REGIONAL STRATIGRAPHIC SETTING AND PALEOECOLOGY OF A CHAETETID "REEF" IN THE HOUX-HIGGINSVILLE LIMESTONE (PENNSYLVANIAN) OF SOUTHEAST KANSAS

by

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CHAPTER 1

INTRODUCTION

General Statement and Location of Study

A reefal buildup of chaetetids and associated fauna is exposed in an abandoned quarry (owned by Mrs. Wm. T. Niggeman, Girard, Kansas) in the SE 1/4, sec. 12, T.30 S., R.22 E., Crawford County, Kansas (Figure 1). These rocks have been known until recently as part of the Higginsville Limestone Member of the Fort Scott Formation. They belong to the Marmaton Group and are Desmoinesian, or Middle Pennsylvanian, in age (Figure 2). Knight (1985) reassigned rocks of the Fort Scott Formation as shown in Figure 3; these are the rock unit names that will be used herein. Thus, limestone in the quarry that is the main focus of this study belongs to the Houx-Higginsville Member of the Wolverine Creek Formation. The top few centimeters of the underlying Little Osage shale are exposed in the quarry floor and approximately 4 meters (13 feet) of the overlying Labette Shale are exposed in the southwest corner of the quarry.

A limited study along the outcrop belt from northeast Oklahoma through southeast Kansas to northern Missouri was undertaken to establish a regional setting for the chaetetid "reef" exposed in the quarry. This allowed placement of the rocks within a regional framework of sixth-order transgressive-regressive units (Busch and

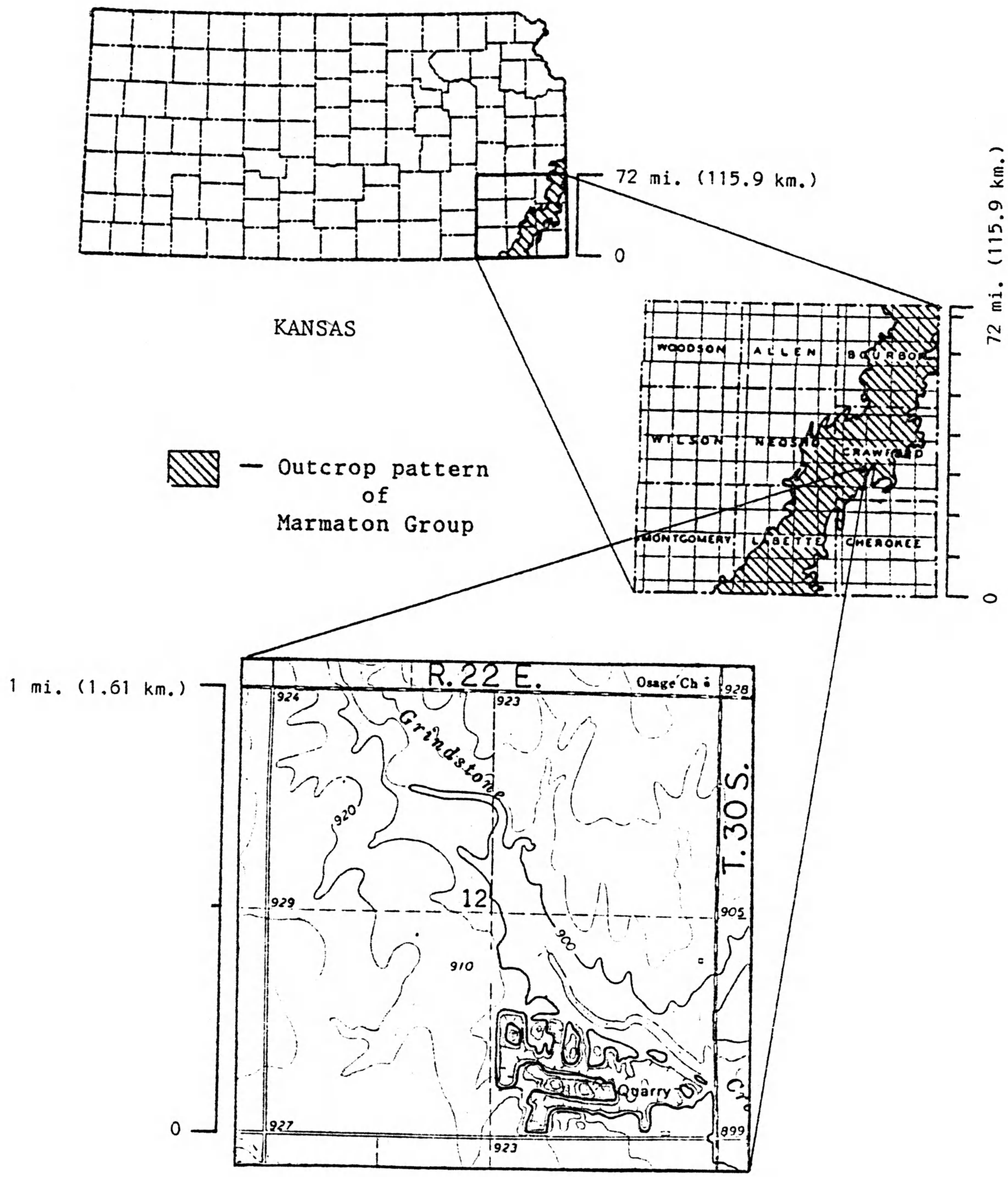


Figure 1. Location Map. Quarry is in SE¼, sec.12, T.30S., R.22E., USGS Grindstone Creek 7.5' Quadrangle, Crawford County, Kansas. (Outcrop pattern from Jewett, et al., 1964).

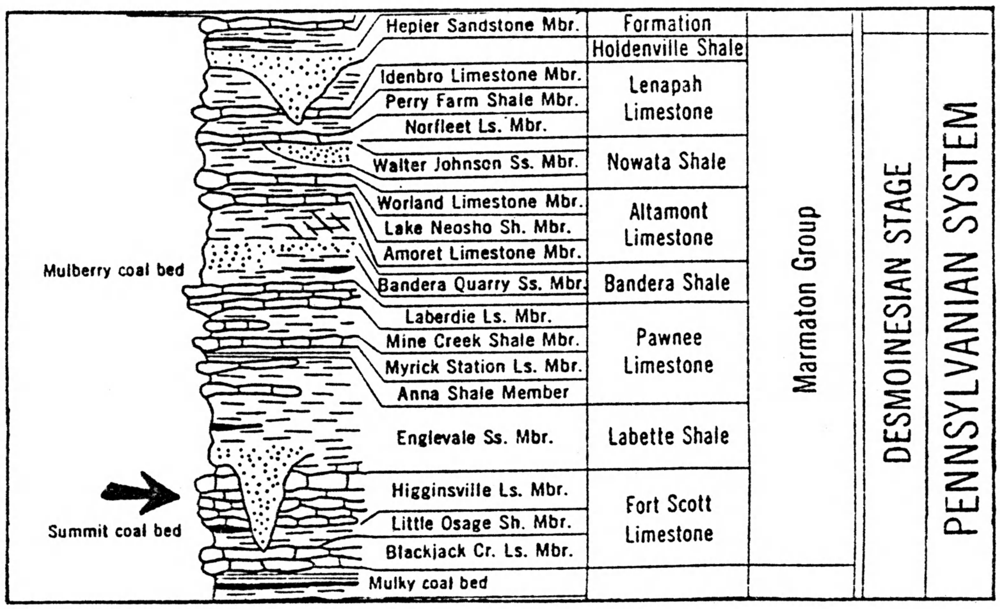


Figure 2. Stratigraphic Column of the Marmaton Group (from Zeller, 1968). The study site is within the Higginsville Limestone Member of the Fort Scott Formation (Desmoinesian).

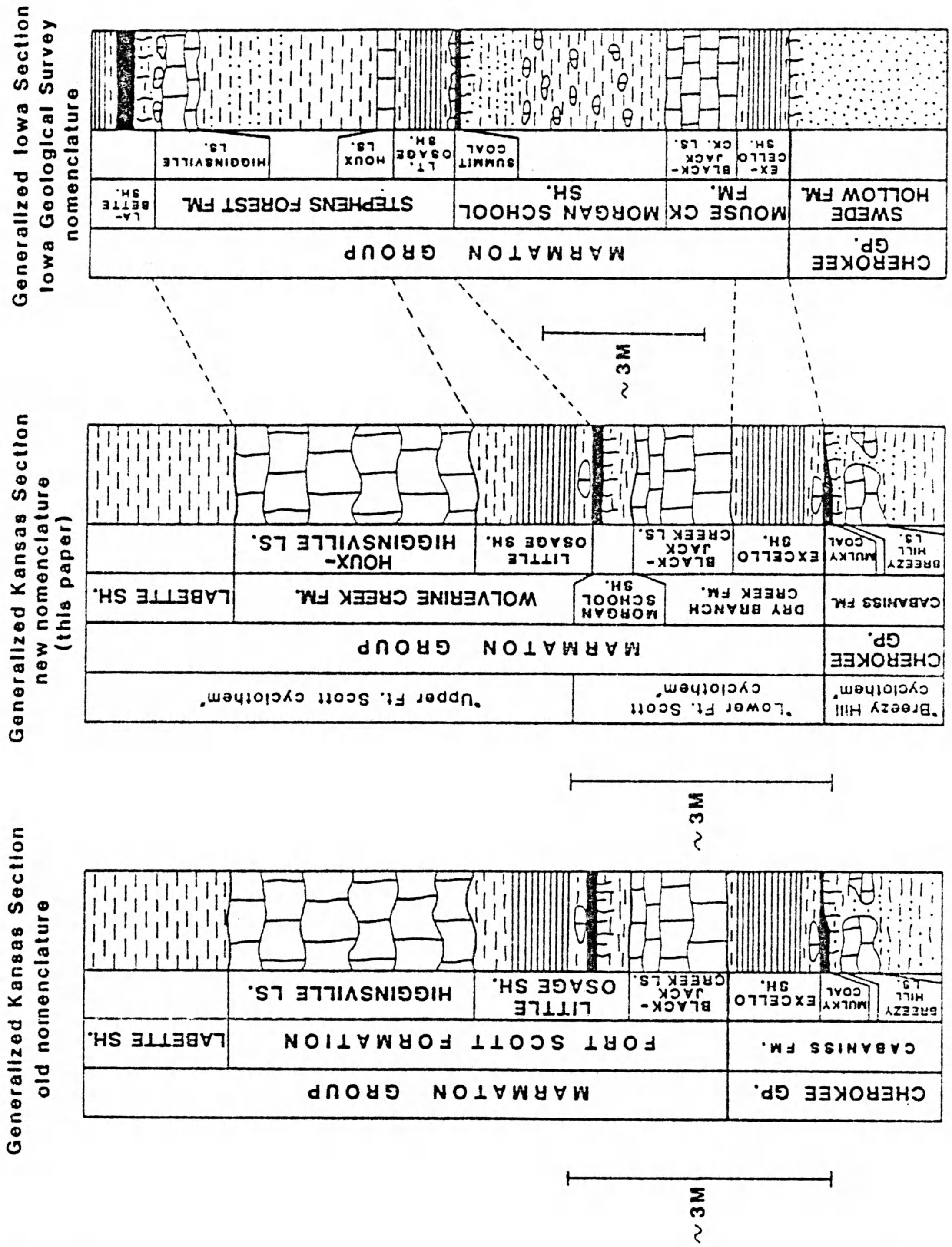


Figure 3. Generalized stratigraphic columns comparing old nomenclature in Kansas with new nomenclature in Kansas and Iowa (from Knight, 1985, Fig. 3).

Rollins, 1984) recording eustatic sea level changes within the Pennsylvanian epeiric seas of the Midcontinent. Sixth-order transgressive-regressive units (T-R units) can be grouped into fifth-order T-R units, which are equivalent in scale to Heckel's (1977) basic Kansas cyclothem. Using Heckel's (1977) model, the Houx-Higginsville Limestone is a regressive limestone within Knight's (1985) "Upper Fort Scott cyclothem" (Figure 3).

Purpose of Study

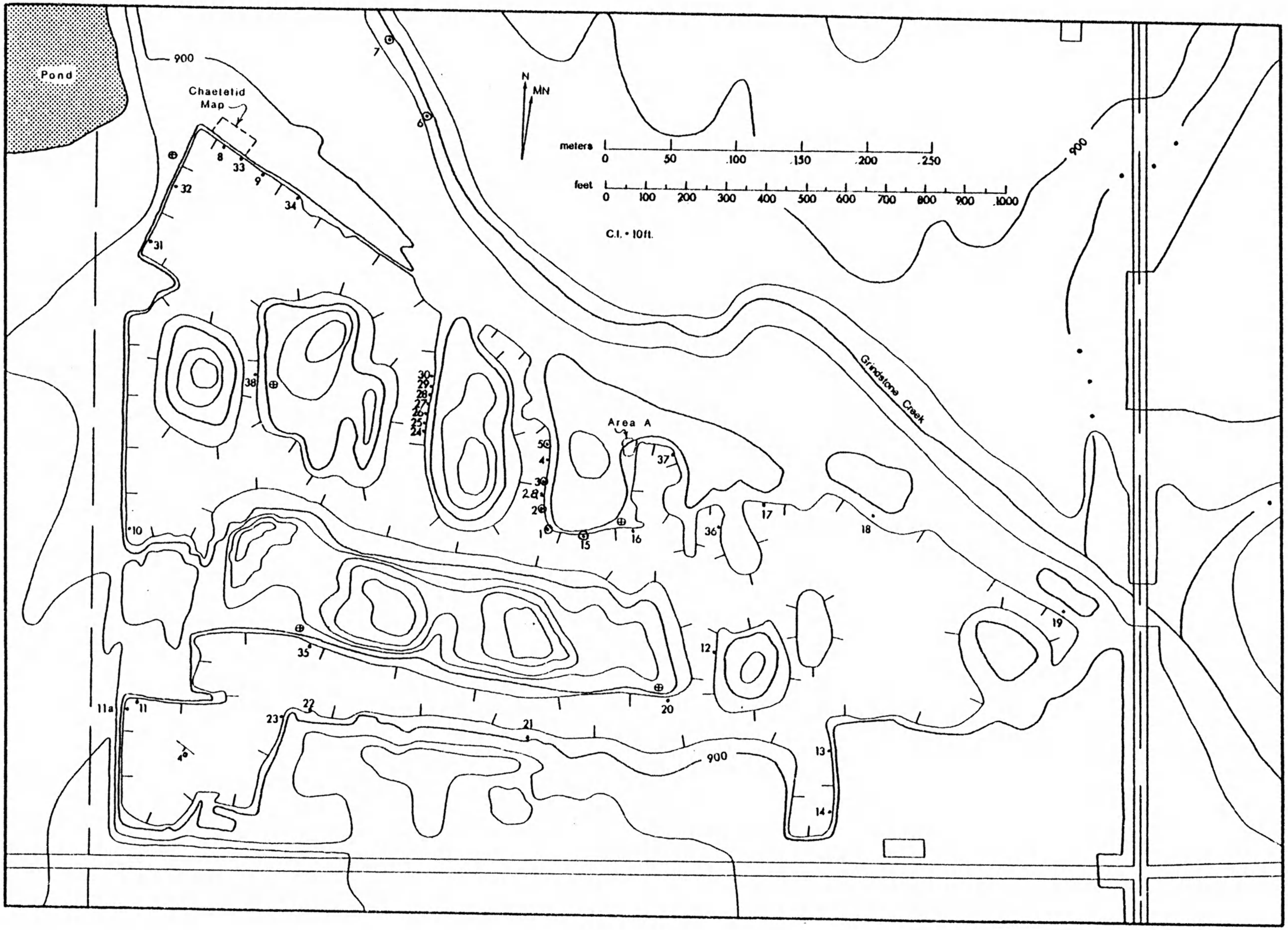
This study was undertaken in two phases:

(1) The main thrust and the most emphasis was placed upon a detailed study of rocks in the Niggeman quarry (referred to herein as Locality 700), especially within the interval containing the chaetetid buildups.

(2) A secondary focus has been the regional study which correlated and placed rocks of the Niggeman quarry within the sixth-order transgressive-regressive units of the Upper Fort Scott cyclothem.

The Niggeman quarry offers an exceptional three-dimensional view of chaetetid buildups because of the way the quarry was developed. Two main trenches, 6 to 9 meters (20-30 feet) deep and over 30 meters (100 feet) wide, run the length of the quarry, with smaller trenches excavated at right angles (Figure 4). Overall the quarry covers an area 0.8 km (1/2 mile) long and 0.4 km (1/4 mile) wide.

Figure 4. Topographic map of Niggeman quarry, SE 1/4, sec.12, T.30S., R.22E., Crawford County, Kansas (enlarged and revised from USGS Grindstone Creek 7.5' quadrangle), showing station positions (dots) and numbers. Circled dots represent stations for which no stratigraphic sections were drawn; for all other stations, stratigraphic sections are included in Appendix B. Circled + signs are horizontal dip symbols. Directional trends of chaetetid clumps were measured in Area A.


Pond
900
Chaetetid Map
N
MN
meters
0
50
100
150
200
250
feet
0
100
200
300
400
500
600
700
800
900
1000
C.I. = 10 ft.
Grindstone Creek
Area A
900
900
1 2 3 4 5 6 7 8 9 10 11 11a 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38

Thus, the quarry faces allowed a three-dimensional study of the chaetetid reef environment, including details of the paleoecology, sedimentology, and stratigraphy. Objectives of the study include the following:

(1) Documentation of vertical and lateral facies relationships, both within the quarry and regionally, including stratigraphic, sedimentological, taphonomical, and paleoecological aspects.

(2) Interpretation of the environment of deposition, its changes through time, its relationship to the larger geologic framework (i.e., different marine and nonmarine environments and topographic features and changing sea level conditions), and why the chaetetid reefs developed where they did.

(3) Documentation of biological aspects, such as organism associations, species abundance, and possible ecological requirements.

(4) Possible predictions of where and when conditions may have been favorable for chaetetid reef development elsewhere in the geologic record.

Methods of Study

Field work for this study was concentrated in the Niggeman quarry, where 33 stratigraphic sections were measured and described in detail (see Appendix B). Seven other stations within the quarry were also examined but no stratigraphic columns were drawn at those stations. General observations were also made between stations throughout the quarry. USDA aerial photos and USGS topographic maps (enlarged to a scale of approximately 1:2500) were used for topographic control of the study site. The enlarged topographic map was revised and refined by the use of aerial photos along with field measurements and observations. The location of each station in the quarry was plotted on the revised topographic map (Figure 4).

For the regional study, nine exposures were examined, detailed stratigraphic sections were measured and described for each, and oriented samples were collected at appropriate intervals. In addition, 20 stratigraphic sections were selected from the literature (Knight, 1985; Jeffries, 1958; Schell, 1955) and were drawn according to their descriptions (see Appendix A).

Within the Niggeman quarry, oriented samples were collected at most stations. Some stations were sampled in detail to get a representation of the overall vertical sequence. Other samples were collected which showed lateral changes within the quarry or which were otherwise unique.

A basic set of questions (after Ager, 1963, and Flugel, 1982) were addressed at each site, including observations on paleoecology, taphonomy, bedding, sedimentary structures and features, and vertical and lateral changes in macro- and microfacies. Black and white photos and line drawings were used to document the observed features.

Eight detailed vertical profiles were drawn to show vertical and lateral facies relationships, concentrating especially on chaetetid occurrences. A small surface map showing areal distribution of chaetetids was drawn by setting up a grid in the field and carefully measuring and plotting chaetetids showing on the surface. Three detailed species maps of vertical sections in the chaetetid "reef" interval were drawn to show exact occurrences and distributions of the different organisms and sedimentological features.

Laboratory study for this project included detailed microscopic examination of over 200 samples of rocks and fossils. Over half of those samples were cut and polished, and over 70 acetate peels prepared. In addition, 117 thin sections were prepared from 52 samples. Of those, 98 thin sections from 44 samples from the quarry are described in detail in Appendix C. All thin sections were studied with a polarizing petrographic microscope, and five thin sections were stained to determine the types of carbonate cements. X-ray diffraction studies were done on two samples.

All shale samples from the Labette Shale at station 11a (see section 11 in Appendix B) and shale samples 700-11-3, 700-11-4, and 700-11-6 from bed 5 at station 11 were washed using the kerosene method. They were first dried overnight in beakers in a drying oven. The beakers were then filled with kerosene until the samples were completely covered, and these were placed in a warm oven overnight. The next day the kerosene was drained off and hot water was added until the samples were covered. These were allowed to sit overnight, and the next day the samples were washed through sieves down to 250 micron size. The samples were then examined under a binocular microscope.

Previous Work

Naming of Units.--Swallow (1866) first applied the name "Fort Scott Limestone" to the upper limestone member (Higginsville Limestone) of what in recent times has been called the Fort Scott Limestone. Swallow (1866) also applied the name "Fort Scott coal series" to 100 feet of beds including the Higginsville Limestone and the overlying Labette Shale, the "Fort Scott marble" to a limestone in the Cherokee Shale, and the "Fort Scott marble series" to a group of beds that included the Fort Scott marble.

Broadhead (1874) applied the name "Oswego" to beds recognized more recently as the Fort Scott Limestone, from exposures at Oswego, Labette County, Kansas. McGee (1892) gave the name "Summit coal" to a thin coal in the shale between the Blackjack Creek and Higginsville limestones, from exposures in Macon County, Missouri. Bennett (1896) included both limestones, the lower "Cement rock" (Blackjack Creek Limestone) and the upper "Lexington bottom rock" (Higginsville Limestone), as part of the Fort Scott Limestone, but he also continued to use the name Oswego. According to Knight (1985, p. 50), Bennett (1896) "probably intended the type exposure to include a railway cut a short distance east of the Missouri Pacific Railway station in Fort Scott, Kansas."

Adams (1903), recognizing that the name Oswego had previously been used for an Ordovician formation in New York, clearly established the name Fort Scott Limestone to include the two limestones and intervening shale and thin coal at Fort Scott, Kansas.

Naming three units in the Fort Scott Limestone after exposures in Johnson and Lafayette Counties, Missouri, Cline (1941) called the lower limestone the Blackjack Creek Limestone, and the upper one the Higginsville Limestone. He applied the name Houx Limestone to a thin limestone in Missouri above the black shale in the intervening shale unit.

Jewett (1941) applied the name Little Osage Shale to the intervening shale after an exposure in Bourbon County, Kansas. Jewett (1941) recognized that the type exposure chosen by Bennett (1896) was inadequate, and thus redesignated the type section as a quarry in the NE 1/4, sec.19, T.25S., R.25E., Bourbon County, Kansas, northeast of Fort Scott. This exposure has since been partially destroyed by highway construction and by use of the quarry as a sanitary landfill.

The stratigraphy of Lower Marmaton rocks was studied in Missouri by Jeffries (1958), and in Oklahoma by Schell (1955).

Knight (1985) recognized that the Higginsville Limestone, which is a single limestone unit in Kansas and Oklahoma, is split by a siliciclastic wedge in Missouri and Iowa to form the Houx and Higginsville Limestones. Therefore, he proposed the name "Houx-Higginsville Limestone" to replace "Higginsville Limestone" for the single limestone unit in Kansas and Oklahoma. Overall, he proposed the new member and formation names shown in Figure 3 of this paper (Knight's, 1985, Figure 3).

Depositional Models.--The alternating shale/limestone lithology of Midcontinent rocks has inspired a number of interpretations based on cyclic or rhythmic alternations of sedimentary rocks. Early studies of sedimentary rocks in the U.S. and Canada recognized rhythmic or cyclic repetitions of rock types (Udden, 1912). Weller (1930) proposed cyclic "Pennsylvanian Formations" with 8 members, in which each formation was presumed to be at least basinwide. Wanless and Weller (1932, p.1003) proposed the term "cyclothem" (equivalent to Weller's, 1930, "Pennsylvanian Formations") for "a series of beds deposited during a single sedimentary cycle of the type that occurred during the Pennsylvanian and are of formation size." Moore (1936) used the term "megacyclothem" for rock units equivalent to Wanless and Weller's (1932) "cyclothem" and used the term "cyclothem" for smaller limestone-shale couplets within the megacyclothems. Heckel (1977) abandoned the term "megacyclothem" and defined his "Kansas cyclothem" as having 5 members. Heckel's (1977) model is still widely used today.

In this study, another approach has been used in which small-scale genetic deepening-shallowing units are traced across a depositional basin. The model used is the Punctuated Aggradational Cycle (or PAC) approach of Anderson and Goodwin (1980). A PAC is equivalent to Busch and Rollins' (1984) sixth-order transgressive-regressive unit (or sixth-order T-R unit).

Chaetetids.--Chaetetids have previously been included as members of a number of different phyla (see West and Clark, 1984, for a history of chaetetid classifications). Recently, chaetetids have been classified as a type of sclerosponge (West and Clark, 1984). However, even more recently, Reitner (1986) suggested that chaetetids and all other sclerosponges should be included as demosponges.

Chaetetes has long been recognized in the Lower and Middle Pennsylvanian of North America. Occurrences from these strata are reported from Indiana (Lane & Martin, 1966), Illinois (Wanless, 1958), Missouri (Keyes, 1894), Kansas (Beede, 1900), Oklahoma (Morgan, 1924), Texas (Moore & Jeffords, 1945), and various western states (Girty, 1903; White *in* Powell's Report, 1876; and White, 1877). More recently, this genus has been recognized in Upper Mississippian rocks (Stouder, 1938; Duncan, 1965; & 1966) and Sando (1975) described a new species of *Chaetetes* from Wyoming.

In the Great Basin, chaetetids were studied by Dott (1954; 1955), Gordon and Duncan (1970, *in* Tooker and Roberts), Webster (1969), and Rich (1969). They were studied in southwestern Colorado by Soar (1984) and Suneson (1984). Lustig (1971) studied the chaetetid-bearing units in southern Nevada and provided a summary of the literature on *Chaetetes* in the Great Basin. Nelson and Langenheim (1980), based on studies of *Chaetetes* in Clark Co. Nevada, recognized: (1) two biozones based on two separate species of *Chaetetes*, (2) the solid substrate requirement for chaetetid growth, (3) the ability of chaetetids to regenerate after partial "choking" by fine-grained sediment, and (4), perhaps most importantly, that the two stratigraphically different species (the Atokan *C. favosus* and the early Desmoinesian *C. milleporaceous*) might be ecophenotypes of the same Mendelian species.

Lower and Middle Pennsylvanian occurrences of *Chaetetes* in Texas have been documented by Connolly & Stanton (1983), Connolly (1985), Lambert et al. (1986), Lambert & Stanton (1986), Moore & Jeffords (1945), Spaw (1977), Winston (1963), and Sutherland (1984). Chaetetes in the Marble Falls Formation in the Llano area was recognized in transgressive as well as regressive limestones by Winston (1963, p.82), who noted some reef occurrences containing individual colonies of Chaetetes exceeding "ten feet" in height. Spaw (1977) studied Chaetetes-bearing Middle Pennsylvanian units in the Hueco and northern Franklin mountains of Texas and New Mexico, but reported no reefs or reef-like structures. Moore & Jeffords (1945) conducted a taxonomic study of the Lower Pennsylvanian corals of Texas and adjacent states in which three new species of Chaetetes were described. Connolly & Stanton (1983) confirmed the shallow-water occurrence for the Morrowan (Lower Pennsylvanian) Chaetetes in the Hueco Mountains of West Texas and recognized a Chaetetes paleocommunity that colonized non-mobile oolite bars. Here again, no reef structures were reported.

A Chaetetes range zone was recognized in the Morrowan of northeastern Oklahoma by Henry (1970) and further commented on by Sutherland & Manger (1977), and by Sutherland & Henry (1977), who stated (p. 437) "...Chaetetes is common as scattered colonies in a growing position as much as 30.5 cm (1 ft) in diameter; these never formed extensive patch reefs."

Morgan (1924), in a study of the Homer Limestone in the Stonewall Quadrangle of Oklahoma, described Chaetetes schucherti, a new species from the Middle Pennsylvanian (Desmoinesian) and said that they formed a reef, but Tanner (1956), who studied the same rocks and recognized a

Chaetetes facies within it, did not mention any reef or reef-like structure.

West (in press) gives a survey of changes in Carboniferous reef mound communities, and provides a good summary of publications on Chaetetes and other Carboniferous reef builders.

Several stratigraphic and environmental studies have been completed on Chaetetes-bearing units in southeastern Kansas, some of which have extended to northeastern Oklahoma and across Missouri into Iowa. The Altamont Formation in Iowa, Missouri, Kansas,and northern Oklahoma was studied by Schenk (1963, 1967), who recognized a coral biofacies dominated by Chaetetes milleporaceous. A Chaetetes biostrome in the Amoret Limestone Member in Madison County, Iowa, was documented by DeVries (1955). Mathewson (1977), studying the Amoret Limestone Member in Labette County, Kansas, recognized astrorhizae on some chaetetid specimens, which considerably strengthened their affinity with sclerosponges (demosponges). The Amoret Limestone is interpreted to be a transgressive limestone in Heckel's (1977) model.

The chaetetid reef examined for this study was first documented by Heckel et al. (1979). Knight (1985) completed a regional stratigraphic and environmental study of the Fort Scott Formation (part of which he now calls the Wolverine Creek Formation, which includes the Houx-Higginsville Limestone) in southeastern Kansas, northeastern Oklahoma, and across Missouri into Iowa. He included both surface and subsurface information. Knight's (1985) study provided a general framework within which this study could begin its more detailed examination of regional stratigraphy and the paleoenvironmental setting of the chaetetid "reef" at the Niggeman quarry.

CHAPTER 2

REGIONAL STUDY

Introduction

Stratified rocks of the Midcontinent have been studied according to a number of different approaches, most of which have reflected the alternating shale-limestone lithology of Midcontinent rocks (e.g., Wanless and Weller, 1932; Moore, 1936; and Heckel, 1977). This chapter examines rocks of the Marmaton Group in southeast Kansas, northeast Oklahoma, and western Missouri using yet another method of analysis, one in which the genetic sixth-order transgressive-regressive units of Busch and Rollins (1984) are used. Special emphasis is placed upon that portion of the Houx-Higginsville Limestone Member containing the chaetetid unit that is the main subject of this thesis.

First there will be a discussion of how the units were recognized and correlated. Then it will be shown how these units can be used to make very refined paleogeographic reconstructions.

Interpretive Perspective

One of the more recent traditional-type approaches to analysis of Midcontinent rocks has used Heckel's (1977) model of the basic Kansas cyclothem (Figure 5). Using this model, sea level change is considered to be gradual and long-term, resulting in a Walther's Law succession of

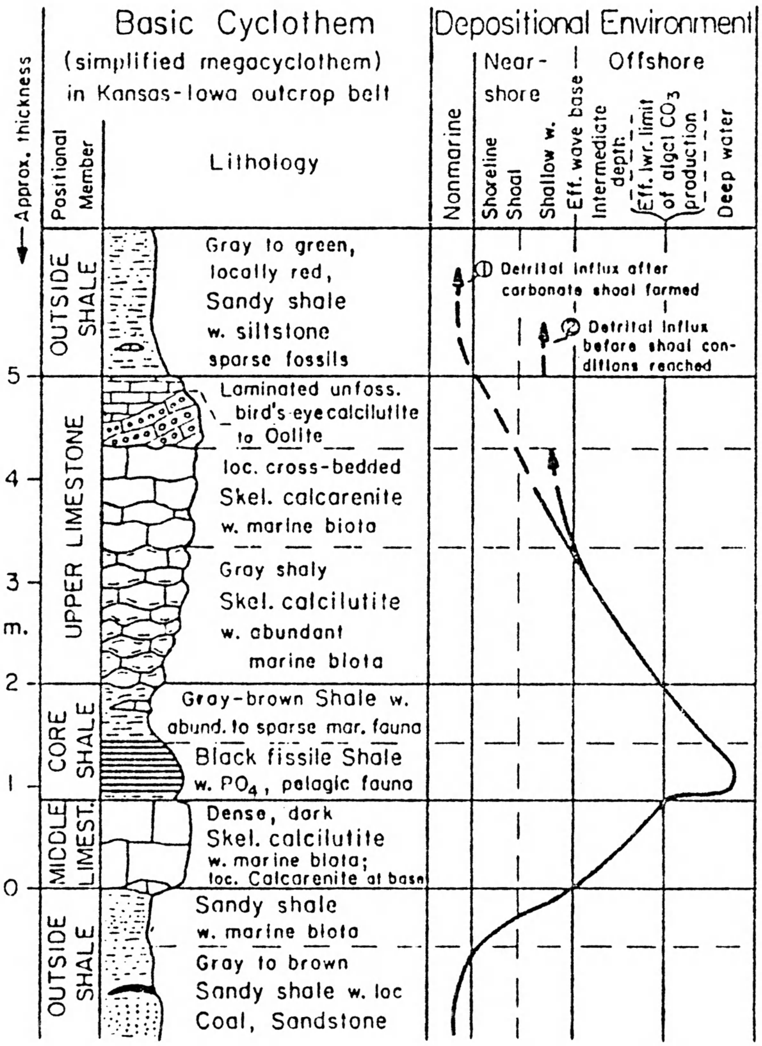


Figure 5. Heckel's basic Kansas cyclothem (modified from Heckel, 1977, p. 1047).

lithofacies from the Outside (or nonmarine) Shale, to a transgressive Middle Limestone, to the deepest marine Core Shale, through a regressive Upper Limestone, and back again to an Outside Shale. This is a rock-stratigraphic approach in which an attempt is made to trace cycles or rhythms of specific lithofacies across a depositional basin. The rock units thus traced are likely to be diachronous over the outcrop area.

This model can be useful in a very broad sense or as an initial reconnaissance tool, but when the rocks are examined in greater detail, with thinner intervals the subject of interest, a much more complex sea level history emerges.

The Model used herein is the Punctuated Aggradational Cycle (or PAC) approach of Anderson and Goodwin (1980) (see Figure 6). A PAC is equivalent to Busch and Rollins' (1984) sixth-order transgressive-regressive unit (or sixth-order T-R unit). This technique traces these small-scale genetic deepening-shallowing units across a depositional basin and uses that to interpret the rocks.

PACs can be grouped into cyclothemic PAC sequences or, as Goodwin and Anderson now prefer to call them, Shallowing PAC Sequences (Goodwin and Anderson, 1985; Goodwin, 1987, pers. comm.) (see Figure 6). Busch and Rollins (1984) would designate these as fifth-order T-R units. They are equivalent in scale to Heckel's (1977) Kansas cyclothem. A sixth-order T-R unit represents tens of thousands of years whereas a fifth-order T-R unit represents roughly 400,000 years of deposition (Busch and Rollins, 1984). The genesis of both is believed to be a result of eustatic sea level fluctuations brought on by climatic

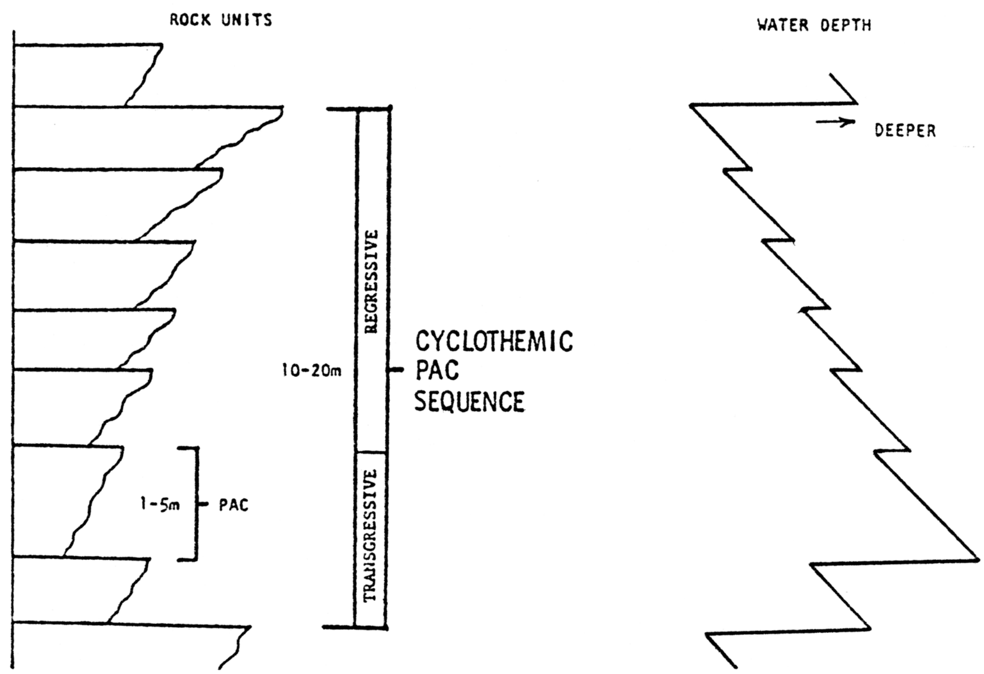


Figure 6 Concept of punctuated aggradational cycles, or PAC's, (sixth-order T-R units) and cyclothemic PAC sequences (fifth-order T-R units) (modified from Anderson and Goodwin, 1980).

changes associated with Milankovitch-type variations in Earth's orbit (Busch and Rollins, 1984; Goodwin and Anderson, 1985; Goodwin, et al., 1986).

As shown in Figure 7, each PAC is bounded by a surface representing a punctuation event, usually rapid marine transgression, and may or may not have a thin layer of transgressive deposits at its base. The remainder of the T-R unit represents aggradation and progradation of sediments during long periods of sea level stasis or slow regression.

The change in rock type from the top of one PAC to the base of the next overlying one may be a result of changing from a terrestrial to a marine environment, or from shallow to deeper marine, or from an arid terrestrial to a humid terrestrial environment. In the latter case, the genetic surface would be called a climate change surface (Busch, 1984) rather than a transgressive surface.

The PAC approach is a time-stratigraphic approach in which genetic units are correlated across a depositional basin. The bounding genetic surfaces are essentially geologically synchronous and thus have a real time-significance in interpreting the rocks. This can give a tremendous advantage over methods in which diachronous rock facies are traced across a basin (see Goodwin, et al., 1986)

Setting

The rock units studied are from what has been known until recently as the Fort Scott Formation and part of the overlying Labette Shale (Figure 2). They belong to the Marmaton Group and are Desmoinesian or

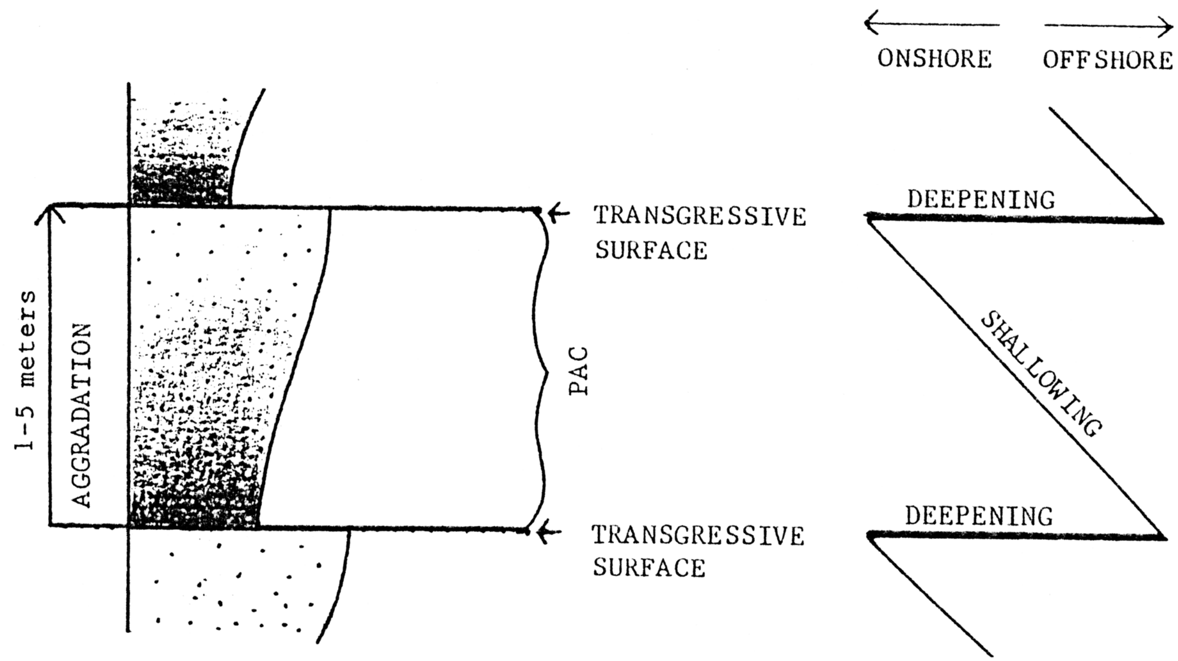


Figure 7.

PUNCTUATED AGGRADATIONAL CYCLE CONCEPT (modified from Goodwin and Anderson, 1985, Fig. 1, p. 517).

Middle Pennsylvanian in age.

Knight (1985) in his doctoral dissertation reassigned rocks of the Fort Scott Formation and underlying Excello Shale as shown in Figure 3. He grouped them into the Lower Fort Scott Cyclothem and the Upper Fort Scott cyclothem. This chapter examines rocks from the Upper Fort Scott cyclothem, from the top of the Morgan School Shale, through the Little Osage Shale, the Houx-Higginsville Limestone, and part of the Labette Shale.

These rock units crop out in a belt trending from northeast Oklahoma, through southeast Kansas, and across western Missouri to Iowa. The localities used are shown in Figure 8 and the stratigraphic sections are shown in Plate 1 and described in Appendix A. Exposures in southeast Kansas and westernmost Missouri, from locality SOS to locality BUT, were examined in detail for this study. All other localities were taken from the literature (Knight, 1985; Jeffries, 1958; Schell, 1955). It may be instructive to note the differences between Plate 1, in which members are delineated according to lithologies, and Plate 2, in which genetic units are traced using the PAC approach.

Sixth-Order T-R Units

Rocks in the quarry face shown in Figure 9, from locality 700 in Crawford County, Kansas, show most of the Upper Fort Scott cyclothem. The Little Osage Shale forms the floor of the quarry. The Houx-Higginsville Limestone, filling most of the photo, is over 5 meters

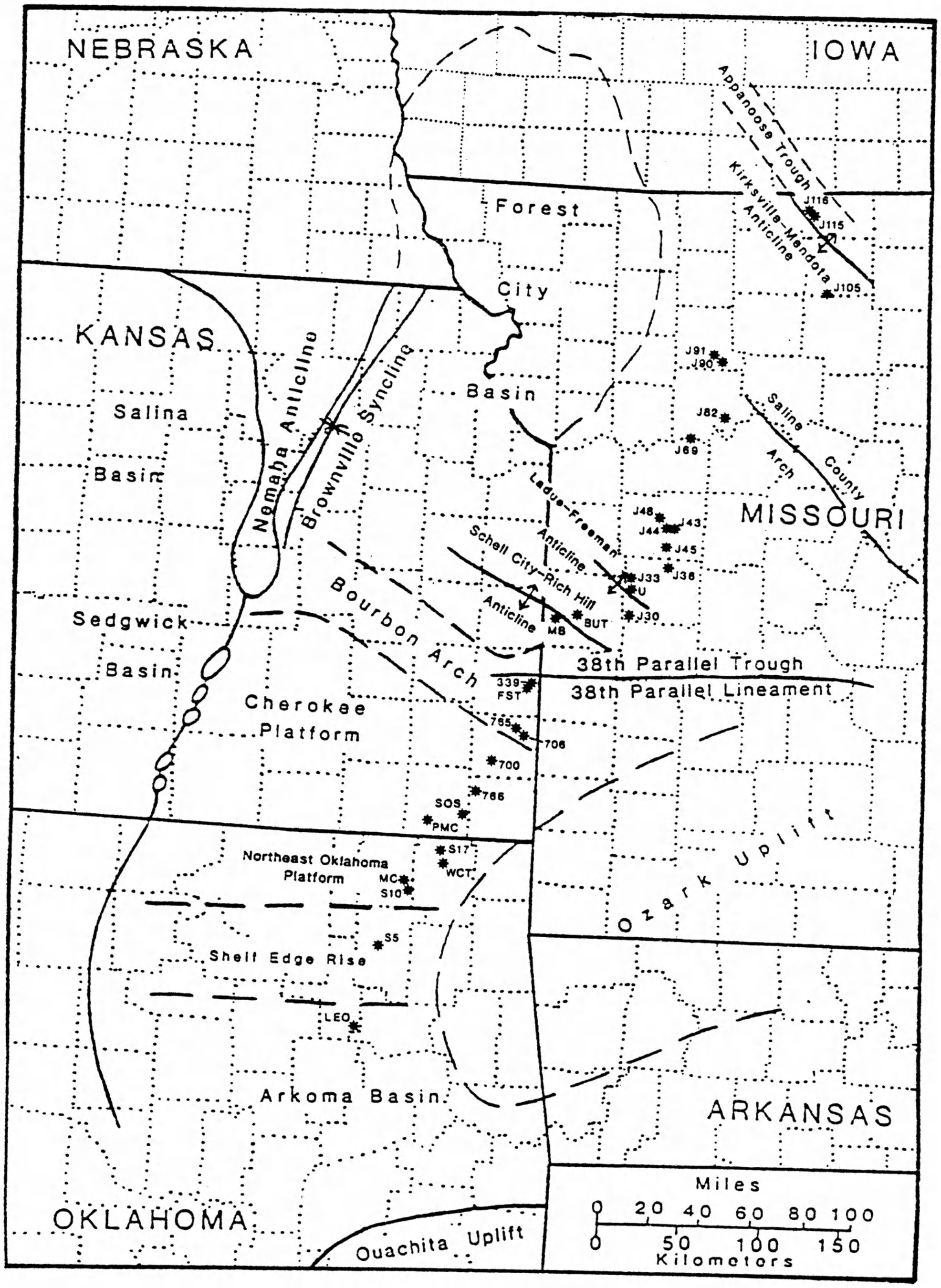


Figure 8. Map of localities (shown by stars) used in regional study of "upper Fort Scott cyclothem". (Structural map from Knight, 1985, fig. 7, p.38).

Figure 9. Overall outcrop at station 31, Locality 700. Hammer sits on top of Little Osage Shale at its contact with the Houx-Higginsville Limestone, which extends upward to where the soil and vegetation occurs. Base of clipboard is even with cherty layer in bed 3 (see stratigraphic section 700 in Appendix A, and section 31 in Appendix B). Hammer is approximately 31 cm long.

thick here, with well developed chaetetid colonies from 2 to 4.5 meters above the base of the limestone. The Labette Shale is on top. Five PACs (or sixth-order T-R units) have been recognized here, beginning at the base of the Little Osage Shale, with a boundary at the top of the Little Osage Shale, two boundaries within the Houx-Higginsville Limestone, and one within the Labette Shale (Figure 9) (also see Plate 2 and Appendix A, p. A15).

The stratigraphic column in Figure 10 is a composite section from localities 339 and FST (see Plate 2 and Appendix A, p. A22 and A23) near Fort Scott, Kansas. The rocks here are very similar to those shown in Figure 9 and, although over 50 kilometers away, they show the same genetic changes. The Houx-Higginsville Limestone here again is approximately 5 meters thick; so PAC 3 is approximately 1 meter thick. The terrestrially deposited Morgan School Shale represents the top of the Lower Fort Scott cyclothem. The remainder of the section represents the Upper Fort Scott cyclothem.

PAC 1 was deposited during the deepest marine transgression of the Upper Fort Scott cyclothem. Its lower boundary is a climate change surface overlain by a thin coal. Actual marine transgression soon followed this event and there occurred deposition of black fissile shale with phosphate nodules below an oxygen minimum zone during deepest marine transgression (Heckel, 1977). Heckel (1977) would call this his "core shale." It occurs over the entire outcrop area.

As sea level slowly fell, deposition of a thin limestone was followed by deposition of a thin mudstone with abundant root casts, <u>Crurithyris</u>, and <u>Chondrites</u>. This same mudstone facies occurs at this

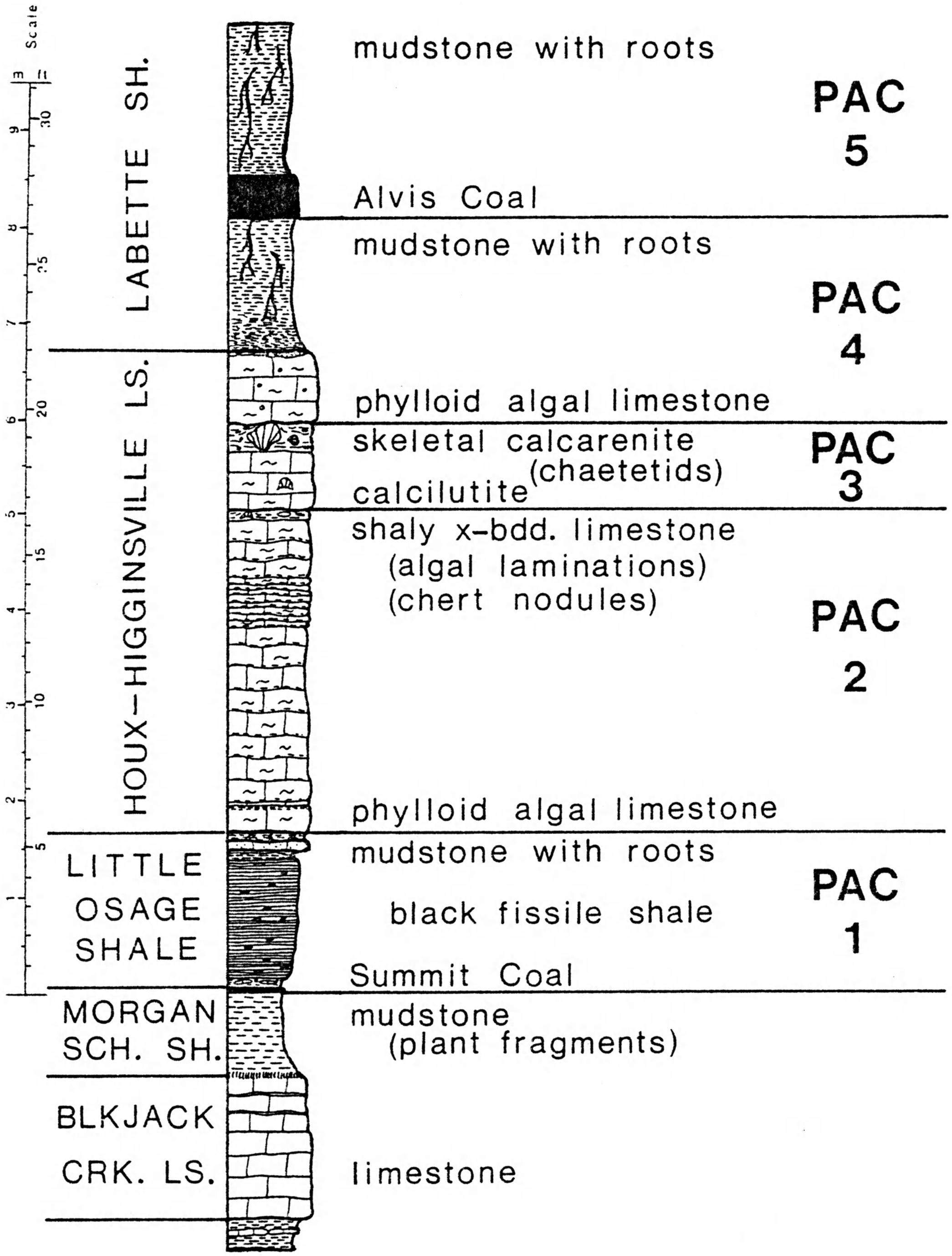


Figure 10. Stratigraphic column from Fort Scott, Kansas, showing PAC's at localities 339 (from top of Little Osage Shale upward) and FST (from top of Little Osage Shale downward).

point in the section at localities 700 and BUT as well. It is interpreted to represent marginal marine to lagoonal or possibly even paralic mudflat deposition. At other localities in southeast Kansas (SOS, 766, 765, MB on pp. A14, A15, A20, A26 in Appendix A), a nonfossiliferous to sparsely fossiliferous grayish orange claystone occurs at the top of PAC 1.

Following this, a rapid marine transgression culminated in a long period of more open marine conditions in which phylloid algal limestone was deposited (Figures 9 and 10). This facies extends over a wide area in southeast Kansas and western Missouri (see Plate 2). At the top of PAC 2 at locality 339 (Figure 10), there occurs shaly cross-bedded limestone with algal laminations and chert nodules. This is interpreted to represent a very nearshore environment. At locality 700, the top of PAC 2 exhibits strongly cross-laminated shaly calcarenite with a nodular chert layer; this is interpreted to be very shallow marine. At other localities the change here may be more subtle (see Plate 2 and Appendix A).

PAC 3 represents another deepening event, although not as deep as the last one. At locality 339 we see fossiliferous limestone with chaetetids. At localities 700 and 706, this PAC contains very well-developed chaetetids [referred to as a chaetetid reef by Heckel et. al. (1979, p. 35) and Knight (1985)] in a fusulinid packstone matrix. The chaetetid "reef" at locality 700 and its relationship to the regional geology is the main subject of this investigation.

The top of PAC 3 at locality 339 (Figure 10) is represented by strongly cross-laminated, coarse grained, shelly calcarenite with some toppled chaetetids. The top of PAC 3 at localities 700 and 706 is represented by a thin paralic to terrestrial shale. At locality BUT the top of the Houx-Higginsville Limestone exhibits paleokarstic features suggesting subaerial exposure prior to deposition of PAC 4(see Plate 2 and Appendix A).

In PAC 4 we return to more open marine phylloid algal limestone at most southeast Kansas localities, with marginal marine shale at locality BUT. At all localities the top of PAC 4 contains terrestrial mudstone with roots.

The lower boundary of PAC 5 is represented at locality 339 and at many other localities by a climate change surface (Busch, 1984) which is overlain by the Alvis coal. At this level at locality 700 we see a pale orange shale with abundant Aviculopecten and Permophorus (see Plate 2 and Appendix A). At several localities the Alvis Coal was overlain by a thin limestone or marginal marine shale before sea level again receded and terrestrial mudstone with roots was deposited at the top of PAC 5.

Now that sixth-order genetic units have been correlated across southeast Kansas and western Missouri, we can move 300 kilometers away and examine exposures of the Upper Fort Scott cyclothem in northern Missouri. Figure 11 is a composite section from Jeffries (1958) in which the largest portion (up through the Higginsville Limestone) is from his locality 116 and the remainder is from his locality 115, 2 mi. (3.2 km) away.

PAC 1 at this locality is just under 2 meters thick. It is very similar to the southeast Kansas localities in that black fissile shale

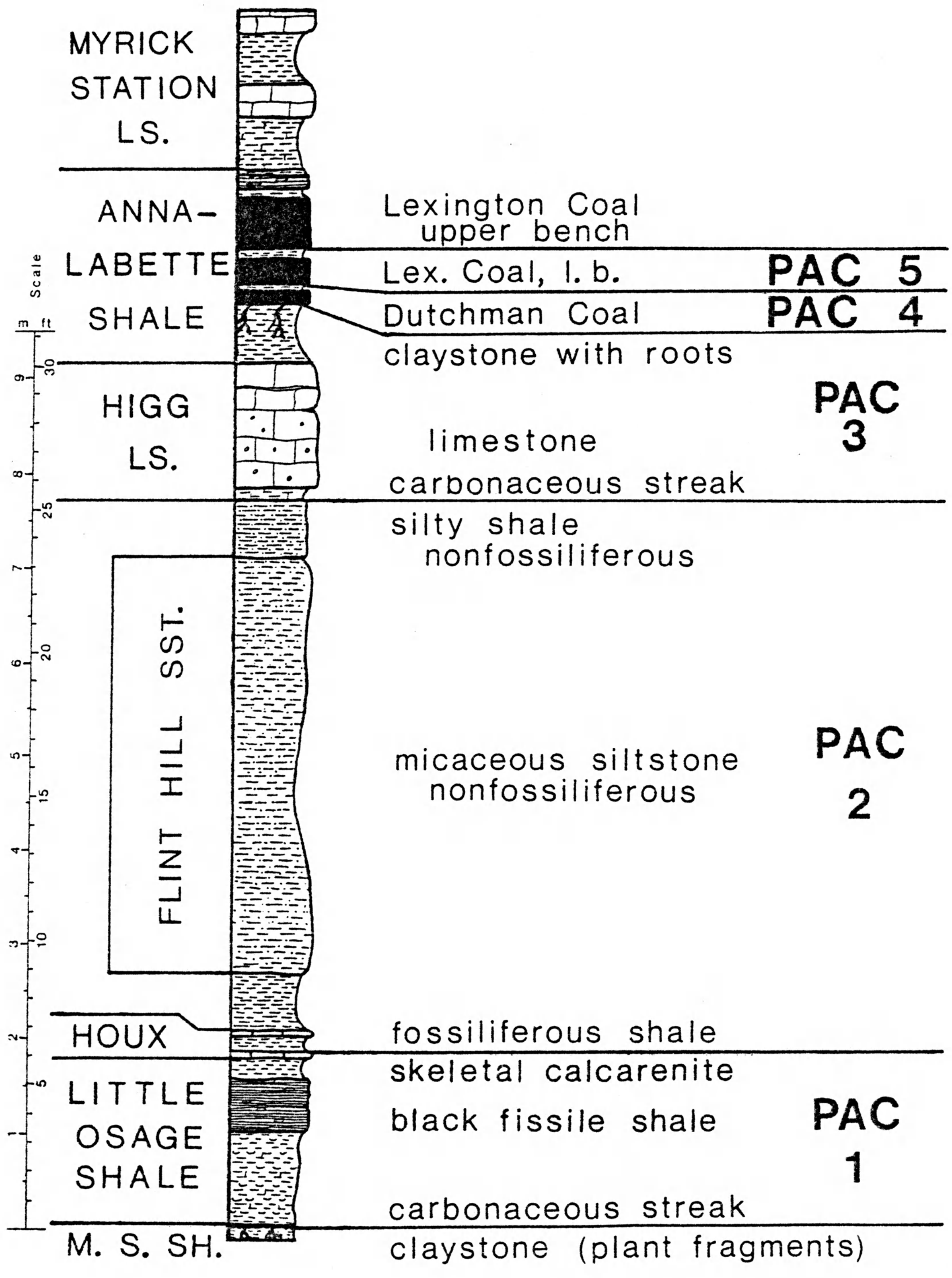


Figure 11. Stratigraphic column from northern Missouri, showing PAC's at localities 116 (from top of Higginsville Limestone downward) and 115 (from top of Higginsville Limestone upward).

was deposited during the deepest marine transgression. At the top of PAC 1 is a thin skeletal calcarenite.

PAC 2 at locality 116 begins with fossiliferous marine shale followed by a thin skeletal calcarenite. This is overlain by a thick nonfossiliferous clastic unit called the Flint Hill Sandstone. At many localities in Missouri the Houx Limestone contains thicker limestone beds but it is consistently split in the middle by a shale parting (localities J91 and J82) or by a nonfossiliferous shale up to 2 meters thick (J48) that in some cases (J44, J45) exhibits a red-gray color or iron staining suggesting subaerial oxidation. These features, along with the great lateral persistence and consistent position of the shale and its possible correlation with thin, sometimes rooted mudstone between limestones at the top of the Little Osage Shale at localities BUT, MB, 339, and FST suggest that the lower boundary of PAC 2 should be placed at the top of this shale parting.

PAC 3 contains a 1.4 meter thick limestone overlain by terrestrial claystone with carbonized fossil roots. At many localities in Missouri (J91, J82, J48, BUT), in addition to the southeast Kansas localities, this PAC contains chaetetids.

PAC 4 is represented here by the Dutchman Coal overlain by a very thin gray claystone. PAC 5 is represented by the lower bench of the Lexington Coal overlain by a thin gray claystone. The bases of both these PAC's are climate change surfaces. The base of the upper bench of the Lexington Coal is another climate change surface at the base of the next overlying fifth-order T-R unit.

Placing sixth-order T-R unit boundaries at the bases of coals is consistent with Busch's (1984) concept of climate change surfaces. This concept states that eustatic sea level rise resulting from glacial melting is accompanied by a warmer, more humid climate. Thus in the marine environment sedimentation reflects deepening sea water conditions, whereas sedimentation on land reflects a change in climate. That climate change may result in widespread humid coal-forming environments.

Stach, et al. (1982, p.6), in discussing coal-forming environments, said "the warmer and wetter the climate, the more luxuriant is the flora." Busch and West (1987) viewed coal benches as "facies developed in humid, ideal coal-forming environments (on top of the climate change surface)" and viewed the partings between coal benches as "facies developed during deterioration of the more ideal coal-forming environment, probably under cooler, less humid conditions (beneath the climate change surface)." Holbrook (1973) regarded widespread coals as transgressive facies atop regressive paleosols, and Ramsbottom (1984) has even termed coals "failed marine zones." Detailed study of vertical maceral changes within the coals may shed further light on transgressions and regressions as was done by Toprak (1984) in coals in Turkey.

In Plate 2 the PACs are correlated among all the localities covered in Appendix A, from northeast Oklahoma through southeast Kansas to northern Missouri. PAC 1 includes all of the Little Osage Shale at all localities but also includes the lower part of the Houx Limestone from locality J36 northward.

PAC 2 includes a large lower portion of the Houx-Higginsville

Limestone from locality S10 in northeast Oklahoma to locality J48 in west-central Missouri, and includes the upper part of the Houx Limestone and the Flint Hill Sandstone clastic wedge from locality J69 northward in Missouri. That portion of the Houx-Higginsville Limestone included in PAC 2 is primarily wavy-bedded phylloid algal limestone.

PAC 3, the chaetetid PAC, consists of the middle portion of the Houx-Higginsville Limestone from locality PMC in southeast Kansas to locality J48 in west-central Missouri. From there northward, it consists of the Higginsville Limestone and, in some cases, part of the overlying Labette Shale. The chaetetid facies occurs sporadically within this PAC over most of the outcrop area, usually associated with topographic highs (see section on chaetetid occurrences, p. 56). At localities 700 and 706, where the chaetetids are very well developed, they occur in a fusulinid packstone matrix, and at the other chaetetid localities there are usually common to abundant fusulinids. At the non-chaetetid-bearing localities, this PAC contains fossiliferous limestone with or without fusulinids.

PAC 4 includes the upper part of the Houx-Higginsville Limestone and part of the Labette Shale from locality PMC in southeast Kansas to locality J48 in west-central Missouri. It is believed to correlate to the Dutchman Coal in northern Missouri (locality J115).

Within PAC 5, the Alvis Coal of southeast Kansas and western Missouri (localities 339 to J44) is correlated with the lower bench of the Lexington Coal in northern Missouri (J115). At this level at locality 700 is a marginal marine shale. At localities BUT to J44, the Alvis Coal is overlain by a marginal marine shale or thin marine limestone which in turn is overlain by terrestrial mudstone.

PAC's 2 through 5 were not correlated in the southern part of the study area because of a lack of exposures or a lack of adequate descriptions in the literature. Correlation of PACs 4 and 5 between localities J48 and J115 is not shown in Plate 2, but many of Jeffries' (1958) measured sections in this area show the same pattern of genetic changes (i.e., the same number and positions of coals or coal smuts). These correlative coal localities are addressed in a later section of this paper concerning paleogeographic reconstructions.

Sea Level Curves

Figure 12 shows Knight's (1985) sea level curve for the Upper Fort Scott cyclothem. He used Heckel's (1977) cyclothem approach to examine these rocks. Notice the smooth curve reminiscent of Heckel's cyclothem curve (Figure 5), although he does show a strong sea level change at the top of the Houx-Higginsville Limestone; this is the position of the base of PAC 4. Also, Knight (1985) correlated the Flint Hill Sandstone to the middle part of the Houx-Higginsville Limestone. This paper correlates it to the lower part.

A sea level curve developed using the PAC approach to the same rocks is shown in Figure 13. The initial transgression within the Little Osage Shale looks basically the same as Knight's (1985), but also shown are several other deepening-shallowing events. If the rocks had been examined only at a fifth-order scale, the curve might very well have resembled Heckel's (1977) cyclothem curve. However, by

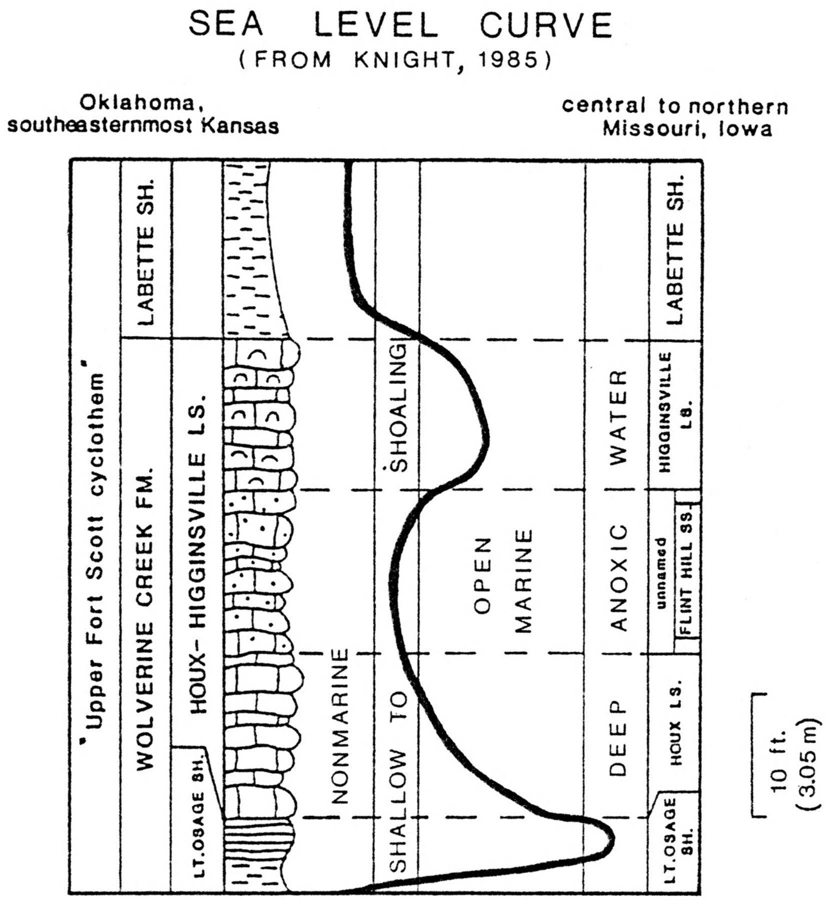


Figure 12. Knight's (1985) sea level curve developed by using the cyclothem approach (modified from Knight, 1985, fig. 42, p. 258).

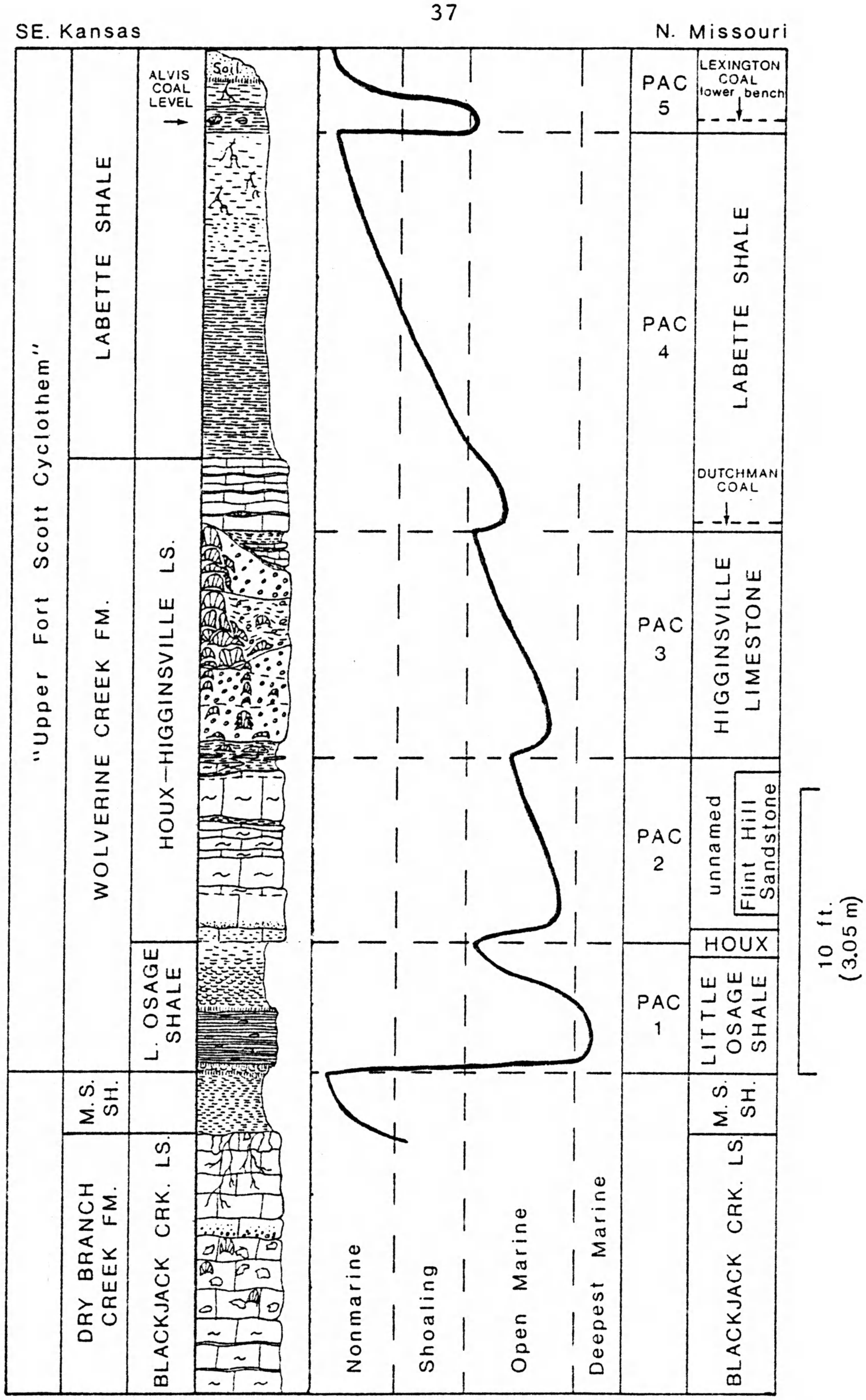


Figure 13. Sea level curve developed based on recognized PAC's in this study. Stratigraphic column from the top of the Little Osage Shale upward is from locality 700; below that is from locality 766, 13.5 mi. (21.7 km.) apart.

examining the rocks centimeter by centimeter and recording genetic changes, a smaller, sixth-order scale is seen in which 5 PACs occur within the Upper Fort Scott cyclothem (5th order T-R unit), each deepening event being slightly less deep than the previous ones.

Paleogeographic Reconstructions

Examination of rocks along the outcrop belt of the "Upper Fort Scott cyclothem" by using the PAC approach has yielded considerable information concerning depositional environments at each of the localities. This information has allowed the development of a series of detailed paleogeographic maps and topographic profiles showing the changes from one PAC to the next over the outcrop area (Figures 14-24).

Figure 14 is the key to the patterns used to plot inferred depositional environments on the maps. Patterns 5-8 are intended to represent a spectrum of relative sea water depths. Pattern 5 represents the shallowest environment with the succeeding patterns being increasingly deeper and pattern 8 representing deposition of the black fissile shale under deepest marine conditions. There is no such implied spectrum represented by the patterns used for terrestrial shale, sandstone, or coal; these are all simply treated as terrestrial deposits. Pattern 4 represents paralic deposition or something close to paralic.

Figure 15 is the map for the top of the Morgan School Shale just before the first major transgression, or just before PAC 1 (see Figure 13). The inferred depositional environments are plotted on a structure

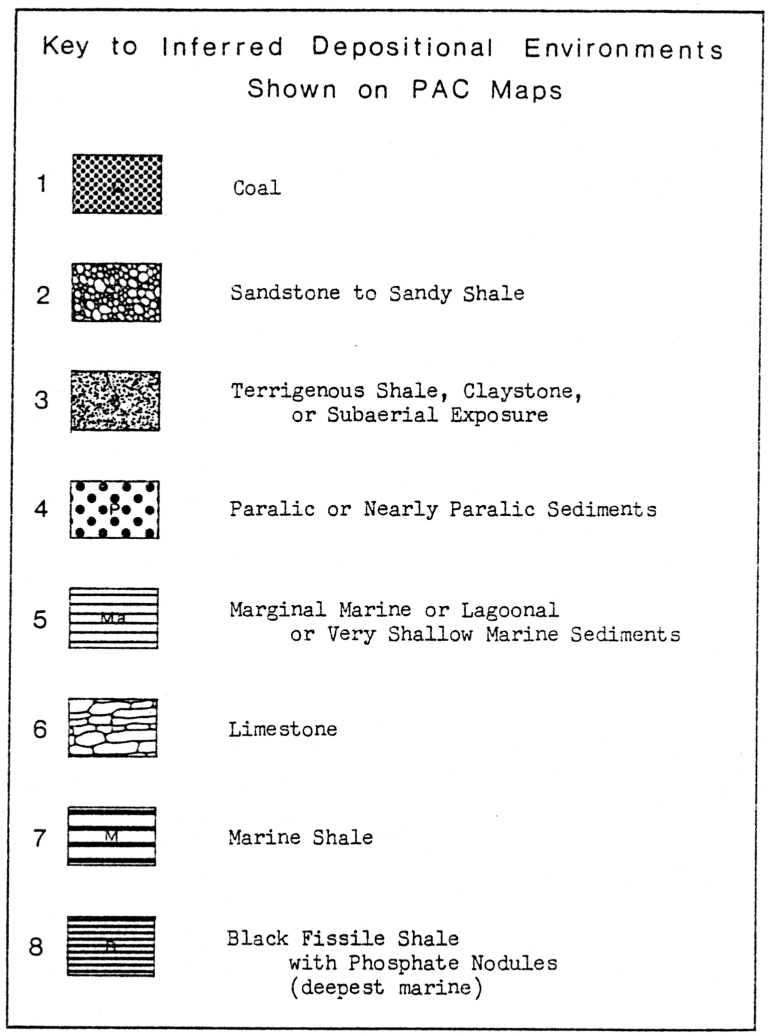


Figure 14. Key to patterns used in Figures 15 - 24 to show inferred depositional environments.

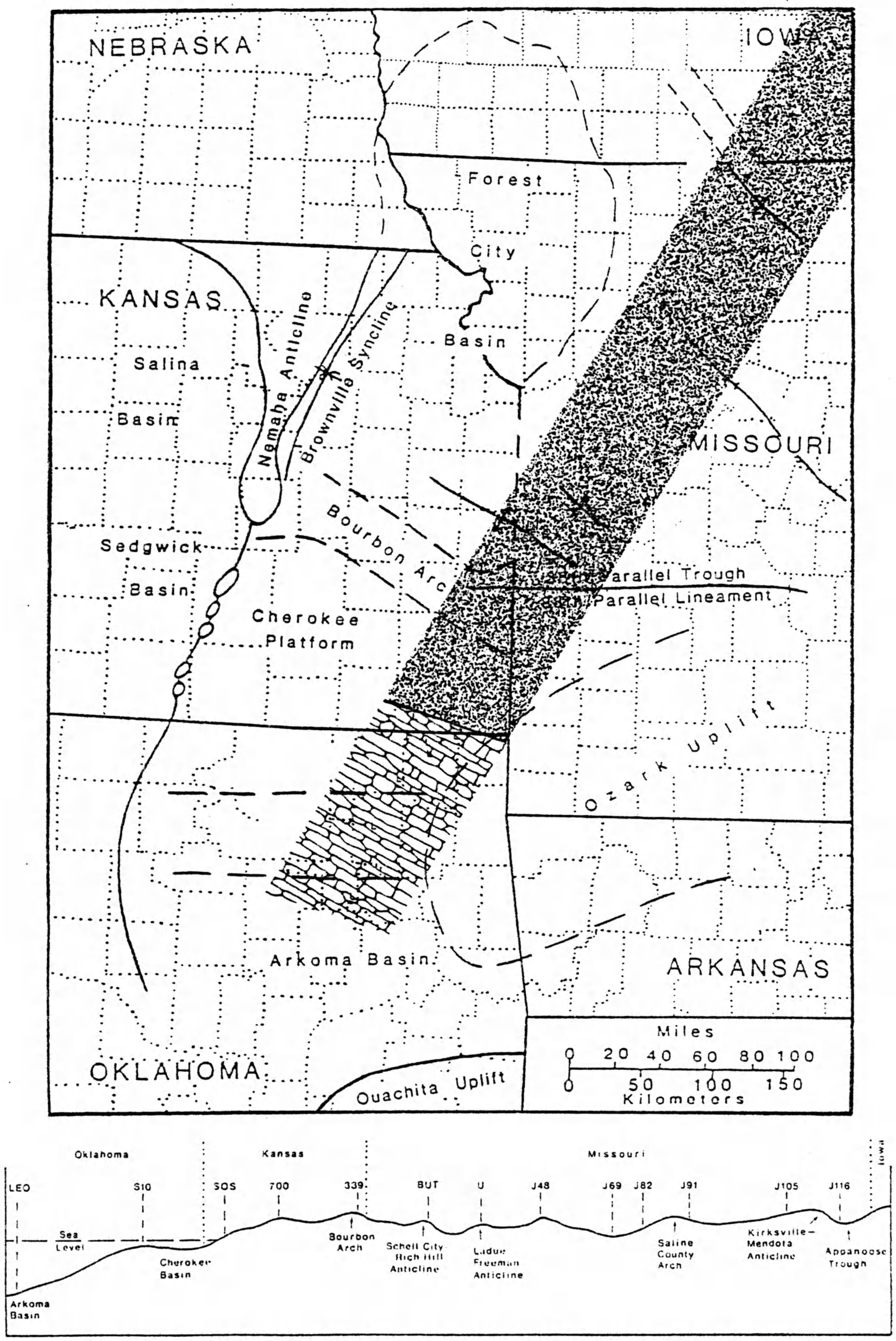


Figure 15. Paleogeographic map and topographic profile showing inferred depositional environments during maximum PAC O regression. Relief in the topographic profile is only relative and exhibits great vertical exaggeration. See Figure 14 for key to patterns used on map.

