 17; Rights: 18; plus 7 with indeterminate curvature.

Figured Specimens

NMBMMR-LW-0042, -0061.

Genus *Idiognathodus* Gunnell, 1931

Type species: *Idiognathodus claviformis* Gunnell, 1931, p. 249, pl. 29, figs. 21, 22.

Diagnosis

Mature members of *Idiognathodus* (abbreviated '*Ius.*' herein) possess a long free blade which attaches to the platform in a medial position and continues as a short median carina. No trough is developed. The elongate platform is ornamented with transverse ridges and/or nodes.

The above characteristics differentiate *Idiognathodus* from the genera *Idiognathoides* and *Streptognathodus*. To summarize:

1) Members of <u>Idiognathodus</u> have a median carina, but lack a median oral trough.

2) Members of <u>Idiognathoides</u> have no median carina, but possess a median trough.

3) Species belonging to the genus <u>Streptognathodus</u> exhibit both a median carina and a median, oral trough.

<u>Idiognathodus</u> is currently differentiated from <u>Streptognathodus</u> merely on the presence of a longitudnal trough which interrupts the posterior transverse ornamentation on the oral surface of the platform of the latter genus.

Description

An extensive description is given by Ellison (1941, p. 133-134). An additional description given by Lane and Straka (1974, p. 79) is presented below:

> This platform form-genus displays either Class II or Class IIIb symmetry. The carina is flanked on each side by one to three rostral ridges.
> Nodose lobes are commonly developed on the anterior inner margin and may be weakly to strongly developed on the anterior outer margin. The posterior half of the platform bears transverse nodes or ridges. In lower view, a large, deep, asymmetrical, gnathodid-type basal cavity is developed.

Remarks

It is clear that the <u>Idiognathodus</u>/<u>Streptognathodus</u> plexus is in desperate need of reorganization. If it is indeed valid to assign forms possessing "an oral trough which disrupts the posterior transverse ridges" to a separate genus (Streptognathodus), then some means must be put forth to determine placement of the multitude of transitional forms between the two end-member genera (Idiognathodus and Streptognathodus). Many transitional forms which possessed features characteristic of both of the aforementioned genera were encountered in this study.

Descriptions of species belonging to Streptognathodus and those belonging to Idiognathodus often overlap, thus illustrating the very subtle differences between the to genera. This is exemplified by several authors having assigned some species to Idiognathodus and described (and illustrated) them as "possibly possessing a slit-like oral trough on the posterior portion of the tongue (a feature seemingly characteristic of streptognathodids); meanwhile, other authors stick by the strict definition of Idiognathodus with no development of an oral trough.

Even though it has been reported by many authors that idiognathodids and streptognathodids intergrade morphologically throughout their respective ranges, Merrill (in Lane and others, 1971), Ellison (1941), and von Bitter (1972) maintain that platform elements with distinctive features typical of Streptognathodus attain numerical superiority over those with features distinctive of Idiognathodus, in the Upper Pennsylvanian.

It is herein proposed, that Streptognathodus be distinguished from Idiognathodus by possessing a distinct, comparatively broad and deep, oral trough which extends the length of the platform, and into which the posterior transverse ridges disappear. This trough, which bears a median carina within the anterior half of the platform, descends into the oral surface of the platform. A transverse cross section through the posterior half of the platform would reveal a broad, "V" shaped profile of low to moderate relief of the slightly concave-up oral surface.

Members of Idiognathodus do not possess a trough, but may exhibit an oral, slit-like groove, which interrupts the transverse ornamentation on the posterior portion of the tongue only. This groove is usually short, not necessarily median, and may be discontinuous in the posterior half of the platform. The posterior transverse ornamentation appears to be perched on top of the upper surface of the platform. Generally, a transverse cross section through the posterior half of the platform would reveal little relief of the flat to slightly concave-up upper surface of the platform.

In summary, all streptognathodids possess a long, distinct, relatively broad, median oral trough which plunges into the oral surface of the platform and into which the posterior transverse ridges disappear. In contrast, idiognathodids may possess a short, relatively indistinct, sometimes discontinuous, slit-like oral groove, which may or may not be median, disrupts only the posterior transverse ornamentation, and does not plunge into the oral surface of the platform.

Range

Lower Pennsylvanian (upper Morrowan) through Lower Permian (Wolfcampian).

Idiognathodus delicatus Gunnell, 1931

[Pl. 1, Figs. 1 (=juvenile); 2, 3, 4, 5, 6 (=morphotype 1); 7, 8, 9, 10, 11 (=morphotype 2); 12, 13, 14, 15 (=morphotype 3); 16, 17, 18, 19, 20 (morphotype 4); 21, 22, 23 (=morphotype 5)]

Idiognathodus delicatus Gunnell, 1931, p. 250, pl. 29, figs. 23-25; Ellison, 1941, p. 134-135, pl. 22, figs. 31-36 (includes synonomy through 1941); Ellison and Graves, 1941, pl. 3, figs. 20, 23; Mclaughlin, 1952, p. 619, pl. 83, figs. 8-11; Stibane, 1967, p. 334, pl. 37, figs. 9-11; Webster, 1969, p. 35-37, pl. 6, figs. 6-12; Thompson, 1970, p. 1046, pl. 139, figs. 24, 28; Merrill and King, 1971, p. 658, pl. 76, figs. 13-22; Lane and Straka in Lane et al., 1971, pl. 1, fig. 27; von Bitter, 1972, p. 58, pl. 3, fig. 4; Baesemann, 1973, p. 699-703, pl. 1, figs. 18, 19, 23, 24; Higgins, 1975, p. 47, pl. 17, fig. 7; pl. 18, figs. 1-3, 7; ?Merrill, 1975, p. 63-64, figs. 14(4-7, 24, 25), 15(6, 7, 19, 20, 26-32), 16(7-13, 41-49), 17(5-7, 17-26, 41-45, 58-62); Sweet in Ziegler, 1975, p. 169-171, Idiognathodus pl. 1, figs. 1g, 1h; Bender, 1980, p. 10-11, pl. 3, figs. 4-8, 10, 11, 28-31, 36-38; Landing and Wardlaw, 1981, p. 1260, pl. 2, figs. 1-4.

Idiognathodus magnificus Stauffer and Plummer, pl. 4, figs. 8, 18-20; Ellison and Graves, 1941, pl. 3, figs. 25, 26; Sweet *in* Ziegler, 1975, p. 175-177, *Idiognathodus* pl. 1, figs. 7a, 7b.

Idiognathodus cf. *magnificus* Stauffer and Plummer. Clarke, 1960, p. 28, pl. V, figs. 1-5.

Idiognathodus sp. cf. *I. magnificus* Stauffer and Plummer. Murray and Chronic, 1965, p. 601, pl. 71, figs. 7-12.

Idiognathodus meekerensis Murray and Chronic, 1965, p. 601, pl. 71, figs. 7-12; Stibane, 1967, p. 334, taf. 37, figs. 12-22.

Streptognathodus angustus Dunn, 1966, p. 1302, pl. 158, figs. 11-13.

Streptognathodus parvus Dunn, 1966, pl. 158, figs. 9, 10.

Idiognathodus incurvus Dunn, 1966, p. 1301, pl. 158, figs. 2, 3.

Idiognathodus humerus Dunn. Lane and Straka *in* Lane et al., 1971, pl. 1, fig. 17.

Idiognathodus cf. *delicatus* Gunnell. Merrill, 1974, pl. 1, figs. 14-16, 21, 22, 30-32; pl. 2, figs. 28-30.

Diagnosis

Members belonging to *Idiognathodus delicatus* exhibit a wide variety of morphological features during their ontogenetic development. Immature specimens bear a carina that extends the length of the platform. The carina appears to shorten anteriorly with age until, in mature to gerontic specimens, it is only present within the anterior one-third of the platform. Transverse ridges located within the posterior two-thirds of the platform, range from zero to twelve and generally increase in number with age.

Inner and outer accessory lobes, possessing a varying number of nodes, are present in mature specimens, but the outer accessory lobe or both lobes may be absent in the younger specimens. Outer lobes or nodes do not appear to be present in the absence of the inner lobes or nodes. A somewhat indistinct, short, slit-like, oral groove (not a trough) may be developed in the posterior portion of the tongue in some specimens (see "Remarks" concerning the genus _Idiognathodus_).

Specimens classified as _Idiognathodus_ _delicatus_ display Class II symmetry. Subequal numbers of both left and right elements of this species were recovered.

Description

For original and revised descriptions, see Sweet _in_ Ziegler (1975, p. 169).

Remarks

A wide variety of ornamentation typifies this species. The lengthy synonomy encompasses many forms believed to represent the ontogenetic development through the various growth stages of this species. This ontogenetic development is best outlined by Webster (1969) below:

> The platform of immature individuals consists of a median carina and two subparallel lateral parapets, all of subequal height and denticle size, which are terminated by mutual coalescence at the posterior end. Transverse ridges are developed on the posterior end in minute forms, and with continued growth, ridges are added anteriorly, ultimately covering the platform. Depending upon growth stage and variation, the number of ridges ranges from one to twelve. Accessory lobes are developed simultaneously or independently; if independently, the larger inner lobe develops first and may appear before or after the anterior end of the platform is covered with transverse ridges. The accessory lobes may be set off by a narrow groove, or merge smoothly into the transversely ridged portion of the platform....

Idiognathodus delicatus, as herein described, includes in its synonomy many forms thought by previous authors, to represent many "different" species based generally on subtle or weakly differentiated morphological features. These species are herein considered morphotypes of Ius. delicatus and are thought to be representative of the various growth stages of this species.

Idiognathodus magnificus Stauffer and Plummer, for example, has been described by previous authors as always being very large and robust, by conodont standards. Because members of Ius. magnificus match the description of Ius. delicatus and their appearance seems to represent an advanced ontogenetic stage (of the latter species), Ius. magnificus is herein synonomized with Ius. delicatus (as first suggested by Ellison, 1941, p. 135) as a gerontic form of the latter species.

Similarly, specimens of Streptognathodus parvus Dunn and Streptognathodus angustus Dunn are consistently of relatively small size, by conodont standards, and their morphological characteristics are similar to each other, and to those of Ius. delicatus. The former two species of Streptognathodus more nearly match the description for the genus Idiognathodus and are herein considered to be early growth stages of Idiognathodus delicatus.

It was felt by the author, that the multitude of species synonomized herein should be considered morphotypes of Ius. delicatus rather than remain as separate species for the following reasons:

1) Most of the morphotypes (discussed later in this paper) first appeared in the same sample (NWP-120.1). The lack of the unrepresented morphotypes can be attributed to the low conodont recovery from this sample. In addition to their coincident lowest appearances, all the morphotypes have the same range (at least through the top of the stratigraphic section of this study).

2) Nearly identical specimens, some bearing a slit-like oral groove (not a trough) interrupting the posterior transverse ridges, and some with no groove, were recovered from the same samples. The only observable difference between these two types of specimens appears to be the presence or absence of the oral groove.

Therefore, given the homeomorphy of these specimens, the presence of a groove in some specimens is not considered, alone (in this investigation), to be a significant criterion for assignment of these specimens to a new genus (Streptognathodus).

3) All specimens of morphotype 5 (morphotypes are discussed below) are invariably the largest (and presumably the oldest) specimens of those assigned to Ius. delicatus.

4) Except for a few slightly smaller specimens (presumably juveniles), members of morphotype 1 consistently represent the smallest (and therefore presumably immature) specimens of those described as Ius. delicatus. All other morphotypes display a small range of sizes, proportionally increasing in length and width during their ontogenetic development from morphotype 1 to morphotype 5.

In this study, specimens of Ius. delicatus were visually subdivided into the following morphotypes based on their mutual similarity (presumably representing various ontogenetic stages). It must be noted that there is a total intergradation of forms between the two end-member morphotypes. The following are arranged in approximate ontogenetic order, from youngest to oldest, although morphotypes 2, 3, and 4, may develop approximately at the same time.

Juveniles: Juveniles of Idiognathodus delicatus are characterized by possessing a carina that extends the total length or nearly the total length of the relatively narrow platform. No complete transverse ridges are visible on the platform. The carina is flanked by deep sulci on either side which become shallower and gradually shortened anteriorly with age, as transverse ridges are added posteriorly. The very delicate, large, flaring, asymmetrical, basal cavity flange is rarely preserved. The anterior blade decreases in height posteriorly. The platform widens and lengthens during its ontogenetic development.

Only eight juvenile specimens were recovered. This relatively low recovery may be due to the presumption that these smaller specimens are comparatively hydrodynamically light and may have been transported away more readily.

Morphotype 1: This morphotype displays features similar to those of Streptognathodus angustus Dunn. These consistently small-sized platforms consist of a long carina which extends one-half to three-quarters or more the length of the narrow platform. No nodes or accessory lobes are developed. The oral surface of the tongue on the posterior half of the platform is flat to slightly concave.

The carina may appear to breakup into nodes near its terminus in some specimens. This is considered a preliminary stage to the addition of transverse ridges, and is not otherwise considered significant. The transverse ridges on the posterior portion of the platform number from one to seven and are continuous between the inner and outer margins, or may be disrupted by a very narrow, slit-like, longitudnal groove on the oral surface.

In lateral view, the laterally compressed blade possesses denticles which decrease in size and height posteriorly. In aboral view, the basal cavity is asymmetrical with a medial longitudnal groove. The delicate flared portion of the original gnathodid-type basal cavity has broken off in most specimens, resulting in a misleading narrow appearance of the cavity.

Morphotype 1 intergrades with both the forms considered herein as "juveniles" and as morphotype 2. Morphotype 1 differs from the juvenile specimens by possessing a carina that does not extend to the posterior tip and by possession of one or more transverse ridges. It can be distinguished from morphotype 2 by the absence of any accessory lobes or nodes.

Morphotype 2: Morphotype 2 exhibits the characteristics of *Streptognathodus parvus* Dunn and other similar appearing species by the development of an inner accessory lobe of one to six nodes (commonly only one or two), the apparent shortening of the carina to one-half to two-thirds the length of the platform, and the addition of more transverse ridges between the end of the carina and the posterior tip.

Morphotype 2 is transitional to morphotype 3 and nearly the only difference, besides the generally increased size, is the length of the carina, which is shorter in the case of the latter. Morphotype 2 is distinguished from morphotype 1 by the appearance of nodes along the inner side of the platform.

Morphotype 3: Morphotype 3 represents a form similar to morphotype 2 but differs by being generally larger (increased length and width) and possessing a shorter carina. This morphotype is very similar to morphotype 4 and may have actually developed simultaneously with the latter. The two differ primarily by the lack of outer accessory nodes on the platform of specimens belonging to morphotype 3. The carina of both morphotypes is comparable in length, in fact, it shortens only slightly between this stage and the gerontic stage (morphotype 5) of this species.

Morphotype 4: Morphotype 4 is considered the mature form of *Idiognathodus delicatus* and it is to this morphotype that the original description of *Ius. delicatus* (Gunnell, 1931) refers. This morphotype is characterized by possessing accessory nodes or nodose accessory lobes abutting the inner and outer anterior part of the platform.

The outer lobe usually consists of one to four nodes, while the generally larger inner nodose lobe consists of one or more, but usually three or more nodes which may be arranged into one or two rows subparallel to the anterior extension of the inner platform margin. The nodes on the outer accessory lobe, if arranged into a row, are subparallel to, or concave towards the carina.

The carina extends from one-third to less than one-half the length of the platform. As on all morphotypes of Ius. delicatus, a short, subtle, slit-like, longitudnal groove may be present on the oral surface of the tongue.

Morphotype 5: Finally, morphotype 5 represents the gerontic stage of Ius. delicatus and displays features characteristic of Idiognathodus magnificus Stauffer and Plummer (see Sweet in Ziegler, 1975, p. 175-177, Idiognathodus pl. 1, figs. 7a, 7b). In addition to the description of morphotype 5 above, the following characteristics were observed:

1) The basal cavity of morphotype 5 broadens and flares-out beneath the outer ornamented accessory lobe.
2) The carina is shortened to less than or equal to one-third the length of the platform.
3) Although this morphotype displays many of the same features as those of morphotype 4, the platforms of morphotype 5 are much broader and more robust (notice the much decreased L/W ratio in Figure 15).

