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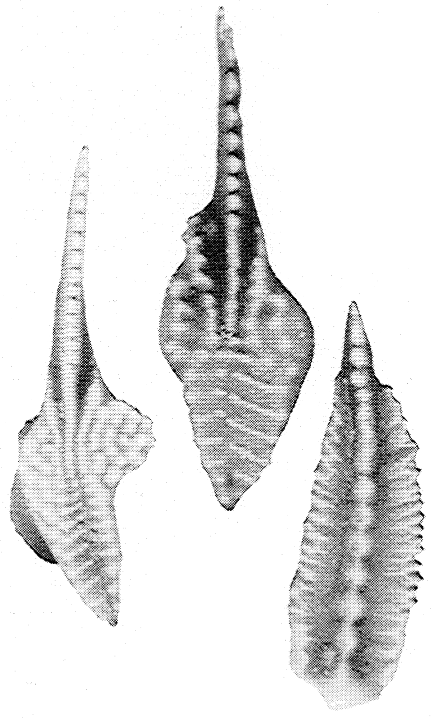
CONODONT DISTRIBUTION, PALEOECOLOGY, AND PRELIMINARY BIOSTRATIGRAPHY OF THE UPPER CHEROKEE AND MARMATON GROUPS (UPPER DESMOINESIAN, MIDDLE PENNSYLVANIAN) FROM TWO CORES IN SOUTH-CENTRAL IOWA



by
John W. Swade

edited by
Philip H. Heckel

Donald L. Koch
State Geologist and Director

1985

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EDITOR'S PREFACE

This publication is derived from a a Master of Science thesis in geology completed by John W. Swade at the University of Iowa in May 1982. This thesis represented a partial culmination of several years of work for the Iowa Geological Survey by Swade on conodonts from Pennsylvanian cores taken in southern Iowa as part of the Survey's Coal Project, which was funded by the State of Iowa for the purpose of further understanding the coal-bearing strata in the State.

About the time that the thesis was successfully defended and accepted, Swade learned that he was suffering from inoperable cancer and had perhaps only a few months to live. From June 1982 until he became incapacitated in late January 1983, he worked as much as possible studying equivalent and younger conodont faunas from both outcrop and cores in Iowa and neighboring states, while he imparted as much of his voluminous knowledge of Pennsylvanian conodonts as was practicable to P. H. Heckel, his thesis supervisor. From September 1982 until his death in March 1983, he was supported as a Research Fellow by the Petroleum Research Fund, administered by the Amercian Chemical Society through a grant to P. H. Heckel, for the purpose of working out the lithostratigraphy, correlation, and depositional-diagenetic history of Middle and Upper Pennsylvanian rocks of the Midcontinent. Swade's position in the project was to provide a sound conodont-based biostratigraphic framework to aid in correlating the marine cycles of deposition along the Midcontinent outcrop and into the subsurface of both the Midcontinent and Illinois basins.

Because Swade left a large collection of Midcontinent Pennsylvanian conodonts collected at precisely located stratigraphic horizons in both outcrops and cores, his work on their biostratigraphy is being carried on by P. H. Heckel, and his students and associates. This publication is the first step in this continuing work. Most of it is Swade's thesis, edited mainly for more recent stratigraphic usage. The chapter on systematic paleontology, however, did not appear in the thesis because of time constraints on final deposit of the thesis for awarding the degree in May 1982, in view of Swade's medical condition. This chapter (along with the abstract) has been written by P. H. Heckel from diagnostic comments made by Swade in the chapter on biostratigraphic aspects supplemented by verbal comments from Swade during their collaboration in late 1982, and by later review of the critical conodont faunas from the two cores. Much help was received from G. Klapper in this undertaking, and the chapter has been reviewed by B. J. Witzke and J. F. Baesemann as well. Swade's (1982) concepts of species are retained in this report, including his use of open nomenclature, whether or not the writer or reviewers of this chapter fully agreed with them.

CONODONT DISTRIBUTION, PALEOECOLOGY, AND PRELIMINARY BIOSTRATIGRAPHY OF THE UPPER CHEROKEE AND MARMATON GROUPS (UPPER DESMOINESIAN, MIDDLE PENNSYLVANIAN) FROM TWO CORES IN SOUTH-CENTRAL IOWA

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ABSTRACT

The conodont faunas of six successive upper Desmoinesian cyclothems, studied sequentially in two overlapping cores from south-central Iowa, show a cyclic succession similar to that described by Heckel and Baesemann (1975) from the higher Missourian sequence cropping out in eastern Kansas. Offshore phosphatic shales, ranging from black fissile to green clayey facies, show extremely high conodont abundance (typically thousands/kilogram) and carry mainly *Idiognathodus*, *Neognathodus*, *Idioprioniodus*, and *Gondolella* (in certain cycles). Nearshore sandy shales are characterized by a variety of sparse faunas (no more than tens/kilogram) usually dominated by *Adetognathus* or *Idiognathodus*. Regressive (upper) limestones generally show diminishing-upward conodont abundances (hundreds to tens/kilogram), generally dominated by *Idiognathodus*, with *Neognathodus*, *Anchignathodus* and sometimes *Aethotaxis* at horizons throughout; *Idioprioniodus* generally occurs only toward the base, and *Adetognathus* and *Stepanovites* occur only toward the top; *Diplognathodus* dominates the youngest regressive limestone studied (Cooper Creek). Transgressive deposits consist mainly of thin shales and limestones in the cycles studied, and, where thick enough for vertical differentiation of faunas, show upward-increasing conodont abundance with *Adetognathus* dominance toward the base, *Idiognathodus* dominance upward, *Idioprioniodus* mainly toward the top, and *Neognathodus*, *Anchignathodus* and *Diplognathodus* at horizons throughout. "Super" limestones, which lie above upper limestones and apparently represent minor transgressive-regressive cycles of deposition, show a variety of conodont faunas like those of the upper limestone; these also generally diminish in abundance upward with mixed dominance of *Idiognathodus* and, toward the top, *Adetognathus*.

The onshore-offshore trends and lithologic preferences exhibited by the conodont genera in these cores allow construction of a model for upper Desmoinesian conodont paleoecology based on principles reviewed by Klapper and Barrick (1978). The four genera found abundantly in the anoxic black shales were pelagic and probably inhabited different parts of the overlying stratified water column. *Idiognathodus* and *Neognathodus*, which are also common in most other facies of the sequence, probably inhabited the warm well-oxygenated, surface water layer. *Idioprioniodus*, which is confined to offshore parts of all cycles, probably inhabited slightly cooler, less oxygenated water near the top of the thermocline. *Gondolella*, which is further confined to the middle parts of certain phosphatic offshore shales, probably inhabited an even deeper, and probably colder and less oxygenated, water layer that did not become involved in the upwelling in every cycle in this area. *Adetognathus*, which dominates many nearshore deposits, probably inhabited the shoreline water mass of fluctuating conditions brought about by fresh-water influx and attendant turbidity. The rare but similar occurrences of *Stepanovites* suggest a similar though perhaps more restricted habitat. Near confinement of *Anchignathodus* and *Aethotaxis* to carbonate lithotopes indicates a warm clear-water habitat, which was possibly benthic in view of their apparent absence in similar water at the top of the stratified water column over the black shales. The scattered distribution of *Diplognathodus* makes it the most difficult genus to interpret, but an intermediate position between the nearshore fluctuating water mass and the offshore stratified succession of water masses is suggested.

Biostratigraphic trends are apparent in the abundant offshore phosphatic shale faunas upward through the six cyclothems. The Oakley Shale of the Verdigris cycle is characterized by subequal dominance of *Idiognathodus* spp. 1 and 2, and occurrence of *Gondolella* sp. 1. The Excello Shale of the lower Fort Scott cycle is characterized by dominance of *I.* sp. 1, and *G.* sp. 2. (in the middle) with occurrence of *I.* spp. 2 and 3. The Little Osage Shale of the upper Fort Scott cycle is characterized by dominance of *I.* sp. 1, with occurrence of *I.* spp. 2, 3, and 4, and lack of *Gondolella*. The fauna of the Anna Shale of the Pawnee cycle closely resembles that of the Little Osage. The Lake Neosho Shale of the Altamont cycle is the only shale in which *Neognathodus* predominates over *Idiognathodus;* furthermore, only *I.* sp. 5 occurs in the lower and middle part, whereas only *I.* sp. 1 occurs in the upper part, and *Gondolella* is absent throughout. The thin shale below the Cooper Creek Limestone (Lost Branch Formation) is characterized by dominance of *I.* sp. 6 over *I.* sp. 1, occurrence of *G.* sp. 3 and *G. denuda,* and the youngest abundant occurrence of *Neognathodus*. *Diplognathodus coloradoensis* was found only in the Verdigris cycle but has been reported elsewhere from the lower Fort Scott cycle. *D. iowensis* n. sp. ranges from the lower Fort Scott to the Cooper Creek. *D.* n. sp. 2 ranges from the Pawnee through the Cooper Creek, and *D. illinoisensis* was found only in the Cooper Creek. The possibility of correlating cycles throughout the Midcontinent by means of these distinctions in conodont faunas of the offshore shales is strongly suggested by the discovery of similar distinctive faunas in previously correlated horizons in Kansas and Illinois.

AUTHOR'S ACKNOWLEDGMENTS

I wish to express sincere gratitude for the patient support and guidance provided by Professors Philip H. Heckel and Gilbert Klapper, both of the University of Iowa, during the long realization of the goals of this project. I also thank Professor Robert L. Brenner for serving with them on the committee. Special thanks are due the Iowa Geological Survey for making available the cores studied, laboratory facilities and supplies used to process the core materials, and financial support during the early phases of the research. Dr. Mathew J. Avcin, former head of the I.G.S. Coal Project, directed much of the preliminary research and along with Professors Lawerence L. DeMott and Duane D. Moore, both of Knox College, Galesburg, Illinois, fostered my interest in Pennsylvanian geology and encouraged my pursuit of conodont studies. Joyce Chrisinger drafted the plates, and with Elise Zylstra and Stephan Shank, assisted in preparing the text figures. Karen P. Witzke typed the initial version of the manuscript. Mary Pat Heitman and Lois Bair typed the final version of the report. I especially wish to thank my wife, Darcy, for moral support and material assistance at many stages during the completion of this project.

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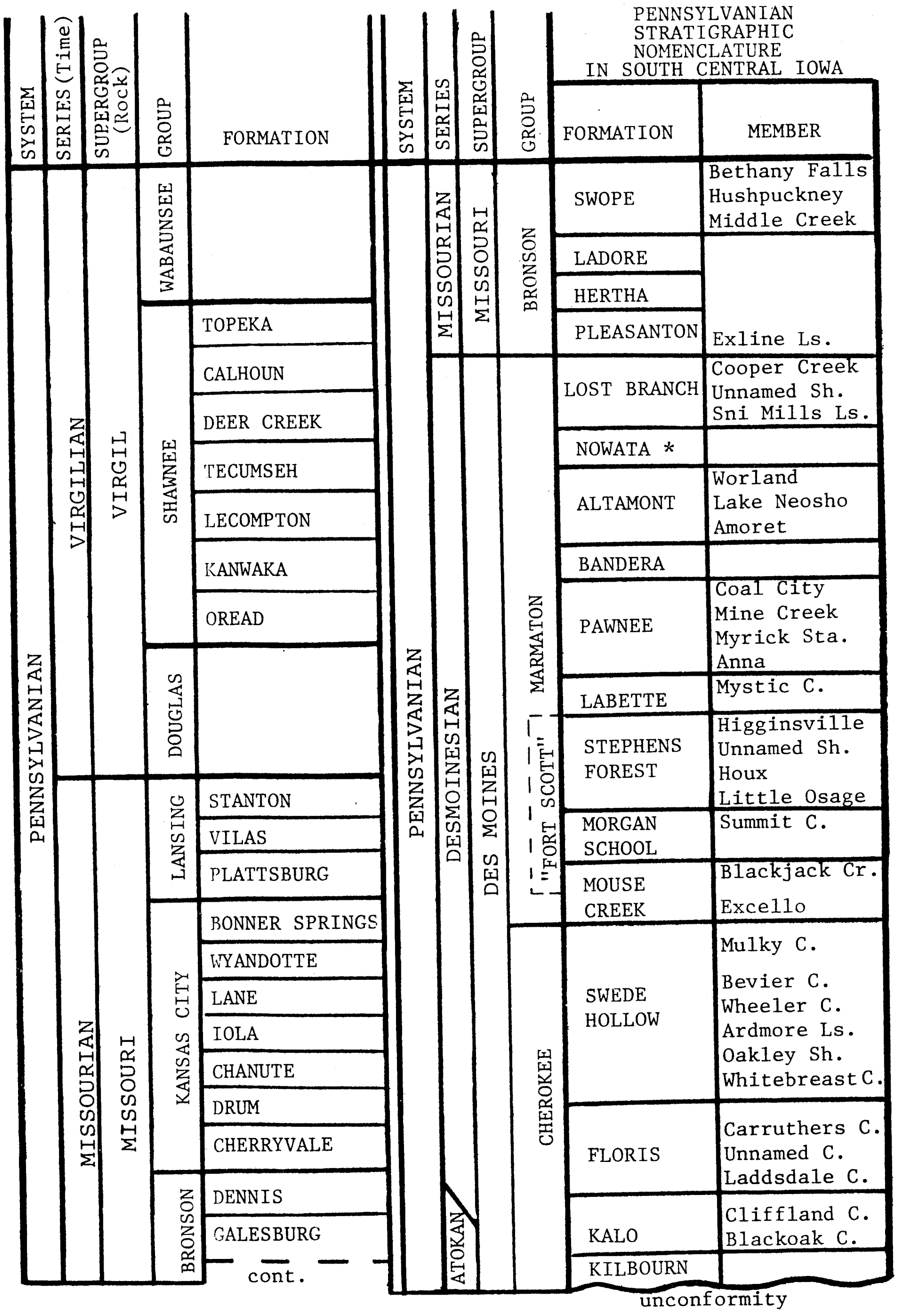
INTRODUCTION

Studies of Middle and Upper Pennsylvanian conodonts in the Midcontinent region have not proceeded toward the goal of developing an effective biostratigraphy as rapidly as have conodont studies in other parts of the geologic column. Early work summarized by Ellison (1941) showed that almost all of the ramiform elements he identified range unchanged from the upper Cherokee Group of the Desmoinesian Series to the lower Shawnee Group of the Virgilian Series (Fig. 1). Although considerable variation was noted among the platform elements, their use in discrimination of strata below the group level was considered to be unreliable. In part, this resulted from the observation that within any one formation, there exist striking variations in the vertical distribution of the conodont faunas. Merrill (1962, 1968, 1973a) postulated that the observed variation was the result of a high degree of environmental control. This concept ran contrary to the generally accepted view that conodonts were probably pelagic, and because of this, their distribution was likely to be facies independent (e.g., Müller, 1962).

Merrill (1973a) described empirical biofacies for groups of Pennsylvanian conodont taxa, which are now known to represent multielement apparatuses rather than provincial faunas as he had implied. Von Bitter (1972) studied collections spanning the Shawnee Group of the lower Virgilian Series in northeastern Kansas in an effort to evaluate and quantify Merrill's biofacies. His cluster analyses revealed enough systematic variaton to permit the partial reconstruction of at least six multielement apparatuses and showed a high degree of mutual exclusion between platform elements of *Cavusgnathus (=Adetognathus* of this paper) and those of *Streptognathodus* (included in *Idiognathodus* of this paper). Baesemann (1973) studied collections spanning the Missourian Series of northeastern Kansas and used restricted mutual occurrences to delineate the apparatus constituents of the genera *Adetognathus*, *Aethotaxis*, *Ozarkodina (=Anchignathodus* of this paper, =Pennsylvanian and younger *Hindeodus* of Sweet, 1977), *Idiognathodus*, and *Idioprioniodus*. Heckel and Baesemann (1975) used the distributional data from Baesemann (1973) in combination with a newly integrated environmental interpretation of the Missourian sequence to produce a model for Missourian conodont paleoecology that was largely patterned after the general model of vertical stratification of living zones proposed by Seddon and Sweet (1971). They briefly discussed the probable relationship of their model to the upper Desmoinesian Marmaton Group, but noted both the lack of good understanding of the environmental sequence there and the lack of comprehensive study of upper Desmoinesian conodonts since Ellison (1941). Merrill (1975) published an extensive study of Desmoinesian conodont faunas from northwestern Illinois, which showed certain aspects of their distribution in rocks equivalent to the Marmaton Group of the Midcontinent outcrop, but applied a different environmental interpretation to the lithologic succession.

It therefore seems appropriate to extend detailed knowledge of the succession of conodont faunas and lithotopes in which they are found downward from the work of Baesemann (1973) into the upper Desmoinesian strata of the Midcontinent sequence. The purpose of this study is threefold: 1) A detailed description of the succession of lithotopes and conodonts faunas from the upper Cherokee Group through the Marmaton Group (late Desmoinesian) in a continuous stratigraphic section derived from two overlapping core segments in south-central Iowa; 2) Interpretation of paleoenvironments, leading to the development of a working model for late Middle Pennsylvanian conodont paleoe-



SYSTEM	SERIES (Time)	SUPERGROUP (Rock)	GROUP	FORMATION
PENNSYLVANIAN	VIRGILIAN	VIRGIL	WABAUNSEE	
			SHAWNEE	TOPEKA
				CALHOUN
				DEER CREEK
				TECUMSEH
				LECOMPTON
				KANWAKA
				OREAD
			DOUGLAS	
	MISSOURIAN	MISSOURI	LANSING	STANTON
				VILAS
				PLATTSBURG
			KANSAS CITY	BONNER SPRINGS
				WYANDOTTE
				LANE
				IOLA
				CHANUTE
				DRUM
				CHERRYVALE
			BRONSON	DENNIS
				GALESBURG
				cont.

PENNSYLVANIAN STRATIGRAPHIC NOMENCLATURE IN SOUTH CENTRAL IOWA

SYSTEM	SERIES	SUPERGROUP	GROUP		FORMATION	MEMBER
PENNSYLVANIAN	MISSOURIAN	MISSOURI	BRONSON		SWOPE	Bethany Falls Hushpuckney Middle Creek
					LADORE	
					HERTHA	
					PLEASANTON	Exline Ls.
	DESMOINESIAN	DES MOINES	MARMATON		LOST BRANCH	Cooper Creek Unnamed Sh. Sni Mills Ls.
					NOWATA *	
					ALTAMONT	Worland Lake Neosho Amoret
					BANDERA	
					PAWNEE	Coal City Mine Creek Myrick Sta. Anna
					LABETTE	Mystic C.
				"FORT SCOTT"	STEPHENS FOREST	Higginsville Unnamed Sh. Houx Little Osage
					MORGAN SCHOOL	Summit C.
					MOUSE CREEK	Blackjack Cr. Excello
			CHEROKEE		SWEDE HOLLOW	Mulky C. Bevier C. Wheeler C. Ardmore Ls. Oakley Sh. Whitebreast C.
					FLORIS	Carruthers C. Unnamed C. Laddsdale C.
	ATOKAN				KALO	Cliffland C. Blackoak C.
					KILBOURN	

unconformity

Figure 1. Pennsylvanian stratigraphic nomenclature in south-central Iowa (after Ravn *et al.*, 1984). *Lenapah Limestone is now recognized within interval indicated as Nowata (see Fig. 3), and what had been called "Lenapah" in Iowa is now provisionally termed Lost Branch by Heckel (1984).

cology in light of recent depositional models for the origin of the cyclic Pennsylvanian sequence; 3) To describe in preliminary fashion the succession of conodont faunas found in the six exceedingly conodont-rich shales that occur in the sequence, which may be used as the basis for establishing definite correlation of the formations in which they are found along the Midcontinent outcrop and perhaps into adjacent basins.

Cores Analyzed

Toward these goals, portions of two cores made available by the drilling program of the Iowa Geological Survey Coal Project have been extensively sampled for conodonts. The two cores studied are CP #22, drilled at SE 1/4, SW 1/4, SE 1/4, section 36, T70N, R19W, three miles northwest of Mystic, Appanoose County, and CP #37, drilled at NE 1/4, SE 1/4, NE 1/4, section 2, T72N, R26W, three miles northwest of Osceola, Clarke County, Iowa. They are situated about 40 miles (65 km) apart on the northeast side of the Forest City Basin (Fig. 2). The present erosional outcrop roughly parallels the trend of depositional strike in south-central Iowa (Schenk, 1967) where basinward dip is to the southwest.

CP#22 encountered 425.5 feet (129.7 m) of Pennsylvanian strata ranging from the Atokan Kilbourn Formation (Cherokee Group) to the Desmoinesian Altamont Formation (Marmaton Group) (Fig. 1). Ravn and others (1984) illustrated portions of CP #22 as reference sections for their newly proposed Kilbourn, Mouse Creek, Morgan School, and Stephens Forest formations. The upper 204.5 feet were examined in this study, and include the latter three formations listed above, and the overlying Labette, Pawnee, Bandera, and Altamont formations (Fig. 3). CP #37 encountered 636 feet (194 m) of section ranging from the Desmoinesian Kalo Formation (Cherokee Group) to the Missourian Swope Formation (Bronson Group). The succession of Pawnee, Bandera, Altamont, Nowata, and Lost Branch formations overlaps with CP #22 to complete the Marmaton Group section examined for this study.

Techniques

Individual conodont samples generally consisted of one-half of the 2-inch (5.1 cm) core, in continuous 0.5-foot (15.2 cm) vertical segments through portions thought to represent marine deposits, although smaller sample intervals were used where indicated by lithologic breaks. Spot samples at 1-or 2-foot (30 or 60 cm) intervals were taken from probable marginally marine shales. Samples ranged in weight from 200 to about 500 grams. Limestones were processed in a 9% Formic Acid solution; grey shales in Stoddards Solvent, and organic shales in commercially available sodium hypochlorite bleach. All samples were washed using a U.S. Standard Sieve Series 18 mesh (1mm) upper screen and U.S. Standard Sieve Series 200 mesh (0.075 mm) lower screen. Separation of large-volume residues with tetrabromoethane greatly eased the burden of picking. A total of 208 samples were examined, and in excess of 22,000 identifiable conodont elements assigned to nine multielement genera were recovered. Detailed element distribution is compiled on Plates 1-3. Conodont data are also presented in summary form along with graphic section and information on distribution of other fossil groups in figures included in the descriptive portion of the text, as indicated on Figure 3.

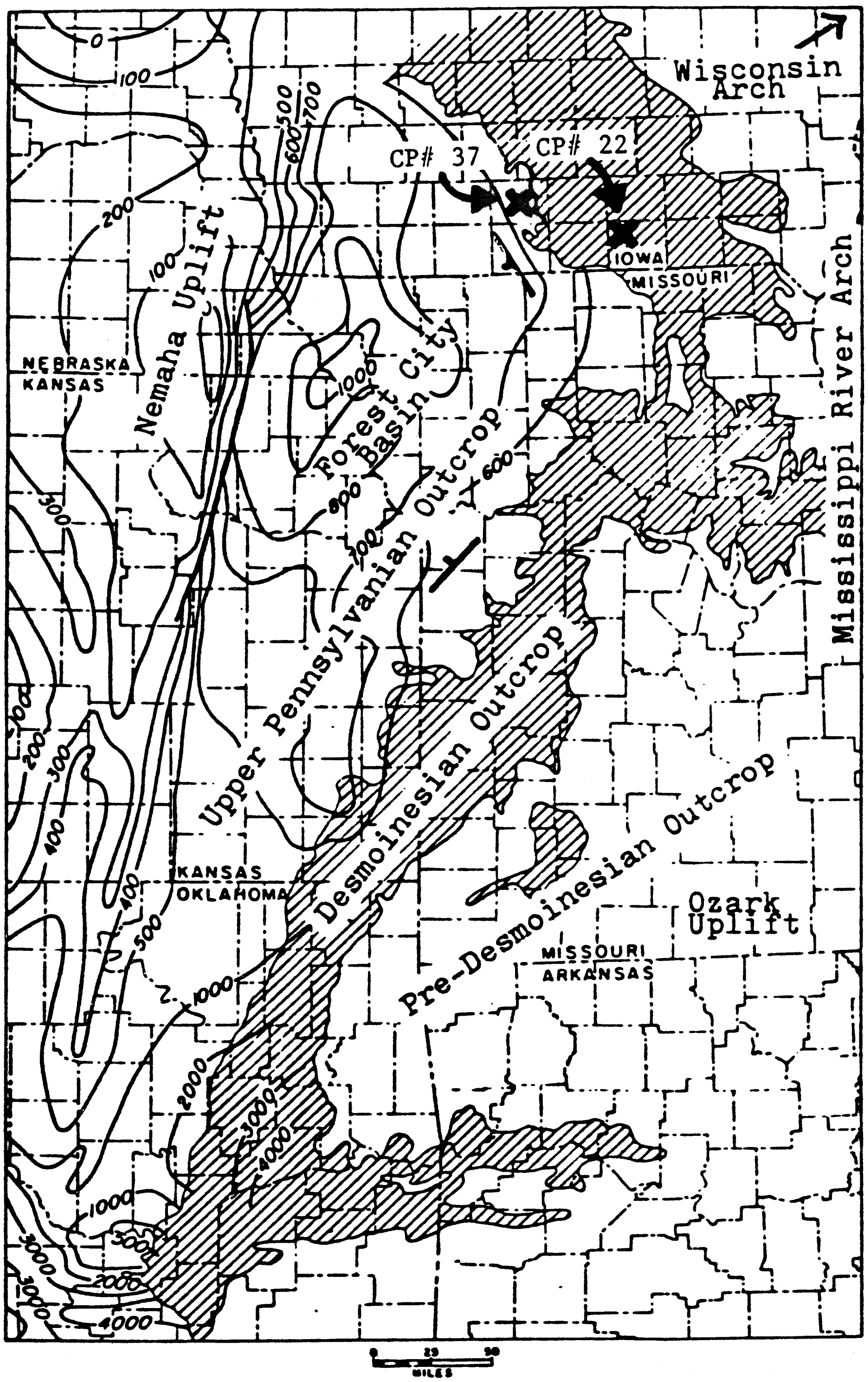


Figure 2. Midcontinent Desmoinesian outcrop and isopachous map (contours in feet) showing core locations and Pennsylvanian structural features (modified after O'Brien, 1977, Figure 2).

STRATIGRAPHY

Most Pennsylvanian stratigraphic units occur in orderly vertical lithic sequences, and many such sequences are repeated through succession. These sequences have historically been considered to represent cycles of sedimentation (Udden, 1912), and the basic repeating package of sediments is termed a cyclothem (Wanless and Weller, 1932). A cyclothem, particularly the ideal cyclothem as conceptualized by workers in the Illinois Basin (e.g., Willman and Payne, 1942), is considered to reflect a fluctuation in the relative stand of sea level. A number of recent studies (e.g., Crowell, 1978) have demonstrated widespread glaciation in the southern hemisphere during the late Paleozoic, and most modern Midcontinent workers accept the hypothesis of Wanless and Shepard (1936) that individual sea level fluctuations are related to episodic glacial maxima and minima, although the geometry and rate of subsidence of the depositional basin clearly exert broad control over the individual patterns of sedimentation that resulted. In any one area, in this case south-central Iowa, the succession of Middle Pennsylvanian strata is characterized by an increase in the effects of marine invasion upwards in the section that corresponds with the early "transgressive" portion of the Absaroka Sequence (Sloss, 1963).

Cherokee Group

Four formations of the Cherokee Group have recently been proposed by Ravn and others (1984), in ascending order, Kilbourn, Kalo, Floris, and Swede Hollow (Fig. 1). These formations reflect four major episodes of sedimentation, each characterized by different depositional regimes, and each showing the progressively increased effects of marine sedimentation.

The base of the Kilbourn Formation is marked by a pronounced unconformity that separates the Absaroka Sequence from the underlying Kaskaskia Sequence of Late Devonian and Mississippian age. The Kilbourn is characterized by alluvial, fluvial, and estuarine sediments that essentially represent the infilling of the erosional topography developed on the Mississippian surface. Fully marine sediments are apparently restricted to former valley axes and include dark shales and argillaceous skeletal calcilutites that occasionally contain thin zones of non-skeletal phosphate nodules.

The base of the overlying Kalo Formation is marked by the Blackoak Coal, which is the lowest bed in the section that is traceable over most of south-central Iowa. The Kalo is characterized by two widespread coal horizons, the Blackoak and the Cliffland, which are split by local detrital wedges and are usually overlain by marginally marine "prodeltaic" shales. The few local limestones that occur in the Kalo are generally argillaceous and/or arenaceous skeletal calcarenites.

In some areas, the lower portion of the overlying Floris Formation is similar to the Kalo, with several coals split by detrital wedges, but the coals are often overlain by thin marine shales and occasionally by skeletal calcilutites. The Floris is quite complex laterally, however, and includes thick channel sandstones that locally have replaced earlier Pennsylvanian strata. The upper part of the Floris, above the major channelling horizons, contains at least one and perhaps as many as three marine intervals that are somewhat more laterally extensive and appear to foreshadow the upper Desmoinesian eustatic cyclothems that are the subject of the present study.

The Swede Hollow Formation is the uppermost of the four subdivisions of the Cherokee Group proposed by Ravn and others (1984). The basal member, the Whitebreast Coal, is overlain by the Oakley Shale and Ardmore Limestone members, which constitute a marine interval that has long been recognized as the most reliable marker horizon within the Cherokee Group (e.g., Moore, 1936). This interval is traceable across the Midcontinent from Oklahoma to Iowa and across the Illinois Basin into Indiana. The sequence of beds in it remains relatively constant across this large area and may be considered archetypical of the Illinois-type cyclothem discussed by Heckel (1977, pp. 1060-61). The stratigraphic sequence in the upper part of the Swede Hollow is characterized by two or more deltaic clastic wedges separated by coals that are generally less persistent and more variable laterally. The upper Swede Hollow as a whole, however, forms a package of relatively constant thickness across the larger Midcontinent area.

Marmaton Group

The stratigraphic sequence in the Marmaton Group and younger Pennsylvanian strata in the Midcontinent is characterized by formations dominated by marine limestones that alternate with detrital formations that represent near-

Figure 3. Generalized columns showing stratigraphic intervals studied in cores CP #22 and CP #37, their correlation, and the cyclothems recognized. Intervals in brackets to right of columns show approximate sections illustrated in detail in denoted figures along with summary data on the distribution of conodonts and other fossil groups. Names in formation column generally follow Iowa stratigraphic nomenclature of Ravn and others (1984); names in cyclothem column follow terminology of O'Brien (1977), with modifications from Heckel (1984) for recognition of Lenapah, for Lost Branch in place of Cooper Creek, and for Verdigris in place of Ardmore. The latter changes are made because cyclothems are given the name of the entire formation that contains the strata deposited during the marine inundation rather than just one member of the formation, which in the case of both the Ardmore and Cooper Creek do not even carry the diagnostic conodonts. The Verdigris Formation in Missouri (Searight and Howe, 1961) includes the Ardmore Limestone Member and the underlying conodont-rich shale, thus is the appropriate name for the cyclothem; the Lost Branch Formation is defined as including the Cooper Creek Limestone Member, the underlying conodont-rich shale, and the Sni Mills Limestone Member (Heckel, 1984; also ms. in review).

