SEQUENCE STRATIGRAPHY OF PENNSYLVANIAN PERMIAN BOUNDARY STRATA FROM THE NORTH AMERICAN MIDCONTINENT

By

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SEQUENCE STRATIGRAPHY OF PENNSYLVANIAN
PERMIAN BOUNDARY STRATA FROM THE
NORTH AMERICAN MID-CONTINENT

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Finally I would like to thank my parents and grandparents for their continued support of every kind.

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INTRODUCTION

Purpose

The purpose of this study is three-fold. 1) Develop a sequence-stratigraphic framework for the Carboniferous-Permian boundary strata (Foraker Limestone-Roca Shale Formations; figure 1) from the North American Mid-Continent, 2) establish type sections for the Foraker Limestone and Red Eagle Limestone and 3) produce an updated sea-level fluctuation curve for this interval.

Scope and area of study

This study is an investigation of the Foraker Limestone through Roca Shale, lower Council Grove Group, Upper Carboniferous-Lower Permian from northern Kansas through northern Oklahoma (figure 2). Data was obtained from 7 outcrops and 3 Oklahoma Geological Survey cores (figure 3). Three of the outcrops are located in Kansas and four are in Oklahoma, the sampled cores are from Oklahoma. Two localities were in northern Kansas, one was in southern Kansas, Elk County. The Oklahoma outcrops and cores (provided by the Oklahoma Geological Survey)are located in Osage County. At the seven outcrops, four hundred and sixty-eight samples were taken from these sites, 121 thin sections were prepared, and 356 samples were processed for conodonts. The stratigraphic interval studied in this thesis brackets Carboniferous-Permian boundary strata based on conodont biostratigraphic correlation between the southern Ural Mountains and the Mid-Continent (based on conodont

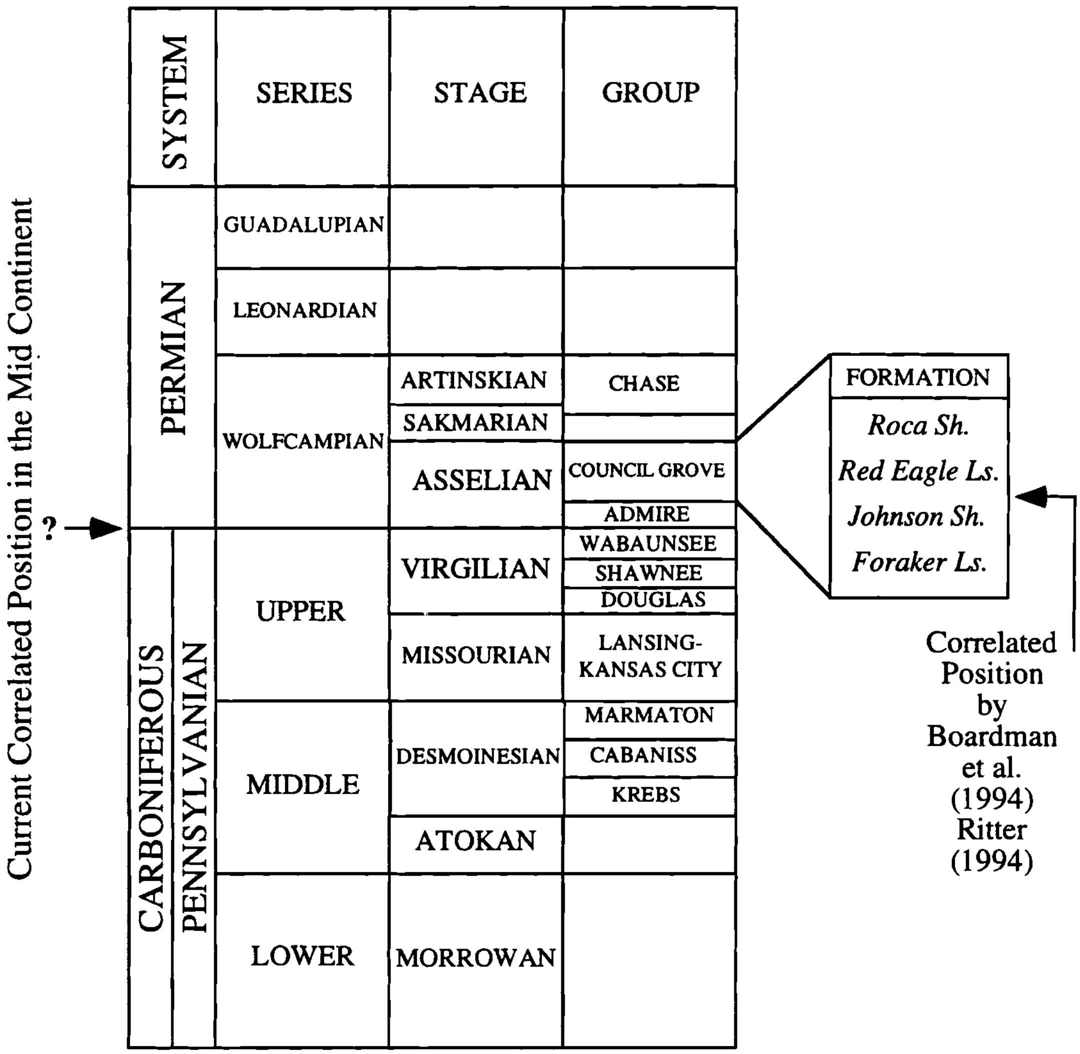


Figure 1
Carboniferous - Permian boundary strata
in the Mid-Continent.

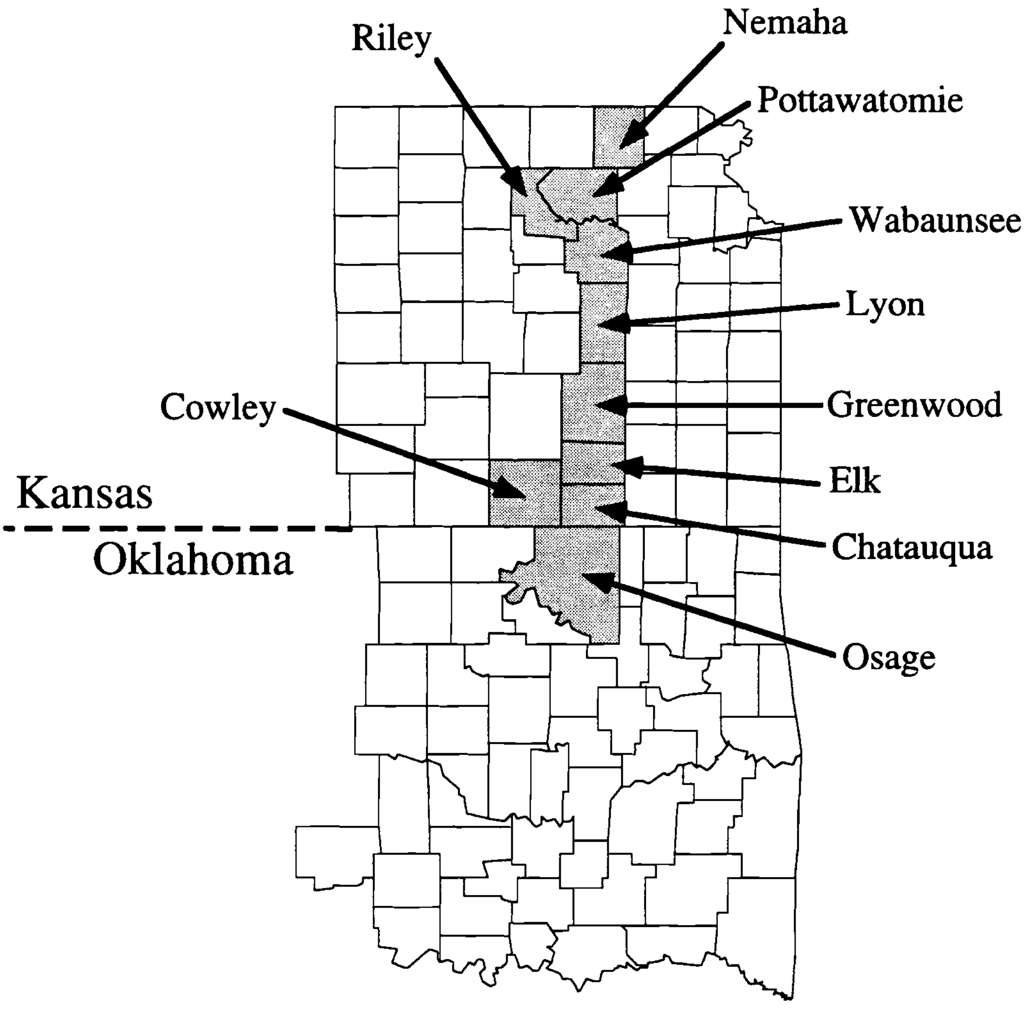


Figure 2
Location of Counties mentioned in study

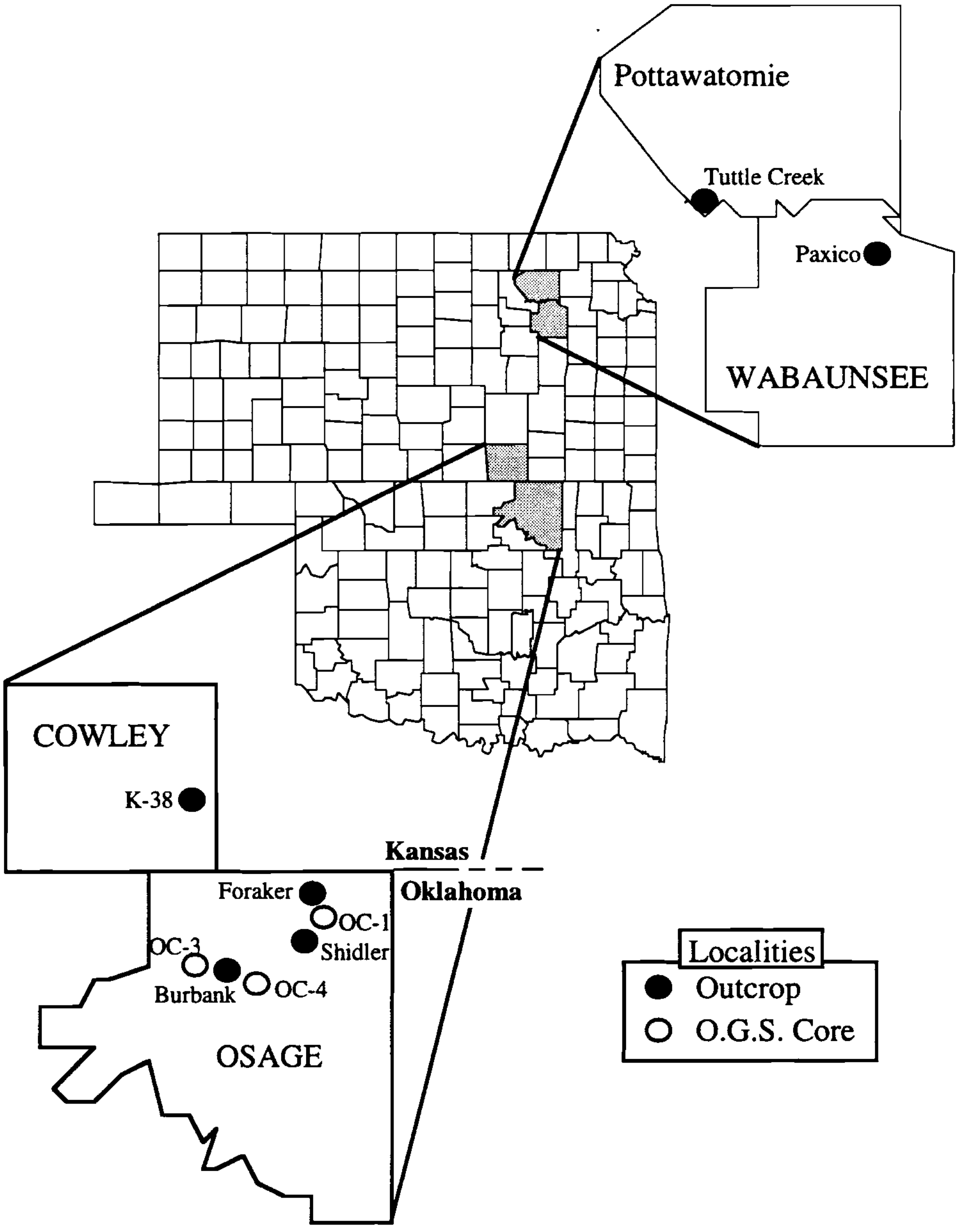


Figure 3
Localities of studied outcrops and cores

biostratigraphic correlation by Boardman, Nestell and Wardlaw 1994 and Ritter 1994).

Method of study

Lithostratigraphic analysis was the primary method of analysis for this study. The primary criterion for selecting sections for detailed analysis was to use long stratigraphic sections, where there was no question as to the correct stratigraphic superposition, from northern Kansas to northern Oklahoma. Each section sampled was measured (with metric equivalent), and a preliminary description was made, noting color (G.S.A. Rock Color Chart, 7th printing, 1991), fossil content, and lithology. Samples of each bed were collected, numbered, stored in ziploc bags and brought back to the lab. Samples from the eight localities totaled more than one ton of rock for analysis.

Analysis of each sample consisted of three steps; 1. processing for microfossils, primarily conodonts: 2. preparation for thin-section analysis: 3. a final correlation utilizing all available data.

The first step for each sample was to process and sample for conodonts. In preparing a carbonate sample, 500 grams of sample were broken into small chunks with a hand sledge, placed in a plastic bucket, and mixed with 6 quarts of water and 600 ml of Formic acid. This sat for 24 hours, allowing the solution to dissolve the carbonate rock that entombed the conodonts. In preparing a shale sample 1 kilogram of sample rock was dried in an oven, soaked in stoddards solvent, and rinsed with warm water. Black shales were soaked in bleach, for up to two months, to break down the organics. All the samples were then poured through two sieves. The residue from the smaller (180 mesh) sieve collected the conodonts, was removed, put in an oven to dry, then placed in a numbered envelope. This residue was then sorted under a microscope and picked for conodonts. The conodonts were counted, identified, and saved for interpretations of depositional environment and sea-level fluctuation.

The second step for each sample was to prepare it as a thin section. Rock was removed from each bag and a small billet was cut from each sample to the size of a standard microscope slide. The billet was then glued to a slide and ground thin enough for light to pass through. Half of each slide was stained to determine if dolomite was present. Each thin section was then analyzed under a microscope, noting lithology and microfaunal content.

The final step was to compile all available data and construct a long stratigraphic correlation of the stratigraphic section from the Foraker Limestone through Roca Shale.

STRATIGRAPHY OF THE STUDY AREA

Geological setting

The Foraker Limestone through Roca Shale of the Council Grove Group were deposited in latest Pennsylvanian and Earliest Permian time. This stratigraphic interval consists of limestones, shales, nonmarine red silty shales and siltstones with sparse sandstones (Rascoe et al. 1983). Deposition for these rocks was in cyclic transgressive and regressive flooding of epiric seas, caused by glaciations.

By the time the Foraker and Red Eagle were undergoing deposition the tectonic activity of the Mid-continent had ceased (Roscoe and Adler 1983) (figure 4). The Ouachita Orogeny occurred in the Mid-Pennsylvanian (Morrowan through Desmoinesian) as a result of the collision between the North and South American plates (Rascoe et al. 1983). In this collision were developed for the Ouachita foldbelt, the Arkoma Basin, the Amarillo-Wichita chain, the Apishapa, and Nemaha uplifts, the Cimarron Arch, and some small structures associated with the Las Animas Arch. Closer to the time of the lower Council Grove deposition was the Arbuckle Orogeny in the Late Pennsylvanian. This was a localized orogenic episode during which accumulated sediments in the Ardmore Basin were folded and faulted by compression from the southwest (Rascoe et al. 1983).

During the deposition of the Foraker Limestone through Roca Shale the primary source area for siliclastic sediments from the south and southwest (Wichita and Ouachita region). As made evident by silty shales in northern outcrops studied there appears to have been minor influx of clastic sediment from a northern source area. This could have been wind swept sediment from eroding lowlands to the north-northwest. This resulted in a northern depositional basin, the Falls City Basin. The northern outcrops show the black to gray marine shales while the southern outcrops are typical of shallower marine carbonate rocks.

The locality of this region during the Early Permian was much closer to the equator than the region is today (figure 5). The climatic conditions would have been warm and equatorial, consistent with the deposition of carbonates in shallow marine environment.(figure 6)

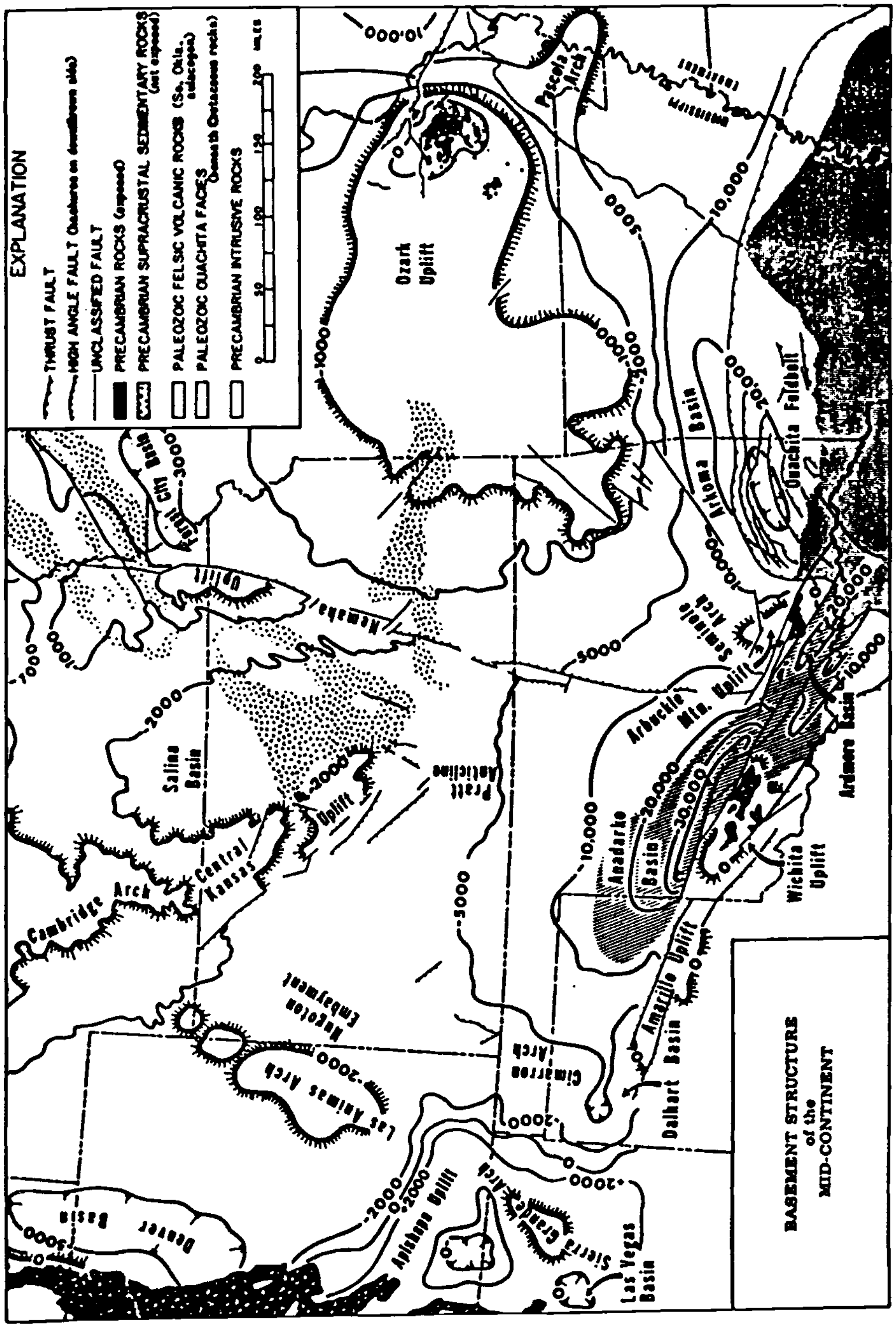


Figure 4
Basement Structure of the Mid-Continent
(Rascoe et al. 1983).

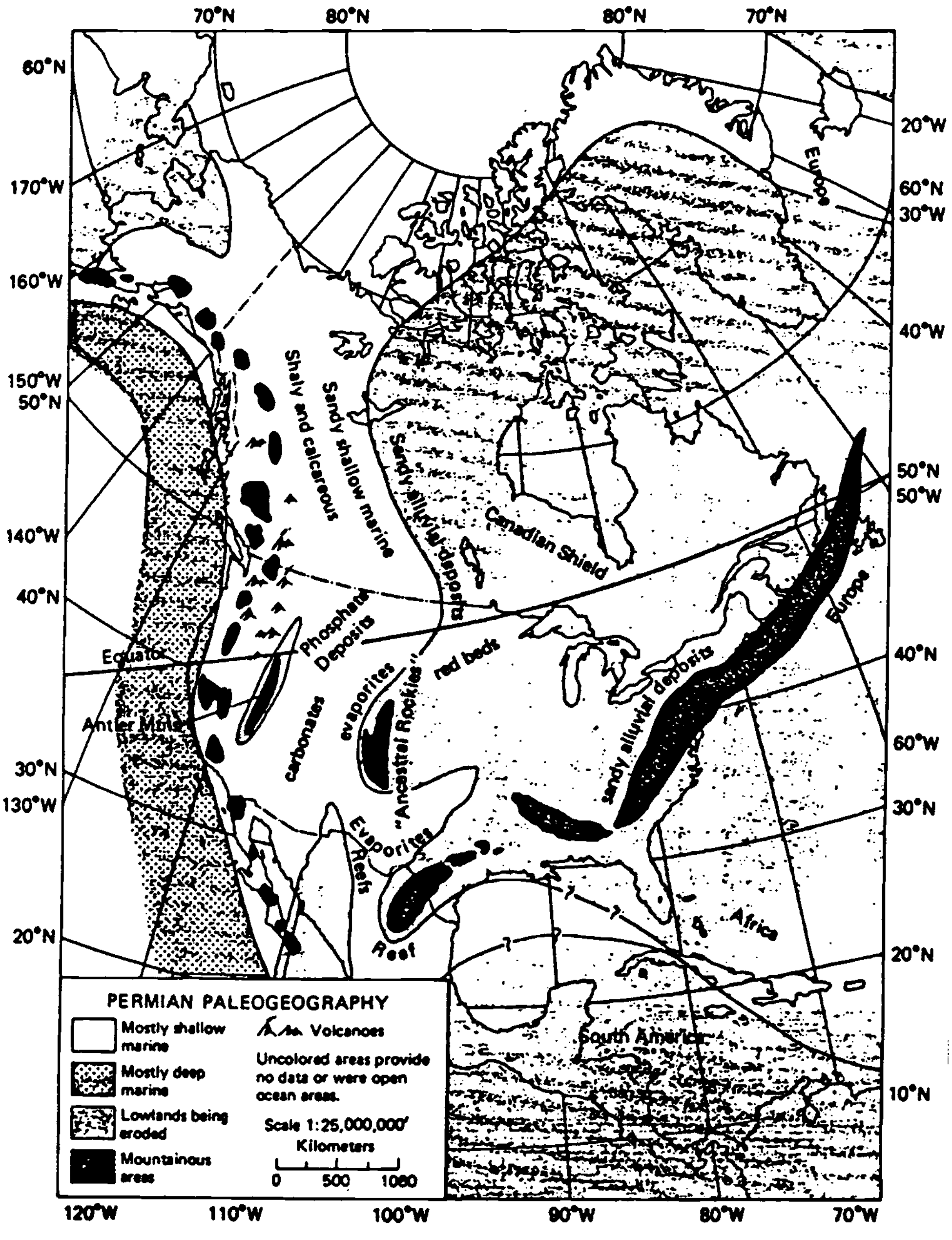


Figure 5
Permian Paleogeography, showing relation of the Mid-Continent to the equator (Friedman 1994).

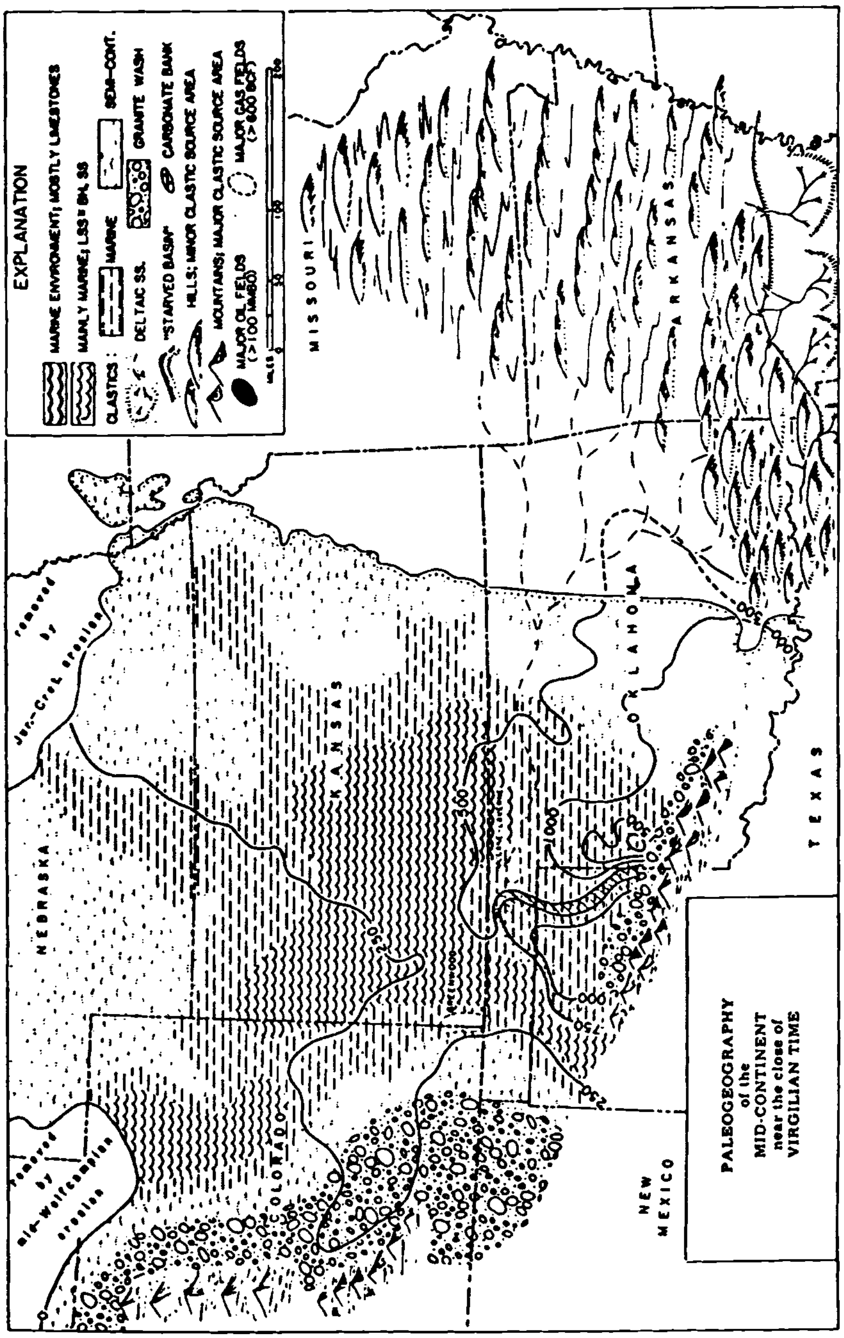


Figure 6
Paleogeography of the Mid-Continent near the close of Virgillian time
(Rascoe et al. 1983).