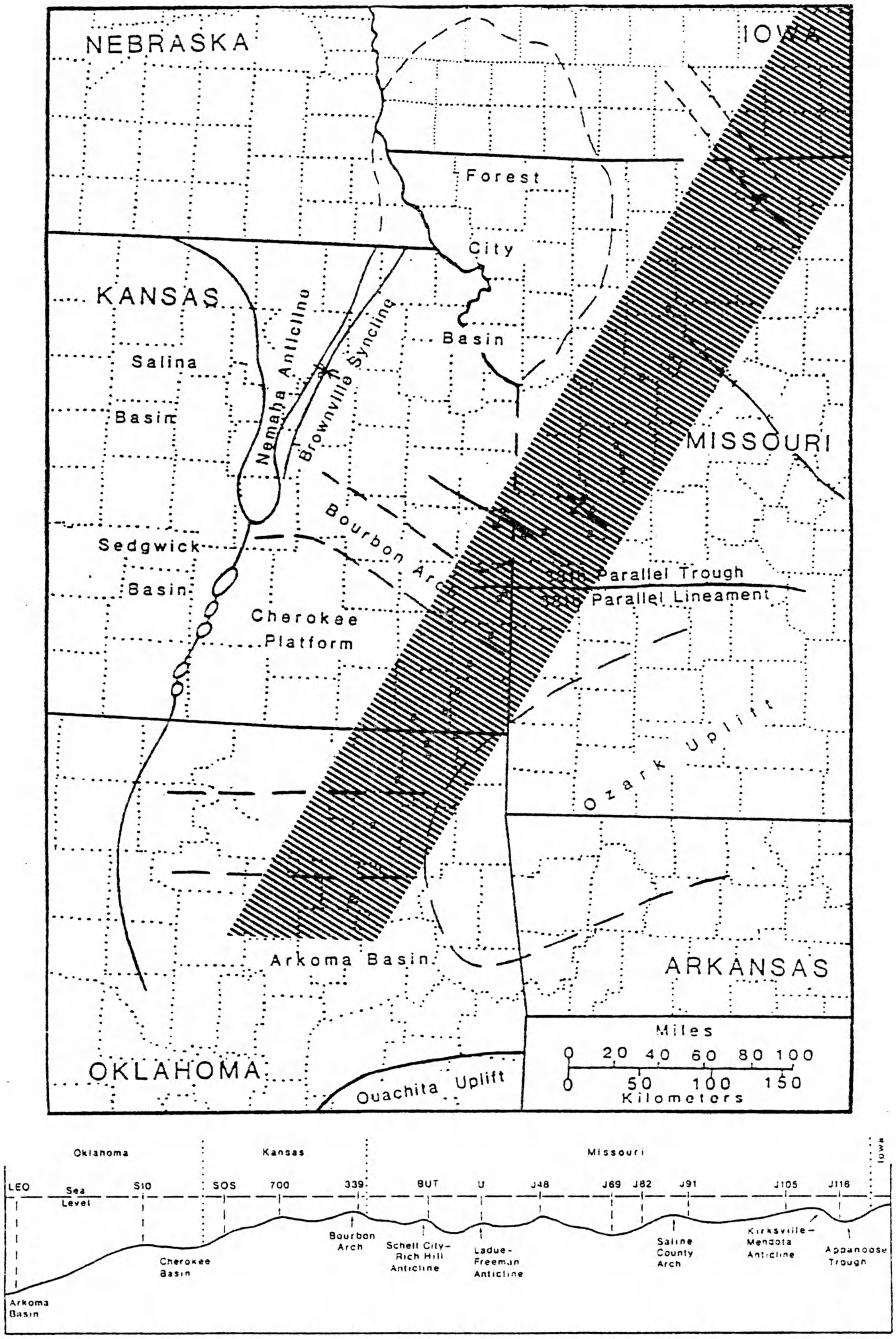


Figure 16. Maximum PAC 1 transgression (see Figures 14 and 15 for further explanation).

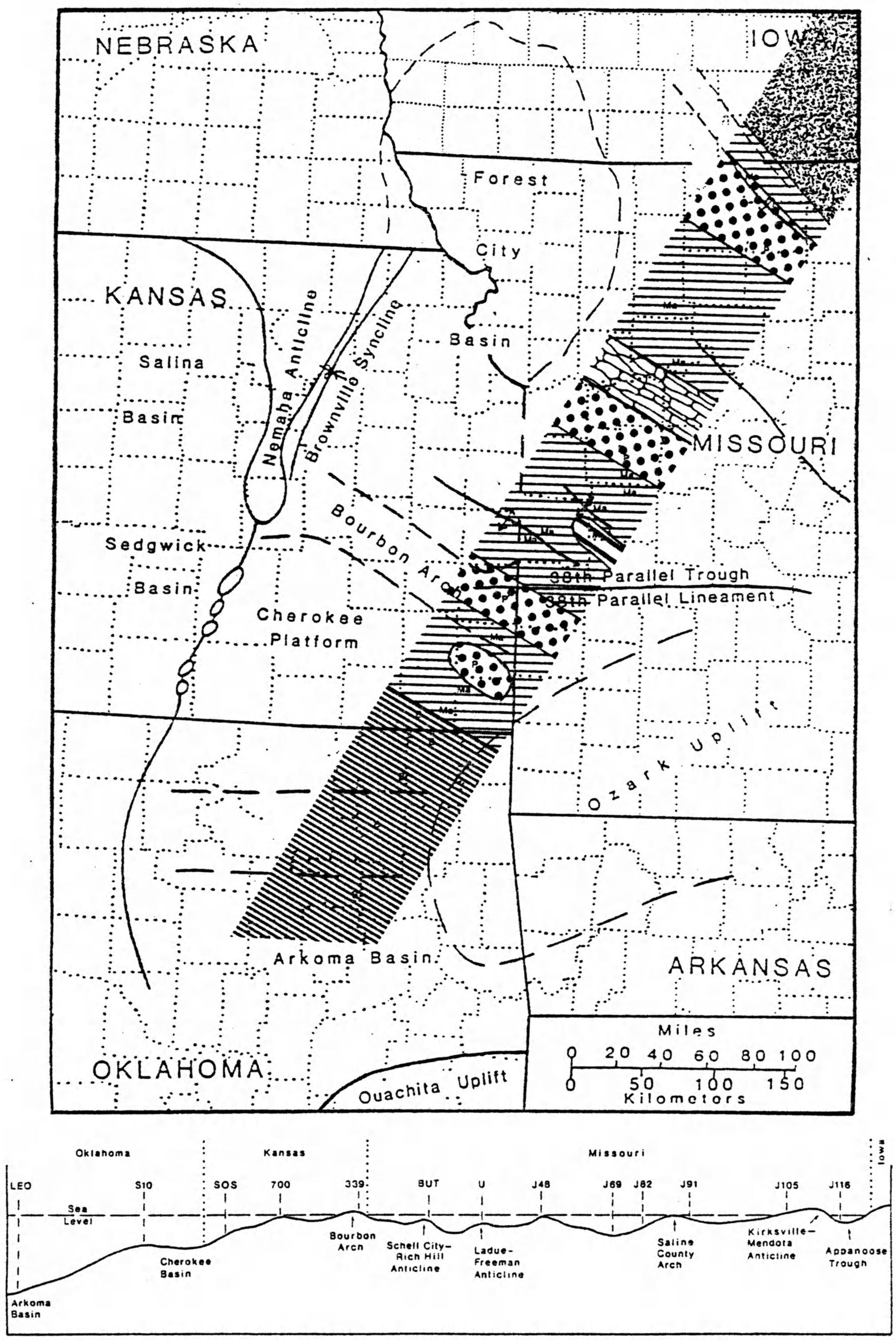


Figure 17. Maximum PAC 1 regression (see Figures 14 and 15 for further explanation).

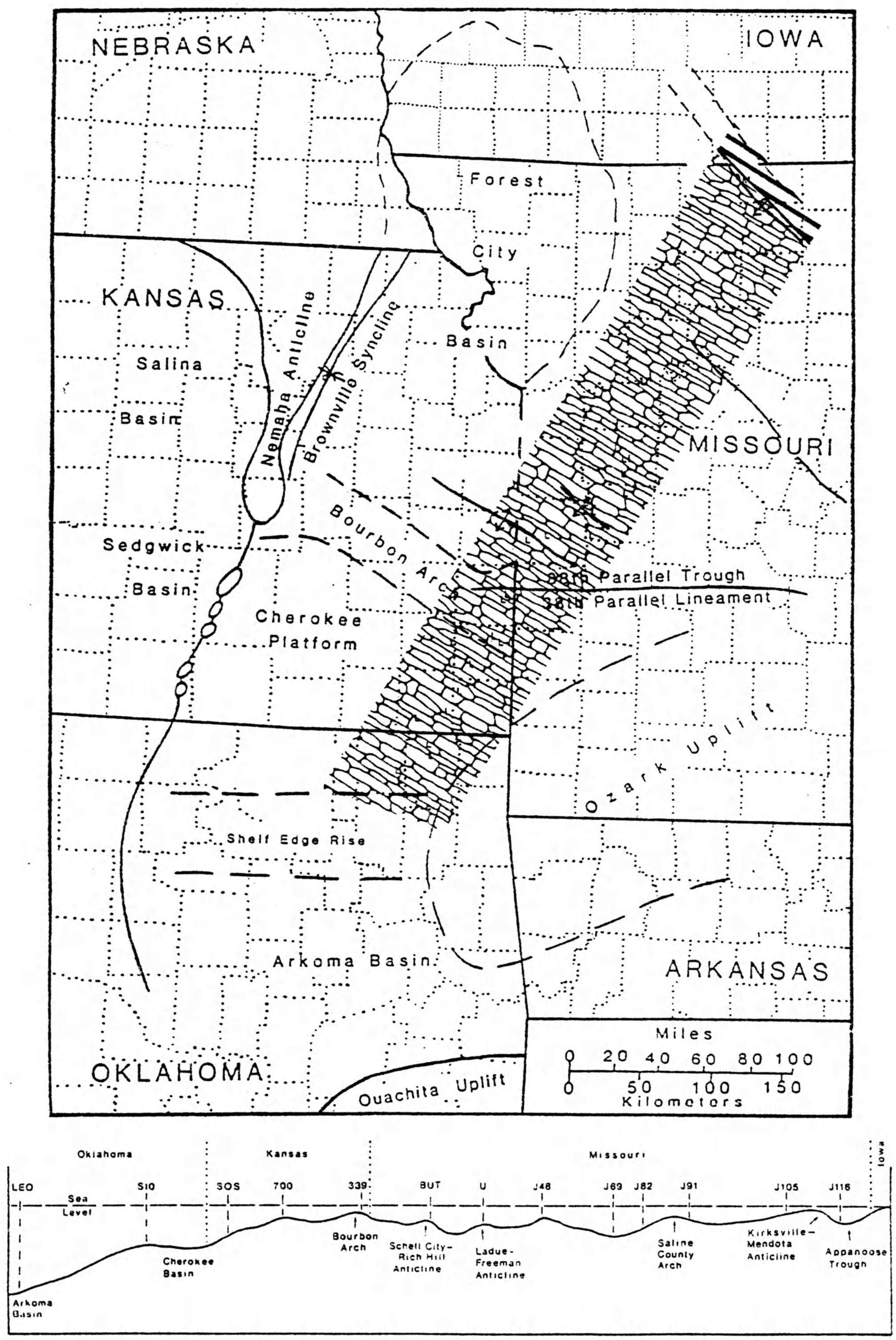


Figure 18. Maximum PAC 2 transgression (see Figures 14 and 15 for further explanation).

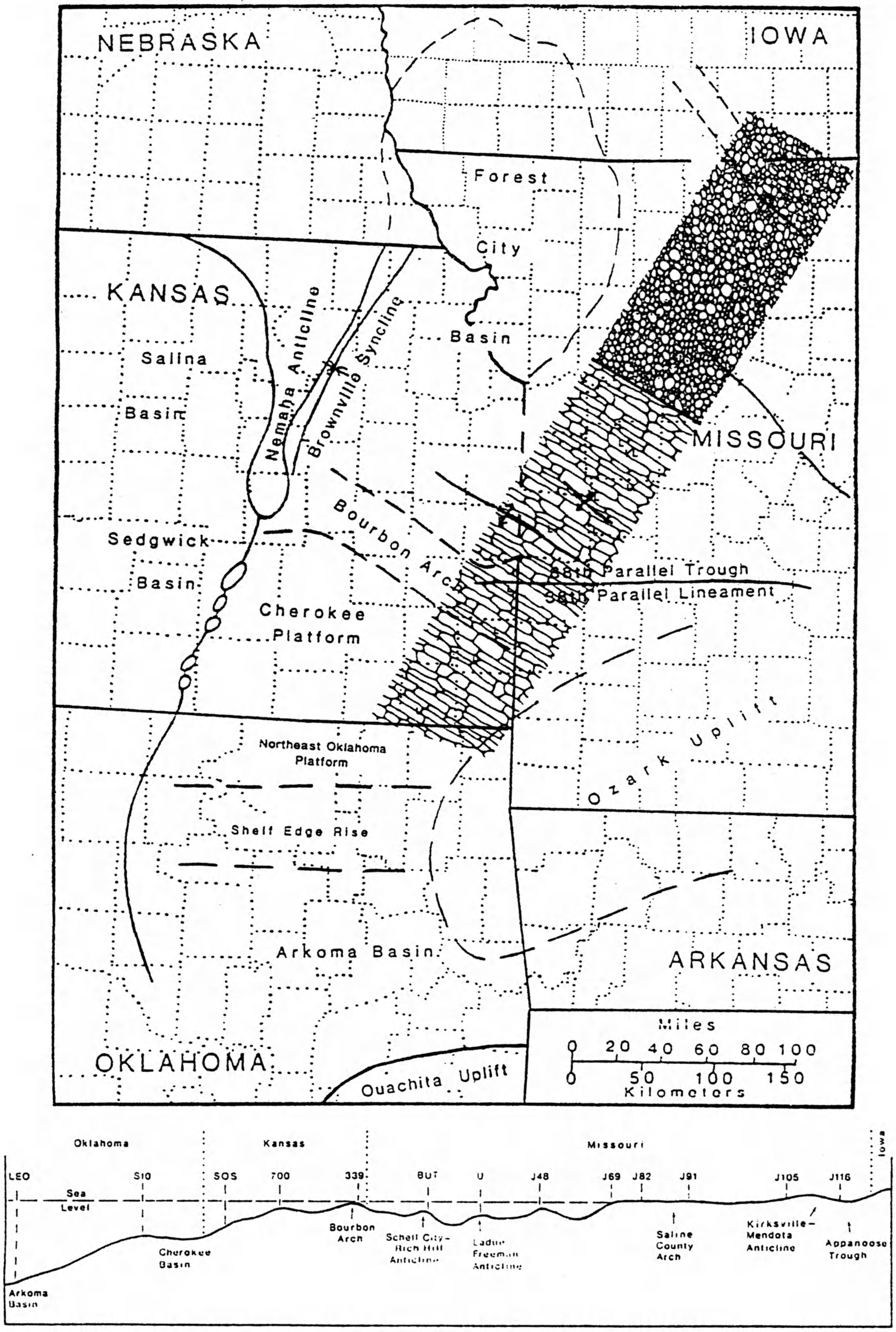


Figure 19. Maximum PAC 2 regression (see Figures 14 and 15 for further explanation).

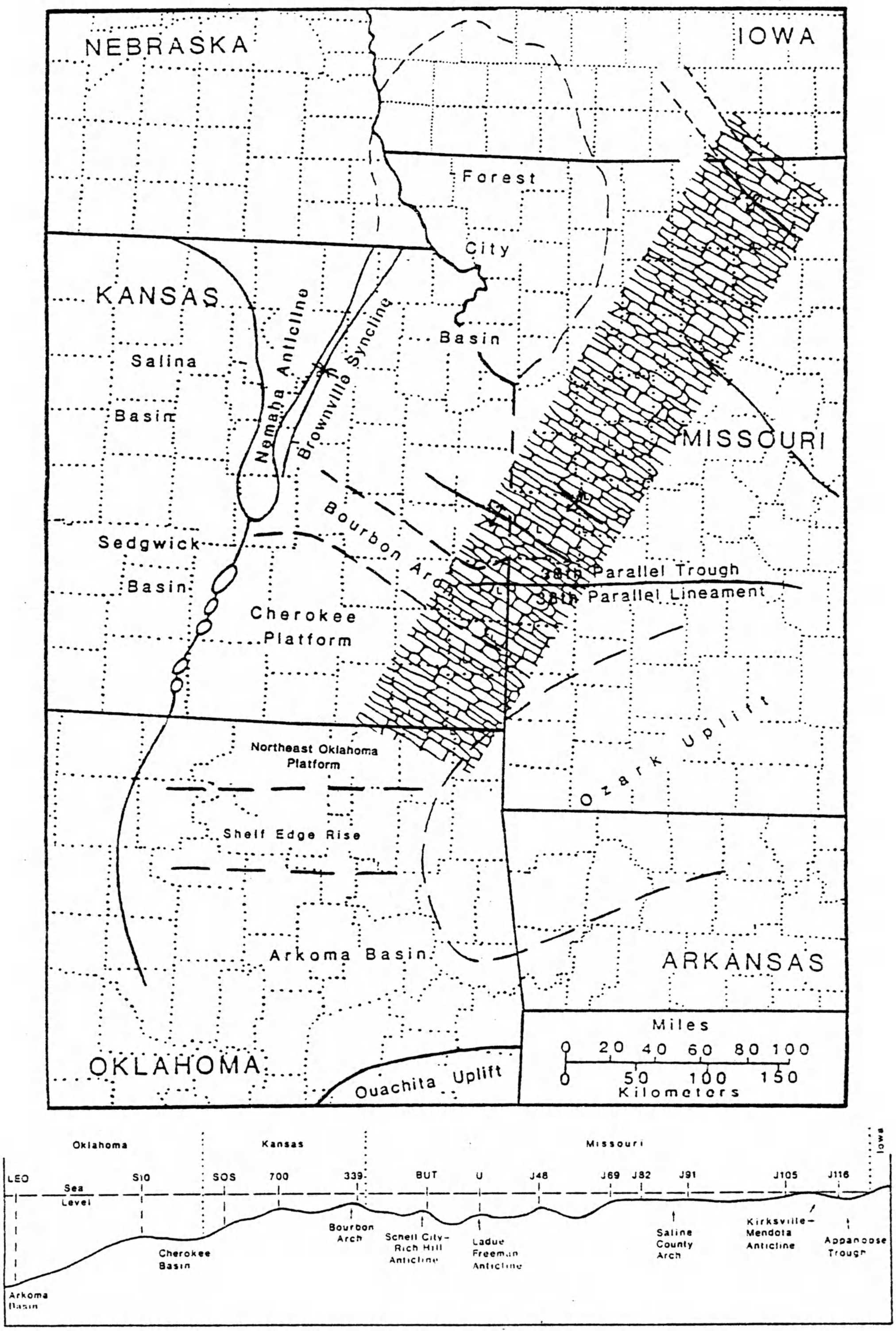
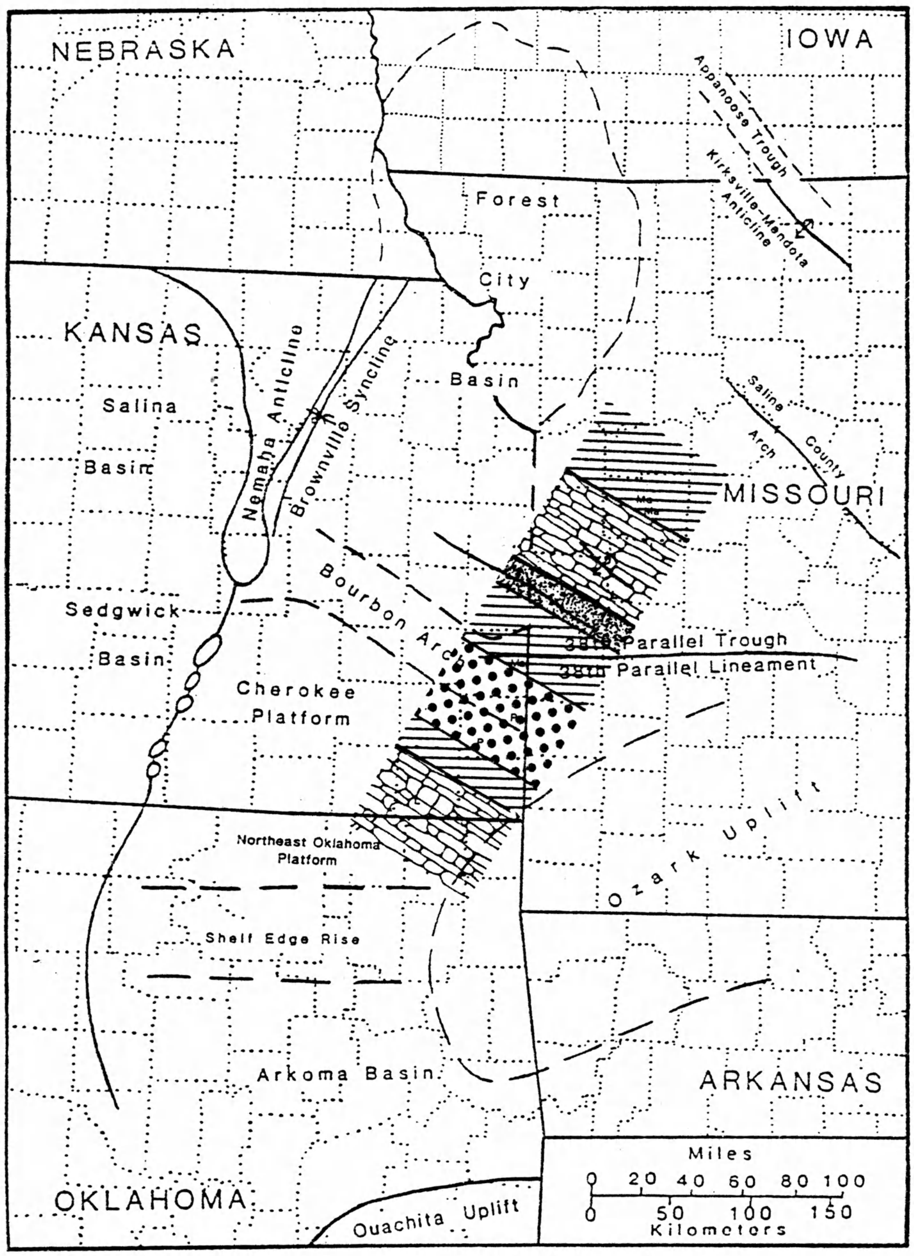


Figure 20. Maximum PAC 3 transgression (see Figures 14 and 15 for further explanation).



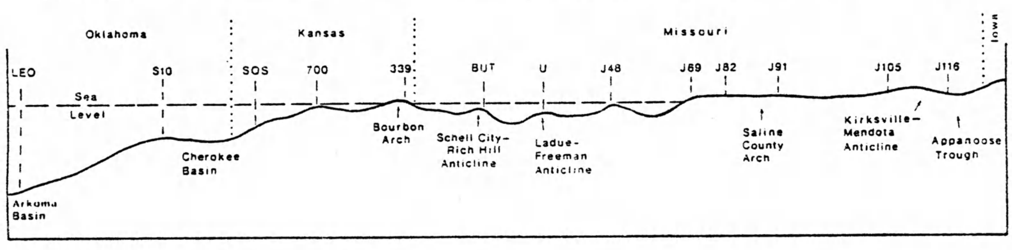
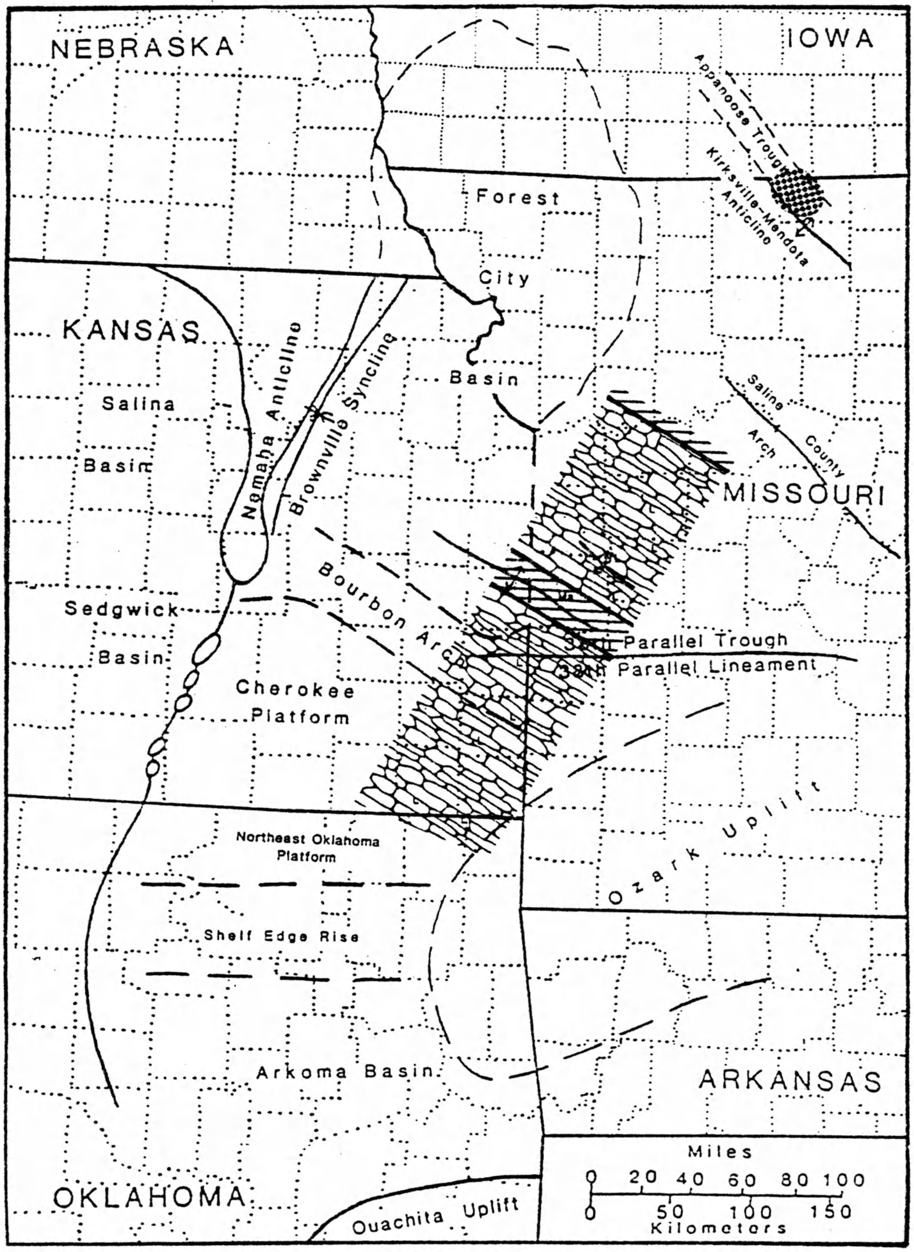


Figure 21. Maximum PAC 3 regression (see Figures 14 and 15 for further explanation).



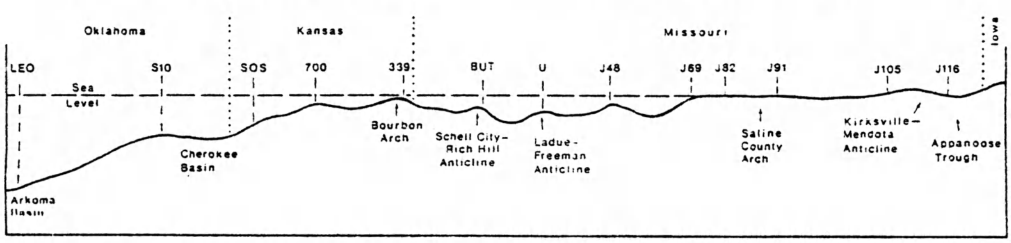


Figure 22. Maximum PAC 4 transgression (see Figures 14 and 15 for further explanation).

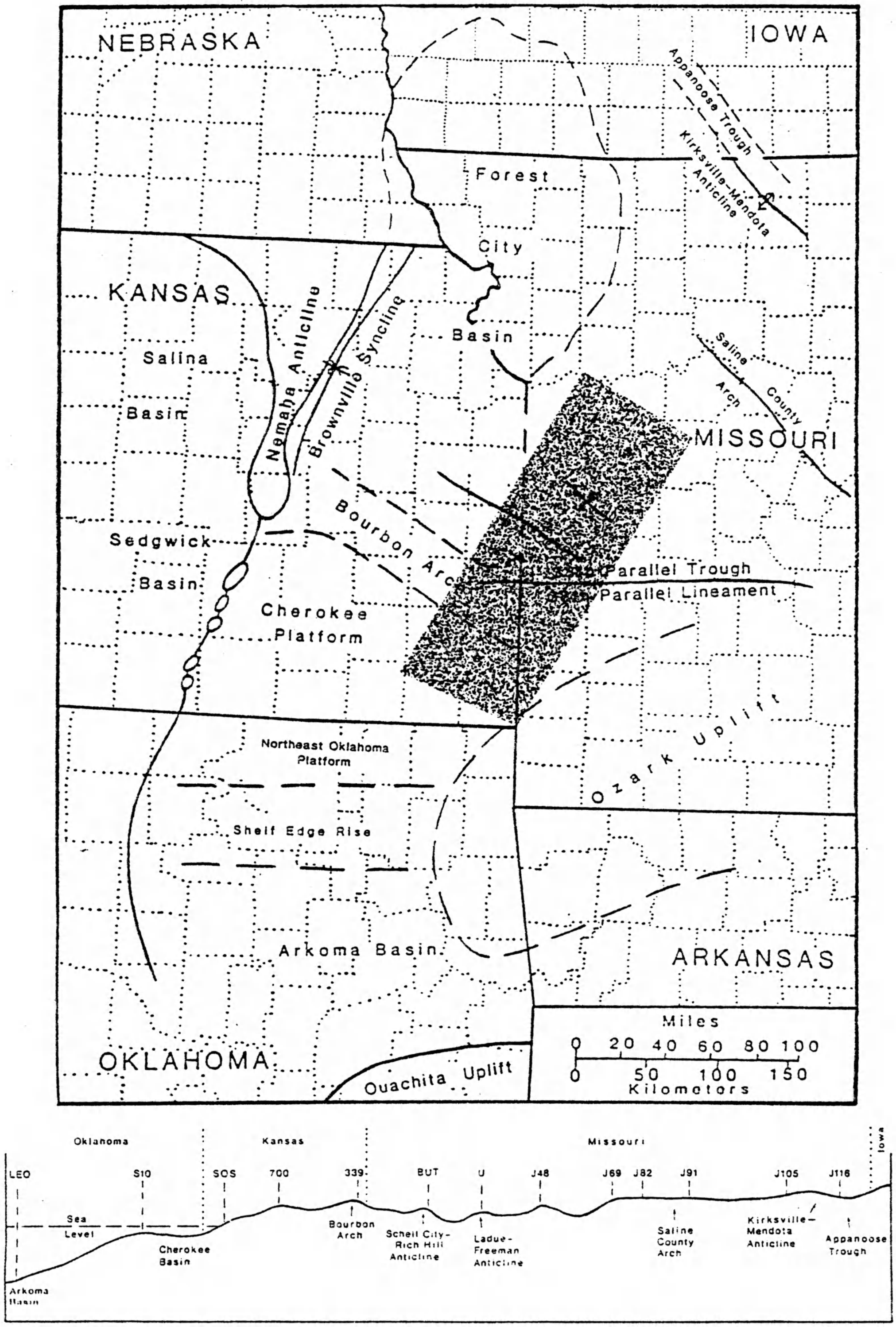


Figure 23. Maximum PAC 4 regression (see Figures 14 and 15 for further explanation).

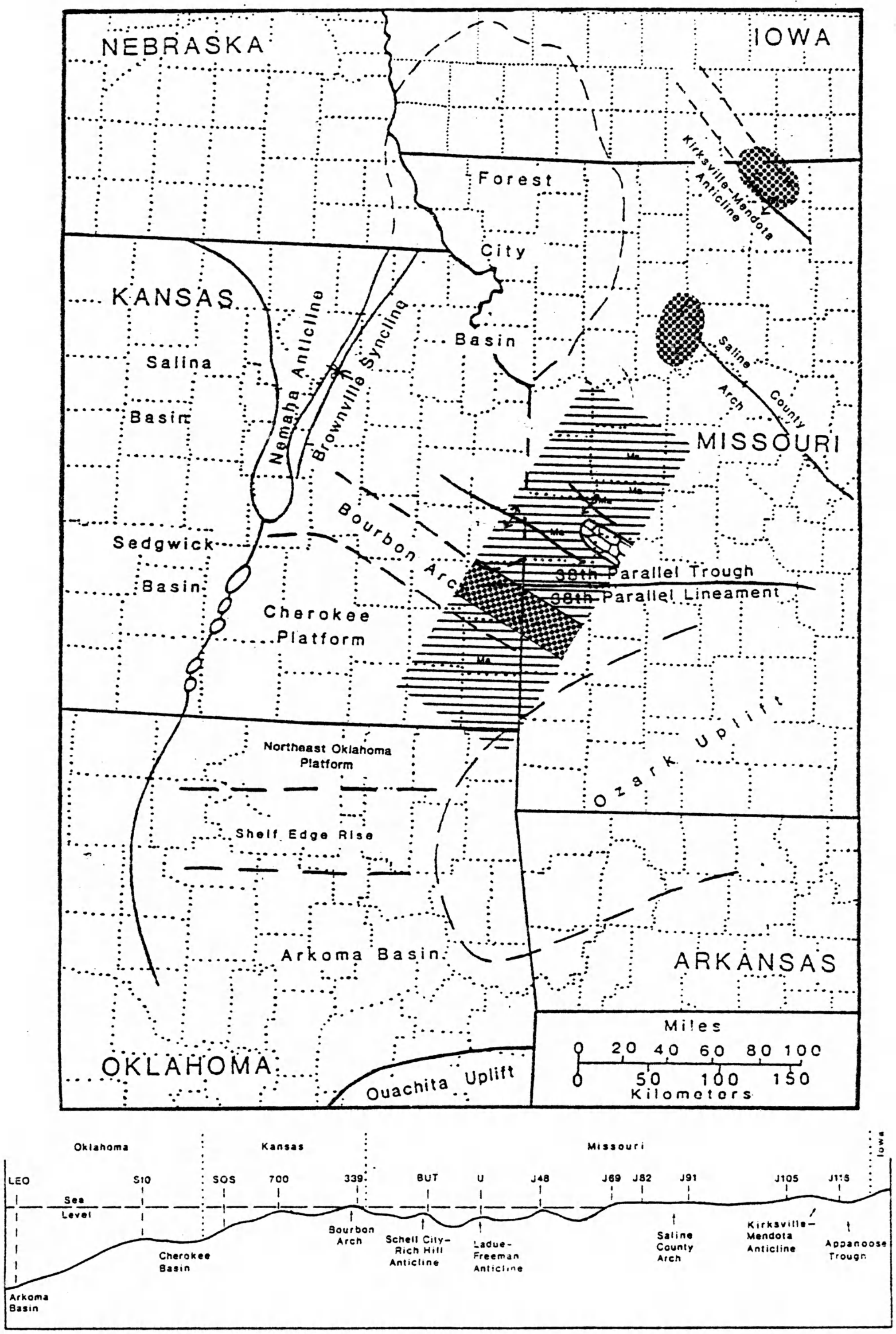


Figure 24. Maximum PAC 5 transgression (see Figures 14 and 15 for further explanation).

map taken from Knight (1985). The topographic profile was developed for this study by using inferred relative ocean depths plotted on the PAC maps with some input taken from Knight's (1985) structure map. The most important map in developing the topographic profile was the one for the maximum regression of PAC 1 (Figure 17) because it showed the most variability in depositional environments (a facies mosaic) across the study area, making it possible to pick out topographic highs and lows. The other PAC maps were then used to refine the topographic profile.

The maximum regression of PAC 0 (Figure 15) resulted in the occurrence of the terrestrially deposited Morgan School Shale from northern Missouri through southeast Kansas nearly to the Oklahoma border. South of that, limestone was deposited right to the top of the PAC. Inferred sea level is shown as being quite low.

During maximum transgression of PAC 1 (Figure 16), the black fissile Little Osage Shale was deposited everywhere in the study area. This was the most extensive sea level rise recorded in the Upper Fort Scott cyclothem. A high sea level is shown on the topographic profile.

The rock types at the top of PAC 1 record the most environmentally sensitive PAC regression (Figure 17), which made this map the most important in developing the topographic profile. It is evident that there is an overall trend from onshore in the northeast, where terrestrial deposits are shown, to offshore in the southwest, where deepest marine deposits are shown. In the middle there is a great deal of variation between shallow marine and paralic deposition, which clearly reveals topographic highs and lows. Note sea level position on the topographic profile.

During maximum PAC 2 sea level rise (Figure 18) limestone was deposited everywhere with the exception of a small amount of marine shale in the Appanoose Trough. Sea level was high but not as high as during deposition of the black fissile shale of PAC 1.

During maximum regression of PAC 2 (Figure 19) the Flint Hill Sandstone clastic wedge was deposited in northern Missouri. As a result the topographic profile was changed for this and all of the succeeding PAC's. The profile is drawn higher and flatter from locality J69 northward, as if it had been filled in and built up by progradation of the Flint Hill Sandstone.

The PAC 3 sea level rise (Figure 20) resulted in limestone deposition over the entire outcrop area. This is the chaetetid PAC. It was the last time within the Upper Fort Scott cyclothem that sea level rose high enough to inundate the area north of locality J69.

The PAC 3 sea level fall (Figure 21) resulted in considerable variability in depositional environments over the study area and the map thus reveals the topographic highs and lows again.

During the PAC 4 maximum transgression (Figure 22) limestone and marginal marine shale were deposited in southeast Kansas and western Missouri, while the Dutchman Coal was deposited in the Appanoose Trough in northern MIssouri. Sea level had risen only a little.

The PAC 4 regression was considerable (Figure 23), resulting in deposition of terrestrial shale wherever this interval is exposed in the study area.

The PAC 5 sea level rise (Figure 24), the last one in the Upper

Fort Scott cyclothem, initiated development of coal swamps which eventually became the Alvis Coal in southeast Kansas and western Missouri. Sea level apparently rose enough to result in deposition of a thin marginal marine shale or limestone over the top of the Alvis Coal in this area. In northern Missouri, the lower bench of the Lexington Coal was forming. Shortly afterward sea level again dropped to the point that terrestrial shale or mudstone was deposited over most of the area.

Distribution of Coals

Figure 25 is a map showing distribution of the Summit Coal at the top of the Morgan School Shale over the study area. Localities shown that were not specifically used in the PAC study were taken from Jeffries (1958).

Accumulation of the coal occurred over most of the outcrop area and was especially thick (up to 60 cm) on the northeastern flank of the Saline County Arch. This may mean that, although the PAC 1 sea level rise was relatively rapid, it was at least slow enough to allow migration of coal forming environments across the area ahead of the advancing sea. If this were the case, then perhaps there was a slight pause in the rise when the strand line was just south of the Saline County Arch, allowing the coals to become thickest just north of there.

On the other hand, it could be that the climate change which brought on the sea level rise simply created widespread, warm, moist, coal-forming environments over the entire area at once. Then this was

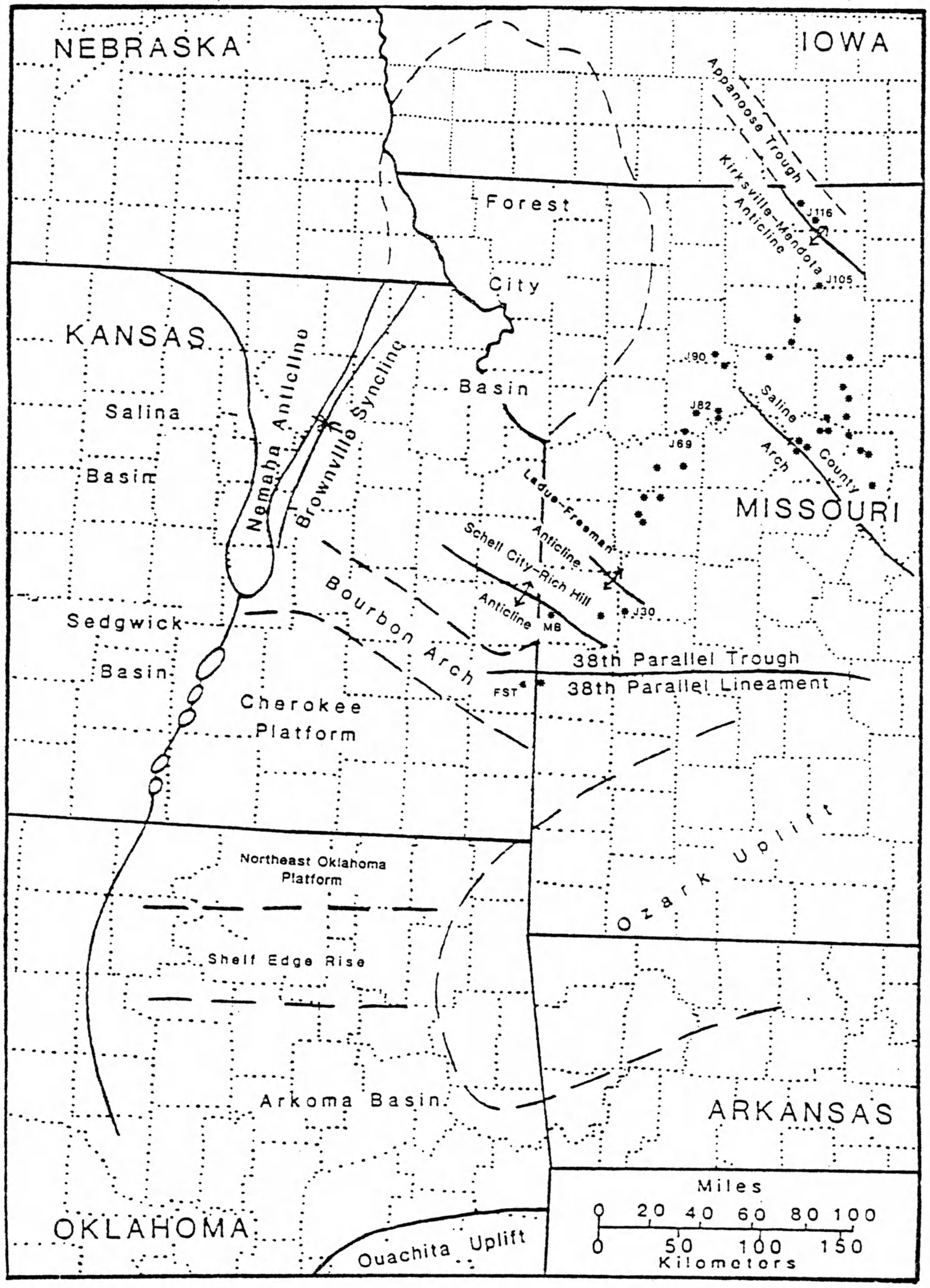


Figure 25. Map of Summit Coal occurrences (Base of PAC 1). Labelled localities are used in this study; others are from Jeffries (1958).

inundated by the advancing sea. If this were the case, then the area northeast of the Saline County Arch was either a more favorable coal forming environment or it had a longer time to develop before it was inundated by the sea. Testing of how near to open water the coals formed might be accomplished by studying the regional distribution of macerals in each coal bench as was done by Toprak (1984) in Turkish coals. He inferred an increase in inertinite and a decrease in exinite away from open water. In any case, it appears that the PAC 1 sea level rise was not entirely instantaneous but was still geologically quite rapid.

Distribution of the Alvis Coal and the lower bench of the Lexington Coal is shown in Figure 26. Open stars represent the Alvis Coal, closed stars the lower bench of the Lexington Coal. Localities shown that were not specifically used in the PAC study were taken from Jeffries (1958).

At many of the Lexington Coal localities, the lower bench is very thin or merely a smut with the exception of those localities in the Appanoose Trough where it is over 30 cm thick. At all of the Alvis Coal localities, with the exception of locality 339, the Alvis Coal is overlain by a thin marginal marine shale or limestone. Thus, PAC 5 maximum sea level reached only as far as the Alvis Coal localities shown. The lower bench of the Lexington Coal was not transgressed by the PAC 5 sea and became thickest in the Appanoose trough.

The greater thickness of coal in the Appanoose Trough presumably is a result of a more favorable coal forming environment there, but it also had more time to develop because it was never drowned by the PAC 5 transgressing sea. This supports the interpretation that coals at the

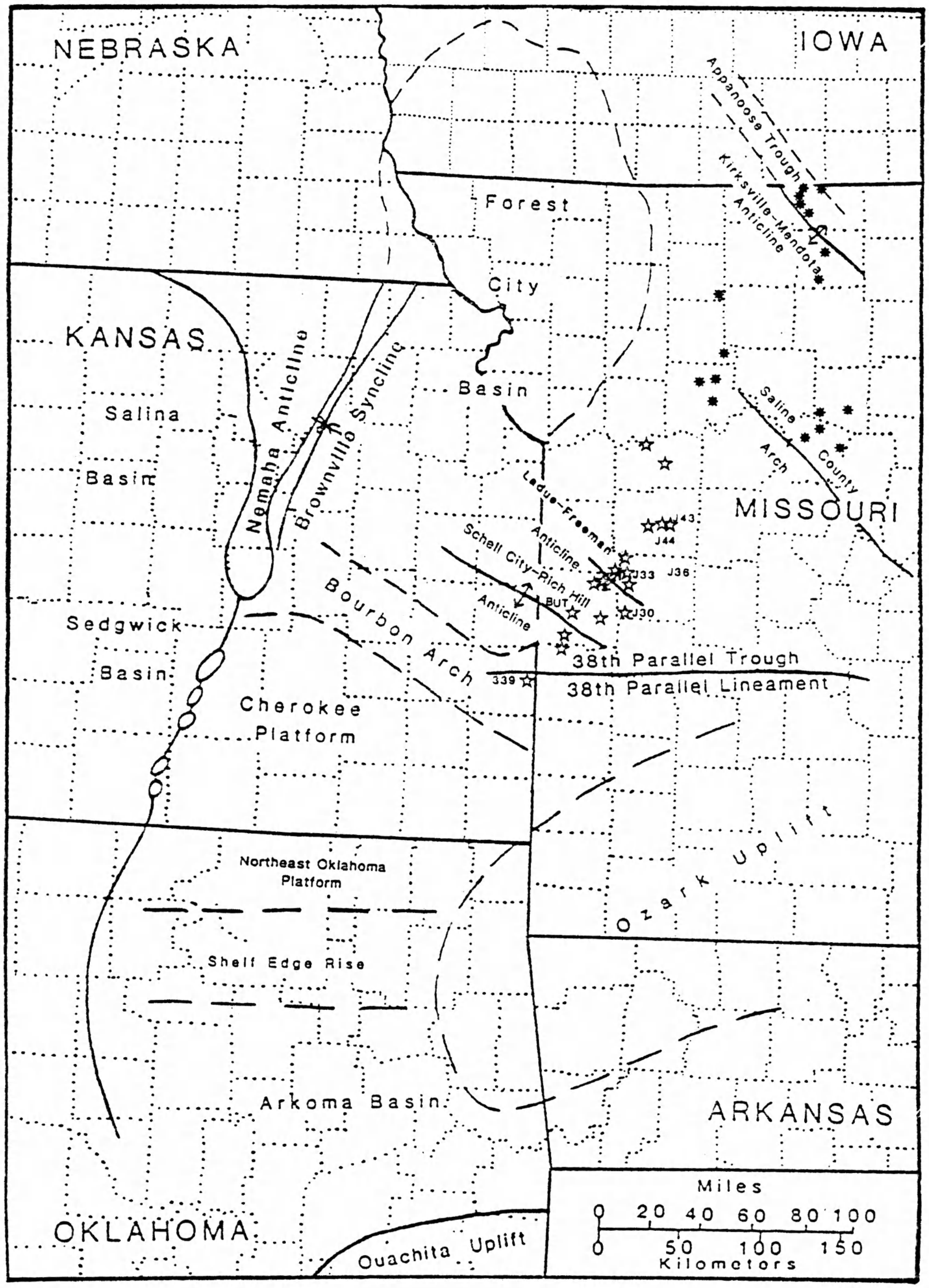


Figure 26. Map showing distribution of coals at base of PAC 5. Open stars = Alvis Coal. Closed stars = lower bench of Lexington Coal. Labelled localities are used in this study; others are from Jeffries (1958).

base of PAC 1 north of the Saline County Arch became thicker because they had more time to develop before being inundated by the sea.

Chaetetid Occurrences

Occurrences of chaetetids in the Houx-Higginsville and Higginsville Limestones were plotted on the map and topographic profile shown in Figure 27. Open stars simply represent chaetetid presence, whereas the closed stars represent localities in which chaetetids are large or abundant. It is also generally the case, at localities personally examined in the field for this study (700 to BUT), that those localities shown by open stars have only laminar to low domical chaetetid growth forms, whereas the localities shown by closed stars have growth forms of all types but with a predominance of larger columnar forms. Localities shown that were not specifically used in the PAC study were taken from Jeffries (1958). Sea level shown on the topographic profile (Figure 27) is the same as that shown for the maximum transgression of PAC 3 (Figure 20), as this is the point at which chaetetid development was most extensive.

It appears from the map and profile that we can infer certain trends in conditions favorable for chaetetid development. Immediately apparent is that they favored topographic highs and especially the flanks of topographic highs (e.g., large structural features such as the Bourbon Arch and Saline County Arch), but only within certain depth ranges. They generally do not occur in the very shallowest environ-

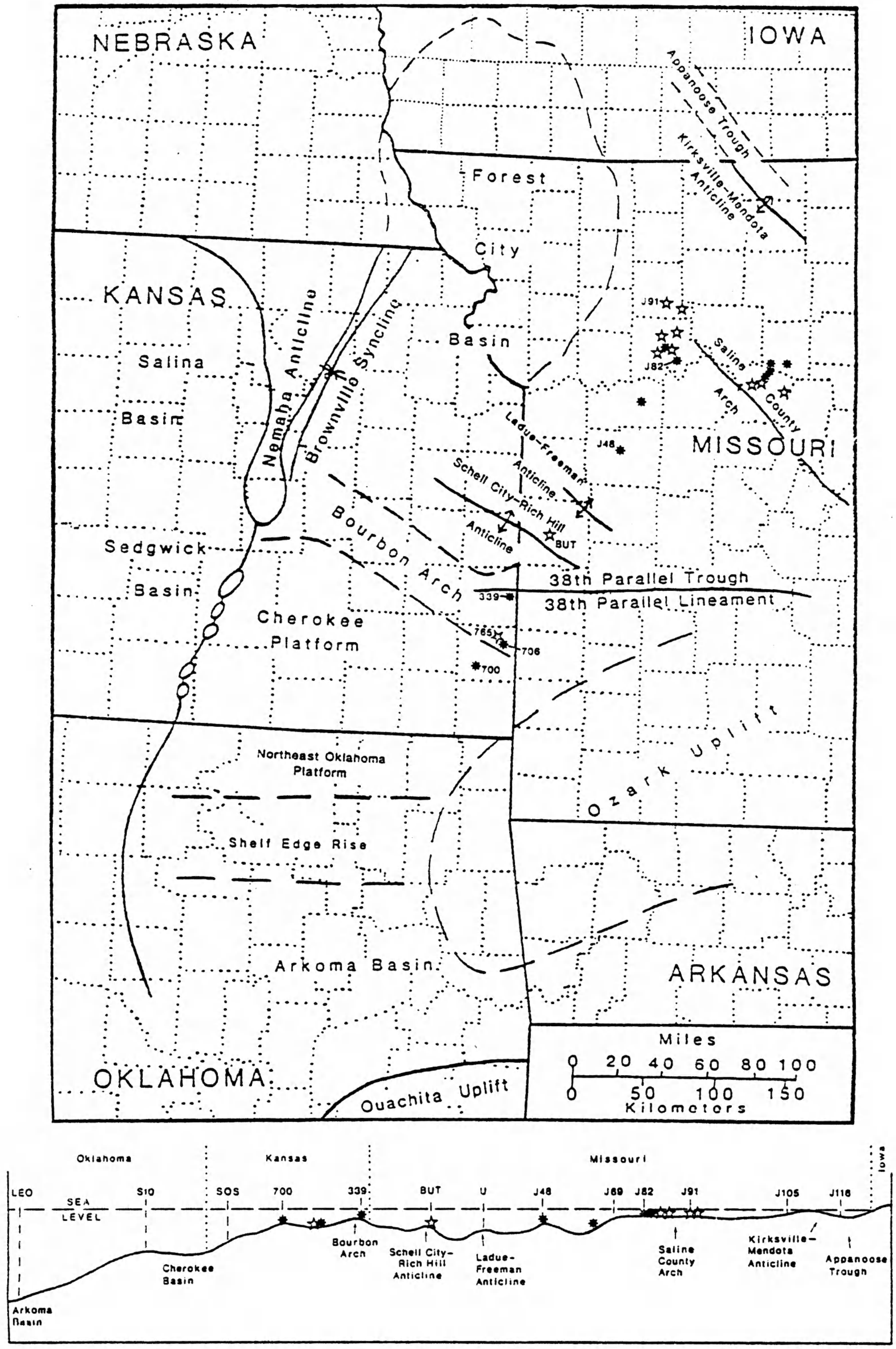


Figure 27. Map showing occurrences of chaetetids in Houx - Higginsville Limestone. Open stars = chaetetid presence. Closed stars = abundant or large chaetetids. Labelled localities are used in this study; others are from Jeffries (1958).

ments within the zone of strongest wave activity, nor do they occur in the deeper troughs and basins.

Many workers have inferred very shallow water environments for chaetetids, and some have stated that chaetetids preferred topographic highs. Spaw (1977) and DeVries (1955) noted that chaetetids occurred on slight topographic highs, and in Soar's (1984) study, they occurred as a cap facies on the crests of phylloid algal mud mounds in water depths "probably less than 25 meters, and perhaps 10 meters and shallower" (Soar, 1984, p. 62). Lambert, et al. (1986, p A27) stated that chaetetids "flourished at depths of 2-5 m and less" and "were apparently restricted to uppermost subtidal depths" and even grew into the intertidal zone. Connolly and Stanton (1983), and Lambert and Stanton (1986) favored very shallow subtidal depths and occasional tidal emergence.

Among authors favoring moderate to shallow depths, Suneson (1984, p. 77) stated that chaetetids did not do well in shallow water "pummelled by wave action" and that "deeper water was less densely populated by Chaetetes." West and Clark (1984, p. 337) stated that "chaetetids appear to have lived within the photic zone, and in many cases exhibit evidence of wave action." In Kotila (1973, fig. 4, p. 99) chaetetids were shown occurring below the low tide line on the seaward flank of algal banks, whereas Rich (1969, fig. 10, p. 357) placed them in protected environments behind high-energy shoals although he did say they "tolerated a broad range of environmental conditions" (Rich, 1969, p. 360). DeVries (1955) also favored a broad range of environmental conditions. Nelson and Langenheim (1980, p. 1 &

15) inferred chaetetid occurrence in "normal marine waters somewhat below tidal range, at, or just below wave base"..."in quiet or moderately agitated water."

Few authors favored a deep water environment for chaetetids. Winston (1963) noted the occurrence of chaetetid columns over 10 feet high in the Marble Falls Formation of Texas that he thought had been free-standing before being broken at the base and toppled. He inferred deep water for these occurrences, but he also observed chaetetids in high-energy shallow water facies.

Sedimentologic and stratigraphic evidence seen at locality 700 in Crawford County, Kansas, supports a moderate to shallow water interpretation. The quarry faces there give an excellent view of very well-developed chaetetid colonies. It appears that the chaetetids initially got started in relatively quiet water where they became embedded in a massively bedded fusulinid packstone. Shallower water and increasing wave activity up section is indicated by increasing cross bedding in the fusulinid packstone matrix and an increasing number of toppled chaetetids. In the upper part of the chaetetid-bearing interval only the larger "clumps" of chaetetids persisted and virtually no new chaetetid growth was initiated. At the top of this interval, a thin marginal-marine to paralic mudstone filled in the hollows around the chaetetids (see stratigraphic column in Figure 13) and terminated chaetetid growth. So apparently chaetetid growth began not too far below wave base and persisted well into normal wave base and possibly into the intertidal zone as the water shallowed, but optimum chaetetid growth occurred at or just below normal wave base.

Because of the abundance and excellent preservation of fusulinids associated with the chaetetids at localities 700 and 706, one might infer that they lived in the same environment or at least not too far away. If this is the case, we may be able to take a clue from Connolly (1987, p. 149), who stated that, "Late Paleozoic fusulinids favored shallow depths and estimates less than 100 feet seem reasonable." In any case, it appears that chaetetids in this area generally were not deep water dwellers.

The question arises: Why do we not see chaetetids in PAC 2? Although maximum water depth was somewhat greater than during PAC 3 and this may have been a factor, certainly there were areas of topographic highs that were well within the depth ranges favorable for chaetetid growth. Other factors must have been involved.

One possibility is that suspended material in the water column may have been greater during PAC 3 time. It may not have been enough to foul the feeding apparatuses of the chaetetids but could have interfered with photosynthesis of the phylloid algae just enough that chaetetids had the competitive advantage. Perhaps during PAC 2, if the waters were clearer and allowed the algae to get a good start, the algae simply overwhelmed the substrate so that chaetetids didn't have a chance to get started. Then it required something major, such as the regression at the top of PAC 2, to kill off the algae and allow the chaetetids to grow. Perhaps because of a lower sea level during PAC 3, features such as the Bourbon Arch, Saline County Arch, and so forth reached into wave base, allowing sediments to be reworked, thus contributing to the amounts of suspended matter in the water. Thin section study of the rocks may shed some light on this problem.

Conclusion

Use of the PAC approach to stratigraphic analysis, in which genetic sixth-order T-R units are traced over a wide area, can give a very refined and accurate picture of paleogeography, paleotopography, structural controls, and subtle small-scale sea level changes. It can also be used to more accurately place and interpret depositional environments within the geologic record; environments favorable for coal formation or for chaetetid growth can be better understood. Additionally it can be seen how all of these features changed over time with the deposition of each successive transgressive-regressive unit.

CHAPTER 3

STRATIGRAPHY AT LOCALITY 700

Introduction

The Niggeman quarry was exploited for its nearly pure limestone in the Houx-Higginsville Limestone Member at this locality. It was excavated to the base of the Houx-Higginsville Limestone, exposing only the top few centimeters of the underlying Little Osage Shale. In the southwest corner of the quarry, approximately 4 meters (13 feet) of the Labette Shale are exposed overlying the Houx-Higginsville Limestone.

Dip of the beds was measured with a Brunton compass at different points in the quarry. The beds were all essentially horizontal, perhaps dipping one degree in one direction or another but with no consistent direction of dip, with one exception. Using the 3-point method in the vicinity of stations 11 & 23 to the southwest corner of the quarry (Figure 4), with the base of interval 6 as the datum plane, the strike and dip were measured as N.50-55°W., 3.5-4.5°SW. Nowhere else in the quarry do dips such as this occur. It is unclear whether this represents primary depositional dip or a later structural event. If it is primary, it may be a reflection of its location on the southwest flanks of the Bourbon Arch (see Figure 8), and could have been a break in slope toward deeper waters to the southwest.

Stratigraphic Intervals

Thirty three stratigraphic sections in the quarry were measured and described in detail (see Figure 4 and Appendix B). Of the sections measured, those at stations 31, 11, 11a, and 24 are described in the most detail in Appendix B; descriptions of the other stations are referred and compared to those detailed sections, while noting differences and important accessory information. The stratigraphic columns are partitioned into separate beds based on differences in lithology, sedimentary features, and fossil content. In addition, several of these beds are subdivided into intervals. Thin section descriptions of limestone samples from the Houx-Higginsville Limestone are recorded in Appendix C. To see how the stratigraphic sections relate to the PACs, refer to Figures 28 & 13.

Bed 1.--Beginning at the base of section 31 (Appendix B), only a few centimeters of the top of the Little Osage Shale are exposed (Figure 9). Trenches were dug through the talus to expose the contact with the overlying Houx-Higginsville Limestone at stations 31, 32, & 8. The field photo at station 8 shows this contact the best (Figure 29). It can be seen that the contact is sharp.

The Little Osage Shale, as exposed at stations 31, 32, & 8, is very dark gray to nearly black shale to mudstone very similar to its occurrence at other localities (see Appendix A). It has the smell of hydrogen sulfide when wet or when freshly broken. It is characterized by the presence of abundant Chondrites and articulated specimens of

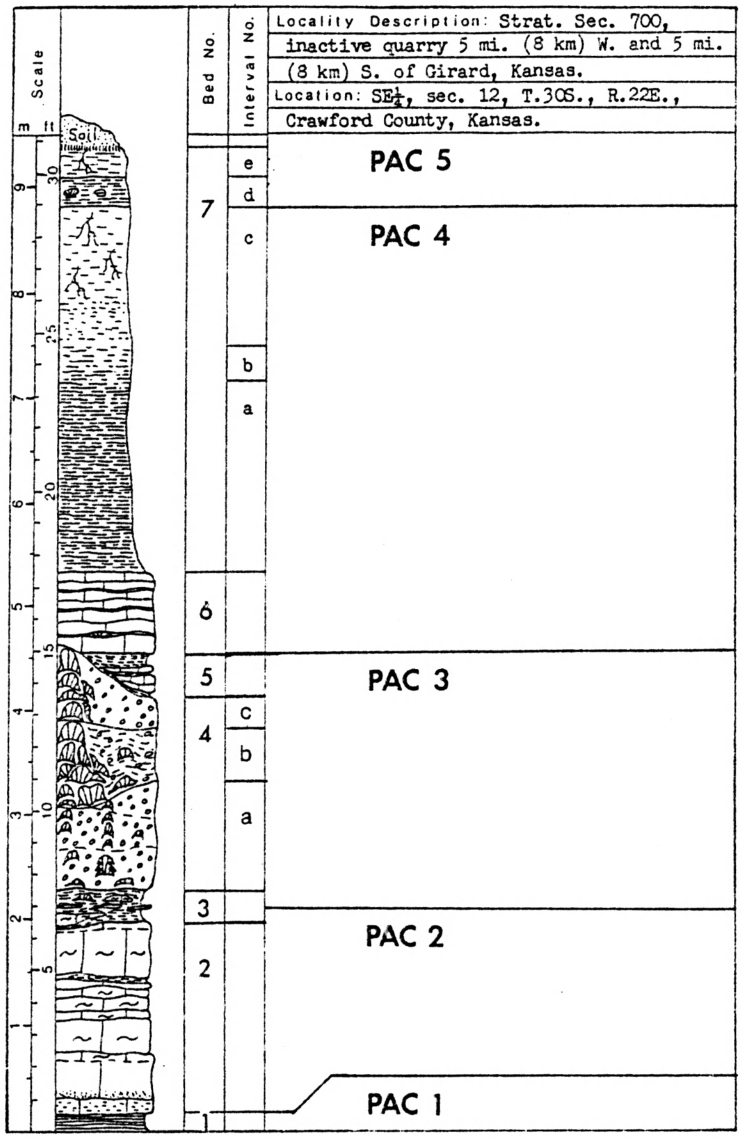


Figure 28. Stratigraphic column of rocks in Niggeman quarry, showing the PAC's. (For lithologic descriptions of beds & intervals, see strat. sec. 700 in Appendix A, or strat. secs. 31, 11 & 11a in Appendix B).

Figure 29. Contact between Little Osage Shale and Houx-Higginsville Limestone at station 8 shows up as a sharp line just above the hammer head. Hammer sits on Little Osage Shale. Bottom 15 cm. of Houx-Higginsville Limestone has a sharp upper contact here. Hammer is approximately 31 cm long.

<u>Crurithyris</u> <u>planoconvexa</u> with little else (see sta.31 in Appendix B). The upper 2.5 cm contains root casts and small (§1 mm) secondary(?) gypsum crystals. This upper 2.5 cm is interpreted to represent a shallowing of sea level from the deep marine deposition of the black fissile shale (see Figure 13) to marginal marine or lagoonal or possibly paralic mudflat deposition. Where this shale has been excavated to slightly lower levels (e.g., in the flat area just south of station 19 in Figure 4), it exhibits phosphate nodules.

<u>Bed 2</u>.--The basal 1.8 m (bed 2 in Appendix B) of the Houx-Higginsville Limestone sharply overlies the Little Osage Shale (Figures 9 and 29; sections 31, 32, & 8 in Appendix B; thin sections 700-31-2 through 12 in Appendix C). This bed is subdivided based upon black shaly partings which separate the otherwise massive dense limestone into separate and distinct intervals ('a'-'h'). Its basal 15 cm (interval 2'a') is argillaceous dolomitic calcilutite containing <u>Crurithyris</u> <u>planoconvexa</u> and <u>Chondrites</u>. This is sharply overlain here by coarse shelly calcarenite (interval 2'b'); at other stations (32) this contact is gradational. Within interval 2'b', the rock grades from skeletal calcilutite upward to algal calcilutite, which then remains the dominant rock type to the top of bed 2. This algal calcilutite contains an abundant and diverse, open marine fossil assemblage dominated by phylloid algal blades, <u>Composita</u>, and <u>Cleiothyridina</u>, with accessory echinoderm debris, other brachiopods, bryozoans, rugose corals, and foraminiferids. Microscopic examination and thin section study (see thin sections 700-31-2 through 12 in

Appendix C) reveals the presence of Fusulina, Tetrataxis, Polytaxis, palaeotextulariids, ostracodes, ophthalmids, small gastropods, calcispheres, and a matrix of peloidal micrite with aragonite needle "ghosts".

There are separate and distinct layers of this calcilutite (intervals 'a'-'h'), traceable throughout the quarry, that are separated by thin, wavy, dark, clay-rich, cross laminated layers (see sections 31, 32, & 8 in Appendix B). The expression of these cross laminated layers has been considerably enhanced by pressure solution and indeed most of their expression may be a result of diagenesis (Ricken, 1986). However, evidence indicates that diagenetic processes have enhanced already present primary variations in the rock. Evidence includes: (1) differences in fossil content (more fusulinids, echinoderm fragments, and broken skeletal debris in the cross laminated layers), (2) presence of apparently primary cross laminations and imbrication of some larger fragments, (3) differences in fossil preservation (white chalky preservation of shell material as if preserved in a reducing environment), (4) possibly higher clay content (although this is difficult to determine because clay would tend to be concentrated after pressure solution had occurred), and (5) more brownish organic residue in the cross laminated layers (see thin sections 700-31-10 & 11 in Appendix C) as if organic debris had been quickly buried by "energy events" such as storms.

Overall, it appears that the algal calcilutite of bed 2 was deposited under normally quiet, open marine conditions at such a depth that only occasional storm events disturbed the seafloor. The substrate was algal/peloidal mud and a diverse biota lived there, dominated by phylloid algae, brachiopods, and foraminiferids. The infrequent storm events carried in more of the other fossil types.

Bed 3.--Bed 3 (see section 31 in Appendix B) marks a transition in environment between the algal calcilutite of bed 2 and the chaetetid-rich fusulinid packstone of bed 4. The rock is cross laminated, fossiliferous calcarenite to calcilutite. It is fusulinid-rich (3-40%) and the cross laminations are thin, wavy, and separated by black, clay-rich partings. The expression of these dark partings has been considerably enhanced by pressure solution (see thin sections 700-31-16 & 700-slab), but the same evidence as cited for the cross laminated partings in bed 2 can be cited for bed 3, suggesting that pressure solution has exaggerated the primary features.

There is a 2.5-4 cm cherty layer about 2/3 of the way up in this bed that takes the form of a continuous layer of gray chert at some stations, ranging to sparse, flattened chert nodules at other stations, but it is always present and always at the same vertical position at all stations. In places, the cross laminae can be seen to pass without interruption from the calcarenite through the chert, and most of the same fossils are seen in the chert as in the calcarenite but they are obscured by the chert replacement (see thin sections 700-31-16, 700-4-3, and 700-4-8 in Appendix C). Thus it appears that the chert is a result of secondary replacement. However, in places the calcarenite is differentially compacted around chert nodules; so the chert formed relatively early on before substantial compaction. Tiny dolomite rhombs (1%; .01-.02 mm) can be seen in thin section in most of this bed, but especially within and near the chert, where in patches it may constitute up to 10% of the rocks (see thin sections 700-31-16, 700-4-3, & 700-4-2).

Bed 3 is the first level at which chaetetids occur in the Houx-Higginsville Limestone. They are rare, laminar, and very small below the chert, and are common and somewhat larger above the chert layer (see section 31 in Appendix B). Nearly all specimens are *in situ*.

This is also the first level at which *Aulopora* occurs. Small colonies occur attached to the substrate, or skeletal fragments, or capping some chaetetids.

The dominant fossils are fusulinids, shell fragments, and brachiopods, but there are also many of the same fossils as seen in bed 2 (see section 31 in Appendix B). The same ostracodes and all of the same foraminiferids as seen in bed 2 are also seen in bed 3 (i.e., fusulinids, palaeotextulariids, *Tetrataxis*, & *Polytaxis*). Additionally in bed 3, we begin to see *Bradyina*, *Endothyra*, and *Globivalvulina* (see thin sections 700-31-14, 700-24-17, and 700-31-16 in Appendix C).

In a later section of this thesis, two rock slabs from below the chert layer in this bed will be discussed in detail, giving a paleoecological interpretation of the depositional environment. Evidence will be presented to indicate that a series of omission surfaces occurred in this bed, characterized by minor early cementation which created a firm substrate on which organisms could become attached. Frequent storm events brought influxes of sediments that smothered the biota.

Lenses (up to 28 cm x 2.1 m, but usually smaller) of algal calcilutite are common below the chert layer in this bed, and in rare instances can be seen above the chert layer. The rock type is similar to that in bed 2, that is, it is dense and hard and contains algal blades, articulated brachiopods, and most of the other fossils seen in bed 2. However, it also contains laminar chaetetids. The calcarenite laminations in the surrounding matrix drape over and around these lenses and, in some cases, extend into and fade away within the lenses. It is possible that the lenses represent remnant patches of phylloid algae that served as sediment bafflers and as havens in which other organisms could be protected from the higher water energy experienced as sea level shallowed near the end of PAC 2 (see Figures 13 & 28). By the time the upper part of bed 3 was deposited, the last of these phylloid algae patches were being destroyed.

The boundary between PACs 2 & 3 is shown in stratigraphic section 700 (Appendix A) as being at the upper surface of the chert layer. It was placed there because the cross laminations gradually disappear in the upper few centimeters of bed 3 and the contact with bed 4 is somewhat gradational. Thus it appears that there are some transgressive deposits at the base of PAC 3 and it is difficult to place the boundary exactly, but it must be somewhere between the chert in bed 3 and the base of bed 4.

The presence of the chert layer presents a problem in interpreting its formation because it is so thin and consistently at the same level. If a person tries to invoke a mixing zone model (Knauth, 1979) in which chert is believed to form in the zone of mixing of seawater and meteoric groundwater, at least two questions must be faced. First, at what point would the mixing zone have reached this level, at the end of PAC 3, or late in PAC 4, or at some later time? And would the permeability of the limestones have allowed percolation of waters to this level at those times? Secondly, and most importantly, how can the thinness and consistent position of the chert be explained? The mixing zone surely could not be that thin or at such a consistent level for a long enough time.

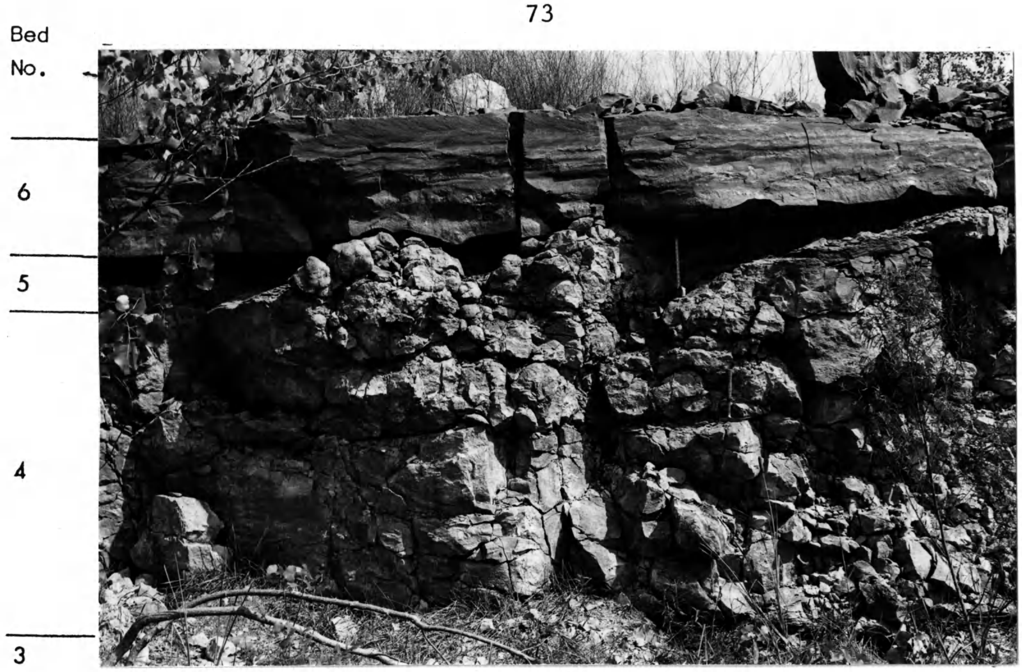
The possibility of evaporite replacement by chert is negated by the presence of abundant stenohaline marine invertebrates and thus an inferred subtidal environment of deposition, and by the absence of evaporite features such as evaporite crystal voids. No evidence of subaerial exposure occurs in bed 3.

Selleck's (1985) model, in which authigenic dolomite is closely associated with nodular chert, is not entirely satisfactory either. He cited euhedral overgrowths of ferroan dolomite on nonferroan detrital cores. There is no evidence of detrital dolomite in bed 3. He also cited the presence of sponge spicules as a source of silica, and although these were not specifically seen in the rocks studied herein, Gray (1980) and Reitner (1986) cited spicule pseudomorphs in Paleozoic chaetetids, and Hartman and Goreau (1970) noted silica spicules in the soft flesh of living "sclerosponges." So it is possible that chaetetid spicules served as the source of silica for the thin chert layer. Possibly the silica was dissolved and carried downward until it reached some impermeable layer or other barrier, at which point it was precipitated (perhaps as opal-CT).

Although the source of silica is a problem for any of these models, Selleck's (1985) model comes closest of any of the hypotheses to fitting the chert occurrence here. In his model, opal-CT is precipitated during very early burial, when "the system was open to diffusion of Mg^{2+} from the overlying seawater reservoir. Subsequent opal-CT to microquartz transformation, and attendant dolomite precipitation, occurred late during the burial history" (Selleck, 1985, p. 141). He stated that the opal-CT to quartz conversion took place in an overall reducing chemical environment, which may have enhanced dolomite precipitation. Perhaps these conditions were achieved at some point in the diagenesis of the rocks. But one still must wonder why the chert is so thin and at such a persistent level.

Bed 4.--Bed 4 and the abundant chaetetid occurrences within it are the main subject of interest of this thesis. Chaetetids and associated organisms will be discussed in detail later. The rock consists of fusulinid wackestone to packstone enclosing chaetetids ranging from individuals to large chaetetid clumps (boundstone) (see Figure 30; sections 31, 11, & 24 in Appendix B; thin sections 700-31-17 through 20 in Appendix C). This bed is described in detail in section 31 of Appendix B.