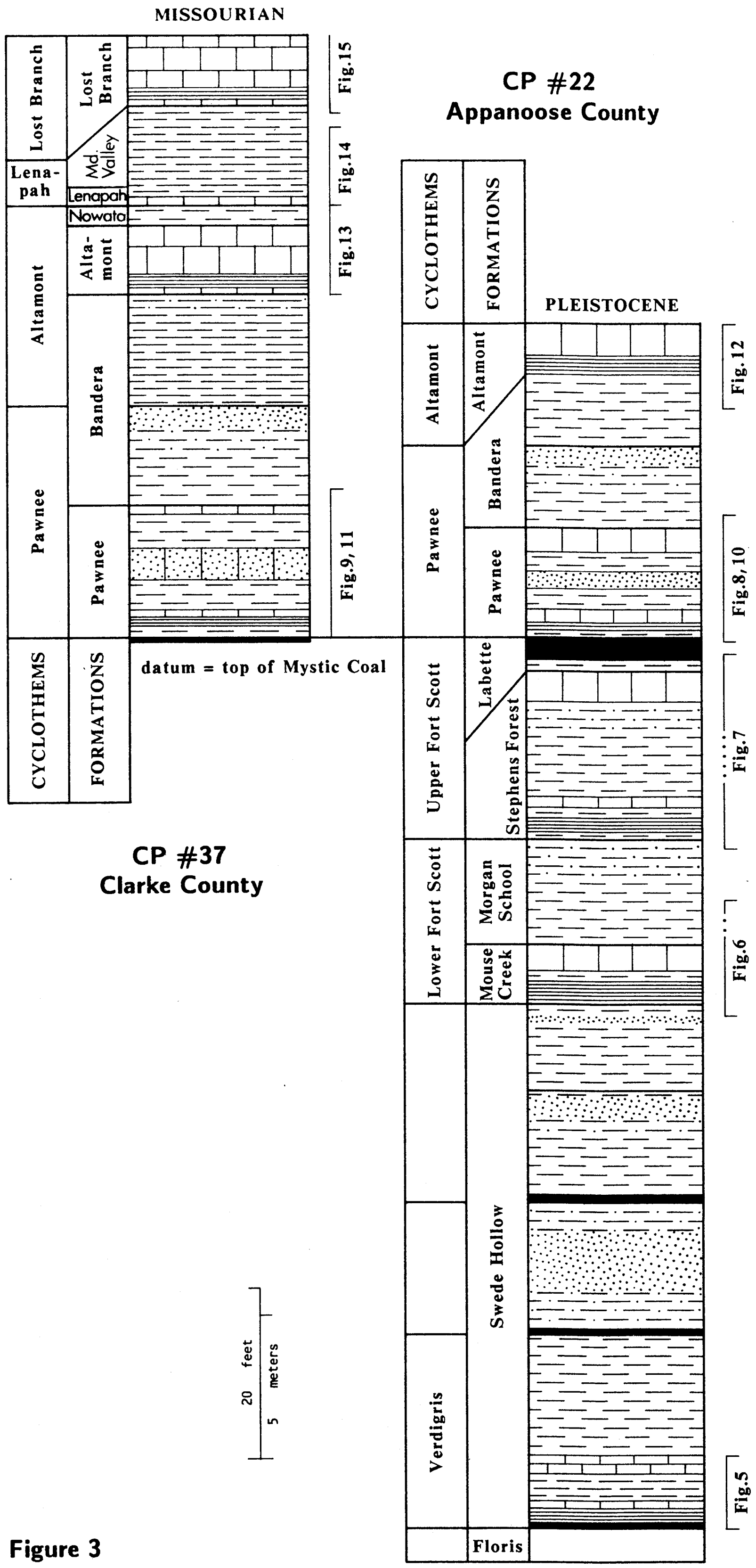

MISSOURIAN
CP #22
Appanoose County
PLEISTOCENE
CP #37
Clarke County
CYCLOTHEMS
FORMATIONS
Lost Branch
Lena-pah
Altamont
Pawnee
Lost Branch
Md. Valley
Lenapah
Nowata
Alta-mont
Bandera
Pawnee
datum = top of Mystic Coal
Fig.15
Fig.14
Fig.13
Fig.9, 11
Altamont
Pawnee
Upper Fort Scott
Lower Fort Scott
Verdigris
Altamont
Bandera
Pawnee
Labette
Stephens Forest
Morgan School
Mouse Creek
Swede Hollow
Floris
Fig.12
Fig.8, 10
Fig.7
Fig.6
Fig.5
20 feet
5 meters

Figure 3

shore to terrestrial environments. Cycles of sedimentation in these repeating deposits were recognized early by Moore (1936, 1949), who termed them megacyclothems. The Marmaton Group cycles have generally been less well known than Upper Pennsylvanian examples, in part due to the thinner limestones and consequent lack of continuous exposures. Weller (1958) had difficulty relating the Marmaton cycles to younger Pennsylvanian cycles and considered them to be incompletely developed. Part of the difficulty may have arisen from his recognition of only four megacyclothems, which corresponded with the then-recognized Fort Scott, Pawnee, Altamont, and Lenapah limestone formations. In actuality, the Fort Scott in south-central Iowa contains the marine portions of two major depositional cycles and thus, five such cycles are present in the group. The revised stratigraphic nomenclature proposed by Ravn and others (1984) was designed to reflect this new understanding and is followed herein (Figs. 1, 3). Major revisions are the inclusion of the Excello Shale Member with the Blackjack Creek Limestone in the lowermost Marmaton Mouse Creek Formation, the division of the remainder of the former Fort Scott into the Morgan School and Stephens Forest formations, and recognition of the newly proposed Lost Branch Formation (Heckel, 1984) as distinct from the Lenapah Formation.

Upper Desmoinesian Eustatic Cyclothems

Recent interpretations of the cyclothemic sequence in the Midcontinent Middle and Upper Pennsylvanian stress the central position of the black phosphatic shale facies. Heckel (1977) presented a synthesis of arguments based on a wide variety of lithologic and paleontologic criteria in support of a deep-water, yet still epicontinental, origin for the black phosphatic shale sandwiched between two marine limestones. These form a sequence that characterize typical "Kansas" cyclothems, which are developed particularly in Upper Pennsylvanian strata along the Midcontinent outcrop from Kansas into Iowa. More recently, Heckel (1980) presented a major regional synthesis of the paleogeography during deposition of a typical Upper Pennsylvanian cyclothem as a result of one complete eustatic rise and fall of sea level, and he described the manner in which the environmental model may be applied to the Illinois-type cyclothems (Fig. 4) that characterize most of the Marmaton Group. The basic cycle of 1) transgressive shale or limestone, 2) deepest-water shale, 3) regressive limestone, followed by 4) detritral influx (usually delta progradation) is supported further by studies of carbonate petrology and diagenesis (Heckel, 1983) and clay mineralogy (Schutter, 1983) and has been applied to many Upper Pennsylvanian cycles (e.g., Ravn, 1981; Mitchell, 1981; Heckel, 1978; Heckel *et al.*, 1979) and to some Middle Pennsylvanian cycles (Schenk, 1967; Price, 1981) along the Midcontinent outcrop belt.

The actual lithologic sequence in the six Upper Desmoinesian eustatic cyclothems that form the basis of this study contains some variations to the basic cycle that can readily be described in terms of the megacyclothemic nomenclature of Moore (1936) and Heckel and Baesemann (1975). In the idealized case of maximum cyclic development, Moore recognized five limestone members, which were designated by relative position as "lower," "middle," "upper," "super," and "fifth." The middle and upper limestone are separated by the most distinctive shale member, which usually contains the black, fissile, phosphatic facies, in the only position that this facies occupies in the sequence. In deference to its central position, Heckel (1977) referred to this member as the "core" shale, an appropriate term, especially in cyclothems in which the black facies is poorly developed or absent. Heckel and Baesemann (1975, p. 506-507) noted that the "lower" and "fifth" limestones are rarely developed in Upper Pennsylvanian cyclothems. "Super" limestones occur in less than half of the Missourian cyclothems and were regarded by Heckel and Baesemann (ibid.) either as separate marine incursions or as higher parts of the upper limestone separated by fortuitous shales. Detrital units that separate the marine-dominated limestone-formation portions of the sequence are termed "outside" shales.

Each individual lithologic sequence in the six Upper Desmoinesian cyclothems studied generally contains three limestone members: middle, upper, and super. Lower limestone do not occur in these cyclothems, and a possible fifth limestone equivalent is noted in only one of the six cyclothems. In the ideal cyclothem, the lower boundary is usually marked by an unconformity, but in the cores examined, only the lower four cycles (up to the base of the Pawnee Limestone in CP #37) contain obvious breaks in sedimentation (O'Brien, 1977). Generally, cyclothemic deposition is considered to commence with the formation of the rooted seatrock below the coal horizon. Significant coals usually occur only at the top of the outside shale below the position of the middle limestone, but local coals have also noted below the super limestones, in particular, below the Higginsville and Coal City members (Van Eck, 1965). The horizon of the transgressive middle limestone is readily apparent, but the precise character of the bed changes markedly upward in the Iowa section, progressing through time from thin marine shales to thicker marine shales and finally marine limestones. The core shale, which represents maximum inundation, is also readily apparent. All are phosphatic, but black, fissile facies are well-developed in only the lower four cyclothems studied. The upper limestone members are the most persistent laterally in the Marmaton Group, and historically are the best recognized in the sequence. This study also indicates that super limestones are developed in five of the six cyclothems (but, see caption to Fig. 16). Rather than merely parts of the upper limestone separated by the intervention of shales during relative stillstand of sea level, most of these apparently resulted from minor eustatic transgressive events.

LITHOLOGIC SUCCESSION AND CONODONT DISTRIBUTION

Swede Hollow Formation

The Swede Hollow Formation is the uppermost of four subdivisions of the Cherokee Group recognized by Ravn and others (1984). It consists of the strata associated depositionally with the youngest major eustatic marine cyclothems of the Cherokee Group along with several overlying deltaic cyclothems. In southeastern Iowa, the unit is generally consistent in thickness, averaging about 100 feet (31 m), and the base is marked by the laterally persistent Whitebreast Coal Member. Overlying the Whitebreast Coal are the Oakley Shale and Ardmore Limestone members, a couplet that represents the marine eustatic core of a cyclothem analogous to the Excello Shale-Blackjack Creek Limestone couplet of the lower Marmaton Group. The remainder of the formation includes at least three clastic wedges of probable deltaic origin that are separated by two laterally traceable coals, the Wheeler and Bevier

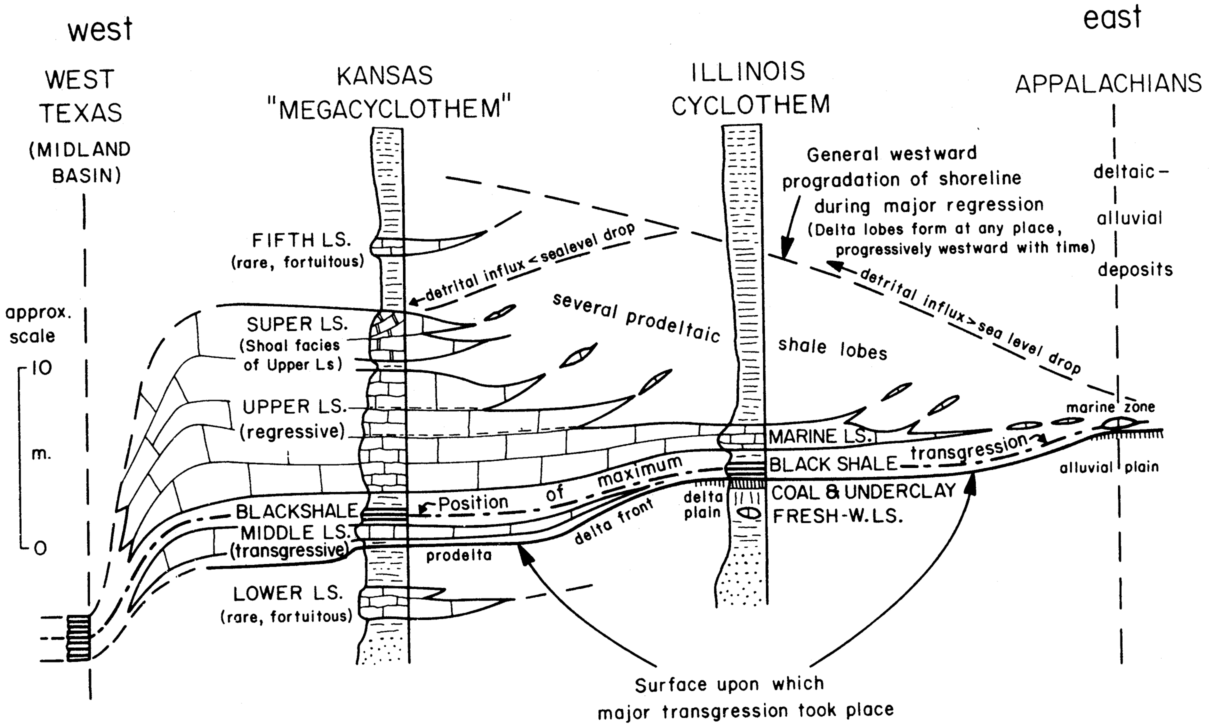


Figure 4. Generalized restored cross section of typical Upper Pennsylvanian eustatic cyclothem along axis of Midcontinent Sea. Shown are relations of members and facies between Kansas- and Illinois-type cyclothems and with marine deposits in Appalachian area and west Texas Basins. (After Heckel, 1980, Fig. 4.).

Coal members. The top of the formation is marked by the Mulky Coal Member and/or the base of the overlying Excello Shale Member of the Mouse Creek Formation.

Whitebreast Coal Member

The Whitebreast coal is notable for its lateral persistence and uniformity of thickness in southeastern Iowa. In CP #22, it is approximately one foot (30 cm) thick (Fig. 5), which is an average value for the area. R. L. Ravn (pers. comm., 1981) examined the miospore assemblage of the unit and biostratigraphically confirmed the previous lithostratigraphic correlations of the Whitebreast with the Colchester (No. 2) Coal of the Illinois Basin, and with the Croweburg Coal in Kansas and Missouri.

Oakley Shale Member

The Oakley Shale in CP #22 is 2.2 feet (67 cm) thick and consists of black, fissile shale with common nonskeletal phosphate in small granular nodules and lamellae, especially in the middle portion. Just above the base is a 0.3-foot-thick (9 cm) heavily pyritic dolomite nodule or lenticular bed with septarian calcite fracture fillings. This sample (22Y) could be only partially disaggregated, and the residue contains only fragments of conodonts. The basal sample of the shale yielded about 1200 conodonts elements/kilogram. The abundance increases in a three-inch zone in the lower middle portion of the shale (sample 22W) to an extrapolated 2770 elements/kilogram. The increase is largely due to the abundant and restricted occurrence of platform and ramiform elements of *Gondolella*, which constitute about 75 percent of the total recovered in that sample. The lower portion of the shale also contains *Idiognathodus* and *Neognathodus* with their platform elements present in a ratio of just over three to one except in sample 22V, which, despite an overall lower extrapolated abundance, yielded a ratio approaching 1:1. *Idioprioniodus* elements make up the remainder of the fauna.

The upper portion of the Oakley in CP #22 differs from lower Marmaton Group black shales in that the contact with the overlying Ardmore Limestone is interbedded. The uppermost sample from the black facies (22T) contains a thin, lenticular, medium grey, skeletal calcarenite composed largely of brachiopod fragments with common bryozoans, echinoderm debris, molluscs and ostracodes. The shale in this sample yielded a second peak of abundance, containing an extrapolated 3500-plus elements/kilogram. The fauna from the upper portion of the black shale is dominated by platform elements of *Idiognathodus* and *Neognathodus* in a ratio of about 3.5:1. *Diplognathodus* elements form a conspicuous part of the fauna with lesser numbers of *Idioprioniodus* elements, and rare *Gondolella* and *Anchignathodus* platforms.

Ardmore Limestone Member

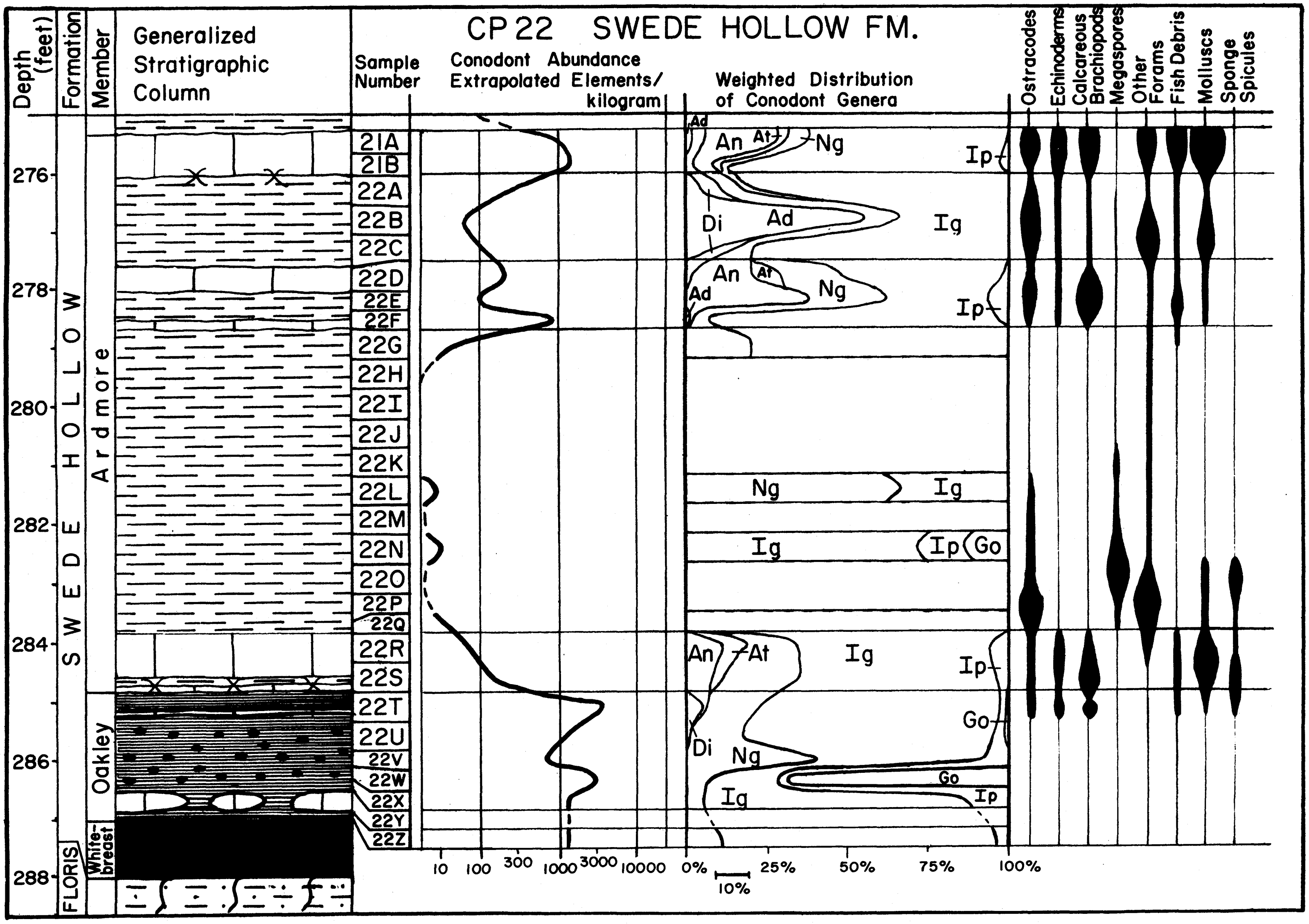
The Ardmore Limestone was named from Missouri, where it is part of the Verdigris Formation, which is the name used in Kansas and Oklahoma. In southeastern Iowa, the Ardmore usually displays a three-part subdivision consisting of two limestone horizons separated by a laterally persistent shale (Ravn *et al.*, 1984). In CP #22, both the upper and lower limestones are represented by multiple beds (Fig. 5). The lower limestone is one foot (30 cm) thick and consists of two beds of medium grey, skeletal calcilutite separated by a thin bioturbated, dark grey, slightly silty shale parting. The extrapolated conodont abundance decreases upward, from over 100 to about 50 elements/kilogram. In addition to *Idiognathodus*, *Neognathodus* and minor *Idioprioniodus*, *Anchignathodus*, and *Aethotaxis* are present.

The middle shale interval of the Ardmore Limestone is about 5 feet (1.5 m) thick, dark grey, sparsely fossiliferous in the lower portion, and increasingly silty upward. The lower portion sporadically yielded *Idiognathodus*, *Neognathodus*, and minor *Gondolella* platforms and *Idioprioniodus* elements, as well as ramiform fragments. Extrapolated abundance is very low, however, only about 10/kilogram. Conodont elements are absent in the upper middle portion of the shale, but small numbers of *Idiognathodus* and *Neognathodus* platforms were found in the uppermost sample.

The upper limestone horizon of the Ardmore in CP #22 includes three limestone beds. The lower two thin beds are medium grey, slightly argillaceous skeletal calcilutite that are separated by 0.5 foot (15 cm) of medium dark grey, calcareous, fossiliferous shale. The upper bed is 0.75 foot (23 cm) thick, massive, light medium grey skeletal calcilutite, mottled by bioturbation, with a diverse macrofauna including corals and trilobites, and chondrites-type burrows affecting the lower contact. It is separated from the lower two beds by 1.7 feet (52 cm) of medium grey, silty shale that contains abundant ostracodes, forams, and molluscs.

Conodont elements range throughout the upper limestone interval of the Ardmore. Extrapolated abundances, however, vary greatly. The lowermost sample (22F) yielded about 800 elements/kilogram but the overlying calcareous shale and limestone contained only about 100 and 200 elements/kilogram, respective-

Figure 5. Distribution of conodonts and other fossils in Swede Hollow Formation in CP #22. Lithologic symbols standard except for:
Phosphorite nodules - ⬬ Root traces - ⊤
Chondrites-type burrows - X̅
Conodont genera are abbreviated as follows: *Adetognathus* -Ad, *Aethotaxis* - At, *Anchignathodus* - An, *Diplognathodus* - Di, *Gondolella* - Go, *Idiognathodus* - Ig, *Idioprioniodus* - Ip, *Neognathodus* - Ng, *Stepanovites* - St. Note change in scale at left side of logarithmic abundance curve. Weighted distribution of conodont genera was calculated on the basis of maximum abundance of platform or any other paired element in the apparatus reconstruction. Distribution of other fossil groups is based on observations from coarse residues of conodont samples and, in part, from thin section descriptions of O'Brien (1977) for CP #37.


CP22 SWEDE HOLLOW FM.
Depth (feet)
Formation
Member
Generalized Stratigraphic Column
Sample Number
Conodont Abundance Extrapolated Elements/kilogram
Weighted Distribution of Conodont Genera
Ostracodes
Echinoderms
Calcareous Brachiopods
Megaspores
Other Forams
Fish Debris
Molluscs
Sponge Spicules
276
278
280
282
284
286
288
SWEDE HOLLOW
FLORIS
Ardmore
Oakley
White-breast
21A
21B
22A
22B
22C
22D
22E
22F
22G
22H
22I
22J
22K
22L
22M
22N
22O
22P
22Q
22R
22S
22T
22U
22V
22W
22X
22Y
22Z
10
100
300
1000
3000
10000
0%
25%
50%
75%
100%
10%
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Ad
Ng
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Ig
Ig
Ip
Go
An
At
Ig
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ly. This interval yielded *Idiognathodus*, *Neognathodus*, *Anchignathodus* and minor *Idioprioniodus* elements with rare *Adetognathus* in only the lowermost sample. *Diplognathodus* and *Aethotaxis* elements occur in the upper of the two limestone beds. The middle shale bed of the upper limestone interval contains a sharply different fauna. *Adetognathus* increases to dominance relative to *Idiognathodus* in the central portion, with minor *Anchignathodus* ranging throughout. This central zone yielded the lowest extrapolated abundance, only about 40 elements/kilograms. Minor *Diplognathodus* occur near the base of the shale and also near the top with rare *Neognathodus*. Extrapolated abundance increases from about 200 elements/kilogram in the upper portion of the shale to about 1400/kilogram in the lower portion of the uppermost limestone bed. This bed yielded a well-preserved fauna, which, although dominated by *Idiognathodus* platform and ramiform elements, contains representatives of all the individual element types included in *Anchignathodus* and *Aethotaxis*, as well as minor *Neognathodus*, *Diplognathodus*, and *Idioprioniodus* elements. Rare *Adetognathus* occur in the upper one-half of the bed, and total abundance decreases slightly upward.

Wheeler, Bevier and Mulky Coal Members and Associated Strata

Overlying the Ardmore Limestone are three clastic wedges, each with a named coal member at the top. The first wedge overlies the uppermost bed of the Ardmore and consists of approximately 19 feet (5.8 m) of medium grey, silty shale with the Wheeler Coal at the top. The lower 2.0 feet (61 cm) contain sparse fossil debris, but unfortunately, this shale was not sampled initially, and the core has since been rendered unavailable due to other research purposes. The middle portion of this grey shale is mottled maroon in color suggesting partial oxidation probably related to subaerial weathering during soil formation. Near the top, the shale becomes poorly stratified and rooted, grading upward to the mudstone seatrock of the Wheeler Coal. The Wheeler in CP #22 is 1.4 feet (43 cm) thick.

The Wheeler Coal is overlain by the second clastic wedge, which consists of approximately 18 feet (5.5 cm) of thinly interbedded medium grey, argillaceous siltstone and light grey fine-grained, slightly argillaceous sandstone. This unit is crossbedded and solemarked in the lower portion, and coarsens slightly upward, grading to massive, argillaceous, rooted sandstone in the upper portion. Near the top, the sandstone grades into the rooted mudstone seatrock of the Bevier Coal. The Bevier is 1.25 feet (38 cm) thick in the core.

The Bevier Coal is overlain by the third clastic wedge, which includes in the lower portion a 35-foot-thick (10.7 m) coarsening-upward sequence that grades form medium dark grey, silty shale through thinly interbedded shale and cross-laminated sandstone to massive light grey, fine-grained, calcite-cemented sandstone. The shale in the lower 4.0 feet (1.22 m) contains plant fossils and pyritized pelecypods. A spot sample taken immediately above the Bevier Coal (16A, Plate 1) confirms the presence of small numbers of conodont elements. The fauna consists mainly of *Idiognathodus* elements, but includes *Adetognathus* elements and *Neognathodus* platforms. The massive sandstone grades upward through a rooted siltstone to a silty mudstone that contains several poorly defined smut zones, probably equivalent to a coal horizon elsewhere. The upper portion of the third clastic wedge includes an additional coarsening-upward clastic sequence that grades by alteration from mottled maroon shale to fine-grained, argillaceous, calcareous sandstone, which in turn grades upward into rooted mudstone seatrock of the Mulky Coal. The Mulky, however, is represented by only a thin coal smut in this core.

Mouse Creek Formation

The Mouse Creek Formation (Ravn *et al.*, 1984) is defined to include marine strata associated with the lowermost depositional cycle of the Marmaton Group (the lower Fort Scott cyclothem of O'Brien, 1977). In southeastern and south-central Iowa, the Mouse Creek is a thin unit, ranging from about 4.0 to 7.0 feet (1.2 to 2.1 m) which includes two laterally persistent members, the distinctive black Excello Shale and the overlying Blackjack Creek Limestone.

Excello Shale Member

In CP #22, the Excello Shale is 2.7 feet (82 cm) thick and rests, apparently conformably, on the thin coal smut considered to be equivalent to the horizon of the Mulky Coal (Fig. 6). The Excello exhibits a three-part subdivision, which parallels that described throughout the southern Mid-continent by James (1970), although he did not examine the unit in Iowa. The lower portion, considered by James to be transgressive in nature, is represented in the core by less than 0.2 foot (6 cm) of dark grey, slightly silty shale with minor carbonaceous plant debris. The middle portion, 1.5 feet (46 cm) thick, is dark green-grey to black, laminated clay shale with abundant lenses and lamellae of granular, nonskeletal phosphate and no apparent macrofauna. The contact between the middle and upper portions is an abrupt gradation. The upper portion is 1.0 foot (30 cm) thick and consists of mottled medium grey and light to medium grey-green, silty shale with common calcareous brachiopod debris. James (1970) described the upper portion of the Excello as a bioturbated interval, and this in part may account for the mottled coloration and slightly disturbed bedding observed in the core, but the only indisputable bioturbation noted is a zone of chondrites-type burrows that extend downward from the base of the overlying Blackjack Creek Limestone.

The Excello Shale yielded an extrapolated abundance in excess of 1000 elements/kilogram in each of six samples. *Idiognathodus*, *Neognathodus*, and *Idioprioniodus* occur through the entire interval. The ratio of *Idiognathodus* platforms to *Neognathodus* is over 5:1 near the top and bottom, but drops to about 2:1 in zones in the middle of the shale. *Gondolella* has a narrower vertical range, occurring only in the middle two samples from the black phosphatic facies. The presence of *Gondolella* in those samples coincide with an increase in the overall abundance to an extrapolated maximum of 5130 elements/kilogram in sample 14E. In the overlying sample, 14D, *Gondolella* elements constitute in excess of 50% of the total number recovered, and elements of the other three genera area are slightly decreased in abundance relative to other Excello samples. *Diplognathodus* occurs sporadically in the Excello, but is extremely rare, represented by a total of three specimens.

Blackjack Creek Limestone Member

The Blackjack Creek Limestone Member in CP #22 is 3.2 feet (98 cm) thick (Fig. 6). It is dominantly a massive green-grey, argillaceous, skeletal calcilutite with a diverse macrofauna and probable bioturbation expressed by light green-grey, argillaceous mottling. The upper portion includes two thin beds of light medium grey, slightly argillaceous calcilutite with contacts disturbed by soft sediment deformation and/or bioturbation.