Type Locality, Foraker Limestone

The original description of the Foraker Limestone in 1916 by K.C. Heald contains a generalized stratigraphic column. It indicates no specific location, other than it (Foraker Limestone) forms the rim of Ekler Canyon and is prominent in the eastern part of the Foraker quadrangle.

A locality for the Type Foraker is deemed necessary by the North American Code of Stratigraphic Nomenclature. The proposed Foraker North locality provides a complete outcrop of the Foraker that is easily accessible, and has a measured section. (figures 8, 9: photos 1-13) It must be compiled from outcrops along both sides of the road, a task accomplished with only minor difficulty. In addition the Oklahoma State Geological Survey has provided cores that can be used a principle reference section (figures 10, 11, and 12).

The Foraker Limestone is divided into three members, in ascending order, the Americus Limestone, Hughes Creek Shale, and Long Creek Limestone. The Americus Limestone Member consists of upper and lower divisions. The lower Americus is 8 feet (2.44 meters) thick, predominantly gray shale with four thin (less than 12 inches-.30 meters) limestone ledges. The upper Americus is 4 feet 6 inches (1.42 meters) thick consisting of a distinctive thick medium gray limestone ledge with a small shale parting. The Hughes Creek Shale Member is informally subdivided into numbered limestone beds (L.S.1-L.S.7) that are correlatable from the type section in northern Oklahoma through Cowley County in southern Kansas. The Hughes Creek Shale Member is 49 feet (14.94 meters) thick. The lower 17 feet 8 inches (5.41 meters) is predominantly gray silty shales with two prominent limestone ledges, L.S. 1 and L.S. 2. The upper 31 feet 3 inches (9.53 meters) is predominantly limestone with two thin chert beds, one occurring in L.S. 3 and one in L.S.5. There is a covered interval of six feet with L.S. 7 exposed at the top. The Johnson Shale lies directly atop this 13 inch (.33 meter) ledge. The Long Creek Limestone Member is not present at this outcrop, presumably it has pinched out this far south.

The stratigraphic column for the Foraker has been interpreted as follows. The initial flooding occurred at the base of the lower Americus Limestone resulting in a minor transgression. The upper Americus Limestone contains a major flooding event that produces a thin marine condensed section with glauconite, phosphate, and a relatively deeper water *Streptognathodus* conodont fauna.

The Hughes Creek Shale contains four flooding events, the lowermost being a minor event, the upper two major and one minor. The Hughes Creek upper major flooding events also form marine condensed sections with glaucony, phosphate, and a *Streptognathodus* conodont fauna.

The Americus Limestone Member, Hughes Creek Shale Member, Long Creek Limestone Member and (most of) the Johnson Shale comprise a depositional sequence that records six transgressive-regressive events; this record can be traced from Nebraska to Oklahoma. The mechanism responsible for the fluctuation of sea-level was periodic glaciations.

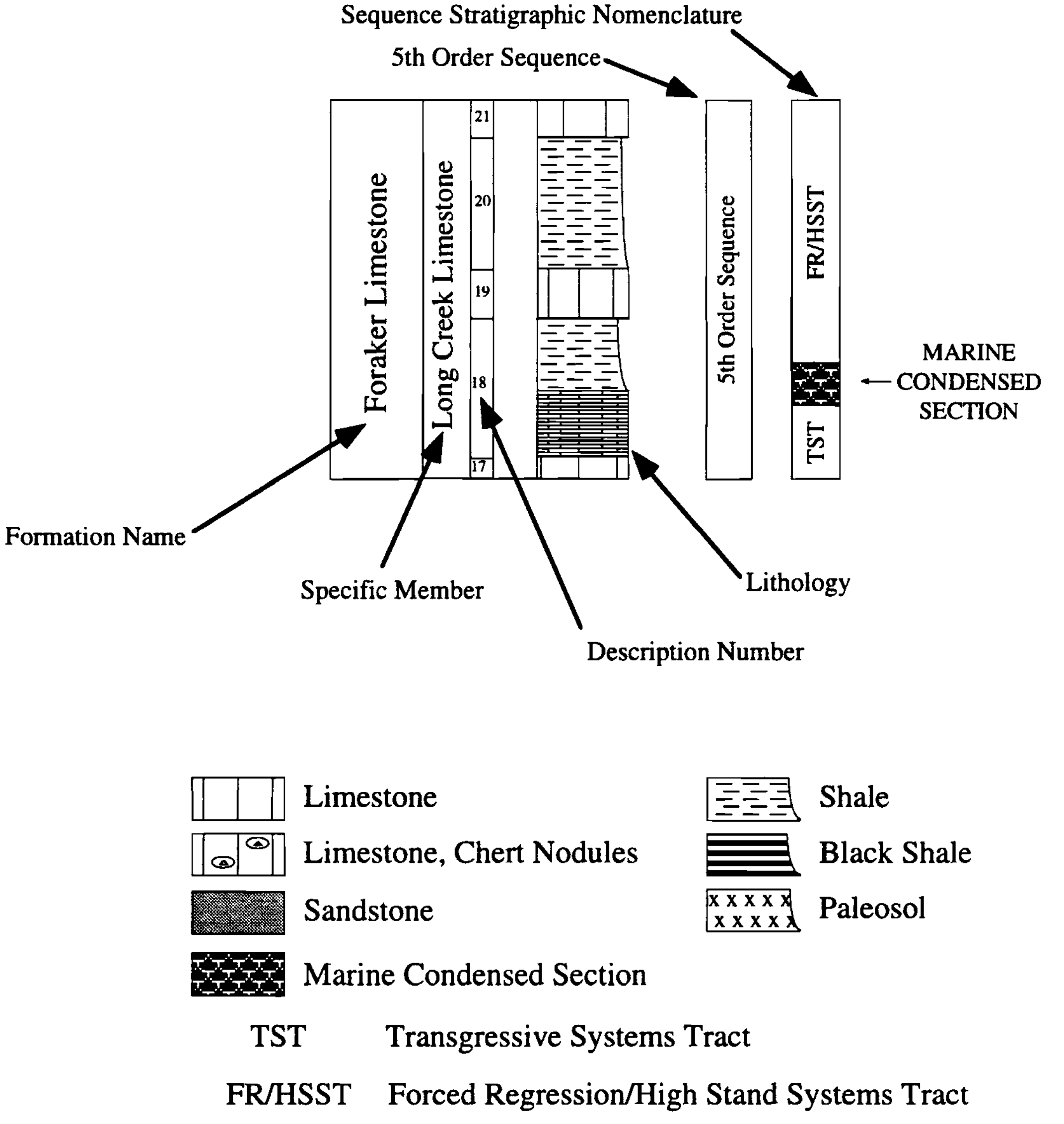


Figure 7
Key to measured sections

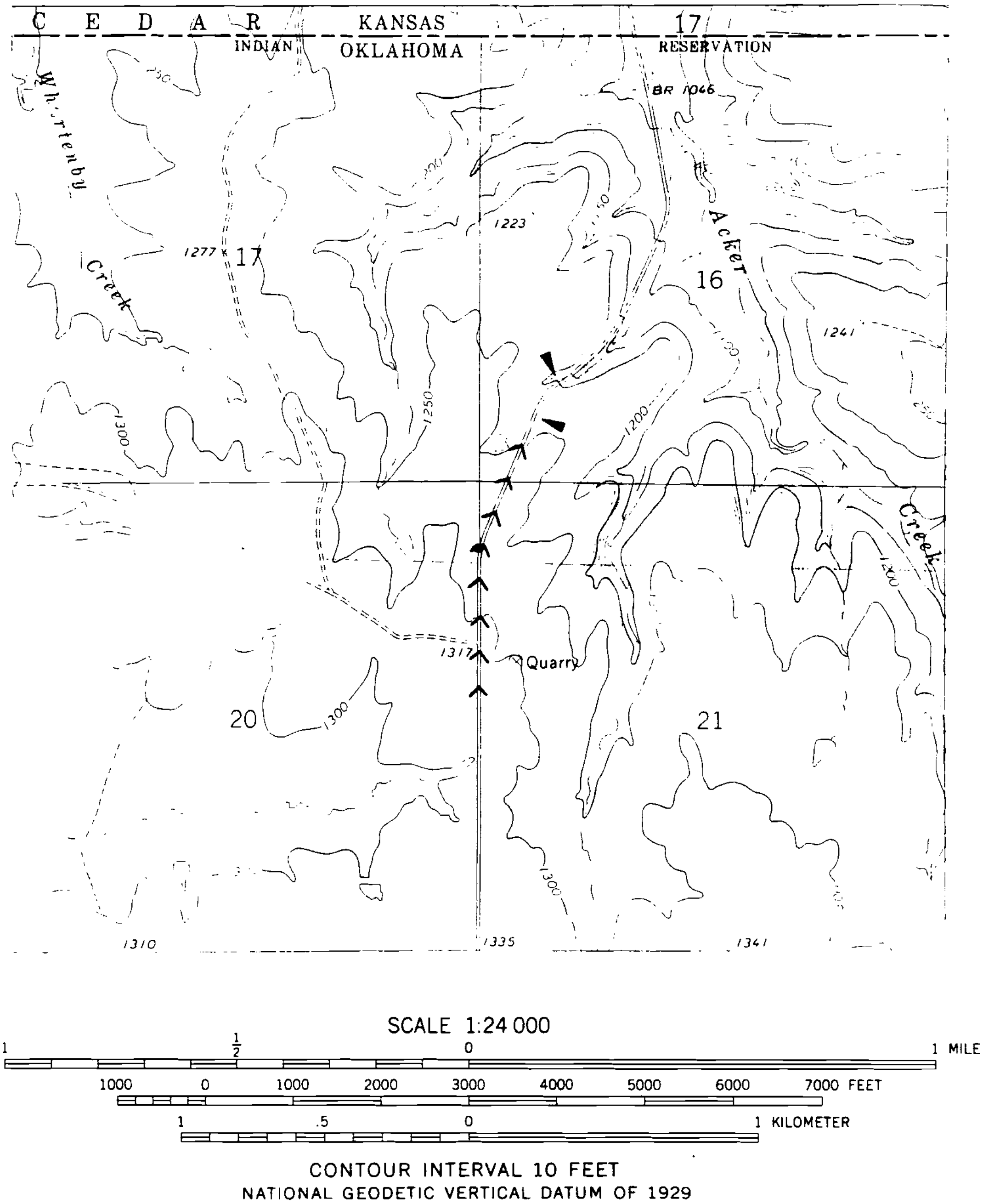


Figure 8
Topographic map showing locality of Foraker North locality, proposed Type Foraker.

Type Locality Foraker North Measured Section

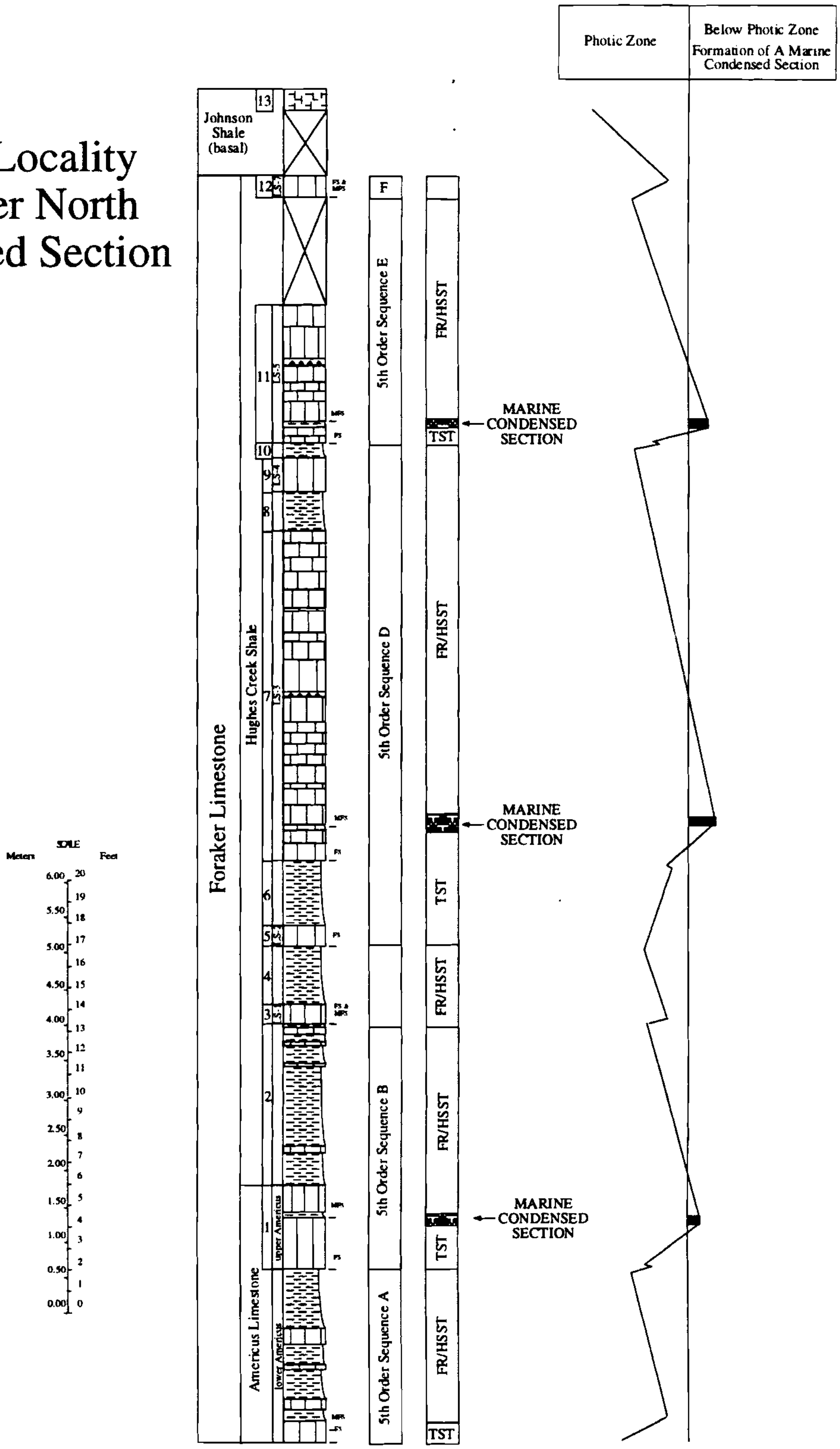


Figure 9

State: Oklahoma **County:** Osage

Locality Description:

Location is a road cut near the town of Foraker. Exposures are good, but must be compiled from both sides of the road.

Foraker North quadrangle T29N R8E, SW1/4, Section 16

Interval measured June 11 1994

UNIT DESCRIPTIONS

1	34 inches (.86 meters)	Upper Americus: medium gray limestone, weathers dark yellowish orange, fusulinids, wackestone.
	3 inches (.08 meters)	Upper Americus: medium yellowish orange calcareous shale, looks weathered. *Streptognathodus* conodont fauna, marine condensed section.
	19 inches (.48 meters)	Upper Americus: light gray to medium light gray limestone, fusulinids, wackestone.
2	106 inches (2.69 meters)	Hughes Creek Shale: dark yellowish orange to pale orange shale, somewhat calcareous, interbedded with thin medium gray limestone beds that weather to a grayish orange. Fusulinids, brachiopod and crinoid fragments.
3	12 inches (.30 meters)	Hughes Creek Shale: Medium dark gray limestone, clean, wackestone.
4	39 inches (.99 meters)	Hughes Creek Shale: Pale orange Shale, slightly calcareous.
5	13 inches (.33 meters)	Hughes Creek Shale: medium gray limestone, wackestone.
6	43 inches (1.09 meters)	Hughes Creek Shale: pale orange calcareous shale.
7	15 inches (.38 meters)	Hughes Creek Shale: very light gray limestone, weathers medium to medium light gray, wackestone.
	3 inches (.08 meters)	Hughes Creek Shale: gray limestone, weathered look, grainy, *Streptognathodus* conodont fauna, wackestone.
	21 inches (.53 meters)	Hughes Creek Shale: light gray limestone, weathers medium to light gray, wackestone.
	70 inches (1.78 meters)	Hughes Creek Shale: very light gray limestone, weathers medium gray,

		fusulinids, wackestone.
	4 inches (.10 meters)	Hughes Creek Shale: medium bluish gray chert bed, fusulinids.
	29 inches (.74 meters)	Hughes Creek Shale: very light gray to white limestone, weathers medium gray, fusulinids, wackestone.
	31 inches (.79 meters)	Hughes Creek Shale: very light gray limestone, weathers medium gray, rare fusulinids, wackestone.
	42 inches (1.07 meters)	Hughes Creek Shale: very light gray limestone, weathers medium gray, fusulinids, wackestone.
8	26 inches (.66 meters)	Hughes Creek Shale: yellowish-orange shaly marl.
9	22 inches (.56 meters)	Hughes Creek Shale: yellowish gray limestone weathers medium light gray, fusulinids, wackestone.
10	9 inches (.23 meters)	Hughes Creek Shale: pale orange limy shale, fusulinids.
11	11 inches (.28 meters)	Hughes Creek Shale: very light gray limestone, weathers medium gray, fusulinids, wackestone.
	3 inches (.08 meters)	Hughes Creek Shale: medium yellowish gray. crumbly limy shale, weathered look, *Streptognathodus* conodont fauna, wackestone.
	37 inches (.94 meters)	Hughes Creek Shale: yellowish gray limestone, weathers medium gray, fusulinids, wackestone.
	4 inches (.10 meters)	Hughes Creek Shale: medium bluish gray chert beds, fusulinids.
	21 inches (.53 meters)	Hughes Creek Shale: dark yellowish orange to moderate yellowish brown limestone, fusulinids, wackestone.
	14 inches (.36 meters)	Hughes Creek Shale: very pale orange limestone, weathers medium light gray, fusulinids, wackestone.
12	13 inches (.33 meters)	Hughes Creek Shale: light gray to medium light gray limestone, wackestone.
13	13 inches (.33 meters)	Johnson Shale: pale yellowish orange boxwork carbonate.

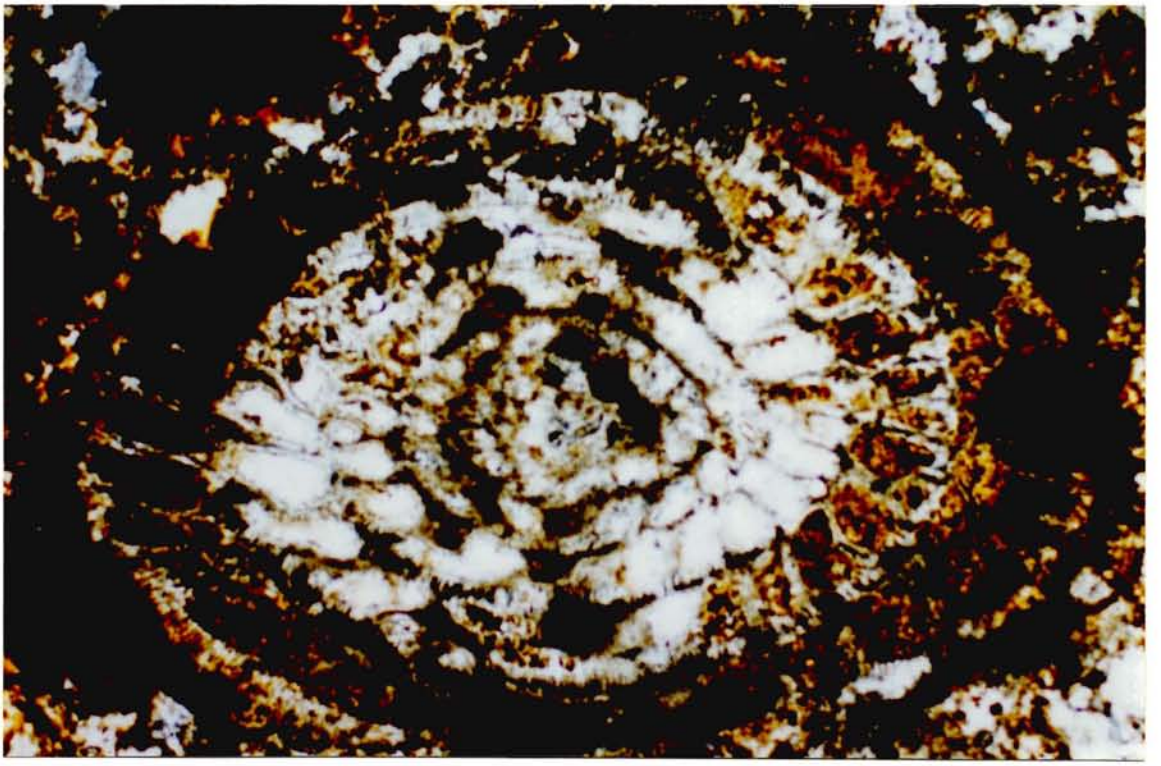


Photo 1

Foraker North Americus Limestone Member

Fusulinid (center) from lower Americus Limestone (measured section unit 1), wackestone

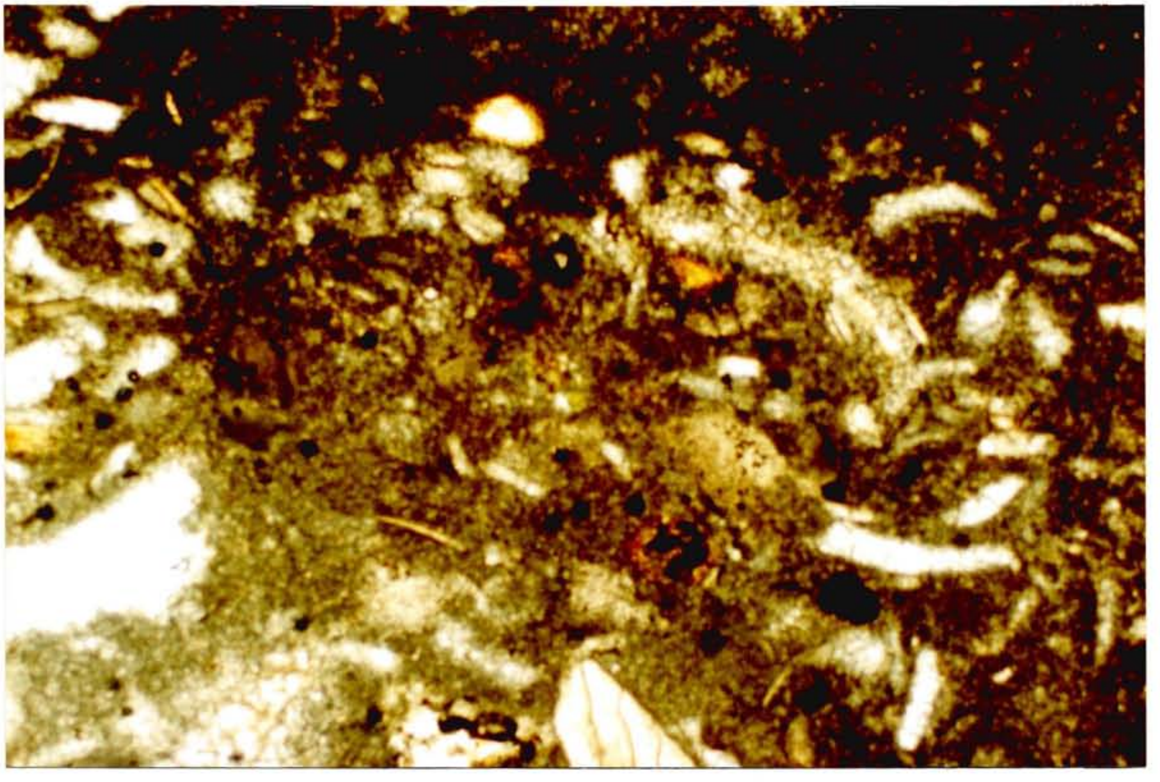


Photo 2

Foraker North Americus Limestone Member

Marine condensed section, from parting in the Americus Limestone (measured section unit 1), phosphate appears as the amber/caramel colored grain, identified fossil fragments are echinoderm and brachiopod, wackestone.

