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CONODONT DISTRIBUTION AND PALEOECOLOGY WITHIN GENETIC UNITS OF THE IOLA LIMESTONE (MISSOURIAN, UPPER PENNSYLVANIAN) OF NORTHEASTERN KANSAS

by

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Disclaimer

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by

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TABLE OF CONTENTS

LIST OF FIGURES

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INTRODUCTION

> "Hence it seems to me that, in analyzing lithologic features of regional sedimentation, we should pin things down to the narrowest possible stratigraphic entity, rather than meaningless large combinations of beds" (R. C. Moore, 1949, p. 165)

General Statement

Many previous studies of the distribution and paleoecology of Pennsylvanian conodonts in the Midcontinent have been done relative to the cyclothem model (e.g., Heckel and Baesemann, 1975; Mitchell, 1981; Swade, 1985; and Wood, 1977) (See Figure 1). The cyclothem approach to stratigraphy involves the recognition of rhythmic or cyclic alternations of certain specific lithofacies or lithofacies associations. Interpretation of conodont distribution patterns based on this approach include: (1) the apparent restriction or dominance of certain conodont taxa (genera or species) in specific lithotypes or lithofacies [e.g., the dominance of Adetognathus in "outside shales" and the upper part of "upper limestones" in facies that represent brackish, nearshore conditions (Heckel and Baesemann, 1975)], and (2) variations in conodont diversity and abundance inferred to reflect different transgressive or regressive stages within the cyclothem [e.g., the highest diversity and greatest abundance of conodonts in "core shales" representing periods of maximum transgression (Heckel, 1986)].

Application of genetic stratigraphy involves the examination of all facies and facies contacts and their relative relationships. The Iola Limestone (a major cycle of Heckel, 1986) may be composed of a number of the smaller transgressive-

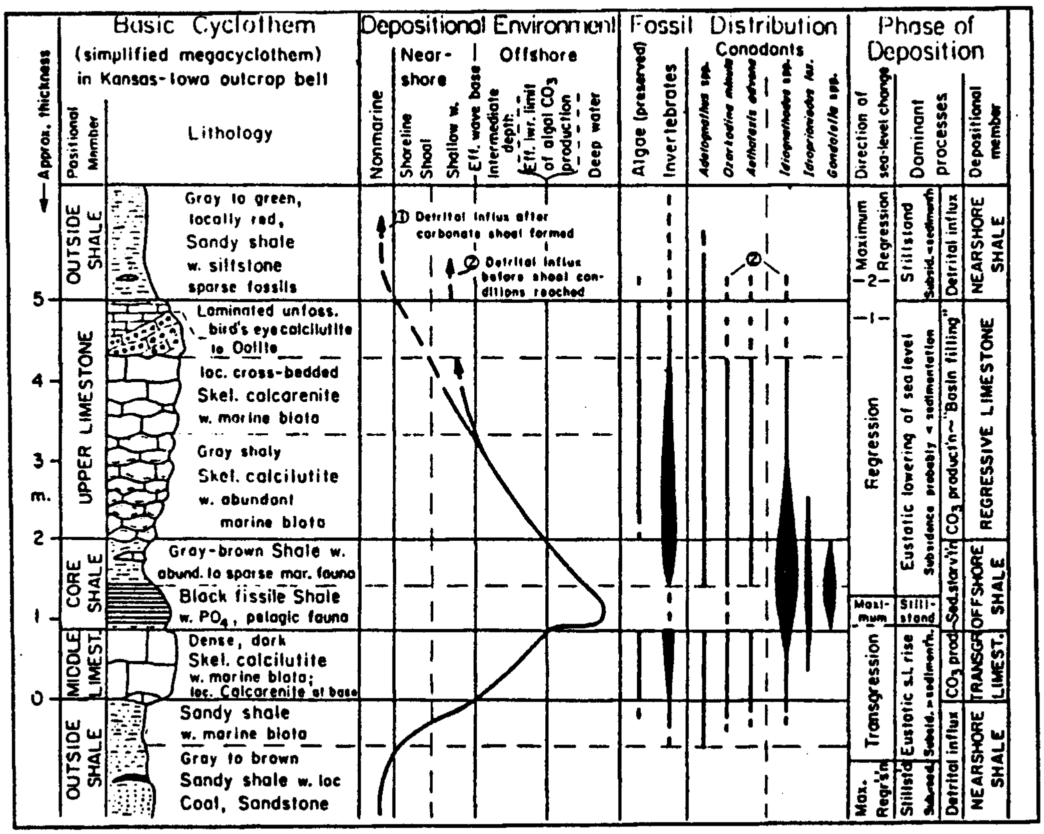

Figure 1. Basic Kansas cyclothem, including conodont and macrofossil distribution patterns (from Heckel, 1977, p. 1047).

regressive (T-R) units (Busch et al., 1985), some of which may be allocyclic (basinally correlative) deepening-shallowing units that can be distinguished from autocyclic (basinally noncorrelative) deepening-shallowing units through correlation (Busch and West, 1987). Correlation of small scale (sixth order of Busch and Rollins, 1984) T-R units is done relative to marker beds and marker horizons. Each sixth order T-R unit (Punctuated Aggradational Cycle of Goodwin and Anderson, 1985) thus represents a thin time-stratigraphic unit with a different set of paleoenvironments relative to adjacent sixth order units (Goodwin and Anderson, 1985). This would seem to indicate that an investigation of conodont distribution patterns relative to a hierarchy of T-R genetic units would provide more detail than one using the cyclothem approach. This study represents one of the first investigations of Pennsylvanian conodont distributions within the framework of genetic stratigraphy.

Purpose and Scope of Investigation

The primary objectives of this study are:

(1) To apply hierarchal genetic stratigraphy (Busch and West, 1987; and Busch and Rollins, 1984) and the PAC approach (Goodwin and Anderson, 1985; and Goodwin et al, 1986) of stratigraphic analysis to the Iola Limestone (see figure 2) in order to delineate and correlate small scale genetic units (sixth order T-R units or PACs) within this formation, and using these correlations to produce detailed relative sea-level curves and facies maps.

(2) To examine and interpret conodont distribution patterns relative to the genetic stratigraphic framework established for the Iola Limestone.

The examination of conodont distribution within small-scale genetic units

SERIES	STAGE	GROUP	FORMATION
UPPER PENNSYLVANIAN	MISSOURIAN	LANSING	Stanton Ls.
			Vilas Sh.
			Plattsburg Ls.
		KANSAS CITY	Bonner Springs Sh.
			Wyandotte Ls
			Lane Sh.
			Iola Ls
			Chanute Sh.
			Drum Ls.
			Cherryvale Sh.
			Dennis Ls.
			Galesburg Sh.
			Swope Ls.
			Ladore Sh.
			Hertha Ls.
		PLEASANTON	Tacket Fm.
			Checkerboard Ls.
			Seminole Fm.

Figure 2. Stratigraphic position of the Iola Limestone (modified from Zeller, 1968, pl. 1).

may enhance our present understanding of their paleoecology, including taphonomy and mode-of-life. This, in turn, could lead to greater ease in interpreting paleoenvironments in which conodonts occur (e.g.the recognition of biofacies or environmental restrictions).

Previous Investigations

The Iola Limestone was first recognized by Haworth and Kirk in 1894, as the limestone underlying the town of Iola in Allen County, Kansas. Later, in 1908, Haworth and Bennett, while tracing beds in eastern Kansas, miscorrelated the Iola Limestone in Allen County with the Wyandotte Limestone of the Kansas City area. This led to confusion in interstate correlations of Upper Pennsylvanian strata between Kansas and Missouri. N. D. Newell in 1932 (in Moore, 1932), corrected this error by recognizing three units within the Iola Limestone: the Paola Limestone Member (named by Newell in 1932, for beds north of Paola, Miami County, Kansas); the Muncie Creek Shale Member (identified by Newell in 1932, at Muncie Creek, Wyandotte County, Kansas); and the Raytown Limestone Member (named for exposures near Raytown, Jackson County, Missouri); and tracing them from the Kansas City area to the type area of the Iola.

The cyclicity of Pennsylvanian strata in the midcontinent was first recognized by R. C. Moore in 1930. The term "cyclothem", coined by Wanless and Weller in 1932, for Pennsylvanian rocks in the Illinois Basin, was adapted by Moore in 1936 for cyclic strata of the midcontinent. By this time, 1936, three workers, N. D. Newell, J. M. Jewett, and R. C. Moore had also accomplished the correlation of most of the major Pennsylvanian cycles in Kansas, including the Iola Limestone.

Heckel and Baesemann (1975), modified the cyclothem model and terminology of Moore, and applied the term cyclothem (a term originally applied to limestone and shale couplets, and used by Heckel to replace the term "megacyclothem") to the repetition of four specific lithofacies that represent one transgressive-regressive cycle of Pennsylvanian strata (see figure 1). These lithofacies are: the "outside shale," a mostly nonmarine, sparsely fossiliferous mudstone unit that is composed locally of sandstone and coals; the "middle limestone," a transgressive limestone with a relatively diverse marine fossil assemblage that directly overlies an "outside shale"; the "core shale," a black, fissile, often phosphatic shale that is generally sandwiched between two gray mudstones, representing the period of maximum transgression of the cyclothem; and the "upper limestone" which represents the regressive stage of the cyclothem.

The phrase "Kansas cyclothem" was coined by Heckel in 1977, for the repetition of these same four lithofacies in Pennsylvanian strata in the midcontinent, which specifically depends on the presence of the "middle" transgressive limestone which distinguishes it from the "Illinois cyclothem". This "middle limestone" is typically absent in "Illinois cyclothems". Heckel (1986) introduced the terms "major," "intermediate," and "minor cycles" to be applied to cyclothems. "Major cycles" have all four of the required lithofacies, and have very well developed and laterally extensive "core shales." "Intermediate cycles" are lacking in at least one of the four repetitive lithofacies, generally either the "middle limestone," or a well developed "core shale." "Minor cycles" are thin units that represent a minor reversal within a more major unit (e.g. a thin limestone unit in the "outside shale" overlying a "major cycle"). Periodicities for "major cycles" were estimated by Heckel (1980) to be 400,000-yrs, and Heckel (1986) suggested that a probable mechanism for "major cycles" is Milankovitch orbital cycles. The Iola Limestone is classified by Heckel (1986) as a "major cycle."

Stratigraphic and petrographic investigations which specifically examined the Iola Limestone include, Mitchell (1981), and Dawson (1984). Mitchell (1981) examined the stratigraphy and petrography of the Iola along its outcrop belt from Iowa to Oklahoma, applying the cyclothem model. Dawson (1984) conducted a detailed petrographic study of the Iola Limestone in Anderson, Allen, Neosho, and Wilson counties in southeastern Kansas, applying the microfacies concept of Carozzi and Textoris (1967), and Flugel (1982).

Recent studies of Pennsylvanian and Permian sedimentary sequences involve the multidisciplined approach of genetic/sequence stratigraphy. Unlike the cyclothem method, which examines only the cyclic or rhythmic alternations of certain specific lithofacies, genetic/sequence stratigraphy involves the examination of all facies and facies contacts and their relative relationships. Examples of this approach include, Busch (1984), Busch and Rollins (1984), Busch et al (1985), and Busch and West (1987). These investigations recognized a nested hierarchy of six scales of transgressive-regressive units (see figures 3 and 4) with inferred periodicities ranging from tens-of-thousand (sixth order T-R units) to hundreds-of-million years (first order T-R units), and whose probable mechanisms range from Milankovitch orbital cycles to variations in the rate of sea floor spreading. For a detailed description of this approach see Busch and West (1987).

AREA AND METHODS OF INVESTIGATION

Field and Laboratory Methods

Sixteen sections of the Iola Limestone were examined in detail along its outcrop belt in Wyandotte, Johnson, and Miami counties of northeastern Kansas (figure 5). Sections were selected and located for study by using USGS 7 1/2

HIERARCHY OF PERMO-CARBONIFEROUS T-R UNITS

BUSCH & ROLLINS, 1984 AND BUSCH, 1984	VAIL *et al.*, 1977	CHANG, 1975 AND RAMSBOTTOM, 1979	MOORE, 1936	GOODWIN AND ANDERSON, 1985	HECKEL, 1977 AND HECKEL, 1986	WANLESS AND WELLER, 1932
FIRST-ORDER 225-300 m.y.	FIRST ORDER DEPOSITIONAL SEQUENCES					
SECOND-ORDER 20-90 m.y.	SECOND ORDER DEPOSITIONAL SEQUENCES	SYNTHEMS				
THIRD-ORDER 7-13 m.y.	THIRD ORDER DEPOSITIONAL SEQUENCES					
FOURTH-ORDER 0.6-3.6 m.y.		MESOTHEMS				
FIFTH-ORDER 300-500 x 10^3 years		CYCLOTHEMS	MEGACYCLOTHEMS	SHALLOWING PAC SEQUENCES	KANSAS CYCLOTHEMS; MAJOR CYCLES	CYCLOTHEMS
SIXTH-ORDER 50-130 x 10^3 years			CYCLOTHEMS	PUNCTUATED AGGRADATIONAL CYCLES (PACs)	MINOR CYCLES	

Figure 3. The hierarchy of Permo-Carboniferous T-R units and their equivalents (from Busch and West, 1987, p. 143).

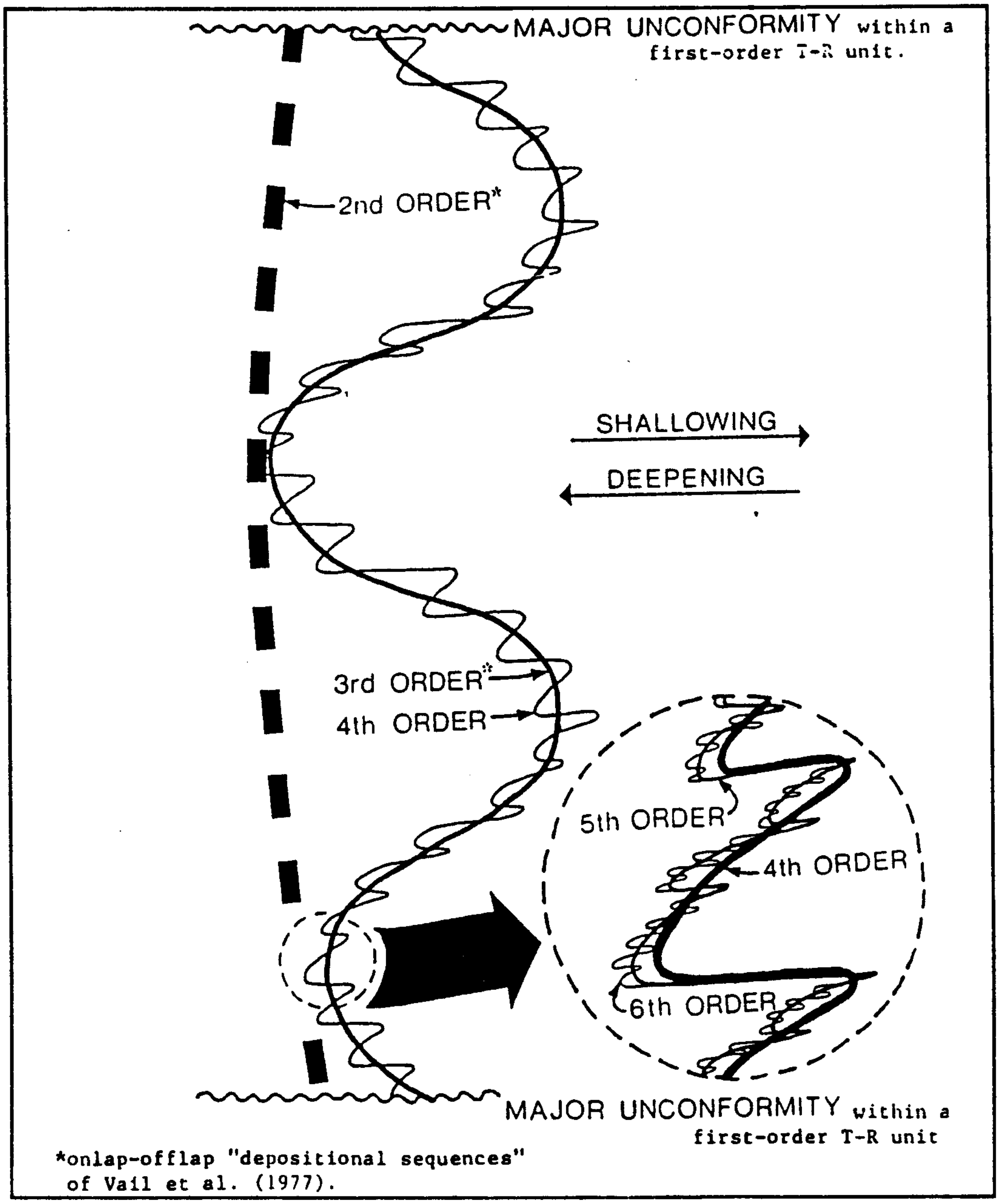

Figure 4. A hierarchy of nested transgressive-regressive units (from Busch and West, 1987, p. 146).

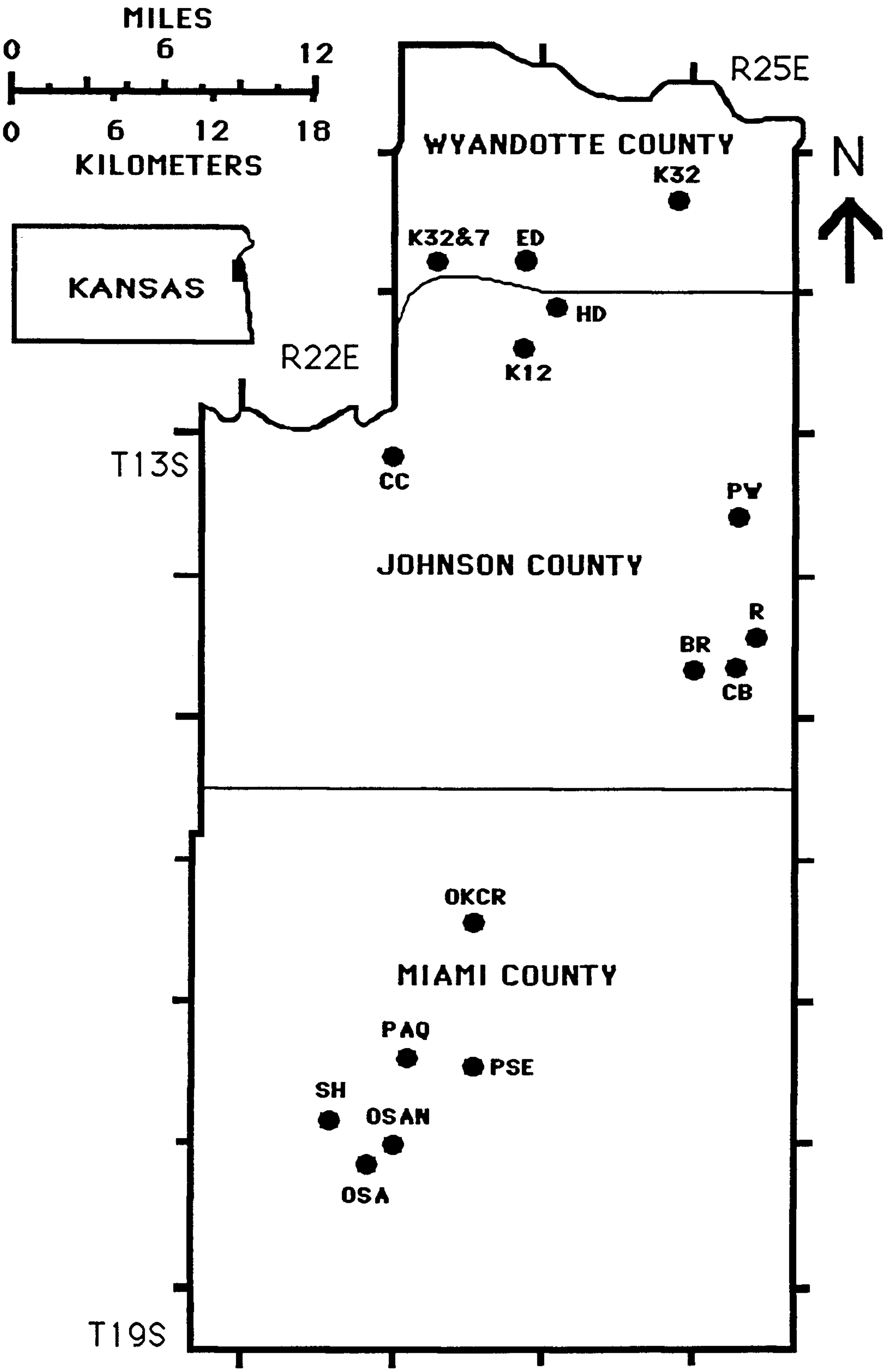

Figure 5. Location map of the sections of the Iola Limestone examined in Wyandotte, Johnson, and Miami counties, Kansas.

minute quadrangles for reconnaissance, and by selecting and revisiting suitable sections described in the literature. Sections were carefully measured and examined on a bed-by-bed basis. Field descriptions include; lithology, color (both fresh and weathered), bedding, texture, composition, biotic composition and condition (taphonomy), sedimentary structures, and contacts between beds.

Over 140 samples, which include both oriented carbonate samples, and spot samples of mudstones and shales, were collected at each lithology change within the Iola Limestone at localities shown in figure 5. Thin sections, acetate peels, and polished slabs were made from limestone samples, and examined using petrographic and binocular microscopes to obtain paleontologic and sedimentologic information. Shale and mudstone samples were processed in Quaternary "O", following the procedure of Zingula (1968). Residues were wet-sieved in nested 18-mesh, 60-mesh, and 140-mesh sieves, oven dried, and all size fractions picked to determine the biotic composition of each sample.

Spot samples for conodonts were taken at two sections, HD (which also includes HDMC, approximately 100 meters east of HD) and OSA (see figure 5), and processed using methods described in detail later in this report.

Recognition and Correlation of Genetic Units

The smallest genetic unit recognized or delineated in this investigation is a sixth order T-R unit (Busch and Rollins, 1984; and Busch and West, 1987) or PAC (Goodwin and Anderson 1985). A sixth order T-R unit is usually defined as a 1 - 5 meter thick, shallowing upward unit, bounded by unconformities, and with an inferred periodicity of tens of thousands of years (see figure 6). Disconformable bounding surfaces are presumed to represent punctuation events (transgressions or climate changes) present as abrupt facies changes from relatively shallow

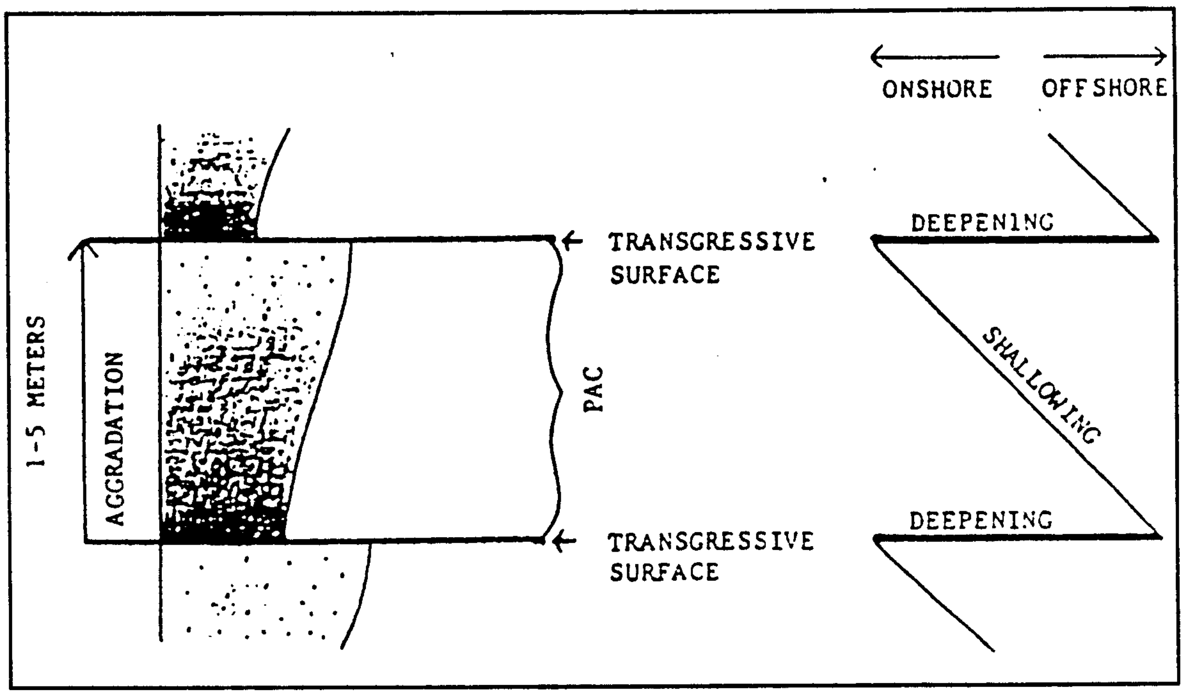

Figure 6. Diagram illustrating the concept of the Punctuated Aggradational Cycle (from Goodwin and Anderson, 1985, p. 517).

facies below to recognizably deeper facies above (Anderson, et al., 1984). Transgressive or climate change surfaces (Busch and West, 1987) mark sharp contacts between facies that may not have been laterally adjacent, therefore, Walther's Law may not be applicable across these boundaries (Goodwin, et al., 1986).

Genetic surfaces can sometimes be recognized in the field as very sharp lithologic contacts, but often they are more cryptic and may be recognized only through analysis of the type, diversity, and condition of the biota in the stratigraphic section being studied. Studies of faunal diversity in modern environments have demonstrated that diversity generally increases from nearshore unstable environments to offshore more stable environments (Bretzky and Lorenz, 1970). Geologists have applied this concept (Stability Time Hypothesis of Sanders, 1969; see figure 7) to the stratigraphic record, in which it was observed that temporal faunal diversity increases from facies representing shallow environments to those facies representing more stable, relatively deeper environments (Johnson, 1970; Walker and Laporte, 1970; Sutton et. al., 1970). It is then possible to use faunal diversity to delineate T-R cycles (Johnson, 1970), and especially stillstands or maximum transgressions, which will have the highest faunal diversity (Donahue and Rollins, 1974).

Many workers have observed that certain taxa appear to be facies dependent, and can hence be used as indicators of relative depth (see figures 8 and 9). This scheme of biofacies has been used to delineate the different phases of cyclothems and other types of T-R units (Elias, 1964; Moore, 1964; Heckel and Baesemann, 1975; Yancey and McLerran, 1988; and Brezinski, 1983). The application of this method would appear to require caution because the basic assumptions are somewhat circular, and commonly, careful taphonomic observations are not made and incorporated in the interpretations.

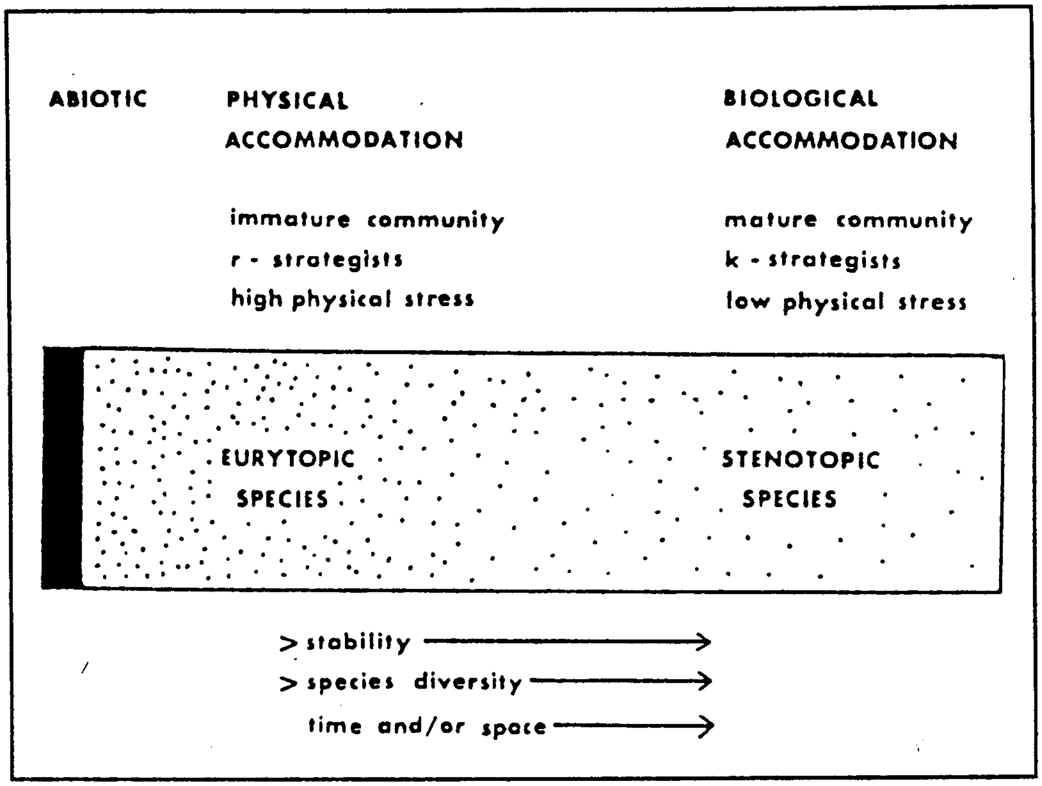

Figure 7. Graphic representation of Sanders' (1968) Stability-Time Hypothesis and its application to fossil communities (from Rollins and Donahue, 1975, p. 256).

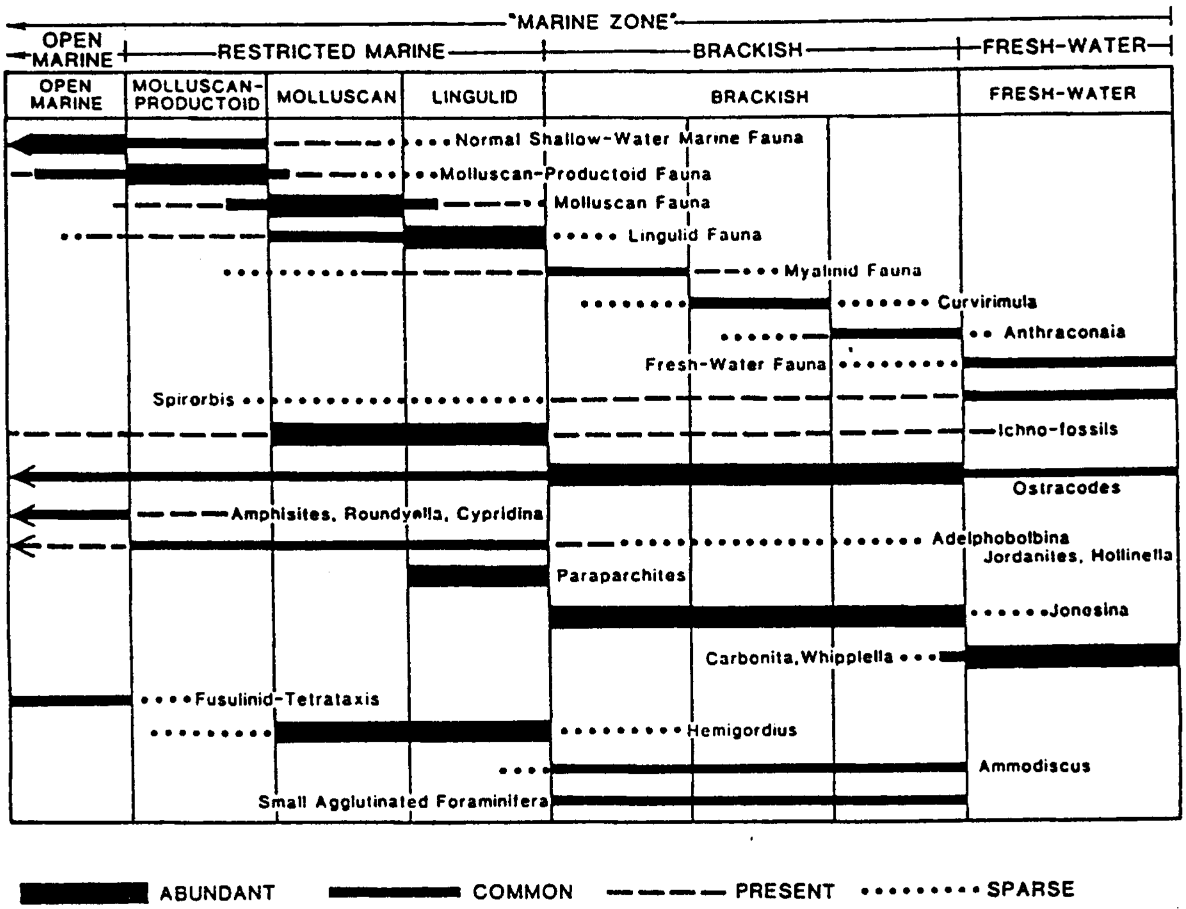

Figure 8. An example of using fossils as paleobathymetric and paleoenvironmental indicators (from Chesnut, 1981, p. 62).

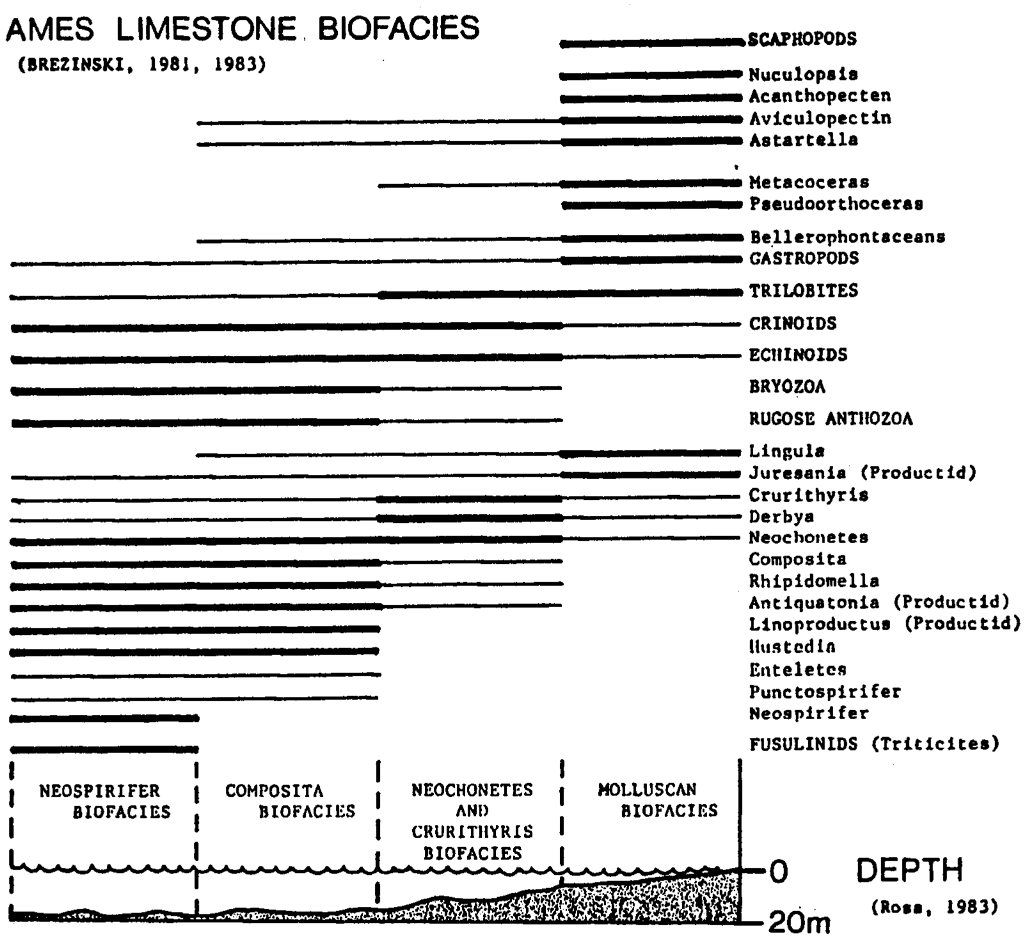

Figure 9. An example of depth-related biofacies from the Upper Pennsylvanian Ames Limestone of the Appalachian Basin (modified from Brezinski, 1983)

Presence/absence data of macrofossils was recorded to determine changes in diversity in the sections studied. Peterson, 1976, claimed presence/absence data to be less affected by taphonomic biases than relative abundance data, and I believe this to be a better method for delineating small-scale T-R units than the use of biofacies.

Genetic units in this study were correlated by tracing and matching transgressive surfaces relative to marker beds or patterns of facies change (Busch and West, 1987; and Goodwin, et al. 1986). The basic assumption when attempting to match these genetic surfaces from section to section is that they are correlative. Correlative surfaces are assumed to be allocyclic and non-correlative surfaces are assumed to be autocyclic (Busch and West, 1987; and West, Busch, and Rollins, 1988) (figure 10). If all units are assumed to be autocyclic, distinguishing between allocyclicity and autocyclicity is not possible. This method requires closely spaced localities, careful selection of marker beds, and careful observation of possible facies changes within marker beds, and no preconceived notions as to correlative surfaces, events, or beds.

GENERAL GEOLOGY

Setting

The Iola Limestone is part of the northeast trending Missourian outcrop belt of mixed carbonates and siliciclastics, extending from Iowa to Oklahoma (figure 11), that dip gently northwest at 20 feet per mile. These sediments were deposited on a carbonate platform north of a detrital dominated shelf and basinal area (Rascoe and Adler, 1983). The study area (shaded on figure 12) is on the southern edge of the Forest City Basin, and is in close proximity to three major

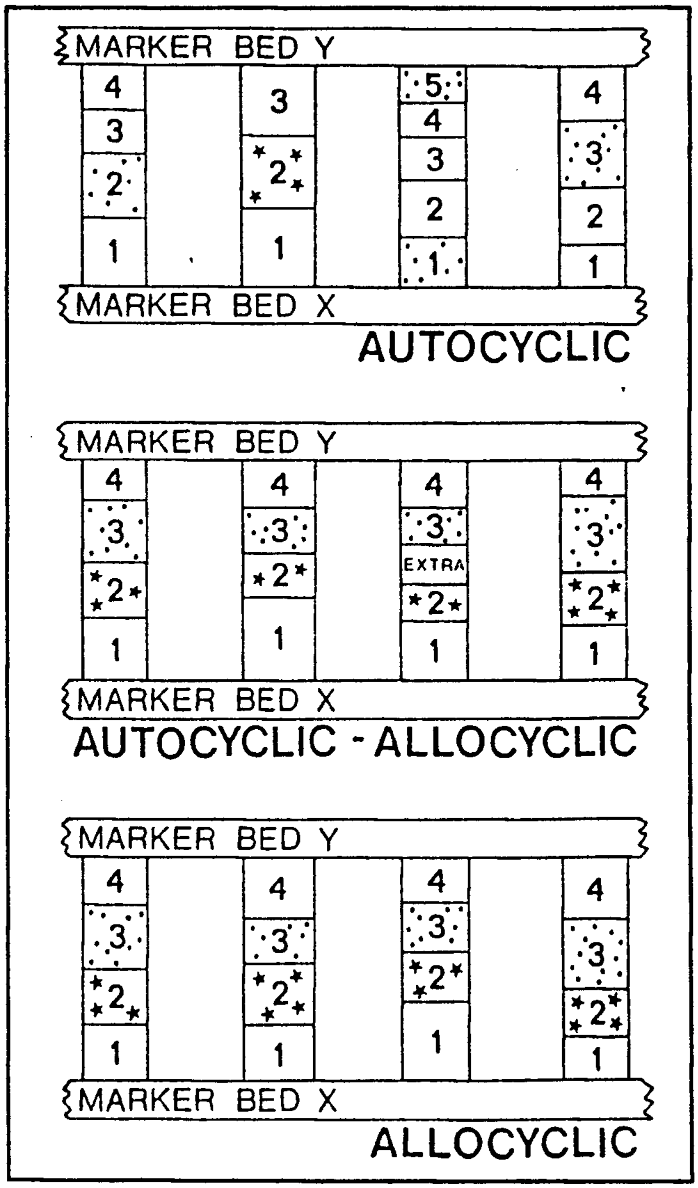

Figure 10. A graphic depiction illustrating the relationships of autocyclic, autocyclic-allocyclic, and allocyclic units (from Busch and West, 1987, p. 142).

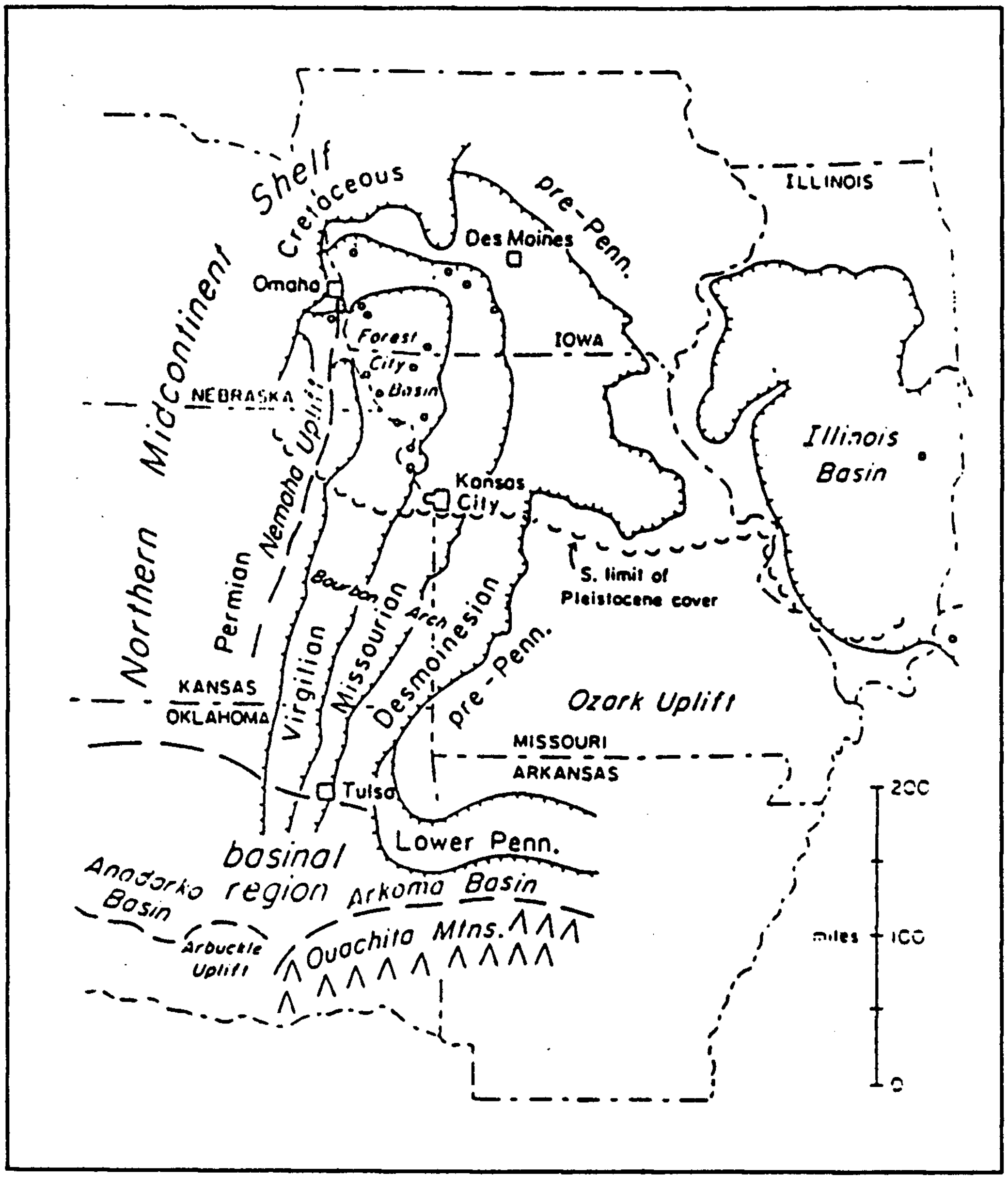

Figure 11. Extent of the Pennsylvanian outcrop belt in the midcontinent region (from Heckel, 1984, p. 7).

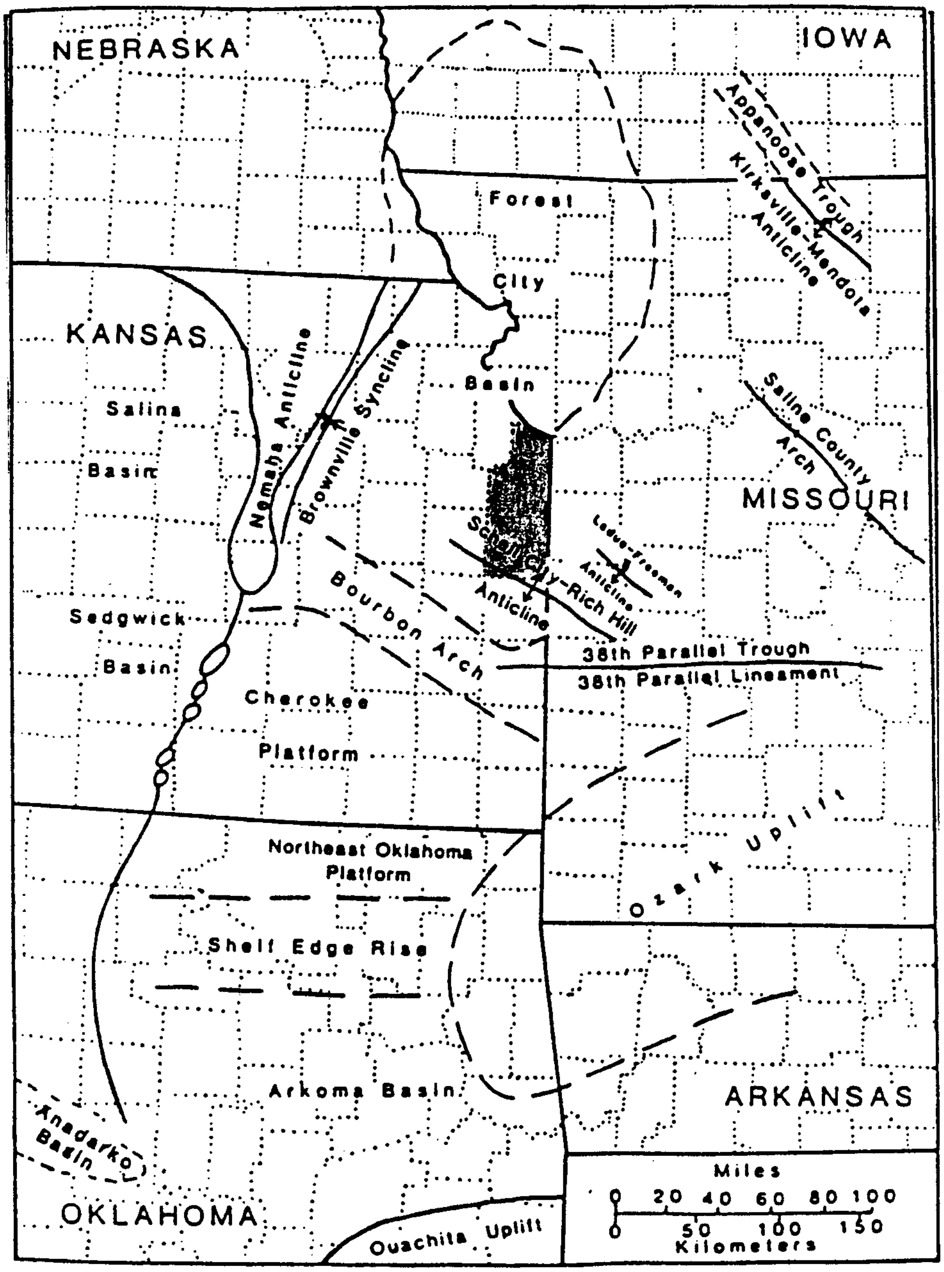

Figure 12. Possible structural influences on sedimentation during the Pennsylvanian in the midcontinent (from Knight, 1985).

structures presumed to be active or minor topographic highs during the Pennsylvanian Period (Knight, 1985). These are: the Nemaha Anticline northwest of the study area, the Bourbon Arch to the southwest, and the Ozark Dome to the southeast. The possible influence on the sedimentation of the Iola Limestone by these major structures and other minor structured will be explored later in this report.

Lithostratigraphy

The Iola Limestone, which overlies the Chanute Shale, and is overlain by the Lane Shale (figure 13), is part of the Linn Subgroup of the Kansas City Group. The Kansas City Group is in the Missourian Stage, Upper Pennsylvanian Series. The following lithologic descriptions are based on measured sections compiled from field and laboratory investigations of the Iola Limestone which are in Appendix 2 of this report.

Chanute Shale.-- Directly underlying the Iola Limestone is the Chanute Shale (Haworth and Bennett, 1908), the type area of which is the town of Chanute in Neosho County, Kansas. The thickness and facies types that comprise the Chanute Shale tend to be variable throughout the study area. Mitchell (1981) observed that the Chanute thins northward across the three county study area of this report, and although I did not observe the complete thickness at sections examined for this investigation, the Chanute ranges in thickness from 3.66 to 9.75 m. (12 to 32 ft.) in the northern part of the study area (O'Conner, 1971), and from 2.44 to 11.6 m. (8 to 38 ft.) in the southern part of the study area (Miller, 1966).

Typical facies encountered in Miami County (figure 14) are as follows. A thick (1.6 m. +) olive gray, blocky mudstone occurs 1 to 3 m. (3.3 to 9.8 ft.) below the base of the Iola Limestone, and is sparsely fossiliferous except for plant

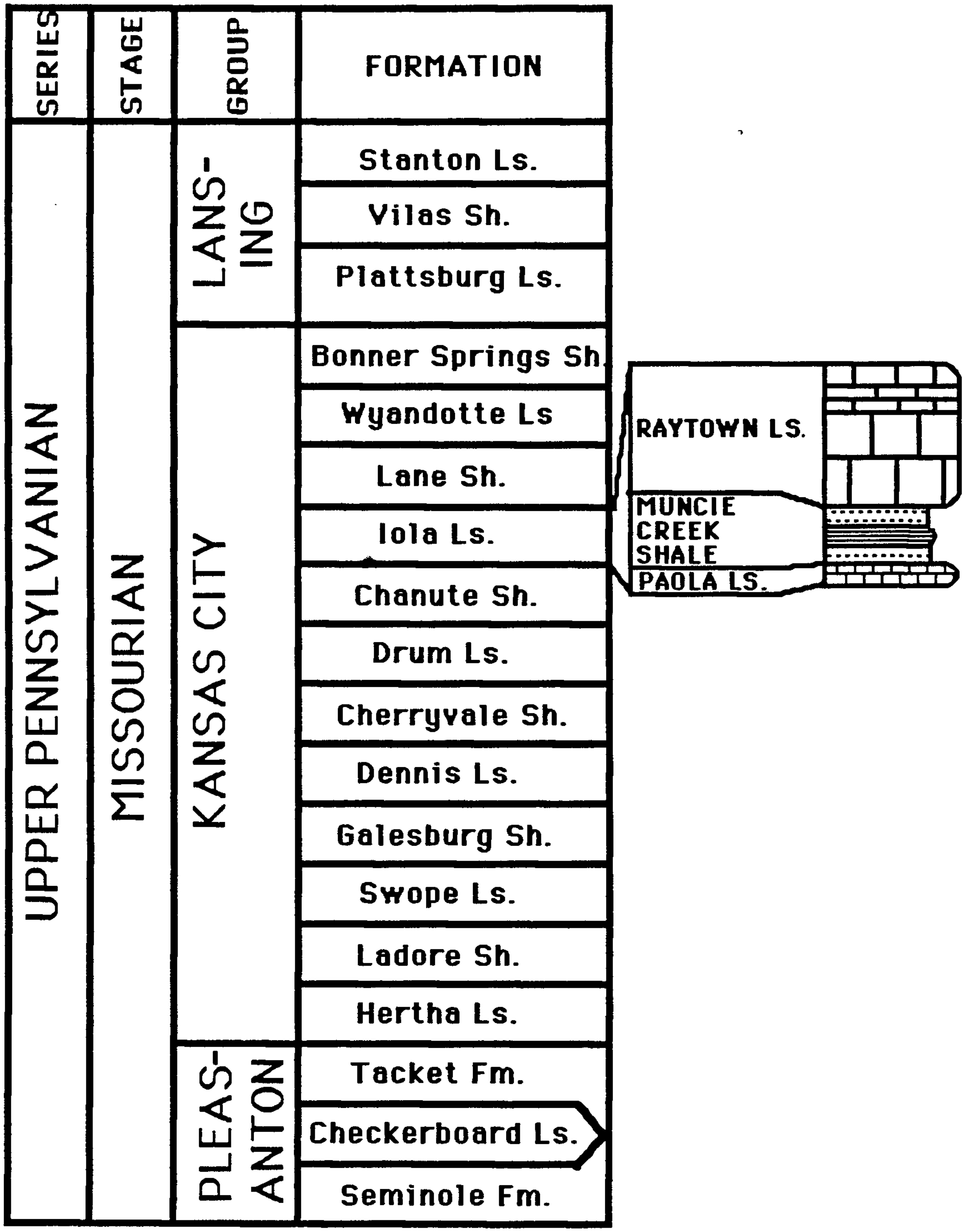

Figure 13. The Iola Limestone and its three members, the Paola Limestone Member, Muncie Creek Shale Member, and Raytown Limestone Member (modified from Zeller, 1968, pl. 1).

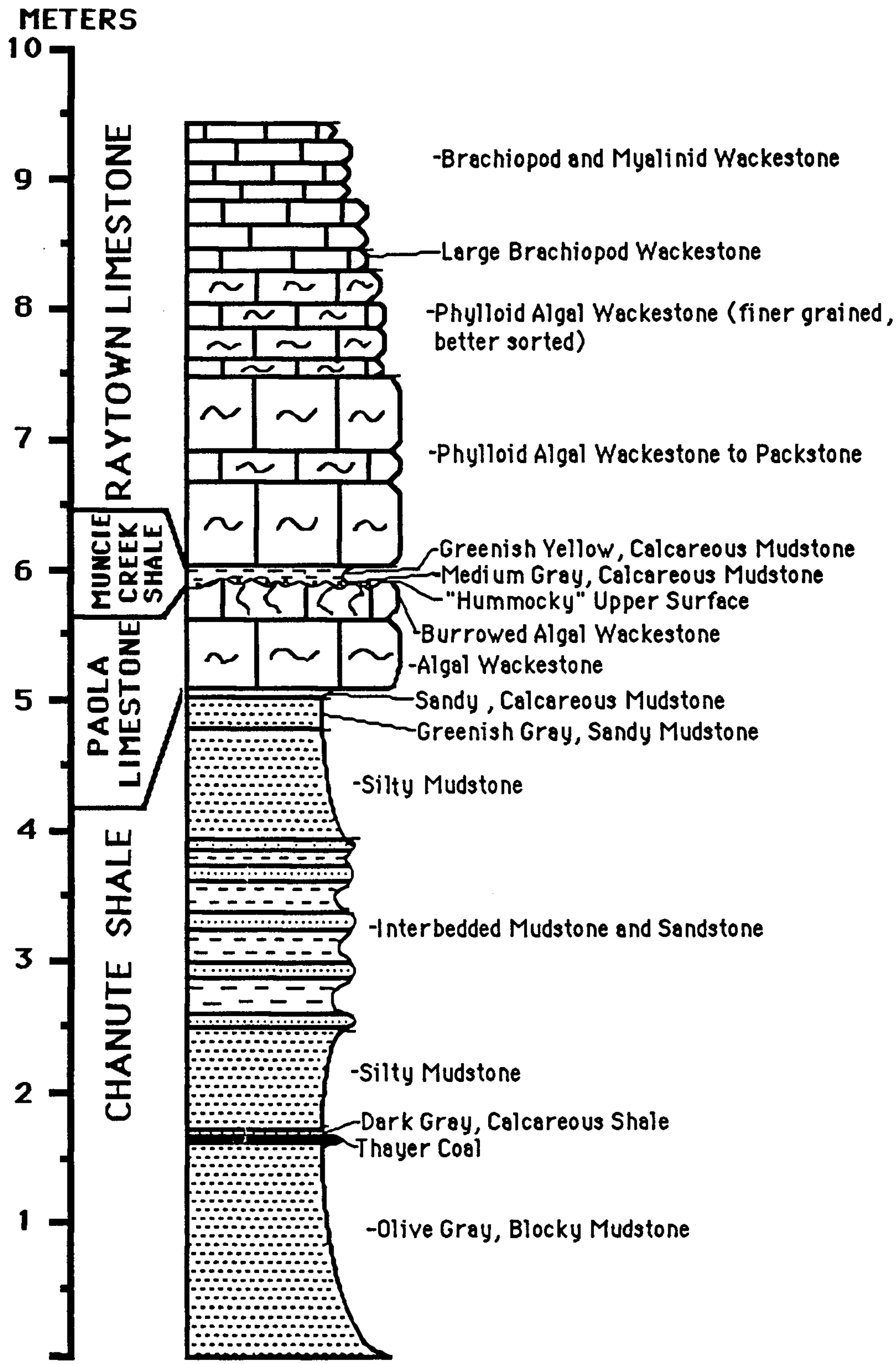

Figure 14. Typical lithologies of the Iola Limestone in the southern part of the study area as represented at section OSA.

fragments. This facies is overlain at two sections (OSA and SH) by a thin (5.1 to 7.6 cm.) bituminous coal (Thayer Coal), which is 1.1 m. (3.6 ft.) below the base of the Iola Limestone at section SH, and 3.3 m. (10.8 ft.) below the base of the Iola at section OSA. Directly overlying the coal is a thin (2.5 to 7.6 cm.) layer of dark gray calcareous shale with a fossil assemblage consisting of Crurithyris, crinoids, echinoids, bivalves, smooth-shelled ostracodes, shark remains, spirorbid worms, and carbonaceous plant debris. Above this is from 0.5 to 3 m. (1.6 to 9.8 ft.) of silty mudstone to interbedded mudstone and very fine grained sandstone, with a fossil assemblage consisting of Lingula, Crurithyris, pectinid bivalves, plant fragments, and where sandy, trace fossils suggestive of Planolites. From 7.6 to 10.2 cm. (3 to 4 in.) below the base of the Iola Limestone at many sections examined in Miami County, and gradationally overlying the silty mudstone, is a light greenish gray, sandy mudstone with abundant plant debris, including large (> 5 cm.) leaf and stem impressions. This facies is sharply overlain by a sandy calcareous mudstone with a marine biota of productid brachiopods, Crurithyris, Hustedia, crinoids, echinoids, bryozoans, encrusting foraminiferids, bivalves and gastropods, which are often disarticulated and fragmented.

The Chanute Shale at sections PW and K12 examined in Wyandotte and Johnson County lacks coal, but commonly had an interbedded sandstone and mudstone facies which are, in part, in the same stratigraphic position as the coal bed. The fossiliferous facies in the upper Chanute at these localities is thicker than in Miami County as illustrated at section HD (figure 15), where it is 66 cm. (26 in.) thick. The fossiliferous facies in the upper Chanute Shale in Wyandotte and Johnson Counties also tends to be less sandy than those in Miami County. The contacts with the underlying facies are, however, still sharp. The contact between the Chanute Shale and the Iola Limestone, throughout the study area, is gradational.