The extrapolated total number of elements recovered from the Blackjack Creek Limestone is greatly reduced compared to the underlying shale, averaging only about 100 elements/kilogram, and abundance tends to decrease slightly upward in the unit. The conodont fauna is numerically dominated by *Idiognathodus* elements. *Anchignathodus* also ranges throughout the Blackjack Creek, but is not found in the overlying or underlying shales. *Idioprioniodus* elements form a minor, but consistent part of the fauna in the lower and middle portions of the member, but diminish rapidly to absence in the uppermost sample examined. *Neognathodus* P elements, on the other hand, occur in significant numbers only in the upper one-half of the member, and diminish downward to absence in the lowermost sample. *Diplognathodus* again is a rare element of the fauna, represented by only a single specimen.

Morgan School Shale

The Morgan School Shale (Ravn *et al.*, 1984) constitutes the lower, terrestrial to marginally marine clastic part of the Little Osage Shale as previously defined, and is associated depositionally with the Mouse Creek Formation. It is a laterally variable unit in south-central Iowa, ranging from 1.0 foot (30 cm) to about 20.0 feet (6.1 m) thick. The Summit Coal Member, at the top of the formation, is usually poorly developed in Iowa, but a laterally persistent smut zone distinctly marks its horizon.

In CP #22, the Morgan School Shale is 16.3 feet (5.0 m) thick and consists of a single, coarsening upward clastic sequence (Fig. 6). The lower 2.0 feet (61 cm) are light green-grey, slightly silty shale with common calcareous brachiopod debris and ostracodes. Extrapolated conodont abundance diminishes rapidly from about 80/kilogram at the base to less than 10/kilogram, and the fauna consists almost entirely of *Idiognathodus* platform elements. The next approximately 10 feet (3 m) grade imperceptibly upward through silty shale to argillaceous siltstone and contain common carbonate nodules. The nodules are dominantly light grey calcilutite, locally dolomitic, up to 3 inches (7.6 cm) thick, and some may represent disrupted lenticular beds. Spot samples through this interval yielded small numbers of *Idiognathodus* elements in most shale samples, but one sample, 12B, yielded an unusual conodont fauna from both the shale and carbonate nodules. The total of 64 elements recovered is dominated by *Idiognathodus* platforms, but includes platform elements of *Adetognathus*, *Anchignathodus*, and *Neognathodus*, as well as platform and ramiform elements of *Gondolella* and rare *Idioprioniodus* elements. All specimens in this mixed fauna are quite small and most are incomplete. The largest specimen recovered is an *Idiognathodus* P element 0.57 mm in length, which includes most of the blade.

The upper portion of the Morgan School consists of light green-grey argillaceous, rooted siltstone with small carbonate nodules that did not yield

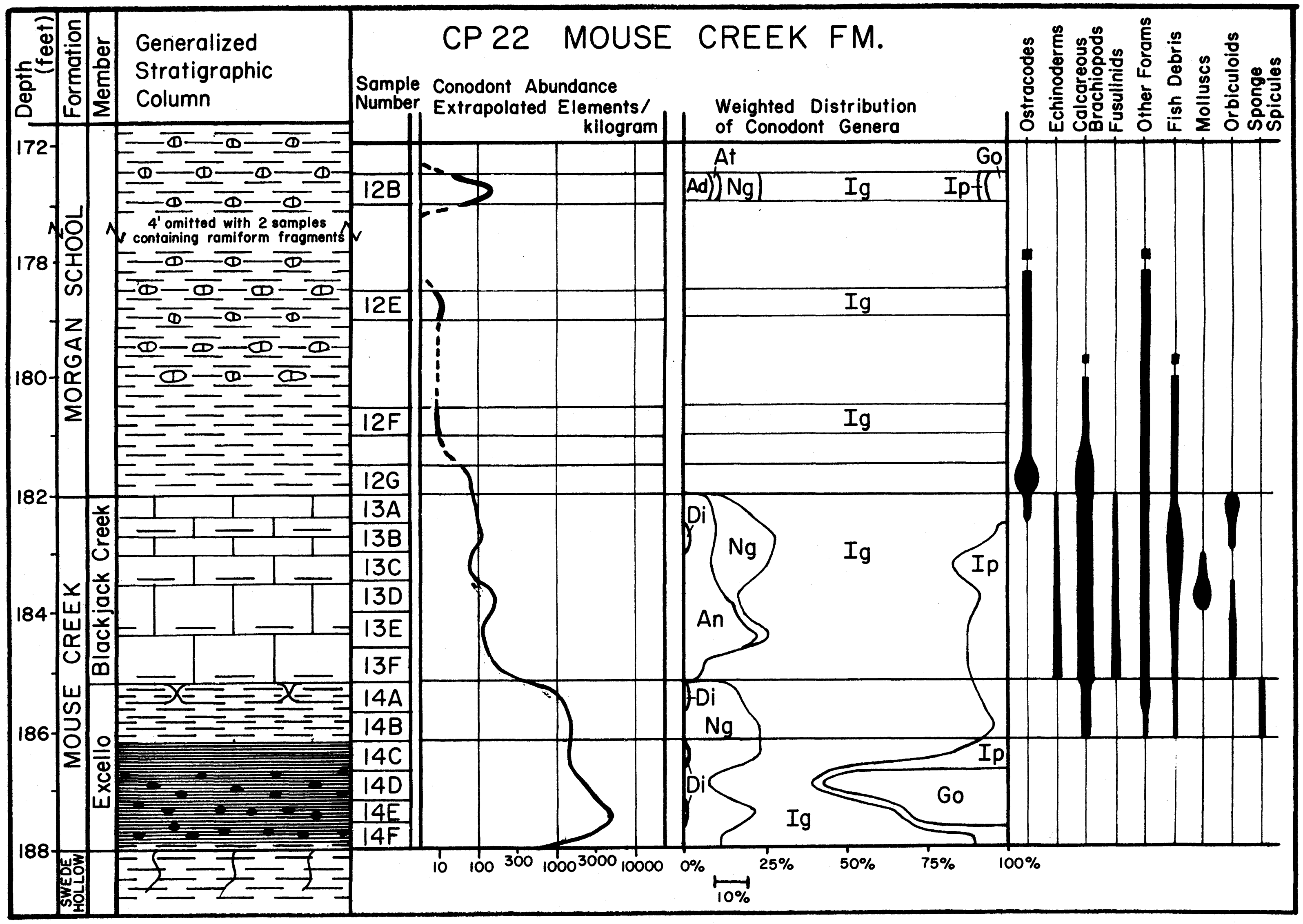


Figure 6. Distribution of conodonts and other fossils in Mouse Creek Formation in CP #22. See figure 5 for explanation.

conodonts. About 0.75 foot (23 cm) below the top, the siltstone grades to a rooted, silty mudstone seatrock that fines upward and darkens in color. The top of the formation is marked by the half-inch thick, vitrain-rich Summit Coal bed. (Fig. 7).

Stephens Forest Formation

The Stephens Forest Formation, as defined by Ravn and others (1984) encompasses the marine-dominated phase of the second depositional cycle above the base of the Marmaton Group (the upper Fort Scott cyclothem of O'Brien, 1977). In southeastern Iowa, the Stephens Forest is generally consistent in thickness, ranging from 23 to 27 feet (7.0 to 8.2 m), and contains four laterally persistent members, in ascending order, the Little Osage Shale, Houx Limestone, an unnamed shale, and Higginsville Limestone members. The upper two members are more variable in character laterally than the lower two and are included in the Stephens Forest because, as Ravn and others (1984) indicate, the Higginsville constitutes a "super" limestone analogous to the Coal City Limestone Member of the Pawnee Formation (Price, 1981).

Little Osage Shale Member

The Little Osage Shale, as redefined by Ravn and others (1984), includes a three-part subdivision paralleling that observed in the Excello Shale. In CP #22, the lower, "transgressive" interval consists of 0.5 foot (15 cm) of thinly interbedded lenticular, medium grey, argillaceous skeletal calcilutites and calcarenties, and medium dark grey, silty shale with carbonaceous plant debris in the lower portion (Fig. 7). This grades abruptly upward into 2.0 feet (61 cm) of black, fissile clay shale with abundant non-skeletal phosphate nodules and lamellae. The middle portion grades abruptly to the upper, bioturbated interval, which consists of approximately one foot (30 cm) of dark grey, slightly silty, fossiliferous shale with chondrites-type burrows carrying lighter colored, slightly coarser argillaceous material downward from the base of the overlying Houx Limestone Member.

The conodont fauna of the lower, transgressive portion of the Little Osage Shale is dominated by *Idiognathodus* elements, with small numbers of platform elements of *Adetognathus*, *Neognathodus*, and *Anchignathodus*. *Diplognathodus* is rare, represented by a single specimen. The extrapolated abundance is approximately 300 elements/kilogram. The abundance increases upward through the lower portion of the black phosphatic shale facies to about 1000 elements/kilograms through the upper half of the black shale and lower half of the grey shale, and decreases upward into the Houx Limestone. The black shale and the overlying bioturbated grey shale contain only three genera, *Idiognathodus*, *Neognathodus*, and *Idioprioniodus*. *Neognathodus* platforms show an increase in proportion relative to *Idiognathodus*, which approaches 1:1 in the zone of maximum abundance, but this ratio decreases upward as *Idiognathodus* platforms become more abundant. *Idioprioniodus* is also most abundant in the lower portion of the black shale, and decreases slightly upward.

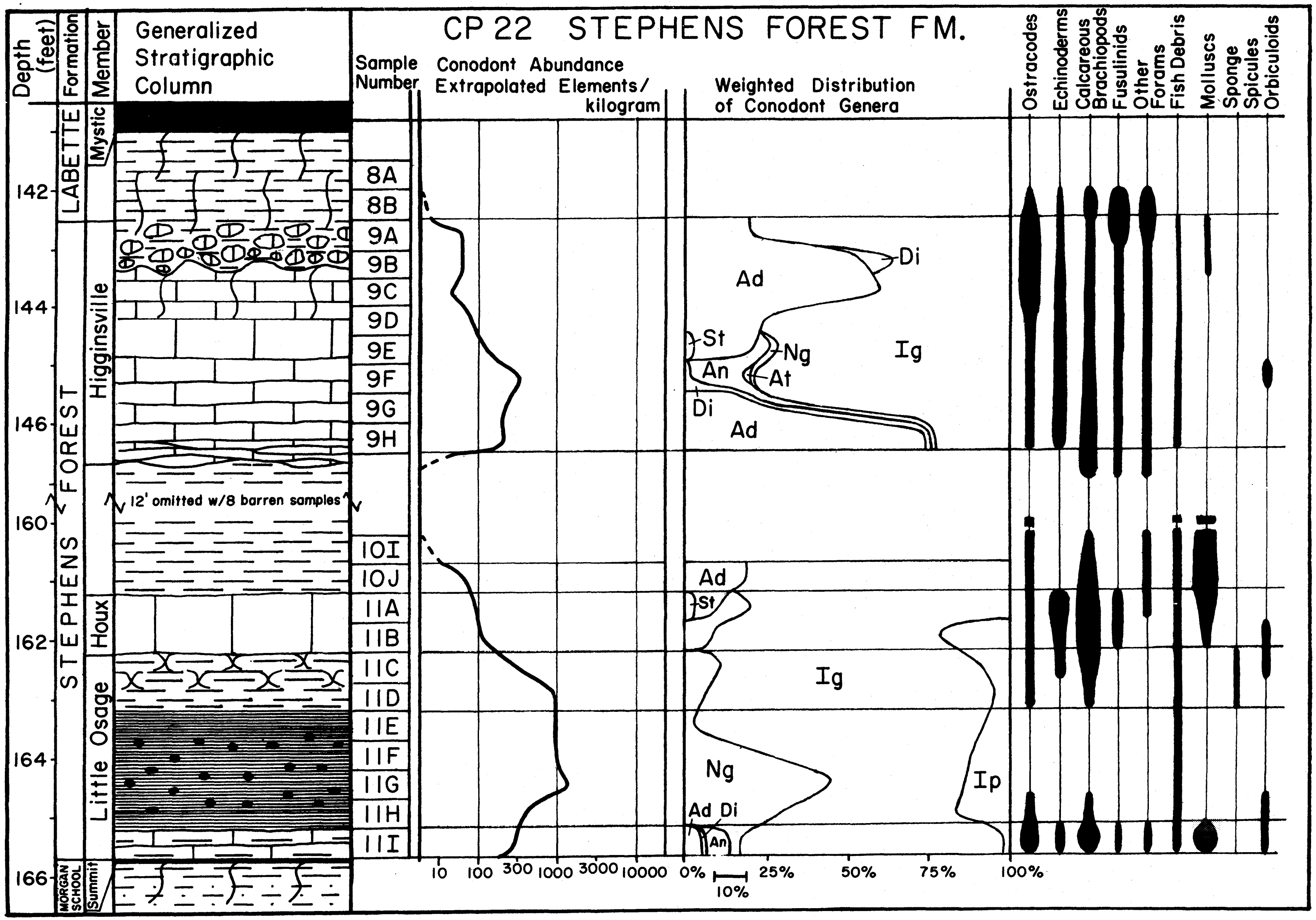


Figure 7. Distribution of conodonts and other fossils in Stephens Forest Formation in CP #22. See figure 5 for explanation.

Houx Limestone Member

The Houx is represented in CP #22 by nearly one foot (30 cm) of light medium grey, slightly argillaceous, skeletal calcilutite (Fig. 7) that is mottled with calcareous, argillaceous siltstone by probable bioturbation. Conodont abundance in the Houx averages about 100 elements/kilogram decreasing slightly upward, and the fauna is dominated by *Idiognathodus* elements. *Anchignathodus* also ranges throughout the Houx, but is absent in both the overlying and underlying shales. *Idioprioniodus* elements occur only in the lower one-half, and minor *Adetognathus* and *Stepanovites* elements are found only in the upper one-half.

Unnamed Shale Member

The unnamed shale member overlying the Houx includes in the lower half approximately 6 feet (1.8 m) of dark grey, slightly silty shale, which contains obvious macrofossil debris only in the lower one foot (30 cm). Identifiable conodonts were found only in the lowermost of 10 samples, and consist mostly of small numbers of *Idiognathodus* platforms and minor *Adetognathus* elements. The dark grey shale grades upward over about 4 feet (1.2 m) by interlamination to light grey, argillaceous, micaeous, cross-laminated siltstone, which may represent the Flint Hill Sandstone Member of north-central Missouri. Sample residues from this portion contain abundant fine-grained, granular siderite. The upper one foot of the member grades to green-grey, slightly silty, calcareous mudstone below the upper contact, which shows relief in the core and may be disconformable.

Higginsville Limestone Member

The Higginsville Limestone in CP #22 is approximately 4.5 feet (1.4 m) thick and consists dominantly of light brown and green-grey, slightly argillaceous skeletal calcilutite (Fig. 7). The lower portion is lenticularly interbedded with green clay partings and becomes more thickly bedded and fossiliferous upward. The middle portion is massive, but contains common vertically anastomosing clay partings along which carbonaceous root impressions are observed to penetrate in the upper half. Near the top, the unit grades upward to fractured limestone beds or nodules in a matrix of medium green, silty mudstone. The contact with the overlying Labette Shale is gradational, but placed in the core at the uppermost limestone nodule.

Conodont faunas through the Higginsville in this core vary vertically in such a way as to suggest three subdivisions. The lower, lenticularly bedded portion yielded dominantly *Adetognathus* elements near the base, but with *Idiognathodus* increasing and *Adetognathus* diminishing upward. *Anchignathodus* and *Diplognathodus* are minor elements in the fauna. The middle portion, represented in the core by sample 9F, had the highest extrapolated abundance of elements in the unit, 330/kilogram. This fauna is dominated by *Idiognathodus*, and *Adetognathus* is conspicuously absent. *Anchignathodus* reaches its maximum, forming about 15% of the fauna. *Diplognathodus*, *Aethotaxis*, and *Neognathodus* are minor elements of the fauna. The upper portion (sample 9E and above) has extrapolated abundances that diminish from approximately 100/kilogram at the bottom to an average of about 30/kilogram toward the top. The faunas recovered contain minor *Anchignathodus, Neognathodus,* and *Stepanovites* elements at the bottom, with *Adetognathus* increasing upward in relation to *Idiognathodus* P elements. Most of the individual samples from the upper portion yielded conodonts from both the clay and limestone fractions, but in numbers too small to produce statistically valid comparative ratios between the genera. Nevertheless, *Adetognathus* and *Idiognathodus* are roughly subequal, and minor *Diplognathodus* elements are present as well.

The laterally variable lithology of the Higginsville Member is reflected also in its conodont faunas. Samples from three feet of Higginsville in another core (CP #10), located approximately ten miles to the southeast, yielded a sharply different conodont fauna (Swade, 1977). There, conodonts are present only in the lower one-half of the Higginsville. In addition to *Idiognathodus, Neognathodus, Anchignathodus,* and *Diplognathodus* elements, *Idioprioniodus* elements were recovered, whereas *Adetognathus* was not found.

Labette Shale

The Labette Shale in Appanoose County is much reduced from its thickness and character elsewhere in the state (Van Eck, 1965). In CP #22 it consists entirely of the 2.4-foot (73 cm) thick Mystic Coal Member and its 1.5-foot (46 cm) thick, mudstone seatrock. The mudstone is medium green-grey, silty, and calcareous in the lower portion, becoming finer and darker in color, with poorly preserved pyritic root traces increasing upward. The lowermost sample (8B) yielded only fragments of ramiform conodont elements, but also contained a diverse and abundant micro- and macrofauna. Most of the material is preserved as pyritic replacements and casts and includes ostracodes, fusulinids, and other calcareous forams, as well as brachiopods and echinoderms.

Pawnee Formation

The Pawnee Formation consists of the marine-dominated portion of the third of the five major eustatic cyclothems present in the Marmaton Group. In Iowa, it includes four laterally persistent members, in ascending order: Anna Shale, Myrick Station Limestone, Mine Creek Shale, and Coal City Limestone. Price (1981) has recently demonstrated that, although variable in thickness and character, these same subdivisions are recognizable across virtually the entire Midcontinent. The Anna Shale and Myrick Station Limestone form the marine-eustatic core of the cyclothem, analogous to the Little Osage Shale-Houx Limestone couplet of the Stephens Forest Formation, whereas the Coal City Limestone is a super limestone, analogous to the Higginsville Limestone Member. The Mine Creek Shale is the most laterally variable member of the Pawnee, ranging from 6 to almost 40 feet (1.8 to 12.2 m) in thickness. Locally along the Iowa outcrop belt, a coal smut is present at or near the top (Van Eck, 1965).

The Pawnee is included in the overlapping interval of the two cores examined in this study (CP #22, CP #37), and thus, some measure of the lateral variability of the members in south-central Iowa is illustrated. The Pawnee in CP #37 has been examined in detail petrologically by O'Brien (1977), and the lithologic descriptions below are derived in part from his study.

Anna Shale Member

The Anna Shale in southeastern Iowa displays a three-part subdivision that parallels the sequence observed in the Excello and Little Osage shale members. In CP #22 the lower, transgressive portion is 0.5 foot (15 cm) thick and consists of dark grey, slightly silty, calcareous shale with fossil debris increasing as it grades downward to lenticularly bedded, argillaceous skeletal calcarenite near the bottom (Fig. 8), which may represent the "middle limestone" of this cycle. A diverse macrofauna including common calcareous brachiopods and ostracodes is present, with several fragments of chaetetids toward the top. The middle black, fissile, non-calcareous shale is one foot (30 cm) thick and contains abundant non-skeletal phosphate lenses and lamellae. The upper "bioturbated" portion is 0.5 foot (15 cm) thick and is dark grey, slightly silty calcareous shale with sparse fossil debris. The only obvious bioturbation consists of chrondrites-type burrows that extend downward from the overlying Myrick Station Limestone.

Only the lower two subdivisions present in the above sequence are represented in the Anna Shale in CP #37 (Fig. 9). The lower, transgressive portion consists of 1.5 feet (46 cm) of fossiliferous, dark brown to black, slightly silty shale with abundant minute carbonaceous particles. A thin zone of fossil debris, including pyritized pelecypods, lingulid brachiopods, ostracodes and minor calcareous brachiopod debris is present just above the base. All but the calcareous brachiopods decrease upward in this shale, and echinoderm debris is first noted several inches (about 10 cm) above the base. Higher thin, lenticular limestones in the unit include a whole-shell gastropod calcilutite in the middle, which is immediately overlain by a millimeter-thick cleated vitrain band, and a thin, argillaceous, skeletal calcarenite near the top. Above a sharp contact, the upper portion of the Anna consists of a 0.7-foot (21 cm) thick, dark grey to black, laminated shale with common nodules and thin lenses of granular non-skeletal phosphate in the lower two-thirds, and no obvious macrofauna.

The upper bioturbated shale of the Anna, recognized in CP #22, is not present in CP #37. Instead, the contact between the black shale and overlying limestone is sharp, and is inclined at about 20 degrees. This contact is not slickensided and probably is conformable, perhaps suggesting that the Myrick Station is wavy bedded in the core.

The conodont faunas from the Anna Shale are similar in both cores. However, the thicker lower unit in CP #37, which shows an apparent lithologic transition between the two types of black shale described by Heckel and Swade (1977), also shows a more completely developed transition in the faunas. The lowermost sample (19G) contains only small numbers of *Adetognathus* elements and a single *Diplognathodus* element. In the remainder of the unit, *Idiognathodus* constitutes about 50% of the fauna. *Adetognathus* elements diminish upward and disappear below the top of the lower bed, and *Diplognathodus* is restricted to the lower shale bed. *Anchignathodus* occurs only in the upper portion, whereas *Neognathodus* and *Idioprioniodus* increase upward into the black, fissile facies. Extrapolated abundances average about 100 elements/kilogram in the lower portion, increasing to over 500/kilogram in the uppermost sample (19C) from the lower shale and to approximately 3200/kilogram

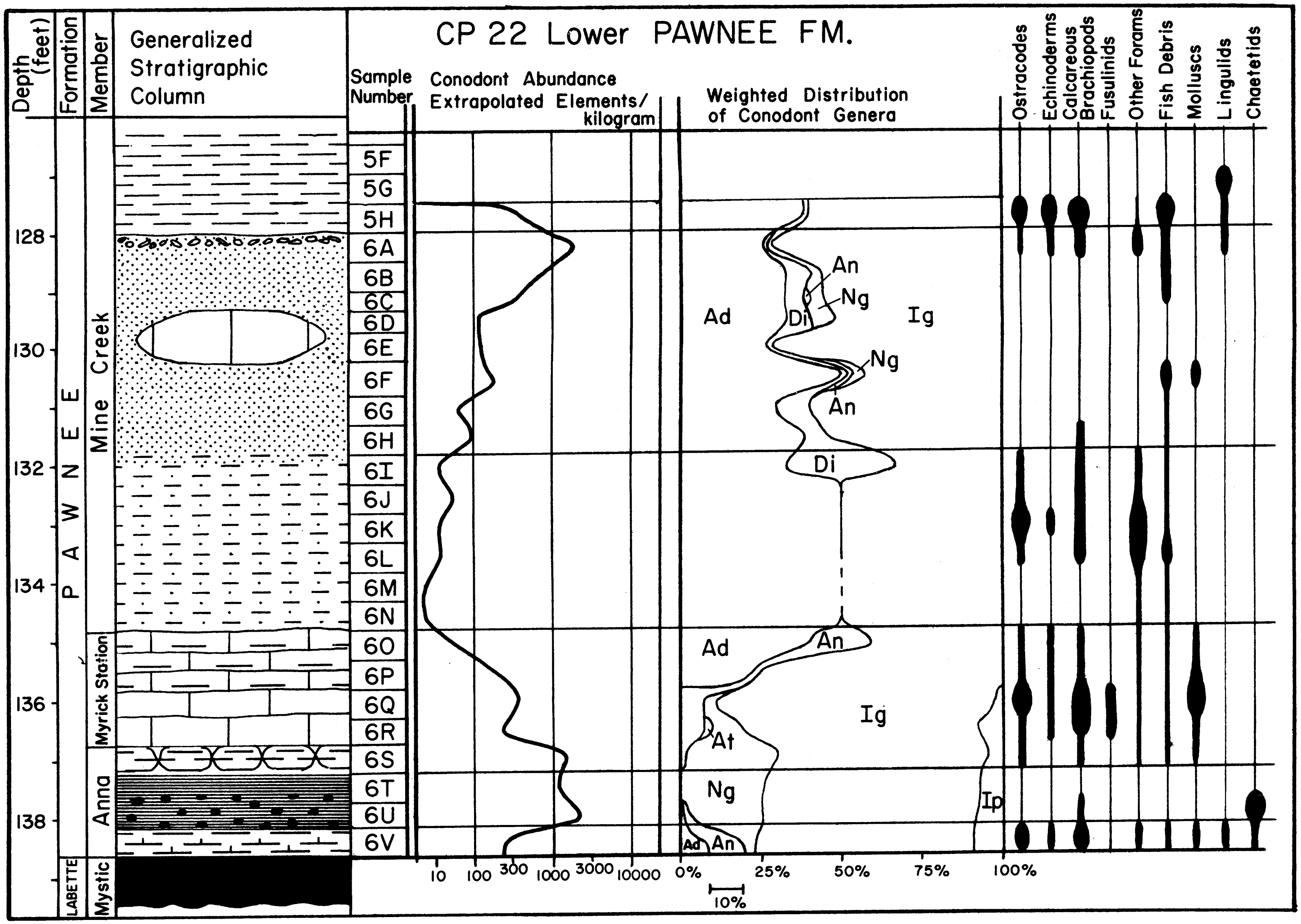


Figure 8. Distribution of conodonts and other fossils in lower Pawnee Formation in CP #22. See figure 5 for explanation.

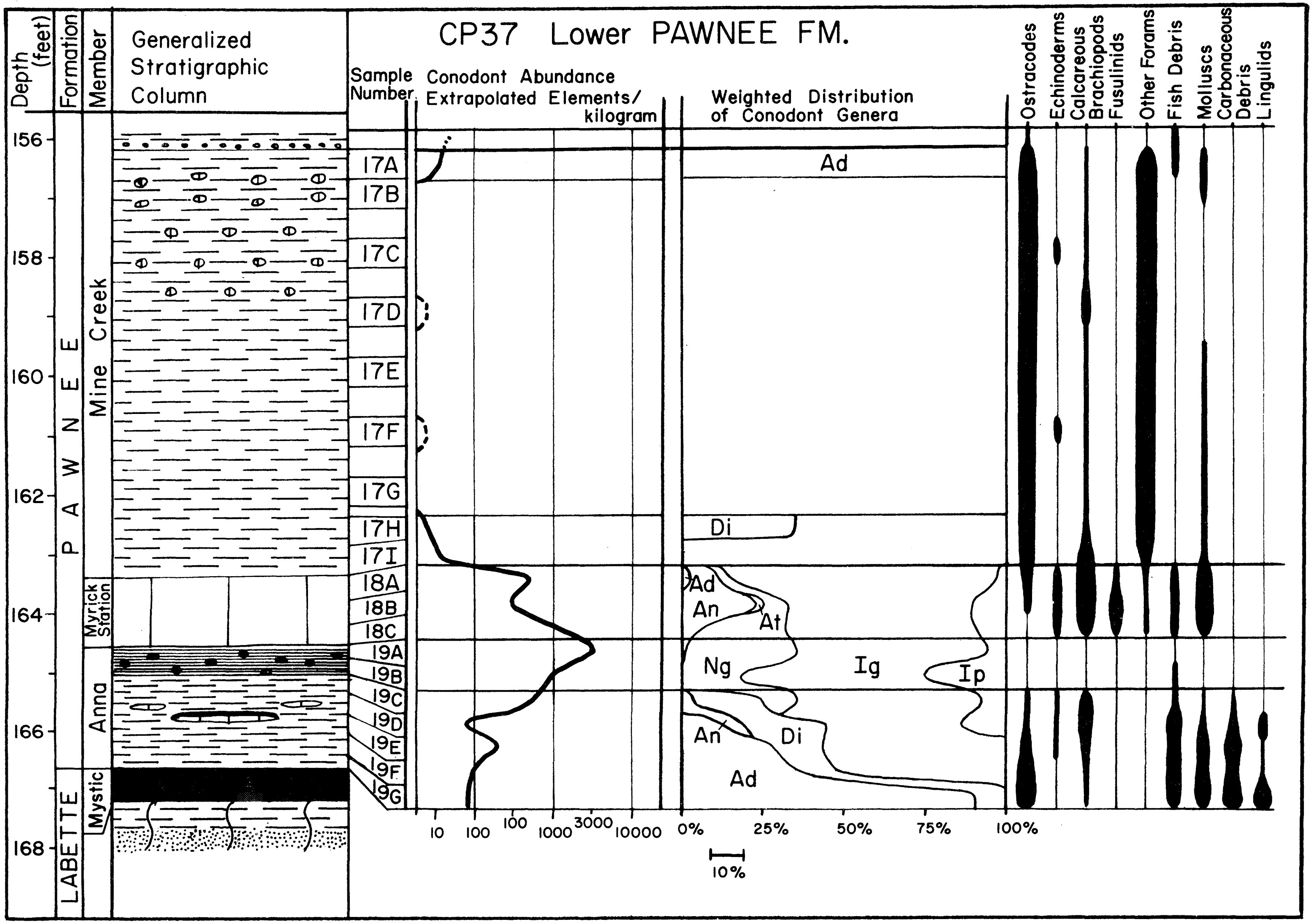


Figure 9. Distribution of conodonts and other fossils in lower Pawnee Formation in CP #37. See figure 5 for explanation.

in the uppermost sample of upper Anna (19A). The fauna from the black, phosphatic shale consists mainly of only three genera, *Idiognathodus, Neognathodus,* and *Idioprioniodus,* with *Idiognathodus* dominant over *Neognathodus* by 2:1. *Anchignathodus* occurs as a minor element near the top, increasing upward into the overlying Myrick Station.

The sequence of faunas in CP #22 is similar, but, especially in the lower portion, is condensed (Fig. 8). The fauna of the lower bed is dominated by *Idiognathodus* elements, with *Adetognathus* and *Anchignathodus,* which diminish upward into the lower portion of the black facies, and *Neognathodus* and *Idioprioniodus,* which increase upward. A maximum abundance of about 2200 elements/kilogram was noted in the lower portion of the black facies, and the abundance remains high upward into the upper bioturbated shale. The black shale fauna consists mainly of *Idiognathodus, Neognathodus,* and *Idioprioniodus,* and small numbers of *Anchignathodus* and *Adetognathus.* The upper shale bed yielded the same four genera as the uppermost sample from the black shale in CP #37: *Idiognathodus, Neognathodus, Idioprioniodus,* and *Anchignathodus,* and in virtually the same proportions.