The relatively few specimens of morphotype 5 recovered may be due to relatively few individuals reaching gerontic age for an undeterminable reason. The reader is referred to Webster (1969, p. 36-37), and Landing and Wardlaw (1981, p. 1260) for further comments.

Biometrics

After individual elements were visually separated into morphotypes based on size and oral ornamentation, then measurements of elements of each morphotype were used to attempt to gain some biometric support for the proposed morphotypes. Length and width measurements and length/width ratios of many platforms were plotted (Figures 14, 15, and 16). Length was measured from the posterior tip to the point on the anterior extension of the slightly shorter, outer margin, where the latter begins to rapidly descend anteriorly (that is, the point where the extension of the outer margin and the carina cease to be nearly equal in height). The width of the platforms, including accessory lobes or nodes, if present, was measured at the widest point. Lengths and widths were measured to the nearest 0.025 mm (25 microns) with the aid of a binocular microscope.

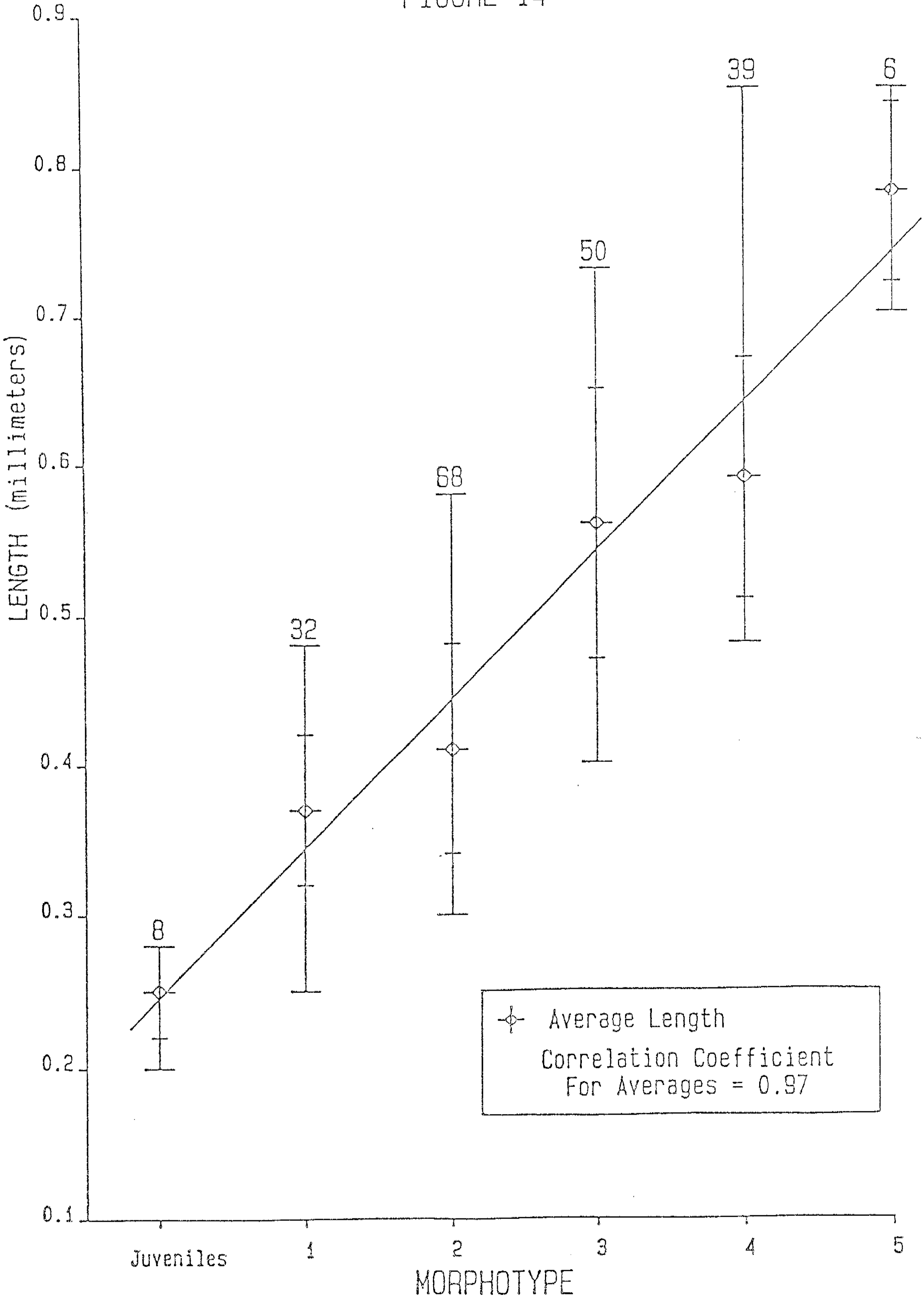
Referring to Figure 14, the vertical lines above each morphotype show the range of variation of the platform lengths measured. The numbers above each of these vertical lines represent the number of platforms sampled. The symbols represent the average platform length for each morphotype.

As one can see from the figure (Figure 14), the average length of each morphotype closely conforms to the best fit line for averages (using a linear regression). This line suggests a continuous increase in the platform length of

FIGURE 14

PLATFORM LENGTH VERSUS MORPHOTYPE FOR SPECIMENS OF *IDIOGNATHODUS DELICATUS*

FIGURE 14


LENGTH (millimeters)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
8
32
68
50
39
6
Average Length
Correlation Coefficient
For Averages = 0.97
Juveniles
1
2
3
4
5
MORPHOTYPE

Ius. delicatus through its growths stages (as proposed herein). The wide variation of lengths of each of the morphotypes is attributed to the intergradation between the morphotypes.

A plot of the length/width ratios (Figure 15) also lends support to the proposed morphotypes as representing growth stages of Ius. delicatus. The length/width ratios reflect the overall progressive widening of the platform (with respect to lengthing), especially with the addition of an inner accessory lobe or nodes in morphotype 2; the addition of an outer accessory lobe or nodes in morphotype 4; and the continued widening of the platform of morphotype 5 as it becomes more robust.

Finally, length versus width measurements were plotted for platforms of each morphotype (Figure 16). When plotted individually, each morphotype had its own grouping of points. Combination of these individual plots into one diagram (Figure 16) illustrates the intergradation between morphotypes and the linear relationship between platform length and width during growth (juvenile to morphotype 5).

While not definitive by themselves, the biometric evidence presented in this report is supportive of the visual distinction of morphotypes. Because of biometric variability and overlap between morphotypes, determination of morphotypes should not be based solely on biometric measurements. For simplicity in the literature, it is recommended that the five morphotypes distinguished in this

FIGURE 15

PLATFORM LENGTH/WIDTH RATIO VERSUS MORPHOTYPE

FOR SPECIMENS OF *IDIOGNATHODUS DELICATUS*

FIGURE 15

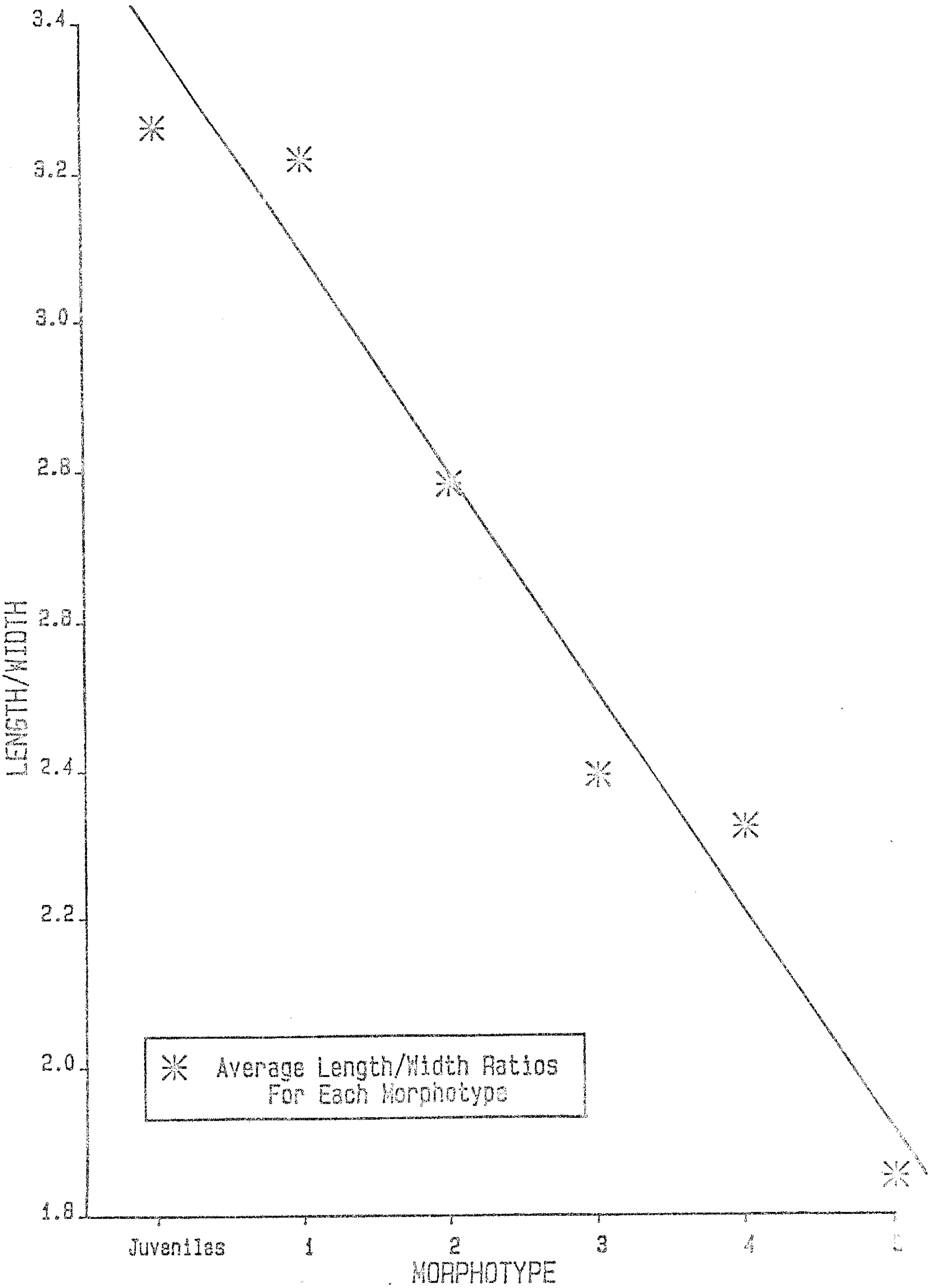

3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
LENGTH/WIDTH
Average Length/Width Ratios For Each Morphotype
Juveniles
1
2
3
4
MORPHOTYPE

FIGURE 16

PLATFORM LENGTH VERSUS WIDTH FOR SPECIMENS OF EACH MORPHOTYPE OF *IDIOGNATHODUS DELICATUS*

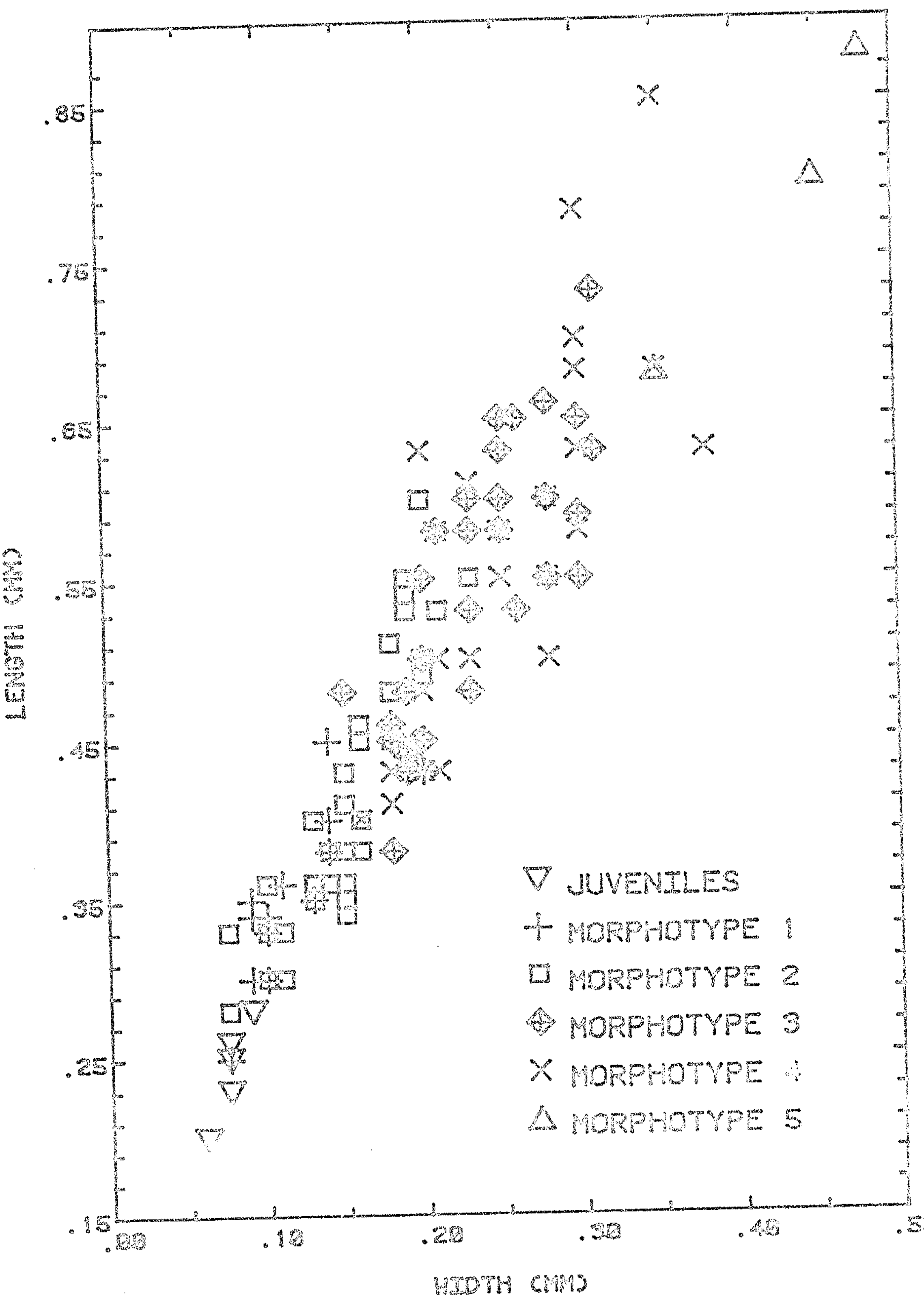


FIGURE 16. PLATFORM LENGTH VS WIDTH

study, as well as the synonomized taxa, be recognized as representing the ontogenetic development of Idiognathodus delicatus.

Range

Specimens of Idiognathodus delicatus were recovered from the upper Morrowan through the lower Derryan of the Horquilla Limestone of the lower New Well Peak section in southwest New Mexico. The total range of this species has been reported as upper Morrowan through Virgilian.

Material

	Lefts	Rights
"Juveniles"	6	2
Morphotype 1	14	18
Morphotype 2	35	35
Morphotype 3	19	31
Morphotype 4	25	22
Morphotype 5	0	6
TOTAL:	99	114

Figured Specimens

NMBMMR-LW-0001 through -0022.

Genus Idiognathoides Harris and Hollingsworth, 1933

Type species: Idiognathoides sinuata Harris and Hollingsworth, 1933, p. 201, pl. 1, fig. 14.