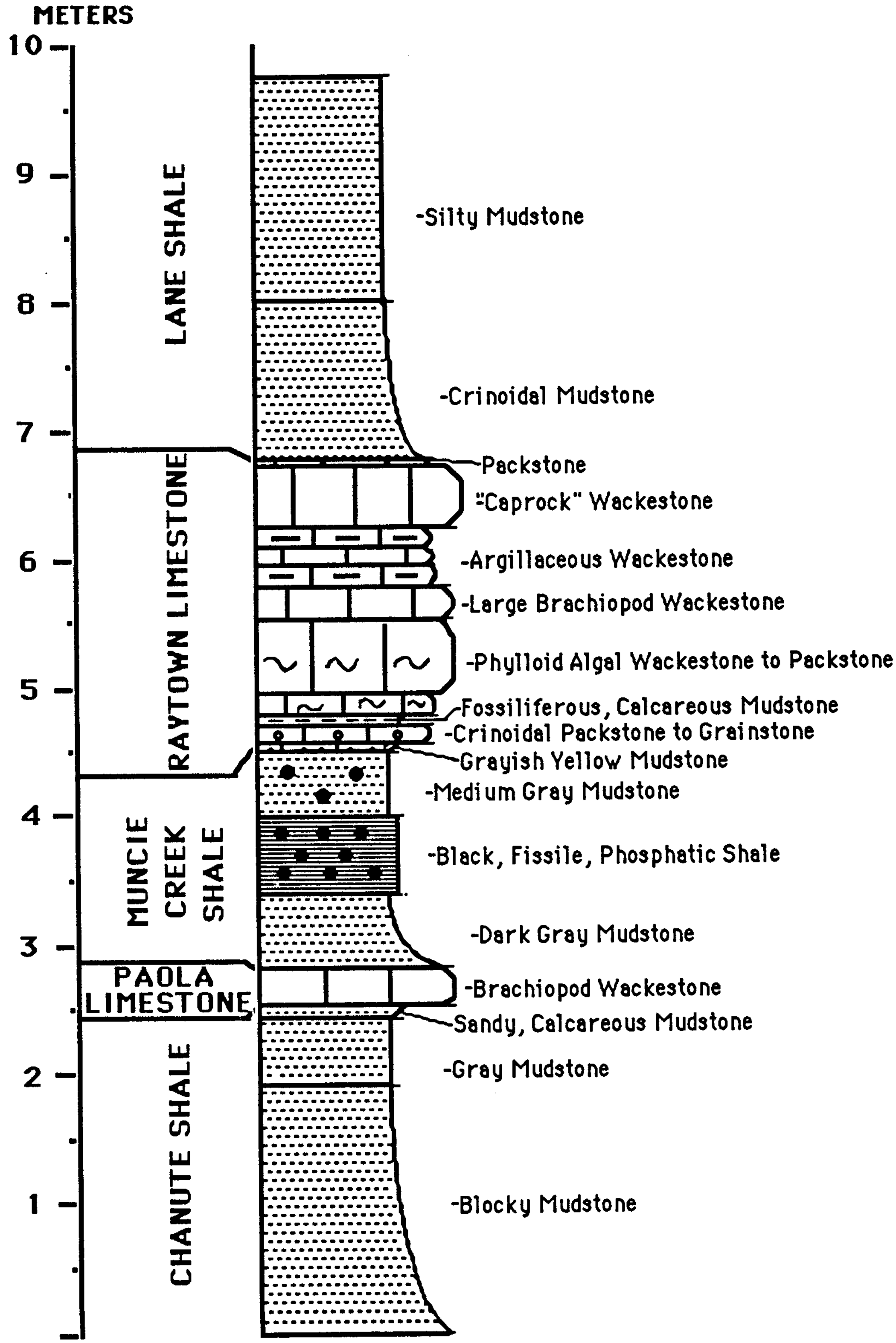

Figure 15. Typical lithologies of the Iola Limestone in the northern part of the study area, as represented at section HD.

Iola Limestone.-- The Iola Limestone (Haworth and Kirk, 1894) consists of three members which are (in ascending order): the Paola Limestone Member, the Muncie Creek Shale Member, and the Raytown Limestone Member. The thickness of the Iola ranges from 3.12 m. (10.2 ft.) to 4.2 m. (13.8 ft.) in the three county study area, and generally thickens southward.

Paola Limestone Member.-- The Paola Limestone Member (Newell, in Moore, 1932) is lithologically rather consistent throughout the study area, where it is primarily a brachiopod and algal wackestone. The thickness of the Paola ranges from 0.30 m. (1.0 ft.) in the northern part of the study area, to 0.83 m. (2.7 ft.) in the south. This increase in thickness also corresponds to an increase in the abundance of phylloid algae.

In Wyandotte and northern Johnson County (figure 15) the Paola is a brownish gray, dense, brittle wackestone with a biota consisting of Crurithyris, chonetid and productid brachiopods, Composita, Hustedia, crinoids, echinoids, gastropods, horn corals, fusulinids, sponges, phylloid algae, ostracodes, encrusting and other small foraminiferids, and abundant shark and other fish remains (hundreds of fragments in 2.5 kg. sample). Rhodoliths are common in the upper part of the unit, and at section HD, small (<2 cm.) phosphate nodules are scattered throughout the upper 7.6 cm. (3 in.). Most of the biota in the upper-most and lower-most part of the Paola at these northern localities is disarticulated and fragmented.

At sections examined in Miami County and southern Johnson County (figure 14) the Paola is also a brownish gray, brittle, and dense wackestone. In the southern part of the study area, phylloid algae are generally more conspicuous, and the upper 1/3 of the Paola is extensively (or at least visibly) bioturbated with large, (often > 1 cm. in diameter and > 10 cm. long) iron stained burrows (Planolites and Thallasinoides-like traces). Rhodoliths occur in at least the upper

1/3 of the Paola, and skeletal grains are fragmented in the upper-most and lower-most part of this member. In many sections south of K12 in Johnson County (eg. PW, R, OKCR, OSAN, and OSA) the Paola has a very "hummocky" (Newell, 1935, p. 54) upper surface. This irregular surface often has phosphate nodules, and sometimes conulariids (as at section PW) embedded in it, and may be encrusted with bryozoans (Dawson, 1984). This contact between the Paola and the overlying Muncie Creek is very sharp.

Muncie Creek Shale Member.-- Dramatic changes in thickness and facies occur over short distance (several kilometers) in the Muncie Creek (Newell, in Moore, 1932) especially in the Kansas City area, where its thickness ranges from 0.11 m. to 1.9 m. (0.36 ft. to 6.2 ft.) (V. Hamilton, personal communication, 1988). Throughout the study area the thickness of the Muncie Creek ranges from 0.10 m. to 1.6 m. (0.33 ft. to 5.3 ft.).

At what is considered a typical section of the Muncie Creek (figure 15, section HD in Johnson County) as described by Heckel (1988), the Muncie Creek consists of four lithologies in ascending order: a basal dark gray mudstone, a black, fissile, phosphatic shale, another medium gray mudstone, and a thin grayish yellow green mudstone.

The basal mudstone is 0.56 m. (1.86 ft.) thick and is poorly indurated. It contains a fossil assemblage consisting of Lingula, gastropods, bryozoans, crinoids, echinoids, pectinid bivalves, chonetid and productid brachiopods, Crurithyris, cephalopods, trilobites, Ammodiscus, encrusting foraminiferids, and the remains of sharks and other fish. Fossils are most abundant at the base of the unit, where they are commonly disarticulated and broken.

Overlying the dark gray mudstone is a black, fissile, phosphatic shale. The black shale is 0.56 m. thick (1.83 ft.) and contains, in the upper two thirds, ovate and spherical phosphate nodules (1-5 cm. in diameter), composed mainly of fluorapatite (Shaffer et al., 1988). The shale contains a biotic assemblage consisting of conulariids, Orbiculoidea, Ammodiscus and other small foraminiferids, sponge spicules, shark remains, and plant fragments. Within the nodules is a biota that includes: plant spores, ostracodes, radiolarians, small foraminiferids, cephalopods, bivalves, sponges, crinoids, plant fragments, and shark and other fish remains.

Sharply overlying the black fissile shale is a medium dark gray mudstone. It is 0.46 m. (1.5 ft.) thick, poorly indurated, and also contains phosphate nodules. The phosphate nodules appear to be more scattered and less abundant than in the underlying shale, and many were observed to contain a conulariid. The fossil assemblage includes: Lingula, gastropods, conulariids, crinoids, echinoids, chonetid and productid brachiopods, cephalopods, pectinid bivalves, Phestia, Astartella, Ammodiscus, sponge spicules, holothurian sclerites, ostracodes, plant fragments, and shark remains. Pyrite-filled burrows resembling Chondrites and Planolites are scattered throughout this mudstone. Fossil abundance is highest in the middle of the unit.

Sharply overlying the gray mudstone is a thin (3 cm.) grayish green, calcareous mudstone. Large (commonly > 5 cm) ovate to spherical calcareous nodules or clasts composed primarily of calcium carbonate with minor amounts of fluorapatite (R.R. West, personal communication, 1988) occur in this mudstone. These nodules/clasts are commonly bored by acrothoracicans. The fossil assemblage includes cephalopods, Lingula, bryozoans, Hustedia, Derbyia, Crurithyris, Punctospirifer, chonetid brachiopods, crinoids, echinoids, trilobites, gastropods, ostracodes, plant fragments, and shark remains. Fossils are generally disarticulated and fragmented, and the contact with the overlying Raytown is gradational.

The four typical Muncie Creek lithologies disappear south of section K12 in

Johnson County, and what is presumed to be the Muncie Creek is a thin (generally < 15 cm.) calcareous mudstone with rounded phosphate nodules at the base.

At section OSA in Miami county (figure 14), what has been called the Muncie Creek consists of two lithologies, a lower medium gray, calcareous mudstone, and an upper greenish yellow, calcareous mudstone.

The medium gray, calcareous mudstone is 0.05 m. (0.17 ft.) thick, and has a sharp basal contact with the upper "hummocky" surface of the Paola. It contains rounded phosphate nodules, and a fossil assemblage which includes: Crurithyris, Hustedia, crinoids, gastropods, bivalves, and shark remains.

Overlying the gray mudstone is a thin (5 cm.), greenish yellow, calcareous mudstone, and the contact is gradational. The biota includes: crinoids, echinoids, Crurithyris, Neospirifer, Chonetinella, Hustedia, small productids, Punctospirifer, bryozoans, small foraminiferids, bivalves, and shark remains. The greenish yellow calcareous mudstone also contains a few sporadically distributed, small (< 1 mm. in diameter) phosphate nodules. The contact with the overlying Raytown is sharp.

Raytown Limestone Member.-- The Raytown Limestone Member (Hinds and Green, 1915) is composed of a number of facies throughout the study area, ranging from calcareous mudstone to phylloid algal packstone to wackestone. The thickness of the Raytown ranges from 2.14 m. (7.02 ft.) in northern Johnson and southern Wyandotte Counties, to 3.76 m. (12.33 ft.) in south-central Miami County. Southward thickening of the Raytown is coincident with an increase in phylloid algae.

The basal lithology of the Raytown in northern Johnson and Wyandotte Counties (figure 15) (e.g. K12, K32R, K32 & 7, HD) is a medium gray, crinoidal and glauconitic packstone to grainstone (the non-abraded, over-packed, invertebrate grainstone of Mitchell, 1981, and Heckel, 1983). It ranges in thickness from 0.03 m. to 0.15 m. (0.08 ft. to 0.5 ft.) throughout the study area and appears to be lenticular, thinning and pinching out at some localities to the south, and becoming less calcareous to the west (CC). It contains a biota consisting primarily of crinoid columnals, but also includes Crurithyris, chonetid brachiopods, echinoids, gastropods, bryozoans, cephalopods, ostracodes, clumps of encrusting foraminiferids and other small foraminiferids, conulariids, and shark and other fish remains.

Calcareous nodules or clasts, that are commonly found in the underlying shale, are incorporated into the base of the packstone. Possible lateral equivalents of the crinoidal packstone in central and southern Johnson County (sections R and PW), and in Miami County (sections PSE, PAQ, and SH) contain rounded phosphate nodules. Most of the biota within the packstone to grainstone is fragmented, and skeletal grains are elongate parallel to bedding.

Sharply overlying the crinoidal packstone at sections HD (figure 15), K32R, K12, and K32 & 7, is a very fossiliferous, grayish green, calcareous mudstone. It ranges in thickness from 0.08 m. to 0.15 m. (0.25 ft. to 0.5 ft.), and contains a biota which includes Chonetinella, Neospirifer, Punctospirifer, Crurithyris, Hustedia, productid, bryozoans, crinoids, echinoids, gastropods, ostracodes, trilobites, bivalves, small foraminiferids, conulariids?, scolecodonts, and fish remains. Possible small (< 1 cm. in diameter) phosphate nodules also occur within the calcareous mudstone, and this lithology is very similar to, and may be the lateral equivalent of, the upper lithology of what has been called the Muncie Creek Shale Member at section OSA and others in Miami and Johnson Counties.

Sharply overlying the fossiliferous, calcareous mudstone in the northern part of the study area (figure 15), and what is presumed to be the Muncie Creek in southern parts of the study area (figure 14), is a light gray, phylloid algal wackestone to packstone. The phylloid algal wackestone ranges in thickness from

0.68 m. (2.25 ft.) in the north to 2.28 m. (7.5 ft.) at the southern localities.

At sections in Johnson County (figure 15) (K12 and HD) the phylloid algal wackestone is a medium to thickly bedded (often with "hummocky" contacts between beds) wackestone to packstone. It has a fossil assemblage which includes phylloid algae, Composita, productid brachiopods, crinoids, echinoids, gastropods, encrusting and other small foraminiferids, ostracodes, bryozoans, and sponge spicules. Brachiopods in this lithology are often articulated.

The phylloid algal wackestone at sections in Miami County (figure 14) (PAQ and OSA) is medium to thickly bedded in the lower part, commonly becoming thinly bedded with shale partings toward the top. The biota is nearly identical to that of this same lithology at northern localities. Coincident with the decrease in bed thickness, is a reduction in grain size and better sorting, with skeletal grains becoming more and more fragmented upward.

The phylloid algal wackestone is sharply overlain by a wackestone containing large brachiopods (figures 14 and 15). This lithology is generally a medium-bedded wackestone layer with large Echinaria, Linoproductus, and commonly Neospirifer (equals the "large fossil bed" of Newell, 1935, p. 53). The biota of this lithology includes, in addition to the above mentioned brachiopods, Composita, Punctospirifer, chonetid brachiopods, crinoids, echinoids, bryozoans, horn corals, cephalopods, bivalves, ostracodes, small foraminiferids, and shark and other fish remains. Most fossils are articulated and unfragmented, and many large brachiopods appear to be in situ. The basal 5 cm. (2 in.) of this unit at section HD and others in northern Johnson County is a crinoidal packstone.

Overlying the large brachiopod wackestone in the Raytown at section HD and others in northern Johnson and southern Wyandotte Counties (figure 15) are three lithologies in ascending order: a medium bedded, argillaceous wackestone, a thick bedded, wackestone caprock, and a thin (3 cm.) brachiopod and crinoidal packstone. Sections in the south generally have the same three lithologies, but at one section (PAQ) the caprock lithology is overlain by a mudstone and a brachiopod and phylloid algal wackestone to packstone known as the Bush City beds (an informal unit described in Mitchell, 1981).

The argillaceous wackestone at section HD (figure 15) is somewhat nodular, with a biota that includes: productid and chonetid brachiopods, Composita, crinoids, echinoids, bryozoans, bivalve fragments, horn corals, phylloid algae, ostracodes, and sponge spicules. Several thin (<1 cm.) packstone layers are present within this unit.

Sharply overlying the argillaceous wackestone at section HD (figure 15) is a 0.46 m. (1.5 ft.) thick, light gray, wackestone caprock. The caprock lithology, which often weathers a mottled dark yellowish orange, earning the upper Raytown the nickname "calico beds" (Newell, 1935, p. 53), contains a fossil assemblage composed of: productid and chonetid brachiopods, Composita, crinoids, echinoids, gastropods, bivalves, phylloid algae, ostracodes, bryozoans, encrusting foraminiferids, and sponge spicules. At the top of the caprock is a thin (3 cm.) skeletal packstone to grainstone with a fossil biota including: Neospirifer, Punctospirifer, chonetid and productid brachiopods, Composita, bryozoans, gastropods, bivalves, inarticulate brachiopods, encrusting foraminiferids, and numerous shark remains (>100 fragments in a 2.0 kg sample). Skeletal grains (specifically large brachiopods) within the packstone are generally disarticulated and fragmented and commonly algal coated and bored by acrothoracicans.

The wackestone caprock of the Raytown is present at all complete sections of this member in Wyandotte and Johnson Counties, and at one section, PAQ, in Miami County. Below the wackestone caprock at section PAQ and section CC, and above the large brachiopod wackestone facies, lies a rather thick (0.79 m.) layer of thin bedded, alternating argillaceous, bryozoan packstone and brachiopod and bryozoan wackestone. The same unit at section OSA and others in Miami County (figure 14) consists of a 0.60 m. (2.0 ft.) layer of medium to thin bedded brachiopod and myalinid wackestone above the large-brachiopod wackestone.

Several rather anomalous facies occur above the main Raytown ledge (crinoidal packstone through caprock lithologies) at several locations, two in east-central Johnson County (O'Conner, 1971) and section PAQ in Miami County, which have been assigned by some to the Raytown (Miller, 1966). At section PAQ, the caprock and skeletal packstone of the upper Raytown are overlain by 2.16 m. (7.10 ft.) of olive to greenish gray mudstone to claystone, and 1.02 m. (3.33 ft.) of medium to thickly bedded brachiopod and phylloid algal wackestone to packstone (Bush City beds). Based on unpublished conodont biostratigraphic data, Ardvidson (1988) assigned the mudstone to the Lane Shale, and the wackestones to the Wyandotte Limestone.

Lane Shale.-- The Lane Shale (Haworth and Kirk, 1895), type area in the town of Lane, Franklin County, Kansas, varies considerably in facies types and in thickness throughout the study area. Crowley (1969) reported that the Lane ranges in thickness, in the three county study area of this report, from less than 3.0 m. (10 ft.) to slightly over 32 m. (105 ft.).

At section HD (figure 15), the Lane Shale sharply overlies the Raytown, and is 13.3 m. (43.7 ft.) thick. Here, the Lane consists of medium dark gray to dark gray, silty to sandy mudstones. There are three major marine zones: (1) a crinoidal, dark gray mudstone in the basal 1.22 m. (4 ft.), (2) a 0.20 m. (0.67 ft.) ironstone and interbedded mudstone 6.0 m. (19.7 ft.) above the base of the Lane, and (3) a 0.13 m. (0.42 ft.) calcareous mudstone underlying the Wyandotte Limestone with a gradational upper contact. These three facies in the Lane Shale contain a molluscan fossil assemblage.

GENETIC STRATIGRAPHY

Recognition of the Iola fifth order T-R unit is based on the pattern of sixth order T-R units above, below, and within this sequence (see Busch and West, 1987, for details on this procedure). Durations of these sixth order T-R units is inferred to be 50,000 to 130,000 years (Busch and West, 1987). Three of the bounding, transgressive surfaces of sixth order T-R units within the Iola fifth order T-R unit can be traced throughout the study area (Leonard, 1989). The Iola fifth order T-R unit (roughly equivalent to the Iola Cyclothem or "major cycle") consists of the upper part of the Chanute Shale, the Iola Limestone and its three members, and most of the Lane Shale (Busch, et. al., 1985; Leonard, 1988; and 1989). The duration of this fifth order T-R unit was probably on the order of 300,000 to 500,000 years, and it comprises one net transgressive-regressive sequence (Busch and West, 1987).

To illustrate the genetic stratigraphy of sixth order T-R units within the sequence studied, two sections [Holliday Drive, HD (which includes HDMC, approximately 100 m. to the east of HD) and Osawatomie, OSA] will be discussed in detail. Because of drastic facies changes within some of the transgressive-regressive units a northern (HD) and southern (OSA) section was chosen rather than a composite section for the sequence. Data upon which these transgressive-regressive units are based in the other sections studied are given in Appendix 2.

Holliday Drive Section

PAC 1.-- The base of sixth order T-R unit 1 or PAC 1 (also the base of the Iola fifth order T-R unit) is recognized by a transgressive (flooding) surface that punctuates an unfossiliferous silty mudstone in the Chanute Shale. The punctuation is a mudstone with a moderate diversity assemblage of marine fossils, and well rounded and fragmented skeletal grains (figures 16 and 17). The Chanute Shale is considered by some (Mitchell, 1981; and Heckel, 1988) as representing a delta plain environment.

Deepening within PAC 1 is recorded by an increase in diversity upward from the transgressive surface, and through the calcareous mudstone in the upper-most part of the Chanute Shale, which contains the brachiopods Crurithyris, Derbyia, and chonetids. These taxa are considered opportunistic and characteristic of the early transgressive phase of deepening-shallowing units (Rollins and Donahue, 1975; and Brezinski, 1983).

Maximum diversity within PAC 1 occurs in the upper-middle parts of the Paola (figure 16), and probably represents the facies deposited during maximum transgression of PAC 1. The fossil assemblage here (figure 17) consists of; Composita and other brachiopods, fusulinids, horn corals, bryozoans, and calcareous sponges. Fossils within this interval are primarily unbroken and articulated. The environmental conditions existing during maximum transgression of PAC 1 appears to have been that of shallow, quiet, open marine waters, below effective wave base.

In the upper part of the Paola disarticulation and fragmentation of skeletons increases suggesting increasing energy levels due to gradual shallowing, or reduced rates of sedimentary accumulation. Rhodoliths and rounded phosphate nodules are also in the upper parts of the Paola. Toomey (1974, 1985) believed rhodoliths to be indicators of nearshore, shallow, well lit environments, although, in and of themselves, they may not be indicative of shallowing. Reid and MacIntyre (1988) maintained that algal nodules of this type cannot be used as environmental indicators.

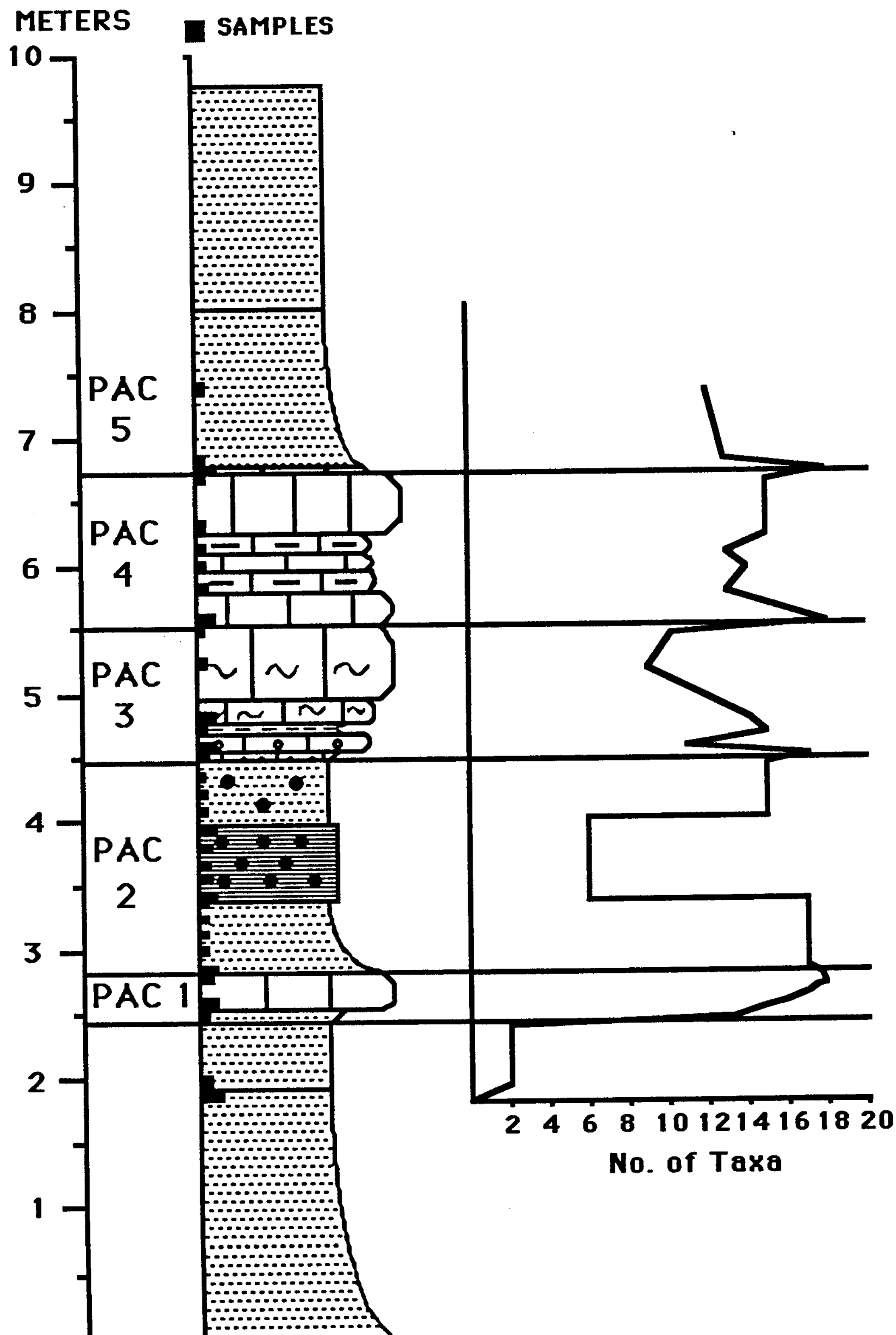

Figure 16. Diversity within genetic units of the Iola Limestone at Holliday Drive (for details of PAC 2 see figure 20).

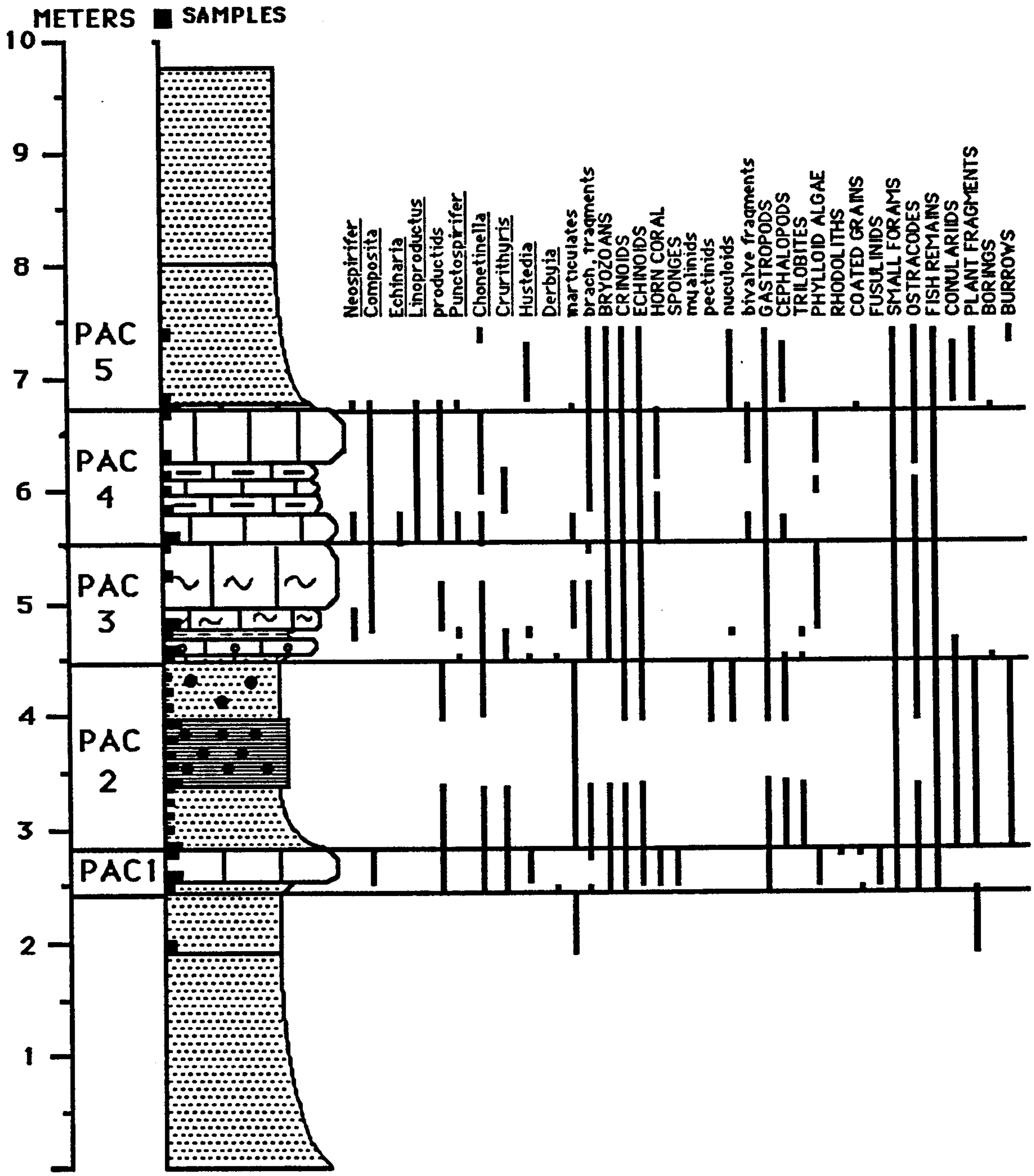

Figure 17. Ranges of taxa within the Iola Limestone and immediately adjacent units at section HD (for details of PAC 2 see figure 19).

PAC 2.-- The transgressive surface of PAC 2 is marked by a very sharp boundary between the dark gray mudstone at base of Muncie Creek, and the underlying shallower? phase of PAC 1 (figure 18). This is the "knife sharp boundary" which Moore (1964) believed to represent a disconformity (paraconformity). Moore (1964), however, believed this disconformity to represent a regressive surface. Biotic diversity varies little across this contact, and if anything it may decrease slightly (figure 16). This surface marks the boundary between a normal marine fossil assemblage, and a fossil assemblage that some (Brezinski, 1983; and Rollins and Donahue, 1975) consider stress tolerant. The stress tolerant assemblage (figure 19) includes: Crurithyris, inarticulate brachiopods, and a diverse assemblage of molluscs (Brezinski, 1983; Boardman et. al., 1984). This increase in stress may be due to the onset of oxygen-depleted conditions caused by climate change in conjunction with rapid transgression (Kauffman, 1986).

Fossil diversity decreases gradually upward from the transgressive surface through the gray mudstone in PAC 2 (figure 20). A decrease in biotic diversity in this case, may actually imply continued deepening. Rhodes and Morse (1971) observed that offshore environments, when stressed by decreasing oxygen levels, may resemble nearshore unstable environments in terms of biotic diversity. Following Bromley and Ekdale (1984), oxygen poor conditions are suggested by the occurrence of Chondrites, Planolites, and Zoophycus in the upper part of the gray mudstone. An increasingly oxygen poor environment may favor soft-bodied infaunal organisms, and reduce the number of epifaunal, shelled organisms (Byers, 1977).

A slight increase in diversity occurs near the top of the dark gray mudstone in PAC 2 (figure 20), possibly an oxygenation event, but lack of data at other localities prevents the author from speculating further about the significance of this

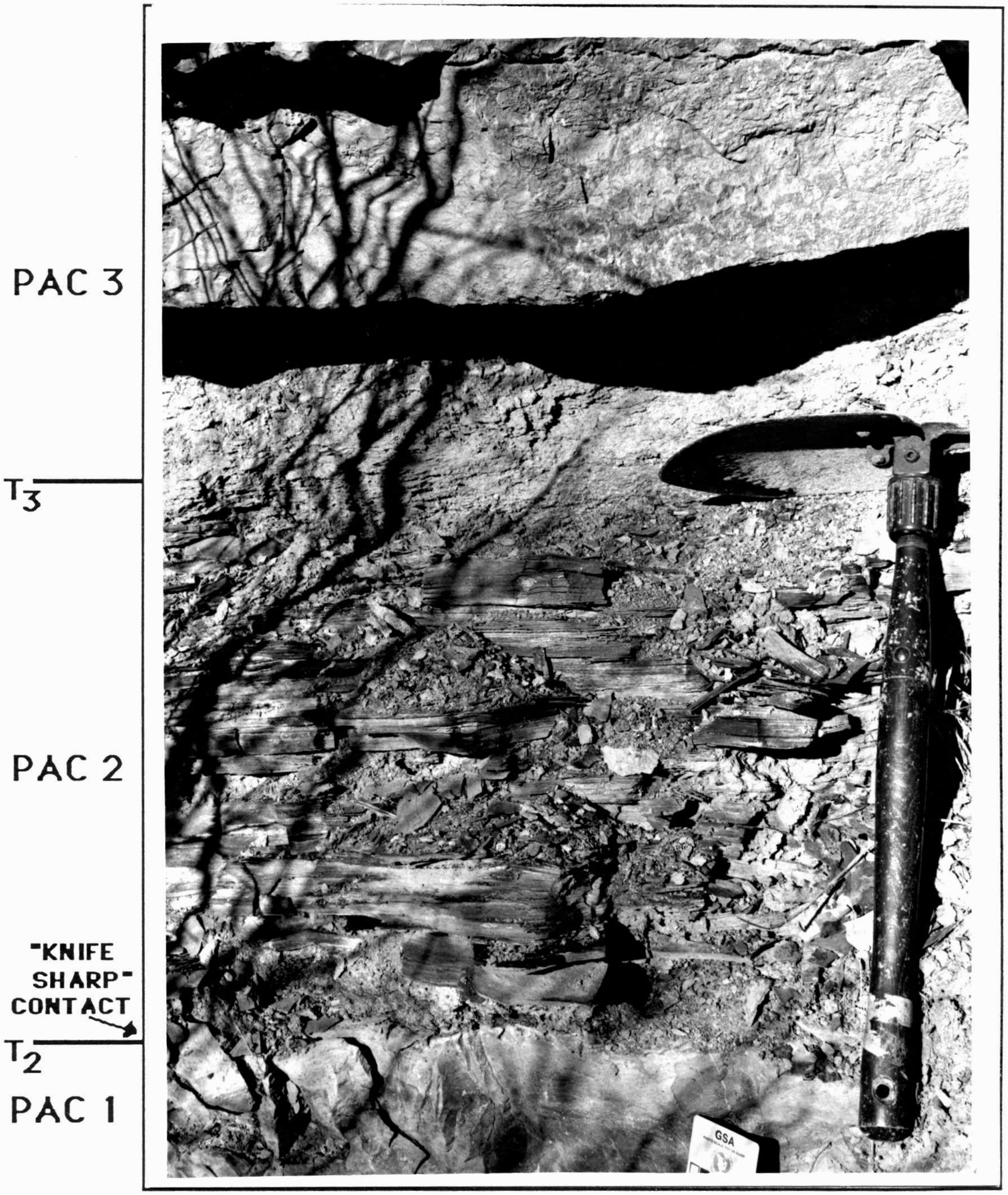

Figure 18. The "knife sharp" contact between PAC 1 and PAC 2 at section K12.

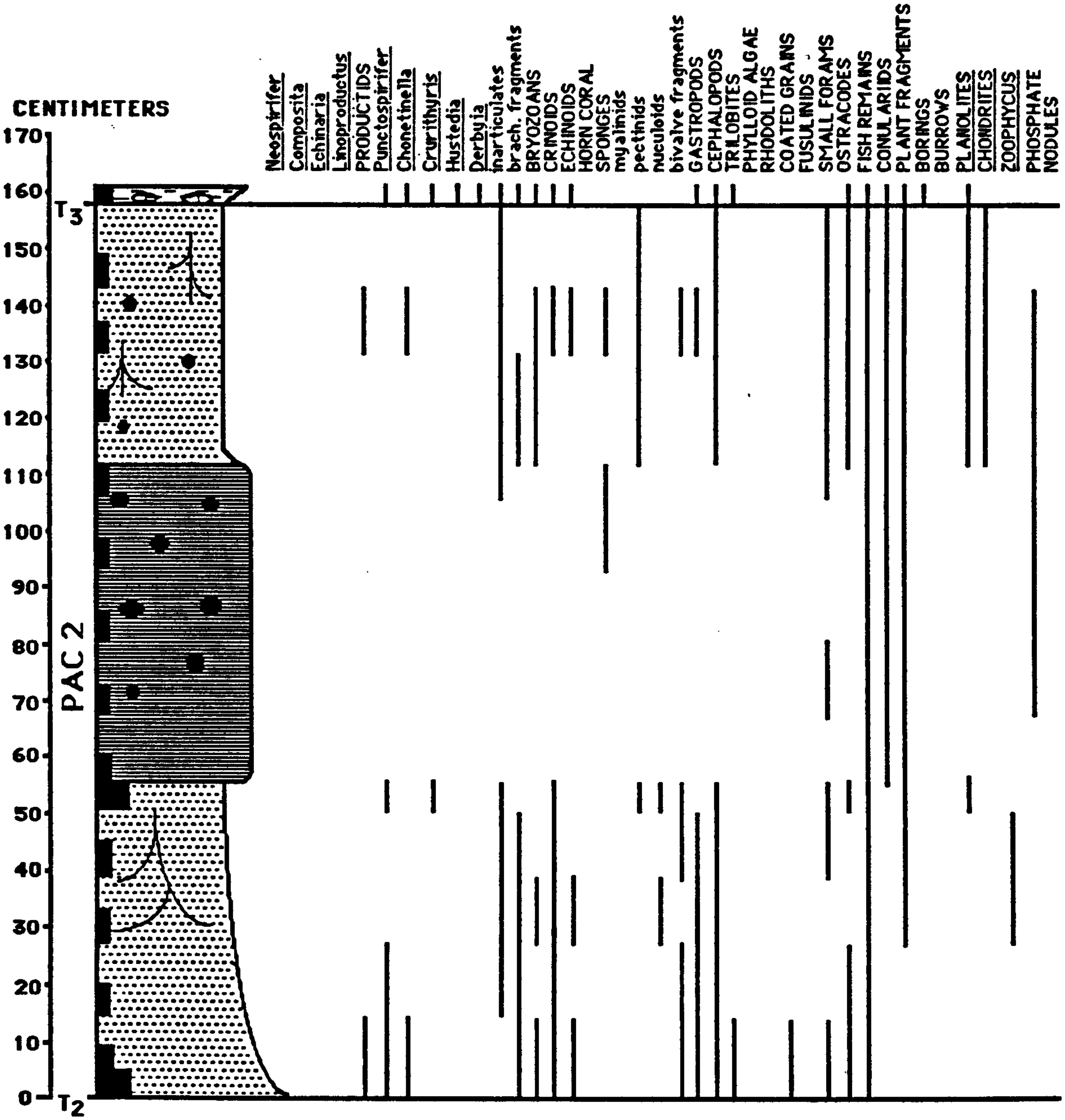

Figure 19. Ranges of taxa within PAC 2 at section HDMC

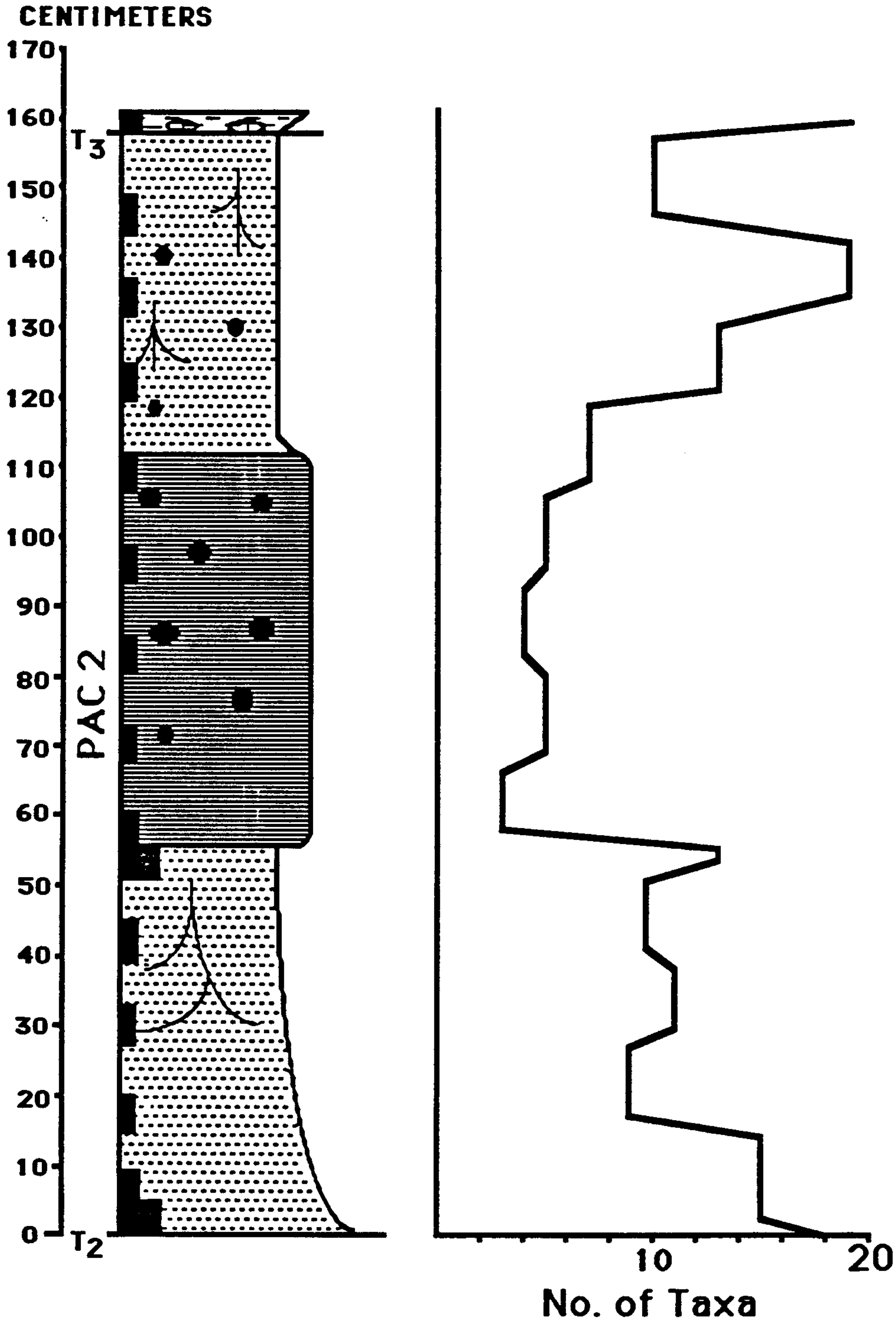

Figure 20. Diversity in samples from PAC 2 at section HDMC.

event.

Maximum transgression within PAC 2 may be represented by the black, fissile, phosphatic shale. This shale contains a biota greatly reduced in benthic forms (figure 19), and includes what is considered by many to be primarily pelagic (radiolarians, conulariids, conodonts, cephalopods), or epipelagic taxa (Orbiculoidea, pectinid bivalves) (Heckel, 1977; Malinky and Mapes, 1982; Malinky, 1984; Boardman, et al., 1984). The black shale also contains Ammodiscus, sponge spicules, shark and fish remains, and plant fragments. Some of these fossils also represent pelagic organisms (shark and fish remains), others were probably transported in (plant fragments), but others (small foraminiferids and sponge spicules) may represent, if not also carried in, benthic organisms living in this environment.

Phosphate nodules from some black shales ("core shale" of Heckel, 1977) have been shown to contain numerous fossils (Nodine-Zeller, et al., 1985). Phosphate nodules from the black fissile shale in PAC 2 contain: plant spores and other plant remains, fish remains (including a paleoniscoid skull), radiolarians, ostracodes, sponges, small foraminiferids (Reophax like), and crinoids. This fossil assemblage consists of organisms that were pelagic (radiolarians and fish), forms that were probably transported in (plant remains), but also taxa that were probably benthic (crinoids, sponges, foraminiferids, and ostracodes).

Phosphate nodules, if early diagenetic in origin, or precipitated directly from the sea water (Kidder,1983; 1985), may actually contain a better representation of the biota that existed in the environment than the black shales themselves, as suggested by Maples (1986) for calcareous concretions in Pennsylvanian black shales in the Illinois Basin. The black shales were probably unsuitable for the preservation of organisms with shells composed of calcite or aragonite, as suggested by Malinky (1984). This is supported by the observation that even in the overlying and underlying gray mudstone, aragonitic shells are absent, probably being completely dissolved, and calcite shells severely corroded. The possibility that the fossil assemblage preserved within the black shale has been taphonomically biased definitely exists.

The presence of possible benthic fossils in what was presumed to be an anoxic environment suggests that: (1) either anoxic condition existed only below the sediment-water interface (as in many modern estuaries), (2) that anoxic conditions were interrupted by periods of oxygenation, or (3) organisms living in this environment were adapted for an oxygen poor environment. Maples (1986) has suggested that brief periods of stagnation would be adequate to produce sediments that appeared as if they had been deposited during permanent anoxic or oxygen poor conditions.

The environment of deposition that existed during maximum transgression of PAC 2 may have been anoxic bottom conditions periodically interrupted by periods of oxygenation, and in a moderately deep (tens-of-meters), offshore environment.

Shallowing in PAC 2 begins near the base of the upper gray mudstone in the Muncie Creek with a gradual increase in diversity upwards. This may suggest better bottom conditions (i.e. more oxygen). This is overlain by a zone with abundant Chondrites suggesting oxygen poor conditions (figure 20). This facies contains a biota (figure 19) of what many would consider opportunistic or stress tolerant taxa, including chonetid and productid brachiopods, Lingula, and a relatively diverse molluscan assemblage (Rollins, Carothers, and Donahue, 1979; and Brezinski, 1983). Above this interval in the gray mudstone lithology, diversity of nearshore taxa decreases (figure 20), suggesting the more stressful conditions of rather shallow water.

The most commonly cited deposition model that attempts to explain the occurrence of Pennsylvanian black phosphatic shales is that of Heckel (1977). As transgression proceeded to a certain depth (100-200 m.) a thermocline developed as wind driven currents were no longer able to mix surface and bottom waters. Eventually, in this tropical setting, the prevailing trade winds established what Heckel calls a "quasi-estuarine circulation cell" (figure 21) in which cool nutrient rich bottom waters from deeper parts of the basin upwell into the epeiric sea. This established anoxic bottom conditions and provided abundant nutrients to plankton in the epicontinental sea, causing algal blooms which contributed further to bottom anoxia and to the organic enrichment of the sediments. The proposed modern analog for this model is off-shore Peru, which is an upwelling zone onto a narrow shelf, and in relatively deep water. Evidence commonly cited for this model of relatively extreme depths (for an epicontinental sea) and upwelling are: (1) the presence of phosphate nodules, which Heckel (1977) and Kidder (1983 and 1985) assumed to have formed due to upwelling, because most modern phosphorite deposits are presumably the result of upwelling, (2) "core shales" presumably display more lateral continuity than other lithofacies in the cyclothem (many of the better developed "core shales" are presumably traceable along the outcrop belt from Iowa to the Oklahoma, and are the least variable in terms of facies changes), and (3) due to the type, abundance, and diversity of certain taxa, including: conodonts, the total lack of benthic fossils, ammonoids, conulariids, radiolarians, lack of benthic calcareous algae, and foraminiferids, which together may suggest great depth and anoxic bottom conditions.

Recent studies of ancient phosphorites have yielded new insights into the formations of these deposits. Soudry and Levy (1988), examining Upper Cretaceous phosphorites in southeastern Israel, and Soudry and Southgate (1989), studying phosphorites of the Middle Cambrian of Australia, believed that the phosphatic nodules and mudstones in these deposits are the remnants of

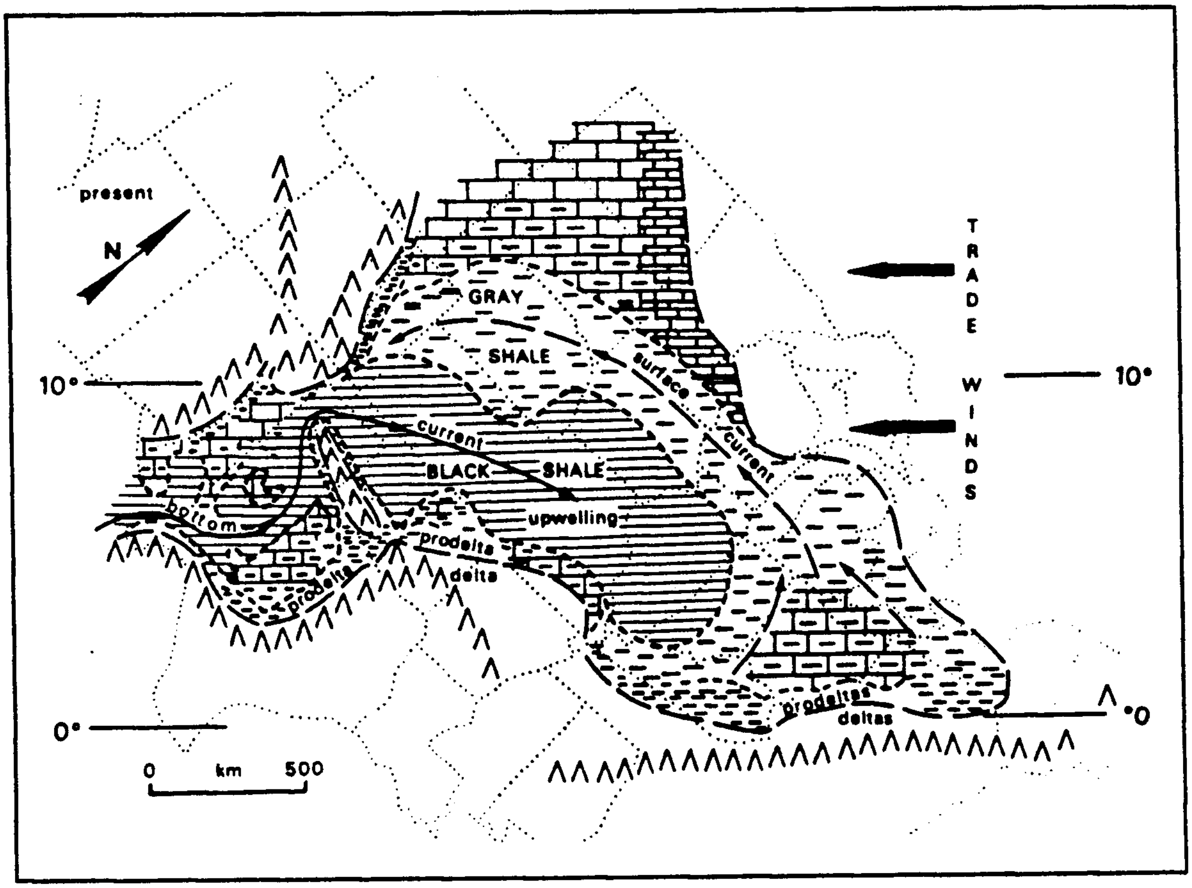

Figure 21. Schematic representation of the "quasi-estuarine circulation cell" and the lithofacies associations presumably resulting from this phenomenon (from Sweet, 1988, p. 160 , as modified from Heckel, 1977)

phosphatized algal mats, which may have formed and become phosphatized under very shallow marine conditions. Shaffer et al. (1988) and I have not recognized microbial structures within the phosphate nodules from Pennsylvanian black shales, but upwelling is not necessarily the only explanation for their formation.

The presumed lateral continuity of the Muncie Creek is questioned by the findings of this report. Although the black fissile facies may extend from Kansas to Iowa, the Muncie Creek is one of the most variable units, in terms of facies and thickness changes over short distances, examined in this study.

Boardman et al. (1984) used paleontologic data from the Pennsylvanian "core shales" as the primary evidence for a deep water environment, and claimed that certain taxa are characteristic of deeper water conditions. The taxa, listed previously, are not necessarily restricted to deposits representing one type of environment, and have been found in deposits interpreted to represent a variety of depths, including shallow. Radiolarians have been described from calcareous nodules from shallow-water marine bands of the Namurian of Great Britain (Holdsworth, 1964). Based on earlier observations of similar deposits, Pulfrey (1932) believed that finding radiolarians in the concretions was of little importance paleoecologically, but significant only because the nodules favored the preservation of radiolarians. Cephalopods, which are the main components of Boardman et al. (1984) "deep water" molluscan community, have been described (goniatites) from the Upper Carboniferous bluish clays of Uruguay (Closs, 1967). The goniatites are contained within phosphate nodules in deposits interpreted as marine intercalations within glacial deposits. Conulariids, which Boardman et al. (1984) claimed are only found within the "core shale" facies, but I have observed conulariids in limestones, both above and below the "core shale" facies, and at the base of the Lane Shale, an "outside shale".

An important factor not discussed in Boardman et al. (1984) is that of taphonomy. Boardman et al.s' depth related paleocommunities may be the result of preservational biases rather than being reflective of depth zonation of organisms. Radiolarians, as referred to earlier in Pulfrey (1932) may not indicate relatively great depths for deposition of black shales, but may be preferentially preserved within phosphate nodules in the black shales, and not preserved in other lithologies.

Cephalopods may not be useful as environmental indicators either (especially depth indicators). Post-mortem drift of the shells of the extant cephalopod Nautilus has been well documented, and cases have been recorded of shells that have drifted in the ocean over a distance of 1000 km. (Saunders and Spinosa, 1979). Some authors suggest that fossil cephalopods may have also been subject to post-mortem drift (Teichert, 1964). While drifting, cephalopod shells will sink in waters where the temperature has rapidly fluctuated, or in water that is below normal salinity (Teichert, 1964). Teichert, 1964, speculated that conditions in ancient epicontinental seas may have led to the transport of cephalopod shells into environments where they may not have lived. Bottom currents (of normal salinity) may have carried empty cephalopod shells into seas that were salinity stratified, and into depositional environments very distant from the place that the animal was actually living.

A modern analog for comparison with depositional environments of epicontinental seas is not likely to exist (Hallam, 1981), and the special conditions or requirements invoked by the Heckel (1977) model for "core shale" deposition would appear to be unnecessary (if not improbable) to explain the occurrence of this deposit (Wenger and Baker, 1986). Recent alternative explanations for Pennsylvanian "core shale" deposition (Hallam, 1981; Wenger and Baker, 1986; and Coveney et al., 1989), along with the proposed models to explain anoxic events of younger deposits (e.g. Cretaceous "early eustatic" anoxic events as described by Kauffman, 1986) are more compatible with the climatic glacio-eustatic model for T-R units, and are favored here as proposing adequate mechanisms for "core shale" deposition.

The climate that existed during maximum transgression of PAC 2 was very likely the hottest and wettest period that existed during the deposition of the Iola fifth order T-R unit. This extreme climate would probably be the period of maximum freshwater input (by rivers) into the epeiric sea (figure 22), not the lowest level of freshwater influence as suggested by Heckel (1977). This period of maximum river discharge, besides creating salinity stratification, may have provided an influx of nutrients into the epeiric sea, which is made more probable by the likely flooding of coal swamps, a tremendous source of organics, dissolved nutrients, and siliciclastics (Teichmuller and Teichmuller, 1982), during maximum transgression, leading to a period of increased primary productivity, in what was already a highly productive setting (Hallam, 1981).

Studies of modern estuarine and marine environments have noted the importance of river discharge for providing limiting nutrients (Caffrey and Day, 1986, and Dieter-Haas, 1983), and as factors or controls affecting sedimentation, circulation, dissolved oxygen levels, and stratification in these environments (Shubel and Pritchard, 1986).

Salinity stratification in conjunction with large amounts of organic debris, conditions attributed more to climatic conditions rather than overall depth, may have led to periods of bottom anoxia or greatly reduced oxygen levels during the deposition of the Muncie Creek (figure 23).

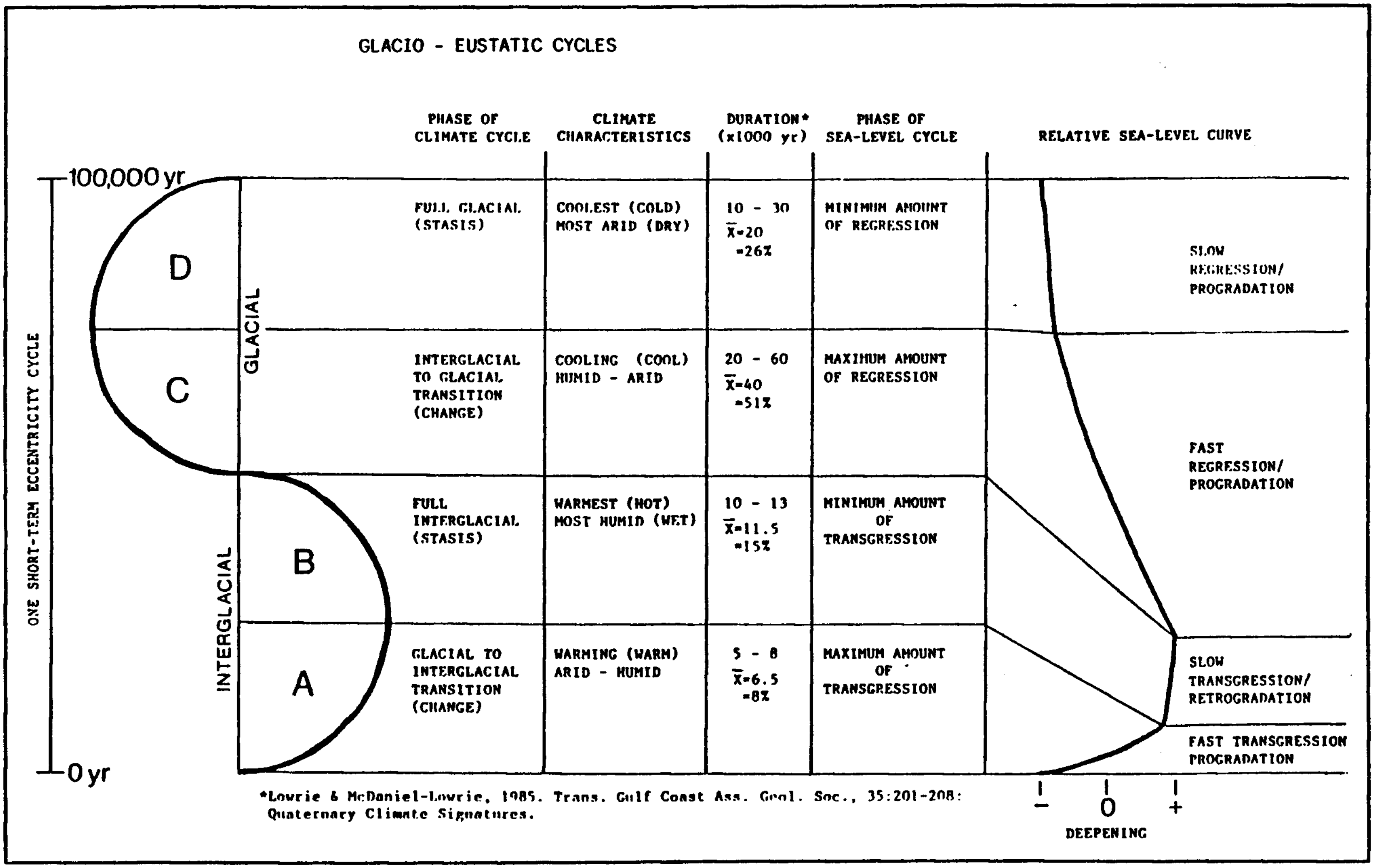

Figure 22. Properties of glacio-eustatic cycles (from Busch, 1988, unpublished figure).

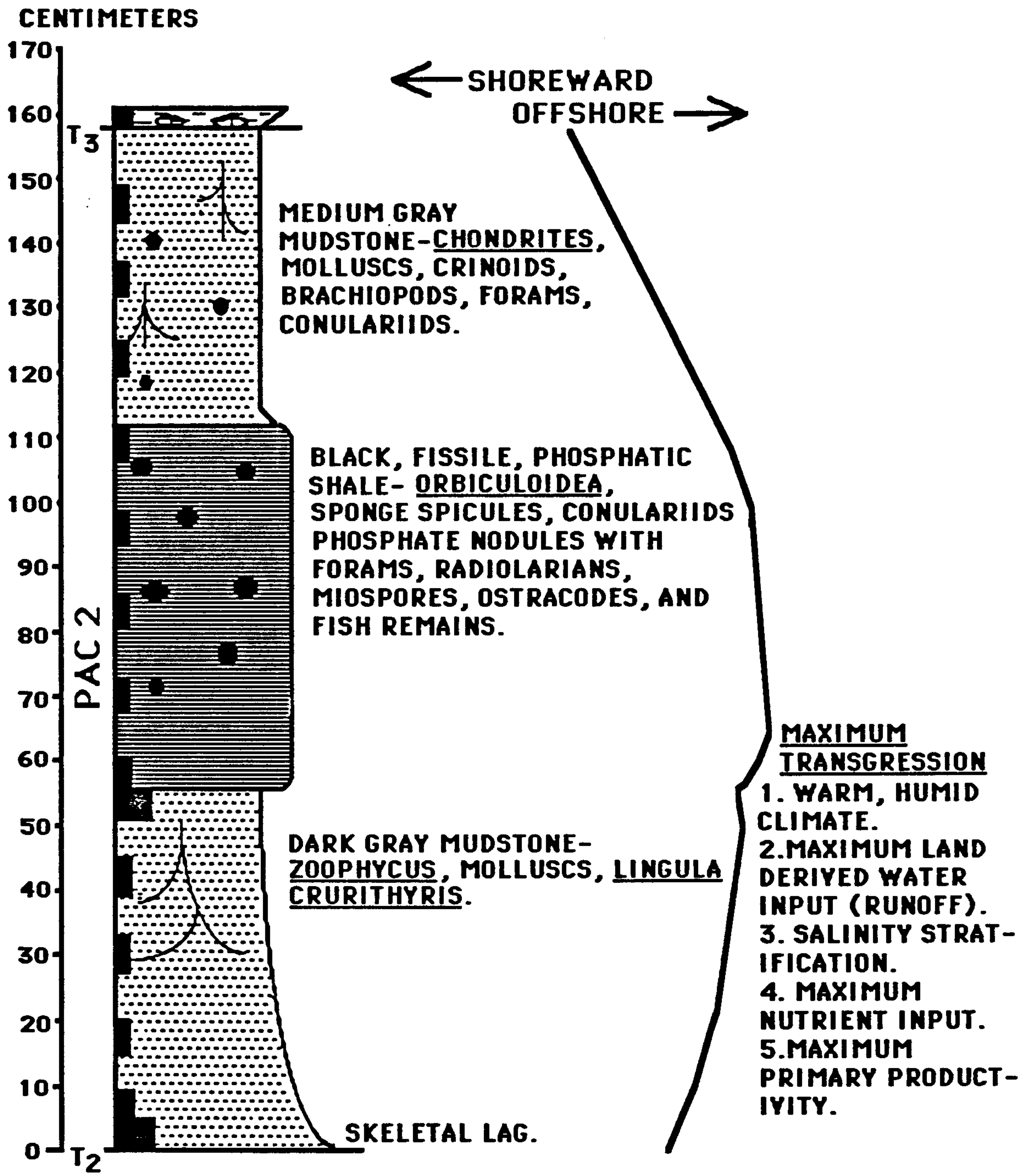

Figure 23. Characteristics and possible mechanisms during maximum transgression of PAC 2.