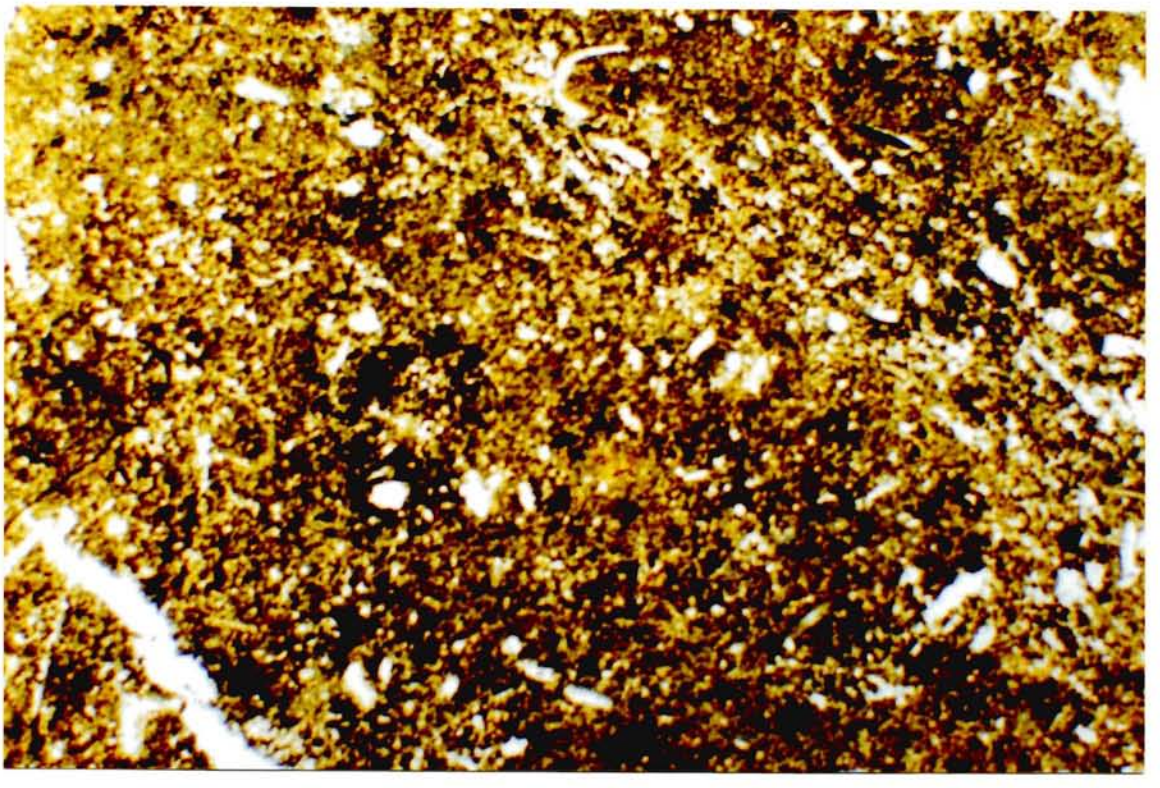


Photo 3

Foraker North　　　　Hughes Creek Shale Member

Wackestone, measured section unit 5, small scattered echinoderm fragments within a lime mud matrix.

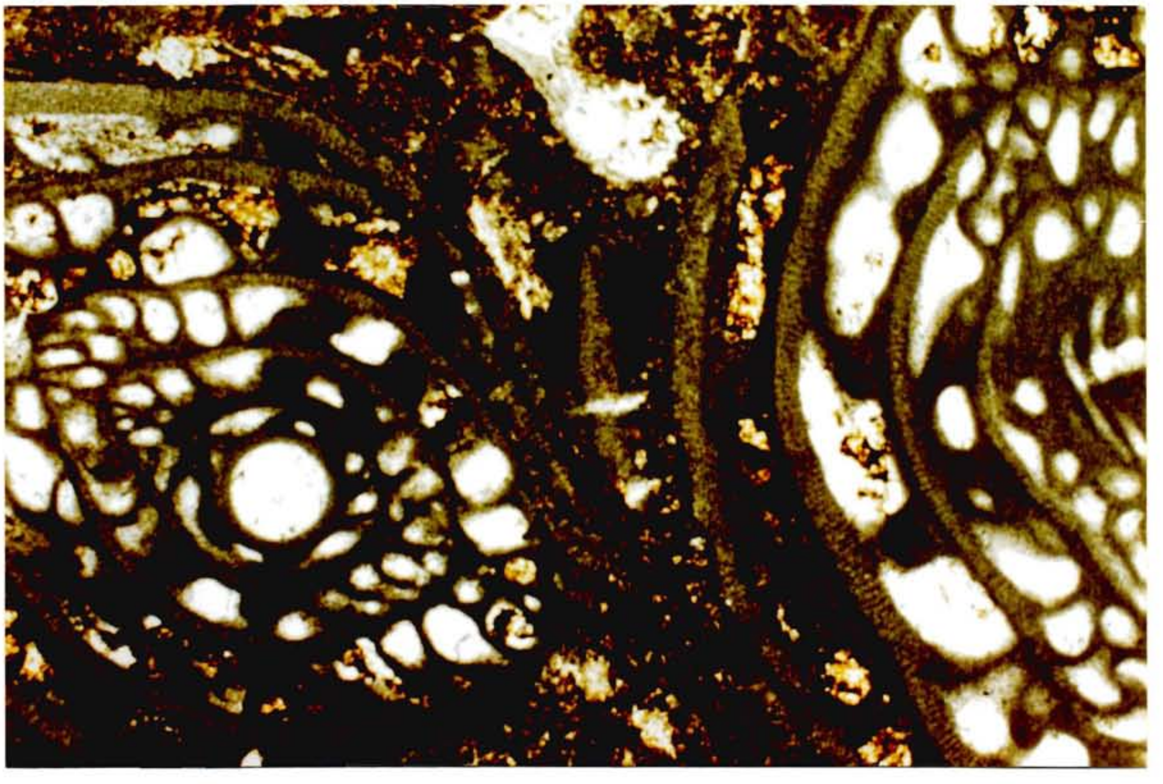


Photo 4

Foraker North Hughes Creek Shale Member

Wackestone, fusulinids pictured, measured section unit 11.

Photo 5

Foraker North Americus Limestone Member

Taken from light duty road, Americus Limestone Member with distinct shale parting at the Type Locality.

Photo 7

Foraker North Hughes Creek Shale Member

Taken from light duty road, Overview of roadcut, slightly overgrown, but accessable, author's geology buggy for scale.

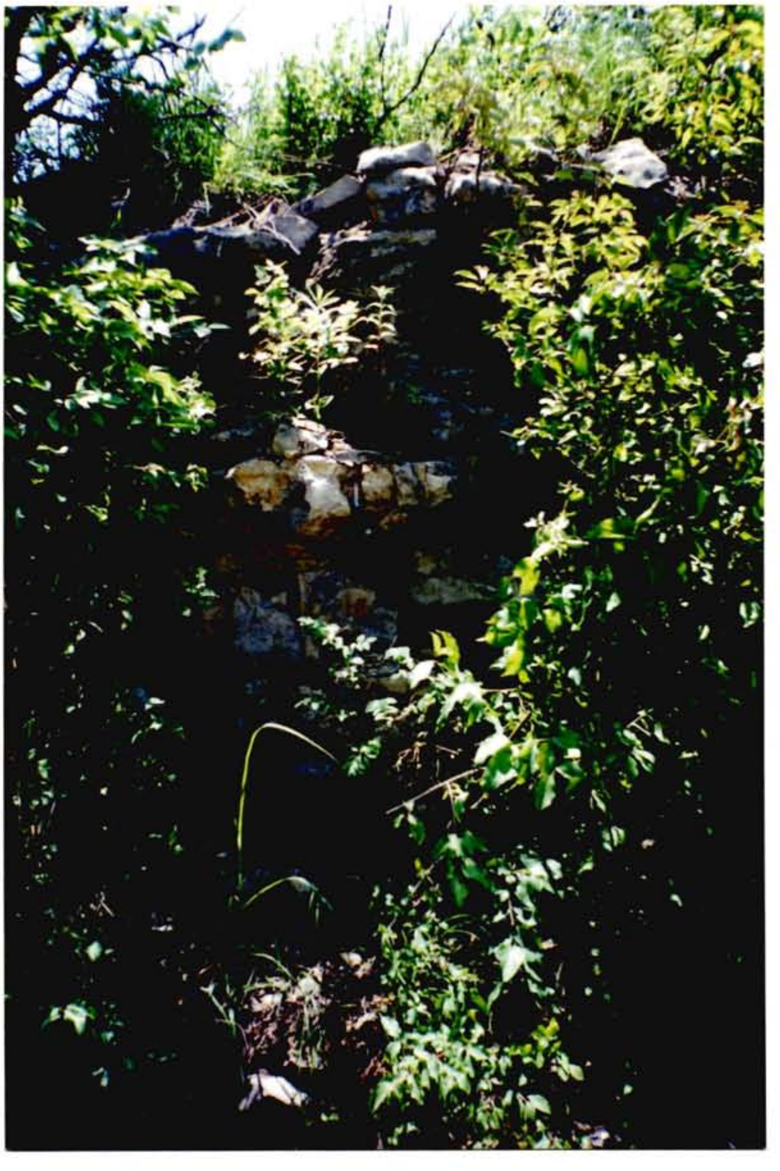


Photo 8

Foraker North Hughes Creek Shale Member

Taken from light duty road, L.S. 3 hammer for scale.

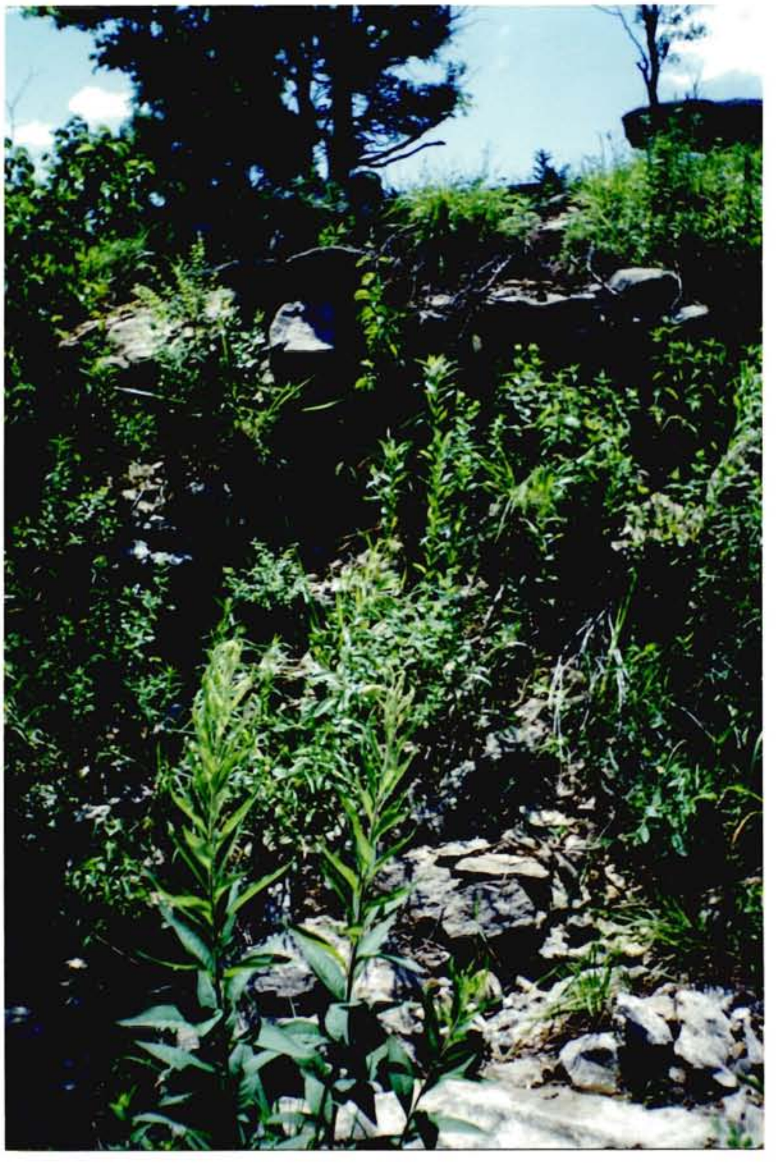


Photo 9

Foraker North Hughes Creek Shale Member

Taken from light duty road, uppermost L.S. 3.

Photo 10

Foraker North Hughes Creek Shale Member

Taken from light duty road, Hammer sets just below the contact of shale unit and L.S. 4.

Photo 11

Foraker North Hughes Creek Shale Member

Taken from light duty road, L.S. 5

Photo 12

Foraker North Hughes Creek Shale Member

Taken from light duty road, L.S. 7.

Photo 13

Foraker North Red Eagle Limestone

Taken from light duty road, Contact with Johnson Shale, below hammer are the basal limestone ledges (scratched white from sampling) of the Red Eagle Limestone.

Core OC-1 Measured Section
Foraker Limestone

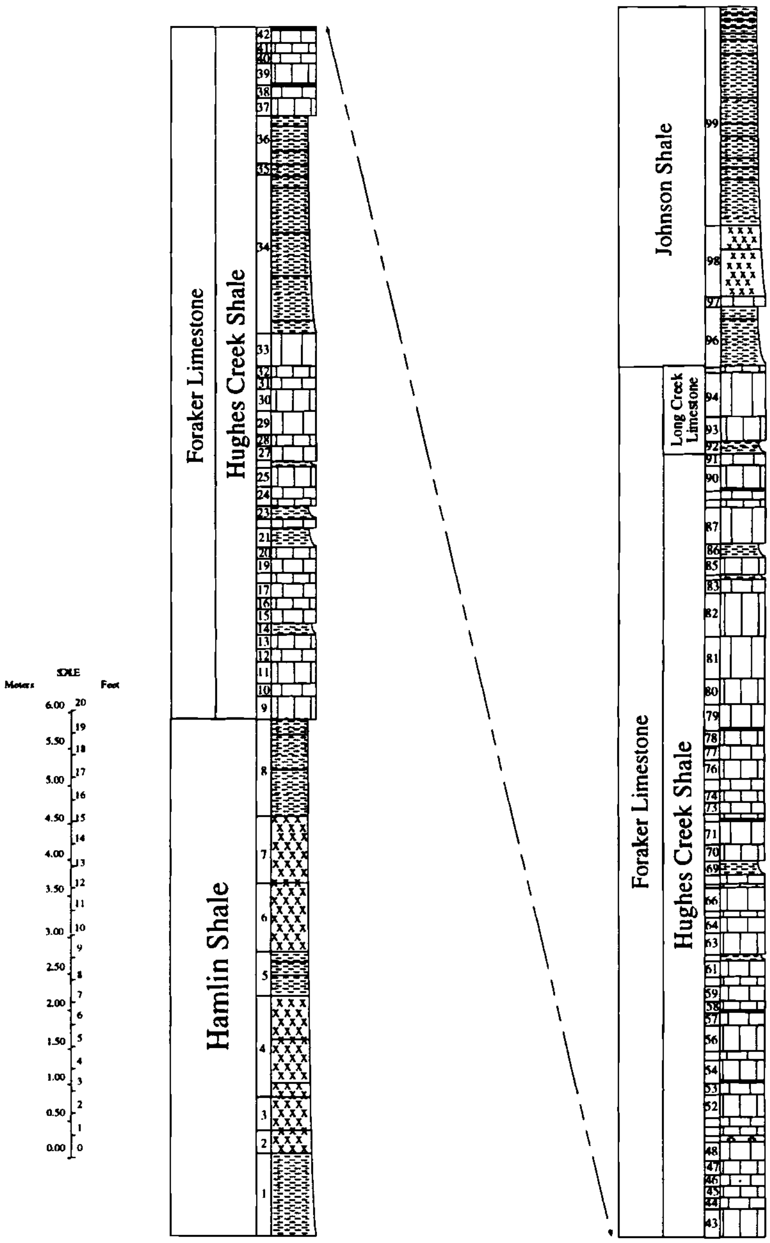


Figure 10

State: Oklahoma **County:** Osage

Locality Description:

This is Oklahoma Geological Survey core hole OC-1. Drilled on the Paul Kelly Ranch.

Interval measured is the Foraker Limestone and the Johnson Shale .

Grainola Quadrangle: SW SW NE 21-29N-6E

UNIT DESCRIPTIONS

1	41 inches (1.04 meters)	Black shale, coal.
2	14 inches (.36 meters)	Hamlin Shale: greenish red shale, crumbly.
3	21 inches (.53 meters)	Hamlin Shale: dusky red shale.
4	58 inches (1.47 meters)	Hamlin Shale: blocky green to greenish gray shale.
5	27 inches (.69 meters)	Hamlin Shale: medium gray to brown crumbly shale.
6	39 inches (.99 meters)	Hamlin Shale: green gray with interbedded brown shale, paleosol.
7	59 inches (1.50 meters)	Hamlin Shale: greenish gray blocky shale, paleosol.
8	29 inches (.74 meters)	Hamlin Shale: medium to dark gray shale
9	13 inches (.33 meters)	Americus Limestone: medium gray to olive gray limestone, mottled, medium gray chunks with olive colored infill.
10	5 inches (.13 meters)	Americus Limestone: medium gray to olive gray limestone, top is fractured, appears as a hardground.
11	10 inches (.25 meters)	Americus Limestone: medium dark gray limestone, grayish black shale stringers, fusulinids.
12	4 inches (.10 meters)	Americus Limestone: grayish black limy shale.

13	7 inches (.18 meters)	Americus Limestone: medium dark gray limestone, crinoids, brachiopods.
14	8 inches (.20 meters)	Americus Limestone: black-grayish black shale.
15	9 inches (.23 meters)	Americus Limestone: medium dark gray to dark gray limestone, some interbedded shale.
16	5 inches (.13 meters)	Americus Limestone: dark gray limy shale.
17	4 inches (.10 meters)	Americus Limestone: dark gray limestone.
18	6 inches (.15 meters)	Americus Limestone: medium dark gray limestone, some shale interbedded.
19	7 inches (.18 meters)	Americus Limestone: grayish black to medium dark gray limestone, interbedded shale.
20	6 inches (.15 meters)	Americus Limestone: dark gray to medium dark gray limestone.
21	10 inches (.25 meters)	Americus Limestone: black shale, pyrite, brachiopods.
22	3 inches (.08 meters)	Americus Limestone: dark gray limestone.
23	6 inches (.15 meters)	Americus Limestone: grayish black shale.
24	8 inches (.20 meters)	Americus Limestone: dark gray limestone, bioturbated, brachiopods.
25	10 inches (.25 meters)	Americus Limestone: medium dark gray limestone.
26	2 inches (.05 meters)	Americus Limestone: thin black shale parting.
27	9 inches (.23 meters)	Americus Limestone: dark gray to medium dark gray limestone, black shale stringers.
28	6 inches (.15 meters)	Americus Limestone: medium dark gray limestone, pyrite.
29	11 inches (.28 meters)	Americus Limestone: medium gray limestone, pyrite, crinoids, abundant fusulinids in basal 2 inches.
30	12 inches (.30 meters)	Americus Limestone: medium dark gray limestone, crinoids, fusulinids, abundant in top 2 inches.

31	5 inches (.13 meters)	Americus Limestone: medium dark gray limestone, black shale stringers, fusulinids.
32	6 inches (.15 meters)	Americus Limestone: medium dark gray limestone, pyrite, fusulinids.
33	15 inches (.38 meters)	Americus Limestone: medium dark gray limestone, fusulinids, top 5 inches are burrowed.
34	85 inches (2.16 meters)	Hughes Creek Shale: dark gray to grayish black shale, rare brachiopods.
35	6 inches (.15 meters)	Hughes Creek Shale: fissile black shale.
36	25 inches (.64 meters)	Hughes Creek Shale: grayish black shale, abundant brachiopods.
37	9 inches (.23 meters)	Hughes Creek Shale: medium dark gray limestone, coated grains, fusulinids.
38	7 inches (.18 meters)	Hughes Creek Shale: medium gray limestone, fusulinids.
39	.5 inch (.01 meter)	Hughes Creek Shale: thin black shale parting.
	9 inches (.23 meters)	Hughes Creek Shale: dark to medium dark gray limestone, sparse fusulinids.
40	4 inches (.10 meters)	Hughes Creek Shale: dark gray limestone, fusulinids.
41	5 inches (.13 meters)	Hughes creek shale: medium gray limestone, abundant fusulinids.
42	7 inches (.18 meters)	Hughes Creek Shale: light gray limestone
	.5 inch (.01 meter)	Hughes Creek Shale: thin black shale parting.
43	14 inches (.36 meters)	Hughes Creek Shale: medium light gray limestone, brachiopod, crinoid, ostracode.
44	6 inches (.15 meters)	Hughes Creek Shale: light gray limestone, abundant fusulinids.
45	7 inches (.18 meters)	Hughes Creek Shale: light gray limestone, sparse fusulinids.
46	6 inches (.15 meters)	Hughes Creek Shale: medium gray limestone, grayish black shale stringers.

47	6 inches (.15 meters)	Hughes Creek Shale: medium light gray limestone, black shale stringers, sparse fusulinids associated with stringers.
48	9 inches (.23 meters)	Hughes Creek Shale: medium light gray limestone.
49	2 inches (.05 meters)	Hughes Creek Shale: medium light bluish gray chert.
50	5 inches (.13 meters)	Hughes Creek Shale: medium light gray limestone, sparse fusulinids.
51	6 inches (.15 meters)	Hughes Creek Shale: medium gray limestone, black shale stringers, sparse fusulinids.
52	11 inches (.28 meters)	Hughes Creek Shale: light to medium light gray limestone, sparse fusulinids.
53	7 inches (.18 meters)	Hughes Creek Shale: light gray to medium light gray limestone, abundant fusulinids.
54	.5 inch (.01 meter)	Hughes Creek Shale: thin black shale parting.
	11 inches (.28 meters)	Hughes Creek Shale: medium light gray limestone, abundant fusulinids.
55	5 inches (.13 meters)	Hughes Creek Shale: grayish black limestone, abundant fusulinids.
56	14 inches (.36 meters)	Hughes Creek Shale: light gray limestone, abundant fusulinids.
57	7 inches (.18 meters)	Hughes Creek Shale: medium gray limestone, fusulinids.
58	.5 inch (.01 meter)	Hughes Creek Shale: thin black shale parting.
	4 inches (.10 meters)	Hughes Creek Shale: medium light to light gray limestone, brachiopods, crinoids, fusulinids.
59	8 inches (.20 meters)	Hughes Creek Shale: medium gray to medium light gray limestone, brachiopods, crinoids.
60	4 inches (.10 meters)	Hughes Creek Shale: medium gray limestone, crinoids.
61	9 inches (.23 meters)	Hughes Creek Shale: medium light gray to medium gray limestone, fusulinids.
62	3 inches (.08 meters)	Hughes Creek Shale: dark gray to grayish black shale, crinoids.

63	12 inches (.30 meters)	Hughes Creek Shale: light gray to medium gray limestone, coated grains, rare fusulinid.
64	9 inches (.23 meters)	Hughes Creek Shale: medium gray limestone, coated grains, brachiopods, crinoids.
65	3 inches (.08 meters)	Hughes Creek Shale: medium gray limestone, small crinoid fragments.
66	12 inches (.30 meters)	Hughes Creek Shale: light gray limestone, thinly bedded.
67	3 inches (.08 meters)	Hughes Creek Shale: light gray limestone, coated grains.
68	5 inches (.13 meters)	Hughes Creek Shale: medium dark gray limestone-shale mix.
69	7 inches (.18 meters)	Hughes Creek Shale: dark gray to black shale, fusulinids in top 3 inches.
70	9 inches (.23 meters)	Hughes Creek Shale: medium light gray limestone, fusulinids.
71	14 inches (.36 meters)	Hughes Creek Shale: medium gray limestone, black shale stringers, fusulinids.
72	.5 inch (.01 meter)	Hughes Creek Shale: thin black shale parting.
	3 inches (.08 meters)	Hughes Creek Shale: medium dark gray limestone, fusulinids.
73	6 inches (.15 meters)	Hughes Creek Shale: medium dark gray limestone, brachiopods.
74	6 inches (.15 meters)	Hughes Creek Shale: medium gray limestone, grainy, sparse fusulinids.
75	6 inches (.15 meters)	Hughes Creek Shale: medium gray limestone, fusulinids.
76	12 inches (.30 meters)	Hughes Creek Shale: medium gray limestone, abundant fusulinids, black shale stringers.
77	7 inches (.18 meters)	Hughes Creek Shale: medium gray limestone, fusulinids.
78	10 inches (.25 meters)	Hughes Creek Shale: medium light gray limestone, black shale stringers, fusulinids, hematite in top 4 inches.
79	.5 inch (.01 meter)	Hughes Creek Shale: thin black shale parting.

	13 inches (.33 meters)	Hughes Creek Shale: medium light gray limestone, abundant fusulinids, basal 3 inches contains brachiopods.
80	16 inches (.41 meters)	Hughes Creek Shale: medium gray limestone, abundant fusulinids.
81	24 inches (.61 meters)	Hughes Creek Shale: medium dark gray limestone, abundant fusulinids.
82	23 inches (.58 meters)	Hughes Creek Shale: dark gray to medium light gray limestone, crinoids, abundant fusulinids.
83	7 inches (.18 meters)	Hughes Creek Shale: medium gray limestone, fusulinids, brachiopods.
84	2 inches (.05 meters)	Hughes Creek Shale: dark gray to black shale, abundant fusulinids.
85	8 inches (.20 meters)	Hughes Creek Shale: dark gray to medium dark gray limestone, grainy, black shale stringers, abundant fusulinids.
86	7 inches (.18 meters)	Hughes Creek Shale: dark gray limy shale.
87	19 inches (.48 meters)	Hughes Creek Shale: dark gray limestone, burrowed, fusulinids.
88	5 inches (.13 meters)	Hughes Creek Shale: light gray slightly brownish limestone, algal coated grains, brachiopods.
89	4 inches (.10 meters)	Hughes Creek Shale: light gray slightly brownish limestone, grainy.
90	.5 inch (,01 meter)	Hughes Creek Shale: thin black shale parting.
	17 inches (.43 meters)	Hughes Creek Shale: light gray slightly brownish limestone, rare fusulinid.
91	5 inches (.13 meters)	Hughes Creek Shale: brownish gray limestone.
92	6 inches (.15 meters)	Hughes Creek Shale: medium gray limy shale.
93	11 inches (.28 meters)	Long Creek Limestone: brownish gray limestone.
94	13 inches (.33 meters)	Long Creek Limestone: gray to medium light gray limestone.
95	3 inches (.08 meters)	Long Creek Limestone: very light gray limestone.