Diagnosis

This genus displays Class II or Class IIIb symmetry.

Members of _Idiognathoides_ are distinguished by possessing a medial trough of variable length, no carina, lateral blade attachment, and a large, deep, asymmetrical, gnathodid-type basal cavity.

Range

Lower Morrowan through Atokan.

Idiognathoides _sinuatus_ Harris and Hollingsworth, 1933
(Pl. 3, Figs. 5, 23, 24, 28)

Sinistral Platform Elements
(Pl. 3, Figs. 23, 28)

Idiognathoides _sinuata_ Harris and Hollingsworth, 1933, p. 201, pl. 1, fig. 14; Lane, 1967, p. 937, pl. 119, figs. 1-9, 12-15; pl. 123, figs. 7, 8, 12; Higgins and Bouckaert, 1968, p. 40, pl. 2, fig. 14; pl. 4, figs. 5, 8, 9; pl. 5, fig. 11; Higgins, 1975, p. 55-56, pl. 16, figs. 1-7, 9-14; pl. 15, figs. 11, 16; pl. 14, figs. 4-6.

Cavusgnathus _sinuata_ (Harris and Hollingsworth). Ellison and Graves, 1941, pl. 3, figs. 1, 5, 7.

Gnathodus _opimus_ Igo and Koike, 1964, p. 189, pl. 28, fig. 18; Webster, 1969, p. 33, pl. 5, figs. 20, 21.

Idiognathoides _sinuatus_ Harris and Hollingsworth. Dunn, 1970a, p. 335, pl. 63, figs. 14, 15, 22, 23; Lane and Straka, 1974, p. 88, fig. 37: 18, 23-26; fig. 41:

20-27; Bender, 1980, p. 13, pl. 1, figs. 17, 19, 21, 22, 26-28, 31; Landing and Wardlaw, 1981, p. 1262-1263, pl. 2, figs. 8-14.

Dextral Platform Elements

(Pl. 3, Figs. 5, 24)

Polygnathodella ouachitensis Harlton, 1933, p. 15, pl. 4, figs. 14a-c; Ellison and Graves, 1941, p. 10, pl. 3, figs. 8, 9; Wirth, 1967, p. 233, pl. 20, figs. 12, 14.

Idiognathoides attenuata Harris and Hollingsworth, 1933, p. 203-204, pl. 1, figs. 9a, 9b.

Idiognathodus corrugata Harris and Hollingsworth, 1933, p. 203-204, pl. 1, figs. 7-8b.

Polygnathodella convexa Ellison and Graves, 1941, p. 9, pl. 3, fig. 12.

Polygnathodella attenuata (Harris and Hollingsworth). Ellison and Graves, 1941, p. 8-9, pl. 3, figs. 11, 13.

Polygnathodella spp. Clarke, 1960, p. 28-29, pl. 5, figs. 11, 16.

Polygnathodella tenuis Clarke, 1960, p. 28, pl. 5, figs. 12, 13.

Idiognathoides corrugata (Harris and Hollingsworth). Lane, 1967, p. 939, pl. 122, figs. 1, 2, 4-7, 9-11; Higgins and Bouckaert, 1968, p. 39, pl. 5, fig. 9; Higgins, 1975, p. 48-49, pl. 15, figs. 2-9.

Idiognathoides corrugatus (Harris and Hollingsworth). Dunn, 1970a, p. 335, pl. 63, figs. 16, 18, 25.

<u>Idiognathoides</u> <u>sinuatus</u> (Harris and Hollingsworth).

Lane and Straka, 1974, p. 88, fig. 37: 14, 15, 20, 36; fig. 41: 1-14; Bender, 1980, p. 13, pl. 1, figs. 18, 20, 23-25, 29, 30, 32, 33; Landing and Wardlaw, 1981, p. 1262-1263, pl. 2, figs. 15-21.

<u>Idiognathoides</u> <u>attenuatus</u> (Harris and Hollingsworth).

Higgins, 1975, p. 48, pl. 15, fig. 1.

Diagnosis

This species displays Class IIIb symmetry.
<u>Sinistral Platform Elements</u>: The blade attaches to the left margin and a medial longitudnal trough of variable length is developed on the oral surface of the platform. No carina is present and the left (outer) margin of the transversely ridged platform is noticeably raised above the right margin.
<u>Dextral Platform Elements</u>: The free blade attaches to the right margin of the transversely ridged platform whose inner and outer margins are of equal height. A short, median longitudnal trough is developed within the anterior third of the platform and no carina is developed (modified from Lane and Straka, 1974).

Description

For descriptions, refer to Lane (1967, p. 939 for dextral element; p. 937 for sinistral element). Further description is provided by Lane and Straka (1974, p. 89, see remarks) and Landing and Wardlaw (1981, p. 1263).

Remarks

The author agrees with Lane and Straka's (1974, p. 89) remarks concerning the synonomy of *Idiognathoides sinuatus* and *I. corrugatus*. Subequal numbers of sinistral and dextral elements were recovered. For further remarks, refer to Lane and Straka (1974, p. 89).

Range

This element-pair has been reported to range from lowermost Morrowan through Atokan. In this study, this species ranges from upper Morrowan through lower Derryan.

Material

Lefts: 23; Rights: 28.

Figured Specimens

NMBMMR-LW-0043, -0058, -0059.

Idiognathoides cf. *I. sulcatus* Higgins and Bouckaert, 1968
(Pl. 3, Fig. 21)

Gnathodus opimus Igo and Koike, 1964, p. 189, pl. 28, figs. 15-17; Igo and Koike, 1965, p. 89, pl. 9, figs. 1-4; Webster, 1969, p. 33, pl. 5, fig. 20.

Idiognathoides aff. *I. nodulifera* (Ellison and Graves). Lane, 1967, p. 938, pl. 123, fig. 16.

Idiognathoides sp. A. Lane, 1967, p. 938, pl. 123, figs.

14, 15, 18, 19.

Idiognathoides sulcata Higgins and Bouckaert, 1968, p. 41, pl. 4, figs. 6, 7; pl. 6, figs. 1-6.

Idiognathoides opimus (Igo and Koike). Dunn, 1970a, p. 335, pl. 63, figs. 24, 28.

Idiognathoides sulcatus Higgins and Bouckaert. Straka and Lane, 1970, p. 42, fig. 1A; Lane and Straka, 1974, p. 90, fig. 36: 1-16, 18-20, 23, 24; fig. 39: 1-10.

Diagnosis

This species displays Class II symmetry. The margins are nearly equal in height and may be unornamented, transversely ridged, or nodose. A medial trough extends to the posterior tip of the platform. The gnathodid-type basal cavity is elliptical in outline (modified from Lane and Straka, 1974). In addition, Lane and Straka (1974) make the following observations:

> _Idiognathoides sulcatus_ is distinguished from _I. noduliferus_ [_Declinognathodus noduliferus_ herein] by the absence of a node on the outer anterior margin and from _Idiognathoides sinuatus_, by the absence of incomplete development of transverse-ridged ornamentation on the platform.

Remarks

Previously designated subspecies, _I. sulcatus sulcatus_ and _I. sulcatus parvus_, could not be distinguished in the few specimens recovered in this study.

Range

This species is restricted to a narrow zone in the lower Morrowan in this study; however, its overall range has been reported from lower Morrowan through upper Morrowan.

Material

Lefts: 2; Rights: 3.

Figured Specimens

NMBMMR-LW-0056.

Genus Neognathodus Dunn, 1970a

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

Diagnosis

From Lane and Straka (1974, p. 93):

> In upper view, the carina extends to or near the posterior tip. The long free blade meets the platform centrally or subcentrally. The outer margin of the platform may be reduced or absent. Deep adcarinal grooves are developed. In lower view, a large, deep, asymmetrical basal cavity is present at the posterior end of the platform.
>
> ...The deep adcarinal grooves distinguish early forms of Neognathodus from Gnathodus and give Neognathodus a polygnathid appearance in upper view. Furthermore, the carina in Gnathodus extends to the posterior tip of the platform; whereas is some representatives of Neognathodus the carina may end just before reaching the posterior tip.

Neognathodus is distinguished from Idiognathoides by the juncture of its blade in a medial position and its subsequent continuation on the platform as a median carina. This platform genus exhibits Class II symmetry.

Range

Lower Morrowan through Desmoinesian.

Neognathodus bassleri (Harris and Hollingsworth, 1933)
(Pl. 3, Fig. 26)

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

Gnathodus bassleri bassleri (Harris and Hollingsworth). Lane, 1967, p. 935, pl. 120, figs. 1, 3-5, 9-12, 15; pl. 123, figs. 1-6; Lane and Straka in Lane et al., 1971, pl. 1, figs. 9, 10.

Neognathodus bassleri (Harris and Hollingsworth). Dunn, 1970a, p. 336, pl. 64, figs. 1, 13; Higgins, 1975, p. 64, pl. 12, figs. 8, 10, 11; pl. 17, figs. 12, 15; Sweet in Ziegler, 1975, p. 197-200, Neognathodus pl. 1, figs. 3a-b.

Neognathodus bassleri bassleri (Harris and Hollingsworth). Merrill and King, 1971, p. 659, pl. 76, figs. 11, 12; Lane and Straka, 1974, p. 95, fig. 37: 16, 17, 19; fig. 42: 17-24. For further synonomy see Sweet in Ziegler (1975, p. 198).

Diagnosis

Lane (1967) gives the following diagnosis:

> In upper view, the nominate subspecies [*Neognathodus bassleri* herein] is distinctly asymmetrical. The blade-carina is positioned close to and parallel with the straight outer margin. The outer margin is approximately equal in height to the carina. In contrast, the inner margin is elevated appreciably above the carina and forms a broad asymmetrical arc from the posterior tip to the point of attachment of the free blade. Both margins of the platform are ornamented with robust [and wedge shaped] transverse ridges which continue to the bottom of the troughs.

The strongly flared inner margin and the closer proximity of the carina to the outer margin of *Neognathodus bassleri* serves to distinguish this species from *N. symmetricus*. *N. bassleri* differs from its proposed descendant *N. bothrops* Merrill by the lack of fusion between its nodose margins and the posterior end of the carina.

Description

The original description can be found in Sweet *in* Ziegler (1975, p. 197).

Remarks

According to Merrill (1972, p. 819), *Neognathodus bassleri* undergoes the evolutionary symmetry-morphological-transition series: *N. bassleri* to *N. bothrops* to *N. medadultimus* to *N. medexultimus* to *N. roundyi* to *N. dilatus*. This evolutionary trend involves progressive reduction of the outer parapet and the gradual loss, with time, of the trough between the outer parapet and the carina. Merrill (1972) indicates that occurrences of these species are time sensitive and thus their presence may be very useful to conodont zonation of the Morrowan through the Desmoinesian.

It must be noted that Merrill (1972) used the aforementioned species of Neognathodus in an acme zonation in the Appalachians. While acme zonations may be very valuable for local biostratigraphic correlation, they are not considered to be useful for interregional correlations, the relative numbers of individuals may be controlled by provinciality, or environmental preference. Of the above species, N. bassleri, N. medadultimus, and N. cf. N. medexultimus (one specimen) are present in the biostratigraphic section of this study.

Neognathodus bassleri is considered to be a direct descendant of N. symmetricus. According to Lane and Straka (1974), "Specimens of N. symmetricus that morphologically approach but do not duplicate N. bassleri have been found within the range of the former." No specimens of N. symmetricus apparently have been found within the range of N. bassleri.

The fact that the ranges of N. bassleri and N. symmetricus are not known to overlap in any previous study, or this one, normally constitutes one of the most distinctive, widely occurring biostratigraphic subdivisions in the Morrowan (Lane and Straka, 1974). In this study, however, a wide stratigraphic gap exists between the highest occurrence of N. symmetricus and the lowest occurrence of N. bassleri.

Exhaustive samples were processed in this "Neognathodus-barren" interval with no success. Conodont recovery in this interval was generally poor, therefore, the depositional environment may not have been suitable for these species of Neognathodus.

Range

This species was only recovered from lower Derryan strata in this study. Previous authors have recorded Morrowan, Derryan (or Atokan) and Desmoinesian occurrences of this species (Sweet in Ziegler,1975, p. 198).

Material

Lefts: 6; Rights: 9; 1 with indeterminate curvature.

Figured Specimens

NMBMMR-LW-0060.

Neognathodus medadultimus Merrill, 1972

(Pl. 3, Figs. 12, 13, 20)

Gnathodus roundyi Gunnell (part). Murray and Chronic, 1965, p. 598, pl. 71, figs. 1 and 2 only.

Streptognathodus columbiensis Stibane, 1967, p. 336, taf. 36, figs. 3-5 only.

Neognathodus n. sp. B Merrill and King, 1971, p. 660.

Neognathodus *medadultimus* Merrill, 1972, p. 824, pl. 1, figs. 2-7; pl. 2, fig. 19; Merrill, 1974, pl. 1, figs. 2-4, 10; pl. 2, fig. 31; Sweet *in* Ziegler, 1975, p. 207, *Neognathodus* pl. 1, fig. 2.

Diagnosis

The most distinguishing characteristic of this species is the junction of the carina and the outer parapet with the concurrent loss of the trough between them. This juncture occurs within the posterior half of the platform. Posterior of this junction, the degree of fusion of the nodes of the carina with those of the outer parapet is variable (see remarks of Merrill, 1972, p. 824-825).

Neognathodus *medadultimus* differs from *N.* *bothrops* that the carina-outer parapet junction occurs within the posterior half of the platform, but anterior of its terminus. The carina and both parapets meet at the posterior terminus in *N.* *bothrops*. *N.* *medadultimus* can be distinguished from its proposed descendant *N.* *medexultimus* in that the carina-outer parapet junction occurs at the halfway point or in the anterior half of the platform of the latter. See remarks on *N.* *bassleri* for further comments.

Description

See Sweet *in* Ziegler (1975, p. 207) for complete description.

Remarks

According to Merrill (1972), *Neognathodus medadultimus* is the descendant of *N. bothrops* and the predecessor of *N. medexultimus*. See remarks concerning *N. bassleri* (this report) for further comments.

Range

The specimens in this study were recovered from lower Derryan strata. A ?Morrowan, Atokan through Desmoinesian range has been reported for *Neognathodus medadultimus*.

Material

Lefts: 8; Rights: 2.

Figured Specimens

NMBMMR-LW-0049, -0050, -0055.

Neognathodus cf. *N. medexultimus* Merrill, 1972
(Pl. 3, Fig. 1)

Neognathodus n. sp. C Merrill and King, 1971, p. 660, pl. 76, figs. 4, 5.

Gnathodus n. sp. C Merrill *in* Lane et al., 1971, p. 409, pl. 1, fig. 22.

Neognathodus medexultimus Merrill, 1972, p. 825, pl. 1, fig. 1; pl. 2, figs. 20-26; Merrill, 1974, pl. 1, fig. 1; pl. 2, fig. 32; Sweet *in* Ziegler, 1975, p. 209-210, *Neognathodus* pl. 1, fig. 1; Bender, 1980, p. 14, pl. 3, figs. 1-3, 12, 13, 32.

Diagnosis

Merrill (1972) notes the following distinguishing characteristics:

> The fusion of the outer nodose row and the carina is more anteriorly located in this species than in Neognathodus medadultimus. The degree of fusion is somewhat variable, but the nodose row and carina become progressively more tightly fused posteriorly. For the anterior portion, where the carina and row approach each other, the same remarks apply as for Neognathodus medadultimus [see Merrill, 1972, p. 824-825].

Description

For description, see original reference (Merrill, 1972, p. 825).

Remarks

Only one specimen was recovered. This specimen, although not well preserved, closely resembles specimens of N. medadultimus of Merrill (1972).

Range

Merrill (1972) noted the lowest appearance of this species in the Atokan of the Appalachians, however, it apparently is not common until the Desmoinesian. The specimen recovered in this study was from the uppermost sample (NWP-169.3) which is upper Derryan in age.

Material

Left: 1.