Myrick Station Limestone Member

The Myrick Station Limestone in southeastern Iowa is typically represented by a single, laterally persistent, massive limestone bed ranging from 1 to 2 feet (30 to 60 cm) thick. In CP #22, the Myrick Station is 2 feet (60 cm) thick and consists of medium dark grey, slightly argillaceous skeletal calcilutite that becomes increasingly argillaceous upward (Fig. 8). The unit is somewhat mottled by bioturbation, and the upper contact is an abrupt gradation. In CP #37, the Myrick Station is 1 foot (30 cm) thick (Fig. 9). The lower 0.2 foot (6 cm) is non-abraded skeletal calcarenite with a diverse macrofauna that grades upward to skeletal calcilutite, mottled by bioturbation.

The conodont faunas from the Myrick Station are closely parallel in CP #22 and CP #37. In CP #22 (Fig. 8), extrapolated abundance increases upward from about 230 elements/kilogram to a secondary peak of about 550/kilogram and then diminishes to less than 10/kilogram near the base of the overlying shale. The fauna is dominated by *Idiognathodus* elements and the secondary abundance peak is due to an increase in their abundance. *Anchignathodus* ranges through the unit. *Neognathodus* and *Idioprioniodus* diminish upward and are absent in the upper half of the unit. *Aethotaxis* is a minor element of the fauna, restricted to the sample with slightly lower abundance at the base of the bed. *Adetognathus* occurs only in the upper half and increases upward in relation to *Idiognathodus.*

In CP #37 (Fig. 9), the extrapolated abundance in the lower portion of the Myrick Station is high, about 1100 elements/kilogram, but there is a second peak in the upper portion of about 500 elements/kilogram, with a relative low of about 270/kilogram in the middle. *Idiognathodus, Neognathodus, Idioprioniodus,* and *Anchignathodus* range throughout, with *Neognathodus* diminishing upward relative to dominant *Idiognathodus.* *Aethotaxis* again is a minor element of the fauna, restricted to the middle of the bed, and *Adetognathus* occurs only in the uppermost sample.

Mine Creek Shale Member

The Mine Creek Shale is a complex and laterally variable unit in southeastern Iowa. It comprises a clastic wedge developed during a eustatic regression (Price, 1981). In both CP #22 and CP #37, a sequence of three distinct subdivisions are present: lower and upper argillaceous units, and a middle arenaceous unit, but both sequences differ in particulars.

CP #22

In CP #22, the lower argillaceous unit is represented by approximately 3 feet (91 cm) of medium grey, argillaceous siltstone (Fig. 8). This grades abruptly to the middle arenaceous unit, which consists of about 4 feet (1.2 m) of medium green-gray argillaceous, calcite-cemented, very fine to fine-grained sandstone that coarsens slightly upward. There is a one-foot-thick (30cm) septarian calcilutite nodule/bed in the middle, and near the top, the unit becomes conglomeratic, containing subrounded limestone clasts, small angular shale clasts and abraded brachiopod debris. This lies in sharp contact with the upper argillaceous unit (Figs. 8 and 10), which consists of approximately 7 feet (2.1 m) of silty, noncalcareous shale that grades from medium grey in the lower one-half to mottled green and maroon in the upper one-half. Macrofossil debris occurs scattered throughout the lower two units, but extends only into the base of the upper unit, which has a poorly preserved coal smut at the top.

Conodont elements generally occur in beds with macrofossil debris. They range throughout the lower two units of the Mine Creek in CP #22, but occur only at the very top and bottom of the upper shale bed. The lower shale unit (Fig. 8) yielded a low abundance of *Adetognathus* and *Idiognathodus* platform elements, generally increasing upward from about 10/kilogram, and in roughly subequal numbers. Extrapolated abundance averages about 100 elements/kilogram in the lower half of the sandstone and increases dramatically to about 1700/kilogram in the uppermost sample, which contains the limestone clasts. The sandstone fauna also is dominated by subequal amounts of *Idiognathodus* platforms and *Adetognathus* platform and ramiform elements. *Diplognathodus* elements are a minor constituent throughout, and *Neognathodus* platforms are minor in the upper portion. *Anchignathodus* occurs sporadically and in only small numbers. The major elements of the fauna extend only into the base (sample 5H) of the overlying shale.

The unusually high abundance at the top of the sandstone is probably a winnowed accumulation brought about by hydrodynamic sorting. In particular, almost all of the *Idiognathodus* platforms recovered are small in size and abraded in appearance with the blade broken off.

CP #37

The lithologic sequence in the Mine Creek Shale in CP #37 is more complex than in the sequence in CP #22, but three similar units are recognizable (Figs. 9 and 11). The lower argillaceous unit is about 7.0 feet (2.1 m) thick and consists of sparsely fossiliferous, variegated, slightly silty mudstone with small calcilutite nodules in the upper portion (Fig. 9).

The middle arenaceous unit in the Mine Creek is 5.0 feet (1.5 m) thick

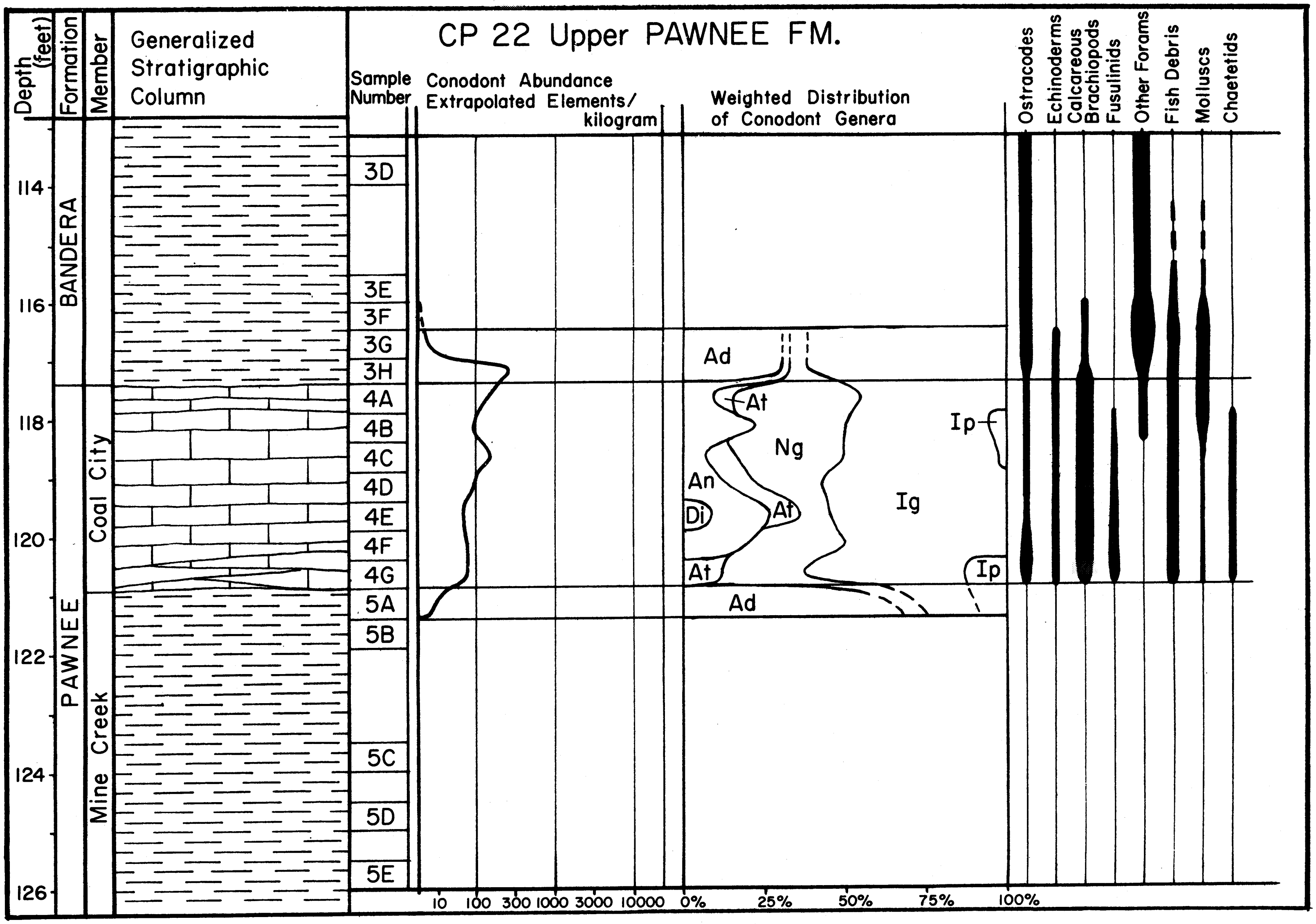


Figure 10. Distribution of conodonts and other fossils in upper Pawnee Formation in CP #22. See figure 5 for explanation.

and comprises two distinct facies (Fig. 11). The lower 2.0 feet (61 cm) consists of several interbedded grey mudstones with a zone of intraclast and sedimentary lithoclast conglomerates near the base. A thin vitrain lamella overlies one of the conglomerates, and other carbonaceous debris is present throughout the mudstone. Thin sandy lamellae that yield a weak positive reaction when tested for phosphate are present in two zones in the middle portion. The contact with the overlying upper calcareous, arenaceous unit is gradational over 0.2 foot (6 cm) in part by bioturbation. The upper part of the arenaceous unit is gradational between bioturbated, sandy skeletal calcilutite and calcareous, very fine-grained sandstone. Two thin calcilutite beds with disturbed bedding are present at the bottom, from which chondrites-type burrows originate.

The upper argillaceous unit of the Mine Creek Shale consists of 6.5 feet (2.0 m) of mottled green and grey mudstone with lingulids and minor molluscs and calcareous brachiopods only in the lower one foot (30 cm), and zones of maroon and gold staining in the middle. Just below the top are thin, interlaminated sandy siltstones and silty shale, some of which are carbonaceous.

Conodont distribution in the Mine Creek in CP #37 varies somewhat from the pattern observed in CP #22. The shale immediately overlying the Myrick Station yielded very small numbers of *Idiognathodus* platforms and a single *Diplognathodus* element, and sporadic occurrences of ramiform fragments were noted in the middle portion.

The mudstones at the base of the middle unit yielded dominantly *Adetognathus* platforms in abundances ranging up to an extrapolated 50/kilogram, with minor *Anchignathodus* overlapping from the limestone above. The sandy limestone unit yielded an extrapolated abundance of about 140 elements/kilogram at the base, which declines upward to about 50/kilogram at the top. The fauna is dominated by delicately preserved *Adetognathus*, with all six element types represented. *Anchignathodus* also ranges throughout, but *Idiognathodus* and *Diplognathodus* elements occur only in the middle. *Stepanovites* elements are rare at the base, and *Aethotaxis* is rare in one sample in the middle.

The upper shale bed of Mine Creek was sampled for conodonts only in the lower one foot and at the top. In the base, conodonts diminish in abundance from just under 100 elements/kilogram to less than 10/kilogram, and the fauna is dominated by *Adetognathus* and low numbers of *Idiognathodus*. The interlaminated interval at the top yielded only seven elements, mostly small *Idiognathodus* platforms.

Coal City Limestone Member

The Coal City Limestone in outcrop in southeastern Iowa is usually a single massive limestone bed ranging from 1.0 to about 4.5 feet (0.3 to 1.4 m) thick. In CP #22 (Fig. 10), it is 3.5 feet (1.1 m) thick and consists dominantly of light grey skeletal calcilutite that is lenticularly bedded near the base and becomes irregularly interbedded upward with slightly more argillaceous calcilutites. A diverse macrofauna includes fusulinids and chaetetids, and the upper contact is an abrupt gradation.

Farther west of the outcrop belt in CP #37 (Fig. 11), the Coal City is reduced to a single bed 0.6 foot (18 cm) thick. The lower 0.1 foot (3 cm) is argillaceous non-abraded skeletal calcarenite that is gradational from the underlying shale. The remainder is skeletal calcilutite that grades abruptly into the overlying shale. The bed is fractured subvertically, and the opening is filled with green mudstone and blocky calcite. The gradational zones at

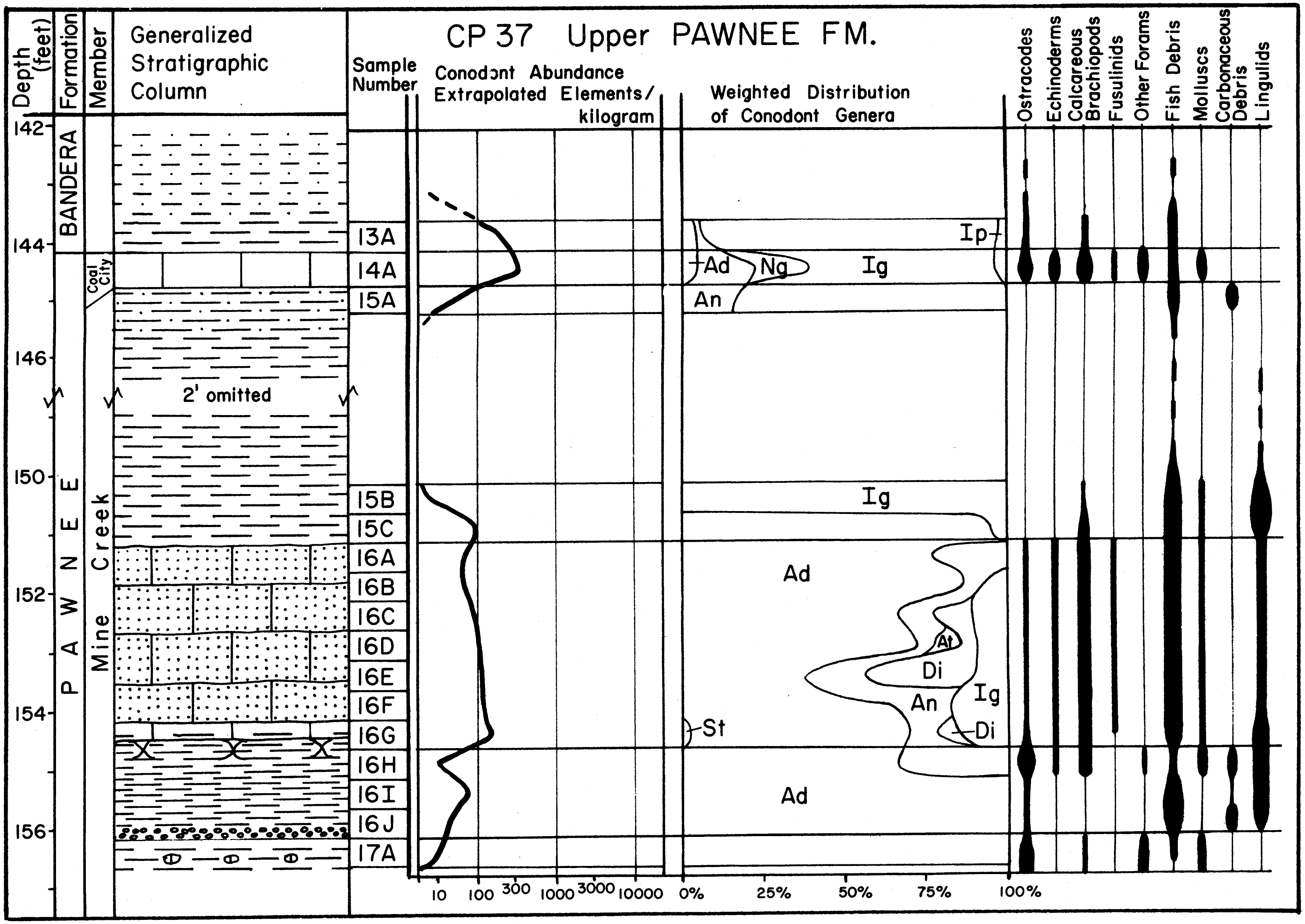


Figure 11. Distribution of conodonts and other fossils in upper Pawnee Formation in CP #37. See figure 5 for explanation.

top and bottom contain lenses of granular glauconite and fine-grained phosphorite.

Conodont faunas from the Coal City in CP #22 are dominated by *Idiognathodus*, *Neognathodus* and *Anchignathodus*. Extrapolated abundance in the lower portion averages about 50 elements/kilogram, but increases to about 150/kilogram in the upper middle. The overall increasing upward trend culminates in a second abundance peak of about 250/kilogram at the base of the overlying shale. *Aethotaxis* is present sporadically throughout the Coal City, whereas *Idioprioniodus* occurs both at the base and in the high abundance zone in the upper portion. *Diplognathodus* is represented by a single element. *Adetognathus* is absent in the limestone, but does occur in both the overlying and underlying shales.

In CP #37, the fauna appears to be condensed, as is the limestone. Extrapolated abundance in the limestone is about 350 elements/kilogram and the fauna is dominated by the same three genera, *Idiognathodus*, *Neognathodus*, and *Anchignathodus*. Both *Adetognathus* and *Idioprioniodus* are present in small numbers, and both extend into the overlying shale, which contains a fauna dominated by *Idiognathodus* platform elements.

Bandera Shale

The Bandera Shale consists of a major clastic wedge developed during the episode of regression that closed Pawnee deposition and preceded the eustatic transgression that was responsible for the Altamont Formation. In southeastern Iowa, the Bandera usually has two distinct subdivisions: a lower coarsening-upward sequence of deltaic clastics, and an upper mudstone that is red in the lower portion and locally includes a coal near the base.

In CP#22, the lower deltaic sequence is about 15.5 feet (4.7 m) thick. It grades upward from green-gray, silty shale by interlamination to light grey, very fine to fine-grained sandstone at the top. The middle portion has lenticular and cross lamination, flame structures and sole markings, and common carbonate nodules, most of which are siderite. The lower few feet (about 90 cm) of the shale (Fig. 10) are fossiliferous, including calcareous brachiopods and molluscs, which diminish upward, and ostracodes and forams, which continue upward. Conodont elements diminish rapidly upward from an extrapolated abundance of about 250/kilogram in the lowermost sample. The fauna is dominated by *Idiognathodus* and *Adetognathus* elements with minor *Neognathodus* and *Anchignathodus* extending from the underlying limestone.

The upper mudstone portion of the Bandera in CP #22 is 14 feet (4.3 m) thick and has minor molluscs and plant debris just above the base. There is a 2-foot (61 cm) zone of maroon mottled, silty, noncalcareous mudstone 2 feet (61 cm) above the base, above which the mudstone grades to green-grey, slightly silty, noncalcareous shale. The upper contact with the overlying Amoret Member of the Altamont Formation is completely gradational and arbitrarily placed in the core below the lowest limestone nodule (Fig. 12). Very small numbers of conodont elements are present in the upper shaly portion, but in the uppermost sample below the limestone nodules, abundance increases to about 65 elements/kilogram, mostly *Neognathodus* platform and *Idiognathodus* ramiform elements.

In CP #37, the lower deltaic sequence is 14.5 feet (4.4 m) thick and grades abruptly from shale at the base through light medium green siltstone to interlaminated and interbedded siltstone and argillaceous, very fine grained, cross-bedded sandstone. The upper portion has thin, lenticular, fine grained, calcareous sand lamellae below the slickensided upper contact. Only the

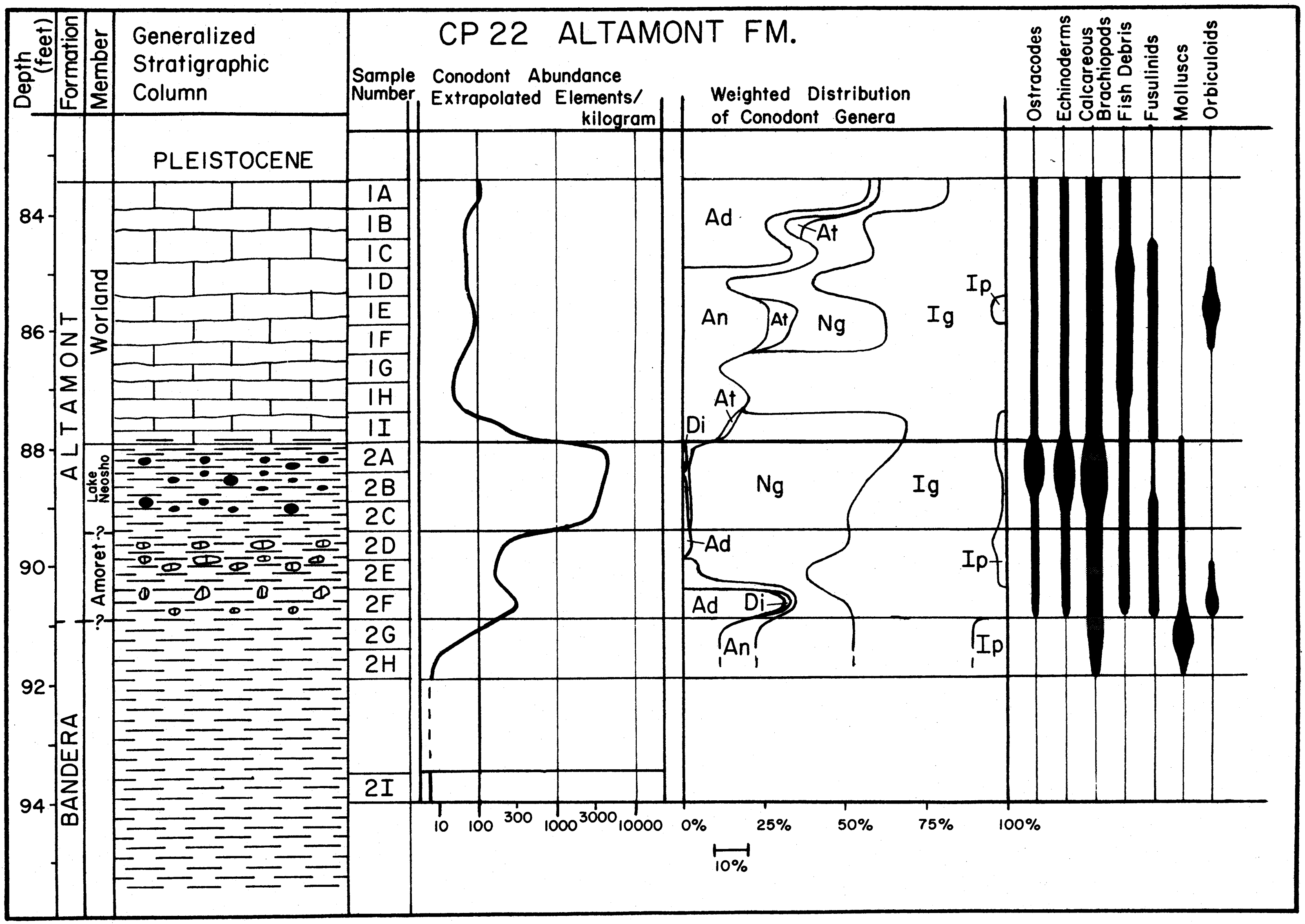


Figure 12. Distribution of conodonts and other fossils in Altamont Formation in CP #22. See figure 5 for explanation.

lowermost 6 inches (15 cm) were sampled (Fig. 11), which were found to contain *Idiognathodus* platforms and minor *Adetognathus*, *Idioprioniodus* and *Anchignathodus* elements in an extrapolated abundance of over 200/kilogram. Presumably, abundance would diminish rapidly upward.

The upper mudstone-dominated portion of the Bandera in CP #37 is about 19 feet (5.8 m) thick. Just above the base is 3.5 feet (1.07 m) of brick red mudstone, which grades upward through maroon and gold mottled mudstones that have a brecciated texture to about 3.5 feet (1.07 m) of grey, argillaceous, sandy siltstone with brown-stained root traces at the top (Fig. 13).

Altamont Formation

The Altamont Formation encompasses the marine-dominated portion of the fourth of the five major eustatic cyclothems in the Marmaton Group. The Altamont is the only formation in the cores upon which a detailed outcrop study has been published. Schenk (1967) described lateral and vertical variations in the three recognized members--Amoret Limestone, Lake Neosho Shale, and Worland Limestone--and interpreted their depositional environments. As a whole, the Altamont averages about 10 feet (3.05 m) in thickness in south-central Iowa.

Amoret Limestone Member

The Amoret Limestone is the first well developed "transgressive" limestone in the Iowa Desmoinesian section. In south-central Iowa it attains a maximum thickness of 2 feet (60 cm) in Madison County (Van Eck, 1965), and although the unit grades laterally into shale, its horizon is laterally traceable. In CP #22 (Fig. 12), the Amoret is developed as a zone of fossiliferous calcilutite nodules about 1.5 feet (46 cm) thick in light green-grey, slightly silty, calcareous shale that is gradational at top and bottom. Conodonts occur in both the nodules and the shale in extrapolated abundances that average about 200 elements/kilogram. Near the bottom, *Adetognathus* constitutes over 25% of the fauna, but only a few rare platform elements were found in the upper portion. *Idiognathodus* platforms are dominant near the bottom, but *Neognathodus* increases in relative abundance upward. *Anchignathodus* and *Diplognathodus* are minor elements in the lower part, whereas *Idioprioniodus* is minor and found only in the upper part.

In CP #37 (Fig. 13), the Amoret is represented by a 0.4-foot-thick (12 cm) bed of slightly argillaceous, bioturbated, skeletal calcilutite with common abraded fossil debris, some with thin oncolitic grain coatings. The lower portion is interlaminated with thin sandstones and green shales that become carbonaceous at the base. Extrapolated conodont abundance is about 200/kilogram, and the fauna is similar to that in the lower portion of the Amoret in CP #22. *Adetognathus* platforms constitute 50% of the fauna, *Idiognathodus* dominates over *Neognathodus*, and *Idioprioniodus* is absent. *Anchignathodus*, *Aethotaxis*, and *Steopanovites* are minor faunal elements.

Lake Neosho Shale Member

The Lake Neosho Shale represents the core shale of the Altamont cyclothem. Compared to homologous shales in lower Marmaton Group cyclothems, it

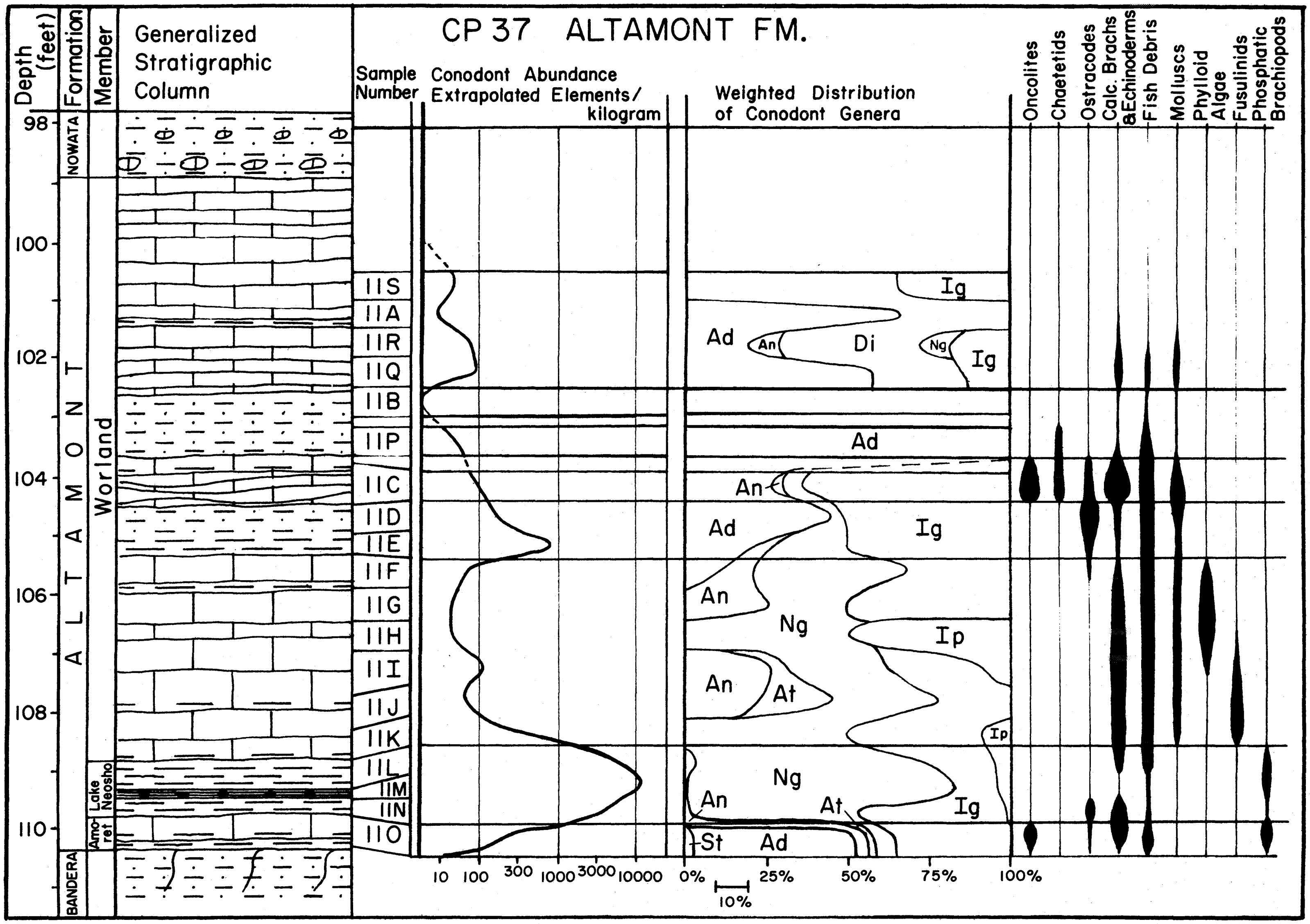


Figure 13. Distribution of conodonts and other fossils in Altamont Formation in CP #37. See figure 5 for explanation.

shows a slightly reduced lateral extent of its black fissile phosphatic facies. It is characterized in northern Oklahoma and southeastern Kansas by a three-part subdivision: lower and upper grey shale with a medial black phosphatic bed (Schenk, 1967). To the north, however, in the Iowa outcrop area, the Lake Neosho rarely contains the same fissile black lithology that characterizes the core shales of older Desmoinesian cyclothems. In CP #22, it consists of 1.5 feet (46 cm) of green-gray, calcareous, laminated shale with an abundant and diverse macrofauna (Fig. 12). Thin, irregular granular non-skeletal phosphate lenses and lamellae increase upward, and the upper contact is an abrupt gradation to limestone.