96	27 inches (.69 meters)	Johnson Shale : medium gray shale, slightly calcareous, fusulinids in top half inch.
97	3 inches (.08 meters)	Johnson Shale : brownish to medium gray limestone, algal coated grains.
98	38 inches (.97 meters)	Johnson Shale : greenish gray slightly reddish in top 12 inches bedded paleosol.
99	118 inches (3.02 meters)	Johnson Shale : medium dark gray shale, crumbly to blocky.

Core OC-3 Measured Section

Foraker Limestone

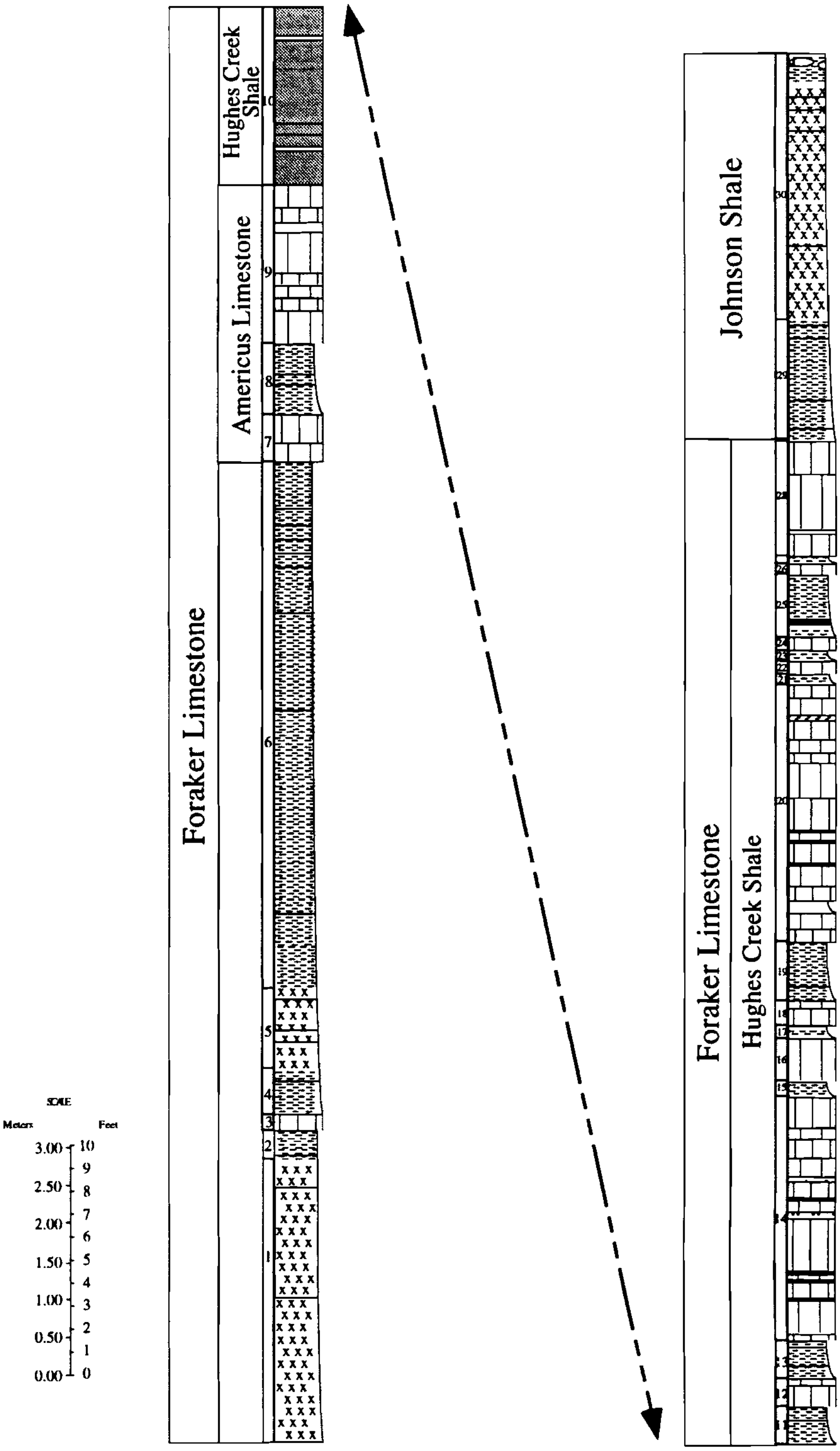


Figure 11

State: Oklahoma **County:** Osage

Locality Description:
The measured section is of Oklahoma Geological Survey Core OC-3.

Interval measured is the Hamlin Shale through Johnson Shale

UNIT DESCRIPTIONS

1	132 inches (3.35 meters)	Hamlin Shale: dusky red to green shale, blocky mudstone in places.
2	13 inches (.33 meters)	Hamlin Shale: dark gray shale
3	8 inches (.20 meters)	Hamlin Shale: medium gray limestone, bioturbated, brachiopods.
4	18 inches (.46 meters)	Hamlin Shale: fissile black shale.
5	43 inches (1.03 meters)	Hamlin Shale: green to dusky red shale
6	264 inches (6.71 meters)	Hamlin Shale: medium dark gray shale, calcareous, sparse marine fossils.
7	26 inches (.66 meters)	Americus Limestone: dark gray limestone, small fossil fragments near base.
8	39 inches (.99 meters)	Americus Limestone: dark gray shale, middle six inches is fissile black shale, inarticulate brachiopods near base, fusulinids near top.
9	84 inches (2.13 meters)	Americus Limestone: medium gray limestone, fusulinids abundant, crinoids.
10	92 inches (2.34 meters)	Hughes Creek Shale: olive gray to yellowish sandstone, some limy stringers near the base and top.
11	19 inches (.48 meters)	Hughes Creek Shale: medium gray shale, sbundant fusulinids at top.
12	17 inches (.43 meters)	Hughes Creek Shale: dark gray limestone, fusulinids.
13	21 inches (.53 meters)	Hughes Creek Shale: dark gray shale, crinoids, fusulinids.

14	136 inches (3.45 meters)	Hughes Creek Shale: medium dark gray limestone, basal inch contains coated grains, crinoids, fusulinids, (abundant 4 feet 6 inches from base), dark gray to black shale stringers throughout, two thin dark gray chert beds are present.
15	10 inches (.25 meters)	Hughes Creek Shale: dark gray calcareous shale.
16	19 inches (.48 meters)	Hughes Creek Shale: medium gray limestone, top and bottom two inches are bioturbated.
17	6 inches (.15 meters)	Hughes Creek Shale: dark gray to black shale, crinoid, fusulinid.
18	19 inches (.48 meters)	Hughes Creek Shale: medium gray limestone, algal coated grains, slightly bioturbated.
19	22 inches (.56 meters)	Hughes Creek Shale: dark gray shale, middle 3 inches contains abundant fusulinids.
20	150 inches (3.81 meters)	Hughes Creek Shale: medium light gray limestone, brachiopods, crinoids, fusulinids, (abundant 3 feet 6 inches and 11 feet from the base).
21	6 inches (.15 meters)	Hughes Creek Shale: dark gray calcareous shale, fusulinids.
22	6 inches (.15 meters)	Hughes Creek Shale: dark gray limy shale, abundant fusulinids.
23	6 inches (.15 meters)	Hughes Creek Shale:dark gray to black shale, fusulinids.
24	6 inches (.15 meters)	Hughes Creek Shale: dark gray limestone, crinoids, fusulinids.
25	33 inches (.84 meters)	Hughes Creek Shale: dark gray shale, calcareous, 7 inches from base is a thin 1 inch brown-reddish layer.
26	8 inches (.20 meters)	Hughes Creek Shale: dark gray limestone, brachiopods, crinoids, fusulinids.
27	4 inches (.10 meters)	Hughes Creek Shale: dark gray shale/mudstone
28	57 inches (1.45 meters)	Hughes Creek Shale: basal foot dark gray limestone, otherwise yellowish gray limestone, fusulinids, brachiopods, crinoids.
29	66 inches (1.68 meters)	Johnson Shale: light gray to greenish shale, in places blocky mudstone.

30	96 inches (2.44 meters)	Johnson Shale: dusky red to red blocky mudstone.
31	26 inches (.66 meters)	Johnson Shale: medium dark gray shale, some lenticular limestones near the top.

Core OC-4 Measured Section

Foraker Limestone

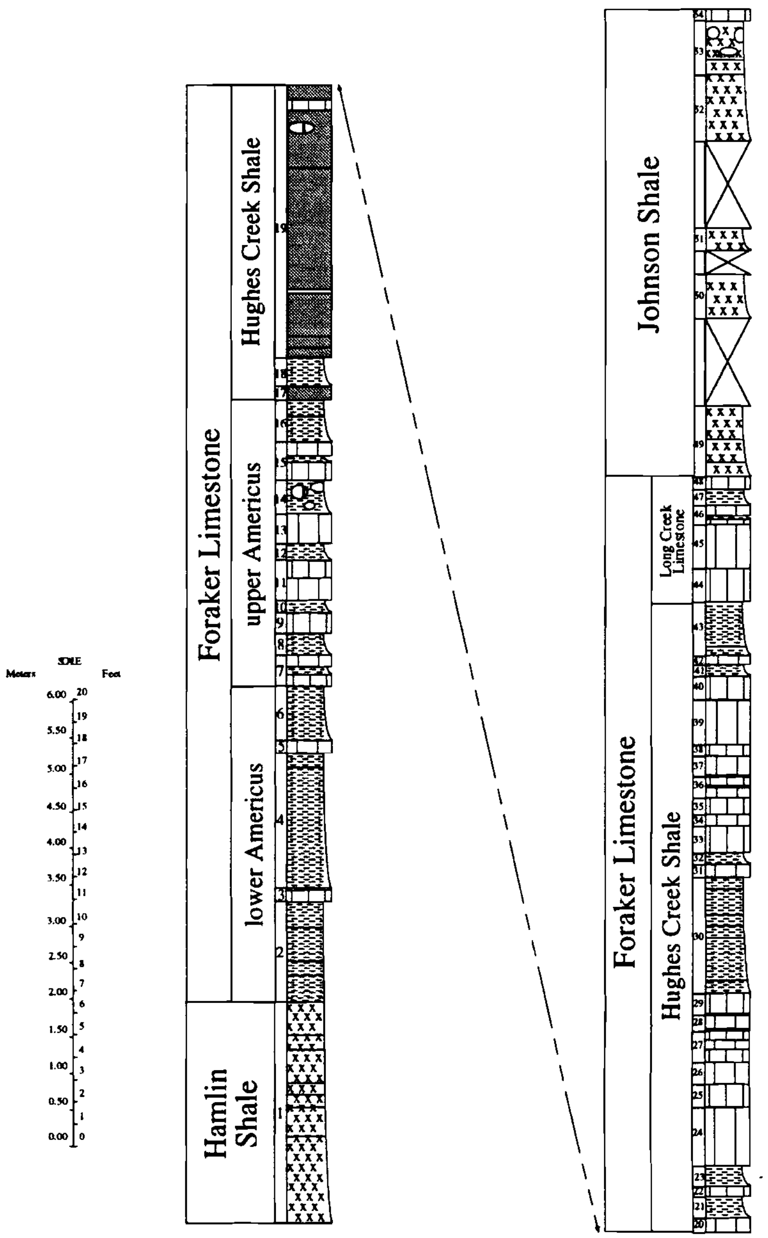


Figure 12

State: Oklahoma **County:** Osage

Locality Description:

This is Oklahoma Geological Survey core hole OC-4. Drilled on the Y Ranch, owned by Dale Kelly.

Interval measured is the Foraker Limestone and Johnson Shale

Burbank Quadrangle: NE NE 24-25N-5E

UNIT DESCRIPTIONS

1	120 inches (3.04 meters)	Hamlin Shale: grayish dusky red to reddish green. top 18 inches is mottled gray and dusky red with caliche.
2	56 inches (1.42 meters)	Lower Americus: medium gray to medium dark gray limy shale, blocky in areas, top 14 inches is calcareous.
3	4 inches (.10 meters)	Lower Americus: medium gray, limestone, abundant brachiopods.
	.5 inch (.01 meter)	Lower Americus: reddish brown thin shale
4	67 inches (1.70 meters)	Lower Americus: medium gray limestone, slightly brownish, banded, top 28 inches calcite viens, blocky.
	7 inches (.18 meters)	Lower Americus: dark gray calcareous shale
5	5 inches (.13 meters)	Lower Americus: medium to medium dark gray limestone, brachiopods, crinoids.
6	31 inches (.79 meters)	Lower Americus: grayish black calcareous shale
7	5 inches (.13 meters)	Upper Americus: dark gray limestone, brachiopods.
	3 inches (.08 meters)	Upper Americus: grayish black shale.
	5 inches (.13 meters)	Upper Americus: dark gray limestone, extremely clean.
8	12 inches (.30 meters)	Upper Americus: fissile black shale, lower 3 inches somewhat limy, brachiopods.
9	10 inches (.25 meters)	Upper Americus: medium dark gray limestone.

10	7 inches (.18 meters)	Upper Americus: medium dark gray shale, brachiopods.
11	13 inches (.33 meters)	Upper Americus: medium dark gray limestone, some fusulinids.
	9 inches (.23 meters)	Upper Americus: dark gray limestone, large crinoids, abundant fusulinids.
12	7 inches (.18 meters)	Upper Americus: medium gray shale, fusulinids.
13	14 inches (.36 meters)	Upper Americus: medium gray limestone, crinoids, abundant fusulinids.
14	20 inches (.51 meters)	Upper Americus: dark gray to blackish calcareous shale with limestone nodules, crinoids, top inch is dark gray calcareous shale.
15	10 inches (.25 meters)	Upper Americus: dark gray limestone, crinoids, brachiopods.
	4 inches (.10 meters)	Upper Americus: medium gray calcareous shale
	7 inches (.18 meters)	Upper Americus: dark gray limestone, crinoids, brachiopods.
16	13 inches (.33 meters)	Hughes Creek Shale: grayish black calcareous shale, brachiopods, crinoids.
	7 inches (.18 meters)	Hughes Creek Shale: medium dark gray fissile shale.
17	8 inches (.20 meters)	Hughes Creek Shale: sandy shale
18	15 inches (.38 meters)	Hughes Creek Shale: medium dadrk gray shale, brachiopods.
19	142 inches (3.61 meters)	Hughes Creek Shale: light yellow gray sandy shale mixture, predominantly sand. top 24 inches fairly clean sandstone.
	4 inches (.10 meters)	Hughes Creek Shale: medium dark gray limestone
	11 inches (.28 meters)	Hughes Creek Shale: light yellowish gray sandstone.
20	6 inches (.15 meters)	Hughes Creek Shale : medium dark gray limestone.
21	12 inches (.30 meters)	Hughes Creek Shale : medium to medium dark gray shale, brachiopods and fusulinids.
22	3 inches (.08 meters)	Hughes Creek Shale : medium dark gray limestone, fusulinids.

23	13 inches (.33 meters)	Hughes Creek Shale : grayish black shale, crinoids, brachiopods.
24	21 inches (.53 meters)	Hughes Creek Shale : medium to medium dark gray limestone, crinoids, fusulinids, ostracodes. bottom 2 inches abundant fusulinids.
25	12 inches (.30 meters)	Hughes Creek Shale : medium gray limestone, crinoids, fusulinids, thin black shale stringers at top.
26	12 inches (.30 meters)	Hughes Creek Shale : medium light gray limestone, shale stringers, crinoids, fusulinids.
27	24 inches (.61 meters)	Hughes Creek Shale : medium gray to medium dark gray limestone, thin black shale stringers, crinoids, abundant fusulinids.
28	8 inches (.20 meters)	Hughes Creek Shale : medium light gray limestone, fusulinids.
29	9 inches (.23 meters)	Hughes Creek Shale : medium gray slight olive tint, limestone, crinoids and fusulinids.
30	68 inches (1.73 meters)	Hughes Creek Shale : medium gray to medium dark gray calcareous shale. fusulinids at the basal 8 inches and top 8 inches, brachiopods in the middle 52 inches, no fusulinids.
31	6 inches (.15 meters)	Hughes Creek Shale: medium gray to medium dark gray limestone, fusulinids, top 2 inches are burrowed.
32	4 inches (.10 meters)	Long Creek Limestone : medium gray calcareous shale.
33	15 inches (.38 meters)	Long Creek Limestone : medium dark gray limestone, crinoids, fusulinids, ostracode, trilobite.
34	10 inches (.25 meters)	Long Creek Limestone : medium gray limestone, fusulinids, brachiopods, crinoids, some shale stringers.
35	12 inches (.30 meters)	Long Creek Limestone : medium gray limestone, fusulinids, crinoids.
36	6 inches (.15 meters)	Long Creek Limestone : medium gray limestone, fair amount of the mineral pyrite.
	.5 inch (.01 meters)	Long Creek Limestone : thin black shale parting, crinoids.
	2 inches (.05 meters)	Long Creek Limestone : medium gray limestone.
	.5 inch (.01 meters)	Long Creek Limestone : thin black shale parting, fusulinids.

37	12 inches (.30 meters)	Long Creek Limestone : medium gray limestone, some fusulinids near base.
38	7 inches (.18 meters)	Long Creek Limestone : medium gray limestone, abundant fusulinids.
39	25 inches (.64 meters)	Long Creek Limestone : medium dark gray limestone, fusulinids.
40	12 inches (.30 meters)	Long Creek Limestone : medium gray limestone, some fusulinids.
41	6 inches (.15 meters)	Long Creek Limestone : dark gray shale.
42	4 inches (.10 meters)	Long Creek Limestone : dark gray limestone, fusulinids.
43	3 inches (.08 meters)	Long Creek Limestone : black crumbly shale
	30 inches (.76 meters)	Long Creek Limestone : medium dark gray shale, non calcareous. organic remains?
44	19 inches (..48 meters)	Long Creek Limestone : medium gray limestone, small marine fossils (brachiopod) dark shale stringers.
45	24 inches (.61 meters)	Long Creek Limestone : light gray, slight olive gray limestone, ostracodes, crinoids, few fusulinids.
46	2 inches (.05 meters)	Long Creek Limestone : white caliche
	2 inches (.05 meters)	Long Creek Limestone : medium gray shale, crumbly.
	3 inches (.08 meters)	Long Creek Limestone : medium gray limestone.
47	8 inches (.20 meters)	Johnson Shale : gray - green crumbly shale.
48	5 inches (.13 meters)	Johnson Shale : brownish gray limestone, small marine fossils, crinoids.
49	20 inches (.51 meters)	Johnson Shale : grayish green mottled mudstone paleosol.
	22 inches (.56 meters)	Johnson Shale : mottled reddish gray paleosol.
	1 inch (.03 meters)	Johnson Shale : reddish gray paleosol.
50	24 inches (.61 meters)	Johnson Shale : grayish red paleosol.

51	12 inches (.30 meters)	Johnson Shale : grayish red paleosol.
52	36 inches (.91 meters)	Johnson Shale : grayish red paleosol.
53	31 inches (.79 meters)	Johnson Shale : pale grayish orange paleosol, caliche nodules in top 18 inches.
54	5 inches (.13 meters)	Red Eagle Limestone: dark gray - black limestone, brachiopods.

<u>**Principle Reference Section, Red Eagle Limestone**</u>

The current type locality for the Red Eagle Limestone was described by K.C. Heald in 1916. The locality was named for excellent exposures near the Red Eagle School southwest of Foraker. However the only measured section given by Heald (1916) is on a tributary of Hay Creek, a quarter of a mile east of corner of sections 1, 2, 11, and 12, T.26N., R.5E.. The section, according to Heald, is all limestone, varied in color, fossil content and lithology, measuring 16 feet 6 inches (5.03 meters).

Currently numerous attempts to locate and sample this locality have failed. As a result a new locality a principle reference section for the Red Eagle Limestone is proposed adjacent to the town of Burbank, Osage County, Oklahoma (figure 13). The new locality provides easily located and measured sections of the Red Eagle. (figure 14, photos 14-32) The bounding paleosols of the Red Eagle sequence (Johnson Shale and Roca Shale) are exposed, allowing for a complete and accurate measurement of the Red Eagle Limestone to be made. In addition two cores have been made available by the Oklahoma Geological Survey to serve as references (figures 15, 16)

The Red Eagle Limestone along with the upper Johnson Shale comprises a single transgressive-regressive stratigraphic sequence complete with marine condensed sections. The rise and fall of sea-level responsible for the strata deposited is a result of periodic glaciations.

The basal 17 feet 4 inches (5.19 meters) of the Johnson Shale is predominantly reddish to green blocky mudstone. This is capped by a 4 inch (.10 meters) <u>Chonited</u> lag deposit, and 15 inches (.38 meters) of gray shale. The basal 10 inches (.25 meters) of the Red Eagle Limestone is tightly interbedded gray shale and thin limestones topped by a 38 inch (.96

meters) algal (phylloidal) limestone. Above is 25 inches of predominantly limestone, with four thin gray shale partings. The upper 24 feet 4 inches (7.33 meters) is mostly medium gray wackestone although two small gray shale partings

exist. The Red Eagle is capped by the Roca Shale a 16 feet 4 inches (5 meters) thick red blocky mudstone, to red fissile shale.

The stratigraphic column has been interpreted in this manner; The Red Eagle Sequence is bounded at the base by a blocky red mudstone, identified as a paleosol, evidenced by root traces and caliche nodules.

An initial marine transgression in the Johnson Shale then deposits a thick fossiliferous shale, thin lenticular limestones interbedded with shales, a carbonate lag deposit, and a fossiliferous shale capped by a thin *Chonited* lag deposit.

At this point there is a maximum transgression of sea-level in the Red Eagle Limestone resulting in a thin marine condensed section with glauconite, phosphate and offshore marine *Streptognathodus* conodont fauna. The *Streptognathodus nodulinearis* and *flagulatus* (in Russian sense) identified in this condensed section is correletable with the conodont fauna at the base of the Permian at the type Permian locality in Kazakhstan, Soviet Union. A rapid regression occurs depositing a thick cabonate, in shallow marine conditions as evidenced by the abundance of phylloid algae. A second, thicker, maximum transgression occurs with the distinct marine condensed section characteristics; glauconite, phosphate, and deep marine *Streptognathodus* conodonts.

The rock above the upper marine condensed section consists entirely of fossiliferous shallow marine carbonates. In some sections they appear as limy shales, however they consist of greater than 2/3 limestone.

The sequence is capped by the Roca Shale, a blocky red shale, paleosol evidenced by root traces and caliche nodules.

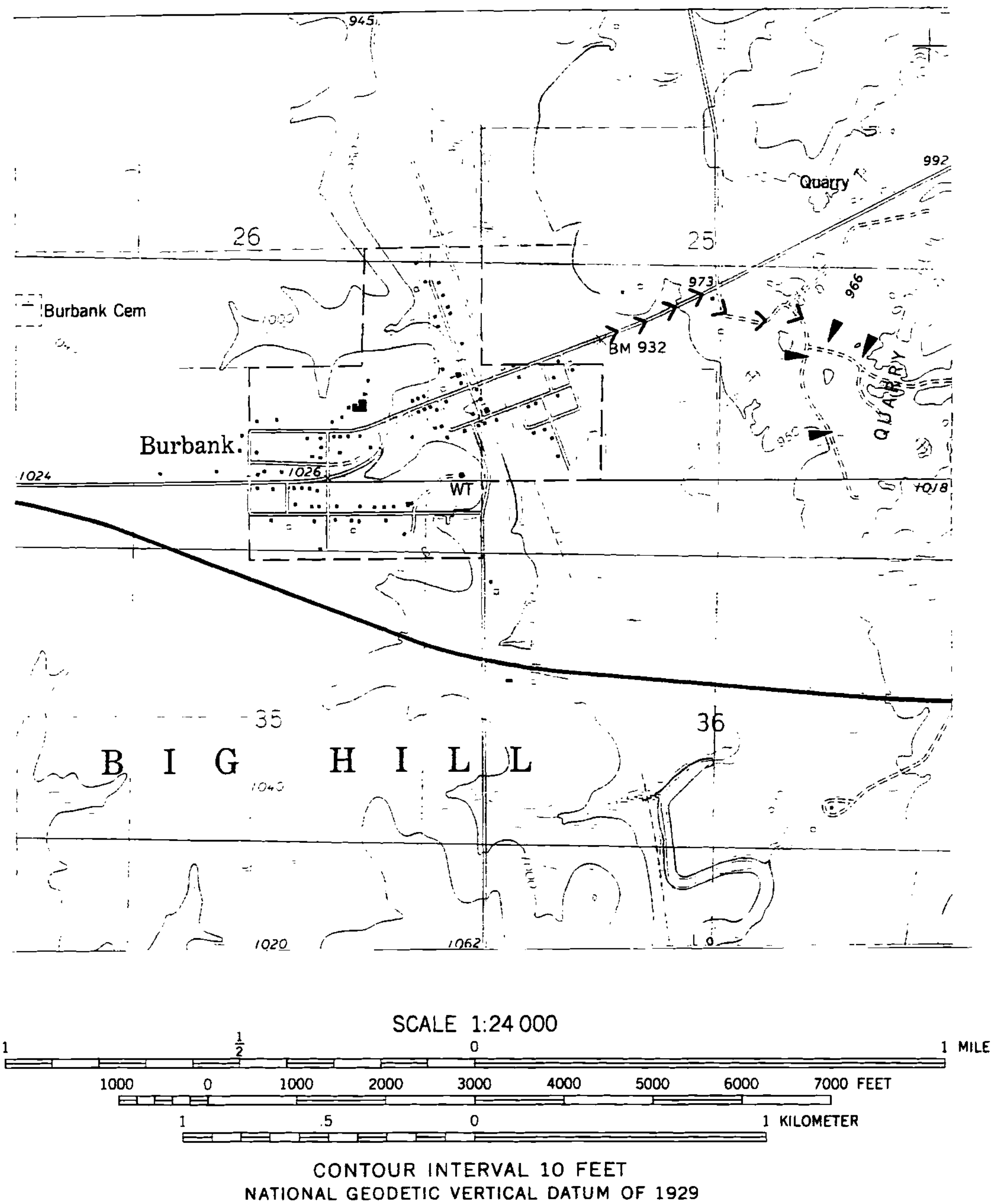


Figure 13
Topographic map showing locality of Burbank Quarry, proposed Principle Reference Section for the Red Eagle Limestone.