PAC 3.-- The existence of PAC 3 as an allocyclic unit is in question because the lower bounding transgressive surface is a lenticular marker bed (crinoidal packstone to grainstone) which is not present at all localities within the study area. At section HD the base of this unit is marked by a grayish yellow green, glauconitic claystone with a relatively diverse biota (figures 17 and 20) that sharply overlies the upper gray mudstone of PAC 2. This punctuation event is also suggested by calcareous nodules/clasts, which range in color from light gray to grayish brown (possibly representing several lithologies). These nodules/clasts are commonly bored by acrothoracicans, and are somewhat similar to the hiatus concretions described by Kennedy and Garrison (1975), however these have fewer epizoans, and only small amounts of phosphate.

Three centimeters above the proposed transgressive surface in PAC 3 is a skeletal packstone to grainstone, which has incorporated the bored calcareous nodules into its base. This packstone/grainstone is glauconitic with abundant disarticulated and fragmented skeletal grains (primarily crinoids). This unit probably records continued deepening in PAC 3, but as Mitchell (1981), and Heckel (1983) point out, the skeletal grains show very little evidence of abrasion and rounding, and, although the skeletal packstone is a rather reliable marker bed in the Kansas City area, it becomes lenticular to the south.

Maximum biotic diversity, and probable maximum transgression of PAC 3 occurs within a calcareous mudstone 18 cm. above the basal transgressive surface (figure 16). This facies contains a fossil assemblage which includes (figure 17): Neospirifer, Chonetinella, Hustedia, productids, Punctospirifer, bryozoans, crinoids, echinoids, gastropods, bivalves, and trilobites. This assemblage is very similar to the later transgressive stage community described by Rollins, Carothers, and Donahue (1979) for the Upper Pennsylvanian Cambridge Limestone, and to the Neospirifer and Composita biofacies thought to be representative of stillstand by Brezinski (1983).

Diversity in PAC 3 gradually decreases from the calcareous mudstones into a skeletal wackestone (which sharply overlies the calcareous mudstone). Diversity continues to decrease upward through the phylloid algal wackestone to packstone facies of the Raytown Limestone Member (figure 16), suggesting continued shallowing.

PAC 4.-- The phylloid algal wackestone to packstone facies in PAC 3 is sharply overlain by a thin (less than 3 cm.) crinoidal packstone which grades upward into a brachiopod wackestone (figure 24). This sharp change is accompanied by an abrupt increase in biotic diversity, and marks the transgressive surface (flooding event) of PAC 4 (figure 16).

Maximum diversity within PAC 4 occurs within the brachiopod wackestone, "large fossil bed" of Newell (1935, p. 53), in the upper Raytown (figure 16). The biota in this lithology (figure 17) consists of Neospirifer, Echinaria, Composita, Linoproductus, Punctospirifer, chonetid brachiopods, cephalopods, crinoids, echinoids, bryozoans, bivalves, inarticulate brachiopods, and horn corals, and is very similar to the open-marine Composita-Neospirifer biofacies of Brezinski (1983). The depositional environment represented here probably is one of quiet, open marine conditions, below active wave base.

Shallowing in PAC 4 is represented by a gradual decrease in biotic diversity (figure 16) from the large brachiopod wackestone into an argillaceous wackestone in the upper part of the Raytown (figure 25). Within the argillaceous wackestone is a thin (<3 cm.) argillaceous packstone layer with large (commonly >5 cm.) fenestrate bryozoan fronds. At other localities (PAQ, and CC) the Raytown, above the large brachiopod wackestone, consists of alternating layers of argillaceous, bryozoan packstone and brachiopod, crinoid wackestone. The bryozoan fragments in the argillaceous packstone commonly consist of large

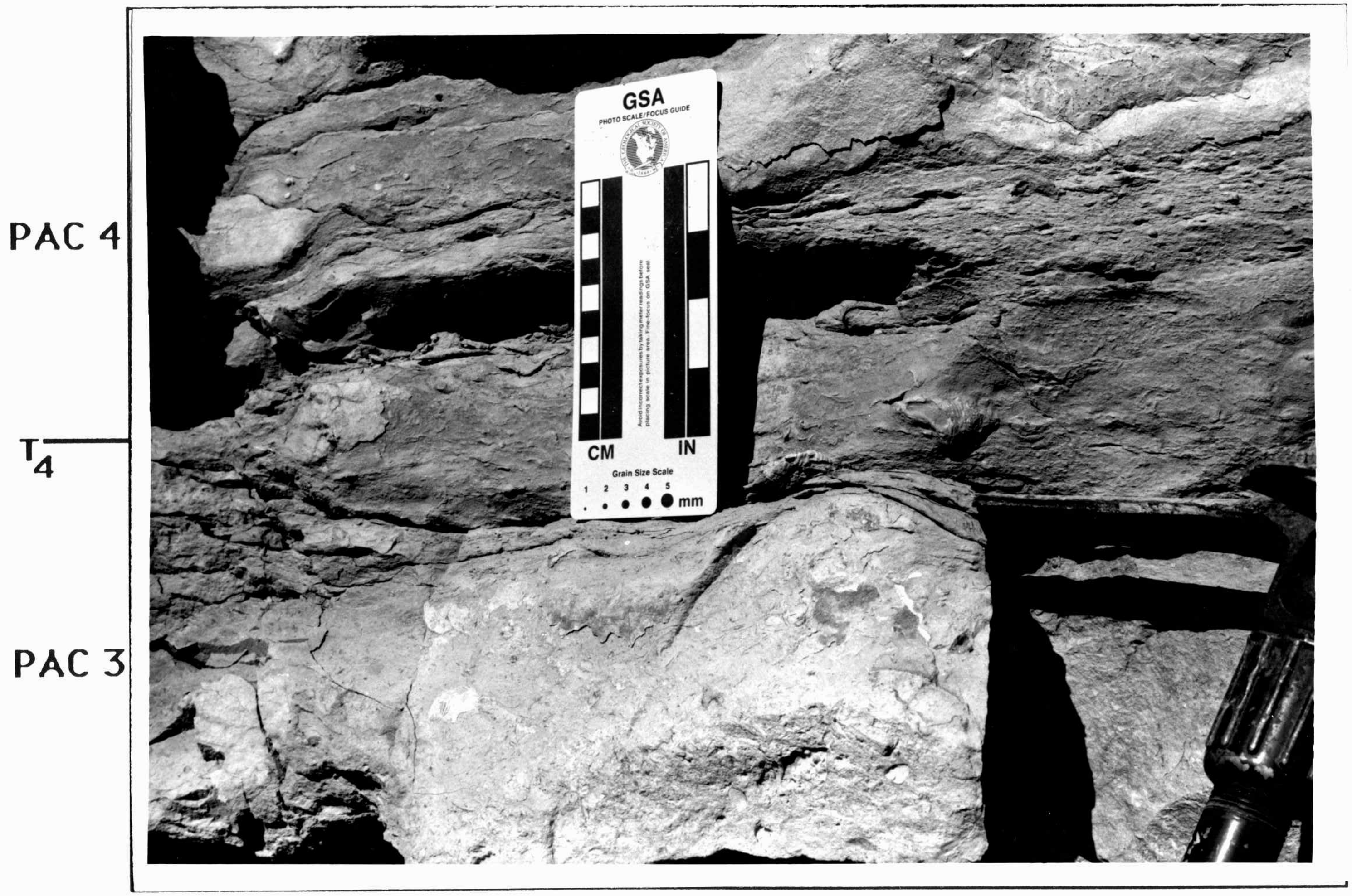

Figure 24. Transgressive surface (T 4) at the base of PAC 4 at section HD.

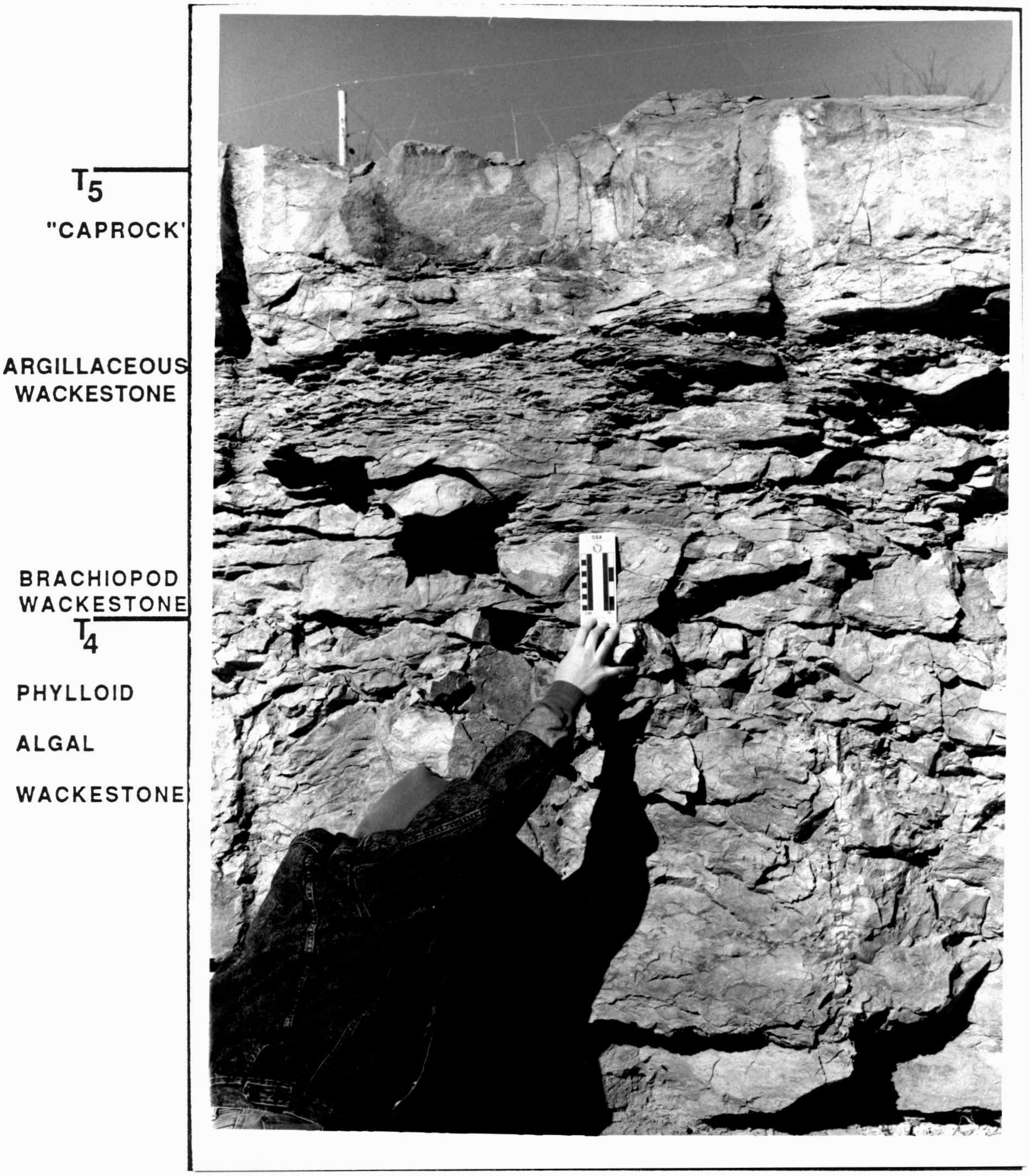

Figure 25. The lithologies representing PAC 4 (between surfaces T 4 and T 5) at section K12.

(commonly >8 cm.) fenestrate fronds, and relatively long (> 10 columnals) crinoid stem segments. The enhanced preservation of fossils in the argillaceous packstone, along with its mud content, suggests that it may represent a series of tempestites (Kreisa and Bambach, 1982). The upper Raytown at section HD may contain the distal equivalent (thin packstone) of these possible tempestite beds. Dawson (1984) believed that the Raytown represented a sequence of gradually (or normally) deposited sediments separated by intermittent periods of storm related sedimentation.

The caprock lithology that overlies the argillaceous wackestone probably represents continued shallowing under normal (non-tempestite) depositional conditions in the upper part of PAC 4. This is suggested by the low diversity, largely disarticulated and fragmented, molluscan-dominated fossil assemblage within this lithology.

PAC 5.-- The skeletal packstone to grainstone at the top of the Raytown Limestone Member at section HD represents the beginning of PAC 5. This lithology sharply overlies a wackestone (the caprock lithology), and contains a moderately diverse fossil assemblage (figure 16) (though probably not in situ). Heckel (1988) believed the skeletal packstone to be a possible storm bed, though much of the evidence gathered for this report (presented in the following paragraph) suggests this is unlikely, though still a possibility.

The skeletal packstone is present at most localities in the northern part of the field area (HD, K32&7, K32, ED, CC, K12, CB, AND R) and at some in the south (PAQ, and OKCR), especially those that include a complete section of the Raytown. The skeletal packstone is, however, less conspicuous in the south. Skeletal grains in the packstone are primarily fragmented and disarticulated, though some large valves of disarticulated brachiopods have been preserved. Phosphatic grains are moderately (> 50 grains per 2 kg. sample) abundant (shark remains, conodonts, and glauconite) suggesting slow rates of deposition (Flugel, 1982). Many of the skeletal grains (especially brachiopod valves) are lightly encrusted by algae, and often bored by acrothoracicans.

Directly overlying the skeletal packstone at the top of the Raytown is a fossiliferous, silty mudstone (base of the Lane Shale). This unit has a moderately diverse (> 15 taxa) biota (figure 16), but is primarily composed of crinoids (including Delocrinus and Endelocrinus, as described by Strimple and Moore, 1971) and a relatively diverse molluscan assemblage including: nuculoid bivalves, several types of gastropods, and cephalopods (figure 17), suggestive of increased environmental stress (Brezinski, 1983; and Rollins and Donahue, 1975). At one locality, K12, this unit contains conulariids, a taxa presumably restricted to the "core shale" (Boardman, et. al., 1984). The occurrence of this taxa represents either, preferential preservation in certain environments, or a facies-free habit (possible pelagic habit).

Heckel (1988), and Mitchell (1981) believed that the fossiliferous silty mudstone is the result of Raytown carbonate production being "smothered" by a terriginous influx of clastic sediments from deltas prograding from the northeast to the southwest. Increased rates of sedimentation may explain the state of preservation of the fossil assemblage in the silty mudstone. Many fossils in this unit are whole and unabraded.

Diversity continues to decrease, and the rocks reflect shallowing upward through the fossiliferous, silty mudstone into a very argillaceous crinoidal packstone layer (13 cm. thick) 1.09 m. above the base of the Lane Shale. Above the crinoidal packstone layer, diversity drops off dramatically with very few taxa represented. The trace fossils Asterosoma and Asteriacites occur on lenses of very fine grained sand, interbedded with silty mudstone that is 1.73 m. (5.7 ft.) above the crinoidal packstone. These trace fossils belong to the Cruziana

Association of Seilacher (1978) which he inferred to represent shallow to marginal marine environments.

Sea Level Curve.-- A relative sea level curve was constructed for the five sixth order T-R units (PAC's) in the Iola Limestone at Holliday Drive (HD) (figure 26). The deepening-shallowing units in this sequence may record a combination of climate change, glacio-eustacy, and tectonic subsidence. Because tectonic subsidence was not calculated the resulting sea level curve for the sixth order T-R units must be considered as relative (Vail, 1987; and F. Hamilton, personal communication, 1989).

The Iola Limestone at section HD appears to be composed of at least five deepening-shallowing units (PACs or sixth order T-R units). This curve differs from the Heckel (1977) curve for a "classic" Kansas cyclothem. The curve for this investigation illustrates the possible existence of five small-scale transgressive-regressive events, whereas Heckel (1977) believed that the Iola cyclothem represented one deepening-shallowing event. The net results are, however, the same, suggesting differences in the scale of observation.

Both scales of T-R units (fifth and sixth order) display relatively rapid transgressions, followed by more gradual regressive phases, suggesting at least the possibility for glacio-eustacy as a mechanism for these cycles in the Iola Limestone (figure 22).

Osawatomie Section (OSA)

PAC 1.-- The transgressive surface of PAC 1 at Osawatomie is marked by a sandy, calcareous mudstone, with a moderately diverse marine biota (figure 27), that sharply overlies a greenish gray sandy mudstone with plant fragments (figure 28). The transgressive surface of PAC 1 at OSA differs from the surface at the

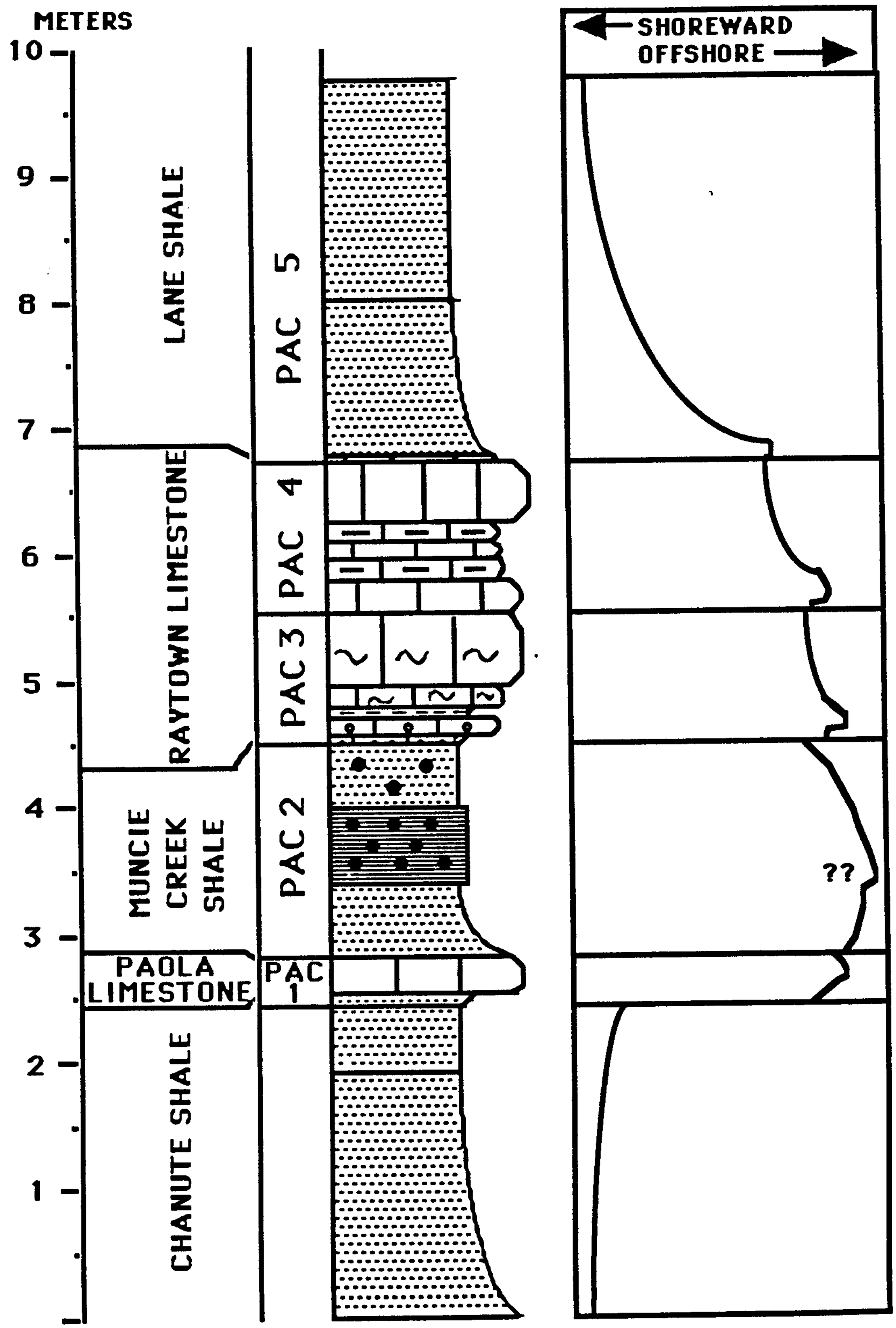

Figure 26. Relative sea-level curve for the Iola Limestone at Holliday Drive.

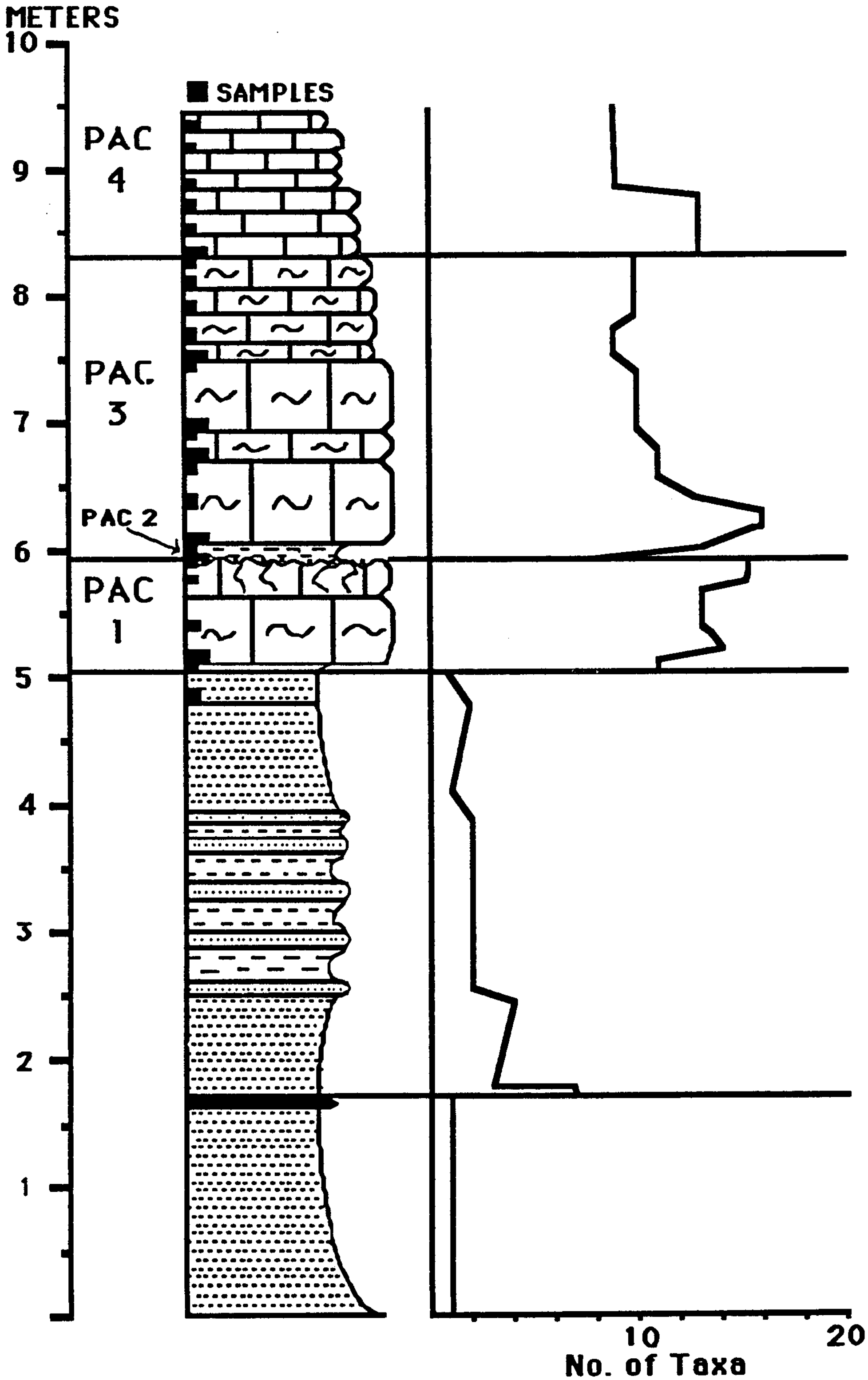

Figure 27. Diversity within genetic units of the Iola Limestone and adjacent units at Osawatomie.

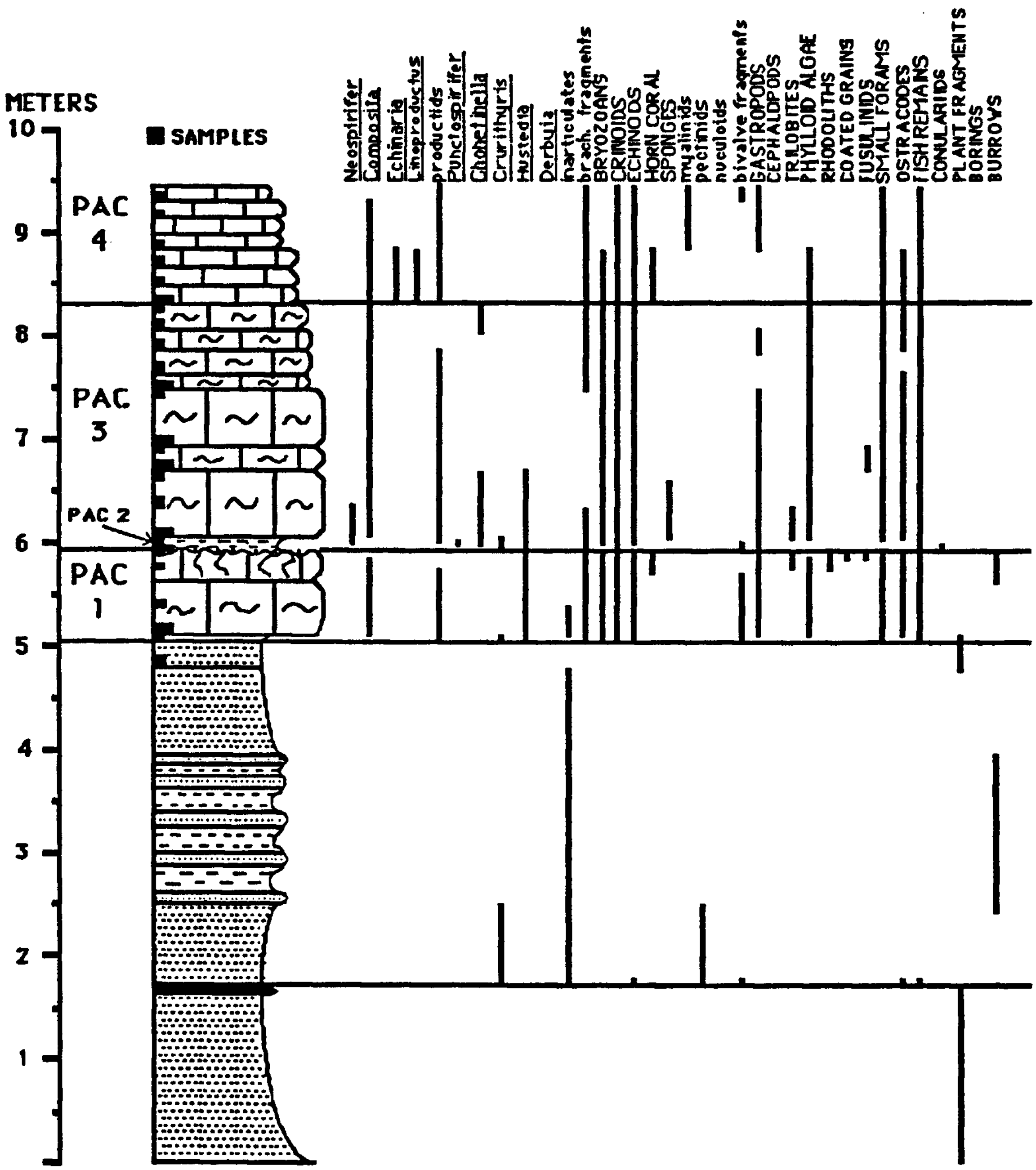

Figure 28. Ranges of taxa within genetic units of the Iola Limestone and adjacent units at Osawatomie.

same approximate position at section HD in that it is marked by a sandy lithology, but the biota is very similar to that of HD, and the condition of the fossil assemblage is similar (fragmented and rounded).

Biotic diversity increases rapidly above the transgressive surface in PAC 1, through the sandy calcareous mudstone, and into an algal wackestone (figure 27). The algal wackestone represents maximum biotic diversity within PAC 1, and hence maximum transgression. The biota of this facies includes (figure 28) phylloid algae, Composita, productids, crinoids, echinoids, crinoids, echinoids, bryozoans, inarticulate brachiopods, and bivalves. The fossil assemblage, at the probable maximum transgression of PAC 1 at OSA, is very similar to that of maximum transgression of PAC 1 at HD, except that phylloid algae are much more conspicuous. Phylloid algae appear to thrive in shallow water (Elias, 1964). Phylloid algal bioherms in the Iola Limestone appear to be restricted to areas directly over the Bourbon Arch in Allen County, Kansas, (Dawson, 1984). If the Bourbon Arch was a paleotopographic high during Iola deposition, as suggested by Mitchell (1981), the abundance of phylloid algae may indicate that water depth was less during maximum transgression of PAC 1 at OSA than it was at HD at this time. The depositional environment, however, still was quiet, relatively open marine, well lit waters, below effective wave base. Dawson (1984) believed that this part of the Paola, and the entire member, represented a period of maximum marine inundation during the Iola depositional phase.

A decrease in diversity upward from the algal wackestone in the Paola into a bioturbated, rhodolith-bearing wackestone (figure 27) suggests shallowing upward. The wackestone contains a biota that is primarily fragmented and disarticulated, plus oval and discoidal rhodoliths. I agree with Dawson (1984) who suggested that the rhodoliths in the Paola formed in shallow, offshore, near storm wave base environment (attributing their shape to periodic wave agitation).

Toomey (1974, 1985) attributed the growth of rhodoliths to a shallow, well lit, nearshore environment. The wackestone at the top of the Paola is also conspicuously bioturbated, with iron-stained, open, Thallasinoides? and Planolites?. The burrowers in this unit may have had an effect on cementation, with the open burrow system contributing to the possible early submarine cementation of the wackestone (Bromley, 1967b, and 1975). Early cementation may explain why the burrow system is well preserved. Dawson (1984) described several generations of burrows in the upper Paola.

PAC 2.-- The lower bounding surface for PAC 2 at OSA appears to be a hardground and omission surface. It is represented by the "hummocky" surface at the top of the Paola (figure 29). Hardgrounds, as described by Fursich and Wendt, 1976, are omission surfaces at which the underlying sediments had become at least partially lithified. Lithification occurs because of early cementation during periods of nondeposition. In the Paola, early cementation may have been enhanced by an open burrow system (Dawson, 1984). The characters of hardgrounds are described in greater detail by Lindstrom (1979), Bromley (1978), Dravies (1979), and Fursich and Wendt (1976). For a detailed interpretation of the diagenetic evolution of this surface in the Paola see Dawson (1984).

Directly overlying the omission surface is a 5-cm. medium gray, calcareous mudstone, with numerous rounded and oval phosphate nodules. Biotic diversity is relatively low (figure 27), consisting of crinoids, bivalves, gastropods, Crurithyris, Hustedia, and shark remains. This unit may represent a lag deposit, and in combination with the underlying hardground, the omission surface and overlying lag deposit may represent a relatively long period of time (possibly equivalent to the entire Muncie Creek at HD). Phosphate nodules in this lithology may have a different origin than the phosphate nodules in the fissile black shale at section HD. Phosphates, especially in the form of nodules, are commonly associated with

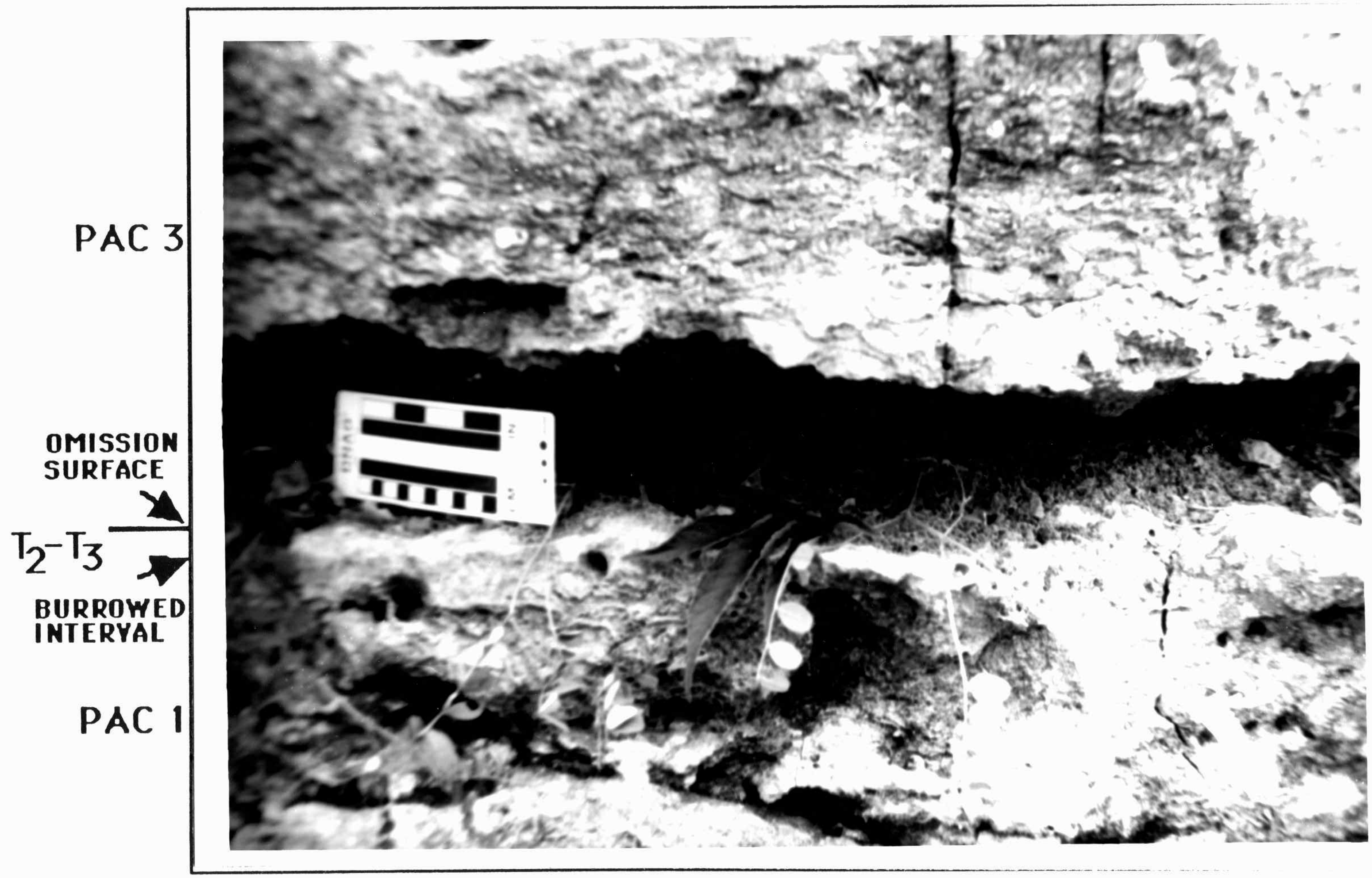

Figure 29. "Hummocky" omission surface at the base of PAC 2 at Osawatomie

hardgrounds, omission surfaces, and erosion surfaces (Bromley, 1967a). Some authors believe that phosphate nodules are the result of erosion, and mineralization of the eroded particles during diagenesis. Such nodules would be considered lag intraclasts (Bromley, 1975; Kennedy and Garrison, 1975; and Baird, 1978).

PAC 3.-- A dark yellow green, calcareous mudstone (5 cm. thick), with a relatively diverse fossil assemblage occurs above the thin (5 cm.) calcareous mudstone lag lithology (figure 27). This calcareous mudstone contains Neospirifer, Chonetinella, Hustedia, Crurithyris, Punctospirifer, productid brachiopods, crinoids, echinoids, bryozoans, bivalves , and small (< 1 mm. in diameter) phosphate? nodules. Moldic preservation of fossils is common in this lithology. It is possible to conclude from this description that this calcareous mudstone facies is very similar, both in composition and appearance, to the calcareous mudstone which represents maximum transgression during PAC 3 at HD. If this is the case, then the transgressive surface for PAC 3 lies below the fossiliferous calcareous mudstone (either in the lag or just below it), and what remains of PAC 2 (and the Muncie Creek) is the omission surface and possibly the calcareous mudstone lag. This situation may represent a "cryptic unconformity" (in which a PAC boundary is missing, because it merged with another PAC boundary), and the only continuously traceable part of the supposed "laterally continuous 'core shale'" is the basal transgressive surface.

The possibility also exists, however, that the fossiliferous mudstone at OSA may be a shallow water equivalent to some lithology in PAC 2 at HD. The evidence, however, appears to support a "cryptic unconformity". This is especially true when the other sections are considered. At section PW (just 12.5 miles southeast of section HD), the apparent equivalent of the crinoidal packstone to grainstone near the base of PAC 3 at section HD is almost in contact with the underlying "hummocky" omission surface at the top of the Paola Limestone Member. Also at locality PW, the data suggest that PAC 2 (and the Muncie Creek Shale Member) may be represented by not much more than an omission surface.

Sharply overlying the fossiliferous calcareous mudstone is a thick-bedded, algal wackestone to packstone in the Raytown. A relatively diverse biota occurs at the base of this lithology, but diversity gradually decreases upwards (figure 27), supporting an upward shallowing in either PAC 2 or PAC 3, depending on one's interpretation. Above the thick-bedded algal wackestone is a more thinly bedded algal wackestone to packstone. Based on biotic diversity, shallowing continues, and the size of skeletal grains decreases, but sorting of the grains increases, suggesting at least slightly higher energy. Bedding thickness is also much less, another suggestion of changes in energy levels (Hardie and Ginsburg, 1977). Thicknesses of phylloid algal lithologies in the Raytown at OSA is greater than that at section HD, possibly related to the paleotopography.

PAC 4.-- There is a slight increase in diversity upward from the phylloid algal wackestone into an overlying brachiopod wackestone ("large fossil bed") marking the punctuation event for PAC 4 (figure 27). The brachiopod wackestone is characterized by the large productids Echinaria and Linoproductus, plus crinoids, echinoids, horn coral, bryozoans, Composita, and minor (< 1% of skeletal grains in thin section) amounts of phylloid algae (figure 28). This lithology also has a higher biotic diversity than the rest of the upper Raytown at OSA, and probably represents maximum transgression of PAC 4. Maximum transgression during PAC 4 at section OSA may be slightly shallower than the facies marking maximum transgression of PAC 4 at section HD. This shallower water interpretation is based on the lower diversity, and the absence of Neospirifer and of other brachiopod genera.

Shallowing in PAC 4 at section OSA is represented by a gradual decrease in diversity upward from the brachiopod wackestone into the overlying thin to medium bedded wackestones (figure 27). Along with decreasing diversity, many skeletal grains are fragmented and disarticulated, and myalinid bivalves occur. According to Yancey and McLerran (1988), myalinids are an indicator of relatively shallow marine conditions.

A complete section of the Raytown Limestone Member is not present at OSA because of erosion, and therefore PAC 5 is absent.

Sea Level Curve.-- At least three sixth order T-R units, as illustrated by the relative sea level curve (figure 30), occur in the sequence exposed at Osawatomie. The curve may be modified slightly, depending on the location of the transgressive surface for PAC 3, which has not been satisfactorily determined yet, and the interpretation of PAC 2.

Correlation of Genetic Units

Correlations were made by tracing the bounding transgressive surfaces of the PACs (or sixth order T-R units) from section-to-section, relative to sequential position of diagnostic beds and marker horizons. Two cross sections were constructed; one roughly north-south (figure 31), and one roughly northwest-southeast (figure 32). These two sections were arranged so as to maximize possible structural relationships (e.g. as close as possible, considering the limitation of measured sections, to depositional strike and depositional dip) (figure 33). The top of the Paola (base of PAC 2) was used as datum.

PAC 1 was correlated across the study area by tracing its transgressive surface relative to the Paola (marker bed), a unit which showed only minor changes throughout the study area. PAC 1 gradually thickens southward (figure 31), and appears to be related to an increase in phylloid algae. The increase in

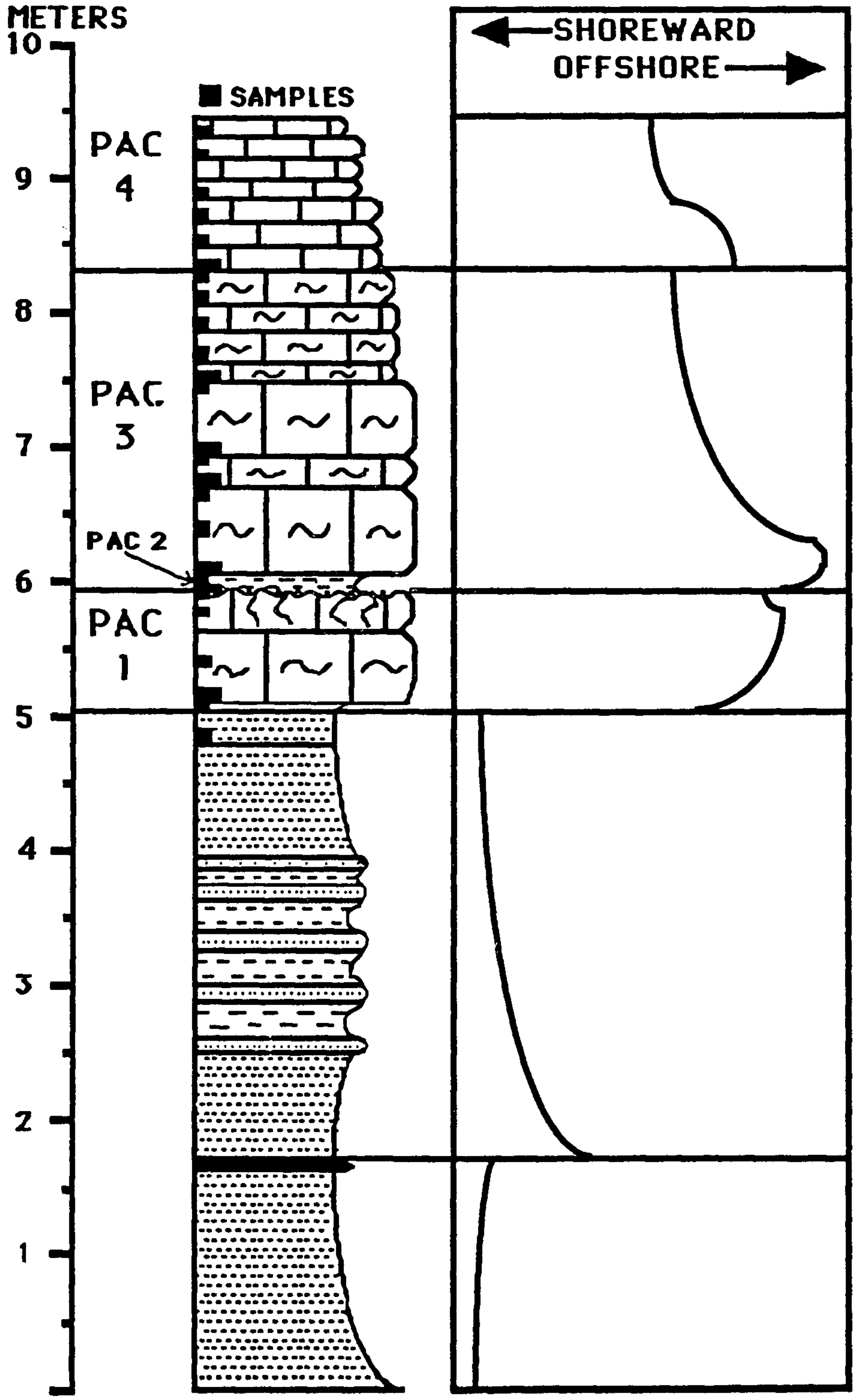

Figure 30. Relative sea-level curve for the Iola Limestone and adjacent units at Osawatomie.

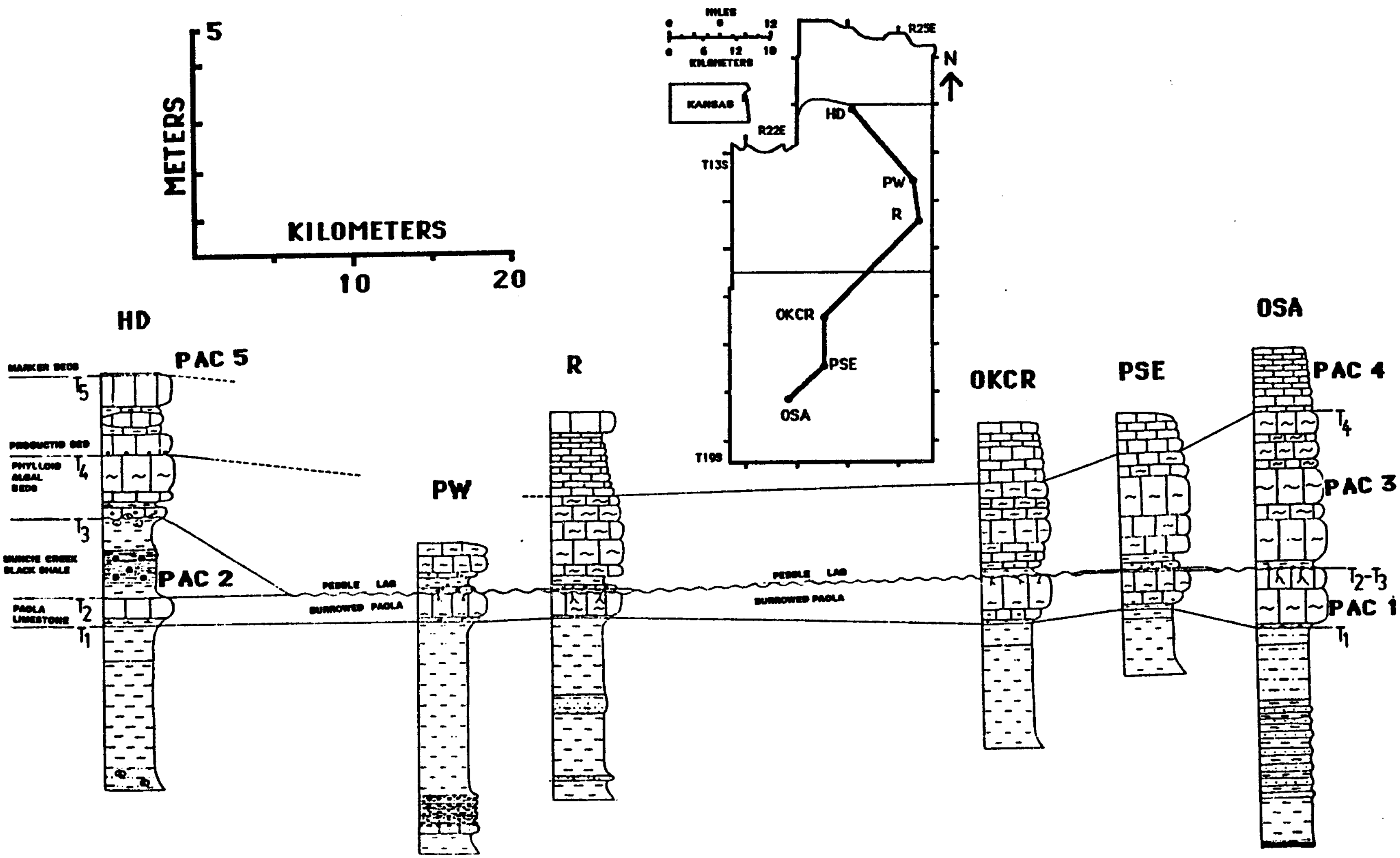

Figure 31. Correlation of PACs at sections HD, PW, R, OKCR,PSE, and OSA along a line that runs roughly north-south.

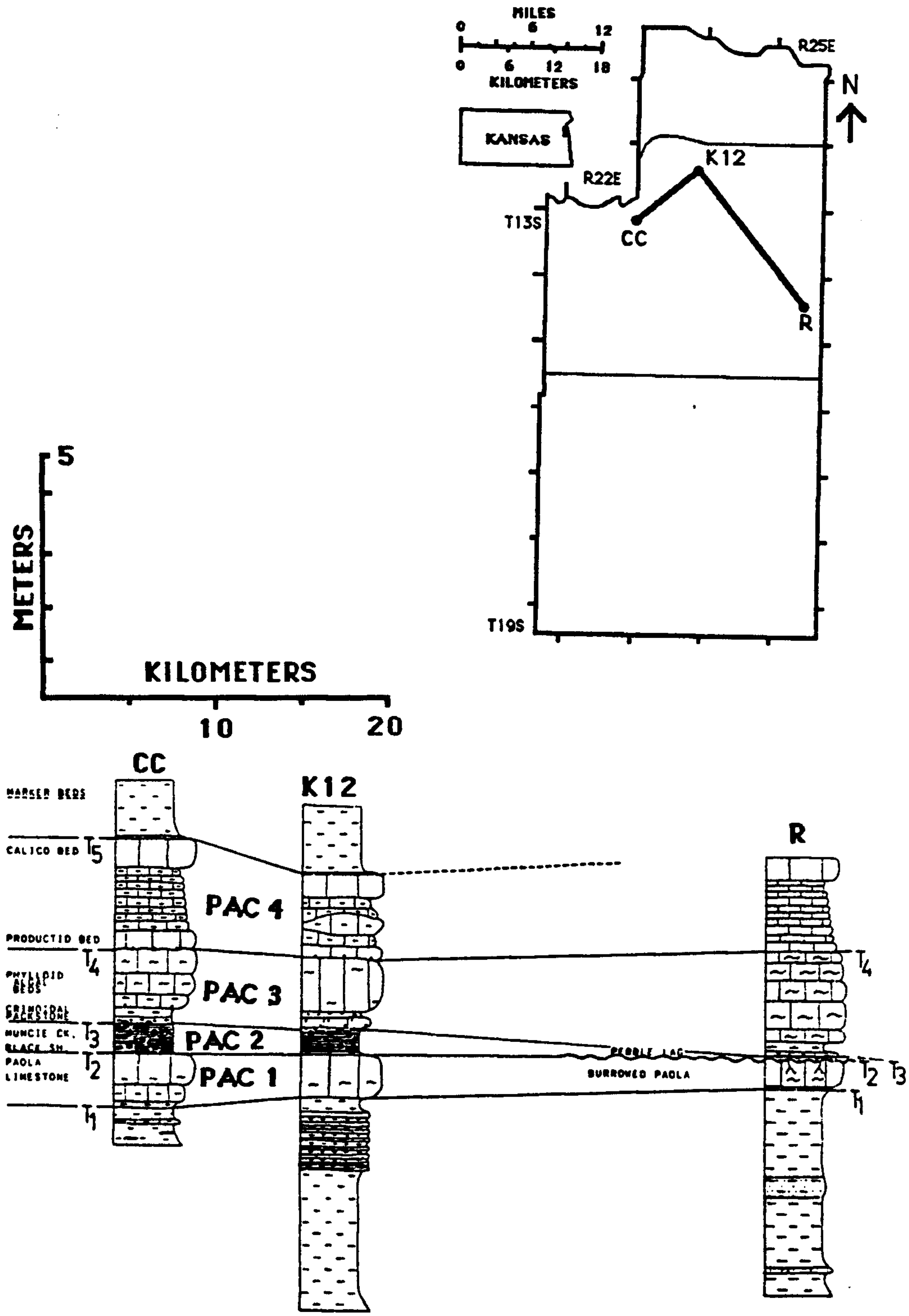

Figure 32. Correlation of PACs at sections CC, K12, and R along a line that trends roughly northwest-southeast.

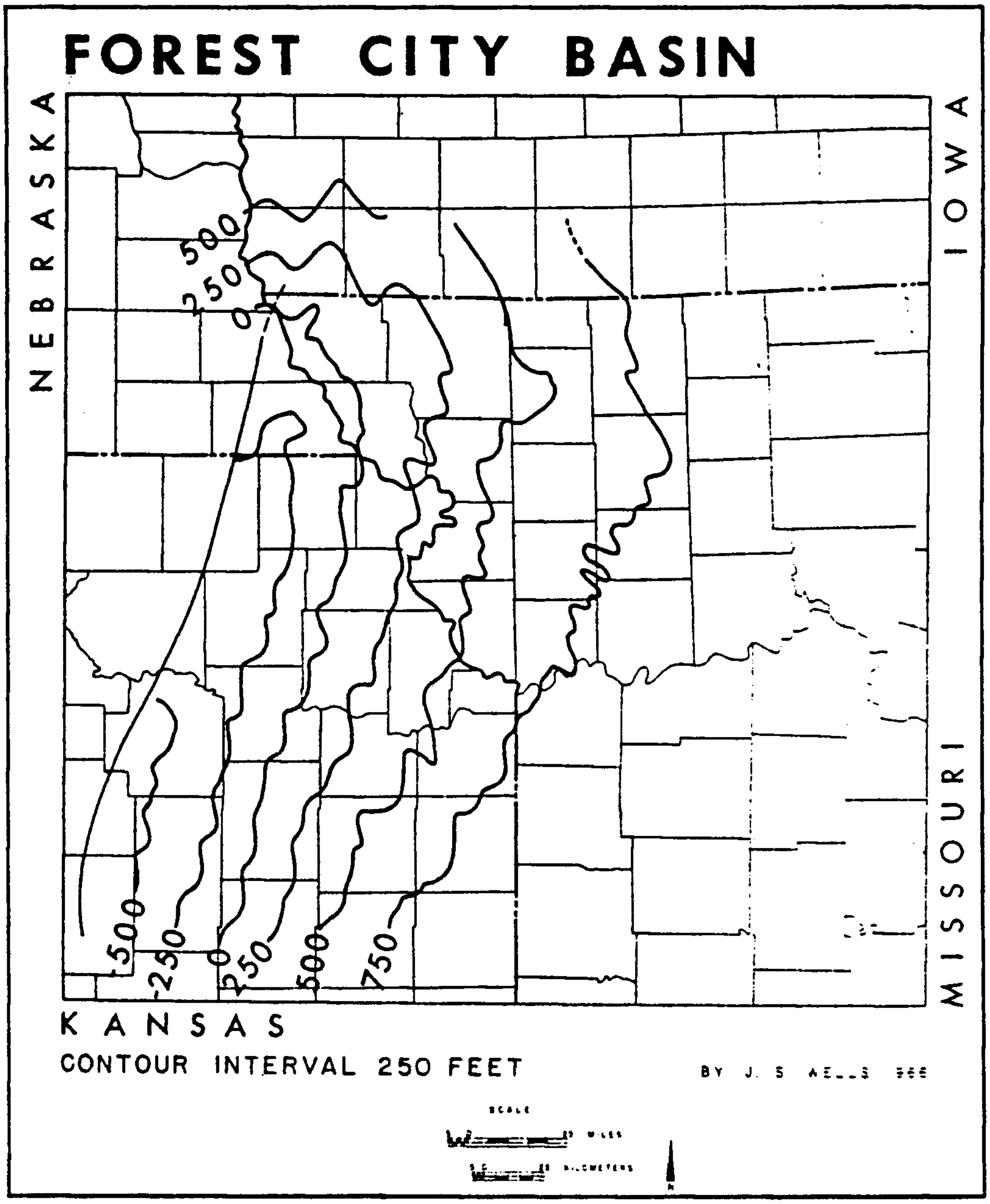

Figure 33. Structure contour map on the base of the Kansas City Group in the Forest City Basin (from Anderson and Wells, 1968, p. 275).

phylloid algae may indicate shallower water or less turbid water in the south. A shallower water interpretation seems reasonable because of the possible influence of certain structures, such as the Bourbon Arch and the Schell City-Rich Hill Anticline (figure 34), and possible minor paleotopographic highs (figure 37), during the deposition of PAC 1. PAC 1 thins eastward, which may be due to removal by erosion of the top of PAC 1 at section R (figure 32).

The base of PAC 2 was traced across the field area relative to the Paola, the black, fissile, phosphatic shale of the Muncie Creek, and the crinoidal packstone which overlies the Muncie Creek. In both cross sections (figures 31 and 32), PAC 2 thins dramatically or may disappear entirely (except for the transgressive surface) from north to south in Johnson County. Mitchell (1981) concluded that the disappearance of the black, fissile, phosphatic shale in the Muncie Creek was related to the Bourbon Arch, which may have been structurally active during the deposition of the Iola Limestone. Mitchell believed that the Bourbon Arch acted as a topographic high, with the water near this structure being too shallow to develop a thermocline (figures 34 and 35). The Muncie Creek displays considerable facies variability over a relatively short distance, suggesting the possibility that along with the Bourbon Arch, minor paleotopographic features may have had an effect on Muncie Creek sedimentation. In his study of the algal bioherms in the Wyandotte Limestone, Crowley (1969) included an isopach map of the Lane Shale (figure 36). From this isopach map, a northeast southwest trending band of thick Lane Shale is obvious (hatchered area on map). The Lane Shale is thin just south of this band. Johnson County sections studied for this report have been plotted on the isopach map of the Lane Shale. A line can be drawn that separates sections containing a black, phosphatic Muncie Creek (points northwest of the line), from sections containing only a thin gray Muncie Creek (lag), or possibly no Muncie Creek at all (points southeast of the line). The band

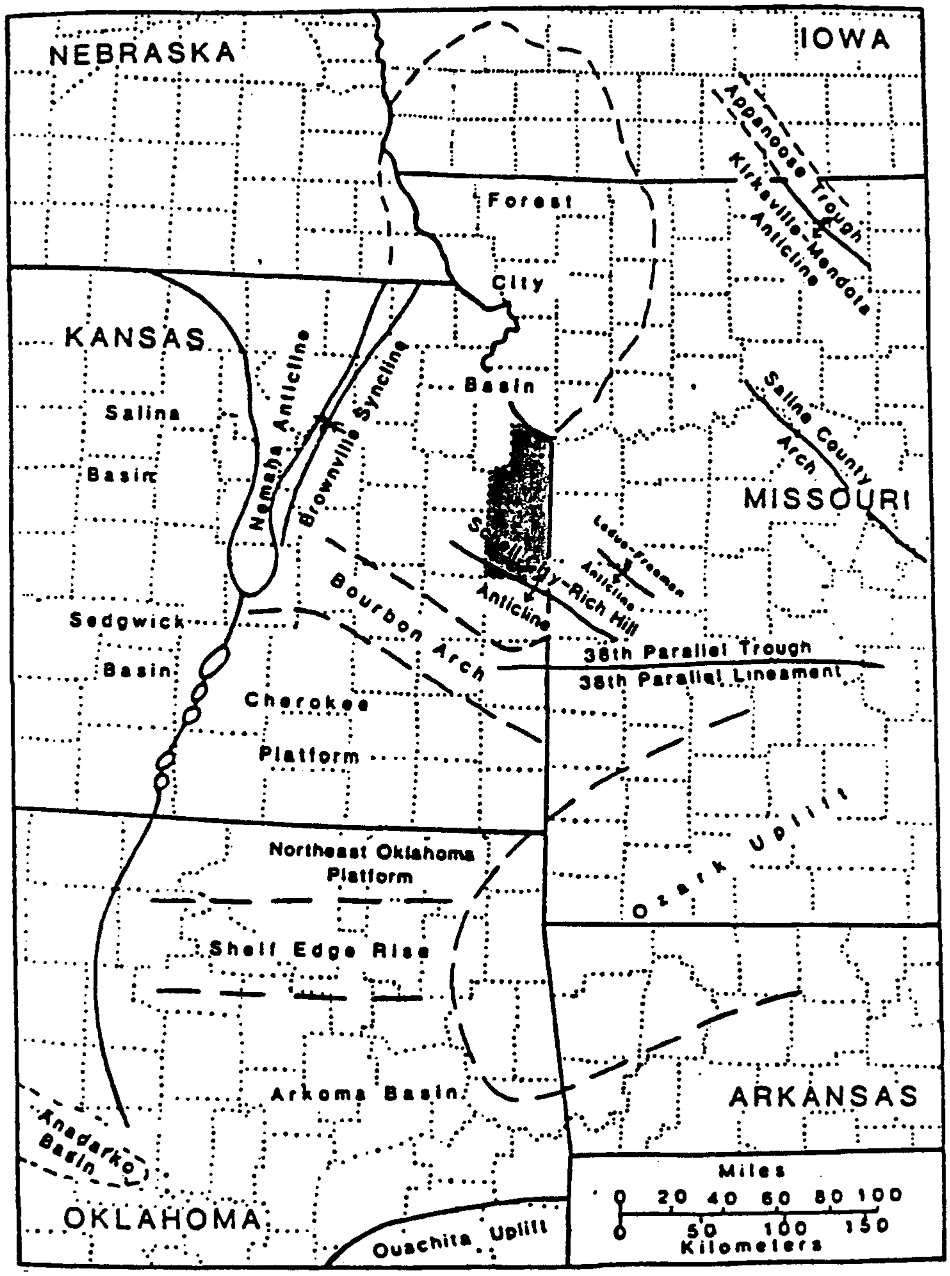

Figure 34. Possible structural influences on sedimentation during the Pennsylvanian in the Midcontinent (from Knight, 1985).