Figured Specimen

NMBMMR-LW-0039.

Neognathodus symmetricus (Lane, 1967)

(Pl. 3, Figs. 6, 22)

Gnathodus wapanuckensis (Harlton). Ellison and Graves, 1941, pl. 2, figs. 13-17.

Gnathodus bassleri symmetricus Lane, 1967, p. 935, pl. 120, figs. 2, 13, 14, 17; pl. 121, figs. 6, 9; Lane and Straka in Lane et al., 1971, pl. 1, figs. 7, 8.

Neognathodus bassleri (Harris and Hollingsworth). Dunn, 1970a, p. 336, pl. 64, fig. 12.

Neognathodus bassleri symmetricus (Lane, 1967). Lane and Straka, 1974, p. 96, fig. 37: 22, 31, 32, 37-39; fig. 39: 16-18, 21-24.

Neognathodus symmetricus (Lane, 1967). Sweet in Ziegler, 1975, p. 213, Neognathodus pl. 1, fig. 9.

Diagnosis

The original diagnosis is as follows (Lane, 1967):

> Gnathodus bassleri symmetricus [Neognathodus symmetricus herein] is almost symmetrical in upper view. Both the inner and outer margins generally parallel the carina. The inner side, however, may be slightly arcuate and elevated above the carina; the carina is generally centered between the margins. The margins may be ornamented with nodes

and/or transverse ridges which extend to the bottom of the troughs.

Neognathodus symmetricus differs from *N. bassleri* by being more symmetrical, having the carina centered between the margins, and by possessing a slightly deeper basal cavity. In addition, the margins of *N. symmetricus* may be ornamented with nodes and/or transverse ridges, while the margins of *N. bassleri* always display only transverse ridges. *Neognathodus symmetricus* is considered the precursor of *N. bassleri* (modified from Lane, 1967).

Description

See Lane (1967, p. 935) for original description.

Remarks

Specimens of *Neognathodus symmetricus* were recovered from only two samples. The ranges of *N. bassleri* and *N. symmetricus* do not overlap in this study; in fact the lowest appearance of *N. bassleri* is somewhat stratigraphically above the highest occurrence of *N. symmetricus*. See remarks for *N. bassleri* for further discussion.

Range

This narrow ranging species has only been reported from middle Morrowan strata; thus, the specimens recovered herein are considered to represent the middle Morrowan of the Horquilla Limestone in southwestern New Mexico.

Material

Lefts: 18; Rights: 16.

Figured Specimens

NMBMMR-LW-0044, -0057.

Genus *Rachistognathus* Dunn, 1966

Type species: *Rachistognathus primus* Dunn, 1966, p. 1301, pl. 157, figs. la-lc.

Diagnosis

The members of this genus display Class IIIa symmetry.

Description

For original description, see Dunn (1966, p. 1301).

Remarks

It should be noted that in Dunn's (1966) original designation and description of *Rachistognathus*, he indicates that members of this genus lack a medial trough (characteristic of the cavusgnathids), thus in part, distinguishing them from *Cavusgnathus*. Later when he synonomized *Cavusgnathus transitoria* Dunn and established *Rachistognathus transitorius*, as well as when he established *Rachistognathus muricatus* by synonomizing *Cavusgnathus* *muricata* Dunn, *Idiognathoides minuta* Higgins and Bouckaert, and *Gnathodus muricatus* (Dunn), he now included forms within *Rachistognathus* which possessed medial troughs (Dunn, 1970a, p. 338-339). This is contradictory with his original description of *Rachistognathus*.

It is clear that *Rachistognathus muricatus* and *R. primus* belong in the same genus. *R. primus* (as herein described) meets all of the requirements of the original description of the genus *Rachistognathus*. *R. muricatus* does not meet all of these requirements because the original description of the genus *Rachistognathus* Dunn, 1966 excludes members possessing a medial trough. Therefore, it is herein recommended that the original description of the genus *Rachistognathus* be amended appropriately to include these "troughed members". The author agrees with Lane and Straka's (1974, p. 97) provisional treatment of this genus.

Range

Rachistognathid forms are restricted to the lowermost Pennsylvanian *Rachistognathus primus* Zone of the Horquilla Limestone in this study. Lane and Straka (1974, p. 97) report members of *Rachistognathus* range from their uppermost Mississippian *Rachistognathus muricatus* Zone to at least the top of their *Neognathodus bassleri bassleri* Zone in southern Nevada. This apparently represents the widest range reported for this genus in the United States.

Rachistognathus muricatus (Dunn, 1965)

(Pl. 3, Figs. 2, 15)

Cavusgnathus muricata Dunn, 1965, p. 1147, pl. 140, figs. 1a-c, 4.

Cavusgnathus transitoria Dunn, 1966, p. 1299, pl. 157, figs. 9, 13.

?Gnathodus muricatus (Dunn). Webster, 1969, p. 32, pl. 5, figs. 1, 2, 4-7 (non fig. 3 = R. primus).

Rachistognathus muricatus (Dunn). Dunn, 1970a, p. 338, pl. 61, figs. 5-7; Lane and Straka, 1974, p. 97, fig. 35: 16, 17, 19, 23, 24, 28-31, 35, 37.

Rachistognathus transitorius (Dunn). Dunn, 1970a, p. 339, pl. 61, fig. 14.

Spathognathodus muricatus (Dunn). Lane and Straka in Lane et al., 1971, pl. 1, fig. 1.

Diagnosis

Lane and Straka (1974, p. 97) give the following diagnosis of this species:

> This form-species displays Class IIIa symmetry. The blade is always attached to the left margin of the platform and (based on curvature) both lefts and rights are present. The platform is flanked by two parallel rows of circular to slightly oval nodes; this produces a slit-like trough and usually continues to the posterior end of the platform. In some specimens, the left row of nodes ends about two-thirds of the way posteriorly, and an offset, but centrally located row of nodes continues to the posterior end of the platform.

Rachistognathus muricatus can be distinguished from

R. primus by the presence of a trough, however, this trough may be discontinuous and hard to discern. In addition, the oral platform surface of R. primus appears essentially flat with its "outwardly radiating" nodes perched upon this flat surface. For further comments, refer to the "Remarks" for the genus Rachistognathus, the "Remarks" for R. primus in this paper, and the "Remarks" for R. primus in Lane and Straka (1974, p. 99).

Description

The original description is given by Dunn (1965, p. 1147).

Remarks

Rachistognathus transitorius (Dunn) was proposed by Dunn (1970a, p. 339) as a transitional species between R. primus and R. muricatus. Extensive study of the Rachistognathus specimens recovered in this study, as well as those illustrated by other authors reveals that there is a total intergradation of forms between the R. muricatus and R. primus end-members and naming of a separate species for one of these gradational forms seems futile.

Rachistognathus transitorius (Dunn) is herein placed in synonomy with R. muricatus rather than R. primus (as in Lane and Straka, 1974, p. 98-100), because its description (Dunn, 1966, p. 1299) more closely resembles that of R. muricatus (Dunn, 1965, p. 1147-1148), especially its possession of a median longitudnal trough, and sharp, discreet nodes on the parapets.

Rachistognathus muricatus was only recovered from one sample in this study. It is found in association with R. primus and transitional forms (transitional between R. primus and R. muricatus).

Range

This species is restricted to the lowermost Morrowan in this report. Previous authors note the range of this species from uppermost Mississippian to middle Morrowan.

Material

Lefts: 2; plus 2 left-sided individuals with indeterminate curvature. All specimens are left-sided.

Figured Specimens

NMBMMR-LW-0040, -0051.

Rachistognathus primus Dunn, 1966
(Pl. 3, Figs. 7, 8, 9, 14, 17)

Rachistognathus prima Dunn, 1966, p. 1301, pl. 157, figs. 1, 2.

?Gnathodus muricatus (Dunn). Webster, 1969, p. 32, pl. 5, fig. 3 (non figs. 1, 2, 4-7 = R. muricatus).

Rachistognathus primus Dunn. Dunn, 1970a, p. 338, pl.

63, figs. 26, 27; Lane and Straka, 1974, p. 98, fig. 35: 18, 20-22, 25-27, 32-34, 36, 38, 39, ?40; fig. 44: ?6.

Spathognathodus muricatus (Dunn). Lane and Straka in Lane et al., 1971, pl. 1, fig. 2.

Diagnosis

Lane and Straka's (1974, 98-99) diagnosis of this species is given below:

> This form-species displays Class IIIa symmetry. The conodont elements are all left-sided with respect to blade attachment. A nodose carina is strongly developed in the posterior part of the trough [platform] and either dies out as a series of nodes alongside the posterior end of the blade or is continuous with the blade as a ridge. The upper surface is characterized by development of irregular sized and shaped nodes or ridges along the margins, or both.
>
> A characteristic, nondenticulated straight profile is developed in the upper outline of the blade, posterior to the blade-platform junction and extends posteriorly one-quarter to one-third the length of the platform.

Rachistognathus primus can be distinguished from R. muricatus by the lack of a median oral trough and by the outward radiating pattern of its nodules aligned on the parapets.

Description

See Dunn (1966, p. 1301) for original description.

Remarks

This species was recovered from only two samples

(NWP-33.2 and NWP-37.1). Previous authors that have worked with this species have indicated that R. primus is always found in mutual occurrence with R. muricatus and that the latter species appears before, and ranges into younger strata than R. primus.

Range

Previous workers have indicated a short, exclusively lowermost Morrowan occurrence of this species, therefore, the specimens of Rachistognathus primus recovered in this study are interpreted to represent early Morrowan age.

Material

Lefts: 5; Rights: 3; 2 left-sided individuals with indeterminate curvature. All specimens are left-sided.

Figured Specimens

NMBMMR-LW-0045, -0046, -0046.

PLATES

PLATE 1

All Figures are X 40

Figures: 1--Idiognathodus delicatus (Gunnell). Juvenile: oral view, left element, NMBMMR-LW-0001.

2-6--Idiognathodus delicatus (Gunnell). Morphotype 1: 2, oral view, right element, NMBMMR-LW-0002; 3, oral view, right element, NMBMMR-LW-0003; 4, oral view, left element, NMBMMR-LW-0004; 5, oral view, left element, NMBMMR-LW-0005; 6, oral view, right element, NMBMMR-LW-0006.

7-11--Idiognathodus delicatus (Gunnell). Morphotype 2: 7, oral view, right element, NMBMMR-LW-0007; 8, oral view, left element, NMBMMR-LW-0008; 9, oral view, right element, NMBMMR-LW-0009; 10, oral view, left element, NMBMMR-LW-0010; 11, oral view, right element, NMBMMR-LW-0011.

12-15--Idiognathodus delicatus (Gunnell). Morphotype 3: 12, oral view, right element, NMBMMR-LW-0012; 13, oral view, right element, NMBMMR-LW-0013; 14, oral view, left element, NMBMMR-LW-0014; 15, oral view, left element, NMBMMR-LW-0015.

16-20--Idiognathodus delicatus (Gunnell). Morphotype 4: 16, oral view, right element, NMBMMR-LW-0016; 17, oral view, left element, NMBMMR-LW-0017; 18, oral view, left element, NMBMMR-LW-0018; 19, oral view, left element, NMBMMR-LW-0019; 20, oral view, right element, NMBMMR-LW-0020.

21-23--*Idiognathodus delicatus* (Gunnell). Morphotype 5: 21, 23, oral and aboral views, right element, NMBMMR-LW-0021; 22, oral view, right element, NMBMMR-LW-0022.

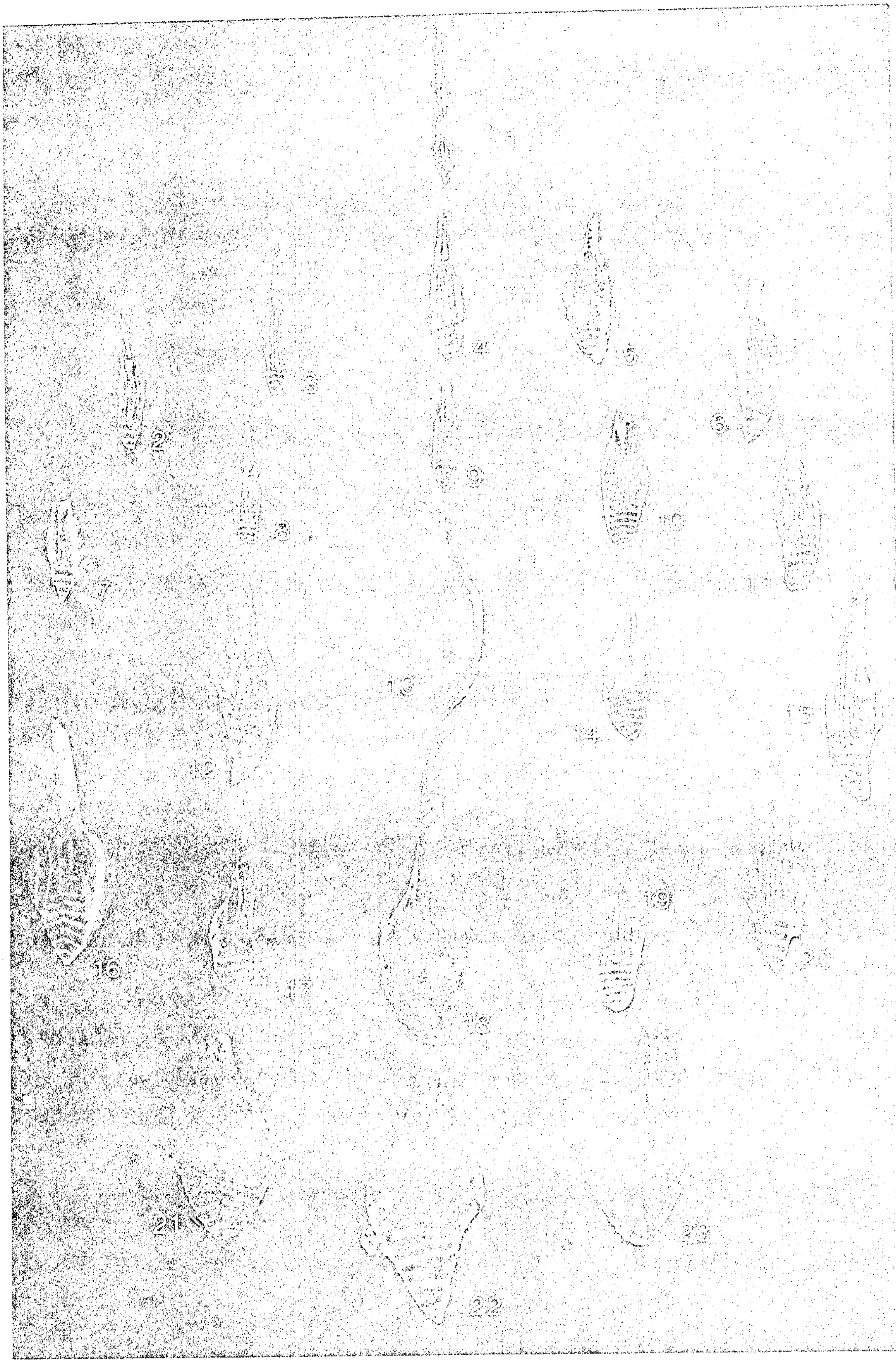

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PLATE 2

All Figures are X 40

Figures: 1, 7, 8, 12, 13, 15, 17, 18--Adetognathus lautus (Gunnell). 1, oral view, sinistral element, NMBMMR-LW-0023; 7, 17, oral and aboral views, sinistral element, NMBMMR-LW-0028; 8, oral view, dextral element, NMBMMR-LW-0029; 12, oral view, dextral element, NMBMMR-LW-0032; 13, oral view, dextral element, NMBMMR-LW-0033; 15, outerlateral view, sinistral element, NMBMMR-LW-0035; 18, oral view, sinistral element, NMBMMR-LW-0037.