The Lake Neosho in CP #37 (Fig. 13), situated farther basinward of the Iowa outcrop, displays the three-part subdivision of the Kansas sequence, although somewhat condensed. The dark medial shale is 0.15 foot (4.6 cm) thick and does contain common thin granular phosphatic lamellae, but instead of being black and fissile, it is dark grey and weakly laminated. The upper and lower shale beds are 0.5 and 0.3 foot (15 and 9 cm) thick, respectively, and are green, calcareous, and fossiliferous.

Conodont faunas from the Lake Neosho apparently display only slight lateral variability and are, in general, quite distinctive. In both cores, faunas are dominated by *Neognathodus* and *Idiognathodus* elements. IN CP #22 (Fig. 12), extrapolated abundance averages about 3300 elements/kilogram, increasing slightly upward, and *Neognathodus* platform elements increase upward relative to *Idiognathodus* platforms from a ratio of about 1:1 to over 3:1 near the top. In CP #37 (Fig. 13), the upper and lower shale display a similar abundance and ratio of *Neognathodus* to *Idiognathodus* platforms, but the thin medial phosphatic shale yielded in excess of 12,000 elements/kilogram and the ratio exceeded 4:1. Both cores contain common *Idioprioniodus* and rare *Anchignathodus* elements throughout the Lake Neosho. In addition, CP #22 yielded rare *Adeotognathus* platforms, and near the top, a single *Diplognathodus* element.

Worland Limestone Member

The Worland Limestone is one of the thickest limestones in the Marmaton Group in Iowa, reaching 8 feet (2.4 m) in Appanoose County, and is characterized especially in the upper portion by green shale partings and rapidly changing litho-and biofacies. In CP #22 (Fig. 12) from Appanoose County, only about 5 feet (1.5 m) of Worland was recovered, as the upper portion was lost to pre-Pleistocene erosion. It consists of light grey, skeletal calcilutite that is greenish and argillaceous in irregular zones and has three thin clay partings in the upper portion.

In core CP #37 from Clarke County (Fig. 13), the Worland is considerably more complex and contains two distinct subunits: the lower, which probably represents the usual "upper" limestone, and the upper, which may represent a "super" limestone development. The lower unit is about 3.5 feet (1.1 m) thick and consists of non-abraded skeletal calcilutite with interbedded argillaceous limestone and macrofauna that includes fusulinids near the bottom and common phylloid algae near the top. The upper unit of the Worland actually consists of four distinct beds. The lowest bed is 0.9 foot (27 cm) of green, argillaceous, calcareous siltstone with minor fossil debris that, at the base, grades to shale and contains irregular, fine-grained phosphatic lenses. The second bed is 0.9 foot (27 cm) of mottled argillaceous calcilutite and nodular, abraded skeletal calcarenites with common oncolitic grain coatings.

The third bed is 1 foot (30 cm) of sparsely fossiliferous, green calcareous siltstone. The uppermost bed is about 3.5 feet (1.1 m) thick and consists dominantly of barren, thinly bedded calcilutites that become less argillaceous and more arenaceous upward and, in the upper 1.5 feet (46 cm), become cross-laminated and lenticular with thin pelletoidal beds and zones of sedimentary boudinage. The upper contact is rubbly and nodular, in part gradational to limestone nodules in the lower portion of the Nowata Shale.

The conodont faunas from the Worland in CP #22 and from the lower unit of the Worland in CP #37 are quite similar. Extrapolated abundance decreases from about 200 elements/kilogram in the lowermost sample to less than 100/kilogram, and in some zones, as few as 20/kilogram. Both cores show, in general, *Idiognathodus, Neognathodus,* and *Anchignathodus* throughout, with occasional *Aethotaxis* in certain zones. *Idioprioniodus* occurs in low abundance only in the lowermost sample and again in a zone about 2 feet above the base. *Adetognathus* occurs only near the top, increasing to over 50% in the uppermost sample recovered in CP #22 (1A). It occurs only in the uppermost sample of the lower Worland (11F) in CP #37, although it does increase in relative abundance upward into the overlying shale.

The upper portion of the Worland Limestone, studied only in CP #37 (Fig. 13), yielded a sequence of conodont faunas that bear heavily on its environmental interpretation. The phosphatic shale at the base yielded an extrapolated abundance of 790 elements/kilogram, which diminishes upward to zero at the top of the second siltstone bed. *Adetognathus* generally increases upward in relation to *Idiognathodus,* and *Neognathodus* decreases. *Anchignathodus* is present in the phosphatic shale, and rarely in the oncolitic limestone (sample 11C). The second siltstone bed yielded only 7 *Adetognathus* platforms near the base. The second limestone bed was sampled only in the lower portion, but the fauna appears to be distinctive. Extrapolated abundance generally decreases upward from about 90 elements/kilogram to about 20/kilogram in the middle of the bed (sample 11S). The small number of elements recovered is dominated by *Adetognathus* platforms and ramiforms, and *Diplognathodus* elements, with minor *Idiognathodus,* and in one sample rare *Anchignathodus* and *Neognathodus.*

Nowata Shale

The Nowata Shale is a terrestrial sequence that records the regressive episode that followed deposition of the Altamont Formation. In CP #37, the Nowata is a 4-foot (1.2 m) thick soil profile consisting of barren mudstone that grades abruptly from green to brick red in the middle and to grey with maroon mottling near the top. Irregular carbonate nodules diminish upward, and have a brecciated appearance and no internal structure. Its upper contact is sharp and undulatory, probably burrowed.

Lenapah Formation

The Lenapah is the next marine horizon above the Altamont. Although previous work in Iowa had included this thin, shaly, marginally marine sequence and overlying terrestrial rocks in the Nowata and correlated the higher Cooper Creek Limestone with the Lenapah, Swade (1982) suspected that this lower sequence was equivalent to the Lenapah because conodonts he found just below the Cooper Creek were similar to those found by Parkinson (1982) above the type

Lenapah. In CP #37, the Lenapah is about 3.3 feet (1.0 m) thick and consists of a 0.2-foot (6 cm) thick bed of skeletal calcilutite that includes calcareous brachiopods, molluscs, and echinoderm debris, which is overlain by grey silty shale that becomes decreasingly calcareous and fossiliferous upward. The conodonts in this sequence are mainly *Adetognathus* in low numbers and one *Anchignathodus* according to analysis by Darcy L. Swade (Figure 14). This is consistent with recent work on the Lenapah in Missouri, where *Neognathodus*-dominated faunas are replaced northward toward Iowa by *Adetognathus*-dominated faunas (Greenberg, 1985).

"Mound Valley" Formation

Heckel (ms. in review) has proposed the name "Mound Valley" provisionally for the terrestrial strata that lie above the Lenapah and below the "Lost Branch" Formation (see below) with which the Cooper Creek Limestone is now included. In CP #37 the Mound Valley consists of about 10 feet (3 m) of barren, red silty mudstone with common irregular carbonate nodules in the lower portion; it probably largely represents a soil profile.

"Lost Branch" Formation

Recent work by Parkinson (1982) and Heckel (1984; ms. in review) has revealed a long-standing miscorrelation of the Lenapah Formation. In its type area in northern Oklahoma, the Lenapah consists of a three-part limestone-shale-limestone sequence. Although this sequence resembles that of a cyclothem, Parkinson (1982) has demonstrated that the central shale does not contain a phosphatic facies or a zone of high conodont abundance, both of which characterize the core shales of other more widespread eustatic cyclothems. The black fissile phosphatic shale that does occur in this part of the Oklahoma section overlies the Dawson Coal, several feet above the top of the type Lenapah.

Previous workers have applied the name Lenapah widely across the Midcontinent for the uppermost laterally traceable limestone formation in the Desmoinesian. In Iowa, this limestone is represented by the Cooper Creek Member, named for outcrops in Appanoose County. Ravn and others (1984), recognizing the miscorrelation, refer the Cooper Creek to a widespread marine formation provisionally termed "Lost Branch" (Heckel, 1984) pending formal naming (Heckel, ms. in review).

Lithologic examination by O'Brien (1977) and this study demonstrates the three-part nature of this limestone formation in the subsurface of Clarke County, Iowa (CP #37). The lower two units, which Swade (1982) recognized as unnamed members, are very thin, but they clearly represent the transgressive "middle" limestone and the core shale of the "Lost Branch" cyclothem. The Cooper Creek is the "upper" limestone member.

The results of this study indicate also that the Exline Limestone, known to occur above the Cooper Creek in Appanoose County, is present in CP#37. Although it seems to represent a "super" limestone development of this cyclothem in this core, better stratigraphic differentiation in Missouri along with distinct faunal differences indicate that it is best treated as a separate cycle of Missourian age (Heckel, 1984).

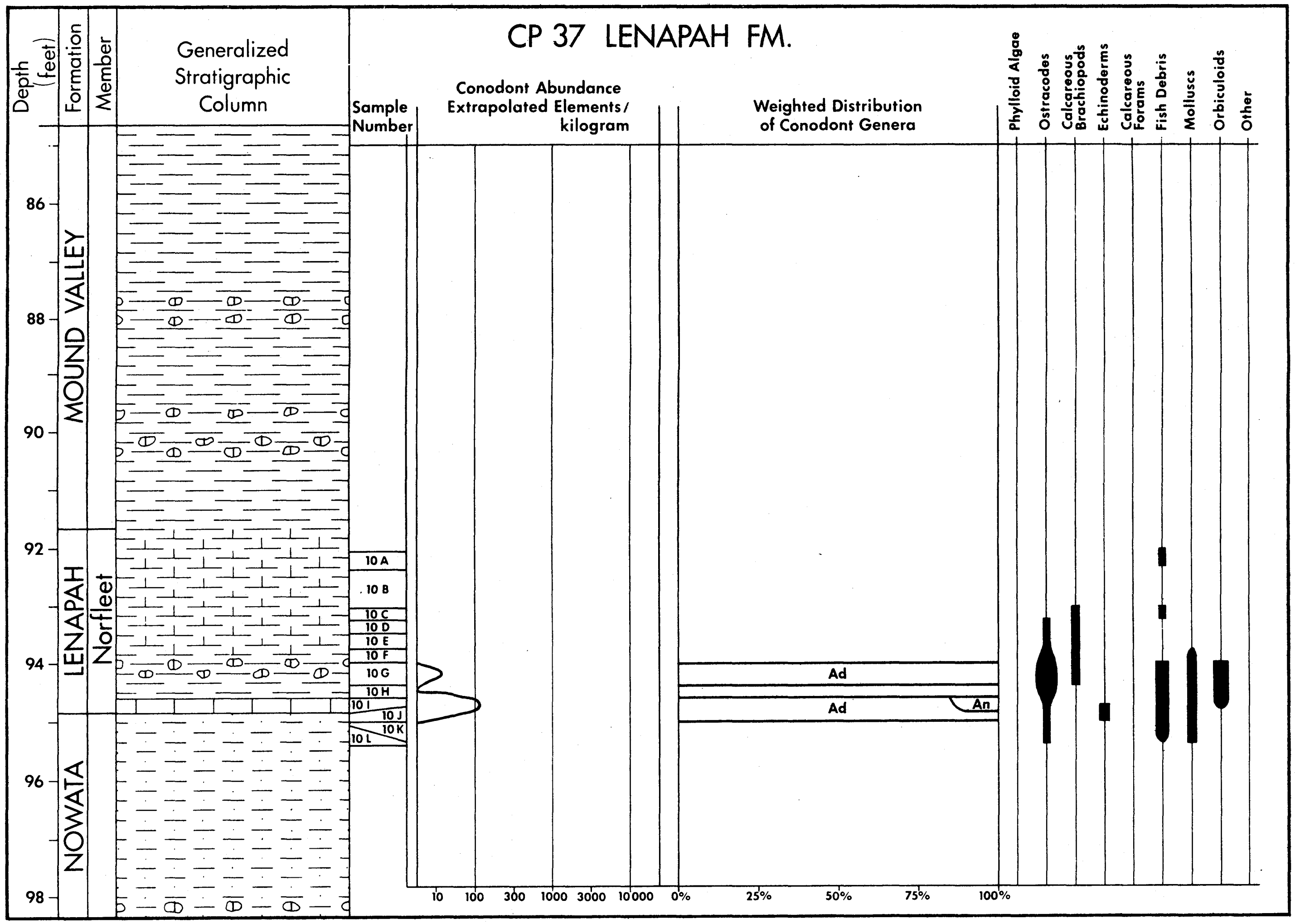


Figure 14. Distribution of conodonts and other fossils in Lenapah Formation in CP #37. See Figure 5 for explanation. This portion of CP #37 was analyzed by Darcy L. Swade in 1984. Because the raw data was not included on Plate 3, it is given here: samples 10A-10F--barren; 10G--1 *Adetognathus gigantus* platform, 2 unidentified raminforms; 10H--barren; 10I--4 *Adetognathus* sp. platforms, 1 *Anchignathodus* sp. platform, assorted unidentified ramiform fragments; 10J--1 *Adetognathus* sp. platform, 2 unidentified ramiform fragments; 10K-10L--barren.

Sni Mills Limestone Member

The transgressive "middle" limestone member is now recognized as the Sni Mills Limestone, which was named in Missouri (Heckel, 1984; ms. in review). It is represented in CP #37 by a 0.1-to 0.15-foot (3 to 4.6 cm) thick, light grey, skeletal calcilutite (Fig. 15). The lower contact is abruptly gradational by interlamination. The top of the Nowata Shale was included in the sample (9X) with the limestone, and the results composited. Both the shale and limestone fractions yielded conodonts with an overall extrapolated abundance of about 160 elements/kilogram, and the fauna seems to be mixed. *Idiognathodus* dominates, with minor *Neognathodus*, *Gondolella*, *Adetognathus*, *Idioprioniodus*, and *Diplognathodus* elements.

Unnamed Shale Member

The unnamed "core" shale member is represented in CP #37 by less than 0.1 foot (3 cm) of green fossiliferous shale. The lower contact is sharp, irregular, and draped by a 5-mm-thick band of fine-grained nonskeletal phosphorite. Granular phosphorite also occurs in the middle of the shale. Extrapolated conodont abundance approaches 11,000 elements/kilogram. The fauna is dominated by *Idiognathodus* elements, and the ratio relative to *Neognathodus* platforms is about 4.5:1. *Gondolella* and *Idioprioniodus* elements combined constitute about 15% of the fauna. Two specimens each of *Adetognathus* platforms and *Anchignathodus* elements, and a single *Diplognathodus* element were recovered.

Cooper Creek Limestone Member

The Cooper Creek Limestone attains a maximum thickness of about 7 feet (2.1 m) in outcrop in its type area in Appanoose County, where it is characterized by a brecciated appearance, with darker-colored limestone "clasts" in a lighter, more argillaceous matrix (Van Eck, 1965).

In CP #37 (fig. 15) from Clarke County, the Cooper Creek is 8.5 feet (2.6 m) thick. The unit is dominated by skeletal calcilutite with the characteristic mottling, bioturbation independent of mottling, and a diverse, unabraded macrofauna including common red and green phylloid algal blades. The lower 1.5 feet (46 cm) are generally more argillaceous, and thin mudstone partings increase downward. The upper portion is more nodular in appearance, with irregular mudstones increasing upward to a 0.3-foot (9 cm) green, arenaceous mudstone layer at the top.

Conodonts occur throughout the Cooper Creek, but abundances are quite low near the base and near the top. A maximum extrapolated abundance of 220 elements/kilogram occurs in the lower middle portion (sample 90), and abundance decreases upward to 50/kilogram in the top mudstone (9F). In general, a sequence of three faunas seems to be represented. The lower, slightly more argillaceous portion is dominated by *Idiognathodus*, with minor to subequal *Anchignathodus* and minor *Neognathodus*. *Diplognathodus* increases upward relative to *Idiognathodus*, and rare *Aethotaxis* and *Idioprioniodus* occur only in a slightly higher abundance zone (9S). The thick middle portion yielded unusual collections dominated by *Diplognathodus* elements. *Idiognathodus* is secondary throughout, with minor *Anchignathodus*, *Aethotaxis*, and *Neognathodus*, and rare *Idioprioniodus* more sporadic in occurrence. The

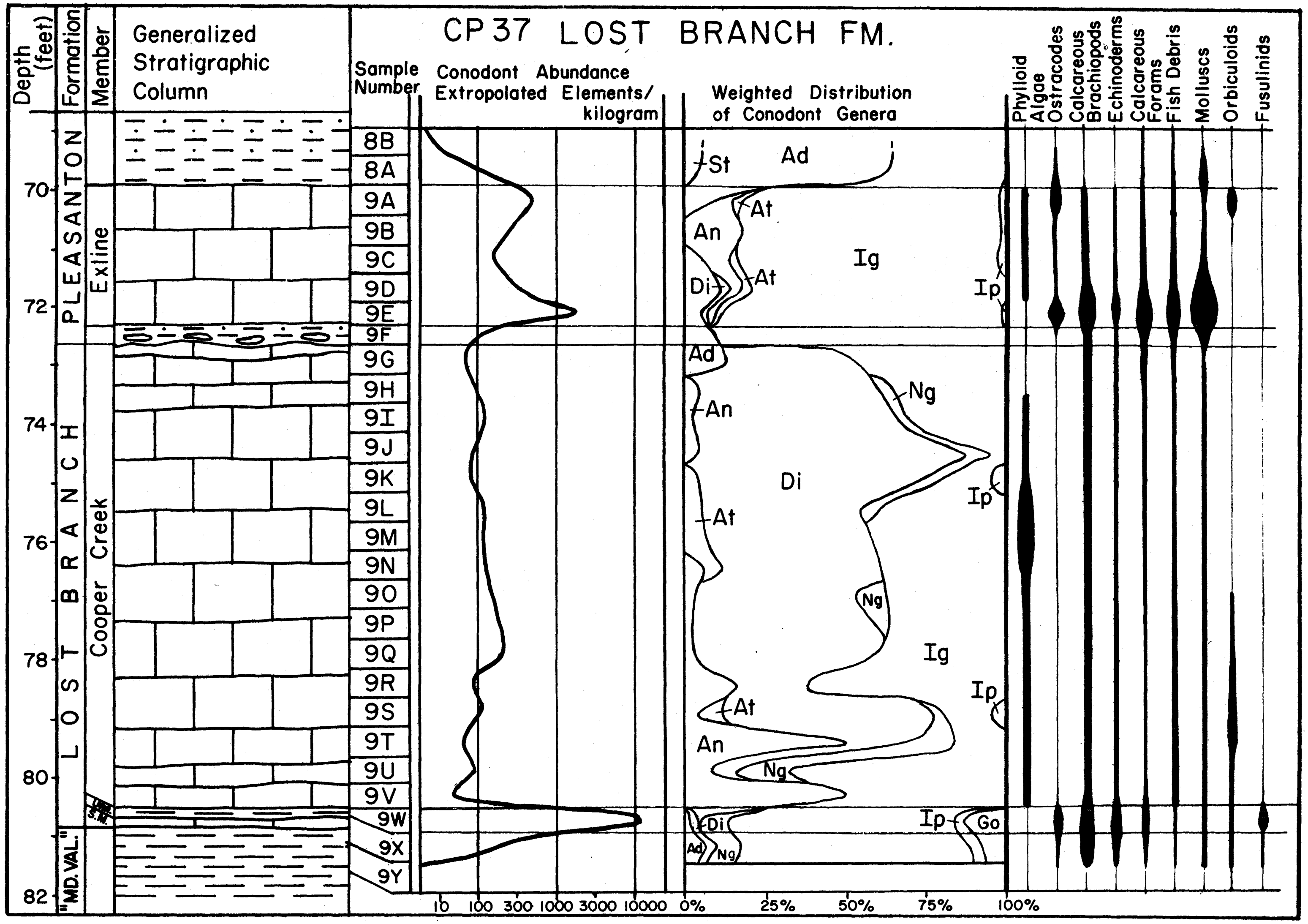


Figure 15. Distribution of conodonts and other fossils in "Lost Branch" and Pleasanton Formations in CP #37. See figure 5 for explanation. Thin shale between Cooper Creek and Sni Mills limestones is currently unnamed.

upper portion, represented by the top sample (9G), contains *Idiognathodus*, *Diplognathodus* and the only *Adetognathus* recovered from the Cooper Creek Limestone.

Pleasanton Formation

The Pleasanton Formation is currently recognized in Iowa as consisting of two unnamed shale members separated by the Exline Limestone Member.

Lower Shale Member

The lower shale member is represented by the 0.3-foot (9 cm) mudstone sampled as 9F in CP #37 (Fig. 15), which contains *Idiognathodus* and *Adetognathus*. Clastic wedges belonging to this shale member locally intervene to separate the Exline and Cooper Creek limestones on outcrop in Iowa, northern Missouri, and northwestern Illinois.

Exline Limestone Member

The Exline Limestone, named also from outcrop in Appanoose County, is a thin discrete bed that occurs stratigraphically close above the Cooper Creek. It can be traced southward into Missouri (Cline, 1941) and has been identified in western Illinois (Willman et al., 1975).

In CP #37 in Clarke County, Iowa (Fig. 15), the Exline is represented by a 2.5-foot-thick (76 cm), irregularly bedded, skeletal calcilutite with grey argillaceous partings similar to the overlying shale and generally increasing upward. The macrofauna is diverse, and especially in the lower portion, is dominated numerically by small molluscs, most of which are preserved as phosphatic internal molds.

Extrapolated conodont abundance increases dramatically, to a maximum of over 1700 elements/kilogram, in the lowermost sample (9E), which also appears to contain the most nonskeletal phosphate. Abundance decreases to about 150 elements/kilogram in the middle of the unit, and increases again at the top to over 750/kilogram. *Idiognathodus* elements dominate the fauna, and *Neognathodus* is conspicuously absent. *Anchignathodus* is better represented than in the underlying Cooper Creek, and *Adetognathus* is prominant near both the bottom and top. Rare *Aethotaxis* and *Idioprioniodus* generally range throughout, and rare *Diplognathodus* elements occur only in the lower part.

Upper Shale Member

Although higher strata are present in CP #37 and were examined petrographically by O'Brien (1977), time constraints did not permit their inclusion in the present study. The base of the overlying shale member of the Pleasanton Formation was sampled, however, in conjunction with the Exline Limestone Member (Fig. 15). It consists of green, silty, weakly laminated shale, which becomes increasingly arenaceous upward. Conodont elements diminish upward from the lowermost sample, which yielded an extrapolated 85 elements/kilogram. This fauna is dominated by *Adetognathus* platforms, with lesser numbers of *Idiognathodus* platforms and rare *Stepanovites* elements.

DEVELOPMENT OF A MODEL FOR UPPER DESMOINESIAN CONODONT PALEOECOLOGY

Review of Eustatic Model for Pennsylvanian Cyclothems

Wanless and Shepard (1936) and Heckel (1980) attributed the widespread, discrete nature of Middle and Upper Pennsylvanian cyclothems to eustatic fluctuations of sea level. Heckel (1980) described the paleogeography of the Midcontinent during one cycle in terms of six phases of deposition. The Upper Cherokee and Marmaton Group cyclothems in south-central Iowa display a vertical sequence of basically eight members (Fig. 16) that can be related to the generalized model in the following manner.

Early Transgression

The top of the underlying outside shale is considered to represent deposition during the earliest phase of transgression. Generally, these deposits show evidence of rising water tables prior to incursion of marine water. They overlie the deltaic clastics that closed the preceding depositional cycle, which represent terrestrial environments that range from the active delta plain to low uplands that experienced processes of soil formation, and usually consist of sandy rooted mudstones. Locally, where channeling affected the deposits of the preceding cycle, fluvial sandstones may fill the channels, stranded in response to the rise in water level. The top of the rooted mudstone represents the time at which the elevation of the local water table caused formation of extensive marginal swamps upon the previously well-drained soil. These swamps migrated away from the basin centers and deposited a blanket of peat, which, if not later destroyed, formed the significant coal that characterizes some upper Desmoinesian cyclothems. The top of the coal marks the change from nonmarine to marine environments with sufficient water depths and/or salinities to prevent accumulation of the peat-forming plant material.

Late Transgression

The middle limestone or its shale equivalent represents deposition during the later, marine phase of transgression. The degree of development of the middle limestone is one of the principal differences between the conceptualized Illinois- and Kansas-type cyclothems. In the Missourian cyclothems in Kansas, it is usually represented by dark skeletal calcilutites, some of which grade upward from thin shoal-water calcarenites. In the Desmoinesian cyclothems of south-central Iowa, there is a pronounced trend upward in the section toward increased development of the middle limestone. The sharp contact between the Oakley Shale and underlying Whitebreast Coal is typical of the Illinois-type cyclothem, and is thought to result from a rate of transgression sufficiently rapid to prevent the establishment of carbonate-producing algae upon a widespread peat (Heckel, 1977). In the three succeeding cyclothems (lower and upper Fort Scott, Pawnee), the marine transgression is represented by thin, dark fossiliferous shales. These vary laterally, grading locally into lenticular skeletal calcarenites, dense nodular calcilutites, or zones of pyritic shell hash in black shale. These clearly represent deposition from above to below effective wave base, but not necessarily below the photic zone

	CYCLOTHEMS CYCLIC PHASES	VERDIGRIS	LOWER FORT SCOTT	UPPER FORT SCOTT	PAWNEE	ALTAMONT	LOST BRANCH
NONMARINE	CLASTICS	Deltaic Clastic Wedge (Interbedded)	MORGAN SCHOOL SHALE Deltaic Clastic Wedge	LOWER LABETTE Deltaic Clastics or Underclay	LOWER BANDERA Deltaic Clastics	LOWER NOWATA Soil	PLEASANTON FORMATION Deltaic Clastics
MARINE	SUPER LS.	UPPER ARDMORE LIMESTONE		HIGGINSVILLE LIMESTONE	COAL CITY LIMESTONE	UPPER WORLAND LIMESTONE	EXLINE LIMESTONE
	MARGINALLY MARINE CLASTICS	Dark Grey Sh.		Deltaic Clastic Wedge	MINE CREEK SHALE Clastic Wedge	Thin Clastics or diastem	Thin Clastics or Diastem
	UPPER LS. - REGRESSIVE	LOWER ARDMORE LIMESTONE (Grey Sh. or interbedded	BLACKJACK CREEK LIMESTONE (Grey Sh.)	HOUX LIMESTONE (Grey Sh.)	MYRICK STATION LIMESTONE (Grey Sh.)	LOWER WORLAND LIMESTONE (Green Sh.)	COOPER CREEK LIMESTONE
	MAXIMUM INUNDATION	Black Fissile Phosphatic OAKLEY SHALE	Black Fissile Phosphatic EXCELLO SHALE	Black Fissile Phosphatic LITTLE OSAGE SHALE	Black Fissile Phosphatic ANNA SHALE	Dark Phosphatic LAKE NEOSHO SHALE	Green Phosphatic UNNAMED SHALE
	MIDDLE LS. - TRANSGRESSIVE	(Sharp Contact)	Thin Grey Sh.	Fossiliferous Shale Wedge	Fossiliferous Shale Wedge	(Green Sh.) AMORET LIMESTONE (or Sh. =)	SNI MILLS LIMESTONE
NONMARINE	COAL	WHITEBREAST C.	MULKY COAL	SUMMIT COAL	MYSTIC COAL	Marginally Marine Sh. or Local Coal UPPER BANDERA	MOUND VALLEY Soil
	CLASTICS	(Rooting)	(Rooting)	(Rooting)	(Rooting) UPPER LABETTE Fluvial Clastics		

Figure 16. Relationship of cyclic phases of deposition in the six cyclothems studied. Since this diagram was constructed by Swade (1982), K. L. Knight (dissertation in prep.) has noted an upper bed of the Blackjack Creek Limestone in western Missouri that may lie in the position of the super limestone of the lower Fort Scott cyclothem, equivalent to the nodular horizon in the Morgan School Shale in CP #22; and Heckel (1984) and M.A. Nielsen (thesis in prep.) have data suggesting that the Exline Limestone is not as closely related to the Cooper Creek Limestone or Lost Branch cyclothem as this diagram suggests.

or resulting from exceedingly rapid transgression. Bottom conditions resulting from the proximity of a thick bed of peat may also have been responsible for inhibiting much algal carbonate production. The upper two cyclothems (Altamont, Lost Branch) are more reminiscent of the Kansas-type, with thin, skeletal calcilutites having diverse macrofaunas and common oncolitic grain coatings. Evidently these later two transgressions were slow enough and did not deposit enough peat to prevent algal carbonate deposition in sporadically agitated, clear-water marine environments.

Maximum Transgression

The core shale, and in particular, the black, fissile, phosphatic facies that it usually contains, represents deposition at maximum eustatic transgression. This facies developed when water in the epicontinental sea became deep enough to establish a thermocline that prevented bottom oxygenation by wind-driven vertical circulation (Heckel, 1977). Orientation of the Midcontinent sea in the trade wind belt north of the Pennsylvanian paleoequator resulted in establishment of large-scale quasi-estuarine circulation in which cold, oxygen-poor, phosphate-rich water from intermediate depths of the western ocean was drawn in along the bottom through deep basins in West Texas to upwell in the Midcontinent. A circulatory trap resulted, in which settling phosphatic and organic matter derived from phytoplankton blooms enriched the incoming deep water and further depleted its oxygen content, and eventually resulted in anoxic conditions above the sediment-water interface and in precipitation of non-skeletal phosphorite.

The lower four of the six cyclothems studied contain well-developed black phosphatic facies dominating their cores. Each of these shales grades upward into thin nonsandy grey shales with sparse benthic faunas representing low-oxygen conditions peripheral to the anoxic bottom, which record the breakup of the thermocline across the basin as eustatic regression began.

The core shales of the upper two cyclothems studied apparently left smaller areas of the basin affected by anoxic bottom conditions. The Lake Neosho Shale in CP #37 probably represents deposition near the margin of the anoxic conditions at maximum transgression as reflected by the thin, dark phosphatic bed sandwiched between green, fossiliferous shale. Eastward in CP #22 and elsewhere along the outcrop in south-central Iowa, only green phosphatic shale is present, whereas in other parts of the basin, a central black fissile facies is well developed (Schenk, 1967). The extremely thin phosphatic shale below the Cooper Creek Limestone evidently represents conditions of nearly complete sediment-starvation at maximum, transgression in a basin insufficiently deep to develop an extensive thermocline. The black fissile facies in this, the Lost Branch, cyclothem is restricted to the central and southern Midcontinent area (Heckel, ms. in review).