Red Eagle Limestone
Principle Reference Section
Measured Section

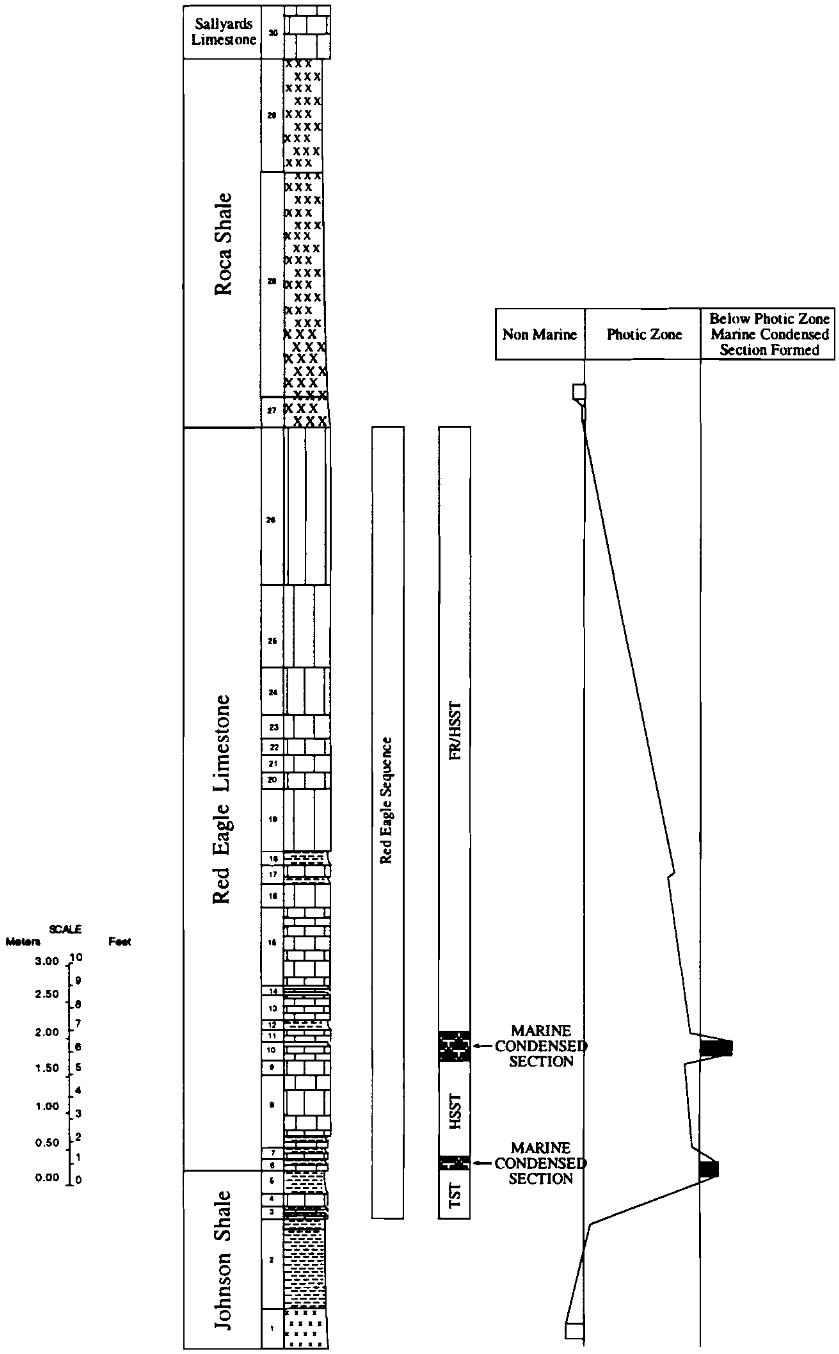


Figure 14

State: Oklahoma **County:** Osage

Locality Description:

Location is the Burbank Quarry in Burbank Oklahoma. The section measured is from the Johnson Shale through the Roca Shale.

Burbank quadrangle T26N R5E, SE1/4 Section 25

Interval measured is the Johnson shale, Red Eagle limestone, and Roca shale.

UNIT DESCRIPTIONS

1	162 inches (4.1 meters)	Johnson Shale: grayish-red to blackish red shale; paleosol.
2	37 inches (.94 meters)	Johnson Shale: grayish yellow at the bottom to a yellowish gray shale near the top.
3	1.5 inches (.04 meters)	Johnson Shale: medium gray lenticular limestone.
	2 inches (.05 meters)	Johnson Shale: greenish-gray shale.
	1 inch (.03 meters)	Johnson Shale: medium gray lenticular limestone.
	1 inch (.03 meters)	Johnson Shale: greenish-tan shale.
4	4 inches (.10 meters)	Johnson Shale: medium-gray lenticular limestone, abundant debris, lag deposit.
5	13 inches (.33 meters)	Johnson Shale: greenish-gray shale.
	2 inches (.05 meters)	Johnson Shale: medium light gray shale *Chonetid* brachiopods, lag deposit.
6	2 inches (.06 meters)	Red Eagle Limestone: medium dark gray limestone weathers very pale orange, crinoids, abundant brachiopods, marine condensed section, glauconite, phosphate, abundant *Streptognathodus* conodonts, wackestone.
7	1.5 inches (.04 meters)	Red Eagle Limestone: green-gray shale.
	3 inches (.08 meters)	Red Eagle Limestone: gray limestone, wackestone
	1 inch	Red Eagle Limestone: green-gray shale.

	(.03 meters)	
	1.5 inches (.04 meters)	Red Eagle Limestone: light olive gray to medium light gray limestone, wackestone, algae, large amounts of recrystallized calcite, brachiopods.
	2 inches (.05 meters)	Red Eagle Limestone: light to medium gray shale.
8	34 inches (.86 meters)	Red Eagle Limestone: medium light to light olive gray limestone, algae, weathers irregular, brachiopods, crinoids, large amounts of recrystallized calcite, bryozoa, algal wackestone.
9	4 inches (.10 meters)	Red Eagle Limestone: medium light to light olive gray limestone, phylloidal algae, calcite recrystallization, brachiopods, crinoid, bryozoa, ostracode, hematite, *Adetognathus* conodont, algal wackestone.
10	3.5 inches (.09 meters)	Red Eagle Limestone: medium gray, limestone, weathers to a pale grayish orange, crinoids, brachiopods, bivalves, rare fusulinids, ostracodes, glauconite, phosphate, abundant *Streptognathodus* conodonts, packstone.
	2 inches (.05 meters)	Red Eagle Limestone: medium gray shale, marine condensed section.
11	4 inches (.10 meters)	Red Eagle Limestone: medium light gray shale, fusulinids, brachiopods, bivalve, bryozoa, echinoderm, ostracode, trilobite, glauconite, phosphate, abundant *Streptognathodus* conodonts. packstone.
12	1.5 inches (.04 meters)	Red Eagle Limestone: medium light gray shale.
13	5 inches (.13 meters)	Red Eagle Limestone: medium to medium light gray limestone, weathers pale grayish orange, brachiopods, ostracodes, algae, foraminifera, bivalve, wackestone.
	5 inches (.13 meters)	Red Eagle Limestone: medium light gray limy shale, crinoids, brachiopods, fusulinids, coral, ostracode, algae, wackestone
14	4 inches (.10 meters)	Red Eagle Limestone: light gray to medium light gray limy shale, weathers pale grayish orange, calcification evident, phylloidal algae, brachiopods, crinoids, bryozoa, *Diplognathodus* conodont, wackestone.
15	11 inches (.28 meters)	Red Eagle Limestone: medium light gray limestone, weathers grayish orange, crinoids, brachiopods

		bryozoa, algae, ostracode, *Streptognathodus*. wackestone.
	12.5 inches (.32 meters)	Red Eagle Limestone: medium light gray shale.
	18 inches (.46 meters)	Red Eagle Limestone: medium to medium light gray limestone, brachiopods, bryozoa, algae, *Diplognathodus* conodonts. wackestone.
16	20.5 inches (.52 meters)	Red Eagle Limestone: medium light gray to medium gray limestone, weathers very pale orange, brachiopods, corals, foraminifera, crinoids, trilobite, echinoderm, bryozoa, small amount hematite. wackestone
17	3 inches (.08 meters)	Red Eagle Limestone: medium gray limy shale, crinoids, brachiopods.
	5 inches (.13 meters)	Red Eagle Limestone: light to medium light gray limestone, crinoids, brachiopods, bryozoa, ostracode, echinoderm, wackestone.
18	6 inches (.15 meters)	Red Eagle Limestone: medium light gray limy shale crinoids, brachiopods, coral, ostracode, hematite, wackestone.
19	33.5 inches (.85 meters)	Red Eagle Limestone: medium light gray limestone, brachiopods, ostracodes, echinoderms, bryozoa, crinoids, hematite, *Diplognathodus* conodont, wackestone.
20	10.5 inches (.27 meters)	Red Eagle Limestone: medium light gray limy shale, bryozoa, brachiopod, crinoid, hematite, wackestone.
21	6 inches (.15 meters)	Red Eagle Limestone: medium light gray limestone, echinoderm, bryozoa, foraminifera, hematite, wackestone.
22	6 inches (.15 meters)	Red Eagle Limestone: medium light gray limy shale.
23	14 inches (.36 meters)	Red Eagle Limestone: medium to medium light gray limestone, crinoids. wackestone
24	22 inches (.56 meters)	Red Eagle Limestone: light gray limestone, bryozoa, ostracodes, brachiopods, crinoid, foraminifera, wackestone.
25	43.5 inches (1.10 meters)	Red Eagle Limestone: light to medium light gray limestone, brachiopod, crinoid, bryozoa, ostracode, hematite, wackestone.
26	83 inches (2.11 meters)	Red Eagle Limestone: light to medium light gray limestone, massive, brachiopod, crinoid, echinoderm, bivalve, ostracode, wackestone.

27	16 inches (.41 meters)	Roca Shale: light gray-green shale, blocky mudstone.
28	123 inches (3.12 meters)	Roca Shale: dusky red to very dusky red shale.
29	58 inches (1.47 meters)	Roca Shale: light brown to green shale.
30	26 inches (.66 meters)	Sallyards Limestone: light gray green limestone

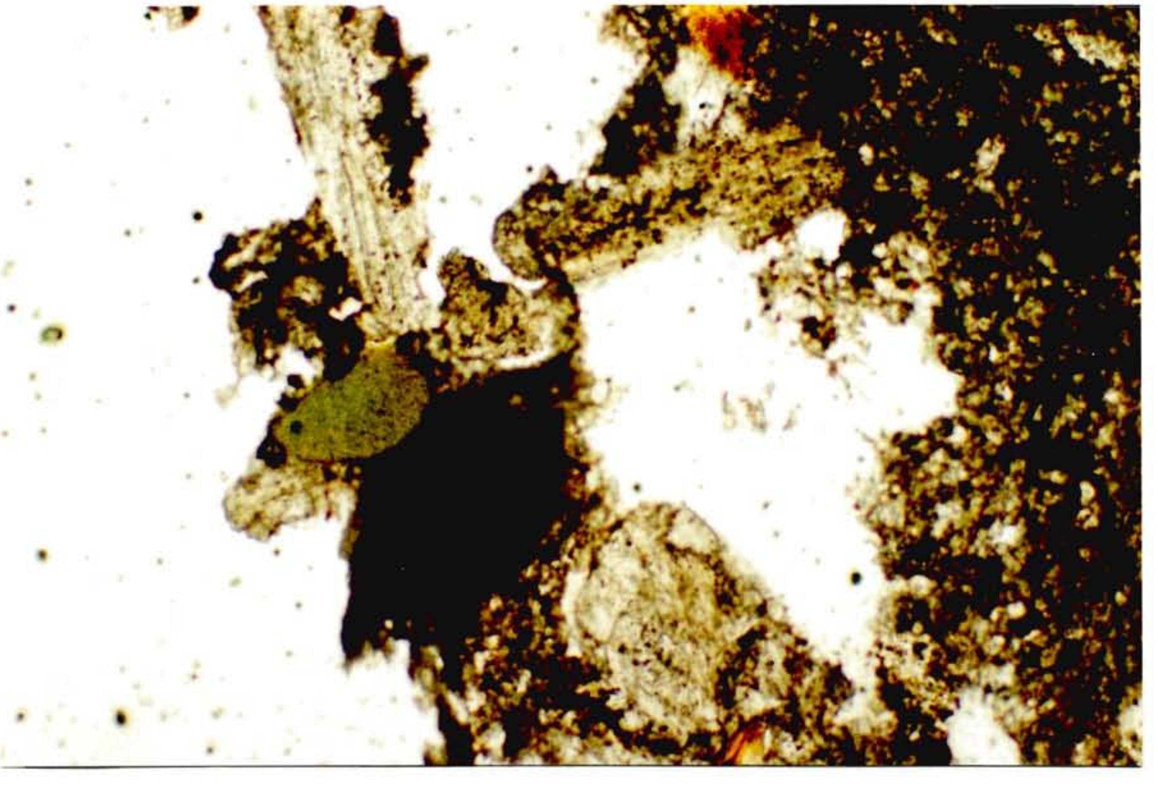


Photo 14

Burbank Quarry Red Eagle Limestone

Marine condensed section, measured section unit 6, phosphate appears as the amber/caramel grains, glauconite is the green grain near the center, wackestone.

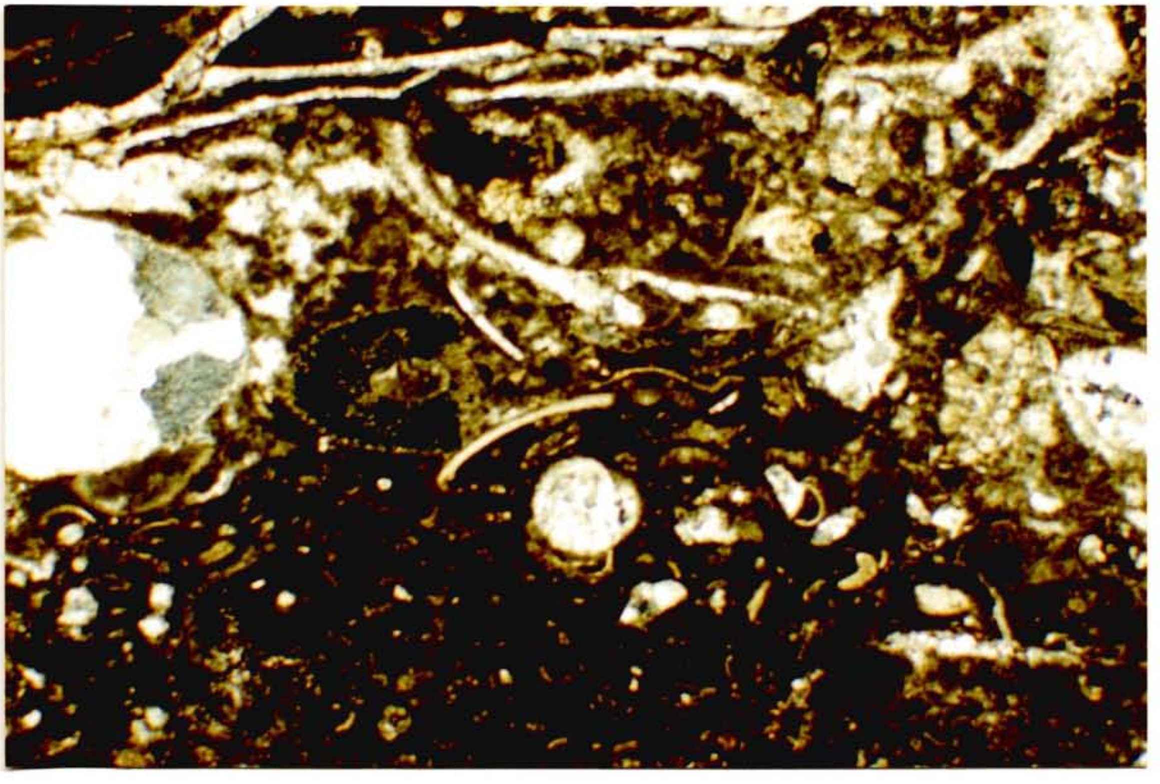


Photo 15

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 8, fossil assemblage includes echinoderm, ostracode, brachiopod, and coral.

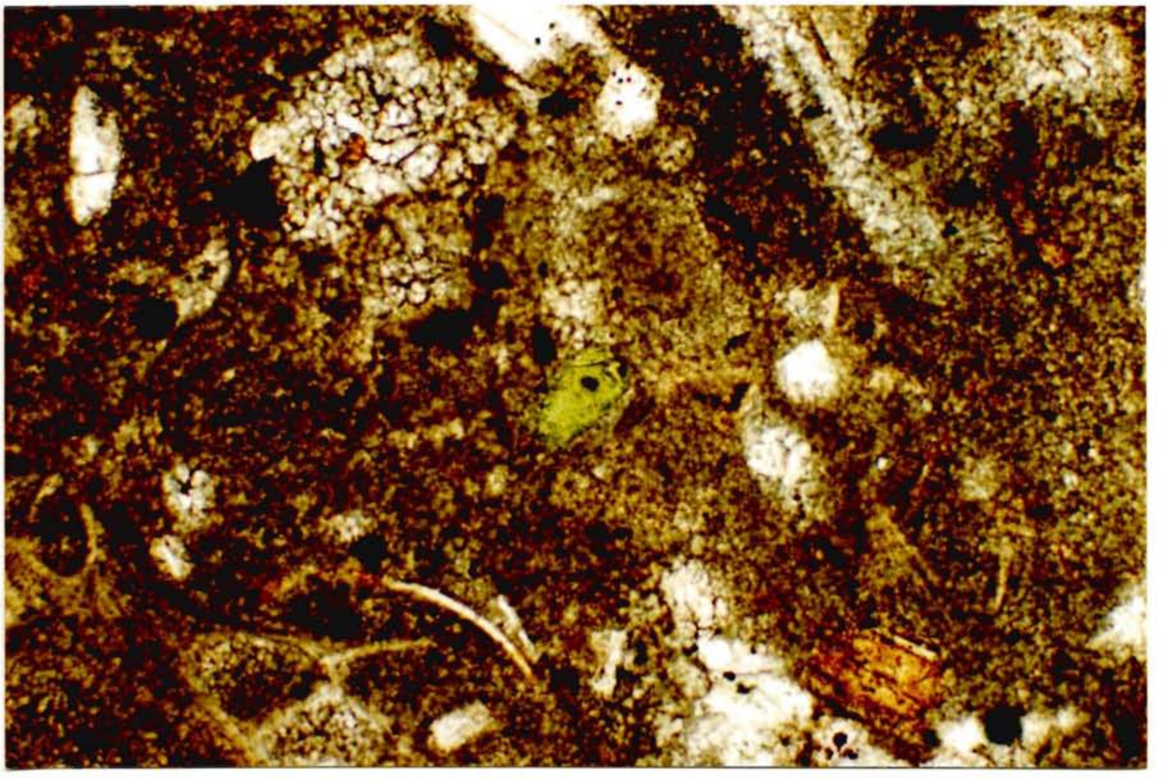


Photo 16

Burbank Quarry Red Eagle Limestone

Marine condensed section, measured section unit 11, phosphate is the amber/caramel grain, glauconite is the green grain (center), echinoderm fragments, wackestone.

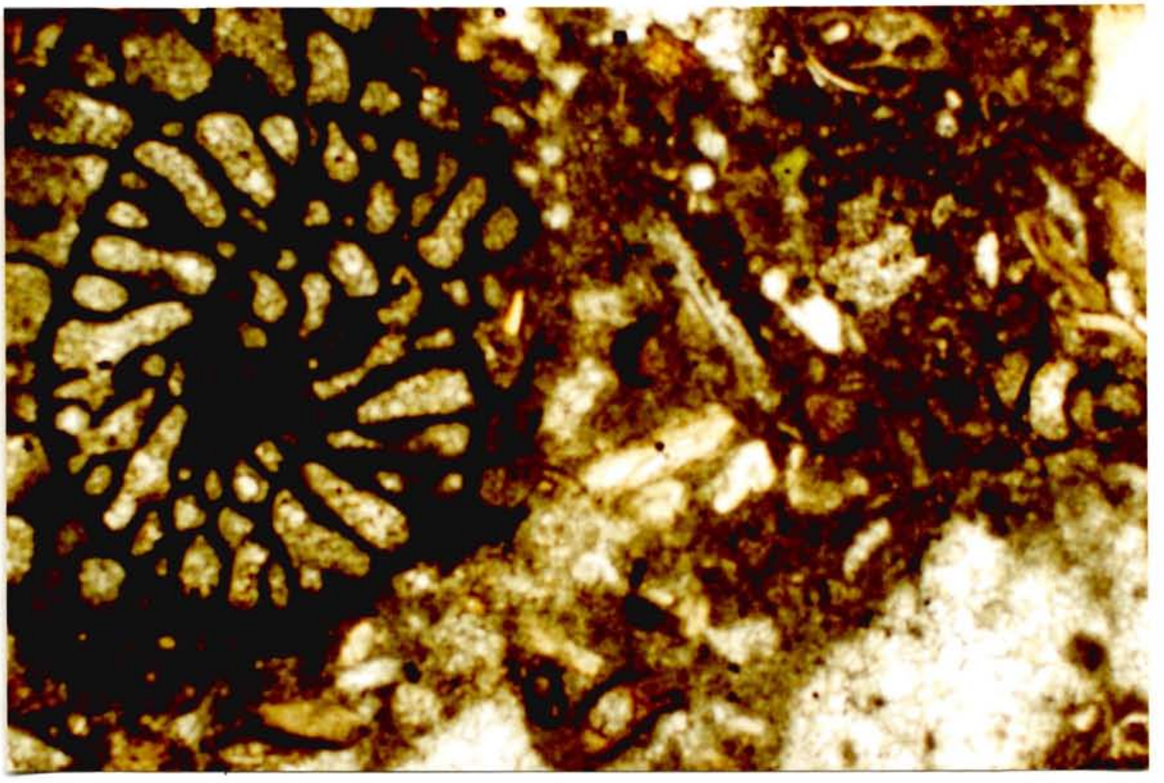


Photo 17

Burbank Quarry Red Eagle Limestone

Marine condensed section, measured section unit 11, phosphate is the amber/caramel grain, glauconite is the green grain, echinoderm, fusulinid, and foraminifera are also present, wackestone.

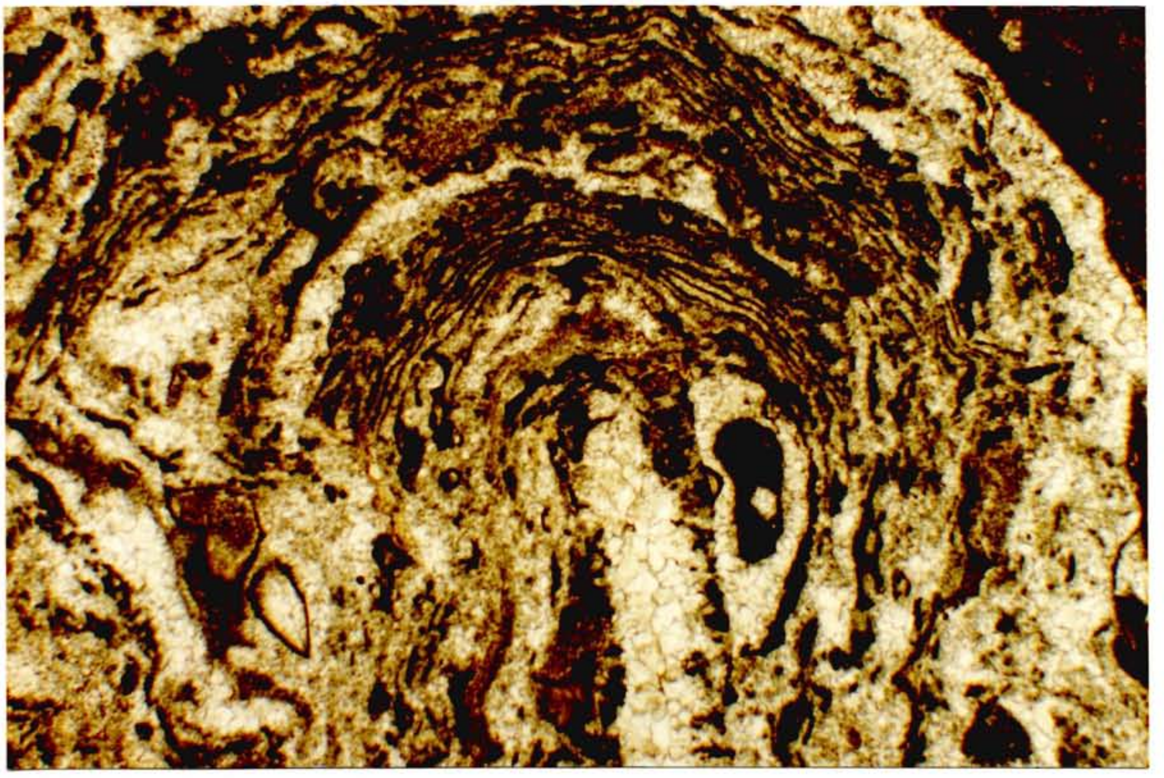


Photo 18

Burbank Quarry Red Eagle Limestone

Wackestone, algal (pictured), measured section unit 12.