2, 3--Diplognathodus cf. D. coloradoensis (Murray and Chronic). Oral and lateral views, NMBMMR-LW-0024.

4, 9--Gnathodus bilineatus (Roundy). 4, Beta morphotype, oral view, right element (broken platform), NMBMMR-LW-0025; 9, Gamma morphotype, oral view, right element, NMBMMR-LW-0030.

5--Cavusgnathus cf. C. unicornis Youngquist and Miller. Oral view, right element (broken platform), NMBMMR-LW-0026.

6, 11--Adetognathus unicornis (Rexroad and Burton). Oral and outerlateral views, right element (broken platform), NMBMMR-LW-0027.

10, 21--Cavusgnathus cf. C. naviculus (Hinde). 10, oral view (broken platform), NMBMMR-LW-0031; 21, oral view (broken platform), NMBMMR-LW-0038.

14, 16, 19, 20--*Adetognathus inflexus* Dunn. 14, 19, oral and aboral views, right element, NMBMMR-LW-0034; 16, 20, outerlateral and oral views, right element, NMBMMR-LW-0036.

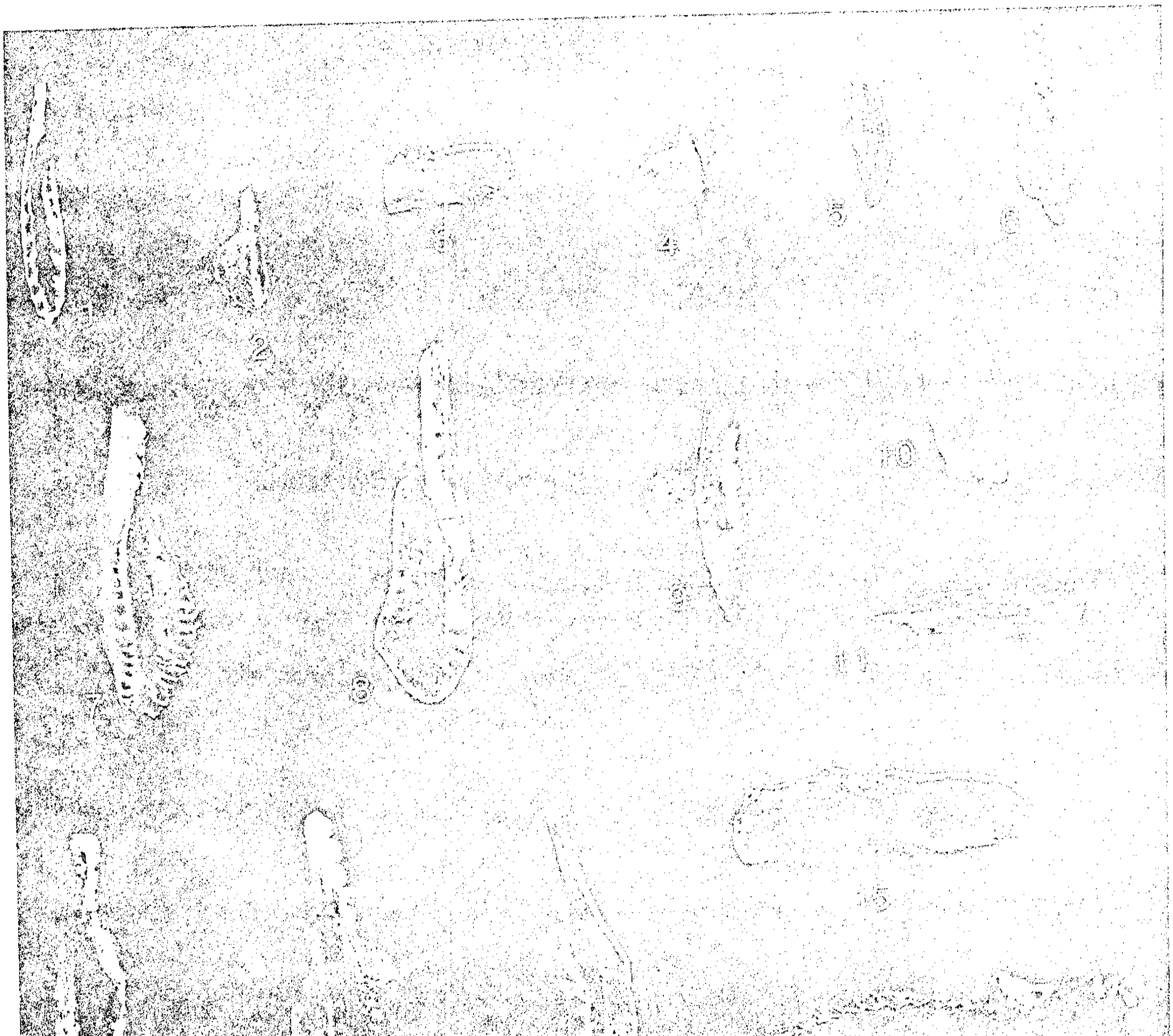


PLATE 3

All Figures are X 40

Figures: 1--Neognathodus cf. N. medexultimus Merrill. Oral view, left element (broken specimen), NMBMMR-LW-0039.

2, 15--Rachistognathus muricatus (Dunn). 2, oral view (broken platform), NMBMMR-LW-0040; 15, innerlateral view, left element, NMBMMR-LW-0051.

3, 10, 11, 18, 25--Declinognathodus noduliferus (Ellison and Graves). 3, 11, oral and innerlateral views, right element, NMBMMR-LW-0041; 10, oral view, right element, NMBMMR-LW-0048; 18, 25, oral and aboral views, left element, NMBMMR-LW-0053.

4, 27, 29--Hindeodus minutus (Ellison). 4, 29, oral and outerlateral views, right element, NMBMMR-LW-0042; 27, outerlateral view, left element, NMBMMR-LW-0061.

5, 23, 24, 28--Idiognathoides sinuatus Harris and Hollingsworth. 5, oral view, dextral element, NMBMMR-LW-0043; 23, 28, oral and innerlateral views, sinistral element, NMBMMR-LW-0058; 24, oral view, dextral element, NMBMMR-LW-0059.

6, 22--Neognathodus symmetricus (Lane). 6, oral view, left element, NMBMMR-LW-0044; 22, oral view, right element, NMBMMR-LW-0057.

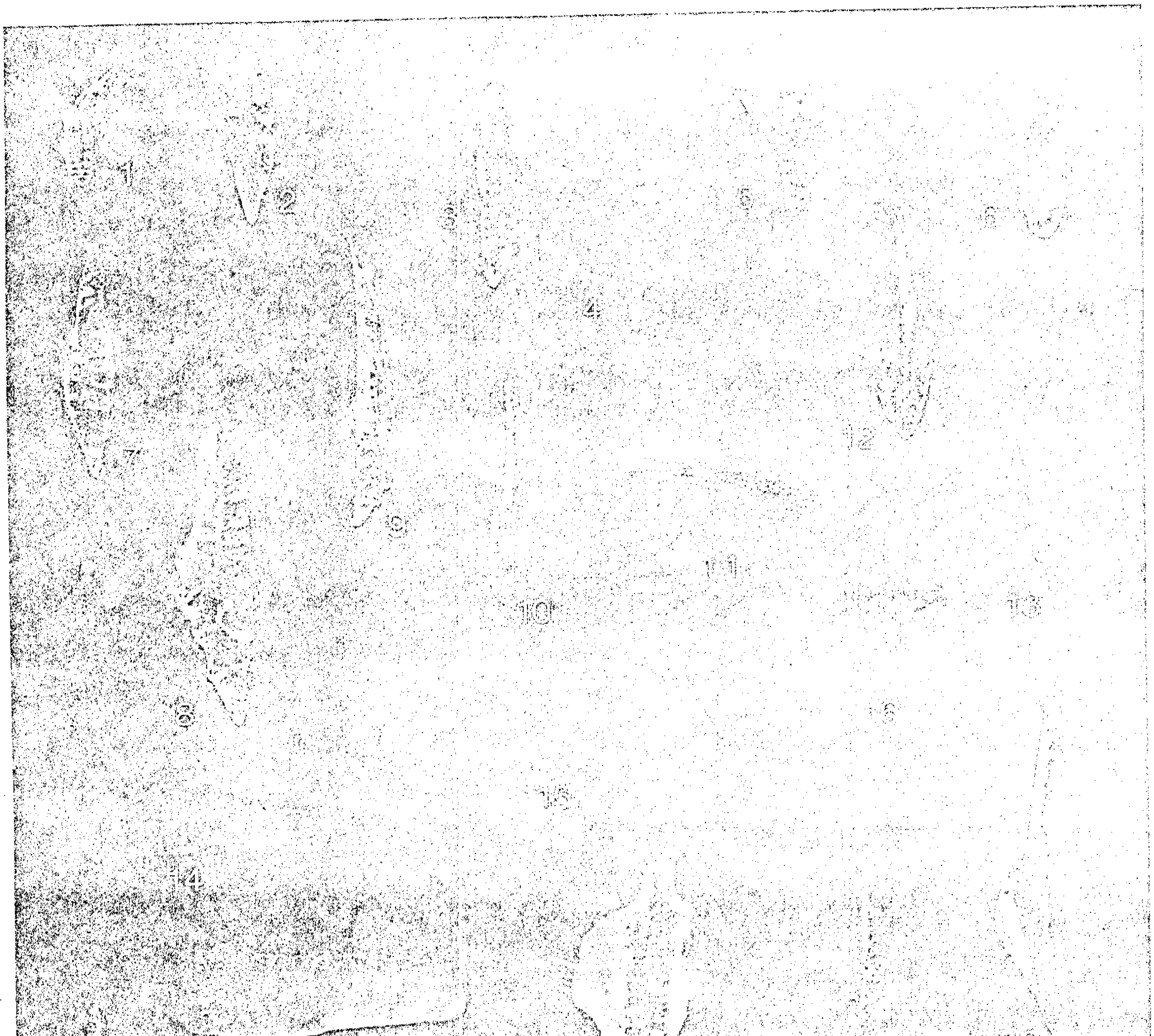
7-9, 14, 17--*Rachistognathus primus* Dunn. 7, oral view, left element, NMBMMR-LW-0045; 8, 17, oral and outerlateral views, left element, NMBMMR-LW-0046; 9, 14, oral and innerlateral views, right element, NMBMMR-LW-0047.

12, 13, 20--*Neognathodus medadultimus* Merrill. 12, oral view, right element, NMBMMR-LW-0049; 13, oral view, left element, NMBMMR-LW-0050; 20, oral view, left element, NMBMMR-LW-0055.

16, 19--*Gnathodus commutatus commutatus* (Branson and Mehl). 16, outerlateral view, right element, NMBMMR-LW-0052; 19, oral view, right element, NMBMMR-LW-0054.

21--*Idiognathoides* cf. *I. sulcatus* Higgins and Bouckaert. Oral view, left element, NMBMMR-LW-0056.

26--*Neognathodus bassleri* (Harris and Hollingsworth). Oral view, left element, NMBMMR-LW-0060.



APPENDICES

APPENDIX A

GLOSSARY OF TECHNICAL TERMS

APPENDIX A

GLOSSARY

Bed Thickness -

Term	Thickness
Fissile	< 2 mm (< 1/16")
Laminated	2 mm to 6 mm (1/16" to 1/4")
Platy	6 mm to 2.5 cm (1/4" to 1")
Very Thin	2.5 cm to 15 cm (1" to 6")
Thin	15 cm to 31 cm (6" to 1')
Medium	31 cm to 61 cm (1' to 2')
Thick	61 cm to 1.2 m (2' to 4')
Very Thick	1.2 m to 1.8 m (4' to 6')
Massive	> 1.8 m (>6')

Biotic Diversity - The number of different kinds of taxa at the same or different taxonomic levels.

Carbonate Mud - Classified in this report as all material less than 20 microns in size. Considered equivalent to its presumed post-depositional replacement--micrite.

Carboniferous - Mississippian and Pennsylvanian systems

Chesterian - Late Mississippian age

Coated Grain - A carbonate grain enclosed within a dark, concentric micritic layer (micrite envelope believed to represent micritic replacement of original organic matter of encrusting, or boring algae).

Cover - The degree to which the outcrop is covered with colluvium and vegetation.

Term	Amount of Cover
Little Cover	< 30 %
Partly Covered	30 % to 60 %
Mostly Covered	60 % to 90 %
Covered	> 90 %

Derryan - Early Pennsylvanian

Environmental Stability - Refers to the degree of fluctuation between near normal marine environmental conditions and restricted marine environmental conditions.

Eurytopic - Refers to organisms which can tolerate a wide range of salinities.

Fresh Surface - Fresh, dry, fractured surface of rock.

Gnathoidal - (or gnathodid-type) - Broad, flaring, conodont basal cavity typical of gnathodids, idiognathodids, and others.

Grapestone - [= aggregate, in part, of Lees (1975)] - Irregularly shaped clusters of two or more grains cemented by micrite or by algae forming a grape-like appearance (modified from Flugel, 1982).

Ius. - Abbreviation for the genus Idiognathodus.

Lachrymiform - Narrow, elongate, conodont basal cavity typical of adetognathids, cavusgnathids, and others.

Limestone Classification - (used in Appendix E) - A classification which combines the classifications of Folk (1962)--a classification based on dominant allochem grains, and Dunham (1962)--a classification based on depositional texture, in order to better and more easily define a carbonate rock type. Use of this classification enables the reader to better discern the predominant grain-types and depositional texture with the use of one word. Allochem modifiers [from Folk's (1962) classification) are used as prefixes to the textural rootwords derived from Dunham's (1962) classification. Modifiers may additionally be added (example: silty oograinstone). This classification is adopted from Thompson and Jacka (1981). See Thompson and Jacka (ibid.) for further explanation.

Matrix - Mechanically deposited intragranular and intergranular material. In rocks in which some grains are much larger than others, matrix is the fine-grained intergranular material in which the larger grains are imbedded.

Morrowan - early Pennsylvanian age

Mud - Considered equivalent to carbonate mud in this study.

Mudstone - Same as lime mudstone [Dunham's (1962) limestone rock classification] in this report.

Ooid - Small (< 2 mm), generally spherical to elliptical grains with a nucleus surrounded by concentric laminae and sometimes displaying radial structures (modified from Flugel, 1982). Internal structure may be obliterated during micritization.

Pellets - All grains classified as pellets in this investigation be small, organically bound primary sedimentary grains of fecal origin. Pellets are now composed predominantly of micrite (presumably originally carbonate mud), generally have uniform shape (rounded, ovoid, cylindrical, etc.), and exhibit no internal structure.

Peloids - Small (< 2 mm) aggregate grains of cryptocrystalline carbonate with no internal structure and possessing a variety of shapes.

Reniform Chert - Kidney-shaped chert nodules.

Rock color - Determined by comparison with the Standard GSA Chart of Goddard and others (1951).

Roundness - Based on visual estimation charts. Terms: angular, subangular, rounded, subrounded.

Running (or moving)Average - Process of averaging previous, current, and succeeding values for the purpose of smoothing curves.

Stenotopic - Refers to organisms which are tolerant of only a narrow range of salinity.

Topographic Expression - [Adopted from Thompson and Jacka, 1981]

Term	Vertical Projection Above Baseline
Slope	< 9 cm (< 4")
Slight Ledge	9 cm to 30 cm (4" to 1')
Moderate ledge	30 cm to 0.9 m (1' to 3')
Fairly Prominent Ledge	0.9 m to 3 m (3' to 10')
Prominent Ledge	3 m to 9 m (10' to 30')

Unknown Shelly Fragments - Based dominantly on shape, this term refers to unidentifiable shell-shaped grains which have been broken or diagenetically replaced beyond recognition.