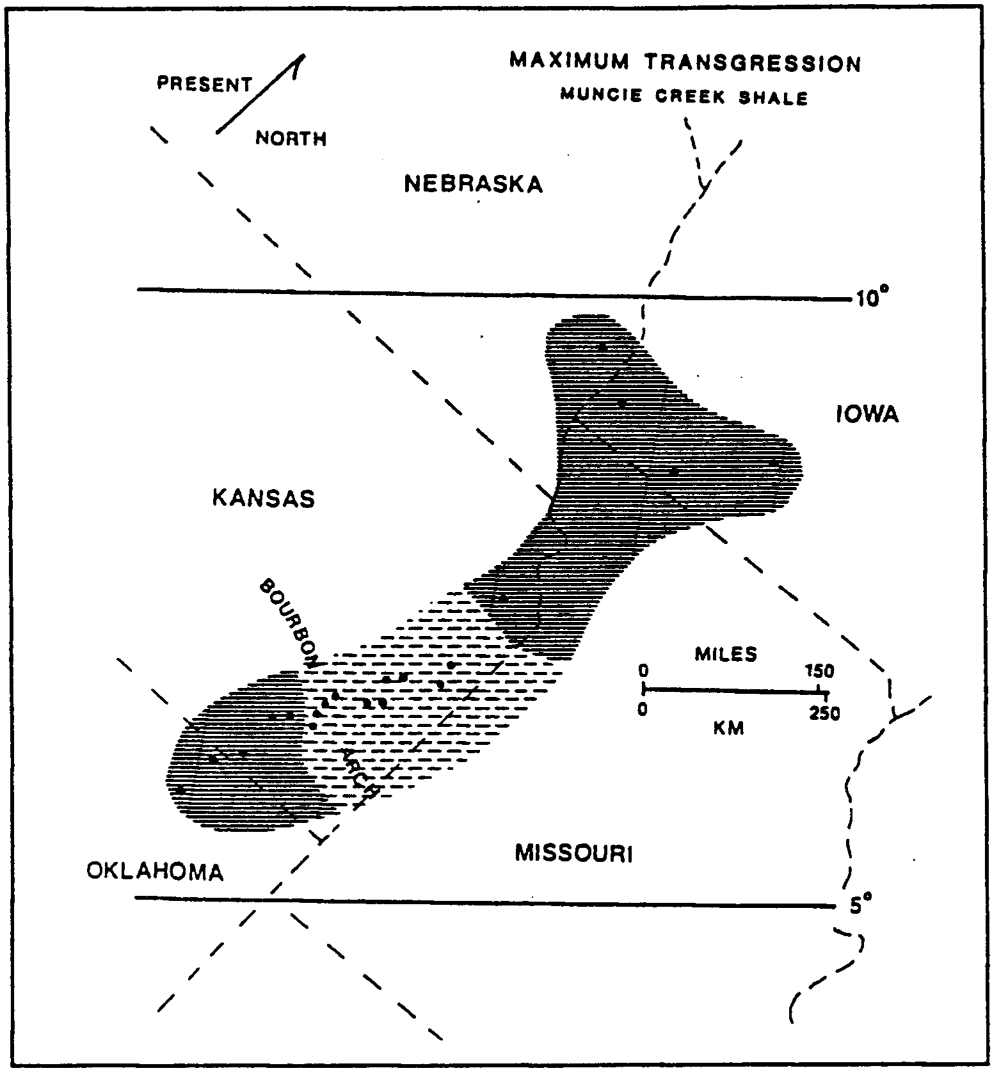

Figure 35. Facies map of the Muncie Creek "core shale" along its outcrop belt. Dashed pattern = gray shale, horizontal lines = black, fissile shale (from Mitchell, 1981, p. 126).

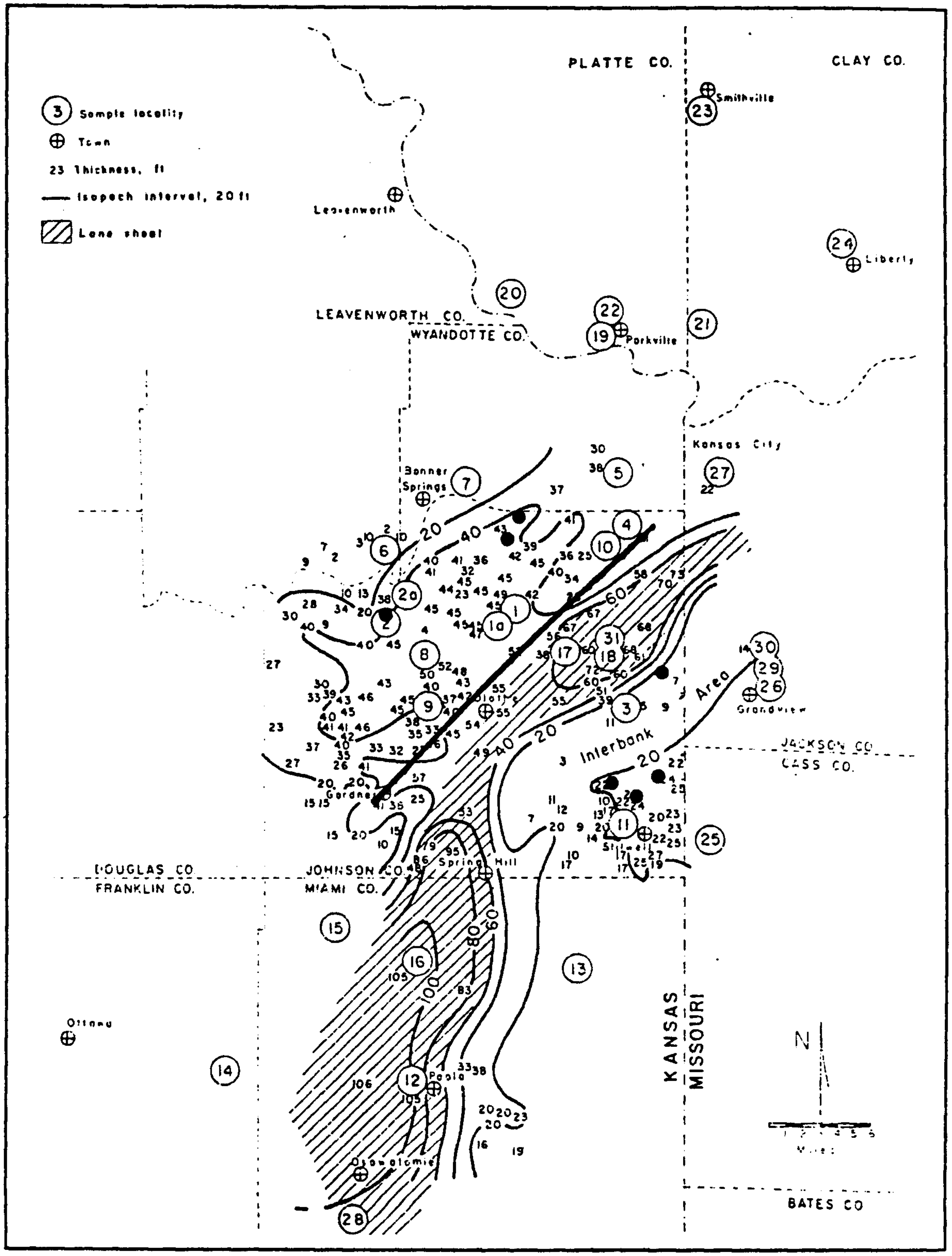

Figure 36. Isopach map of the Lane Shale in Johnson and Miami counties. Northeast trending line is approximate midline between sections that do (in the NW), and those that do not (in the SE) contain a black, fissile Muncie Creek Shale (black dots represent sections examined for this study) (modified from Crowley, 1969, p. 8).

of thick Lane Shale near the middle of Johnson County may represent a northeast trending trough northwest of what may have been a paleotopographic high. Crowley (1969), however, did not believe this area of thick Lane Shale represented a trough, because thickness changes in the underlying Iola Limestone did not seem to reflect the existence of such a trough. One would expect, however, that accommodation space was necessary for a thick unit of Lane Shale to be deposited, as it seems unlikely that this lithology (mudstone) could form a mound or bank of this size.

The two cross sections (figures 31 and 32) illustrate the change of the lower bounding surface of PAC 2 from north to south, changes which appear to be in conjunction with changes in PAC 2. This surface appears to reflect this structural influence. Dawson (1984) documented the omission surface or hardground near the top of the Paola, and noted that it seemed to be best developed beneath the algal mound facies of the overlying Raytown Limestone Member. Recall that the algal mound facies occurs on the Bourbon Arch. Minor paleotopographic variations, as well as the Bourbon Arch, may have had an affect on the characteristics of the transgressive surface at the base of PAC 2.

Figure 37 is a structure contour map on the base of the Kansas City Group in Miami County constructed by Miller (1966) with locations of sections examined for this report indicated. Sections denoted by H are localities where the base of PAC 2 is a well developed, "hummocky" omission surface. These localities seem to be restricted to the flanks of small anticlines. Sections denoted by P, and H + P are localities where the "hummocky" omission surface is absent or less developed. Note that these localities are in the low areas between the small anticlines.

PAC 3 was correlated by tracing its basal transgressive surface relative to (1) the black, fissile, phosphatic shale of the Muncie Creek, (2) the crinoidal

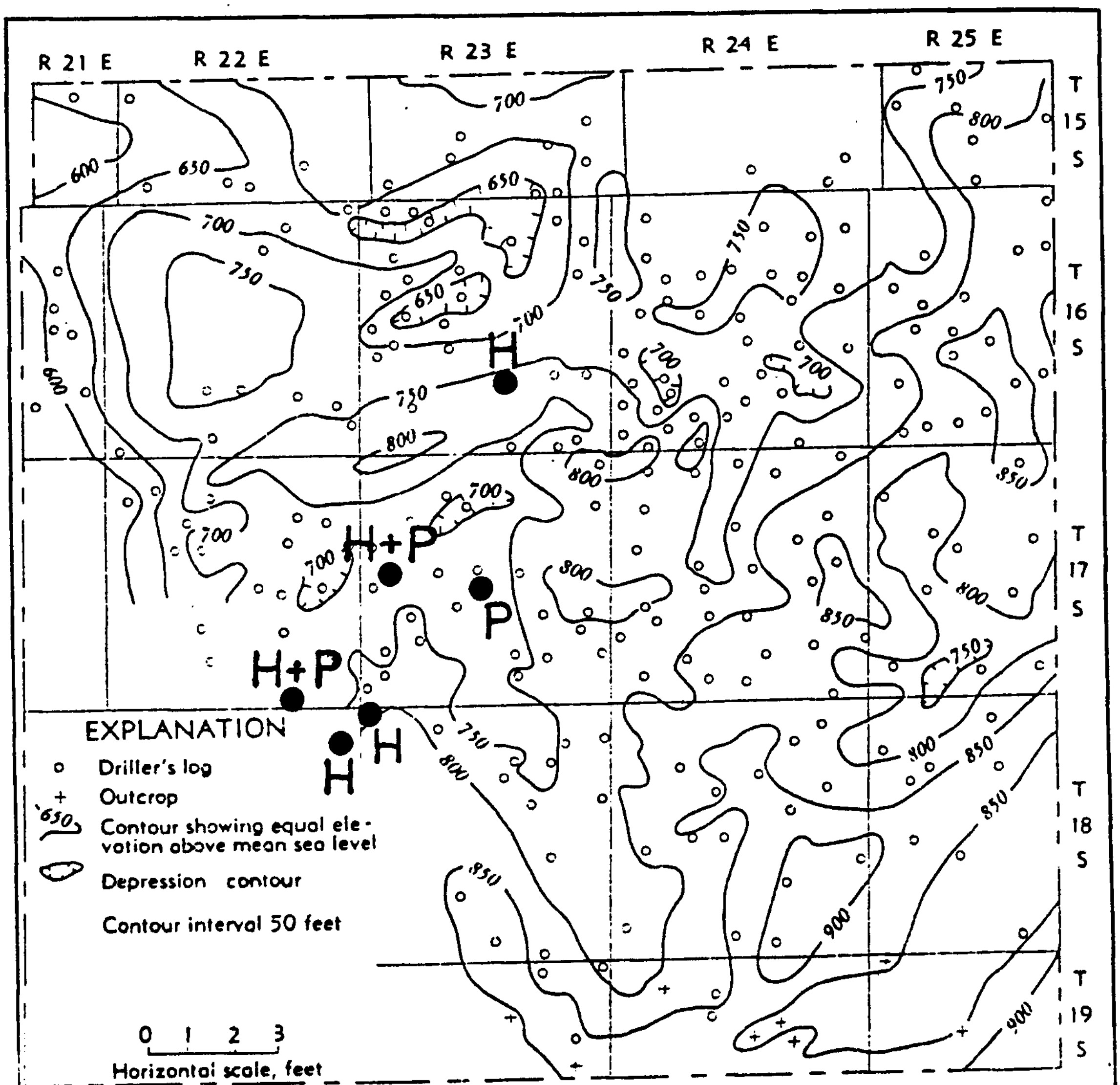

Figure 37. Structure contour on the base of the Kansas City Group in Miami County, Kansas. Black dots are the location of sections studied and H = hardground, P = crinoidal grainstone to packstone, and H + P = the presence of both features (modified from Miller, 1966, p. 8).

packstone (with some difficulty, see discussion for OSA, PAC 2), and (3) the fossiliferous calcareous mudstone that overlies the crinoidal packstone.

Tracing the basal transgressive surface of PAC 3 was difficult because the crinoidal packstone to grainstone marker bed is lenticular. The lenticular character of this unit suggests that minor paleotopographic variations may have influenced deposition (or nondeposition). In figure 37, sections with the crinoidal packstone to grainstone facies, denoted by P, or H + P, occur in a low area between several small anticlinal features. Sections that do not contain the crinoidal packstone to grainstone facies, represented by H, appear to be on the flanks of the small anticlinal features. More sections need to be examined relative to this structural contour map to strengthen the above interpretation.

PAC 3, as seen in figures 31 and 32, increases in thickness from north to south, corresponding to an increase in phylloid algae, and a decrease in bedding thickness in the upper parts of the PAC. This may be indicative of an overall shallowing trend from north to south in PAC 3 as one approaches the Bourbon Arch. However it may, at least in part, be the result of the affects of more local paleotopographic features, such as those seen affecting some of the underlying units, or it may be related to turbidity.

The transgressive surface at the base of PAC 4 was traced relative to the underlying phylloid algal wackestone, and to the overlying productid or brachiopod wackestone ("large fossil bed"). Trends observed in figure 31 include a slight decrease in bed thickness from north to south across the study area, a trend observed to the southeast and southwest away from section K12 in figure 32. Hardie and Ginsburg (1977) suggested that changes in bedding may be related to changes in energy levels. Shallowing or proximity of storm events may have caused an increase in energy levels which could be responsible for the change in bed thickness.

Facies Maps

Facies maps were constructed for the facies interpreted to represent maximum transgression within PACs 1 through 4 of the Iola Limestone (figures 38 through 42).

Maximum transgression during PAC 1 is represented by a phylloid algal wackestone throughout most of the study area (figure 39). In the northwest corner of the study area (section HD), maximum transgression in PAC 1 is represented by a brachiopod wackestone, with only minor amounts of phylloid algae. This part of the study area may have been slightly deeper, or more turbid during the period of maximum transgression of PAC 1.

The period of maximum transgression during PAC 2 consists of a phosphatic, black fissile shale in the northwest part of the field area, which is absent in the southeastern part of the study area (figure 40). In the southeast, maximum transgression in PAC 2 is represented by a thin gray shale (lag?), or only by the basal (transgressive) surface of PAC 2. This may be due to nondeposition, or reduced deposition and erosion as a result of shallowing because of major structural features (Bourbon Arch) and minor paleotopographic features.

Maximum transgression of PAC 3 is reflected by relatively high biotic diversity in a calcareous mudstone facies (figure 41). This facies occurs throughout the study area. The overlying sixth order T-R unit, PAC 4, is characterized by a Neospirifer-productid wackestone facies throughout most of the study area (figure 42), except in the southeast corner, where there is a slightly less diverse, Echinaria-bryozoan facies. This too may indicate gradual shallowing as one approaches the Bourbon Arch, or it may be due to the influence of a local, minor paleotopographic variations (figure 37).

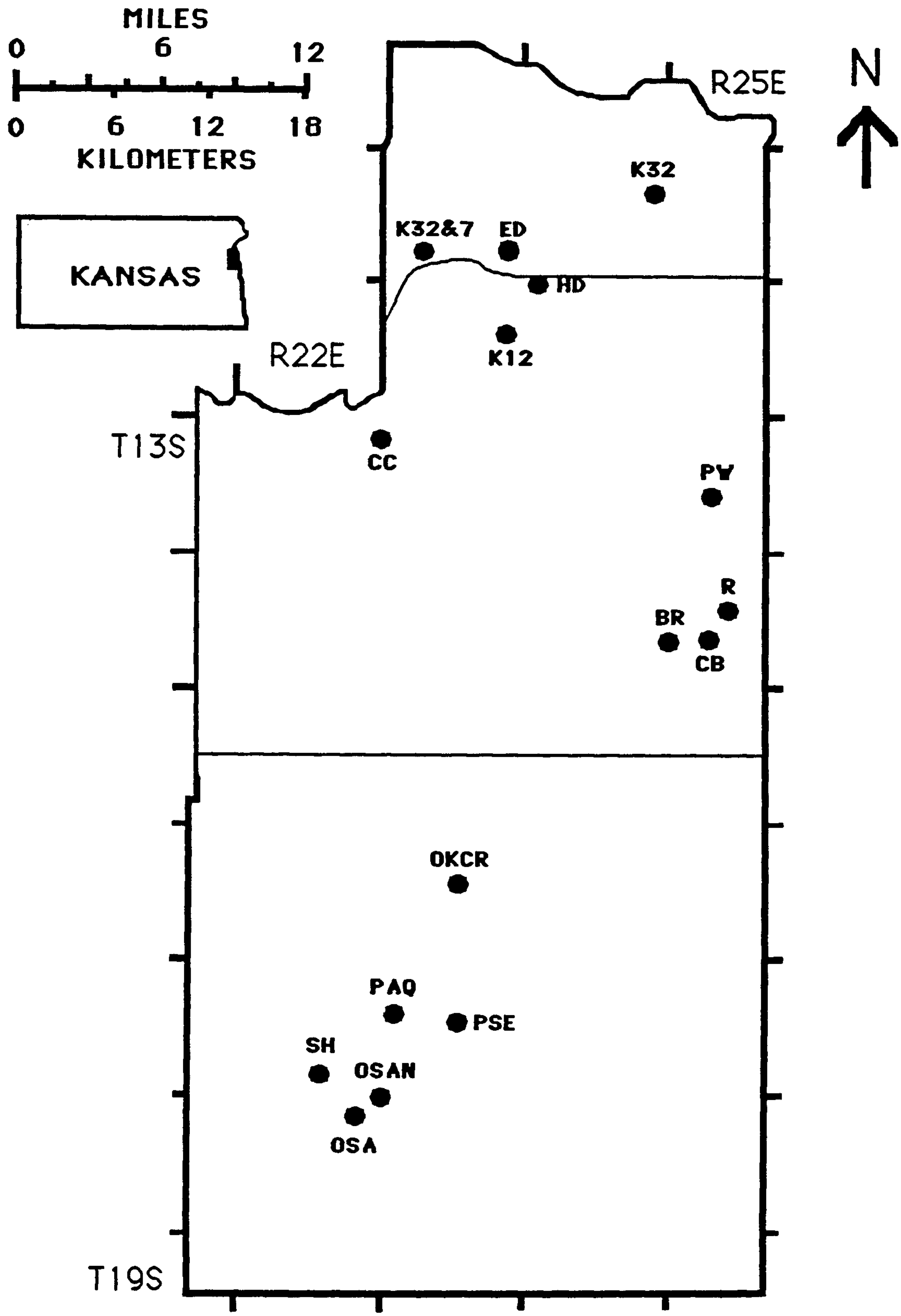

Figure 38. Base map showing locations of measured sections.

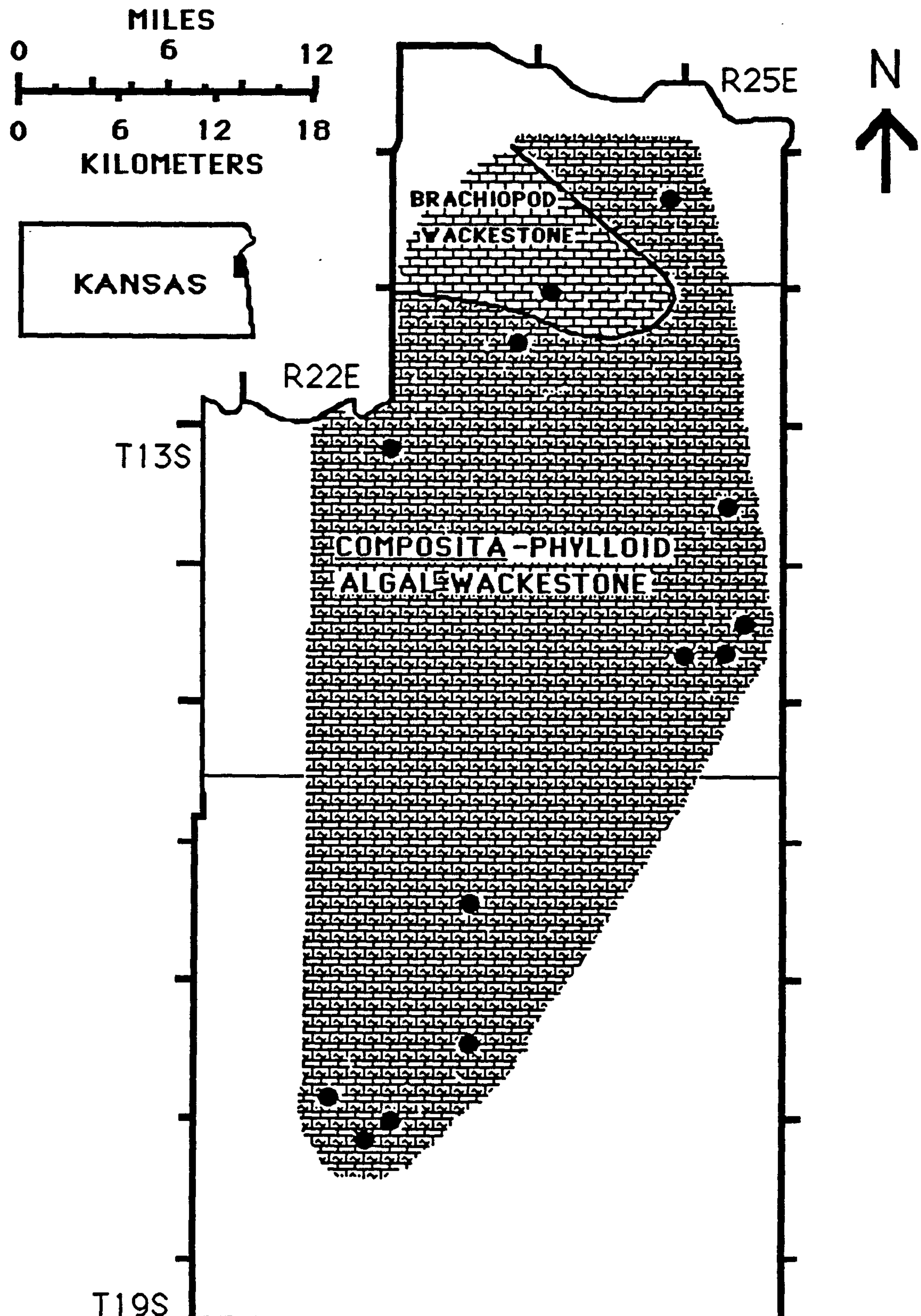

Figure 39. Facies map of PAC 1 during maximum transgression.

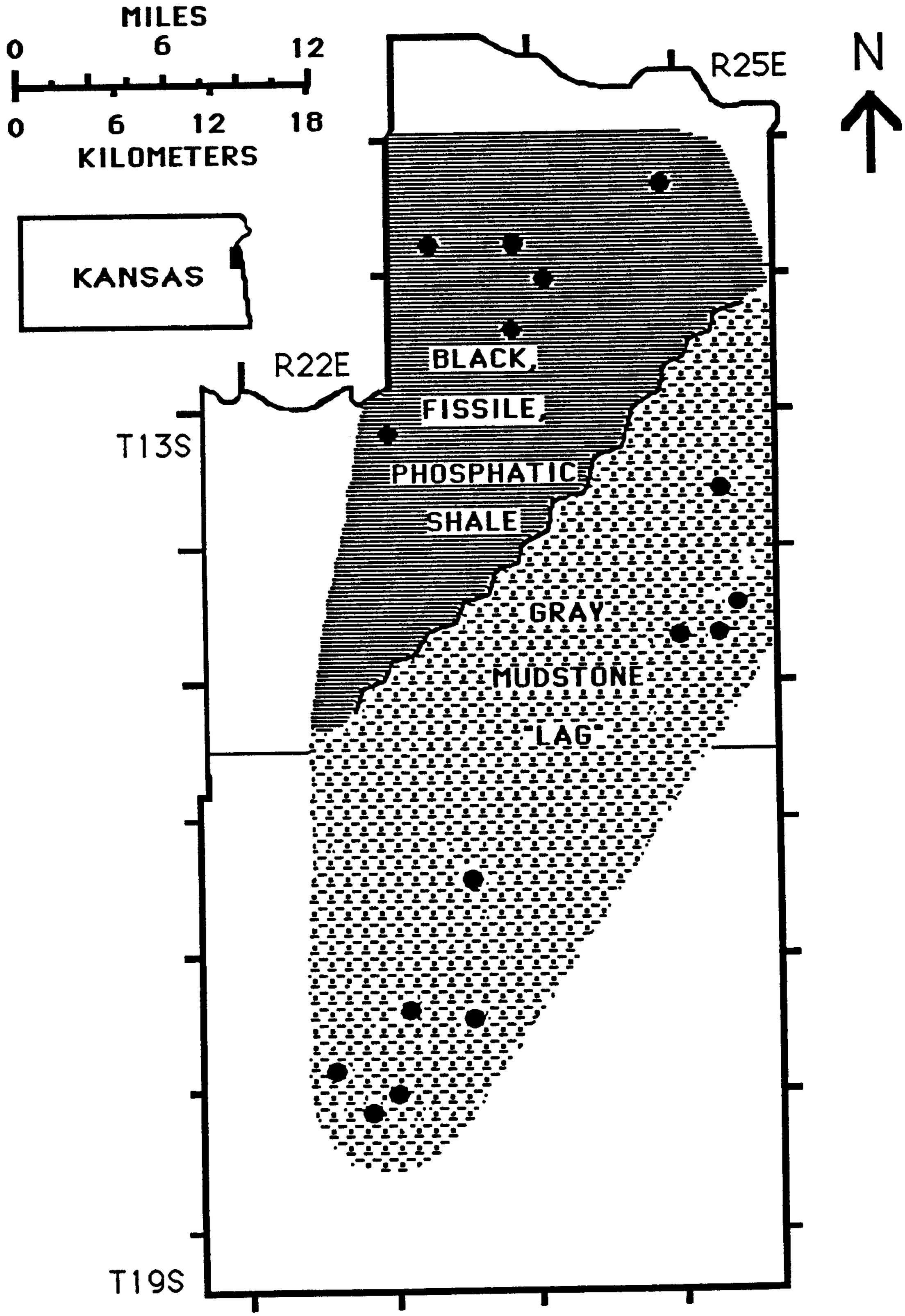

Figure 40. Facies map of PAC 2 during the maximum transgressive phase.

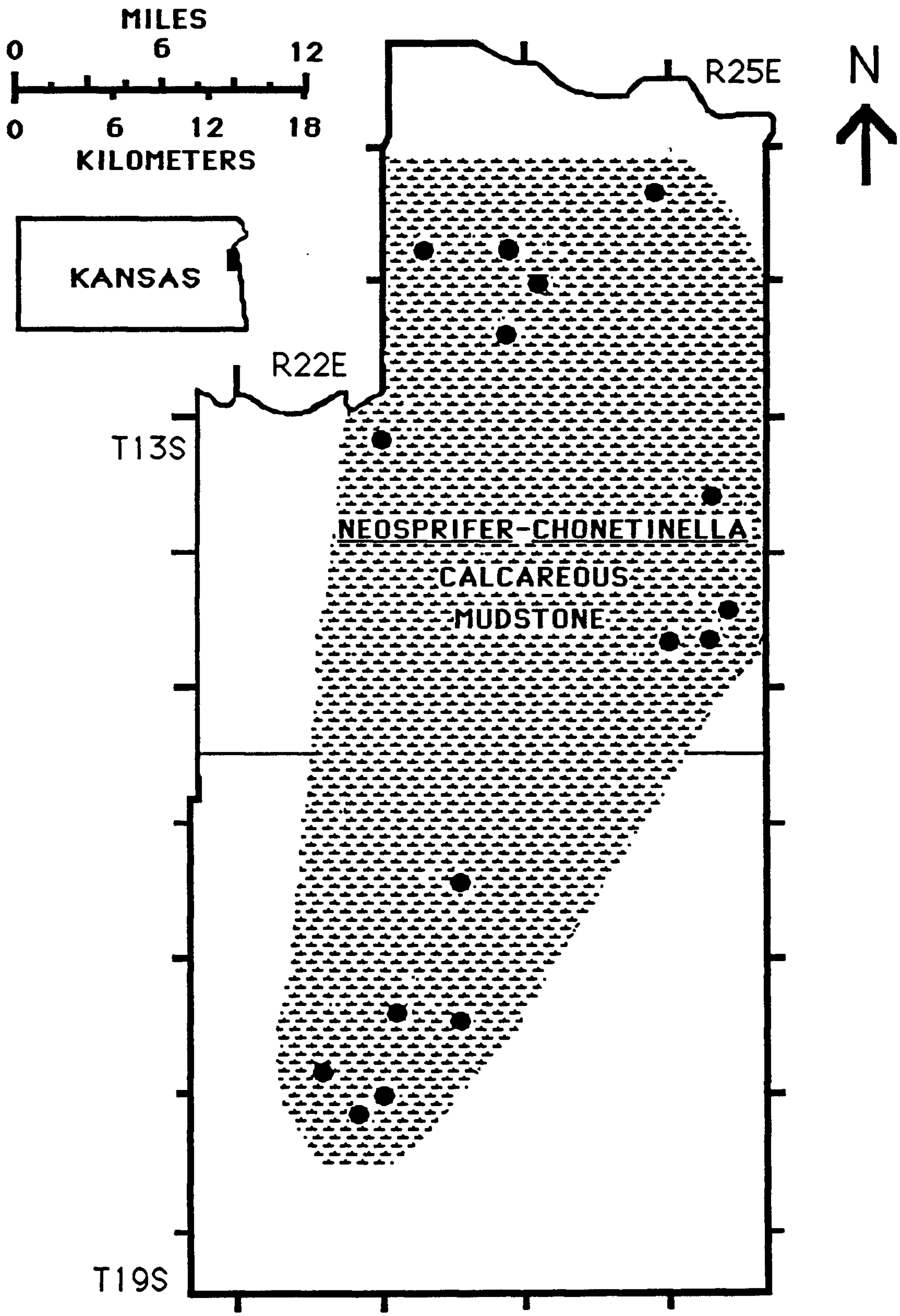

Figure 41. Facies map of PAC 3 during maximum transgression.

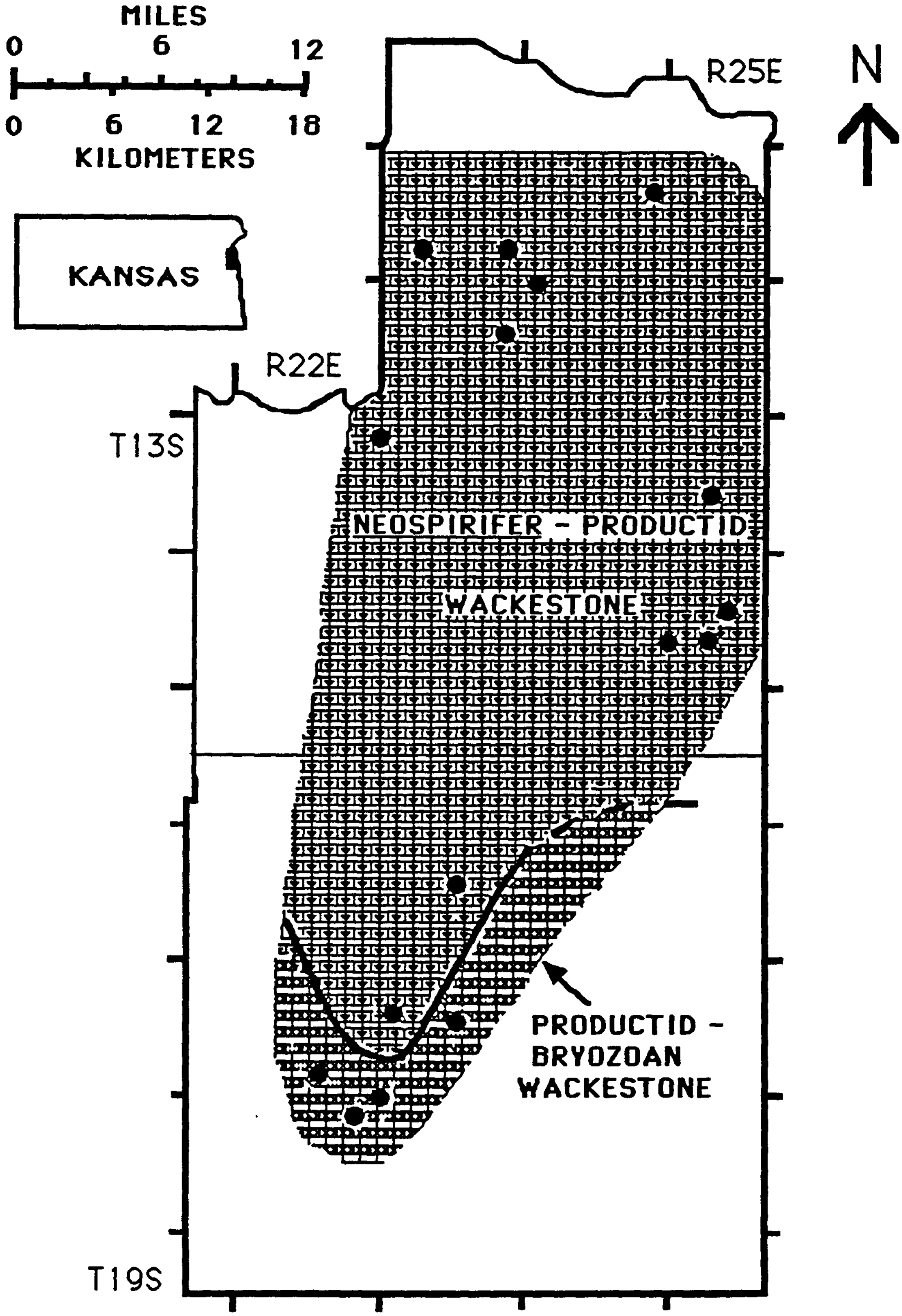

Figure 42. Facies map of PAC 4 during maximum transgression.

CONODONT DISTRIBUTION PATTERNS

Introduction

The term conodont is the name given to a tooth-like microfossil that is composed of carbonate apatite (essentially the mineral francolite), ranges in size from 0.1 to 1.0 mm, and that is found nearly worldwide in most marine rocks that range in age from Cambrian to the Triassic.

The first conodont elements were described by C. H. Pander in 1856, but the remains of what probably represents the conodont animal were not found and described until 1983 (Briggs **et al.**). The conodont animal, which has been tentatively classified as a jawless craniate (Aldridge et al. 1986), an organism similar to the present day hag fish (Mixine). It was elongate, 40.5 mm long and approximately 1.90 mm wide, and was presumably a swimmer (based on the shape and presence of fins). Conodont elements themselves presumably functioned as teeth, the rationale behind this being they look like teeth, so they must have functioned as teeth (Briggs **et al.** 1983). Nicoll (1987) conducted a detailed study of a specific element (Pa) and concluded that different element types may serve different functions. Four fossils of the conodont animal were recovered by 1985 from the Lower Carboniferous of Scotland (Aldridge et al. 1986), 5 more as of 1987 (Aldridge et. al., 1988), and in the last three years a great deal has been learned about the possible affinities of these organisms, but very little is yet known about the paleobiology and paleoecology of this fossil group.

Conodonts almost always occur as individual elements, which resulted in the practice of form taxonomy. Each individual element was examined as if it were representative of an entire organism, and was often delineated from other form taxa on the basis of very subtle micromorphologic features.

On rare occasions, conodont elements were found in close proximity, and with apparent symmetry and relationship to one another on the bedding planes of black fissile shales, in coprolites, and as fused clusters. It soon became apparent that individual conodont elements were parts of an apparatus of some type within the conodont animal. Assemblages found on bedding planes, in coprolites, or fused together are known as natural assemblages. Within the last two decades, conodont workers have developed taxonomies based on natural assemblages. Bedding plane assemblages and fused clusters are relatively uncommon, and most conodont apparatuses are reconstructed using statistical parameters.

Conodont apparatuses are classified on the number of different types of elements they contain (Sweet, 1981). The two basic categories of elements are unimembrate (an apparatus with one type of element) and multimembrate (an apparatus with more than one type of element). Multimembrate apparatuses can be further subdivided based on the number of element types. Many important Pennsylvanian conodont genera are sexi- or septimembrate apparatuses (figure 43). This type of apparatus consists of six or seven different types of elements grouped around a plane of bilateral symmetry. P elements (often the name given platforms in the apparatus) are generally pectiniform or specialized ramiform elements in the posterior part of the apparatus. M elements are thought to be transitional between P's and S's, and are generally arched dolobrate or bipennate elements. S elements consist of three to four element types which form a symmetry transition series from alate, to bipennate or digyrate, and finally to bipennate or dolobrate (for an explanation of shape categories, see Sweet, 1981).

Conodont elements, because of their composition, are very durable, and remain identifiable even after the lithologies in which they are found have been dolomitized or subjected to relatively high degrees of metamorphism. This

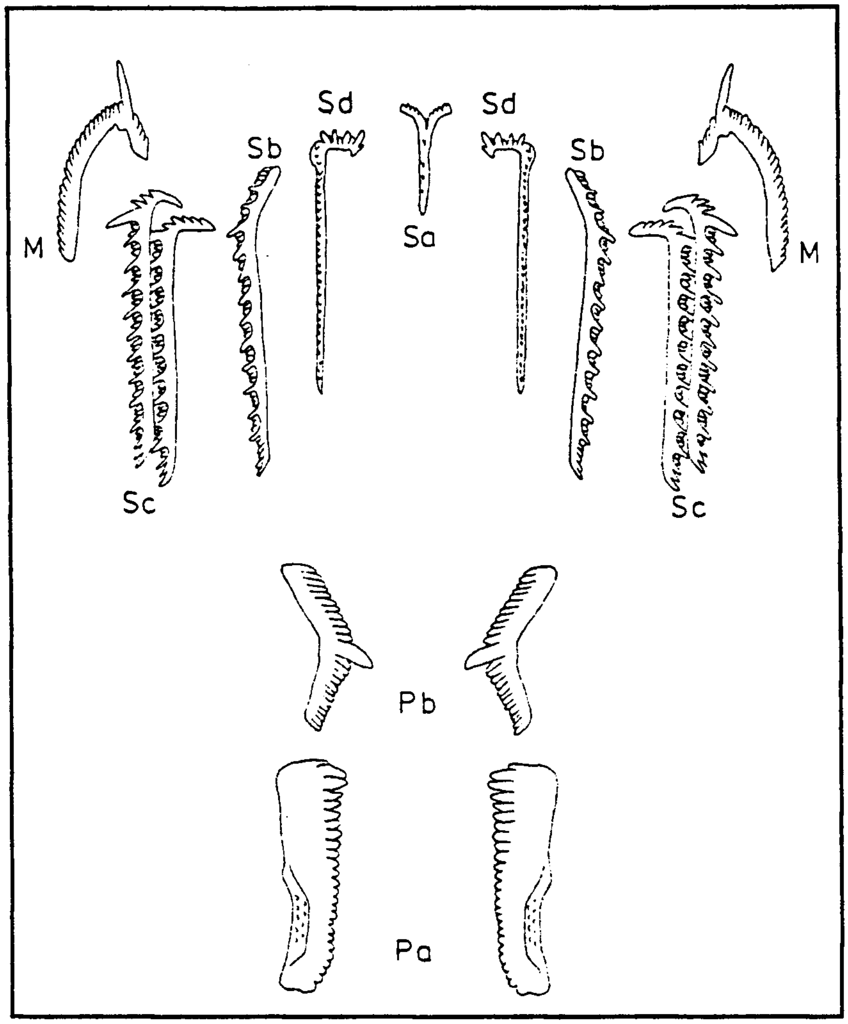

Figure 43. Diagramatic illustration of multielement composition of a Carboniferous polygnathacean apparatus (from Aldridge , 1987 , p. 17).

durability is also responsible for the relative ease of extraction of conodonts from most lithologies. Considering the widespread geographic distribution of conodonts, their apparent rapid evolution, and the supposed relative lack of environmental control on conodont distribution, it is apparent why these fossils have been one of the most useful groups for Paleozoic biostratigraphy.

To establish a biostratigraphic scheme for conodonts that would have a high degree of accuracy in terms of zonal duration and usefulness for correlation, we need to know more about the paleobiology and paleoecology of the conodont animal (Hoffman, 1986).

Previous Investigations

Early investigations of Pennsylvanian conodonts in the midcontinent were primarily descriptive, and generally involved very detailed and meticulous form taxonomic practices. Some of these early investigators include Stauffer and Plummer (1932), and Gunnell (1933). In 1941, Ellison refined and revised the work of the early investigators, and his paper remained the "standard" for Pennsylvanian conodont studies for over three decades.

Baesemann (1973) examined the conodont distribution patterns within the Lansing and Kansas City Groups in the midcontinent, applying apparatus taxonomy. Data from this investigation was used in the Heckel and Baesemann (1975) study that examined conodont distribution patterns relative to the cyclothem model. Results from this study include: highest abundance and diversity of conodonts within the "core shale" of the cyclothem, lowest conodont diversity and abundance in the "outside shale", and increasing diversity and abundance of conodonts towards the "core shale", but decreasing abundance and diversity away from this facies in both middle and upper limestones (figure 44). Heckel and

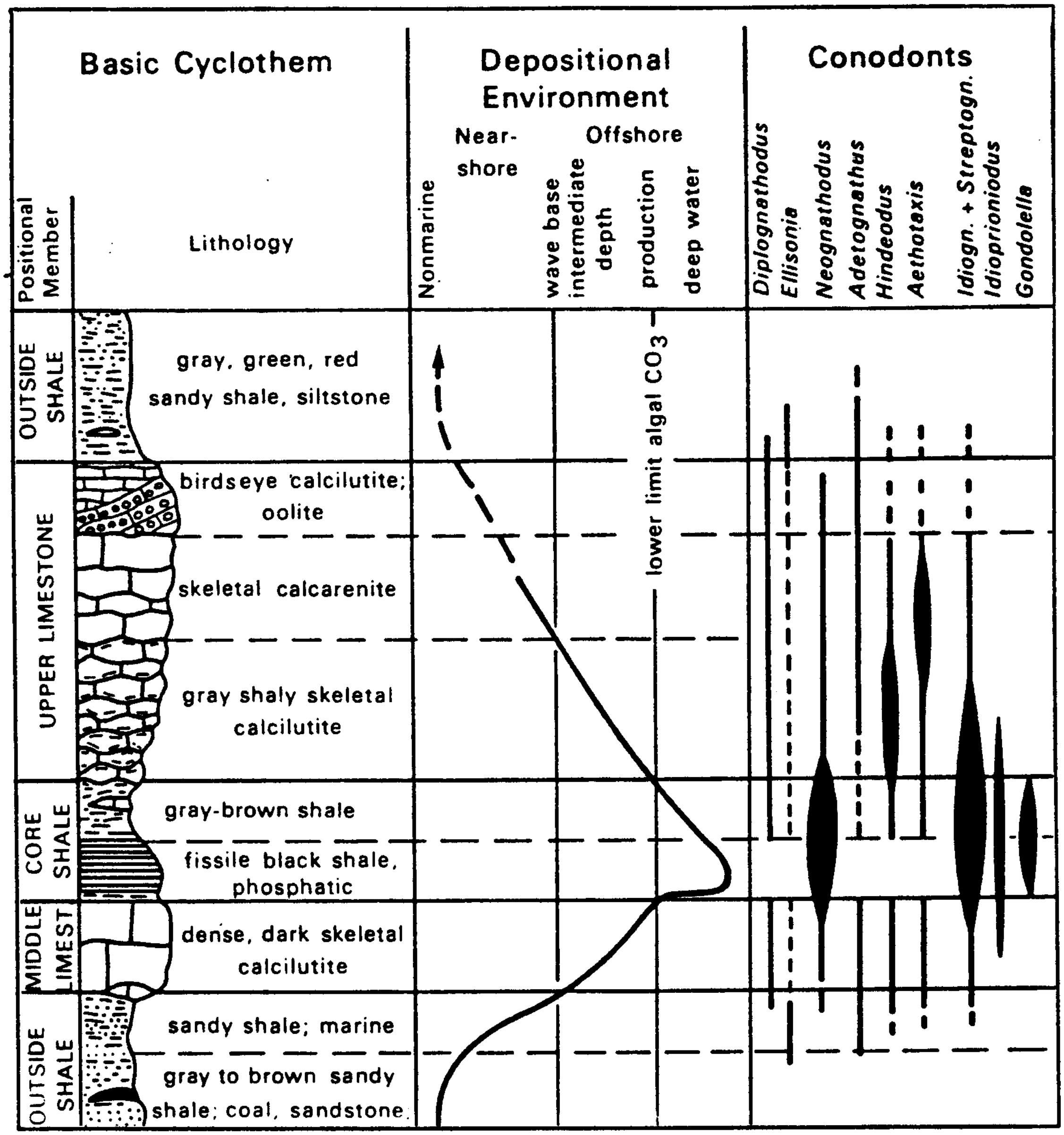

Figure 44. Distribution of conodont genera in a Kansas cyclothem (from Sweet, 1988, p. 162, as modified from Heckel, 1977).

Baesemann (1975) also established conodont biofacies based on the Seddon and Sweet (1971) mode-of-life model. They concluded that certain conodont species or genera were pelagic, and segregated into zones relative to depth (see figure 45). Adetognathus an inhabitant of surface waters was the dominant conodont in nearshore deposits and Gondolella an inhabitant of the deepest waters, was only found in deep-water deposits. Later studies, Wood (1977) and Mitchell (1981), generally agreed with the findings of Heckel and Baesemann (1975), although Swade (1985) concluded that certain genera may have been nektobenthic (e.g. Aethotaxis and Anchignathodus), while others were probably pelagic (e.g. Gondolella, Idioprioniodus, and Idiognathodus) (figure 45).

The relative lack of information on the life-habits of the conodont animal is illustrated by the recent debate on the proposed mode-of-life for the conodont animal. Seddon and Sweet (1971) have proposed a mode-of-life model in which the conodont animal is seen as being pelagic with different species or types segregated bathymetrically (figure 45). This model implies that there would be very little substrate control on the distribution of the conodont animal, and that the abundance and diversity of elements would be greatest in sediments deposited in deep marine environments simply because these environments would be receiving elements derived from a number of stacked depth zones.

The Seddon and Sweet (1971) model differs greatly from the Barnes and Fahraeus (1975) mode-of-life model in which the conodont animal is proposed to have been a nektobenthic organism. In this model, the conodont animal was segregated laterally, and it implies that there was a great deal of substrate control on the distribution of both the conodont animal and its elements. Both models were based primarily on conodont distributional data, and the validity of both studies has been questioned by Klapper and Barrick (1978). Klapper and Barrick, by using distributional data from modern marine organisms, determined that it was

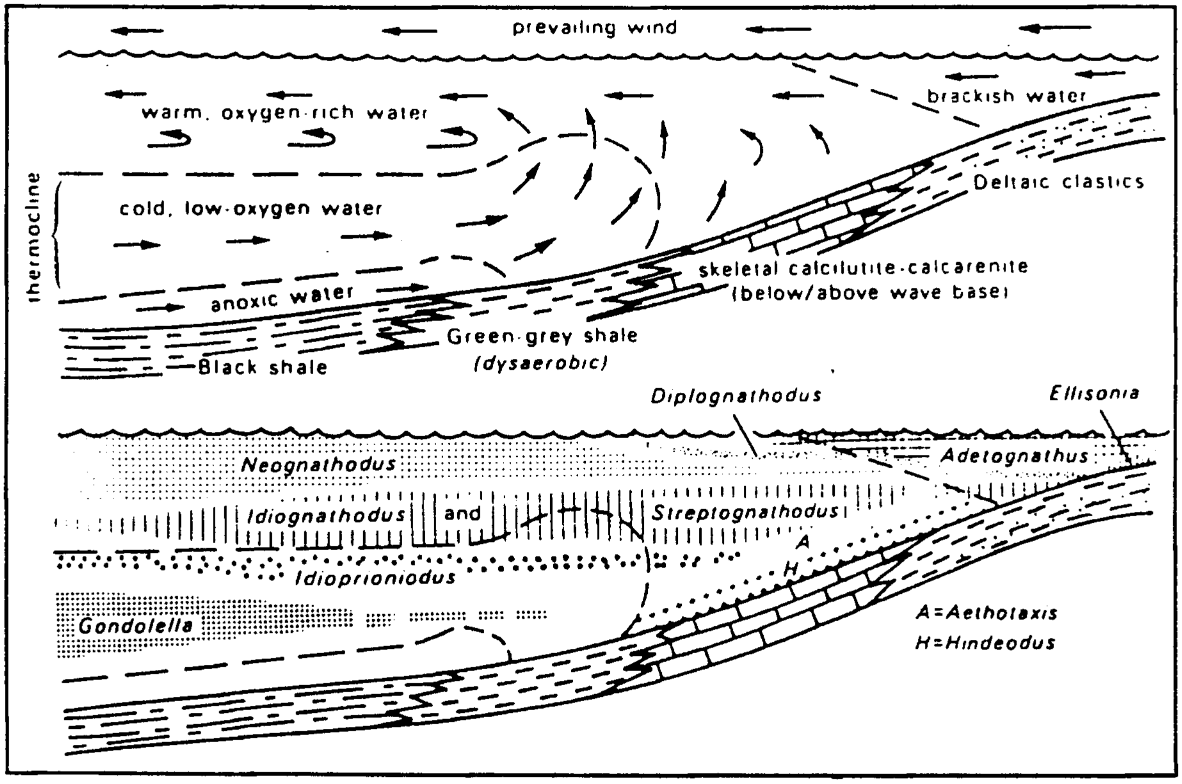

Figure 45. Illustration of the "quasi-estuarine circulation cell" and the Seddon and Sweet, 1971, mode-of-life model for conodonts (from Swade, 1985, p. 50).

nearly impossible to create a mode-of-life model from distributional data alone.

The actual mode-of-life for the conodont animal may remain a mystery, but based on a number of recent studies that deal with the possibility that many conodonts may have distributions restricted by environment (Davis and Webster, 1985, Driese, Carr and Clark, 1984, Grayson, Merrill, and Miller, 1987, Grayson, Merrill, and Turner, 1989, and Merrill, 1989) it seems that (at least in the Pennsylvanian) conodonts were environmentally sensitive even at the generic level (Driese, Carr, and Clark, 1984). The possibility of environmental control on the distribution of conodonts has important implications for the presently accepted conodont biostratigraphy.

The current thrust of Pennsylvanian conodont studies involves conodont biostratigraphy as a method for inter- and intrabasinal correlation of the "core shale" (Boardman and Heckel, 1988; and Heckel, 1989). This method of conodont biostratigraphy assumes that each core shale has its own characteristic conodont assemblage (Boardman and Heckel, 1988; and Barrick, 1989).

Methods of Investigation

Two of the sections examined in this study, HD and OSA, and one partial section HDMC, were spot sampled for conodonts. HDMC is a section of the Muncie Creek Shale Member situated approximately 100 m. to the west of HD, and chosen because samples of the Muncie Creek were easier to collect at this locality than at HD. Samples were taken at intervals not greater than 60 cm., and often as small as 8 cm., relative to the small scale genetic units recognized in the Iola Limestone earlier in this report. Fifty-nine samples were collected, each averaging 2 Kg. per sample.

Limestone samples were dissolved in 10% glacial acetic acid following the methods described by Collinson (1963). These insoluble residues were wet-sieved using nested 18, 60, 120, and 230 mesh sieves, and allowed to air dry. Shale and mudstone samples were first oven-dried, then disaggregated in Quaternary "O" following the methods of Zingula (1968). Residues from the mudstone and shale samples were then wet-sieved in nested 18, 60, 140, and 200 mesh sieves, and then oven-dried. Many large residues were reduced using a Frantz Isodynamic Magnetic Separator following the methods described by Dow (1960). Very large residues were further reduced by splitting with a standard sample splitter.

All samples were then picked for conodonts and all other biotic components. A total of 12,319 individual conodont elements were picked and (when possible) identified to genus. Descriptions and illustrations used for this task are from, Robinson, ed.,1981; Baesemann, 1973; Clark and Mosher, 1966; Ellison, 1941; Gunnell, 1933; Merrill, 1975; Merrill and Merrill, 1974; Stauffer and Plummer, 1932; and Rhodes, 1952.

Information recorded for each element included; genus, element type and shape, and condition of the element. Generic abundances in each residue are given as, percent Pa's for those having a pectiniform element in this position, and percent of the most common element in those genera that have ramiform Pa elements or no Pa elements. Total conodont abundance in each residue is recorded as elements per kilogram. Conditions of elements is noted as "percent broken" for residues from limestone samples. Percentages of element types (P's versus M's plus S's) were recorded because McGoff and Briggs (1988) suggested that these elements will behave differently relative to transportation and deposition.

Data were processed using the spreadsheet program Quattro, version 1.0, a product of Borland Corporation (see Appendix 3).

Holliday Drive (HD) - PAC 1

Four samples (in ascending order: C1, C2, P1, and P3) were collected from PAC 1 at the Holliday Drive section. C1 and C2 are from the silty mudstone in the Chanute Shale, and P1 and P2 are from the Paola Limestone Member (figure 46). Conodont abundance (elements per kilogram) is highest in C2 (>800), an abrupt increase from sample C1. Abundance then decreases abruptly in P1 and P3 (figure 47).

The diversity of conodonts in PAC 1 (number of genera per sample) increases from one in C1 (Adetognathus), to seven in P1, and then decreases to four genera in P3 near the top of the Paola (figure 47). Conodont genera in the most diverse sample , P1, include (from highest percentage to least): Streptognathodus (S., identified following the Treatise description, distinguished from Idiognathodus by the presence of a median trough on the upper side of the platform), Hindeodus (Hind., equals Anchignathodus of others), Adetognathus (A., equals Cavusgnathus of others), Aethotaxis (Aeth.), Idioprioniodus (Idioprio.), Idiognathodus (Id.), and possibly Ellisonia (Ellis.) (figure 48).

The most common genus near the base of PAC 1 is Adetognathus. It is the only conodont present in C1 (figure 48), and it becomes less common upward in PAC 1. Adetognathus comprises less than 20% of the elements in C2, and less than 2% of the elements in P1. Streptognathodus is the most common conodont in the upper part of PAC 1, comprising more than 34% of all elements in P1, and decreasing to slightly less than 16% in P3.

The percentage of P elements versus M plus S elements were recorded for all samples examined because of possible sedimentologic implications which will be discussed later. P elements are the dominant element type in the lower three samples of PAC 1 (figure 49), making up 100% of C1, nearly 50% of C2 (the rest

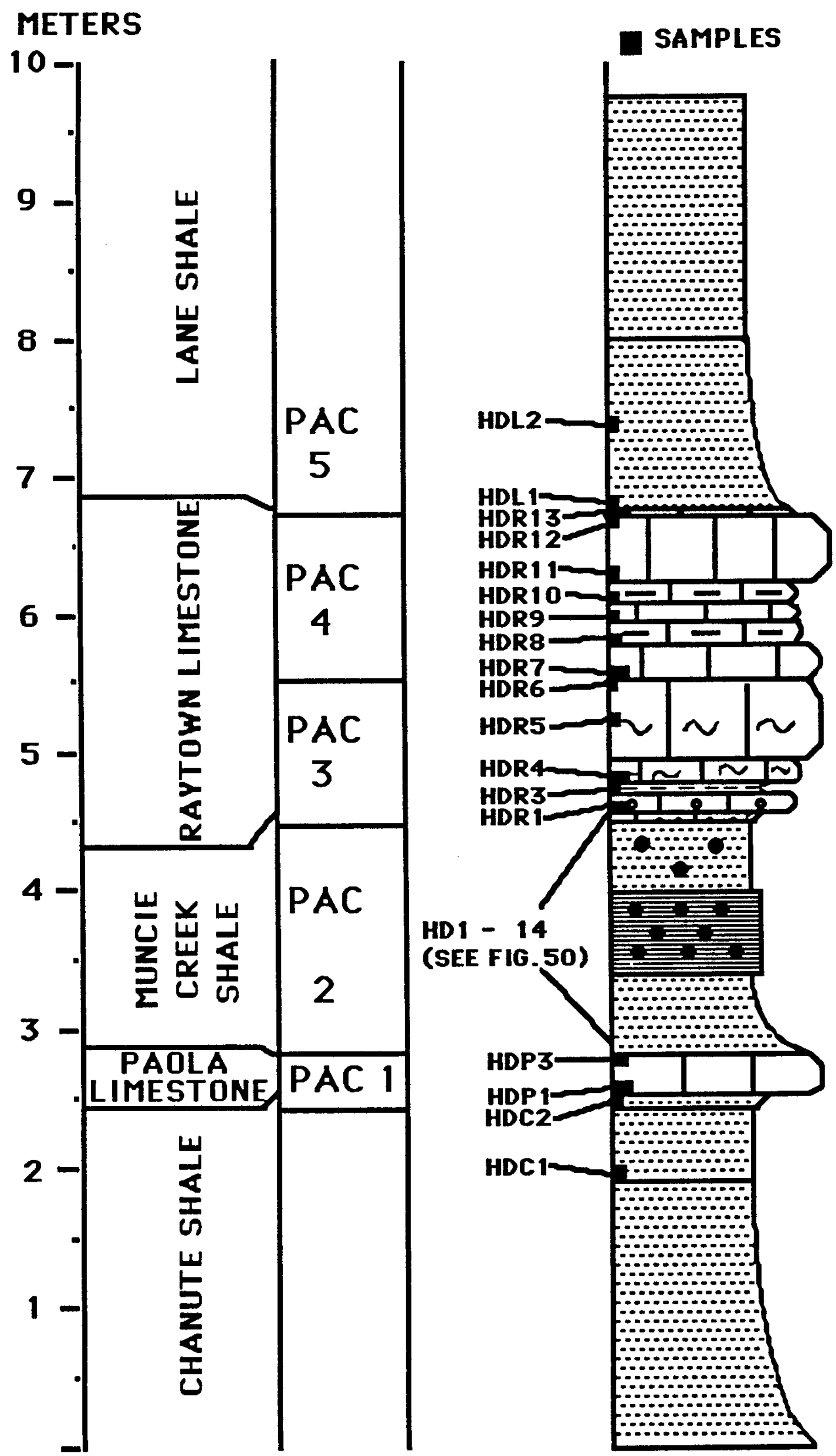

Figure 46. Conodont samples collected at section HD.