The main features are the three intervals ('a', 'b', 'c') and the changes in the matrix and chaetetid occurrences from one to the other. Interval 'a' has a massive matrix with only 5-15% chaetetids that begin in the lower part as laminar individuals, but in the upper part have begun to form tall ragged columns. The homogeneity of the matrix and



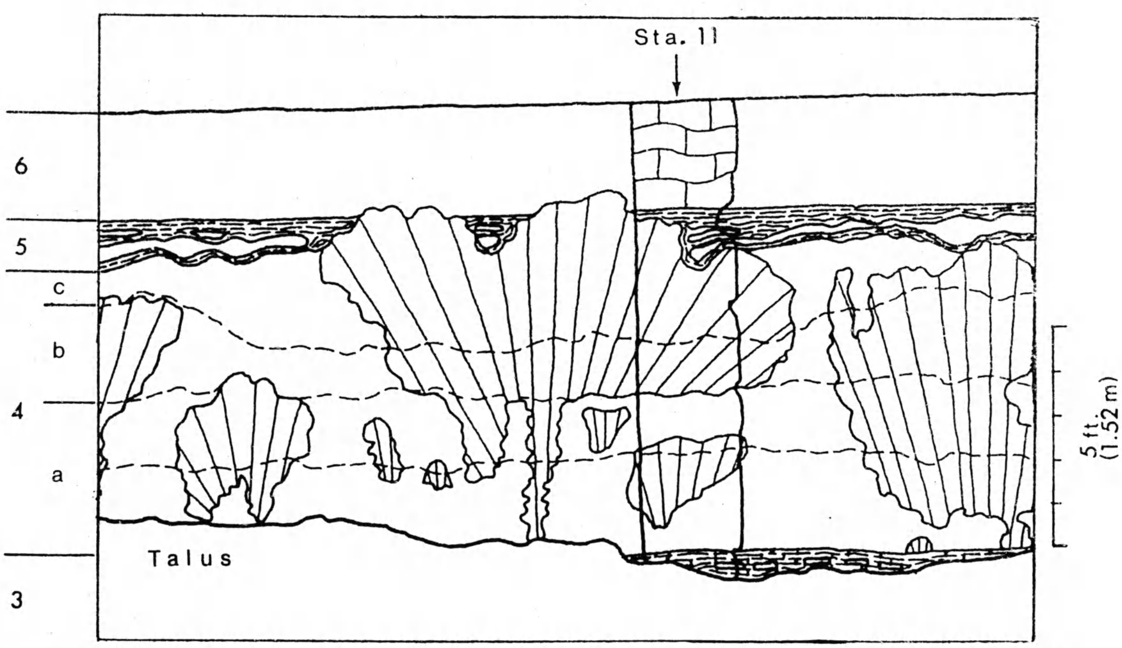


Figure 30. Photo & sketch of upper part of Houx-Higginsville Limestone at station 11. Chert of bed 3 is just below ground level. All three intervals ('a','b', 'c') of bed 4 can be seen, although interval 4'c' is relatively thin here. Two chaetetid clumps near the center protrude through bed 5 into bed 6. Tape measure sitting vertically in the hollow just to the right of the right chaetetid clump is extended 12 in. (30.5 cm.). Bed 5 fills in the hollows around chaetetid clumps, creating a flat surface upon which bed 6 was deposited. Note horizontally striped appearance of bed 6.

lack of features indicating high water energy suggest that this interval was deposited in quiet water below wave base.

In interval 'b', large chaetetid clumps (up to 6 m across) occur, usually built upon columns in interval 'a' that have expanded dramatically and coalesced into clumps in interval 'b'. The matrix is darker in this interval, suggesting a higher clay content, and is more cross laminated, especially around and within chaetetid clumps. Distinct cross lamination "events" can be seen at some stations (i.e., station 2a). the apparent maximum relief of chaetetids on the seafloor was probably 12-18 in. (30-45 cm) as indicated by the cross laminations (discussed further later). This interval probably was deposited near or within normal wave base.

Interval 'c' is generally thinner than the other 2 intervals and in most cases contains chaetetids only where large clumps persist upward from interval 'b'. These clumps commonly protrude through bed 5 and a few centimeters into bed 6, some of which is a result of compaction as evidenced by the presence of compaction slickensides on some chaetetid heads that protrude into bed 6. Only a few single, low domical chaetetids occur away from the clumps. The matrix is generally massive, grading upward to cross laminated in the top few centimeters, and is sometimes cross laminated around chaetetids. It may represent a slight deepening of sea level (and thus perhaps another PAC event) before the regression that resulted in deposition of bed 5.

Fusulinids and chaetetids by far are the most abundant fossils in bed 4. Chaetetids show many growth interruptions (some rather severe due to sedimentation, <u>Aulopora</u> overgrowth, and sometimes toppling.

Aulopora is in turn often overgrown by chaetetids. Other abundant fossil types apparently were living among the chaetetids, including brachiopods, bryozoans, rugose corals, crinoids, echinoids, gastropods, encrusting algae, ostracodes, and other foraminiferids (see section 31 in Appendix B, and thin sections 700-31-17 through 20 in Appendix C). The matrix around the fusulinids is peloidal and micritic. The other foraminiferids that are quite common include *Tetrataxis* sp., palaeotextulariids, *Bradyina* sp., *Endothyra* sp., and *Globivalvulina* sp.

Bed 5.--The sediments of bed 5 filled in the hollows between the chaetetid clumps of bed 4, resulting in a relatively flat surface upon which bed 6 was deposited (Figures 30 and 31). The rock type of bed 5 consists of 5 intervals: ('a') basal very thin shale, ('b') relatively well-developed limestone lenses, ('c') thin shale parting, ('d') less well-developed limestone lenses, and ('e') a layer of siltstone to mudstone (see sections 31, 11, & 24 in Appendix B; thin sections 700-24-6 & 8 in Appendix C).

Interval 'a' is usually a very thin, pale yellowish brown, calcareous shale parting that separates the lower limestone lens (interval 5'b') from the fusulinid packstone of bed 4. It contains fossil and plant fragments apparently as lag deposits.

Interval 'b' is the most consistent and well developed of the limestone lenses. This limestone is generally continuous except where it pinches out against chaetetid clumps. It has wavy upper and lower contacts and it pinches and swells according to the underlying topography even where no chaetetids occur, suggesting early consolidation

Figure 31. Bed 5 at station 15, showing 2 limestone lenses ('b' & 'd') enclosed in shale ('a','c','e'). Lower limestone is well developed; upper limestone is flaky to nodular. Tape measure extended 12 in. (30.5 cm.).

and perhaps partial early lithification of underlying beds (i.e., bed 4). It contains abundant plant fragments, root traces, and large vertical burrows, along with marine fossils and fossil fragments (see section 31 in Appendix B). An exceptionally large gastropod (110 mm long and 125 mm wide) from this interval was determined to be "an undescribed species of Bellerophon" that is "absolutely the largest bellerophontid I've ever seen or heard of from the Pennsylvanian" (Barry Kues, 1986, pers. comm.). At station 23 (see Appendix B), a thin lag deposit containing abundant marine fossils was found at the base of this limestone. Thin section study (thin section 700-24-8 in Appendix C) shows that the calcilutite is peloidal, micritic, and contains small high-spired gastropods, ostracodes, rare fusulinids, Globivalvulina sp., Endothyra sp., Bradyina sp., and palaeotextulariids.

Interval 'c' occurs as a thin, pale yellowish brown, silty shale parting between the two limestone lenses ('b' & 'd') (see section 11 in Appendix B). It is flaky, poorly indurated, and contains plant fragments, root traces, a few marine fossil fragments, and minor gypsum crystals (§1 mm).

Interval 'd' is a thin, flaky to nodular limestone that occurs in widely scattered, small patches (see section 11 in Appendix B). At many stations it does not occur at all (e.g., station 31). At a few stations it is relatively well developed and well indurated (e.g., in the area of stations 15-16 and 2-5). It contains plant fragments, root traces, small gastropods, ostracodes, a few fusulinids, skeletal fragments, and small gypsum veins (§0.75 mm thick). Thin section study (thin section 700-24-6 in Appendix C) also reveals palaeotextulariids, encrusting foraminiferids, Globivalvulina sp., small low-spired gastropods, and other skeletal debris.

The lower 2/3 of interval 'e' consists of discontinous lenses of gray flaky siltstone with plant fragments and root traces, separated by thin layers (1-10 mm) of light gray mudstone and brown plant-rich shale. The upper 1/3 consists of brown silty mudstone that is flat and thinly laminated and contains small shell fragments (productid?) and rare, small, weathered ironstone nodules.

Bed 5 probably represents deposition of mud and intertidal limestone lenses in an intertidal to low supratidal mudflat environment, thus creating the flat surface upon which bed 6 was deposited.

Bed 6.--Bed 6 marks the last PAC-scale transgression (PAC 4) resulting in limestone deposition at this locality within the Upper Fort Scott cyclothem (see Figures 28 & 13). It consists of dense, hard, olive gray calcilutite in medium beds ('a'-'d') separated by dark gray, thin, argillaceous, cross-laminated layers (see sections 31, 11, & 24 in Appendix B; thin section 700-32-2, 3, & 6 and 700-11-8). Each of intervals 'b', 'c', & 'd' also have minor, thin, cross laminated layers within them. Parts of interval 'd' and sometimes 'c' are commonly missing because they were bulldozed away during quarrying. The main rock type weathers yellowish gray and the cross laminated partings weather reddish brown and so, in outcrop, bed 6 takes on a red and gray striped appearance (Figure 30).

The first cross laminated parting (at the top of interval 'a') is the most distinct. It contains laminar chaetetids and has conspicuous cross laminations and often weathers preferentially, forming thin re-entrants (Figures 32; also see Figure 30). Cross laminations in all of the partings have wavelengths up to 40 cm and amplitudes up to 15 cm, but their dimensions are usually about 1/3 to 1/2 of that.

Fusulinids are common (1-10%) in intervals 'a' & 'b' (especially in interval 'b' and the upper part of interval 'a'), but they are rare to absent in intervals 'c' & 'd'. Bellerophontids are common (1-3%) from the upper part of interval 'b' and upward, but they are absent below that point. Other common fossils include algal blades and fragments, encrusting red algae, Composita, oncolitic skeletal fragments, a few other brachiopods and crinoid fragments, Ditomopyge, and sand-size skeletal debris (see sections 31 & 24 in Appendix B). Intervals 'c' & 'd' are slightly dolomitic and interval 'd' may show some roots and burrow mottling. Thin section study (thin sections 700-32-6, 3 & 2 and 700-11-8 in Appendix C) reveals only a few minor palaeotextulariids, ostracodes, Tetrataxis sp., Bradyina sp., Endothyra sp., Globivalvulina sp., and encrusting foraminiferids.

Chaetetids occur only in the upper part of interval 'a' (sparse) and in the cross laminated parting at the top of interval 'a' (very common). They are nearly all small laminar forms; the largest one seen was 20 cm across and 10 cm high, but most are much thinner.

Bed 6 probably represents a rapid transgression at its base (see Figures 13 & 28), with a minor hiatus at the top of interval 'a'. Sea level did not rise very high nor stay there for long and thus diversity

Interval No.

6b

6a

5e

Figure 32. Part of bed 6 at station 20. Hammer sits on top of interval 'a'; note re-entrant where parting has weathered away and note laminar chaetetids within parting. Interval 'b' (from the hammer head to the top of the photo) shows another wavy parting within it. Bed 6 is much thicker here than at most other stations in the quarry. Hammer is approximately 31 cm long.

was relatively low in comparison to beds 2 and 4. The upper 1/2 to 2/3 represents gradual shallowing of sea level and a gradual change from shallow marine to a more lagoonal environment, thus resulting in a lowering of diversity and the occurrence of some root traces in the top of interval 'd'. Sea level may have retreated enough for a thin (6 mm) layer of gypsum to form on top of interval 'd' (see base of section 11a in Appendix B).

Bed 7.--The Labette Shale (bed 7) is only exposed well in the southwestern corner of the quarry. Therefore, the only stratigraphic section for which it is recorded is at station 11a. It is described in detail in Appendix B.

Basically, it consists of horizontally laminated, mudstone to claystone that is dark gray to black with orange "wisps" in the bottom part (interval 'a') and grayish orange in the top part (interval 'c'). Interval 'b' represents 30 cm of section over which interval 'a' grades into interval 'c'. Interval 'a' has ostracodes, *Bathysiphon*, ammodiscids, small high-spired gastropods, and sand size shell fragments. Very thin lenses (6 mm) of clear gypsum occur at the very base of interval 'a', directly upon the surface of the limestone of bed 6. The next higher 3-4 cm in interval 'a' has small burrows, *Crurithyris*, and kirkbyacean ostracodes. Interval 'c' has plant fragments, root traces, some burrow mottling, and a few very fine shelly calcarenite laminae.

Interval 'd' is laminated claystone to shale that is characterized by abundant *Aviculopecten* (many articulated), along with *Permophorus*, fragments of productids and crinoids, and small limonite nodules. The fossils weather reddish orange.

Interval 'e' is variegated gray and grayish orange clay-rich shale with plant fragments, root traces, and a few thin laminae that contain basically the same fossils as in interval 'd'.

From the sediment types, sedimentary features, and fossil types present, it is likely that bed 7 represents aggradation of sediments accompanied by slow regression in a lagoonal to deltaic mudflat to subaerial environment. Given this, it is tempting to attribute interval 'd' to some sort of delta switching event. However, its correlation across several hundreds of miles with "events" at other localities leads to the conclusion that it represents another small PAC (PAC 5 in the regional picture; see Figure 13). Then interval 'e' represents subsequent slow regression again.

Lateral Relationships

Introduction.--The rock types and features of each stratigraphic bed are very nearly the same from one station to another throughout the quarry. That is, there is good lateral continuity of the beds. No lateral changes were noted in beds 1 and 7, whereas in bed 2 the only change noted was a variation of the upper contact of interval 2'a' from sharp at some stations (i.e., stations 8 & 31) to gradational at others (station 32). However, a few minor changes do occur in the remaining beds and are discussed in the following pages. Vertical profiles of quarry faces were sketched, concentrating on chaetetid occurrences, but some stratigraphic relationships are also shown (Figures 33-39).

Bed 3.--Bed 3 is continuous, and relatively consistent in thickness and position throughout the quarry. Its thickness ranges from 12 to 18 in. (30-46 cm) and is usually within the 14-16 in. (35-41 cm) range. These thickness variations can occur within only a few meters laterally.

The chert layer is also consistent in its thickness and vertical position. It varies from being a continuous layer to being a layer of nodules to occurring only as scattered sparse chert nodules, but always at the same vertical position. There are no apparent trends in terms of the chert layer being more continuous in one part of the quarry than in another; the changes may occur within a few meters laterally.

The algal calcilutite lenses below the chert are all fairly consistent in size and position and rock type throughout the quarry (see Figure 33). Algal calcilutite lenses above the chert were only found at stations 2a & 16.

Thin section study revealed no significant changes laterally, nor did acetate peel or polished section studies.

Bed 4.--Bed 4, the chaetetid reef bed, is also continuous and of consistent thickness throughout the quarry and chaetetid clumps are all generally within the same size ranges (see stratigraphic sections in Appendix B, and vertical profiles in Figures 33-39). All three intervals ('a', 'b', 'c') occur everywhere in the quarry but may be

Figure 33. Detailed vertical profile of quarry face at stations 24-30, showing all chaetetid occurrences in bed 4. Note different sizes of chaetetid clumps as well as individual domical to columnar chaetetids. Columns in interval 4'a' commonly expand and merge to form clumps in interval 4'b'; larger clumps often protrude into base of bed 6. Dashed lines represent cross laminated argillaceous partings within the fusulinid packstone. Bed 3 shows the sizes and distribution of algal calcilutite lenses below the nodular chert layer. Bed 5 fills low places between chaetetid clumps and has discontinuous limestone lenses within the shale. Bed 6 is flat and continuous; most of interval 6'd' has been bulldozed away here.

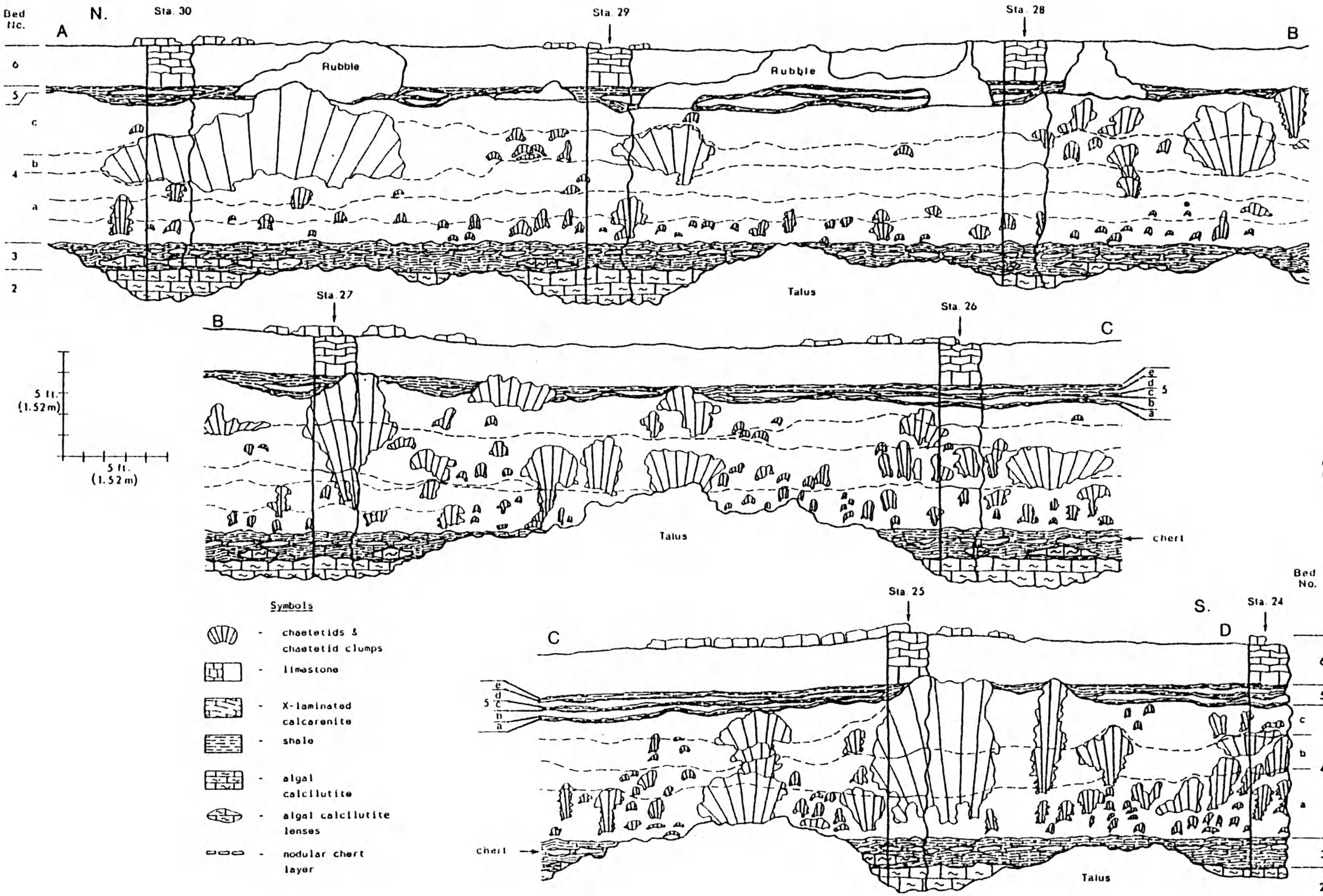

Bed No.
N.
A
Sta. 30
Sta. 29
Sta. 28
B
6
5
c
b
4
a
3
2
Rubble
Rubble
Talus
B
Sta. 27
Sta. 26
C
e
d
c
b
a
5
5 ft.
(1.52m)
5 ft.
(1.52m)
Talus
chert
Bed No.
Sta. 25
S.
Sta. 24
C
D
5
chert
Talus
Symbols
- chaetetids & chaetetid clumps
- limestone
- X-laminated calcarenite
- shale
- algal calcilutite
- algal calcilutite lenses
- nodular chert layer

Figure 34. Detailed vertical profile of quarry face at stations 2-5, showing all chaetetid occurrences in bed 4. Clumps in left half are especially large; in right half they are small. The area around station 2a shows only one small domical chaetetid in intervals 4'b' & 'c'. Many clumps protrude into interval 6'a'. Dashed lines represent cross laminated partings separating intervals 4'a', 'b', & 'c'. The limestone lenses in bed 5 are both relatively continuous here. At station 2a, bed 3 shows an algal calcilutite lens above the chert. For key to symbols, see Figure 33.

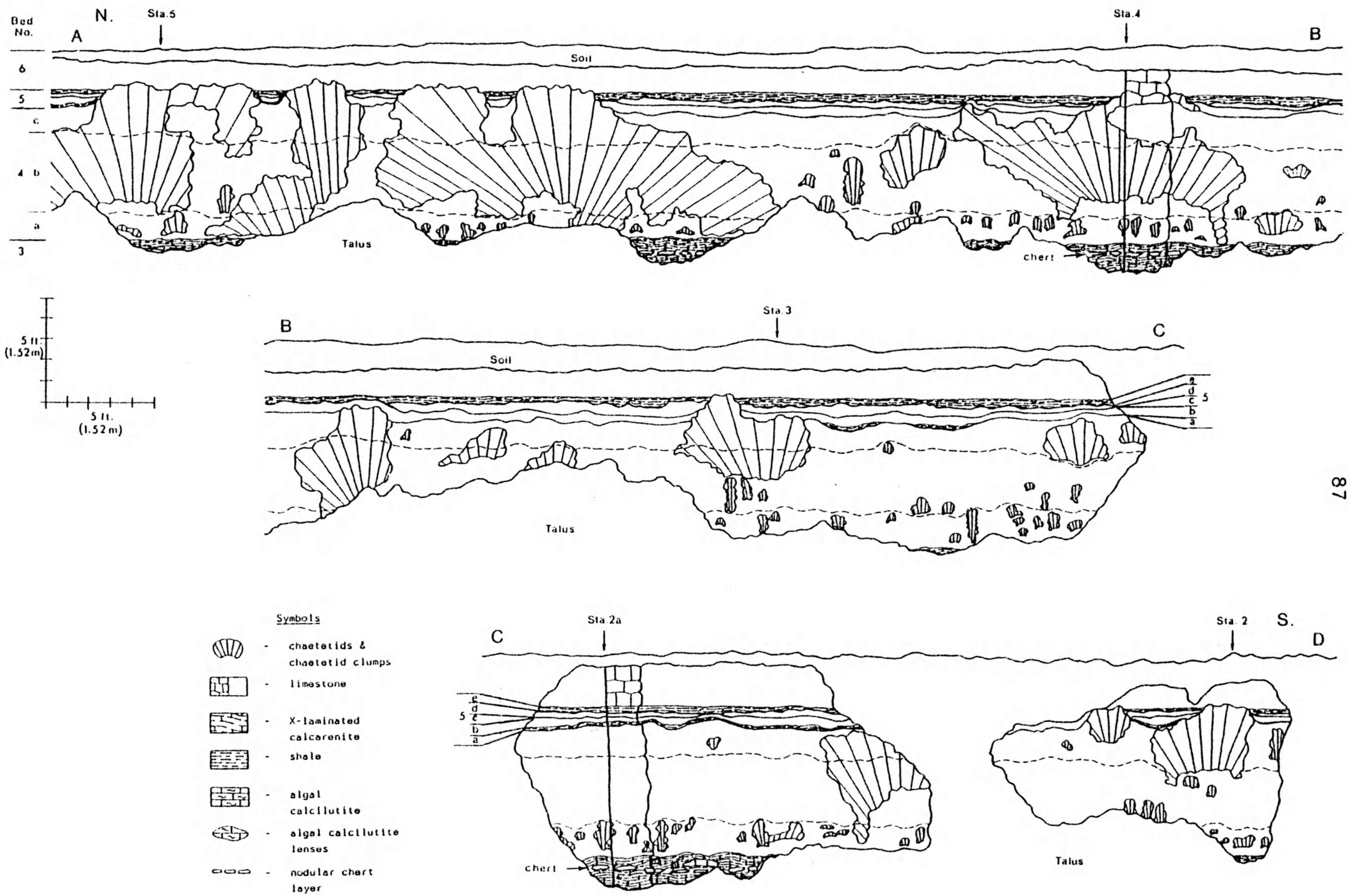
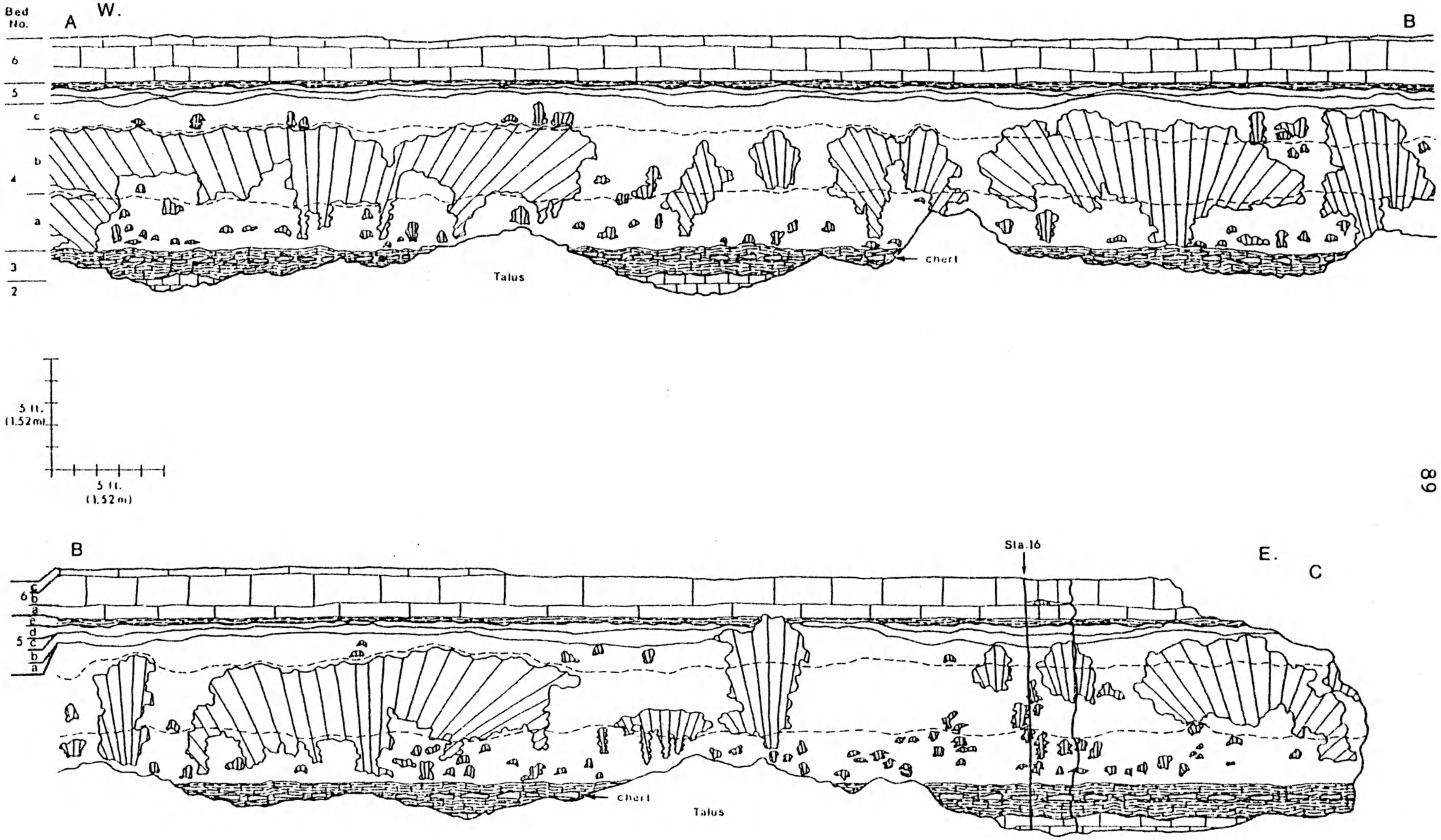
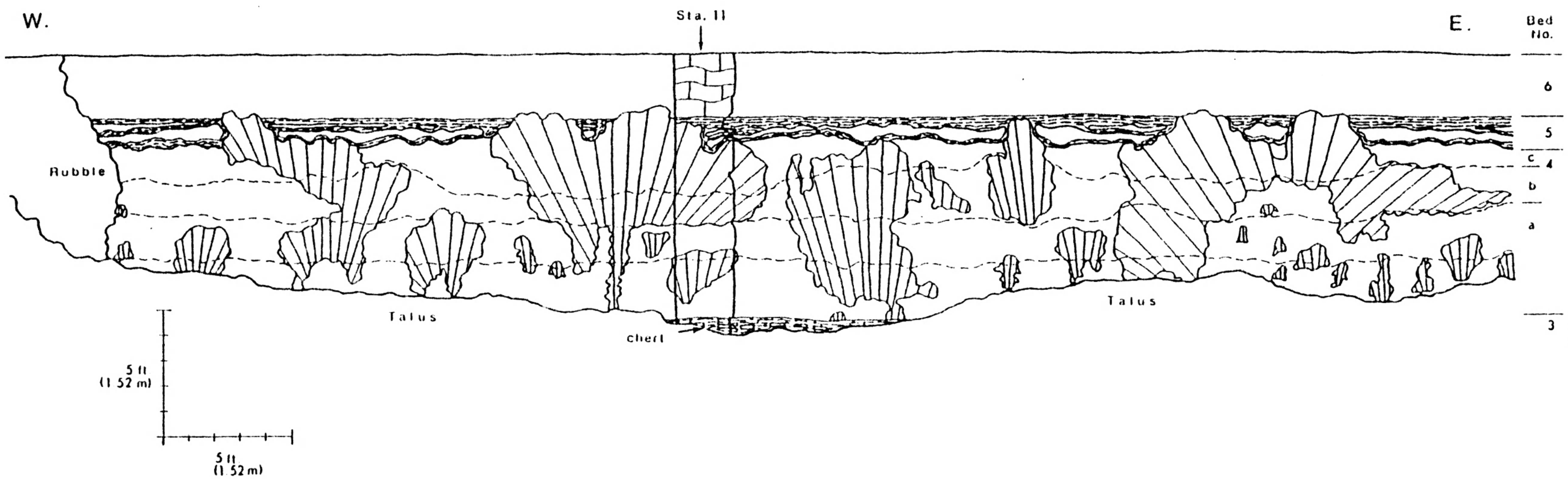

Bed No.
N.
Sta.5
A
Sta.4
B
Soil
6
5
c
4 b
a
3
Talus
chert
5 ft. (1.52 m)
5 ft. (1.52 m)
B
Sta.3
C
Soil
e
d
c
b
a
5
Talus
Symbols
chaetetids & chaetetid clumps
limestone
X-laminated calcarenite
shale
algal calcilutite
algal calcilutite lenses
nodular chert layer
C
Sta.2a
Sta. 2
S.
D
chert
Talus

Figure 35. Detailed vertical profile of quarry face west and a little east of station 16, showing all chaetetid occurrences in bed 4. Note the especially large and numerous chaetetid clumps in interval 4'b', and the way they began as narrow ragged columns in interval 4'a'. Interval 4'c' shows a relative paucity of chaetetids. Dashed lines represent cross laminated partings separating intervals 4'a', 'b', & 'c'. Both limestone lenses in bed 5 are well developed and relatively continuous. Interval 6'b' is relatively thick at station 16 but it thins abruptly 50 ft. (15.2 m) to the left (west) of station 16. For key to symbols, see Figure 33.



Bed No.
A
W.
B
6
5
c
b
4
a
3
2
chert
Talus
5 ft. (1.52m)
5 ft. (1.52m)
B
Sta.16
E.
C
6 c b a
5 e d c b a
chert
Talus

Figure 36. Detailed vertical profile of quarry face at station 11, showing all chaetetid occurrences in bed 4. Chaetetid clumps are large and numerous, and many of them protrude into the base of bed 6. Dashed lines represent cross laminated partings separating intervals 4'a', 'b', & 'c'. Bed 5 fills the hollows between chaetetid clumps; the lower limestone lenses are well developed and the upper limestone lenses are very thin, patchy, and flaky to nodular. Bed 6 is flat and of uniform thickness; none of it has been bulldozed away. For key to symbols, see Figure 33.



W.
Sta. 11
E.
Bed No.
6
5
c
4
b
a
3
Rubble
Talus
chert
Talus
5 ft (1.52 m)
5 ft (1.52 m)

Figure 37. Detailed vertical profile of quarry face at station 35, showing all chaetetid occurrences in bed 4. Chaetetid clumps are large, numerous, and of relatively uniform size. The small chaetetid at the top of bed 4 at station 35 was silicified while nothing around it was. Solid horizontal lines in bed 4 separate intervals 4'a', 'b', & 'c'. Dashed line represents a minor cross laminated parting in 4'a'. In bed 5, both limestone lenses are well developed although the upper one is less so. For key to symbols, see Figure 33.

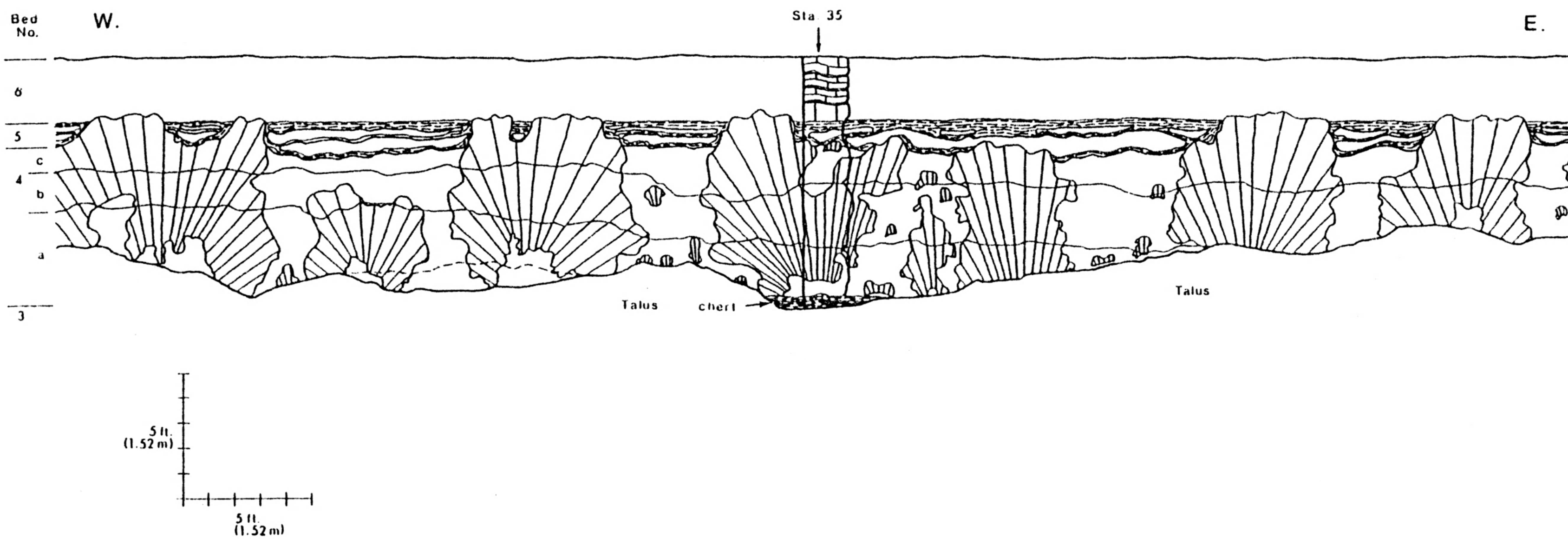

Bed No.
W.
Sta. 35
E.
6
5
c
4
b
a
3
Talus
chert
Talus
5 ft. (1.52 m)
5 ft. (1.52 m)

Figure 38. Detailed vertical profile of quarry face at station 20, showing all chaetetid occurrences in bed 4. Although chaetetid clumps are large, they are less numerous and more raggged in outline than at some other stations. Dashed lines represent cross laminated partings separating intervals 4'a', 'b', & 'c'. In bed 5, the lower limestone lenses are fairly well developed, but the upper ones are very patchy and thin and even absent in many places. Bed 6 is exceptionally thick here, mostly due to increased thickness of interval 6'b'. For key to symbols, see Figure 33.

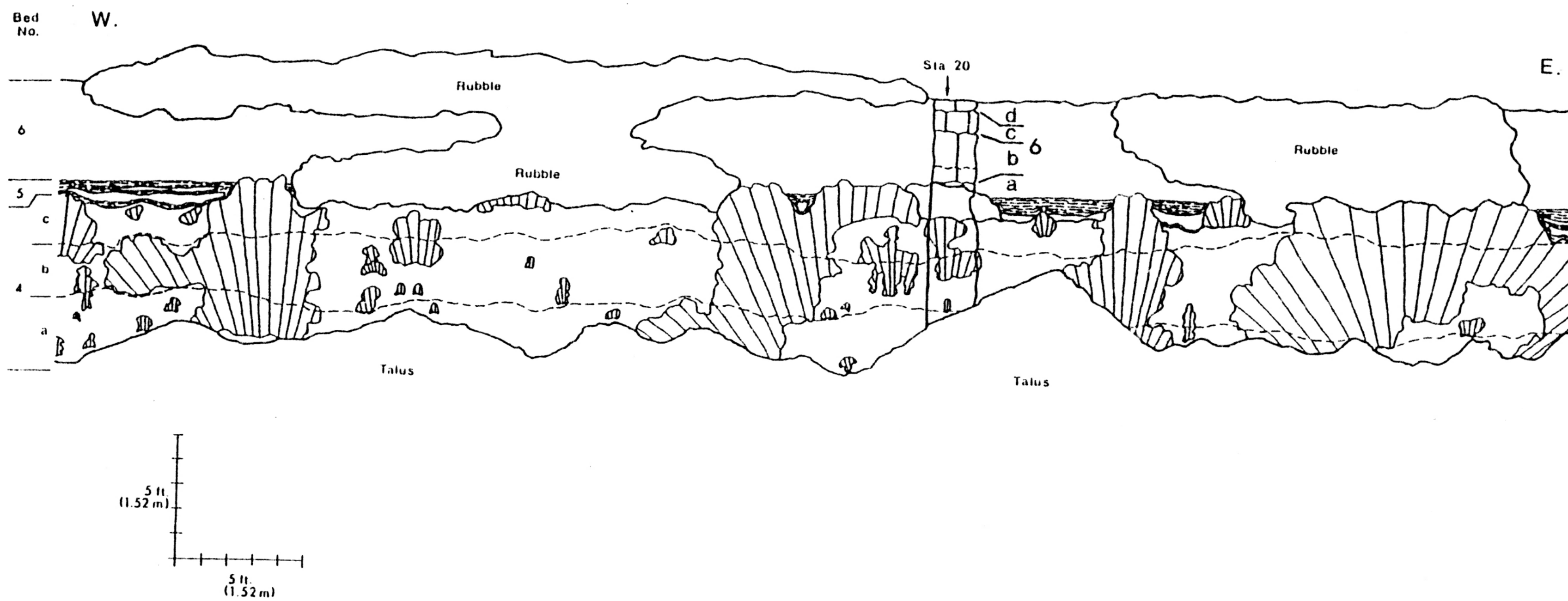
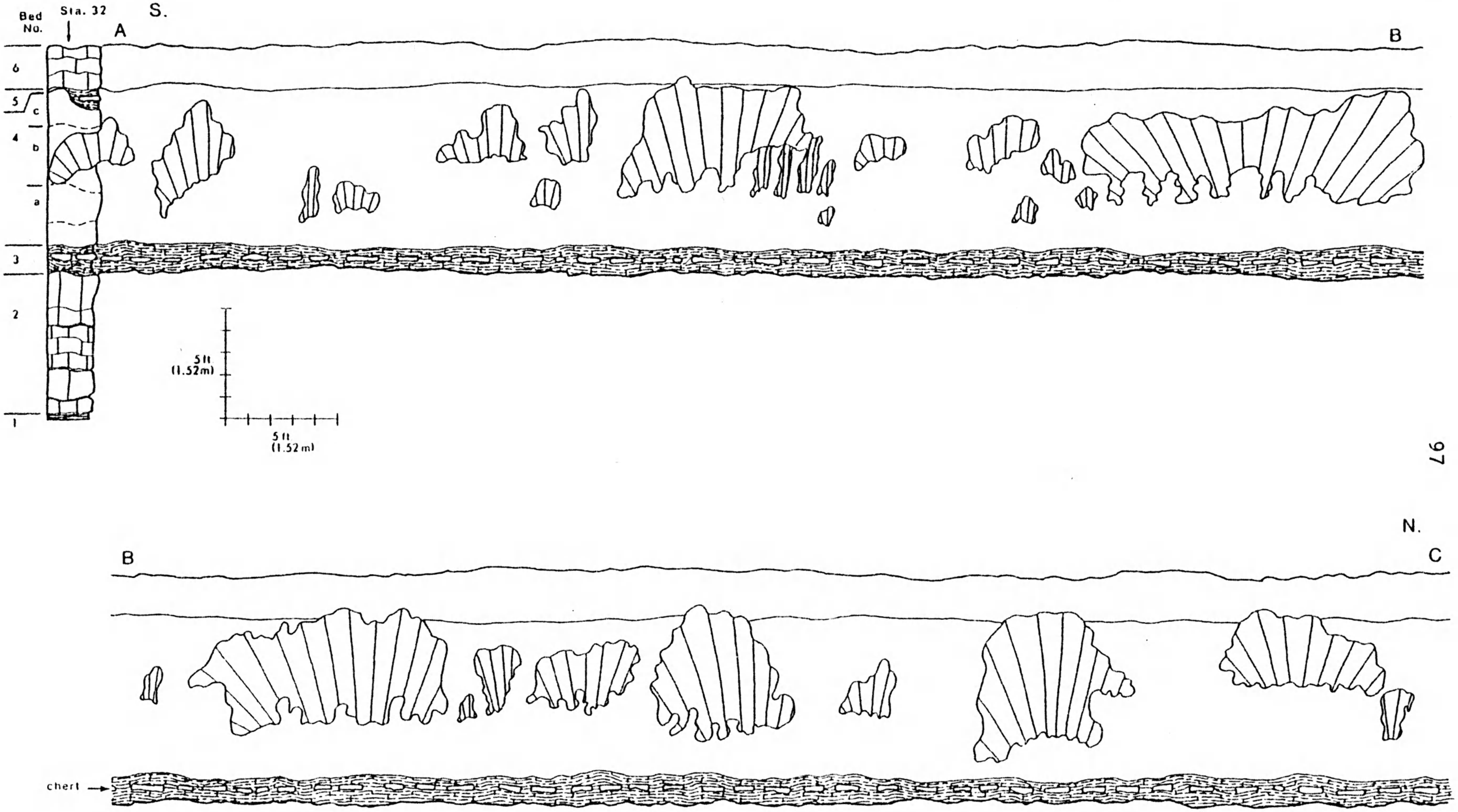

Bed
No.
W.
E.
6
5
c
b
4
a
Rubble
Rubble
Rubble
Sta 20
d
c
b
a
6
Talus
Talus
5 ft.
(1.52 m)
5 ft.
(1.52 m)

Figure 39. Generalized vertical profile of quarry face north of station 32, showing only major chaetetid clumps. Note that most major chaetetid occurrences are within the middle part of bed 4, many having begun as narrow ragged columns that merged upsection to form large clumps. Some chaetetid clumps are large and many protrude into bed 6. The cross laminated partings in bed 4 are not shown, nor is any of bed 5, but they are similar to other stations. For key to symbols, see Figure 33.


Bed No.
Sta. 32
S.
A
B
6
5
c
4
b
a
3
2
1
5 ft (1.52m)
5 ft (1.52 m)
B
N.
C
chert

difficult to follow through chaetetid clumps. Interval 'c' generally stays about the same thickness, except where chaetetid clumps protrude upward into bed 6. Intervals 'a' & 'b' vary up to 2 ft. (61 cm) in thickness, one becoming thicker at the others expense; no consistent pattern of thickness change exists, but the changes usually take place over tens of meters.

Minor cross laminated partings in interval 4'a' are obscure and inconsistent (see stratigraphic sections in Appendix B, and vertical profiles in Figures 33-38). The lower one is the most consistent, being easily visible in the areas of stations 24-30, 20, and 11, obscure but visible at stations 32-33, 35, 23, 16, and 4, and very obscure or absent at other stations. An upper one at stations 26-30 merges with the base of interval 'b' between stations 26 and 27 (see Figure 33), and is very obscure or absent at most stations.

The fusulinid packstone matrix around the chaetetids is generally the same all over the quarry, but there are some differences at stations 17, 20, and 21 (see Appendix B). At station 17, interval 4'a' is very similar to other stations, but interval 4'b' appears to be more strongly cross laminated and contains 5-10% angular fragments randomly oriented in the matrix between *in situ* chaetetids, as if the fragments had been washed in and deposited there. Also at station 17, interval 4'c' has thin wavy beds of fusulinid-bearing (§10% in places, much less than at most stations) skeletal calcarenite containing laminar to low domical chaetetids, chaetetid fragments, skeletal debris, and some algal baldes. At station 20, the matrix of interval 4'b' is very strongly cross laminated and fusulinid-poor (§10% in places), a number of chaetetids have been toppled onto their sides, and a lot of growth interruptions occur among the chaetetids. At station 21, the matrix of intervals 4'b' & 'c' is very dark, strongly cross laminated, and generally fusulinid-poor (§10% in places), the chaetetids exhibit more brecciation due to compaction, and some chaetetids have numerous borings. In general, bed 4 at stations 17, 20, and 21 appears to exhibit more evidence of current and wave energy, as if a channel or rip current situation may have existed there, although station 12, which is between stations 17 & 20, does not exhibit these differences (see quarry map, Figure 4).

Thin section study revealed more angular to rounded skeletal debris and fewer fusulinids in bed 4 at stations 17, 18, & 21 (see thin sections 700-17-2, 700-18-2, & 700-21-1) than at other stations This is consistent with the outcrop findings cited above.

Bed 5.--Bed 5 is consistent throughout the quarry in that it fills the hollows between chaetetid clumps nearly to the upper surfaces of those clumps, thus creating a relatively flat surface upon which bed 6 was deposited. It is also consistent in that its maximum thickness is always 12-16 in. (30.5-40.6 cm). It pinches out against chaetetid clumps. Figure 40 shows a typical occurrence of this interval.

Characteristically, the shale of bed 5 encloses the limestone lenses. The lower limestone lens (interval 5'b') pinches and swells according to the underlying topography, but it is well developed everywhere in the quarry. The upper limestone lens (interval 5'd') is much more patchy in its occurrence; it is well developed in some areas

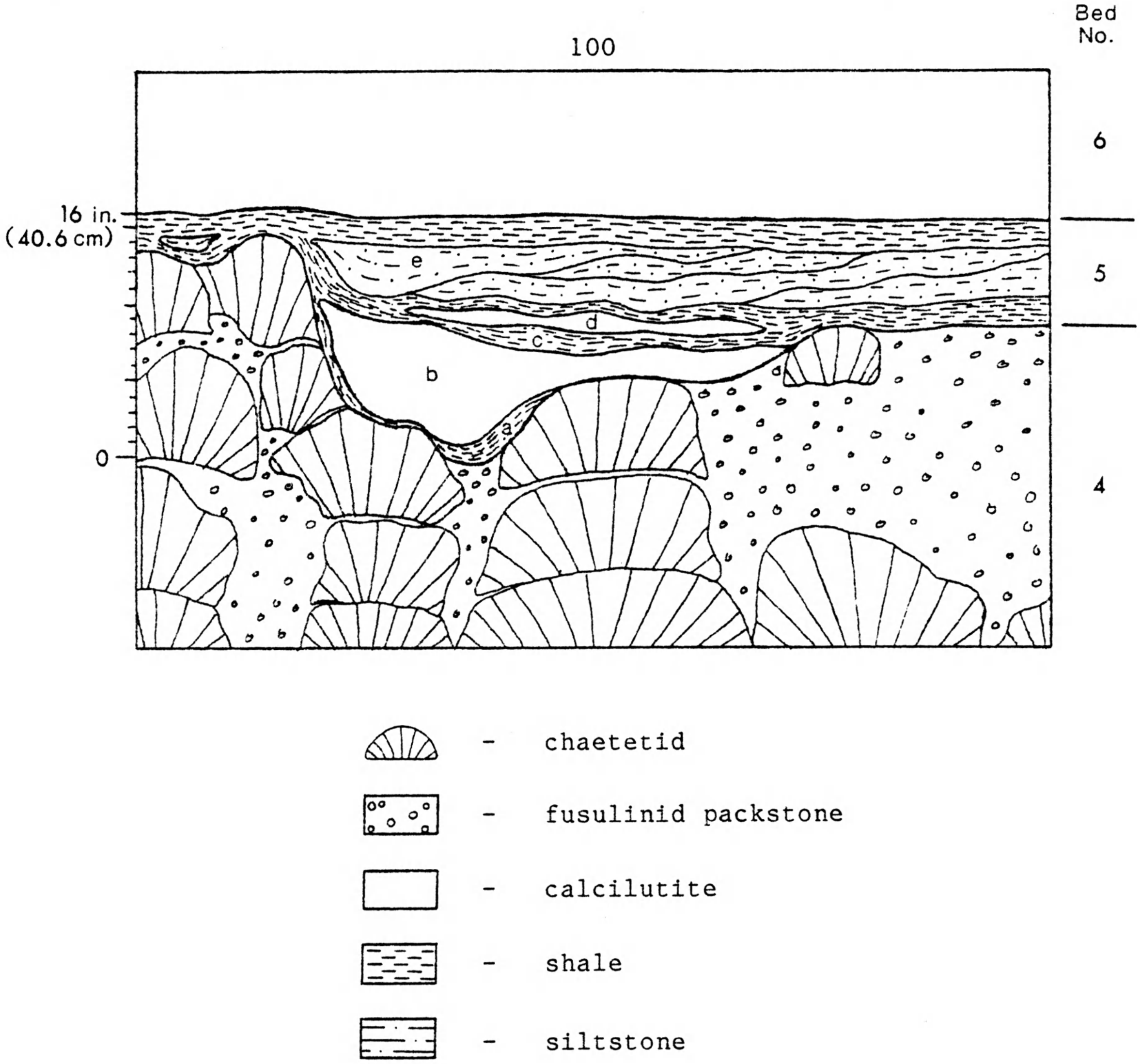


Figure 40. Sketch of bed 5 at station 11, showing how it fills in hollows around chaetetids. Both limestone lense (intervals 5'b' & 5'd') occur but the upper one is thin and poorly indurated. The gray flaky siltstone of interval 5'e' is well developed here and is overlain by brown silty shale. Plant fragments and root traces are common throughout this bed.

(stations 15-16, 24-30, 32, 35, 37, 38), patchy to well developed in others (stations 2-5), very patchy at others (stations 10, 11, 20, 22, 23, 36), and even absent at some (stations 12, 13, 14, 21, 31). Generally speaking, that translates to interval 5'd' being well developed in the north central to west central parts of the quarry, and poorly developed elsewhere, especially in the southeastern and southern portions of the quarry. Perhaps the areas where interval 5'd' is well developed were slightly lower topographically than those where it is poorly developed.

Bed 6.-- Bed 6 is continuous and generally of consistent thickness throughout the quarry and contains the same number of main intervals ('a'-'d') where upper portions have not been bulldozed away during quarrying. However, at stations 20 & 21, this bed is 3-4 ft. thick (.91-1.22 m), as opposed to 2-2.5 ft. thick (.61-.76 m) at most other stations. The increase in thickness occurs within intervals 'b' & 'c'. Interval 'b' is up to 26 in. (66 cm) thick at station 20, and interval 'c' has 2 extra cross laminated partings within it at station 21. At station 16, interval 6'b' is also relatively thick (15 in.; 38 cm), but 50 feet (15 m) west of station 16 it thins abruptly to 12 in. (30.5 cm) or less (see Figure 35).

The greater thickness of bed 6 at stations 20, 21, & 16 may be related to the greater energy exhibited by bed 4 at stations 20, 21, & 17, suggesting the existence of some common causal factor. A channel or rip current situation was suggested for bed 4. Perhaps there was still a minor topographic low at this spot when bed 6 was deposited, resulting in a greater thickness of sediments.

CHAPTER 4

CHAETETIDS

Introduction

The genus Chaetetes, which Reitner (1986) considers to be a demosponge, has a stratigraphic range from Ordovician to Miocene, but it is most conspicuous in Carboniferous rocks (West and Clark, 1984). As demosponges, they have representatives living today in reef cavities in several locations in the Caribbean and western Pacific (Jackson, 1971; Hartman and Goreau, 1970; Lang, et al., 1975). Carboniferous chaetetids were commonly the dominant frame builders of small bioherms and were associated with other frame building organisms in relatively shallow water (Connolly & Stanton, 1983; Lambert, et al., 1986; and Lambert & Stanton, 1986). They occur in North America, Eurasia, and Australia, apparently in localities that were tropical to low-temperate at the time of their development (West and Clark, 1984).

Chaetetid Morphology and Ecology

Chaetetids form massive colonies of cerioid to meandroid tubes (calicles) which have generally polygonal cross sections. Calicles may be from 0.1 to 0.6 mm in diameter, averaging 0.33 mm, each of which originally contained a functional unit of the colony. Calicles are horizontally partitioned by irregularly spaced tabulae, and structures termed pseudosepta also project toward the center of the tubes (West and Clark, 1984).

Chaetetid colonies take on three dominant growth forms: laminar; ragged, low domical; and columnar (West and Clark, 1984, Figure 3). "Colony increase is by longitudinal fission (pseudosepta extending completely across a calicle to divide it into two), by peripheral expansion (new, full sized calicles initiated at basal margin), or by intercalicle budding (new calicles arising by separation of existing calicle walls)" (West and Clark, 1984, p. 338). Colony surfaces sometimes exhibit tubercles, mamelons, and astrorhizae. Spicule pseudomorphs have also been recognized (Gray, 1980; Reitner, 1986).

Hartman and Goreau (1970, p.208), in discussing modern Carribbean "sclerosponges", stated that "the living tissue of the sponge forms a thin veneer over the surface of the extensive calcareous skeleton and is organized into functional units, each of which fills one of the pits in the surface of the skeleton." The pits continue into the skeletal mass, some reaching the base. The lumen of the pits is secondarily filled with aragonite as the organism grows upward (Hartman and Goreau, 1970, p.207) so that the skeleton becomes virtually a solid mass of calcareous material with numerous shallow pits on its surface.

Incurrent pores open into cavities in each tissue-filled pit and branch repeatedly through the tissue, where nutrients and gases are extracted. From there, fluid movement continues into fine excurrent channels which gradually merge into larger and larger canals, finally converging in star-shaped patterns upon exhalent oscular openings. These star-shaped patterns,if impressed upon the growing skeleton, form the astrorhizae that are commonly preserved on recent sclerosponges but are rarely preserved on chaetetids.

The Jamaican sclerosponges examined by Hartman and Goreau (1970) occurred at depths from 8 m to 95 m, but optimum depths varied according to individual species. All six species exhibited a low tolerance for light, some preferring twilight, others retreating to the near-total darkness of deep caves and tunnels. In addition, a low tolerance for sedimentation was observed.

The modern "sclerosponges" studied by Hartman and Goreau (1970, p.239) were predominantly confined to benthic habitats of the lower photic zone, "where the ambient light flux is less than 1% of the surface." However, among studies of ancient chaetetids, most authors favor a more shallow environment (see pp.57-61). Apparently, chaetetids occurred in environments reaching to the lower limits of the photic zone, but they favored environments from just below wave base to well within wave base. West and Clark (1984, p.337) stated that chaetetid occurrences "in many cases exhibit evidence of wave action." Indeed, this study cites evidence to indicate that chaetetids thrived in the zone from just below normal wave base to very near the surface of the sea.

Some authors have attempted to correlate the different growth forms to different environments. Spaw (1977) suggested that laminar forms were adapted to areas of frequent fluctuations of the physical and biological environment, whereas bulbous forms were adapted to stable, deep-water environments. Bottjer (1982), in studying Devonian stromatoporoids, suggested that laminar to low domical forms grew in areas of higher circulation, with laminar forms developing on a loose substrate and low domical forms on a firmer substrate. He also suggested that mamelonated and digitate forms grew in areas of less circulation where greater surface area was beneficial, and that their bases were either laminar or hemispherical depending upon the type of substrate. West and Clark (1984, p.339) concurred by stating that "laminar and ragged to smooth low domical colonies occur in mudstones and could reflect the degree of substrate firmness and sedimentation rate," and that "domical to high domical (columnar) forms occur in "cleaner" carbonate units suggesting both a firmer substrate and less sedimentation." Mathewson (1977) suggested that crowding may have been important in controlling the growth form. In studying stromatoporoids, Kershaw (1981) and Stearn (1982) indicated that different species exhibit different growth forms in the same environment, and Nelson and Langenheim (1980) suggested that different chaetetid forms, previously considered to be separate species, may actually be ecophenotypes of the same species. Thus, both genetic and environmental factors are important in controlling growth form.

Apparently it was important that a firm or stable substrate be available for initial chaetetid colonization. Chaetetids have been reported as being attached to shell fragments, oncolites, and lithic fragments (West and Clark, 1984), and in some cases, the colonies were tumbled around until they reached a large enough size that they became stable and then they grew upward into large columns. Other authors have suggested that sediments had been stabilized by sediment-binding organisms such as Multithecopora or algal mats (Lustig, 1971), or encrusting foraminiferids (Spaw, 1977) before chaetetids became attached. Connolly and Stanton (1983) cited an instance of chaetetids colonizing non-mobile oolite bars between intervals of ooid formation. Many of these factors will be explored in this chapter on chaetetid occurrences in the Niggeman quarry.

Chaetetid Occurrences in the Niggeman Quarry (Locality 700)

Chaetetids in the Houx-Higginsville Limestone in the Niggeman quarry occur in three stratigraphic beds: 3, 4, and 6 (as designated in Chapter 3 and Appendix B). Essentially, chaetetid occurrence in bed 3 represents their first attempts at colonization of this area within the Upper Fort Scott cyclothem. In bed 4, they became very well developed, forming large clumps throughout the quarry area. None occur in bed 5. Then in interval 6'a', a few small laminar forms became established before they disappeared altogether from the remainder of the Upper Fort Scott cyclothem.

Growth Forms and Surfaces of Attachment.--Chaetetid growth forms in bed 3 are primarily small and laminar, with only a few being low domical and none being columnar in form. Sizes range from less than 2 mm across up to 17 cm across and 4 cm high below the chert layer, and up to 20 cm across and 8 cm high above the chert layer (see stratigraphic section 31 in Appendix B). They commonly became attached on the carbonate mud substrate (suggesting partial early marine cementation; see Chapter 3), on shell fragments, or on encrusting algal mats (see thin section description 700-24-17 in Appendix C).

Bed 4 is the chaetetid "reef" bed and shows the greatest development of chaetetids (see vertical profiles in Figures 33 & 34). In interval 4'a', chaetetids occur as scattered laminar to low domical colonies and narrow ragged columns, constituting 5-15% of the rock. The predominant trend is for the small laminar to low domical forms to occur in the lower part of the interval and to grade upward to narrow ragged columns in the upper part. Usually the columns are built of small laminar to low domical forms stacked one on top of another (Figure 41). The lone chaetetids or the ones at the bases of the columns appear to have become attached upon the substrate and/or upon shell debris. The chaetetids stacked in columns are attached on other chaetetids, on Aulopora overgrowths, on thin layers of sediments that define growth interruptions within the columns, and occasionally on algal overgrowths that have encrusted underlying chaetetids.

In interval 4'b', all growth forms of chaetetids occur but the predominant forms are domical to columnar. They combine to form large clumps that are commonly 1-3 m across and often reach over 6 m across (Figures 41 & 30). The clumps consist of large colonies of chaetetids stacked together (laterally and vertically) with abundant cavities between them, in which numerous other organisms lived (see Chapter 5 on associated organisms, esp. Figures 48, 49, & 50). One of the largest individual chaetetid colonies within a clump that was recorded in the quarry was 71 cm across and 38 cm high (see section 23 in Appendix B).

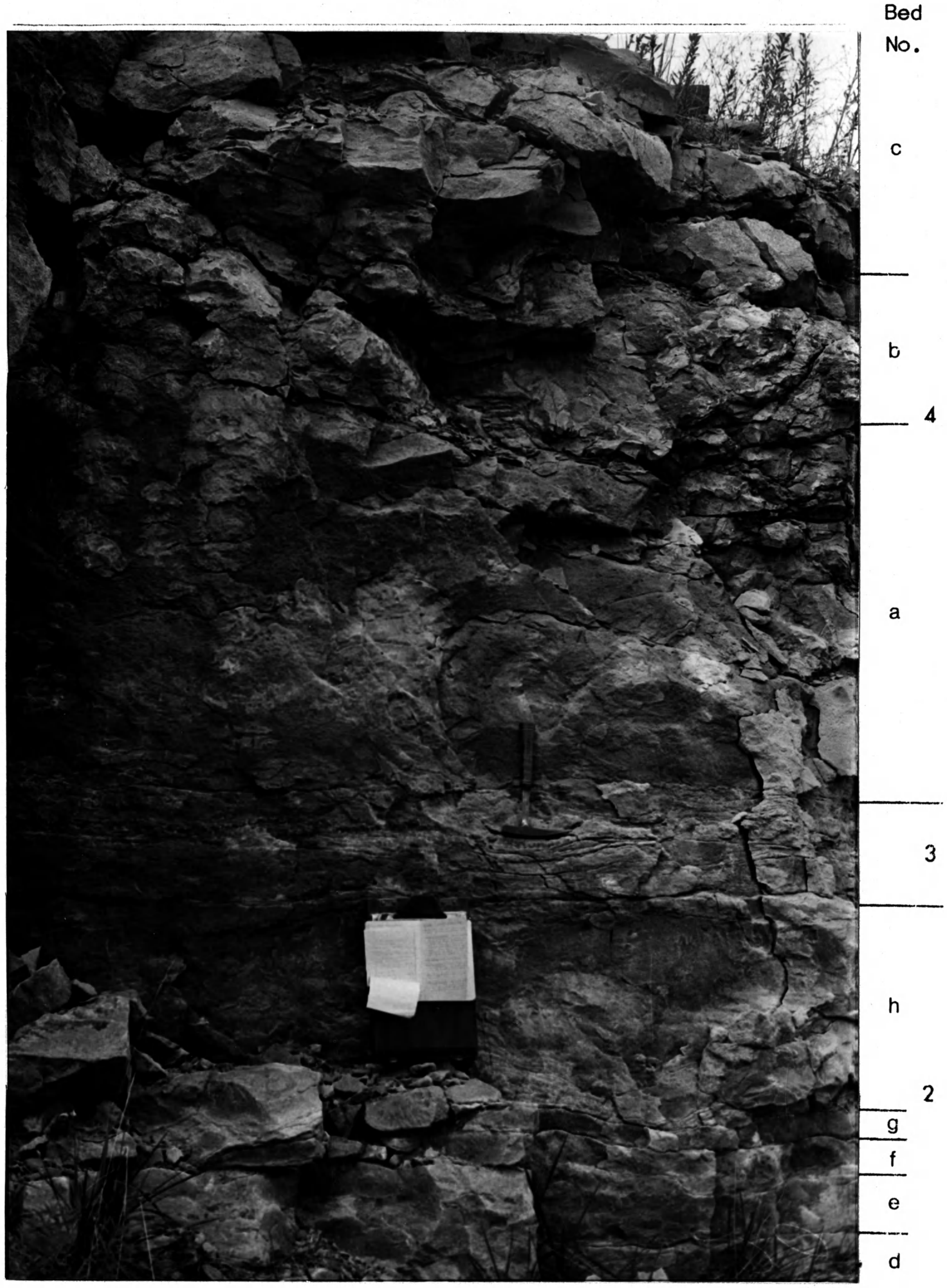


Figure 41. Interval 4'a', 10 ft. (3.05 m.) south of station 32, showing laminar chaetetids in lower part and narrow ragged columns in upper part. Columns merge in interval 4'b' to form large chaetetid clump. Hammer head is sitting on chert layer in bed 3; top of clipboard is at base of bed 3. Note stacking of chaetetids in the columns and clumps. Hammer is approximately 31 cm long.

Most of the larger chaetetid clumps continue through interval 4'c' and protrude through bed 5 a few centimeters into bed 6. Between the clumps in interval 4'b' are individual domical to columnar chaetetids and small clumps of only a few colonies (see Figures 33 & 34). In the quarry faces, there are some gaps up to 4.5 m wide between clumps where virtually no chaetetids occur. The surfaces of attachment of chaetetids in this interval are as in interval 4'a'.

It could be that chaetetids got started during deposition of interval 4'a' at random locations on the seafloor, either on skeletal debris or directly on the substrate wherever it was firm enough. Once established, they then provided the firm substrate upon which subsequent chaetetids could attach. Thus clumps formed in interval 4'b'. As the clumps developed and sea level shallowed (i.e., later in PAC 3; see Figure 13), water energy would effectively have been channeled between the clumps creating high energy conditions there under which other chaetetids could not become attached, therefore perpetuating gaps between clumps.

In interval 4'c', the major chaetetid occurrences are of clumps that have continued upward from interval 4'b'. These clumps have not changed in character from interval 4'b', except that they taper off and terminate at the top of this interval (see Figures 33, 34, & 30). A few columnar chaetetids occur between clumps in this interval, but they are rare. Also a few rare small clumps got their start within this interval, but for the most part, very little new chaetetid growth was initiated here.

Bed 5 is devoid of chaetetids and thus the next and the last occurrence of chaetetids in these rocks is in interval 6'a', predominantly in the cross laminated parting at the top of interval 6'a' (see Figure 32). Here they are small and laminar, very rarely approaching a domical growth form. The largest one seen was 20 cm across and 10 cm high, but most are much smaller. The surfaces of attachment include the carbonate mud substrate and mats of encrusting red algae (see thin section description 700-32-5 in Appendix C).

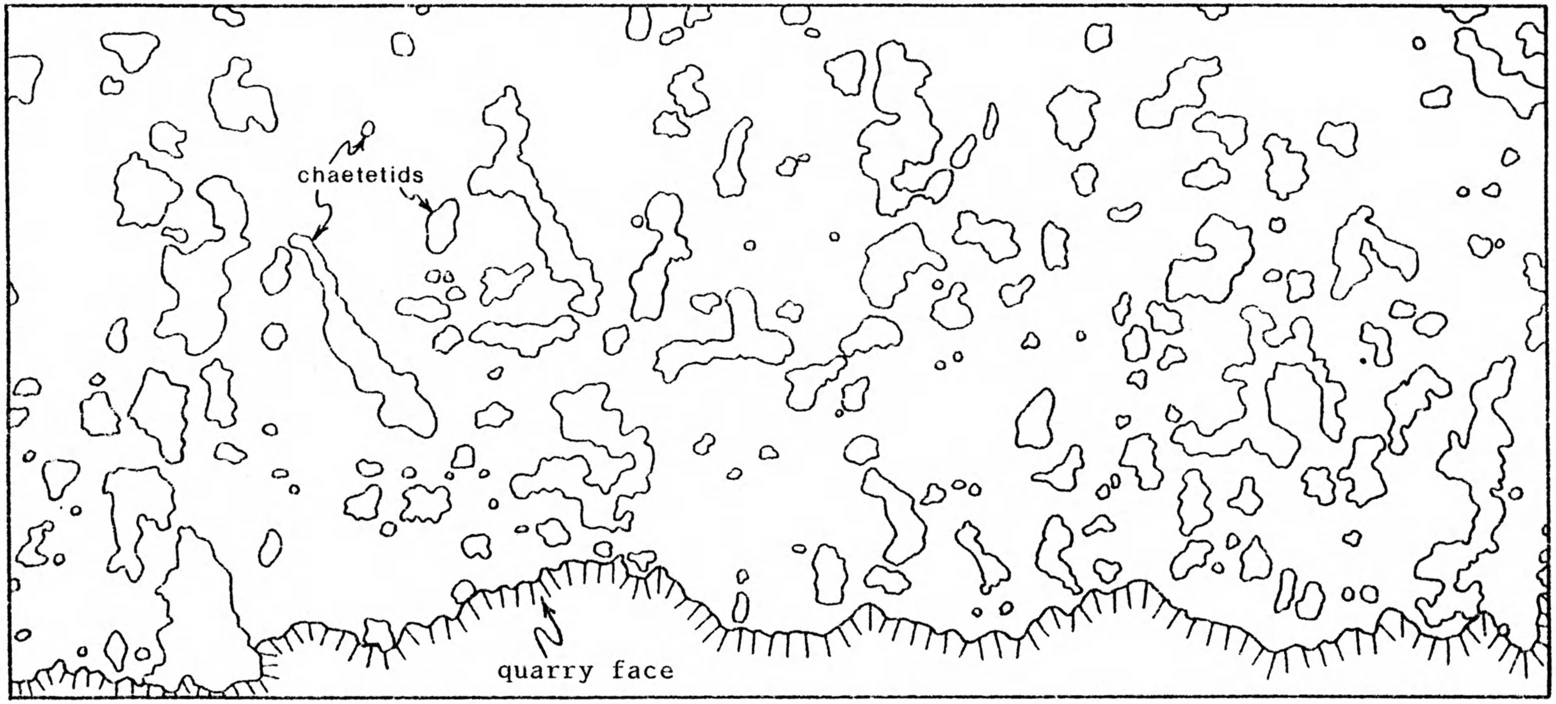
Lateral and Areal Distributions and Paleocurrents.--Six detailed and two general vertical profiles were drawn in the field, showing exact dimensions, shapes, and positions of chaetetids in bed 4 (Figures 33-39 & 42B). The six detailed profiles (Figures 33-38) also show lateral relationships within bed 5 and thicknesses and positions of beds 3 and 6. The profile for stations 24-30 (Figure 33) was drawn with the most detail and accuracy of all the intervals shown.

The most obvious characteristic in all the profiles is the presence of large chaetetid clumps, which in size, fall somewhere between James' (1983, fig.5, p.349) classification of "coral knobs" and "patch reefs". The clumps usually start as narrow ragged columns in interval 4'a' that expand and merge to form clumps in interval 4'b'. Some clumps terminate within interval 4'c', but many persist and protrude into the base of bed 6. Very little new chaetetid growth is initiated in interval 4'c'. Bed 5 fills the low places between chaetetid clumps and apparently represents the smothering and termination of growth of chaetetids in bed 4. The distribution of

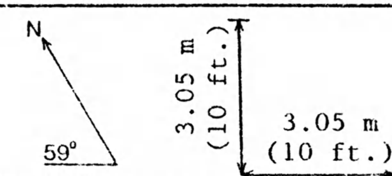
Figure 42.

A. Map view of chaetetid distribution as shown on the surface above stations 8 & 33 at northwest corner of quarry. Beds 5 & 6 and part of 4'c' have been bulldozed away to expose the chaetetids on the surface. Closed irregular areas represent chaetetids.

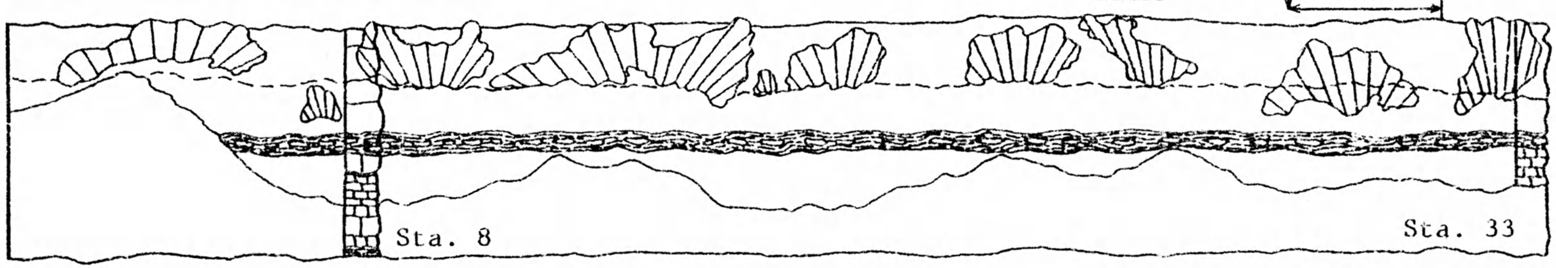
B. Generalized vertical profile of quarry face coinciding with lower edge of chaetetid distribution map, showing only major chaetetid clumps. Dashed line represents cross laminated parting separating intervals 4'a' & 'b'. For other symbols, see Figure 33. Combining figures 42A & B gives a 3-dimensional impression of chaetetid distribution here.



A. Map view of chaetetid distribution.



B. Profile along quarry face.



chaetetids and chaetetid clumps is consistent throughout the quarry, and thus gives no indication of an end to the chaetetid buildups in any direction nor of a windward or leeward orientation. The detail of Figure 33 can almost give an impression of how chaetetid distribution on the seafloor may have appeared when the chaetetids were alive.

The chaetetid distribution map and vertical profile in Figure 42, when used in combination, can give a 3-dimensional impression of chaetetid distribution on the seafloor. In the area of the map, the overlying rocks have been bulldozed away down to the tops of most chaetetid clumps. Chaetetids thus exposed on the surface were mapped in detail. The major chaetetid clumps exposed in the quarry face were then recorded on the vertical profile.

Visually, there are no readily apparent directional trends in the distribution of chaetetids, unless perhaps some vague preference for a northerly or northeasterly alignment (note N-arrow in Figure 42; also see Figure 43). This vague alignment may be due to gentle or sporadic currents from the south-southwest or north-northeast, resulting in some sort of incipient ridge and groove system in the chaetetid buildup. It may be possible to test this statistically.

A look at the profiles for stations 2-5 and 16 (Figures 34 & 35) reveals that the area between stations 2 and 4 has sparsely distributed chaetetid clumps, whereas just around the corner between stations 15 & 16 (see Figure 43), large and numerous chaetetid clumps occur. This suggests some sort of linear development of chaetetids parallel to the quarry face at stations 15 and 16. A small area nearby (shown as Area A on Figure 43), where overlying beds have been scraped away, reveals

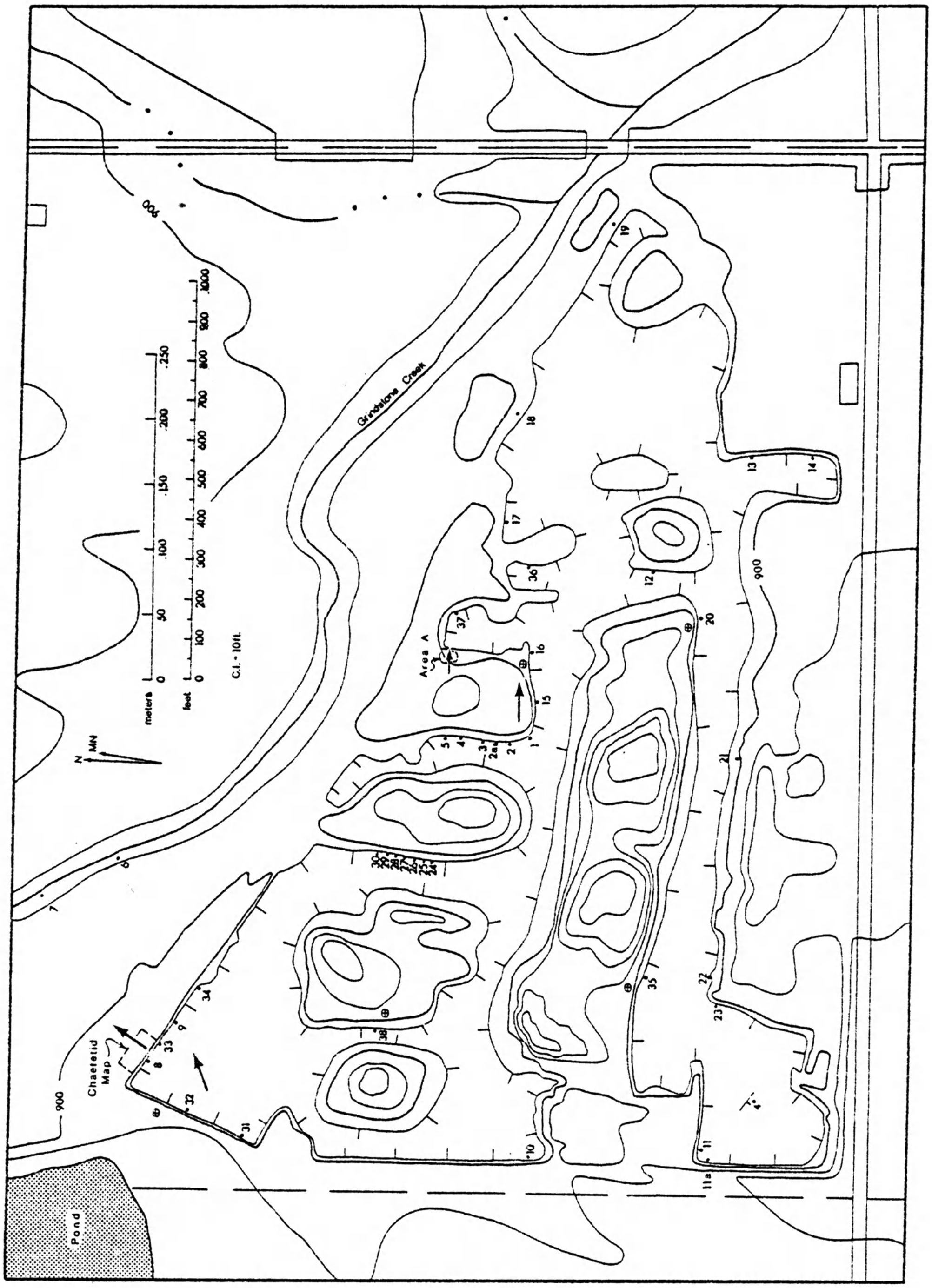


Figure 43. Quarry map with arrows showing inferred paleocurrent directional trends in the northwest and north central parts of the quarry. See text for explanation.

chaetetids on the surface in three roughly linear parallel trends 25-30 ft. (7.6-9.1m) long. Each trend, containing abundant chaetetids as if protruding from underlying clumps, is 4-8ft. (1.2-2.4m) wide and separated from the others by approximately 8ft. (2.4m) of rock with no chaetetids. These linear trends run approximately east-west, parallel to the quarry face at stations 15 and 16. This may suggest a prevailing current from either the west or the east.