APPENDIX B

FIELD DESCRIPTIONS (AND RESIDUE ANALYSIS) OF MEASURED SECTION

APPENDIX B

--near equivalence of units described herein, with those described by Zeller (1965) is indicated
--terms are defined in Appendix A

UNIT-INTERVAL	THICKNESS (METERS)	CUMULATIVE THICKNESS	FIELD DESCRIPTION AND RESIDUE ANALYSIS
27	Overlying Strata		Mudstone (lithographic). Slight ledges; little cover; light brownish gray (5 YR 6/1) weathers to light gray (N7); barren of fossil grains; thin bedded; = ZELLER Unit #22.
26	8.2	173.8	Packstone to wackestone. Slight ledges; little cover; medium gray (N5) weathers to light gray (N7); Crinozoans, bryozoans, forams, brachiopods (3 genera--including spiriferids), pelecypods, pellets, ostracodes; bedded chert (20%) through middle beds only; thin bedded; fossil content decreases upward; gradational contact with underlying unit.
25	3.6	165.6	Packstone (coated grain). Slight ledges; mostly covered; olive gray (5 Y 4/1) weathers to light gray (N7); algae(?) coated fossil grains, crinozoans, forams; medium bedded; vuggy porosity on weathered surface.
24	10.0	162.0	Wackestone to packstone. Moderate ledges; mostly covered; medium gray (N5) weathers to light brownish gray (5 YR 6/1); crinozoans, peloids, forams, pelecypods, brachiopods (2 genera), bryozoans, calcispheres; bedded chert (20%) in lowermost bed only; medium bedded; decreased fossil content near top; increased peloidal content upwards.
23	5.7	152.0	Wackestone. Moderate ledges; partly covered; medium gray (N5) weathers to medium light gray (N6); crinozoans, forams, brachiopods, silt (trace); reniform chert (<5%); very thick bedded to medium bedded upward; partially silicified.
22	4.0	146.3	Packstone to wackestone. Slight ledges; mostly covered; medium light gray (N6) weathers to light olive gray (5 Y 6/1); crinozoans, brachiopods (3 genera), bryozoans, trilobites, unknown molluscan shell fragments; reniform chert in upper half (5%); thin bedded unit characterized by grayish orange-pink laminations and lamellae which appear to "flow" around discrete limestone nodules; upper 1/3 exhibits wavy laminations; partially silicified.
21	10.1	142.3	Wackestone. Slight to moderate ledges, mostly covered; medium gray (N5) weathers to light brownish gray (5 YR 6/1); crinozoans, forams, pelecypods, peloids, bryozoans, ostracodes, brachiopods, calcispheres; sparse chert nodules; minor interbedded mudstone; burrowed (?); = ZELLER Unit #21 (in part).

APPENDIX B (continued)

UNIT-INTERVAL	THICKNESS (METERS)	CUMULATIVE THICKNESS	FIELD DESCRIPTION AND RESIDUE ANALYSIS
20	6.3	132.2	Packstone. Fairly prominent ledges/slope (upper); partly/ mostly (upper) covered; medium gray (N5) weathers to light brown gray (5 YR 6/1); crinozoans, brachiopods [three genera observed--including spiriferids (*Composita*), and strophomenids (*Derbyia*?)], spiriferids), forams, peloids, pelecypods, gastropods, ostracodes, horn corals, bryozoans, silt; brown, ovoid to elongate chert nodules; trace dolomite; thin bedding in upper and lower thirds, very thick bedded in middle 1/3; trace silicification; biotic abundance increases upwards.
19	4.5	125.9	Wackestone. Fairly prominent ledges; partly covered; medium gray (N5) weathers to light olive gray (5 Y 6/1); Chaetetes (25%), crinozoans, brachiopods (2 genera including *Composita*), bryozoans, forams; thick bedded; increase in fossil grains upward; large distinct Chaetetes heads (15cm); minor silicification; lower 1.2 meters matches description of ZELLER Unit #18.
18	2.5	121.4	Mudstone (dolomitized). Slight ledges; mostly covered; grayish red (5 R 5/2) weathers to pale red (10 R 6/2); crinozoans, brachiopods, bryozoans; thin bedded; fossil content decreases upward; diagenetic hematitic intergranular material; smooth weathered surface; = ZELLER Unit #17.
17-B	2.2	118.9	Wackestone. Slight ledges; mostly covered; dark gray (N3) weathers to medium light gray (N6); brachiopods (3 genera), crinozoans, trace bryozoans and trilobites; bedded and nodular chert (10%); thin bedded; similar to interval "A", but slightly dolomitic, fewer and smaller reddish blebs, and thinner bedded; = ZELLER Unit #16.
17-A	5.3	116.7	Mudstone (lithographic). Prominent ledges; medium dark gray (N4) weathers to light olive gray (5 Y 6/1); minor crinozoans, trace forams and brachiopods; reniform chert nodules (5%); massive beds; intergranular hematite (5%); minor silicification; = ZELLER Unit #15.
16	18.2	111.4	Wackestone. Moderate ledges; little cover; medium gray (N5) weathers to medium light gray; crinozoans; brachiopods (2 genera--including spiriferids), pellets, horn corals, bryozoans, forams, pelecypods, rare chert nodules; thick to medium bedded; trace silicification; lowest bed partially dolomitized; fossil content increases upward to middle of unit, then decreases; = ZELLER Unit #14.
15	2.0	93.2	Covered. Slope.

APPENDIX B (continued)

UNIT-INTERVAL	THICKNESS (METERS)	CUMULATIVE THICKNESS	FIELD DESCRIPTION AND RESIDUE ANALYSIS
14	4.1	91.2	Mudstone (bioturbated). Fairly prominent ledges; partly covered; medium gray (N5) weathers to medium gray (N5); calcispheres, peloids (pellets), crinozoans, brachiopods (2 genera); minor chert nodules in upper 1/3; thick bedded; fossil grains in upper 1/3 only; lower 1/3: light and medium gray mottled, bioturbated zone; middle 1/3; finely layered; upper 1/3: silicified vertical burrows.
13	2.5	87.1	Packstone. Fairly prominent ledge; little cover; dark gray (N3) weathers to light gray (N7); pellets, crinozoans, brachiopods (2 genera--chonetids, productids), gastropods, ostracodes, trilobites, silt; bedded chert in lower half, bedded and nodular chert upper half (10%); thick bedded; minor grain concentrations in layers.
12	3.7	84.6	Mudstone. Moderate ledges; partly covered; medium gray (N5) weathers to medium light gray (N6); calcispheres, trace brachiopods (two genera); medium to thick bedded; trace silicification.
11	5.2	80.9	Oolite to oolitic packstone. Prominent ledges; no cover; medium gray (N5) weathers to light olive gray (5 Y 6/1); ooids, brachiopods (four genera--including productids), crinozoans, forams, grapestone grains, solitary corals (trace); thick to medium bedded; trace silicification.
10	5.6	75.7	Mudstone. Fairly prominent ledges; little cover; medium dark gray (N4) weathers to medium gray (N5); crinozoans, peloids, ostracodes, trilobites, brachiopods; chert (35%), nodular (lower) to bedded (upper); very thick bedded; trace silicification.
9-D	1.7	70.1	Oolite. Slight ledges; mostly covered; medium dark gray (N4) weathers to light brown gray (5 YR 6/1); ooids, brachiopods, trace small colonial corals; thin bedded; mud content decreases upward.
9-C	3.4	68.4	Mudstone (locally oolitic). Slight ledges; partly covered; dark gray (N3) weathers to light brown gray (5 YR 6/1); ooids, brachiopods (four genera--including spiriferids (Composita), and chonetids), bryozoans, crinozoans, gastropods, forams; solitary corals; decreasing fossil content upwards; dominantly barren mudstone with local oolitic concentrations.
9-B	3.8	65.0	Wackestone. Moderate ledges; partly covered; medium dark gray (N4) weathers to light brown gray (5 YR 6/1); pelecypods, crinozoans, brachiopods, dominantly unbroken (two genera--including chonetids); trace colonial corals; bedded chert (10%); minor silicification; minor intergranular hematite; thick bedded; = ZELLER Unit #6.

APPENDIX B (continued)

UNIT-INTERVAL	THICKNESS (METERS)	CUMULATIVE THICKNESS	FIELD DESCRIPTION AND RESIDUE ANALYSIS
9-A	2.0	61.2	Mudstone. Moderate ledges; partly covered; medium gray (N5) weathers to light gray (N7); crinozoans, brachiopods, trace colonial corals; reddish brown reniform chert nodules (30%); medium bedded; = ZELLER Unit #5.
8-B	4.2	59.2	Mudstone to packstone. Fairly prominent ledges; partly covered; dark gray (N3) weathers to light brownish gray (5 YR 6/1); crinozoans, ooids, dominantly unbroken brachiopods (four genera--including chonetids, spiriferids), forams, gastropods; trilobites, trace encrusting and stick bryozoans; rare chert nodules; increasing fossil content upwards to topmost encrinite bed; trace silicification; = ZELLER Unit #4.
8-A	4.3	55.0	Mudstone (barren). Moderate ledges; mostly covered; dark gray (N3) weathers to light brownish gray (5 YR 6/1); ostracodes, brachiopods [four genera--including spiriferids (*Composita*), productids?, strophomenids (*Derbyia*?)], trace fenestrate bryozoans; thin to medium bedded; fossil grains concentrated in thin layers; relatively high clay content; = ZELLER Unit #3.
7-B	2.0	50.7	Oolite. Moderate ledges; mostly covered; medium gray (N5) weathers to medium light gray (N6); ooids, brachiopods, crinozoans; medium bedded.
7-A	5.5	48.7	Mudstone to packstone. Fairly prominent ledges; little cover; medium gray (N5) weathers to medium dark gray (N5); brachiopods (four genera--including *Composita*, chonetids), ooids, crinozoans, pelecypods, forams (lowest occurrence of fusulinids in the Horquilla Limestone), encrusting, fenestrate, and stick bryozoans, grapestone fragments, peloids, ostracodes, trace horn and colonial corals; local large chert nodules; trace silicification; medium bedded; increased fossil content upward; shell hash zone near top of interval exhibits cross-bedded and rippled shell hash; unbroken brachiopods (lower), broken (upper); increased ooids and shell hash upwards (therefore increased energy); thin light/dark banding in lower mudstone; = ZELLER Unit #2.
6-D	5.8	43.2	Mudstone (partially dolomitized). Moderate ledges; partly covered; Grayish red (10 R 4/2) near bottom to dark gray (N3) near top, weathers to moderate red (5 R 5/4)/light gray (N3); brachiopods, crinozoans, trace amounts of ooids, silt, trilobites, ostracodes, and bryozoans; thin bedded to very thick bedded near top of interval; minor silicification; clastic, fossil, and ooid content decreases upward (upper half of interval is barren mudstone).
6-C	2.3	37.4	Siltstone (calcareous). Slope; mostly covered; grayish red (5 R 4/2) weathers to brownish gray (5 YR 4/1); trace brachiopods, crinozoans and ooids; friable; fissile bedding; interbedded with thin beds of wackestone [with the following characteristics: crinozoans, brachiopods (two genera--including *Composita*), algae(?) coated fossil grains, silt, trace trilobites, "stick" bryozoans] near top; top marked by last silty layer.

APPENDIX B (continued)

UNIT-INTERVAL	THICKNESS (METERS)	CUMULATIVE THICKNESS	FIELD DESCRIPTION AND RESIDUE ANALYSIS
6-B	2.1	35.1	Wackestone. Fairly prominent ledges; little cover; medium dark gray (N4) weathers to medium light gray (N6); unbroken brachiopods [four genera--including chonetids, productids, and strophomenids (_Derbyia?_)], crinozoans, trace bryozoans; minor ovoid chert nodules; thick bedded; interbedded wackestones/mudstones.
6-A	1.3	33.0	Wackestone (burrowed). Moderate ledges; little cover; moderate reddish brown (10 R 4/6) weathers to dark reddish brown (10 R 3/4); algae(?) coated fossil grains, crinozoans, silt, brachiopods (two genera--including chonetids, productids), trace forams, ostracodes, bryozoans, trilobites, planispiral gastropods; medium bedded; partial silicification; medium dark gray limestone near top of interval, silty zone in middle, underlain by thin dark reddish brown calcareous shale just above unconformity; increasing lime content and decreasing red clastics upward; = ZELLER Unit #1.
HORQUILLA LIMESTONE (Pennsylvanian)			
/\U N C O N F O R M I T Y\/\/\/\/\/\/\/\/\/\/\/\/			
PARADISE FORMATION (Mississippian)			
5	4.5	31.7	Sandstone. Slope; partly covered; Dusky red (5 R 3/4) and light gray (N7) weathers to very dark red (5 R 2/6) and grayish black (N2); medium bedded; characteristic red and gray (oxidation--reduction zone) "zebra" pattern appearance; some unbroken brachiopods visible near top of unit; slight increased fossil content upwards to trace brachiopods, crinozoans, and ooids; silica intergranular cement; upper boundary bounded by a regional unconformity.
4-B	7.4	27.2	Wackestone (oolitic). Moderate ledges; little cover; medium dark gray (N4) with moderate reddish brown (10 R 4/6) streaks weathers to dark gray (N3) /dark reddish brown (10 R 3/4); ooids, crinozoans, bryozoans, brachiopods, intraclasts, trace forams, gastropods; medium bedded; minor silicification; thin colored banding; slight increasing biotic abundance upwards (from barren to rare fossil content.
4-A	2.0	19.8	Oolite. Moderate ledges; little cover; grayish red (5 R 4/2) weathers to pale yellow brown (10 YR 6/2); ooids, silt, trace crinozoans, brachiopods and bryozoans; medium bedded; local oolitic wackestone; minor hematite staining.
3-B (upper)	1.5	17.8	Mudstone (barren). Slope; little cover; dark reddish brown (10 R 3/4) weathers to moderate reddish brown (10 R 4/6); trace silt and ooids; thin bedded; much hematitic staining in matrix and in spherical bodies (of unknown origin).

APPENDIX B (continued)

UNIT-INTERVAL	THICKNESS (METERS)	CUMULATIVE THICKNESS	FIELD DESCRIPTION AND RESIDUE ANALYSIS
3-B (lower)	1.2	16.3	Wackestone (oolitic). Slight ledge; mostly covered; gray red (5 YR 4/2) weathers to pale red brown (10 R 5/4); ooids, silt, brachiopods (2 genera), crinozoans, trilobites, forams; thin bedded; minor silicification; minor hematitic staining in matrix and spherical bodies.
3-A	2.8	15.1	Covered. Probably siltstone; slope.
2-C	4.1	12.3	Oolite. Moderate to slight ledges upward; partly covered; brownish black (5 YR 2/1) weathers to grayish red (10 R 4/2); upper and lower halves of this interval yield different characteristics--Lower 1/2: abundant ooids and well sorted silt, brachiopods, crinozoans; intergranular hematite; platy, wavy, irregular bedding; exhibits mottled color pattern (light/dark) on wet surface; Upper 1/2: abundant ooids, minor very well sorted silt; medium bedded.
2-B	1.4	8.2	Covered. Slope.
2-A	2.8	6.8	Oolite. Slight ledge; partly covered; grayish red (10 R 4/2) weathers to pale yellowish brown (10 YR 6/2); ooids, silt, brachiopods, crinozoans, molluscan shell fragments; thin bedded; minor silicification; primary porosity (?) in horizontal, elongate forms now filled with hematitic stained blocky spar; increased carbonate mud content upwards; alternating resistant and non-resistant beds throughout unit 2.
1-D	2.3	4.0	Covered. Slope.
1-C	0.2	1.7	Shale (calcareous). Slope; mostly covered; dark reddish brown (10 R 3/4) weathers to grayish red (5 R 4/2), minor small intraclasts and silt, brachiopods and crinozoans; thin bedded.
1-B	0.5	1.5	Limestone breccia. Slight ledge; partly covered; dark reddish brown (10 R 3/4) weathers to moderate reddish brown (10 R 4/6); intraclasts, crinozoans, silt, ooids; laminated to thin bedded; clast supported with intraclasts of mainly light gray mudstone; flat intraclasts lie horizontal in bed; hematitic stained fine-grained fossiliferous matrix.
1-A	1.0	1.0	Mudstone to wackestone. Slight ledge; mostly covered; dark reddish brown (10 R 3/4) weathers to grayish red (10 R 4/2); silt, brachiopods (two genera--including chonetids), crinozoans, pelecypods, trilobites; thin bedded; moderate hematitic staining; trace dolomite; alternating thin beds of barren mudstone and silty wackestone with very thin red shale interbeds; trace dolomite.