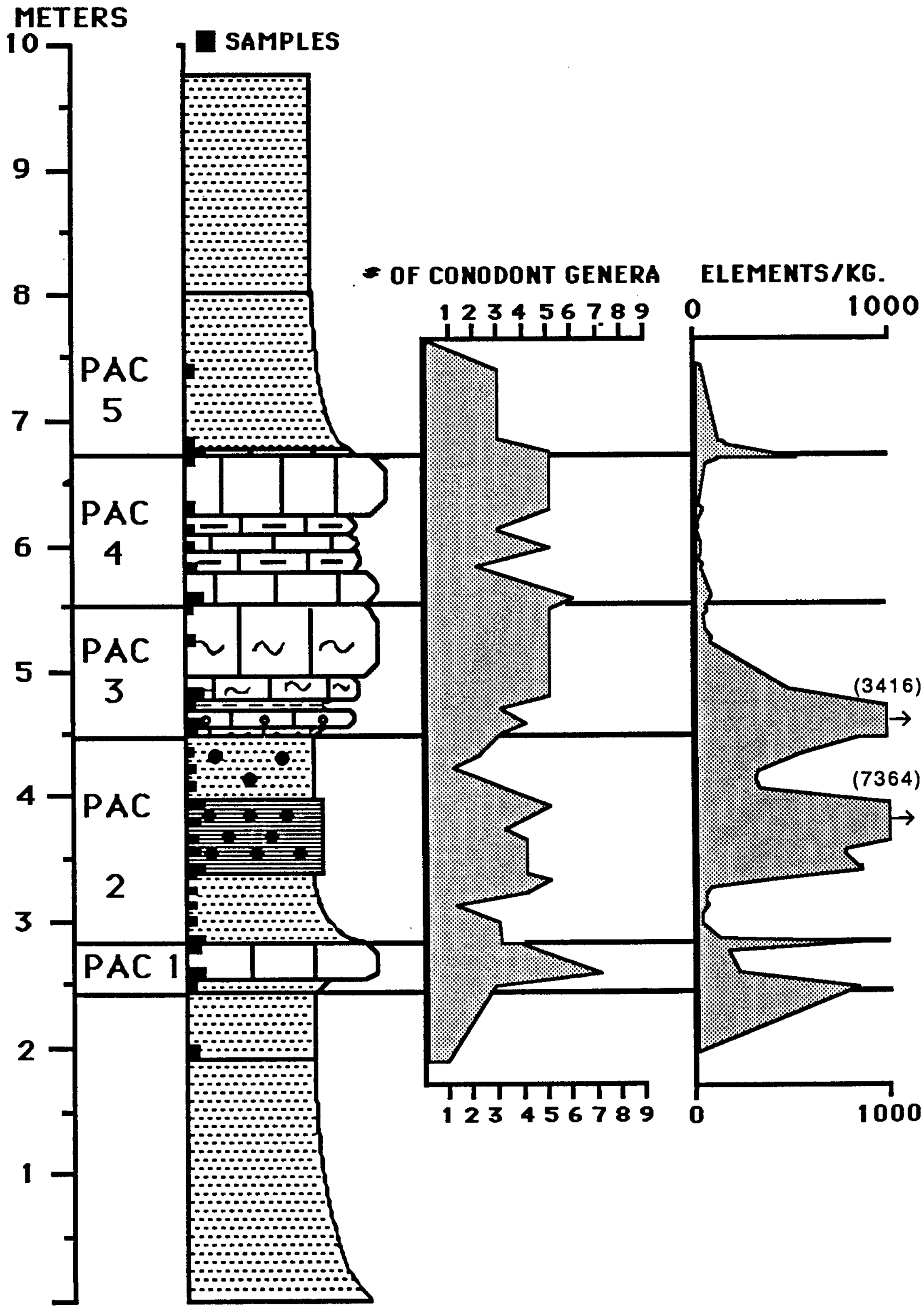

Figure 47. Diversity and abundance of conodonts in samples from section HD.

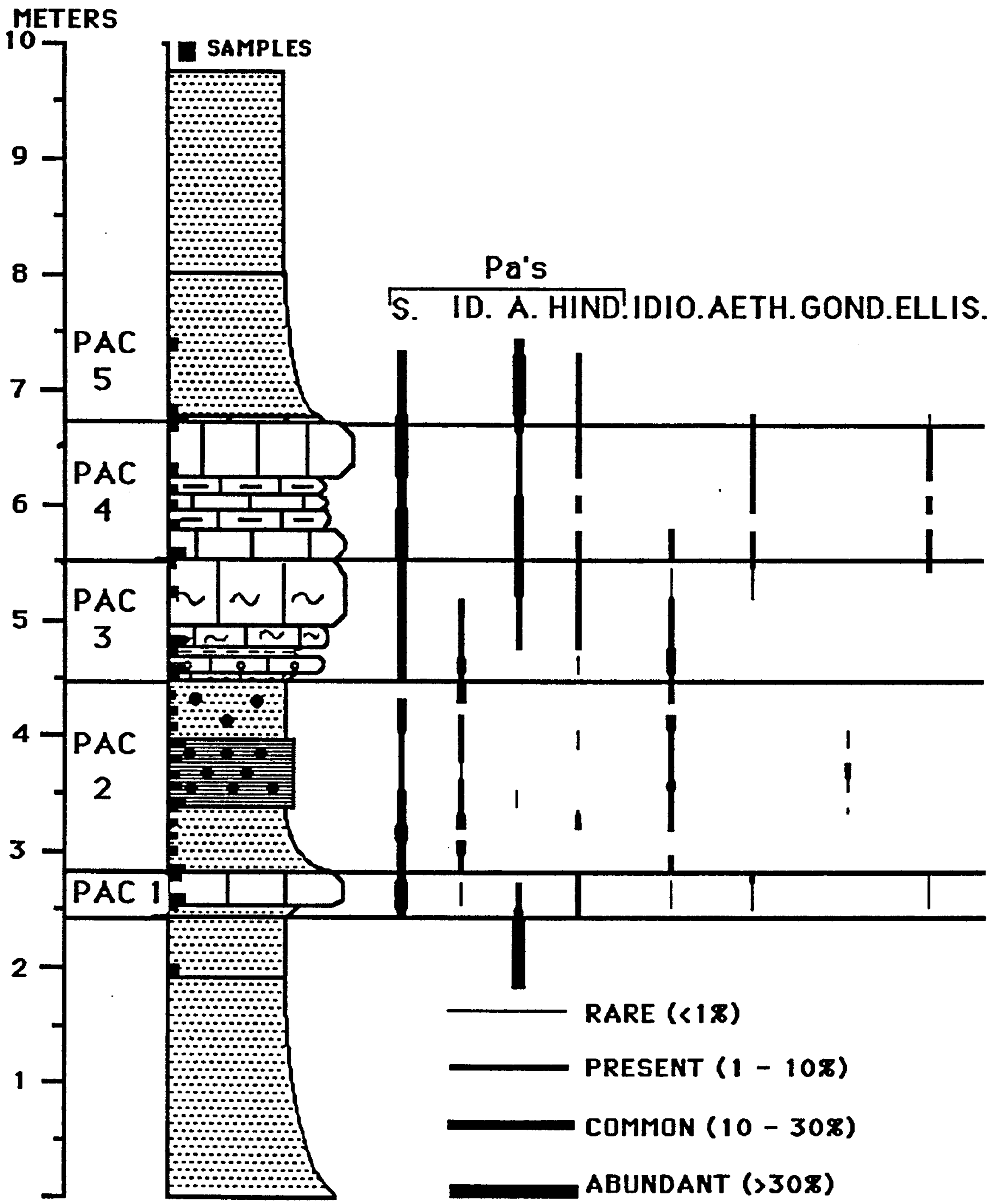

Figure 48. The range of conodont genera at section HD. S = Streptognathodus, Id. = Idiognathodus, A = Adetognathus, Hind. = Hindeodus, Idio. = Idioprioniodus, Aeth. = Aethotaxis, Gond. = Gondolella, and Ellis. = Ellisonia.

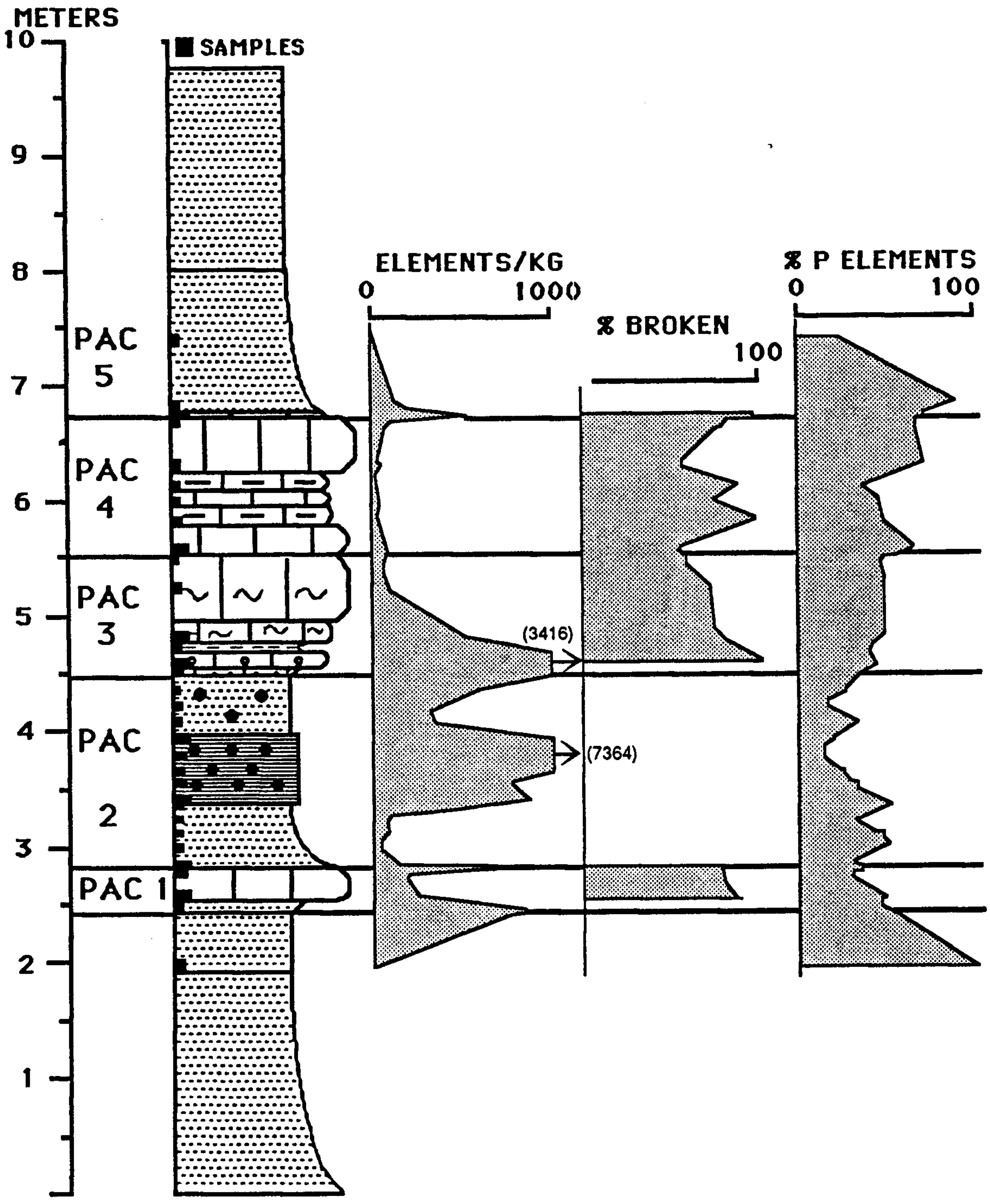

Figure 49. Relative abundance and taphonomic characteristics of conodont elements at section HD. (NOTE: → = off scale)

of the elements were indeterminant), and 50% of P1. M plus S elements only occur in the upper two samples of PAC 1, and in percentages greater than P elements only in P3, where 55% of the elements are M plus S.

Holliday Drive (HDMC) - PAC 2

Fourteen samples were collected from the interval representing PAC 2 (Muncie Creek), from HDP4 at the base, to HD2 at the top (figure 50). Overall conodont abundance (elements per kilogram) shows considerable range within PAC 2 (figure 47). At the base of PAC 2, HDP4 contains nearly 1000 elements per kilogram, an increase over sample P3 in the top of PAC 1 which contains less than 200 elements per kilogram. Overall abundance of conodont elements then drops dramatically in samples HD14 through HD11. Abundance again increases abruptly to nearly 500 elements per kilogram in HD10. From HD10, abundance increases to around 800 in HD9, decreases slightly to less than 750 in HD8, then increases abruptly to 4000 elements per kilogram in HD7. Abundance of conodonts reaches its maximum in PAC 2 (HD6) at 7000 elements per kilogram (off the scale in figure 47). Abundance decreases to 4500 in HD5, and continues to drop to 500 or less in HD4, HD3, and HD2.

Generic diversity in PAC 2 also displays a considerable range (figure 47). In HDP4, at the base of PAC 2, three genera are present, which is one less than in P3, but the genera are different (figure 48). The number of genera decreases from three in HDP4 to one in sample HD12. In HD11 and HD10 diversity increase to four, reaches five in HD9, and ranges between three and four in HD8 through HD6. Diversity in HD5 again increases to five. Where diversity is highest (e.g. HD5 and HD9), conodonts include (from most common to least), Streptognathodus, Idioprioniodus, Idiognathodus, Gondolella, and Hindeodus.

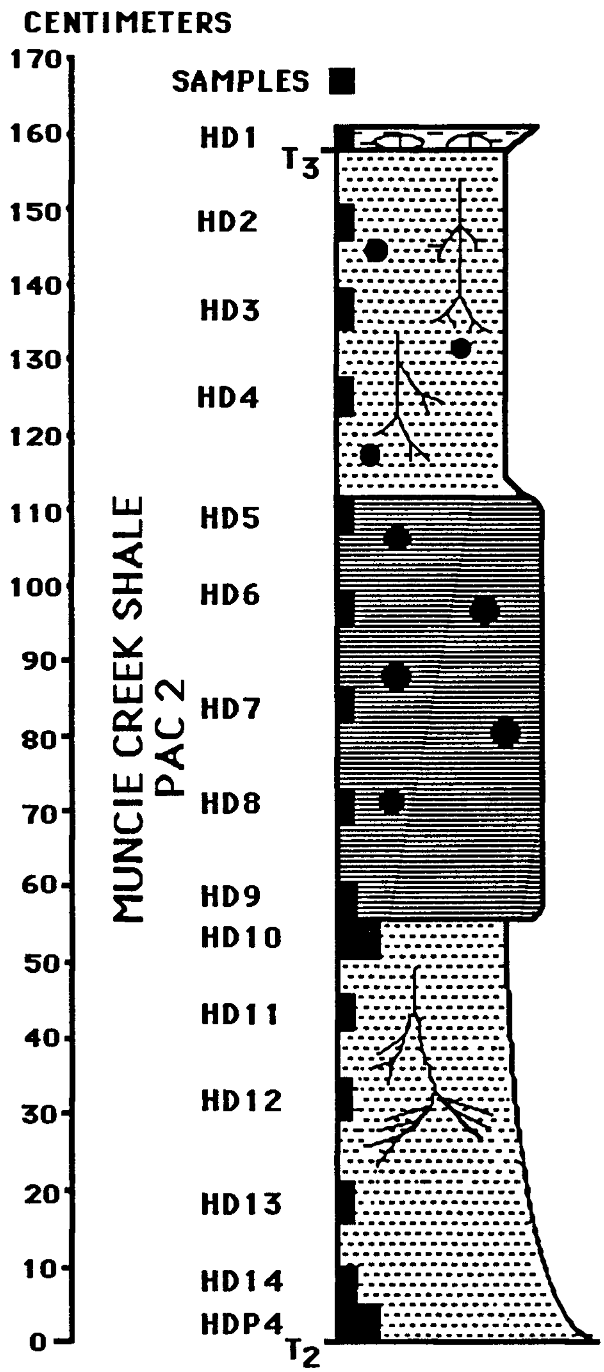

Figure 50. Conodont samples collected from the Muncie Creek Shale Member at section HDMC.

Streptognathodus is generally the most common element in PAC 2 (figure 48), except in HD11 and HD13, where Streptognathodus occurs in equal proportions to Idiognathodus. In HD2 and HD6, however, Idiognathodus and Idioprioniodus are the most common element, respectively. Gondolella, which was absent in samples from PAC 1, is present in four samples in PAC 2. Gondolella is approximately 0.5% of the elements in HD5 and HD10, slightly less than 0.5% in HD8, and 8.5% in HD7.

Comparison of percentages of P elements, versus M plus S elements indicate that the later generally occur in greater quantities than the former (figure 49). In some residues the quantities are very much greater, as in HD3 where more than 80% are M plus S, and less than 15% are P elements. Four samples in PAC 2 (HD9, HD10, HD12, and HD13) contain more P elements than M plus S elements (figure 49). P elements in these samples make up at least 50% of the conodont elements, and M plus S are generally less than 10%, with the remaining 40% being indeterminate elements (elements that have been broken to the point that it is impossible to determine their apparatus position).

Holliday Drive (HD) - PAC 3

Six samples were collected from PAC 3 (figure 46) including: the uppermost part of the Muncie Creek (HD1), and three facies from the Raytown, the crinoidal packstone to grainstone (R1), fossiliferous calcareous mudstone (R3), and phylloid algal wackestone (R4 through R6). Abundance of conodont elements in PAC 3 begins with an abrupt increase from the uppermost sample in the underlying PAC, HD2 (figure 47). This is an order of magnitude increase from 500+ elements in HD2 (PAC 2) to 5000+ elements in HD1 (PAC 3). Overall conodont abundance drops sharply above HD1 in PAC 3 (see figure 47) to just over 500 in R1 and R3, to below 500 in R4, and again drops sharply to just under 100 in R5, and finally only 50+ in R6.

Conodont diversity in PAC 3 ranges from three genera in two of the three lower samples, HD1 and R3, to four in R1, and increases to five genera in the upper three samples, R4, R5, and R6 (figure 47). The three lower samples (HD1 through R3) all contain Streptognathodus, Idiognathodus, and Idioprioniodus. Sample R4 contains the same genera as the lower samples, plus Adetognathus and Hindeodus. Samples R5 and R6 are similar in that both lack Idiognathodus, and both contain Aethotaxis, but differ in that R6 may also contain Ellisonia (figure 48).

Streptognathodus is the most common conodont in PAC 3, ranging from less than 16% of the elements in HD1, to as high as nearly 28% of all elements in R4 (figure 48). The second most common genus in the lower three samples of PAC 3 is Idioprioniodus. Slightly over 12% of the conodont elements in sample R1 are Idioprioniodus, but this genus decreases in importance upward through PAC 3, occurring last in R5 where it comprises less than 2% of the elements. Idiognathodus is only slightly less common than Idioprioniodus in the lower samples of PAC 3 , and follows a similar trend, high percentages (nearly 12%) in R1, decreases upwards, and last appears in R4 where it makes up less than 4% of the total elements. The second most common conodont in the upper three samples is Adetognathus (figure 48). It makes up less than 8% of sample R4, increasing upward to around 18% in R6. The next most common conodont in the upper three samples of is Hindeodus, in which the trend is just opposite to that observed for Adetognathus (slightly less than 8% in R4, to slightly less than 4% in R6.

The percentage of P elements versus M plus S elements, and the percentage of broken elements in each sample was recorded for PAC 3 (figure

49). P elements are more abundant than M plus S elements in all samples from PAC 3, but the difference in percentages between these element types decreases upward through the PAC. The difference between P elements and M plus S elements is greatest in R1, where P elements comprise over 43% of the sample, and M plus S only 17% (a difference of 28%). The difference is lowest (less than 3%) in R6 where P elements are 47% of the sample and M plus S elements make up nearly 44% (again the remaining percentages in both cases are made up of elements that were broken to the point that assignment to an apparatus position was impossible). The percent of broken elements in PAC 3 decreases steadily upward (figure 49), with all the elements in R1 broken, to R6 in which only 55% are broken.

Holliday Drive (HD) - PAC 4

Six samples were collected from PAC 4 at the Holliday Drive Section (see figure 46). These included: one from the brachiopod wackestone (R7), three from the argillaceous wackestone (R8, R9, and R10), and two from the "caprock" lithology (R11 and R12). All samples within PAC 4 contain less than 100 elements per kilogram (see figure 47). R7, at the base of PAC 4, contains over 70 elements per kilogram. This is a slight increase over the uppermost sample (R6) in PAC 3 which has slightly over 50 elements per kilogram. Overall abundance of conodonts within PAC 4 drops to below 50 elements per kilogram in most of the remaining samples (R8 through R11). A rather abrupt increase (to 70+ elements) occurs in R12, the uppermost sample of PAC 4.

Maximum conodont diversity within PAC 4 (figure 47) is in the basal sample, R7, and includes the six genera (from most to least common) Streptognathodus, Adetognathus, Hindeodus, Aethotaxis, possibly Ellisonia, and

Idioprioniodus. Generic diversity drops, to three genera in sample R8, but increases to five in sample R9, with little change throughout the rest of the PAC (three genera in R10, but five in both R11 and R12).

The most common conodont within PAC 4, as with the lower three PAC's, is Streptognathodus (figure 48). The dominance of Streptognathodus fluctuates from around 36% in R7 and R8, to slightly more than 24% in R9. Streptognathodus increases again in R10 (over 28%), and rises sharply to its maximum in PAC 4 of over 60% in R11. Adetognathus is the second most abundant genus in samples of PAC 4, except in R11, where Aethotaxis makes up nearly 6% of the elements, making it second only to Streptognathodus. Adetognathus is most abundant in R12.

All samples in PAC 4 contain higher percentages of P elements than M plus S elements (figure 49). The greatest difference between the proportions of these element types (56%) is in R11, where P elements comprise 69% of the sample, and M plus S slightly less than 13%. The smallest difference in element types occurs in R9 (8%), where P elements make up nearly 45% of the sample, and M plus S elements nearly 37% (with the remaining percentage in both samples being indeterminate elements). The percentage of broken elements is lowest in R7 (the lowermost sample of the PAC) where nearly 55% of the conodont elements are broken. Highest breakage is 97% in R8.

Holliday Drive (HD) - PAC 5

Three samples (R13, L1, and L2) were collected from PAC 5 including: one from the skeletal packstone in the Raytown (R13), and two from the fossiliferous mudstone at the base of the Lane Shale (L1 and L2) (figure 46). Maximum conodont abundance (nearly 500 elements per kilogram) occurs in R13, the basal sample of PAC 5 (figure 47). This is a sharp increase in abundance over the uppermost sample in PAC 4, where conodont abundance was just over 80 elements per kilogram (figure 47). The number of elements per kilogram in samples above R13 drops rather abruptly, to 150 in L1, and less than 25 elements per kilogram in L2.

Along with abundance, conodont diversity is also at its maximum in R13, with five genera present (figure 47). Diversity drops to three in L1, and to one in L2. In R13 the genera (from most to least common) are: Streptognathodus, Adetognathus, Hindeodus, Aethotaxis, and possibly Ellisonia. Streptognathodus is 34% of the genera in R13 (the base of PAC 5), slightly over 18% in L1, and is absent from L2 (figure 48). Adetognathus is the most common element in samples L1 and L2, 56% in L1, and 14% in L2.

P elements greatly outnumber M plus S elements in the lower two samples, comprising nearly 75% of the conodont elements in sample R13, and over 80% in sample L1 (figure 49). In sample L2, M plus S elements make up nearly 72% of the elements present. Over 95% of the conodont elements in sample R13 are broken (figure 49).

Osawatomie Section (OSA) - PAC 1

Five samples were collected from PAC 1 at Osawatomie (figure 51). These included: one from the upper part of the Chanute Shale (CO12), and four from the Paola (CO13, CO14, CO15, and CO16). The conodont abundance pattern is similar to that of PAC 1 at the Holliday Drive section, being relatively high in the lower part of the PAC (245 in CO12, and 250 in CO13), and decreasing through the upper part of the unit (slightly over 160 in CO14, 100 in CO15, and slightly less than 100 in CO16) (figure 52).

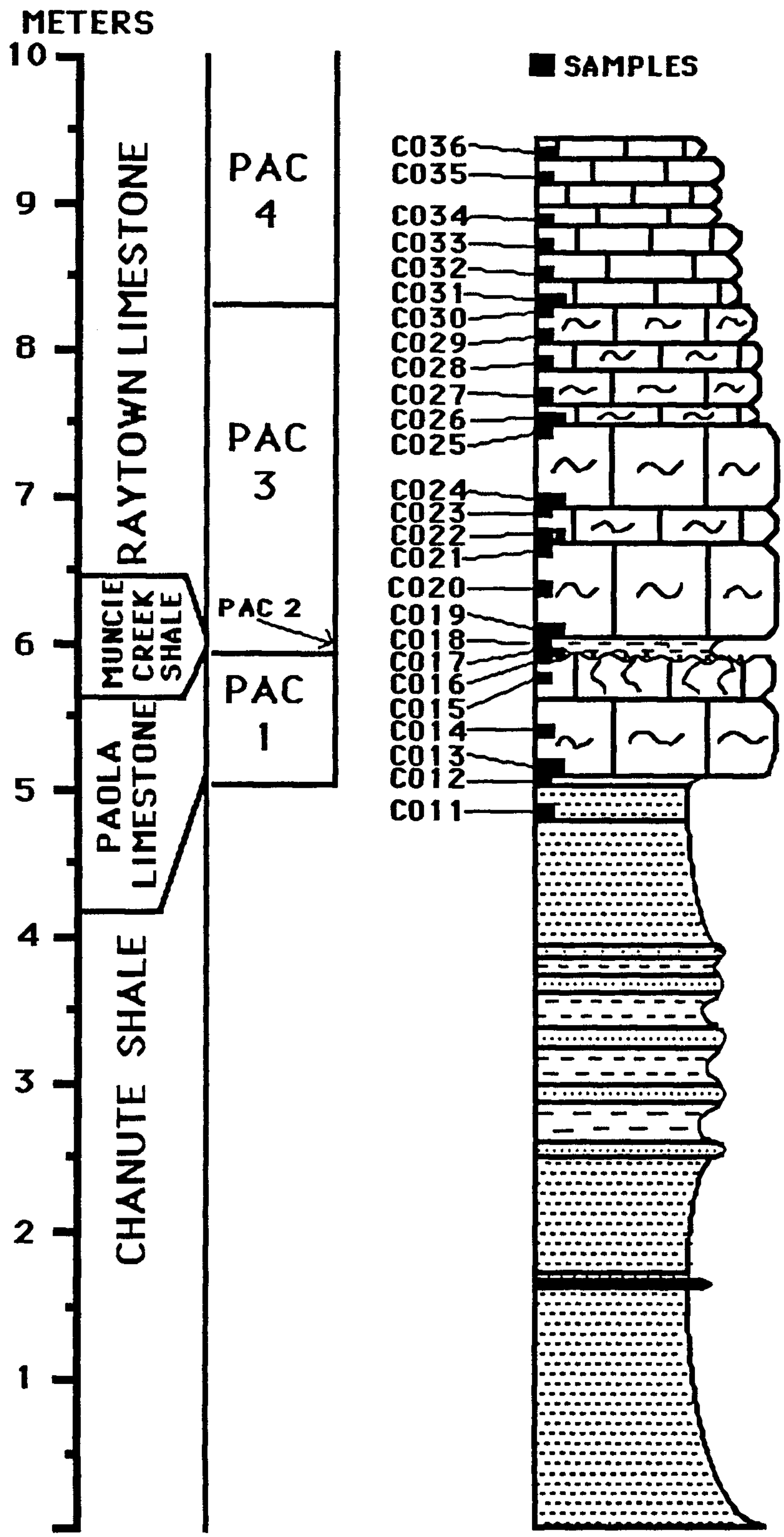

Figure 51. Conodont samples collected at section OSA.

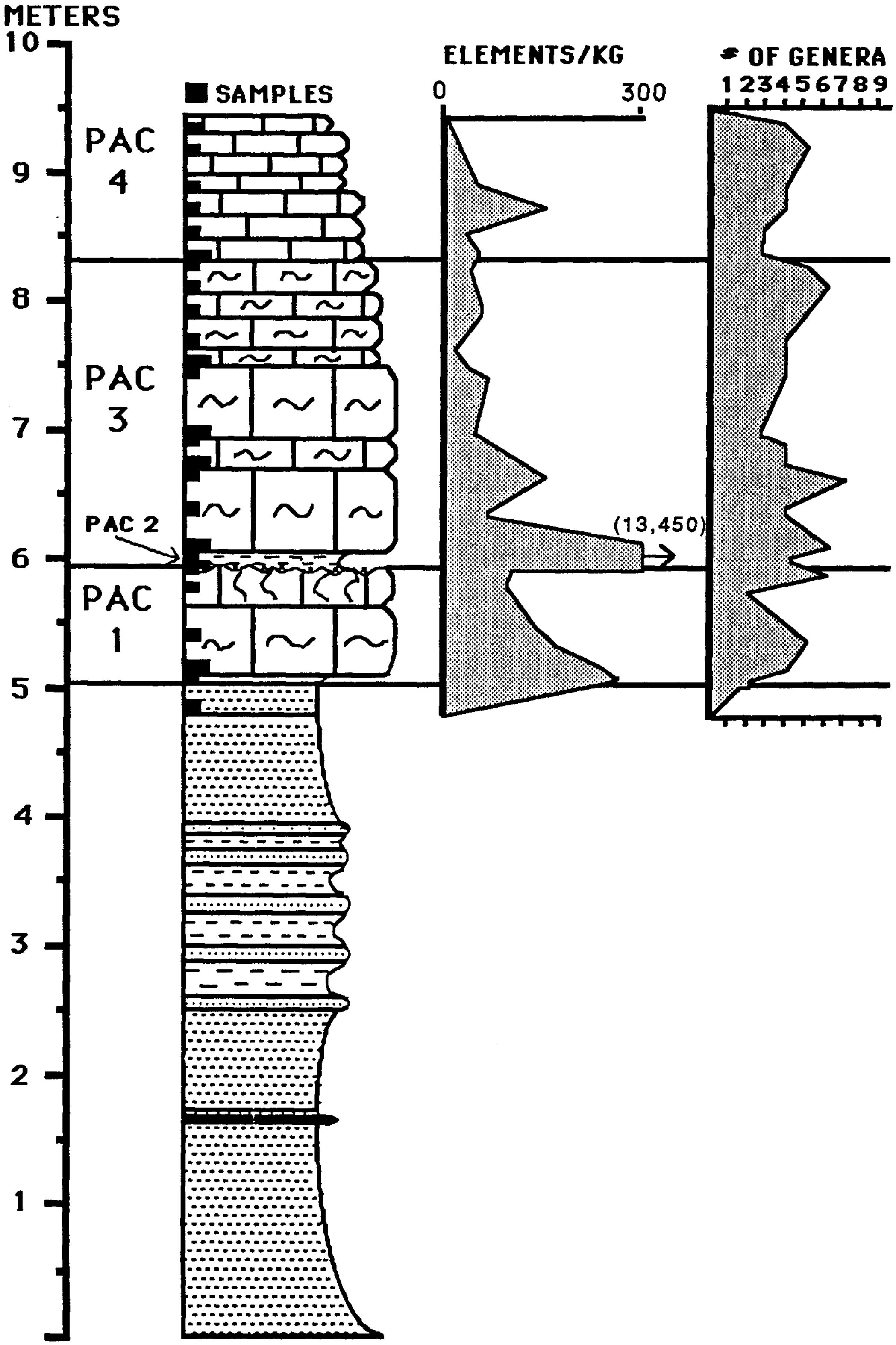

Figure 52. Abundance and number of conodont genera in samples from section OSA. (NOTE: → = off scale)

The pattern of conodont diversity in PAC 1 at OSA differs from that in PAC 1 at HD in that there are two peaks (or maxima) instead of one (figures 47 and 52). Diversity in PAC 1 at HD is highest in one sample near the middle of the PAC (seven genera in P1). Diversity in PAC 1 at OSA is relatively high in two samples, one sample near the base (five genera in CO14), and one at the top (six genera in CO16) (figure 52). The conodont genera in PAC 1 at OSA (CO16) include: Streptognathodus, Hindeodus, Aethotaxis, Idiognathodus, Idioprioniodus, and possibly Ellisonia (figure 53). This is a very similar assemblage to that of maximum diversity in PAC 1 at HD, except it lacks Adetognathus (note: CO16 at OSA is in a lithology that possesses an open burrow system, so the possibility of contamination from the overlying unit is quite high).

Trends of individual genera are also very similar for samples in PAC 1 at both HD and OSA (figures 48 and 53). Adetognathus is the most common genus in the lowermost sample (CO12) in PAC 1 at section OSA, where it makes up over 40% of the genera present. It decreases in abundance abruptly above CO12 (to slightly over 13% in CO13, and less than 1% in CO14), and is absent from CO15 and CO16. Streptognathodus is the most common genus in samples above CO12, reaching a maximum of 34% of the conodont elements in CO13 at the base of the Paola, and decreasing to 15% of the elements in CO16 at the top of the Paola (a trend similar to the one seen in PAC 1 at section HD). Hindeodus is the next most common genus in PAC 1 at OSA. It is most common in CO13, where it makes up nearly 4% of the conodont elements, and decreases in abundance to 3% or less in the remaining three samples (CO14, CO15, and CO16).

Percentages of P elements are higher than M plus S elements in all of the samples from PAC 1 at OSA (figure 54). In the lower samples (CO12 and CO13) of PAC 1, percentages of P elements are much higher than and M plus S

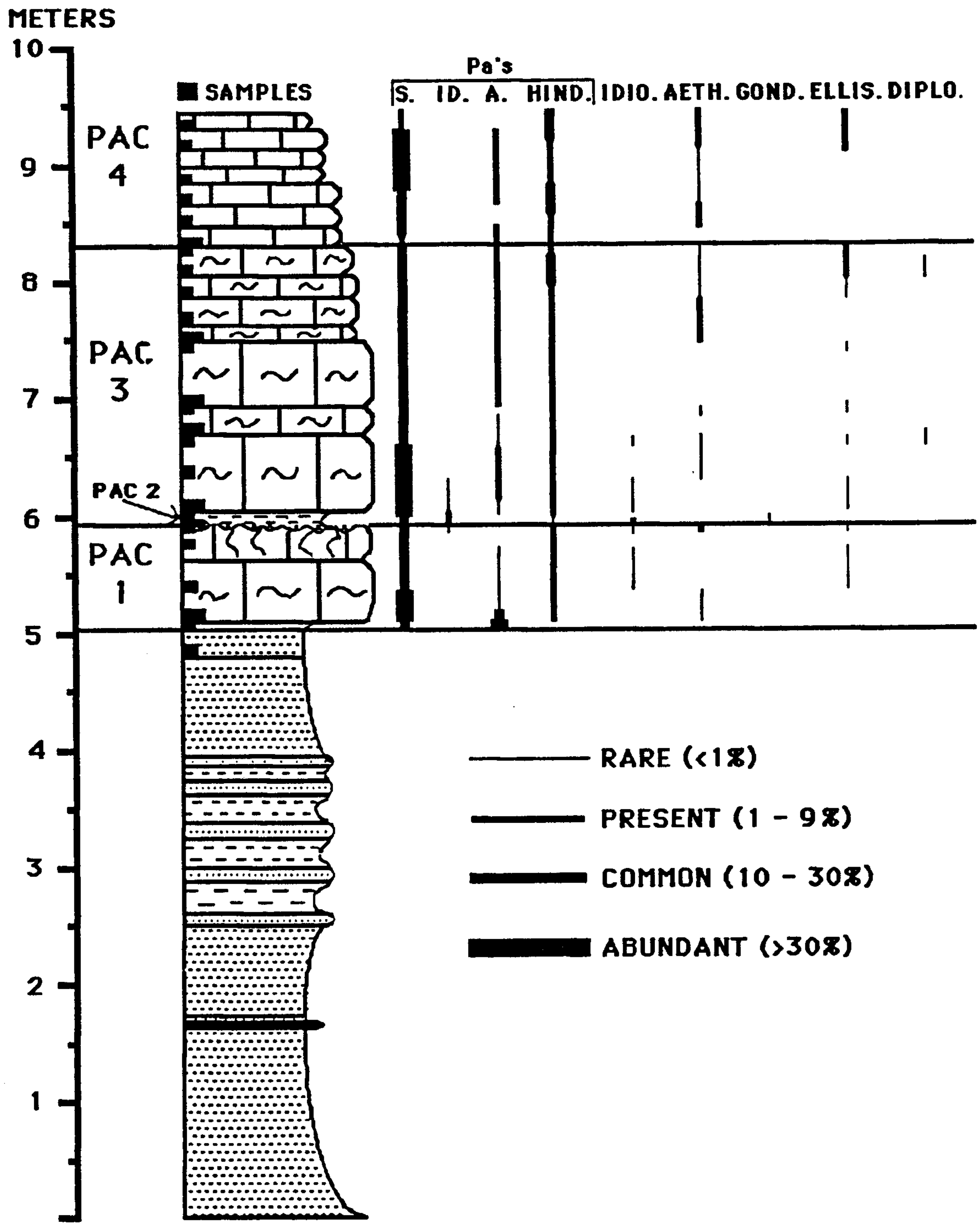

Figure 53. Ranges of conodont genera at section OSA. (for abreviations see figure 48)

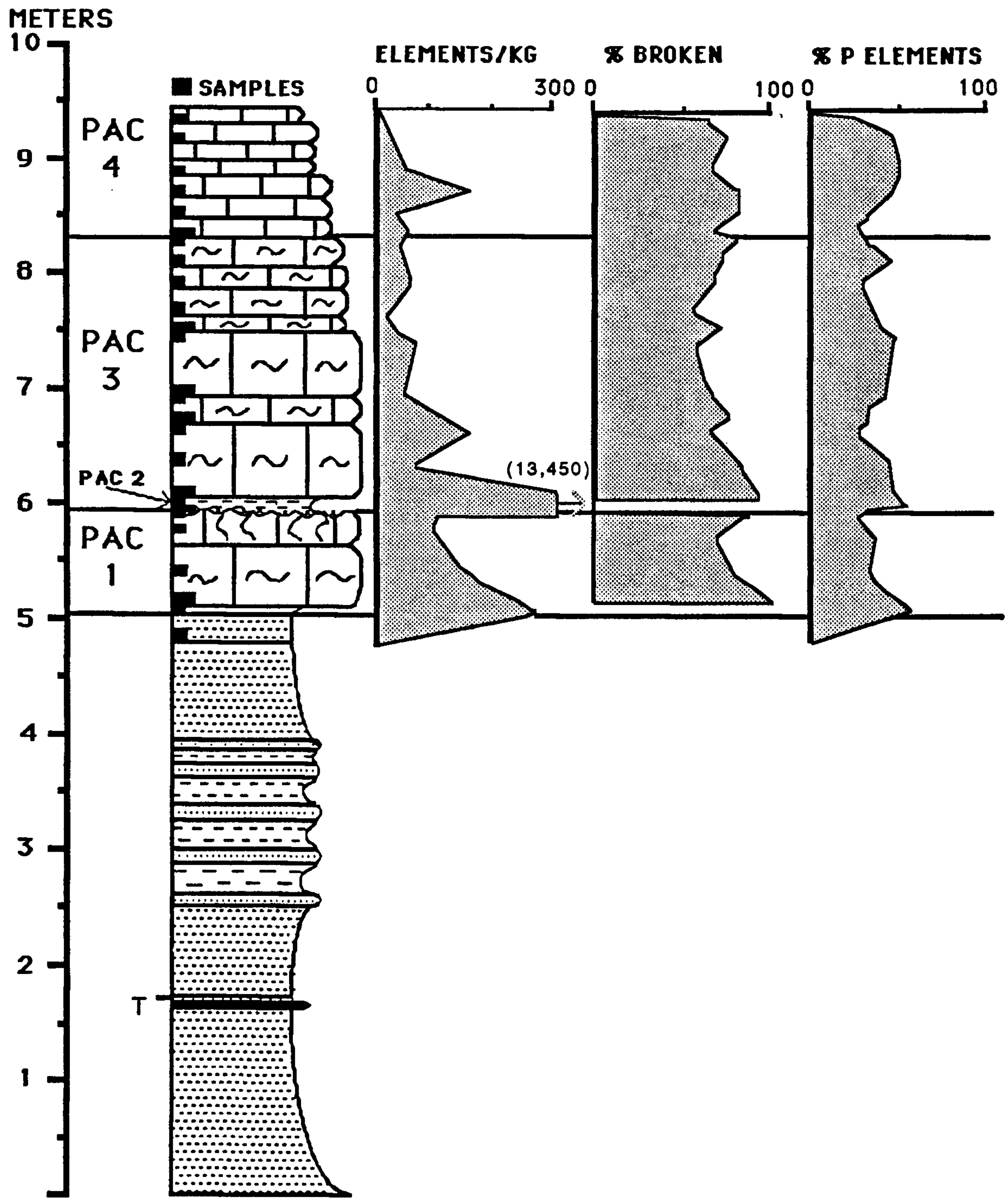

Figure 54. Relative abundance and taphonomic characteristics of conodont elements at section OSA.

elements (as much as 55% higher). This difference decreases in the upper samples of the PAC (CO14 to CO16) where percentages of P elements are less than 33% of the elements, and M plus S elements comprise more than 50% of the elements. The percentage of broken elements in PAC 1 is greater than 60% in all samples. This percentage decreases upward in PAC 1, from over 90% in CO13 to slightly over 61% in CO15. Above CO15, the percentage of broken elements increases to over 80% in sample CO16.

Osawatomie (OSA) - PAC 2

One sample (CO17) was collected from PAC 2 at OSA (figure 51). PAC 2 at OSA is represented by a calcareous mudstone lag facies that overlies an omission surface (see discussion of genetic stratigraphy of PAC 2 at OSA). Conodont abundance in CO17 is over 13,000 elements per kilogram (figure 52), an extremely abrupt increase over the uppermost sample in PAC 1, CO16, which contains slightly less than 100 elements per kilogram. This is also much higher than any sample in PAC 2 at section HD. Diversity in PAC 2 at OSA is relatively high (five genera) (figure 52), and (from most to least common) includes: Streptognathodus, Idiognathodus, Idioprioniodus, Gondolella, and Hindeodus (figure 53). The percentage of P elements in CO17 is 35%, whereas the percentage of M plus S elements is slightly less than 10% (figure 54) (the remaining percentage consisting of elements broken to the degree as to make assignment to an apparatus position impossible).

Osawatomie - PAC 3

Thirteen samples were collected from PAC 3 at OSA. All samples were from the Raytown, and included: one (CO18) from the fossiliferous, calcareous mudstone at the base of the PAC, and twelve from the phylloid algal wackestone to packstone (CO19 to CO30) (figure 51). Conodont abundance changes four times in PAC 3 (figure 52). Abundance in the lowermost sample in PAC 3, CO18, is over 2700 elements per kilogram, but decreases sharply upward in PAC 3 to just over 60 in CO19 and CO20 (figure 52). Sample CO21 contains 150 elements per kilogram (an increase over CO20), and abundance decreases upward to 50 elements/kg. in CO24. Sample CO25 contains over 70 elements per kilogram (increasing from CO24), and abundance decreases upward through the next two samples (CO26 and CO27) to 20 in Co27. Abundance increases to 60 in CO28, and decreases upward through the next two samples (CO29 and CO30) to slightly over 45 elements per kilogram in CO30.

Samples containing the highest diversity within PAC 3 include: CO19 and CO29 with six genera each, and CO21 with seven genera (figure 52). These samples generally include: Streptognathodus, Adetognathus, Hindeodus, Aethotaxis, Idioprioniodus, Diplognathodus, and possibly Ellisonia (figure 53). CO19, however, lacks Aethotaxis and Diplognathodus, but contains Idiognathodus. The most common conodont within PAC 3 is Streptognathodus, which is most abundant (over 40%) in CO18, and least abundant (12%) in Co28 (figure 53). The second most common conodont in PAC 3 is Hindeodus, which is most abundant (11%) in CO29, and least abundant (slightly less than 3%) in CO21 (figure 53). Streptognathodus is most abundant in the lower part of PAC 3, but Hindeodus is most abundant in the upper part.

The percent of P elements in the basal part of PAC 3 is higher than that of the M plus S elements, but the percentage of M plus S elements increases upwards from 3% in CO18 (52% P elements), to 41% in CO20 (44% P elements) (figure 54). The percentage of M plus S elements is greater than that of the P elements in CO21 through CO24, but the percentage of P elements increases upwards from 27% in CO21 (69% M plus S elements), to around 43% in CO24 (47% M plus S elements). CO25 has a slightly higher percentage of P elements than M plus S elements (48% P elements, 44% M plus S elements), but the inverse is true for samples CO26 through CO28, with the percentage of M plus S elements increasing upwards from 51% in CO26 (39% P elements), to 62% in CO28 (28% P elements). Sample CO29 contains a slightly higher percentage of P elements (nearly 45%) than M plus S elements (nearly 38%), but in the overlying sample, CO30, M plus S elements are more abundant (55%) than P elements (30%). The vertical pattern of element types in PAC 3 is very similar to the vertical pattern in conodont abundance in PAC 3, and both patterns are quite similar (figure 54).

The percentage of broken conodont elements also fluctuates in PAC 3 (figures 54), decreasing upwards from 82% in CO20 to slightly over 60% in CO25. The percentage of broken elements then increases to 70% in CO26, but drops to 55% in CO27, and then increases upwards from 67% in CO28, to over 78% in CO30.

Osawatomie (OSA) - PAC 4

Six samples were collected from PAC 4, which includes the upper part of the Raytown at OSA (figure 51). Conodont abundance in PAC 4 fluctuates several times (figure 52). The basal sample of PAC 4, CO31, contains 51 elements per kilogram, a slight increase over the uppermost sample in PAC 3, CO30, which contains slightly less than 48. Above sample CO31, abundance decreases to less than 30 in CO32, but increases abruptly to slightly over 150 elements per kilogram in sample CO33. Above CO33, abundance decreases upward from 48 in CO34 to less than 18 in sample CO36.

Conodont diversity in PAC 4 increases upward from three genera in CO31 and CO32, four in CO33 and CO34, five in CO35, and then decreases to three in the uppermost sample, CO36 (figure 52). Conodont genera (from most to least common) contained within the most diverse sample in PAC 4 (CO35) include: Streptognathodus, Adetognathus, Aethotaxis, possibly Ellisonia, and Hindeodus. Streptognathodus is the most common genus in all but the uppermost and lowermost samples of PAC 4 (figure 53). It is most common in the middle of the PAC (more than 36% CO34), and least common in the upper part of the PAC (less than 5% in CO36). Hindeodus is the most common genus in CO31 and CO36 (less than 8% and over 11% respectively), and is second in CO32 and CO33 (over 6% and over 13% respectively). The second most common genus in CO34 and CO35 is Adetognathus (over 6% and over 9% respectively).

The percentage M plus S elements is higher than P elements at the base of PAC 4, CO31 (60% M plus S and nearly 28% P elements), but the percentage of P elements increases upward from 28% in CO31 to nearly 35% in CO32 (figure 54). Above CO32 (CO33, CO34, and CO35) the percentage of P elements is greater than M plus S elements (from 14% to 19% greater), but in CO36 the percentage of M plus S elements is over 30% higher than that of P elements (25% P elements, over 56% M plus S elements). Diversity (figure 52) and the percentage of P elements seem to follow a similar trend, as the highest diversity (in CO33, CO34, and CO35) is coincident with a higher percentages of P elements. The percentage of broken elements in PAC 4 is greater than 60% for all samples, and fluctuates very little throughout the PAC.

DISCUSSION

Diversity

Previous investigators (Heckel and Baesemann, 1975; Mitchell, 1981; Swade, 1985; and Heckel, 1986) have generally concluded that the highest conodont diversity occurs in the "core shale" (figure 44). Furthermore, they have suggested that this indicates maximum transgression within the cyclothem, and that diversity decreases in the overlying and underlying units. Data presented here (figures 47 and 52) suggests that conodont diversity patterns in the Iola cyclothem (Iola fifth order T-R unit), and in smaller scale genetic units composing this interval, are more complex than previously reported.

Maximum transgression within most PAC's (as interpreted from macrofossil diversity and sedimentilogical features) is coincident with the highest conodont diversity in the PAC. The exceptions to the previous statement include: PAC 3 at both OSA and HD, PAC 4 at OSA, and PAC 5. Recall that PAC 5 was not examined throughout its entire thickness, and its exposure is limited. PAC 1 at section HD (figure 47), has its highest diversity of conodont genera in sample P1 (possibly seven) near the base of the Paola, an interval which also contains the highest diversity of macrofossils (figure 17), and is interpreted as representing maximum transgression in PAC 1 at HD. PAC 1 at OSA contains two samples (CO13, and CO14) with relatively high conodont diversity (four to five genera) in the interval near the lower part of the Paola (figure 52) which has the highest macrofossil diversity (figure 28), and represents maximum transgression for PAC 1 at OSA. Maximum conodont diversity, however, occurs in sample CO16 of PAC 1 at section OSA, but this may be anomalous because it is in a lithology that contains an open burrow system, making contamination from the overlying shale unit possible.

Conodont diversity within PAC 2 at HDMC (see figure 47) is also relatively high (five genera) in the interval representing maximum transgression (black, fissile, phosphatic shale). Diversity is, however, also high in several other intervals within PAC 2 including: P4 at the base of the PAC (figure 50), and sample HD10 in the gray mudstone facies, with both samples being in facies with high macrofossil diversity (figure 20). PAC 2 at section OSA, represented by a thin mudstone facies (figure 14), also contains relatively high conodont diversity (figure 52), but if this mudstone facies represents a lag deposit, the diversity is obviously time averaged (possibly during a long period of erosion and/or nondeposition). Conodont diversity in PAC 4 at HD (figure 47) is highest near the base of the PAC (six genera), the interval that also contains the highest macrofossil diversity (figure 17).

The remaining PAC's, PAC 3, and PAC 4 at OSA, have high conodont diversities (figure 52) in intervals probably not representing maximum transgression for the PAC's, and where macrofossil diversity is relatively low (generally in the upper parts of the PAC) (figures 28). This trend in diversity is primarily due to the addition of the Aethotaxis and Ellisonia? in the upper part of the PAC's, genera that are thought to indicate shallow-water environments (Swade, 1985).

PAC's 1 (at both sections) and 4 (at HD) are relatively simple cases in which maximum conodont diversity coincides with maximum macrofossil diversity (figures 17, 28, 47, and 52), and hence maximum transgression. PAC 2 is a more complex example, but high conodont diversity is still apparently coincident with maximum transgression in the PAC, but PAC's 3 (at both sections) and 4 (at OSA) display little correlation between high conodont diversity and maximum transgression within PAC's. This may imply that generic diversity of conodonts may not be an adequate indicator for paleodepth determinations, especially if it is the only characteristic examined. It may suggest that conodonts were not sensitive (or as sensitive) to the ecologic parameters controlling macrofossil distribution, or it could be possible that this ecologic sensitivity may exist only at the species level.

Conodont Occurrence Patterns

Streptognathodus.-- Streptognathodus is part of the Idiognathodus/Streptognathodus plexus, a group characterized by carminiscaphate elements in the Pa position, and a seximembrate apparatus. The taxonomy for this group is rather chaotic, a factor that became vividly apparent to the author in the early stages of this report. As recorded earlier, identification of Streptognathodus was made strictly following descriptions in Ellison (1941), and the Treatise of Invertebrate Paleontology (Supplement 2, Conodonta). This genus was easily recognized in this study, because the dominant form is a simple, often unornamented, deep troughed form of Streptognathodus (S. elegantulus?, along with S. gracilis? and S. excelsus? in certain samples).

PAC 2, and the upper part of PAC 1 and lower part of PAC 3 contained elements of the Id./S. plexus that appeared to be intermediate between the two genera (e.g. very shallow or incomplete troughs) making positive identification of Streptognathodus rather difficult.

Streptognathodus (and the Id./S. plexus) often displays what some consider a rather ubiquitous occurrence in marine facies. It is the name-giver of a biofacies that has been interpreted as representing normal marine and stenohaline conditions (Heckel and Baesemann, 1975; Mitchell, 1981; Swade, 1985; Merrill and von Bitter, 1984). Streptognathodus is part of the "longitudinally troughed microbiofacies" of Merrill and Martin (1976, p. 353), considered to be the least restricted and generally most dominant microbiofacies in Upper Pennsylvanian rocks.

Streptognathodus is the most common element in the majority of samples studied. In parts of some genetic units, the occurrence of Streptognathodus is subordinate to Adetognathus, as in the basal samples of PAC 1, and the upper samples of PAC 5 (figure 48), and to Hindeodus in uppermost and lowermost samples of PAC 4 at section OSA (figure 53). Within PAC 2 at section HD, Streptognathodus is proportionally less or equal to Idiognathodus (samples HD2, HD11, and HD13), and Idioprioniodus (samples HD4, HD6, and HD8) in certain samples. The dominance of Idioprioniodus may be artificial. Only Pa elements are included in the percentage of Streptognathodus (because of the difficulty in identifying all of the element types of this genus), but all elements types of Idioprioniodus are included. The highest percentage of Streptognathodus commonly corresponds with maximum conodont diversity (PAC 1 and PAC 5 at HD, and PAC 4 at both sections). The distribution of Streptognathodus within sixth order T-R units of the Iola fifth order T-R unit appears to be in agreement with many of the previous interpretations concerning the genus.

Idiognathodus.-- Idiognathodus, part of the Id./S. plexus, is generally considered equivalent to Streptognathodus in terms of its environmental significance (Heckel and Baesemann, 1975; Mitchell, 1981; Swade, 1985; and Merrill and von Bitter, 1984). Merrill (1989) believed Idiognathodus to be a stenohaline genus. Higgins (1981) reported that Idiognathodus may have a relatively shallow water preference because it is found in facies directly above coal seams in the Namurian marine bands of Great Britain. Merrill and Martin (1976, p. 353) made Idiognathodus part of the "ridged microbiofacies", which appears to be the most environmentally restricted microbiofacies.

Idiognathodus occurs in the upper part of PAC 1 and lower part of PAC 3 (Figures 48 and 53), though it is a relatively minor component (generally less than 4%, except in HD1 at the base of PAC 3, where it is slightly less than 10% of the elements). Idiognathodus is most common in PAC 2, and is the major component of HD2 in the upper gray mudstone facies of the Muncie Creek (figure 43); and in samples HD11 and HD13 in the lower gray mudstone facies of the Muncie Creek. Idiognathodus is present in most samples of PAC 2 (except HD3) a unit that I have reported as being primarily the result of climate change.

Idiognathodus has characteristics that suggest that it could be an ecophenotype within the same conodont animal that contains Streptognathodus. These characteristics are: (1) possible restriction to climatically different facies, (2) chaotic taxonomy of the Idiognathodus/Streptognathodus plexus, and (3) possible intermediate forms within genera of the Id./S. plexus) Purnell (1988) suggested that the Taphrognathus and Cloghergnathus were ecophenotypic variants of the same genus because there are elements that appear to be intermediate in form. The possibility of intermediate forms is enhanced by the interpretations of van den Boogard and Bless (1985) concerning the ontogeny of certain species of Idiognathodus. In their study Streptognathodus morphologies were most common in small elements (juveniles?), and morphologies of large specimens (adults?) were almost exclusively Idiognathodus.

Nicoll (1987) considered the Pa element to be the most "radical" element in the conodont apparatus, having the greatest morphological variation, and suggested that these morphological variations are related to variation in prey. Nicoll (1987) noted that some vertebrates have teeth in the back part of their mouths that have morphologies associated with the preferred food type. It is possible that an environmental change, in response to changing climatic conditions, may have resulted in a change in the food types available to the conodont animal containing either Streptognathodus or Idiognathodus. The possibility of Streptognathodus and Idiognathodus being ecophenotypes of the same genus may have implications for the biostratigraphy of "core shales".

Adetognathus.-- Merrill and von Bitter (1984) stated that the Adetognathus (Cavusgnathus) biofacies is one of the easiest to recognize, and one that represents shallow, unstable conditions, a conclusion that most other Pennsylvanian conodont workers agree with (Heckel and Baesemann, 1975; Mitchell, 1981; Swade, 1985; Merrill and Martin, 1976; and Merrill, 1989). Closely associated with the shallow, Adetognathus biofacies is the genus Ellisonia, claimed to represent abnormal salinities (brackish or hypersaline) in shallow water (Merrill and von Bitter, 1984).

Adetognathus is the most common conodont element in samples in the upper part of PAC 5 (figure 48), and the lower part of PAC 1 (figures 48 and 53). This genus is found throughout the Iola Limestone, including one sample (as a minor component) near the base of the black, fissile shale in PAC 2. Within PAC 3, Adetognathus is present and increases in abundance upward from the middle of the PAC. Similarly, in PACs 4 and 5, the percentage of this conodont increases upward. Ellisonia is present in the upper part of PACs 3 and 4, and in the lower part of PAC 5 but is never more than 2% of any sample. Both Adetognathus and Ellisonia are most common in the within shallowing or initially deepening parts of some sixth order T-R units (base of PAC 1 at both sections,the top of PACs 3 and 4 at both sections, and the top of PAC 5 at HD).

Gondolella and Idioprioniodus.-- Conodont workers appear to be divided as to their interpretation of the environmental significance of both Gondolella and Idioprioniodus. Certain investigators believe these genera to be deep water indicators (Heckel and Baesemann, 1975; Mitchell, 1981; and Swade, 1985), while others believe Gondolella and Idioprioniodus to be most common in deposits representing shallow water conditions (Merrill and Martin, 1976; Merrill, 1975; Merrill and von Bitter, 1984). Merrill (1989) noted that the Gondolella biofacies may interfinger with the Adetognathus biofacies. The differences in opinions concerning the environmental limits of these two genera, is largely based on differences in opinion over interpretations of the depositional environment represented by the facies in which Gondolella and Idioprioniodus are commonly found (see Heckel and Baesemann, 1975; Heckel, 1977; Merrill, 1975; and Merrill and Martin, 1976). This illustrates the circular reasoning often involved in the application of biofacies. The environmental significance of a taxa is defined strictly from environmental interpretations of the lithofacies in which it is found. Subsequent occurrences of that taxa are then interpreted as representing that same environment.

Gondolella was found in only five of the samples studied. Four of these samples were collected from the black, fissile Muncie Creek in PAC 2 at HD (figure 48), and the remaining sample was collected from the mudstone lag facies in PAC 2 at section OSA (figure 53). Gondolella rarely comprises more than 2% of the conodont fraction of a sample, and does so in only one instance, sample HD7, where it makes up 8.5% of the conodont elements.

Idioprioniodus has a very similar distribution pattern to that of Idiognathodus, and is most common in the black, fissile facies of PAC 2 at HD (figure 48). Here it is, in one sample (HD5), high, slightly over 18% Both Idioprioniodus and Gondolella occur in what has been interpreted as the deepest part of the Iola interval, but because the facies in this part of the Iola may be the result of factors other than depth, these other factors may have been responsible for the distribution gradient of these genera.

Hindeodus and Aethotaxis.-- Hindeodus and Aethotaxis are commonly placed within the same biofacies, which presumably represented shallow, well oxygenated, and possibly turbulent conditions within carbonate lithotopes (Heckel and Baesemann, 1975; Swade 1985; Merrill and von Bitter, 1984).

Hindeodus is present within most samples of PAC 1, where it is the second most common conodont, but decreases in percentage upward through this PAC. Hindeodus is a minor component of the uppermost and lowermost samples in PAC 2, and is found in samples in the upper half of PAC 3, increasing in abundance upward. Aethotaxis is a minor component in samples in the upper parts of both PAC 1 and PAC 3, and increases in percentage upward. Both Hindeodus and Aethotaxis are present in most samples in PAC 4, and are minor components in the basal part of PAC 5. The distribution of Hindeodus is somewhat similar to that of Streptognathodus, following similar trends of increasing and decreasing in abundance in PACs 1, 3, and 5. Aethotaxis is less common, and restricted to the shallower parts of certain PACs (PACs 1, 3, and 4 at both HD and OSA).

Diplognathodus.-- Very little data exists on the distributional patterns of Diplognathodus (Swade, 1985; and Merrill and von Bitter, 1984). This study is no exception, as Diplognathodus was found only in two samples, in the upper and lower parts of PAC 3 at Osawatomie, and in proportions generally less than 2% of the total elements within each sample.

Abundance

Merrill has proposed (1989) that the overall abundance of conodonts within a facies may be indicative of the rates of sedimentation for that facies. If the number of conodont elements is high, then the rates of sedimentation were probably low, and inversely, if the number of conodont elements is low, then the rates of sedimentation may have been relatively high. Sandberg (1969) and Davis

(1975) have suggested that a high abundance of conodonts within a given facies may indicate low rates of sedimentation, reworking, or both, and that both are characteristics of disconformities.

The number of elements per kilogram in samples (CO12 at OSA, and C2 at HD) at the base of PAC 1 is relatively high at both sections (figures 47 and 52), and this is an abrupt increase in conodont abundance over the underlying facies, which lacked conodonts. From this high at the base, conodont abundance decreases through the rest of PAC 1. Conodont abundance patterns of PAC 1 (at both HD and OSA) suggests: (1) a basal disconformity, and (2) that the overlying sequence accumulated more rapidly than the basal part (i.e. increased rates of sedimentation).

The abundance of conodonts at the base of PAC 2 (section HD) is rather high (figure 47), compared to data from the top of the underlying PAC, and could also represent a basal disconformity. The number of elements per kilogram is also high in the black fissile shale of PAC 2, but is rather low throughout the gray mudstone above and below the black shale. This pattern suggests low rates of sedimentation in the black fissile shale, but relatively higher rates of sedimentation for the gray mudstones. The gray mudstone "lag" facies that probably represents PAC 2 at Osawatomie (OSA) contains an extremely high number of elements per kilogram (figure 52), supporting a disconformity at this level.