In an attempt to determine the orientation of a possible paleocurrent, directional indicators were examined in the cross laminated calcarenite of bed 3 in the northwest corner of the quarry (in the area of stations 31, 32, 8, & 33). Orientations of crests or troughs of wavy layers, assumed to be current or wave ripples, were measured with a brunton compass. Paleocurrent orientation was assumed to have been perpendicular to the ripples. Subtle imbrication of shell debris and the occurrence of pebble-sized skeletal and lithic fragments on the "lee" side of an in situ chaetetid suggested that the paleocurrent came from the southwest. Twenty directional measurements of ripple troughs and crests revealed a paleocurrent direction ranging from N.36^{o}E. to N.109^{o}E., with a mean of N.67.7^{o}E (data are recorded in Appendix D).

The overall conclusion, based on chaetetid distribution in bed 4 and paleocurrent directional indicators in bed 3, is that the prevailing paleocurrent moved in a northeasterly direction (see Figure 43). This roughly coincides with Heckel's (1977, fig.6, p.1056) pattern of sea bottom circulation for this area during the Pennsylvanian.

Toppling, Overturning, and Growth Interruptions.--Toppled and overturned chaetetids are somewhat rare in the rocks of the quarry, except in bed 3, where very small overturned chaetetids are relatively common (see chapter 6). Within bed 4, toppling and overturning occurred primarily in a few small areas in interval 4'b'. In bed 6, no toppling nor overturning was observed.

At station 20, several medium-sized domical chaetetids were seen lying on their sides (Figure 44). They occurred within strongly cross laminated, dark, fusulinid-rich, skeletal calcarenite in the upper part of interval 4'b'. This indicates high water energy within this interval and corroborates higher energy at this station.

At the top of interval 4'b', 1.5 m south of station 3, a small chaetetid (12 cm across) was rolled over on its top and then growth was re-initiated (Figure 45). Aulopora overgrowths, a brachiopod (Composita), and a rugose coral (Lophphyllidium) were included within it.

Growth interruptions are ubiquitous among the chaetetids in the quarry. Hardly a chaetetid occurs without numerous growth interruptions. Many of the growth interruptions are defined only by a line which marks a break in continuity of the calicles. More commonly they are defined by thin sediment layers or possible algal overgrowths. Some of the more obvious and quite common growth interruptions are a result of Aulopora overgrowths. Often they occur in cycles, chaetetid and Aulopora each in turn overgrowing the other several times (Figure 46).

Figure 44. Two chaetetid heads lying on their sides near the top of interval 4'b' at station 20. One chaetetid, just left of the pencil, offers a side view. The other, just left of the pencil point (directly on top of the first toppled chaetetid), offers a view of its underside. Pencil is 15 cm long.

A.

B.

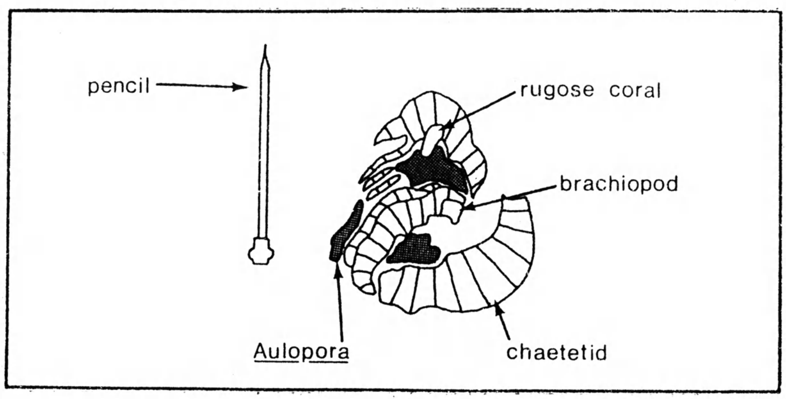


Figure 45. A. Closeup of chaetetid in interval 4'b' south of sta. 3 that had been rolled over before growth was re-initiated on the other side. B. Field sketch of chaetetid in above photo. Note Aulopora overgrowths, and intergrown brachiopod and rugose coral. Pencil is 15 cm long.

A.

B.

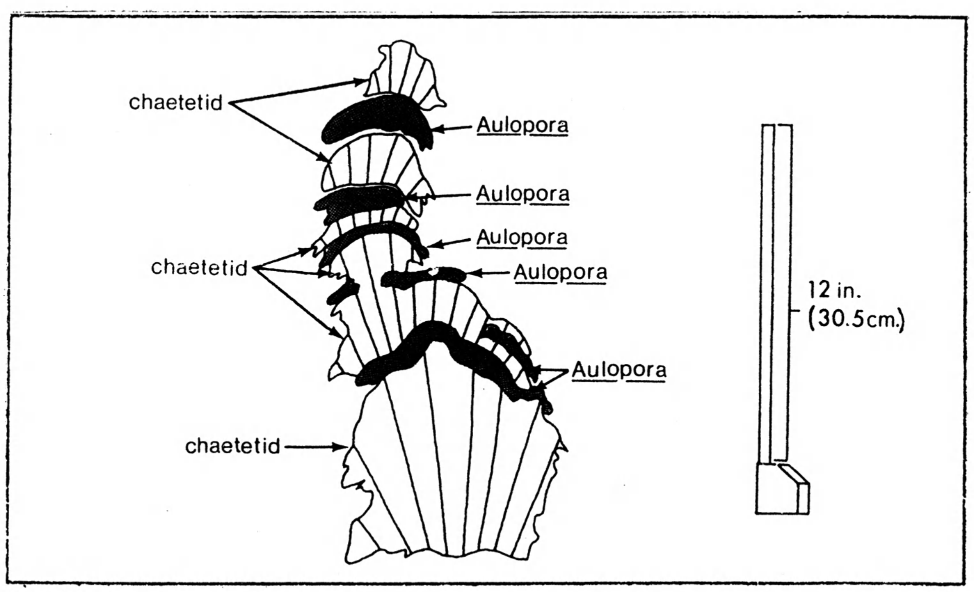


Figure 46. A. Closeup of chaetetid with 6 cycles of chaetetid/Aulopora overgrowths. Tape measure is extended 12 in. (30.5 cm.). B. Field sketch of chaetetid in photo.

Relief.--Cross laminations in the fusulinid packstone matrix of interval 4'b' sometimes drape over the chaetetids, giving some indication of the amount of relief of the chaetetids on the seafloor when they were alive (Figure 47). Judging from this, relief was apparently on the order of 12-18 inches (30-46 cm), but may have been greater in places. Certainly the chaetetid columns were not freestanding on the seafloor because they are commonly very narrow at the base and wide at the top, and would easily have toppled over. Apparently sedimentation was more or less keeping pace with chaetetid growth.

Chaetetid clumps may have had greater relief because they were large and wide and would have had no problem with toppling. In some cases, where the cross laminated partings that separate interval 4'b' from 4'c' cannot be traced through chaetetid clumps, it is possible that the clumps existed in whole before interval 4'c' was deposited (see large clump at station 30 in Figure 33). If that were the case, some clumps may have had a relief of 40 inches (1.02 m). In view of the fact that bed 5, which fills hollows between chaetetid clumps, has a maximum thickness of 18 inches (46 cm), and some chaetetid clumps protrude up to 6 inches (15 cm) into bed 6, it appears that many clumps had a relief of 24 inches (61 cm) before they were covered over by bed 5.

Figure 47. View of cross laminated fusulinid packstone matrix draping over a chaetetid (directly above hammer) within interval 4'b', 3.7 m. east of station 33. Maximum relief indicated here is 30 cm. Hammer is approximately 31 cm. long.

Discussion

From the evidence presented, some general inferences may be made. Apparently the major development of chaetetids (in bed 4) occurred at depths not far below wave base to well within normal wave base. This conclusion is based upon the persistent evidence of wave energy in the rocks, such as cross laminations and toppled or overturned chaetetids.

The uniform development of chaetetids throughout the quarry suggests that the environment was uniform over this area. One possible exception is the area of stations 20, 21, 16, and 17, where more energy indicators occur and bed 6 is thicker (see lateral relationships in Chapter 3); there may have been some sort of channel or rip current situation here, or it could have been an inlet within the outer edge of the chaetetid "field". However, the overall uniform and flat-lying environment, with the evidence for high wave energy, plus the occurrence of a diverse stenohaline fauna (to be discussed in Chapter 5) under apparently well-aerated conditions, a lack of terrigenous detritus, and the paleogeographic location of the "reef" at the time of its development (see Figure 20), all lead to the conclusion that these chaetetid clumps developed in a very shallow, flat shelf environment many kilometers from shore.

CHAPTER 5

ORGANISMS ASSOCIATED WITH CHAETETIDS

Introduction

Field observations and laboratory study of rock samples revealed a wide variety of organisms associated with the chaetetid "reef" examined for this study. Virtually all of the organisms lived in the same environment as the chaetetids, most within cavities among the chaetetids, or on the chaetetids, many actually attached to the chaetetids. This chapter will examine the types of species in bed 4 (the chaetetid "reef" bed) and different aspects of their distribution, preservation, relation to sediment, life positions, associations, and paleoecological implications.

Species Types, Positions, and Preservation

The most important and abundant species present in bed 4 are fusulinids (*Fusulina* sp.) (5-50% of the rock on a 1 sq. m scale), *Chaetetes* sp. (0-85%), and *Aulopora* sp. (0-5%). Also quite abundant are *Lophophyllidium* sp., crinoids, echinoids, *Fistulipora* sp., *Composita* (*subtilita* and *ovata*), other foraminiferids (*Tetrataxis* sp., palaeotextulariids, *Bradyina* sp., *Endothyra* sp., *Polytaxis* sp., and *Globivalvulina* sp.), and ostracodes. Other fossils that occur include

Hustedia mormoni, Neospirifer sp., Punctospirifer kentuckyensis, Meekella striatocostata, Chonetina flemingii, Mesolobus mesolobus, Derbyia crassa, fenestrate and ramose bryozoan fragments, (Rhombopora sp., Prismopora sp., and others), productid fragments (Desmoinesia?), Pseudomonotis sp., encrusting algae (Osagia and Archaeolithophyllum?), Spirorbis sp., encrusting ophthalmid foraminiferids, small gastropods, algal blades and fragments, one sponge specimen (sphinctozoan?), pellets, and one very small specimen of Michelinia(?) (seen in thin section 700-31-8).

Most of the fossils are well preserved and unabraded, many in life position. Of course, most (95%) of the chaetetids and Aulopora are in life position. The majority of brachiopods, 60-70% of the rugose corals, nearly all of the encrusting bryozoans, the encrusting algae, Pseudomonotis sp., and the sphinctozoan(?) sponge (identified in thin section 700-31-19, Appendix C) were all found in situ. Most of the crinoid and echinoid debris exhibit some evidence of transportation (i.e., abrasion, breakage, alignment parallel to cross laminations), although some occurrences suggest that whole or partial specimens may have disarticulated in place (discussed later in this chapter). No specimens of fenestrate and ramose bryozoans were observed in place; all were broken and abraded (no holdfasts were recognized, perhaps due to lack of identification experience). No algal blades or fragments could be demonstrated to be in place. All of the fusulinids and other foraminiferids occur "floating" in a micritic matrix or they are in grain-to-grain contact, and their excellent preservation suggests they were living there or very nearby. Many of the specimens of Tetrataxis sp., Polytaxis sp., and ophthalmid foraminiferids very likely lived attached to chaetetids, Aulopora, and other in situ fossils.

Fossils that were originally calcitic (e.g., brachiopods) have preserved the original shell material. Aragonitic (e.g., gastropods) and Mg-calcite (e.g., algae) skeletal debris has been largely replaced by calcite (see Chapter 7 and thin section descriptions in Appendix C). Some shells exhibit patchy micritization (see thin section descriptions), some of it probably caused by endolithic algae. Very minor pyritization and chertification also occur. Compaction deformation is evident some places but for the most part it is minor.

Associations and Distribution

Associations and relationships among fossils and their distributions were noted in the field and in the samples collected. Sketches, photos, and detailed species maps were made to illustrate these relationships.

Three detailed species maps of quarry faces were developed by marking off each area with string and then carefully measuring and plotting on graph paper the species occurrences within that area. Two of the maps are of 2-foot (.61 m) wide vertical sections from the base of bed 3 to the top of bed 5, with the main emphasis on bed 4 (Figures 48 & 49), both drawn at an original scale of 15/16 inch = 1 foot (1:12.8). The third map is of a 2-foot (.61 m) square area in interval 4'b' (Figure 50), drawn at a scale of 1 7/8 inches = 1 foot (1:6.4).

Figure 48

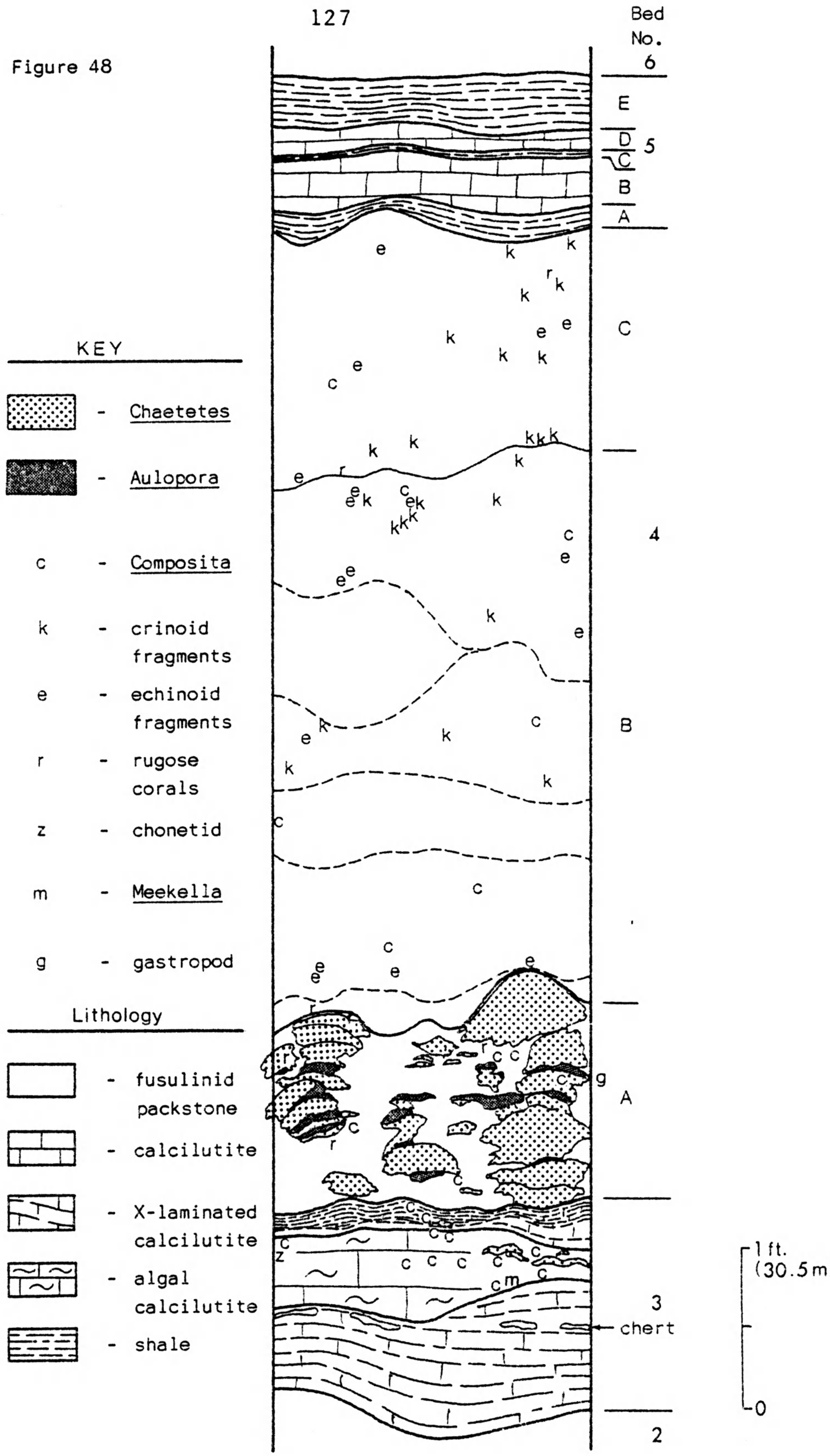
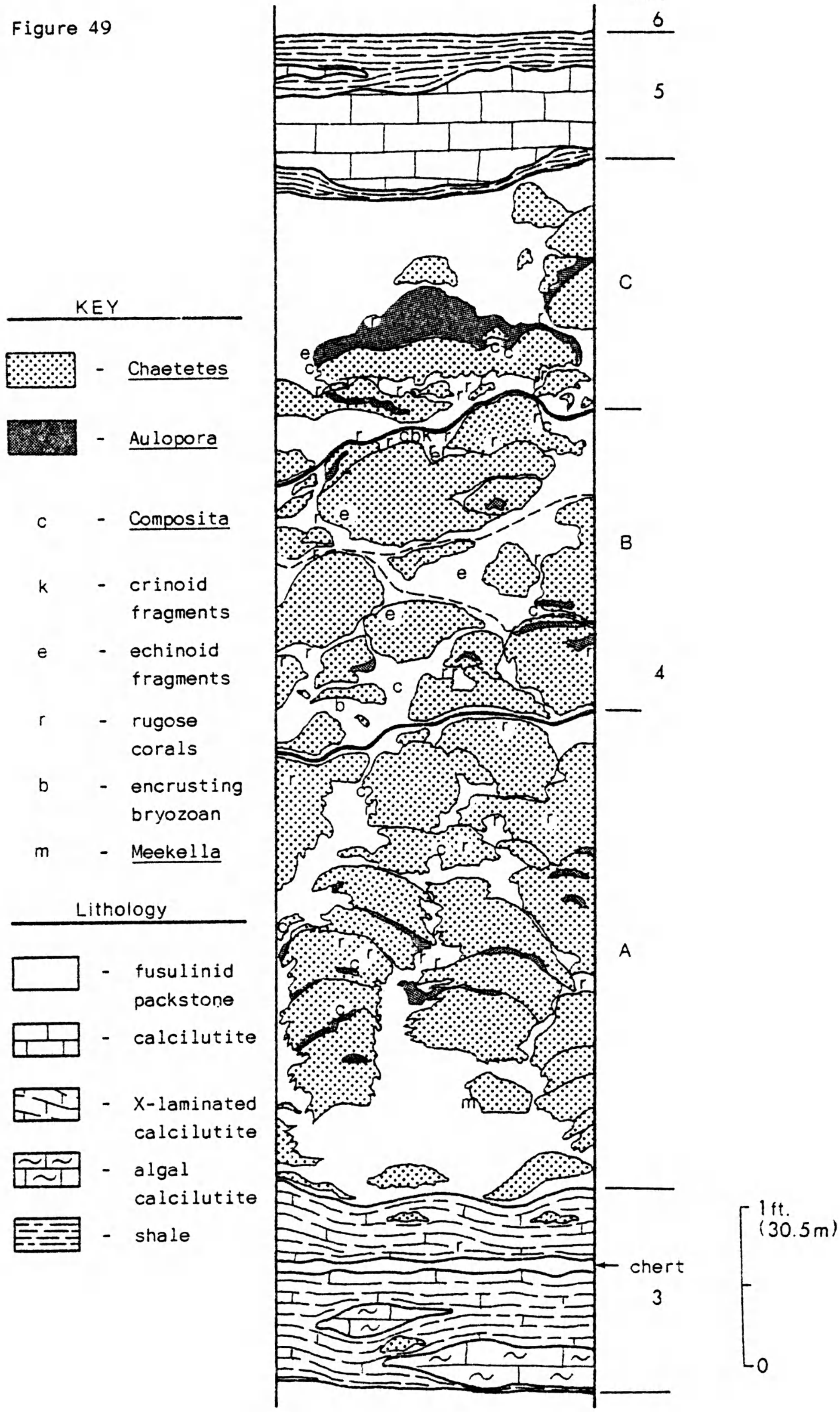

Bed No.
6
E
D
C
5
B
A
C
4
B
A
3
chert
2
KEY
Chaetetes
Aulopora
c - Composita
k - crinoid fragments
e - echinoid fragments
r - rugose corals
z - chonetid
m - Meekella
g - gastropod
Lithology
fusulinid packstone
calcilutite
X-laminated calcilutite
algal calcilutite
shale
1 ft.
(30.5m)
0

Figure 49. Species Map at Sta. 24, a 2-foot (.61 m) wide vertical section at station 24, showing species occurrences in bed 4 and lithologic relationships in beds 3 and 5. Of the fossils shown, only the crinoid and echinoid fragments have been transported; all the rest are apparently in situ. The matrix (fusulinid packstone) in bed 4 is cross laminated in most of the chaetetid-rich areas, and is strongly cross laminated in interval 4'b'.

Figure 49


Bed No.
6
5
C
B
4
A
chert
3
1 ft. (30.5m)
0
KEY
Chaetetes
Aulopora
c - Composita
k - crinoid fragments
e - echinoid fragments
r - rugose corals
b - encrusting bryozoan
m - Meekella
Lithology
fusulinid packstone
calcilutite
X-laminated calcilutite
algal calcilutite
shale

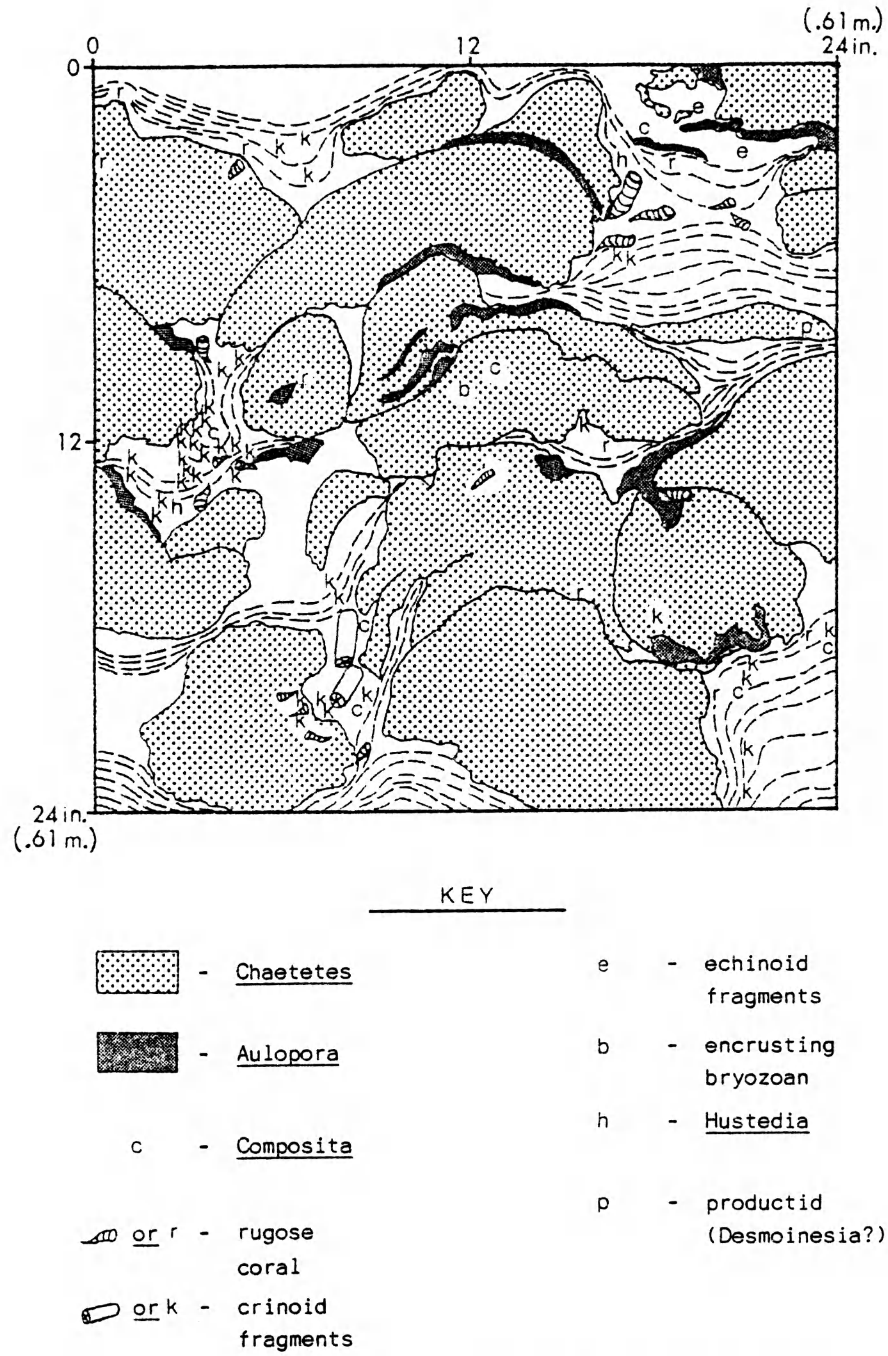


Figure 50. Species Map at Sta. 29, a 2-foot (.61 m.) square vertical section covering most of interval 4'b', 3 ft. (.91 m.) south of station 29. Crinoid and echinoid fragments have been transported at least a little; all others are apparently in life position. The matrix is strongly cross laminated fusulinid wackestone; cross laminations are accurately drawn in the sketch.

The area at station 2a (Figure 48) was chosen because of the lack of chaetetids above interval 4'a' (also see Figure 34 and section 2a in Appendix B). Chaetetids and Aulopora are well developed in interval 4'a', but apparently were terminated by the "energy event" that initiated deposition of interval 4'b'. They do not occur above this point at this station. Within interval 4'b', 3 or 4 other cross laminated partings occur. Crinoid and echinoid debris is a common constituent of intervals 4'b' & 'c'. In bed 3, notice the nodular chert and the laminar chaetetids in the algal calcilutite lens. In interval 4'a', notice the cycles of chaetetid/Aulopora overgrowths, and in bed 5, the continuity of both limestone lenses.

The area at station 24 (Figure 49) was chosen because it cuts directly through the middle of a loosely packed chaetetid clump (also see Figure 33 and section 24 in Appendix B). Interval 4'b' is relatively thin here but can be easily traced through the chaetetid occurrences; it exhibits more cross laminations and darker matrix than intervals 4'a' and 4'c'. The chaetetids were already very well established in interval 4'a', forming a clump which continues through interval 4'b' and halfway through interval 4'c', where chaetetids are overgrown by the thickest (4 in.; 10.2 cm) occurrence of Aulopora seen in the quarry. Also note the other Aulopora overgrowths on chaetetids throughout the section. In bed 3, the chert occurs as a thin continuous layer at station 24, algal calcilutite lenses below the chert are small, and a few small laminar chaetetids occur. In bed 5, the lower limestone lens is relatively thick and well developed, and the upper limestone lenses pinches out.

A small area just south of station 29 (Figure 50) was chosen to be drawn at a larger scale because it is directly in the middle of a chaetetid clump and it exhibits many interesting features of species associations and species/sediment relationships that are typical of the chaetetid clumps. Notice the common _Aulopora_ overgrowths on the chaetetids and the well defined cross laminations in the matrix, which has apparently washed in and filled cavities amongst the chaetetids. Also notice the organisms that are apparently in life positions. Rugose corals (_Lophophyllidium_ sp.) are very common, most of them _in situ_, having been attached and living where they now occur, including those within the sediment in the upper right of the sketch (suggesting at least partial early marine cementation). They evidently preferred protected hollows among the chaetetids. _Aulopora_ and _Chaetetes_ attached directly to the substrate (matrix) in some places also suggest early marine cementation of sediments. Most of the brachiopods (_Composita_, _Hustedia_, and a productid) are also _in situ_, and some of the rugose corals and chaetetids are encrusted with bryozoans (_Fistulipora_). Two small hollows between chaetetids (in lower left and left center of sketch) show accumulations of crinoid stems and plates that are well preserved and unabraded, suggesting that partial specimens had been carried in from nearby and became disarticulated in place.

A variety of organisms preferred living in protected hollows in the chaetetid "reef" or attached to the chaetetids. Of course, _Aulopora_ overgrowths on chaetetids have been mentioned several times (see Figures 46 and 48-50) and rugose corals were common "reef" dwellers (Figure 50). Several specimens of the encrusting oyster-like bivalve, *Pseudomonotis* sp., were found on the surfaces of chaetetids, as were many specimens of *Composita*. Many times these attached forms became embedded in and totally encased by growing chaetetids. Several instances of accumulations of crinoid columnals, calyx plates, and cirri were noted in the matrix in hollows between chaetetids, suggesting in-place disarticulation of specimens, and similar occurrences of echinoid plates and spines were found (Figure 51). Evidently the development of these chaetetid bioherms provided favorable environments for the proliferation of many types of organisms, probably including numerous soft-bodied forms for which we find no record.

In the fusulinid packstone away from the chaetetids, we see primarily fusulinids, other foraminiferids, ostracodes, and pellets. Macrofossils sometimes occur as concentrations of broken skeletal debris that apparently are lag-type deposits, but no *in situ* fossils were observed. It is interesting to note that regionally (see Chapter 2), chaetetid occurrences are closely associated with abundant fusulinids (localities 339, BUT, J48, & J91) or are embedded in a fusulinid packstone matrix (localities 700 & 706) (see Appendix A).

Conclusions

A very diverse fauna with stenohaline elements lived in the environment of the chaetetid "reefs", and many of the specimens were buried in the positions and orientations in which they lived. The

Figure 51. Closeup of echinoid spines and plates between chaetetids, as if the echinoid had been living there, then died and became disarticulated in place. Pencil points to echinoid fragments. This horizontal surface is near the top of interval 4'b' and is exposed on the ground surface above station 34. Portion of pencil showing is approximately 10 cm long.

diverse stenohaline fauna and high energy indicators (e.g., cross laminations, toppled chaetetids, shell lag deposits) suggest shallow, well-aerated, open marine conditions. It appears that these chaetetid "reefs" were similar to modern reefs in that they served as havens and homes to a tremendous variety of organisms.

CHAPTER 6

PALEOECOLOGY OF BED 3 (LOCALITY 700)

Introduction

Thin slabs of fossiliferous limestone from just below the chaetetid bed at locality 700 were examined in detail to determine the environmental conditions and paleoecology represented by these rocks. Two slabs, each less than 7 cm thick, were collected approximately 80 meters south of station 34 shown on the topographic map of the quarry (Figure 52). Although the slabs were taken from a loose boulder, their lithology and position in relation to the other rock types of the boulder made it possible to determine the proper orientation and stratigraphic position of the slabs within the Houx-Higginsville Limestone in the quarry. The stratigraphic position of the slabs was 7 to 15 cm below the nodular chert layer in bed 3 shown on stratigraphic section 700 of Appendix A. In other words, they occurred at the top of PAC 2 as interpreted in chapter 2 (see Figures 53 and 13).

The larger slab has maximum dimensions of 65 cm long by 39 cm wide by 7 cm thick, with a total surface area of 1,739 square centimeters. The smaller slab has maximum dimensions of 43 cm long by 23 cm wide by 4.5 cm thick, with a total surface area of 855 square centimeters. Fossil data were taken from the upper surfaces of both slabs and a section perpendicular to bedding was cut from the smaller slab and made into thin sections.

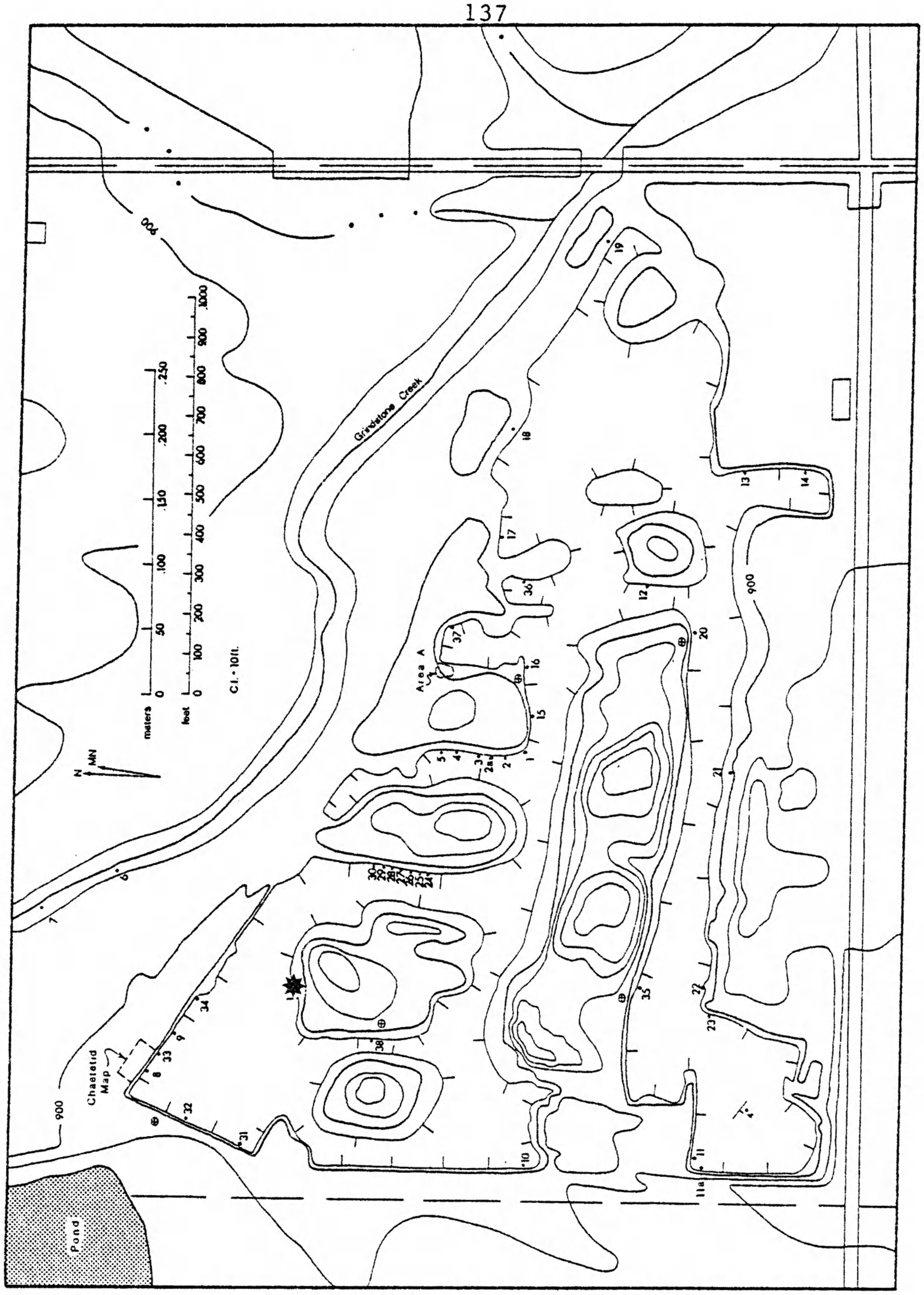


Figure 52. Topographic map of quarry. Star shows location of boulder from which rock slabs for study in this chapter were taken.

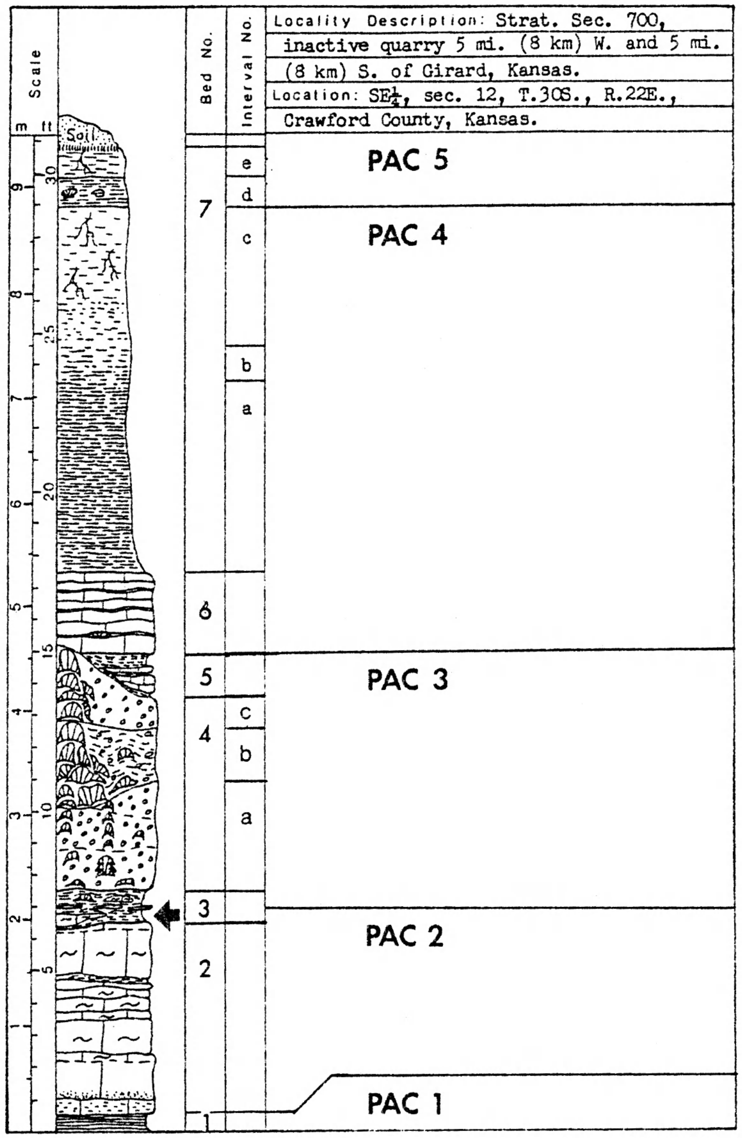


Figure 53. Composite stratigraphic column of rocks in Niggeman quarry, showing the PAC's. Arrow points to stratigraphic position to which the 2 slabs belong.

General Rock Description

The rocks are light gray (N7), fossiliferous calcarenite to calcilutite, fusulinid-rich, laminated and cross laminated with thin, wavy, black clay partings. Most of the grains are fossils (largely fusulinids and brachiopods), and fossil fragments in a micritic matrix. The grains in the rock are poorly sorted, with ratios of grains/matrix ranging from 20/80 to 50/50. The cross laminated, black clay partings have been considerably enhanced by compaction and pressure solution. This will be discussed in a later section, as will the sedimentary structures and features, species abundance, the articulation, orientations, and size distributions of the fossils, and the diagenesis of this interval.

Sedimentary Structures and Features

The cross laminations in these slabs are 0.1 to 5.0 mm thick and form ripples with wavelengths of 6 to 30 cm and amplitudes of 0.2 to 2.5 cm. The particles (especially the fusulinids and skeletal grains) are aligned parallel to the laminations. There may be some imbrication of the fusulinids and larger skeletal grains, suggesting current winnowing. Black, clay-rich films (probably insoluble residues concentrated by pressure solution) coat many of the rippled bedding surfaces. There is little or no bioturbation.

A nonlaminated layer of calcilutite, 0.5 to 1.5 cm thick where not weathered away, occurs on the upper surfaces of the slabs (Figure 54).

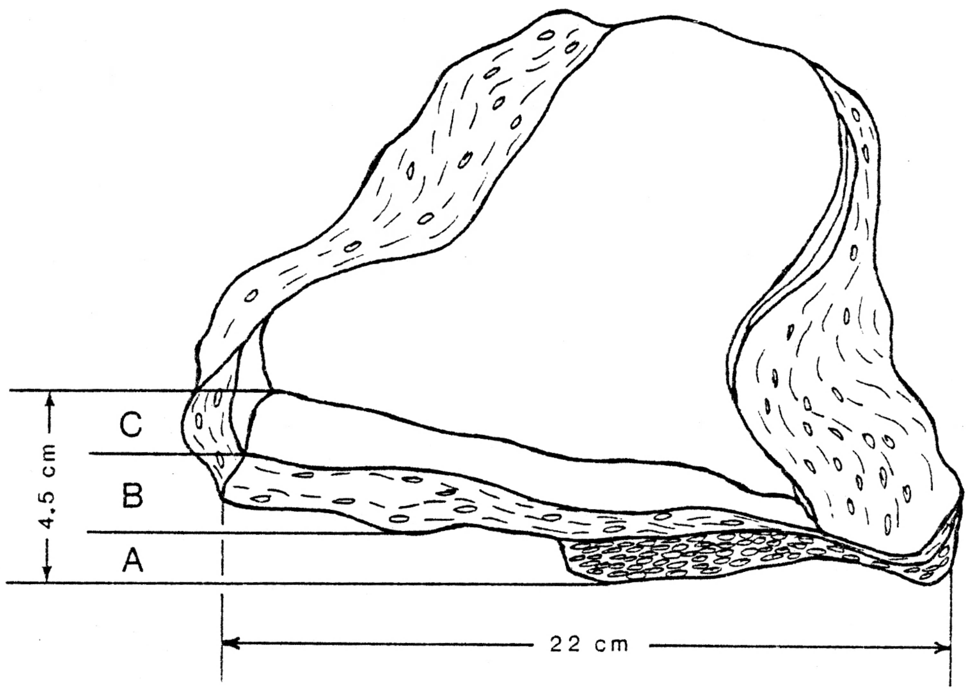


Figure 54. Generalized schematic drawing of smaller rock slab, with vertically cut section facing forward. Layers A & B are cross laminated and fusulinid - rich. Fusulinids are especially concentrated in pockets in layer A. Layer C is nonlaminated calcilutite (carbonate mudstone). Contacts between the layers are not as distinct as shown here.

It contains and covers a large number of articulated brachiopods and small *in situ* corals and chaetetids. Evidence will be presented to suggest that the surface of layer B (Figure 54) represents a temporary omission surface on which living organisms became attached (e.g., *in situ* fistuloporids, chaetetids, corals, and *Crurithyris*), and that the carbonate mud layer (layer C of Figure 54) was washed in as a single event which smothered the fauna. The contact between layers A and B is gradational and the contact between layers B and C is sharp although difficult to pinpoint in places because the matrices are so similar.

Fossils are most abundant in the laminated layers (40-80% of the rock in lenses, 20-40% in the remainder), but the nonlaminated layer also contains a large proportion (15-25% of the rock) of fossils. Some of the fossil concentrations in lenses contain primarily fusulinids.

Fossils

Species Abundance. -- The fossil taxa on the upper surface of each slab were counted and tabulated (Table 1). It can be seen that, in terms of numbers of taxa and individuals, the rocks record a diverse assemblage of organisms. There are 23 different species in all and a total of 340.39 individual specimens per square decimeter, excluding the fenestrate and ramose bryozoan fragments, the crinoid and echinoid skeletal fragments, and unidentifiable shell debris.

Most of the fossils were not differentiated as to which layers they belonged (B or C) because of the difficulty in clearly delineating the layers in places and because of error that might be introduced due

Table 1. Taxa Presence in slabs from Bed 3, Locality 700.

Taxon	Lg. Slab (1,739 sq. cm.)	Sm. Slab (855 sq. cm.)	Total (2,594 sq. cm.)	Total per sq. dm.
Brachiopods				
Chonetina flemingii	1	0	1	0.04
Cleiothyridina orbicularis	55	27	82	3.16
Composita sp. (see Table 2)	84	50	134	5.17
Cooperina sp.	1	0	1	0.04
Crurithyris planoconvexa	107*	**	2,770***	107.00
Derbyia crassa	1	0	1	0.04
Desmoinesia muricatus	14	4	18	0.69
Dielasma bovidens	13	5	18	0.69
Hustedia mormoni	29	17	46	1.77
Bryozoans				
Fistulipora sp.	109	25	134	5.17
fenestrate bryoz. frags.	1	1	2	----
fragile ramose bryoz. frags.	11	3	14	----
Sponge				
Chaetetes sp.	8	4	12	0.46
Corals				
Aulopora sp.	9	2	11	0.42
Lophophyllidium sp.	13	2	15	0.58
Echinoderms				
Crinoids: stems & cirri (articulated with at least 3 or more columnals)	28	19	47	----
Echinoids: plates	51	80	131	----
spines	6	4	10	----
Foraminiferids				
Fusulinids****	54*	**	1,400***	54.00
Tetrataxis sp.	67*	**	1,700***	67.00
Palaeotextulariids	56*	**	1,400***	56.00
Polytaxis sp.	38*	**	900***	38.00
Trilobite				
Ameura sp.	1	0	1	0.04
Annelids				
Spirorbis sp.	2	1	3	0.12
			TOTAL	340.39

* = within 10 X 10 cm area

** = similar to large slab

*** = approximate (extrapolated)

**** = lensoidal concentrations of fusulinids increase their total numbers much higher than indicated here.

to the occurrence of some fossils associated with layer B that protrude through layer C and might wrongly be attributed to layer C. However, it appears overall that 90% of the brachiopods, over 80% of the bryozoans, 50% of the echinoderm fragments, and 90% of the foraminiferids are associated with layer B. All of the chaetetids except one (attached), all of the specimens of *Aulopora* sp., and all of the rugose corals except one (aperture down) occur in layer B. The trilobite fragment and spirorbids are on the surface of layer B.

Foraminiferids are the most abundant fossils in terms of sheer numbers of specimens present. The numbers of foraminiferids tabulated in Table 1 were taken from a 10 X 10 cm area on the large slab that was selected because of its apparently average concentrations of foraminiferids. The numbers listed for the total surface area of the slabs are estimates projected from that 10 X 10 cm area. Although this tabulation makes it appear that specimens of fusulinids are less abundant than specimens of *Tetrataxis* sp. and palaeotextulariids, it does not take into account the concentrations of fusulinids in pockets where they may constitute up to 80% of the rock. Thus, fusulinids (probably *Fusulina girtyi*) are the most abundant fossil in these slabs.

The next most abundant fossils are brachiopods, 10 species in all (including the 2 species of *Composita* delineated in Table 2). By far the most abundant brachiopod is *Crurithyris planoconvexa* (107 specimens per square decimeter). *Composita* sp. and *Cleiothyridina orbicularis* are also quite abundant and *Hustedia mormoni* is very common.

Because of the great abundance of *Crurithyris planoconvexa*, all data for this species were taken from a 10 X 10 cm area (separate from

Table 2. Specimens of Composita that can be assigned a species name.

	C. subtilita	*C. ovata*
Large slab	18 (72%)	7 (28%)
Small slab	10 (66%)	5 (33%)
Total	28 (70%)	12 (30%)

(N = 40 = 30% of total number of *Composita* specimens).

the one used for the foraminiferids) on the large slab. The area was selected because it appeared to contain a more or less typical sample of C. planoconvexa for the slabs. If the number of specimens present in that area is projected to the entire surface area of both slabs, there are an estimated 2,770 specimens present.

Of the 134 specimens of Composita sp. counted on the two slabs, only 29.9% could be assigned species names (Table 2). The remainder were either too fragmented by compaction or the distinguishing features were hidden within the rock. However, the general impression from the portions of the shells that could be seen is that the tally in Table 2 is representative of the sample as a whole. That is, C. subtilita constitutes 70% of the population and C. ovata makes up the remainder.

Among the bryozoans, the fistuliporids are quite abundant. Fenestrate bryozoan fragments are rare and are badly broken and abraded. Fragile ramose bryozoan fragments are relatively common but are also badly broken and abraded, although one (less that 1 cm high), which was lying flat and unattached on the surface of the carbonate mud layer (layer C), was mostly intact with the holdfast, main stem and several branches present.

Colonies of Aulopora sp. are small (1 - 3 cm) and sparsely branched and the rugose corals (Lophophyllidium sp.) are small (0.5 - 1.8 cm long) but fairly common. Chaetetids are small (2 - 52 mm) and common.

Crinoid stems and cirri that were counted (Table 1) were only those that were articulated with at least 3 columnals. Echinoid spines (probably of the genus Archaeocidaris) are present, as well as a number of thick echinoid plates, most of which are ambulacral plates but a few of which could be spine bases.

It is important to note here that in going upward in the stratigraphic section in the quarry, the level from which these slabs were taken records the first occurrence of chaetetids. No chaetetids occur below this point. In the overlying 2 - 2.5 meters, chaetetids become very well developed, especially in the upper part where clumps of chaetetid colonies may be 3 - 6 meters across. So at the time of deposition of the sediments represented by this part of bed 3 (see Figure 53), chaetetids were just barely getting started. The few tiny specimens noted in these slabs represent the first feeble attempt at colonization of the substrate by chaetetids at this locality. The possible factors involved in initiating chaetetid development and where this bed fits into the PAC interpretation of the rocks was discussed in Chapter 2 and will be further discussed later. Conditions apparently were not yet favorable for substantial chaetetid growth at this locality.

Articulation. -- A large majority (66 -90%) of the brachiopods present are articulated (Table 3), with the exception of *Desmoinesia muricatus*, of which 78% are too fragmented to determine the state of articulation, and *Cooperina* sp. and *Derbyia crassa*, of which only one specimen each are present. The state of articulation of most of the remainder (10 - 30%) could not be determined because the specimens are either too fragmented (mostly from compaction) or the critical areas are obscured within the rock.

Table 3. State of Articulation of Brachiopods.
For the disarticulated valves: B = brachial, P = pedicle, and U = undetermined.

Taxon	Articulated	Disarticulated	Indeterminate
Chonetina flemingii			
Large slab	0	1 (P)	0
Small slab	0	0	0
Total	0	1	0
Cleiothyridina orbicularis			
Large slab	38 (69%)	2 (4%)(1B,1U)	15 (27%)
Small slab	16 (59%)	2 (7%)(2U)	9 (33%)
Total	54 (66%)	4 (5%)	24 (29%)
Composita sp.			
Large slab	60 (71%)	2 (2%)(1B,1U)	22 (26%)
Small slab	35 (70%)	4 (8%)(1B,1P,2U)	11 (22%)
Total	95 (71%)	6 (5%)	33 (25%)
Cooperina sp.			
Large slab	0	1 (P)	0
Small slab	0	0	0
Total	0	1	0
Crurithyris planoconvexa			
Large slab (10 X 10 cm. area)	86 (80%)	0 (0%)	21 (20%)
Derbyia			
Large slab	0	1 (B?)	0
Small slab	0	0	0
Total	0	1	0
Desmoinesia muricatus			
Large slab	4 (29%)	0 (0%)	10 (71%)
Small slab	0 (0%)	0 (0%)	4 (100%)
Total	4 (22%)	0	14 (78%)
Dielasma bovidens			
Large slab	12 (86%)	0 (0%)	2 (14%)
Small slab	5 (100%)	0 (0%)	0 (0%)
Total	17 (90%)	0 (0%)	2 (11%)
Hustedia mormoni			
Large slab	19 (66%)	3 (10%)(3U)	7 (24%)
Small slab	12 (71%)	2 (12%)(1P,1U)	3 (18%)
Total	31 (67%)	5 (11%)	10 (22%)

This large proportion of articulated brachiopods suggests that they had been living there and were buried or at least that they were not transported very far. Brett and Baird (1986, p. 211) stated "Disarticulation of bivalved skeletons typically occurs very rapidly (usually a few weeks or less in aerobic, marine environments...). Hence, clusters of intact brachiopod or bivalve shells may mark rapidly smothered seafloors." Some of the articulated shells have black films on their interiors or emanating as small "tongues" from their anterior commissures, suggesting that the soft tissue was present at the time of burial and all that now remains is a black carbon stain. Most of the articulated brachiopods are filled with carbonate mud but a few contain clear spar fillings. They are mostly unabraded and well preserved.

Several crinoid columns (3 mm thick) and cirri (1 mm thick) occur that are articulated in lengths up to 30 mm and 11 mm, respectively, and are virtually unabraded. Meyer and Meyer (1986, p. 301 and 302) stated "crinoid ossicles apparently are not buoyant and do not have to be 'prefossilized' before they are susceptible to traction transport and abrasion" and "in the absence of rapid burial, crinoid skeletons undergo virtually total disarticulation." Thus, one might infer that the crinoid ossicles in these rocks underwent little transportation.

A concentration (7-8 cm across) of echinoid plates, mostly ambulacral plates, occurs on the small slab. Very few, if any, of these plates are spine base plates, and only 5 or 6 very small (less than 4 mm long) echinoid spines are present. These plates are only slightly abraded. This suggests that there was some selective sorting of particles. Perhaps this sorting was related to predation or perhaps an echinoid died and became disarticulated there and currents winnowed out some parts before the remaining ones were buried by sediments.

Fossil Orientations. -- Orientations of some of the taxa were examined to get an idea of the amount of disturbance that occurred prior to or during burial. The results are tabulated in Table 4.

Of the fistuliporids, 56% are in life position, 39% are not in life position, and the position of the remainder could not be determined. It was noted that, of the ones that are not in life position, most are well abraded and many are broken. Some are tilted on edge whereas others are completely turned over. Some of the ones that are in life position are also abraded and broken, and it is difficult to tell if they had actually been attached to the substrate. However, over 75% of the ones in life position are well preserved and conform to the substrate in such a manner as to suggest that they were attached and living there before being buried. Over 80% of the fistuliporids are associated with layer B but a few on the surface of layer C appear to have been attached and living there, thus suggesting that layer C also may have become a temporary omission surface.

Many of the chaetetids, of which 75% are in life position, also are well preserved and conform to the substrate as if they had been attached and living there. They are all very small, some only 2 - 3 mm across. Interestingly, the largest one, 52 mm across, had apparently been turned over. The only one not associated with layer B is attached on the surface of layer C, further evidence that layer C became another omission surface.

Table 4. Orientations of some Taxa

Taxon	In Life Position	Not in Life Position	Indeterminate
Fistuliporids			
Large slab	63 (58%)	42 (39%)	4 (4%)
Small slab	12 (48%)	10 (40%)	3 (12%)
Total	75 (56%)	52 (39%)	7 (5%)
Chaetetids			
Large slab	6 (75%)	2 (25%)	0 (0%)
Small slab	3 (75%)	1 (25%)	0 (0%)
Total	9 (75%)	3 (25%)	0 (0%)
Aulopora colonies			
Large slab	7 (78%)	2 (22%)	0 (0%)
Small slab	1 (50%)	1 (50%)	0 (0%)
Total	8 (73%)	3 (27%)	0 (0%)
Lophophyllidium sp.			
Large slab	5 (39%)	5 (39%)	3 (23%)
Small slab	1 (50%)	1 (50%)	0 (0%)
Total	6 (40%)	6 (40%)	3 (20%)
Crurithyris planoconvexa			
Large slab (10 X 10 cm. area)	62 (58%) (72% of the articulated specimens)	45 (42%)	0 (0%)

The colonies of Aulopora sp., all associated with layer B, are small and sparsely branched, but 73% are apparently in life position, judging from the way they conform to the substrate and how the ends of the calices are turned up. The remainder occur with their calices turned down or occur amongst piles of shell debris so that they could clearly be inferred to be transported fragments.

The rugose corals (all but one associated with layer B) are small and sparsely distributed and only 40% appear to be in life position. They are all moderately to severely abraded.

According to Alexander's (1986) study of Chesterian brachiopods in the Chainman Formation of Utah, many of which are the same species as seen in the rocks of this study, brachiopods such as Cleiothyridina orbicularis, Composita sp., and Hustedia mormoni were probably oriented in life with their pedicles attached to the substrate and their commissures steeply inclined to nearly vertical. On the two rock slabs, these are mostly oriented with their commissures subparallel to the bedding planes, but a few have their commissures steeply inclined upward, and some are buried with their anterior commissures down. This suggests that most were at least slightly reoriented prior to or during burial and some were even torn loose and rolled.

Brachiopods such as Desmoinesia muricatus and Crurithyris planoconvexa probably lived reclining on the pedicle valve with the anterior elevated away from the substrate (Alexander, 1986). Of the 18 specimens of D. muricatus recorded in Table 1, three are articulated and in life position and one is articulated and tilted on edge (see Table 3). The rest are too fragmented by compaction and/or transportation to determine their state of articulation or orientation.

Crurithyris planoconvexa is the most abundant brachiopod on the rock slabs (Table 1) and 80% of them are articulated (Table 3). Of those articulated specimens, 72% are in life position (Table 4). They occur with their pedicle valves half sunk in the mud and their flat brachial valves elevated above the substrate. Of the 107 specimens counted in the 10 X 10 cm area, only 8 occur in layer C, and of those 8, 4 are articulated and in life position and 4 are of indeterminate articulation and not in life position. The occurrence of the overwhelming majority of articulated, life-position specimens on the surface of layer B suggests that layer B represents a temporary omission surface where the *C. planoconvexa* specimens were living and that layer C represents a carbonate mud layer that was washed in as a single event and smothered the organisms that were living there. Some of the specimens are turned over with the brachial valve against the substrate, suggesting enough current energy to reorient a small percentage of them.

Additionally, one pedicle valve of *Cooperina* sp. occurs in life position, attached to the laminated substrate. Also, three spirorbid worm tubes, two of which are well preserved and in life position, are attached to the laminated substrate. This is further evidence that the laminated layers represent temporary omission surfaces.

Specimens of *Tetrataxis* sp. and *Polytaxis* sp. were seen with their oral apertures pressed against chaetetids, shell fragments, and even the substrate, suggesting they were attached and living there as well.

A single brachial(?) valve of *Derbyia crassa* (interior against the substrate), a single valve of Chonetina flemingii, and a pygidium of Ameura sp. are each oriented parallel to the bedding planes, within the laminated layers, and are broken and abraded.

The great abundance of fossils in the two rock slabs, together with their orientations and state of articulation, suggests that they represent a once-thriving fossil community, yet the small sizes of most species suggest that it was an early colonization stage that was destroyed. Even at this early stage, there may have been some vertical partitioning of resources. If put into the terms of Palmer (1982, p. 320), crinoids might have constituted the "canopy layer" and/or the "scrub layer," whereas Cleiothyridina orbicularis, Composita sp., Hustedia mormoni, and Lophophyllidium sp. constituted the "field layer," the low profile brachiopods such as Crurithyris planoconvexa and Desmoinesa muricatus and the fistuliporids made up the "ground layer," and the echinoids were deposit feeders or grazers.

Diagenesis

Thin sections were made from one vertical section which was cut from the smaller of the two rock slabs. The detailed description of these thin sections is included in Appendix C. Examination of these thin sections allowed a determination of a general depositional and diagenetic history of the rocks.

1. First, deposition of the lower layers occurred in a moderately energetic marine environment during a minor sea level lowering at the end of PAC 2 (see Figure 13). Early cementa-

tion began in the form of isopachous fringes of acicular aragonite on the outsides of some brachiopod shells and other allochems, and in the form of a fringe of stubby Mg - calcite crystals on the insides of some articulated brachiopods. Much of the matrix may have been peloidal, micritic, calcitic cement as shown by Scoffin (1987, p. 92 and 93, figures 8.2 and 8.3-F).

2. Early cementation allowed for a relatively firm substrate on which organisms could become attached. More sediments were washed in (i.e., the carbonate mud layer) and then other organisms became attached. Cementation continued at a slow rate. Some shells and fragments were moved around and abraded. This all took place in warm, supersaturated, shallow seas, with early cementation occurring at or just below the sediment-water interface (Scoffin, 1987) in the active marine phreatic zone of Longman (1980). Movement of water through the pore spaces was aided by tides, waves, and currents (Longman, 1980).

3. As sea level rose again during deposition of PAC 3 (see Figure 13) and more sediments were accumulated, the active marine phreatic zone migrated upward, leaving the sediments of this interval within the stagnant marine phreatic zone of Longman (1980). During this time, intragranular cementation in tiny skeletal pores (i.e., in skeletal chambers of foraminiferids and fistuliporids) occurred (Longman, 1980). Other changes that might have come about include micritiza-

tion of foraminiferid and fistuliporid skeletons, algal and fungal micritization of other shells and cement (Longman, 1980), and some crushing of empty shells and minor stylolitization of grain contacts (Heckel, 1983). According to Longman (1980, p. 468), "other than this micritization and the minor intragranular cementation, little diagenesis occurs in the stagnant marine phreatic environment."

4. Sea level fell slowly and rose once again before receding to the point that subaerial deposition occurred at this locality (see Figure 13). Thus, sediments of the rock slabs were progressively subjected to the marine phreatic environment followed by the mixing zone environment followed by the freshwater phreatic environment. In the mixing zone, there may have been slight calcitic cementation, minor neomorphism of aragonite to calcite, leaching of aragonite, and neomorphism of Mg-calcite to calcite (Longman, 1980), and possibly the formation of dolomite rhombs (Scoffin, 1987). In the stagnant freshwater phreatic zone, further neomorphism of aragonite to calcite probably occurred slowly within the grains "across a narrow front" (Longman, 1980, p. 477), thus preserving the structures of the aragonitic shells. As the water table dropped and the rocks were subjected to the active freshwater phreatic zone, final leaching and neomorphism of aragonite shells occurred, resulting in the final recrystallization of unstable grains and of some micrite to calcite and filling of molds with sparry calcite (Longman,

1980). Rare syntaxial overgrowths on echinoderm fragments also developed in this environment (Longman, 1980).

5. Subsequent addition of sediments resulted in compaction, which fractured some shells and deformed the internal sparry calcite casts within, and caused significant pressure solution features such as microstylolites, grain-to-grain sutured contacts, and secondary clay seams (see Bathurst, 1975, p. 471-472, and Ricken, 1986).
6. Further late diagenesis resulted in the filling of compaction fractures with sparry calcite. This could have occurred at any time since original compaction of the sediments.

Conclusion

The evidence gathered from the two rock slabs from bed 3 is consistent in supporting the interpretation that a diverse fossil community had become established at that locality at that time. Early cementation of the sediments allowed colonization of the substrate by a variety of attached organisms, resulting in a fairly well balanced, early stage hardground community. For some species, several generations had become established, but for chaetetids, only the first feeble efforts at colonization had been attempted.

The waters were well aerated and somewhat agitated, apparently being periodically or even regularly affected by normal wave base. Occasional storm events brought influxes of sediments to the area. One such event caused the burial of the local fauna by a carbonate mud layer (layer C). Subsequent sedimentation and changes in sea level across the area resulted in a complex diagenetic history ranging from early marine cementation, through several marine and freshwater phreatic environments, and finally to late stage mobilization and reprecipitation of calcite.

CHAPTER 7

DIAGENESIS

Introduction

Thin section examination of samples, in conjunction with field study, and visual and microscopic observations of hand samples, polished sections, and acetate peels, allowed further insights into the depositional and diagenetic history of the Houx-Higginsville Limestone at locality 700. Preliminary results of staining of some thin sections by Dr. Stephen Kershaw, visiting professor at KSU, has yielded information concerning the ferroan and nonferroan content of calcite and dolomite in the rocks. Throughout this chapter please refer to the detailed descriptions of thin sections in Appendix C.

Pervasive Diagenetic Features

Some diagenetic features are pervasive throughout the Houx-Higginsville Limestone in the Niggeman quarry. One aspect of this is the overriding aggrading neomorphism, manifested predominantly by replacement of micritic matrix by patchy pseudosparite and sparite, and replacement of unstable grains by sparry calcite. Scoffin (1987, p.105) stated that aggrading neomorphism is "very rare in sea water though it has been reported in a few (more commonly deeper-water) areas," and thus it normally happens in a freshwater setting.

The neomorphic spar is a mixture of ferroan and nonferroan calcite (dominantly ferroan) with minor patchy ferroan dolomite. Some algal blades and brachiopod fragments are nonferroan and some are ferroan calcite, and chaetetid skeletal pores have two generations of cement: a nonferroan calcite fringe and ferroan calcite fill. The chaetetid pore cements suggest an early marine cement fringe followed by later filling in an anaerobic environment, perhaps burial. The differences among algal blades and brachiopod fragments suggests either two generations of recrystallization or differences in replacement due to taxonomic differences. The mixture of ferroan and nonferroan neomorphic spar, some of which is gradational between the two, suggests a fluctuating environment due to movement of pore waters in the meteoric zone. Lack of any preserved microstructure in algal blades suggests they were dissolved, then replaced later.

Another pervasive feature is the presence of peloidal, micritic, calcitic cement (Scoffin, 1987). These micritic peloids apparently grow in marine "interstitial water by chemical precipitation, but they also can contain small quantities of incorporated extraneous material such as clay minerals" (Scoffin, 1987, p.96). Post-burial neomorphism may bring about some crystal enlargement, obscuring the peloidal texture and producing a clotted texture sometimes referred to as "structure grumeleuse" (Scoffin, 1987, p.96). Some of these peloids may be actual fecal pellets, and indeed some were recognized as such (see thin sections 700-31-9, 700-31-17, 700-2a-2, 700-24-11, and 700-32-5 in Appendix C).

A diagenetic feature seen in all limestone intervals is the micritization of skeletal walls in all foraminiferids and fistuliporids and clear spar filling of their skeletal chambers. Articulated ostracodes are also filled with clear spar, but their shells commonly preserve original calcite and microstrucutre. In a few instances, particularly in bed 6, the spar filling has been partially micritized. In most cases, the spar filling and skeletal walls have undergone later recrystallization in which relict structure has been preserved; crystals are now a mixture of ferroan and nonferroan calcite. Some authors have suggested that micritization of skeletal pores occurs in the stagnant marine phreatic zone (Longman, 1980). Later recrystallization could have occurred under changing pore water conditions in the meteoric zone, or during later anaerobic burial diagenesis.

Several generations of cement can be found throughout most of the section. Early marine cementation is rather unevenly distributed and will be discussed later. Spar filling of larger skeletal voids (e.g., of articulated brachiopods) and shelter voids commonly show several (sometimes 3 or more) layers of cement, suggesting that the rocks were subjected to several episodes of alternating sea water and fresh water environments, which fits into the regional model of fluctuating sea level. Investigation of separate generations of cement was done by Knight (1985) and is currently underway at Kansas State University by Dr. Stephen Kershaw.

Very minor patchy chertification and pyritization occur throughout the section, usually within or closely associated with small skeletal fragments or along the edges of chaetetids. This suggests local reducing microenvironments, possibly associated with decay of organic debris.

Compaction features can also be found throughout the section, although they are somewhat unevenly distributed. In outcrop and in hand sample, differential compaction is indicated by draping of laminae over resistant objects such as chaetetids, by compaction fractures, and by compaction slickensides on the flanks of chaetetids. In thin section, very minor early compaction is evidenced by partial crushing of some articulated brachiopods (thin section 700-31-11). Late stage compaction is indicated by grain-to-grain sutured contacts and microstylolites, which preferentially occur at specific periodic intervals (i.e., enhancing cross laminated, clay-rich layers, such as in beds 2 and 3), and by crushing of some spar-filled articulated brachiopods and coincident deformation of spar filling (thin section 700-31-8). Compaction was presumably the result of accumulation of overlying sediments which are now eroded away. Many compaction fractures are filled with a mixture of ferroan and nonferroan calcite, indicating late stage mobilization of calcite, perhaps under fluctuating meteoric conditions or during burial.

Unevenly Distributed Diagenetic Features

Some diagenetic features tend to be more prevalent in some beds than in others. One example is the occurrence of early marine cement, most often as fringes of Mg-calcite blades, and less frequently as aragonite needle fringes (now replaced) or as radiaxial fibrous mosaic (Bathurst, 1975, and Scoffin, 1987). In bed 2, minor early marine cement was found only in intervals 2'b' & 'd' (thin sections 700-31-4 and 700-31-7) and in intervals 2'g' & 'h' (thin sections 700-31-11, 700-31-12, & 700-24-18). In bed 3, it is quite common (thin sections 700-31-14, 700-24-17, 700-slab, 700-4-3, & 700-4-8), and in bed 4, it occurs only in intervals 4'b' & 'c' (thin sections 700-2a-1 and 700-31-18). Early marine cement is minor in interval 5'd', and is relatively common in intervals 6'a', 'b', & 'c'.

The greater amount of early marine cement in bed 3, the upper 2/3 of bed 4, and a good part of bed 6 is consistent with the PAC interpretation of the rocks (see Figure 13) in that these beds represent shallowing conditions yet still well within the marine realm. Scoffin (1987, p.94) stated that early marine lithification occurs in "shallow, warm, $CaCO_3$-supersaturated seas of the tropics." He said (p.94 & 95) it requires a high water flux at the sediment-water interface brought about by current, tidal, and wave action, good permeability in the surface sediments, and a stable substrate combined with a slow sedimentation rate.

Dolomitization is also rather unevenly distributed and appears to favor either more porous beds or those deposited under the most shallow conditions. Interval 2'a' is heavily dolomitized (thin sections 700-8-1 and 700-31-2), but the remainder of bed 2 shows very little or no dolomite, except for very minor occurrences in interval 2'h'. In bed 3, dolomite occurs primarily as euhedral rhombs closely associated with the chert layer (thin sections 700-31-14, 700-31-16, 700-4-3, & 700-4-8). In interval 4'a', dolomitization is minor, in interval 4'b' the matrix is very heavily dolomitized in places, and in interval 4'c' dolomitization is patchy (thin sections 700-31-17, 700-31-18, 700-31-20, & 700-24-11). Dolomitization is strong in intervals 5'b' & 'd' (thin sections 700-24-6 & 700-24-8) and in intervals 6'c' & 'd' (thin sections 700-32-2 & 700-11-8).

X-ray diffractograms revealed that in sample 700-31-8 (interval 4'b'), much dolomite is present (approximately 4:1 over calcite) along with calcite and some quartz (probably detrital). In sample 700-32-5 (interval 6'a'), no dolomite, calcite, or quartz occurs, but there is some carbonate, probably ankerite.

The association of dolomite occurrences with more permeable layers (i.e., bed 3 and intervals 4'b' & 'c') may be related to the reflux model of dolomite generation (Scoffin, 1987, p.135). In this model, Mg-rich waters seep slowly downward through permeable layers from an overlying hypersaline lake or sabkha environment (which may have occurred during periods of lower sea level) and cause dolomitization of the carbonates. The association of dolomite rhombs with the chert in bed 3 may be a result of the conversion of opal-CT to microcrystalline quartz "late during the burial history" (Selleck, 1985, p.141). This conversion results in "expulsion of Mg^{2+} concentration in the adjacent pore fluids," thus favoring the precipitation of dolomite (Selleck, 1985, p.139).

According to Scoffin (1987, p.136), dolomite may form "in the mixing zone at the basal perimeter of a freshwater lens," where the solution may be undersaturated with respect to calcite but supersaturated with respect to dolomite. This may account for dolomite in some of the beds deposited in shallow water (e.g., bed 6), which may have been subjected to the mixing zone environment early on in their diagenetic history.

Dolomite in bed 5 (i.e., in the limestone lenses) is probably related to their being formed in an intertidal to supratidal mudflat environment, where surface evaporation increases the concentration of dissolved salts near the surface, thus favoring dolomite formation.

Another possibility is that some of the dolomite formed later during burial. Scoffin (1987, p.137) stated that "the source of Mg for burial dolomitization may be from shales during compaction." He also stated (p.136) that these late-stage dolomites "are commonly ferroan and can approach ankerite in composition (especially where associated with terrigenous rocks)". Thin section study of sample 700-32-5 (interval 6'a') revealed that 10-20% of the matrix is clear, silt-sized, euhedral rhombohedrons (very possibly ankerite as shown by x-ray diffractogram). This is most likely a result of late-stage burial diagenesis.

Very minor chertification occurs through most of the section, usually associated with fossil fragments, but in bed 3 is a thin (2.5-4 cm), dense layer of chert that is continuous to nodular. The occurrence of this chert layer presents some interesting problems that were discussed in chapter 3.

Syntaxial overgrowths on echinoderm fragments are rather rare in these rocks. Minor ones occur in intervals 2'a' & 'f' (thin sections 700-31-2, 700-8-1, and 700-31-10) and interval 6'd' (thin section 700-11-8). Slightly more developed, but still not common, ones occur in bed 3 (thin section 700-slab) and interval 4'c' (thin sections 700-31-19 & 700-31-20). These syntaxial overgrowths apparently form in the active freshwater phreatic zone (Longman, 1980), thus explaining their presence within or near more permeable layers through which groundwater would have moved more freely.

An interesting feature in bed 4 which deserves mentioning is the preservation of the fusulinids. Some are very well preserved, showing much detail and micritic walls. Others very nearby, some even in contact with well preserved ones, appear to have been dissolved, "probably in undersaturated meteoric water" (Knight, 1985, p.197), and subsequently filled with a clear spar mosaic. Some relict structure is preserved in a few. Knight (1985) suggested differences in original composition, from aragonite to calcite, resulting in differential preservation. Another possibility is that the diagenetic environment was not homogeneous, affecting some and not others. It is also likely that some were fresh when incorporated into the sediments and others were weathered and worn, and thus diagenesis affected them differently.

Diagenetic History

A detailed diagenetic history for bed 3 is included at the end of Chapter 6. Much of this is similar to the diagenetic history for all of the Houx-Higginsville Limestone at locality 700, but a review and any additional information will be cited here.

1. Deposition of the sediments occurred in water of fluctuating depth (see Figure 13), from relatively quiet, deep water in bed 2 to increasingly shallower water deposition upsection. Much of the matrix may have been peloidal, micritic, calcitic cement. Early marine cementation apparently was favored in the shallow water intervals where water energy was great enough to maintain a flux of water through the pore spaces. During times of intertidal to subaerial deposition (bed 5), some dolomite may have formed.

2. As organisms lived and died, new ones became attached and lived on the old dead ones, and sediments accumulated. Some transporting and abrasion of fragments occurred.

3. As sediments lower in the section became subjected to the stagnant marine phreatic zone, intragranular cement formed in tiny skeletal pores (i.e., foraminiferids and bryozoans) while skeletal walls became micritized. Algal and fungal micritization of fossils may also have occurred, as well as minor compaction.

4. As sea level fell, the sediments were exposed to the mixing zone, where chertification, partial neomorphism, and some dolomitization took place.

5. Further sea level fall resulted in the rocks being progressively subjected to more meteoric waters. Thus aggrading neomorphism became the overriding diagenetic feature. Unstable grains were leached away and replaced by stable cements or altered slowly. Pseudosparite and sparite began to replace the micritic matrix, and void spaces were filled with spar cement. Changing pore water conditions caused a fluctuation between aerobic and anaerobic conditions, resulting in both ferroan and nonferroan calcite cements. Changing sea level and several episodes of exposure to meteoric waters may have resulted in several generations of cements. Some syntaxial overgrowths on echinoderm fragments developed.

6. Subsequent sea level rises and falls and an increasing sediment load overlying the Houx-Higginsville Limestone caused compaction features to develop. Late stage dolomitization and ankerite formation may have occurred under these conditions.

7. Filling of compaction fractures with sparry ferroan and nonferroan calcite could have occurred at any time since original compaction of the sediments.

CHAPTER 8

CONCLUSION

Rocks of the Houx-Higginsville Limestone, as exposed in the Niggeman quarry in Crawford County, Kansas, represent a "regressive limestone" in Knight's (1985) "Upper Fort Scott cyclothem". Whereas this study is in general agreement with that "broad-brush" interpretation, it recognizes that the record of sea level change recorded in the rocks is much more complex. Five individual sixth-order transgressive-regressive units (sixth-order T-R units, or PAC's) were recognized in the Upper Fort Scott cyclothem, all of which were recognized in rocks at the Niggeman quarry and indeed throughout the outcrop area of this unit.

Each PAC represents a small-scale deepening-shallowing event of sea level change within the larger Upper Fort Scott fifth-order unit (i.e., the Upper Fort Scott cyclothem): a shallowing PAC sequence of Goodwin and Anderson (1985). These changes can be traced in outcrop more than 500 kilometers (312 miles), from northeast Oklahoma, through southeast Kansas, and northeastward across Missouri to Iowa. Interpretation of depositional environment at each locality for each PAC facilitated the construction of detailed paleogeographic maps and topographic profiles showing the changes from one PAC to the next.

It is probable that epeiric seas covering this area during the Demoinesian age were never very deep. Connolly (1987, p.149) favored depths "less than 100 feet" for fusulinid occurrences, and Stewart (1975, p.138) stated that "at no time" during deposition of the Marmaton Group did the water "greatly exceed 100 feet." Stewart (1975, p.138) also stated that "relief of coastal land areas may have ranged from a few feet to a few tens of feet." This study is in agreement with those estimates.

Rocks at the Niggeman quarry correlate well with those at other localities in terms of the number and position of PACs. The chaetetid "reef" interval in the Niggeman quarry makes up the bulk of PAC 3.

The stratigraphy at the Niggeman quarry is centered around the Houx-Higginsville Limestone because that is the rock that was sought during exploitation of the quarry. Only the top few centimeters of the black fissile Little Osage Shale (Heckel's, 1977, "core shale") are exposed in the quarry floor. The next rock interval (bed 2, less than 2 m thick) is dense, hard, algal calcilutite with a diverse stenohaline marine fauna. It represents deposition of lime muds and fossil debris in a deep, quiet-water setting which occasionally felt the influence of storms, thus resulting in thin cross laminated layers within the otherwise massive calcilutite.

Bed 3 (35 cm thick) is cross laminated, shelly, fusulinid-rich calcarenite. It contains a thin (2-4 cm) chert layer near its middle and has the first occurrences of small laminar chaetetids. Below the chert are small lenses of algal calcilutite. This interval represents a sea level shallowing and exhibits evidence of high wave energy and early marine cementation. Many of the surfaces within the interval represent temporary omission surfaces upon which abundant and diverse, "pioneer" faunas lived. The presence of such a thin chert layer at such a persistent level poses some interesting diagenetic problems.