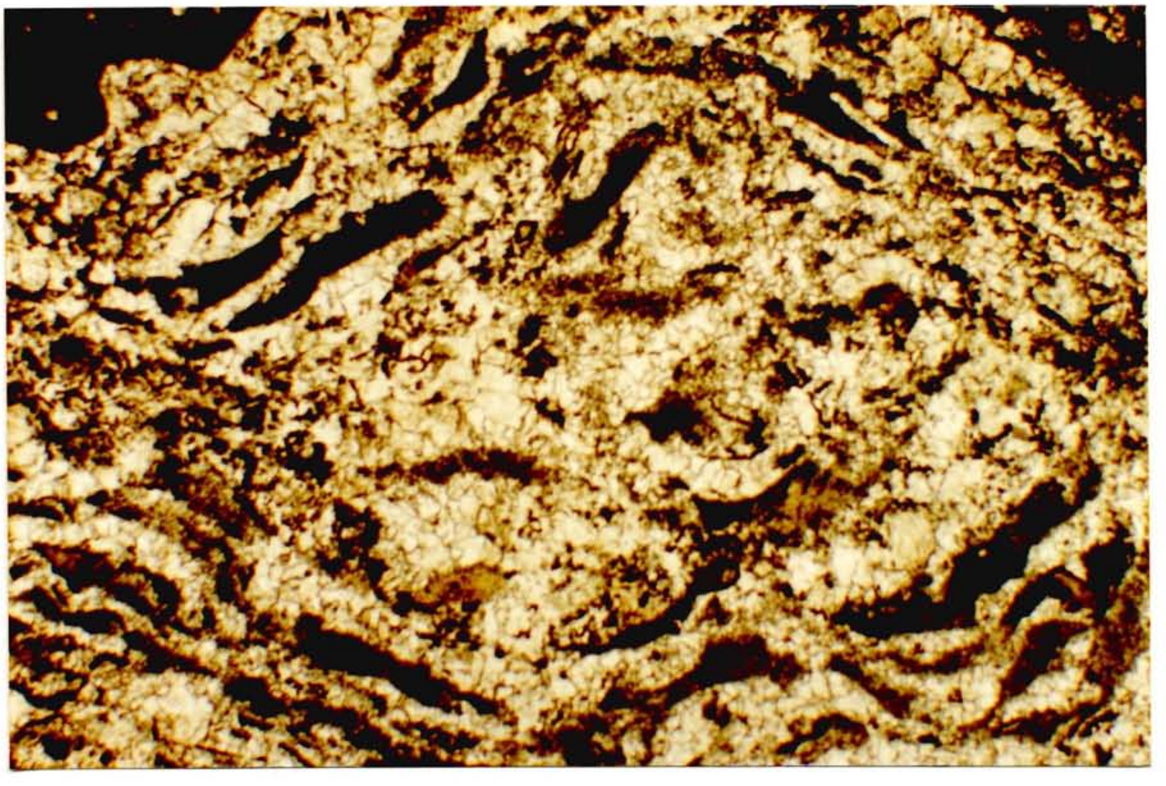


Photo 19

Burbank Quarry Red Eagle Limestone

Wackestone, algal (pictured), measured section unit 13.

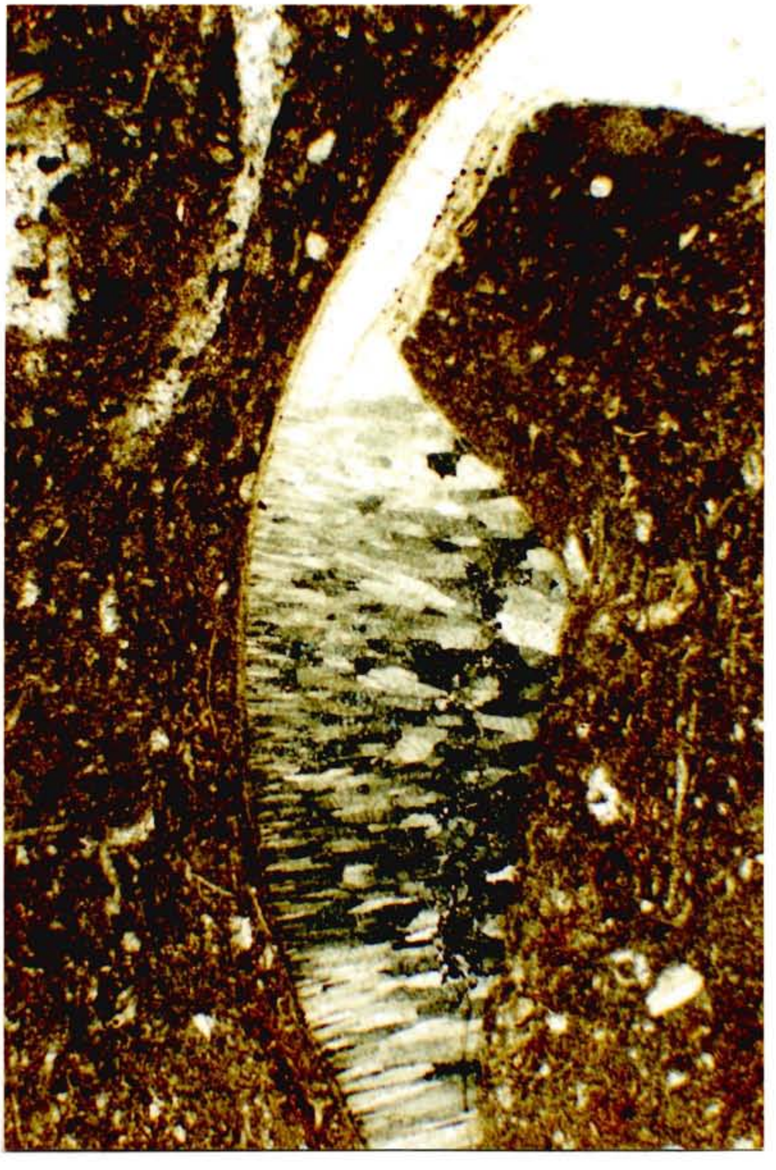


Photo 20

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 15, brachiopod.

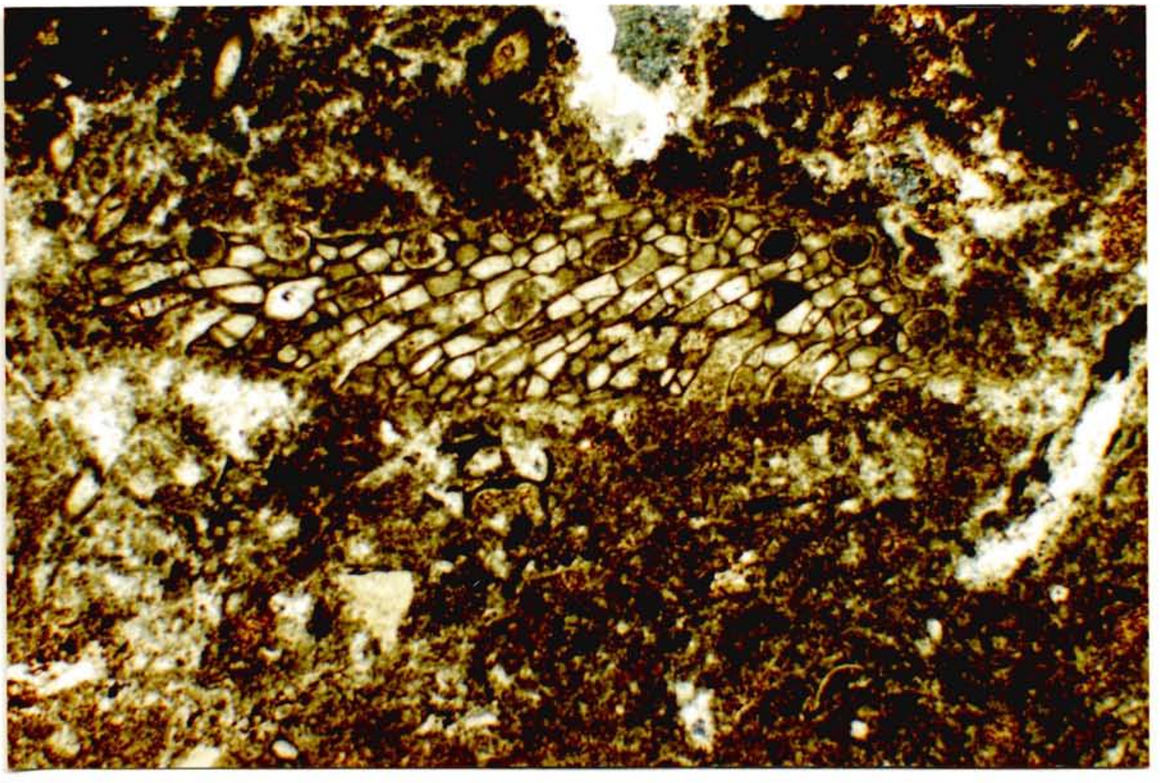


Photo 21

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 16, fossil content includes coral (center), ostracode, and echinoderm fragments.

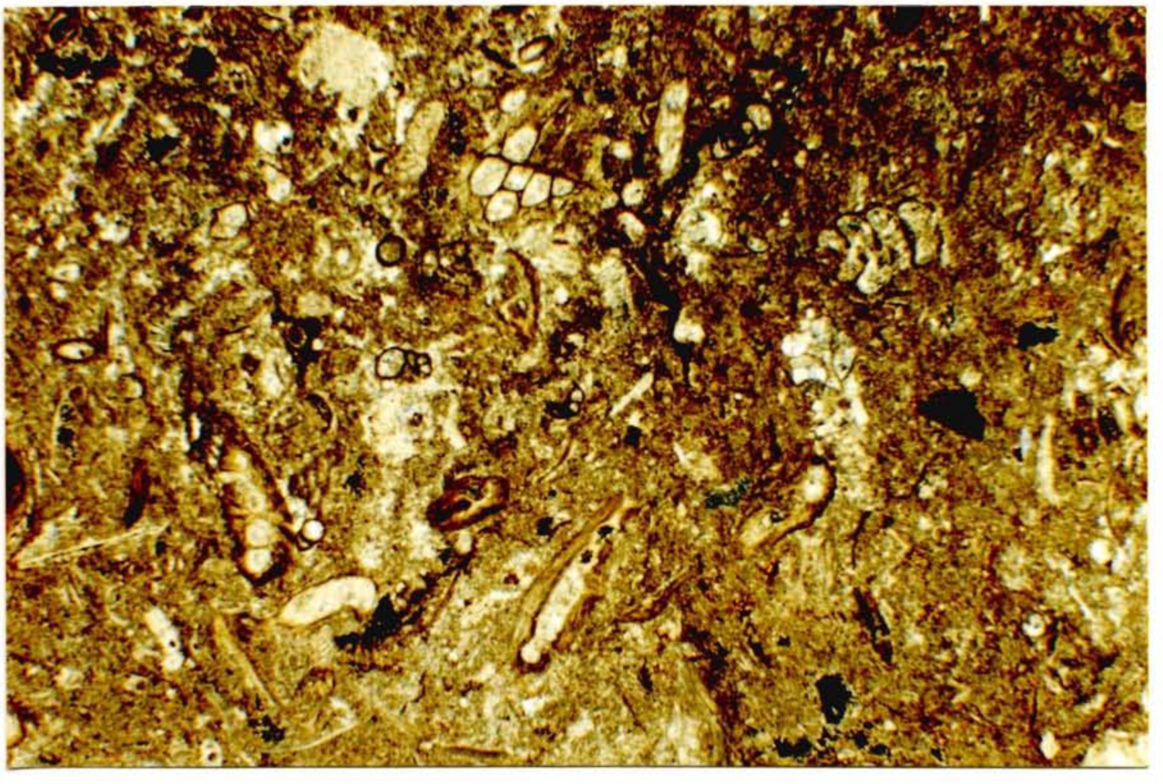


Photo 22

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 17, fossil content includes coral, ostracode, foraminifera, and echinoderm fragments.

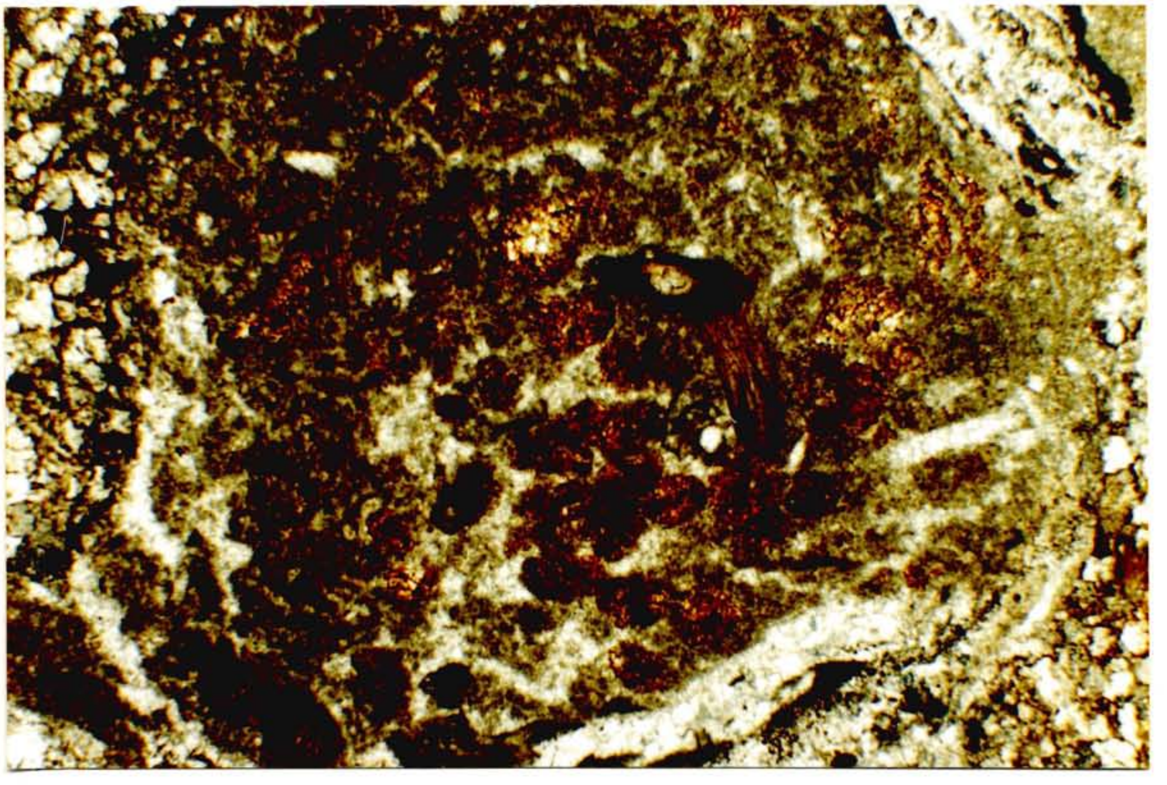


Photo 23

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 19, fossil content includes coral, bryozoa (center), and echinoderm fragments, reddish color in center is hematite.

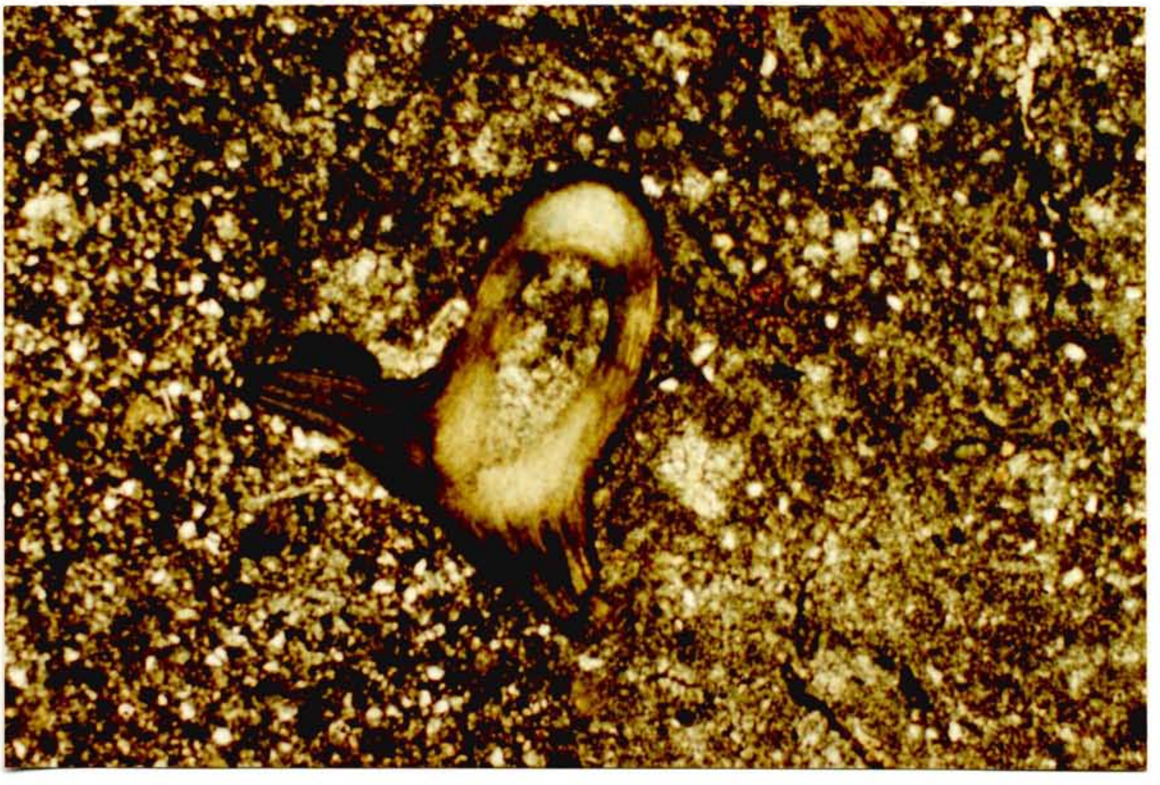


Photo 24

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 21, bryozoa (center).

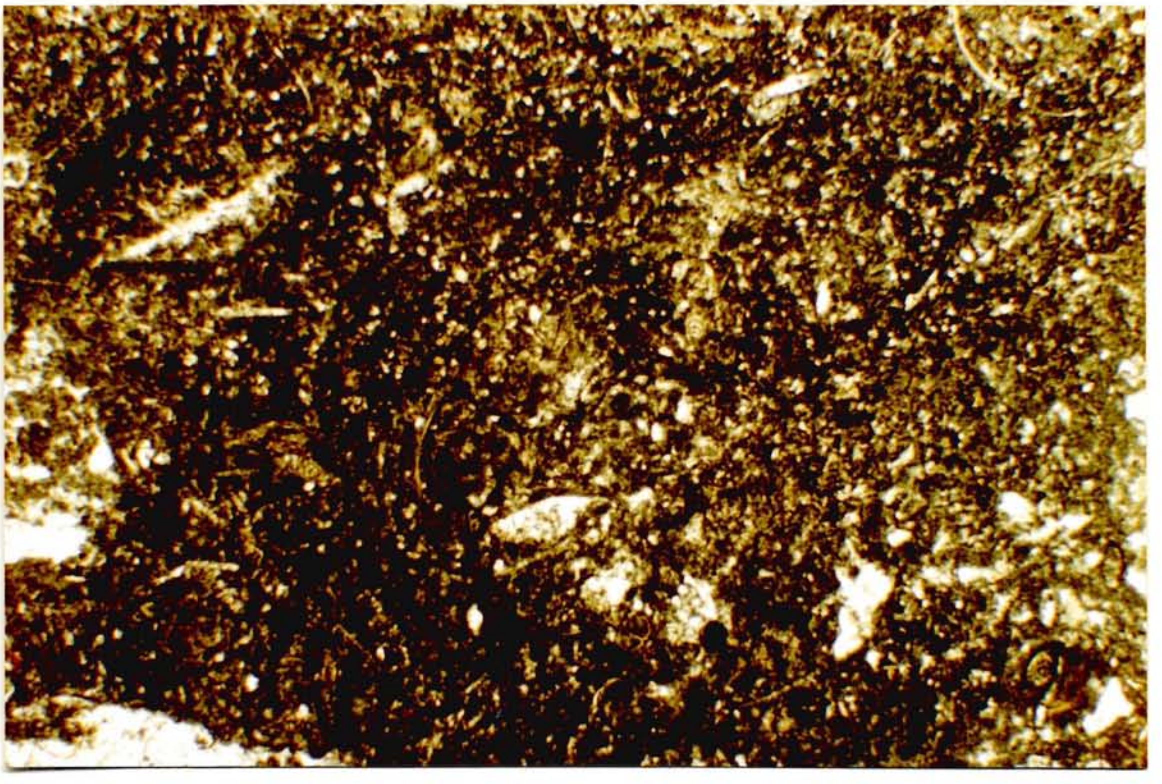


Photo 25

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 23, ostracode and echinoderm fossil remains.

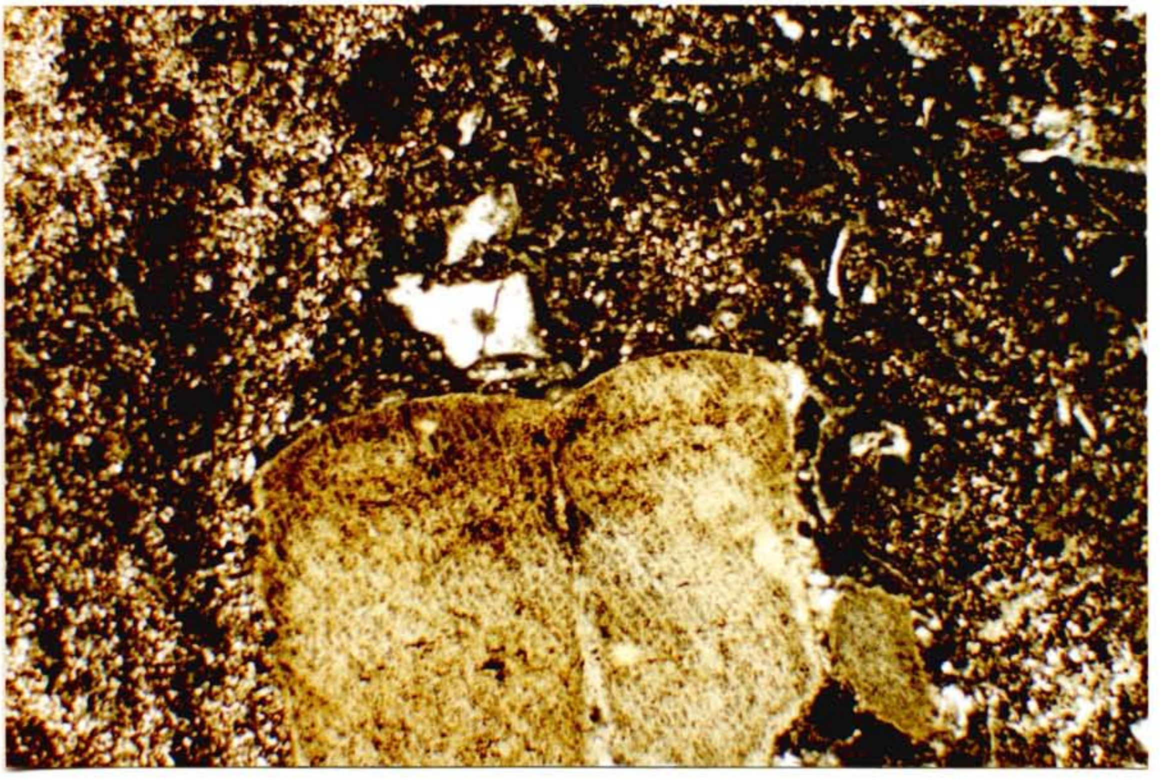


Photo 26

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 25, large echinoderm (crinoid).

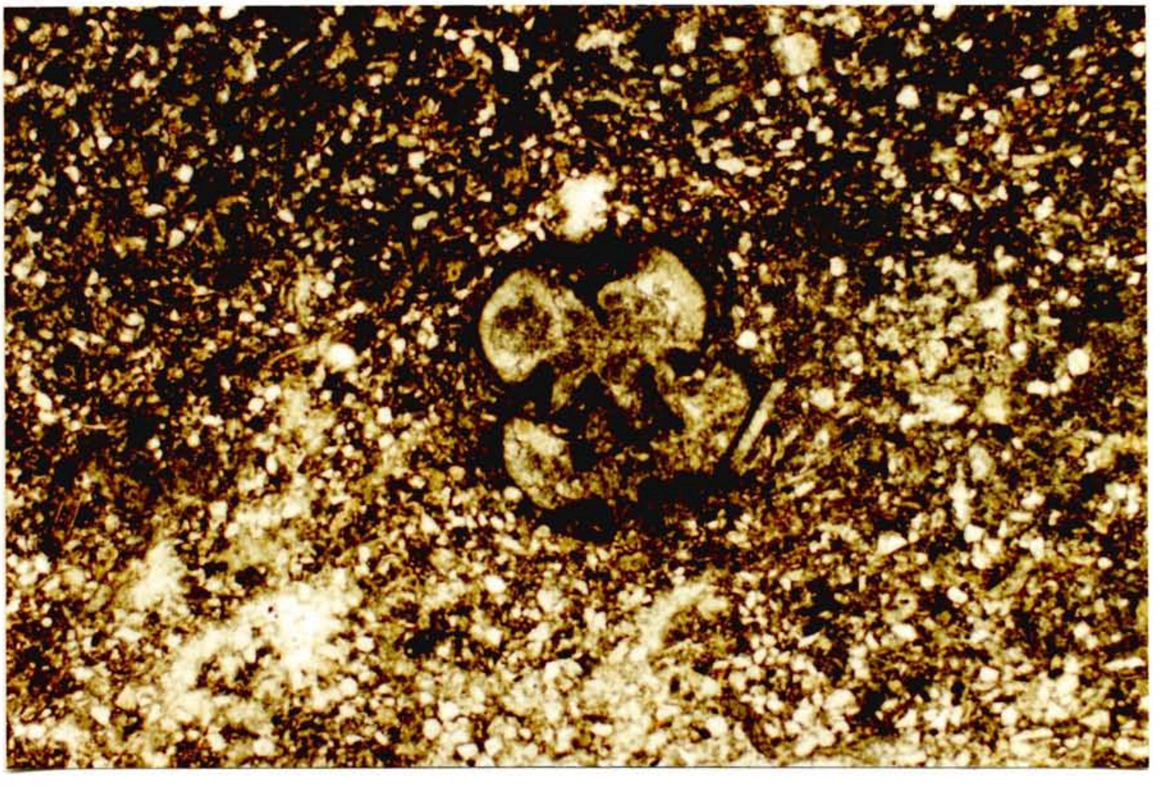


Photo 27

Burbank Quarry Red Eagle Limestone

Wackestone, measured section unit 26, echinoderm (center).