The number of elements per kilogram at the base of PAC 3 (at HD), like the two underlying PACs, is high relative to the number at the top of the underlying PAC (figure 47). Again the presence of a disconformity is suggested. At the Holliday Drive section, conodont abundance is high in the basal samples of PAC 3, but decreases rather rapidly upward. Again this can be interpreted as an increase in the rates of sedimentation upward. While the overall trend in PAC 3 at section OSA is an upward decrease in conodont abundance, this trend is punctuated with thin intervals of higher abundance (figure 52) producing a cyclicity. This cyclicity can be interpreted as fluctuations in rates of sedimentation, and possibly, several minor disconformities.

There is only a very slight increase, relative to the upper sample in PAC 3, in conodont abundance at the base of PAC 4 at both Osawatomie and Holliday Drive (figures 47 and 52). The number of conodont elements per kilogram in samples PAC 4 at the Holliday Drive section is low (figure 47), suggesting high rates of sedimentation for this interval. An abrupt increase in the number of elements per kilogram occurs near the middle of PAC 4 at Osawatomie. This "peak" is not coincident with the abrupt change in macrofossil diversity at the base of this PAC. If one chooses to rely on conodonts, this may indicate that the inferred basal disconformity for PAC 4(transgressive flooding surface) was placed in the wrong interval at the Osawatomie section. Overall conodont abundance decreases rapidly above the middle part of PAC 4 at OSA, to nearly zero.

Conodont abundance is high at the base of PAC 5 (a PAC only studied at HD), compared to the upper samples of the underlying PAC, supporting a disconformity. Conodont abundance decreases dramatically above the lower part of PAC 5, suggesting a substantial increase in the rates of sedimentation through the remainder of this interval. This is compatible with previous interpretations of this sequence (see discussion of section HD, PAC 5).

Taphonomic Implications

An investigation into the rates of settling (which presumable correlates with the amount of current energy required to move a sedimentary particle) of the apparatus of polygnathaceans has recently been conducted by McGoff and Briggs (1988). They concluded (though not surprisingly) that the generally robust P elements are less apt to be sorted or winnowed away by the activity of currents than are the more delicate M and S elements. M plus S elements outnumber P elements in a seximembrate apparatus (as occurs in members of the Idiognathodus/Streptognathodus plexus) by a ratio of 9 to 4, so a major deviation from this ratio in any particular lithology may suggest sorting of the conodont elements.

Trends in the percentage of broken elements may reflect the energy level for the depositional environment represented by the lithology from which conodonts are recovered. High energy, the result of current, wave, or storm activity would result in a higher percentage of broken elements. Low energy levels would be recorded in by low percentage of broken conodont elements. Also, a high percentage of broken elements may also reflect low rates of sediment accumulation. Low accumulation rates would result in longer periods of esposure for the conodont elements and a higher probabiltity for breakage.

The percentage of P elements relative to M plus S elements is relatively high in the lower parts of PAC 1 at both Osawatomie and Holliday Drive (figures 49 and 54), but decreases gradually upward. The percentage of broken elements also decreases slightly upward in PAC 1, except for the uppermost part of PAC 1 at Osawatomie. Here the percentage of broken elements increases sharply, which, because of the open burrow system, suggesting a high probability that samples from this interval were contaminated by the overlying lithology. A high percentage of both P elements and broken elements suggests either a higher energy environment, or longer periods of exposure for conodont elements (i.e. lower rates of sedimentation) in the basal part of PAC 1.

The percentage of M plus S elements is slightly higher than P elements in the basal sample of PAC 2 at Holliday Drive (figure 49). M plus S elements also occur in higher percentages than P elements in samples from: (1) the upper gray mudstone, (2) the basal part of the lower gray mudstone, and (3) throughout most of the black fissile shale facies. In the upper part of the lower gray mudstone, and in the lower part of the black fissile shale, the percentage of P elements is very much higher than that of M plus S elements. This relationship may indicate slower rates of sedimentation, and longer periods of exposure for elements in this interval. The percentage of P elements in the gray mudstone "lag" facies at Osawatomie, as one might expect, is very much higher than that of M plus S elements in this facies. Long periods of very low rates of sedimentation, followed by very long periods of exposure could produce the observed relationships.

The net trend for PAC 3 at both Osawatomie and Holliday Drive, is high percentages of P elements and broken elements near the base of the PAC, decreasing proportionally upwards. PAC 3 at HD has a high percentage of P elements versus M plus S elements throughout, but the difference between the two percentages decreases upward in this PAC. The percentage of broken conodont elements also decreases upward in PAC 3 at section HD, possibly indicating better preservational conditions in the upper part of the PAC. Such conditions would be increased rates of sedimentation, and decreased periods of exposure. There is a similarity in the trends of: (1) percentage of P elements, (2) the percentage of broken conodont elements, and (3) conodont abundance, in PAC 3 at section OSA. The overall trend, for both percentages, is an upward decrease, but there are thin, punctuated intervals where these percentages increase substantially, suggesting higher energy, and/or decreased rates of sedimentation for these intervals.

There is a high percentage of P elements and broken elements throughout PAC 4 at Osawatomie and Holliday Drive, suggesting a relatively high energy regime for facies within this unit.

PAC 5 at HD has very high percentages of P elements in the two lower samples, but this trend is completely reversed in the upper sample of the PAC, which has percentages of M plus S elements that are very much higher than those of the P elements. This reversal coincides with the reduction of conodont abundance in this PAC, and may have been the result of the same sedimentological factors (higher rates of sedimentation).

Abundance, the percentage of broken elements, and the percentage of P elements observed in residues from Holliday Drive, Osawatomie, and both sections combined, were analyzed statistically to determine any significant correlation (figure 55). No significant correlation ($p < 0.01$) exists between these three variables in residues from Holliday Drive, but there is a positive correlation between abundance (elements/kg.) and the percentage of broken elements in residues from Osawatomie ($r = 0.66$), and in the residues from both sections combined ($r = 0.41$). This suggests that similar factors may control these two variables.

Treatment of conodonts as sedimentary particles (as with percentages of total elements, elements types, and breakage), appears to bring with it a higher degree of accuracy in characterizing small scale deepening-shallowing units (PACs) than does their treatment as biological entities. Trends of abundance, type (durability), and breakage do appear to reflect the existence of small scale genetic units within the Iola Limestone, but they also suggest a great deal of complexity within this unit.

HOLLIDAY DRIVE N = 15

	% BROKEN	%P elements	ELEMENTS/KG
% BROKEN		-0.25 +	0.42 +
%P elements	-0.25 +		-0.09 +
ELEMENTS/KG	0.42 +	-0.09 +	

OSAWATOMIE N = 22

	% BROKEN	%P elements	ELEMENTS/KG
% BROKEN		0.30	0.66 **
%P elements	0.30 +		0.34 +
ELEMENTS/KG	0.66 **	0.34 +	

ALL SAMPLES N = 37

	% BROKEN	%P elements	ELEMENTS/KG
% BROKEN		0.04 +	0.41 *
%P elements	0.04 +		0.06 +
ELEMENTS/KG	0.41 *	0.06 +	

+ $p > 0.01$
* $p = 0.01$
** $p = 0.001$

Figure 55. Statistical correlation (r values) between three variables of conodont occurence. Values were calculated from the percentage broken, percentage of P elements, and the number of elements/kg. observed in residues from Holliday Drive, Osawatomie, and both sections combined.

CONCLUSIONS

The application of hierarchal genetic stratigraphy to the interval containing the Iola Limestone provides evidence suggesting the following:

(1) The most marine part of the Iola fifth order T-R unit (primarily the Iola Limestone) is composed of at least five smaller-scale (sixth order) T-R units. Three of these (PAC 1, PAC 3, and PAC 4) can be correlated across the field area. These small-scale genetic units comprise a net deepening-shallowing sequence in the lower part of the Iola fifth order T-R unit or in Heckel's (1986) major cycle.

(2) The interval representing maximum transgression during the Iola fifth order T-R unit (and also representing maximum transgression during PAC 2) consists of a black, fissile, phosphatic shale. Although this facies is presumably the result of upwelling across a very gradually sloping shelf (Heckel, 1977), I believe that the evidence suggests that upwelling was not required, and that climate change and rapid transgression are more reasonable explanations. Rapid transgression at the base of PAC 2 may have flooded coal swamps to the east. The warm, humid climate during maximum transgression may have resulted in periods of maximum river flow which not only carried nutrients and sediments from the coal swamps into the epieric sea (possibly resulting in algal blooms), but may have also created density stratification leading to periods of oxygen deficiency in parts of this sea.

(3) Sedimentation within sixth order T-R units appears to have been influenced by both regional and local structures or paleotopographic highs and lows. Regional features, such as the Bourbon Arch, appear to have influenced the thickness of the sixth order T-R units. PAC 1 and PAC 3, which contain a phylloid algal facies, show a substantial increase in thickness towards the Bourbon Arch,

whereas the black fissile facies of PAC 2 disappears entirely in this same direction.

Local features seem to have influenced the distribution of certain facies and surfaces. The crinoidal packstone to grainstone facies at the base of PAC 2 is lenticular, and seems to be absent over what may be subtle paleotopographic highs, and present in the lows (see figure 32). The omission surface or hardground which is the upper bounding surface of PAC 1 in the southern part of the field area, appears to be present over local paleotopographic highs, but is absent in places which may have been topographic lows (see figure 32). The black shale facies in PAC 2 is absent over much of the field area. This suggests that local features, in conjunction with the Bourbon Arch, may have influenced the distribution of the black shale facies. Since paleotopography did appear to have a greater influence of the facies that comprise PAC 2 than on the PACs that surround this unit, the possibility exists that PAC 2 may represent relatively shallower conditions than either PAC 1 or PAC 3. If this is the case, then this interval (the Iola fifth order T-R unit) would not represent a "major cycle" (Heckel, 1986), or a fifth order T-R unit (Busch and Rollins, 1984).

Within the genetic stratigraphic framework established for the Iola Limestone by this investigation, conodont distribution patterns suggest the following:

(1) At the generic level, the range of conodont taxa and their relative abundance appear to reflect deepening and shallowing only at the scale of the fifth order T-R unit or cyclothem. The distribution of most taxa does not appear to be sensitive to the bounding surfaces of the smaller sixth order T-R units. This may have implications to studies that apply conodont biofacies.

(2) Conodonts in the Iola Limestone, when considered as sedimentary particles (elements/kilogram, percent broken, proportions of robust versus delicate

elements), do have distributions that delineate the smaller sixth order T-R units. This especially holds true for the relative abundance of elements. Relative abundance of conodont elements (in elements/kilogram) is highest at most transgressive surfaces (where rates of sedimentation were presumably low), and low within the units themselves (where rates of sedimentation were relatively higher).

Work that could be done to test the findings of this investigation include:

(1) Trace or attempt to correlate genetic surfaces in the Iola limestone over a much larger area to attempt to further define the surfaces and the units which they bound;

(2) Conduct a detailed petrographic and diagenetic study of the facies within the sixth order T-R units of the Iola Limestone to provide additional information concerning the history of these facies;

(3) Determine the statistical significance of the conodont distribution within sixth order T-R units relative to the lithofacies, and the distribution of macrofossils within these units;

(4) Conduct a detailed taxonomic study on conodont elements recovered in this investigation to determine the occurrence of species in the sixth order T-R units, and compare this with the occurrence of genera; and

(5) Examine conodont elements as silt-sized particles, taking into consideration the possible effects of factors such as reworking and concentration.

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APPENDIX 1 - LEGEND OF SYMBOLS

LEGEND

SYMBOLS

MUDSTONE/SHALE

CALCAREOUS MUDSTONE

BLACK FISSILE SHALE

SANDSTONE

LIMESTONE

ARGILLACEOUS LIMESTONE

CRINOIDAL LIMESTONE

ALGAL LIMESTONE

BURROWED LIMESTONE

PRODUCTID-BRYOZOAN WACHESTONE

NEOSPIRIFER-PRODUCTID WACKSTONE

T= TRANSGRESSIVE SURFACE

T?= POSSIBLE TRANSGRESSIVE SURFACE

APPENDIX 2 - MEASURED SECTIONS

Holliday Drive (HD)
west of Interstate 435,
south side of Holliday Drive,
Edwardsville Quadrangle
SW NE NW sec. 6, T12S R24E
Johnson County, Kansas

26. Wyandotte (Frisbie) Limestone: (5.50 ft.,1.68 m.) Algal wackestone; lt. brownish gray (5 YR 4/1) fresh, weathers grayish yellow (5 Y 8/4) to lt. gray (N7), wavy bedded, blocky to slabby, several mudstone partings, argillaceous at base; phylloid algae, Composita, crinoids, brachiopod fragments, bryozoans; small algal mounds developed locally, gradational basal contact.

25. Lane Shale: (0.42 ft., 0.13 m.) Calcareous shale; med. gray fresh (N5), weathers moderate reddish brown (10 R 4/6), platy to flaggy, poorly indurated; crinoids, bryozoans, productids, gastropods; sharp basal contact.

T?

24. Lane Shale: (0.42 ft., 0.13 m.) Silty mudstone; med. gray fresh (N5), weathers lt. gray (N7) to mottled dark yellowish orange (10 YR 6/6), platy, poorly indurated, micaceous; abundant plant fragments, Lingula; gradational basal contact.

23. Lane Shale: (22.50 ft., 6.86 m.) Silty mudstone;med. dark gray fresh (N4), weathers med. light gray (N6), platy, poorly indurated, micaceous; thin (< 1 inch) sandy lenses (decreasing in abundance upward) with nearly horizontal trace fossils (Asterosoma), plant fragments, ironstone nodules (less common than in underlying units); sharp basal contact.

22. Lane Shale: (0.67 ft., 0.20 m.) 2 ironstone layers and interbedded dark gray (N3) mudstone; ironstone is dark yellowish orange (10 YR 6/6), nodular, with bellerophontacean gastropods, nuculoid bivalves, plant fragments, and wood fragments; sharp basal contact.

T?

21. Lane Shale: (10.0 ft., 3.05 m.) Silty mudstone; med. dark gray (N4), weathers med. to lt. gray (N5 to N7), platy, poorly indurated, micaceous; sandy lenses (indurated), with nearly horizontal trace fossils and plant fragments, ironstone nodules and discontinuous layers of ironstone (basally); gradational basal contact.

20. Lane Shale: (5.67 ft., 1.73 m.) Silty mudstone; med. dark gray fresh (N4), weathers med. to lt. gray (N5 to N7), platy, poorly indurated, micaceous; ironstone nodules (isolated and in discontinuous layers); gradational basal contact.

19. Lane Shale: (4.0 ft., 1.22 m.) Silty mudstone; med. dark gray fresh (N4), weathers med. to lt. gray (N5 to N7), platy, poorly indurated, micaceous; layer of ironstone nodules at top of unit (traceable locally) overlain by 13 cm. layer of abundant crinoids and bellerophontacean gastropods, high-spired gastropods, nuculoid bivalves, other bivalves, bellerophontacean

gastropods, horizontal trace fossils; the middle part of the unit (61 cm. from the base) also contains abundant crinoids, as well as ostracodes (smooth shelled and ornamented), echinoids, brachiopod fragments and spines, microgastropods and bellerophontacean gastropods, ramose and fenestrate bryozoans, Phestia, chonetid brachiopods, cephalopod fragments, scaphopods (Plagioglypta-like), carbonized plant fragments, encrusting tolypamminid and nodosariid forams, scolecodonts, shark and other fish remains, sponge spicules (monaxon and triaxon), and holothurian sclerites; many skeletal fragments have light algal crust, many others are pyritized; basal portions of the unit (from the base to 14 cm. above the base) contain crinoids, brachiopod fragments and spines, ramose and fenestrate bryozoans, bivalve fragments, Hustedia, echinoids, high-spired gastropods, carbonized plant fragments, ostracodes (smooth shelled and ornamented),tolypamminid forams, sponge spicules (monaxon and triaxon), acanthodians, paleoniscoids, and shark remains; many skeletal grains are lightly algal coated, and many others are pyritized, sharp basal contact.

18. Raytown Limestone: (0.08 ft., 0.03 m.) Skeletal packstone to grainstone; med gray fresh (N5), weathers lt. gray (N7), thin bedded, flaggy, lenticular, somewhat argillaceous, minor glauconite; Neospirifer, Composita, productids (Linoproductus and Echinaria), Punctospirifer, fenestrate and ramose bryozoans, crinoids, high-spired gastropods (as steinkerns), bivalve fragments, inarticulate brachiopods, tolypamminid forams, shark remains (including Cladodus), acanthodians, paleoniscoids; skeletal grains are often lightly algal coated, and is elongate parallel to bedding, productids and spirifers are not found in life position, and are sometimes bored (acrothoracicans), possibly a transgressive lag, sharp basal contact.

T5

17. Raytown Limestone: (1.5 ft., 0.46 m.) Wackestone; lt. gray fresh (N7), weathers mottled dark yellowish orange (10 YR 6/6), thick bedded, blocky, forms prominent ledge; Linoproductus, chonetid brachiopods, Composita, crinoids, echinoids, horn coral, bivalve fragments, phylloid algae, brachiopod spines and fragments, small (<1/2 inch in width) bellerophontacean, low-, and high-spired gastropods, fenestrate and ramose bryozoans, ostracodes, Tolypammina, Hyperammina, sponge spicules (monaxon), shark remains, acanthodians, paleoniscoids; productids often in life position, sharp basal contact.

16. Raytown Limestone: (0.42 ft., 0.13 m. - thickness variable) Argillaceous wackestone; lt. gray fresh (N7), weathers grayish orange (10 YR 7/4) to mottled dark yellowish orange (10 YR 6/6), med. bedded, flaggy; Linoproductus, Crurithyris, crinoids, Composita, chonetid brachiopods, horn coral, echinoids, fenestrate and ramose bryozoans, bellerophontacean gastropods, Tolypammina, Hyperammina, sponge spicules (monaxon), shark remains, and paleoniscoids; gradational basal contact.

15. Raytown Limestone: (0.42 ft., 0.13 m. - variable thickness) Wackestone; lt. gray fresh (N7), weathers med. gray (N5) to mottled dark yellowish orange (10 YR 6/6), med. bedded, nodular weathering; Linoproductus, Composita, chonetid brachiopods, small bellerophontacean gastropods, crinoids, rare phylloid algae, ramose and fenestrate bryozoans, brachiopod spines, bivalve fragments, echinoids, horn coral, ostracodes, Tolypammina,

Hyperammina, sponge spicules (monaxon and multi-rayed), shark remains, paleoniscoids, and acanthodians; thin layer (< 1 cm.) of fragmented skeletal grains basally; gradational basal contact.

14. Raytown Limestone: (0.50 ft., 0.15 m. - variable thickness) Argillaceous wackestone; lt. gray fresh (N7), weathers med. gray (N5) to mottled dark yellowish orange (10 YR 6/6), med. to thin bedded, flaggy, med. gray (N5) shale partings; Linoproductus, fenestrate bryozoans, crinoids, echinoids (both plates and spines), brachiopod spines, Composita, high-spired gastropods, ostracodes, Tolypammina, Ammovertella, Hyperammina, sponge spicules (monaxon), shark remains, paleoniscoids, and acanthodians; gradational basal contact.

13. Raytown Limestone: (1.0 ft., 0.30 m.) Wackestone; lt. gray fresh (N7), weathers med. gray (N5) to dark yellowish orange (10 YR 6/6), thick bedded, blocky; Linoproductus, Echinaria, Composita, Neospirifer, Punctospirifer, chonetid brachiopods, coiled cephalopod, crinoids, echinoids, fenestrate and ramose bryozoans, horn coral, bivalve fragments, inarticulate brachiopods, ostracodes, Tolypammina, Ammovertella, Hyperammina, and nodosariid-like forams, sponge spicules (monaxon), shark remains, paleoniscoids, acanthodians; many productid and spiriferid brachiopods appear to be in life position in upper portions of unit, geopedal infillings in brachiopods, apparent crinoidal transgressive lag at the base of the unit, sharp basal contact.

T4

12. Raytown Limestone: (1.75 ft., 0.53 m.) Algal packstone to wackestone; lt. gray fresh (N7), weathers grayish orange (10 YR 7/4) to med. gray (N5), wavy bedded, blocky, "hummocky" surface near the middle of the unit and at the top of the unit; phylloid algae (often forming "umbrella" structures), Composita, crinoids, echinoids, brachiopod spines, low-spired gastropods, Tolypammina, Ammovertella, Hyperammina, and nodosariid forams, sponge spicules (monaxon and triaxon), holothurian sclerites, shark remains, acanthodians, and paleoniscoids; Composita often appears to be in life position, gradational basal contact.

11. Raytown Limestone: (0.50 ft., 0.15 m.) Wackestone; lt. gray fresh (N7), weathers grayish orange (10 YR 7/4) to med. gray (N5), med. bedded, slabby, glauconitic; crinoids (including calyx plates), phylloid algae (increasing in abundance upward in the unit), Composita, high- and low-spired gastropods, chonetid brachiopods, echinoids, Neospirifer, echinoids, fenestrate and ramose bryozoans, productid brachiopods, conulariid ? fragments, inarticulate brachiopods, ostracodes, Tolypammina, Ammovertella, Ammodiscus, shark remains, paleoniscoids, and acanthodians; some skeletal debris preserved only as molds, possible lag deposit at base, sharp basal contact.

10. Raytown Limestone: (0.25 ft., 0.08 m.) Calcareous claystone; med. gray (N5) to grayish yellow green (5 GY 7/2) in top inch, weathers lt. gray (N7), platy, poorly indurated; Chonetinella, Neospirifer, Crurithyris, Hustedia, productids, Punctospirifer, fenestrate and ramose bryozoans, crinoids, ostracodes (smooth shelled and ornamented), echinoids, platycerid gastropods, high- and low-spired gastropods, echinoids, trilobites, Phestia,

conulariid? fragments, nodosariid forams, scolecodonts, shark remains, paleoniscoids, small (< 1 cm.) phosphate nodules?; some skeletal debris preserved only as molds, sharp basal contact.

9. Raytown Limestone: (0.50 ft., 0.15 m.) Skeletal packstone to grainstone; med. gray fresh (N5) weathers grayish orange (10 YR 7/4) to lt. gray (N7), med. bedded, slabby, glauconitic; abundant crinoids, Crurithyris, Chonetinella, brachiopod fragments, conulariids, gastropods, echinoids, fenestrate bryozoans, low spired gastropods, cephalopod fragments, ostracodes, Tolypammina (in clumps), Ammovertella, Ammodiscus, shark remains, and paleoniscoids, flattened to rounded calcareous nodules in base (lithoclasts ?); skeletal grains often elongate parallel to bedding, possible transgressive lag, gradational basal contact.

8. Muncie Creek Shale: (0.08 ft., 0.03 m.) Claystone; grayish yellow green (5 GY 7/2), mottled dark yellowish orange (10 YR 6/6), platy, poorly indurated, glauconitic; large (>5 cm) flattened to nearly spherical calcareous nodules (often bored), cephalopods, Lingula, ramose bryozoans, Hustedia, Crurithyris, Derbyia, crinoids, echinoids, trilobites, Punctospirifer, chonetid brachiopods, plant fragments (carbonized), low-spired gastropods, brachiopod spines, ostracodes (smooth shelled), shark fragments, pyrite lined burrows; some skeletal debris is pyritized, sharp basal contact.

T3

7. Muncie Creek Shale: (1.50 ft., 0.46 m.) Claystone; med. dark gray fresh (N4), weathers med. gray (N5), platy to blocky, poorly indurated; Lingula, gastropods, conulariids (often as the nucleation point for phosphate nodules), some phosphate nodules, pyrite filled burrows, crinoids, bivalve fragments, productid and chonetid brachiopods, echinoids, high spired gastropods, plant fragments, Ammodiscus, sponge spicules (monaxon and triaxon), holothurian sclerites, ostracodes (smooth shelled), cephalopod fragments, shark remains; fossils most abundant in the middle of the unit, sharp basal contact.

6. Muncie Creek Shale: (1.67 ft., 0.51 m.) Clayshale; black (N1), weathers med. to lt. gray (N5 to N7), fissile, indurated; flattened and spherical phosphate nodules, conulariids, Orbiculoidea, Ammodiscus, tube-like forams?, sponge spicules (monaxon and triaxon), shark remains (including Cladodus), plant fragments; gradational basal contact.

T?

5. Muncie Creek Shale: (0.75 ft., 0.23 m.) Clayshale; dark gray (N3), platy to fissile, poorly indurated, Lingula, brachiopod, bivalve, and cephalopod fragments, microgastropods, fenestrate and ramose bryozoans, crinoids, echinoids, chonetid and productid brachiopods, Crurithyris, trilobites, pellets, plant fragments, ostracodes (smooth shelled and ornamented), Ammodiscus, tolypamminid forams, shark remains, acanthodians, Zoophycus; some skeletal fragments pyritized, and often flattened on bedding planes, very sharp basal contact.

T2

4. Paola Limestone: (1.00 ft., 0.30 m.) Wackestone to packstone in upper 0.08

ft.; lt. brownish gray (5 YR 6/1) fresh, weathers med. gray (N5), med. to thick bedded, blocky; crinoids (abundant basally), Crurithyris, chonetid brachiopods, echinoids (spines and plates), productid brachiopods, high- and low- spired gastropods, horn corals, fusulinids, Composita, Hustedia, calcareous sponges, phosphate nodules and rhodoliths in upper 0.25 ft., ostracodes, sponge spicules (monaxon and multi-rayed), holothurian sclerites, tolypamminid and nodosariid forams, abundant shark remains, acanthodians, and paleoniscoids; skeletal grains often pyritized, most skeletal grains in upper 5 cm. disarticulated and fragmented, gradational basal contact.

3. Chanute Shale: (0.42 ft., 0.13 m.) Calcareous shale; greenish gray fresh (5 GY 6/1), weathers mottled dark yellowish orange (10 YR 6/6), platy, poorly indurated; crinoids, fenestrate and ramose bryozoans, Crurithyris, chonetid and productid brachiopods, Derbyia, bivalve fragments, encrusting algae and tolypamminid forams, ostracodes (ornamented and smooth shelled), shark remains, pyrite; gradational basal contact.

2. Chanute Shale: (1.75 ft., 0.53 m.) Mudstone; med. dark gray (N4), weathers lt. gray (N7), platy, poorly indurated, sandy; Lingula, productids, brachiopod spines, bivalve fragments, crinoids, echinoids, high- and low-spired gastropods, fenestrate and ramose bryozoans, carbonized plant fragments, shark remains; quartz grains, skeletal fragments often well rounded, sharp basal contact.

T1.1

1. Chanute Shale: (6.25 ft., 1.91 m.+) Silty mudstone; lt. olive gray fresh (5 Y5/2), weathers med. to lt. gray (N5 to N7), platy to blocky, poorly indurated, calcareous nodules basally and becomes sandy basally.

Holliday Drive (HDMC)
Muncie Creek
100 yards west of HD
Edwardsville Quadrangle
SW NE NW sec.6 T12S R24E
Johnson County, Kansas

4. Muncie Creek Shale: (0.08 ft., 0.03 m.) Claystone; grayish yellow green (5 GY 7/2), mottled dark yellowish orange (10 YR 6/6), platy, poorly indurated, glauconitic; large (>5 cm) flattened to nearly spherical calcareous nodules (often bored), cephalopods, Lingula, ramose bryozoans, Hustedia, Crurithyris, Derbyia, crinoids, echinoids, trilobites, Punctospirifer, chonetid brachiopods, plant fragments (carbonized), low-spired gastropods, brachiopod spines, ostracodes (smooth shelled), shark fragments, pyrite lined burrows; some skeletal grains are pyritized, sharp basal contact.

T3

3. Muncie Creek Shale: (1.50 ft., 0.46 m) Claystone; med. dark gray fresh (N4), weathers med. gray (N5) to yellowish gray (5 Y 8/1), platy to blocky, poorly indurated; Pyrite filled burrows, up to 0.5 cm wide (Planolites, and Chondrites), Lingula, gastropods, conulariids (often as the nucleation point for phosphate nodules), some phosphate nodules, crinoids, bivalve fragments, productid and chonetid brachiopods, echinoids, high spired gastropods, orthoconic and coiled cephalopods, pectins, Phestia, Astartella, plant fragments, Ammodiscus, sponge spicules (monaxon and triaxon), holothurian sclerites, ostracodes (smooth shelled), cephalopod fragments, shark remains; fossils most abundant in the middle of the unit, becoming less fossiliferous upwards and towards base, sharp basal contact.

2. Muncie Creek Shale: (1.83 ft., 0.56 m.) Clayshale; black (N1), weathers med. to lt. gray (N5 to N7), fissile, indurated; flattened and spherical phosphate nodules (most abundant in upper half of unit), conulariids, Orbiculoidea, Ammodiscus, tube-like forams?, sponge spicules (monaxon and triaxon), shark remains (including Cladodus), plant fragments, biota found in phosphate nodules includes, miospores, ostracodes, radiolarians, cephalopod and bivalve fragments, radiolarians, small forams (Ammodiscus, and Rheophax like), lycopods and other plant remains, paleoniscoid, shark, and other fish remains, sponges, and crinoids; gradational basal contact.

T?

1. Muncie Creek Shale: (1.83 ft., 0.56 m.) Clayshale; dark gray (N3), weathers lt. brownish gray (5 YR 6/1), platy to fissile, poorly indurated, Lingula, brachiopod, bivalve, and cephalopod fragments, microgastropods, fenestrate and ramose bryozoans, crinoids, pectins, echinoids, chonetid and productid brachiopods, Crurithyris, trilobites, pellets, plant fragments, ostracodes (smooth shelled and ornamented), Ammodiscus, tolypamminid forams, shark remains, acanthodians, Zoophycus; some skeletal fragments pyritized, and often flattened on bedding planes, biota decreases in abundance upwards, very sharp basal contact.

T2

Osawatomie (OSA)
east side of U. S. highway 169,
just north of the Marias des Cygnes River bridge,
Paola West Quadrangle
SE SE SW sec.1, T18S R22E
Miami County, Kansas

22. Raytown Limestone: (0.42 ft., 0.13 m.) Wackestone; lt. gray (N7) fresh, weathers med. gray (N5), med. bedded, slabby, spar filled vugs; crinoids, echinoids, high spired gastropods, productids, bivalve fragments, encrusting tolypamminid forams, nodosariid forams, Hyperammina, shark remains, paleoniscoids; many skeletal grains are fragmented, thin (< 1 cm.) caliche crust (modern?) on top surface; basal contact sharp..

21. Raytown Limestone: (1.58 ft., 0.48 m.) Wackestone; lt. gray (N7) fresh, weathers med. gray (N5), med. to thin bedded, slabby; crinoids, productids, Composita, myalinids (often articulated, but not in situ), echinoids, high and low spired gastropods, encrusting forams (tolypamminids), small forams (Nodosaria-like), Hyperammina, sponge spicules (monaxon, triaxon, and ornate 6-rayed), holothurian sclerites, shark remains, paleoniscoids, pellets; basal contact sharp.

20. Raytown Limestone: (1.67 ft., 0.52 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), thin to med. bedded, slabby; crinoids, fenestrate and ramose bryozoans, Linoproductus, Echinaria, Composita, phylloid algae, echinoids, horn coral, holothurian sclerites (hooks and wheels), sponge spicules (monaxon, triaxon, and six rayed), ostracodes, brachiopod spines, shark denticles and spines, paleoniscoid denticles, acanthodian scales, tolypamminid and Nodosaria-like forams; sharp contact lithologically, sharp faunal change.

T4

19. Raytown Limestone: (0.92 ft., 0.28 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), thick bedded, blocky; crinoids, phylloid algae, Composita, chonetid brachiopods, echinoid plates and spines, fenestrate (large fronds) and ramose bryozoans, ostracodes, Ammovertella, Tolypammina, Hyperammina,and nodosariid forams, sponge spicules (triaxon, and ornate multi-rayed forms), holothurian sclerites (hooks and wheels), paleoniscoids and acanthodians, shark remains, quartz silt and sand; basal contact sharp.

18. Raytown Limestone: (0.42 ft., 0.13 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; crinoids, phylloid algae, Composita, productids, crinoids, echinoids, low spired gastropods, ostracodes, Tolypammina, Hyperammina, Ammovertella, sponge spicules (ornate, multi-rayed forms), shark remains, paleoniscoids; basal contact sharp.

17. Raytown Limestone: (0.84 ft., 0.25 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), thick bedded, blocky; phylloid algae, crinoids, Composita, productid brachiopods, Hyperammina, Tolypammina, Ammovertella, paleoniscoids, minor pyrite;

basal contact sharp.

16. Raytown Limestone: (0.34 ft., 0.10 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), medium bedded, slabby, spar filled vugs, textural and bedding change relative to underlying units (bedding thickness is reduced and skeletal debris becomes finer grained), crinoids, phylloid algae, Composita, productid brachiopods, brachiopod spines, echinoids, low spired gastropods, Hyperammina, Tolypammina, sponge spicules (triaxon), holothurian sclerites, shark remains, paleoniscoids; basal contact sharp.

15. Raytown Limestone: (1.75 ft., 0.53 m.) Algal wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy bedded, blocky, hummocky upper surface; phylloid algae, Composita, crinoids, fenestrate, ramose, and cystoporate? bryozoans, brachiopod spines, echinoids, low spired gastropods, high spired gastropods, productid brachiopods, ostracodes, Hyperammina, Ammovertella, Tolypammina, and nodosariid forams, sponge spicules (triaxon and monaxon), holothurian sclerites, shark remains, acanthodians, scolecodonts; basal contact sharp.

14. Raytown Limestone: (0.75 ft., 0.23 m.) Algal wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy bedded, blocky; phylloid algae, Composita, crinoids, fusulinids, echinoids, brachiopod spines, chonetid brachiopods, Hustedia, fenestrate and ramose bryozoans, productid brachiopods, high spired gastropods, ostracodes, Tolypammina, Hyperammina, Ammovertella, and nodosariid forams, sponge spicules (monaxon, triaxon, and robust multi-rayed forms), holothurian sclerites, shark remains, paleoniscoids, acanthodians, scolecodonts; basal contact sharp.

13. Raytown Limestone: (2.08 ft., 0.64 m.) Algal wackestone to packstone (at base); lt. gray fresh (N7), weathers pale yellowish orange (10 YR 8/6) to mottled dk. yellowish orange (10 YR 6/6), thick bedded, blocky; phylloid algae, Composita, chonetid brachiopods, crinoids (most abundant basally), productid brachiopods, Neospirifer, Hustedia, brachiopod spines, ostracodes, fenestrate and ramose bryozoans, sponges, trilobites, echinoids, high spired gastropods, Hyperammina, Tolypammina, Ammovertella, and nodosariid forams, sponge spicules (monaxon and triaxon), shark remains, paleoniscoids, acanthodians; skeletal grains in basal 6 cm. fragmented and parallel to bedding, sharp basal contact.

12. Muncie Creek Shale: (0.17 ft., 0.05 m.) Calcareous mudstone; dk. greenish yellow (10 Y 6/6), weathers lt. gray (N7) to dark yellowish orange (10 YR 6/6), platy, poorly indurated; crinoids (both columnals and calyx plates), Crurithyris, Neospirifer, Chonetinella, Hustedia, small productids, Punctospirifer, fenestrate and ramose bryozoans, echinoids, small forams, brachiopod spines, several small (<1mm) phosphate nodules, bivalve fragments, shark remains; moldic preservation of fossils common, gradational basal contact.

11. Muncie Creek Shale: (0.17 ft., 0.05 m.) Calcareous mudstone; med. gray (N5) fresh, weathers lt. gray (N7) to mottled dark yellowish orange (10 YR 6/6), platy, poorly indurated; phosphate nodules (oval to nearly round) basally, Crurithyris, Hustedia, crinoids, small (<3mm wide) low-spired

gastropods, bivalve fragments, gastropod fragments, brachiopod spines, shark remains; moldic preservation of fossils common, sharp basal contact.

T2

10. Paola Limestone: (1.00 ft., 0.31 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. (N7) to med. gray (N5), med. bedded, blocky, hummocky or irregular upper surface (scoured); burrows, rhodoliths (both oval and laminar types) throughout, phylloid algae near the base of unit, bellerophontacean, high, and low spired gastropods, fusulinids, trilobites, crinoids, echinoids, horn corals, fenestrate and ramose bryozoans, Composita (near the base of unit), ostracodes, Hyperammina, Tolypammina, Ammovertella, sponge spicules (triaxon), holothurian sclerites (wheels), shark remains, paleoniscoids, scaphopods?, algal coated grains; many skeletal grains fragmented, few articulated brachiopods, basal contact sharp.

9. Paola Limestone: (1.75 ft. 0.53 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers med. (N5) to lt. gray (N7), med. to thick bedded (upwards), blocky, sandy and micaceous basally; burrows and rhodoliths (Archaeolithophyllum ?) near top, phylloid algae, Composita, crinoids (very abundant near the base of the unit), Hustedia, echinoids, brachiopod spines, fenestrate and ramose bryozoans, productid brachiopods, Lingula, bivalve fragments, high spired gastropods, plant fragments (basally), ostracodes, Hyperammina, Tolypammina, Ammovertella, and nodosariid forams, sponge spicules (triaxon), holothurian sclerites, numerous shark remains, paleoniscoids, acanthodians, pyrite, glauconite?; some skeletal fragments are pyritized, articulated brachiopods common in most of unit, except near top where many are fragmented, gradational basal contact.

8. Chanute Shale: (0.25 ft., 0.08 m.) Sandy calcareous mudstone; med. gray fresh (N5), weathers mottled dark yellowish orange (10 YR 6/6), platy to flaggy, moderately indurated, sandy and micaceous; very fine quartz sand, minor pyrite, crinoids, productid brachiopods, Crurithyris, Hustedia, echinoids, ramose bryozoans, brachiopod spines, bivalve fragments, plant fragments, Tolypammina, Ammovertella, shark remains; sharp basal contact.

T1

7. Chanute Shale: (0.75 ft., 0.23 m.) Sandy mudstone; olive gray (5 YR 3/2) fresh, weathers mottled orange brown, platy, poorly indurated; abundant plant fragments; gradational basal contact.

6. Chanute Shale: (2.75 ft. 0.84 m.) Silty mudstone; medium dark gray (N4) fresh, weathers med. gray (N5), platy to flaggy, poorly indurated; sparse sandy calcareous lenses near base, Lingula; gradational basal contact.

5. Chanute Shale: (4.75 ft., 1.45 m.) Interbedded silty mudstone and very fine grained sandstone; medium dark gray fresh (N4), weathers med. gray (N5), platy, micaceous, poorly indurated; numerous (indurated) sandy calcareous lenses, Lingula, Planolites like trace fossils (associated with sandy lenses); gradational basal contact.

4. Chanute Shale: (2.17 ft., 0.66 m.) Mudstone; medium dark gray (N4) fresh,

weathers med. gray (N5), platy, silty, poorly indurated; Lingula, Crurithyris, pectinid bivalves, rare sandy calcareous lenses; sharp basal contact.

3. Chanute Shale: (0.08 ft., 0.03 m.) Calcareous shale; dark gray (N3) fresh, weathers med. gray (N5), platy to fissile, moderately indurated; crinoids, Crurithyris, plant fragments; sharp basal contact.

T

2. Chanute Shale (Thayer Coal): (0.25 ft., 0.08 m.) Bituminous coal.

CC (Climate Change Surface?)

1. Chanute Shale: (5.25 ft., 1.60 m.+) Mudstone; olive gray (5 YR 3/2), weathers med. gray (N5), blocky, silty; selenite, plant fragments (increasing in abundance upward).

Patrician Woods (PW)
just west of the Patrician Woods
Housing Development
Lenexa Quadrangle
Center of sec. 21, T13S R25E
Johnson County, Kansas

11. Raytown Limestone: (1.50 ft., 0.46 m.) Packstone to wackestone; lt. med. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), wavy bedded, blocky; phylloid algae, crinoids, Composita, fenestrate and ramose bryozoans; brachiopods often articulated, and some in life position, gradational basal contact.

10. Raytown Limestone: (0.25 ft., 0.08 m.) Packstone to wackestone (crinoidal); lt. med. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), thin bedded, slabby; crinoids, phylloid algae, Composita, echinoids, bryozoans; sharp basal contact.

9. Muncie Creek Shale: (0.17 ft., 0.05 m.) Claystone; dk. yellowish green (10 Y 6/6), weathers mottled dk. yellowish orange (10 YR 6/6) (possibly due to modern rooting), platy, poorly indurated, slightly calcareous; Chonetinella, Composita, Crurithyris, Neospirifer, fenestrate and ramose bryozoan, crinoids columnals, and calyx plates, echinoids; gradational basal contact.

8. Muncie Creek Shale: (0.25 ft., 0.08 m.) Claystone; med. gray (N5) fresh, weathers lt. gray (N7), platy, poorly indurated, calcareous; small (<1 mm) phosphate nodules, Crurithyris, Hustedia, crinoids, ramose bryozoans, rare (1-3) Composita and Punctospirifer, ostracodes; sharp basal contact.

7. Muncie Creek Shale: (0.25 ft., 0.08 m.) Packstone to grainstone; very argillaceous, med. gray (N5) fresh, weathers to a mottled dk. yellowish orange (10 YR 6/6), thin bedded, flaggy; crinoids, fenestrate bryozoans, Crurithyris, conulariids, phosphate nodules in base; becomes shaley at base, sharp basal contact.

T2-T3

6. Paola Limestone: (1.17 ft., 0.36 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6), thick bedded, massive, flaggy at base; rhodoliths in upper 1/3, burrowed or rooted in upper 2/3, crinoids, Crurithyris, phylloid algae (mostly in the bottom 2/3 of the unit), bellerophontacean gastropods, conulariids and phosphate nodules often embedded in upper surface of the unit; skeletal grains disarticulated and fragmented in upper 1/3, gradational basal contact.

5. Paola limestone: (0.25 ft., 0.08 m.) Grainstone to packstone; lt. brownish gray (5 YR 6/1) to med. gray (N5) upward, weathers pale yellowish orange (10 YR 8/6), thin bedded, flaggy, sandy; crinoids, fenestrate and ramose bryozoans, Hustedia, Crurithyris, chonetid and productid brachiopods; sharp basal contact.

T1

4. Chanute Shale: (8.50 ft., 2.59 m.) Siltstone to mudstone; dark greenish

yellow (10 Y 6/6), platy, silty to sandy, slightly micaceous, poorly indurated; numerous plant fragments; sharp basal contact.

3. Chanute Shale: (1.42 ft.,0.43 m.) very fine grained , thin bedded (1/4 to 1 inch), lt. gray (N7) sandstone interbedded with thin beds of sandy siltstone; carbonized plant fragments, ostracodes?, nearly horizontal trace fossils; gradational basal contact.

2. Chanute Shale: (0.42 ft., 0.13 m.) Interbedded lt. gray (N7) sandy limestone, and micaceous siltstone; plant fragments and carbonized wood fragments; sharp basal contact.

T

1. Chanute Shale: (1.00 ft., 0.30 m.) Silty mudstone; med. dark gray (N4), platy, micaceous, poorly indurated; plant fragments, becomes sandy toward the top.

Redel (R)
South of the town of Redel
Stilwell Quadrangle
NE SE SE sec. 16, T14S, R25E
Johnson County, Kansas

18. Raytown Limestone: (1.08 ft., 0.33 m.) Wackestone; lt. gray (N7) fresh, weathers lt. yellowish ornange (10 YR 8/6), caps the section, possibly not in situ, thick bedded, blocky; Echinaria, Linoproductus, Neospirifer, crinoids, fenestrate bryozoans.

T?

17. Raytown Limestone: (3.08 ft., 0.94 m.) Packstone to wackestone; med. lt. gray (N6) fresh, weathers med. dk. gray (N4), med. to thin bedded upwards, slabby to flaggy; somewhat argillaceous, fenestrate bryozoans, Neospirifer, crinoids, Echinaria, rugose coral; brachiopods often articulated and in situ, sharp basal contact.

T4

16. Raytown Limestone: (0.50 ft., 0.15 m.) Wackestone; med. lt. gray (N6) fresh, weathers med. dark gray (N4), med. bedded, blocky to slabby; Linoproductus, crinoids, Composita, some phylloid algae; skeletal grains generally disarticulated, sharp basal contact.

15. Raytown Limestone: (0.75 ft., 0.23 m.) Wackestone to packstone; med. lt. gray (N6) fresh, weathers med. dark gray (N4), med. bedded, blocky; Linoproductus, crinoids, phylloid algae, Composita; sharp basal contact.

14. Raytown Limestone: (0.83 ft., 0.25 m.) Algal packstone to wackestone; med. lt. gray fresh, weathers med. dk. gray (N4) wavy bedded, slabby to flaggy, phylloid algae, Composita, (thickness of bed variable, and appears to pinch out several meters to the south).

13. Raytown Limestone: (1.20 ft., 0.36 m.) Algal packstone; med. lt. gray (N6), weathers pale yellowish orange (10 YR 8/6), wavy bedded, blocky; phylloid algae, Composita, crinoids; brachiopods often articulated, gradational contact.

12. Raytown Limestone: (0.58 ft., 0.18 m.) Packstone; med. lt. gray (N6), weathers pale yellowish orange (10 YR 8/6), med. bedded, slabby; crinoids basally, phylloid algae increasing upwards, Composita, gastropods, chonetid brachiopods; sharp basal contact.

11. Muncie Creek Shale: (0.17 ft., 0.05 m.) Calcareous claystone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), poorly indurated, platy; Chonetinella, Crurithyris, Neospirifer, fenestrate and ramose bryozoans, crinoids, small (<3mm) phosphate nodules, echinoids; gradational basal contact.

10. Muncie Creek Shale: (0.25 ft., 0.08 m.) Calcareous claystone; med. gray (N5) fresh, weathers lt. gray (N7), platy, poorly indurated; Crurithyris, Hustedia, crinoids; sharp basal contact.

9. Muncie Creek Shale: (0.25 ft., 0.08 m.) Argillaceous packstone to grainstone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. gray (N7), thin bedded flaggy, crinoids, fenestrate bryozoans, Crurithyris, Hustedia; sharp basal contact.

T3

8. Muncie Creek Shale: (0.08 ft., 0.03 m.) Calcareous clay-shale; med. gray (N5) fresh, weathers lt. gray (N7), platy to fissile, poorly indurated, phosphate nodules, Crurithyris, crinoids; sharp basal contact.

T2

7. Paola Limestone: (1.25 ft., 0.38 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6), thick bedded, blocky, argillaceous and flaggy at base; borrowing (Thallasinoides-like) in upper 2/3, rhodoliths in upper 1/3, crinoids most abundant basally, phylloid algae, Composita, bellerophontacean gastropods, small high-spired gastropods, trilobites (Ditomopyge?); gradational basal contact.

6. Paola Limestone: (0.17 ft., 0.05 m.) Crinoidal packstone to grainstone; lt. brownish gray (5 YR 6/1) to med. lt. gray (N6) fresh, weathers lt. gray (N7), thin bedded, slabby; crinoids (crinoidal lag?), fenestrate bryozoans, Crurithyris, Hustedia?; sharp basal contact.

T1

5. Chanute Shale: (3.75 ft., 1.14 m.) Siltstone; olive gray (5 YR 3/2), platy, poorly indurated; abundant plant fragments, carbonaceous near top and bottom;

4. Chanute Shale: (0.83 ft., 0.25 m.) Interbedded very fine grained sandstone and siltstone, med. gray (N5), thin bedded, platy, moderately well indurated near top; plant fragments, small high-spired gastropods, horizontal and vertical trace fossils, small cone shaped trace fossils.

3. Chanute Shale: (2.92 ft., 0.89 m.) Siltstone; med. dark gray (N4), slightly micaceous, silty, platy to flaggy, poorly indurated; Lingula, bellerophontacean gastropods, small planispiral gastropods, becomes sandier with increasing plant fragments near the top; sharp basal contact.

T

2. Chanute Shale: (0.25 ft., 0.08 m.) Sandy argillaceous mudstone; med. gray (N5) fresh, weathers dk. yellowish orange (10 YR 6/6), thin bedded, flaggy, moderately well indurated; nearly horizontal trace fossils (Planolites like); gradational basal contact.

1. Chanute Shale: (1.00 ft., 0.30 m.+) Siltstone: med. dark gray (N4), platy, slightly micaceous, poorly indurated; plant fragments.

Camp Branch (CB)
West side of Missouri Pacific Railroad cut
Stilwell Quadrangle
NW NW NE sec. 28, T14S R25E
Johnson County, Kansas

12. Raytown Limestone: (2.83 ft., 0.86 m.) Packstone; med. lt. gray (N6) fresh, weathers med. dark gray (N4) to mottled dk. yellowish orange (10 YR 6/6), thin to med. bedded, slabby to flaggy, argillaceous; fenestrate bryozoans, Neospirifer, Chonetinella, Linoproductus, Echinaria, crinoids; brachiopods on the top surface of bed appear to be bored, sharp basal contact.

T4

11. Raytown Limestone: (0.83 ft, 0.25 m.) Wackestone; med. gray (N5) fresh, weathers pale yellowish orange (10 YR 8/6) to mottled dk. yellowish orange (10 YR 6/6), med. bedded, blocky, flaggy and argillaceous at base; phylloid algae and Composita dominant in bottom 2/3, Linoproductus and crinoids in upper 1/3; sharp basal contact.

10. Raytown Limestone: (1.42 ft.,0.43 m.) Algal wackestone to packstone; med. gray (N5) fresh, weathers pale yellowish orange (10 YR 8/6), med. bedded, blocky to slabby; phylloid algae, Composita, crinoids, echinoids, bryozoans; sharp basal contact.

9. Raytown Limestone: (1.0 ft., 0.30 m.) Algal wackestone to packstone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), thick bedded, blocky; phylloid algae, Composita, crinoids, echinoids, bryozoans; sharp basal contact.

8. Raytown Limestone: (1.16 ft., 0.36 m.) Algal wackestone to packstone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), thick bedded, blocky; phylloid algae, Composita, crinoids, Chonetinella, echinoids, bryozoans; sharp basal contact.

7. Muncie Creek Shale: (0.16 ft., 0.05 m.) Claystone; calcareous, dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy, poorly indurated; Chonetinella, Crurithyris, fenestrate and ramose bryozoans, Neospirifer, Composita, crinoids; gradational basal contact.

6. Muncie Creek Shale: (0.16 ft., 0.05 m.) Calcareous claystone; med. gray (N5) fresh, weathers lt. gray (N7) to lt. brownish gray (5 YR 6/1), platy, poorly indurated; Crurithyris, Hustedia, crinoids, phosphate nodules basally; sharp basal contact.

T2

5. Paola Limestone: (1.33 ft., 0.41 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6), thick bedded, flaggy at base, rest is blocky; crinoids abundant at base, hummocky upper surface, upper 2/3 burrowed or rooted, rhodoliths in upper 1/3, phylloid algae, Composita, bellerophontacean gastropods, fusulinids, trilobites, encrusting forams; gradational lower contact.

4. Paola Limestone: (0.25 ft., 0.08 m.) Skeletal packstone; med. gray (N5) to lt. brownish gray (5 YR 6/1) (upwards) fresh, weathers tan, thin bedded, slabby to flaggy; crinoids, Crurithyris, Hustedia?, fenestrate and ramose bryozoans; overlain by thin (1 cm.) shaley parting, sharp basal contact.

T1

3. Chanute Shale: (1.75 ft., 0.53 m.) Silty mudstone; dark gray (N5) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; Lingula, plant fragments; gradational basal contact.

2. Chanute Shale: (2.0 ft., 0.61 m.) Silty mudstone; olive (5 YR 3/2) gray fresh, weathers lt. gray (N7), platy, somewhat micaceous, some sand, poorly indurated; plant fragments; gradational lower contact.

1. Chanute Shale: (2.0 ft., 0.61 m. +) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), micaceous, platy; Lingula, plant fragments.

Blue River (BR)
approximately 0.33 miles
east of Kansas Highway 69
Stilwell Quadrangle
NW SW SW sec. 20, T14S R25E
Johnson County, Kansas

11. Raytown Limestone: (1.83 ft., 0.56 m.) Packstone to wackestone (packstone in upper 0.02 m.); med. lt. gray (N6) fresh, weathers med. gray (N5) to pale yellowish orange (10 YR 8/6), argillaceous, thin bedded, flaggy to slabby; fenestrate bryozoans, Linoproductus, Chonetinella, Neospirifer, Composita, crinoids, horn coral; skeletal grains on top surface often bored and encrusted with algae, sharp lower contact.

T?

10. Raytown Limestone: (0.42 ft., 0.13 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6), thin bedded, flaggy to slabby; crinoids, phylloid algae, underlain by 1 inch shaley parting; sharp basal contact.

9. Raytown Limestone: (1.50 ft., 0.46 m.) Wackestone to packstone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), wavy bedded, blocky to slabby; Linoproductus, phylloid algae, Composita, Chonetinella near the top, crinoids; sharp basal contact.

T4

8. Raytown Limestone: (0.83 ft., 0.25 m.) Algal packstone to wackestone; med. lt. gray (N6), weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), wavy bedded, blocky; phylloid algae, Composita, crinoids; sharp basal contact.

7. Raytown Limestone: (0.50 ft., 0.15 m.) Algal packstone to wackestone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), med. bedded, slabby; phylloid algae, Composita, large crinoids (> 0.5 cm. in diameter); sharp basal contact.

6. Raytown Limestone: (0.67 ft., 0.20 m.) Wackestone to packstone; med. lt. gray (N6) fresh, weathers lt. gray (N7) to pale yellowish ornage (10 YR 8/6), med. bedded, blocky; crinoids dominant basally, phylloid algae increases in abundance upward, Composita, echinoids; sharp basal contact.

5. Muncie Creek Shale: (0.17 ft., 0.05 m.) Calcareous clay-shale; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy to fissile, poorly indurated; Chonetinella, Crurithyris, fenestrate and ramose bryozoans, crinoids, Neospirifer, Hustedia, gradational basal contact.

4. Muncie Creek Shale: (0.17 ft., 0.05 m.) Calcareous claystone: med. gray (N5) fresh, weathers lt. gray (N7) to lt. brownish gray (5 YR 6/1), platy, poorly indurated; phosphate nodules basally, Crurithyris, Hustedia, crinoids, cephalopod fragments, rare chonetid brachiopods and Neospirifer,

brachiopod spines; sharp basal contact.

T2

3. Paola Limestone: (1.50 ft., 0.46 m.) Wackestone to packstone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), thick bedded, blocky; phylloid algae, Composita, small high-spired gastropods, bellerophontacean gastropods, rhodoliths in upper 1/3, burrowing in upper 2/3, hummocky upper surface; gradational basal contact.

2. Paola Limestone: (0.17 ft., 0.05 m.) Crinoidal packstone to grainstone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6), thin bedded, flaggy; crinoids, Hustedia?, Crurithyris; sharp basal contact.

T1

1. Chanute Shale: (1.75 ft., 0.53 m.) Siltstone; olive gray (5 YR 3/2) fresh, weathers lt. gray (N7) and mottled dk. yellowish orange (10 YR 6/6), poorly indurated, sandy, carbonaceous; plant fragments.

Cedar Creek (CC)
North side of Kansas Highway 10
De Soto Quadrangle
NE SW NW sec. 6, T13S R23E
Johnson County, Kansas

25. Wyandotte Limestone: (1.00 ft., 0.30 m. +) Algal wackestone to packstone; lt gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy bedded, blocky; phylloid algae, Composita, crinoids; gradational basal contact.

24. Lane Shale: (0.33 ft., 0.10 m.) Calcareous shale; med. gray (N5) fresh, weathers moderate reddish brown (10 R 4/6), platy to fissile, poorly indurated; crinoids (possible crinoidal lag), Crurithyris, productids, bryozoans; sharp basal contact.

T

23. Lane Shale: (6.33 ft., 1.93 m.) Silty mudstone; olive gray (5 YR 3/2) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), micaceous, platy, poorly indurated; plant fragments, nearly horizontal trace fossils; gradational basal contact.

22. Lane Shale: (12.50 ft., 3.81 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; scattered sandy lenses, plant fragments, nearly horizontal trace fossils; gradational basal contact.

21. Lane Shale: (7.58 ft., 2.31 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, micaceous, scattered sandy lenses; nearly horizontal trace fossils, plant fragments; gradational basal contact.

T?

20. Lane Shale: (0.58 ft., 0.18 m.) Silty mudstone; olive gray (5 YR 3/2) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated; plant fragments; gradational basal contact.

19. Lane Shale: (7.92 ft., 2.41 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; plant fragments, sandy lenses with nearly horizontal trace fossils and possible ripple marks, rare ironstone nodules; gradational basal contact.

18. Lane Shale: (2.92 ft., 0.89 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; sandy lenses with nearly horizontal trace fossils, ironstone nodules in upper 1/2 of unit, plant fragments (very abundant in sandy lenses); gradational basal contact.

T?

17. Lane Shale: (2.5 ft., 0.76 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, poorly indurated, micaceous; crinoids, bellerophontacean and planispiral gastropods, ironstone nodules; sharp basal contact.

16. Raytown Limestone: (0.17 ft., 0.05 m.) Packstone to grainstone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), thin bedded, flaggy, argillaceous; fenestrate and ramose bryozoans, Neospirifer, crinoids, Composita, brachiopod spines and shell fragments; sharp basal contact.

T5

15. Raytown LImestone: (1.41 ft., 0.43 m.) Wackestone; med. lt. gray (N6) fresh, weathers mottled dk. yellowish orange (10 YR 6/6), thick bedded, blocky; Echinaria, Linoproductus, Neospirifer, crinoids; sharp basal contact.

T?

14. Raytown Limestone: (2.83 ft., 0.86 m.) Packstone to wackestone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6) to mottled dk. yellowish orange (10 YR 6/6), thin bedded, slabby to flaggy, argillaceous; fenestrate bryozoans, Echinaria, Linoproductus, Chonetinella, crinoids, Composita, rugose coral; sharp basal contact.

13. Raytown Limestone: (0.67 ft., 0.20 m.) Packstone to wackestone (upward); lt. gray (N7), weathers med. gray (N5) to pale yellowish orange (10 YR 8/6), med. bedded. slabby; crinoids (possible crinoidal lag at base), Linoproductus, fenestrate bryozoans; sharp basal contact.

T4

12. Raytown Limestone: (1.17 ft., 0.35 m.) Algal packstone to wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to mottled dk. yellowish orange (10 YR 6/6), wavy bedded, blocky to slabby; phylloid algae, Composita, crinoids, Linoproductus; sharp basal contact.

11. Raytown Limestone: (0.92 ft., 0.28 m.) Algal packstone to wackestone; lt. gray (N7), weathers pale yellowish orange (10 YR 8/6) to mottled dk. yellowish orange (10 YR 6/6), wavy bedded, blocky; phylloid algae, Composita, crinoids; gradational basal contact.

10. Raytown Limestone: (0.67 ft., 0.20 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to dk. yellowish orange (10 YR 6/6), med. bedded, slabby; crinoids dominant in lower 1/2, phylloid algae (increasing in abundance upward), Composita, bellerophontacean gastropods, Girtyocoelia?; sharp basal contact.

9. Muncie Creek Shale: (0.33 ft., 0.10 m.) Claystone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated, slightly calcareous; Chonetinella, Neospirifer, Crurithyris (most brachiopods preserved only as molds), fenestrate and ramose bryozoans, crinoids; gradational basal contact.

8. Muncie Creek Shale: (0.33 ft., 0.10 m.) Calcareous shale; med. dark gray (N4) fresh, weathers lt. gray (N7), platy to fissile, moderately well indurated, glauconitic; crinoids (possible crinoidal lag), Crurithyris, large phosphate nodules at base (possibly reworked); sharp basal contact.

T3

7. Muncie Creek Shale: (1.25 ft., 0.38 m.) Clayshale; dark gray (N3) to black (N1) fresh, weathers med. lt. gray (N6), papery, moderately well indurated; phosphate laminae and nodules, microfossils, conulariids, inarticulate brachiopods; gradational basal contact.

T?

7. Muncie Creek Shale: (0.08 ft., 0.02 m.) Clayshale; dark gray (N3) fresh, weathers med. gray (N5), platy to fissile, poorly indurated; Lingula; very sharp basal contact.

T2

6. Paola Limestone: (1.33 ft., 0.41 m.) Wackestone to packstone; med. lt. gray (N6) to lt. brownish gray (5 YR 6/1), weathers pale yellowish orange (10 YR 8/6), thick bedded, blocky; phylloid algae, Composita, crinoids, rugose coral, bellerophontacean gastropods, rhodoliths near top; gradational basal contact.

5. Paola Limestone: (0.67 ft., 0.20 m.) Wackestone to packstone (upwards); lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6), medium bedded, slabby; crinoids dominant at base, increasing phylloid algae upward, Composita; gradational basal contact.

4. Chanute Shale: (0.25 ft., 0.08 m.) Calcareous shale; lt. brownish gray (5 YR 6/1) fresh, weathers med. gray (N5), platy to fissile, moderately well indurated; small productid brachiopods, brachiopod spines and shell fragments, Derbyia, crinoids; sharp basal contact.

T1

3. Chanute Shale: (0.58 ft., 0.18 m.) Silty mudstone; olive gray (5 YR 3/2) fresh, weathers lt. gray (N7), platy, poorly indurated; Crurithyris, pectinid bivalves, plant fragments; sharp basal contact.