APPENDIX C

POINT COUNT ANALYSIS

APPENDIX C

UNIT-INTERVAL SAMPLE (NWP-)	1-A 0.0	1-A 0.4	2-A 4.5	2-A 6.8	2-C 9.4	2-C 11.3	3-B 15.8
	Percentage of thin section						
Pelmatozoans:	0.6	11.5	0.5	----	1.2	----	2.3
Brachiopods (total):	----	2.4	0.3	0.2	----	----	11.0
Impunctate:	----	0.8	----	----	----	----	2.0
Pseudopunctate:	----	0.3	0.3	----	----	----	1.0
Punctate:	----	----	----	----	----	----	----
Bryozoans (total):	----	----	----	----	0.7	----	----
fenestrate:	----	----	----	----	0.7	----	----
digitate:	----	----	----	----	----	----	----
Molluscs (total):	----	1.8	0.3	----	0.2	----	0.3
Pelecypods:	----	0.5	----	----	0.2	----	----
Gastropods:	----	----	----	----	----	----	----
Foraminifers (total):	----	----	----	----	0.2	----	1.2
uniserial:	----	----	----	----	0.2	----	0.3
biserial:	----	----	----	----	----	----	0.3
miliolids:	----	----	----	----	----	----	0.3
fusulinids:	----	----	----	----	----	----	----
Ostracodes:	----	----	----	----	----	----	----
Trilobites:	----	0.5	----	----	0.2	----	0.3
Unidentified shelly:	----	----	0.3	0.2	----	----	5.0
Calcispheres:	----	----	----	----	----	----	----
Ooids:	----	----	47.8	57.8	38.8	40.3	11.2
Peloids (non-pelletal):	----	----	----	----	----	----	----
pellets:	----	----	----	----	----	----	----
Grapestones:	----	----	----	----	----	----	----
Coated grains:	----	----	----	----	----	----	----
Intraclasts:	----	----	----	----	----	----	----
Sand (very fine):	----	----	4.8	5.5	20.1	----	----
Silt:	13.7	3.9	----	----	----	6.9	2.3
Clay:	1.9	6.5	TR*	----	----	----	----
Opaques (total):	----	2.6	0.5	0.7	12.2	2.1	2.8
hematite:	----	----	----	0.7	12.2	2.1	2.8
black:	----	2.1	----	----	----	----	----
Original carbonate mud:	80.8	64.8	----	27.9	22.7	47.5	52.0
Spar cement:	----	1.0	42.6	----	----	----	0.8
Chert:	0.2	0.8	----	----	----	----	4.0
Intergranular silicification:	----	----	----	4.2	----	----	2.5
Dolomite:	0.4	0.3	----	----	----	----	----
Pore space:	----	----	----	----	----	----	0.3
Unrecognizable:	2.4	3.9	2.9	3.5	3.7	3.2	4.0

*TR--Trace occurrence; observed but not point counted.

APPENDIX C (continued)

UNIT-INTERVAL SAMPLE (NWP-)	4-A 18.8	4-B 25.1	5 29.7	6-A 32.5	6-B 33.2	6-C 37.1	6-D 40.3
	Percentage of Thin Section						
Pelmatozoans:	3.6	18.4	----	7.8	3.2	17.7	0.8
Brachiopods (total):	1.5	1.7	0.2	1.4	25.9	4.9	----
Impunctate:	----	1.7	----	1.4	6.7	4.9	----
Pseudopunctate:	----	----	----	----	19.2	----	----
Punctate:	----	----	----	----	----	----	----
Bryozoans (total):	TR*	5.9	----	0.5	----	TR*	----
fenestrate:	----	4.0	----	0.5	----	----	----
digitate:	----	1.3	----	----	----	----	----
Molluscs (total):	----	0.3	----	----	0.2	----	----
Pelecypods:	----	0.3	----	----	0.2	----	----
Gastropods:	----	TR*	----	----	----	----	----
Foraminifers (total):	----	0.3	----	0.7	----	----	----
uniserial:	----	----	----	----	----	----	----
biserial:	----	----	----	----	----	----	----
miliolids:	----	----	----	TR*	----	----	----
fusulinids:	----	----	----	----	----	----	----
Ostracodes:	----	----	----	----	----	0.5	----
Trilobites:	0.3	----	----	----	0.2	0.7	----
Unidentified shelly:	----	----	----	1.6	----	1.9	----
Calcispheres:	----	----	----	----	----	----	----
Ooids:	18.0	8.7	----	----	----	----	----
Peloids (non-pelletal):	----	----	----	----	----	----	----
pellets:	----	----	----	----	----	----	----
Grapestones:	----	----	----	----	----	----	----
Coated grains:	----	----	----	14.4	----	4.7	----
Intraclasts:	----	3.1	----	----	----	----	----
Sand (fine):	25.5	----	80.2	----	----	----	----
Silt:	----	0.6	----	3.0	4.6	0.9	0.3
Clay:	----	----	----	----	----	----	----
Opaques (total):	7.7	2.8	4.7	0.5	0.7	TR*	0.8
hematite:	7.7	2.5	4.7	0.5	----	----	0.8
black:	----	0.3	----	----	0.7	----	----
Original carbonate mud:	35.8	1.1	----	51.1	62.0	63.9	68.0
Spar cement:	----	50.4	----	----	----	----	----
Chert:	0.3	----	9.7	----	----	0.7	0.3
Intergranular silicification:	3.4	3.9	4.0	15.3	TR*	0.2	2.9
Dolomite:	----	----	----	----	----	----	25.0
Pore space:	----	----	----	----	----	----	----
Unrecognizable:	3.9	2.8	1.2	3.7	3.2	3.9	1.9

*--TR=Trace occurrence; observed but not point counted

APPENDIX C (continued)

UNIT-INTERVAL SAMPLE (NWP-)	7-A 43.7	7-A 44.6	7-A 48.2	8-A 52.7	8-B 57.2	9-B 61.7	9-C 66.2
		Percentage of Thin Section					
Pelmatozoans:	1.7	16.4	15.5	0.3	5.3	3.1	2.6
Brachiopods (total):	0.7	12.8	3.8	0.3	----	0.3	1.2
Impunctate:	----	11.4	2.0	----	----	----	0.5
Pseudopunctate:	----	1.4	0.3	----	----	----	----
Punctate:	----	----	----	----	----	----	----
Bryozoans (total):	----	0.5	1.0	----	0.2	----	4.0
fenestrate:	----	0.5	----	----	----	----	3.3
digitate:	----	----	----	----	----	----	----
Molluscs (total):	----	4.1	1.3	0.3	0.2	7.0	1.4
Pelecypods:	----	2.3	----	0.3	----	7.0	1.4
Gastropods:	----	----	1.3	----	0.2	----	----
Foraminifers (total):	----	----	2.5	----	2.6	----	1.6
uniserial:	----	----	----	----	----	----	----
biserial:	----	----	----	----	----	----	----
miliolids:	----	----	0.5	----	2.1	----	1.2
fusulinids:	----	----	1.0**	----	0.5	----	0.2
Ostracodes:	----	----	0.5	----	1.0	0.3	----
Trilobites:	----	0.2	0.8	----	0.2	----	0.2
Unidentified shelly:	----	----	0.3	0.8	0.2	----	3.5
Calcispheres:	----	----	----	----	1.2	----	----
Ooids:	----	----	11.0	----	----	----	42.4
Peloids (non-pelletal):	----	----	2.0	----	----	----	----
pellets:	----	----	----	----	----	----	----
Grapestones:	----	----	10.4	----	----	----	0.9
Coated grains:	----	----	----	----	----	----	----
Intraclasts:	----	----	----	----	----	----	----
Sand (very fine):	----	----	----	----	----	----	----
Silt:	2.0	1.1	----	0.3	1.2	1.1	----
Clay:	----	----	----	----	----	----	----
Opaques (total):	----	----	0.3	TR*	----	----	----
hematite:	----	----	----	TR*	----	----	----
black:	----	----	0.3	----	----	----	----
Original carbonate mud:	94.9	59.8	4.8	97.2	83.1	78.9	0.9
Spar cement:	----	----	38.9	----	1.2	----	38.2
Chert:	----	----	----	----	1.2	1.1	----
Intergranular silicification:	----	0.5	----	TR*	1.9	3.7	----
Dolomite:	----	----	----	----	----	----	----
Pore space:	----	----	----	----	----	----	----
Unrecognizable:	0.7	4.6	6.9	0.8	0.5	4.5	3.1

*--TR=Trace occurrence; observed but not point counted
**--Lowest occurrence of fusulinids in the Horquilla Limestone

APPENDIX C (continued)

UNIT-INTERVAL SAMPLE (NWP-)	9-C 67.8	10 72.2	11 77.0	11 80.0	12 81.3	12 82.8	13 84.8
	Percentage of Thin Section						
Pelmatozoans:	0.7	5.5	1.2	11.5	----	0.3	8.5
Brachiopods (total):	TR*	0.7	----	4.9	----	0.8	1.2
Impunctate:	----	0.7	----	2.1	----	----	1.2
Pseudopunctate:	----	----	----	----	----	0.8	----
Punctate:	----	----	----	0.5	----	----	----
Bryozoans (total):	----	----	----	2.3	----	----	0.7
fenestrate:	----	----	----	2.1	----	----	----
digitate:	----	----	----	----	----	----	----
Molluscs (total):	TR*	TR*	0.5	2.1	0.2	----	1.0
Pelecypods:	TR*	TR*	----	1.9	0.2	----	1.0
Gastropods:	----	----	----	0.2	----	----	----
Foraminifers (total):	----	----	----	2.0	----	----	0.7
uniserial:	----	----	----	0.2	----	----	----
biserial:	----	----	----	----	----	----	----
miliolids:	----	----	----	0.9	----	----	----
fusulinids:	----	----	----	----	----	----	0.2
Ostracodes:	----	1.4	----	0.9	TR*	----	3.2
Trilobites:	----	0.7	----	0.9	----	0.3	1.2
Unidentified shelly:	----	0.5	0.2	4.7	0.7	0.3	0.5
Calcispheres:	----	----	----	----	5.3	----	----
Ooids:	----	----	66.2	14.8	----	----	----
Peloids (non-pelletal):	----	2.9	----	----	----	----	----
pellets:	----	----	----	----	----	----	20.3
Grapestones:	----	----	0.9	----	----	----	----
Coated grains:	----	----	----	----	----	----	----
Intraclasts:	----	----	----	----	----	----	----
Sand (very fine):	0.2	----	----	----	----	----	----
Silt:	----	0.5	----	----	----	----	2.5
Clay:	----	----	----	----	----	----	----
Opaques (total):	----	0.2	----	----	----	1.6	----
hematite:	----	0.2	----	----	----	1.3	----
black:	----	----	----	----	----	0.3	----
Original carbonate mud:	97.9	82.5	----	15.5	89.7	95.4	56.0
Spar cement:	----	----	25.7	36.8	----	----	0.5
Chert:	----	----	----	0.2	----	----	----
Intergranular silicification:	----	2.9	2.5	----	1.1	----	----
Dolomite:	----	----	----	----	----	----	----
Pore space:	----	----	----	----	----	----	----
Unrecognizable:	1.2	2.2	2.8	3.4	3.0	1.3	3.7

*--TR=Trace occurrence; observed but not point counted

APPENDIX C (continued)

UNIT-INTERVAL SAMPLE (NWP-)	14 87.6	14 89.5	16 93.5	16 97.2	16 100.1	16 104.1	16 108.9
	Percentage of Thin Section						
Pelmatozoans:	0.5	----	6.4	8.4	7.6	7.4	1.9
Brachiopods (total):	----	----	5.0	20.9	0.3	0.3	2.8
Impunctate:	----	----	5.0	18.6	----	----	1.1
Pseudopunctate:	----	----	----	1.9	----	----	0.3
Punctate:	----	----	----	----	----	----	----
Bryozoans (total):	----	----	----	8.2	0.8	----	2.8
fenestrate:	----	----	----	4.5	0.5	----	2.8
digitate:	----	----	----	----	----	----	----
Molluscs (total):	0.6	----	0.5	0.2	1.3	----	0.6
Pelecypods:	0.3	----	----	0.2	1.3	----	----
Gastropods:	----	----	----	----	----	----	0.6
Foraminifers (total):	----	----	----	----	5.3	0.9	5.3
uniserial:	----	----	----	----	----	----	0.3
biserial:	----	----	----	----	----	----	0.3
miliolids:	----	----	----	----	0.8	0.3	0.8
fusulinids:	----	----	----	----	1.0	----	1.1
Ostracodes:	----	----	1.1	----	0.8	0.8	----
Trilobites:	TR*	----	----	----	0.5	----	0.6
Unidentified shelly:	----	----	----	----	5.5	----	----
Calcispheres:	----	21.6	----	----	----	----	----
Ooids:	----	----	----	----	----	----	----
Peloids (non-pelletal):	----	----	----	----	----	----	----
pellets:	----	2.3	----	----	18.1	1.7	----
Grapestones:	----	----	----	----	----	----	----
Coated grains:	----	----	----	----	----	----	----
Intraclasts:	----	----	----	----	----	----	----
Sand (very fine):	----	----	----	----	----	----	----
Silt:	----	----	0.8	0.2	----	0.3	0.3
Clay:	----	----	----	----	----	----	----
Opaques (total):	0.3	1.4	0.8	0.2	TR*	0.3	----
hematite:	0.3	1.4	----	0.2	----	0.3	----
black:	TR*	----	0.8	----	TR*	----	----
Original carbonate mud:	95.1	70.2	52.7	58.5	54.4	82.7	79.5
Spar cement:	----	----	----	----	----	0.8	3.1
Chert:	----	----	----	----	----	0.6	----
Intergranular silicification:	----	----	----	----	----	1.1	0.6
Dolomite:	----	----	28.4	----	----	----	----
Pore space:	----	----	----	----	0.8	----	----
Unrecognizable:	3.5	4.5	4.3	3.3	4.6	3.1	2.5

*--TR=Trace occurrence; observed but not point counted

APPENDIX C (continued)

UNIT-INTERVAL SAMPLE (NWP-)	17-A 113.1	17-B 117.8	18 120.1	19 123.2	19 125.2	20 128.1	20 131.5
	Percentage of Thin Section						
Pelmatozoans:	2.4	3.6	6.8	6.8	7.1	2.0	15.2
Brachiopods (total):	1.3	4.8	----	2.0	3.0	----	1.4
Impunctate:	----	3.1	----	0.6	2.5	----	----
Pseudopunctate:	----	0.7	----	----	----	----	----
Punctate:	----	1.0	----	----	0.5	----	----
Bryozoans (total):	0.5	0.7	----	1.7	10.5	----	1.1
fenestrate:	----	----	----	1.7	9.6	----	----
digitate:	----	0.7	----	----	0.9	----	----
Molluscs (total):	----	----	----	0.6	----	0.4	4.8
Pelecypods:	----	----	----	0.3	----	0.4	3.7
Gastropods:	----	----	----	----	----	----	1.1
Foraminifers (total):	1.3	0.2	----	4.5	0.2	7.4	6.4
uniserial:	----	----	----	----	----	----	----
biserial:	----	----	----	----	----	0.2	----
miliolids:	----	----	----	3.1	----	0.7	1.8
fusulinids:	----	0.2	----	----	TR*	1.1	0.5
Ostracodes:	0.2	----	----	0.6	----	0.7	1.4
Trilobites:	----	0.7	----	----	0.2	0.7	----
Unidentified shelly:	3.7	----	----	----	0.7	3.8	3.2
Calcispheres:	----	----	----	0.6	----	0.7	----
Ooids:	----	----	----	----	----	----	----
Peloids (non-pelletal):	----	----	----	0.8	0.5	1.3	2.3
pellets:	----	----	----	----	----	----	----
Grapestones:	----	----	----	----	----	----	----
Coated grains:	----	----	----	----	----	----	----
Intraclasts:	----	----	----	1.1	----	----	----
Sand (very fine):	----	----	----	----	----	----	----
Silt:	----	----	----	0.3	----	0.2	1.7
Clay:	----	----	----	----	----	----	----
Opaques (total):	----	----	0.5	----	1.4	0.2	----
hematite:	----	----	0.3	----	1.4	0.2	----
black:	----	----	0.2	----	----	----	----
Original carbonate mud:	82.8	87.1	22.8	72.2	72.3	75.4	55.2
Spar cement:	----	----	----	----	----	0.9	0.3
Chert:	----	----	----	1.1	----	0.2	0.6
Intergranular silicification:	5.0	----	----	3.4	----	1.8	0.6
Dolomite:	----	----	68.7	----	----	----	----
Pore space:	----	----	----	0.3	----	0.7	1.4
Unrecognizable:	2.7	2.9	1.2	4.0	4.1	3.6	4.4