Bed 4 (2 m thick) is the chaetetid "reef" bed. It contains large buildups (clumps) of chaetetids up to 6 m across and 1-2 m high, surrounded by a matrix of fusulinid packstone to wackestone. The fusulinid packstone matrix is massive in the lower 1/3, cross laminated and darker in the middle 1/3, and massive to cross laminated in the upper 1/3. This interval represents an initial deepening then gradual shallowing of sea level so that the lower part was deposited below normal wave base and the upper parts were deposited from just below to well within normal wave base. Some chaetetid clumps persisted to nearly the end of the sea level shallowing until either subaerial exposure or smothering by sediments terminated them. Many clumps protrude through bed 5 into the basal few centimeters of bed 6.

Bed 5 (0-41 cm) filled in the low places between chaetetid clumps, and produced a flat surface (probably in a mudflat environment) upon which bed 6 was subsequently deposited. Bed 5 consists of shale with two layers of calcilutite lenses. The lower limestone lenses are relatively well developed and continuous, and they pinch out against chaetetid clumps. The upper limestone lenses are thin and very patchy and discontinuous, nodular to well indurated; in some places they do not occur. Overlying the limestone lenses is a gray to brown shale. Bed 5 contains plant fragments and root traces throughout, and in the limestone lenses it also has vertical burrows, small gastropods, and lag deposits of marine shelled invertebrates. This interval is interpreted to represent an intertidal to low supratidal mudflat environment during a sea level lowering. The limestone lenses in the lower part developed in low places or in a lagoonal setting, whereas the upper shale represents subaerial exposure.

Bed 6 (.61-1.2 m) indicates another sea level rise (PAC 4), although not to previous levels within this cyclothem. It consists of dense argillaceous calcilutite with moderate, cross laminated partings defining specific intervals. It contains phylloid algal fragments, encrusting algae, brachiopods, and other fossils, with fusulinids in the lower half, and bellerophontids in the upper half. In addition, there are laminar chaetetids at the top of interval 6'a'. Bed 6 represents deposition in an open to restricted marine environment and indicates shallowing upward until the upper surface was exposed.

Bed 7 is mudstone to claystone, grading from dark gray with yellow "wisps" in the lower part to grayish orange in the upper part. Fossils are scarce, consisting primarily of ostracodes and foraminiferids, with some high-spired gastropods in the lower part and plant fragments and root traces in the upper part. It represents further sea level lowering and deposition of deltaic muds to subaerial exposure. At the top is a thin (25 cm) layer that is rich in <u>Aviculopecten</u> and <u>Permophorus</u>, with a few other marine shell fragments; it represents a minor sea level rise.

Chaetetids in rocks of the Niggeman quarry take on all of the possible growth forms. In bed 3 and interval 6'a', they are small and mostly laminar, with some low domical forms. In interval 4'a', they begin near the base as laminar forms. Gradually, as you go upsection, they take more domical forms, which then begin to stack into tall ragged columns. Within interval 4'b', these columns merge into large clumps of chaetetids, some over 6 m across. Many of these clumps persist through interval 4'c', but very little new chaetetid growth is initiated in interval 4'c'. Chaetetid growth was terminated when bed 5 covered them.

Maximum relief of the chaetetid clumps on the seafloor was probably on the order of 30-45 cm, but may have been up to 60 cm on occasion. The clumps are relatively uniformly distributed and of consistent size throughout the quarry, suggesting that the environment was uniform. However, there was apparently something slightly different in the south-central part of the quarry, perhaps a channel or low place or rip current situation; toppling and overturning of chaetetids and cross laminations in the matrix are more pronounced here. Evidence indicates that the chaetetid clumps developed on a flat, shallow shelf many kilometers from shore.

A wide variety of organisms enjoyed the relative security of living among the chaetetids, taking advantage of protected cavities and the firm substrate the clumps offered. Rugose corals, pediculate brachiopods, bryozoans, crinoids, echinoids, bivalves, gastropods, and foraminiferids lived there. Aulopora sp. was a very common encruster on chaetetids and many times itself was overgrown by chaetetids. Away from the clumps, diversity was much lower, primarily consisting of fusulinids and other foraminiferids.

Diagenesis in the Houx-Higginsville Limestone reflects the changing sea level conditions inferred for these rocks. Some early marine lithification occurred and some early burial diagenetic features. Fluctuating sea level resulted in fluctuating diagenetic conditions, causing several generations of cement to form. However, the overall history of change from marine deposition through the mixing zone environment to exposure to meteoric waters resulted in features indicating an overriding aggrading neomorphism. There were probably several generations of cementing, alteration, and replacement. There was also some late stage burial diagenesis and compaction, and even later spar filling of compaction fissures.

Study of the rocks in the Niggeman quarry and other exposures of the Houx-Higginsville Limestone has given a reasonable impression of the environment of deposition at the Niggeman quarry locality during Desmoinesian times and of where it fits within the regional picture. Different scales of sea level change caused changes in the environment of deposition and thus changes in the rocks. Much of that information is documented herein. It is hoped that subsequent studies, even more detailed and more refined, will further add to our knowledge of these rocks.

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REGIONAL STRATIGRAPHIC SETTING AND PALEOECOLOGY OF A CHAETETID "REEF" IN THE HOUX-HIGGINSVILLE LIMESTONE (PENNSYLVANIAN) OF SOUTHEAST KANSAS

by

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ABSTRACT

The Houx-Higginsville Limestone Member of the Wolverine Creek Formation (previously known as the Higginsville Limestone Member of the Fort Scott Formation) (Desmoinesian) contains a reefal buildup of chaetetids exposed in a quarry in Crawford County, Kansas. This chaetetid buildup was studied to determine its paleoecology and its position in the regional stratigraphy.

The Houx-Higginsville Limestone is a "regressive limestone" in Knight's (1985) "upper Fort Scott cyclothem", which is equivalent in scale to a fifth-order transgressive-regressive unit (T-R unit) of Busch and Rollins (1984). A detailed regional study in northeast Oklahoma, southeast Kansas, and Missouri has revealed 5 individual sixth-order transgressive-regressive units (or PAC's of Anderson and Goodwin, 1980) within this fifth-order unit, thus indicating a complex history of sea level change. This facilitated the construction of detailed paleogeographic maps and topographic profiles along the outcrop belt. An overall trend exists of deeper water to the southwest in the Arkoma Basin and a shoreline which fluctuated from southeast Kansas to northern Missouri.

The stratigraphy in the quarry in Crawford County, Kansas, correlates well with the regional sixth-order T-R units. PAC 1 includes the Little Osage Shale exposed on the floor of the quarry. The Houx-Higginsville Limestone begins at its base with 2 m of algal calcilutite (PAC 2) representing deposition in deep quiet water. This is overlain by .3 m of cross laminated fusulinid calcarenite, deposited in shallow water at the end of PAC 2. PAC 3, the chaetetid PAC, is

represented here by 2 m of fusulinid packstone enclosing large clumps of chaetetids, and is overlain by 0-35 cm of shale with limestone lenses deposited in an intertidal mudflat environment. Another deepening/shallowing event (PAC 4) resulted in 1 m of marine-deposited calcilutite overlain by 4 m of deltaic to terrestrially deposited mudstone (Labette Shale); this contains a thin pecten-rich shale near the top which represents the PAC 5 deepening event.

Chaetetids in the quarry take on all possible growth forms. They begin at the base of the chaetetid bed as laminar to low domical forms which build into columns upward, forming large clumps (1-6 m across) of chaetetids in the upper 1/2 to 2/3 of the chaetetid bed. The chaetetid clumps are uniformly distributed throughout the quarry, and probably developed on a flat shallow shelf many kilometers from shore, at depths from somewhat below wave base to well within wave base. Maximum relief of chaetetids on the sea floor was probably 30-60 cm, and paleocurrent was from the southwest. Chaetetid growth was terminated by an influx of sediments and subaerial exposure during sea level shallowing at the end of PAC 3 time.

A wide variety of organisms lived within and around the chaetetid clumps, including rugose corals, brachiopods, bryozoans, echinoids, crinoids, bivalves, gastropods, and foraminiferids. Aulopora sp. commonly encrusted and was encrusted by chaetetids. Fusulinids were ubiquitous. Away from the chaetetids, diversity was much lower.

Fluctuating sea level resulted in fluctuating diagenetic conditions, causing several generations of nonferroan and ferroan calcite and dolomite cement. However, the overall history of change from marine deposition to subaerial exposure resulted in an overriding aggrading neomorphism. There was also some late stage burial diagenesis and compaction, and later spar filling of compaction fissures.

APPENDIX A

Stratigraphic Sections of Localities Used in Regional Study

(For locality map, see Figure 8)
(For lithologic symbols, see next page)

Lithologic Symbols

- fusulinid packstone	- black fissile shale with phosphate nodules
- X-laminated fusulinid wackestone	- shale
- calcilutite	- calcareous shale
- algal calcilutite	- flaky shale
- wavy-bedded limestone	- claystone
- clay-rich limestone	- silty to sandy shale to siltstone
- intraclastic or breccia limestone	- sandstone
- sandy or silty limestone	- coal
- X-laminated calcarenite	
- chert nodules	- limestone nodules
- chaetetids	- brachiopods
- root traces & casts	- pectens
- sharp contact	- gradational contact

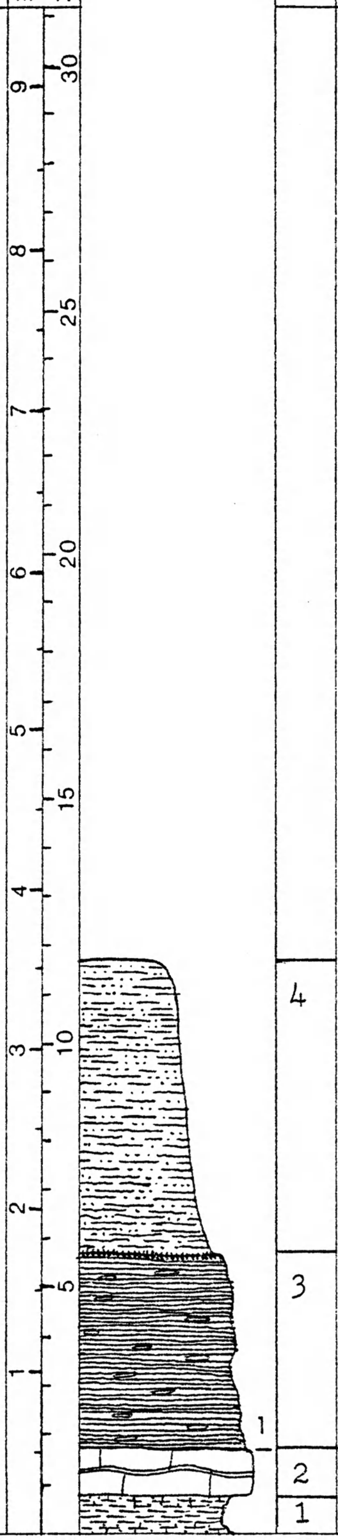
Sample No. | Scale (m, ft) | PAC No. | Bed No. | Interval No.

Locality Description: Strat. Sec. LEO, cut bank along south side of Arkansas River.

Location: SW¼SW¼ sec. 21, T.17N., R.14E., Tulsa County, Oklahoma.

Measured By: K. L. Knight Date: 1985

Remarks: taken from Knight (1985)



Description

Bed No.

Labette Shale

4 Shale: (6ft.0in.; 1.83m), silty with thin sandstones.

Wolverine Creek Formation
Little Osage Shale Member

3 Shale: (4ft.0in.; 1.22m), black, fissile with phosphatic nodules, grades into overlying gray shale.

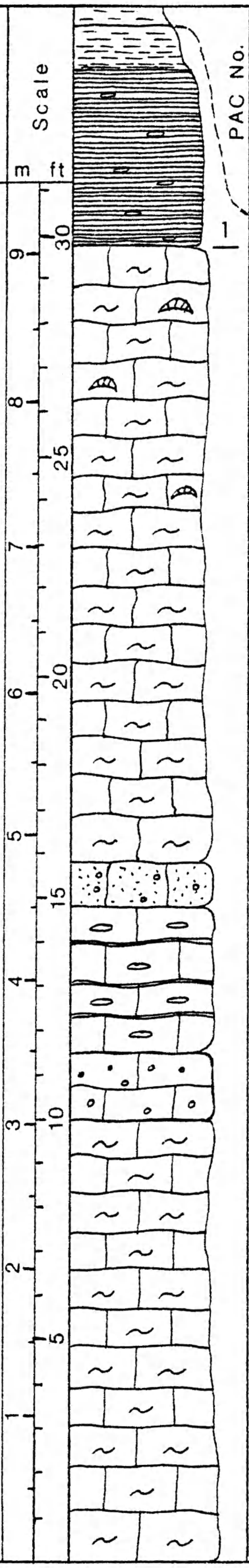
Dry Branch Creek Formation
Blackjack Creek Limestone Member

2 Limestone: (1ft.0in.; .305m), skeletal calcilutite with thin irregular beds.

Excello Shale Member

1 Shale: (9in.; 22.9cm), base a sandy orange-brown calcareous siltstone, middle is black flakey shale, top is same as bottom with calcareous nodules.

Sample No.	Scale (m ft)	PAC No.	Bed No.	Interval No.
			3	
		1	2	
			1	e
				d
				c
				b
				a



Locality Description: Strat. Sec. S5, "Claremore Mound Section", south bank of Verdigris River.

Location: approx. ctr. sec. 13, T.22N., R.15E., Rogers County, Oklahoma.

Measured By: B. J. Schell Date: 1955

Remarks: modified from Schell (1955)

Description

Bed No.

Labette Formation

3 Shale: (no thickness given), gray to yellow clay shale with abundant clay ironstone bands.

Wolverine Creek Formation

Little Osage Shale Member

2 Shale: (5ft.0in.; 1.524m), black to dark gray, fissile, with phosphate nodules, grading upward to lighter clay shales. Fossils: Orbiculoidea, conodonts, some plant fragments.

Dry Branch Creek Formation

Blackjack Creek Limestone Member

1e. "Algal Limestone": (14ft.0in.; 4.27m), light gray to light buff, with coarse fossil detritus, discontinuous to lenticular bedding, a few very thin clay stringers. Sharp contacts. Fossils: algal detritus, brachiopods (Echinaria, Crurithyris), solitary tetracorals, Chaetetes, bryozoans, fusulinids.

d. "Microfragmental Limestone": (1ft.0in.; .305m), medium to dark gray, weathers lighter gray, even textured sand-size clastic particles, in one massive bed. Gradational lower contact. Fossils: mostly fusulinids and other Foraminifera with some small gastropods.

c. "Lithographic Limestone": (3ft.4in.; 1.015m), medium gray, weathers to light chalky gray, has lithographic texture with abundant microfossils, 1-2% clay, some chert nodules; wavy, discontinuous, black shale stringers; weathers into thin flagstones. Gradational contacts. Fossils: fusulinids and very small macrofossils.

b. "Microfragmental Limestone": (1ft.6in.; .457m), medium gray, weathers lighter, even textured sand size grains, very minor clay, weathers into flagstones. Gradational contacts. Fossils: fusulinids and other Foraminifera with some small gastropods and brachiopods.

a. "Algal Limestone": (10ft.0in.; 3.05m), light gray to cream, weathers buff in spots, coarsely fragmental due to large grained fossil detritus, massive when fresh but weathers to irregular discontinuous horizontal lenses. Gradational contacts. Fossils: algal detritus, abundant brachiopods (chonetids, Crurithyris, Phricodothyris), solitary tetracorals, bryozoans, productids.

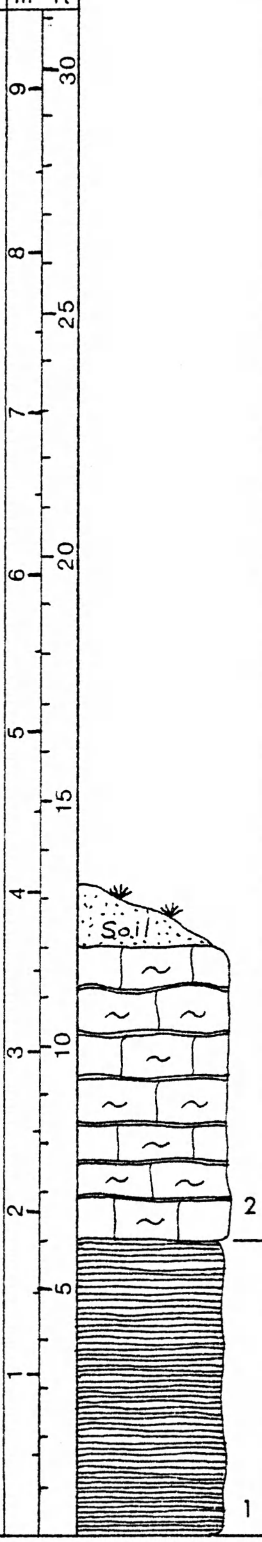
Excello Shale (not shown here)

Shale: (5ft.3in.; 1.60m), black, fissile, with phosphate nodules, conodonts, and fish scales or spines.

Sample No.	Scale (m ft)		PAC No.	Bed No.	Interval No.	Locality Description: Strat. Sec. S10, composite section with units 1-1d measured in quarry, "S.$\frac{1}{4}$ corner" sec. 27, and units 1e-3 measured in roadcut, N.$\frac{1}{2}$ of E. line, sec. 26, T.26N., R.17E., Nowata Co., Okla.

Measured By: B. J. Schell Date: 1955

Remarks: modified from Schell (1955)



Bed No. 3 / Bed No. 2

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

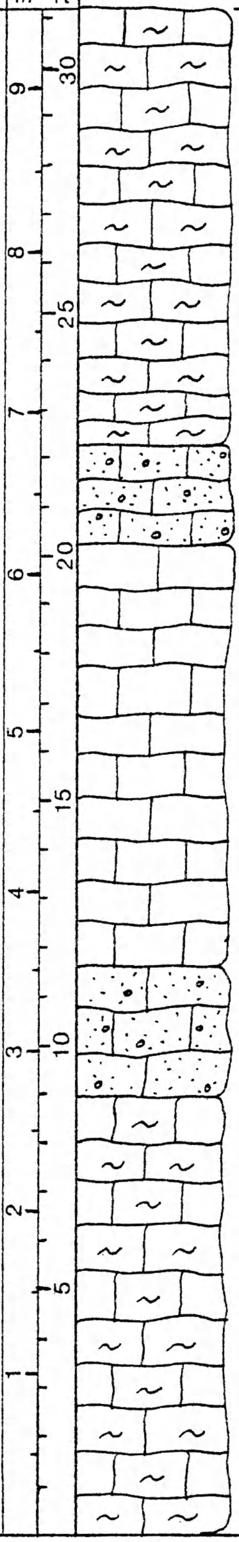
3 "Algal Limestone": (6ft.0in.; 1.83m), medium gray to cream, basal layer weathers to a distinct bright yellow; bioclastic with poorly sorted fossil detritus, very small clay content, thin discontinuous wavy beds. Sharp basal contact. Fossils: abundant algal fragments, small brachiopods, bryozoans, and solitary tetracorals.

Little Osage Shale Member

2 Shale: (6ft.oin.; 1.83m), dark gray to black, weathers dark blue-gray, fissile, hard, platy, with phosphate nodules. Sharp contacts. Fossils: a few Orbiculoidea and conodonts.

(Continued on next page)

Sample No. | Scale (m ft) | PAC No. | Bed No. | Interval No.



Locality Description: Strat. Sec. S10.

(Continued from previous page)

Location:

Measured By: Date:

Remarks:

Bed No. 1

Description

Bed No.

(Continued from previous page)

Dry Branch Creek Formation

Blackjack Creek Limestone Member

1e. "Algal Limestone": (9ft.0in.; 2.74m), light to medium gray and cream, weathers buff in spots; bioclastic with poorly sorted fossil detritus, very slight clay content, some chert nodules, thin discontinuous wavy beds. Sharp contacts. Fossils: abundant algal fragments, small brachiopods, crinoid stems, solitary tetracorals, and ramose bryozoans.

d. "Microfragmental Limestone": (2ft.0in.; .61m), medium to light gray, bioclastic, well sorted, largely fragmental fossil detritus, slight amount of clay, beds up to 6 in. (15.24cm) thick and more continuous than in overlying algal unit. Gradational basal contact. Fossils: very abundant fusulinids and other Foraminifera, with common small gastropods, brachiopods, and other fossil fragments, and a few nearly complete Linoproductus.

c. "Lithographic Limestone": (8ft.8in.; 2.64m), medium to dark gray, lithographic to bioclastic, common fossil material in a cryptocrystalline matrix; 3- to 6-inch (7.62- to 15.24-cm) wavy beds with very thin carbonaceous fusulinid-rich black shale partings. Gradational contacts. Fossils: abundant Antiquatonia, Linoproductus, Composita, crinoid stems, echinoid spines, encrusting bryozoans, and large fusulinids.

b. "Microfragmental Limestone": (2ft.8in.; .81m). Same as unit 1d.

a. "Algal Limestone": (9ft.0in.; 2.74m). Same as unit 1e except that bedding is better developed with beds averaging about 3 inches (7.62 cm). A 3-foot (.91m) bed occurs in the middle of the interval and Syringopora corals are rather common.

Excello Shale (not shown here)

Shale: (3ft.8in.; 1.12m), black, fissile, with phosphate nodules.

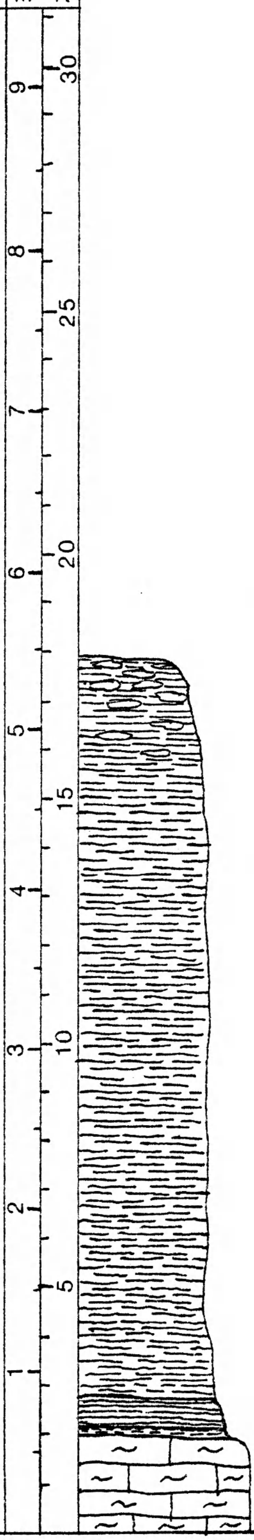
Sample No.	Scale (m, ft)		Bed No.	Interval No.	

Locality Description: Strat. Sec. MC, N-S road along creek just south of Martin Cemetery.

Location: SW¼NW¼ sec. 2, T.26N., R.17E., Nowata County, Oklahoma.

Measured By: K. L. Knight Date: 1985

Remarks: taken from Knight (1985)



Description

Bed No.

Labette Shale

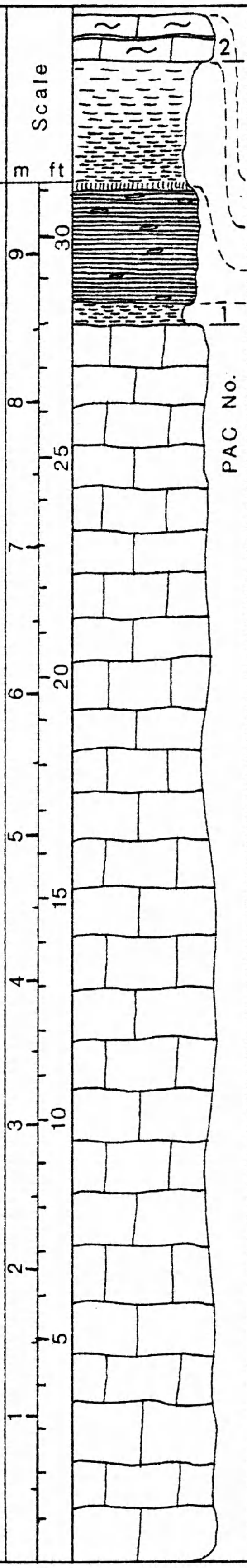
Bed No.	Interval No.	Description
2	c	2c. Shale: (10-15 ft.; 3.05-4.57 m), gray to brown with concretionary brown rubble eroding from top.
	b	b. Shale: (6-8in.; 15.2-20.3cm), dark gray, (no nodules).
	a	a. Claystone: (1-2in.; 2.54-5.08cm), brown.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

Bed No.	Interval No.	Description
1		1 Calcilutite: (approx. 2 ft.; .61m), fossiliferous, abundant algal blades, base covered in creek.

A7

Sample No. | Scale | Bed No. | Interval No.



Bed No.	Interval No.
3	
2	c
	b
	a
1	

Locality Description: Strat. Sec. WCT, in a gas pipe trench along side of county road (now filled in).

Location: NW$\frac{1}{4}$ sec. 25, T.28N., R.19E., Craig County, Oklahoma.

Measured By: K. L. Knight Date: 1985

Remarks: taken from Knight (1985)

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

3 Calcilutite: (approx. 1ft.; .305m), light gray, orange-brown weathering, wavy bedded, fossiliferous with algal blades, brachiopods, top eroded.

Little Osage Shale Member

2c. Shale: (2ft.10in.; .864m), interbedded shale to claystone, basal 1-2 in. (2.54-5.08cm) light to dark gray claystone gradational with black shale below, overlain by 1 in. (2.54cm) rusty, platy-like shale which is overlain by interbedded dark gray to black shale and yellow to gray-blue claystone.

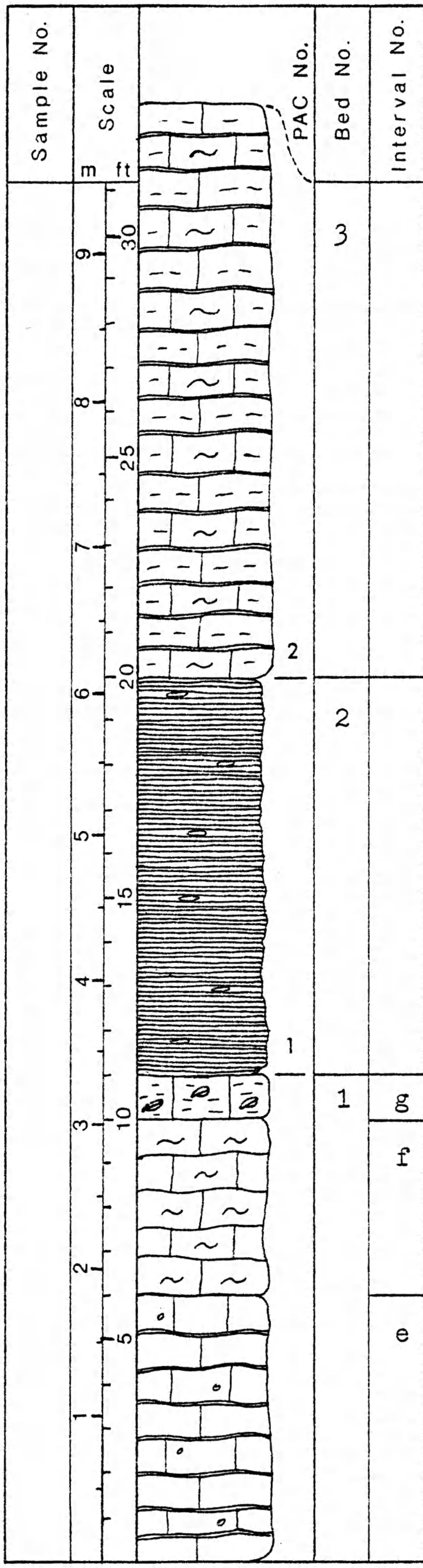
b. Shale: (2ft.8in.; .814m), black, fissile to irregular chunks at top, phosphatic nodules, sharp base.

a. Claystone: (6in.; 15.2cm), gray-blue to yellow.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

1 Calcilutite: (approx. 28ft.; 8.53m), light to medium gray-blue on fresh surface, fossiliferous with brachiopods, crinoids, top contains shell hash of large brachiopods and bryozoans, measured over a long distance so thickness is uncertain.

Excello Shale Member (not shown here)
Claystone: (2ft.10in.; .864m), gray-blue to yellow, laminated, about 2 in. (5.08cm) up there is a 2 in. (5.08cm) zone of dark gray to black laminated shale overlying a thin nodular calcilutite, sharp base.
Shale: (3ft.8in.; 1.12m), black, fissile to chunky, phosphatic nodules, sharp contacts.



Locality Description: Strat. Sec. S17, "Cabin Creek Section", measured along creek and adjacent scarp.

Location: NW¼,NW¼ sec. 35, T.29N., R.19E., Craig County, Oklahoma.

Measured By: B. J. Schell Date: 1955

Remarks: Modified from Schell (1955)

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

3 Limestone: (13ft.0in.; 3.96m), medium gray, weathers to light gray or light yellow buff, bioclastic, poorly sorted fossil detritus in a dominantly microcrystalline matrix, some clay content and chert nodules, thin wavy beds. Sharp basal contact. Fossils: algal fragments, small crinoid fragments, brachiopods (Crurithyris, Hustedia), and a few bellerophontid gastropods.

Little Osage Shale Member

2 Shale: (9ft.0in.; 2.74m), dark gray to black, fissile, with phosphate nodules. Sharp contacts.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

1g. "Impure Brachiopod Limestone": (1ft.0in.; .305m), dark gray to black, bioclastic with a clay-rich matrix and carbonaceous material, thin platy beds 1-3 inches (2.54-7.62cm) thick. Sharp contacts. Fossils: very abundant Composita and large productids, with ramose bryozoans replaced by orange iron oxide, a few burrowing pelecypods and crinoids.

f. "Algal Limestone": (4ft.0in., 1.22m), medium to light gray, weathers light gray; bioclastic, poorly sorted fossil detritus, small percentage of clay and some chert present as fossil replacement; poorly bedded with thin discontinuous wavy beds. Sharp contacts. Fossils: algal fragments, productids, small spiriferids, bryozoans, gastropods, crinoid fragments.

At another locality within ½ mile (.8km) both units 1d and 1e grade into a very fossiliferous zone dominated by bellerophontids, other gastropods, and crinoids, with some burrowing pelecypods. Much of the fossil material is replaced by chert.

e. "Lithographic Limestone": (6ft.0in.; 1.83m), medium gray, weathers light chalky gray, lithographic, with fossil material scarce, slight amount of clay, thin discontinuous wavy beds. Gradational basal contact. Fossils: scarce, with fusulinids, productids, and a few crinoid stems.

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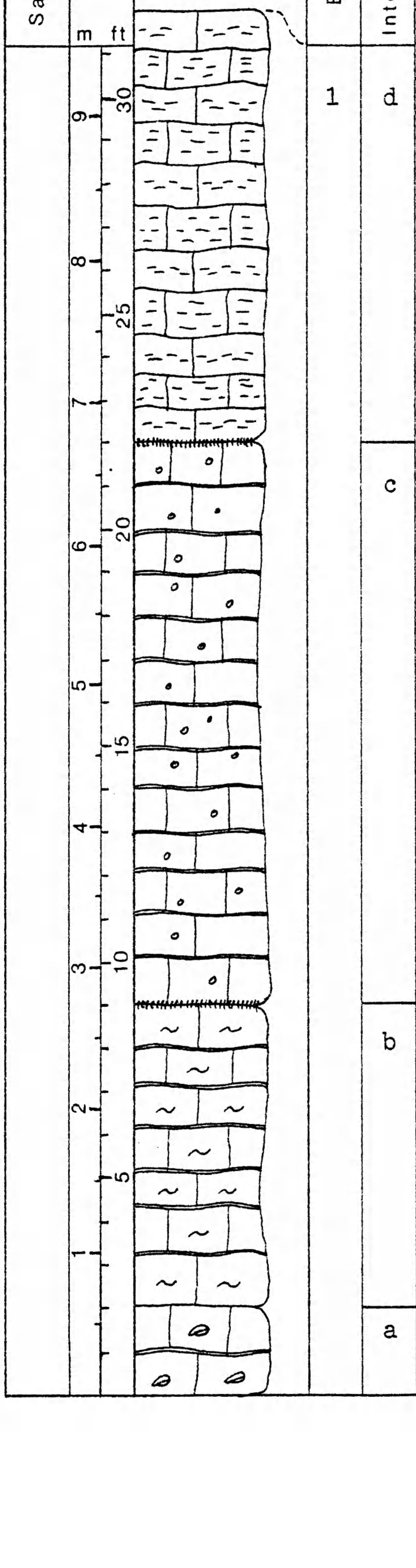
Locality Description: Strat. Sec. S17.

(Continued from previous page)

Location:

Measured By: Date:

Remarks:



Description

Bed No.

(Continued from previous page)

Blackjack Creek Limestone Member (Continued)

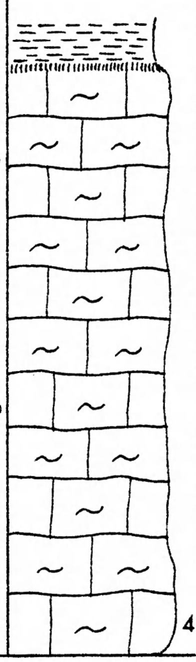
d. "Layered Microcrystalline Limestone": (10ft.0in.; 3.05m), medium to light gray, weathers dull brown, microcrystalline, even grained, massive with beds several feet thick. Within the beds is a well developed lamination (.1-.5 in.; .25-1.27cm), which may or may not parallel the bedding, in which alternate layers are clay-rich. Sharp contacts. Fossils: scarce, with a few pectinids, small gastropods, and small brachiopods.

c. "Lithographic Limestone": (13ft.0in.; 3.96m), medium gray, weathers light chalky gray, microcrystalline, even grained with some fossil remains; thin, discontinuous beds with irregular very thin stringers (2-.5 in.; 0-1.27cm) of clay-size material. Gradational contacts. Fossils: common fusulinids, with large productids, and a few crinoid remains.

b. "Algal Limestone": (7ft.0in.; 2.13m), medium to light gray or cream, weathers lighter, bioclastic, poorly sorted fossil detritus in a microcrystalline matrix, small amount of chert fossil replacement. Thin, discontinuous wavy beds seldom over 1 ft. (.305m) thick. Gradational contacts. Fossils: abundant algal fragments, with small productids and spiriferids, especially Crurithyris, and a few fenestellid and ramose bryozoans and solitary tetracorals.

a. "Brachiopod Limestone": (2ft.0in.; .61m). Identical to unit 1b except that the bedding is more continuous and the algal material is much less conspicuous. "The faunal suite is dominated by a flood of Crurithyris" (Jeffries, 1955, p. 213).

Excello Shale (not shown here)
Shale: (7ft.6in.; 2.29m), dark gray to black, fissile, with phosphate nodules.

Sample No.	Scale (m ft)		PAC No.	Bed No.	Interval No.
				4	c

Locality Description: PMC; core, SW$\frac{1}{4}$ sec.19, T.34S., R.18E., Labette Co., Ks., drilled in 1925 by Pittsburg & Midway Coal Mining Co. (309-393ft. in core; 94.2-119.8m). Stored at Ks. Geol. Surv., Lawrence, Ks.

Measured By: K. L. Knight Date: 1985

Remarks: taken from Knight (1985)

Description

Bed No.

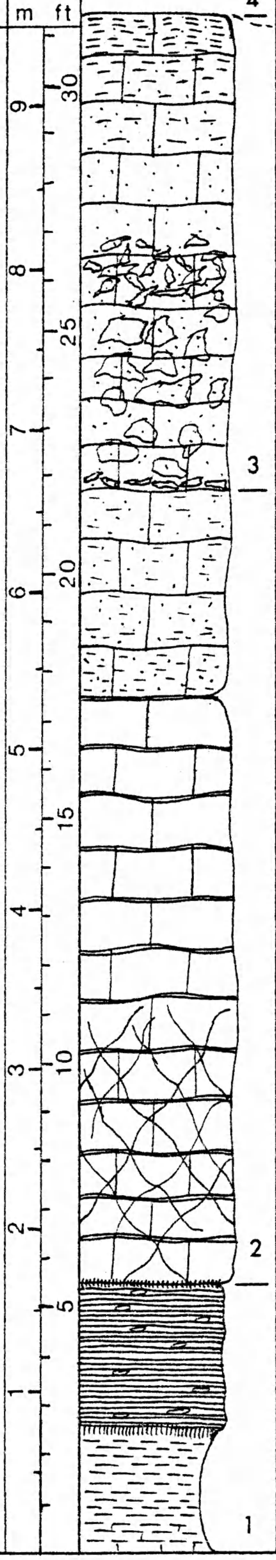
Wolverine Creek Formation

Houx-Higginsville Limestone Member

4c. Limestone: (12ft.0in.; 3.66m), light to medium gray phylloid algal wackestone, gradational contact with overlying gray-brown shale.

(Continued on next page)

Sample No.	Scale		PAC No.	Bed No.	Interval No.



Locality Description: Strat. Sec. PMC.

(Continued from previous page).

Location:

Measured By: Date:

Remarks:

Description

Bed No.

(Continued from previous page)

Bed 4, Interval b

4b. Limestone: (14ft.0in.; 4.27m), light to medium gray; includes a vertical succession of: 1)basal mudstone, bioturbated, with peloids (<1%), low diversity fauna (<1%) including ostracodes, foraminifers, brachiopods, and gastropods in a clay-free microspar matrix; 2)calcisphere and peloidal wackestone with abundant structureless peloids and wall-less spheres (0.02-0.05mm) in a microspar matrix, and a biota of low diversity; 3)a layered sequence beginning with a basal layer of matrix-supported angular chert intraclasts overlain by in-place breccia grading upward to angular intraclasts in grain-to-grain contact, of which the intraclasts are wackestone to packstone filled with calcispheres, calcite blebs, and occasional echinoderm fragments, and the microspar matrix includes calcispheres, calcite blebs, and echinoderm, brachiopod, bryozoan, ostracode, and foraminifer fragments; 4)laminated peloidal wackestone to packstone containing abundant peloids, a few calcispheres, brachiopods, foraminifers, and echinoderms concentrated in a burrow or lens, and a microspar matrix with patchy dolomite.

Interval a

a. Limestone: (12ft.0in.; 3.66m), light gray mudstone to wackestone, diverse marine fauna, shaly fusulinid-rich partings 1-3 cm thick, abundant fractures in bottom half.

Little Osage Shale Member

Bed 3, Interval b

3b. Shale: (3ft.0in.; .914m), black, fissile, phosphatic nodules, gradational contacts.

Interval a

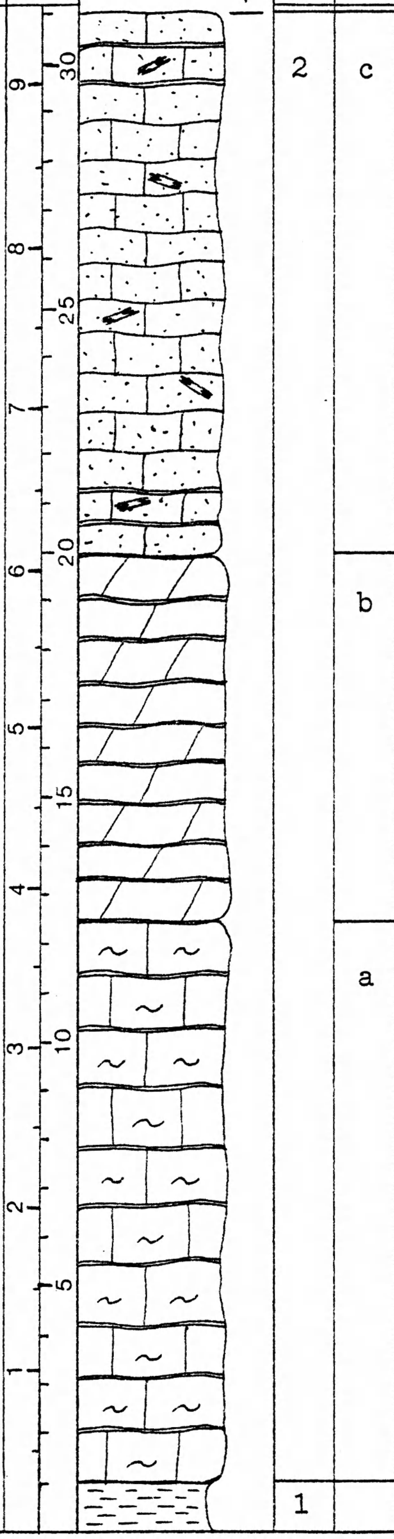
a. Shale: (2ft.6in.; .762m), gray, calcareous near base.

(Continued on next page)

Sample No.	Scale		PAC No.	Bed No.	Interval No.	Locality Description: Strat. Sec. PMC. (Continued from previous page).
	m ft		1			Location:

Measured By: Date:

Remarks:



Description

Bed No.

(Continued from previous page)

Dry Branch Creek Formation
Blackjack Creek Limestone Member

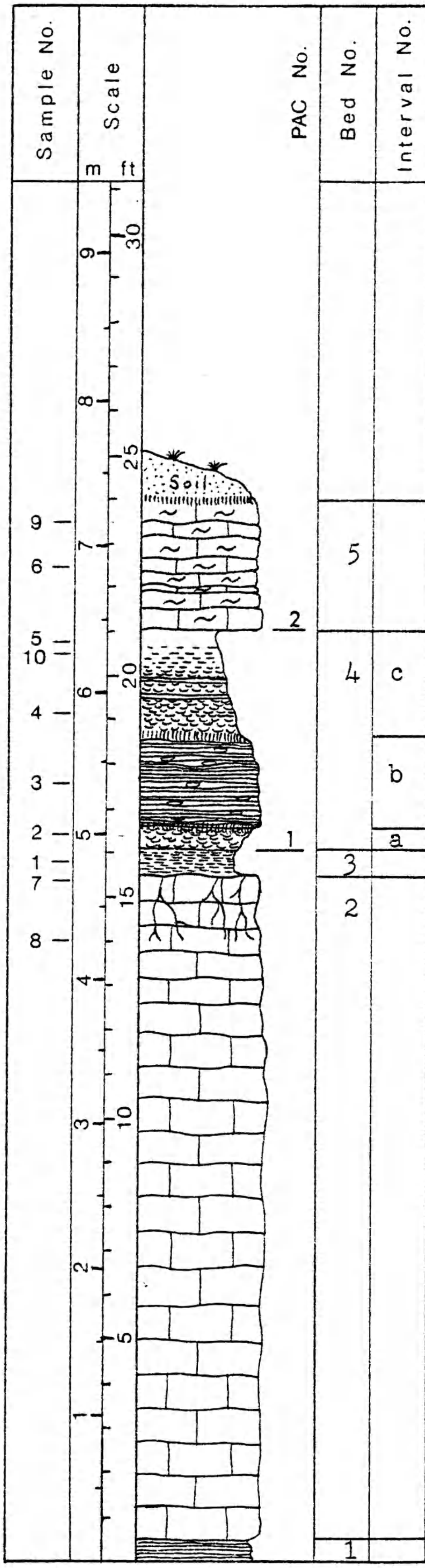
2c. Limestone: (11ft.0in.; 3.35m), light gray intraclast, peloid wackestone to packstone, shaly partings near top and base.

b. Dolostone: (7ft.6in.; 2.29m), dark gray, argillaceous, fusulinid-rich shaly partings, diverse marine fauna.

a. Limestone: (11ft.6in.; 3.51m), light gray phylloid algal wackestone, shaly partings.

Excello Shale Member

1 Shale: (1ft.6in.; .457m), dark gray, fossiliferous, gradational contacts.



Locality Description: Strat. Sec. SOS, roadcut along Hwy. 59 by southern Oswego city limits.

Location: E. ctr. sec. 21, T.33S., R.21E., Labette County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks: same as Knight's (1985) loc. SOS

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

5 Algal Calcilutite: (3ft.; .91m), medium gray (N5), weathers grayish orange (10 YR 7/4), dense, hard; layers 1-6 in. (2.5-15.2cm) thick (accurately shown on strat. column) separated by thin wavy shaly partings. Sharp basal contact. Fossils: algal blades (10%; some encrusted by Fistulipora, some with attached tetrataxids), Composita (many articulated, in life position), fenestrate and ramose bryozoan fragments, chonetids, echinoid & crinoid debris, Crurithyris (some articulated), productid fragments, pectens(?), Cleiothyridina.

Little Osage Shale Member

4c. Shale grading upward to claystone: (2ft.4in.; .71m), shale is grayish black (N2), weathers brownish gray (5 YR 4/1) to moderate brown (5 YR 4/4), crumbly & flakey; claystone is grayish orange (10 YR 7/4), soft, flakey. The first claystone layer (1cm) occurs 17 in. (43cm) from the top, then another 13 in. (33cm) from the top, then claystone with wisps of dark gray shale grades upward to claystone. Gradational lower contact. Fossils: shale has burrows (Chondrites?), conodonts (broken), Orbiculoidea, and a fish scale; claystone has Crurithyris (abundant, disarticulated and broken, primarily as internal and external molds), Schizodontus (articulated), Permophorus (disarticulated), other brachiopod molds, and productids.

b. Shale: (25in.; .64m), black (N1), weathers grayish brown (5 YR 3/2) to moderate yellowish brown (10 YR 5/4); hard, fissile, with papery partings when weathered, phosphate nodules (some brachiopod shell nuclei; compaction slickensides on sides). Gradational contacts. Fossils: conodonts (hindeodellids & unidentified types), Orbiculoidea, plant fragments, Dunbarella, productids.

a. Shale: (7in.; 17.8cm), dark gray (N3) to grayish black (N2), medium induration, flakey, crumbly, contains silt-size mica flakes oriented parallel to bedding. Sharp basal contact. Fossils: plant fragments, brachiopod fragments (Crurithyris, Desmoinesiana, other), ostracodes, chonetids, fish bones, fish scales, conodonts (hindeodellids, other).

Morgan School Shale Formation

3 Claystone: (7.5in.; 19cm), medium gray (N5) to medium bluish gray (5 B 5/1), with grayish yellow (5 Y 8/4) blebs & stringers of sticky clay; very soft and clay-rich. Sharp contacts. Fossils: plant fragments, root traces.

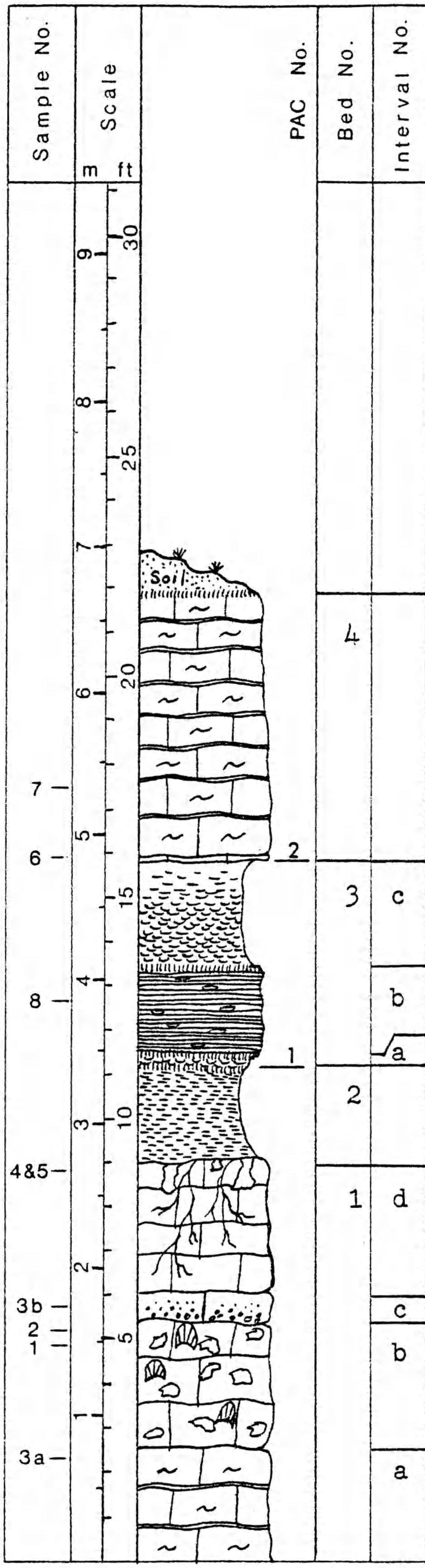
Dry Branch Creek Formation

Blackjack Creek Limestone Member

2 Calcilutite to medium calcarenite: (15ft.; 4.6m), yellowish gray (5Y 7/2), weathers grayish orange (10YR7/4); thin, wavy beds (some partings are stylolites). Sharp contacts. Fossils: root casts in upper 18 in. (.46m), fusulinids, burrows, microgastropods, echinoid pieces, ostracodes, plant fragments, Composita, Ozarkodina, gastropods, Palaeobigenerina, brachiopod fragments.

Excello Shale Member

1 Shale: (thickness uncertain), black, poorly exposed.



Locality Description: Strat. Sec. 766, old abandoned quarry just north of Sherman, Kansas.

Location: W.ctr.,NE¼,sec. 13, T.32S., R.21E., Cherokee County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks: same as Knight's (1985) loc. SQ

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

4 Algal Calcilutite: (6ft.; 1.83m), light olive gray (5 Y 6/1), weathers very pale orange (10 YR 8/2); dense, hard, layers (up to 9 in.; 22.9cm) separated by dark, shaly, fusulinid-bearing, wavy, thin laminae. Sharp basal contact. Fossils: algal blades (5-10%), Composita (many articulated), echinoid pieces, crinoid columnals, ophthalmids.
Basal layer (1.5in.; 3.8cm) is coarse calcilutite with horizontal algal(?) and evaporite(?) laminae, fenestrae, Bairdia, Crurithyris (on bottom), horizontal burrows (on top), brachiopod fragments.

Little Osage Shale Member

3c. Shale: (2ft.5in.; .737m), dark gray and crumbly at base grading upward to grayish orange claystone at top. Crurithyris and Orbiculoidea in upper 1 ft. (.305m).

b. Shale: (2ft.; .61m), grayish black (N2) to black (N1), weathers to light gray (N7) and dark yellowish orange (10 YR 6/6); fissile, with papery partings, phosphate nodules (some bivalve shell nuclei). Gradational contacts. A large plant fragment and a cephalopod were found.

a. Shale: (2-3in.; 5-7.6cm), dark gray, flakey, crumbly. Gradational contacts. Some brachiopod fragments and possible plant fragments.

Morgan School Shale Formation

2 Claystone: (2ft.3in.; .69m), blue gray with orange rusty plate-like partings, very soft, sticky, underclay-like. Sharp basal contact. Root traces, plant fragments.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

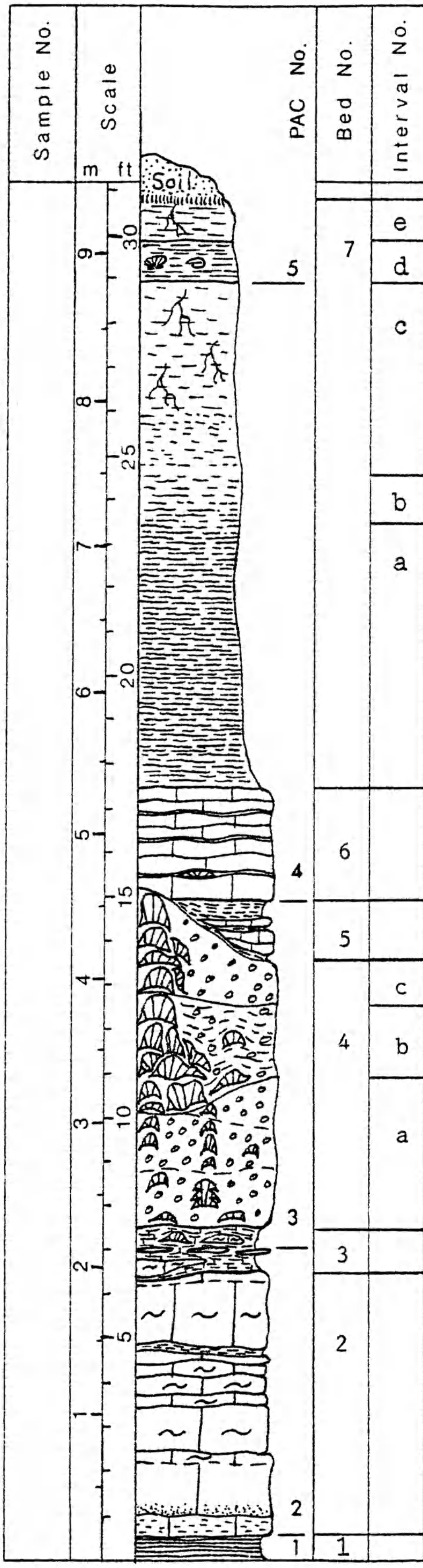
1d. Medium to Coarse Calcarenite: (3ft.; .91m), pale yellowish brown (10 YR 6/2), weathers dark yellowish orange (10 YR 6/6); dense, hard, well indurated. Top surface has vertical hollows (up to 6 in. (15.2cm) across and 12 in. (30.5cm) deep) filled with white chalky substance which contains fusulinids, root casts, and shell fragments. Sharp contacts. Fossils: fusulinids (5%), shell fragments (crinoid, echinoid, brachiopod, other), root traces, Neospirifer.

c. Medium Calcarenite: (6-8in.; 15.2-20.3cm), pale yellowish brown (10 YR 6/2), hard, well indurated. Angular sand size grains and 5-10% larger shell fragments (brachiopod, fusulinid, crinoid) in a micritic to sparry matrix. Normal grading. Sharp contacts. Fossils: fusulinids, root casts, bellerophontids(?), echinoid fragments, pecten(?) fragments. Incipient Osagia coating and small lenses of crinoidal hash.

b. Calcarenite: (3ft.; .91m), medium light gray (N6) mottled with yellowish gray (5 Y 7/2), weathers very pale orange (10 YR 8/2), hard, well indurated. Strongly bioturbated. Contains rounded to subangular clasts (1-2in.; 2.5-5cm) of algal calcilutite covered by algal encrustations, ophthalmids, Fistulipora, and serpulid worm tubes. Sharp contacts. Fossils: fusulinids, shell fragments (crinoids, echinoids, productids, Composita, Derbyia), ophthalmids, palaeotextulariids, Fistulipora, Chaetetes (1%), Aulopora, horn corals. Top surface is weathered and pitted.

a. Calcilutite: (2ft.6in.; .76m), light gray (N7), dense, hard, medium bedded with thin wavy shaly partings. Fossils: algal blades, Composita, Cleiothyridina, Tetrataxis, echinoid fragments, fenestrate bryozoans, productid spines, Pseudomonotus.

A15



Locality Description: Strat. Sec. 700, inactive quarry 5 mi. (8 km) W. and 5 mi. (8 km) S. of Girard, Kansas.

Location: SE$\frac{1}{4}$, sec. 12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks: owned by Mrs. Wm. T. Niggeman

Description

Bed No.

Labette Shale Formation

7e. Clayshale: (11in.; 27.9cm), alternating laminae of grayish orange (10 YR 7/4) and medium gray (N5); soft to fairly hard, poorly indurated. Contains plant fragments, root traces, and occasional paper-thin layers with fragments of Aviculopecten, productid spines, small crinoid stems, and Bathysiphon.

d. Claystone to Shale: (10in.; 25.4cm), very pale orange (10 YR 8/2), to grayish orange (10 YR 7/4) with medium gray (N5) wisps and lenses; fairly hard to soft, full of shelly layers containing Aviculopecten (very abundant, in good condition), Permophorus(?), fragments of productids and crinoids, and small limonite nodules.

c. Clayshale to Shale: (4ft.8in.; 1.42m), grayish orange (10 YR 7/4) with yellowish gray (5 Y 8/1) clay wisps and occasional thin (.5-1.5in.; 1.3-3.8cm) layers of pale yellowish orange (10 YR 8/6) clayshale; poor to medium induration and hardness, subfissile. Contains plant fragments and root traces throughout with some burrow mottling, occasional very thin (<1.5mm) very fine shelly calcarenite lenses and very rare abraded fragments of crinoids (<1mm), pectens (<2mm), Bairdia, and Bathysiphon.

b. Shale to Mudstone: (1ft.; .305m), grades from and alternates with underlying medium dark gray (N4) shale to overlying grayish orange (10 YR 7/4) shale. Portions are nonfossiliferous and portions contain productid spines, plant fragments (<2mm), smooth ostracodes (common), Bathysiphon, ammodiscid foraminiferids, and very thin (<1mm) very fine shelly calcarenite lenses.

a. Shale: (6ft.; 1.83m), medium dark gray (N4) to black (N1) with grayish orange (10 YR 7/4) wisps; fissile, poorly indurated, calcareous. Fossils: ostracodes (articulated, very common in lower 2/3; smooth types, hollinellids, and Bairdia), Bathysiphon (common in lower 2/3), ammodiscid foraminiferids (common throughout), small high-spired gastropods (abundant in lower 1/4), very small corroded shell fragments throughout (productid, crinoid, echinoid, bryozoan). The bottom 1.5 in. (3.8cm) additionally has burrows, Crurithyris, kirkbyacean ostracodes, and the bottom surface has lenses of clear gypsum ($\frac{1}{4}$in. thick; 6mm).

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6. Calcilutite: (2ft.6in.; .76m), olive gray (5 Y 4/1) to dark gray (N3), weathers yellowish gray (5 Y 7/2) to dark yellowish orange (10 YR 6/6); dense, hard, argillaceous, massive beds (4-10in.; 10.2-25.4cm) separated by thin, finely cross laminated layers that are medium dark gray (N4) to olive black (5 Y 2/1) and weather moderate brown (5 YR 4/4). Sharp basal contact. Top surface is highly weathered and pitted. Calcilutite contains algal blades and fusulinids (in lower half), Composita, crinoids, productids (Antequatonia), Meekella, Ditomopyge, shark pavement tooth, bellerophontids (in upper half); most fossils are unbroken, unabraded, many in life position. The dark thin layers are more argillaceous and contain generally the same fossil types but more broken & abraded, also sand size shell fragments; the first parting (6-8in. (15.2-20.3cm) above the base) also has laminar Chaetetes, the largest 8 in. (20.3cm) across and 4 in. (10.2cm) high, but most are smaller.

(Descriptions continued on next page)

Stratigraphic Section 700

(Descriptions continued from previous page)

Houx-Higginsville Limestone Member (continued)

5. Shale with calcilutite lenses: (0-16in.; 0-40.6cm), shale below limestone lenses is light brownish gray (5 YR 6/1) to pale yellowish brown (10 YR 6/2), flaky, silty, poorly indurated, with common fusulinids, *Chondrites*, plant fragments, root(?) traces, rounded shell fragments (clay-coated), and *Crurithyris* valves. Lower calcilutite lenses are pinkish gray (5 YR 8/1), weather light gray (N7), have medium density and hardness, and contain abundant plant fragments and root traces, large vertical burrows, *Ameura*, *Straparollus*, bellerophontids (one exceptionally large), and in some places has coarse basal lag deposits containing *Meekella*, *Punctospirifer*, *Ameura*, *Fistulipora*, echinoid and crinoid pieces, fenestrate and ramose bryozoan fragments, fusulinids, *Composita*, and fragments of productids, *Neospirifer*, and *Aulopora*. The shale between the limestone lenses is brownish gray (5 YR4/1), flaky, silty, poorly indurated, and contains plant fragments, root traces, echinoid spines, a few small fusulinids, low-spired gastropods, and small, abraded fragments of pectens(?), productids, and crinoids. The upper limestone lenses are coarse calcilutite to fine calcarenite, medium hard, poorly indurated, nodular, thin, patchy, with plant fragments, *Bairdia*, sparse fusulinids, myalinid(?) fragments, angular shell fragments (very fine sand size), and gypsum veins (<.75mm; primary?). Above the limestone lenses is soft mudstone, grading from medium light gray (N6) upward to olive black (5 Y 2/1), noncalcareous, very poorly indurated, flaky, with root traces, plant fragments, small high-spired gastropods, and bivalve fragments in the lower part, and small worn fragments of productids, *Composita*, chonetids, bryozoans, and weathered ironstone nodules in the upper 2 in. (5.1cm).

4. Fusulinid Packstone: (6-7.5ft.; 1.83-2.29m), medium light gray (N6) to medium dark gray (N4), weathers brownish gray (5 YR 4/1) to moderate brown (5 YR4/4); hard, well indurated, primarily massive but with cross laminations in the middle part and in the top 3-4 in. (7.6-10.2cm) and around chaetetids. In the bottom 1/3, chaetetids (10-30% of the rock) begin as small laminar forms which build into columns. In the middle 1/3, the chaetetid columns have coalesced into large clumps (50-80% of the rock), many reaching 15-20 ft. (4.5-6.1m) across. In the top 1/3 or less, chaetetids are reduced in number to 10-25% of the rock and occur primarily as

(Descriptions continued on next page)

Stratigraphic Section 700

(Descriptions continued from previous page)

Houx-Higginsville Limestone Member (continued)

4. (continued)
continuations of clumps persisting from the middle horizon. Chaetetid clumps commonly protrude 2-6 in. (5-15.2cm) into interval e. In many cases chaetetids and Aulopora have each in turn overgrown the other. Some smaller chaetetids are overturned in upper half. Gradational lower contact, sharp upper contact. Fossils: fusulinids (<50%), Chaetetes, Aulopora, Lophophyllidium, Composita, crinoids, echinoids (many have apparently disarticulated in place), chonetids, Derbyia, Pseudomonotis, Fistulipora, Hustedia, Neospirifer, Punctospirifer, Meekella, gastropods.

3. Calcarenite: (12-14in.; 30.5-35.6cm), light gray (N7), weathering olive gray (5 Y 4/1); fusulinid-rich, laminated and cross laminated with thin wavy dark shaly partings. Fusulinids have long axes aligned parallel to bedding, and larger fossil fragments are imbricated. Contains a 1-1.5 in. (2.5-3.8cm) light gray (N7) chert layer (continuous to nodular) at its middle. Contains lenses (up to 7 ft. x 11 in. (2.1 x .28m)) of medium light gray (N6) algal calcilutite below the chert layer. Laminar chaetetids are rare and small (up to 6.75 in. (17.1cm) across and up to 1.5 in. (3.8cm) thick) below the chert layer, sparse and slightly larger (up to 8 x 3 in.; 20.3 x 7.6 cm) above the chert layer; a few small Aulopora cap some chaetetids. Fossils: fusulinids (5-20%), Chaetetes, Aulopora, Composita, crinoid & echinoid pieces, horn corals, Hustedia, Cleiothyridina, Derbyia, productid fragments, Crurithyris(?), Fistulipora, Ditomopyge, Tetrataxis, palaeobigenerinids.

2. Algal Calcilutite: (6ft.; 1.83m), medium gray (N5), weathers olive gray (5 Y 4/1); dense, hard. Massive layers (2-20 in.; 5-50 cm; accurately shown in stratigraphic column) are separated by thin, wavy, dark shaly laminae. Algal blades occur in all but the bottom 20 in. (50cm). The bottom 6 in. (15.2cm) is medium gray (N5) argillaceous dolomitic(?) calcilutite showing only Crurithyris and abundant dark gray (N3) Chondrites with productids in upper 1/2 in. (1cm); this layer is sharply overlain by coarse calcarenite containing poorly sorted angular shell fragments (crinoid, echinoid, chonetid, productid, other brachiopod, & bryozoan debris). Sharp contacts. Fossils in the algal calcilutite: algal blades (5%), Composita (articulated, in life position),

(Descriptions continued on next page)

Stratigraphic Section 700

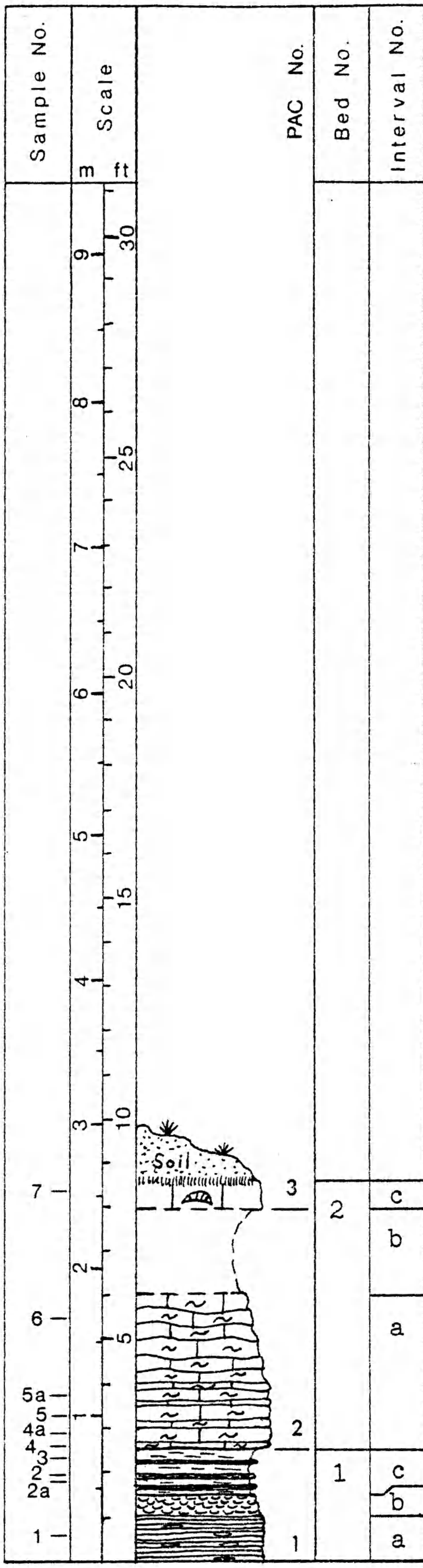
(Descriptions continued from previous page)

Houx-Higginsville Limestone Member (continued)

2. (continued)
crinoids, *Cleiothyridina*, marginiferids, horn corals, *Fistulipora*, *Rhombopora*, fenestrate bryozoan fragments, chonetids, echinoid fragments, *Mesolobus* fragments, *Cancrinella*, productid spines, *Ditomopyge*, *Hustedia*, *Tetrataxis*, nuculoid bivalves, small high-spired gastropods, *Annuliconcha interlineata*, *Krotovia*, bellerophontids, fish tooth or scale. All shell debris in black laminae are chalky.

Little Osage Shale Member

1. Shale: (6 in. exposed; 15.2cm), dark gray (N3) to grayish black (N2), fair hardness, fissile, falls apart when wet, noncalcareous. Sharp upper contact. Fossils: *Crurithyris* (abundant, with original shell material); small, light olive gray (5 Y 6/1) burrows (*Chondrites*); with some *Orbiculoidea*, platform-type conodonts, *Bathysiphon*(?), a fish scale, ammodiscid foraminiferid, and small pyritic burrow(?) fillings. Upper 1 in. (2.5cm) contains roots and small (<1mm) secondary gypsum crystals.



Locality Description: Strat. Sec. 765, exposed in creek bank (branch of Bone Crk) in pasture south of gravel road.

Location: ctr. of N. sec. line, sec. 22, T.28S., R.24E., Crawford Co., Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

2c. Limestone: (4-8in.; 10-20cm), light gray (N7), weathers dark yellowish orange (10 YR 6/6); poorly exposed on slope in pasture. Contains chaetetids (stacked laminar forms) with large cracks on their upper surfaces (desiccation?) and irregular silicified patches. Also contains brachiopods (Composita(?)), echinoid and crinoid fragments.

b. Covered: (2ft.; .61m).

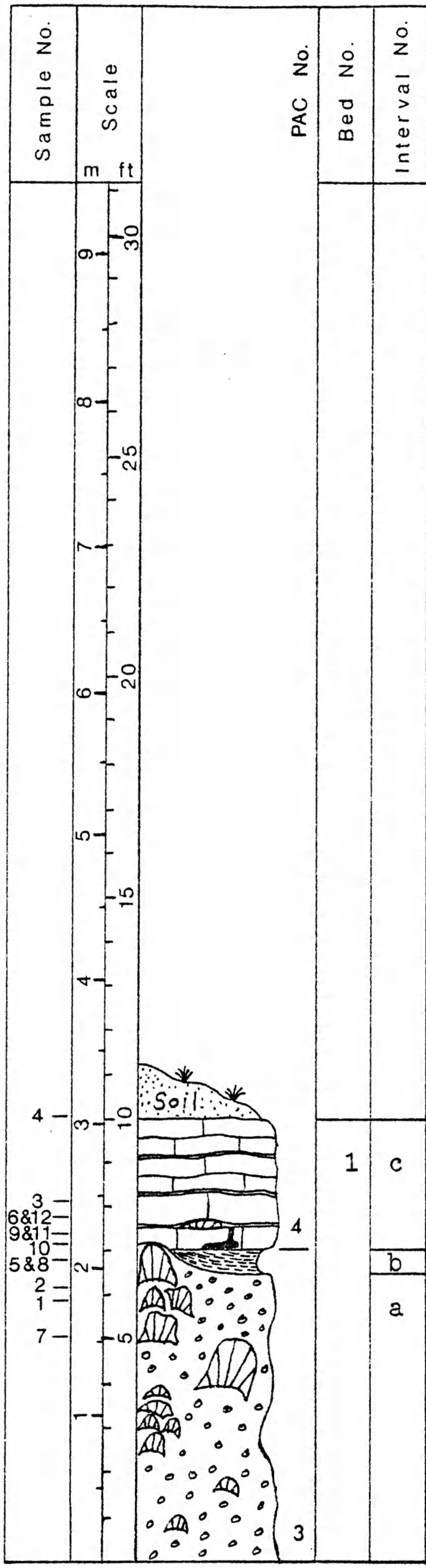
a. Calcilutite: (3.5ft.; 1.07m), medium gray (N5), weathers dark yellowish orange (10 YR 6/6); dense, hard, with abundant fossils; layers (1-5in.; 2.5-12.7cm) separated by thin, wavy, shaly black partings. Sharp basal contact. Fossils: algal blades (10-20%), angular shell fragments (brachiopods, crinoids, echinoids), Composita (some articulated and in life position), bryozoans (Fistulipora, Rhombopora, several fenestrate types), Mesolobus, Chonetes, Hustedia (articulated), Crurithyris (mostly disarticulated), Cleiothyridina, productids (Cancrinella and other fragments), Ditomopyge, Ameura, fusulinids (sparse), Tetrataxis, ophthalmids, bellerophontids, and low-spired gastropods.

Little Osage Shale Member

1c. Shale to Clayshale: (1ft.; .305m), grades upward from alternating grayish black (N2) shale and dark yellowish orange(10 YR 6/6) clayshale to strictly dark yellowish orange (10 YR 6/6) clayshale. Dark shale is fissile to crumbly with irregular wavy partings and contains Crurithyris (1-6mm, abundant, many with original shell material, mostly disarticulated), horizontal burrows (2x25mm, dark yellowish orange (10 YR 6/6), straight to arcuate), productid spines (Cancrinella?), Orbiculoidea fragments, plant fragments. The yellowish clayshale is very soft, clay-rich, slightly calcareous, and contains medium light gray (N6) stringers and subangular to rounded clasts (0.2-25.0mm) of claystone like the matrix and of black (N1) fissile shale; also contains burrow mottling, grapestones (sparse, ≤2mm), shell fragments (<1%, very fine to coarse sand size, broken and abraded; Crurithyris, Mesolobus), roots(?), and Orbiculoidea (may be only in the black shale clasts).

b. Shale: (6in.; 15.2cm), grayish black (N2), fissile but with very wavy partings, poorly indurated, with a few small phosphate nodules.

a. Shale: (1ft. exposed; .305m), black (N1) to grayish black (N2), weathers pale brown (5 YR 5/2); fissile, hard, with papery partings. Contains phosphate nodules (with nuclei of bivalves and Orbiculoidea; differential compaction around the nodules, a few with minor chalcopyrite mineralization), conodonts (hindeodellids, platform types), Dunbarella (common).



Locality Description: Strat. Sec. 706, abandoned quarry ½mi. (.8km) S. and ½ mi. (.8km) W. of Englevale, Kansas.

Location: NW¼, sec. 25, T.28S., R.24E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks: owned by Rose Cukjati

Description

Bed No.

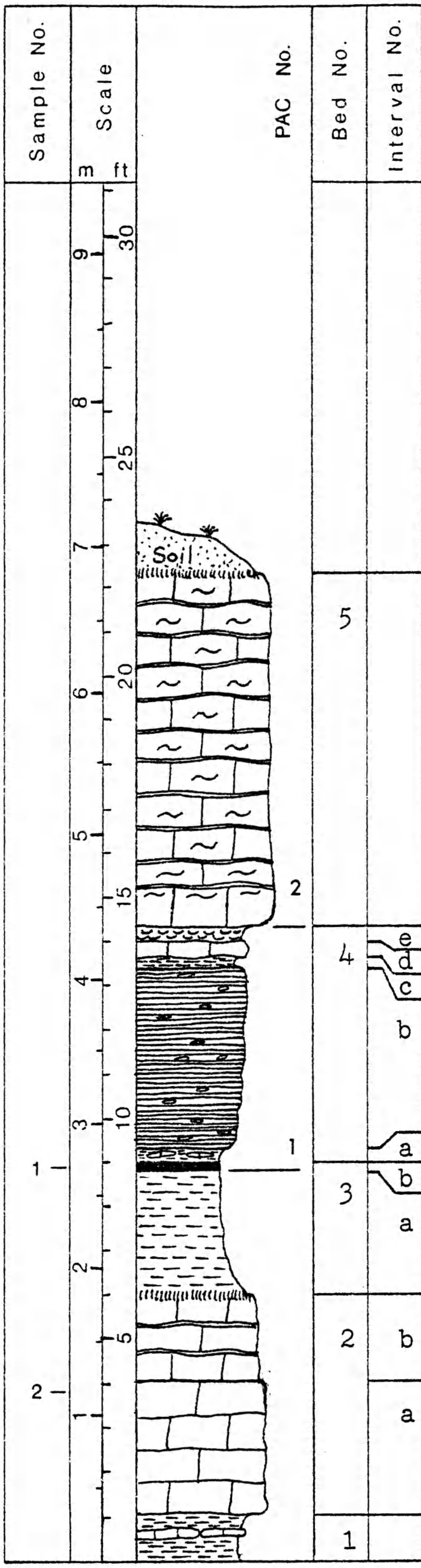
Wolverine Creek Formation
Houx-Higginsville Limestone Member

1c. Calcilutite: (3ft.; .91m), medium dark gray (N4), weathers light gray (N7); dense, hard, argillaceous. Four main intervals of calcilutite are separated by thin, dark gray (N3) weathering moderate yellowish brown (10 YR 5/4), muddier calcarenite. The calcilutite is massive; the thin dark layers are finely cross laminated and contain 5-10% sand to granule size shell debris (same types as in calcilutite) oriented subparallel to laminations. The lowest dark thin layer has laminar chaetetids. Minor dark thin layers occur in the middles of the top 2 calcilutite layers. Sharp basal contact. Fossils: algal blades (1-10%), brachiopods (2%; Composita, Meekella, with productids near base), crinoids, echinoids, fusulinids, horn corals, small bellerophontids(?), Fistulipora, Thalassinoides (in bottom 6 in. (15.2cm)). The bottom surface exhibits Thalassinoides, Neospirifer, productids, Composita, Lophophyllidium, Derbyia, Ditomopyge, Ameura, and fusulinids. The top surface is highly weathered, dark yellowish orange (10 YR 6/6), and has a 3/8 in. (.95cm) hard crust that is dusky yellowish brown (10 YR 2/2) and apparently iron rich.

b. Shale: (0-6in.; 0-15.2cm), grades from pale yellowish brown (10 YR 6/2) or grayish orange (10 YR 7/4) at the base upward through light olive gray (5 Y 6/1) in the middle and dark gray (N3) or medium gray (N4) at the top. Very soft, loose, flakey. Contains subangular to subrounded shaly clasts (sand to granule size), very broken and abraded shell fragments (algae- and clay-coated; fragments of Composita, productids, crinoids, chonetids). Bottom part has crinoid stems (slightly rounded); upper part is mostly nonfossiliferous with some plant fragments.

a. Fusulinid Packstone: (7 ft. exposed; 2.1m), medium light gray (N6), weathers grayish orange (10 YR 7/4); hard, well indurated, mostly massive but exhibits cross laminations around chaetetids and in the top 3-10 in. (7.6-25.4cm); fusulinids (up to 50%) in micritic matrix with other shelly debris. Sharp upper contact. Fossils: fusulinids, Chaetetes, brachiopods (mostly Composita, some Punctospirifer, other), crinoid and echinoid pieces, Aulopora, and bryozoans (encrusting and 2 or 3 types of branching).

Chaetetids occur as scattered individuals (up to 14x14 in. (.35x.35m)) and sporadic small clumps (up to 22 in. (.56m) across and 20 in. (.51m) high). Some chaetetids protrude 2-3 in. (5-7.6cm) into interval c.



Locality Description: Strat. Sec. FST, S. side of railroad, at N. edge of Old Ft. Scott property, W. of U.S.Hwy.69 overpass.

Location: NE$\frac{1}{4}$NW$\frac{1}{4}$, sec. 30, T.25S., R.25E., Bourbon County, Kansas.

Measured By: D. R. Suchy   Date: 1986

Remarks: part of Knight's (1985) Loc. FST.