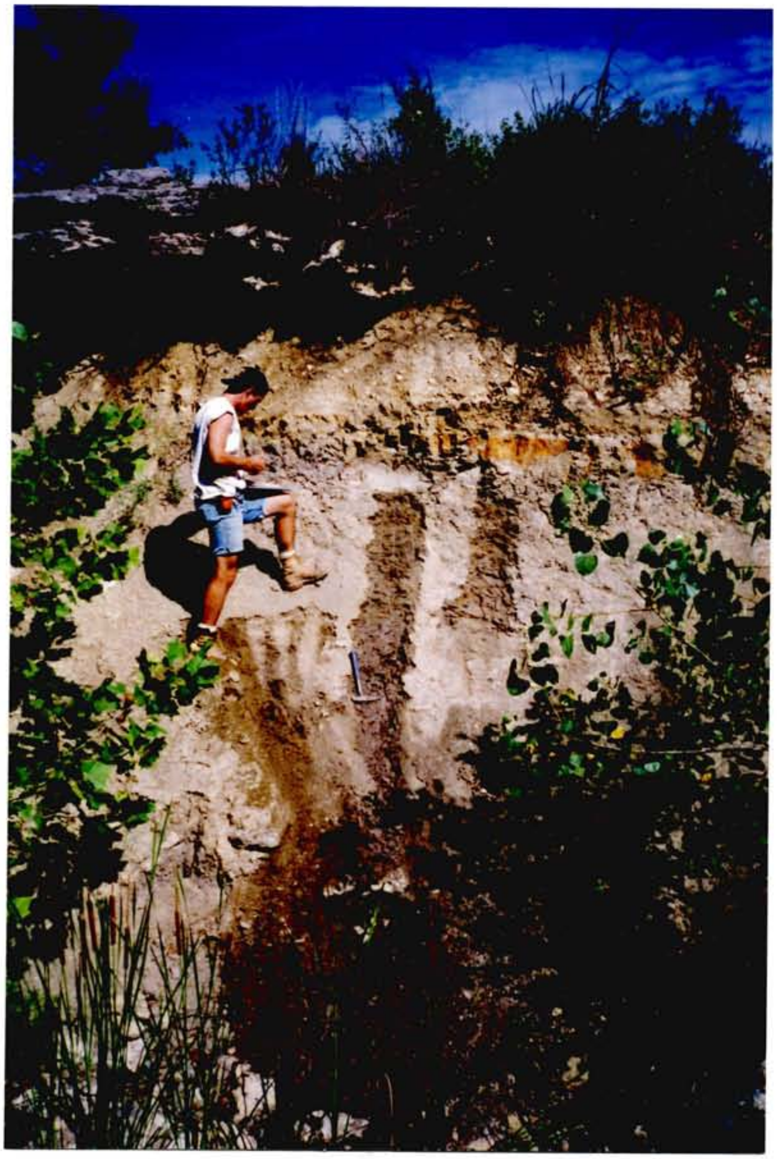


Photo 28

Burbank Quarry Johnson Shale

Taken along stream in quarry, Hammer indicates contact of red and gray shale, upper limestone ledge is the Red Eagle Limestone.

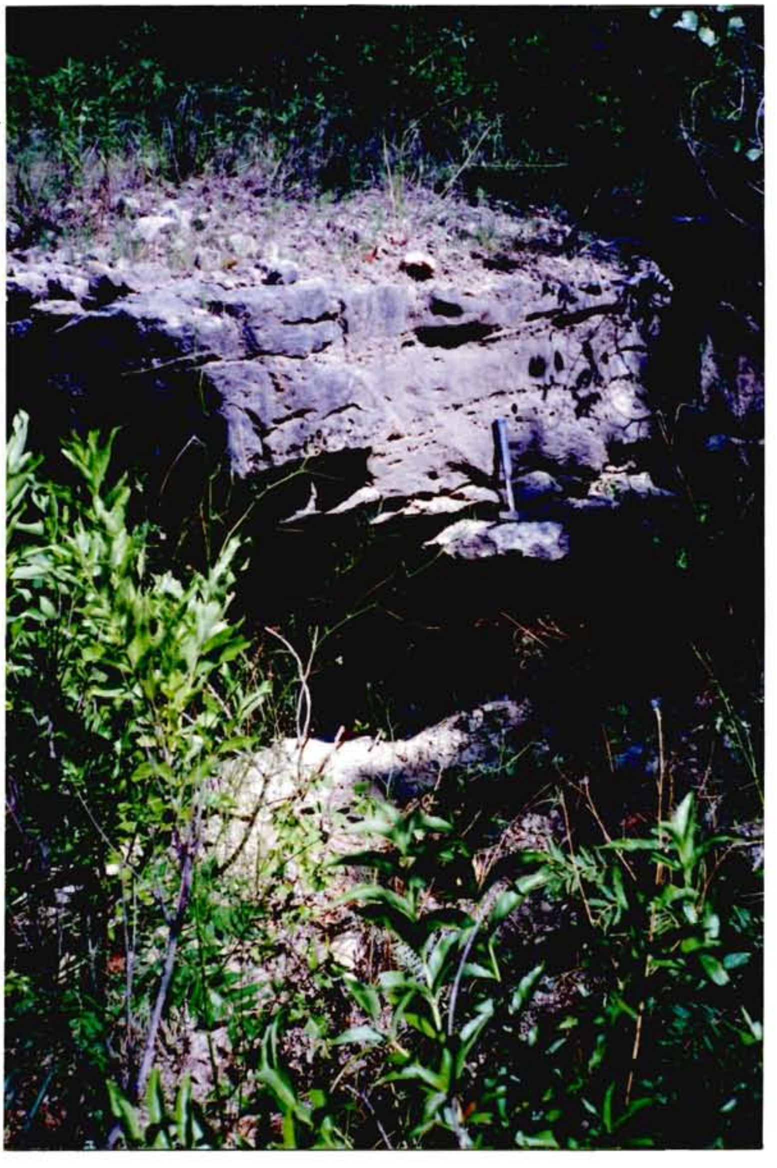


Photo 29

Burbank Quarry Red Eagle Limestone

Taken along stream in quarry, next to dirt road, Massive limestone is the Red Eagle Limestone (measured section description unit 7), the shale below is the Johnson Shale.

Photo 30

Burbank Quarry Red Eagle Limestone

Taken along dirt road, Hammer indicates measured section description units 14-15.

Photo 31

Burbank Quarry   Red Eagle Limestone

Taken along dirt road, Hammer indicates measured section description unit 22.

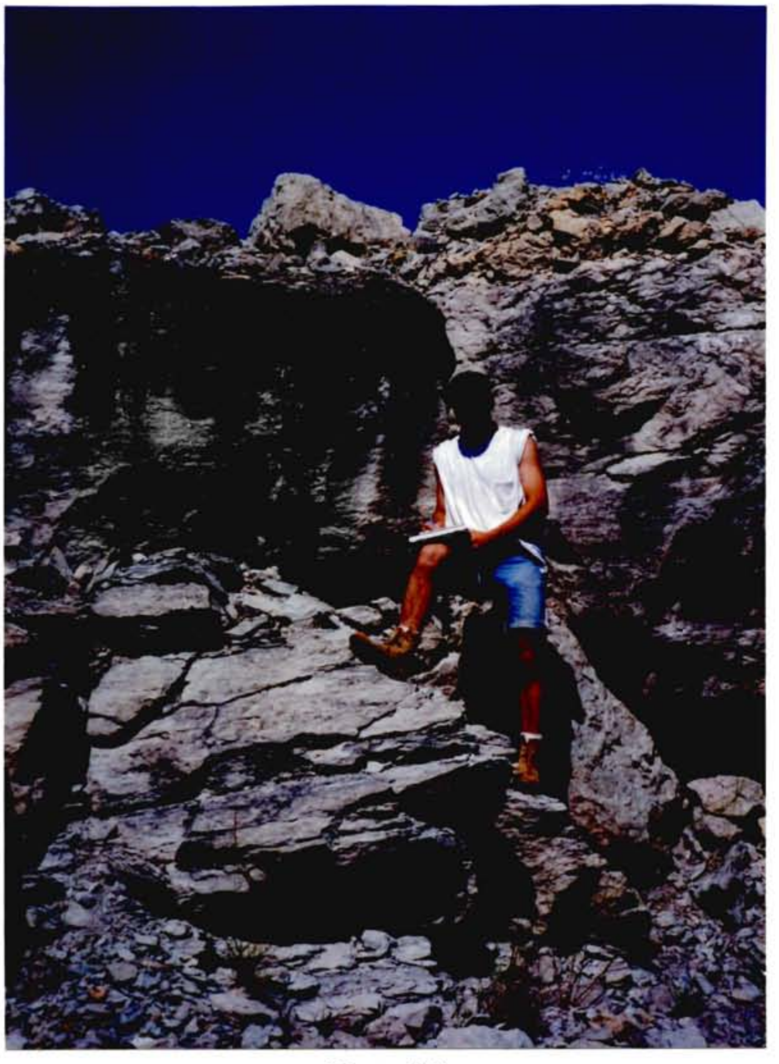


Photo 32

Burbank Quarry Red Eagle Limestone

Taken along dirt road, Massive limestone block behind author is the uppermost Red Eagle Limestone, measured section description unit 26.

Core OC-1 Measured Section

Red Eagle Limestone

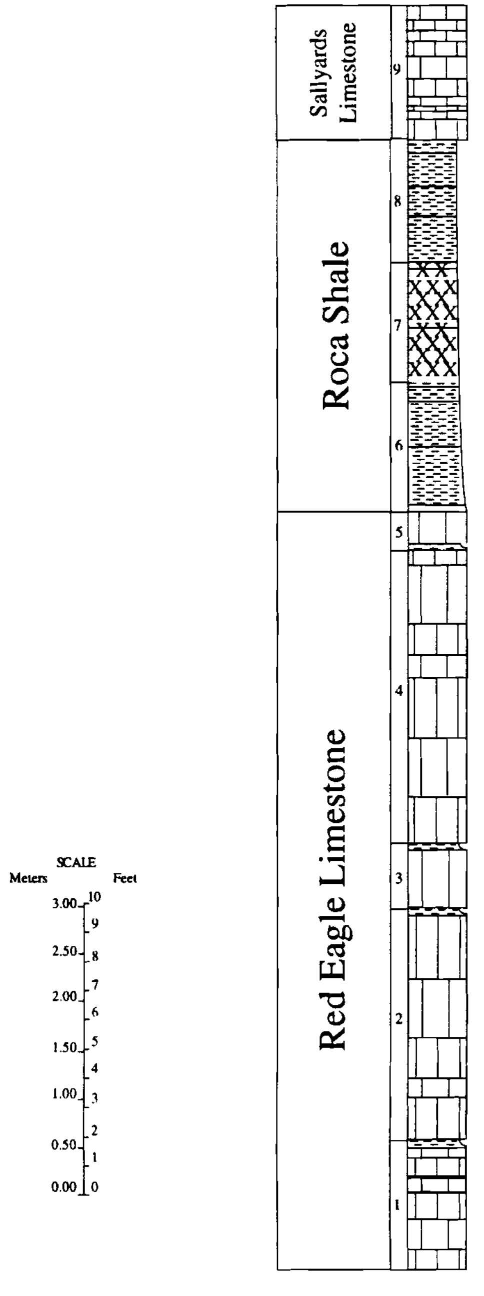


Figure 15

State: Oklahoma **County:** Osage

Locality Description:

The measured section is Oklahoma Geological Survey core OC-1, drilled on the Paul Kelly Ranch .

Grainola quadrangle: SW SW NE 21-29N-6E

Interval measured is from the Red Eagle Limestone to the Sallyards Limestone.

UNIT DESCRIPTIONS

1	54 inches (1.37 meters)	Red Eagle Limestone: medium gray limestone, fusulinids, brachiopods, crinoids.
	2 inches (.05 meters)	Red Eagle Limestone: dark gray shale
2	93 inches (2.36 meters)	Red Eagle Limestone: gray limestone, bioturbated, brachiopods, pyrite, algal coated grains, fusulinids.
	1 inch (.03 meters)	Red Eagle Limestone: fissile black shale, fossil fragments.
3	25 inches (.64 meters)	Red Eagle Limestone: very light gray limestone, brachiopods.
	1 inch (.03 meters)	Red Eagle Limestone: medium gray calcareous shale
4	127 inches (3.23 meters)	Red Eagle Limestone: very light gray limestone, brachiopods, ostracodes, pyrite, some algal coated grains.
5	1 inch (.03 meters)	Red Eagle Limestone: greenish gray shale
	13 inches (.33 meters)	Red Eagle Limestone: light gray to white limestone.
6	50 inches (1.27 meters)	Roca Shale: medium gray slightly green, blocky mudstone to shale.
7	56 inches (1.42 meters)	Roca Shale: blackish red to dusky red blocky mudstone, basal somewhat shaly.
8	50 inches (1.27 meters)	Roca Shale: medium gray blocky mudstone to shale, crumbly.
9	42 inches (1.06 meters)	Sallyards Limestone: medium gray limestone, brachiopods, crinoids, fusulinids, some algal coated grains.

Core OC-3 Measured Section

Red Eagle Limestone

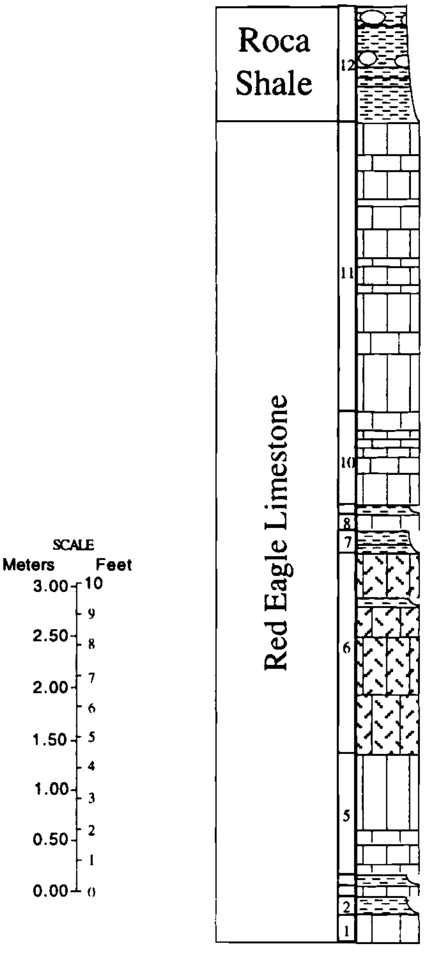


Figure 16

State: Oklahoma **County:** Osage

Locality Description:

The measured section is Oklahoma Geological Survey core OC-3 .

Interval measured is from the Red Eagle Limestone to the Roca Shale.

UNIT DESCRIPTIONS

1	11 inches (.28 meters)	Red Eagle Limestone: grayish black limestone, brachiopods abundant.
2	7 inches (.18 meters)	Red Eagle Limestone: medium gray shale, top 2 inches is full of chonited brachiopods.
3	4 inches (.10 meters)	Red Eagle Limestone: medium gray limestone, fusulinids, brachiopods, crinoids.
4	3 inches	Red Eagle Limestone: grayish black shale.
5	41 inches (1.04 meters)	Red Eagle Limestone: medium gray limestone, basal is bioturbated, with solitary corals, upper has crinoids, brachiopods, trilobite.
6	86 inches (2.18 meters)	Red Eagle Limestone: olive gray limestone, extremely algal.
7	11 inches (.28 meters)	Red Eagle Limestone: dark gray shale, crinoids.
8	7 inches (.18 meters)	Red Eagle Limestone: medium dark gray limestone, top is bioturbated.
9	3 inches (.08 meters)	Red Eagle Limestone: grayish black limy shale
10	44 inches (1.18 meters)	Red Eagle Limestone: medium gray limestone, fusulinid, crinoid, bioturbated.
11	106 inches (2.69 meters)	Red Eagle Limestone: medium gray to light olive gray limestone, places bioturbated, crinoids, corals, sparse fusulinids.
12	42 inches 1.07 meters)	Roca Shale: red to dusky red blocky mudstone, caliche nodules.

Lithostratigraphy

Foraker Limestone

The Foraker Limestone was named by Heald (1916) for exposures in Ekler Canyon, Osage County Oklahoma.

> "The Foraker Limestone, which forms the rim of Ekler Canyon and is prominent along the line of bluffs in the eastern part of the quadrangle, is about 74 feet thick. Although the great part of this thickness is made up of limestone, much of the rock is so soft and thin bedded as to give no outcrop. Some soft shale is also present. The heavy limestone may be easily recognized by the large number of Fusulinas which it contains, the rock in places being fairly jammed with them. Another distinguishing mark is the great abundance of chert concretions which occur in this limestone. The fresh surface of the chert has in general a light blue-gray color, and the concretions usually include fossils which show white against a bluish background. The most common fossil in the chert is Fusulina secalica Say, but there are also small brachiopods and a few corals and crinoid stems."

Along with his description, Heald provided a generalized stratigraphic column showing the Foraker Limestone, in which he recognized no divisions (figure 17).

The Foraker Limestone is currently divided into three members. In ascending order they are the Americus Limestone Member, The Hughes Creek Shale Member, and the Long Creek Limestone Member.

Americus Limestone Member

The Americus Limestone name was proposed by Kirk in 1896, for exposures near Americus, Lyon County Kansas. He described the rock as "2 thin beds of limestone separated by about 4 feet of shale." The Kansas

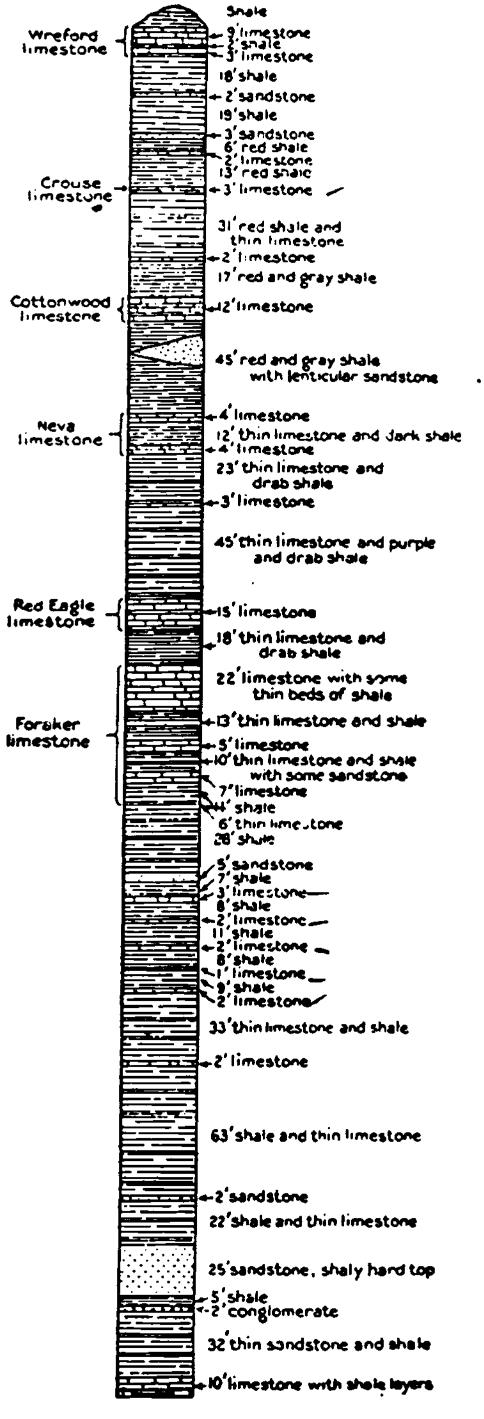


Figure 17
Generalized stratigraphic column of the Foraker Limestone (Heald 1916).

Geological Survey has followed this definition of the limits of the Americus Limestone (Mudge and Yochelson, 1962 p.30).

A thorough description of the Americus Limestone was done by Mudge and Yochelson (the units referred to correspond to those in figure 18). The Americus Limestone units 3 and 5 were grouped because locally they form one bed of limestone. In Kansas the two limestone beds are generally separated by a thin shale, also the Houchen Creek Limestone Member coalesces with the lower (unit 3) limestone of the Americus. The thickness of the Americus varies due to the lenticular nature of the shale in units 2 and 4. North of Lyon County there is an average thickness of 4 feet, to the south it averages about 12 feet. (Mudge and Yochelson 1962)

In addition to the description of the Americus several remarks were made concerning the shale parting (unit 4). The shale can vary from clayey to silty, the southern portion the shale contains numerous fusulinids, north of Greenwood County fossils were rare.

The Hughes Creek Shale Member

The Hughes Creek Shale was named by Condra in 1927, with this type description.

> "*Hughes Creek Shale, named from Hughes Creek, Nemaha County, Nebraska; formed of blue argillaceous shale, dark shales,* and thin limestones; combined thickness 35 to 50 feet; in three zones, the top one formed of three sub zones at places.
>
> Although the zones of this unit persist quite uniformly in the Nebraska sections, they are less regular in Kansas. The lowest zone (C) is formed of bluish shale and thin limy seams which carry some fossils. Its thickness is 10 feet or more. Next above (zone B) are four or five dark gray, earthy, thin fossiliferous limestones and interbedded shales with a combined thickness of 12 to 20 feet. Its upper shales carry Orbiculoidea missourensis, Chonetes granulifer,

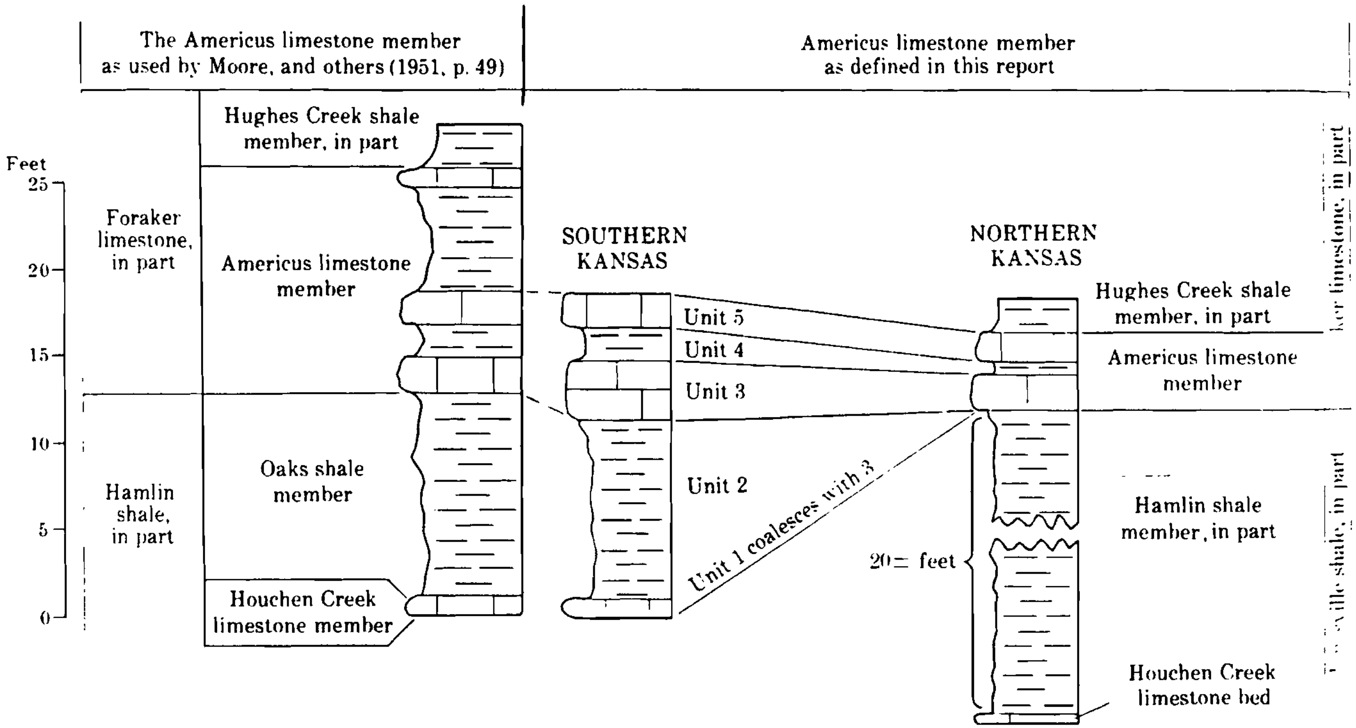


Figure 18
Americus Limestone Member as described by Mudge and Yochelson (1962).

> and other brachiopods. The limestones have a few bryozoa and brachiopods and at places in Kansas are nearly filled with Fusulina.
> The top zone (A), where typical is formed from the base upward of three sub-zones, as follows: Six feet or more of bluish, argillaceous shale with very fossiliferous calcareous seams above the middle; about 2 feet of thin arenaceous-limy, fossiliferous seams separated by blue shale; and 10 to 12 feet or more of bluish to dark argillaceous shale. The lower sub-zone has a distinctive persistent fauna in the calcareous seams. This has been of assistance in correlation. It is rich in large Fusulina, bryozoa and brachiopods. The genera Thamniscus, Meekopora, Septora, Fenestella, Polypora, Rhombopora, Stenopora, Chonetes, Productus, Spirifer, Spiriferina, Composita and Hustedia are represented by abundant specimens. The second sub-zone has many productus cora, Echinoid spines, and Bryozoa. (Condra, 1927, p.85)

Mudge and Yochelson added insight to the trends of the Hughes Creek, noting that to the north (Brown County) is about 92 percent shale and 8 percent limestone, to the south (Cowley County) it is 35 percent shale and 65 percent limestone (figure 19). The shales vary from silty to clayey, and generally are thin-bedded (Mudge and Yochelson). The Hughes Creek Shale Member thickens south of Lyons County, where the units 2 and 4 are 10 and 12 feet thick respectively. The appearance of thin blue chert beds is also an exclusively southern feature (Mudge and Yochelson p.33).