Opposing models that focus on an alternative interpretation of the depositional environment of the black, phosphatic shale facies still exist (see Merrill, 1975; Merrill and Martin, 1976). Merrill and von Bitter (1976) summarized the delta-algal bank model in which the black shale facies was deposited in shallow-water, nearshore environments, either in restricted lagoons behind algal banks or between delta lobes, probably beneath an algal flotant such as had been described by Zangerl and Richardson (1963) for Middle Pennsylvanian black shales in Indiana. These models are largely discounted for the Midcontinent Desmoinesian black phosphatic shales studied owing to their great lateral continuity and usual position between fully marine beds.

Local occurrences of dark shallow-water shales are noted in the Midcontinent (e.g., the lower Anna Shale in CP #37), but as Heckel and Swade (1977) indicated, they are laterally discontinuous and further distinguished by containing sandy lamellae and sparse benthic faunas, and by lacking non-skeletal phosphorite.

Early Regression

The upper limestone members of the cyclic sequence record marine deposition following the maximum transgressive phase. The grey or green shale that immediately underlies this limestone probably represents the return of at least partially oxygenated bottom conditons following the retreat of the thermocline, but perhaps at depths still sufficient to be below the effective photic zone. The base of the limestone represents the establishment of carbonate mud-producing algae in the lower photic zone. Carbonate deposition continued through most of the eustatic regression under fully marine conditions below effective wave base. The Desmoinesian upper limestones studied are generally uniform skeletal calcilutites and lack the shoal-water facies common in the upper parts of thicker Missourian upper limestones. In the lower four cyclothems (Verdigris through Pawnee), the upper limestones are generally thin, argillaceous, mottled by bioturbation and lack phylloid algae. The upper two cyclothems (Altamont, Lost Branch) contain thicker upper limestones that are generally wavy-bedded, skeletal calcilutites with green clay partings and common phylloid algae, and are more reminiscent of younger Pennsylvanian upper limestones. Carbonate production in the upper limestones generally was terminated by fine detrital influx that marked the approach of shoreline later during eustatic regression, although in most cyclothems, these prodeltaic deposits still represent marine environments.

Late Regression

The late phase of marine regression is represented by the super limestone member, which represents a resumption of carbonate mud production and return of more fully marine conditions. Unlike the upper limestones, the super limestones are laterally variable in thickness and character, and in addition to below-wave-base carbonates, often include common abraded and coated-grain skeletal calcarenites, carbonate tidal flat and other shoal-water deposits. Their relatively great lateral extent seems to support the interpretation that they resulted from minor eustatic transgressive events instead of from fortuitous events of delta progradation and abandonment. For example, Price (1981) has demonstrated the lateral persistence of the Coal City (and equivalent Laberdie) Limestone over most of the Midcontinent. He also determined that on lower parts of the shelf, the Coal City is underlain by dark grey to black shale that merges laterally in Oklahoma with the upper portion of the Anna Shale. The increase in the area affected by low-oxygen bottom conditions prior to and during deposition of the Coal City is more easiy accounted for by eustatic transgression than by delta abandonment models. The latest stage of regression is represented by the progradation of deltaic clastics that rapidly overwhelmed marine conditions and closed out the depositional cycle.

Maximum Regression

The maximum phase of regression is represented in the cyclic sequence by an episode of subaerial exposure that typically left little sedimentary record. Local erosion may have produced unconformities, but more commonly, the effect of subaerial exposure was in-place weathering of the underlying strata and formation of paleosols represented in the cyclic sequence by the rooted, sandy mudstone seatrock of the next higher coal, or in the case of the top of the Altamont cyclothem, where the exposed surface was limestone instead of clastic materials, by the red, weathered residuum and possible caliche that overlies the Worland Limestone.

Summary of Depositional Trends and Conodont Distribution

Application of the eustatic model of Heckel (1980) to the six Upper Desmoinesian cyclothems studied permits recognition of analogous cyclic phases in each vertical sequence (Fig. 16). The vertical cyclic sequence was related by Heckel (1977) to a series of laterally contiguous depositional environments that developed in the epicontinental sea under the influence (at higher sea level stands) of an upwelling water mass. The well established interpretation of marine depositional environments provides a firm basis for the development of a model for conodont paleoecology. Identification of analogous cyclic phases also reveals a series of trends developed within the individual members of successive cyclothems, which may lead to the interpretation of larger-scale trends in the pattern of Pennsylvanian depositional history.

Middle Limestones

As previously noted, the lithologic character of the middle limestone changes markedly upward in the Upper Desmoinesian cyclothems studied. The lower two cyclothems (Verdigris, lower Fort Scott) have little or no equivalent of the middle limestone developed. The thin grey shale below the black, phosphatic facies in the lower Fort Scott in CP #22 was not sampled independently, but the basal sample (14F) contained only *Idiognathodus*, *Neognathodus* and *Idioprioniodus*.

The middle two cyclothems (upper Fort Scott, Pawnee) have fossiliferous shale wedges that are equivalent to the "middle limestone" member of the sequence. Conodont abundance in these shales averages about 300 elements/kilogram. Where thin, as in the Little Osage or Anna in CP #22, the faunas are dominated by *Idiognathodus*, but appear somewhat mixed, containing minor *Neognathodus* and *Idioprioniodus*, as well as *Adetognathus*, *Anchignathodus* and *Diplognathodus*.

Where the shale is thicker, as in the lower Anna Shale in CP #37, a more complete record of the succession of conodont faunas during transgression is recorded (Fig. 9). Only *Adetognathus* and minor *Diplognathodus* occur at the base; *Adetognathus* diminishes upward as *Idiognathodus* increases; *Anchignathodus*, *Neognathodus* and *Idioprioniodus* occur only in the upper part and are associated with a more normal marine macrofauna. This sequence is mirrored above the core shale (upper Anna) in the upper limestone (Myrick Station), and thus bears heavily on the interpretation of the vertical and lateral relationships in the paleoecologic model.

In the upper two cyclothems (Altamont, Lost Branch) the middle limestone consists of thin skeletal calcilutites that yield an average of about 200 conodont elements/kilogram. This same six genera are present, and a similar sequence of faunas to that in the lower Anna in CP #37 is observed where the bed is thick, as in the Amoret Member of the Altamont in CP #22 (Fig. 12).

Core Shales

The greatest abundance of conodonts in the entire cyclic sequence occurs in the core shales. As indicated previously, the cores of the lower four cyclothems are dominated by black, fissile, phosphatic facies. Each of these four black shales (Oakley, Excello, Little Osage, and Anna) yields conodonts in abundances ranging from 1000 to over 3000 elements/kilogram. The faunas are principally restricted to four genera: *Idiognathodus*, *Neognathodus*, *Idioprioniodus*, and *Gondolella*. *Idiognathodus* platforms generally dominate over *Neognathodus* by ratios of 2:1 to 5:1, but both the Oakley and Little Osage contain zones in the central part of the bed in which the ratio decreases to approximately 1:1. *Idioprioniodus* is a consistent faunal element averaging 5 to 10% of the totals. *Gondolella* occurs in only the lower two of the four black core shales, the Oakley and the Excello, and its abundant occurrence is restricted to thin, central zones within these shales. Its abundance seems to be superimposed upon the numbers of the other three genera, which remain generally constant in all four shales. *Diplognathodus* elements are extremely rare in the black shale, represented by only two specimens from the Excello shale. *D. coloradoensis* is also found in the uppermost sample from the Oakley, but that sample contained interbedded calcarenites, probably indicating deposition marginal to the fully anoxic bottom. The grey shales above the black facies in the Excello, Little Osage, and Anna Shales contain only the same three genera, *Idiognathodus*, *Neognathodus* and *Idioprioniodus*, in similar abundance as in the lower part, about 1000 elements/kilogram, but generally decreasing upward.

The Lake Neosho, the core shale of the Altamont Cyclothem, represents deposition marginal to the area of anoxic bottom and generally, consists of green fossiliferous shale. Conodont abundance averages about 3500 elements/kilogram, and the fauna is dominated by *Neognathodus* and *Idiognathodus* with minor *Idioprioniodus*. *Neognathodus* platforms dominate over *Idiognathodus* by a ratio of 3:1. Rare elements of *Anchignathodus*, *Diplognathodus* and *Adetognathus* were observed. In CP #37, a central, thin, dark phosphatic facies is developed, and it yielded about 12,000 elements/kilogram with the ratio of *Neognathodus* to *Idiognathodus* platforms exceeding 4:1.

The unnamed phosphatic shale below the Cooper Creek Limestone represents extremely slow deposition during maximum transgression. It yielded in excess of 10,000 conodont elements/kilogram, dominated by *Idiognathodus* elements, but with a restricted common occurrence of *Gondolella*, lesser numbers of *Neognathodus* and *Idioprioniodus*, and rare elements of *Diplognathodus* and *Adetognathus*.

Upper Limestones

Although the upper limestones in the lower four cyclothems (Verdigris-Pawnee) differ somewhat lithologically from the upper limestones in the upper two cyclothems (Altamont, Lost Branch), the conodont faunas are generally similar in all six. In general, abundances in the lower four average about

100 elements/kilogram, ranging as high as 300/kilogram in some samples, and generally diminishing upward. In the upper two cyclothems it is usually lower, from 20 to 100 elements/kilogram through most of the bed. The faunas are perhaps the most diverse of any in the cyclic sequence, as representatives of eight of the nine genera recognized are found in the upper limestones, and generally a distinctive sequence is observed. *Idiognathodus* dominates, and *Neognathodus* and *Anchignathodus* also range throughout; *Anchignathodus* is often restricted to the limestone. Where the limestone is thin, *Idioprioniodus* and *Aethotaxis* may also range throughout, but where the bed is thicker, *Idioprioniodus* decreases upward and disappears below the top, whereas *Aethotaxis* occurs in more sporadic zones, often only in the middle of the bed. *Adetognathus* and very rare *Stepanovites* occur only in the upper portion of the upper limestones. *Diplognathodus* is absent in most upper limestones. It is represented by only a single specimen from the Blackjack Creek, but in the lower-abundance faunas from the Cooper Creek Limestone in CP #37, it numerically dominates in most samples.

Marginally Marine Clastics

The detrital unit that separates the upper and super limestones in five of the six cyclothems studied generally consists of deltaic clastics that are of variable character. In the Verdigris cyclothem it consists of dark grey shale that probably represents a distal "prodeltaic" deposit. Sparse conodonts occur in the lower half of the unit and just below the top; these are dominantly small *Idiognathodus* and *Neognathodus* platform elements, with scarce *Gondolella* and *Idioprioniodus* elements in one horizon. The Morgan School Shale is a single, coarsening upward, deltaic clastic wedge. A super limestone is not well developed in the lower Fort Scott cyclothem in Iowa, although a zone of limestone nodules several feet above the top of the Blackjack Creek Limestone did yield a diverse group of small conodont elements; this zone may represent the upper bed of the Blackjack Creek Limestone in western Missouri (K.L. Knight, dissertation in prep.). The Houx and Higginsville limestones of the upper Fort Scott cyclothem are also separated by a single deltaic clastic wedge, which includes the Flint Hill Sandstone in Missouri. Conodonts occur only in shale in the lower 0.5 foot (15 cm) and consist of scarce *Adetognathus* platforms.

The most complex detrital unit in the cyclothems studied is the Mine Creek Shale. Its three subunits apparently represent an incomplete prodelta wedge, a delta-abandonment sandy carbonate unit, and a second prodeltaic wedge. The succession is well developed in CP #37 and contains a sequence of conodont faunas that are important in the formulation of the paleoecologic model. The lower prodeltaic shale contains scarce *Idiognathodus* and *Diplognathodus* elements in only the lower 1.0 foot (30 cm). The middle subunit begins with lagoonal shales and a thin carbonaceous zone at the base, which yield only *Adetognathus* elements. These shales are overlain by quartz-sandy calcilutite that represents a winnowed deposit at or just below effective wave base (O'Brien, 1977). Its conodont fauna is dominated by *Adetognathus*, but also contains *Idiognathodus*, *Anchignathodus* and *Diplognathodus* throughout, and rare *Aethotaxis* and *Stepanovites* in some samples. *Neognathodus*, *Idioprioniodus* and *Gondolella* are absent. The third subunit, the upper prodeltaic shale, contains only *Adetognathus* and *Idiognathodus* in the lower 1.0 foot (30 cm).

In the upper two cyclothems, the upper and super limestones are separated by thin shales. In the Altamont cyclothem, a 0.9-foot (27 cm) shale overlies the "upper" limestone portion of the Worland. A ten-fold increase in conodont abundance may indicate the presence of a diastem at the base of the shale, and a change in conodont faunas also occurs across this interval. For the present, however, little can be inferred concerning the lateral relations of this horizon, as the "super" portion of the Worland has not been located in outcrop. In core CP #37, a 0.3-foot (9 cm) silty shale separating the Cooper Creek and Exline limestones yielded small numbers of *Idiognathodus* and *Adetognathus* platforms. This shale may represent the thin edge of a delta wedge, as the Exline is known to become increasingly separated from the Cooper Creek southward into Missouri (Cline, 1941).

Super Limestones

The super limestone members of the cyclic sequence, as noted earlier, are perhaps the most variable of the cyclic sequence. Lateral variations in thickness, lithotype, and conodont fauna are particularly well developed in the Higginsville Limestone (Swade, 1977) and in the Coal City Limestone in this study. As a whole, the five super limestones contain diverse conodont faunas, including the same eight genera found in the upper limestones and in a similar sequence of faunas.

The super limestone portion of the Ardmore Limestone consists of interbedded limestone and shale. Conodont faunas indicate two peaks of abundance in limestones dominated by *Idiognathodus* separated by a shale with lower abundance dominated by *Adetognathus*. The two peaks probably indicate episodes of slower deposition although it cannot be determined whether these are related to fluctuations in sea level or in rate of clastic influx.

The Higginsville Limestone in CP #22 contains a sequence of three faunas (Fig. 7). The lower and upper parts are dominated by *Adetognathus* and *Idiognathodus*, with minor *Diplognathodus* and rare *Stepanovites*. The thin middle zone, which contains the greatest abundance, is dominated by *Idiognathodus*, with *Anchignathodus*, *Aethotaxis*, *Neognathodus*, and *Diplognathodus*, but no *Adetognathus*. The fauna of the Coal City Limestone in CP #22 contains the same five genera as does the middle Higginsville, plus minor *Idioprioniodus*. *Adetognathus* occurs only in the over-and underlying shales.

The super limestone portion of the Worland in CP #37 consists of limestone and interbedded shale. A thin phosphatic shale at the base yielded the greatest abundance of conodonts. The shale and the overlying shoal-water carbonate contain *Idiognathodus* and *Adetognathus*, and minor *Neognathodus* and *Anchignathodus*. The second shale bed yielded only *Adetognathus*. The upper part of the Worland consists of lagoonal or tidal-flat carbonates and yielded a different fauna, dominated by *Adetognathus* and *Diplognathodus*, with minor *Idiognathodus*, and rare *Anchignathodus* and *Neognathodus*.

The Exline Limestone in CP #37 represents a carbonate environment at or below wave base (O'Brien, 1977) with the greatest conodont abundance at the base. The fauna is mixed, dominated by *Idiognathodus* elements with *Anchignathodus*, *Adetognathus*, and minor *Aethotaxis*, *Diplognathodus*, and *Idioprioniodus*.

Outside Shales

Five of the six cyclothems concluded with the deposition of deltaic clastics, except for the Altamont, in which the Worland Limestone was exposed to subaerial weathering with little or no detrital deposition. In general, only the basal portions of the prodeltaic shales contain conodonts, as is the usual case with the detrital unit between the upper and super limestones. These sparse faunas are dominated by *Adetognathus* and *Idiognathodus* platforms, with minor *Neognathodus* and *Anchignathodus*, and rare *Diplognathodus* and *Stepanovites*.

Model for Conodont Paleoecology

Application of the eustatic model elaborated by Heckel (1977, 1980) to the lithologic succession in the six Upper Desmoinesian cyclothems studied permits the identification of marine depositional environments and their relationship to the overlying water masses present in the epicontinental sea (Fig. 17A). Klapper and Barrick (1978) reviewed the ecologic models proposed to explain the distribution patterns of conodonts. They examined possible modern analogues and concluded that it is not possible to distinguish between a pelagic or benthic mode of life solely on the basis of preserved distributional patterns. They did conclude, following Seddon and Sweet (1971), Heckel and Baesemann (1975) and Merrill and von Bitter (1976), that a pelagic mode was strongly indicated for those genera observed to occur in black shales that lack benthic faunas and are interpreted as representing anoxic bottom conditions. The well developed black shales in the cyclothems studied yielded four genera, *Idiognathodus*, *Neognathodus*, *Idioprioniodus* and *Gondolella*, and therefore, these are considered to have been pelagic organisms.

Two other Middle Pennsylvanian genera were possibly also pelagic, *Diplognathodus* and *Adetognathus*. *Diplognathodus coloradoensis* occurs in the uppermost sample of the Oakley Shale and is also known to occur in a phosphatic black shale in the older Floris Formation in CP #22. *D. iowensis* n. sp. is rare in the Excello Shale and *D.* n. sp. 2 occurs with *Adetognathus* elements in the lower part of the Anna Shale in CP #37. Elsewhere, however, *Diplognathodus* elements seem conspicuously absent in some of the black shales, for example, the black phosphatic facies of the upper Anna in CP #37. *Adetognathus* is also considered to have been possibly pelagic, based on suggestive evidence offered by the occurrence of *Cavusgnathus*, a closely related Mississippian genus, in bedding plane assemblages in black shales (Norby, 1976). If these two genera were pelagic, their absence in the black phosphatic shales may be related to the extremely low bottom gradients in the epicontinental sea, and the resuling great distance from their preferred nearshore habitats out to the anoxic basin centers.

Having established a pelagic mode of life for four, and possibly six of the nine genera recognized, it is then possible to relate their distribution pattern to the three water masses present in the Midcontinent Sea, following the model proposed by Klapper and Barrick (1978, Fig. 3). *Idiognathodus* and *Neognathodus* were offshore surface-dwelling conodonts adapted to warm, well-oxygenated waters (Fig. 17B). *Idiognathodus* apparently dominated in the onshore area, whereas *Neognathodus* became relatively more abundant offshore, but both are widely distributed, possibly in part by post-mortem transport while settling. *Idioprioniodus* and *Gondolella* were offshore, deep-dwelling conodonts adapted to cooler, low-oxygen water. The occurrence of *Gondolella* in two of the black shales, and not in two others suggests that it may have

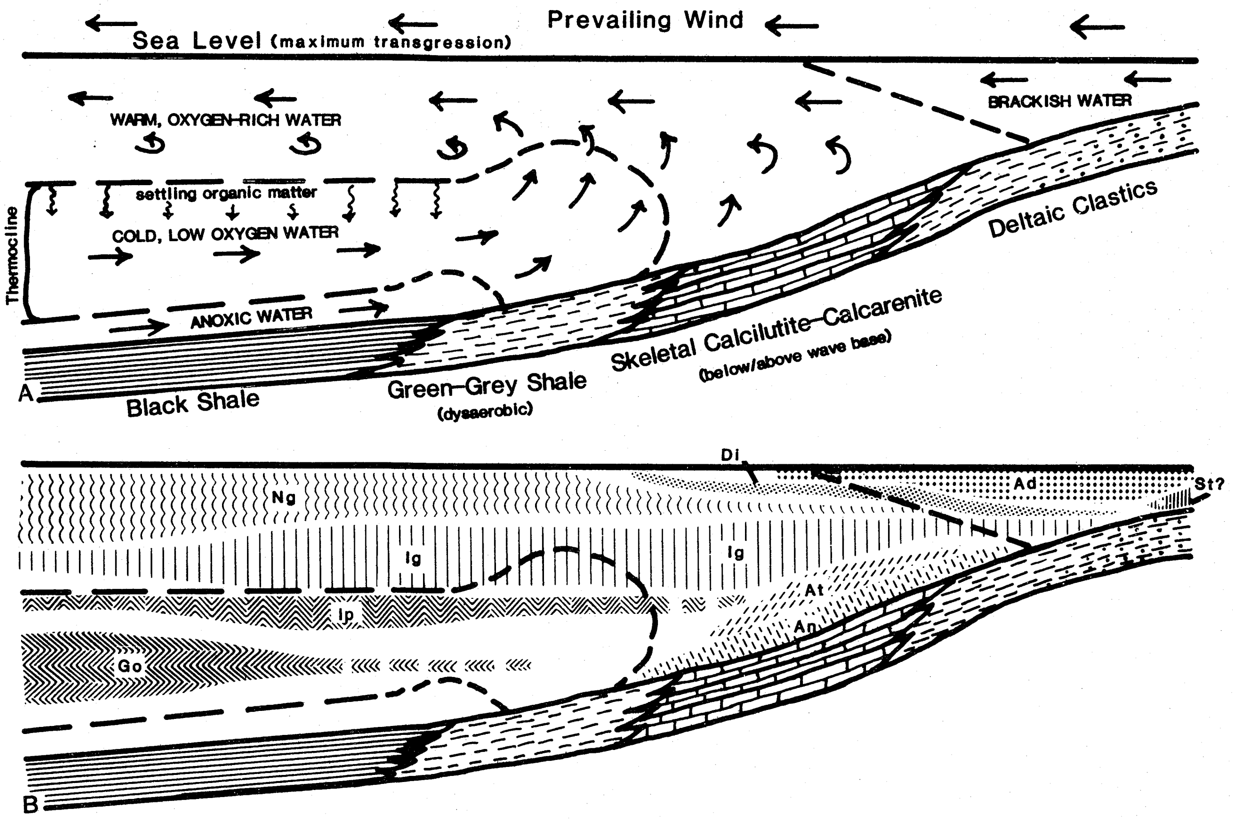


Figure 17. Generalized restored cross sections of Midcontinent sea at maximum transgression. *A*, Relation of water masses involved in quasi-estuarine circulation to sedimentary lithotopes. Vertical scale greatly exaggerated. *B*, Interpreted paleoecological distribution of conodont genera. *Idiognathodus*, *Neognathodus*, *Idioprioniodus*, and *Gondolella* were pelagic organisms; the remainder may have been either pelagic or benthic.

inhabited a different deep cold-water mass than *Idioprioniodus* and that its migration into the Midcontinent Sea was only possible when that mass became involved in the upwelling. The occurrence of *Gondolella* in marginally marine shales in the same two cyclothems is limited to scarce, small-sized elements perhaps belonging to errant juveniles that occasinally left their home water mass. *Adetognathus* exhibits a distribution pattern compatible with life in the nearshore water mass that is characterized by fluctuating environmental conditions, particularly the brackish salinities that result from fresh-water influx. *Diplognathodus* is rare enough in the present study that firm conclusions regarding its distribution cannot be drawn, but its occurrence seems to range from onshore to offshore environments, near the area affected by anoxic bottom conditions. This wide distribution may result from its small size and greater susceptibility to transport while settling.

Two other Middle Pennsylvanian genera exhibit distribution patterns that may indicate a nektobenthic habitat following the reasoning of Barnes and Fahraeus (1975), but as Klapper and Barrick (1978) indicated, this can by no means be proved. *Anchignathodus* and *Aethotaxis* are both strongly restricted to carbonate lithotopes representing oxygenated conditions in the photic zone. *Anchignathodus* generally appears to range farther onshore than *Aethotaxis*, and its occurrence in calcareous shales that separate limestone beds may suggest that it was somewhat more tolerant of turbid waters. These interpretations of the habitats of *Adetognathus*, *Anchignathodus*, and *Aethotaxis* are consistent with interpretations made for them by previous workers (e.g., Merrill, 1975; Merrill and von Bitter, 1976; Heckel and Baesemann, 1975), but the interpretation for *Gondolella* and *Idioprioniodus* differs sharply from that of Merrill (1975) or Merrill and von Bitter (1976, Fig. 11).

Stepanovites is the only other genus represented in the present collections, and it is too rare to permit any firm conclusions regarding its paleoecology. Its occurrence, however, appears closely linked to that of *Adetognathus*.

BIOSTRATIGRAPHIC ASPECTS OF THE CONODONT FAUNAS

Precise correlation of Upper Cherokee and Marmaton Group strata of the Midcontinent can be based on conodont faunas from the six laterally persistent phosphatic shales present in the section. These are, in ascending order, the Oakley Shale, Excello Shale, Little Osage Shale, Anna Shale, Lake Neosho Shale, and the unnamed phosphatic shale below the Cooper Creek Limestone. Each of these shale horizons can be traced over the entire Midcontinent region, and each supposedly has a direct lithostratigraphic equivalent in the Illinois Basin. Detailed lithologic characteristics of these shales and associated strata are observed to change laterally, particularly near the margins of the depositional basins, and more pronounced variation may be expected in attempting to correlate between basins. Previous interstate correlations have generally been based on knowledge of the sequence of formational units, and misidentification of key shale horizons has resulted in errors (e.g., Hertha Limestone/Tacket Shale: Ravn, 1981; Lenapah Limestone/supposed northern equivalents: Parkinson, 1982; Heckel, 1984). An independent means of confirming correlations such as may be provided by the conodonts is thus highly desirable.

The conclusions of Heckel (1977) regarding the offshore origin and depositional environment of these phosphatic shale units lead directly to the interpretation that these beds represent the closest approximation of stratigraphic timelines available in the sequence, as developed by Israelsky (1949) for horizons in the Gulf Coast Tertiary. The faunas from these shales, although restricted to only four genera, are abundant and, from preliminary data, apparently laterally consistent, reflecting the condensed nature of their deposition under offshore, sediment-starved conditions. As has been elaborated earlier, these shale faunas are dominated by platform elements of *Idiognathodus*, *Neognathodus* and *Gondolella*, and by *Idioprioniodus* elements. No uniformly applicable system for the recognition of species has yet been proposed for Middle and Upper Pennsylvanian *Idiognathodus* (see Merrill, 1975, 1983), and, although a system has been proposed for *Neognathodus* (Merrill, 1975), thorough application to the present collections is considered beyond the scope of this study. Pennsylvanian species of *Gondolella* are currently being examined (von Bitter and Merrill, 1980), but revision of the broad-platformed species has not yet been published. At present, elements of *Idioprioniodus* are useful only for discrimination between the Desmoinesian and Missourian stages (Merrill and Merrill, 1974). Nevertheless, vertical variation in the detailed nature and proportions of the three platform genera can be used to describe assemblage biozones that are practical for the identification of the six phosphatic shales for intrabasinal correlation (Fig. 18).

Diplognathodus, a rare conodont in the black shales, is only a little more common in nearer-shore lithotopes, but, where present, it appears to exhibit a zonation useful for biostratigraphy (Fig. 19). *D. coloradoensis* is the only species present in the Verdigris cyclothem and in older, upper Floris Formation cyclothems. It ranges up to the lower Fort Scott cyclothem (Hanover) in Illinois, where it is rare (Merrill, 1975). *D. iowensis* n. sp. ranges from the lower Fort Scott through the Lost Branch cyclothem. *D.* n. sp. 2 ranges from the Pawnee cyclothem through the Lost Branch, and *D. illinoisensis* occurs only in the Lost Branch.

Each of the six upper Desmoinesian cyclothems can be uniquely characterized by means of its conodont fauna, using the assemblage biozones for the three pelagic platform genera in conjunction with the *Diplognathodus* zonation. It is hoped that further work will demonstrate the applicability of these characterizations to interbasinal correlation.

Verdigris Cyclothem

The Verdigris cyclothem can be recognized by the conodont fauna of the Oakley Shale. Most characteristic is the occurrence of *Gondolella* sp.1, a relatively narrow, smooth-platformed variant that von Bitter and Merrill (1980, p.2) regard as transitional between *G. laevis* and *G. bella*. Among the *Idiognathodus* platforms, two distinct forms are noted, with few intermediates. *I.* sp. 1 represents the longest-ranging form and generally conforms to conservative *I. delicatus* of many workers. *I.* sp. 2 is a narrow-platformed variant, with ridges instead of nodes on the small accessory lobes. Large specimens usually have poorly defined ornamentation on the upper surface. *Neognathodus* platforms in the Oakley are dominantly *N. medexultimus* and *N. roundyi*, with a few *N. medadultimus* among the largest specimens and a few *N. dilatus* among the smallest. Faunas similar in each of these regards have also been recovered from the Oakley in three additional cores (CP# 53, Monroe County; CP #41, Marion County; CP #37, Clarke County) and in outcrop in Lucas County at the type of locality of the Swede Hollow Formation. The Verdigris cyclothem can also be recognized by the youngest common occurrence of *Diplognathodus coloradoensis*.

Lower Fort Scott Cyclothem

The lower Fort Scott cyclothem can be identified on the basis of conodonts from the Excello Shale. Most characteristic is the occurrence of abundant *Gondolella* sp. 2, a broad-platformed species that has parallel transverse ridges. The *Idiognathodus* are mostly conservative *I.* sp. 1, and a few are *I.* sp. 2, but among the largest specimens there are many that have only a few, generally incomplete transverse ridges, and instead, most of the upper surface is occupied by rows of nodes, often arranged in concentric arcs on both accessory lobes. This variant could probably be called *I.* cf. *I. claviformis*. Herein, it is referred to as *I.* sp. 3. *Neognathodus* platforms in the Excello generally range from small specimens of the *N. metanodosus*-*N. dilatus* type to larger *N. roundyi*-*N. medexultimus*, with a few *N. polynodosus*. The Excello also contains the youngest, rare occurrence of *Diplognathodus coloradoensis* according to data in Merrill (1975), and the oldest, rare occurrence of *D. iowensis* n. sp. Additional samples of the Excello that are known to contain *Gondolella* sp. 2 are available from four other cores in Iowa (CP #10, Appanoose County; CP #37, Clarke County; CP #41 Marion County; CP #53, Monroe County), from outcrop in Lucas County, Iowa, at the type locality of the Mouse Creek Formation, from outcrops at Fort Scott, Bourbon County, Kansas, and at Jubilee College Park, Fulton County, Illinois.

Upper Fort Scott Cyclothem

The upper Fort Scott cyclothem is difficult to characterize in regard to its conodont faunas. The Little Osage Shale contains *Idiognathodus* and *Neognathodus* platforms similar to those in both Excello and Anna Shale faunas, but lacks *Gondolella*. The most common idiognathodids are generalized *I.* sp. 1, and among the larger specimens, the *I.* sp. 3 forms are common; in addition, a few specimens of the narrow *I.* sp. 2 are present, as are rare *I.* sp. 4, a variant with pits on the upper surface instead of nodes. The *Neognathodus* are dominantly *N. medexultimus* and *N. roundyi* but instead of *N. polynodosus* as in the Excello, the Little Osage contains a few *N. medadultimus*. The only *Diplognathodus* species present in the upper Fort Scott is *D. iowensis*. Additional samples from the Little Osage that yield similar faunas are available from two cores (CP #10, Appanoose County; CP #37, Clarke County), from outcrop in Lucas County, Iowa, at the type locality of the Stephens Forest Formation, and from outcrop at Fort Scott, Bourbon County, Kansas, not far from the type section of the Little Osage Shale.