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

5 Algal Calcilutite: (8ft.; 2.4m), gray, dense, hard; thin to medium beds (1-12in.; 1.5-30.5cm) separated by thin, wavy, shaly partings (1/8-1½in.; 0.3-3.8cm). Bottom layer of calcilutite is 11in. (27.9cm) thick and shows no algal blades in bottom 2/3 and up to 10% algal blades in upper 1/3 with a few brachiopods and crinoids. Subsequent layers contain abundant algal blades (up to 40-50%), crinoid pieces, brachiopods (mostly Composita, many articulated and in life position), and a few horn corals. Matrix is micritic. The thin wavy partings contain fine silt to gravel size calcareous grains and shelly debris (brachiopods, crinoids; many are broken but little abraded) in a dark shaly matrix.

Little Osage Shale Member

4e. Shale: (4-5in.; 10.2-12.7cm), dark gray, flakey, laminated. Sharp contacts. Mostly nonfossiliferous.

d. Calcilutite: (2.5-5in.; 6.4-12.7cm), gray, with sharp contacts, rare brachiopods.

c. Shale: (3in.; 7.6cm), dark gray to black, flakey to fissile, with Dunbarella, small horizontal burrows.

b. Shale: (4ft.; 1.22m), black, fissile, with phosphate nodules.

a. Shale: (3-4in.; 7.6-10.2cm), medium dark gray, soft, with limestone nodules and brachiopods (productids(?); some are pyritized).

Morgan School Shale Formation

3b. Coal: (2-4in.; 5.1-10.2cm), black (N1), weathers light brown (5 YR 5/6) to dark yellowish orange (10 YR 6/6). Contains abundant plant fragments and iron-stained lenses with pyritized brachiopods (productids, mostly fragments).

a. Shale: (32in.; .81m), light gray at base, medium dark gray at top, clay-rich, flakey, soft, a few orange horizontal laminations. Gradational basal contact. Plant fragments.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

2b. Argillaceous Calcilutite: (2ft.; .61m), light gray, wavy bedded, nodular, with occasional irregular, discontinuous, wavy shaly laminae. Contains abundant brachiopods.

a. Calcilutite: (3ft.; .91m), medium light gray (N6), weathers grayish orange (10 YR 7/4); dense, hard, massive. Sharp contacts. Fossils: abundant brachiopods (Composita), crinoids, some fenestrate bryozoans, a few fusulinids and algal blades.

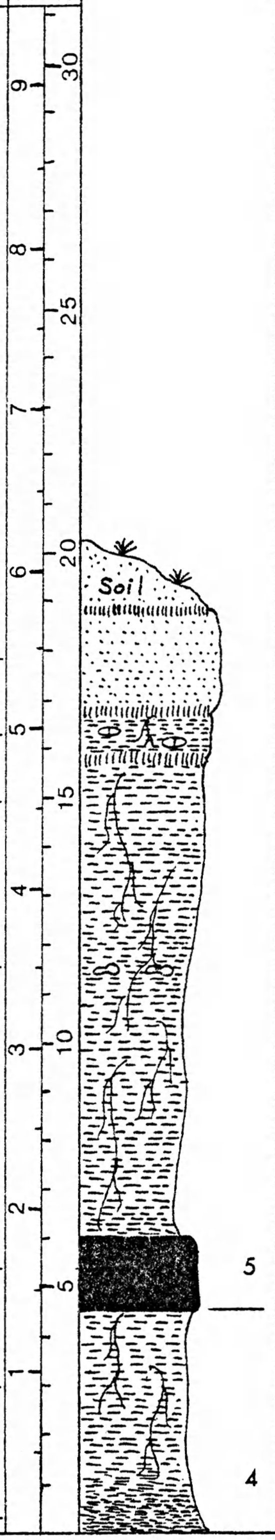
Excello Shale Member

1 Shale: (8-10 in. exposed; 20.3-25.4cm), gray, soft, laminated. Approximately 3-4 in. (7.6-10.2cm) below top is a 2-3 in. (5-7.6cm) layer that contains nodules of gray calcilutite containing sparse brachiopods.

Sample No.	Scale (m ft)	PAC No.	Bed No.	Interval No.	Locality Description: Strat. Sec. 339, old cement quarry approximately 1 mi. (1.6km) NNE. of Fort Scott, Kansas. Location: Ctr. of W½SW¼, sec. 17, T.25S., R.25E., Bourbon County, Kansas.

Measured By: D. R. Suchy . Date: Jan.,1987

Remarks:



Description

Bed No.

Labette Shale Formation

Sample No.	PAC No.	Bed No.	Interval No.	Description
1		3	e	3e. Sandstone: (2ft.; .61m), light gray (N7), weathers dark yellowish orange (10 YR 6/6); very fine to fine grained, siliciclastic, massive, grading laterally to thin bedded and nodular. Irregular nodular base. Gradational basal contact. Fossils: a few very small unidentified shell fragments, burrows(?).
2			d	d. Claystone: (1ft.; .305m), pale olive (10 Y 6/2), weathers dark yellowish orange (10 YR 6/6); very soft, nonindurated; contains limestone nodules, very small to 3.5 in. (9cm), that exhibit abundant root traces. Gradational contacts. Fossils: roots, a pecten fragment.
3, 4			c	c. Claystone: (9ft.9in.; 2.97m), pale olive (10 Y 6/2), very soft, nonindurated Sharp basal contact. Calcareous ironstone nodules occur 5 ft. 6 in. (1.68m) above the base. Fossils: root traces, plant fragments.
5	5		b	b. Coal: (18in.; .46m), black (N1), blocky.
6, 7	4		a	a. Claystone: (4ft.6in.; 1.37m), medium dark gray (N4), very soft, nonindurated, calcareous. Contains root traces, plant fragments (abundant), and limey nodules (7mm). Bottom 6-12 in. (15.2-30.5cm) is grayish black (N2) to black (N1), with no fossils.

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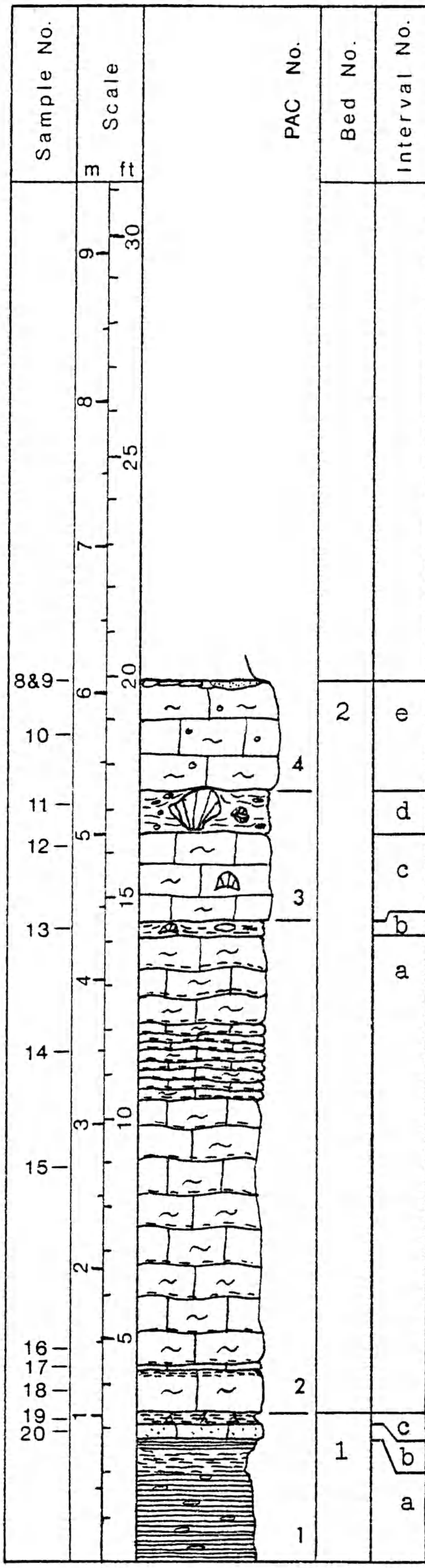


Locality Description: Strat. Sec. 339.

(Continued from previous page).

Location:

Measured By: Date:

Remarks:

Description

Bed No.

(Continued from previous page)

Wolverine Creek Formation
Houx-Higginsville Limestone Member

2e. Algal Calcilutite: (2ft.6in.; .76m), light olive gray (5 Y 6/1), weathers grayish orange (10 YR 7/4); massive, dense, hard. Top 3–6 in. (7.6–15.2cm) is highly weathered and nodular with some iron-stained nodules and some thin (0–4in.; 0–10.2cm) lenses of shelly, intraclast-bearing coarse calcarenite (lag deposit). Main rock body contains algal blades (up to 5%), fusulinids (1–2%), crinoid stems, horn corals, Chonetes (wide size range; articulated), Linoproductus (in life position), Composita, brachiopod fragments, echinoid spines, fenestrate bryozoans, Dialasma, gastropod (2.5mm, low conospiral), bivalve(?) fragment.
The weathered layer at the top contains fusulinids (5–15%), articulated Chonetes and Derbyia that are stained grayish red purple (5 RP 4/2), Wilkingia (internal mold, in life position), crinoid pieces, productid spines, Neospirifer, echinoid spines, Composita valve, Bairdia, Cruritbyris, shell fragments (abraded, jumbled; marginiferids, Rhombopora, other ramose bryozoans, fenestrate bryozoans, pectens).
The coarse calcarenite lenses at the top contain fusulinids (up to 50%) and shell fragments (all rounded and broken; many of the species listed above plus Ameura).

d. Calcarenite: (1ft.; .305m), medium gray (N5), weathers dark yellowish orange (10 YR 6/6); medium to coarse grained, cross laminated, with abundant shelly debris (broken and abraded) and fusulinids aligned parallel to laminations. In-place Chaetetes (up to 12in. (30.5cm) wide and 14in. (35.6cm) high) have laminae draped over them. Some smaller chaetetids have been rolled over and a few have been silicified. Sharp contacts. Other fossils: crinoid and echinoid pieces, Teguliferina(?) (on underside of chaetetid), Tetrataxis, ramose and encrusting bryozoans, Cruritbyris, Composita, other brachiopod fragments.

c. Calcilutite: (2ft.; .61m), medium gray (N5), weathers moderate yellowish brown (10 YR 5/4); dense, hard, massive. Contains algal blades, unidentified brachiopod fragments, Chaetetes (some with borings), crinoid fragments, fusulinids (rare).

b. Calcilutite: (4in.; 10.2cm), light gray (N7), weathers dark yellowish orange (10 YR 6/6); dense, hard, with wavy shaly laminae. Some algal(?) laminations. Chaetetes (mostly laminar; some with algal crusts on top). Chert nodules. Other fossils: crinoid pieces, brachiopod fragments, palaeobigenerinids, fusulinids.
No Chaetetes occur below this layer.

a. Calcilutite: (10ft.9in.; 3.28m), medium gray (N5), weathers grayish orange (10 YR 7/4); dense, hard, thin to medium wavy beds separated by dark shaly laminae. Beds are thinner at some zones within this interval. Chert nodules scattered sparsely throughout. Calcilutite contains algal blades (1–10%), fusulinids (1–5%), crinoid & echinoid pieces, Composita (very common, many articulated), Cleiothyridina, Derbyia, Punctospirifer, Meekella, chonetid fragments, productid spines, Prismopora, Rhombopora, fenestrate bryozoans, Fistulipora, palaeobigenerinids, Polytaxis, Tetrataxis, spirorbid worms, gastropod (2mm).

(Descriptions continued on next page)

Stratigraphic Section 339

(Descriptions continued from previous page)

2a. (Continued)

Dark shaly partings show many of the same fossil types as in the calcilutite but they are more broken, abraded, and in jumbled positions. Some microstylolites occur.

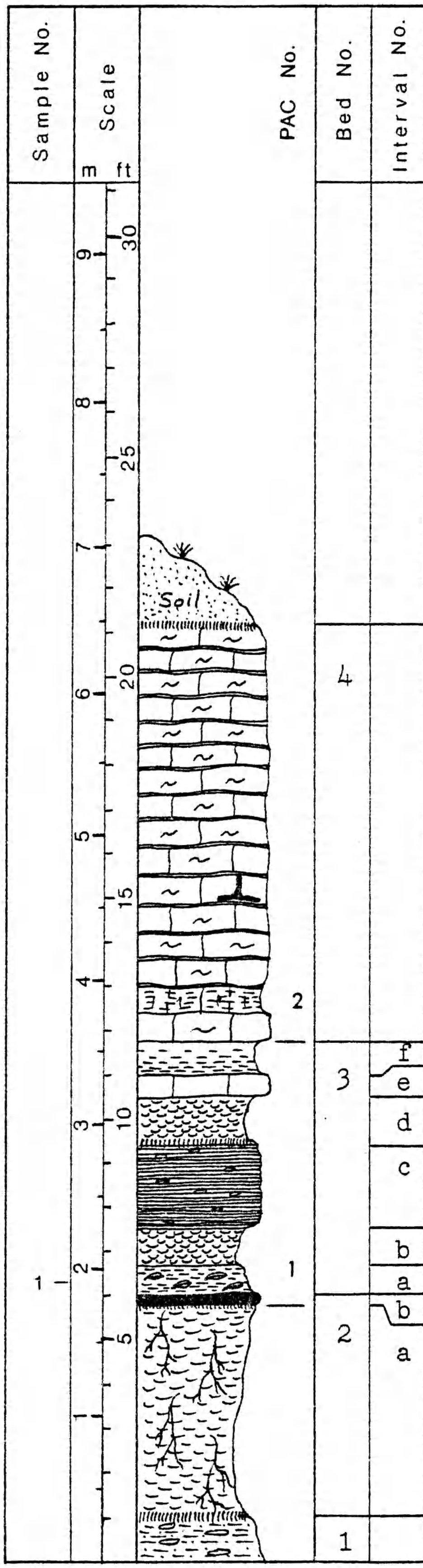
Bottom 11 in. (30cm) is calcilutite to very fine calcarenite similar to the rest of this interval but has a dark gray (N3) muddy layer on top which contains crinoid pieces, brachiopod fragments (Composita, Crurithyris, Punctospirifer), productid spines, branching bryozoan fragments, and Tetrataxis(?). Bottom surface shows Crurithyris, Mesolobus, marginiferid fragments, Dialasma.

Little Osage Shale Member

1c. Shale: (3in.; 7.6cm), dark gray (N3), weathers light olive gray (5 Y 6/1); calcareous, medium induration, blocky to crumbly. Sharp contacts. Fossils: roots (abundant), Crurithyris (some articulated), small burrows (Chondrites?).

b. Calcisiltite: (4-5in.; 10.2-12.7cm), medium dark gray (N4), weathers yellowish gray (5 Y 8/1); dense, very hard. Sharp contacts. Fossils: Orbiculoidea, marginiferids, small burrows, chonetids, Crurithyris, conodonts on bottom (hindeodellids), roots on top.

a. Shale: (2ft.9in.; .84m), black (N1) to grayish black (N2). Top 3 in. (7.6cm) is fissile; next lower 6-7 in. (15.2-17.8cm) is soft, crumbly, flakey; remainder is hard, fissile, with phosphate nodules and conodonts.



Locality Description: Strat. Sec. MB, NE. cutbank of Marais Des Cygnes River at Marble Bridge.

Location: $NW\frac{1}{4}NW\frac{1}{4}$, sec.2, T.39N., R.33W., Bates County, Missouri.

Measured By: D. R. Suchy Date: 1986

Remarks: same as Knight's (1985) Loc. MB

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

4 Calcilutite: (9ft.6in.; 2.9m), light gray (N7); dense, hard, thin to medium beds separated by wavy dark shaly partings. The bottom 8 in. (20.3cm) limestone bed is overlain by a 6-8 in. (15.2-20.3cm) shaly layer with limestone thin beds and lenses. Sharp basal contact. Fossils: algal blades (1-10%), brachiopods (Composita, others), crinoids, echinoids. Thalassinoides occur on the underside of a layer 2.5 ft. (.76m) above the base.

Little Osage Shale Member

3f. Shale to mudstone: (9in.; 23cm), medium gray (N5) shale at the base grading upward to dark yellowish orange (10 YR 6/6) soft mudstone at the top. Sparse brachiopods (Crurithyris?).

e. Calcilutite: (5-6in.; 12.7-15.2cm), medium gray (N5), weathers dark yellowish orange (10 YR 6/6); dense, hard. sharp contacts. Fossils: brachiopods (<2%; Composita, chonetids, productids).

d. Shale: (13in.; 33cm), brownish gray (5 YR 4/1), flakey. Black mottling near base, yellow mottling near top. Top 2 in. (5.1cm) is alternating light gray and yellowish tan laminae with abundant small brachiopods. Chonetids and productids in upper half (increase upsection).

c. Shale: (23in.; .58m), black, fissile, with phosphate nodules. Sharp basal contact, gradational upper contact.

b. Shale: (10in.; 25.4cm), dark gray (N3), weathers grayish orange (10 YR 7/4), flakey to somewhat fissile. Sparsely fossiliferous (a few small chonetids). Top 1 in. (2.54cm) is a yellowish calcareous layer with up to 10% small brachiopods (<$\frac{1}{4}$in.; <6mm).

a. Mudstone: (8in.; 20.3cm), weathers grayish orange (10 YR 7/4), poorly indurated, crumbly. Abundant productids (20%): Desmoinesia, articulated, stained light brown (5 YR 5/6) to dark yellowish orange (10 YR 6/6), lower ones in life position, upper ones in hydrodynamically stable position. Also contains Mesolobus (disarticulated but in good condition), plant(?) fragments, Meekospira.

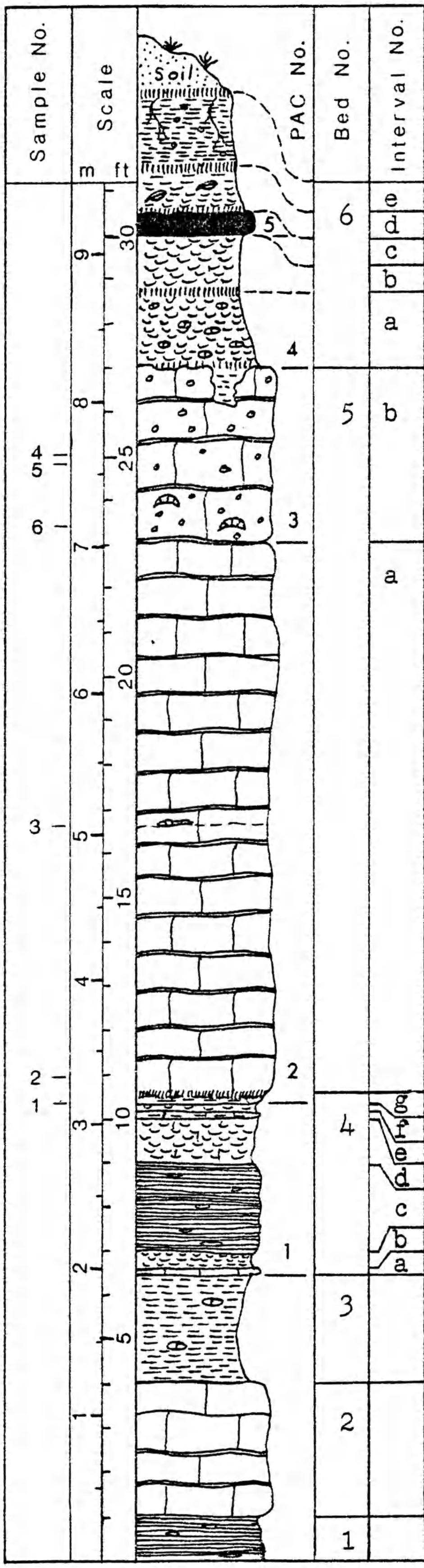
Morgan School Shale Formation

2b. Coal: (2-3in.; 5.1-7.6cm), black, blocky. Gradational basal contact, sharp upper contact.

a. Claystone: (4ft.9in.; 1.45m), gray, mottled with orange and green, soft, flakey, no bedding. Contains plant fragments and root traces throughout, with thin (1/8-1/2in; 3-13mm) wavy coal seams near top.

Dry Branch Creek Formation
Blackjack Creek Limestone Member
(Knight (1985) calls this interval part of the Morgan School Shale, but this author favors calling it part of the Blackjack Creek Limestone).

1 Siltstone: (1 ft. exposed; .305m), light gray, very soft. Contains white limestone nodules that contain abundant brachiopods.



Locality Description: Strat. Sec. BUT and part of J17; active quarry 2 mi. (3.2km) W. & $\frac{1}{2}$ mi. (.8km) S. of Butler, Missouri.

Location: $SW\frac{1}{4}SE\frac{1}{4}$, sec. 19, T.40N., R.31W., Bates County, Missouri.

Measured By: D. R. Suchy Date: 1986

Remarks: partial J17 from Jeffries (1958)

Description

Bed No.

Labette Shale Formation

6e. Shale: (20in.; .51m), yellowish gray, clay-rich, soft. Abundant black root traces and a few fusulinids and very small chonetids.

d. Shale: (12in.; .305m), gray-brown, flakey. The top 3 in. (7.6cm) is tan-orange and grades into overlying layer. Abundant productids, chonetids, and Composita.

c. Coal: (6in.; 15.2cm), black. Top 1.5 in. (3.8cm) grades to fossiliferous shale with thin (1/8-1/4in.; 3-6mm) coal seams.

b. Shale: (16in.; .41m), gray, soft, flakey. Scattered plant fragments.

a. Shale: (20in.; .51m), gray, soft, flakey. Small limestone nodules that are rich in fusulinids. Gradational lower contact.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

5b. Calcilutite: (4ft.; 1.22m), light gray (N7) to very light gray (N8), medium density, medium hardness. Massive beds (6-18in.; 15.2-45.7cm) separated by wavy shaly partings. This interval has thicker beds, more highly cross laminated shaly partings, lighter color, less density and more fusulinids than interval 5a. Some layers (up to 1cm) are a fusulinid packstone (lag deposit) with fragments of crinoids, brachiopods, chonetids, & bryozoans. The top 3-4 in. (7.6-10.2cm) is yellow-orange and karstic, with some karst hollows extending 1 ft. (.305m) down into the limestone. Some small chert nodules occur in bottom 1 ft. (.305m). Fossils: fusulinids (5-15%), crinoid pieces, a crinoid calyx (Delocrinus?; articulated, compressed), Derbyia, Mesolobus, Chonetinella, Composita, brachiopod fragments, Fistulipora, Bairdia, pseudozygopleurids, ophthalmids, and palaeotextulariids. Chaetetids are sparse and small (<5in.; <12.7cm), laminar to low domical, and one had been rolled over when 4.5 in (11.4cm) across and then growth resumed on the opposite side.

a. Calcilutite: (12ft.6in.; 3.81m), light gray (N7), dense, hard. Beds (1-12in.; 2.5-30.5cm) are separated by thin (1/8-3.5in.; 3mm-9cm), wavy, shaly partings. Gradational basal contact.

The calcilutite contains medium dark gray (N4) burrow(?) mottling (pelleted?) and generally <5% macrofossils: crinoid pieces, Composita (some articulated, some (<5mm) with geopetal structures indicating overturning), fusulinids, algal blades, horn corals, Meekella, Dialasma, brachiopod fragments. The bottom 2 in. (5cm) grades upward from medium calcarenite with subangular shelly debris in a micritic matrix to calcilutite. Sample BUT-3 showed Osagia, some of which had become stabilized, then grew upward and were overgrown by very small laminar Chaetetes, which in turn was covered by coarser lime mud and shelly debris. Some very small (<2mm) patches and fossils have been replaced by framboidal pyrite.

The shaly partings are generally black, cross laminated, and contain broken and abraded shell fragments (brachiopods, crinoids, horn corals, fusulinids) in higher percentage (10-25%) than in the calcilutite. Some of the thicker shaly partings contain lithoclasts (subangular, up to 3 in. (7.6cm) across) and rolled, mud-filled Composita. Shaly partings can be traced horizontally throughout quarry.

(Descriptions continued on next page)

Stratigraphic Section BUT

(Descriptions continued from previous page)

Little Osage Shale Member

4g. Shale: (2.5in.; 6.4cm), dark gray (N3), medium hard, blocky to fissile, calcareous. Gradational contacts. Fossils: burrows (10-15%; horizontal, up to 2x25mm, light gray (N7)), Crurithyris (2-3%, unbroken, unabraded).

f. Shale: (2in.; 5.1cm), medium gray (N5) to light gray (N7), medium induration and hardness, slightly fissile, very calcareous (nearly argillaceous calcilutite). Fossils: root traces (1%), Crurithyris (1%), Neospirifer fragment, brachiopod fragments, burrows (<<1%), other shell fragments, some with pyrite linings.

(All measurements and descriptions below this point are taken from Jeffries (1958), Stratigraphic Section 17, at same locality).

e. Shale: (2in.; 5.1cm), tan-gray, very calcareous; contains small fragments of fossils.

d. Shale: (1ft.; .305m), dark gray, flaky, calcareous.

c. Shale: (2ft.; .61m), black, fissile; contains abundant flattened phosphatic nodules.

b. Shale: (5in.; 12.7cm), dark gray to black, flaky.

a. Limestone: (1in.; 2.54cm), gray, fine grained, shaly; contains abundant fragments of fossils.

Morgan School Shale Formation

3 Clay: (2ft.6in.; .76m), gray, in part calcareous; contains sparse iron-stained limestone nodules.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

2 Limestone: (3ft.; .91m), gray, fine grained, sublithographic; weathered surface nodular; shale partings in lower part; sparsely fossiliferous.

Excello Shale Member

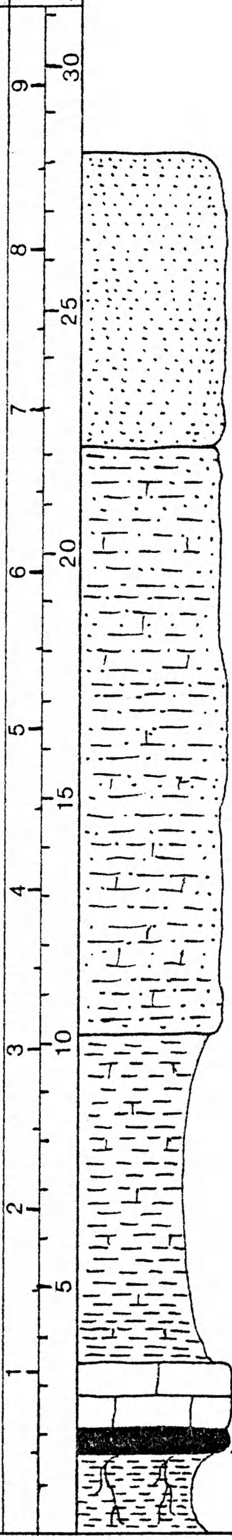
1 Shale: (1ft.; .305m), black, fissile; contains abundant flattened phosphatic nodules; also contains sparse limestone nodules up to 1 ft. (.305m) in diameter.

Sample No.	Scale (m, ft)		PAC No.	Bed No.	Interval No.	

Locality Description: Strat. Sec. J30, units 1a–2c measured in N. ditch of Co. Rd. H, ctr. of S. line of SW$\frac{1}{4}$ sec. 16, units 3–4f measured in quarry SE$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 16, T.40N., R.28W., Henry Co., Mo.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)



Description

Bed No.

Anna Shale of Pawnee Formation–Labette Formation

PAC No.	Bed No.	Interval No.	Description
	5	f	5f. Sandstone: (6ft.0in.; 1.83m), composed of fine subrounded quartz grains, friable; bedding thin to medium; heavy iron stain on surface; contains plant impressions.
		e	e. Alternating shale and siltstone: (12ft.0in.; 3.66m), tan to tan-gray, very calcareous, thin bedded; contains thin beds of limestone.
		d	d. Shale: (6ft.9in.; 2.06m), dark gray at base to gray at top, flaky to platy, calcareous.
5		c	c. Limestone: (1ft.4in.; .405m), dark gray, very shaly; contains abundant brachiopods.
		b	b. Alvis coal: coal: (6in.; .152m), black, shiny, blocky.
4		a	a. Clay: (1ft.8in.; .509m), gray, slightly flaky; contains carbonized fossil roots.

(Continued on next page)

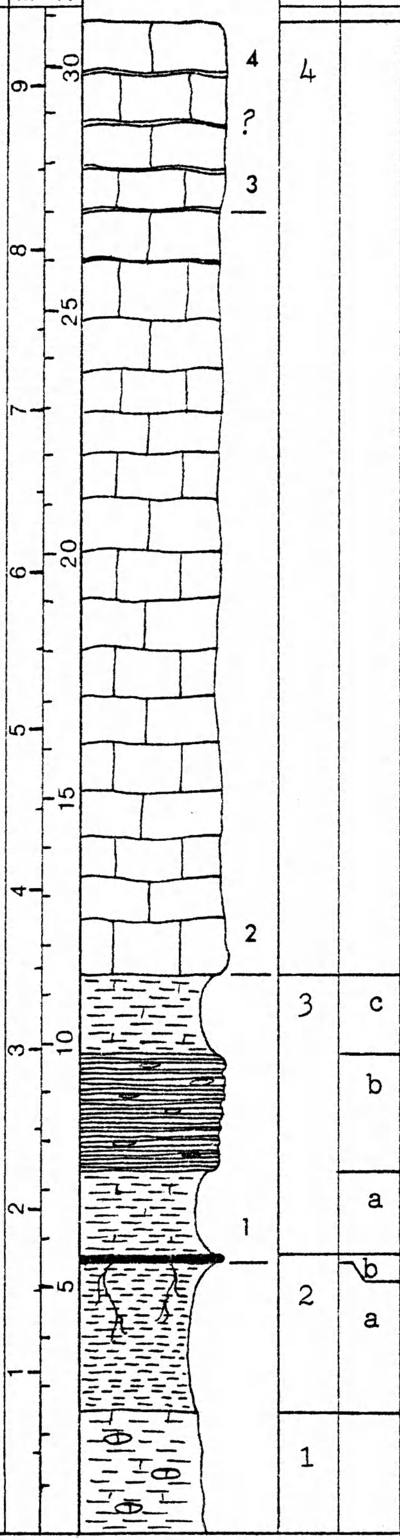
Sample No.	Scale		PAC No.	Bed No.	Interval No.	Locality Description: Strat. Sec. J30

(Continued from previous page)

Location:

Measured By: Date:

Remarks:



Description

Bed No.

(Continued from previous page)

Wolverine Creek Formation
Houx-Higginsville Limestone Member

4 Limestone: (19ft.6in.; 5.94m), light gray, in part with medium gray mottling, fine grained; fracture smooth, subconchoidal; bedding wavy, especially at top, developed by green-gray shale partings; fossiliferous.

Little Osage Shale Member

3c. Shale: (1ft.8in.; .509m), dark gray to gray, calcareous; weathers to brown-gray; contains brachiopods.

b. Shale: (2ft.5in.; .737m), black, fissile; contains abundant small flattened phosphatic nodules.

a. Shale: (1ft.8in.; .509m), dark gray to brown, platy, calcareous; contains brachiopods.

Morgan School Shale Formation

2b. Summit Coal: coal: (2in.; 5.1cm), black, shaly.

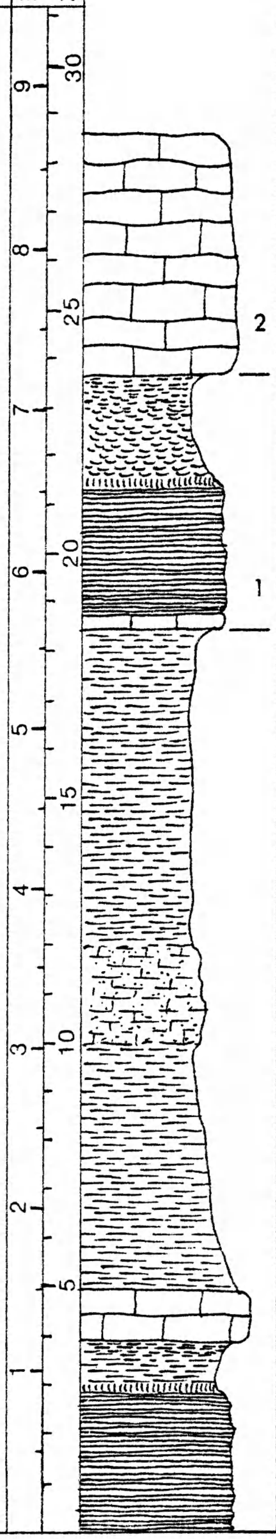
a. Clay: (3ft.0in.; .914m), gray; top part contains carbonized fossil roots.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

(Jeffries (1958) does not place the upper boundary of the Blackjack Creek Limestone at this point but this paper favors its placement here).

1 Shale: (2ft.6in.; .762m), yellow-brown, very calcareous; contains abundant limestone nodules; base not exposed.

Sample No.	Scale (m, ft)		PAC No.	Bed No.	Interval No.	
						Locality Description: Strat. Sec. U, road cut at top of hill on Hwy. K, 2.5mi. (4.02km) N. of Hwy. 18.
						Location: SW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 34, T.42N., R.28W., Henry Co., Missouri.
						Measured By: K. L. Knight Date: 1985
						Remarks: taken from Knight (1985)



Bed No.: 5; 4 (c, b, a); 3; ?; 2; 1 (b, a)

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

5 Limestone: (approx. 5 ft.; 1.52m), calcilutite with algal blades, crinoids, brachiopods, and fusulinids; top eroded.

Little Osage Shale Member

4c. Shale: (2ft.3in.; .686m), dark gray, flakey with gradational base, grades into green claystone at top.

b. Shale: (2ft.8in.; .814m), black, fissile.

a. Limestone: (3in.; 7.62cm), nodular, contains brachiopods.

Morgan School Shale

3 Shale: (13ft.5in.; 4.09m), gray, brachiopods, 2 ft. (.61m) silty limestone zone weathering as nodules on outcrop about 5ft. (1.52m) up in shale.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

(Knight (1985) places the upper boundary of the Blackjack Creek Limestone at this point, but it may fit better at the top of the silty limestone zone described in the Morgan School Shale).

2 Limestone: (1ft.0in.; .305m), massive fossiliferous calcilutite.

Excello Shale Member

1b. Shale: (1ft.0in.; .305m), dark gray, grades into black shale below and green claystone above.

a. Shale: (3ft.0in.; .914m), black, fissile.

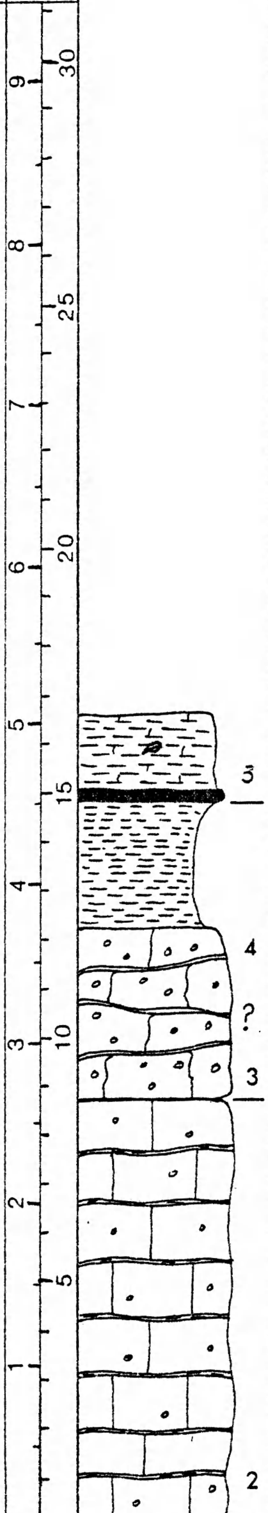
Sample No.	Scale (m ft)		PAC No.	Bed No.	Interval No.

Locality Description: Strat. Sec. J33, about 2 mi. SW of Urich, in south highwall of quarry.

Location: SW$\frac{1}{4}$SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 17, T.42N., R.28W., Henry County, Missouri.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)



Description

Bed No.

Bed No.	Interval No.	
2	c	**Anna Shale of Pawnee Formation-Labette Formation** 2c. Shale: (1ft.6in.; .457m), dark gray, calcareous; contains a few thin limestone beds; also contains abundant *Mesolobus* and sparse *Derbyia*.
	b	b. *Alvis Coal*: coal: (3in.; 7.6cm), black weathered.
	a	a. Clay: (2ft.7in.: .787m), gray, poorly exposed.
1	b	**Wolverine Creek Formation** **Houx-Higginsville Limestone Member** 1b. Limestone: (3ft.6in.; 1.07m), light gray, fine grained, very nodular; fracture uneven; in part has brecciated appearance; bedding thin, wavy, developed by shaly partings; contains fusulinids.
	a	a. Limestone: (8ft.9in.; 2.67m), light gray with medium gray mottling, fine grained; fracture smooth, subconchoidal; bedding medium, developed by green-gray shaly partings; contains *Derbyia*, *Composita*, *Marginifera*, *Chonetes*, *Antiquatonia*, *Phricodothyris*, *Meekella*, large fusulinids, small crinoid columnals, and horn corals.

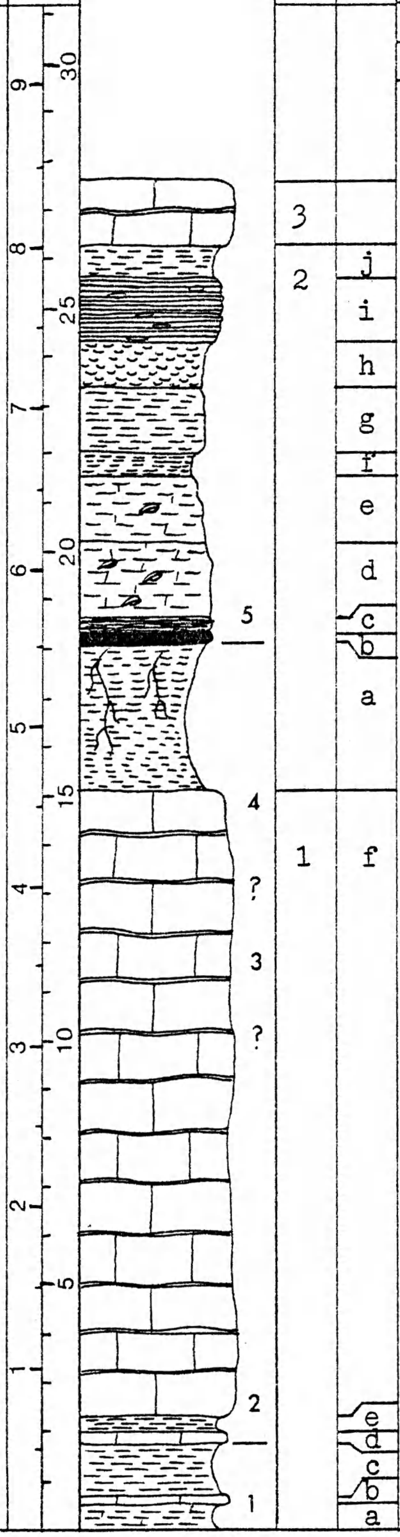
Sample No.	Scale (m, ft)		PAC No.	Bed No.	Interval No.	

Locality Description: Strat. Sec. J36, about 0.6mi. (.97km) SE of Shawnee Mound, in quarry.

Location: $NE\frac{1}{4}SE\frac{1}{4}$ sec. 11, T.43N., R.26W., Henry County, Missouri.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)



Description

Bed No.

Pawnee Formation
Myrick Station Limestone Member

3 Limestone: (1ft.4in.; .405m), gray, fine grained; fracture uneven; weathered surface tan, rounded; bedding wavy.

Anna Shale of Pawnee Formation-Labette Formation

2j. Shale: (8in.; .204m), gray to tan-gray, massive, weathered.

i. Shale: (1ft.3in.; .381m), black, platy to fissile; contains abundant small rounded phosphatic nodules.

h. Shale: (11in.; .279m), dark gray, flaky to platy; much sulfur on bedding surfaces.

g. Shale: (1ft.3in.; .381m), alternating brown-gray and dark gray, platy.

f. Shale: (6in.; .152m), brown to gray, soft, massive.

e. Shale: (1ft.4in.; .405m), alternating dark gray and brown-gray, slightly calcareous; contains brachiopods.

d. Shale: (1ft.6in.; .457m), dark gray, very calcareous, platy; contains abundant brachiopods.

c. Shale: (4in.; 10.1cm), dark gray, carbonaceous, flaky.

b. Alvis Coal: coal: (3in.; 7.6cm), black, shiny, blocky.

a. Clay: (3ft.0in.; .914m), gray, massive; contains carbonized fossil roots.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

1f. Higginsville Limestone: limestone: (12ft.10in.; 3.91m), light gray with medium gray mottling in lower part, fine grained; fracture smooth, subconchoidal; bedding wavy, developed by thin shaly partings; fossiliferous.

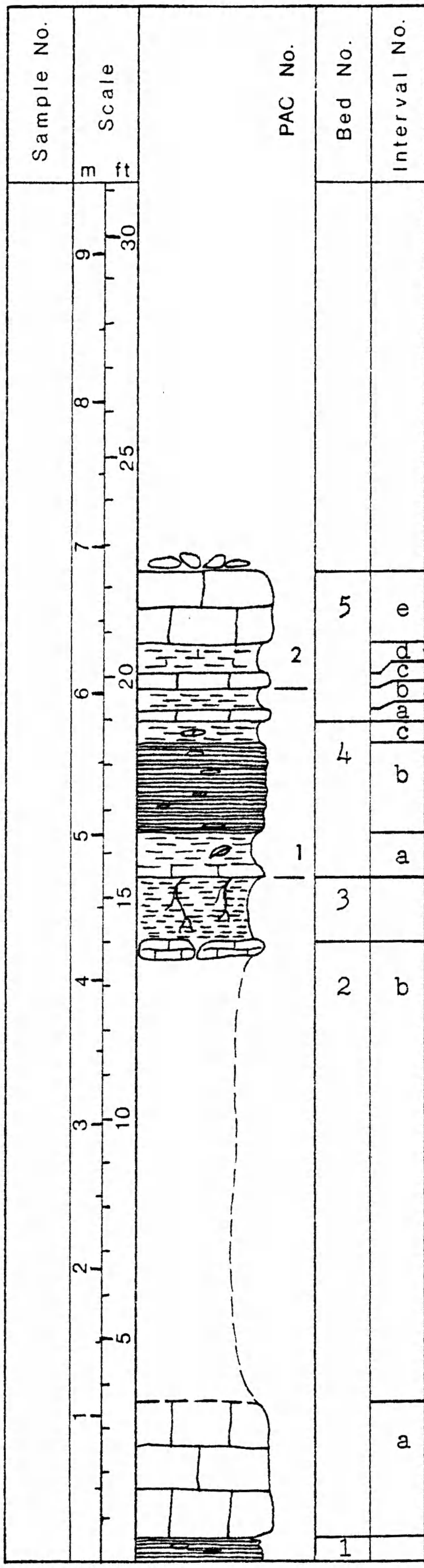
e. Shale: (4in.; 10.1cm), gray, platy, calcareous; contains abundant brachiopods, horn corals, bryozoans, and large crinoid columnals.

d. Limestone: (3in.; 38.1cm), gray, fine grained, earthy, nodular; contains abundant Crurithyris.

c. Shale: (1ft.1in.; .330m), dark gray, platy; contains irregular green markings.

b. Houx Limestone: limestone: (2in.; 5.1cm), gray, fine grained, earthy, slightly slabby; contains small brachiopods.

a. Shale: (no thickness given), dark gray, calcareous, platy; contains irregular green markings; in floor of quarry.



Locality Description: Strat. Sec. J45, about 2 mi. (3.2km) W. of Cornelia, in N. ditch of gravel rd. W. of T-rd. south.

Location: along S. line of SW¼SE¼ sec. 34, T.45N., R.26W., Johnson County, Missouri.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

5e. Higginsville Limestone: limestone: (1ft.8in.;.509m), gray, fine grained; fracture smooth; weathered surface gray, rounded; contains abundant fossils; much chert resting on the top of this unit.

d. Shale: (8in.; 20.4cm), gray to green-tan, calcareous; contains limestone nodules; abundantly fossiliferous, mainly large crinoid columnals and Crurithyris.

c. Limestone: (4in.; 10.1cm), gray, fine grained, slightly earthy; occurs in one nodular bed.

b. Shale: (6in.; 15.2cm), gray to green-tan, iron stained.

a. Houx Limestone: limestone: (3in.; 7.6cm), gray, fine grained; contains much green clay; occurs in one nodular bed.

Little Osage Shale Member

4c. Shale: (6in.; 15.2cm), gray to tan-green, calcareous; contains limestone nodules.

b. Shale: (2ft.0in.; .61m), black to dark gray, very platy to fissile; contains small flattened phosphatic nodules.

a. Shale: (1ft.0in.; .305m), gray, very calcareous: in part a limestone; contains abundant brachiopods.

Morgan School Shale Formation

3 Clay; (1ft.5in.; .432m), gray; contains sparse carbonized fossil roots.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

2b. Cover: (10ft. 5in.; 3.175m), nodular limestone zone near top.

a. Limestone: (3ft.2in.; .965m), tan-gray, fine grained; fracture angular; weathered surface brown, slightly blocky; contains abundant brachiopods and crinoid columnals.

Excello Shale

1 Shale: (2ft.4in.; .710m), black, fissile; contains abundant small flattened phosphatic nodules.

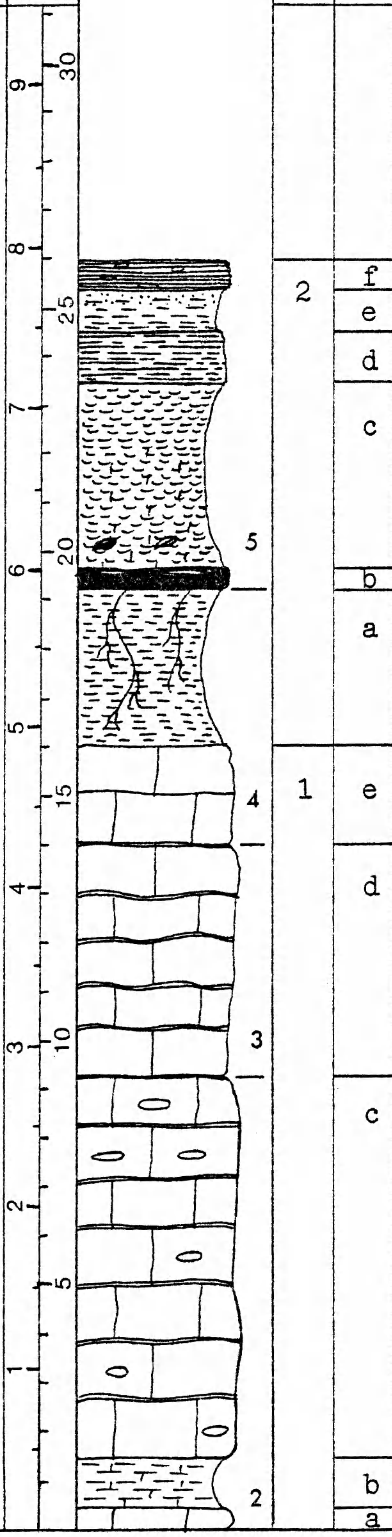
Sample No.	Scale	PAC No.	Bed No.	Interval No.	
	m ft				

Locality Description: Strat. Sec. J43, about 6 miles (9.66km) south of Warrensburg in S. highwall of quarry.

Location: near ctr. of S. line of SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 13, T.45N., R.26W., Johnson Co., Mo.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)



Description

Bed No.

Anna Shale of Pawnee Formation—Labette Formation

2f. Shale: (7in.; .178m), black, fissile; contains abundant rounded phosphatic nodules.

e. Shale: (10in.; .254m), gray to yellow-tan at top, platy; top part silty.

d. Shale: (1ft.0in.; .305m), black, platy, almost fissile.

c. Shale: (3ft.10in.; 1.17m), gray, flaky, very calcareous, especially near base which contains abundant brachiopods.

b. Alvis Coal: coal: (5in.; 12.7cm), black; upper part has many clay partings.

a. Clay: (3ft.3in.; .991m), gray, soft; contains carbonized fossil roots.

Wolverine Creek Formation
Houx-Higginsville Limestone Member
Higginsville Limestone:

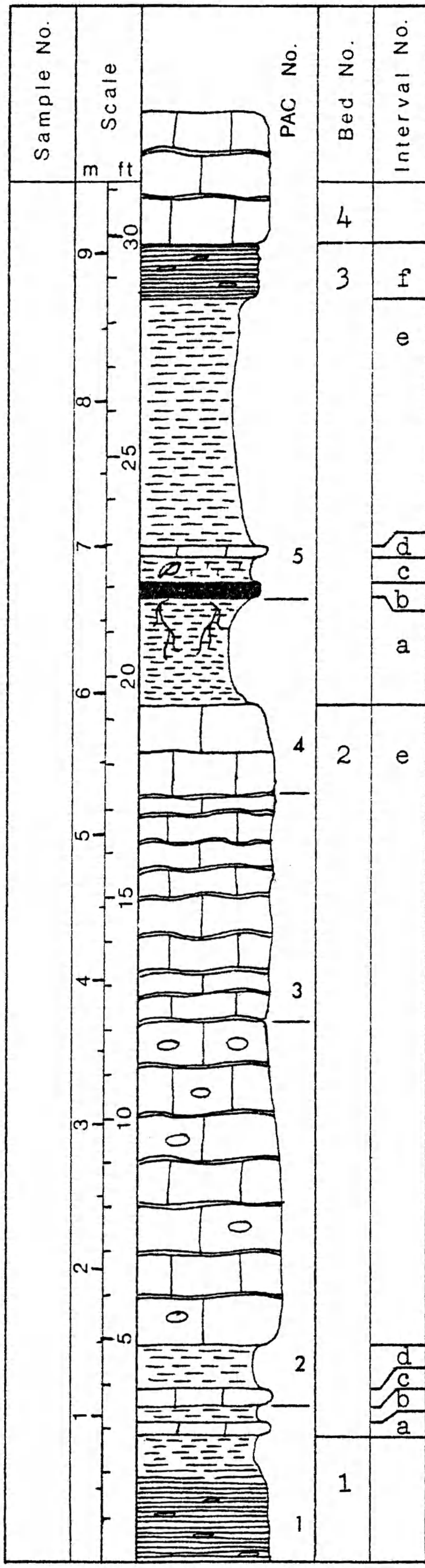
1e. Limestone: (2ft.0in.; .61m), gray, fine grained; fracture smooth; blocky.

d. Limestone: (4ft.9in.; 1.45m), gray, fine grained; fracture smooth; bedding very wavy, developed by abundant shale partings.

c. Limestone: (7ft.10in.; 2.39m), light gray, fine grained; fracture smooth, conchoidal; bedding slightly wavy; contains gray chert with white mottling and splintery fracture.

b. Shale: (1ft.0in.; .305m), dark gray to light gray, calcareous; contains abundant fossils.

a. Limestone: (5in.; 12.7cm), gray, fine grained, slightly earthy; in one blocky bed; cut by regularly spaced fractures; used as quarry floor.



Locality Description: Strat. Sec. J44, about 6 mi. (9.66km) S. of Warrensburg. Units 1-2b in ditch draining quarry, units 2c-4 in E. highwall of quarry, W½NW¼SE¼ sec. 13, T.45N., R26W., Johnson Co., Mo.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)

Description

Bed No.

Pawnee Formation

Myrick Station Limestone

4 Limestone: (3ft.0in.; .914m), light gray, fine grained; fracture smooth; bedding wavy; weathered surface light brown; fossiliferous.

Anna Shale of Pawnee Formation-Labette Formation

3f. Shale: (1ft.3in.; .381m), black, very platy to fissile; contains abundant phosphatic nodules, both flattened and rounded.

e. Shale: (5ft.7in.; 1.70m), like unit 3c but becomes very carbonaceous at top; contains brachiopods better preserved than in unit 3c; also contains *Pecten*-like pelecypods and small high-spired gastropods.

d. Limestone: (3in.; 7.6cm), dark brown-gray, very shaly; contains abundant fragmental fossils.

c. Shale: (7in.; 17.8cm), dark gray, platy, very calcareous; contains abundant brachiopods.

b. Alvis Coal: coal: (4in.; 10.1cm), in part contains much clay.

a. Clay: (2ft.5in.; .737m), gray; top part contains abundant carbonized fossil roots and much sulfur.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

2e. Higginsville Limestone: limestone: (14ft.6in.; 4.42m), gray, fine grained; fracture smooth, conchoidal; bedding wavy, upper part thin and very wavy except for uppermost blocky bed; contains green shale partings.

(Positions of uppermost blocky bed, thin wavy beds, and chert nodules are taken from stratigraphic section J43).

d. Shale: (1ft.0in.; .305m), gray to dark gray with green irregular markings, in part iron stained; lower part contains large crinoid columnals; upper part contains limestone nodules and abundant *Crurithyris*.

c. Limestone: (5in.; 12.7cm), gray, fine grained; fracture smooth; in one slightly blocky bed.

b. Shale: (4in.; 10.1cm), gray, lower part red-gray, flaky, calcareous.

a. Houx Limestone: limestone: (4in.; 10.1cm), gray, fine grained, earthy; contains streaks of green-gray shale; red zone in upper ¼inch; occurs in one bed.

Little Osage Shale Member

1 Shale: (2ft.10in.; .864m), dark gray, platy to fissile; contains both flattened and rounded phosphatic nodules; upper part is lighter gray and contains irregular green-gray markings (worm burrows?).

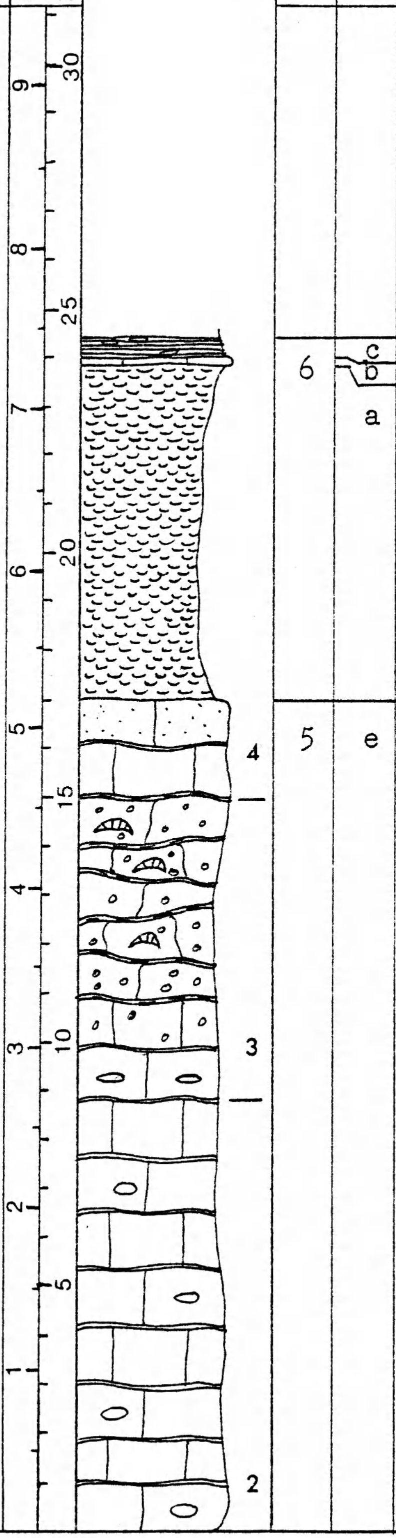
Sample No.	Scale (m, ft)		PAC No.	Bed No.	Interval No.

Locality Description: Strat. Sec. J48, about 6 mi. (9.66km) W. of Warrensburg in S. cut of "new" U.S. Hwy. 50.

Location: SW¼SW¼ sec. 13, T.46N., R.27W., Johnson County, Missouri.

Measured By: N. W. Jeffries **Date:** 1958

Remarks: taken from Jeffries (1958)



Description

Bed No.

Anna Shale of Pawnee Formation-Labette Formation

6c. Shale: (5in.; 12.7cm), black, fissile; contains abundant flattened phosphatic nodules; top not exposed.

b. Shale: (2in.; 5.1cm), gray, calcareous; contains abundant brachiopods, almost a coquina.

a. Shale: (6ft.10in.; 2.08m), dark gray, flaky.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

5e. Higginsville Limestone: limestone: (17ft.0in.; 5.18m), light gray to tan-gray, fine grained; of two types, a nodular phase and a sublithographic phase; upper part contains small "algal" pellets; fracture varies from uneven in the nodular limestone phase to subconchoidal in the sublithographic phase; bedding wavy and irregular, especially at top; contains light brown chert which has a splintery fracture; chert occurs as irregularly shaped nodules; fossiliferous, with abundant fusulinids and Chaetetes.

(Positions of wavy irregular beds and chert nodules are taken from stratigraphic section J43).

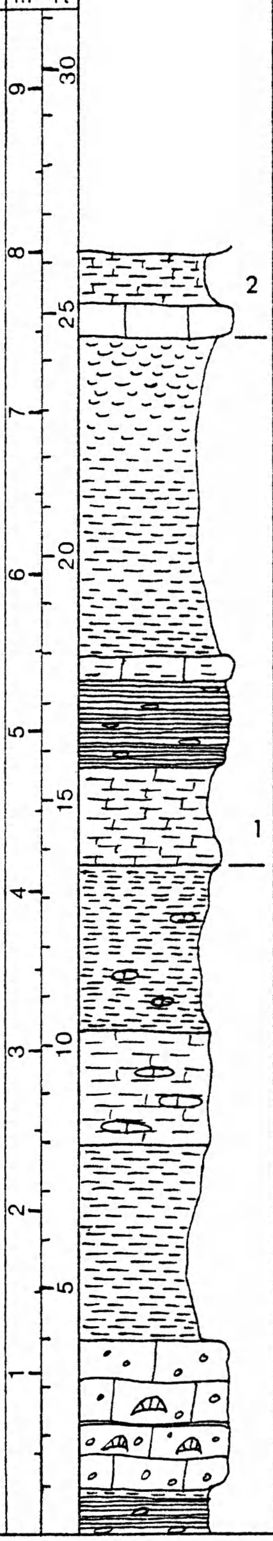
(Continued on next page)

Sample No.	Scale (m ft)		PAC No.	Bed No.	Interval No.	Locality Description: Strat. Sec. J48. (Continued from previous page).

Location:

Measured By: Date:

Remarks:



Description

Bed No.

(Continued from previous page)

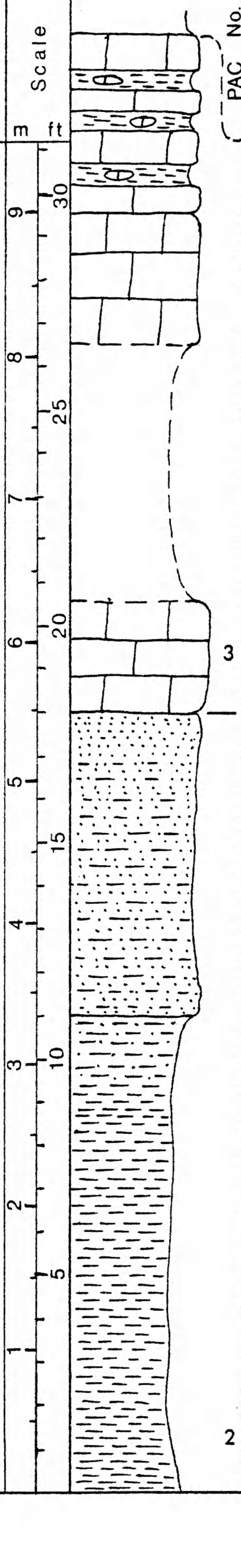
PAC No.	Bed No.	Interval No.	Description
2	5	d	5d. Shale: (1ft.1in.; .330m), green-gray to tan, calcareous; contains thin beds of limestone and <u>Crurithyris</u> coquina; fossiliferous, with <u>Crurithyris</u>, <u>Marginifera</u>, <u>Composita</u>, <u>Punctospirifer</u>, <u>Mesolobus</u>, <u>Cleiothyridina</u>, <u>Neospirifer</u>, horn corals, ostracods, and small foraminifera.
		c	c. Limestone: (8in.; .204m), light gray, fine grained; fracture subconchoidal; weathered surface tan-gray; occurs in one blocky bed.
		b	b. Shale: (6ft.6in.; 1.98m), dark gray at base grading upward to gray, varies from platy to flaky.
		a	a. <u>Houx Limestone</u>: limestone: (6in.; 15.2cm), gray to tan-gray, fine grained, slabby, very shaly, grades laterally into calcareous shale; sparsely fossiliferous.
	4	b	<u>Little Osage Shale Member</u> 4b. Shale: (1ft.9in.; .533m), black, fissile; contains abundant flattened phosphatic nodules.
1		a	a. Shale: (2ft.0in.; .61m), dark gray, very calcareous, base almost a limestone; contains abundant <u>Marginifera muricatina</u>, <u>Chonetes</u>, <u>Mesolobus</u>, and sparse <u>Neospirifer</u>.
	? 3		<u>Morgan School Shale Formation</u> 3 Clay: (3ft.5in.; 1.04m), gray, fairly hard; contains sparse gray limestone nodules and irregular vein fillings of limestone.
	2	c	<u>Dry Branch Creek Formation</u> <u>Blackjack Creek Limestone Member</u> 2c. Shale: (2ft.4in.;.710m), tan to green-tan, very calcareous, in part a yellow-tan earthy nodular limestone; no fossils observed.
		b	b. Shale: (4ft.0in.; 1.22m), gray to green-gray, platy.
		a	a. Limestone: (3ft.0in.; .914m), tan-gray, fine grained; fracture uneven; weathered surface yellow-brown, slightly blocky; sparsely fossiliferous, with <u>Chaetetes</u>, brachiopods, crinoid columnals, and sparse large fusulinids; occurs in two beds.
	1		<u>Excello Shale</u> 1 Shale: (11in.; .279m), top 1in. (2.54cm) is gray, platy. Bottom 10 in. (25.4cm) is black, fissile, contains abundant phosphatic nodules; also contains sparse <u>Orbiculoidea</u>.

Sample No. | Scale (m, ft) | PAC No. | Bed No. | Interval No.

Locality Description: Strat. Sec. J69, 0.5mi. (.8km) W. of Hodge in bluff of Missouri River; composite section measured at various points in SW¼SW¼SW¼ sec.11, T.51N., R.25W., Lafayette Co., Mo.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)



Bed No.	Interval No.
7	b
	a
6	
5	f
	e
	d

Description

Bed No.

<u>Myrick Station Limestone</u>

7b. Alternating limestone and shale: (4ft.2in.; 1.27m), limestone, gray, fine grained, in beds 5-6 in. (12.7-15.2cm) thick; shale, tan to gray, platy, calcareous, contains limestone nodules.

a. Limestone: (3ft.0in.; .914m), tan to gray, fine grained, slightly earthy; weathered surface irregular, tan; occurs in one massive bed.

<u>Anna Shale of Pawnee Formation-Labette Formation</u>

6 Cover: (6ft.0in.; 1.83m), to west of unit 5f, in small cliff at abandoned coal drift just west of private road.

<u>Wolverine Creek Formation</u>

<u>Houx-Higginsville Limestone Member</u>

5f. <u>Higginsville Limestone</u>: limestone: (2ft.7in.; .787m), gray, fine grained; weathers to tan; contains few fossils; lower part shaly and nodular; poorly exposed.

e. <u>Flint Hill Sandstone</u>: alternating siltstone and sandstone: (7ft.0in.; 2.13m), coarsest at top, tan, thin bedded; contains much clay and mica.

d. Shale: (11ft.0in.; 3.35m), gray to light gray, platy, becoming silty toward top; exposed along road cut east of unit 5e.

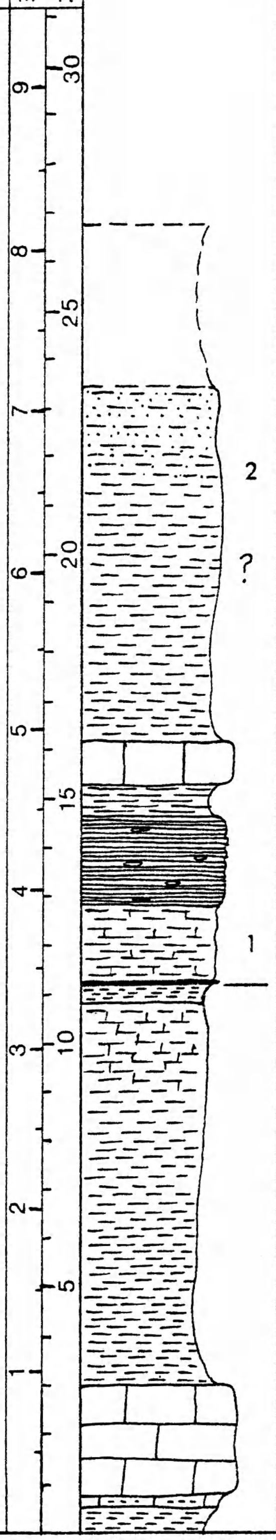
(Continued on next page)

Sample No.	Scale (m, ft)		PAC No.	Bed No.	Interval No.	Locality Description: Strat. Sec. J69. (Continued from previous page)

Location:

Measured By: Date:

Remarks:



Description

Bed No.

(Continued from previous page)

Bed 5

5c. Cover: (3ft.3in.; .991m).

b. Shale: (7ft.5in.; 2.26m), gray to green-gray, platy; in upper part contains much silty and micaceous sandstone; sandstone beds weather out as tan fragments; poorly exposed.

a. Houx Limestone: limestone: (10in.; 25.4cm), gray, fine grained, slightly shaly; weathered surface tan; contains a few small fragmental fossils; occurs in one bed but weathers to nodular slabs.

Bed 4

Little Osage Shale Member

4c. Shale: (8in.; 20.4cm), like unit 4b but softer and forming re-entrant.

b. Shale: (1ft.9in.; .533m), black, fissile; cut by vertical joints; contains abundant phosphatic nodules; forms ledge.

a. Alternating shaly limestone and shale: (1ft.7in.; .483m), shale, dark gray, calcareous; limestone, gray, very impure; contains abundant poorly preserved brachiopods.

Bed 3

Morgan School Shale Formation

3b. Summit Coal: coal: (0.5in.; 1.27cm), shaly.

a. Clay: (4in.; 10.1cm), gray, massive, soft.

Bed 2

Dry Branch Creek Formation

Blackjack Creek Limestone Member

(Jeffries (1958) places the upper boundary of the Blackjack Creek Limestone at the top of unit 2b, but this author favors placing it here to more closely correspond to its position at other localities).

2c. Shale: (7ft.11in.; 2.413m), gray at base grading upward into dark gray, platy, in part calcareous; upper part contains abundant but poorly preserved brachiopods; poorly exposed; fresh samples obtained by digging.

b. Limestone: (2ft.3in.; .686m), light gray to tan-gray, fine grained; fracture irregular; sparsely fossiliferous; occurs in one bed.

a. Limestone: (3in.; 7.6cm), brown, very earthy; weathered surface tan to brown; in re-entrant.

Bed 1

Excello Shale Member

1 Shale: (5in.; 12.7cm), light green to tan-green, slightly platy, soft.

Locality Description: Strat. Sec. J82, 3mi. (4.83km) NW. of Wakenda, in south cut banks of small E-trending drain.

Location: $NE\frac{1}{4}NW\frac{1}{4}$ sec. 5, T.52N., R.22W., Carroll County, Missouri.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)

Sample No.	Scale (m ft)	PAC No.	Bed No.	Interval No.
			7	
			6	
		3	5	h
		2		g

Description

Bed No.

Pawnee Formation

Myrick Station Limestone

7 Limestone: (3ft.6in.; 1.067m), gray, fine grained, in part medium grained; fracture angular, splintery; weathered surface light brown-gray, slightly blocky; tends to be smooth; bedding medium, slightly wavy; fossiliferous, with *Phricodothyris* abundant in lower beds.

Anna Shale of Pawnee Formation–Labette Formation

6 Cover: (3ft.0in.; .914m), in part gray clay.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

5h. Higginsville Limestone: limestone: (3ft.9in.; 1.14m), light to medium gray, fine grained, very nodular; fracture uneven; weathered surface gray to tan-gray, uneven; bedding medium, wavy, irregular; fossiliferous, with brachiopods and large colonies of *Chaetetes*.

g. Shale to clay: (2ft.6in.; .762m), light gray to almost white, orange stained; upper part contains small clay-ironstone nodules.

(Continued on next page)

Locality Description: Strat. Sec. J82.

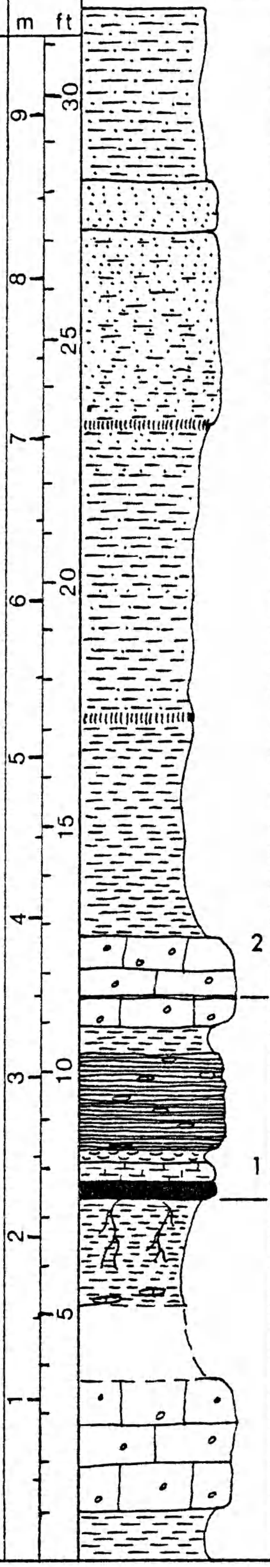
(Continued from previous page).

Location:

Measured By: Date:

Remarks:

Sample No.	Scale (m ft)	PAC No.	Bed No.	Interval No.
			5	f
				e
				d
				c
				b
		2		a
			4	d
				c
		1		b
				a
			3	b
				a
			?	
			2	b
				a
			1	



Description

Bed No.

(Continued from previous page)

Flint Hill Sandstone: (units 5c through 5f)

5f. Shale and siltstone: (3ft.6in.; 1.067m), green-gray, iron stained, thin bedded.

e. Sandstone: (1ft.0in.; .305m), fine grained, dirty; speckled with iron stains; occurs in one bed.

d. Sandstone: (4ft.0in.; 1.22m), tan, fine grained, micaceous; bedding thin, uneven; contains thin shaly partings; becomes coarser grained toward top.

c. Shale: (6ft.0in.; 1.83m), like unit 5b but contains thin beds of micaceous siltstone and fine-grained micaceous sandstone; grades into unit below and unit above.

b. Shale: (4ft.6in.; 1.37m), dark gray to gray, platy; iron stains along fractures.

a. Houx Limestone: limestone: (1ft8in.; .509m), gray to blue-gray, fine grained, slightly shaly; fracture uneven; weathered surface tan-gray, blocky; fossiliferous, with fragmental brachiopods, crinoid columnals, fusulinids, and sparse gastropods; forms ledge with shaly parting in lower part.

Little Osage Shale Member

4d. Shale: (7in.; 17.8cm), dark gray, platy.

c. Shale: (2ft.0in.; .61m), black, fissile; contains abundant small flattened phosphatic nodules.

b. Shale: (3in.; 7.6cm), dark gray to black, flaky, carbonaceous.

a. Shale: (5in.; 12.7cm), dark gray, very calcareous, in part a limestone; abundantly fossiliferous, with *Derbyia*, *Mesolobus*, *Composita*, *Marginifera muricatina*, and *Chonetina*.

Morgan School Shale Formation

3b. Summit Coal: coal: (4in.; 10.1cm), black, shiny, blocky.

a. Clay: (2ft.2in.; .66m), gray, massive; lower part slightly calcareous and contains calcareous nodules; upper part contains carbonized fossil roots.

Dry Branch Creek Formation

Blackjack Creek Limestone Member

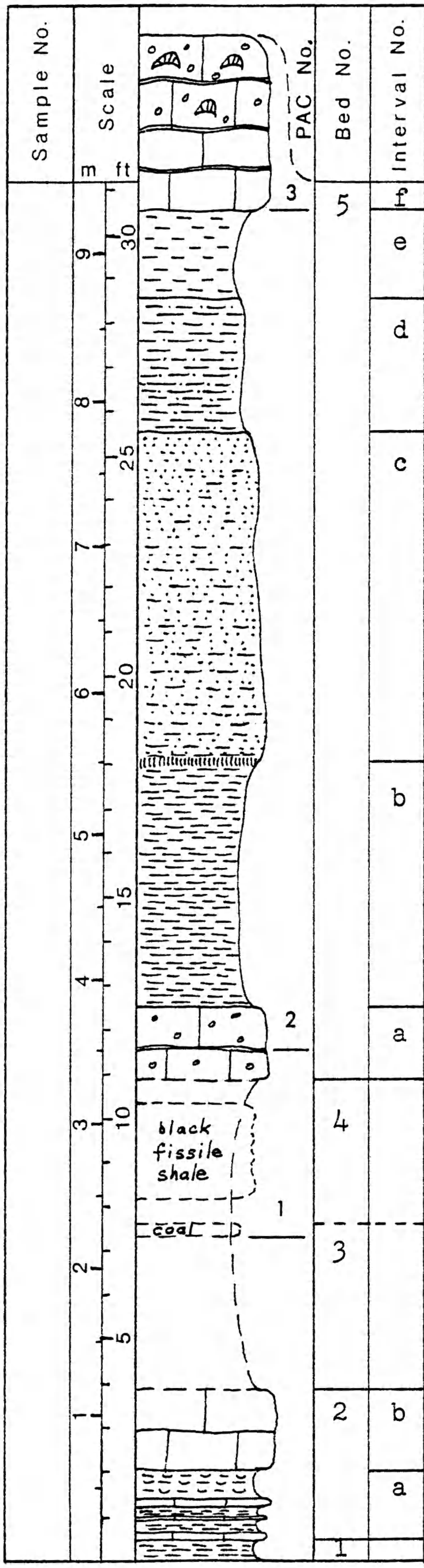
(Jeffries (1958) places the upper boundary of the Blackjack Creek Limestone at the top of unit 2a, but this author favors its placement at the top of the limestone nodules near the base of unit 3a).

2b. Cover: (1ft.6in.; .457m).

a. Limestone: (2ft.8in.; .814m), tan-gray to gray, fine grained, slightly earthy; fracture uneven; weathered surface light brown, slightly blocky, uneven; sparsely fossiliferous, with *Marginifera*, *Antiquatonia*, crinoid columnals, and fusulinids.

Excello Shale Member

1 Shale: (1ft.0in.; .305m), gray to green, platy; base not exposed; in bottom of drain.



Locality Description: Sec. J91 (partial J90) 3.5mi. (5.6km) NW of Avalon; units 1-4 measured S. of bridge E. of T-rd N. in NE corner sec.4, others at T-rd S. in NW corner sec.3, T.56N., R.23W., Livingston Co.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

5f. Higginsville Limestone: limestone: (4ft.0in.; 1.22m), gray; of three types, a nodular phase, a sublithographic phase, and an "algal" pellet phase; weathered surface tan-gray, uneven, slightly rounded; bedding medium, wavy; contains brachiopods, Chaetetes, and fusulinids common near top.

e. Shale: (2ft.0in.; .61m), light gray, soft, iron stained.

Flint Hill Sandstone (units 5c-5d)

d. Shale: (4ft.0in.; 1.22m), tan-gray; contains thin beds of iron-stained siltstone.

c. Sandstone and siltstone: (7ft.6in.; 2.29m), tan; bedding thin at base, medium at top; coarser grained toward top.

b. Shale: (5ft.6in.; 1.68m), dark gray, platy; grades upward into unit above.

a. Houx Limestone: limestone: (1ft.8in.; .509m), dark gray, fine grained; fracture angular, splintery; weathered surface tan-gray, slightly blocky; fossiliferous, with fusulinids common and brachiopods abundant; also contains sparse horn corals; shaly parting 9 inches above base; large blocks pushed to north of T-road.

Little Osage Shale Member and
Morgan School Shale Formation

4&3 Cover: (7ft.0in.; 2.13m), a few exposures of gray clay in lower part; black fissile shale float in upper part. Positions of unit 4 (Little Osage Shale) and unit 3 (Morgan School Shale) taken from Jeffries' (1958) stratigraphic section 90, measured about 2 mi. (3.2km) north of Avalon in cuts of gravel road, along N. line of NW¼NW¼ sec. 12, T.56N., R.23W., Livingston Co., Missouri.

Dry Branch Creek Formation
Blackjack Creek Limestone Member

2b. Limestone: (1ft.10in.; .559m), tan-gray, fine grained, earthy; weathered surface yellow-brown, uneven, nodular; sparsely fossiliferous; occurs in one bed.

a. Alternating shale and limestone: (1ft.7in.; .483m), shale, gray, platy to flaky, calcareous; limestone, light brown, fine grained, earthy; occurs as nodules.