2. Chanute Shale: (0.17 ft., 0.05 m.) Argillaceous wackestone; med. gray (N5) fresh, weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6); Crurithyris, crinoids, small planispiral gastropods; sharp basal contact.

T

1. Chanute Shale: (0.92 ft., 0.28 m. +) Silty mudstone; med. dark gray (N4) fresh, mottled lt. gray (N7), platy, micaceous, poorly indurated; sandy lenses with nearly horizontal trace fossils, plant fragments, Crurithyris, Lingula, small crinoids (< 1/4 inch in diameter).

Edwardsville (ED)
Approximately 0.25 miles east of Edwardsville on K32
Edwardsville Quadrangle
NW SW sec. 24, T11S R23E
Wyandotte County, Kansas

10. Raytown Limestone: (0.17 ft., 0.05 m.) Packstone to grainstone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), thin bedded, flaggy; fenestrate and ramose bryozoans, Neospirifer, crinoids, Linoproductus; sharp basal contact.

T5

9. Raytown Limestone: (1.00 ft., 0.30 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, mottled dk. yellowish orange (10 YR 6/6), thick bedded, blocky; Linoproductus, Neospirifer, Composita, crinoids, some phylloid algae, gastropods; sharp basal contact.

T?

8. Raytown Limestone: (1.33 ft., 0.41 m.) Argillaceous wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), thin to med. bedded, slabby to flaggy; Linoproductus, crinoids, fenestrate bryozoans, Composita; gradational basal contact.

7. Raytown Limestone: (0.83 ft., 0.25 m.) Wackestone; med. lt. gray (N6) fresh, weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6), thick bedded, blocky, argillaceous and flaggy towards the top; Linoproductus, Echinaria, Neospirifer, crinoids at base (possible crinoidal lag), fenestrate bryozoans; sharp basal contact.

T4

6. Raytown Limestone: (1.92 ft., 0.58 m.) Algal wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy bedded, blocky; phylloid algae, Composita, crinoids; gradational basal contact.

5. Raytown Limestone: (0.42 ft., 0.13 m.) Wackestone; lt. gray (N7), weathers pale yellowish orange (10 YR 8/6), med. bedded, slabby; crinoids, increasing phylloid algae upwards, chonetid brachiopods; sharp basal contact.

4. Raytown Limestone?: (0.33 ft., 0.10 m.) Calcareous claystone; dk. greenish yellow (10 Y 6/6) fresh, mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated; Chonetinella, fenestrate and ramose bryozoans, crinoids, Neospirifer, Composita; sharp basal contact.

3. Raytown Limestone?: (0.42 ft., 0.13 m.) Crinoidal packstone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), med. bedded, slabby to flaggy; crinoids (possible crinoidal lag), Crurithyris, Hustedia, Chonetinella, glauconite; gradational basal contact.

2. Muncie Creek Shale: (0.08 ft., 0.02 m.) Claystone; dk. greenish yellow (10 Y 6/6) fresh, weathers mottled lt. brownish gray (5 YR 6/1), large

calcareous nodules (often bored?), Crurithyris; sharp basal contact.

T3

1. Muncie Creek Shale: (1.41 ft., 0.43 m. +) Clayshale; dark gray (N3) to black (N1), papery to fissile, moderately well indurated; phosphate nodules, Crurithyris, inarticulate brachiopods, conulariids.

Kansas Highway 12 (K12)
North side of highway
Edwardsville Quadrangle
NE SW NW sec. 13, T12S R23E
Johnson County, Kansas

19. Wyandotte Limestone: (1.0 ft., 0.30 m. +) Algal wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy bedded, slabby; phylloid algae, Composita, crinoids; gradational basal contact.

18. Lane Shale: (0.42 ft., 0.13 m.) Calcareous mudstone; med. gray (N5) fresh, weathers dk. yellowish orange (10 YR 6/6), platy to fissile; crinoids (possible crinoidal lag), Hustedia?, Crurithyris, small productid brachiopods, fenestrate and ramose bryozoans; sharp basal contact.

T

17. Lane Shale: (2.58 ft., 0.79 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), micaceous, platy; increasing plant fragments upward.

16. Lane Shale: (41.00 ft., 12.50 m.) Covered.

15. Lane Shale: (3.0 ft., 0.91 m.) Silty mudstone; dark gray (N3) fresh, weathers lt. gray (N7), platy, micaceous; ironstone nodules at top of bed, abundant crinoid fragments, cephalopod shell fragments, Crurithyris, bellerophontacean gastropods, conulariids, nautiloids, high spired gastropods; sharp basal contact.

14. Raytown Limestone: (0.08 ft., 0.02 m.) Packstone to grainstone; med. lt. gray (N5) fresh, weathers pale yellowish orange (10 YR 8/6), thin bedded, flaggy, possibly a transgressive lag; crinoids, Neospirifer, Linoproductus, fenestrate bryozoans; sharp basal contact.

T5

13. Raytown Limestone: (1.00 ft., 0.30 m.) Wackestone; lt. gray (N7) fresh, weathers mottled dk. yellowish orange (10 YR 6/6), thick bedded, blocky; Linoproductus, microgastropods, crinoids, high spired gastropods, fenestrate bryozoans, Composita; sharp basal contact.

12. Raytown Limestone: (2.17 ft., 0.66 m.) Argillaceous wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), thin to med. bedded, flaggy; crinoids, Linoproductus, Echinaria, horn coral, fenestrate and ramose bryozoans (often the main components of thin packstone layers); bryozoans in muddy packstone layers often preserved as relatively large fronds (> 5 cm.), gradational basal contact.

11. Raytown Limestone: (0.58 ft., 0.18 m.) Packstone to wackestone (upward); lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. lt. gray N6), med. bedded, slabby, possible transgressive lag at base; Linoproductus, crinoids, fenestrate bryozoans, Neospirifer; sharp basal contact.

T4

10. Raytown Limestone: (2.67 ft., 0.81 m.) Algal packstone to wackestone, lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, blocky; phylloid algae, Composita, crinoids, rugose coral; sharp basal contact.

9. Raytown Limestone?: (0.25 ft., 0.08 m.) Calcareous mudstone; med. gray (N5) fresh, weathers lt. gray (N7), platy; chonetid brachiopods, Hustedia?, Neospirifer, crinoids, fenestrate bryozoans; sharp basal contact.

8. Raytown Limestone?: (0.33 ft., 0.10 m.) Crinoidal packstone; med. gray (N5), weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6), somewhat argillaceous, med. bedded, flaggy, glauconitic; crinoids, fenestrate and ramose bryozoans, Crurithyris; gradational basal contact.

7. Muncie Creek Shale: (0.08 ft., 0.02 m.) Claystone; dk. greenish yellow (10 Y 6/6), weathers lt. gray (N7), platy; large (> 2 cm. in diameter) flattened to spherical calcareous nodules, Crurithyris, bryozoans; sharp basal contact.

T3

6. Muncie Creek Shale: (1.08 ft., 0.33 m.) Clayshale; dk. gray (N3) to black (N1) fresh, weathers med. to lt. gray (N5 to N7), papery to fissile; phosphate nodules, conulariids; sharp basal contact.

5. Muncie Creek Shale: (0.08 ft., 0.02 m.) Claystone; dark gray (N3), platy to fissile; Crurithyris, brachiopod fragments, brachiopod spines; sharp basal contact.

T2

4. Paola Limestone: (1.92 ft., 0.58 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6), thick bedded, blocky; crinoidal at base, phylloid algae, Composita, crinoids echinoids, rhodoliths near top; gradational basal contact.

3. Chanute Shale: (0.67 ft., 0.20 m.) Silty mudstone; dark gray (N3) fresh, weathers med. to lt. gray (N5 to N7), platy to flaggy, micaceous, somewhat calcareous; brachiopod shell fragments, crinoids, small productids, fenestrate and ramose bryozoans, ostracodes; sharp basal contact.

T1

2. Chanute Shale: (2.50 ft., 0.76 m.) Interbedded very fine grained sandstone with siltstone; med. gray (N5) fresh, weathers lt. gray (N7), micaceous; skeletal lenses contain Rhipidomella, pectinids, productids, nuculoid bivalves, myalinids. Sandstones are lenticular and internally laminated.

T0

1. Chanute Shale: (6.00 ft., 1.83 m.+) Mudstone; olive gray (5 YR 3/2), blocky, crumbly; plant fragments, possibly a paleosol.

Paola Quarry (PAQ)
an abandoned quarry
approximately 0.5 miles east of Paola
Paola East Quadrangle
NW SW SW sec. 18, T17S R23E
Miami County, Kansas

20. Raytown Limestone?: (1.41 ft., 0.43 m.) Wackestone to packstone; lt brownish gray (5 YR 6/1) fresh, weathers dk. yellowish orange (10 YR 6/6), thick bedded, slabby to blocky; phylloid algae, crinoids, Composita; sharp basal contact.

19. Raytown Limestone?: (0.42 ft., 0.13 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers dk. yellowish orange (10 YR 6/6), med. bedded, slabby; phylloid algae, crinoids, Composita; sharp basal contact.

18. Raytown Limestone?: (0.83ft., 0.25 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers dk. yellowish orange (10 YR 6/6), thick bedded, slabby; phylloid algae, crinoids, Chonetinella, Composita; sharp basal contact.

17. Raytown Limestone?: (0.67 ft., 0.20 m.) Packstone to wackestone (upward); lt. brownish gray (5 YR 6/1) fresh, weathers dk. yellowish orange (10 YR 6/6), med. bedded, slabby, thin packstone (< 0.50 cm. thick) at base of unit; crinoids, phylloid algae, Chonetinella, Composita, rugose coral; gradational basal contact.

16. Raytown Limestone?: (0.83 ft., 0.25 m.) Claystone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy, poorly indurated; calcareous skeletal lenses containing small planispiral gastropods, crinoids, Crurithyris, Hustedia, Meekella?, chonetid brachiopods, fenestrate and ramose bryozoans, small bivalves?; sharp basal contact.

T?

15. Raytown Limestone?: (6.25 ft., 1.90 m.) Mudstone; olive gray (5 YR 3/2) fresh, weathers lt. gray (N7), platy, poorly indurated; plant fragments, nearly horizontal trace fossils, Lingula, Crurithyris, brachiopod shell fragments and spines; sharp basal contact.

T5

14. Raytown Limestone: (0.92 ft., 0.28 m.) Wackestone; lt. gray (N7) fresh, weathers mottled dk. yellowish orange (10 YR 6/6), thick bedded, blocky, possibly cross bedded; Neospirifer, Echinaria, fenestrate bryozoans, pectinid? bivalves, trilobites, many shell fragments on the upper surface of bed are bored, and bryozoan holdfasts are present; sharp basal contact.

13. Raytown Limestone: (2.58 ft., 0.79 m.) Wackestone to packstone; lt. to med. gray (bands) (N7 to N5), thin to med. bedded, slabby to flaggy; argillaceous bands with abundant fenestrate bryozoans, crinoids, Linoproductus, Echinaria, Composita; gradational basal contact.

12. Raytown Limestone: (1.33 ft., 0.41 m.) Wackestone to packstone; lt. to

med. gray (bands) (N7 to N5), thin to med. bedded, slabby to flaggy; argillaceous bands containing fenestrate bryozoans and crinoids, Linoproductus, Echinaria, Composita, ramose bryozoans; sharp basal contact.

T4

11. Raytown Limestone: (0.58 ft., 0.18 m.) Wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), med. bedded, slabby, hummocky upper surface; phylloid algae, Composita, small Linoproductus, Chonetinella; sharp basal contact.

10. Raytown Limestone: (0.33 ft., 0.10 m.) Wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, slabby; shale parting (< 0.25 inches thick) at top of unit, phylloid algae, Composita, small Linoproductus, Chonetinella, crinoids (especially in shale parting); sharp basal contact.

9. Raytown Limestone: (0.33 ft., 0.10 m.) Wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, slabby to flaggy; shale parting at top of unit (< 0.50 inches thick), phylloid algae, Composita, crinoids; sharp basal contact.

8. Raytown Limestone: (0.58 ft., 0.18 m.) Wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, slabby to flaggy; shale parting at the top of the unit (> 0.50 inches thick), phylloid algae, Composita, crinoids; sharp basal contact.

7. Raytown Limestone: (1.25 ft., 0.38 m.) Algal packstone to wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, blocky; phylloid algae, Composita, crinoids, productids, fenestrate bryozoa, void filling and replacement spar (especially in and around phylloid algae); sharp basal contact.

6. Raytown Limestone: (0.67 ft., 0.20 m.) Algal packstone to wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, slabby to blocky; phylloid algae, Composita, crinoids, productids, fenestrate bryozoans; sharp basal contact.

5. Raytown Limestone: (0.42 ft., 0.13 m.) Algal packstone to wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, slabby to flaggy; phylloid algae, Composita, crinoids; sharp basal contact.

4. Raytown Limestone: (3.17 ft., 0.96 m.) Algal packstone to wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, blocky, void filling and replacement spar; phylloid algae, Composita, crinoids, chonetid brachiopods, bivalves?, fenestrate bryozoans; sharp basal contact.

3. Raytown Limestone: (0.17 ft., 0.05 m.) Crinoidal packstone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. gray (N7), thin bedded, flaggy; crinoids, Crurithyris?, intraclasts (possible reworked phosphate nodules); sharp basal contact.

2. Muncie Creek Shale: (0.08 to 0.42 ft., 0.02 m. to 0.13 m.) Claystone; dark gray fresh, weathers lt. gray, dk. greenish yellow (10 Y 6/6) near top, platy, often with lenticular argillaceous packstone at base; Crurithyris, crinoids, phosphate nodules at base; sharp basal contact.

T2

1. Paola Limestone: (0.17 ft., 0.05 m.+) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. gray (N7), thick bedded, blocky, hummocky upper surface; rhodoliths, burrows; base not exposed.

Paola East (PE)
West side of Highway 169
East of Miola Lake
Paola East Quadrangle
W1/2 SE1/4 sec. 11, T17S R23E
Miami County, Kansas

12. Wyandotte Limestone (Frisbie LS Mbr?): (1.83 ft., 0.56 m.+) Algal packstone to wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), med. to thick bedded, blocky; phylloid algae, Composita, crinoids; sharp basal contact.

11. Wyandotte Limestone: (0.17 ft., 0.05 m.) Crinoidal packstone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), thin bedded, flaggy; crinoids, brachiopod shell fragments, small productids, fenestrate bryozoans; sharp basal contact.

T?

10. Wyandotte Limestone: (0.58 ft., 0.18 m.) Wackestone; med. gray fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), med. bedded, slabby; productids, Composita, crinoids; sharp basal contact.

9. Wyandotte Limestone: (0.17 ft., 0.05 m.) Crinoidal packstone; med. gray fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), thin bedded, flaggy, argillaceous; crinoids, brachiopod shell fragments, pyrite; gradational basal contact.

8. Lane Shale: (1.00 ft., 0.30 m.) Calcareous shale; med. dark gray (N4) fresh, weather mottled dk. yellowish orange (10 YR 6/6) to lt. gray (N7), platy to fissile, poorly indurated; crinoids, bellerophontacean gastropods, bivalves, bryozoans; sharp basal contact.

T?

7. Lane Shale: (0.50 ft., 0.15 m.) Silty mudstone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy, poorly indurated; plant fragments; gradational basal contact.

6. Lane Shale: (3.33 ft., 1.02 m.) Silty mudstone; med. dark gray (N4), weathers lt. gray (N7), platy, micaceous, poorly indurated; scattered ironstone nodules near base, pectinid bivalves, Lingula; gradational basal contact.

5. Lane Shale: (2.58 ft., 0.79 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; Lingula, pectinids, gastropods, pyrite, scattered ironstone nodules throughout; laterally traceable (locally) layer of ironstone at the top of the unit; sharp basal contact.

T?

4. Lane Shale: (1.17 ft., 0.35 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, poorly indurated; pyrite, scattered ironstone

nodules, pectinid bivalves, Lingula, nearly horizontal trace fossils, layer of ironstone at top of unit (not laterally extensive); sharp basal contact.

3. Lane Shale: (0.83 ft., 0.25 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, poorly indurated; Lingula, nearly horizontal trace fossils, meshwork-like trace fossil, ironstone layer at top (not laterally extensive); gradational basal contact.

2. Lane Shale: (2.08 ft., 0.63 m.) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; scattered ironstone nodules and ironstone layer at the top of the unit (poorly developed and not laterally extensive), Lingula, pectinid bivalves, nearly horizontal trace fossils, calcareous worm tube?; gradational basal contact.

1. Lane Shale: (0.50 ft., 0.15 m.+) Silty mudstone; med. dark gray (N4) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; ironstone layer (traceable locally), Lingula, plant fragments?; base not exposed.

Somerset (S)
west side of section road
approximately 1.0 miles south of Somerset
Paola East Quadrangle
SE SE sec. 5, T17S R24E
Miami County, Kansas

5. Wyandotte Limestone (Frisbie LS Mbr.?): (0.50 ft., 0.15 m.+) Argillaceous packstone to wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers med. to lt. gray (N5 to N7), thin bedded, slabby; crinoids, productids, *Composita*; gradational basal contact.

4. Lane Shale: (0.83 ft., 0.25 m.) Calcareous shale; med. gray (N5) fresh, weathers dk. yellowish orange (10 YR 6/6), platy to fissile, poorly indurated; crinoids, *Crurithyris*, rugose coral; sharp basal contact.

T?

3. Lane Shale: (2.92 ft., 0.89 m.) Silty mudstone; med. dark gray (N4) to dk. greenish yellow (10 Y6/6) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated; numerous plant fragments; gradational basal contact.

2. Lane Shale: (7.58 ft., 2.31 m.) Silty mudstone; med. dark gray (N4) to dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; sandy lenses (mostly infillings of trace fossils?), scattered ironstone nodules, *Lingula*, pectinid bivalves, rare plant fragments; sharp basal contact.

T?

1. Lane Shale: (1.75 ft., 0.53 m.+) Silty mudstone; med. dark gray N4) fresh, weathers lt. gray (N7), platy, micaceous, poorly indurated; locally traceable layer of ironstone at the top of the unit and scattered ironstone nodules throughout the unit, *Lingula*, nearly horizontal trace fossils, rare sandy lenses; base not exposed.

Paola Southeast (PSE)
section road, east of
Highway 169
Paola East Quadrangle
SW NW sec. 22, T17S R23E
Miami County, Kansas

14. Raytown Limestone: (2.00 ft., 0.61 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), thin to med. bedded, slabby to flaggy; Linoproductus, crinoids, phylloid algae, Composita, fenestrate bryozoans; sharp basal contact.

T4

13. Raytown Limestone: (1.17 ft., 0.35 m.) Wackestone to packstone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), thin to med. bedded, slabby to flaggy, textural and bedding change (skeletal component becomes finer grained, and bedding thickness is reduced) relative to underlying units; phylloid algae, Composita, chonetid brachiopods, crinoids, Linoproductus, fenestrate bryozoans; sharp basal contact.

12. Raytown Limestone: (1.92 ft., 0.58 m.) Algal packstone to wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), thick bedded, blocky, void filling and replacement spar, unit appears to be thickening to the west (algal mound development?); phylloid algae, Composita, crinoids; sharp basal contact.

11. Raytown Limestone: (0.92 ft., 0.28 m.) Algal packstone to wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), med. bedded, blocky; phylloid algae, Composita, crinoids; sharp basal contact.

10. Raytown Limestone: (0.83 ft., 0.25 m.) Packstone to wackestone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6), med. bedded, blocky; crinoids (possible crinoidal lag at base of unit), phylloid algae increases in abundance upward in the unit, chonetid brachiopods, Composita, sponges (Girtyocoelia?); sharp basal contact.

9. Muncie Creek Shale: (0.25 ft., 0.08 m.) Claystone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), mottled, platy, poorly indurated; calcareous, Crurithyris, crinoids, chonetid brachiopods, fenestrate and ramose bryozoans, Hustedia, Composita, Neospirifer; gradational basal contact.

8. Muncie Creek Shale: (0.17 ft., 0.05 m.) Claystone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. to med. gray (N7 to N5), platy, poorly indurated, calcareous; fossils preserved primarily as molds, Hustedia, crinoids, small (<5cm) phosphate nodules, bryozoans, crinoids, Crurithyris, ostracodes; sharp basal contact.

7. Muncie Creek Shale: (0.33 ft., 0.10 m.) Argillaceous packstone; med. gray (N5) fresh, weathers lt. gray (N7), mottled, thin bedded, flaggy; phosphate

nodules towards the base of the unit, crinoids, brachiopod shell fragments, Crurithyris, chonetid? brachiopods, fenestrate bryozoans; sharp basal contact.

T3

6. Muncie Creek Shale: (0.17 ft., 0.05 m.) Claystone; lt. brownisn gray (5 YR 6/1) fresh, weathers med. lt. gray (N6), platy, poorly indurated, slightly calcareous; sparsely fossiliferous, Lingula?, crinoids, Crurithyris, Hustedia; sharp basal contact.

T2

5. Paola Limestone: (1.00 ft., 0.30 m.) Wackestone to packstone; med. lt. gray (N6) fresh, weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6), thick bedded, blocky; rhodoliths in upper 1/3 of unit, phylloid algae increases in abundance upward in the unit until the rhodolith zone, Composita, crinoids; gradational basal contact.

4. Paola Limestone: (0.67 ft., 0.20 m.) Packstone to wackestone; med. lt. gray (N6) fresh, weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6), med. bedded, slabby; crinoids, phylloid algae near top of unit, Neospirifer, small productid brachiopods, Composita, Crurithyris?; gradational basal contact.

3. Chanute Shale: (0.25 ft., 0.08 m.) Calcareous shale; med. gray (N5) fresh, weathers lt. gray, platy to fissile, moderately well indurated; crinoids, productid brachiopods, brachiopod shell fragments; sharp basal contact.

T1

2. Chanute Shale: (0.42 ft., 0.13 m.) Siltstone; lt. greenish yellow (10 Y 6/6) to lt. brownish gray (5 YR 6/1) (upwards) fresh, weathers lt. gray (N7), platy, poorly indurated, sandy, micaceous; Lingula, plant fragments; gradational basal contact.

1. Chanute Shale: (2.75 ft., 0.84 m.) Silty mudstone; olive gray (5 YR 3/2) fresh, weathers lt. gray (N7), platy to flaggy, poorly indurated; plant fragments; base not exposed.

Old KC Road (OKCR)
East side of the
Old Kansas City Road
Spring Hill Quadrangle
SW SW NE sec. 22. T16S R23E
Miami County, Kansas

13. Raytown Limestone: (1.25 ft., 0.38 m.) Wackestone to packstone; med. lt. gray (N6) fresh, weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6), med. to thin bedded, slabby to flaggy; brachiopod shell fragments, small (< 0.50 cm. in diameter) crinoids, Composita, Linoproductus; sharp basal contact.

12. Raytown Limestone: (1.67 ft., 0.51 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. to med. gray (N7 to N5), thin to med. bedded, flaggy to slabby, several thin (< 1.0 cm. thick) shaley partings, change in bedding relative to underlying units (a decrease in bedding thickness); Linoproductus, Neospirifer, large (> 0.50 cm in diameter) crinoids, fenestrate bryozoans, phylloid algae; sharp basal contact.

T4

11. Raytown Limestone: (3.0 ft., 0.91 m.) varies from 0.81 m. (2.67 ft.), to 1.09 m. (3.58 ft.) locally, Algal packstone to wackestone; lt. gray fresh (N7), weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. to thick bedded, slabby to blocky; phylloid algae, crinoids, Composita in lower 1/2 of unit, Linoproductus increases in abundance upwards, sponges; sharp basal contact.

10. Raytown Limestone: (0.42 ft., 0.13 m.) Wackestone to packstone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. to med. gray. (N7 to N5), med. bedded, slabby, hummocky upper surface; phylloid algae increases in abundance upward in the unit, chonetid brachiopods, Composita, crinoids; sharp basal contact.

9. Raytown Limestone: (0.42 ft., 0.13 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. to med. gray (N7 to N5), med. bedded, slabby, shaley parting at the top of the unit; Composita, crinoids, bellerophontacean gastropods, sponges; sharp basal contact.

8. Raytown Limestone: (0.25 ft., 0.08 m.) Wackestone to packstone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. to med. gray (N7 to N5), thin bedded, flaggy; crinoids, Composita; basal contact sharp.

7. Muncie Creek Shale: (0.17 ft., 0.05 m.) Claystone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated, calcareous; fossils commonly preserved as molds only, chonetid brachiopods, Neospirifer, Crurithyris, crinoids, fenestrate and ramose bryozoans, trilobites, Mesolobus?, echinoids, Composita, ostracodes; gradational basal contact.

6. Muncie Creek Shale: (0.17 ft., 0.05 m.) Claystone; med. gray (N5) fresh, weathers lt. gray (N7) to lt. brownish gray (5 YR 6/1), platy, poorly indurated; phosphate nodules basally, Crurithyris, Hustedia, rare Neospirifer, cephalopod fragments?; sharp basal contact.

T3

5. <u>Paola Limestone:</u> (1.67 ft., 0.51 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers med. to lt. gray (N5 to N7), thick bedded, blocky, hummocky upper surface; burrows in upper 2/3 of unit, rhodoliths in upper 1/3 of unit, phylloid algae in lower 2/3 of unit, bellerophontacean gastropods and fusulinids (predominantly algal coated) near top of unit, <u>Composita</u>, brachiopod shell fragments, crinoids (abundant basally); sharp basal contact.

4. <u>Paola Limestone:</u> (0.50 ft., 0.15 m.) Wackestone to packstone; med. lt. gray (N6) fresh, weathers pale yellowish orange (10 YR 8/6) to lt. gray (N7), med. bedded, slabby; <u>Composita</u>, crinoids, <u>Crurithyris</u>, phylloid algae; gradational basal contact.

3. <u>Chanute Shale:</u> (0.17 ft., 0.05 m.) Sandy calcareous mudstone; med. gray (N5) fresh, weathers dk. yellowish orange (10 YR 6/6), highly weathered, platy, poorly indurated; crinoids, brachiopod shell fragments; sharp basal contact.

T1

2. <u>Chanute Shale:</u> (1.08 ft., 0.33 m.) Siltstone; dk. greenish yellow (10 Y 6/6) fresh, weathers med. gray (N5) to mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated; abundant plant fragments; gradational basal contact.

1. <u>Chanute Shale:</u> (5.0 ft., 1.52 m.+) Silty mudstone; med. to med. dark gray (N5 to N4) fresh, weathers lt. gray (N7), platy to flaggy, poorly indurated; scattered plant fragments; base not exposed.

State Hospital (SH)
<1/2 mile north of the Kansas State Hospital
East side of the Old Kansas City Road
Osawatomie Quadrangle
SE SE SW sec. 35, T17S R22E
Miami County, Kansas

18. Raytown Limestone: (1.92 ft., 0.58 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers med. gray (N5), thin to med. bedded, slabby to flaggy; crinoids, productid brachiopods, fenestrate bryozoans, phylloid algae; sharp basal contact.

17. Raytown Limestone: (0.17 ft., 0.05 m.) Wackestone to packstone; lt. brownish gray (5 YR 6/1) fresh, weathers med. gray (N5), thin bedded, flaggy, textural and bedding change relative to underlying units (skeletal debris is finer grained and bedding thicknesses are reduced); crinoids, phylloid algae, fenestrate bryozoans; sharp basal contact.

T4

16. Raytown Limestone: (0.42 ft., 0.13 m.) Packstone to wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers med. gray (N5), med. bedded, slabby; phylloid algae, Composita, crinoids; sharp basal contact.

15. Raytown Limestone: (1.41 ft., 0.43 m.) Algal packstone to wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, blocky, void filling and replacement spar (especially in and around phylloid algae); phylloid algae, Composita, crinoids; sharp basal contact.

14. Raytown Limestone: (1.41 ft., 0.43 m.) Packstone to wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6), wavy-bedded, blocky; crinoids dominant basally, phylloid algae increases in abundance upward, Composita, gastropods, sponges; sharp basal contact.

13. Muncie Creek Shale: (0.08 ft., 0.02 m.) Claystone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated; crinoids, Crurithyris, Composita, chonetid brachiopods, Neospirifer, fenestrate and ramose bryozoans, Punctospirifer, Hustedia; gradational basal contact.

12. Muncie Creek Shale: (0.25 ft., 0.08 m.) Claystone; dark gray (N5) fresh, weathers lt. gray (N7), platy, poorly indurated; Crurithyris, crinoids, ramose bryozoans, Hustedia, small (<1/2mm) phosphate nodules; sharp basal contact.

11. Muncie Creek Shale: (0.17 ft., 0.05 m.) Argillaceous packstone; med. gray (N5) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), thin bedded, flaggy, moderately well indurated; phosphate nodules at base, crinoids, bryozoans, Crurithyris; sharp basal contact.

T3

10. Paola Limestone: (1.67 ft., 0.51 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to mottled dk.

yellowish orange (10 YR 6/6), thick bedded, blocky; rhodoliths in upper 1/3, burrowed in upper 2/3, bellerophontacean gastropods, fusulinids (skeletal grains in the upper part of the unit are often algal coated), phylloid algae, Composita; gradational basal contact.

9. Paola Limestone: (0.33 ft., 0.10 m.) Argillaceous packstone; med. lt. gray (N6) fresh, weathers lt. gray (N7) to pale yellowish orange (10 YR 8/6), thin bedded, flaggy; crinoids, Crurithyris, fenestrate bryozoans; gradational basal contact.

8. Chanute Shale: (0.17 ft., 0.05 m.) Calcareous shale; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy to fissile, poorly indurated; crinoids (possible crinoidal lag at base), Crurithyris, small productids, bryozoans; sharp basal contact.

T1

7. Chanute Shale: (0.17 ft., 0.05 m.) Silty mudstone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy, poorly indurated; numerous plant fragments; gradational basal contact.

6. Chanute Shale: (3.17 ft., 0.96 m.) Silty mudstone, med. dark gray (N4) fresh, weathers med. to lt. gray (N5 to N7) to mottled dk. yellowish orange (10 YR 6/6), platy to flaggy, poorly indurated; Lingula, small pectins, Crurithyris; sharp basal contact.

T

5. Chanute Shale (Thayer Coal?): (0.17 ft., 0.05 m.) Bituminous coal.

CC

4. Chanute Shale: (4.33 ft., 1.32 m.) Mudstone; olive gray (5 YR 3/2) fresh, weathers med. to lt. gray (N5 to N7) to mottled dk. yellowish orange (10 YR 6/6), platy to flaggy, poorly indurated; plant fragments (increasing in abundance upward), possible paleosol; sharp basal contact.

3. Chanute Shale: (2.50 ft., 0.76 m.) Mudstone; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy, poorly indurated; carbonate nodules (caliche?); sharp basal contact.

2. Chanute Shale?: (0.75 ft., 0.23 m.) Interbedded thin (< 1 inch) limestone with platy, greenish gray mudstone; limestone = mudstone to wackestone, dk. greenish yellow (10 Y 6/6) fresh, thin bedded, flaggy; ostracodes; gradational basal contact.

1. Drum Limestone: (1.92 ft., 0.58 m.+) Wackestone; med. lt. gray (N6) fresh, weathers lt. gray (N7), med. bedded, blocky to slabby; ostracodes, bivalves; base not exposed.

Osawatomie North (OSAN)
Southeast side of Kansas Highway 169
Approximately 1.5 miles northwest of Osawatomie
Osawatomie Quadrangle
SE NW NW sec. 6, T18S R23E
Miami County, Kansas

21. Raytown Limestone: (1.0 ft., 0.30 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; fenestrate bryozoans, crinoids, Composita; sharp basal contact.

20. Raytown Limestone: (0.33 ft., 0.10 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; fenestrate bryozoans, productids, crinoids, Neospirifer; sharp basal contact.

19. Raytown Limestone: (0.17 ft., 0.05 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), thin bedded, slabby, productids, crinoids; sharp basal contact.

18. Raytown Limestone: (0.50 ft., 0.15 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; productids, fenestrate bryozoans, crinoids; sharp basal contact.

T4

17. Raytown Limestone: (0.42 ft., 0.13 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; small (<1/4" in diameter) crinoids, Composita, bryozoans, phylloid algae; sharp basal contact.

16. Raytown Limestone: (0.58 ft., 0.18 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; small crinoids, Composita, bryozoans, phylloid algae; sharp basal contact.

15. Raytown Limestone: (0.33 ft., 0.10 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; small crinoids, phylloid algae, Composita; bedding and textural change relative to underlying beds (bedding thickness is reduced and size of skeletal grains becomes smaller); sharp basal contact.

14. Raytown Limestone: (1.67 ft., 0.51 m.) Algal wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), wavy bedded, blocky, hummocky upper surface, void filling and replacement spar (mostly related to phylloid algae); phylloid algae, Composita, large crinoids (many > 1/4" in diameter); sharp basal contact.

13. Raytown Limestone: (0.17 ft., 0.05 m.) Algal wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), wavy-bedded, slabby; phylloid algae, crinoids, Composita; sharp basal contact.

12. Raytown Limestone: (0.25 ft., 0.08 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; phylloid algae, Composita, chonetid brachiopods, horn coral; sharp basal contact.

11. Raytown Limestone: (0.33 ft., 0.10 m.) Algal wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded, slabby; phylloid algae, Composita, crinoids; sharp basal contact.

10. Raytown Limestone: (1.0 ft., 0.30 m.) Algal wackestone to packstone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), wavy- bedded, blocky; phylloid algae, Composita, crinoids, bryozoans; sharp basal contact.

9. Raytown Limestone: (0.67 ft., 0.20 m.) Wackestone; lt. gray (N7) fresh, weathers pale yellowish orange (10 YR 8/6) to med. gray (N5), med. bedded., blocky, vertical spar filled fractures at base; phylloid algae (increasing in abundance upward), Composita, brachiopod fragments, crinoids (dominant basally), sponges, gastropods; sharp basal contact.

8. Muncie Creek Shale: (0.08 ft., 0.02 m.) Clayshale; dk. greenish yellow (10 Y 6/6) fresh, weathers lt. gray (N7), platy, poorly indurated; Crurithyris, Chonetinella, crinoids, bryozoans, echinoid spines; gradational basal contact.

7. Muncie Creek Shale: (0.17 ft., 0.05 m.) Clayshale; med. gray (N5), weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated; phosphate nodules (rounded, possibly reworked), Crurithyris, Hustedia, crinoids; sharp basal contact.

T3

6. Paola Limestone: (1.92 ft., 0.58 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. to med. gray (N7 to N5), thick bedded, blocky, hummocky or irregular upper surface; burrowed in upper 2/3 of unit, rhodoliths in upper 1/3 of bed, phylloid algae in bottom 2/3 of unit, Composita, gastropods; sharp basal contact.

5. Paola Limestone: (0.50 ft., 0.15 m.) Wackestone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), med. bedded, blocky; phylloid algae, crinoids, Composita; gradational basal contact.

4. Paola Limestone: (0.25 ft., 0.08 m.) Packstone; lt. brownish gray (5 YR 6/1) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), thin bedded, flaggy; crinoids, Crurithyris, brachiopod fragments; gradational basal contact.

3. Chanute Shale: (0.08 ft., 0.02 m.) Sandy calcareous shale; med. gray (N5) fresh, weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6), platy, moderately indurated; crinoids, Crurithyris, brachiopod fragments, plant fragments; sharp basal contact.

T1

2. Chanute Shale: (0.33 ft., 0.10 m.) Sandy siltstone; dk. greenish yellow (10 Y 6/6), weathers mottled dk. yellowish orange (10 YR 6/6), platy, poorly indurated; abundant plant fragments; sharp basal contact.

1. Chanute Shale: (3.0 ft.+, 0.91 m.+) Silty mudstone; olive gray (5 YR 3/2), weathers med. to lt. gray (N5 to N7), platy, poorly indurated, slightly micaceous, calcareous lenses; Lingula, Crurithyris; base not exposed.

Kansas Highways 32 and 7 (K32&7)
Near the intersection of Kansas Highways 32 and 7
Approximately 0.25 miles east of Bonner Springs
Bonner Springs Quadrangle
NW SW Sec. 28 T11S R23E
Wyandotte County, Kansas

20. Wyandotte Limestone: (0.33 ft., 0.10 m.) Wackestone; lt. gray (N7) fresh, weathers mottled dk. yellowish orange (10 YR 6/6), sandy, thin bedded, slabby to flaggy; crinoids, Composita, fenestrate and ramose bryozoans, rhodoliths; gradational lower contact.

19. Lane Shale: (0.50 ft., 0.15 m.) Calcareous mudstone; dk. greenish yellow (10 Y 6/6) fresh, weathers mottled dk. yellowish orange (10 YR 6/6), sandy, poorly indurated, platy; crinoids, small productids, high and low spired gastropods, nuculoid bivalves; sharp lower contact.

T

18. Lane Shale: (0.25 ft., 0.08 m.) Silty mudstone; med. gray (N5) fresh, weathers lt. gray (N7), micaceous, poorly indurated, platy; numerous plant fragments; sharp lower contact.

17. Lane Shale: (11.66 ft., 3.56 m.) Silty mudstone interbedded with lenses of very fine grnd. sandstone; med. gray (N5) fresh, weathers lt. gray (N7), mudstone poorly indurated, sandstone moderately indurated, platy to flaggy; plant fragments, carbonized plant fragments and trace fossils (Asterosoma, Asteriacites, and Planolites like) in sandstone lenses; lenses of sandstone more continuous in upper 1/3, sharp lower contact.

T?

16. Lane Shale: (9.58 ft., 2.92 m.) Silty mudstone; med. gray (N5) fresh, weathers lt. gray (N7), micaceous, poorly indurated, platy; scattered sandstone lenses and ironstone nodules, plant fragments and trace fossils (Planolites like, and Asterosoma); sharp lower contact.

15. Lane Shale: (0.25 ft., 0.08 m.) Mudstone and ironstone layer; mudstone is med. gray (N5) fresh, weathers lt. gray (N7), poorly indurated, platy, and with numerous crinoid columnals and bellerophontacean gastropods; ironstone is reddish brown, well indurated, and flaggy; sharp basal contact.

14. Lane Shale: (1.42 ft., 0.43 m.) Mudstone; med. gray (N5) fresh, weathers lt. gray (N7), poorly indurated, platy; Lingula, pectinid bivalves; gradational basal contact.

13. Lane Shale: (0.25 ft., 0.08 m.) Mudstone: med. gray (N5) fresh, weather lt. gray (N7), silty, poorly indurated, platy; Crurithyris, productid brachiopods, pectinid bivalves; fenestrate and ramose bryozoans, crinoids; skeletal material often replaced by pyrite, and in elongate and flattened parallel to bedding; gradational basal contact.

12. Raytown Limestone: (0.08 ft., 0.03 m.) Skeletal packstone; med. gray (N5)

fresh, weathers pale yellowish orange (10 YR 8/6), thin bedded, flaggy; Neospirifer, productid brachiopods, chonetid brachiopods, Composita, crinoids, fenestrate and ramose bryozoans; skeletal grains fragmented and disarticulated, large brachiopods often with lt. algal coating and barnacle borings; sharp basal contact.

T5

11. Raytown Limestone: (1.25 ft., 0.38 m.) Wackestone; lt. gray (N7), weathers mottled dk. yellowish orange (10 YR 6/6), thick bedded, blocky; productid brachiopods, crinoids, fenestrate bryozoans, bellerophontacean gastropods; most skeletal grains fn. grained and fragmented, some large brachiopods whole; sharp basal contact.

10. Raytown Limestone: (0.58 ft., 0.18 m.) Argillaceous wackestone to packstone; lt. gray (N7), weathers med. gray (N5) to mottled dk. yellowish orange (10 YR 6/6), med. bedded, flaggy; productid brachiopods, chonetid brachiopods, Composita, fenestrate bryozoans, crinoids, phylloid algae; brachiopods often articulated, minor fragmentation of skeletal grains; gradational basal contact.

9. Raytown Limestone: (0.75 ft., 0.23 m.) Brachiopod wackestone to packstone (at base); lt. gray (N7), weathers med. gray (N5), med. bedded, blocky; Echinaria, Linoproductus, Neospirifer, crinoids, fenestrate and ramose bryozoans; thin (< 3 cm) crinoidal lag at base; large brachiopods often whole; sharp basal contact.

T4

8. Raytown Limestone: (2.17 ft., 0.66 m.) Algal wackestone; lt. gray (N7), weathers pale yellowish orange (10 YR 8/6), wavy-bedded, blocky; phylloid algae, Composita, crinoids, fenestrate bryozoans, productids; vug filling and replacement spar in brachiopods and replacing algae, brachiopods articulated; sharp basal contact.

7. Raytown Limestone: (0.33 ft., 0.10 m.) Wackestone; lt. gray (N7), weathers pale yellowish orange (10 YR 8/6), med. bedded, blocky; crinoids, phylloid algae, Composita, chonetid brachiopods, productid brachiopods, fenestrate and ramose bryozoans; skeletal grains fragmented, especially near base; sharp basal contact.

6. Raytown Limestone: (0.25 ft.. 0.08 m.) Calcareous shale; med. gray (N5) to dk. greenish yellow (10 Y 6/6), weathers mottled dk. yellowish orange (10 YR 6/6), poorly indurated, platy; chonetid brachiopods, Neospirifer, Punctospirifer, crinoids, fenestrate and ramose bryozoans, low-spired gastropods, platycerid gastropods, ostracodes; moldic preservation common; sharp basal contact.

5. Raytown Limestone: (0.42 ft., 0.12 m.) Crinoidal packstone to grainstone; med. gray (N5), weathers dk. greenish yellow (10 Y 6/6) to lt. gray, glauconitic, med. bedded, slabby; crinoids, productid brachiopods, fenestrate and ramose bryozoans, conulariids, calcareous nodules in base; skeletal grains fragmented and disarticulated; gradational basal contact.

4. Muncie Creek Shale: (0.17 ft., 0.05 m.) Calcareous mudstone; dk. greenish yellow (10 Y 6/6), weathers lt. gray (N7), poorly indurated, platy; fenestrate and ramose bryozoans, productid brachiopods, Crurithyris, crinoids, large (up to 15 cm) calcareous nodules, pyrite lined burrows; moldic preservation common; sharp basal contact.

T3

3. Muncie Creek Shale: (0.92 ft., 0.28 m.) Mudstone; med. gray (N5), weathers lt. gray (N7), moderately indurated, platy; pyrite lined burrows, rounded phosphate nodules, pectinid bivalves, Crurithyris, conulariids; moldic preservation and pyrite replacement common; sharp basal contact.

2. Muncie Creek Shale: (1.33 ft., 0.41 m.) Shale; black (N1), weathers med. to lt. gray (N5 to N7), finely laminated, fissile; rounded and ovate phosphate nodules, phosphate laminae, conulariids, conodonts; better preserved fossils in phosphate nodules; sharp basal contact.

1. Muncie Creek Shale: (1.00 ft., 0.30 m.) Shale to mudstone; med. dk. gray (N4), laminated, platy to fissile; Lingula, Crurithyris, gastropods; sharp basal contact.

T2

0. Paola Limestone: (0.25 ft.+, 0.08 m.+) Wackestone; lt. brownish gray (5 YR 6/1), brittle, blocky; crinoids, phylloid algae, brachiopods; skeletal grains fragmented and disarticulated; base covered.

Kansas Highway 32 River Section (K32R)
Just west of the I-70 and I-635 interchange
Shawnee Quadrangle
SW SW SE Sec12 T11S R24E
Wyandotte County, Kansas

17. Raytown Limestone: (0.17 ft., 0.05 m.) Packstone; med. lt. gray (N6), weathers lt. gray (N7), thin bedded, flaggy; crinoids, productid brachiopods, Neospirifer, fenestrate and ramose bryozoans, shark remains; barnacle borings common on large brachiopods, skeletal grains fragmented and disarticulated; sharp basal contact.

T5

16. Raytown Limestone: (1.25 ft., 0.38 m.) Wackestone; lt. gray (N7), weathered mottled dk. yellowish orange (10 YR 6/6), thick bedded, blocky; crinoids, fenestrate and ramose bryozoans, productid brachiopods, gastropods, bivalve fragments; most skeletal grains are fine grained and fragmented; sharp basal contact.

15. Raytown Limestone: (0.83 ft., 0.25 m.) Argillaceous wackestone; med. lt. gray (N6), weathers mottled dk. yellowish orange (10 YR 6/6), med. bedded, flaggy; productid brachiopods, fenestrate bryozoans, crinoids, chonetid brachiopods; skeletal grains only moderately fragmented, some brachiopods articulated; gradational basal contact.

14. Raytown Limestone: (0.75 ft., 0.23 m.) Brachiopod wackestone; lt. gray (N7), weathers pale yellowish orange (10 YR 8/6) to mottled dk. yellowish orange (10 YR 6/6), med. bedded, slabby; Echinaria, Linoproductus, Neospirifer, Composita, crinoids, fenestrate and ramose bryozoans; productids are quite large (up to 8 cm), brachiopods often articulated; sharp basal contact.

T4

13. Raytown Limestone: (1.00 ft., 0.30 m.) Algal wackestone; lt. gray (N7); weathers pale yellowish orange (10 YR 8/6); wavy bedded, blocky; phylloid algae, Composita, crinoids, productids, fenestrate bryozoans; skeletal grains only moderately fragmented, some brachiopods articulated; hummocky basal contact.

12. Raytown Limestone: (0.75 ft., 0.23 m.) Algal wackestone; lt. gray (N7), weathers pale yellowish orange (10 YR 8/6), wavy bedded, slabby; phylloid algae, Composita, crinoids, fenestrate bryozoans; brachiopods often articulated; hummocky basal contact.

11. Raytown Limestone: (0.75 ft., 0.23 m.) Algal wackestone; lt. gray (N7), weather pale yellowish orange (10 YR 8/6), wavy-bedded, slabby; phylloid algae, crinoids, Composita, gastropods; skeletal grains fragmented, especially at base; sharp basal contact.

10. Raytown Limestone: (0.50 ft., 0.15 m.) Calcareous mudstone; med. lt. gray (N6); weathers lt. gray (N7) to mottled dk. yellowish orange (10 YR 6/6),

poorly indurated, platy; chonetid brachiopods, Neospirifer, Punctospirifer, fenestrate and ramose bryozoans, crinoids, low spired gastropods; moldic preservation common; sharp basal contact.

9. Raytown Limestone: (0.50 ft., 0.15 m.) Crinoidal packstone to grainstone; med. lt. gray (N6), weathers pale yellowish orange (10 YR 8/6), glauconitic, med. bedded, slabby; crinoids, productids, bryozoans, calcareous nodules at base; fossils fragmented and disarticulated; gradational basal contact.

8. Muncie Creek Shale: (0.17 ft., 0.05 m.) Calcareous mudstone; dk. greenish yellow (10 Y 6/6), weathers lt. gray (N7), poorly indurated, platy; productids, Crurithyris, fenestrate and ramose bryozoans, crinoids, large (up to 15 cm) calcareous nodules; moldic preservation common; sharp basal; contact.

T3

7. Muncie Creek Shale: (0.42 ft., 0.13 m.) Mudstone; med. gray (N5), weathers lt. gray (N7), moderately indurated, platy; rounded phosphate nodules, Crurithyris, pectinid bivalves, conulariids; sharp basal contact.

6. Muncie Creek Shale: (0.50 ft., 0.15 m.) Shale; black (N1), weathers med. gray (N5), papery, finely laminated, fissile; phosphate nodules and laminae, conulariids, conodonts; sharp basal contact.

5. Muncie Creek Shale: (0.50 ft., 0.15 m.) Shale to mudstone; med. dark gray (N4), weathers med. lt. gray (N6), poorly indurated, platy to fissile; Lingula, Crurithyris; sharp basal contact.

T2

4. Paola Limestone: (1.08 ft., 0.33 m.) Algal wackestone to packstone (at base); lt. brownish gray (5 YR 6/1), weathers lt. gray (N7), thick bedded, blocky; phylloid algae, fenestrate bryozoans, Composita, crinoids; fossils fragmented near the top and near the base; gradational basal contact.

3. Chanute Shale: (0.17 ft., 0.05 m.) Sandy calcareous mudstone; med. gray (N5), weathers mottled dk. yellowish orange (10 YR 6/6), poorly indurated, platy; productids, crinoids, fenestrate and ramose bryozoans, bivalve fragments; fossils fragmented and abraded; sharp basal contact.

T1

2. Chanute Shale: (1.50 ft., 0.46 m.) Silty mudstone; med. gray (N5), weathers lt. gray (N7), micaceous, poorly indurated, platy; Lingula, plant fragments, selenite on bedding planes; gradational basal contact.

1. Chanute Shale: (1.83 ft.+, 0.56 m.+) Mudstone; olive gray (5 YR 3/2), weathers lt. gray (N7), poorly indurated, platy to flaggy, root traces; base not exposed.

APPENDIX 3 - CONODONT DATA

EXPLANATION

The following data is a printout of three QUATTRO spreadsheet files. The three files were too large to fit on one page, in fact each file takes up 14 to 15 pages each. On the screen, the files read from left to right for each sample, but on printed copies the files read from left to right and from page to page for each sample. Samples are listed in columns at the far left of the page, the component categories for each sample is a row at the top of the page.

HDL1 is the second sample from the top on page 236. The residue from the 60 - mesh sieve was split 5 times before picking (1/32 picked), and the residue from the 140 -mesh sieve was split 3 times (1/8 picked). For example, the total for HDL1 (the row labeled total) is 32 times 1 (the number of components in the 60 mesh residue) plus 8 times 5 (the number of components in the 140 mesh residue) equaling 72.

Sample	Streptognathodus Pa	Idiognathodus Pa	Id./S. Pa
HDL2	0	0	0
HDL1			
60 split 5 times	1	0	0
140 spit 3 times	5	0	3
total (calc.)	72	0	24
HDR13			
60	11	0	0
120 split 2 times	88	0	49
total (calc.)	363	0	196
HDR12			
60	5	0	1
120 split 1 time	34	0	17
total (calc.)	73	0	35
HDR11			
60	2	0	0
120 split 1 time	30	0	8
total (calc.)	62	0	16
HDR10	5	0	8
HDR9	12	0	5
HDR8			
60	2	0	1
120 split 1 time	7	0	8
total (calc.)	16	0	17
HDR7			
60	28	0	6
120 split 1 time	25	0	6
total (calc.)	78	0	18
HDR6	30	0	10
HDR5	56	0	13
HDR4			
60 split 2 times	17	7	9
120 split 2 times	68	3	38
total (calc.)	340	40	188
HDR3			
60 split 5 times	8	4	4
140 split 5 times	8	1	20
total (calc.)	512	160	768
HDR1			
60 split 2 times	100	102	93
120 slit 4 times	94	32	177
total (calc.)	1904	920	3204

Sample	Pb	M	Sa	Sb	Sc	Sb-Sc?	Adetognathus	Pa	Pb	M
HDL2	0	0	0	0	0	0		5	3	1
HDL1										
60 split 5 times	0	0	0	0	0	0		6	0	0
140 spit 3 times	0	0	0	0	0	3		3	1	0
total (calc.)	0	0	0	0	0	24		216	8	0
HDR13										
60	0	0	0	0	0	0		10	0	0
120 split 2 times	2	0	0	0	0	2		70	0	0
total (calc.)	8	0	0	0	0	8		290	0	0
HDR12										
60	0	0	0	0	0	0		0	0	0
120 split 1 time	3	1	0	0	1	2		22	1	0
total (calc.)	6	2	0	0	2	4		44	2	0
HDR11										
60	0	0	0	0	0	0		0	0	0
120 split 1 time	0	0	0	0	0	1		1	2	0
total (calc.)	0	0	0	0	0	2		2	4	0
HDR10	0	0	0	0	0	1		1	0	0
HDR9	0	0	0	0	2	2		7	1	0
HDR8										
60	0	0	0	0	0	0		1	0	0
120 split 1 time	0	0	0	0	0	2		2	0	0
total (calc.)	0	0	0	0	0	4		5	0	0
HDR7										
60	2	0	0	0	0	2		9	4	0
120 split 1 time	1	1	1	0	1	3		15	2	0
total (calc.)	4	2	2	0	2	8		39	8	0
HDR6	6	3	0	3	0	11		24	4	1
HDR5	4	1	2	2	5	20		31	8	5
HDR4										
60 split 2 times	0	0	0	0	0	1		3	1	0
120 split 2 times	10	5	2	3	1	35		17	2	2
total (calc.)	40	20	8	12	4	144		80	12	8
HDR3										
60 split 5 times	1	0	0	0	0	0		0	0	0
140 split 5 times	1	0	0	0	0	5		0	0	0
total (calc.)	64	0	0	0	0	160		0	0	0
HDR1										
60 split 2 times	1	0	0	0	0	0		0	0	0
120 slit 4 times	16	4	0	0	0	40		0	0	0
total (calc.)	260	64	0	0	0	640		0	0	0

Sample	Sa	Sb	Sc	Sb or Sc	Hindeodus Pa	Pb	M	Sa	Sb	Sc
HDL2	0	0	0	26	0	0	0	0	0	0
HDL1										
60 split 5 times	0	0	0	0	0	0	0	0	0	0
140 spit 3 times	0	0	1	0	1	1	0	0	0	0
total (calc.)	0	0	8	0	8	8	0	0	0	0
HDR13										
60	0	0	0	0	6	0	0	0	0	0
120 split 2 times	0	0	0	0	17	4	0	0	0	2
total (calc.)	0	0	0	0	74	16	0	0	0	8
HDR12										
60	0	0	0	0	0	1	0	0	0	0
120 split 1 time	0	0	0	2	5	1	0	0	0	2
total (calc.)	0	0	0	4	10	3	0	0	0	4
HDR11										
60	0	0	0	0	2	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	2	0	0	0	0	0
HDR10	0	0	0	0	0	0	0	0	0	0
HDR9	1	0	0	2	1	1	0	0	1	5
HDR8										
60	0	0	0	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0	0	0	0
HDR7										
60	0	0	1	0	4	1	0	0	0	4
120 split 1 time	0	0	2	1	2	0	0	0	0	5
total (calc.)	0	0	5	2	8	1	0	0	0	14
HDR6	0	1	20	9	6	6	1	1	4	8
HDR5	0	0	18	20	11	6	4	0	6	5
HDR4										
60 split 2 times	0	0	1	0	0	0	0	0	1	2
120 split 2 times	0	0	5	6	20	3	6	3	5	15
total (calc.)	0	0	24	24	80	12	24	12	24	68
HDR3										
60 split 5 times	0	0	0	0	0	0	0	0	0	0
140 split 5 times	0	0	0	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0	0	0	0
HDR1										
60 split 2 times	0	0	0	0	1	0	0	0	0	0
120 slit 4 times	0	0	0	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	4	0	0	0	0	0

Sample	Idioprioniodus P	M	S	Aethotaxis M	Sa	Sb	Sc
HDL2	0	0	0	0	0	0	0
HDL1							
60 split 5 times	0	0	0	0	0	0	0
140 spit 3 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HDR13							
60	0	0	0	0	0	0	0
120 split 2 times	0	0	0	0	3	0	8
total (calc.)	0	0	0	0	12	0	32
HDR12							
60	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	2
total (calc.)	0	0	0	0	0	0	4
HDR11							
60	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	3	0
total (calc.)	0	0	0	0	0	6	0
HDR10	0	0	0	0	1	0	0
HDR9	0	0	0	0	0	2	2
HDR8							
60	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HDR7							
60	0	0	1	0	0	0	2
120 split 1 time	0	0	1	0	0	0	2
total (calc.)	0	0	3	0	0	0	6
HDR6	0	0	0	0	0	1	1
HDR5	0	0	1	0	0	0	1
HDR4							
60 split 2 times	1	0	1	0	0	0	0
120 split 2 times	0	0	2	0	0	0	0
total (calc.)	4	0	12	0	0	0	0
HDR3							
60 split 5 times	0	0	2	0	0	0	0
140 split 5 times	2	0	3	0	0	0	0
total (calc.)	64	0	160	0	0	0	0
HDR1							
60 split 2 times	7	1	26	0	0	0	0
120 slit 4 times	22	1	34	0	0	0	0
total (calc.)	380	20	648	0	0	0	0

Sample	Gondolella Pa	Ellisonia Pa	Pb	M	Sa	Sb	Sc
HDL2	0	0	0	0	0	0	0
HDL1							
60 split 5 times	0	0	0	0	0	0	0
140 spit 3 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HDR13							
60	0	0	0	0	0	0	3
120 split 2 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	3
HDR12							
60	0	0	0	0	0	0	1
120 split 1 time	0	0	0	1	0	0	0
total (calc.)	0	0	0	2	0	0	1
HDR11							
60	0	0	0	0	0	0	3
120 split 1 time	0	0	0	0	0	0	1
total (calc.)	0	0	0	0	0	0	5
HDR10	0	0	0	0	0	0	0
HDR9	0	0	0	0	0	0	1
HDR8							
60	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HDR7							
60	0	0	0	0	0	0	6
120 split 1 time	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	6
HDR6	0	0	1	0	1	0	6
HDR5	0	0	0	0	0	0	0
HDR4							
60 split 2 times	0	0	0	0	0	0	0
120 split 2 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HDR3							
60 split 5 times	0	0	0	0	0	0	0
140 split 5 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HDR1							
60 split 2 times	0	0	0	0	0	0	0
120 slit 4 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0

Sample	Diplognathodus Pa	Pb	M	Sa	Sb	Sc	Indeterm.
HDL2	0	0	0	0	0	0	0
HDL1							
60 split 5 times	0	0	0	0	0	0	0
140 spit 3 times	0	0	0	0	0	0	2
total (calc.)	0	0	0	0	0	0	16
HDR13							
60	0	0	0	0	0	0	0
120 split 2 times	0	0	0	0	0	0	18
total (calc.)	0	0	0	0	0	0	72
HDR12							
60	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	5
total (calc.)	0	0	0	0	0	0	10
HDR11							
60	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	1
total (calc.)	0	0	0	0	0	0	2
HDR10	0	0	0	0	0	0	1
HDR9	0	0	0	0	0	0	4
HDR8							
60	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	1
total (calc.)	0	0	0	0	0	0	2
HDR7							
60	0	0	0	0	0	0	2
120 split 1 time	0	0	0	0	0	0	4
total (calc.)	0	0	0	0	0	0	10
HDR6	0	0	0	0	0	0	5
HDR5	0	0	0	0	0	0	16
HDR4							
60 split 2 times	0	0	0	0	0	0	0
120 split 2 times	0	0	0	0	0	0	13
total (calc.)	0	0	0	0	0	0	52
HDR3							
60 split 5 times	0	0	0	0	0	0	1
140 split 5 times	0	0	0	0	0	0	2
total (calc.)	0	0	0	0	0	0	96
HDR1							
60 split 2 times	0	0	0	0	0	0	0
120 slit 4 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0

Sample	Whole	Broken	%Broken	FeO Coated	Dissolution
HDL2	4	31	88.57143	0	0
HDL1					
60 split 5 times	1	5		0	0
140 spit 3 times	1	19		0	0
total (calc.)	40	312	81.25	0	0
HDR13					
60	4	26		0	0
120 split 2 times	11	252		0	2
total (calc.)	48	1034	95.56377	0	8
HDR12					
60	3	5		0	0
120 split 1 time	14	79		0	1
total (calc.)	31	163	79.12621	0	2
HDR11					
60	2	5		0	0
120 split 1 time	22	25		4	0
total (calc.)	46	55	54.45545	8	0
HDR10	2	15	88.23529	1	3
HDR9	13	36	73.46939	3	2
HDR8					
60	1	3		0	0
120 split 1 time	0	20		1	0
total (calc.)	1	43	97.72727	2	0
HDR7					
60	33	39		1	3
120 split 1 time	34	38		2	10
total (calc.)	101	115	53.24074	5	23
HDR6	72	89	54.60123	11	44
HDR5	93	142	60.42553	6	68
HDR4					
60 split 2 times	10	34		0	1
120 split 2 times	67	197		2	9
total (calc.)	308	924	75	8	40
HDR3					
60 split 5 times	2	18		0	0
140 split 5 times	0	42		0	0
total (calc.)	64	1920	96.77419	0	0
HDR1					
60 split 2 times	4	327		25	1
120 slit 4 times	1	419		8	0
total (calc.)	32	8012	99.60219	228	4

Sample	Sinestral	Dextral	Total	Elements/Kg.
HDL2	4	0	35	16.7
HDL1				
60 split 5 times	5	1	7	
140 spit 3 times	4	2	20	
total (calc.)	192	48	384	146.9
HDR13				
60	11	6	30	
120 split 2 times	45	41	263	
total (calc.)	191	170	1082	484.7
HDR12				
60	1	3	8	
120 split 1 time	16	18	99	
total (calc.)	33	39	206	84.2
HDR11				
60	2	0	7	
120 split 1 time	10	18	47	
total (calc.)	22	36	101	34.2
HDR10	1	1	17	8.9
HDR9	10	8	49	18.3
HDR8				
60	0	3	4	
120 split 1 time	6	2	20	
total (calc.)	12	7	44	16.2
HDR7				
60	17	20	72	
120 split 1 time	20	16	72	
total (calc.)	57	52	216	83.9
HDR6	26	25	163	61.4
HDR5	42	37	235	89
HDR4				
60 split 2 times	10	12	44	
120 split 2 times	46	32	264	
total (calc.)	224	176	1232	470.58823529
HDR3				
60 split 5 times	7	3	20	
140 split 5 times	1	6	42	
total (calc.)	256	288	1984	3379.8977853
HDR1				
60 split 2 times	84	74	331	
120 slit 4 times	39	32	420	
total (calc.)	960	808	8044	3415.7112527