*--TR=Trace occurrence; observed but not point counted

APPENDIX C (continued)

UNIT-INTERVAL SAMPLE (NWP-)	21 135.6	21 138.3	21 142.2	22 142.7	22 144.6	22 145.1	23 147.3
	Percentage of Thin Section						
Pelmatozoans:	1.8	8.5	1.2	43.2	35.1	15.8	12.5
Brachiopods (total):	0.5	0.5	0.5	5.2	5.6	4.2	0.3
Impunctate:	----	----	----	5.2	4.8	2.6	----
Pseudopunctate:	----	0.5	----	----	----	1.6	----
Punctate:	----	----	----	----	0.8	----	----
Bryozoans (total):	----	0.5	2.7	2.2	2.4	1.3	----
fenestrate:	----	----	2.7	----	----	----	----
digitate:	----	----	----	1.7	0.4	1.3	----
Molluscs (total):	2.6	0.5	2.2	1.0	----	0.4	----
Pelecypods:	1.8	----	0.5	----	----	----	----
Gastropods:	0.8	0.5	0.2	----	----	----	----
Foraminifers (total):	7.7	2.1	6.1	----	----	----	2.1
uniserial:	----	----	----	----	----	----	----
biserial:	----	----	----	----	----	----	----
miliolids:	2.3	1.0	1.0	----	----	----	----
fusulinids:	1.3	0.3	TR*	----	----	----	----
Ostracodes:	1.3	1.5	2.0	----	----	1.0	0.5
Trilobites:	----	0.3	----	1.0	2.4	0.5	----
Unidentified shelly:	1.8	3.3	4.2	----	----	----	1.6
Calcispheres:	1.6	----	0.2	----	----	----	----
Ooids:	----	----	----	----	----	----	----
Peloids (non-pelletal):	1.0	2.8	0.2	----	----	----	----
pellets:	----	----	----	----	----	----	----
Grapestones:	----	----	----	----	----	----	----
Coated grains:	----	----	----	----	----	----	----
Intraclasts:	----	----	----	----	----	----	----
Sand (very fine):	----	----	----	----	----	1.0	----
Silt:	----	----	----	0.6	----	----	0.3
Clay:	----	----	----	----	----	----	----
Opaques (total):	----	----	----	----	----	----	----
hematite:	----	----	----	----	----	----	----
black:	----	----	----	----	----	----	----
Original carbonate mud:	73.0	74.2	73.3	39.4	48.8	58.4	67.5
Spar cement:	1.0	----	1.0	----	----	----	----
Chert:	0.3	----	----	0.4	----	----	----
Intergranular silicification:	0.8	----	----	4.0	----	14.5	10.1
Dolomite:	----	----	----	----	----	----	----
Pore space:	1.8	----	----	----	----	----	----
Unrecognizable:	4.8	5.8	6.4	3.0	5.7	2.9	5.1

*--TR=Trace occurrence; observed but not point counted

APPENDIX C (continued)

UNIT-INTERVAL	24	24	25	26	26	26
SAMPLE (NWP-)	154.8	160.5	163.5	166.8	169.3	172.2
	Percentage of Thin Section					
Pelmatozoans:	1.4	1.4	2.6	23.6	7.6	4.6
Brachiopods (total):	----	----	----	3.6	3.0	1.0
Impunctate:	----	----	----	2.3	----	----
Pseudopunctate:	----	----	----	----	----	----
Punctate:	----	----	----	----	----	----
Bryozoans (total):	----	3.5	----	5.6	3.6	1.0
fenestrate:	----	3.5	----	5.3	1.5	----
digitate:	----	----	----	----	----	----
Molluscs (total):	0.3	----	1.9	5.6	----	----
Pelecypods:	----	----	----	2.8	----	----
Gastropods:	----	----	0.8	----	----	----
Foraminifers (total):	17.8	11.7	6.1	1.9	11.7	8.3
uniserial:	----	1.4	----	----	----	0.7
biserial:	----	1.9	0.8	0.3	TR*	TR*
miliolids:	10.6	----	----	0.3	1.7	1.2
fusulinids:	1.7	1.4	2.9	TR*	5.5	1.9
Ostracodes:	0.9	0.7	0.3	----	1.1	0.7
Trilobites:	----	----	----	0.5	0.3	----
Unidentified shelly:	0.6	0.7	5.1	0.3	0.3	1.2
Calcispheres:	----	3.8	----	----	0.8	----
Ooids:	----	----	----	0.3	----	----
Peloids (non-pelletal):	3.7	5.0	0.8	----	6.0	----
pellets:	----	----	----	2.8	----	----
Grapestones:	----	----	----	----	----	----
Coated grains:	----	----	25.6	----	----	----
Intraclasts:	----	----	----	----	----	----
Sand (very fine):	----	----	----	----	----	----
Silt:	0.6	0.2	----	----	0.3	----
Clay:	----	----	----	----	----	----
Opaques (total):	----	----	----	----	----	0.7
hematite:	----	----	----	----	----	----
black:	----	----	----	----	----	0.7
Original carbonate mud:	63.8	65.4	42.7	8.0	60.0	74.6
Spar cement:	----	----	1.3	41.8	----	----
Chert:	0.6	----	----	----	----	----
Intergranular silicification:	2.6	----	----	0.5	1.4	----
Dolomite:	----	----	----	----	----	----
Pore space:	----	----	----	----	----	----
Unrecognizable:	7.7	7.6	13.6	5.8	3.9	7.9

*--TR=Trace occurrence; observed but not point counted

APPENDIX D

CONODONT PLATFORM ELEMENT TABULATIONS

APPENDIX D

--Left number=# of "lefts", center number=# of "rights", right number=# of elements with indeterminate curvature.

SAMPLE NUMBER	0.0	0.4	1.7	4.5	9.4	11.3	15.8	25.1	29.7	31.8	32.5	33.2	37.1	43.7	44.6
KILOGRAMS PROCESSED	1.0	1.0	1.0	2.0	1.0	1.0	2.0	1.5	1.0	1.0	2.5	3.0	2.0	1.5	1.5
CONODONTS RECOVERED PER KILOGRAM	0	17	0	5	2	0	53	34	0	0	1	4	85	0	3
Adetognathus unicornis		0/0/3					0/1/1	0/0/1							
Cavusgnathus cf. C. unicornis				0/3/0			0/2/0								
Gnathodus commutatus commutatus				0/0/2			0/2/2	0/2/1							
Gnathodus cf. G. girtyi girtyi				1/0/0											
Gnathodus bilineatus							7/6/0	0/1/0							
Cavusgnathus cf. C. naviculus							0/0/1	1/2/2							
Rachistognathus primus												1/2/1	4/1/1		
Rachistognathus muricatus													2/0/2		
Adetognathus lautus												0/1/0	2/4/0		1/0/0
Declinognathodus noduliferus													21/46/0		
Idiognathoides cf. I. sulcatus															
Adetognathus inflexus															
Hindeodus minutus															
Neognathodus symmetricus															
Neognathodus bassleri															
Idiognathoides sinuatus															
Idiognathodus delicatus															
Neognathodus medadultimus															
Diplognathodus cf. D. coloradoensis															
Neognathodus cf. N. medexultimus															

APPENDIX D (continued)

SAMPLE NUMBER	52.7	57.2	61.7	66.2	67.8	72.2	77.0	80.0	81.3	84.8	87.6	89.5	93.5	97.2	104.1
KILOGRAMS PROCESSED	2.0	2.0	1.0	2.0	1.0	2.0	1.0	1.0	2.0	1.5	1.0	1.0	3.5	2.0	2.0
CONODONTS RECOVERED PER KILOGRAM	7	2	10	2	3	9	5	101	5	14	0	0	26	43	0
Adetognathus unicornis															
Cavusgnathus cf. C. unicornis															
Gnathodus commutatus commutatus															
Gnathodus cf. G. girtyi girtyi															
Gnathodus bilineatus															
Cavusgnathus cf. C. naviculus															
Rachistognathus primus															
Rachistognathus muricatus															
Adetognathus lautus		0/1/0	2/0/0	1/0/2	2/0/0	3/2/1	1/1/0	14/15/2	0/1/0	1/0/1			6/3/0	2/2/1	
Declinognathodus noduliferus															
Idiognathoides cf. I. sulcatus	1/3/0		1/0/0												
Adetognathus inflexus							0/1/0	0/8/0							
Hindeodus minutus								1/1/0					1/0/0		
Neognathodus symmetricus								16/16/0		2/0/0					
Neognathodus bassleri															
Idiognathoides sinuatus													8/10/0	13/14/0	
Idiognathodus delicatus															
Neognathodus medadultimus															
Diplognathodus cf. D. coloradoensis															
Neognathodus cf. N. medexultimus															

APPENDIX D (continued)

SAMPLE NUMBER KILOGRAMS PROCESSED CONODONTS RECOVERED PER KILOGRAM	108.9 1.0 0	113.1 1.5 1	120.1 2.0 5	123.2 1.0 4	128.1 2.0 5	131.5 1.0 0	135.6 2.0 1	142.2 2.0 2	142.7 2.0 8	147.3 2.0 7	154.8 2.0 81	160.5 2.0 15	166.8 1.0 526	169.3 1.0 95
Adetognathus unicornis														
Cavusgnathus cf. C. unicornis														
Gnathodus commutatus commutatus														
Gnathodus cf. G. girtyi girtyi														
Gnathodus bilineatus														
Cavusgnathus cf. C. naviculus														
Rachistognathus primus														
Rachistognathus muricatus														
Adetognathus lautus			1/0/0	3/0/0	3/0/0				2/1/0	4/5/0	8/5/1			
Declinognathodus noduliferus													9/13/0	
Idiognathoides cf. I. sulcatus														
Adetognathus inflexus					0/1/0		0/1/0		0/4/0		0/5/0	0/1/0		
Hindeodus minutus											11/11/1		4/2/5	0/4/1
Neognathodus symmetricus														
Neognathodus bassleri			0/1/0										6/8/1	
Idiognathoides sinuatus					0/1/0								2/3/0	
Idiognathodus delicatus			1/4/0								18/14/0	13/13/0	48/53/0	19/30/0
Neognathodus medadultimus											0/1/0		6/0/0	2/1/0
Diplognathodus cf. D. coloradoensis											0/0/4			0/0/1
Neognathodus cf. N. medexultimus														1/0/0

APPENDIX E

PURPOSE AND CLASSIFICATION OF SAMPLES COLLECTED IN THE NEW WELL PEAK SECTION OF THE SOUTHERN BIG HATCHET MOUNTAINS

APPENDIX E

SAMPLE NUMBER*	ROCK CLASSIFICATION**	CONODONT SAMPLE	PETROGRAPHIC SAMPLE
NWP-0.0 [1B]	Barren mudstone	X	X
NWP-0.4 [1A]	Crinoid biowackestone	X	X
NWP-1.7 [2B]	Calcareous shale	X	
NWP-4.5 [3B]	Silty oograinstone	X	X
NWP-6.8P	Silty oopackstone		X
NWP-9.4 [2A]	Silty oopackstone	X	X
NWP-11.3 [4B]	Silty oopackstone	X	X
NWP-15.8 [5B]	Brachiopod oowackestone	X	X
NWP-18.8P	Sandy oowackestone		X
NWP-25.1 [3A]	Crinoid oowackestone	X	X
NWP-29.7 [4A]	Sandstone	X	X
NWP-31.0P	Sandstone		X
NWP-31.8 [1d]	Calcareous shale	X	
NWP-32.5 [5A,1C]	Burrowed biowackestone	X	X
NWP-33.2 [6B]	Brachiopod biowackestone	X	X
NWP-37.1 [6A]	Crinoid biowackestone	X	X
NWP-40.3P	Barren mudstone		X
NWP-43.7 [7B]	Barren mudstone	X	X
NWP-44.6 [7A]	Crinoid biowackestone	X	X
NWP-48.2P	Crinoid oopackstone		X
NWP-52.7 [8A]	Barren mudstone	X	X
NWP-57.2 [8B]	Crinoid biowackestone	X	X
NWP-61.7 [9A]	Pelecypod biowackestone	X	X
NWP-66.2 [9B]	Bryozoan oograinstone	X	X
NWP-67.8 [10A]	Barren mudstone	X	X
NWP-72.2 [10B]	Crinoid biopelwackestone	X	X
NWP-77.0 [11A]	Grapestone oograinstone	X	X
NWP-80.0 [2C]	Crinoid oopackstone	X	X
NWP-81.3 [11B]	Barren mudstone	X	X
NWP-82.8P	Barren mudstone		X
NWP-84.8 [12A]	Crinoid biopelwackestone	X	X
NWP-87.6 [3C]	Barren mudstone	X	X
NWP-89.5 [12B]	Calcispheric mudstone	X	X
NWP-93.5 [13B]	Crinoid biowackestone	X	X
NWP-97.2 [13A]	Brachiopod biowackestone	X	X
NWP-100.1P	Crinoid biopelwackestone		X
NWP-104.1 [14B]	Crinoid biowackestone	X	X
NWP-108.9 [4C]	Foram biowackestone	X	X
NWP-113.1 [14A]	Fossiliferous mudstone	X	X
NWP-117.8P	Brachiopod biowackestone		X
NWP-120.1 [15B]	Crinoidal mudstone	X	X

*NWP-# = meters from base of section.
**explanation of rock classification discussed in Appendix A.

APPENDIX E (continued)

SAMPLE NUMBER*	ROCK CLASSIFICATION**	CONODONT SAMPLE	PETROGRAPHIC SAMPLE
NWP-123.2 [5C]	Crinoidal biowackestone	X	X
NWP-125.2P	Bryozoan biowackestone		X
NWP-128.1 [15A]	Foram biowackestone	X	X
NWP-131.5 [6C]	Crinoid biopackstone	X	X
NWP-135.6 [16B]	Foram biowackestone	X	X
NWP-138.3P	?Burrowed biowackestone		X
NWP-142.2 [17B]	Foram biowackestone	X	X
NWP-142.7 [7C]	Crinoid biopackstone	X	X
NWP-144.6P	Crinoid biopackstone		X
NWP-145.1 [U-22]	Crinoid biowackestone		X
NWP-147.3 [16A]	Crinoid biowackestone	X	X
NWP-154.8 [18B]	Foram biopackstone	X	X
NWP-160.5 [2D]	Foram biowackestone	X	X
NWP-163.5P	Coated grain biopackstone		X
NWP-166.8 [19B]	Crinoid biopackstone	X	X
NWP-169.3 [8C]	Foram biowackestone	X	X
NWP-172.2P	Foram biopackstone		X

*NWP-# = meters from base of section.
**explanation of rock classification discussed in Appendix A.

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