Excello Shale Member

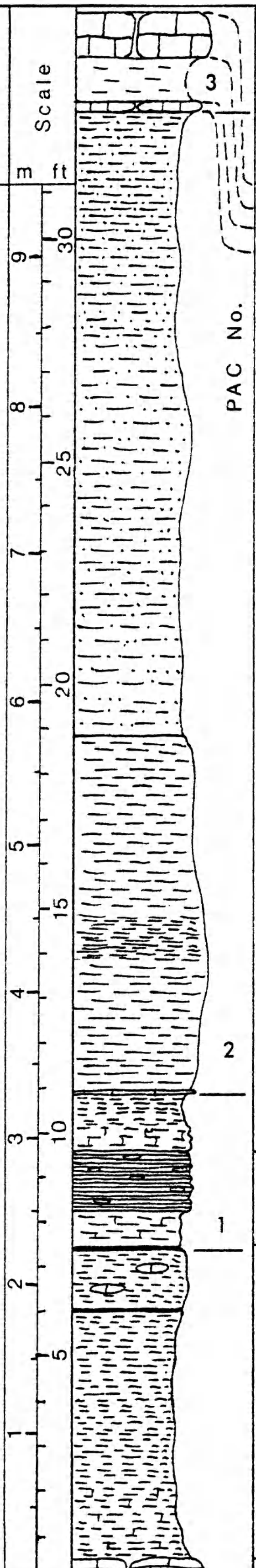
1 Shale: (6in.; 15.2cm), gray, platy; in bed of drain.

Locality Description: Strat. Sec. J105, 3.5 mi. (5.6km) SW of Yarrow in SW cut of gravel rd. in S bluff of small tributary to Chariton R., in SE¼SE¼NE¼ sec. 32, T.61N., R.16W., Adair Co., Mo.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)

Sample No. | Scale (m, ft) | Bed No. | Interval No.



Bed No.	Interval No.
4	g
	f
	e
	d
	c
	b
	a
3	b
	a
2	d
	c
	b
	a
1	

Description

Bed No.

<u>Wolverine Creek Formation</u>
<u>Houx-Higginsville Limestone Member</u>

4g. <u>Higginsville Limestone</u>: limestone: (1ft.0in.; .305m), light brown, fine grained, earthy; fracture uneven; weathered surface light brown, knobby; sparsely fossiliferous; mainly as fragments.

f. Cover: (1ft.0in.; .305m), in part iron-stained clay.

e. Limestone: (3in.; 7.6cm), light brown, slightly earthy; occurs as zone of weathered limestone nodules.

d. <u>Flint Hill Sandstone</u>: siltstone and fine-grained sandstone: (14ft.0in.; 4.27m), green-tan to tan to gray, thin bedded, micaceous; shaly at top; poorly exposed.

c. Shale: (8ft.0in.; 2.44m), green-gray to tan-green, platy to blocky; bedding planes smooth and flat; contains 1 ft. (.305m) maroon zone about 3 ft. (.91m) above base.

<u>Houx Limestone</u> (units 4a&b)

b. Limestone: (0.5in.; 1.3cm), medium gray; contains abundant small white fragments of fossils; weathered; as small plates.

a. Shale: (1ft.3in.; .381m), dark gray, platy to flaky; contains abundant irregular gray limestone beds at base; clayey at top.

<u>Little Osage Shale Member</u>

3b. Shale: (1ft.4in.; .405m), black, platy to fissile; contains abundant small flattened phosphatic nodules.

a. Shale: (10in.; 25.4cm), dark gray, flaky to platy, calcareous, carbonaceous; contains abundant fossils, <u>Mesolobus</u> and <u>Marginifera muricatina</u>.

<u>Morgan School Shale Formation</u>

2d. <u>Summit Coal</u>: clay: (0.5in.; 1.3cm), coaly.

c. Clay: (1ft.4in.; .405m), tan-gray to gray, calcareous; contains gray lithographic limestone nodules having septarian structure filled by coarsely crystalline calcite.

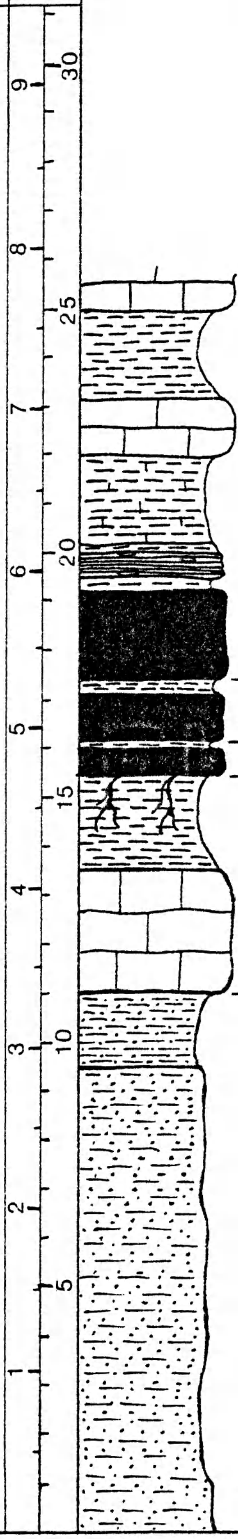
b. Clay: (0.5in.; 1.3cm), coaly.

a. Clay: (5ft.6in.; 1.68m), tan-gray at base to gray at top, massive; lower part calcareous.

<u>Dry Branch Creek Formation</u>
<u>Blackjack Creek Limestone Member</u>

1 Limestone: (no thickness given), yellow-tan, fine grained, earthy, nodular; weathered surface yellow-tan; contains <u>Mesolobus</u> and small fusulinids; only top exposed.

Sample No.	Scale (m, ft)		PAC No.	Bed No.	Interval No.



PAC No.: 5, 4, 3, 2

Bed No. 3: d, c, b, a; Bed No. 2: i, h, g, f, e, d, c, b, a; Bed No. 1: c, b, a

Locality Description: Strat. Sec. J115, 1.7mi. (2.7km) N. of Graysville at coal drift. Composite section.

Location: $E\frac{1}{2}NW\frac{1}{4}NW\frac{1}{4}$ sec.2, T.65N., R.17W., Putnam County, Missouri.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958)

Description

Bed No.

Pawnee Formation
Myrick Station Limestone

3d. Limestone: (not measured), roof rock of mine portal, not studied.

c. Shale: (1ft.10in.; .56m), gray, slightly blocky.

b. Limestone: (1ft.2in.; .36m), yellow-tan, fine grained, earthy; fracture uneven; weathers to yellow-tan; sparsely fossiliferous.

a. Shale: (1ft.10in.; .56m), tan-gray, calcareous, 2 inch beds.

Anna Shale of Pawnee Formation-Labette Formation

2i. Shale: (2in.; 5.08cm), dark gray, platy; contains light gray irregular markings.

h. Shale: (6in.; 15.2cm), black, fissile; contains sparse flattened phosphatic nodules.

g. Shale: (3in.; 7.6cm), dark gray, platy.

f. Lexington Coal, upper bench: Coal: (1ft.10in.; .56m), black, shiny, blocky.

e. Clay: (3in.; 7.6cm), gray; contains much sulfur.

d. Lexington Coal, lower bench: Coal: (1ft.0in.; .305m), black, shiny, blocky.

c. Clay: (2in.; 5.08cm), gray.

b. "Dutchman Coal": Coal: (6in.; 15.2cm), black, shiny, blocky.

a. Clay: (2ft.0in.; .61m), gray, massive; upper part contains carbonized fossil roots.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

1c. Higginsville Limestone: Limestone: (2ft.6in.; .762m), yellow-tan to tan-gray, fine grained, earthy; fracture irregular; weathered surface yellow-brown, irregular; contains abundant fragmental fossils, with *Antequatonia*, *Mesolobus*, *Crurithyris*, *Derbyia*, *Marginifera*, *Chonetes*, small fusulinids, and large and small crinoid columnals.

b. Shale: (1ft.6in.; .46m), tan-gray, silty, poorly bedded.

a. Flint Hill Sandstone: Siltstone and Shale: (9ft.6in.; 2.90m), gray, weathering to tan to light gray, thin bedded; base not exposed.

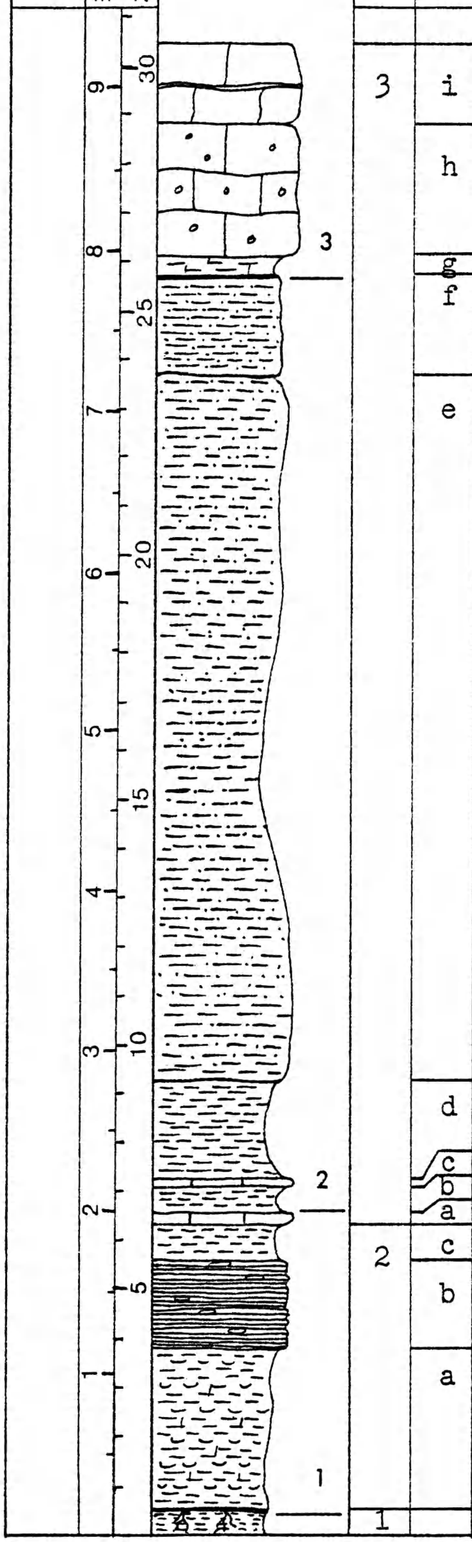
Sample No.	Scale (m ft)		PAC No.	Bed No.	Interval No.	

Locality Description: Strat. Sec. J116, 1.8 mi. (2.9km) NE of Hartford in N. bluff of small drain W. of farm house.

Location: SW¼SE¼SE¼ sec. 28, T.66N., R.17W., Putnam County, Missouri.

Measured By: N. W. Jeffries Date: 1958

Remarks: taken from Jeffries (1958).



Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member
Higginsville Limestone (units 3g through 3i)

3i. Limestone: (1ft.7in.; .483m), gray, fine grained, nodular; contains shaly partings, especially at base; weathered surface gray, rough; weathers out as loose nodules; fossiliferous, with *Marginifera muricatina*, *Composita*, *Derbyia*, and *Mesolobus*.

h. Limestone: (2ft.9in.; .838m), tan-gray, fine grained, earthy; fracture uneven; weathered surface light brown, slightly blocky; breaks out in irregular blocks; contains *Mesolobus*, *Antiquatonia*, *Derbyia*, *Marginifera muricatina*, *Neospirifer*, large and small crinoid columnals, and small fusulinids.

g. Shale: (5in.; 12.7cm), yellow-tan, calcareous, poorly bedded; fossiliferous, with *Marginifera muricatina*, *Derbyia*, *Mesolobus*, and *Chonetes*.

top of f. Clay: (streak), carbonaceous.

f. Shale: (2ft.0in.; .61m), poorly bedded, light gray, silty.

e. Flint Hill Sandstone: shale and siltstone: (14ft.6in.; 4.42m), gray, thin bedded, slightly micaceous, weathering to light gray and tan; middle part poorly exposed.

d. Shale: (2ft.0in.; .61m), gray, platy.

Houx Limestone (units 3a through 3c)

c. Limestone: (2in.; 5.1cm), like unit 3a.

b. Shale: (6in.; 15.2cm), gray, calcareous, poorly bedded; fossiliferous, with abundant *Mesolobus*.

a. Limestone: (3in.; 7.6cm), medium gray, fine grained, shaly; fracture uneven; weathered surface tan to gray, slabby; contains abundant fragmental fossils, *Mesolobus* and small crinoid columnals abundant.

Little Osage Shale Member

2c. Shale: (9in.; 22.9cm), gray, platy.

b. Shale: (1ft.10in.; .559m), black, fissile to platy at top; contains thin phosphatic beds and small flattened phosphatic nodules, cut by vertical joints.

a. Shale: (3ft.4in.; 1.015m), dark gray, platy to flaky, in part calcareous; fossiliferous zones, containing *Antiquatonia*, *Linoproductus*, *Mesolobus*, and *Marginifera muricatina*.

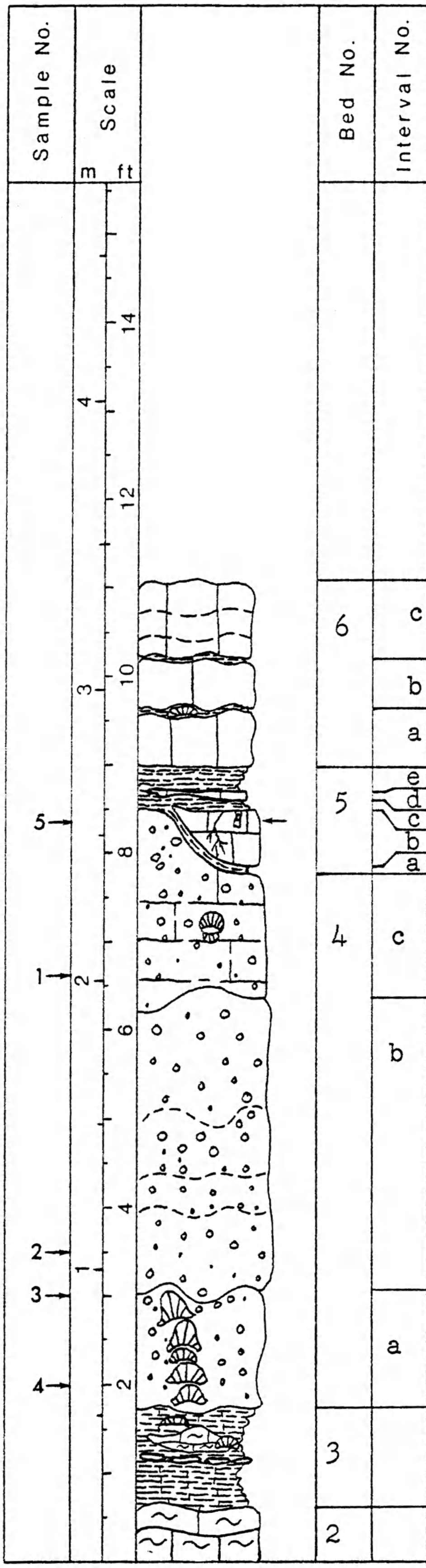
Morgan School Shale Formation

1 Clay: (6in.; 15.2cm), gray, massive; contains abundant carbonized fossil plant material; carbonaceous at top; base not exposed.

APPENDIX B

Stratigraphic Sections
from Locality 700
(Niggeman Quarry)

(For lithologic symbols, see Appendix A)



Locality Description: Station 2a, Locality 700, N. central part of quarry.

Location: SE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a–c. Calcilutite: (2ft.; .61m), very similar to Stas. 31, 11, & 24. Intervals 'a' & 'b' are 7in. (17.8cm) each, interval 'c' is 10in. (25.4cm) and contains 2 minor, argillaceous, cross-laminated partings. Interval 'd' has been scraped away.

5a–e. Shale with Calcilutite Lenses: (6–14in.; 15.2–35.6cm), very similar to Stas. 24 & 11, with 2 layers of limestone lenses enclosed in shale. The lower limestone lens (interval b) is 7–8in. (17.8–20.3cm) thick, has burrows and root traces along with marine fossils, and pinches and swells according to the underlying topography of interval 4. The upper limestone lens (interval d) is 1–1.5in. (2.5–3.8cm) thick, flaky to globular. The remainder is shale, soft, flaky, & brown near the top, tan & calcareous at the base.

4a–c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone: (6.75–7.5ft.; 2.06–2.29m), very similar to Sta. 31 but has virtually no chaetetids in intervals b & c for 7ft. (2.1m) on either side of this station. The three intervals (a,b,c) are well-defined, separated by thin, argillaceous, cross-laminated partings. Interval 'a' (16–17in.; 40.6–43.2cm) has 10% chaetetids, occurring as scattered laminar to ragged columnar colonies with intermittent *Aulopora* overgrowths; matrix is massive with minor cross laminations. Interval 'b' (3–3.5ft.; .91–1.07m) has no chaetetids, has abundant echinoid & crinoid debris and common fragments of brachiopods, *Aulopora*, and rugose corals; three minor cross laminated partings occur in the fusulinid packstone at 11, 16, & 24 in. (27.9, 40.6, & 61.0 cm) from its base. Interval 'c' (16–20in.; 40.6–50.8cm) has one chaetetid (5in. across; 12.7cm) that had been rolled over once and started anew and has 2 intervals of *Aulopora* overgrowth; the fusulinid wackestone to packstone also contains echinoid & crinoid fragments and a few phylloid algal blades; it is massive but has cross laminations in the top 2–4in. (5.1–10.2cm). At Sta. 2, several chaetetids with attached specimens of *Pseudomonotis* were found.

3. Fossiliferous Calcarenite to Calcilutite: (14in.; 35.6cm), very similar to Sta. 31. Cherty layer is continuous to nodular. Note small algal calcilutite lens above chert layer.

2. Algal to Skeletal Calcilutite: (6in. exposed; 15.2cm), very similar to Stas. 31 & 24.

Sample No. | Scale (m ft) | Bed No. | Interval No.

Locality Description: Station 4, Locality 700, N. central part of quarry.

Location: NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy   Date: 1986

Remarks:

Sample No.: 14, 11, 10, 4, 12, 1, 2, 5, 3,8, 6, 7

Scale: m 1, 2, 3, 4; ft 2, 4, 6, 8, 10, 12, 14

Bed No.	Interval No.
6	b
	a
5	c-e
	b
	a
4	c
	b
	a
3	

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-b. Calcilutite: (14in. remaining; 35.6cm), very similar to Stas. 31, 11, & 24, but intervals c & d have been bulldozed away. Interval 'a' (7-8in.; 17.8-20.3cm) has >10% algal blades and no fusulinids; it additionally contains Antequatonia, Composita, & Ditomopyge. Interval 'b' (6in.; 15.2cm) has fusulinids, Composita, and other fossils similar to Sta. 31.

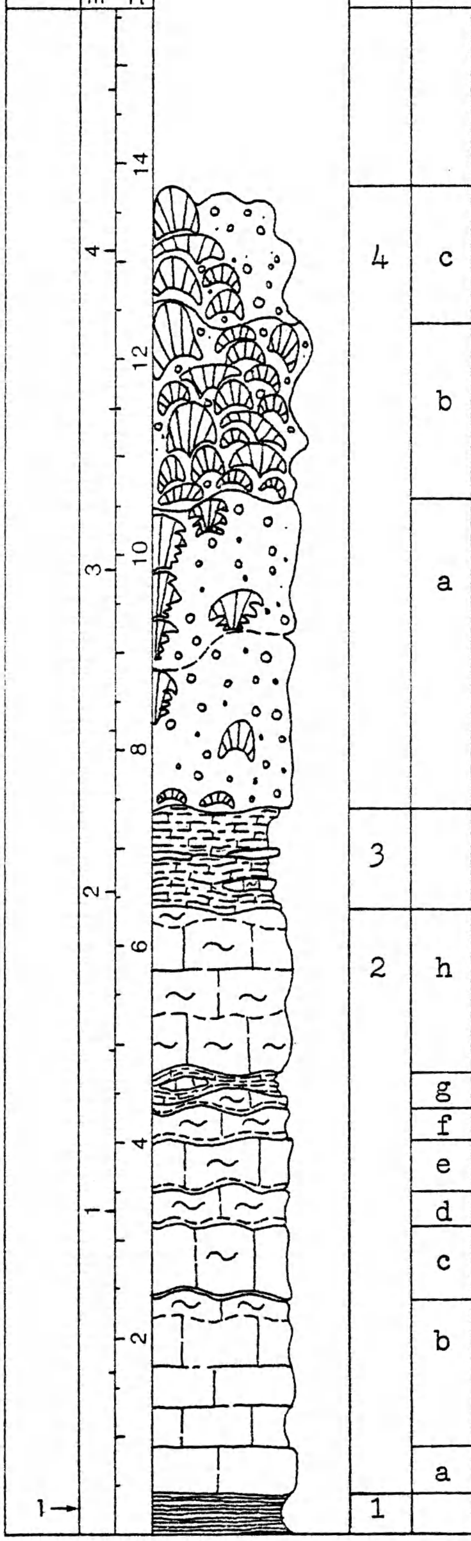
5a-e. Shale with Calcilutite Lenses: (10in.; 25.4cm), very similar to Stas. 24,11, & 31. Contains only the lower limestone lens (interval 'b', 7-8in. thick; 17.8-20.3cm); interval 'd' is missing. A trilobite (Ameura) cephalon fragment was found in interval 'a' between chaetetid heads.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.5-7.25ft.; 1.98-2.21m), very similar to Sta. 31. Interval 'a' (2ft.; .61m) is 10-15% chaetetids, occurring as isolated laminar to ragged columnar forms; some columns coalesce into clumps in interval'b'; matrix is massive with a minor cross laminated parting 14in. (35.6cm) above base. Interval 'b' (2.5-3ft; .76-.91m) is up to 75% chaetetids, occurring in large clumps; matrix has common cross laminations. Interval 'c' (1.5-2.5ft.; .46-.76m) has chaetetids only where clumps continue upward from interval 'b'; matrix is massive; a specimen of Pseudomonotis attached to a chaetetid was found near the top of this interval.

3. Fossiliferous Calcarenite to Calcilutite: (16in.; 40.6cm), very similar to sta. 31. Chert is a solid 1.0-1.5in. (2.5-3.8cm) layer here.

B3

Sample No.	Scale (m, ft)		Bed No.	Interval No.	
					Locality Description: Station 8, Locality 700, NW corner of quarry.
					Location: ctr.N½SW¼NW¼SE¼, sec.12, T.30S., R.22E., Crawford County, Kansas.
					Measured By: D. R. Suchy Date: 1986
					Remarks:



Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.0-6.5ft.; 1.83-1.98m), very similar to Stas. 31 & 24. Interval 'a' (34-39in.; .86-.99m) is 5-15% chaetetids and shows a minor, thin cross laminated parting near its middle. Interval 'b' (1.75-2.0ft.; .53-.61m) is 50-80% chaetetids (in large clumps); the matrix between chaetetids is dark gray (N3) to grayish black (N2) fusulinid wackestone that is strongly cross laminated around & between chaetetids, it weathers dark reddish brown (10 R 3/4). Interval 'c' (10-16in.; 25.4-40.6cm) has been partly bulldozed away; it contains chaetetids primarily where clumps continue upsection from interval 'b'.

3. Fossiliferous Calcarenite to Calcilutite: (12-14in.; 30.5-35.6cm), very similar to Sta. 31, but chert occurs only as widely scattered lenticular nodules. Algal calcilutite lenses below the chert are sparse & small (2.5x7in. to 6x30in.; 6.4x17.8cm to 15.2x76.2cm).

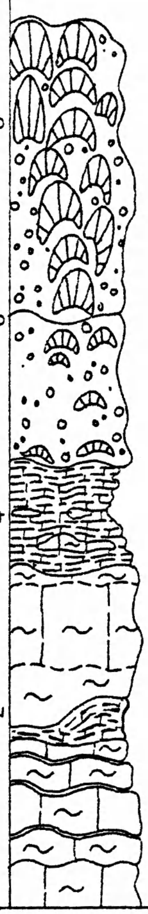
2a-h. Algal to Skeletal Calcilutite: (6.5ft.; 1.98m), very similar to Sta. 31, showing the same intervals at roughly the same thicknesses. The dark, argillaceous, cross laminated partings undulate with a wavelength of 8-14in. (20.3-35.6cm) and amplitude of 1-1.5in. (2.5-3.8 cm). Interval 'a' has sharp upper & lower contacts. Interval 'b' has a subtle argillaceous parting 2-3in. (5.1-7.6cm) from its top. Interval 'g' has a 2-4in. (5.1-10.2cm) thick, argillaceous, cross laminated layer on top. Interval 'h' has a very minor, argillaceous parting 6-8in. (15.2-20.3cm) above its base and a 1-3in. (2.5-7.6cm) thick algal calcilutite layer on top that is discontinuous.

Little Osage Shale Member

1. Shale: (4in. exposed; 10.2 cm), black, fissile, very similar to Sta. 31.

Sample No.	Scale (m / ft)		Bed No.	Interval No.	Locality Description: Station 9, Locality 700, NW corner of quarry. Location: NE¼SW¼NW¼SE¼, sec. 12, T.30S., R.22E., Crawford County, Kansas. Measured By: D. R. Suchy Date: 1986 Remarks:

Scale: m: 1, 2, 3, 4; ft: 2, 4, 6, 8, 10, 12, 14



Description

Bed No.

<u>Wolverine Creek Formation</u>
<u>Houx-Higginsville Limestone Member</u>

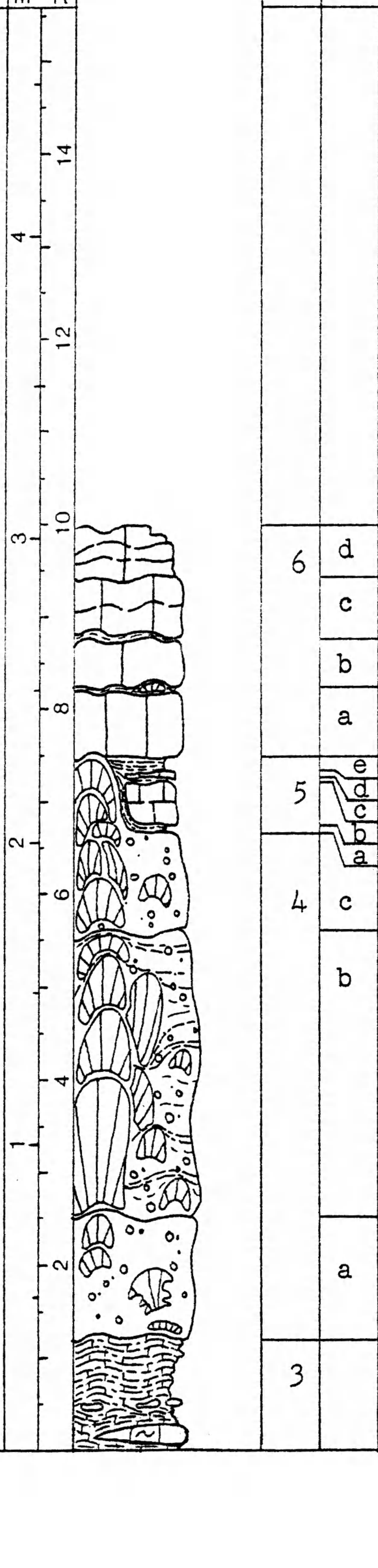
4a-b. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (4.5ft. remaining; 1.37m), very similar to Stas. 31 & 8, but interval 'c' has been bulldozed away. Many chaetetids show overgrowths of <u>Aulopora</u>. In interval 'b', chaetetids make up 50-75% of the rock and the fusulinid packstone laminae drape over & between chaetetids, giving the impression that maximum relief of chaetetids on the seafloor may have been no more than 18in. (46cm).

3. Fossiliferous Calcarenite to Calcilutite: (12in.; 30.5cm), very similar to Sta. 31.

2c-h. Algal to Skeletal Calcilutite: (3.5ft. exposed; 1.07m), very similar to Stas. 31 & 8. Covered below interval 'c'.

Bed No.	Interval No.
4	b
4	a
3	
2	h
2	g
2	f
2	e
2	d
2	c

Sample No.	Scale (m, ft)		Bed No.	Interval No.	
					Locality Description: Station 10, Locality 700, W. central edge of quarry.
					Location: $SW\frac{1}{4}NW\frac{1}{4}SW\frac{1}{4}SE\frac{1}{4}$, sec. 12, T.30S., R.22E., Crawford County, Kansas.
					Measured By: D. R. Suchy Date: 1986
					Remarks:



Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

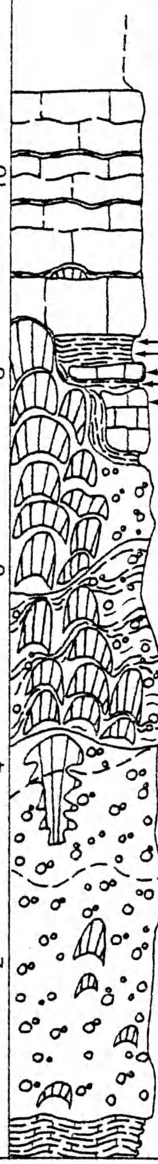
6a-d. Calcilutite: (2ft.6in.; .76m), very similar to Stas. 31, 11, & 24. Mostly too fragmented by bulldozing to get good measurements, but interval 'a' is 9in. (23cm) and interval 'b' is 7in. (18cm).

5a-e. Shale with Calcilutite Lenses: (0-10in.; 0-25.4cm), very similar to Stas. 11 & 24, with 2 layers of limestone lenses enclosed in shale. Interval 'b' is well developed in low places; interval 'd' is very patchy.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone); (6-7ft.; 1.83-2.13m), very similar to Stas. 31 & 24. Interval 'a' is 15-18in. (38-46cm), interval 'b' is 3ft. (.91m), and interval 'c' is 18-24in. (46-61cm). Up to 5% of interval 'b' is chaetetid breccia, much of it due to compaction. A large crinoid columnal (1.125in. in diameter; 2.9cm) was seen 2in. (5cm) above the base of interval 'b' and apparently had been transported.

3. Fossiliferous Calcarenite to Calcilutite: (12-14in. exposed; 30.5-35.6cm), very similar to Sta. 31. Chert occurs as small nodules. Algal calcilutite lenses are present below chert.

Sample No.	Scale (m, ft)		Bed No.	Interval No.
8, 9, 10, 11			6	d, c, b, a
3, 4, 5, 6, 2,7			5	e, d, c, b, a
12			4	c, b
13				a
			3	



Locality Description: Station 11, Locality 700, near SW corner of quarry.

Location: NW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (30in.; 76.2cm), very similar to Sta. 31. Has 4 main intervals (a-d) separated by more argillaceous cross-laminated partings. Each of intervals b-d has a minor argillaceous parting in about the middle of the interval. Interval 'd' is very similar to interval 'c' at Sta. 31 but is more dolomitic (see thin section description 700-11-8) and additionally contains encrusting red algae, *Cleiothyridina*, and minor foraminiferids (see thin section description 700-11-8).

5a-e. Shale with Calcilutite Lenses: (0-16in.; 0-40.6cm). Sharp contacts. Interval 'a' (0-1.5in.;0-3.8cm) and interval 'b' (0-8in.; 0-20.3cm) are very similar to Sta. 31. Interval 'c' (0-1.5in.; 0-3.8cm) is siltshale, pale yellowish brown (10 YR 6/2), flaky, poorly indurated, and contains plant fragments, root traces, pecten(?) fragments, echinoid spines, a few small fusulinids, minor gypsum crystals (<1mm), small & abraded fragments of productids & crinoids, low-spired gastropods. Interval 'd' (0-3in.; 0-7.6cm) consists of lenses of nodular coarse calcilutite to fine calcarenite, light gray (5 Y 6/1), medium hardness, medium to poor induration, and contains plant fragments, ostracodes (*Bairdia*, common), fusulinids (sparse), skeletal fragments (very fine sand size, angular, abundant), gypsum veins (<0.75mm thick), and myalinid(?) bivalves (also see thin section description 700-24-6). Interval 'e' (0-6in.; 0-15.2cm) is mudstone; bottom 4-5in. (10.2-12.7cm) are medium light gray (N6) mudstone (clay-rich, chippy, soft, noncalcareous) lenses separated by thin layers (1/16-3/8in.; 0.2-1.0cm) of brownish black (5 YR 2/1) plant-rich shale and contains root traces, plant fragments, small high-spired gastropods (*Worthenia* & others), small broken & abraded shell fragments, minor gypsum crystals (<1mm), and myalinid fragments; top 1.5 in. (3.8cm) is olive black (5 Y 2/1) mudstone, soft, very flaky, nonindurated, slightly calcareous (dolomitic?), thinly laminated, and contains small clay-coated, chalky shell fragments (productids, *Composita*, chonetids, foraminiferids, and bryozoans) and dark reddish brown (10 R 3/4) ironstone nodules (some weathered & abraded, one is foraminiferid-coated).

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.5-8.0ft; 2.0-2.4m), very similar to Sta.31. Interval 'a' (3.5-4.0ft.; 1.1-1.2m) is 5-10% chaetetids, laminar at the base to tall narrow ragged columns higher up; matrix is massive fusulinid packstone; a very thin interval 2.5ft. (0.76m) from the base exhibits cross laminations in the matrix and growth interruptions in the chaetetids due to sedimentation. Interval 'b' (18-24in.; 0.46-0.61m) is 25-35% chaetetids, shows more cross laminations in the matrix and more broken shelly debris (crinoids, echinoids, bryozoans, brachiopods, rugose corals, & *Aulopora* fragments); also has more *Aulopora*/chaetetid overgrowth cycles than interval 'c'. Interval 'c' (12-32in.; .35-.81m) is 25% chaetids and is thickest where chaetetid clumps continue from interval 'b' through interval 'c' and into interval '6a'; between clumps is fusulinid packstone.

3. Fossiliferous Calcarenite to Calcilutite: (4-6in. exposed; 10.2-15.2cm), fusulinid-rich, cross laminated, very similar to Sta. 31.

Sample No. | Scale (m, ft) | Bed No. | Interval No.

Locality Description: Station 12, Locality 700, S. central part of quarry.

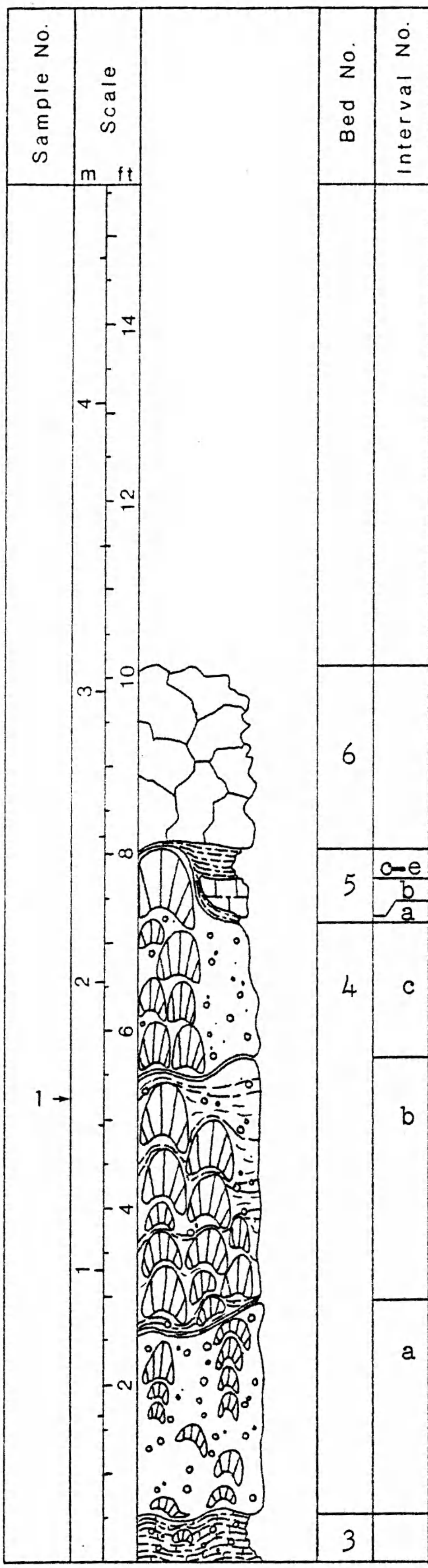
Location: NE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.



Wolverine Creek Formation

Houx-Higginsville Limestone Member

6. Calcilutite: (2ft.; .61m), very similar to Stas. 31, 11, & 24, but too fragmented by bulldozing to distinguish details.

5a-e. Shale with Calcilutite Lenses: (0-10in.; 0-25.4cm), very similar to Sta. 31, with only the lower limestone lens (interval 'b'; 8in.; 20cm) present; interval 'd' is missing. Poor exposure.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.5-7.5ft.; 1.98-2.29m), very similar to Stas. 31 & 24. Interval 'a' (2-2.5ft.; .61-.76m) is 10-20% chaetetids, occurring as small individuals and ragged columns that merge into clumps in interval 'b'; matrix is mostly massive. Interval 'b' (2.5-3ft.; .76-.91m) is 40-50% chaetetids, occurring in clumps of various sizes up to 20 ft. across (6.1m) (which continue into interval 'c') and also as scattered individuals; matrix is dark gray, strongly cross laminated, with abundant shelly debris (crinoids, echinoids, brachiopods, rugose corals, *Aulopora*). Interval 'c' (1.5-2.5ft.; .46-.76m) is 25% chaetetids, occurring primarily as clumps continued upsection from interval 'b'; matrix is massive grading upward to cross laminated. In interval 'a' is a chaetetid column (16in. high; 41cm) showing 6 cycles of chaetetid/*Aulopora* overgrowths; also another chaetetid has an *in situ* rugose coral surrounded by *Aulopora* on its surface, then this was overgrown by a chaetetid.

3. Fossiliferous Calcarenite to Calcilutite: (6in. exposed; 15.2 cm), very similar to Sta. 31.

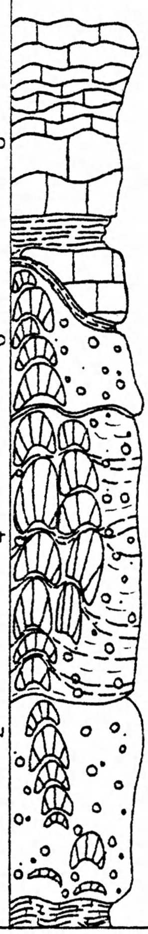
Locality Description: Station 13, Locality 700, SE. part of quarry.

Location: SE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m / ft)	Bed No.	Interval No.
	m: 4, 3, 2, 1 / ft: 14, 12, 10, 8, 6, 4, 2		
1→			
		6	c,d
			b
			a
		5	c,e
			b
			a
		4	c
			b
			a
		3	



Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

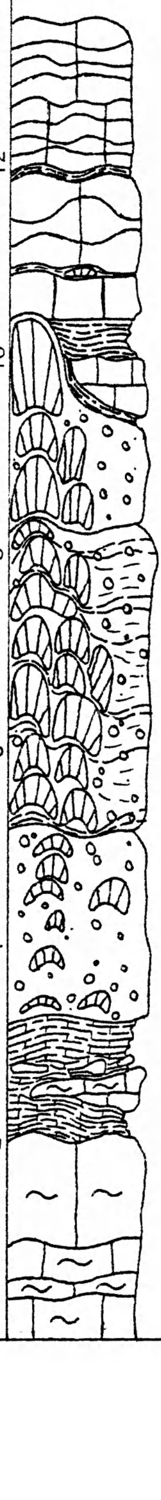
6a–d. Calcilutite: (20–24in.: 51–61cm), very similar to Stas. 31, 11, & 24. Exposure is weathered, dirty, & mossy, the oldest part of the quarry. Beds are weathered out in relief, revealing wavy bedding planes with wavelengths of 6–18in. (15–46cm) and amplitudes of 1–2in. (2.5–5.1cm).

5a–e. Shale with Calcilutite Lenses: (6–14in.; 15.2–35.6cm), very similar to Sta. 31, with only the lower limestone (interval 'b') present within the shale; interval 'd' is missing. Poor exposure.

4a–c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6–7ft.; 1.83–2.13m), similar to Stas. 31 & 24, but poorly exposed. Interval 'a' is 2ft. thick (.61m), interval 'b' is 3ft. (.91m), and interval 'c' is 1–2ft. (.30–.61m) thick.

3. Fossiliferous Calcarenite to Calcilutite; (3in. exposed; 7.6cm), similar to Sta. 31. Cross laminated.

Sample No.	Scale (m, ft)		Bed No.	Interval No.	
					Locality Description: Station 14, Locality 700, SE. part of quarry.
					Location: SE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.
					Measured By: D. R. Suchy Date: 1986
					Remarks:



Scale: m — 1, 2, 3, 4; ft — 2, 4, 6, 8, 10, 12, 14

Bed No.	Interval No.
6	d, c, b, a
5	c,e, b, a
4	c, b, a
3	
2	

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (3ft.; .91m), very similar to Stas. 31, 11, & 24. Not as weathered as Sta. 13 but still difficult to delineate upper intervals.

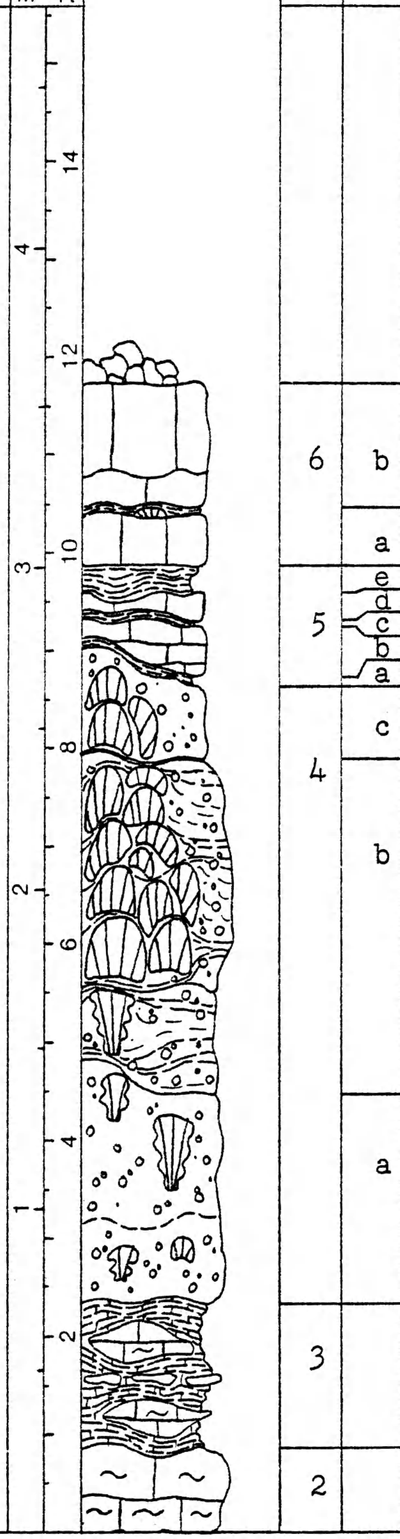
5a-e. Shale with Calcilutite Lenses: (0-12in.; 0-30.5cm), similar to Stas. 31 & 13, with only the lower limestone lens (interval 'b') present within the shale; interval 'd' is missing.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6-7ft.; 1.83-2.13m), similar to Stas. 31 & 24 & 13.

3. Fossiliferous Calcarenite to Calcilutite: (12-15in; 30.5-38.1cm), very similar to Sta. 31. Chert layer is nodular and 5/8-2in. (1.6-5.1cm) thick. Small algal calcilutite lenses present below chert.

2. Algal to Skeletal Calcilutite: (2ft. exposed; .61m), very similar to Stas. 31 & 8.

Sample No. | Scale (m, ft) | Bed No. | Interval No.



Locality Description: Station 16, Locality 700, near center of quarry.

Location: $SW\frac{1}{4}NW\frac{1}{4}SE\frac{1}{4}SE\frac{1}{4}$, sec. 12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-b. Calcilutite: (22in.; 56cm), very similar to Stas. 31, 11, & 24, but intervals 'c' & 'd' have been bulldozed away. Interval 'a' is 6in. (15.2cm) thick. Interval 'b' is 15in. (38.1cm) thick with a very minor, cross laminated interval 4in. (10.2cm) above its base; 50ft. (15.2m) west of this station, interval 'b' thins to 12in. (30.5cm). Interval 'c' is present 25ft. (7.6m) west of this station, where it is 6in. (15.2cm) thick.

5a-e. Shale with Calcilutite Lenses: (8-16in.; 20.3-40.6cm), very similar to Stas. 11 & 24, with both limestone lenses (intervals b & d) well developed within the shale.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6-7.5ft.; 1.83-2.29m), very similar to Stas. 31 & 24. Interval 'a' (2ft.; .61m) is massive, with 5-10% chaetetids. Interval 'b' (3-3.5ft.; .91-1.07m) is 30% chaetetids in a cross laminated matrix with a prominent cross laminated interval 10-14in. (25.4-35.6cm) above its base. Interval 'c' (12-18in.; 30.5-45.7cm) is 5% chaetetids, occurring as continuations of clumps from interval 'b'.

3. Fossiliferous Calcarenite to Calcilutite: (18in.; 45.7cm), very similar to Sta. 31, but has algal calcilutite lenses (5-9in. thick; 12.7-22.9cm) above and below the chert. Chert occurs as nodules (up to 3x7in.; 7.6-17.8cm). The cross laminations undulate with a wavelength of 12-14in. (30.5-121.9cm) and an amplitude of 1-3in. (2.5-7.6cm). One chert nodule contains a silicified laminar chaetetid within it; other non-silicified chaetetids occur in this interval.

2. Algal to Skeletal Calcilutite: (10in. exposed; 25.4cm), very similar to Stas. 31 & 8.

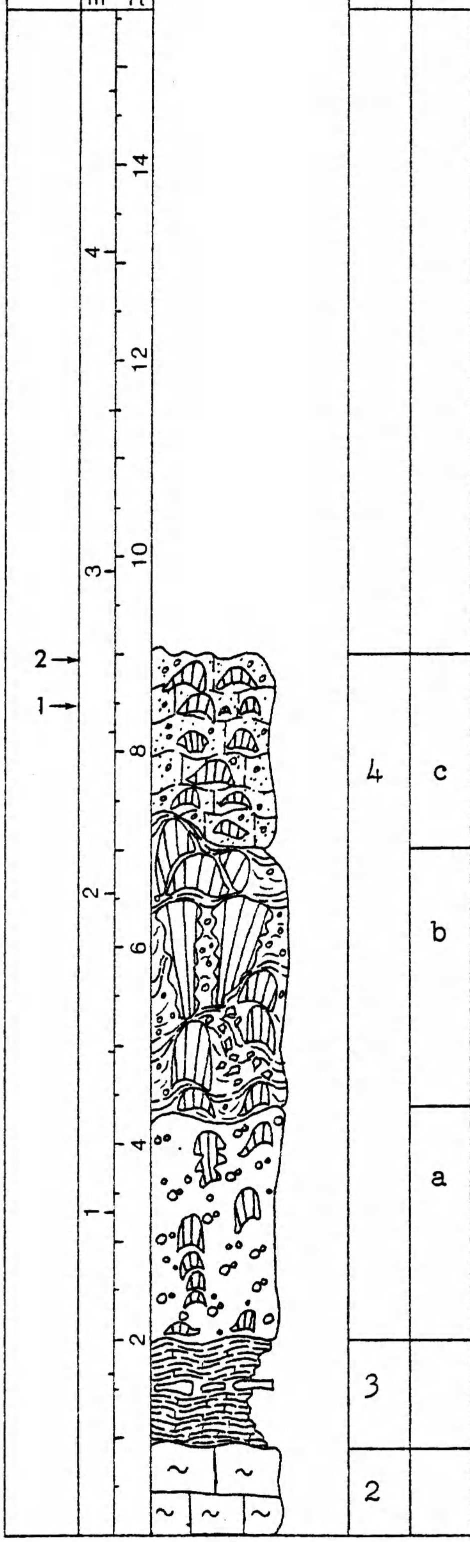
Sample No. | Scale (m, ft) | Bed No. | Interval No.

Locality Description: Station 17, Locality 700, NE. part of quarry.

Location: $SE\frac{1}{4}NW\frac{1}{4}SE\frac{1}{4}SE\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:



Description

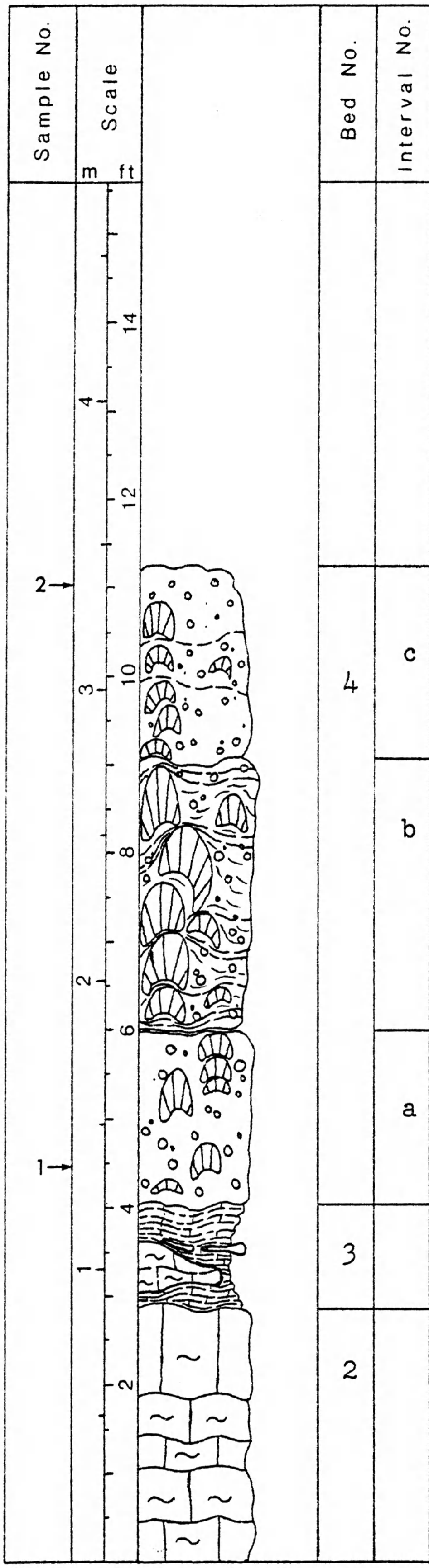
Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (7ft.; 2.13m), similar to Stas. 31 & 24, but with some differences. Interval 'a' (2-2.25ft.; .61-.69m) has 10-15% chaetetids as laminar individuals to ragged columns in massive fusulinid packstone matrix. Interval 'b' (2.5-3ft.; .76-.91m) contains 50% *in situ* chaetetids plus angular chaetetid fragments and other fossil fragments (*Aulopora*, crinoids, echinoids, rugose corals, brachiopods) randomly oriented in matrix between chaetetid heads; matrix is dark gray, cross laminated fusulinid wackestone. Interval 'c' (18-24in.; 45.7-61.0cm) is highly weathered, forming thin wavy beds containing laminar to low domical chaetetids, chaetetid fragments, some algal blades, and skeletal debris (crinoids, echinoids, brachiopods, fistuliporids, *Aulopora*, and sand-size skeletal fragments) in a fusulinid-bearing (<10% in places) skeletal calcarenite matrix.

3. Fossiliferous Calcarenite to Calcilutite: (12in.; 30.5cm), very similar to Sta. 31. Algal calcilutite lenses below nodular chert layer; cross laminated fusulinid-rich calcilutite to calcarenite matrix.

2. Algal to Skeletal Calcilutite: (12in. exposed; 30.5cm), very similar to Stas. 31 & 8.



Locality Description: Station 18, Locality 700, NE. part of quarry.

Location: SE¼NW¼SE¼SE¼, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation

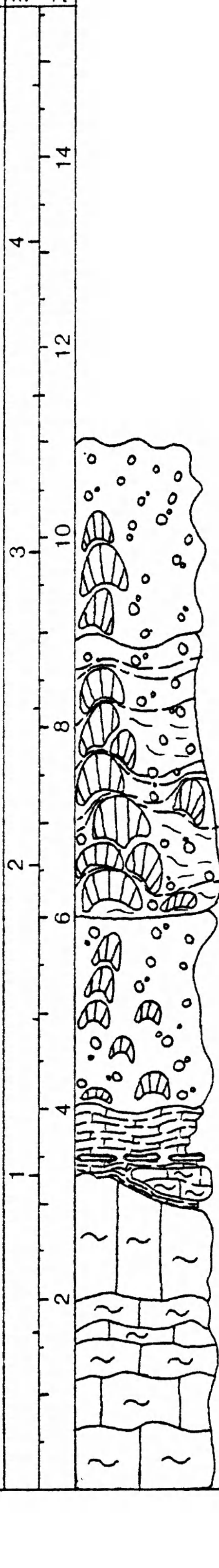
Houx-Higginsville Limestone Member

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (7ft.3in.; 2.21m), very similar to Stas. 31 & 24. Interval 'a' is 2ft. thick (.61m) and massive. Interval 'b' is 3ft. thick (.91m) and cross laminated. Interval 'c' is 2-2,25ft. thick (.61-.69m) and shows 2 or 3 minor cross laminated partings.

3. Fossiliferous Calcarenite to Calcilutite: (14in.; 35.6cm), very similar to Sta. 31. Chert layer represented by small chert nodules. Algal calcilutite lenses present below chert.

2. Algal to Skeletal Calcilutite (3 ft. exposed; .91m), very similar to Stas. 31 & 8.

Sample No.	Scale (m, ft)		Bed No.	Interval No.
			4	c
				b
				a
			3	
			2	



Locality Description: Station 19, Locality 700, NE. corner of quarry.

Location: NE$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackstone to Packstone): (7ft.; 2.13m), similar to Stas. 31 & 24.

3. Fossiliferous Calcarenite to Calcilutite: (6-12in.; 15.2-30.5cm), very similar to Sta. 31. Chert layer represented by small chert nodules. Algal calcilutite lenses present below chert. Cross laminations undulate with a wavelength of 12-48in. (30.5-121.9cm) and amplitude of 2-6in. (5.1-15.2cm).

2. Algal to Skeletal Calcilutite: (3ft. exposed; .91m), very similar to Stas. 31 & 8.

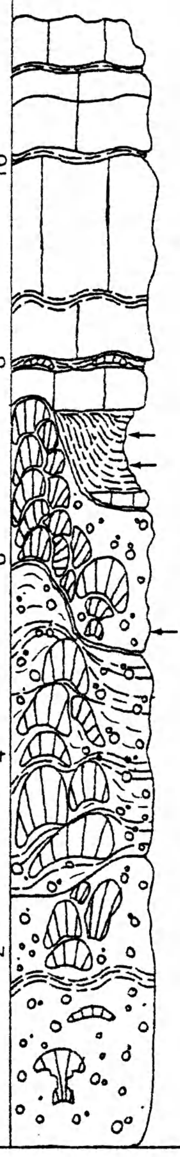
Locality Description: Station 20, Locality 700, S. central part of quarry.

Location: NW$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy   Date: 1986

Remarks:

Sample No.	Scale (m)	Scale (ft)	Bed No.	Interval No.
		14		
	4			
		12		
			6	d
				c
	3	10		b
		8		a
1			5	c,e
2,3				b
	2			a
		6	4	c
4				
				b
		4		
5	1			
				a
		2		
6				



Description

Bed No.

<u>Wolverine Creek Formation</u>
<u>Houx-Higginsville Limestone Member</u>

6a-d. Calcilutite: 4 ft.; 1.22m), very similar to Stas. 31, 11, & 24, but much thicker, especially interval 'b'. <u>Interval 'a'</u> is 6-7in. (15.2-17.8cm) thick and has laminar chaetetids in cross laminated parting on top. <u>Interval 'b'</u> is 26in. (66.0cm) thick and has a minor, cross laminated layer 8-9in. (20.3-22.9cm) above its base. <u>Interval 'c'</u> is 9-10in. (22.9-24.5cm) thick and has a minor, cross laminated layer in its middle. Interval 'd' is 6in. (15.2cm) thick and is highly weathered. The cross laminations in the partings (especially at the top of interval 'a') have wavelengths of up to 16in. (15.2cm).

5a-e. Shale with Calcilutite Lenses: (0-12in.; 30.5cm), similar to Stas. 31,11, & 24, but limestone lenses are less well developed. Only the lower limestone lens (interval b; 2-3in.; 5.1-7.6cm) is present here; the upper limestone lens (interval d) occurs 30ft. (9.1m) west of this station as a small, thin, patchy lens. Rare, small, weathered, reddish ironstone nodules occur within the shale; thin gypsum veins (1mm thick) crosscut the ironstone nodules and extend into the shale.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.5-7.5ft. exposed: 1.98-2.29m), very similar to Stas. 31 & 24, but cross bedding occurs throughout most of the interval. <u>Interval 'a'</u> (2.5-3ft.; .76-.91m) is 10-15% chaetetids, mostly laminar individuals to ragged columns, but some clumps got started in the interval; matrix is massive fusulinid packstone; subtle, minor, cross laminated layer occurs 8-14in. (20.3-35.6cm) below its upper boundary. <u>Interval 'b'</u> (2-3.5ft.; .61-1.07m) is 20-40% chaetetids, occurring as clumps and individual domical to columnar forms; matrix is dark gray fusulinid packstone to wackestone, strongly cross laminated; some chaetetids are toppled onto their sides & some are fragmented, there are many growth interruptions defined by sediment layers and <u>Aulopora</u> overgrowths. <u>Interval 'c'</u> (1.5-2.5ft.; .46-.76m) is 25% chaetetids, occurring as clumps continued from interval 'b'; matrix is fusulinid wackestone.

B16

Sample No.	Scale (m, ft)		Bed No.	Interval No.	

Locality Description: Station 21, Locality 700, ctr. of S. side of quarry.

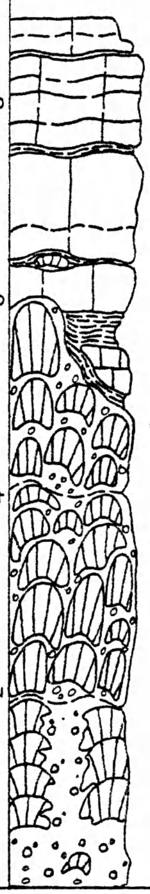
Location: SE$\frac{1}{4}$SE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.



Sample No.	Bed No.	Interval No.
	6	d
	6	c
	6	b
	6	a
4	5	c, e
	5	b
	5	a
	4	c
2.3	4	b
1	4	a

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (3ft.; .91m), similar to Stas. 31, 11, & 24, but intervals 'b' & 'c' are thicker. Interval 'a' is 6in. (15.2cm) thick and, in the cross laminated layer on top, contains laminar chaetetids, 5-10% fusulinids, and 2-3% other sand to granule-size shelly debris (brachiopods, crinoids, echinoids). Interval 'b' (12-14in.; 30.5-35.6cm) shows a minor, cross laminated layer 4in. (10.2cm) above its base; the cross laminated layer on top contains 3-5% shelly debris and Composita, many of which are articulated and well preserved. Interval 'c' (12in.; 30.5cm) includes 3 minor cross laminated layers. Interval 'd' (4-5in.; 10.2-12.7cm) is highly weathered in its upper 2in. (5.1cm).

5a-e. Shale with Calcilutite Lenses: (0-12in.; 0-30.5cm), similar to Stas. 31,11, &24, containing only the lower limestone lens (interval b) in small isolated patches; interval 'd' is missing.

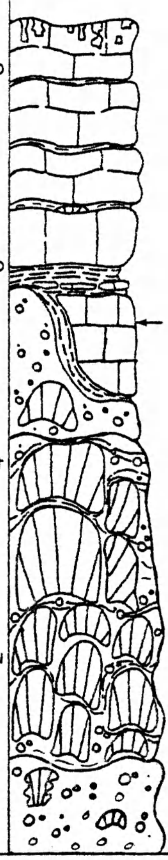
4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6ft.; exposed; 1.83m), very similar to Stas. 31 & 24. Poorly exposed. Largely a chaetetid clump which is up to 20ft.(6.1m) across, and has started at its base from numerous ragged columns 8-18in. (20.3-45.7cm) across and 2ft. (.61m) high. Intervals a, b, & c are difficult to differentiate because chaetetids seem to continue through them without a break. The matrix is relatively fusulinid-poor (as low as 10%) in places, but some cross laminated pockets around chaetetids contain 25-50% fusulinids. Some chaetetid breccia caused by compaction. Voids filled with coarsely crystalline sparry calcite (clear to brown).

Locality Description: Station 22,
Locality 700, SW. part of quarry.

Location: NE$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m / ft)		Bed No.	Interval No.
			6	d, c, b, a
2,3 →			5	e, d, c, b, a
1 →			4	c, b, a

Scale: m 1, 2, 3, 4; ft 2, 4, 6, 8, 10, 12, 14

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2.5ft.; .76m), very similar to Stas. 32, 11, & 24. Upper 3-4in. (7.6-10.2cm) of interval 'd' is highly weathered.

5a-e. Shale with Calcilutite Lenses: (3-16in.; 7.6-40.6cm), very similar to Stas. 11 & 24, with 2 layers of limestone lenses enclosed in shale. Interval 'b' is up to 13in. (33cm) thick and contains vertical burrows, roots & gastropods, along with fragments of brachiopods, crinoids, echinoids, & fusulinids. Interval 'd' is less than 2in. (5.1cm) thick, very patchy, and contains gastropods.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (5ft. exposed; 1.52m), very similar to Stas. 31 & 24. Interval 'a' (1ft. exposed; .305m) is less than 25% chaetetids. Interval 'b' (3-3.5ft.; .91-1.07m) is 85-90% chaetetids representing a chaetetid clump; cross laminated matrix; the largest individual chaetetid is 16in. (40.6cm) across & 15in. (38.1cm) high with one major and one minor growth interruption by *Aulopora* overgrowth. Some large (.5-1.5in.; 1.3-3.8cm) euhedral crystals of clear to brown calcite fill vugs & fractures.

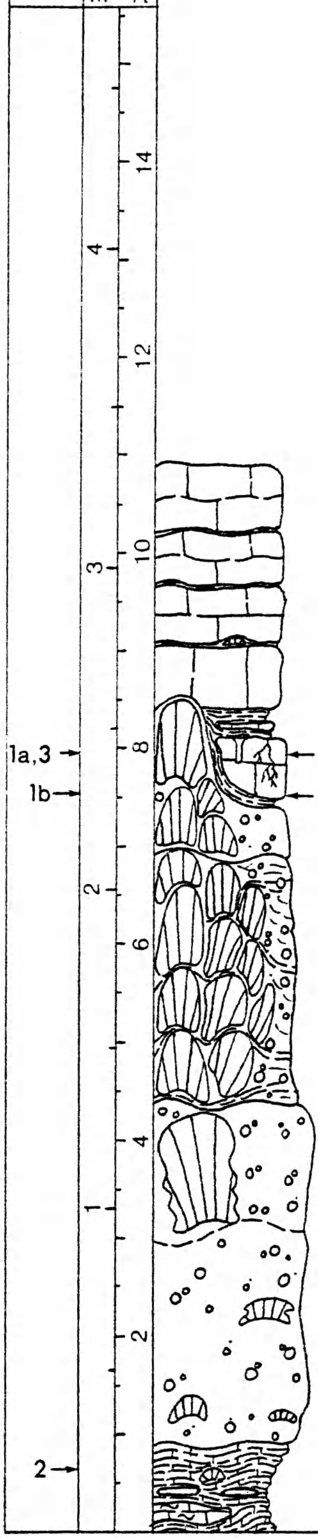
Locality Description: Station 23, Locality 700, SW. part of quarry.

Location: $NE\frac{1}{4}SW\frac{1}{4}SW\frac{1}{4}SE\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m, ft)	Bed No.	Interval No.
		6	d
		6	c
		6	b
		6	a
		5	e
1a,3		5	d
		5	c
1b		5	b
		5	a
		4	c
		4	b
		4	a
2		3	



Description

Bed No.

Wolverine Creek Formation

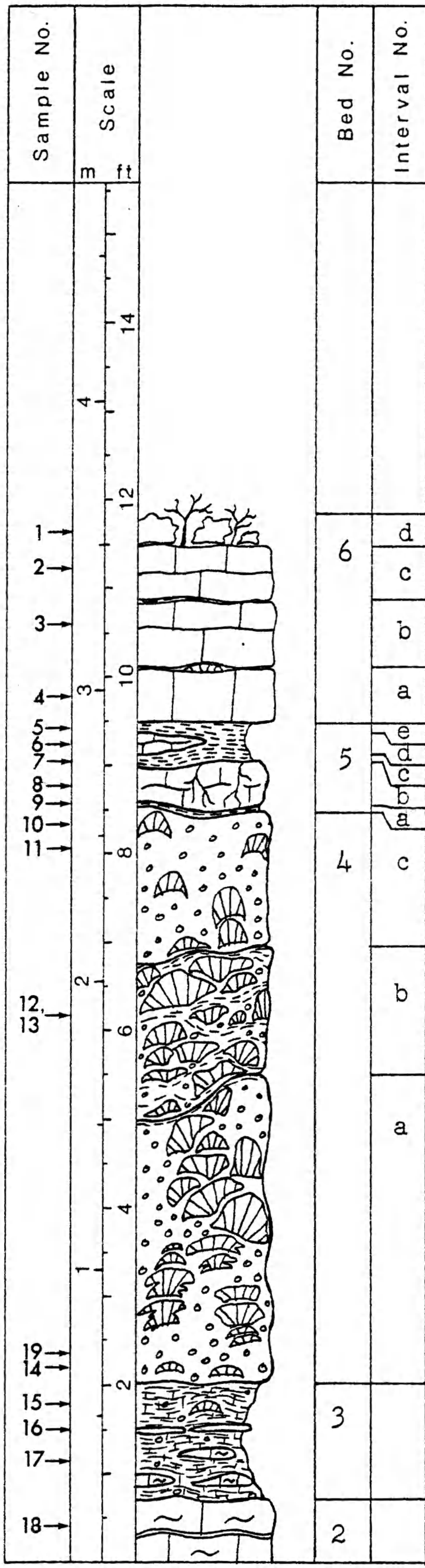
Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2.5ft.; .76m), very similar to Stas. 31, 11, & 24. The four intervals (a, b, c, d) are well defined and minor cross laminated layers occur in the middles of of intervals b, c, & d.

5a-e. Shale with Calcilutite Lenses: (0-12in.; 0-30.5cm), very similar to Stas. 11 & 24, with 2 layers of limestone lenses enclosed in shale. Interval 'b' (0-8in.; 0-20.3cm) is well developed and has root traces and a black vertical burrow (1in. wide and 2.5in. deep; 2.5x6.4cm) that has intraclasts and a crinoid columnal in its base: a thin lag deposit (.25-.75in. thick (.6-1.9cm) and covering an irregular area 12x18in. (30.5x45.7cm)) found on the bottom of a boulder from this interval contained abundant fossil fragments, including crinoids, echinoids, Composita, Fistulipora, 2 or 3 genera of fenestrate bryozoans (Fenestrella, Polypora?), ramose bryozoans (Rhombopora?), Aulopora, Meekella striatocostata, Ameura, Punctospirifer, Crurithyris, fusulinids, productids, and Neospirifer. Interval 'd' is thin (1-1.5in.; 2.5-3.8cm).

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.5-7.5ft.; 1.98-2.29m), very similar to Stas. 31 & 24. Interval 'a' (3.5ft.; 1.07m) is 5% chaetetids in lower part, 10-20% chaetetids in upper part; subtle cross laminated parting 2-2.5ft. (.61-.76m) above base. Interval 'b' (2.5ft.; .76m) is 50-75% chaetetids, with some clumps 10-20ft. (3.05-6.10m) across and up to 6ft. (1.83m) high (extending above & below this interval, some extending into the base of interval 6); one individual chaetetid is 28in. (71cm) across and 15in. (38cm) high and has a 2in. (5.1cm) layer of Aulopora on top. Interval 'c' (18in.; .46m) is generally chaetetid-free except where clumps continue upward from interval 'b'.

3. Fossiliferous Calcarenite to Calcilutite: (12in. exposed; 30.5cm), very similar to Sta. 31. Cherty layer has rare, small (1x2-3in.; 2.5x5.1-7.6cm) chert nodules. Laminar chaetetids common in upper part, some attached to shelly debris. Algal calcilutite lenses in lower part.



Locality Description: Station 24, Locality 700, western N. central part of quarry.

Location: NW¼NE¼SW¼SE¼, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2ft.; .61m), very similar to Stas. 31 & 11. Many fossils are unbroken, unabraded, & articulated, apparently in life position. Fusulinids are common (1-10%) in intervals a & b and rare to absent in intervals c & d. Bellerophontids are absent below the top of interval b and are common (1-3%) above that point. Interval d is poorly exposed or scraped away but may additionally have small fenestrae, burrow mottling, and possible root(?) traces.

5a-e. Shale with Calcilutite Lenses: (12 in.; .305m), very similar to Sta. 11. Contains 2 layers of limestone lenses (intervals b & d) surrounded by shale; both limestone layers show abundant root traces and a few plant fragments, but interval b has more shelled fossils (1-2% fusulinids & algal blades).

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6ft.6in.; 2.0m), very similar to Sta. 31. In interval 'a', chaetetids (25-30%) start out small & laminar and increase in size and number upsection; the fusulinid packstone matrix is massive, light brownish gray (5 YR 6/1), with a small amount of cross lamination next to some chaetetids. Interval 'b' is mostly chaetetids (>75%), some of which are brecciated; the matrix is fusulinid wackestone, medium dark gray (N4) to dark gray (N3), weathering light brown (5 YR 5/6) to moderate brown (5 YR 4/4), strongly cross laminated around the chaetetids. In interval 'c', chaetetids (25%) are fairly large (10-14in. across (25.4-35.6cm) and 12-18in. high (30.5-45.7cm)), columnar, restricted primarily to the lower 2/3 of the interval (there are <5% chaetetids in the upper 6-12in. (15.2-30.5cm)), and are nearly all capped by *Aulopora* at this station; the matrix is fusulinid packstone to wackestone, medium light gray (N6), weathering brownish gray (5 YR 4/1), grading from massive in the lower part to cross laminated at the top.

3. Fossiliferous Calcarenite to Calcilutite: (16in.; 40.6cm), fusulinid-rich (10-20%), argillaceous, very similar to Sta. 31. Chert layer is continuous to nodular. Algal calcilutite lenses below chert are small and discontinuous.

2. Algal to Skeletal Calcilutite: (6-8in. exposed; 15.2-20.3cm), very similar to Stas. 31 &8. The most obvious fossils are phylloid algal blades (5%) and Composita (1-2%); no chaetetids, no fusulinids. Wavy bedded.

Locality Description: Station 25

Locality 700, western N. central part of quarry.

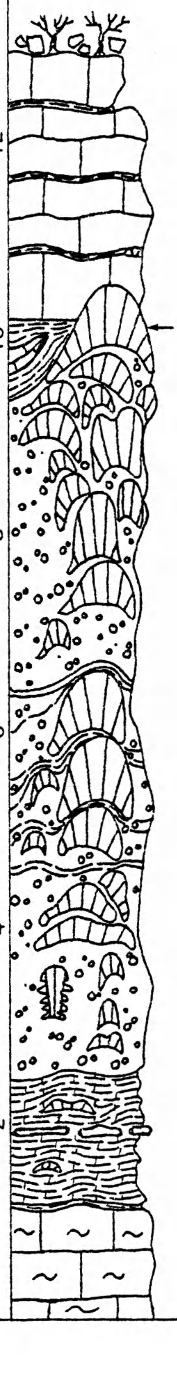
Location: NW¼NE¼SW¼SE¼, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m, ft)	Bed No.	Interval No.
1		6	d
			c
4			b
3			a
2		5	c, e
			b
			a
		4	c
			b
			a
		3	
		2	

Scale: m 1, 2, 3, 4; ft 2, 4, 6, 8, 10, 12, 14



Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2ft.8in.; .81m), very similar to Stas. 24, 31, & 11. Rare laminar chaetetids at top of interval 'a'. Interval 'd' is 6-8 in. (15.2-20.3cm) thick here and additionally contains small high-spired gastropods.

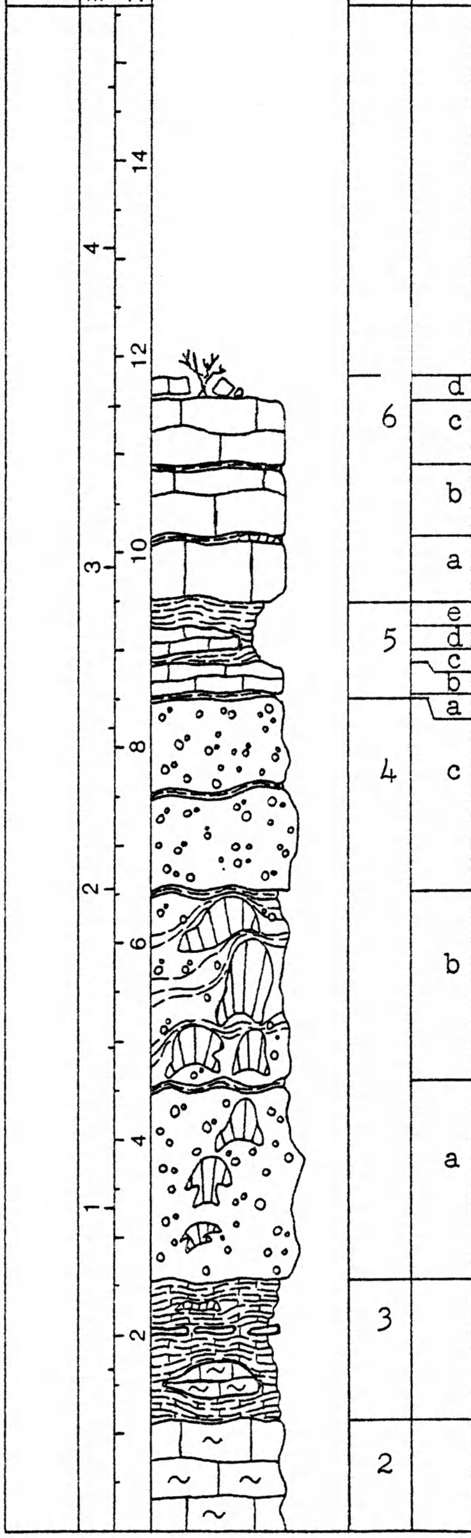
5a-e. Shale with Calcilutite Lenses: (0-10in.; 0-25.4cm), very similar to Stas. 24 & 11, but the limestone lenses (intervals b & d) pinch out nearby and all of interval 5 pinches out against a large chaetetid clump here.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to to Packstone): (7-8ft.; 2.1-2.4m), very similar to Stas. 24 & 31. A large chaetetid clump (6 ft. across; 1.8m) protrudes through interval 5 and 4-6 in. (10.2-15.2cm) into interval 6. Interval 'a' (2-2.5ft.; .61-.76m) is 30-40% chaetetids, grading from sparse, small, laminar forms near the base to common, ragged, columnar forms higher up. Interval 'b' (2ft.; .61m) is 75-85% chaetetids, some brecciated; this interval is more difficult to distinguish here than at Sta. 24 due to the large chaetetid clump, but can still be distinguished by the darker gray, more argillaceous fusulinid wackestone washed in around and between chaetetids.

3. Fossiliferous Calcarenite to Calcilutite: (16in.;40.6cm), very similar to Stas. 24 & 31. Cherty layer (1-1.5in.; 2.5-3.8cm) is 6 in. (15.2cm) below top of interval.

2. Algal to Skeletal Calcilutite: (10 in. exposed; 25.4cm), very similar to Stas. 24 & 31.

Sample No.	Scale (m, ft)		Bed No.	Interval No.	
					Locality Description: Station 26, Locality 700, western N. central part of quarry.
					Location: NW¼NE¼SW¼SE¼, sec.12, T.30S., R.22E., Crawford County, Kansas.
					Measured By: D. R. Suchy Date: 1986
					Remarks:



Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2-2.3ft.; .61-.70m), very similar to Stas. 24, 31, & 11. Interval 'd' is poorly exposed, showing 4-5in. (10.2-12.7cm).

5a-e. Shale with Calcilutite Lenses: (12in.; 30.5cm), very similar to Stas. 24 & 11, with 2 layers of limestone lenses enclosed in shale.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6ft.; 1.8m), very similar to Stas. 24 & 31. Interval 'a' (2ft.; .61m) is 10-15% chaetetids in massive fusulinid packstone. Interval 'b' (2ft.; .61m) is 50-60% chaetetids (within 5ft. (1.5m) to either side of this station) in cross laminated matrix. Interval 'c' (2ft.; .61m) has less than 5% chaetetids within 10ft. (3.05m) to either side of this station; a shaly parting exists 1 ft. (.305m) below the top of this interval. A chaetetid fragment with an attached *Pseudomonotis* was collected 90-100ft. (27-30m) west of this station from float on quarry floor.

3. Fossiliferous Calcarenite to Calcilutite: (16in.; 40.6cm), very similar to Stas. 24 & 31. Cherty layer 6in. (15.2cm) below top; algal calcilutite lenses (6x18in.; 15.2x45.7cm) in bottom part.