Sample	Sample Weight in Kg. Total =	Pa	Pb
HDL2	2.152	5	3
HDL1			
60 split 5 times		7	0
140 spit 3 times		9	2
total (calc.)	2.396	296	16
HDR13			
60		27	0
120 split 2'times		175	6
total (calc.)	2.224	727	24
HDR12			
60		5	1
120 split 1 time		61	5
total (calc.)	2.446	127	11
HDR11			
60		4	0
120 split 1 time		31	2
total (calc.)	2.949	66	4
HDR10	1.902	6	0
HDR9	2.676	20	2
HDR8			
60		3	0
120 split 1 time		9	0
total (calc.)	2.721	21	0
HDR7			
60		41	7
120 split 1 time		42	3
total (calc.)	2.574	125	13
HDR6	2.656	60	17
HDR5	2.629	98	18
HDR4			
60 split 2 times		27	1
120 split 2 times		108	15
total (calc.)	2.618	540	64
HDR3			
60 split 5 times		12	1
140 split 5 times		9	1
total (calc.)	0.587	672	64
HDR1			
60 split 2 times		203	1
120 slit 4 times		126	16
total (calc.)	2.355	2828	260

Sample	M	Sa	Sb	Sc	Sb+Sc ?	Total P's
HDL2	1	0	0	0	26	8
HDL1						
60 split 5 times	0	0	0	0	0	7
140 spit 3 times	0	0	0	1	3	11
total (calc.)	0	0	0	8	24	312
HDR13						
60	0	0	0	3	0	27
120 split 2 times	0	3	0	10	2	181
total (calc.)	0	12	0	43	8	751
HDR12						
60	0	0	0	1	0	6
120 split 1 time	2	0	0	5	4	66
total (calc.)	4	0	0	11	8	138
HDR11						
60	0	0	0	3	0	4
120 split 1 time	0	0	3	1	1	33
total (calc.)	0	0	6	5	2	70
HDR10	0	1	0	0	1	6
HDR9	0	1	3	10	4	22
HDR8						
60	0	0	0	0	0	3
120 split 1 time	0	0	0	0	2	9
total (calc.)	0	0	0	0	4	21
HDR7						
60	0	0	0	13	2	48
120 split 1 time	1	1	0	10	4	45
total (calc.)	2	2	0	33	10	138
HDR6	5	2	9	35	20	77
HDR5	10	2	8	29	40	116
HDR4						
60 split 2 times	0	0	1	3	1	29
120 split 2 times	13	5	8	21	41	123
total (calc.)	52	20	36	96	168	608
HDR3						
60 split 5 times	0	0	0	0	0	13
140 split 5 times	0	0	0	0	5	12
total (calc.)	0	0	0	0	160	800
HDR1						
60 split 2 times	1	0	0	0	0	211
120 slit 4 times	5	0	0	0	40	164
total (calc.)	84	0	0	0	640	3468

Sample	Total M + S's	% P's	% M + S's	Total S. + Id.
HDL2	27	22.857	77.14286	0
HDL1				
60 split 5 times	0			
140 spit 3 times	4			
total (calc.)	32	81.25	8.333333	72
HDR13				
60	3			
120 split 2 times	15			
total (calc.)	63	69.409	5.822551	363
HDR12				
60	1			
120 split 1 time	11			
total (calc.)	23	66.99	11.16505	73
HDR11				
60	3			
120 split 1 time	5			
total (calc.)	13	69.307	12.87129	62
HDR10	2	35.294	11.76471	5
HDR9	18	44.898	36.73469	12
HDR8				
60	0			
120 split 1 time	2			
total (calc.)	4	47.727	9.090909	16
HDR7				
60	16			
120 split 1 time	17			
total (calc.)	50	63.889	23.14815	78
HDR6	71	47.239	43.55828	30
HDR5	90	49.362	38.29787	56
HDR4				
60 split 2 times	6			
120 split 2 times	90			
total (calc.)	384	49.351	31.16883	380
HDR3				
60 split 5 times	2			
140 split 5 times	8			
total (calc.)	320	40.323	16.12903	672
HDR1				
60 split 2 times	28			
120 slit 4 times	80			
total (calc.)	1392	43.113	17.30482	2824

Sample	Total Adeto.	% S. Pa's	%Id. Pa's	%A. Pa's	%Hind.Pa'
HDL2	5	0	0	14.28571	0
HDL1					
60 split 5 times					
140 spit 3 times					
total (calc.)	216	18.75	0	56.25	2.083333
HDR13					
60					
120 split 2 times					
total (calc.)	290	33.5489834	0	26.80222	6.839187
HDR12					
60					
120 split 1 time					
total (calc.)	44	35.4368932	0	21.35922	4.854369
HDR11					
60					
120 split 1 time					
total (calc.)	2	61.3861386	0	1.980198	1.980198
HDR10	1	29.4117647	0	5.882353	0
HDR9	7	24.4897959	0	14.28571	2.040816
HDR8					
60					
120 split 1 time					
total (calc.)	5	36.3636364	0	11.36364	0
HDR7					
60					
120 split 1 time					
total (calc.)	39	36.1111111	0	18.05556	3.703704
HDR6	24	18.404908	0	14.72393	3.680982
HDR5	31	23.8297872	0	13.19149	4.680851
HDR4					
60 split 2 times					
120 split 2 times					
total (calc.)	80	27.5974026	3.246753	6.493506	6.493506
HDR3					
60 split 5 times					
140 split 5 times					
total (calc.)	0	25.8064516	8.064516	0	0
HDR1					
60 split 2 times					
120 slit 4 times					
total (calc.)	0	23.669816	11.4371	0	0.049727

Sample	%Idioprio.	%Aetho.	%Gond.	%Ellis.	%Diplo.
HDL2	0	0	0	0	0
HDL1					
60 split 5 times					
140 spit 3 times					
total (calc.)	0	0	0	0	0
HDR13					
60					
120 split 2 times					
total (calc.)	0	4.066543	0	0.277264	0
HDR12					
60					
120 split 1 time					
total (calc.)	0	1.941748	0	1.456311	0
HDR11					
60					
120 split 1 time					
total (calc.)	0	5.940594	0	4.950495	0
HDR10	0	5.882353	0	0	0
HDR9	0	8.163265	0	2.040816	0
HDR8					
60					
120 split 1 time					
total (calc.)	0	0	0	0	0
HDR7					
60					
120 split 1 time					
total (calc.)	1.3888889	2.777778	0	2.777778	0
HDR6	0	1.226994	0	4.907975	0
HDR5	0.4255319	0.425532	0	0	0
HDR4					
60 split 2 times					
120 split 2 times					
total (calc.)	1.2987013	0	0	0	0
HDR3					
60 split 5 times					
140 split 5 times					
total (calc.)	11.290323	0	0	0	0
HDR1					
60 split 2 times					
120 slit 4 times					
total (calc.)	13.028344	0	0	0	0

Sample	%Indet.
HDL2	0
HDL1	
60 split 5 times	
140 spit 3 times	
total (calc.)	4.166667
HDR13	
60	
120 split 2 times	
total (calc.)	6.654344
HDR12	
60	
120 split 1 time	
total (calc.)	4.854369
HDR11	
60	
120 split 1 time	
total (calc.)	1.980198
HDR10	5.882353
HDR9	8.163265
HDR8	
60	
120 split 1 time	
total (calc.)	4.545455
HDR7	
60	
120 split 1 time	
total (calc.)	4.62963
HDR6	3.067485
HDR5	6.808511
HDR4	
60 split 2 times	
120 split 2 times	
total (calc.)	4.220779
HDR3	
60 split 5 times	
140 split 5 times	
total (calc.)	4.83871
HDR1	
60 split 2 times	
120 slit 4 times	
total (calc.)	0

Sample	Streptognathodus Pa	Idiognath Pa	Id./S Pa	Pb
HD1				
60 split 6 times	5	4	3	1
140 split 6 times	12	7	34	6
total (calc.)	1088	704	2368	448
HD2				
60 split 4 times	0	2	3	1
140 split 4 times	0	0	.1	0
total (calc.)	0	32	64	16
HD3				
60 split 3 times	1	0	1	0
140 split 4 times	1	0	0	0
total (calc.)	24	0	8	0
HD4				
60 split 3 times	3	3	7	0
140 split 3 times	1	0	5	1
total (calc.)	32	24	96	8
HD5				
60 split 4 times	10	12	19	1
140 split 4 times	24	10	51	20
total (calc.)	544	352	1120	336
HD6				
60 split 6 times	9	4	16	1
140 split 7 times	4	0	13	0
total (calc.)	1088	256	2688	64
HD7				
60 split 6 times	2	1	2	0
140 split 7 times	4	0	4	6
total (calc.)	640	64	640	768
HD8				
60	117	78	247	54
140	19	1	27	95
total	136	79	274	149
HD9				
60	55	10	49	16
60 and 140 split 1 time	207	28	189	84
total (calc.)	469	66	427	184
HD10				
60	14	16	34	5
140 split 1 time	41	4	8	14
total (calc.)	96	24	50	33
HD11	6	6	14	0
HD12	17	0	7	6
HD13	2	2	5	2
HD14				
60 split 1 time	4	1	6	0
140	19	2	17	8
total (calc.)	27	4	29	8
HDP4				
60	102	33	95	6
140 split 2 times	25	0	23	10
total	202	33	187	46
HDP3	81	0	30	39
HDP1	246	1	112	37
HDC2				
60 split 5 times	1	0	0	0
140 split 6 times	3	0	5	0
total (calc.)	224	0	320	0
HDC1	0	0	0	0

Sample	M	Sa	Sb	Sc	Sb-Sc?	Adetognathus Pa	Pb
HD1							
60 split 6 times	0	0	0	0	1	0	0
140 split 6 times	0	0	0	0	16	0	0
total (calc.)	0	0	0	0	1088	0	0
HD2							
60 split 4 times	0	0	0	0	3	0	0
140 split 4 times	0	0	0	0	4	0	0
total (calc.)	0	0	0	0	112	0	0
HD3							
60 split 3 times	0	0	0	0	3	0	0
140 split 4 times	1	0	0	0	6	0	0
total (calc.)	16	0	0	0	120	0	0
HD4							
60 split 3 times	0	0	0	0	2	0	0
140 split 3 times	1	0	0	0	7	0	0
total (calc.)	8	0	0	0	72	0	0
HD5							
60 split 4 times	0	0	0	0	7	0	0
140 split 4 times	3	0	0	3	213	0	0
total (calc.)	48	0	0	48	3520	0	0
HD6							
60 split 6 times	0	0	0	1	16	0	0
140 split 7 times	4	0	0	0	55	0	0
total (calc.)	512	0	0	64	8064	0	0
HD7							
60 split 6 times	0	0	0	0	6	0	0
140 split 7 times	1	0	0	0	25	0	0
total (calc.)	128	0	0	0	3584	0	0
HD8							
60	1	0	0	1	127	0	0
140	18	2	0	5	331	0	0
total	19	2	0	6	458	0	0
HD9							
60	1	0	0	0	22	1	0
60 and 140 split 1 ti	15	0	0	1	182	4	0
total (calc.)	31	0	0	2	386	9	0
HD10							
60	0	0	0	0	3	0	0
140 split 1 time	2	0	0	0	47	0	0
total (calc.)	4	0	0	0	97	0	0
HD11	1	0	0	0	19	0	0
HD12	0	0	0	0	18	0	0
HD13	0	0	0	0	1	0	0
HD14							
60 split 1 time	0	0	0	0	0	0	0
140	5	0	0	0	51	0	0
total (calc.)	5	0	0	0	51	0	0
HDP4							
60	0	0	0	0	9	0	0
140 split 2 times	1	0	0	0	77	0	0
total	4	0	0	0	317	0	0
HDP3	36	23	0	19	149	0	0
HDP1	17	3	4	13	118	11	0
HDC2							
60 split 5 times	0	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	3	0
total (calc.)	0	0	0	0	0	192	0
HDC1	0	0	0	0	0	1	0

Sample	M	Sa	Sb	Sc	Sb or Sc	Hindeodus	Pa	Pb
HD1								
60 split 6 times	0	0	0	0	0		0	0
140 split 6 times	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HD2								
60 split 4 times	0	0	0	0	0		0	0
140 split 4 times	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HD3								
60 split 3 times	0	0	0	0	0		0	0
140 split 4 times	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HD4								
60 split 3 times	0	0	0	0	0		0	0
140 split 3 times	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HD5								
60 split 4 times	0	0	0	0	0		0	0
140 split 4 times	0	0	0	0	0		1	0
total (calc.)	0	0	0	0	0		16	0
HD6								
60 split 6 times	0	0	0	0	0		0	0
140 split 7 times	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HD7								
60 split 6 times	0	0	0	0	0		0	0
140 split 7 times	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HD8								
60	0	0	0	0	0		0	0
140	0	0	0	0	0		0	0
total	0	0	0	0	0		0	0
HD9								
60	0	0	0	0	0		0	0
60 and 140 split 1 ti	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HD10								
60	0	0	0	0	0		1	0
140 split 1 time	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		1	0
HD11	0	0	0	0	0		2	1
HD12	0	0	0	0	0		0	0
HD13	0	0	0	0	0		0	0
HD14								
60 split 1 time	0	0	0	0	0		0	0
140	0	0	0	0	0		0	0
total (calc.)	0	0	0	0	0		0	0
HDP4								
60	0	0	0	0	0		3	1
140 split 2 times	0	0	0	0	0		4	0
total	0	0	0	0	0		19	1
HDP3	0	0	0	0	0		27	19
HDP1	0	0	0	0	0		35	6
HDC2								
60 split 5 times	0	0	0	0	0		0	0
140 split 6 times	0	0	0	0	0		1	0
total (calc.)	0	0	0	0	0		64	0
HDC1	0	0	0	0	0		0	0

Sample	M	Sa	Sb	Sc	Idioprioniodus P	M	S
HD1							
60 split 6 times	0	0	0	0	2	0	1
140 split 6 times	0	0	0	0	3	0	5
total (calc.)	0	0	0	0	320	0	384
HD2							
60 split 4 times	0	0	0	0	0	0	0
140 split 4 times	0	0	0	0	1	0	0
total (calc.)	0	0	0	0	16	0	0
HD3							
60 split 3 times	0	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HD4							
60 split 3 times	0	0	0	0	0	0	0
140 split 3 times	0	0	0	0	3	0	1
total (calc.)	0	0	0	0	24	0	8
HD5							
60 split 4 times	0	0	0	0	0	0	3
140 split 4 times	0	0	1	0	6	0	15
total (calc.)	0	0	16	0	96	0	288
HD6							
60 split 6 times	0	0	0	0	2	0	4
140 split 7 times	0	0	0	1	2	0	7
total (calc.)	0	0	0	128	384	0	1152
HD7							
60 split 6 times	0	0	0	0	1	0	2
140 split 7 times	0	0	0	0	0	0	3
total (calc.)	0	0	0	0	64	0	512
HD8							
60	0	0	0	0	63	0	85
140	0	0	0	0	0	0	96
total	0	0	0	0	63	0	181
HD9							
60	0	0	0	0	5	0	5
60 and 140 split 1 ti	0	0	0	0	35	0	34
total (calc.)	0	0	0	0	75	0	73
HD10							
60	0	0	0	0	2	0	4
140 split 1 time	0	0	0	0	6	0	7
total (calc.)	0	0	0	0	14	0	18
HD11	0	0	0	0	0	0	1
HD12	0	0	0	0	0	0	0
HD13	0	0	0	0	0	0	0
HD14							
60 split 1 time	0	0	0	0	0	0	0
140	0	0	0	0	0	0	2
total (calc.)	0	0	0	0	0	0	2
HDP4							
60	0	0	0	0	1	0	12
140 split 2 times	1	0	0	2	6	0	5
total	4	0	0	8	25	0	32
HDP3	8	2	9	31	0	0	0
HDP1	5	5	11	23	1	0	1
HDC2							
60 split 5 times	0	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0	0
HDC1	0	0	0	0	0	0	0

Sample	Aethotaxis	M	Sa	Sb	Sc	Gondolella Pa
HD1						
60 split 6 times		0	0	0	0	0
140 split 6 times		0	0	0	0	0
total (calc.)		0	0	0	0	0
HD2						
60 split 4 times		0	0	0	0	0
140 split 4 times		0	0	0	0	0
total (calc.)		0	0	0	0	0
HD3						
60 split 3 times		0	0	0	0	0
140 split 4 times		0	0	0	0	0
total (calc.)		0	0	0	0	0
HD4						
60 split 3 times		0	0	0	0	0
140 split 3 times		0	0	0	0	0
total (calc.)		0	0	0	0	0
HD5						
60 split 4 times		0	0	0	0	0
140 split 4 times		0	0	0	0	2
total (calc.)		0	0	0	0	32
HD6						
60 split 6 times		0	0	0	0	0
140 split 7 times		0	0	0	0	0
total (calc.)		0	0	0	0	0
HD7						
60 split 6 times		0	0	0	0	6
140 split 7 times		0	0	0	0	3
total (calc.)		0	0	0	0	768
HD8						
60		0	0	0	0	3
140		0	0	0	0	3
total		0	0	0	0	6
HD9						
60		0	0	0	0	0
60 and 140 split 1 ti		0	0	0	0	0
total (calc.)		0	0	0	0	0
HD10						
60		0	0	0	0	0
140 split 1 time		0	0	0	0	1
total (calc.)		0	0	0	0	2
HD11		0	0	0	0	0
HD12		0	0	0	0	0
HD13		0	0	0	0	0
HD14						
60 split 1 time		0	0	0	0	0
140		0	0	0	0	0
total (calc.)		0	0	0	0	0
HDP4						
60		0	0	0	0	0
140 split 2 times		0	0	0	0	0
total		0	0	0	0	0
HDP3		1	2	5	8	0
HDP1		0	3	0	2	0
HDC2						
60 split 5 times		0	0	0	0	0
140 split 6 times		0	0	0	0	0
total (calc.)		0	0	0	0	0
HDC1		0	0	0	0	0

Sample	Ellisonia Pa	Pb	M	Sa	Sb	Sc
HD1						
60 split 6 times	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD2						
60 split 4 times	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD3						
60 split 3 times	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD4						
60 split 3 times	0	0	0	0	0	0
140 split 3 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD5						
60 split 4 times	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD6						
60 split 6 times	0	0	0	0	0	0
140 split 7 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD7						
60 split 6 times	0	0	0	0	0	0
140 split 7 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD8						
60	0	0	0	0	0	0
140	0	0	0	0	0	0
total	0	0	0	0	0	0
HD9						
60	0	0	0	0	0	0
60 and 140 split 1 ti	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD10						
60	0	0	0	0	0	0
140 split 1 time	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD11	0	0	0	0	0	0
HD12	0	0	0	0	0	0
HD13	0	0	0	0	0	0
HD14						
60 split 1 time	0	0	0	0	0	0
140	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HDP4						
60	0	0	0	0	0	0
140 split 2 times	0	0	0	0	0	0
total	0	0	0	0	0	0
HDP3	0	0	0	0	0	3
HDP1	0	0	0	0	0	2
HDC2						
60 split 5 times	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HDC1	0	0	0	0	0	0

Sample	Diplognathodus Pa	Pb	M	Sa	Sb	Sc
HD1						
60 split 6 times	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD2						
60 split 4 times	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD3						
60 split 3 times	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD4						
60 split 3 times	0	0	0	0	0	0
140 split 3 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD5						
60 split 4 times	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD6						
60 split 6 times	0	0	0	0	0	0
140 split 7 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD7						
60 split 6 times	0	0	0	0	0	0
140 split 7 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD8						
60	0	0	0	0	0	0
140	0	0	0	0	0	0
total	0	0	0	0	0	0
HD9						
60	0	0	0	0	0	0
60 and 140 split 1 ti	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD10						
60	0	0	0	0	0	0
140 split 1 time	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HD11	0	0	0	0	0	0
HD12	0	0	0	0	0	0
HD13	0	0	0	0	0	0
HD14						
60 split 1 time	0	0	0	0	0	0
140	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HDP4						
60	0	0	0	0	0	0
140 split 2 times	0	0	0	0	0	0
total	0	0	0	0	0	0
HDP3	0	0	0	0	0	0
HDP1	0	0	0	0	0	0
HDC2						
60 split 5 times	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0
total (calc.)	0	0	0	0	0	0
HDC1	0	0	0	0	0	0

Sample	Indeterm.	Whole	Broken	%Broken	FeO Coated
HD1					
60 split 6 times	0	1	16		0
140 split 6 times	12	1	94		1
total (calc.)	768	128	7040	98.21429	64
HD2					
60 split 4 times	0	0	9		0
140 split 4 times	0	0	6		0
total (calc.)	0	0	240	100	0
HD3					
60 split 3 times	0	0	5		0
140 split 4 times	0	0	8		0
total (calc.)	0	0	168	100	0
HD4					
60 split 3 times	0	0	15		0
140 split 3 times	1	0	20		0
total (calc.)	8	0	280	100	0
HD5					
60 split 4 times	1	0	54		0
140 split 4 times	34	3	380		0
total (calc.)	560	48	6944	99.54128	0
HD6					
60 split 6 times	0	1	52		0
140 split 7 times	9	0	95		0
total (calc.)	1152	64	15488	99.58848	0
HD7					
60 split 6 times	1	2	19		0
140 split 7 times	15	1	60		0
total (calc.)	1984	256	8896	97.2028	0
HD8					
60	0	7	769		0
140	4	0	601		0
total	4	7	1370	99.49165	0
HD9					
60	0	0	164		0
60 and 140 split 1 ti	0	0	779		0
total (calc.)	0	0	1722	100	0
HD10					
60	0	0	79		0
140 split 1 time	0	1	129		0
total (calc.)	0	2	337	99.41003	0
HD11	0	1	49	98	0
HD12	0	0	48	100	0
HD13	0	0	12	100	0
HD14					
60 split 1 time	0	0	11		0
140	0	1	103		0
total (calc.)	0	1	125	99.20635	0
HDP4					
60	0	9	253		0
140 split 2 times	2	4	152		0
total	8	25	861	97.17833	0
HDP3	53	99	429	78.7156	0
HDP1	31	120	567	82.53275	6
HDC2					
60 split 5 times	0	0	1		0
140 split 6 times	3	2	13		0
total (calc.)	192	128	864	87.09677	0
HDC1	0	0	1	100	0

Sample	Dissolution	Sinestral	Dextral	Total
HD1				
60 split 6 times	0	5	4	17
140 split 6 times	0	4	8	95
total (calc.)	0	576	768	7168
HD2				
60 split 4 times	0	1	1	9
140 split 4 times	0	0	0	6
total (calc.)	0	16	16	240
HD3				
60 split 3 times	0	0	1	5
140 split 4 times	0	0	0	8
total (calc.)	0	0	8	168
HD4				
60 split 3 times	0	4	1	15
140 split 3 times	0	0	0	20
total (calc.)	0	32	8	280
HD5				
60 split 4 times	0	24	16	53
140 split 4 times	0	0	0	383
total (calc.)	0	384	256	6976
HD6				
60 split 6 times	0	6	5	53
140 split 7 times	0	0	1	95
total (calc.)	0	384	448	15552
HD7				
60 split 6 times	0	2	1	21
140 split 7 times	0	3	1	61
total (calc.)	0	512	192	9152
HD8				
60	0	71	88	776
140	0	11	4	601
total	0	82	92	1377
HD9				
60	0	31	26	164
60 and 140 split 1 ti	0	111	99	779
total (calc.)	0	253	224	1722
HD10				
60	0	12	11	79
140 split 1 time	0	5	9	130
total (calc.)	0	22	29	339
HD11	0	0	4	50
HD12	0	5	8	48
HD13	0	4	0	12
HD14				
60 split 1 time	0	2	3	11
140	0	12	9	104
total (calc.)	0	16	15	126
HDP4				
60	0	61	48	262
140 split 2 times	0	4	8	156
total	0	77	80	886
HDP3	0	33	43	545
HDP1	0	115	116	687
HDC2				
60 split 5 times	0	0	1	1
140 split 6 times	0	3	2	15
total (calc.)	0	192	160	992
HDC1	0	0	0	1

Sample	Elements/Kg.	Sample Weight in Kg.	Total = Pa
HD1			
60 split 6 times			9
140 split 6 times			19
total (calc.)	5438.5	1.318	1792
HD2			
60 split 4 times			2
140 split 4 times			0
total (calc.)	524	0.458	32
HD3			
60 split 3 times			1
140 split 4 times			1
total (calc.)	362.9	0.463	24
HD4			
60 split 3 times			6
140 split 3 times			1
total (calc.)	308.4	0.908	56
HD5			
60 split 4 times			22
140 split 4 times			37
total (calc.)	4491.951062	1.553	944
HD6			
60 split 6 times			13
140 split 7 times			4
total (calc.)	7363.636364	2.112	1344
HD7			
60 split 6 times			9
140 split 7 times			7
total (calc.)	4001.749016	2.287	1472
HD8			
60			198
140			23
total	706.5161621	1.949	221
HD9			
60			66
60 and 140 split 1 ti			239
total (calc.)	845.7760314	2.036	544
HD10			
60			31
140 split 1 time			46
total (calc.)	446.6403162	0.759	123
HD11	63.85696041	0.783	14
HD12	50.73995772	0.946	17
HD13	12.75239107	0.941	4
HD14			
60 split 1 time			5
140			21
total (calc.)	107.1428571	1.176	31
HDP4			
60			138
140 split 2 times			29
total	886	1	254
HDP3	170.5790297	3.195	108
HDP1	209.4512195	3.28	293
HDC2			
60 split 5 times			1
140 split 6 times			7
total (calc.)	861.1111111	1.152	480
HDC1	0.52882073	1.891	1

Sample	Pb	M	Sa	Sb	Sc
HD1					
60 split 6 times	1	0	0	0	0
140 split 6 times	6	0	0	0	0
total (calc.)	448	0	0	0	0
HD2					
60 split 4 times	1	0	0	0	0
140 split 4 times	0	0	0	0	0
total (calc.)	16	0	0	0	0
HD3					
60 split 3 times	0	0	0	0	0
140 split 4 times	0	1	0	0	0
total (calc.)	0	16	0	0	0
HD4					
60 split 3 times	0	0	0	0	0
140 split 3 times	1	1	0	0	0
total (calc.)	8	8	0	0	0
HD5					
60 split 4 times	1	0	0	0	0
140 split 4 times	20	3	0	1	3
total (calc.)	336	48	0	16	48
HD6					
60 split 6 times	1	0	0	0	1
140 split 7 times	0	4	0	0	1
total (calc.)	64	512	0	0	192
HD7					
60 split 6 times	0	0	0	0	0
140 split 7 times	6	1	0	0	0
total (calc.)	768	128	0	0	0
HD8					
60	54	1	0	0	1
140	95	18	2	0	5
total	149	19	2	0	6
HD9					
60	16	1	0	0	0
60 and 140 split 1 ti	84	15	0	0	1
total (calc.)	184	31	0	0	2
HD10					
60	5	0	0	0	0
140 split 1 time	14	2	0	0	0
total (calc.)	33	4	0	0	0
HD11	1	1	0	0	0
HD12	6	0	0	0	0
HD13	2	0	0	0	0
HD14					
60 split 1 time	0	0	0	0	0
140	8	5	0	0	0
total (calc.)	8	5	0	0	0
HDP4					
60	7	0	0	0	0
140 split 2 times	10	2	0	0	2
total	47	8	0	0	8
HDP3	58	45	27	14	61
HDP1	43	22	11	15	40
HDC2					
60 split 5 times	0	0	0	0	0
140 split 6 times	0	0	0	0	0
total (calc.)	0	0	0	0	0
HDC1	0	0	0	0	0

Sample	Sb+Sc ?	Total P's	Total M + S's	% P's	% M + S's
HD1					
60 split 6 times	1	12	2		
140 split 6 times	16	28	21		
total (calc.)	1088	2560	1472	35.71429	20.53571
HD2					
60 split 4 times	3	3	3		
140 split 4 times	4	1	4		
total (calc.)	112	64	112	26.66667	46.66667
HD3					
60 split 3 times	3	1	3		
140 split 4 times	6	1	7		
total (calc.)	120	24	136	14.28571	80.95238
HD4					
60 split 3 times	2	6	2		
140 split 3 times	7	5	9		
total (calc.)	72	88	88	31.42857	31.42857
HD5					
60 split 4 times	7	23	10		
140 split 4 times	213	63	235		
total (calc.)	3520	1376	3920	19.72477	56.19266
HD6					
60 split 6 times	16	16	21		
140 split 7 times	55	6	67		
total (calc.)	8064	1792	9920	11.52263	63.78601
HD7					
60 split 6 times	6	10	8		
140 split 7 times	25	13	29		
total (calc.)	3584	2304	4224	25.17483	46.15385
HD8					
60	127	315	214		
140	331	118	452		
total	458	433	666	31.44517	48.36601
HD9					
60	22	87	28		
60 and 140 split 1 ti	182	358	232		
total (calc.)	386	803	492	46.63182	28.57143
HD10					
60	3	38	7		
140 split 1 time	47	66	56		
total (calc.)	97	170	119	50.14749	35.10324
HD11	19	15	21	30	42
HD12	18	23	18	47.91667	37.5
HD13	1	6	1	50	8.333333
HD14					
60 split 1 time	0	5	0		
140	51	29	58		
total (calc.)	51	39	58	30.95238	46.03175
HDP4					
60	9	146	21		
140 split 2 times	77	45	86		
total	317	326	365	36.79458	41.19639
HDP3	149	166	296	30.45872	54.31193
HDP1	118	337	207	49.05386	30.131
HDC2					
60 split 5 times	0	1	0		
140 split 6 times	0	7	0		
total (calc.)	0	480	0	48.3871	0
HDC1	0	1	0	100	0

Sample	Total S. + Id.	Total Adeto.	% S. Pa's	%Id. Pa's
HD1				
60 split 6 times				
140 split 6 times				
total (calc.)	1792	0	15.178571	9.8214286
HD2				
60 split 4 times				
140 split 4 times				
total (calc.)	32	0	0	13.333333
HD3				
60 split 3 times				
140 split 4 times				
total (calc.)	24	0	14.285714	0
HD4				
60 split 3 times				
140 split 3 times				
total (calc.)	56	0	11.428571	8.5714286
HD5				
60 split 4 times				
140 split 4 times				
total (calc.)	896	0	7.7981651	5.0458716
HD6				
60 split 6 times				
140 split 7 times				
total (calc.)	1344	0	6.9958848	1.6460905
HD7				
60 split 6 times				
140 split 7 times				
total (calc.)	704	0	6.993007	0.6993007
HD8				
60				
140				
total	215	0	9.8765432	5.7371097
HD9				
60				
60 and 140 split 1 ti				
total (calc.)	535	9	27.235772	3.8327526
HD10				
60				
140 split 1 time				
total (calc.)	120	0	28.318584	7.079646
HD11	12	0	12	12
HD12	17	0	35.416667	0
HD13	4	0	16.666667	16.666667
HD14				
60 split 1 time				
140				
total (calc.)	31	0	21.428571	3.1746032
HDP4				
60				
140 split 2 times				
total	235	0	22.799097	3.724605
HDP3	81	0	14.862385	0
HDP1	247	11	35.80786	0.1455604
HDC2				
60 split 5 times				
140 split 6 times				
total (calc.)	224	192	22.580645	0
HDC1	0	1	0	0

Sample	%A. Pa's	%Hind.Pa's	%Idioprio.	%Aetho.	%Gond.
HD1					
60 split 6 times					
140 split 6 times					
total (calc.)	0	0	9.82142857	0	0
HD2					
60 split 4 times					
140 split 4 times					
total (calc.)	0	0	6.66666667	0	0
HD3					
60 split 3 times					
140 split 4 times					
total (calc.)	0	0	0	0	0
HD4					
60 split 3 times					
140 split 3 times					
total (calc.)	0	0	11.4285714	0	0
HD5					
60 split 4 times					
140 split 4 times					
total (calc.)	0	0.2293578	5.50458716	0	0.458716
HD6					
60 split 6 times					
140 split 7 times					
total (calc.)	0	0	9.87654321	0	0
HD7					
60 split 6 times					
140 split 7 times					
total (calc.)	0	0	6.29370629	0	8.391608
HD8					
60					
140					
total	0	0	17.7196805	0	0.43573
HD9					
60					
60 and 140 split 1 ti					
total (calc.)	0.5226481	0	8.59465738	0	0
HD10					
60					
140 split 1 time					
total (calc.)	0	0.29498525	9.43952802	0	0.589971
HD11	0	4	2	0	0
HD12	0	0	0	0	0
HD13	0	0	0	0	0
HD14					
60 split 1 time					
140					
total (calc.)	0	0	1.58730159	0	0
HDP4					
60					
140 split 2 times					
total	0	2.14446953	6.43340858	0	0
HDP3	0	4.95412844	0	2.9357798	0
HDP1	1.6011645	5.09461426	0.29112082	0.727802	0
HDC2					
60 split 5 times					
140 split 6 times					
total (calc.)	19.354839	6.4516129	0	0	0
HDC1	100	0	0	0	0

Sample	%Ellis.	%Diplo.	%Indet.
HD1			
60 split 6 times			
140 split 6 times			
total (calc.)	0	0	10.71429
HD2			
60 split 4 times			
140 split 4 times			
total (calc.)	0	0	0
HD3			
60 split 3 times			
140 split 4 times			
total (calc.)	0	0	0
HD4			
60 split 3 times			
140 split 3 times			
total (calc.)	0	0	2.857143
HD5			
60 split 4 times			
140 split 4 times			
total (calc.)	0	0	8.027523
HD6			
60 split 6 times			
140 split 7 times			
total (calc.)	0	0	7.407407
HD7			
60 split 6 times			
140 split 7 times			
total (calc.)	0	0	21.67832
HD8			
60			
140			
total	0	0	0.290487
HD9			
60			
60 and 140 split 1 ti			
total (calc.)	0	0	0
HD10			
60			
140 split 1 time			
total (calc.)	0	0	0
HD11	0	0	0
HD12	0	0	0
HD13	0	0	0
HD14			
60 split 1 time			
140			
total (calc.)	0	0	0
HDP4			
60			
140 split 2 times			
total	0	0	0.902935
HDP3	0.550459	0	9.724771
HDP1	0.291121	0	4.512373
HDC2			
60 split 5 times			
140 split 6 times			
total (calc.)	0	0	19.35484
HDC1	0	0	0

Sample	Streptognathodus Pa	Idiognathodus Pa	Id./S.
OSACo36	2	0	
OSACo35	14	0	
OSACo34	50	0	
OSACo33	90	0	
OSACo32	10	0	
OSACo31	8	0	
OSACo30	23	0	
OSACo29	35	0	
OSACo28	21	0	
OSACo27	9	0	
OSACo26	19	0	
OSACo25	45	0	
OSACo24	32	0	
OSACo23	49	0	
OSACo22	48	0	
OSACo21	65	0	
OSACo20	48	0	
OSACo19			
60	34	3	
120 split 1 time	135	0	
total (calculated)	304	3	
OSACo18			
60 split 6 times	5	2	
140 split 7 times	14	1	
total (calculated)	2112	256	
OSACo17			
60 split 5 times	26	14	
140 split 5 times	50	18	
total (calculated)	2432	1024	
OSACo16	39	1	
OSACo15	62	0	
OSACo14	91	0	
OSACo13			
60 spit 2 times	2	0	
140 split 4 times	13	0	
total (calculated)	216	0	
OSACo12			
60 split 5 times	0	0	
140 split 6 times	1	0	
total (calculated)	64	0	

Sample	Pa	Pb	M	Sa	Sb	Sc	Sb-Sc?	Adetognathus Pa
OSACo36	1	3	1	0	1	5	10	0
OSACo35	8	0	1	0	0	2	1	4
OSACo34	9	3	1	1	2	8	23	7
OSACo33	43	12	4	3	3	15	47	26
OSACo32	1	1	2	0	0	2	9	0
OSACo31	3	5	1	3	0	5	25	3
OSACo30	8	0	2	1	0	4	37	3
OSACo29	13	6	0	0	0	2	18	3
OSACo28	5	3	1	2	1	13	34	5
OSACo27	0	1	3	1	1	2	8	2
OSACo26	3	4	4	3	0	3	13	1
OSACo25	1	7	3	2	7	11	24	8
OSACo24	5	6	4	1	0	5	26	3
OSACo23	12	18	14	4	2	8	64	0
OSACo22	17	23	17	13	4	16	80	1
OSACo21	10	26	20	10	16	40	98	3
OSACo20	19	7	7	1	1	0	32	2
OSACo19								
60	7	0	1	0	0	0	1	0
120 split 1 time	142	15	8	1	2	4	45	2
total (calculated)	291	30	17	2	4	8	91	4
OSACo18								
60 split 6 times	6	0	0	0	0	0	0	0
140 split 7 times	15	0	0	0	0	0	1	0
total (calculated)	2304	0	0	0	0	0	128	0
OSACo17								
60 split 5 times	25	0	0	0	0	0	1	0
140 split 5 times	174	9	1	0	0	0	18	0
total (calculated)	6368	288	32	0	0	0	608	0
OSACo16	32	17	19	7	1	6	60	0
OSACo15	8	30	17	3	11	22	78	0
OSACo14	14	29	35	4	12	24	143	1
OSACo13								
60 spit 2 times	0	0	0	0	0	0	0	1
140 split 4 times	8	1	0	0	0	0	3	5
total (calculated)	128	16	0	0	0	0	48	84
OSACo12								
60 split 5 times	0	0	0	0	0	0	0	1
140 split 6 times	1	0	1	0	0	0	0	2
total (calculated)	64	0	64	0	0	0	0	160

Sample	Pb	M	Sa	Sb	Sc	Sb or Sc	Hindeodus Pa	Pb	M
OSACo36	1	0	0	0	0	0	5	0	1
OSACo35	2	0	0	0	1	0	1	0	0
OSACo34	0	0	0	0	0	1	5	3	3
OSACo33	1	1	0	0	4	0	57	10	9
OSACo32	1	0	0	0	3	0	4	7	4
OSACo31	1	1	1	0	4	0	9	6	4
OSACo30	0	0	0	0	0	1	8	1	3
OSACo29	0	0	0	0	5	0	18	9	9
OSACo28	1	1	0	0	5	0	9	10	10
OSACo27	0	0	1	0	1	0	2	0	2
OSACo26	1	0	0	0	4	0	8	4	6
OSACo25	0	3	0	0	3	2	16	13	6
OSACo24	0	0	0	0	0	0	5	8	3
OSACo23	3	1	0	0	3	0	9	8	7
OSACo22	1	1	0	0	1	0	20	11	7
OSACo21	1	0	1	0	11	0	15	11	15
OSACo20	0	0	0	0	0	1	6	1	1
OSACo19									
60	0	0	0	0	0	0	1	0	0
120 split 1 time	0	0	0	0	0	0	22	0	2
total (calculated)	0	0	0	0	0	0	45	0	4
OSACo18									
60 split 6 times	0	0	0	0	0	0	0	0	0
140 split 7 times	0	0	0	0	0	0	2	0	0
total (calculated)	0	0	0	0	0	0	256	0	0
OSACo17									
60 split 5 times	0	0	0	0	0	0	0	0	0
140 split 5 times	0	0	0	0	0	0	2	2	0
total (calculated)	0	0	0	0	0	0	64	64	0
OSACo16	0	0	0	0	0	0	6	7	8
OSACo15	0	0	0	0	0	0	9	3	2
OSACo14	0	1	0	0	0	0	8	12	4
OSACo13									
60 spit 2 times	0	0	0	0	0	0	2	0	0
140 split 4 times	0	0	0	0	0	0	1	2	0
total (calculated)	0	0	0	0	0	0	24	32	0
OSACo12									
60 split 5 times	0	0	0	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0	0

Sample	Sa	Sb	Sc	Idioprioniodus P	M	S	Aethotaxis
OSACo36	1	0	2	0	0	0	
OSACo35	0	1	0	0	0	0	
OSACo34	1	4	1	0	0	0	
OSACo33	5	16	25	0	0	0	
OSACo32	1	1	8	0	0	0	
OSACo31	2	10	13	0	0	0	
OSACo30	1	1	8	0	0	0	
OSACo29	1	7	15	0	0	0	
OSACo28	0	11	29	0	0	0	
OSACo27	0	2	2	0	0	0	
OSACo26	0	2	12	0	0	0	
OSACo25	1	7	12	0	0	0	
OSACo24	2	8	11	0	0	0	
OSACo23	1	5	20	0	0	0	
OSACo22	5	14	45	0	0	0	
OSACo21	6	18	69	0	0	1	
OSACo20	0	0	16	0	0	0	
OSACo19							
60	0	0	0	1	0	0	
120 split 1 time	0	3	5	0	0	1	
total (calculated)	0	6	10	1	0	2	
OSACo18							
60 split 6 times	0	0	0	0	0	0	
140 split 7 times	0	0	0	0	0	0	
total (calculated)	0	0	0	0	0	0	
OSACo17							
60 split 5 times	0	0	0	0	0	5	
140 split 5 times	0	0	0	2	0	10	
total (calculated)	0	0	0	64	0	480	
OSACo16	4	15	17	0	0	1	
OSACo15	0	10	23	0	0	0	
OSACo14	1	13	54	1	0	0	
OSACo13							
60 spit 2 times	0	0	0	0	0	0	
140 split 4 times	0	0	0	0	0	0	
total (calculated)	0	0	0	0	0	0	
OSACo12							
60 split 5 times	0	0	0	0	0	0	
140 split 6 times	0	0	0	0	0	0	
total (calculated)	0	0	0	0	0	0	

Sample	M	Sa	Sb	Sc	Gondolella Pa	Ellisonia Pa	Pb	M
OSACo36	0	2	0	2	0	0	0	0
OSACo35	0	2	0	1	0	0	0	0
OSACo34	0	1	0	0	0	0	0	0
OSACo33	0	2	2	0	0	0	0	0
OSACo32	0	0	0	3	0	0	0	0
OSACo31	0	0	0	0	0	0	0	0
OSACo30	0	1	0	0	0	0	0	0
OSACo29	0	0	0	1	0	0	0	0
OSACo28	0	1	0	0	0	0	0	0
OSACo27	0	0	0	1	0	0	0	0
OSACo26	0	0	0	1	0	0	0	0
OSACo25	0	0	0	0	0	0	0	0
OSACo24	0	0	0	0	0	0	0	0
OSACo23	0	0	0	2	0	0	0	0
OSACo22	0	0	0	0	0	0	0	0
OSACo21	0	1	0	1	0	0	0	0
OSACo20	0	1	0	0	0	0	0	0
OSACo19								
60	0	0	0	0	0	0	0	0
120 split 1 time	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0
OSACo18								
60 split 6 times	0	0	0	0	0	0	0	0
140 split 7 times	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0
OSACo17								
60 split 5 times	0	0	0	0	0	0	0	0
140 split 5 times	0	0	0	0	3	0	0	0
total (calculated)	0	0	0	0	96	0	0	0
OSACo16	0	1	0	2	0	0	0	0
OSACo15	0	0	0	0	0	0	0	0
OSACo14	0	0	0	0	0	0	0	1
OSACo13								
60 spit 2 times	0	1	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0	0	0
total (calculated)	0	4	0	0	0	0	0	0
OSACo12								
60 split 5 times	0	0	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0

Sample	Sa	Sb	Sc	Diplognathodus Pa	Pb	M	Sa	Sb	Sc
OSACo36	0	0	0	0	0	0	0	0	0
OSACo35	0	0	3	0	0	0	0	0	0
OSACo34	0	0	0	0	0	0	0	0	0
OSACo33	0	0	0	0	0	0	0	0	0
OSACo32	0	0	0	0	0	0	0	0	0
OSACo31	0	0	0	0	0	0	0	0	0
OSACo30	0	0	4	0	0	0	0	0	0
OSACo29	0	0	3	1	0	0	0	0	0
OSACo28	0	0	1	0	0	0	0	0	0
OSACo27	0	0	0	0	0	0	0	0	0
OSACo26	0	0	0	0	0	0	0	0	0
OSACo25	0	0	1	0	0	0	0	0	0
OSACo24	0	0	0	0	0	0	0	0	0
OSACo23	0	0	1	0	0	0	0	0	0
OSACo22	0	0	0	0	0	0	0	0	0
OSACo21	0	1	0	1	0	0	0	0	0
OSACo20	0	0	0	0	0	0	0	0	0
OSACo19									
60	0	0	0	0	0	0	0	0	0
120 split 1 time	0	0	2	0	0	0	0	0	0
total (calculated)	0	0	4	0	0	0	0	0	0
OSACo18									
60 split 6 times	0	0	0	0	0	0	0	0	0
140 split 7 times	0	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0	0
OSACo17									
60 split 5 times	0	0	0	0	0	0	0	0	0
140 split 5 times	0	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0	0
OSACo16	0	0	1	0	0	0	0	0	0
OSACo15	0	0	0	0	0	0	0	0	0
OSACo14	0	1	0	0	0	0	0	0	0
OSACo13									
60 spit 2 times	0	0	0	0	0	0	0	0	0
140 split 4 times	0	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0	0
OSACo12									
60 split 5 times	0	0	0	0	0	0	0	0	0
140 split 6 times	0	0	0	0	0	0	0	0	0
total (calculated)	0	0	0	0	0	0	0	0	0

Sample	Indeterm.	Whole	Broken	%Broken	FeO Coated
OSACo36	7	16	28	63.63636	1
OSACo35	4	13	32	71.11111	4
OSACo34	14	46	91	66.42336	9
OSACo33	54	84	345	80.41958	25
OSACo32	9	13	53	80.30303	0
OSACo31	11	36	78	67.82609	3
OSACo30	9	25	90	78.26087	0
OSACo29	15	45	114	70.80745	3
OSACo28	12	57	118	67.42857	0
OSACo27	4	19	23	54.7619	0
OSACo26	6	28	66	70.21277	0
OSACo25	12	74	110	59.78261	1
OSACo24	7	46	80	63.49206	6
OSACo23	11	70	171	70.66116	8
OSACo22	6	84	246	74.54545	13
OSACo21	5	154	291	65.39326	3
OSACo20	3	27	119	81.50685	1
OSACo19					
60	0	7	41		1
120 split 1 time	4	33	359		7
total (calculated)	8	73	759	91.00719	15
OSACo18					
60 split 6 times	0	0	13		0
140 split 7 times	0	2	31		0
total (calculated)	0	256	4800	94.93671	0
OSACo17					
60 split 5 times	0	0	71		0
140 split 5 times	4	1	292		0
total (calculated)	128	32	11616	99.72527	0
OSACo16	17	49	212	81.22605	18
OSACo15	0	93	185	66.54676	4
OSACo14	3	111	341	75.44248	7
OSACo13					
60 spit 2 times	0	1	5		0
140 split 4 times	5	3	35		0
total (calculated)	80	52	580	91.77215	0
OSACo12					
60 split 5 times	0	0	1		0
140 split 6 times	0	1	4		0
total (calculated)	0	64	288	81.81818	0

Sample	Dissolution	Sinestral	Dextral	Total
OSACo36	8	ND	ND	44
OSACo35	4	ND	ND	45
OSACo34	3	15	13	137
OSACo33	13	51	37	429
OSACo32	1	2	8	66
OSACo31	5	4	7	115
OSACo30	1	15	7	115
OSACo29	9	21	13	161
OSACo28	3	9	15	175
OSACo27	1	5	6	42
OSACo26	3	9	10	94
OSACo25	7	25	23	184
OSACo24	14	15	16	126
OSACo23	5	17	26	242
OSACo22	24	19	28	330
OSACo21	42	34	30	445
OSACo20	15	17	20	146
OSACo19				
60	0	17	17	48
120 split 1 time	1	58	58	393
total (calculated)	2	133	133	834
OSACo18				
60 split 6 times	0	2	4	13
140 split 7 times	0	4	7	33
total (calculated)	0	640	1152	5056
OSACo17				
60 split 5 times	0	17	20	71
140 split 5 times	0	18	29	293
total (calculated)	0	1120	1568	11648
OSACo16	2	23	14	261
OSACo15	12	30	27	278
OSACo14	50	48	40	452
OSACo13				
60 spit 2 times	0	0	3	6
140 split 4 times	0	6	5	38
total (calculated)	0	96	92	632
OSACo12				
60 split 5 times	0	1	0	1
140 split 6 times	0	0	1	5
total (calculated)	0	32	64	352

Sample	Elements/Kg.	Sample Weight in Kg.	Total = Pa
OSACo36	17.28880157	2.545	7
OSACo35	20	2.25	19
OSACo34	47.81849913	2.865	62
OSACo33	152.3978686	2.815	173
OSACo32	27.5	2.4	14
OSACo31	51.8018018	2.22	20
OSACo30	46	2.5	34
OSACo29	55.80589255	2.885	57
OSACo28	58.13953488	3.01	35
OSACo27	19.26605505	2.18	13
OSACo26	40.51724138	2.32	28
OSACo25	73.6	2.5	69
OSACo24	49.02723735	2.57	40
OSACo23	94.34697856	2.565	58
OSACo22	132	2.5	69
OSACo21	151.3605442	2.94	84
OSACo20	63.47826087	2.3	56
OSACo19			
60			38
120 split 1 time			159
total (calculated)	327.7013752	2.545	356
OSACo18			
60 split 6 times			7
140 split 7 times			17
total (calculated)	2774.972558	1.822	2624
OSACo17			
60 split 5 times			40
140 split 5 times			73
total (calculated)	13450.34642	0.866	3616
OSACo16	98.49056604	2.65	46
OSACo15	100.3610108	2.77	71
OSACo14	162.5314635	2.781	100
OSACo13			
60 spit 2 times			5
140 split 4 times			19
total (calculated)	265.993266	2.376	324
OSACo12			
60 split 5 times			1
140 split 6 times			3
total (calculated)	245.9818309	1.431	224

Sample	Pb	M	Sa	Sb	Sc
OSACo36	4	2	3	1	9
OSACo35	2	1	2	1	7
OSACo34	6	4	3	6	9
OSACo33	23	14	10	21	44
OSACo32	9	6	1	1	16
OSACo31	12	6	6	10	22
OSACo30	1	5	3	1	16
OSACo29	15	9	1	7	26
OSACo28	14	12	3	12	48
OSACo27	1	5	2	3	6
OSACo26	9	10	3	2	20
OSACo25	20	12	3	14	27
OSACo24	14	7	3	8	16
OSACo23	29	22	5	7	34
OSACo22	35	25	18	18	62
OSACo21	38	35	18	35	121
OSACo20	8	8	2	1	16
OSACo19					
60	0	1	0	0	0
120 split 1 time	15	10	1	5	11
total (calculated)	30	21	2	10	22
OSACo18					
60 split 6 times	0	0	0	0	0
140 split 7 times	0	0	0	0	0
total (calculated)	0	0	0	0	0
OSACo17					
60 split 5 times	0	0	0	0	0
140 split 5 times	11	1	0	0	0
total (calculated)	352	32	0	0	0
OSACo16	24	27	12	16	26
OSACo15	33	19	3	21	45
OSACo14	41	41	5	26	78
OSACo13					
60 spit 2 times	0	0	1	0	0
140 split 4 times	3	0	0	0	0
total (calculated)	48	0	4	0	0
OSACo12					
60 split 5 times	0	0	0	0	0
140 split 6 times	0	1	0	0	0
total (calculated)	0	64	0	0	0

Sample	Sb+Sc ?	Total P's	Total M + S's	% P's
OSACo36	10	11	25	25
OSACo35	1	21	12	46.666666667
OSACo34	24	68	46	49.635036496
OSACo33	47	196	136	45.687645688
OSACo32	9	23	33	34.848484848
OSACo31	25	32	69	27.826086957
OSACo30	38	35	63	30.434782609
OSACo29	18	72	61	44.720496894
OSACo28	34	49	109	28
OSACo27	8	14	24	33.333333333
OSACo26	13	37	48	39.361702128
OSACo25	26	89	82	48.369565217
OSACo24	26	54	60	42.857142857
OSACo23	64	87	132	35.950413223
OSACo22	80	104	203	31.515151515
OSACo21	98	122	308	27.415730337
OSACo20	33	64	60	43.835616438
OSACo19				
60	1	39	2	
120 split 1 time	45	174	73	
total (calculated)	91	387	148	46.402877698
OSACo18				
60 split 6 times	0	7	0	
140 split 7 times	1	17	1	
total (calculated)	128	2624	128	51.898734177
OSACo17				
60 split 5 times	1	40	6	
140 split 5 times	18	86	29	
total (calculated)	608	4032	1120	34.615384615
OSACo16	60	70	142	26.819923372
OSACo15	78	104	166	37.410071942
OSACo14	143	142	293	31.415929204
OSACo13				
60 spit 2 times	0	5	1	
140 split 4 times	3	22	3	
total (calculated)	48	372	52	58.860759494
OSACo12				
60 split 5 times	0	1	0	
140 split 6 times	0	3	1	
total (calculated)	0	224	64	63.636363636

Sample	% M + S's	Total S. + Id. Pa's
OSACo36	56.818181818	2
OSACo35	26.666666667	14
OSACo34	33.576642336	50
OSACo33	31.701631702	90
OSACo32	50	10
OSACo31	60	8
OSACo30	54.782608696	23
OSACo29	37.888198758	35
OSACo28	62.285714286	21
OSACo27	57.142857143	9
OSACo26	51.063829787	19
OSACo25	44.565217391	45
OSACo24	47.619047619	32
OSACo23	54.545454545	49
OSACo22	61.515151515	48
OSACo21	69.213483146	65
OSACo20	41.095890411	48
OSACo19 60 120 split 1 time total (calculated)	17.745803357	307
OSACo18 60 split 6 times 140 split 7 times total (calculated)	2.5316455696	2368
OSACo17 60 split 5 times 140 split 5 times total (calculated)	9.6153846154	3456
OSACo16	54.406130268	40
OSACo15	59.712230216	62
OSACo14	64.82300885	91
OSACo13 60 spit 2 times 140 split 4 times total (calculated)	8.2278481013	216
OSACo12 60 split 5 times 140 split 6 times total (calculated)	18.181818182	64

Sample	Total Adeto. Pa's	% S. Pa's	%Id. Pa's
OSACo36	0	4.5454545455	0
OSACo35	4	31.111111111	0
OSACo34	7	36.496350365	0
OSACo33	26	20.979020979	0
OSACo32	0	15.151515152	0
OSACo31	3	6.9565217391	0
OSACo30	3	20	0
OSACo29	3	21.739130435	0
OSACo28	5	12	0
OSACo27	2	21.428571429	0
OSACo26	1	20.212765957	0
OSACo25	8	24.456521739	0
OSACo24	3	25.396825397	0
OSACo23	0	20.247933884	0
OSACo22	1	14.545454545	0
OSACo21	3	14.606741573	0
OSACo20	2	32.876712329	0
OSACo19			
60			
120 split 1 time			
total (calculated)	4	36.450839329	0.3597122302
OSACo18			
60 split 6 times			
140 split 7 times			
total (calculated)	0	41.772151899	5.0632911392
OSACo17			
60 split 5 times			
140 split 5 times			
total (calculated)	0	20.879120879	8.7912087912
OSACo16	0	14.942528736	0.3831417625
OSACo15	0	22.302158273	0
OSACo14	1	20.132743363	0
OSACo13			
60 spit 2 times			
140 split 4 times			
total (calculated)	84	34.17721519	0
OSACo12			
60 split 5 times			
140 split 6 times			
total (calculated)	160	18.181818182	0

Sample	%A. Pa's	%Hind.Pa's	%Idiopric.	%Aetho.
OSACo36	0	11.36363636	0	9.090909091
OSACo35	8.8888888889	2.222222222	0	6.666666667
OSACo34	5.1094890511	3.649635036	0	0.729927007
OSACo33	6.0606060606	13.28671329	0	0.932400932
OSACo32	0	6.060606061	0	4.545454545
OSACo31	2.6086956522	7.826086957	0	0
OSACo30	2.6086956522	6.956521739	0	0.869565217
OSACo29	1.8633540373	11.18012422	0	0.621118012
OSACo28	2.8571428571	5.142857143	0	0.571428571
OSACo27	4.7619047619	4.761904762	0	2.380952381
OSACo26	1.0638297872	8.510638298	0	1.063829787
OSACo25	4.347826087	8.695652174	0	0
OSACo24	2.380952381	3.968253968	0	0
OSACo23	0	3.719008264	0	0.826446281
OSACo22	0.303030303	6.060606061	0	0
OSACo21	0.6741573034	3.370786517	0.2247191	0.449438202
OSACo20	1.3698630137	4.109589041	0	0.684931507
OSACo19 60 120 split 1 time total (calculated)	0.479616307	5.395683453	0.35971223	0
OSACo18 60 split 6 times 140 split 7 times total (calculated)	0	5.063291139	0	0
OSACo17 60 split 5 times 140 split 5 times total (calculated)	0	0.549450549	4.67032967	0
OSACo16	0	2.298850575	0.38314176	1.149425287
OSACo15	0	3.237410072	0	0
OSACo14	0.2212389381	1.769911504	0.22123894	0
OSACo13 60 spit 2 times 140 split 4 times total (calculated)	13.291139241	3.797468354	0	0.632911392
OSACo12 60 split 5 times 140 split 6 times total (calculated)	45.454545455	0	0	0

Sample	%Gond.	%Ellis.	%Diplo.	%Indet.
OSACo36	0	0	0	15.90909
OSACo35	0	6.666667	0	8.888889
OSACo34	0	0	0	10.21898
OSACo33	0	0	0	12.58741
OSACo32	0	0	0	13.63636
OSACo31	0	0	0	9.565217
OSACo30	0	3.478261	0	7.826087
OSACo29	0	1.863354	0.621118	9.31677
OSACo28	0	0.571429	0	6.857143
OSACo27	0	0	0	9.52381
OSACo26	0	0	0	6.382979
OSACo25	0	0.543478	0	6.521739
OSACo24	0	0	0	5.555556
OSACo23	0	0.413223	0	4.545455
OSACo22	0	0	0	1.818182
OSACo21	0	0.224719	0.224719	1.123596
OSACo20	0	0	0	2.054795
OSACo19 60 120 split 1 time total (calculated)	0	0.479616	0	0.959233
OSACo18 60 split 6 times 140 split 7 times total (calculated)	0	0	0	0
OSACo17 60 split 5 times 140 split 5 times total (calculated)	0.824176	0	0	1.098901
OSACo16	0	0.383142	0	6.51341
OSACo15	0	0	0	0
OSACo14	0	0.442478	0	0.663717
OSACo13 60 spit 2 times 140 split 4 times total (calculated)	0	0	0	12.65823
OSACo12 60 split 5 times 140 split 6 times total (calculated)	0	0	0	0

CONODONT DISTRIBUTION AND PALEOECOLOGY WITHIN GENETIC UNITS OF THE IOLA LIMESTONE (MISSOURIAN, UPPER PENNSYLVANIAN) OF NORTHEASTERN KANSAS

by

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ABSTRACT

The Iola Limestone (Linn Subgroup, Kansas City Group) is the most open marine part of the Iola 5th order T-R unit (temporal equivalent of the Iola cyclothem). The Iola fifth order T-R unit includes the uppermost part of the underlying Chanute Shale, the Paola Limestone Member, Muncie Creek Shale Member, and Raytown Limestone Member (the three members of the Iola Limestone), and most of the overlying Lane Shale. At least five transgressive surfaces, which bound five genetic units (6th order T-R units, or PACs), are recognized within the Iola fifth order T-R unit. These disconformable surfaces, which represent punctuation events bounding deepening-shallowing units, were recognized using (1) the range, diversity, and preservation of fossils as paleobathymetric indicators, in which a transgressive surface can be recognized as the disjunct boundary between a nearshore facies that has been overstepped vertically by an offshore facies, and (2) sedimentological features such as omission surfaces or events as represented by hardgrounds, firmgrounds, or pebble lags.

Correlations of these transgressive surfaces were made relative to marker beds, and at least four of these surfaces, **T1**, **T2**, **T3**, and **T4**, can be traced across the entire study area. The most open genetic (T-R) unit (**PAC 2**) within the Iola contains an offshore molluscan biofacies and is found within the Muncie Creek Shale Member. Lithostratigraphic units, such as the 3 members of the Iola Limestone, are often considered diachronous (although this may not always be true). Correlative T-R units (such as **PAC 1** through **PAC 4**), bound by surfaces which represent geologically instantaneous events, may represent isochronous units.

Conodont distribution patterns within sixth order T-R units of the Iola limestone (part of the Iola fifth order T-R unit) suggest that, at the generic level,

the range of conodonts reflects only the deepening and shallowing of the larger fifth order T-R unit or cyclothem. The distribution of conodonts, when examined as sedimentary particles within sixth order T-R units, does appear to reflect the deepening and shallowing of the smaller sixth order T-R units, and the punctuation events that produced surfaces which bound these units.