Pawnee Cyclothem

The Pawnee is perhaps the most difficult cyclothem to characterize by its conodont faunas. The Anna Shale, like the Little Osage, does not contain *Gondolella*, and the variations in the other two genera are similar to those in either the Little Osage or the Excello. Most abundant are generalized *I.* sp. 1, and the large specimens are usually nodose *I.* sp 3, but examples of both other forms, *I.* sp. 2 and *I.* sp 4, are also noted among the samples available. *Neognathodus* platforms in the Anna in both CP #22 and CP #37 are generally small specimens, dominated by *N. roundyi* and *N. medexultimus*, with *N. dilatus* and *N. metanodosus* among only the smallest examples. *Diplognathodus* n. sp. 2 is the only species observed from the Pawnee cyclothem in the two cores, but

Figure 18. Assemblage biozones of *Idiognathodus*, *Neognathodus* and *Gondolella* platform elements based on collections from the phosphatic core shales with cyclothems in parentheses. All conodonts are enlarged approximately 20X. Numbers in parentheses after the name identify the core and sample from which illustrated specimens were taken. SUI Repository numbers follow.

Unnamed shale below Cooper Creek Limestone (Lost Branch):

1.	*Gondolella* sp. 3	(37-9W)	SUI50917
2.	*G.* sp. 3	(37-9W)	SUI50918
3.	*G. denuda*	(37-9W)	SUI50916
4.	*Idiognathodus* sp. 1	(37-9W)	SUI50912
5.	*I.* sp. 1	(37-9W)	SUI50910
6.	*I.* sp. 6	(37-9W)	SUI50913
7.	*I.* sp. 6	(37-9W)	SUI50911
8.	*Neognathodus roundyi*	(37-9W)	SUI50914
9.	*N. medexultimus*	(37-9W)	SUI50915

Lake Neosho Shale (Altamont):

10.	*Idiognathodus* sp. 1	(22-2A)	SUI50919
11.	*I.* sp. 1	(22-2A)	SUI50920
12.	*I.* sp. 5	(22-2B)	SUI50926
13.	*I.* sp. 5	(22-2C)	SUI50927
14.	*Neognathodus polynoduosus*	(22-2B)	SUI50925
15.	*N. dilatus*	(22-2A)	SUI50924
16.	*N. roundyi*	(22-2A)	SUI50923
17.	*N. medexultimus*	(22-2A)	SUI50922
18.	*N. medadultimus*	(22-2A)	SUI50921

Anna Shale (Pawnee):

19.	*Idiognathodus* sp. 1	(22-6U)	SUI50932
20.	*I.* sp. 1	(22-19A)	SUI50928
21.	*I.* sp. 2	(22-6U)	SUI50933
22.	*I.* sp. 3	(22-6U)	SUI50934
23.	*Neognathodus dilatus*	(22-6U)	SUI50935
24.	*N. roundyi*	(22-19A)	SUI50929
25.	*N. roundyi*	(22-19A)	SUI50930
26.	*N. medexultimus*	(22-19A)	SUI50931

Little Osage Shale (upper Fort Scott):

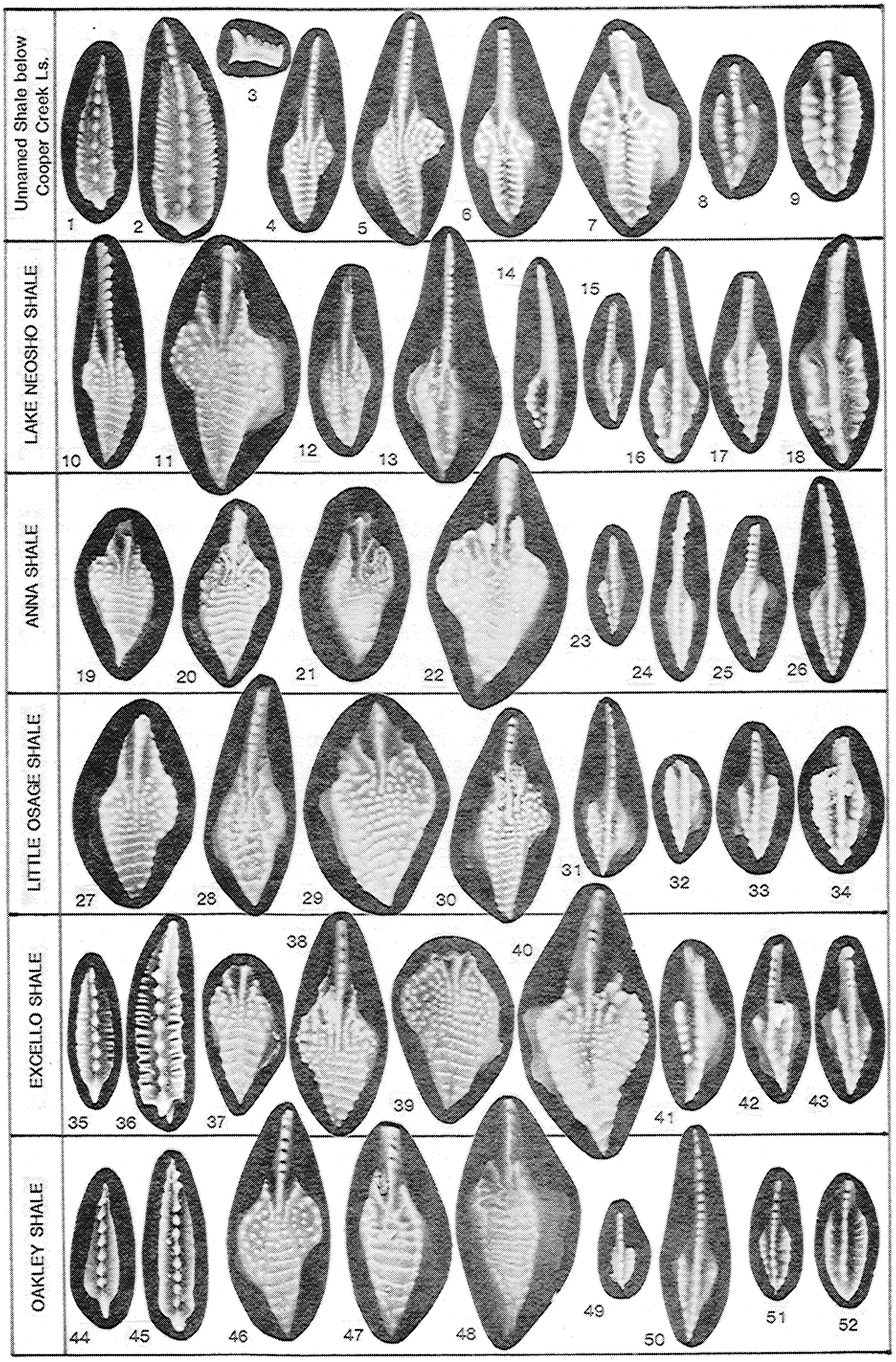
27.	*Idiognathodus* sp. 1	(22-11G)	SUI50936
28.	*I.* sp. 2	(22-11H)	SUI50940
29.	*I.* sp. 3	(22-11F)	SUI50941
30.	*I.* sp. 4	(22-11D)	SUI50943
31.	*Neognathodus roundyi*	(22-11H)	SUI50942
32.	*N. roundyi*	(22-11G)	SUI50937
33.	*N. medexultimus*	(22-11G)	SUI50938
34.	*N. medadultimus*	(22-11G)	SUI50939

Excello Shale (lower Fort Scott):

35.	*Gondolella* sp. 2	(22-14D)	SUI50944
36.	*G.* sp. 2	(22-14D)	SUI50945
37.	*Idiognathodus* sp. 1	(22-14E)	SUI50949
38.	*I.* sp. 1	(22-14E)	SUI50950
39.	*I.* sp. 3	(22-14E)	SUI50951
40.	*I.* sp. 3	(22-14E)	SUI50952
41.	*Neognathodus polynodosus*	(22-14D)	SUI50946
42.	*N. roundyi*	(22-14D)	SUI50947
43.	*N. medexultimus*	(22-14D)	SUI50948

Oakley shale (Verdigris):

44.	*Gondolella* sp. 1	(22-22W)	SUI50960
45.	*G.* sp. 1	(22-22W)	SUI50961
46.	*Idiognathodus* sp. 1	(22-22T)	SUI50953
47.	*I.* sp. 2	(22-22T)	SUI50954
48.	*I.* sp. 2	(22-22T)	SUI50955
49.	*Neognathodus dilatus*	(22-22T)	SUI50956
50.	*N. roundyi*	(22-22T)	SUI50957
51.	*N. medexultimus*	(22-22T)	SUI50958
52.	*N. medadultimus*	(22-22T)	SUI50959


Unnamed Shale below Cooper Creek Ls.
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3
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8
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LAKE NEOSHO SHALE
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ANNA SHALE
19
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21
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26
LITTLE OSAGE SHALE
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EXCELLO SHALE
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OAKLEY SHALE
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as *D. iowensis*, which is found in the two Fort Scott cycles, also occurs in the Cooper Creek Limestone, it may range through the Pawnee interval as well. An outcrop sample of the Anna from near its type locality in Bourbon County, Kansas, contains similar *Idiognathodus* and *Neognathodus* platforms.

Altamont Cyclothem

The Altamont cyclothem can be identified by the conodont fauna of the Lake Neosho Shale. Although, like the two lower cycles, it does not contain *Gondolella*, the *Idiognathodus* and *Neognathodus* platforms are quite distinctive. Two forms of *Idiognathodus* are present and exhibit sharp vertical variation in their distribution. The uppermost sample of Lake Neosho in CP #37 and the overlying Worland Limestone yielded only the generalized *I.* sp. 1, whereas the thin, dark, phosphatic shale and underlying green shale and limestone yielded only a "streptognathodus" form of platform element, *I.* sp. 5. *I.* sp. 5 is characterized by a trough that runs the length of the narrow platform, leaving two raised margins with short transverse ridges or a row of nodes on either side.

The lake Neosho is the only phosphatic shale unit in the entire sequence in which platform elements of *Neognathodus* numerically dominate those of *Idiognathodus*. The *Neognathodus* show a complete intergradational series from small *N. dilatus-N. metanodosus* through *N. roundyi* and *N. medexultimus* to the largest specimens, which are *N. medadultimus*. Two other distinctive variants also occur among intermediate-sized elements: *N. polynodosus*, and a variant with a single node on one side like *N. roundyi*, but with the other parapet also greatly reduced. Other samples of the Lake Neosho that have been examined from outcrop at the type locality in Neosho County, Kansas, and from a core in Sarpy County, Nebraska, generally support these observations.

Lost Branch Cyclothem

The Lost Branch cyclothem can be readily recognized by its conodont fauna, in particular, that of its unnamed phosphatic shale member. Most characteristic is the occurrence of *Gondolella* sp. 3 and the rare occurrence of *G. denuda (G.* cf. *G. gymna* of von Bitter and Merrill, 1980). *G.* sp. 3 is a broad-platformed species with the upper margins of the platform ornamented by transverse ridges, many of which bifurcate.

Idiognathodus platforms in the Lost Branch are diverse and appear to completely intergrade between two end members, the flat-platformed *I.* sp. 1, and a deep-troughed "streptognathodus" form, *I.* sp. 6. *I.* sp 6 has large nodose accessory lobes on both sides and a centrally located trough that separates two rows of distinct, parallel ridges. It generally conforms to the form species, *Streptognathodus excelsus* Stauffer and Plummer (1932).

Neognathodus platforms in the Lost Branch in CP #37 are neither as common nor as diverse as they are known to be elsewhere in this horizon (Lonsdale of Illinois: e.g., author's 1973 senior thesis at Knox College; Merrill, 1975). In general, they are similar to those in the Altamont cyclothem, ranging from the small *N. metanodosus* to large *N. medexultimus*, but a significant number of intermediate- to large-sized specimens present in other collections represent the morphologically simple varieties, *N. polynodosus*, *N. oligonodosus*, and *N. anodosus*.

Diplognathodus is represented in the Lost Branch cyclothem by three

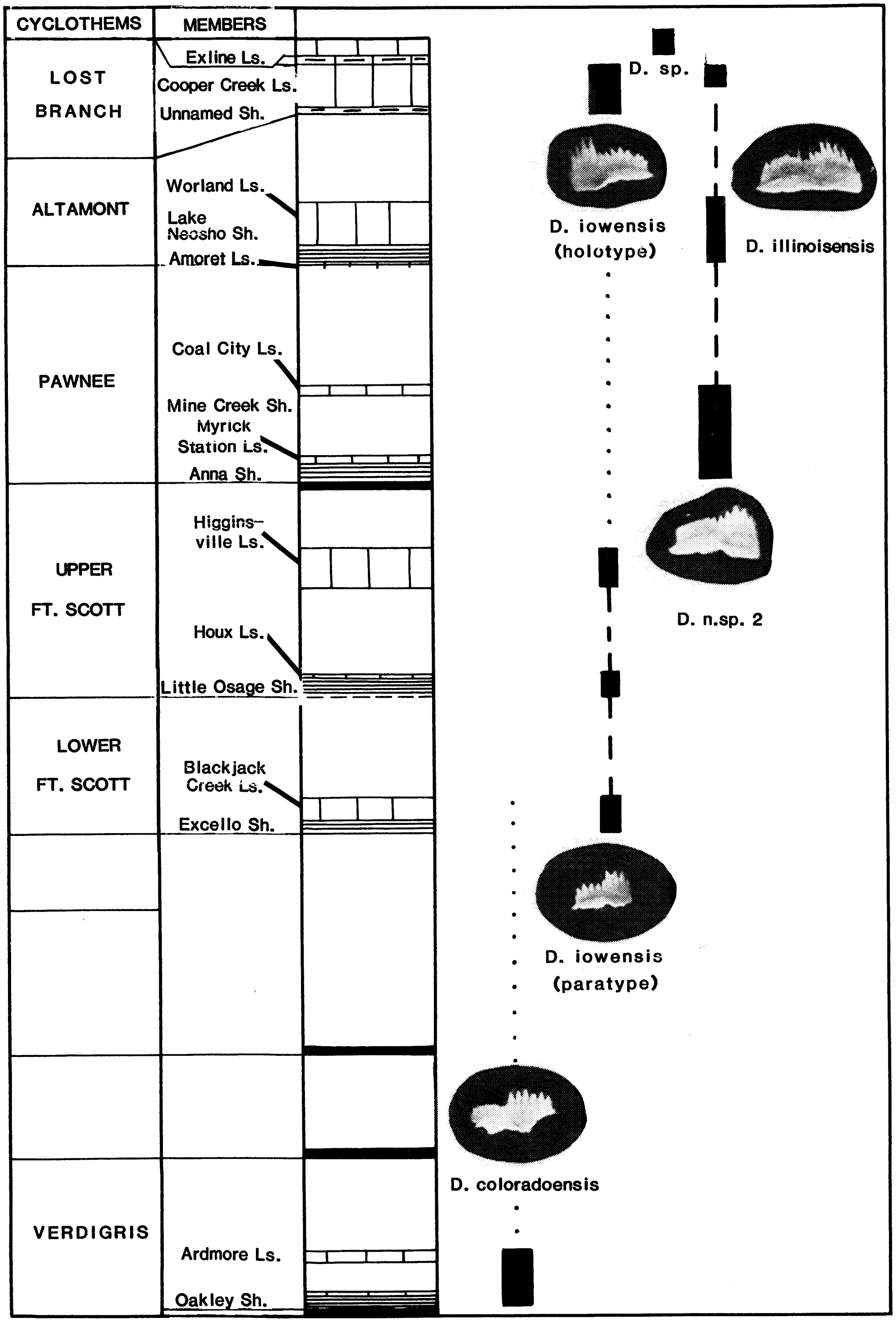

Figure 19. Stratigraphic range chart for species of *Diplognathodus*. Vertical scale approximate. Conodonts are enlarged approximately 40X. Illustrated specimens: *D. coloradoensis* from sample 22-22T (SUI50966), *D. iowensis* from samples 22-9F (SUI50965) and 37-9I (holotype--SUI50964), *D.* n. sp. 2 from sample 37-9H (SUI50963), and *D. illinoisensis* from 37-9X (SUI50962).

morphotypes that appear to exhibit sharp differences in habitat. *D. iowensis* is abundant throughout the Cooper Creek Limestone, *D.* n. sp. 2 occurs in the top quarter of the Cooper Creek Limestone, and *D. illinoisensis* is a rare element in the thin phosphatic shale and underlying limestone below the Cooper Creek (Fig. 19). Another platform element that has its occurrence restricted to the Cooper Creek and overlying Exline Limestone is *Anchignathodus ellisoni* Merrill (1973b), which is distinguished from the long-ranging *A. minutus* (Ellison, 1941) by its greater number of denticles and the angle at which they lie with respect to the cusp.

Exline Limestone

Initially considered part of the Lost Branch cyclothem, the Exline Limestone has a fauna that current work is showing to be quite distinct from that of the Lost Branch. A major difference is the absence of *Neognathodus* in the Exline. Confined to the Exline in this study is a form of *Diplognathodus* that resembles *D. iowensis*, but has less prominant anterior denticles; too few specimens are available to draw further conclusions at this time. In addition, *Adetognathus lautus* (in the sense of Baesemann, 1973) occurs only in the Exline Limestone in this study, but it ranges throughout the Missourian, according to Baesemann (1973).

SYSTEMATIC PALEONTOLOGY

Conodont collections used in this study are reposited at the Department of Geology, University of Iowa, Iowa City, and illustrated reference specimens are assigned SUI catalog numbers. Swade's (1982) concepts of species and his use of open nomenclature are retained in this report.

Genus IDIOGNATHODUS Gunnell, 1931

Idiognathodus GUNNELL, 1931, p. 249
Streptognathodus STAUFFER & PLUMMER, 1932, p. 47
Idiognathodus Gunnell. BAESEMANN, 1973, p. 699

REMARKS. -- The multielement diagnosis of Baesemann (1973) for this genus is followed herein. He synonymized *Streptognathodus* with *Idiognathodus* because all elements other than the platform (P) element are the same, and because the platform end-members of the two form genera seem to intergrade in the Missourian faunas he studied. In collections examined for this study, most juvenile platforms of both form genera are very similar; nearly all bear faint to distinct longitudinal carinate median troughs, the supposed diagnostic feature for *Streptognathodus*, even in faunas in which all mature forms are troughless and thus referable to *Idiognathodus* in its restricted sense as a form genus. The distinction of species within *Idiognathodus* as used herein is based only on mature platform elements. Although intermediate forms exist between many of the six species recognized, they are dominated numerically by the distinctive end-member forms that are regarded as species in the samples studied.

Idiognathodus sp. 1

Fig. 18 -- 4,5,10,11,19,20,27,37,38,46

DIAGNOSIS. -- Presence of transverse ridges in conjunction with well defined, nodose accessory lobes distinguishes *I.* sp. 1 from *I.* spp. 2, 3, and 4. Lack of a deep, well-defined trough distinguishes *I.* sp. 1 from *I.* spp. 5 and 6.

DESCRIPTION. -- In representative mature specimens of *Idiognathodus* sp. 1, the upper surface of the platform element is generally flat and includes moderately to well developed accessory lobes; the inner lobe is wider and more distinctly differentiated than the outer lobe. Length/width ratios of the upper platform surface (including accessory lobes) are close to 2.0. The platform surface posterior to the carina and between the accessory lobes, bears transverse ridges, which are mostly continuous and nearly straight to slightly curved anteriorly on the inner side of the midline. On some specimens, the ridges are slightly broken just to the inner side of the midline to form a narrow, shallow incipient trough. The surface of the accessory lobes is set with curved rows of nodes; one or more interior rows are convex toward the midline of the platform, and the exterior row is convex away from the midline, paralleling the margin of the lobe.

REMARKS. -- This species is a segment of a long-ranging lineage found in all six cyclothems studied. It dominates the faunas of the lower four cycles (Verdigris, lower and upper Fort Scott, Pawnee) and the regressive upper portions of the fifth cycle (Altamont). The slight incipient trough is common only in specimens from the Excello Shale (lower Ft. Scott) and the two younger cycles studied (Altamont, Cooper Creek). *I.* sp. 1 generally conforms to the conservative interpretation of *I. delicatus* of many workers. *I. delicatus* Gunnell, 1931, originally was described from "... the shaly middle portion of the Fort Scott Limestone... at Lexington, Missouri." This horizon is probably the Little Osage Member, which includes the phosphatic shale of the upper Fort Scott cycle of the present study.

MATERIALS. -- Several hundred mature specimens. Illustrated reference specimens: SUI 50910, 50912, 50919, 50920, 50928, 50932, 50936, 50949, 50950, 50953.

Idiognathodus sp. 2

Fig. 18 -- 21,28,47,48

DIAGNOSIS. -- Greater narrowness of the upper platform with greatly reduced, irregularly ridged accessory lobes distinguishes *I.* sp. 2 from *I.* sp. 1. These characteristics plus presence of transverse ridges continuous across the midline distinguish *I.* sp. 2 from *I.* spp. 3 and 4, and lack of a trough distinquishes it from *I.* spp. 5 and 6.

DESCRIPTION. -- In representative mature specimens of *Idiognathodus* sp. 2, the upper surface of the flat platform element with transverse ridges is narrow and elongate, because of greatly reduced width of the accessory lobes, such that even the inner lobe is rarely differentiated from the platform margin. Length/width ratios generally exceed 2.0 and approach 3.0 in a few specimens. The ornamentation of the small accessory lobes consists dominantly of irregular ridges instead of nodes. Many transverse ridges tend to be broken just short of of both margins to produce a row of nodes along the margins. The posteriormost transverse ridges tend to curve slightly posteriorly on the outer side of the midline in some specimens. Large specimens tend toward poorly defined ornamentation on the upper surface.

REMARKS. -- These forms were found mostly in the Oakley Shale (Verdigris cycle) where they appear subdominant with *I.* sp.1. A few specimens, some with slightly more differentiated inner accessory lobes, were recovered from the next three higher cycles (lower and upper Fort Scott, Pawnee).

MATERIAL. -- About 100 mature specimens. Illustrated reference specimens: SUI 50933, 50940, 50954, 50955.

Idiognathodus sp. 3

Fig. 18 -- 22,29,39,40

DIAGNOSIS. -- Wider platform (low length/width ratio) in conjunction with surface ornamentation dominated by rows of nodes, rather than ridges or pits, along with lack of a trough, distinguish *I.* sp. 3 form all other species of *Idiognathodus* recognized in this study.

DESCRIPTION. -- In representative mature specimens of *Idiognathodus* sp. 3, the flat upper surface of the platform element is broad, with length/width ratios of 1.5 to 1.6. Accessory lobes are large and poorly differentiated from the rest of the platform, with a slight sinus only on the inner margin, but not on all specimens. Most of the upper surface is occupied by rows of nodes, grading from transversely arranged on the posterior and the middle, to somewhat concentric on the accessory lobes. On some specimens, a few posterior rows are fused into incomplete and somewhat irregular transverse ridges.

REMARKS. -- This species was found only in three successive cycles (lower and upper Fort Scott, Pawnee) in this study. It may be referable to *I. claviformis* Gunnell 1931, the type species of *Idiognathodus*, which, like *I. delicatus*, was described from the horizon of the Little Osage Shale (upper Fort Scott cycle).

MATERIAL. -- About 50 mature specimens. Illustrated reference specimens: SUI 50934, 50941, 50951, 50952.

Idiognathodus sp. 4

Fig. 18 -- 30

DIAGNOSIS. -- The medial and posterior subreticulate surface pattern of shallow pits basically distinguishes *I.* sp. 4 from *I.* spp. 1, 2, and 3. Good differentiation of the inner accessory lobe and its nodose ornament further distinguish *I.* sp. 4 from *I.* sp. 2, and narrowness of the platform further distinguishes it form *I*. sp. 3. Lack of a trough distinguishes *I*. sp. 4 from *I*. spp. 5 and 6.

DESCRIPTION. -- In representative mature specimens of *Idiognathodus* sp. 4, the flat upper surface of the platform element is narrow, with length/width ratios between 2.0 and 2.5. The inner accessory lobe is nodose and well differentiated, but the outer accessory lobe, although nodose, is essentially not differentiated. Most of the upper surface posterior to the carina and lobes is set with an ornamentation that combines transverse ridges and nodes such that the surface appears covered with a subreticulate pattern of shallow pits.

REMARKS. -- This form is rare and found only in the Little Osage and Anna Shale members (upper Fort Scott, Pawnee cycles); it may be a minor variant of *I*. sp. 1.

MATERIAL. -- In addition to the illustrated specimen (SUI 50943), perhaps 5 other mature specimens.

Idiognathodus sp. 5

Fig. 18 -- 12,13

DIAGNOSIS. -- Presence of a distinct longtitudinal median trough cutting the transverse ridges distinguishes *I*. sp. 5 from *I*. spp. 1, 2, 3, and 4. Narrowness of the upper platform surface with greatly reduced accessory lobes, prominence of the carina extending into the trough, which tends to merge with the adcarinal grooves, and alignment of the transverse ridges across the trough, distinguishes *I*. sp. 5 from *I*. sp. 6.

DESCRIPTION. -- In representative mature specimens of *Idiognathodus* sp. 5, the upper surface of the platform element is broken by a distinct longitudinal, generally U-shaped median trough. A carina extends posteriorly up to halfway along the trough in some specimens. The platform is narrow with length/width ratios generally between 2.0 and 2.5. Accessory lobes are greatly reduced, poorly differentiated, and set with irregular and poorly defined nodes to ridges in most specimens. The posterior part of the platform is set with two marginal rows of short transverse ridges, generally aligned, but not jutting into the trough, and reduced nearly to two lateral rows of nodes in some smaller specimens.

REMARKS. -- This species was found only in the transgressive lower part of the Altamont cycle where it was confined to the Amoret Member and the lower gray and middle dark gray horizons of the Lake Neosho Shale Member. The longitudinal median trough is used by some workers to define the form genus *Streptognathodus*.

MATERIAL. -- About 100 mature specimens. Illustrated reference specimens: SUI 50926, 50927.

Idiognathodus sp. 6

Fig. 18 -- 6,7

DIAGNOSIS. -- Presence of a distinct longitudinal median trough cutting the transverse ridges distinguishes *I.* sp. 6 from *I.* spp. 1, 2, 3, and 4. The broader platform with larger and better differentiated accessory lobes, the shorter carina, the more distinct separation of the canoe-shaped trough from the reduced carina and adcarinal grooves, and the greater tendency toward median offset of transverse ridges to form a zigzag trough, distinguishes *I.* sp. 6 from *I.* sp. 5.

DESCRIPTION. -- In representative mature specimens of *Idiognathodus* sp. 6, the upper surface of the platform element is broken by a distinct, longitudinal, oval to canoe-shaped, median trough, extending from the end of the carina to the posterior end of the element. The carina, which extends along less than one third of the platform, and adcarinal grooves are separated from the trough by small ridges in most specimens. The platform typically is broad, with length/width ratios between 1.5 and 2.0. Accessory lobes are wide, well differentiated, and set with nodes that typically are not regularly arranged; in a few specimens the nodes appear concentrically arranged, and in some others they appear fused into short ridges. The posterior end of the platform along both sides of the trough is set with parallel transverse ridges that in most specimens tend to bend anteriorly at the midline, and become offset from their counterpart across the trough, such that the trace of the deepest part of the trough is a zigzag line.

REMARKS. -- This species was found only in the phosphatic shale below the Cooper Creek Limestone (Lost Branch cycle). It would be assigned to the form genus *Streptognathodus* by some workers, and it resembles *S. excelsus* Stauffer and Plummer (1932, p. 48). It is closely related to *I.* sp. 5, and some larger specimens of *I.* sp. 5 in the Lake Neosho Shale tend to develop a zigzag trough like that of *I.* sp. 6, but still retain a more prominent carina and lack the larger accessory lobes of *I.* sp. 6.

MATERIAL. -- About 100 mature specimens. Illustrated reference specimens: SUI 50911, 50913.

Genus GONDOLELLA Stauffer and Plummer 1932

Gondolella STAUFFER & PLUMMER, 1932, p. 41.
Gondolella Stauffer & Plummer. CLARK & MOSHER, 1966, p. 383.
Gondolella Stauffer & Plummer. MERRILL, 1975, p. 51.
Gondolella Stauffer & Plummer. VON BITTER, 1976, p. 5.
Gondolella Stauffer & Plummer. VON BITTER & MERRILL, 1980, p. 21.

REMARKS. -- Although evidence of the multielement nature of *Gondolella* is recognized in the present faunas, the morphologic variation used to differentiate species of *Gondolella* in this study is restricted to the platform element.

Gondolella sp. 1.

Fig. 18 -- 44, 45

DIAGNOSIS. -- The presence of a smooth to very finely striate, narrow, symmetrical upper platform surface distinguishes *G.* sp. 1 from *G.* spp. 2 and 3.

DESCRIPTION. -- In representative mature specimens of *Gondolella* sp. 1, the platform element has a symmetrical, relatively narrow platform with a length/width ratio (excluding cusp and free blade) of about 4.0. On the upper surface, the carina has a prominent posterior cusp and sharp, narrow, sawtoothed denticles, steeper on the posterior side, generally becoming slightly larger and sharper anteriorly, but not extending beyond the platform in most specimens; in a few specimens, the carina extends anteriorly to form a short free blade bearing no more than one denticle. The platform surface is rounded posteriorly and gently to moderately tapered anteriorly. Lateral furrows are straight and moderately deep posteriorly, but become shallower anteriorly in many specimens. The platform margins are smoothly curved; the upper lateral surfaces appear smooth in most specimens, but show a very fine transverse striation directed anteriorly toward each margin, on close inspection under the light microscope.

REMARKS. -- *G.* sp. 1 was found only in the Oakley Shale (Verdigris cycle), where it is abundant only in the lower middle sample. It may be the same as *G.* n. sp. A of Merrill & King (1971, p. 657) obtained from shales in the Oak Grove Member in northwestern Illinois, the probable correlative of the Verdigris cycle.

MATERIAL. -- A total of 190 specimens (see Plate 1). Illustrated reference specimens: SUI 50960, 50961.

Gondolella sp. 2

Fig. 18 --35, 36

DIAGNOSIS. -- Presence of strong parallel transverse ridges on a relatively broader platform distinguishes *G.* sp. 2 from *G.* sp. 1. Greater prominence of the cusp, more discrete denticles, less differentiation of anterior and posterior denticles, and lack of bifurcation and less anterior outward bending of the transverse ridges distinguishes *G.* sp. 2 from *G.* sp. 3.