2. Algal to Skeletal Calcilutite: (12in. exposed; 30.5cm), very similar to Stas. 24 & 31.

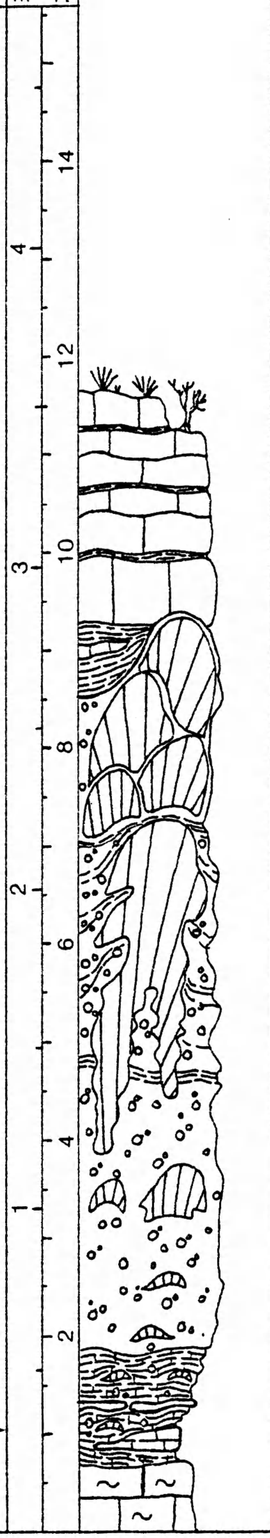
Locality Description: Station 27, Locality 700, western N. central part of quarry.

Location: NW$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m, ft)		Bed No.	Interval No.
			6	d, c, b, a
			5	e, c, b, a
			4	c, b, a
2→			3	
			2	



Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2ft.6in.; .76m), very similar to Stas. 24, 31, & 11, including 6in. (15.2cm) of Interval 'd'.

5a-e. Shale with Calcilutite Lenses: (0-8in.; 0-20.3cm), very similar to Stas. 24, 31, & 11, but only the lower limestone lens (interval 'b'; 2-3in.; 5.1-7.6cm) is present; interval 'd' is absent.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.75-7.5ft.; 2.1-2.3m), very similar to Stas. 24 & 31. A chaetetid clump (4.5ft. across; 1.4m) protruded 2-3in. (5.1-7.6cm) into interval 6. Interval 'a' has 10-15% chaetetids, interval 'b' has 25% chaetetids on either side of the clump, and interval 'c' has <5% chaetetids on either side of the clump.

3. Fossiliferous Calcarenite to Calcilutite: (14in.; 35.6cm), very similar to Stas. 24 & 31. Cherty layer is 1-2.5in. (2.5-6.4cm) thick and undulates with a 2in. (5.1cm) amplitude. Algal calcilutite lens (6x24in.; 15.2x61.0cm) in bottom part. Sparse laminar chaetetids above chert, 1 or 2 very small ones below.

2. Algal to Skeletal Calcilutite: (6-8in. exposed; 15.2-20.3cm), very similar to Stas. 24 & 31.

Locality Description: Station 28, Locality 700, western N. central part of quarry.

Location: NW¼NE¼SW¼SE¼, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m, ft)		Bed No.	Interval No.
1→	m: 1, 2, 3, 4; ft: 2, 4, 6, 8, 10, 12, 14		6	c, b, a
			5	e, d, c, b, a
			4	c, b, a
			3	
			2	

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-c. Calcilutite: (2ft.; .61m), very similar to Stas. 24, 31, & 11, but interval 'd' has been scraped away.

5a-e. Shale with Calcilutite Lenses: (6-12in.; 15.2-30.5cm), very similar to Stas. 24 & 11, with 2 layers of limestone lenses enclosed in shale.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (7-7.5ft.; 2.1-2.3m), very similar to Stas. 24 & 31. Primarily fusulinid packstone with <5% chaetetids (mostly in interval b) for over 6ft. (1.8m) to either side of this station. The 3 main intervals (a,b,c) are separated by cross laminated layers 2-6in. (5.1-15.2cm) thick. The packstone in the middles of intervals 'b' & 'c' is very slightly cross laminated to massive; in interval 'a' it is massive.

3. Fossiliferous Calcarenite to Calcilutite: (18in.; 45.7cm), very similar to Stas. 24 & 31, but with no chaetetids below the cherty layer.

2. Algal to Skeletal Calcilutite: (3-4in. exposed; 7.6-10.2cm), very similar to Stas. 24 & 31.

Sample No. | Scale (m, ft) | Bed No. | Interval No.

Locality Description: Station 29, Locality 700, western N. central part of quarry.

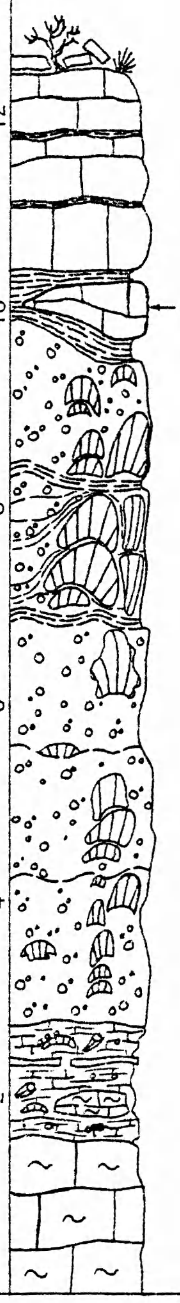
Location: NW$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.



Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2ft.2in.; .66m), very similar to Stas. 24, 31, & 11, including 2in. (5.1cm) of interval 'd' on top, the rest scraped away. Base of interval 'a' shows a shell lag deposit (0.25in. thick; 0.6cm) with sand to granule size fragments of brachiopods (productid, chonetid, other), echinoids, bryozoans (ramose & encrusting), bivalves, fusulinids, other foraminiferids, and a whole productid.

5a-e. Shale with Calcilutite Lenses. (6-12in.; 15.2-30.5cm), very similar to Stas. 24 & 31, with only the lower limestone (interval b) present.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.75-7.25ft.; 2.1-2.2m), very similar to Stas. 24 & 31. Interval 'a' (4ft.3in.; 1.30m) contains 2 minor, thin, cross laminated layers within the fusulinid packstone at 18 & 34in. (45.7 & 86.4cm) above the base, of which the upper one shows shell lag deposits with fragments (sand to small pebble size) of echinoids, crinoids, bryozoans, rugose corals, brachiopods, angular chaetetid fragments, and a chaetetid (3x5in.; 7.6x12.7cm) that had been rolled over. In many cases, chaetetid growth appears to be concentrated in or near these cross laminated layers. Interval 'b' (18in.; 45.7cm) has a chaetetid clump (2.5ft. high & 6ft. across; .76x1.83m) that extends partly into intervals 'a' & 'c'. Interval 'c' (18in.; 45.7cm) is less than 5% chaetetids.

3. Fossiliferous Calcarenite to Calcilutite: (14in.; 35.6cm), very similar to Stas. 24 & 31. Cherty layer is 1in. thick (2.5cm) and lies 4in. (10.2cm) below the top of the interval. Has common laminar chaetetids, Aulopora, & rugose corals above chert layer, rare chaetetids & common rugose corals below chert layer. A 6in. thick (15.2cm) algal calcilutite lens occurs below the chert.

2. Algal to Skeletal Calcilutite: (18in. exposed; 45.7cm), very similar to Stas. 24 & 31.

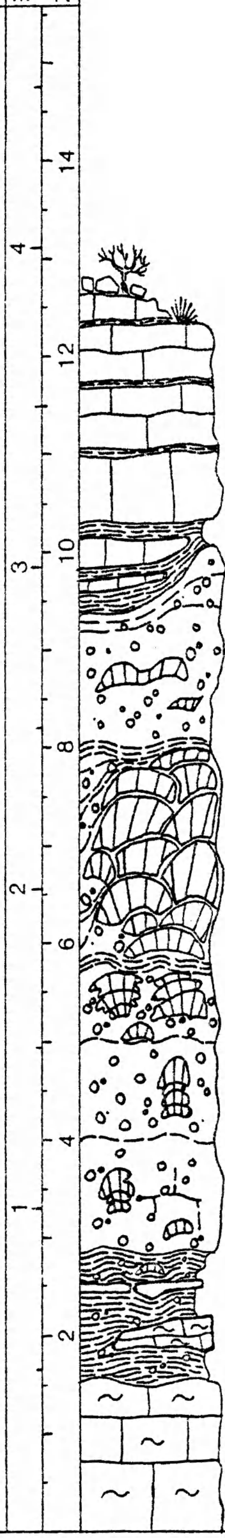
Sample No. | Scale (m, ft) | Bed No. | Interval No.

Locality Description: Station 30, Locality 700, western N. central part of quarry.

Location: NW$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy   Date: 1986

Remarks:



Bed No.	Interval No.
6	d, c, b, a
5	e, d, c, b, a
4	c, b, a
3	
2	

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2ft. 4in.; .71m), very similar to Stas. 24, 31, & 11, including 4in. (10.2cm) of interval 'd'.

5a-e. Shale with Calcilutite Lenses: (2-12in.; 5.1-30.5cm), very similar to Stas. 24 & 11, with two layers of limestone lenses enclosed in shale.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (7-7.5ft.; 2.1-2.3m), very similar to Stas. 24 & 31. Interval 'a' (3ft.; .91m) is 10-20% chaetetids, mostly in upper half; the thin, cross-laminated layers seen at Sta. 29 are also here but are more subtle and difficult to see. Interval 'b' (2ft.; .61m) is 80-90% chaetetids (clump, 3.5x12.5ft.; 1.07x3.81m). Interval 'c' (16-24in.; 40.6-61.0cm) is 10% chaetetids.

3. Fossiliferous Calcarenite to Calcilutite: (16in.; 40.6cm), very similar to Stas. 24 & 31. Same as at Sta. 29 but with only a few chaetetids above the chert, none below; algal calcilutite lens below chert is large (up to 11in.x7ft.; 27.9cmx2.13m).

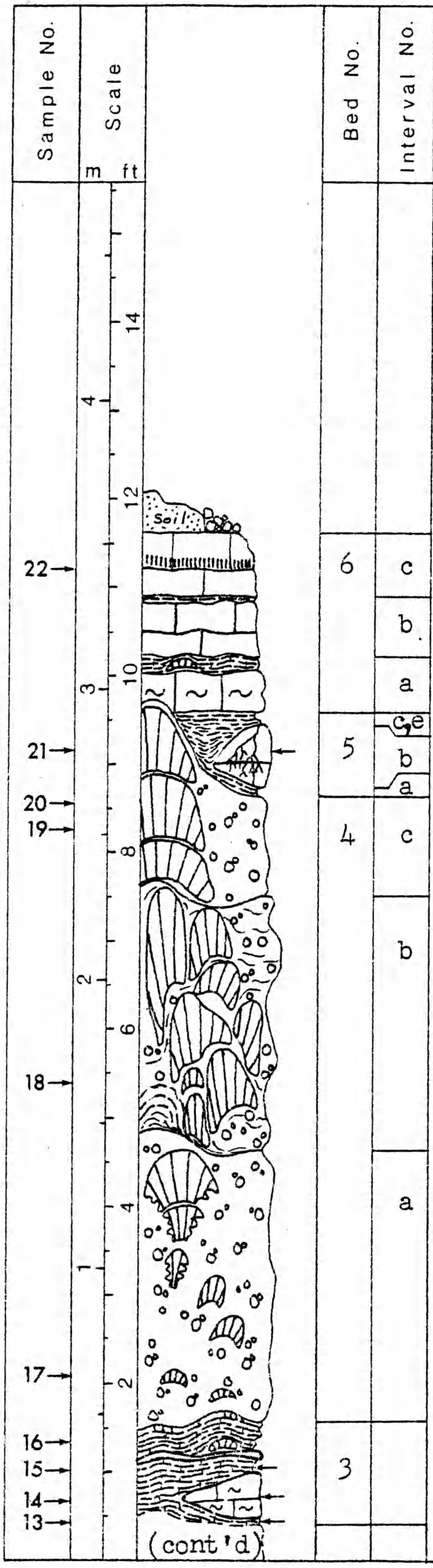
2. Algal to Skeletal Calcilutite: (16in. exposed; 40.6cm), very similar to Stas. 24 & 31.

Locality Description: Station 31, Locality 700, SW corner of NW pit of quarry.

Location: SW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:



Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-c. Calcilutite: (2ft.0in.; .61m), olive gray (5 Y 4/1) to dark gray (N3), weathers yellowish gray (5 Y 7/2) to dark yellowish orange (10 YR 6/6); dense, hard, argillaceous, massive beds (a,b,c,d; 4-9in.; 10.2-22.9cm) separated by thin (1-3in.; 2.5-7.6cm), finely cross laminated layers that are medium dark gray (N4) to olive black (5 Y 2/1) and weather moderate brown (5 YR 4/4). Sharp basal contact. Intervals 'a' & 'b' contain 5-20% fossils, including algal blades & fragments (5-10%), encrusting red algae, fusulinids (1-5%), Composita (1-2%), crinoid fragments, algal encrusted skeletal fragments, productids (Antequatonia), Meekella, Ditomopyge, Cleiothyridina, and sand-size skeletal debris. The shaly parting at the top of interval 'a' and the upper 1/3 of the calcilutite of interval 'a' contain small laminar Chaetetes; none occur above interval 'a'. Interval 'c' is slightly dolomitic and contains 3-20% fossils, including algal fragments (5-15%), Composita (2-3%), bellerophontids (1-3%), unidentified skeletal debris (fine sand size; 5%), productid fragments (<1%), Meekella, crinoid fragments. The dark thin layers (between intervals a & b and b & c, and minor ones in the middles of intervals b & c) are more argillaceous and contain generally the same fossil types but more broken and abraded. The top 4 in. (10.2 cm) is highly weathered. Interval 'd' is weathered or scraped away.

5a-e. Shale with Calcilutite Lenses: (0-12in.; 0-30.5cm). Sharp contacts. Interval 'a' is shale, light brownish gray (5 YR 6/1) to pale yellowish brown (10 YR 6/2), flaky, silty, poorly indurated, with common fusulinids, Chondrites, plant fragments, root(?) traces, and rounded shell fragments(clay-coated). Interval 'b' consists of lenses (0-10in.thick; 0-25.4cm) of calcilutite, pinkish gray (5 YR 8/1) weathering light gray (N7), with medium density and hardness, that contain abundant plant fragments and root traces, large vertical burrows, crinoid & echinoid fragments, Composita, Meekella, productid fragments, small high-spired gastropods, bellerophontids, skeletal fragments, rare fusulinids, Ameura, and Straparollus, (also see Sta. 23 & thin section description 700-24-8). Interval 'd' is missing (see Stas. 11 & 24) and thus interval 'c' grades into interval 'e'. Intervals c & e grade from pale yellowish brown (10 YR 6/2) flaky siltshale at the bottom (with many of the same fossils seen in interval 'b') to medium light gray (N6) chippy mudstone in the middle (with plant fragments, root traces, small gastropods, and small abraded skeletal fragments) to olive black (5 Y 2/1) soft mudstone at the top (with root traces, plant fragments, small high-spired gastropods, weathered ironstone nodules, and small clay-coated skeletal fragments.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone to Grainstone): (7-8ft.; 2.1-2.4m), medium light gray (N6) to medium dark gray (N4), weathers brownish gray (5 YR 4/1) to moderate brown (5 YR 4/4); hard, well indurated, primarily massive but with cross laminations in the middle part (interval b) and in the top 3-4in. (7.6-10.2 cm) and around chaetetids. In interval 'a' (2-3.25ft.; .61-.99m), chaetetids (~5% of the rock) begin as small laminar forms which build into columns; matrix is massive

(Descriptions continued on next page)

(Descriptions continued from previous page)

fusulinid packstone; In interval 'b' (2.5-3.0ft.; .76-.91m), chaetetid columns have coalesced into large clumps (75-85% of the rock), many reaching 15-20ft. (4.5-6.1m) across; matrix is cross laminated and dark. In interval 'c' (1-2ft.; .3-.61m), chaetetids are fewer (0-10% of the rock) and occur primarily where clumps have persisted from interval 'b'; clumps commonly protrude 2-6in. (5-15.2cm) into interval 6a. In many cases, chaetetids and *Aulopora* have each in turn overgrown the other. Somewhat gradational lower contact, sharp upper contact. Fossils: fusulinids (5-50%), *Chaetetes* (0-85%), *Aulopora*, *Lophophyllidium*, *Composita*, crinoids, echinoids. chonetids, *Derbyia*, *Fistulipora*, *Hustedia*, *Neospirifer*, *Punctospirifer*, *Meekella*, gastropods, other foraminiferids & ostracodes (see thin section descriptions), encrusting algae, fenestrate & ramose bryozoan fragments, productid fragments, *Spirorbis*, *Michelinia*(?), and pellets.

3. Fossiliferous Calcarenite to Calcilutite: (12-18in.; 30.5-45.7cm), light gray (N7), weathering olive gray (5 Y 4/1); fusulinid-rich, laminated and cross laminated with thin, wavy, black clay partings. Fusulinids have long axes aligned parallel to bedding, and some larger fossil fragments are imbricated. Contains a 1.0-1.5in. (2.5-3.8cm) light gray (N7) chert layer (continuous to nodular) 5-6in. (12.7-15.2cm) below top of interval. Below the chert layer, within the calcarenite, are lenses (up to 11in.x7ft.; .28x2.1m) of medium light gray (N6) algal calcilutite very similar to that in interval 2. Laminar chaetetids are rare to absent below the chert layer, sparse and slightly larger (up to 3x8in.; 7.6x20.3cm) above the chert layer; a few small *Aulopora* cap some chaetetids. Sharp basal contact, somewhat gradational upper contact. Fossils: fusulinids (3-40%), shell fragments (3-5%), brachiopods (2-3%, including *Composita*, *Cleiothyridina*, *Crurithyris*, *Hustedia*, *Desmoinesia*, *Dielasma*, chonetids, and *Derbyia*), *Chaetetes*, *Aulopora*, crinoid & echinoid debris, *Fistulipora*, fenestrate and ramose bryozoan fragments, palaeotextulariids, *Tetrataxis*, *Polytaxis*, *Lophophyllidium*, *Ameura*, and *Spirorbis*.

(Continued on next page)

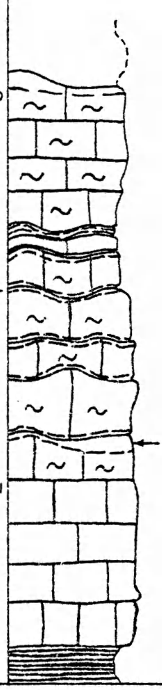
Locality Description: Station 31, Locality 700, continued from previous page.

Location:

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m, ft)	Bed No.	Interval No.
12		2	h
11			g
10, 9			f
8			e
7			d
6			c
23, 5, 4			b
3, 2			a
1		1	



Description

Bed No.

(Continued from previous page)

2a-h. Algal to Skeletal Calcilutite: (5ft.10in.; 1.78m), medium gray (N5), weathers olive gray (5 Y 4/1); dense, hard. Massive layers (a-h;2-20in.; 5-50cm) are separated by thin, wavy, dark, clay-rich, laminated layers (1/16-4in. thick; 0.2-10.2cm; with wavelengths of 6-18in. (15.2-45.7cm) and amplitudes of 1-2in. (2.5-5.1cm)). Algal blades occur in all but the bottom 20in. (50cm). Interval 'a' (6in.; 15.2cm) is medium gray (N5) argillaceous dolomitic calcilutite containing only Crurithyris and dark gray (N3) Chondrites (both abundant) with productids in upper 1/2in. (1cm); this layer is sharply overlain by coarse calcarenite containing poorly sorted angular shell fragments (crinoid, echinoid, chonetid, productid, other brachiopod, & bryozoan debris). Sharp contacts. Fossils in algal calcilutite: algal blades (1-10%), Composita (1-5%), Cleiothyridina (1-5%), crinoid & echinoid debris, Desmoinesia, rugose corals, Fistulipora, Rhombopora, Prismopora, fenestrate bryozoan fragments, chonetids, Mesolobus, Cancrinella, Ditomopyge, Hustedia, Tetrataxis, Polytaxis, ostracodes, palaeotextulariids, encrusting foraminiferids, nuculoid bivalves, small high-spired gastropods, Annuliconcha interlineata, Krotovia, bellerophontids, and a fish tooth or scale. Laminated layers contain generally the same fossils, but shell debris within the black laminae are chalky.

Little Osage Shale Member

1. Shale: (6in. exposed; 15.2cm), dark gray (N3) to grayish black (N2), fissile, fair hardness, falls apart when wet, noncalcareous. Sharp upper contact. Fossils: Crurithyris (abundant, with original shell material); small, light olive gray (5 Y 6/1) burrows (Chondrites); some Orbiculoidea, platform-type conodonts, Bathysiphon(?), a fish scale, ammodiscid foraminiferid, and small pyritic burrow(?) fillings. Upper 1in. (2.5cm) contains roots and small (<1mm) secondary gypsum crystals.

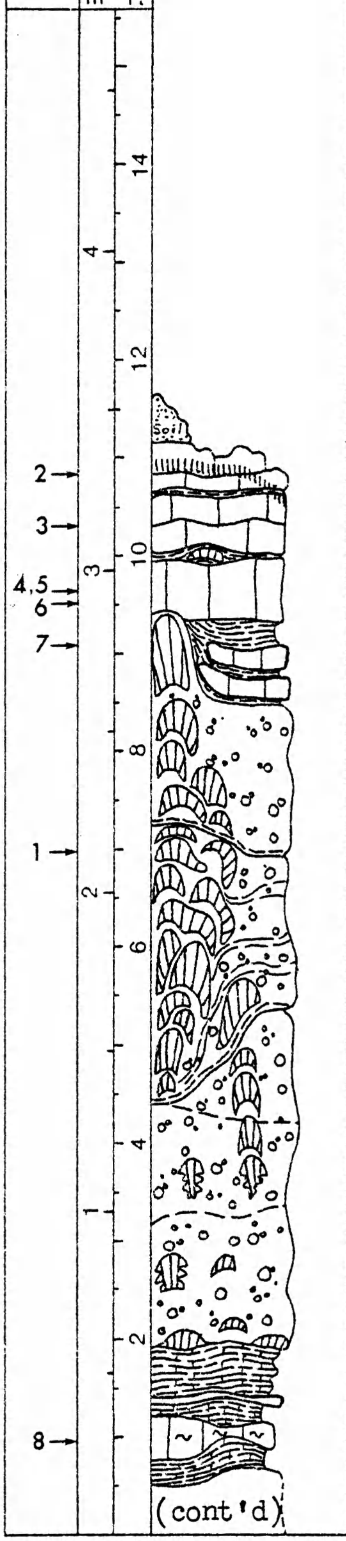
Locality Description: Station 32, Locality 700, near NW. corner of quarry.

Location: NW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m ft)		Bed No.	Interval No.



Bed No.	Interval No.
6	c
	b
	a
5	e
	d
	c
	b
	a
4	c
	b
	a
3	

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-c. Calcilutite: (21in. remaining; 53.3cm), very similar to Stas. 31, 11, & 24, but interval 'd' has been weathered or bulldozed away. Top 2in. (5.1cm) of interval 'c' is highly weathered.. Interval 'a' additionally had a specimen of Wilkingia.

5a-e. Shale with Calcilutite Lenses: (0-12in.; 0-30.5cm), very similar to Stas. 11 & 24, with 2 layers of limestone lenses enclosed in shale. Lower Limestone lens (interval 'b'; up to 10in. thick; 25.4cm) is continuous except where it pinches out against chaetetid clumps. Upper limestone lenses occur as small irregular patches (<3ft. across & 4in. thick; 91cmx10.2cm). Interval 'e' is 0-8in. (0-20.3cm) thick.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.5-7.5ft.; 1.98-2.29m), very similar to Stas. 31 & 24. Interval 'a' (2.5-3.5ft.; .76-1.07m) shows 2 minor argillaceous partings, the lower one regular & continuous, the upper one merging with the base of interval 'b'. Interval 'b' is 10-50% chaetetids, in smaller clumps and with a matrix that is not as dark or as strongly cross laminated as at Sta. 31. Interval 'c' is 0-10% chaetetids, some of which protrude into interval '6a'.

3. Fossiliferous Calcarenite to Calcilutite: (12-16in.; 30.5-40.6cm), very similar to Sta. 31. Chert is 6in. (15.2cm) below top of interval; 5% chaetetids above chert, 1-2% below. Algal calcilutite lens below chert is up to 20ft. (6.1m) long and contains algal blades (1-2%), Composita, fistuliporids, crinoid debris, rugose corals, and most of the chaetetids that occur below the chert.

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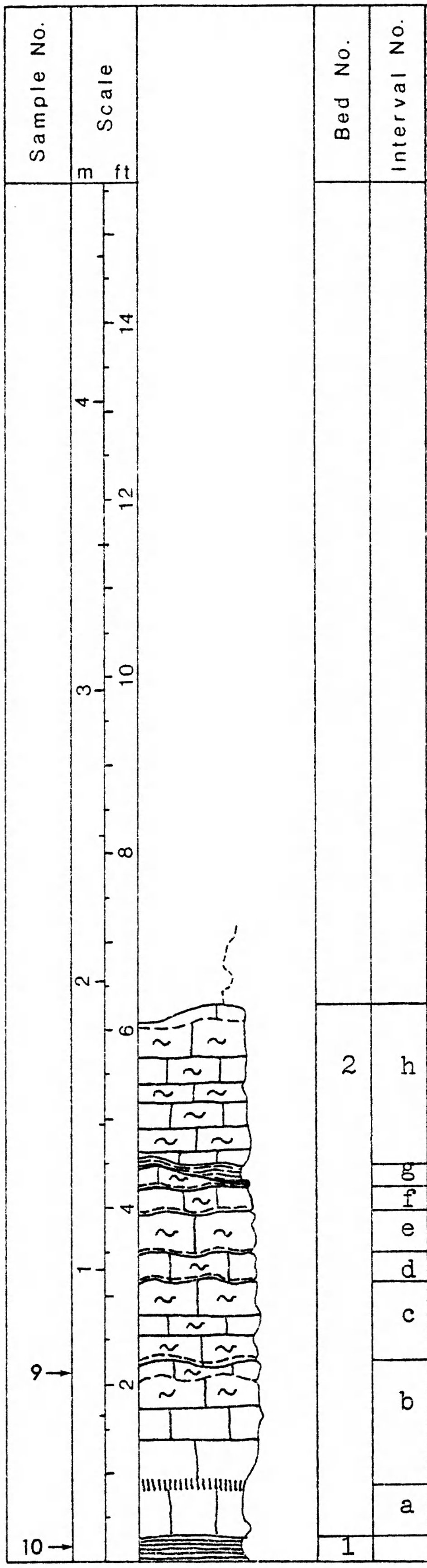


Locality Description: Station 32, Locality 700, continued from previous page.

Location:

Measured By: D. R. Suchy   Date: 1986

Remarks:

Description

Bed No.

(Continued from previous page)

2a-h. Algal to Skeletal Calcilutite: (6ft.; 1.83m), very similar to Stas. 31 & 8. Interval 'a' has a gradational upper contact. The thin (1.5-3in.; 3.8-7.6cm) layer at the top of interval 'b' is more pronounced and continuous than at Sta. 31. Interval 'h' has a wavy, argillaceous parting 1-2.5 in. (2.5-6.4cm) below its upper contact very similar to Sta. 31.

Little Osage Shale Member

1. Shale: (4in. exposed; 10.2cm), black, fissile, very similar to Sta. 31.

Locality Description: Station 33, Locality 700, in NW. part of quarry.

Location: NE$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$SE$\frac{1}{4}$, sec. 12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m, ft)	Bed No.	Interval No.
		4	c
			b
			a
		3	
		2	h
			g
			f
			e

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (7ft.; 2.13m), very similar to Stas. 31 & 24. Interval 'a' (2ft.; .61m) is 5-10% chaetetids, and has a very minor argillaceous parting 10-12in. (25.4-30.5cm) from its base. Interval 'b' is 70-80% chaetetids with a dark, cross laminated matrix (similar to Sta. 8) that drapes over the chaetetids in such a manner to suggest that maximum relief of the chaetetids on the seafloor was 12in. (30.5cm). Interval 'c' (0-12in.; 0-30.5cm) has been scraped away in places, has 5% chaetetids, and pinches out against chaetetid clumps.

3. Fossiliferous Calcarenite to Calcilutite: (12in.; 30.5cm), very similar to Sta. 31. Chert occurs as rare, small (.75x3in.; 1.9x7.6cm) nodules. Algal calcilutite lenses below chert are rare and small (2x4in. to 3x12in.; 5.1x10.2cm to 7.6x30.5cm).

2e-h. Algal to Skeletal Calcilutite: (32in. exposed; 81.3cm), very similar to Stas. 31 & 8. Covered below interval 'e'.

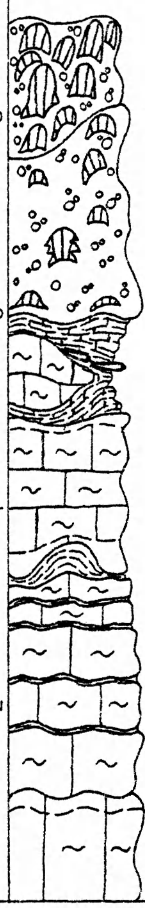
Locality Description: Station 34, Locality 700, in NW. part of quarry.

Location: NE$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$SE$\frac{1}{4}$, sec. 12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m, ft)	Bed No.	Interval No.
		4	b
			a
		3	
		2	h
			g
			f
			e
			d
			c
1→			b



Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

4a-b. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (3ft. remaining; .91m), very similar to Stas. 31 & 24. Interval 'a' (20-30in.; 51-76cm) is 5-10% chaetetids, interval 'b' (12-16in.; 30.5-40.6cm) is 50% chaetetids, and interval 'c' has been bulldozed away. On the upper surface, where overlying layers have been scraped away, can be seen a concentration of echinoid plates and spines in a hollow between chaetetids, suggesting the echinoid died & disarticulated in place.

3. Fossiliferous Calcarenite to Calcilutite: (12-14in.; 30.5-35.6cm), very similar to Sta. 31. Chert occurs in rare, small nodules. Algal calcilutite lenses below chert are 8-12in. (20-30cm) thick and 2.5-6ft. (.76-1.83m) long. Ripples defined by the cross laminations in the upper part have wavelengths of 24-40in. (61-102cm) and amplitudes of 6-7in. (15.2-17.8cm).

2b-h. Algal to Skeletal Calcilutite: (5ft. exposed; 1.52m), very similar to Stas. 31 & 8. Covered by talus below middle of interval 'b'.

Locality Description: Station 35, Locality 700, SW. part of quarry.

Location: NE$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Sample No.	Scale (m / ft)		Bed No.	Interval No.
			6	d, c, b, a
			5	e, d, c, b, a
			4	c, b, a
			3	

Scale: m 1, 2, 3, 4; ft 2, 4, 6, 8, 10, 12, 14

Description

Bed No.

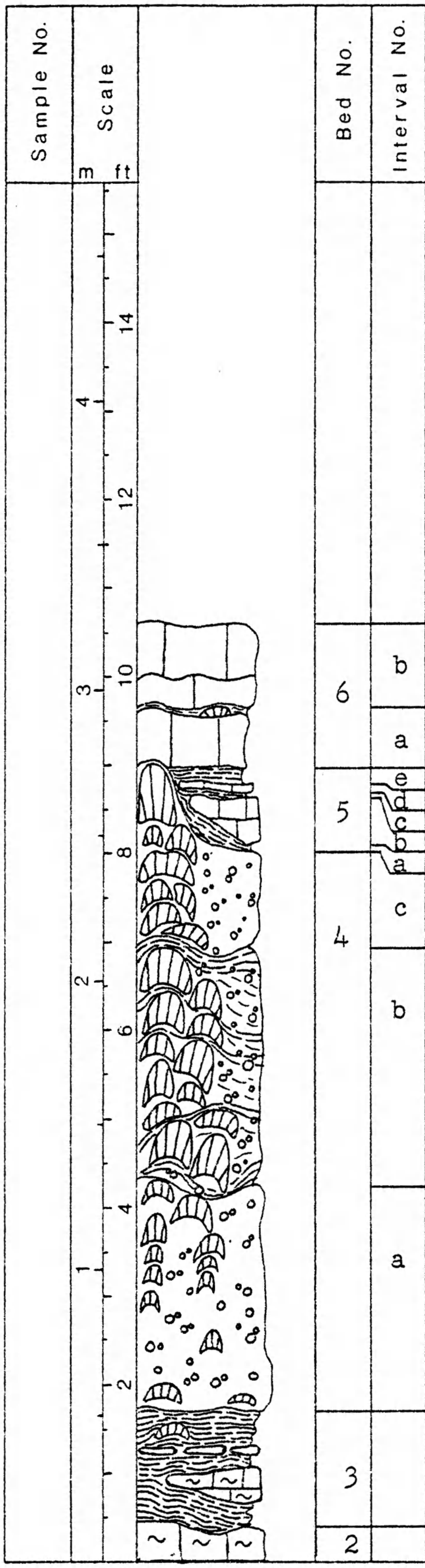
Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2.5ft.; .76m), very similar to Stas. 31, 11, & 24. Four intervals, of which intervals b, c, & d have minor cross laminated layers in the middle of each one.

5a-e. Shale with Calcilutite Lenses: (0-16in.; 0-40.6cm) similar to Stas. 23 & 11, with 2 layers of limestone lenses enclosed in shale. Interval 'a' is 0-10in. (0-25.4cm) and relatively continuous except where it pinches out against chaetetid clumps that protrude upward. Interval 'b' is 0-2in. (0-5.1cm), patchy and discontinous.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (5.75-7.25ft.; 1.75-2.21m), very similar to Stas. 31, 11, & 24. Shows cross laminations in intervals 'b' & 'c', especially around chaetetids. At the top of interval 'c' is a chaetetid (4in. high & 6in. across; 10.2x15.2cm) that has been completely silicified; nothing around it is silicified.

3. Fossiliferous Calcarenite to Calcilutite: (6in. exposed; 15.2cm), very similar to Stas. 31 & 24.



Locality Description: Station 36, Locality 700, eastern N. central part of quarry.

Location: SW¼NW¼SE¼SE¼, sec.12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation
Houx-Higginsville Limestone Member

6a-b. Calcilutite: (20in. remaining; 50.8cm), very similar to Stas. 31, 11, & 24, but intervals 'c' & 'd' have been bulldozed away. Interval 'a' is 7-8in. (17.8-20.3cm) thick with laminar chaetetids on top. Interval 'b' is 12in. (30.5cm) thick.

5a-e. Shale with Calcilutite Lenses: (0-12in.; 0-30.5cm), very similar to Stas. 11 & 24, with 2 layers of limestone lenses enclosed in shale. Interval 'b' (up to 8in. thick; 20.3cm) is well developed and relatively continuous except where it pinches out against protruding chaetetid clumps. Interval 'd' (up to 2-3in.; 5.1-7.6 cm) is thin and discontinuous. The entire interval fills in the hollows between chaetetid clumps.

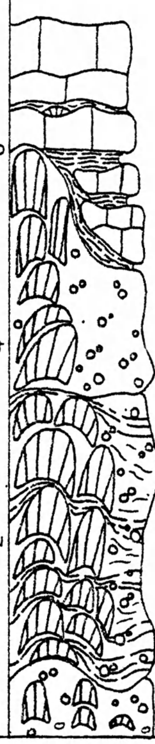
4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.2-7.2ft.; 1.89-2.19m), very similar to Stas. 31 & 24. Interval 'a' is 2.5ft. (.76m) thick, interval 'b' is 3ft. (.91m) thick and cross laminated, and interval 'c' is 1-2ft. (.305-.61m) thick.

3. Fossiliferous Calcarenite to Calcilutite: (16in.; 40.6cm), similar to Sta. 31. Cross laminated, with algal calcilutite lenses below layer of chert nodules.

2. Algal to Skeletal Calcilutite: (4in. exposed; 10.2cm), similar to Stas. 31 & 8.

Sample No.	Scale (m, ft)		Bed No.	Interval No.
			6	b
			6	a
			5	e
			5	d
			5	c
			5	b
			5	a
			4	c
			4	b
			4	a

Scale: m 1, 2, 3, 4; ft 2, 4, 6, 8, 10, 12, 14



Locality Description: Station 37, Locality 700, eastern N. central part of quarry.

Location: NW$\frac{1}{4}$NW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$, sec. 12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-b. Calcilutite: (16-17in.; 40.6-43.2cm), very similar to Stas. 31, 11, & 24, but intervals 'c' & 'd' have been bulldozed away. Interval 'a' is 5-6in. (12.7-15.2cm) thick and has laminar chaetetids on top. Interval 'b' is 10-11in. (25.4-27.9cm) thick and has a minor cross laminated layer 4in. (10.2cm) from its base.

5a-e. Shale with Calcilutite Lenses: (0-16in.; 0-40.6cm), similar to Stas. 24 & 11. Both limestone lenses are well developed, the lower one (interval b) up to 9in. (22.9cm) thick, the upper one (interval d) up to 6in. (15.2cm) thick.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6ft. exposed; 1.83m), very similar to Stas. 31 & 24. Interval 'a' has 6in. (15.2cm) exposed, interval 'b' 3ft. (.91m), and interval 'c' 1.5-2.5ft. (.46-.76m).

Sample No.	Scale (m, ft)		Bed No.	Interval No.

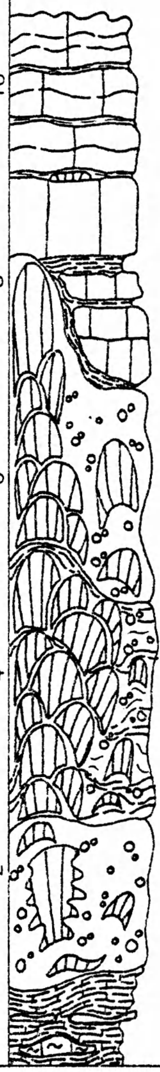
Locality Description: Station 38, Locality 700, W. central part of quarry.

Location: NE$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$, sec. 12, T.30S., R.22E., Crawford County, Kansas.

Measured By: D. R. Suchy Date: 1986

Remarks:

Scale: m 4, 3, 2, 1; ft 14, 12, 10, 8, 6, 4, 2



Bed 6: intervals d, c, b, a
Bed 5: intervals e, d, c, b, a
Bed 4: intervals c, b, a
Bed 3

Description

Bed No.

Wolverine Creek Formation

Houx-Higginsville Limestone Member

6a-d. Calcilutite: (2.5ft.; .76m), very similar to Stas. 31, 11, & 24. Interval 'a' is 10in. (25.4cm) thick, interval 'b' is 6in. (15.2cm), interval 'c' is 7in. 17.8cm), and interval 'd' is 7in. (17.8cm) and highly weathered.

5a-e. Shale with Calcilutite Lenses: (0-16in.; 0-40.6cm), very similar to Stas. 11 & 24, with 2 layers of limestone lenses enclosed in shale. Interval 'b' is up to 9in. (22.9cm) thick, and interval 'd' is up to 5in. (12.7cm) thick.

4a-c. Coarse Fusulinid Calcarenite (Fusulinid Wackestone to Packstone): (6.2-7.5ft.; 1.89-2.29m), very similar to Stas. 31 & 24. Good chaetetid development. Interval 'a' is 18-20in. (45.7cm) thick, interval 'b' is 2-3ft. (.61-.91m) thick, and interval 'c' is 18-24in. (45.7-61.0cm) thick.

3. Fossiliferous Calcarenite to Calcilutite: (12in. exposed; 30.5cm), very similar to Sta. 31. Cross laminated, with algal calcilutite lenses below layer of chert nodules.

APPENDIX C

THIN SECTION DESCRIPTIONS

Thin sections are labelled as follows: locality no.-sta. no.-sample no. For exact position from which samples were taken, see appropriate stratigraphic section in Appendix B.

Interval 2'a'
Thin Sections 700-31-2 and 700-8-1

Medium to Coarse Dolomitic Calcilutite.--well sorted, approximately 3% fossils. Matrix is peloidal, micritic, calcitic cement (Scoffin, 1987, pp.92-93, figs. 8.2 & 8.3-F), clay-rich, and exhibits patches of pseudosparite and sparite with 10-20% dolomite rhombs and granules (.02-.05 mm). Contains Crurithyris planoconvexa, many articulated and original shell material (with very minor pyritization); a few shell clasts. Small burrows (Chondrites?) darker than the matrix, some with a few fine sand size shell fragments (unidentified). Some small (.05-.40 mm) patches of framboidal pyrite scattered through the matrix, more concentrated in the burrows. One echinoderm fragment, mostly micritized, with a very minor syntaxial overgrowth. One ostracode and a few productid fragments. No apparent compaction features, early cementation features, nor micritization of Crurithyris shells.

Base of Interval 2'b'
Thin Section 700-31-3

Lower 2/3 is very similar to 700-31-2 (Interval 2'a'), but with more Crurithyris fragments (some Crurithyris are articulated and micrite-filled). One articulated ostracode (0.7 mm long) filled with clear spar. Fragments of echinoids, productids, trilobites, and ramose bryozoans. Sharp boundary with upper 1/3.

Upper 1/3 is Medium Skeletal Calcarenite.--moderately sorted, approximately 50% skeletal grains and 50% matrix and cement. Matrix is micrite with up to 10% clear spar filling of void spaces. Skeletal grains are subangular to subrounded, imbricated, broken, and abraded: crinoid and echinoid fragments (outer margins micritized, no syntaxial overgrowths), brachiopod fragments (some micritized, some preserving microstructure, some replaced by clear spar), fusulinids (broken, abraded, micritized, inner chambers spar filled), other(?). Most shell edges are micritized. Minor pyritization, minor grain-to-grain sutured contacts. No early cement.

6-8 in. (15-20 cm) below top of Interval 2'b'
Thin Section 700-31-4

Very Fine Algal Calcilutite.--algal mud matrix (dark) with patchy pseudosparite replacement; 20% fossil fragments, most of which are phylloid algae (totally replaced by coarse clear spar). Common brachiopods: some articulated and spar-filled, many fragments, most replaced by clear spar (some of which is syntaxial with pseudosparite replacement of micrite), some with micrite envelopes, some with microstructure preserved. Also contains calcispheres, small high-spired (Meekospira?) and low-spired gastropods (replaced by clear spar), a few crinoid fragments (micritized), bryozoan fragments, encrusting foraminiferids, and an ostracode (micritized, spar-filled). Some isopachous fringes of early cement. No compaction features seen. Microfractures, filled with clear spar, crosscut everything. Some strain recrystallization.

Top 6 in. (15 cm) of Interval 2'b'
Thin Section 700-31-5

Algal Calcilutite.--very fine calcilutite matrix, algal mud, peloidal, micritic; 30% fossil fragments, 60% of which are phylloid algae (totally replaced by clear spar, some with encrusting ophthalmid foraminiferids, one is rounded and has an Osagia coating and an attached ophthalmid). Brachiopods (Composita?, other): some fragments, some articulated with geopetal micrite and spar filling, some calcitized and preserving microstructure, some micritized, some shells chertified. Also contains fistuliporid fragments, productid fragments, ostracodes (articulated, spar-filled), ophthalmids, Tetrataxis sp., Polytaxis sp., calcispheres (walled and unwalled), small low-spired gastropods (replaced by clear spar), and a small geopetally-filled burrow. Very minor pyritization. Some void spaces have linings of coarse clear spar with cores of quartz crystals.

Interval 2'c'
Thin Section 700-31-6

Algal Calcilutite.--very fine calcilutite matrix, peloidal, micritic, algal mud; 5-10% fossils, some of which are phylloid algal blades (replaced by clear spar). Brachiopods: some fragments, some articulated with spar or geopetal micrite and spar fillings, some calcitized (preserving microstructure), some micritized, and some shells partially chertified; cores of a few fillings are quartz. Microstylolites in lower 1 cm. Also contains crinoid columnals (no syntaxial overgrowths), Tetrataxis sp., and fistuliporids (micritized walls, spar-filled chambers).

Interval 2'd'
Thin Section 700-31-7

Algal Calcilutite.--very fine calcilutite matrix, peloidal, micritic, algal mud; 30% fossils, 80% of which are phylloid algal fragments (totally replaced by coarse clear spar). Brachiopods: some fragments, some articulated with geopetal micrite and at least 2 generations of clear spar, and minor early cement fringe; some calcitized (preserving microstructure), some badly micritized. Also contains fistuliporid fragments, productid spines, calcispheres (walled and unwalled), one fusulinid (highly corroded), and a trilobite fragment (which created a shelter void that was secondarily filled with spar), and a few small brownish black streaks of organic residue. Minor early cement. A few microstylolites in lower 0.5 cm and a slightly compacted, articulated, micrite-filled brachiopod.

Interval 2'e'
Thin Section 700-31-8

Algal Calcilutite.--very fine calcilutite matrix, peloidal, micritic, bioturbated, with patchy pseudosparite and sparite replacement; 30-40% fossils, 75-80% of which are phylloid algal fragments (totally replaced by coarse clear spar), most of the remainder are whole and fragmented brachiopods. The phylloid algae has been replaced by ferroan calcite and minor ferroan dolomite (Kershaw, pers. comm. after staining) with no microstructure preserved; some algal blades are encrusted with Osagia, ophthalmids, and fistuliporids. Brachiopods (Composita, Cleiothyridina, Crurithyris, and productid spines): many fragments, many articulated with fillings ranging from clear spar to geopetal micrite and spar to totally micrite; some fillings show at least 2 generations of spar, some micrite fillings show patchy replacement by pseudosparite; shells are preserved as nonferroan calcite (preserving microstructure) with some micritization and very minor chertification. Also contains low-spired (2 mm across) and high-spired (4.5 mm long) gastropods (replaced by clear spar), a few echinoderm fragments (some as ferroan calcite, one silicified), ostracodes (articulated), fistuliporids, palaeotextulariids, and Prismopora(?) (the latter 3 of which have micritized walls and spar-filled chambers), and unidentifiable fragments. Shelter voids beneath algal blades are spar-filled. Microstylolites in upper and lower 0.5 cm of the slide, minor compaction deformation of some articulated brachiopods, and some strain recrystallization. Spar-filled microfractures crosscut everything.

Interval 2'f'
Thin Section 700-31-9

Algal Calcilutite.--very fine calcilutite matrix, peloidal, micritic, bioturbated, with patchy pseudosparite and sparite replacement; 30-40% fossils, 75-80% of which are phylloid algal fragments (totally replaced by spar), most of the remainder brachiopods. Brachiopods: many fragments, many articulated with clear spar to micrite fillings, shells mostly calcite with some micritization. Also contains a few echinoderm fragments (micritized), fistuliporids and ostracodes (articulated) (both with micritized walls and spar-filled chambers), recrystallized mollusk fragments, a small low-spired gastropod (replaced by clear spar, micrite filled), walled calcispheres, pellets, and minor dark brown blebs of organic residue. Some early compaction of micrite-filled, articulated brachiopods.

Lower Half of Interval 2'g'
Thin Section 700-31-10

Algal Calcilutite.--very fine calcilutite matrix, peloidal, micritic (algal mud), with patchy pseudosparite and sparite replacement; 10-20% fossils, 70% of which are phylloid algal blades 20-25% brachiopods, the remainder other. Brachiopods: single valves and fragments, articulated ones with clear spar, to geopetal micrite and spar, to micrite fillings, shells calcitized (preserving microstructure, some syntaxial with portions of pseudosparite matrix) with some micritization. Also contains a few echinoderm fragments (broken, abraded, micritized, with very minor syntaxial overgrowths), fistuliporids and ramose bryozoan fragments (with micritized walls and spar-filled chambers), mollusk fragments with *Osagia* coatings, ostracodes (articulated, spar filled), small low-spired gastropods (replaced by spar, micrite filled), and brown organic residue associated with microstylolites. Some spar-filled shelter voids under algal blades. Some micrite envelopes on replaced shell fragments, some early cement fringes of Mg-calcite blades, and microstylolites in bottom 0.5 cm. A few small dolomite rhombs.

Upper Half of Interval 2'g'
Thin Section 700-31-11

Skeletal Calcilutite.--very fine calcilutite matrix, micritic, with patchy pseudosparite and sparite replacement; 20% fossils and voids (1-5%) and spar-filled voids that crosscut skeletal fragments; no algal blades. Brachiopods: fragments and articulated ones with spar, to geopetal micrite and spar, to micrite fillings, shells calcitized (preserving microstructure) with some micritization. Also contains productid fragments and spines (some slightly chertified), rugose coral fragments, crinoid fragments, fistuliporid and fenestrate bryozoans (micritized walls, spar-filled chambers), ostracodes (articulated, spar-filled), walled calcispheres, small burrows, and minor yellow-brown streaks of organic residue. Patchy early cementation in the form of Mg-calcite blades and possibly acicular aragonite (now calcitized). Some articulated brachiopods are collapsed from early compaction. Microstylolites, stylonodular (Scoffin, 1987, p.116), at intervals 1-2.5 cm apart and 2-12 mm thick.

Interval 2'h'
Thin Sections 700-31-12 and 700-24-18 (very similar)

Skeletal Calcilutite.--fine calcilutite matrix, micritic, with patchy pseudosparite and sparite replacement; 10-15% fossils, of which 2-3% are phylloid algal blades (recrystallized to clear spar). Some squamariacean algae (possibly as mats on the substrate or that have been torn loose and deposited with the micrite). Brachiopods: fragments (broken, abraded, micritized) and articulated ones with clear spar to geopetal micrite and spar filling, shells calcitized (preserving microstructure) with some micritization and very minor chertification. Also contains productid spines and fragments, fistuliporid and fenestrate bryozoans (some transported), Prismopora sp. (micritized walls, spar-filled chambers), ostracodes (articulated, spar-filled), ophthalmids, Tetrataxis sp., Polytaxis sp., palaeotextulariids, Endothyra sp., Bradyina sp., and pellets(?). Some spar filling of shelter voids, and patchy chert replacement (§1%) with a few dolomite rhombs. Early marine cement in the form of Mg-calcite blades lining interiors of articulated brachiopod shells, and possible acicular aragonite fringe (now calcitized) on the exteriors.

Thin Section 700-24-18 (differences from 700-31-12)

Contains slightly more algal blades (some encrusted by ophthalmids) and squamariacean algae, and a small high-spired gastropod (replaced by clear spar). One articulated brachiopod is micrite filled and shell is replaced by microcrystalline spar with the microstructure destroyed and the shell margins totally obscured. Another articulated brachiopod is filled with microcrystalline quartz with a few tiny dolomite rhombs; shell is partially micritized, partially chertified.

Bed 3 (Algal Calcilutite Lens Below Chert)
Thin Section 700-31-14

Algal Calcilutite.--very fine calcilutite matrix, micritic, peloidal (algal mud), with some patchy pseudosparite replacement; 10-20% fossils, half of which are phylloid algal blades (some replaced by ferroan and some by nonferroan calcite (Kershaw, pers. comm. after staining), some identified as Ivanovia sp.; many encrusted by ophthalmids, fistuliporids, Tetrataxis sp., and encrusting algae). Brachiopods: fragments and articulated ones with clear spar, to geopetal micrite and spar, to micrite fillings (one filled with microcrystalline quartz), shells mostly calcitized (some nonferroan, some ferroan) and some partially chertified. Also contains fusulinids (scattered, few), Tetrataxis sp., articulated ostracodes, palaeotextulariids, Bradyina sp., Globivalvulina sp.(?), and fistuliporids, all of which have micritized walls and spar-filled chambers, along with a few walled calcispheres, and a small high-spired gastropod (replaced by spar, micrite filled). Early marine cement in the form of Mg-calcite blades and radiaxial fibrous mosaic lining the interiors of articulated brachiopods. Very minor chertification which includes a few euhedral dolomite rhombs (§.04 mm). Matrix has patchy ankerite or dolomite, and microfractures are filled with ferroan and nonferroan calcite (Kershaw, pers. comm. after staining).

Lower Part of Bed 3
Thin Section 700-24-17

Cross Laminated Fusulinid Calcarenite.--alternating bands of calcarenite and fine calcilutite, fusulinid-rich (5-20%); matrix is micritic, peloidal(?), with some pseudosparite replacement; 10-25% fossils. Calcarenite occurs in cross laminated bands and contains up to 40% fossil fragments (many broken, abraded, micritized) in a micrite matrix, especially fusulinids (usually with micritized walls and spar-filled chambers, but some are totally micritized, including chambers). Has *in situ* chaetetids and *Aulopora* sp. (well preserved wall structure, spar filled chambers) that are sometimes attached on squamariacean algal mats and sometimes covered by algal mats. Brachiopods: many fragments, some articulated with spar to micrite fillings, shells are calcitized (preserving microstructure) and commonly micritized. Also contains rugose corals (broken, but with well preserved wall structure and spar filled chambers), productid spines and fragments, echinoderm fragments (broken, rounded, abraded, partially micritized, minor syntaxial overgrowths), fenestrate bryozoan fragments, ostracodes (articulated, spar filled), ophthalmids (some attached on algal mats), *Tetrataxis* sp., *Globivalvulina* sp. (the latter 6 have micritized walls and spar-filled chambers), and a trilobite fragment. Very minor patchy chertification which contains tiny euhedral dolomite rhombs. Some early marine cement fringes inside articulated brachiopods. Some articulated brachiopods are partially compressed by early compaction. Microstylolites in the cross laminated bands. Spar filled microfractures. Very minor pyritization of some shells.

Lower Part of Bed 3
Thin Section 700-slab

Fossiliferous Fusulinid Calcarenite to Calcilutite.--coarse-grained at the bottom, grading to very fine-grained at the top. Bottom 1 cm is 70-80% fusulinids, middle 1 cm is 30-40% fusulinids, and top 1.5 cm is §3% fusulinids. Matrix is primarily micrite. Contains articulated brachiopods (2%), shell fragments (3-5%), palaeotextulariids and *Tetrataxis* sp. (1%), an attached fistuliporid and chaetetid on the upper surface, crinoid and echinoid fragments, brachiopod fragments (many of the same species listed in Table 1), fistuliporids, and minor fenestrate bryozoan fragments, *Polytaxis* sp., and horn coral fragments. Tangential contacts between grains in bottom 2/3, floating grains in upper 1/3 (carbonate mudstone layer).

Foraminiferid and fistuliporid shells are micritized but internal chambers are filled with clear spar cement. Some brachiopod shells and fragments have been recrystallized to clear spar, and in some cases the individual spar crystals extend beyond the shell boundaries into the shell filling. In many brachiopods, the fine shell structure is preserved. Some articulated brachiopods, the fine shell structure is preserved. Some articulated brachiopods are filled with micrite, some with clear spar cement which may or may not contain floating relic patches of micrite. Rare syntaxial overgrowths on echinoderm fragments do occur and there are some possible corroded dolomite rhombs.

Early cementation features commonly include an isopachous fringe of relict acicular aragonite on the outer surfaces of brachiopod shells and the stubby variety of Mg-calcite crystals (Scoffin, 1987, p.92) lining the inner surfaces of articulated brachiopod shells. In some cases, algal micritization (Bathurst, 1975) appears to have affected the outer surfaces of shells. Early cementation is also indicated by absence of cement fringes on compaction fracture surfaces of shells, similar to that shown by Bathurst (1975, p.433, figure 312).

Common to abundant compaction features include fracturing and flattening of shells. In some cases, the spar fillings of articulated brachiopods were deformed by the compaction fractures of the shells, indicating the clear spar occurred before compaction. Pressure solution in the bottom 2/3 is evidenced by abundant grain-to-grain sutured contacts and microstylolites which usually follow but in some cases cross cut depositional laminations. Late diagenesis is indicated by clear spar fillings of compaction fractures.

Upper Half of Bed 3
Thin Section 700-31-16

Fossiliferous Fusulinid Calcarenite to Calcilutite with Chert Layer.--calcarenite occurs in cross laminated bands (cross laminations accentuated by microstylolites) and consists of fossils and fossil fragments (20-40%) in a micrite matrix; in some pockets, grains have tangential contacts. Fine calcilutite matrix is micritic, peloidal(?), with fine skeletal fragments and tiny dolomite rhombs (1%; .01-.02 mm) scattered throughout. Fusulinids have micritized walls and spar-filled chambers. Brachiopods: many fragments, some articulated (especially *Crurithyris*) with micrite or geopetal micrite and spar fillings, calcitized shells (preserving microstructure), some oriented upside down, on edge, etc. Contains *in situ* *Aulopora* sp. and *Chaetetes* sp. (attached to *Aulopora* sp.). Also contains *Epimastopora* sp., crinoid fragments, echinoid spines, productid spines and fragments, echinoid spines, producitd spines and fragments, ostracodes (articulated, spar-filled), fistuliporid and fenestrate and ramose bryozoan fragments, ophthalmids, palaeotextulariids, *Tetrataxis* sp., *Polytaxis* sp., *Bradyina* sp., and *Globivalvulina* sp. (the latter 8 having micritized walls and spar-filled chambers). Some partial compression of articulated brachiopods, and microstylolites throughout. Common early cement fringes inside articulated brachiopods.

Chert.--(at lower end of this thin section). (For more detailed description see thin section 700-4-3). Contains many of the same fossils as in the surrounding calcarenite but they are chertified and very corroded due to chert replacement. One articulated ostracode has 3 generations of chert fill: (1) thin fringe, (2) thicker botryoidal chalcedony (aragonite replacement?), and (3) quartz core. In micrite near the chert, chertification appears to favor fossil fragments.

Chert in Bed 3
Thin Sections 700-4-3 and 700-4-8

Chert.--thin (3-4 cm) layer of chert that has secondarily replaced the calcarenite and calcilutite. Shows most of the same fossils as listed for thin section 700-31-16, but most are now chertified and highly corroded due to chert replacement. Some fragments (some echinoderms and brachiopods) surrounded by chert are still nonferroan calcite but have badly micritized and corroded edges. Some articulated brachiopods have geopetal micrite fillings (now chertified) and 2 or 3 generations of interior cement (now chertified). Contains many fusulinids (some highly corroded, replaced by chert and minor framboidal pyrite). Also contains productid fragments (well preserved, calcitic), palaeotextulariids, *Bradyina* sp., *Tetrataxis* sp., fistuliporids, a trilobite fragment (the latter 5 chertified), and an ostracode (articulated, filled with calcite and pyrite). Skeletal fragments show little or no compaction or pressure solution. Within the limestone near the chert, fusulinids are preferentially silicified, and there are small patches of chert and ferroan calcite (Kershaw, pers. comm. after staining). Boundary between chert and micrite is sharp and irregular. Chert contains tiny dolomite rhombs (usually 1-2%, but up to 10% in patches in thin section 700-4-8). Fractures and voids filled with microcrystalline quartz; some fractures in the chert have micrite squeezed into them, suggesting the micrite was more plastic than the chert and that the chert formed before compaction.

Interval 4'a'
Thin Section 700-31-17

Fusulinid Calcarenite with Chaetetids (Fusulinid wackestone to packstone to grainstone).--10-50% fusulinids, with other small fossils and fossil fragments in a micritic, peloidal (structure grumeleuse?) matrix with patchy pseudosparite (some ferroan, some nonferroan) replacement and 3-40% spar-filled voids. Fusulinids are totally recrystallized, with micritic walls and spar-filled chambers (ferroan and nonferroan calcite), but wall structure is preserved. *In situ* chaetetids are well preserved, with nonferroan calcite fringe, and ferroan calcite fill (Kershaw, pers. comm. after staining); outer edges (.25-2.0 mm) of some are silicified, and along the inner "silicification front" the walls are silicified and the calcified fill is not. Also contains small angular shell fragments, mostly unidentified, but including brachiopods (replaced by spar, no microstructure preserved), a few fenestrate and ramose bryozoans, fistuliporids, crinoids (abraded, partially micritized, no syntaxial overgrowths), a productid fragment replaced by chert (with tiny dolomite rhombs), productid spines, a few phylloid algal fragments, a high-spired gastropod (7 mm long, totally replaced by clear spar), pellets, ostracodes (articulated, spar-filled), and much foraminiferid debris (including Endothrya sp., Tetrataxis sp., Bradyina sp., Globivalvulina sp., and palaeotextulariids, all with micritized walls and spar-filled chambers). Minor patchy chertification preferentially affects shell material and has closely associated tiny dolomite rhombs. Some fractures in chaetetids have geopetal micrite and spar filling. Early cement is apparently absent or very minor.

Thin Section 700-2a-4 (differences from 700-31-17)

Very similar to 700-31-17, but contains: 40-50% fusulinids; an articulated brachiopod with geopetal micrite and spar filling, micritized shell (partially chertified), and minor early cement (Mg-calcite blades); several brachiopod fragments that are totally replaced by clear spar, some enclosed by micrite envelopes with inner fringes of Mg-calcite blades; and a few microstylolites.

Thin Section 700-18-1 (differences from 700-31-17)

Very similar to 700-31-17, but contains: 10-20% fusulinids, a recrystallized gastropod (1.6 mm across), a few recrystallized algal(?) fragments, and microfractures that are filled with spar and crosscut everything.

Thin Section 700-20-6 (differences from 700-31-17)

Very similar to 700-31-17, but contains: 30-50% fusulinids, some brachiopod fragments that are calcitized and preserve microstructure, a few more crinoid fragments (no syntaxial overgrowths), and fewer spar-filled voids.

Thin Section 700-21-1 (differences from 700-31-17)

Fine to Medium Skeletal Calcarenite.--no fusulinids; cross laminated; skeletal debris in very fine calcarenite matrix (pseudo-sparite?). Contains common angular productid fragments, other small angular productid fragments, other small angular brachiopod fragments (calcitized), small rounded echinoderm fragments (some up to granule size are angular), a rugose coral fragment (broken, abraded, micritized), a Tetrataxis sp. (micritized walls, spar-filled), and an ostracode (articulated, spar-filled, micritized and pyritized shell, partially compressed).

Interval 4'b'
Thin Section 700-31-18

Coarse Fusulinid Calcarenite (Fusulinid wackestone to packstone).--30-50% fusulinids, with other small fossils and fossil fragments in matrix of micrite and microcrystalline spar (over 50% of matrix), granular dolomitic texture (x-ray diffractogram revealed a dolomite/-calcite ratio of 4/1 with some quartz). Matrix is darker than in 700-31-17 and contains blebs and stringers of dark brown organic residue between grains. Fusulinids are worn and abraded and have micritized walls and spar-filled chambers, of which over 50% has been micritized. Contains 2% spar filling of voids. Brachiopod fragments are mostly broken, some with sharp boundaries, some abraded, some calcitized, some micritized. A few articulated brachiopods with spar fillings and calcitized to micritized shells. Skeletal debris (in places 50% of the rock) is fine sand size, angular to rounded. Echinoderm debris is broken, rounded, abraded, badly micritized around margins, and abundant in some pockets; one shows borings; no syntaxial overgrowths. Also contains productid fragments, a small specimen of Michelinia(?), some ramose and fenestrate bryozoan fragments, fistuliporids, ostracodes (articulated), Tetrataxis sp., palaeotextulariids, Globivalvulina sp., Bradyina sp., and Aulopora fragments (the latter 7 of which have micritized walls and spar-filled chambers). Very minor microstylolitization, and very minor chert within a few echinoderm fragments. Some early cement (Mg-calcite blades) lining shells. Microfractures filled with clear spar.

Thin Section 700-2a-2 (differences from 700-31-18)

Very similar to 700-31-18, but fusulinids are better preserved, not so corroded, and matrix is not so dark. Also contains up to 10% spar-filled voids (some larger ones with quartz cores), and some round to oval voids (that may have been fusulinids) are filled with spar. Neomorphic spar is a mixture of ferroan and nonferroan calcite (Kershaw, pers. comm. after staining). Contains a small gastropod (replaced by spar), very well preserved Endothyra sp., a skeletal fragment (brachiopod?) with a micrite envelope and coarse clear spar replacement, and some obvious pellets. Some early marine cement.

Thin Section 700-21-3

Chaetetid specimen with calcitized skeletal walls, empty skeletal chambers, and some borings.

Thin Section 700-24-13 (differences from 700-31-18)

Very similar to 700-31-18, but fusulinids are better preserved, not so micritized, not so corroded, and some chambers are empty (§1%). Matrix is not as dark, has less organic residue. Has 3% spar-filled voids, and no visible microstylolitization. Contains well preserved Bradyina sp., Endothyra sp., Polytaxis sp., some rugose coral fragments, and a Prismopora sp. fragment.

Interval 4'c'
Thin Section 700-31-19

Coarse Fusulinid Calcarenite (Fusulinid wackestone to packstone).--very similar to 700-31-18, but fusulinids are well preserved, and matrix is not as dark. Matrix is peloidal micrite, and some pockets around chaetetids have less than 5% fusulinids. Contains a large chaetetid, very well preserved, with micritized walls and spar-filled chambers. Some fusulinids have been dissolved away (remnants remain) and replaced by clear spar. One fusulinid has oncolitic algal coating. Contains squamariacean algal overgrowths within chaetetid growth interruptions. Contains all the same foraminiferids as in 700-31-18, plus it contains a recrystallized algal blade (micrite envelope, clear spar replacement), sphinctozoan(?) sponge, rugose coral fragments (walls are micritized and pyritized, 50/50, and chambers are filled with clear spar and patchy chert), small low-spired gastropods, and echinoderm fragments (with syntaxial overgrowths). Very minor patchy chertification of chaetetid, and very minor microstylolites.

Thin Section 700-31-20 (differences from 700-31-19)

Very similar to 700-31-19, but fusulinid skeletal walls were highly pyritized and are now reddish brown due to oxidation. Has 40-60% fossils, primarily fusulinids and other foraminiferids. Some fusulinids well preserved, some all or nearly all replaced by clear spar. Also contains ophthalmids and Osagia-coated skeletal fragments.

Has 2-3% spar-filled voids, very minor microstylolites at one end, spar-filled microfractures that crosscut everything, no apparent early cement, and a few tiny dolomite rhombs.

Thin Section 700-2a-1 (compared to 700-31-19)

Very similar to 700-31-19, including some fusulinids being well preserved, others totally replaced by clear spar. Has all the same foraminiferids with the same preservation. Echinoderm fragments have no syntaxial overgrowths. Contains a gastropod, replaced by spar, with a geopetal micrite and spar filling. Some minor microstylolites.

Thin Section 700-4-4 (compared to 700-31-19)

Very similar to 700-31-19, but has alternating layers (0.5-2.0 cm thick) of fusulinid wackestone (30-40% fossils) and micrite (1% fossils). Fusulinids are reddish brown due to oxidation of framboidal pyrite in skeletal walls. Some fusulinids well preserved, others totally replaced by spar. All the same foraminiferids.

Thin Section 700-17-1 (compared to 700-31-19)

Very similar to 700-31-19, but has an *in situ* laminar chaetetid encrusted over the top of *Aulopora* sp. and the muddy substrate. Some fusulinids are reddish brown as in 700-4-4. Fusulinids at different stages of spar replacement. All the same foraminiferids as in 700-31-19. Vertical fracture (.5 cm wide) filled with spar and crosscuts everything.

Thin Section 700-17-2 (compared to 700-31-19)

Skeletal Calcarenite.--40% fossils, 5% fusulinids, with a concentration of crinoid and echinoid debris (10-20%; no syntaxial overgrowths). Contains much sand size, angular skeletal debris.. More weathered than 700-31-19 (probably recent). Also contains ramose and fenestrate bryozoan fragments, fistuliporids, *Meekella* and productid fragments, some algal coatings, *Aulopora* sp. fragments, *Spirorbis* sp., ostracodes, and all of the same foraminiferids as in 700-31-19. No early marine cement.

Thin Section 700-18-2 (compared to 700-31-19)

Similar to 700-31-19, but fewer fusulinids (5-10%), and matrix is more peloidal.

Thin Section 700-24-11 (compared to 700-31-19)

Very similar to 700-31-19, 30-45% fossils and fossil fragments. Some fusulinids replaced by clear spar, some not. No apparent algal coatings on shells. Matrix contains slightly more spar. All the same foraminiferids and ostracodes. Contains one or two algal blades (replaced by spar), crinoid fragments, productid fragments. Patchy dolomitization.

Interval 5'b'
Thin Section 700-24-8

Very Fine Calcilutite.--peloidal, micritic, strongly bioturbated; 1% fossils. Contains burrows filled with granular dolomitic spar and dark brown organic residue. Contains a few foraminiferids (fusulinids, *Globivalvulina* sp., *Endothyra* sp., *Bradyina* sp., and palaeotextulariids, most with micritic walls and spar-filled chambers, some partially replaced by spar), ostracodes (articulated and single valves and fragments), high-spired gastropods (1.5-7.5 mm long; replaced by spar, partially micrite filled), one echinoderm fragment (30% micritized, no syntaxial overgrowths), and unidentified fine sand to silt size shell fragments. A layer (.5 cm thick) near the top of the thin section is 5% fossils, containing all of the above listed fossils plus 2 or 3 algal blades replaced by spar, brachiopod fragments with micritized to pyritized walls and spar-filled chambers; most are fine sand to silt size unidentified skeletal fragments. Spar-filled microfractures crosscut everything.

Interval 5'd'
Thin Section 700-24-6

Fine Calcarenite to Very Fine Calcilutite.-- 30-40% fossils, 80-90% of which are fine sand size fragments of phylloid algae(?). Matrix is granular, dolomitic, and bioturbated. Contains dolomite-filled burrows as in 700-24-8. Also contains low-spired gastropods (.2 mm), productid spines, brachiopod fragments (mostly calcitized, some preserving microstructure, some partially micritized and pyritized, some totally replaced by spar), ostracodes (articulated, spar filled, also fragments), an echinoderm fragment (micritized, abraded), a bryozoan fragment, and very few foraminiferids (fusulinids, ophthalmids, Globivalvulina sp., and palaeotextulariids, all with micritized walls and spar-filled chambers).

Interval 6'a'
Thin Sections 700-32-5 and 700-32-6

Fine Calcilutite to Medium Calcarenite.--primarily angular to rounded skeletal debris in a micrite matrix with patchy pseudosparite replacement; 20-40% fossil debris, 50% of which appears to be sand-size angular phylloid algal fragments replaced by clear spar. Possible burrow mottling. Contains much Archaeolithophyllum (as shown by Toomey, 1983, p.165), which coats algal blade fragments and skeletal debris, and in some cases encrusts the substrate and in turn serves as a substrate upon which small laminar Chaetetes sp. are attached. Brachiopods: angular to rounded fragments (some with oncolitic algal coatings) and articulated ones (Composita) with spar fillings; some shells preserving microstructure, some replaced by clear spar with micrite envelopes, some micritized. Contains phylloid algal blades replaced by clear spar, some identified as Epimastopora sp. Small laminar Chaetetes sp. have calcitized walls and spar-filled chambers. Also contains high- and low-spired gastropods (1.5 mm across), productid fragments and spines, pellets (some pyritized), encrusting and ramose bryozoan fragments, echinoderm fragments (no syntaxial overgrowths), rugose coral fragments (some algal encrusted), Michelinia(?), ostracodes (articulated and fragments, calcitized shell, spar filled), fusulinids (1%), palaeotextulariids, Endothyra sp., Globivalvulina sp. (the latter 7 having micritized walls and spar-filled chambers), and very minor dark brown patches of organic residue. A few microstylolites and a few shells broken by compaction and later filled with spar. Some early marine cement (Mg-calcite blades). Spar-filled microfractures crosscut everything. In places, shows 10-20% of what appear to be dolomite rhombs, but an x-ray diffractogram reveals no dolomite but some other carbonate, probably ankerite.

Interval 6'b'
Thin Section 700-32-3 (compared to 700-32-5)

Very similar to 700-32-5, but contains 20-50% fossil debris, some articulated brachiopods are spar-filled, others micrite-filled and the spar filling of some foraminiferids is partially micritized. Contains all of the same foraminiferids, up to 3% fusulinids, slightly more of the brown organic residue, and a Meekella fragment. Algal encrustations are minor on skeletal fragments and form no substrate mats.

Thin Section 700-11-10 (compared to 700-32-5)

Very similar to 700-32-5, but also contains an articulated brachiopod (spar-filled) with an inner fringe of radiaxial fibrous mosaic, and others with minor early marine cement fringes.

Thin Section 700-24-3 (compared to 700-32-5)

Very similar to 700-32-5, but also has an articulated *Cleiothyridina* with a calcitized shell (preserving microstructure) and a spar filling and is partially broken by compaction. Fragments are aligned horizontally, possibly by compaction. Contains a few microstylolites.

Interval 6'c'
Thin Section 700-32-2

Fine Calcilutite to Medium Calcarenite.--matrix is micritic with up to 50% clear granular dolomite; 20-40% angular fossil debris, 80% of which is sand sized phylloid algal fragments replaced by clear spar. Contains several articulated brachiopods (*Composita*?) with micrite fillings (partially replaced by sparite, parts of which are syntaxial with calcitized shells) and calcitized shells (preserving microstructure). Also contains bellerophontids (replaced by spar, micrite filled), brachiopod fragments, crinoid fragments (with minor algal overgrowths, no syntaxial overgrowths), fistuliporids, ostracodes, productid spines, unwalled calcispheres, *Crurithyris*, patches (§1 mm) of brown organic residue, and only a few foraminiferids (palaeotextulariids, *Tetrataxis* sp., *Globivalvulina* sp.., ophthalmids, and *Bradyina* sp., all with micritized walls and spar-filled chambers). Minor microstylolitization, minor pyritization in tiny patches, and a few tiny dolomite rhombs. Early marine cement in the form of Mg-calcite blades and radiaxial fibrous mosaic lining the interiors of articulated brachiopods. Some weathered areas show reddish brown to dark brown stain.

Interval 6'd'
Thin Section 700-11-8

Fine to Medium Calcilutite.--matrix is micrite and microcrystalline spar with patchy spar replacement and up to 10% small (.01-.02 mm) dolomite rhombs; 5-20% angular fossil debris, 80-90% of which is phylloid algal fragments replaced by clear spar. Contains rounded and angular brachiopod fragments, some calcitized, some micritized, and some articulated brachiopods (*Cleiothyridina* and *Composita*?) with geopetal micrite and spar fill and calcitized to micritized shells.

Also contains a crinoid fragment (nearly totally micritized, with minor syntaxial overgrowth), common bellerophontids (replaced by spar, micrite filled), a few ostracodes (calcitized shell, spar-filled), and very few fusulinids, *Bradyina* sp., palaeotextulariids, and *Globivalvulina* sp. (the latter 4 commonly broken and with their spar fillings partially micritized). Some areas weathered as in 700-32-2. Minor patchy pyritization.

APPENDIX D

PALEOCURRENT DATA

Paleocurrent directional data as inferred from orientations of crests and troughs of wavy layers in bed 3 in the area of stations 31, 32, 8, & 33.

Wave trough or crest orientation	Inferred paleocurrent direction
N.54°W.	N.36°E.
N.18°W.	N.72°E.
N.24°W.	N.66°E.
N.16°W.	N.74°E.
N.10°W.	N.80°E.
N.19°W.	N.71°E.
N.27°W.	N.63°E.
N. 7°W.	N.83°E.
N.34°W.	N.56°E.
N.15°W.	N.75°E
N.24°W.	N.66°E.
N.26°W.	N.64°E.
N.23°W.	N.67°E.
N.20°W.	N.70°E.
N.12°W.	N.78°E.
N.35°W.	N.55°E.
N.19°E.	N.109°E.
N.38°W.	N.52°E.
N.33°W.	N.57°E.
N.30°W.	N.60°E.

PLATE 1
NEBRASKA
IOWA
KANSAS
MISSOURI
OKLAHOMA
ARKANSAS
Forest City Basin
Salina Basin
Sedgwick Basin
Cherokee Platform
Bourbon Arch
38th Parallel Trough
38th Parallel Lineament
Ozark Uplift
Arkoma Basin
Ouachita Uplift
Miles
0 20 40 60 80 100
0 50 100 150
Kilometers
LEO
S5
S10
MC
WCT
S17
PMC
SOS
766
700
765
706
FST
339
MB
BUT
J30
U
J33
J36
J45
J44
J43
J48
J69
J82
J91
J105
J115
J116
Soil
Labette Shale
Little Osage Shale
Blackjack Creek Limestone
Morgan School Shale
Houx-Higginsville Limestone
Little Osage Shale
Myrick Station Limestone
Anna-Labette Shale
Higginsville Limestone
Flint Hill Sandstone
Houx Limestone
black fissile shale
meters
feet
0
1
2
3
4
5
5
10
15
SCALE
0 10 20 30 40 50 60 miles
50 100 kilometers
CORRELATION OF MEMBER BOUNDARIES
OF "FORT SCOTT CYCLOTHEM",
NE. OKLAHOMA, SE. KANSAS, W. MISSOURI
Key
(For lithologic symbols, see Appendix A)
700 Locality Symbol and Position
Member Boundaries:
certain
inferred
DANIEL R. SUCHY


PLATE 2
NEBRASKA
IOWA
KANSAS
MISSOURI
OKLAHOMA
ARKANSAS
Forest City Basin
Salina Basin
Sedgwick Basin
Cherokee Platform
Bourbon Arch
38th Parallel Trough
38th Parallel Lineament
Ozark Uplift
Northeast Oklahoma Platform
Shelf Edge Rise
Arkoma Basin
Ouachita Uplift
Miles
0 20 40 60 80 100
0 50 100 150
Kilometers
LEO
S5
S10
MC
WCT
S17
PMC
SOS
766
700
765
706
339
FST
MB
BUT
J30
U
J33
J36
J45
J44/J43
J48
J69
J82
J91/J90
J105
J115
J116
Soil
Flint Hill Sandstone
1
2
3
4
5
meters
feet
SCALE
miles
0 10 20 30 40 50 60
0 50 100 kilometers
CORRELATION OF SIXTH-ORDER TRANSGRESSIVE-REGRESSIVE UNITS
OF "FORT SCOTT CYCLOTHEM", NE. OKLAHOMA, SE. KANSAS, W. MISSOURI
Key
(For lithologic symbols, see Appendix A)
700 Locality Symbol & Position
Sixth-Order T-R Unit Boundaries:
certain
inferred
position uncertain w/in strat. sec.
Other Boundaries:
member
chaetetid facies
DANIEL R. SUCHY