DESCRIPTION. -- In representative mature specimens of *Gondolella* sp. 2, the platform element is slightly curved laterally, and the platform is relatively broad, with a length/width ratio generally between 3.0 and 3.5. On the upper surface, the carina has a generally prominent posterior cusp and sawtoothed denticles, somewhat subdued posteriorly, but becoming larger and sharper anteriorly. In most specimens the carina extends anteriorly as a short free blade that bears a single denticle. The posterior platform surface ranges from moderately rounded in some specimens to more abruptly rounded in most, to nearly square in a few. The anterior platform surface is gently to moderately tapered anteriorly. Lateral furrows are slightly to moderately deep throughout. The platform margins are curved but irregular because of strong parallel transverse ridges on the platform surface, which bend slightly anteriorly toward the margins on the anterior ends of some specimens.

REMARKS. -- *G.* sp. 2 was found abundantly only in the middle of the black facies of the Excello Shale (lower Fort Scott cycle), and one specimen was found in the top of the Oakley Shale (Verdigris cycle). It is probably the same as *G. bella* Stauffer & Plummer, 1932, as described by Merrill (1975, p. 58) from the Hanover Member of northwestern Illinois, which overlies the Excello Shale there (Willman et al., 1975). The Excello may have been included in Merrill's samples as the "darker less calcareous rock" that "are richest in *Gondolella*" according to Merrill (1975, p. 33).

MATERIAL. -- A total of 434 specimens (see Plate 1). Illustrated reference specimens: SUI 50944, 50945.

Gondolella sp. 3

Fig. 18 --1,2

DIAGNOSIS. -- Presence of strong transverse ridges distinguishes *G.* sp. 3 from *G.* sp. 1. Bifurcation of transverse ridges, greater anterior outward bending of most ridges around all the margin, and much greater fusion of the anteriormost denticles, combined with more nodelike form of the posterior denticles and less prominence of the cusp, distinguishes *G.* sp. 3 from *G.* sp. 2.

DESCRIPTION. -- In representative mature specimens of *Gondolella* sp. 3, the platform element is slightly curved laterally, and the platform is broad, with a length/width ratio generally about 3.0. On the upper surface, the carina has an elongate posterior cusp that is less prominent than in the other two species. The denticles, though having a sawtoothed profile, appear more equidimensional and nodelike toward the posterior of most specimens, but become longer and fuse anteriorly. In many specimens, the carina extends anteriorly as a free blade that bears up to two denticles. The posterior platform surface ranges from moderately to abruptly rounded in most specimens to nearly square in a few. The anterior platform surface is gently to moderately tapered anteriorly. Lateral furrows are shallow and irregular in most specimens. The platform margins are curved but irregular because of strong transverse ridges on the surface, which are directed anteriorly toward the margins, most strongly toward the anterior end. Many ridges bifurcate marginally on many specimens.

REMARKS. -- *G.* sp. 3 was found only in the lower thin shale and limestone below the Cooper Creek Limestone (Lost Branch cycle). It is closely related to *G.* sp. 2, and many smaller specimens tend to resemble *G.* sp. 2, from which it was probably derived. It is probably the same as *G. magna* Stauffer & Plummer, 1932, as described by Merrill (1975, p. 61) from the Lonsdale Member of northwestern Illinois, which, on the basis of its entire conodont fauna, studied by the author in a senior honors thesis at Knox College, is considered equivalent to the Lost Branch cycle (Heckel, 1984).

MATERIAL. -- A total of 32 specimens (see Plate 3). Illustrated reference specimens: SUI 50917, 50918.

Genus DIPLOGNATHODUS Kozur & Merrill, 1975

Diplognathodus KOZUR & MERRILL, in Kozur 1975, p. 9.
Diplognathodus Kozur & Merrill. MERRILL, 1975, p. 46.

REMARKS. -- This genus was erected for small conodonts in which the platform element has a blade-carina that is sharply differentiated into anterior and posterior regions. Other elements are unknown according to Merrill (1975), who recognized two species in northwestern Illinois, *D. coloradoensis* (Murray & Chronic, 1965), and *D. illinoisensis* Merrill, 1975. *D. coloradoensis* was reported by Merrill (1975) from the Hanover (= lower Fort Scott cycle), the Oak Grove (= Verdigris cycle) and older rocks in Illinois, but was found only in the upper Oakley shale of the Verdigris cycle in the present study. *D. illinoisensis* was reported by Merrill (1975) from the Lonsdale Member (= Lost Branch cycle) and questionably from the Sparland Member (may = Altamont cycle) in Illinois, but was found only in the lower part of the Lost Branch cycle in the present study. Two new species are described in the present study.

Diplognathodus iowensis Swade n. sp.

Fig. 19 -- as denoted thereon

HOLOTYPE. -- The specimen so designated on Figure 19: SUI 50964.

DIAGNOSIS. -- Presence of discrete denticles along the entire blade-carina distinguishes *D. iowensis* from *D. coloradoensis* and *D.* n. sp. 2, both of which have most posterior denticles fused. Shorter and higher platform with abruptly higher set of anterior denticles that are fewer in number distinguish *D. iowensis* from *D. illinoisensis*, which has a longer platform element with more denticles and length/height ratio generally greater than 2.0.

DESCRIPTION. -- In representative mature specimens of *Diplognathodus iowensis*, the platform element is short in length and high, with a length/height ratio of 1.4 to 1.7 (maximum of each dimension). In lateral view, the anterior denticles are high, numbering 4 or 5, with the highest either the first or second from the middle of the platform; they shorten slightly anteriorly, with the anteriormost in some specimens greatly reduced to a tiny nick on the end of the blade. Posterior denticles are low, numbering 5 to 8, and their ends generally form a gentle convex-upward curve in most specimens; in a few specimens, the normally small, crowded denticle in the middle of the platform (included in the anterior region by Merrill, 1975, Fig. 10, but regarded herein as part of the posterior set of denticles) is slightly higher and breaks the upward convexity of the posterior curve.

REMARKS. -- *D. iowensis* was found in the lower and upper Fort Scott cycles and in the Lost Branch cycle, where it dominates the fauna of the Cooper Creek Limestone.

MATERIAL. -- A total of 199 specimens (see Plates 1-3). Additional illustrated specimen: SUI 50965.

Diplognathodus n. sp. 2

Fig. 19 -- as denoted thereon

DIAGNOSIS. -- Presence of posterior fused denticles distinguishes *D.* n. sp. 2 from *D. iowensis* and *D. illinoisensis*. In lateral view, the convex-upward curve of the blade-carina over the anterior high denticles and the smooth transition of this curve across the middle to a straighter line over the fused denticles distinguishes *D.* n. sp. 2 from *D. coloradoensis*; the latter has a distinct notch separating anterior and posterior parts of the blade-carina, less of a curve described by the ends of the high anterior denticles, and greater length/height ratio of 2.0 to 2.3.

DESCRIPTION. -- In representative mature specimens of *Diplognathodus* n. sp. 2, the platform element is relatively short with a length/height ratio of 1.6 to 1.8. In lateral view, the anterior denticles are discrete, numbering five to six, with the highest in mid-set, resulting in a prominent upward-convex curve that extends smoothly onto the posterior part of the carina, with little development of a notch in the middle. Most posterior denticles are completely fused into a level, generally smooth surface that slopes downward posteriorly but does not extend to the posterior end of the basal cavity.

REMARKS. -- *D.* n. sp. 2 was found in the Pawnee, Altamont, Lost Branch and Exline cycles.

MATERIALS. -- A total of 98 specimens (see plates 1-3). Illustrated reference specimen: SUI 50963.

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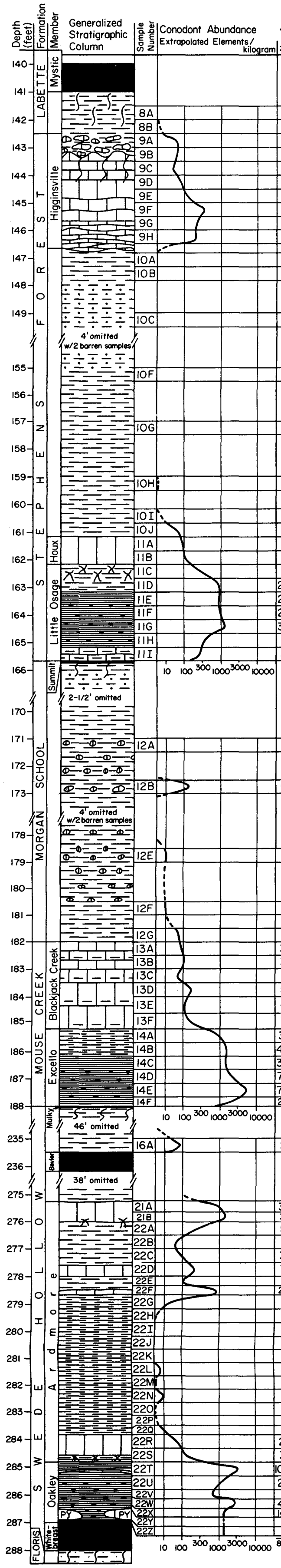
PLATE I CONODONT DISTRIBUTION CP22 SWEDE HOLLOW FORMATION Through LABETTE FORMATION

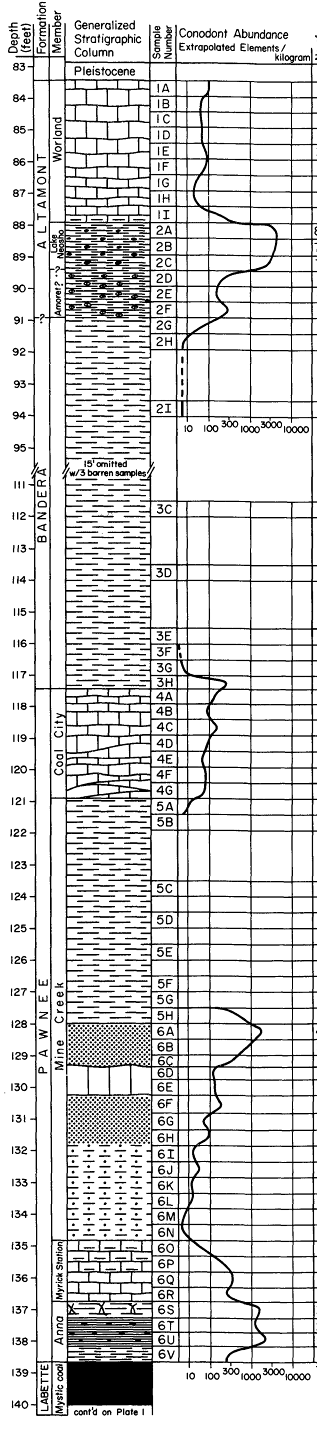


Sample Number	No. of Elements	Adetognathus									Stepanovites			Unassigned			Diplognathodus				Anchignathodus							
		A.lautus	A. gigantus								sp.										A.ellisoni	A. minutus						
		P_d	P_d	P_s	P_f	O	N	A_1	A_2	A_3	N	B_1	B_f	P	O	A_2	D. colo.	D. iow.	D. n.sp.	D. ill.	P	P	P_f	O	N	A_1	A_2	A_3
8A	—																											
8B	f																											
9A	9		1																									
9B	14		3	3				2										1										
9C	10		3	2		1																						
9D	20		2	2	1	1				1?																		
9E	50		1	4							1					1									2			
9F	99																	1				13	3	3	3			
9G	114		5	8	1		1	2										2				1	1	2	4	2		2
9H	96		20	30	11	2	2	2		3				1	1	1		1	1			1				1		
10A	—																											
10B	—																											
10C	—																											
10F	—																											
10G	—																											
10H	f																											
10I	f																											
10J	13			1			1																					
11A	35		1									1										3			1		1	
11B	37																					2		1				
11C	101																						1					
11D	240																											
11E	242																											
11F	237																											
11G	348																											
11H	98																											
11I	120		2	2	1													1				4			8		1	
12A	—																											
12B	64			2	3																	1						
12E	4																											
12F	4																											
12G	14																											
13A	32																					1	1					
13B	34																	1				1	3		1		1	
13C	21																					1			2		1	
13D	52																					4	2	2	1			1
13E	43																					5	2	2			1	
13F	73																					3	1		2	2	1	
14A	311																	1										
14B	422																											
14C	384																	1										
14D	761																											
14E	775																	1										
14F	282																											
16A	24		1	1				1															1					
21A	313			1												1	8					41	3	17	15	12	8	2
21B	371															1	4					15		4	9	5	3	1
22A	59		1		1		1										3					3						
22B	14		2	5	1																	1						
22C	33		2	3	1		1										1								1			
22D	72																1					10		2	3	1		
22E	26																					5	2	5	1			
22F	205																					2						
22G	7																											
22H	f																											
22I	—																											
22J	—																											
22K	—																											
22L	4																1?											
22M	f																											
22N	9																											
22O	f																											
22P	f																											
22Q	2																											
22R	26																					2		1				
22S	38																							2				
22T	1067																42					2						
22U	271																2											
22V	83																											
22W	401																											
22X	149																											
22Y	f																											
22Z	82																											
	8415																											

Sample Number	Aethotaxis						Neognath.		Idiognathodus								Idioprioniodus								Gondolella								
	sp.						spp.		spp.		Ramiform Elements						conjunctus								G.sp.1	G.sp.2	G.sp.3	G.denuda	Ramiforms				
	N	A_1	A_{2a}	A_{2b}	A_3	A_f	P	P_f	P	P_f	O	N	A_1	A_{1c}	A_2	A_3	N_1	N_2	B_1	B_{2a}	B_{2b}	B_{2c}	B_3	B_f	P	P	P	P	O	N	B_1	B_2	B_3
8A																																	
8B																																	
9A									8																								
9B									5																								
9C									4																								
9D									13																								
9E							1		35	1	3	1																					
9F			1	1			1		63		6	1	2			1																	
9G									64	3	7	3	4		1	3																	
9H									21		1		1		1																		
10A																																	
10B																																	
10C																																	
10F																																	
10G																																	
10H																																	
10I																																	
10J									10		1																						
11A									24	1	1		1	1										1									
11B									16	1	1	1		1			1	5	6		1	1		1									
11C							6	1	51	2	7	1	1		1	3	4	3	10	3	5	2	1										
11D							8	3	153	3	29	10	6	1	2	2	3	2	8	4	6	2	1										
11E							4		125	4	38	16	8			4	11	3	11	6	6	3	5										
11F							28	9	89	2	34	18	8	3		4	5	6	13	6	4	6	8										
11G							65	7	67	2	55	15	6	1		4	18	18	37	19	16	12	10										
11H							15	1	28		11	4	2				3	8	7	5	7	3	4										
11I							3	1	73	3	9	1	1		1		1		3	2		1	1										
12A																																	
12B							6		32		5	1	3	1				1								1				3	3	1	
12E									4																								
12F									4																								
12G									13		1																						
13A							2		21		6	1																					
13B							3	2	17		4	1							2														
13C							2		8		1						2	1			1		2										
13D							1		24		5	3					1	1	1	2	1	2											
13E							2		15		6	2					2	1	1		1	2	2										
13F								1	35		5	3	1	2				1	8	5	1	2	1										
14A							22	4	121		53	30	21	8	1	9	5	2	12	7	8	3	6										
14B							55	12	153	2	64	40	24	7	1	15	8	9	17	6	6	7	3										
14C							49	3	107	2	54	17	12	2		4	16	15	28	20	2	17	16	2									
14D							38	3	169		26	8	7			4	9	10	23	7	14	12	10			298			55	30	15	20	4
14E							88	5	197	2	68	25	26	7	6	10	17	12	26	9	10	9	8			136			33	32	24	24	4
14F							20	2	114		39	17	21	7	5	4	4	5	13	13	4	9	6										
16A							1		14		3			1		1																	
21A	2	5	1	2	1		12		119		17	8	21	3	2	8						1		3									
21B	3	2	2	1	3	1	8		192	6	42	20	20	3	6	10		1	7	2	1	1	1										
22A							1		39		5	1	2	1	1	1																	
22B									3						1																		
22C									19	2	1		1	1																			
22D		2			2	1	9	4	27		4	1	2	1			1						1	2									
22E						2	4		5								1	1	1		1												
22F	1?						10		159		12	4	4	1		1		1	1			2	3										
22G							1		4		2																						
22H																																	
22I																																	
22J																																	
22K																																	
22L							2		1																								
22M																																	
22N						1			5									1							1				1				
22O																																	
22P																																	
22Q									1	1																							
22R				1			2	2	10		3		1						1	1	1												
22S				1			6		14	2	6	1	1					1	2		1		1										
22T							48		548	25	143	52	21	7	4	22	15	6	13	9	13	2	4	5	1								
22U							30	5	17	48	26	11	4	4		3	8	4	10	8	4	4	3	11	1								
22V							21	5	25	17	5	3				2	2	5	3	1	3	2											
22W							19	2	40	42	10	9	3	1	1	1	7	4	8	1	6	5	3		189				11	19	20	16	6
22X							4		49	30	8	2	2				6	4	8	6	2	4	6	4									
22Y																																	
22Z							5	2	45	6	7	7	1			1	1	1	5	2	2		1										

PLATE 2

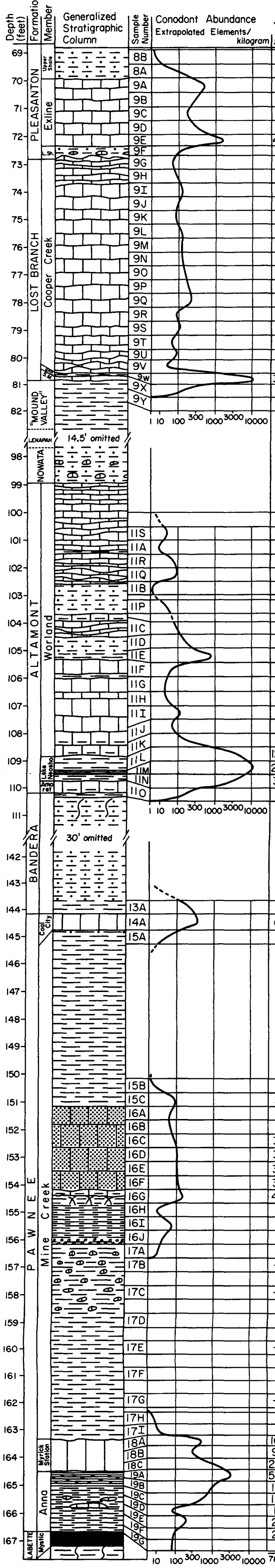
CONODONT DISTRIBUTION CP22 PAWNEE FORMATION Through ALTAMONT FORMATION



Sample Number	No. of Elements	Adetognathus									Stepanovites			Unassigned			Diplognathodus				Anchignathodus							
		A.lautus	A. gigantus								sp.										A.ellisoni	A. minutus						
		P_d	P_d	P_s	P_f	O	N	A_1	A_2	A_3	N	B_1	B_f	P	O	A_2	D. colo.	D. iow.	D. n.sp.	D. ill.	P	P	P_f	O	N	A_1	A_2	A_3
1A	43		10	9	5					1?													1		1		1	
1B	19		2	2	1																			1		1		
1C	25		2	1	1	1																1		1		1	1	
1D	17																					1		1			2	
1E	34																					6		3	1			1
1F	23																					4						
1G	10																									1		
1H	6																					1						
1I	72																					6		2	1	4	2	
2A	887																		1					1	2		1	
2B	724		1				1															1	1	2		1		
2C	731		2	1	1																	5	2	5	2	2		
2D	54		1																									
2E	46																					2					1	
2F	72		5	9	4	3													1							1		
2G	16		1																			1						
2H	1																											
2I	1																											
3C	—																											
3D	—																											
3E	—																											
3F	f																											
3G	1																											
3H	90		7	11	6		1															1	6					
4A	47																					3		1			2	
4B	29																					4			1	1	2	
4C	52																					3			2			
4D	28																					3			1		2	
4E	15																		1			1	4					
4F	19																					2				1		
4G	23																						1					
5A	2				1																			1?				
5B	—																											
5C	—																											
5D	—																											
5E	—																											
5F	—																											
5G	—																											
5H	90		13	9	14		2	2		3																		
6A	498		51	43	12	8	12	7	1	2									1				1					
6B	301		30	32	29	24	17	3	1	2									18									
6C	94		10	7	9	2	3	1		2									5									
6D	29		1	3	6	2	2												2									
6E	60		6	3	5	1	5												1									
6F	64		5	9	15	1	6	1		3									1									
6G	13			1	2	1	1	1											1									
6H	27		1	4	4		1			1									2									
6I	4			1															1									
6J	9			1	2					1?																		
6K	4		1				1									1												
6L	5		1	2																								
6M	1			1																								
6N	1																											
6O	8		2	1																		1						
6P	68		5	6	1	2													1						1		1	
6Q	155																					9		3	1	1	2	2
6R	104															1						6		2	1		2	
6S	330																							2	1			
6T	278																											
6U	532		1	1	2																	3	3					
6V	78			2	4																	6	2					
	5836																											

Sample Number	Aethotaxis						Neognath.		Idiognathodus								Idioprioniodus								Gondolella								
	sp.						spp.		spp.		Ramiform Elements						conjunctus								G.sp.1	G.sp.2	G.sp.3	G.denuda	Ramiforms				
	N	A_1	A_{2a}	A_{2b}	A_3	A_f	P	P_f	P	P_f	O	N	A_1	A_1	A_2	A_3	N_1	N_2	B_1	B_{2a}	B_{2b}	B_{2c}	B_3	B_f	P	P	P	P	O	N	B_1	B_2	B_3
1A							8		7		1	1																					
1B	1						3		7					1																			
1C							2		5		3		2	2		1																	
1D							4		9										1														
1E	1			2		1	6		8		3			1					1	1			1										
1F		1				1	5		6	1		1	2	1	1																		
1G									8		1																						
1H									4		1																						
1I		1					27		13		3	3	1		3	1		1	2	1	1												
2A							426	46	129	5	81	46	19	4	3	10	18	12	45	19	25	12	7										
2B							304	6	232	10	76	38	22	2		14	1	1	6	3	4	1	2	4									
2C							232		225	8	104	71	19	9	3	16	4	2	9	5	3	4	1	2									
2D							19		17		5	4	1					2	3	2													
2E							12		22		5	1					1			1													
2F							11		31		6	2	1			1																	
2G							6		1		1	3					1		2														
2H																				1?													
2I											1																						
3C																																	
3D																																	
3E																																	
3F																																	
3G												1																					
3H						1	4		43	6	11	1			1																		
4A	2	1				1	12		14	2	8		1																				
4B							5		8		3								2	1		1		1									
4C					2	2	14		20		3	1				1	1		2		1			2									
4D					1	2	4		12		2			1					1														
4E	1	1					1		6		1			1																			
4F						1	3		5		5	2																					
4G		1	1	1	1	1	3	2	8		1	1							1	2			1										
5A																																	
5B																																	
5C																																	
5D																																	
5E																																	
5F																																	
5G																																	
5H							1		51		1											1?											
6A							5		320	23	7	4	1			1								2									
6B							7		130	5	13	2	5																				
6C							3		41		9	2	1	1																			
6D							2		14																								
6E								1	37		1	2	1																				
6F							2		22		3		1			2																	
6G									6		1																						
6H								1	14			1																					
6I								1	1																								
6J									3	1	1	1																					
6K									1																								
6L									2																								
6M																																	
6N									1																								
6O									2			2																					
6P									40	1	6	1		1	1	1																	
6Q					1?		5	1	108	10	6		2			2		1	1	1	1	2	1										
6R		1					7	1	51	8	7	1	1	1		2		1	4		4	4	3										
6S		1?					56	6	127	14	45	20	8	2	1	11	3	6	12	7	9	6	3										
6T							33	6	89	6	64	15	7	1		4	10	8	16	7	8	5	5										
6U							59	8	179	15	50	49	9	10	3	5	23	20	35	16	16	15	11	20									
6V							3		45			2					3	1	4	1			3										

PLATE 3 CONODONT DISTRIBUTION CP37 PAWNEE FORMATION Through LOST BRANCH FORMATION



Sample Number	No. of Elements	Adetognathus A.lautus P_d	A. gigantus P_d	A. gigantus P_s	A. gigantus P_f	A. gigantus O	A. gigantus N	A. gigantus A_1	A. gigantus A_2	A. gigantus A_3	Stepanovites sp. N	Stepanovites sp. B_1	Stepanovites sp. B_f	Unassigned P	Unassigned O	Unassigned A_2	Diplognathodus D. colq.	D. iow.	D. n.sp.	D. ill.	Anchignathodus A.ellisoni P	A. minutus P	A. minutus P_f	A. minutus O	A. minutus N	A. minutus A_1	A. minutus A_2	A. minutus A_3	Aethotaxis sp. N	Aethotaxis sp. A_1	Aethotaxis sp. A_{2a}	Aethotaxis sp. A_{2b}	Aethotaxis sp. A_3	Aethotaxis sp. A_f	Neognath. spp. P	Neognath. spp. P_f	Idiognathodus spp. P	Idiognathodus spp. P_f	Idiognathodus Ramiform Elements O	N	A_1	A_{1c}	A_2	A_3	Idioprioniodus conjunctus N_1	N_2	B_1	B_{2a}	B_{2b}	B_{2c}	B_3	B_f	Gondolella G.sp.1 P	G.sp.2 P	G.sp.3 P	G.denuda P	Ramiforms O	N	B_1	B_2	B_3
8B	1																																						1																						
8A	26	2		7	11					1			1	1?																							9																							
9A	171	2	3	7	10																3	4	6	1	2		2	1?	3	4				4			113	10	2	2	1		2				1	1	2		1										
9B	79				1																1	5		2		2											54		3	2	5			3			1														
9C	67			1																		3	1	2	1	1			1	1		1					30		4	4	9	1	2	3	1		1														
9D	109	4		5	1													3			3	2	2	3					2	3		1	1?	2			66	2	6		5		1																		
9E	459	2	6	8	10		1	2		1								9			2	9	1	5	2	1			5	2	3	1					322	32	26	4	11	1		7			4	1			1	2									
9F	26			1	1																		1														21	1	2																						
9G	17			1				1										4	2																		8							1																	
9H	27																	10	2							1									1		8				5																				
9I	52																	23	1		1			1											1		12		4	3	4			2																	
9J	32																	18	2			1													2		1			2	3		2	1																	
9K	27																	18											1						1		3				1		1	1	1																
9L	35																	9													1	1?			1		7		3	2	5	2	2	2																	
9M	40																	15											2								13		2	1	4		2	1																	
9N	33																	9					1	1		1	1		1								7	1	1	2	6		2	1																	
9O	51																	15				1				1	1								3		11		3	5	5	2	1	3																	
9P	74																	25						1			1								2		15	2		2	16		8	3																	
9Q	75																	21				1		1		1	1										15		3	7	15	1	5	4																	
9R	23																	3						2													8		2	2	3	1		2																	
9S	41																	17				1		1		1				2					1		4			3	6		2	1			1				1										
9T	13																	1						3								1?			1		1		1		4		1																		
9U	23																	1			1				1		1?								2		9		6	1			1																		
9V	8																					3					1			1?							3																								
9W	394			2																1		1			1				1?						39	1	179	18	27	14	7		2	6	8	2	6	2	2	4	3	6			31	4	9	11	10	8	2
9X	39			1				1		1										1															2	1	21	1	5								1		1						1					2	
9Y	—																																																												
11S	5																		2																				1	1			1																		
11A	3		1				1												1																																										
11R	22		1	1		2	1	4											5			1												2?	1					1			2	2																	
11Q	20		1	2		1	2	2											2																		1		1		5			3																	
11B	f																																																												
11P	8			6	1					1?																																																			
11C	35		4	4	3	1	1																		1										2		20																								
11D	50		8	12																															2		28																								
11E	159		14	15	1	1	1	1														7					1								33		70	4	7		4		1	1																	
11F	21			1	2																							1							9		6		1	1	1																				
11G	7																					1													1		2		1		1	1																			
11H	8																																		1				1		2	1		1			1		1												
11I	37																					6		2	2		2	1		1?	1			1	7		7		2		1	1		1					1		1										
11J	15																					2			1					2			1		3		2		1		2		1																		
11K	48																																		17		13		5	1	1			1	1	1	2	3	2	1											
11L	1265				1																	23		8	10	6	7	1	1?	2	1				566	8	168	6	148	73	39	8	4	23	36	18	53	16	23	10	9	8									
11M	2010																					1													928	16	151	4	323	196	94	29	8	48	27	31	57	34	26	17	21	18									
11N	355																					2													138		119		45	29	8	5	1	5	2																
11O	45		5	9	1	1							1						6			2				1			1	1					2		11		1		3																				
13A	51			1																		1															47		1							1															
14A	67				2																	8		2	2			1?							7	2	27		7	1	2			1		1	3	1													
15A	7																								1												5		1																						
15B	1																																				1																								
15C	28		7	11	5	2		1		1																											1																								
16A	11		5	1		1		1														3																																							
16B	18		7	6	1																	1																	1		1																				
16C	32		9	2		1	1	3	1	1									3			3			1	1	1										3		1				1																		
16D	37		8	5		5	4	5	1	1									1			1								2?							1			2			2																		
16E	36		4	4		3	4	4	2	1									7			2			1												1			2	1																				
16F	33		6	9	2	2		2														6			1												5																								
16G	49		16	9	1	4	2	2					1?						3			4															7																								
16H	3			1		1																1																																							
16I	14		8	6																																																									
16J	5		3	2																																																									
17A	2			2																																																									
17B	—																																																												
17C	—																																																												
17D	f																																																												
17E	—																																																												
17F	f																																																												
17G	—																																																												
17H	1																		1																																										
17I	3																																				2		1																						
18A	166		1				1															13		2	5	2									3	2	118	6	9	1					3		2	2													
18B	92																					11		8	7	2	3	1		1				2	3	1	27	2	5	2	2	1		1	3	2	1	5		1	2										
18C	227																					9		3			2								36	2	84	4	11	4	1				7	7	19	13	14	6	6	4									
19A	575																								1										107	6	186	8	92	32	33	5	3	11	16	10	22	11	16	12	7	8									
19B	116																																		7	2	26		17	3	6				5	9	13	6	11	7	5										
19C	112																		14			2	2		1		1	1?							7		37		14	13	2	2		2	4	1	2	1	5	2											
19D	19			1				1											4				1	1													7		2	1											1										
19E	26		2	1			2	2											2																		8				7		2																		
19F	20		3	3															2																		9		3																						
19G	9		2	5		1													1																																										
	7816																																																												