<u>**Long Creek Limestone Member**</u>

The Long Creek Limestone was named by Condra in 1927.

> "Long Creek Limestone, named from exposures on Longs Creek, at the foot of the bluff west of the cemetery at Auburn, Nemaha County, Nebraska; stone usually weathered buff to yellowish, somewhat cavernous and irregular; thickness 2 to 7 feet, averaging about 4 feet. This unit usually carries small geodes and a few fossils representing bryozoa, brachiopods, and two or more genera of pelecypods." (G.E. Condra, 1927, p.86)

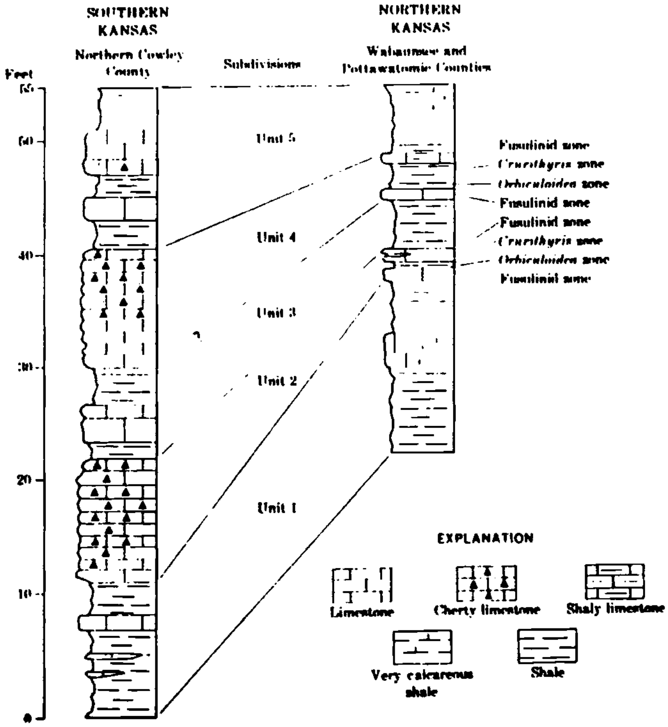


Figure 19
Hughes Creek Shale Member as described by Mudge and Yochelson (1962).

Later it was recognized, also by Condra, as the uppermost member of the Foraker Limestone in 1935.

Mudge and Yochelson studied the Long Creek Limestone, citing it is "distinctly tan to gray orange and generally soft and massive" characteristics. They also state that massive limestones are in the northern outcrops, the southern outcrops are not easily identified because they contain a large amount of shale (Mudge and Yochelson 1962, p.36). These shales vary from silty to clayey, and are gray to olive. Limestones of the Long Creek also vary from thin to massive beds, most being slightly dolomitic, with secondary calcite, quartz, and celestite (Mudge and Yochelson 1962).

Johnson Shale

The Johnson Shale was named by Condra in 1927. A generalized stratigraphic column of the Johnson Shale and Red Eagle Limestone was published along with the following description.

> "From exposures 1 and 1/2 miles north of Johnson, Johnson County, Nebraska; formed of bluish argillaceous shale modified by thin, grayish, sandy layers, calcareous plates, and some gypsiferous material, and geodes; thickness 16 to 18 feet. There are very few fossils." (Condra, 1927, p.86)

Mudge and Yochelson added further to the Johnson Shale, noting that in the southern Counties, Elk and Cowley the Johnson has numerous thin limestone beds that pinch out northward along with decreasing fossil content (1962). The northern exposures of the Johnson Shale tend to be silty and/or clayey while the southern outcrops exhibit an increase in limestone stringers and ledges. The Johnson Shale generally contains red to maroon fissile shales, blocky mudstones and siltstones. These red "zones" commonly contain caliche nodules and root traces. The maximum thickness of the entire Johnson Shale is roughly 25 feet (7.62 meters) in Wabaunsee and Riley Counties, it thins both to the north and to the south.

Red Eagle Limestone

In 1916 the Red Eagle was described and named by K.C. Heald. Heald named the limestone after "excellent" exposures near the Red Eagle School, southwest of Foraker in Osage County Oklahoma. Heald described the Red Eagle as

> ". . a number of distinct beds of limestone, between which are beds of shale in some localities. One of the most distinctive features of the top bed of limestone in much of the quadrangle is the character of the fresh surface, which shows an abundance of tiny grains of crystalline calcite, giving the surface the appearance of having been covered with frost or light snow."
> (Heald 1916, p.24)

While no measured section was given for the exposures near the Red Eagle School, Heald (1916) presented a measured section (figure 20) for exposures in the southwest part of the quadrangle along a tributary of Hay Creek. "At this locality there are no shale partings, but the limestone varies in character. The thickness of the several members is estimated." (Heald 1916).

G.E. Condra named the individual members of the Red Eagle Limestone (figure 21); Glenrock Limestone,

> "Glenrock Limestone, named from exposures high in the valley side just northwest of Glenrock, Nemaha County, Nebraska; dark gray, dense, weathering light gray or slightly buff; thickness 1 to 2 feet. This forms rectangular blocks. The leading fossils are Fusulina, bryozoa, brachiopods, and Pinna sp." (Condra, 1927, p.86)

Section of Red Eagle limestone on tributary of Hay Creek, a quarter of a mile east of corner of secs. 1, 2, 11, and 12, T. 26 N., R. 5 E.

	Ft.	In.
Limestone, gray, thin bedded, slabby, clayey	3	9
Limestone, creamy buff on weathered surface, medium hard; breaks easily but is not glassy brittle; fossiliferous; lower part of bed has much limonite	1	0
Limestone, thin bedded, blocky rather than slabby, light gray, brittle, hard, fossiliferous	4	0
Limestone, dove-gray on fresh surface, massive, clean, hard, brittle, fossiliferous; good bed to burn	1	6
Limestone, dove-gray, pure; makes persistent bed but weathers back under overlying bed		3
Limestone, thin bedded, rough, slabby, whitish gray on weathered surface, blue-gray on fresh surface; in part good limestone, in part rather clayey; fossiliferous (corals, productids)	4	0
Limestone, pigeon-blue on weathered surface, brownish gray on fresh surface, much limonitized; does not weather rough; fossiliferous; medium hard	2	0
	16	6

Figure 20
Hay Creek measured section of the Red Eagle LImestone (Heald1916).

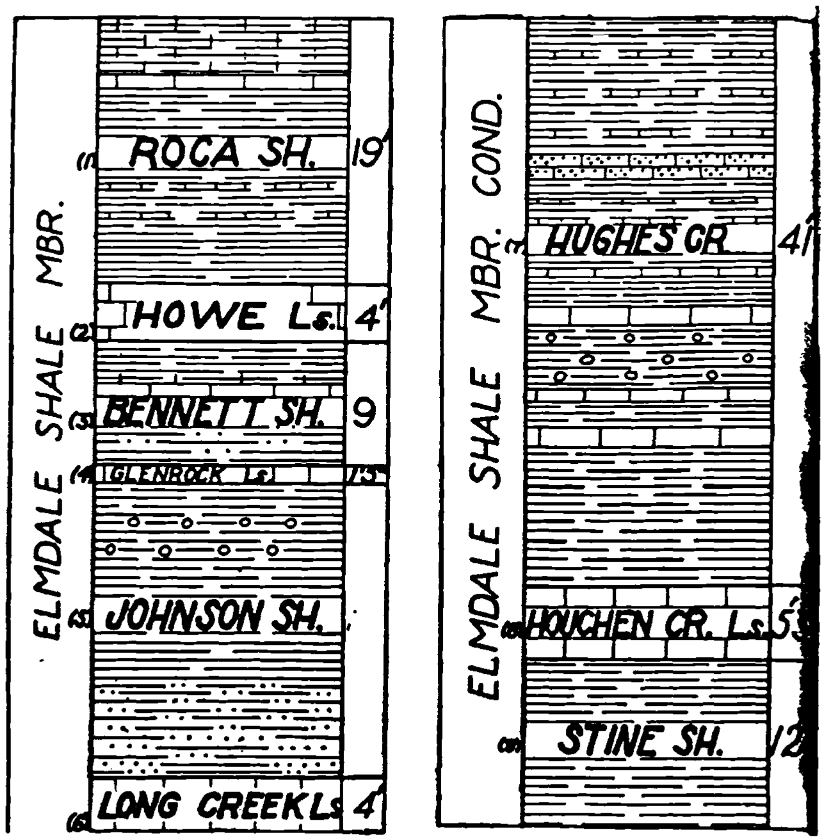


Figure 21
Columnar section of the Elmdale Shale
(Condra 1927).

Bennett Shale, type locality (figure 22 and 23)

> "Bennett Shale, named from exposures along the Little Nemaha and its branches south of Bennett, Lancaster County, Nebraska; formed of bluish gray and nearly black argillaceous shale, with one carbonaceous streak resembling coal and a thin yellowish to brownish limestone; combined thickness 5 to 11 feet." (Condra, 1927, p.86)

and Howe Limestone,

> "Howe Limestone, named from exposures south of Howe, Nebraska; stone in its unweathered condition, dark gray, massive, and dense, with considerable free calcite; weathers buff to yellowish, granular, vesicular or cavernous, and very irregular; thickness about 4 feet. This carries geodes at places. It has few fossils." (Condra, 1927, p.86)

for exposures in southeast Nebraska that could be traced into northern Kansas.

The Red Eagle Limestone to the north of Greenwood County, contains easily distinguishable members; Glenrock Limestone Member, Bennett Shale Member, and Howe Limestone Member, by means of fossil content and lithology (Mudge and Yochelson, 1962). To the south of Greenwood county the Red Eagle Limestone the members become indistinguishable as the entire formation is composed entirely of limestone (Mudge and Yochelson 1962).

O'Connor and Jewett summarized Bass' works in 1952 and created stratigraphic cross sections that traced the Red Eagle Limestone through Kansas. Their work correlated the Red Eagle from Bennett Nebraska to Southern Cowley County Kansas. Their work included the following conclusions. The lithologic characteristics of the Glenrock Limestone Member, Bennett Shale Member, and Howe Limestone Member, in the type area are virtually unchanged as far south as Manhattan Kansas. The

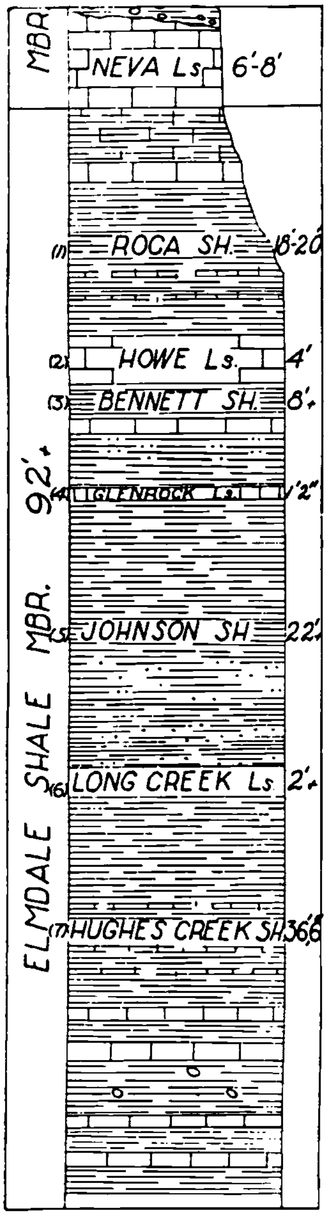


Figure 22
Bennett Shale Member measured section
(Condra 1927).

(3). Bennett Shale, exposed from west of Bennett and the south side of section 10 eastward; thickness about 8' including:

a. Shale, bluish, argillaceous, part calcareous, fossiliferous, 2' 6" to 4'. Fauna: Meekopora prosseri, sea urchin spines, and a few brachiopods.

b. Limestone, just above creek bed southwest of town and gradually higher in the cut-banks down-valley, 1' to 1' 2". This stone is bluish gray, and not very fossiliferous. It weathers buff or yellowish.

c. Shale, well shown in creek bank southwest of town, 3' 7":

(a). Shale, light blue, arenaceous to argillaceous, weathers dark gray, 10".

(b). Shale, nearly black, carbonaceous, resembles coal, 5". This is in the right bank of the creek near water level west of Bennett. It is higher in the slope farther southeast, and near the top of the cut-banks southeast of town.

(c). Shale, dark gray, argillaceous to sandy, somewhat calcareous, 8" to 10". Specimens of Orbiculoidea missouriensis are common.

(d). Shale, 6" to 8".

(e). Shale, dark, argillaceous, in four bands at places, somewhat slabby, bedded to massive, 1' 6". The basal 3" is hard and earthy. It carries Orbiculoidea, Composita subtilita, Ambocoelia planoconvexa, and other fossils.

Figure 23
Bennett Shale Member measured section
(Condra 1927).

Glenrock Limestone thins in central and southern Kansas. The Bennett Shale changes from chiefly shale to chiefly limestone as you move southward. The Howe Limestone can be easily distinguished from the Bennett Shale through Kansas to Oklahoma.

In their correlation O'Connor and Jewett correctly identified and correlated the Bennett Shale Member, primarily based on a layer of *Orbiculoidea* fauna located in the basal foot of the Bennett Shale, noting that south of Greenwood County the Bennett Shale Member becomes a near complete limestone section of 10 to 18 feet (3.04 to 5.49 meters). The minor amounts of shale are restricted to the basal foot (.30 meter) and some thin partings in the middle and upper part. This was the first correlation to recognize the Bennett Shale Member as a northern shale and southern carbonate.

Mudge and Yochelson(1962) and McCrone(1963) arrived at similar conclusions about the lithologic trends of the Red Eagle Limestone. The Glenrock Limestone Member persists as a 3 foot (.91 meter) massive hard limestone through much of the northern Red Eagle outcrops. South of Greenwood County the Glenrock begins to thin and pinches out.

The Bennett Shale Member to the north is dominantly shale, silty and gray to tan-gray, with northern most outcrops having a black fissile shale. In Lyon County the Bennett Shale Member contains a biostrome, originating in the middle of the member. The biostrome has a width of 1 and 1/2 miles and can be traced for 8 miles, trending south west (Mudge and Yochelson 1963). To the south at Elk County the Bennett Shale Member is dominantly limestone. These are medium hard beds, gray in color and separated by thin lentils of gray shale. The limestone weathers into irregular blocks. Generally the limestone (of the Bennett Shale) thins northward and thickens to the south (Mudge and Yochelson 1962) (McCrone 1963).

The Howe Limestone Member is a massive bed that maintains consistent lithology along outcrop. a gray to pale orange limestone, it weathers pale orange to yellowish. The Howe ranges in thickness from 1 to 6 feet (.30 to 1.83 meters).

Roca Shale

The Roca Shale was named by G.E. Condra in 1927,

"named from Roca, Lancaster County, Nebraska; comprised of bluish gray, olive green, and reddish argillaceous shale. There are thin fossiliferous limestone seams in the upper portion; thickness of division 18 to 20 feet in Nebraska and somewhat greater in Kansas. The limestone seams carry many pelecypods, as Pleurophorus sp., Pseudomonotis sp., and Aviculopecten occidentalis." (Condra, 1927, p.86)

The Roca Shale in Kansas is comprised of gray, gray green silty to clayey shale that contain maroon to red zones locally. The red zones are fissile shales, blocky mudstones, and silt stones that contain caliche nodules and root traces. To the north the red zones are located in the upper portion of the Roca Shale, southward these red zones thicken and are found in the middle and lower portion. The average thickness of the Roca Shale is 18.7 feet (5.66 meters) with a maximum of 30.7 feet (9.1 meters) in Wabaunsee County, and a minimum of 8.5 feet (2.44 meters) in Greenwood County.

Lithostratigraphic Interpretation

Foraker Limestone

In 1937 Elias interpreted from the Hamlin Shale to the Johnson Shale as a single cycle, with minor sea level fluctuation. He named it the Foraker Cycle, a single marine invasion with a maximum depth of 110 - 180 feet.

In 1962 Mudge and Yochelson produced a work on the Foraker describing the three members and based on two distinct *Lingula* beds, claimed that it was a two cycle event. Their correlation of the Americus Limestone Member of the Foraker (figure 18) recognized these two units (3 and 5) thin northward, to the south of Wabunsee County they are three beds of limestone separated by thin beds of shale, and in Lyon and northern Greenwood Counties they coalesce to form one bed (Mudge and Yochelson, 1962, p.32). Their correlation of the Hughes Creek Shale of the Foraker Limestone appears in figure 19. The lithology of the Hughes Creek Shale Member changes drastically from north to south, This correlation was based on paleontological zones, marine condensed sections, as well as lithologic similarities and differences of the beds.

At the northern Kansas localities; Tuttle Creek Spillway (figure 24, photos 33-35) and Paxico (figure 25, photos 36-48) the three lithic subdivisions of the Foraker Limestone; Americus Limestone Member, Hughes Creek Shale Member, and Long Creek Limestone Member are recognizable. Localities in southern Kansas and Northern Oklahoma; K-38 (figure 26, photos 49-70) and Shidler Spillway (figure 27, photos 71-87) show that the traditional tripartite (Americus, Hughes Creek, Long Creek) are not identifiable. The southern outcrops instead have seven distinct limestone packages that can be correlated into Oklahoma with relative ease.

The Americus Limestone Member is further divided into the upper Americus and the lower Americus. At the northern localities the Americus Limestone Member is a bedded gray limestone about 3 and 1/2 feet (1.07 meters) thick capped by a six inch gray shale. The upper Americus Limestone Member is a massive gray limestone 1 foot 3 inches (.38 meters) thick. The Americus Limestone Member at the southern Kansas and northern most Oklahoma localities, K-38 and Foraker North, is approximately 12 feet (3.66 meters) thick. The lower Americus Limestone Member is approximately 8 feet (2.44 meters) thick, predominantly gray shale with two to four gray limestone stringers that vary in thickness from one foot to three inches. The upper Americus Limestone Member is approximately five feet thick, very distinct massive gray limestone with a thin, 4 inch, shale parting about the middle. The Southern most Oklahoma locality, Shidler, the Americus Limestone Member is 17 feet thick and no longer resembles the northern exposures. The lower Americus Limestone Member is approximately 8 feet thick and interbedded gray shales and limestones. The upper Americus Limestone Member is approximately 9 feet thick, with gray limestones, some massive some bedded, and gray shales.

At the northern Kansas localities, Tuttle Creek and I-70 Paxico, the Hughes Creek Shale Member is approximately 36 feet thick. Gray silty shales comprises 26 of the 36 foot section. The shales are divided into 4 packages by gray limestones and one two foot black shale. In southern Kansas, K-38 and Foraker North, the Hughes Creek Shale Member thickens to approximately 55 feet (16.76 meters). In addition to its thickening the Hughes Creek Member also develops seven distinct limestone packages. These are predominantly gray limestones with shallow marine fauna and zones of fusulinids. The basal gray shale remains silty, with thin resistant siltstone stringers. Two of the thicker limestone packages, LS 3 and LS 5, contain bluish gray chert concretions and beds. These limestone packages are separated by gray shales that are no longer silty. At the southern localities, Shidler and Ralston (core OC-4), the Hughes Creek Member is approximately 42 feet (12.8 meters) thick. This southern section shows an influx of clastics at the base with a 2 foot thick sandstone, that correlates to the northern silty shales, at the shidler locality that opens up further south becoming twelve feet thick in the OC-4 core. Above that the integrity of the seven limestone ledges is maintained, and they are separated by marine gray shales.

In the northern Kansas localities, Tuttle Creek and I-70 Paxico, the Long Creek Limestone Member is approximately 7-9 feet (2.13-2.74 meters) thick. It consists of bedded (massive at some outcrops) gray limestone. In southern Kansas, K-38 locality, the Long Creek Limestone Member is approximately 8 and 1/2 feet (2.59 meters) thick. It consists of three limestone ledges separated by two gray marine shales. The shales are the dominant lithology, with the three limestone ledges averaging one foot in thickness each. South of the K-38 outcrop, the Long Creek Limestone Member pinches out.

The trends of the Foraker Limestone based on lithostratigraphic and conodont data found in this study are compiled to create a north to south correlation (figure 28).

Tuttle Creek Measured Section

Foraker Limestone

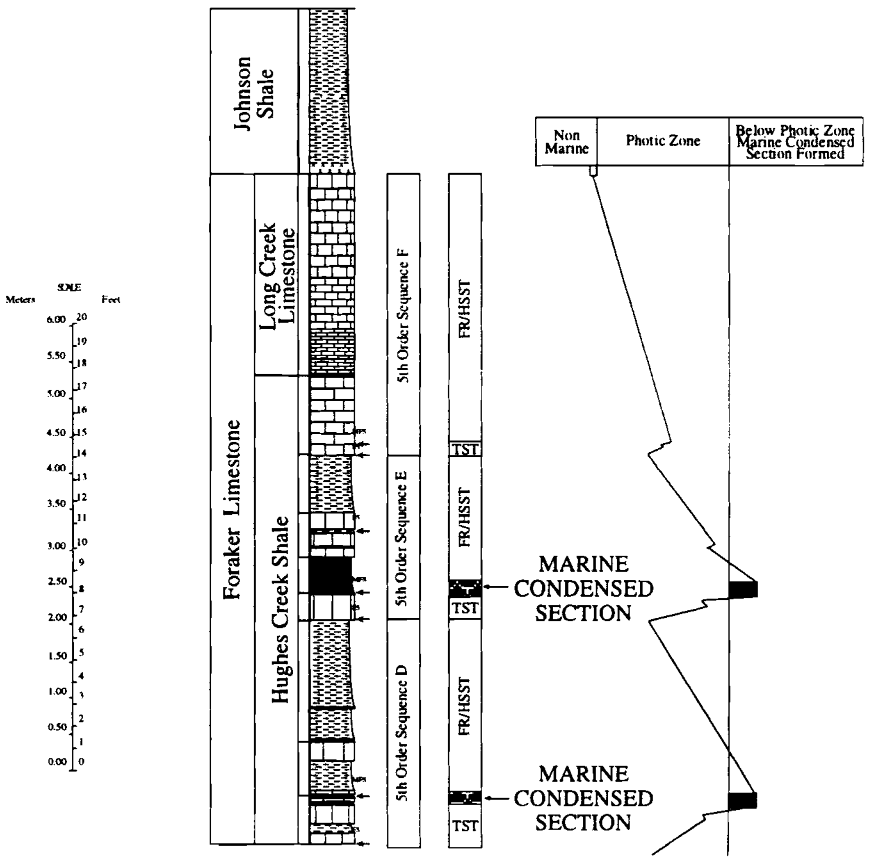


Figure 24

Photo 33

Tuttle Creek   Hughes Creek Shale Member

Taken at Tuttle Spillway, Overview of the Hughes Creek Shale Member, advisor's children standing at base of the measured section.

Photo 34

Tuttle Creek Hughes Creek Shale Member

Taken at Tuttle Spillway, Black shale (upper shale in photo) in the Hughes Creek Shale Member.

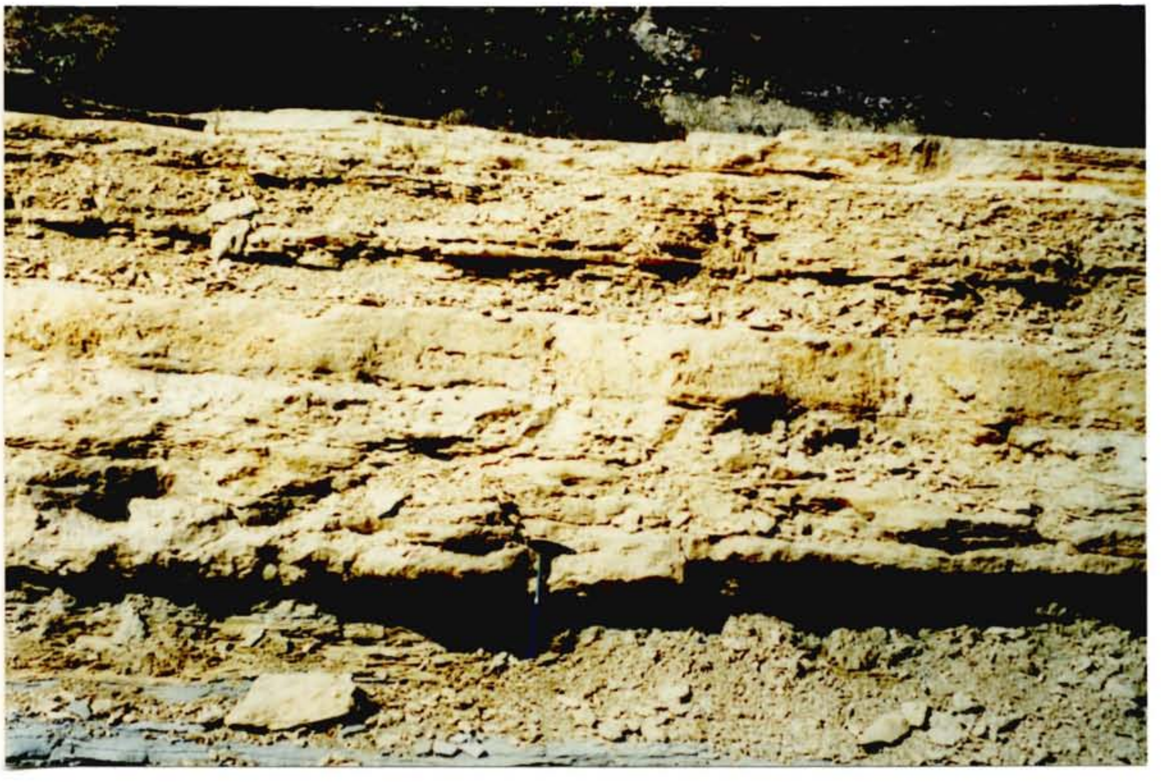


Photo 35

Tuttle Creek   Long Creek Limestone Member

Taken at Tuttle Spillway, Long Creek Limestone Member.

Paxico Measured Section
Foraker Limestone

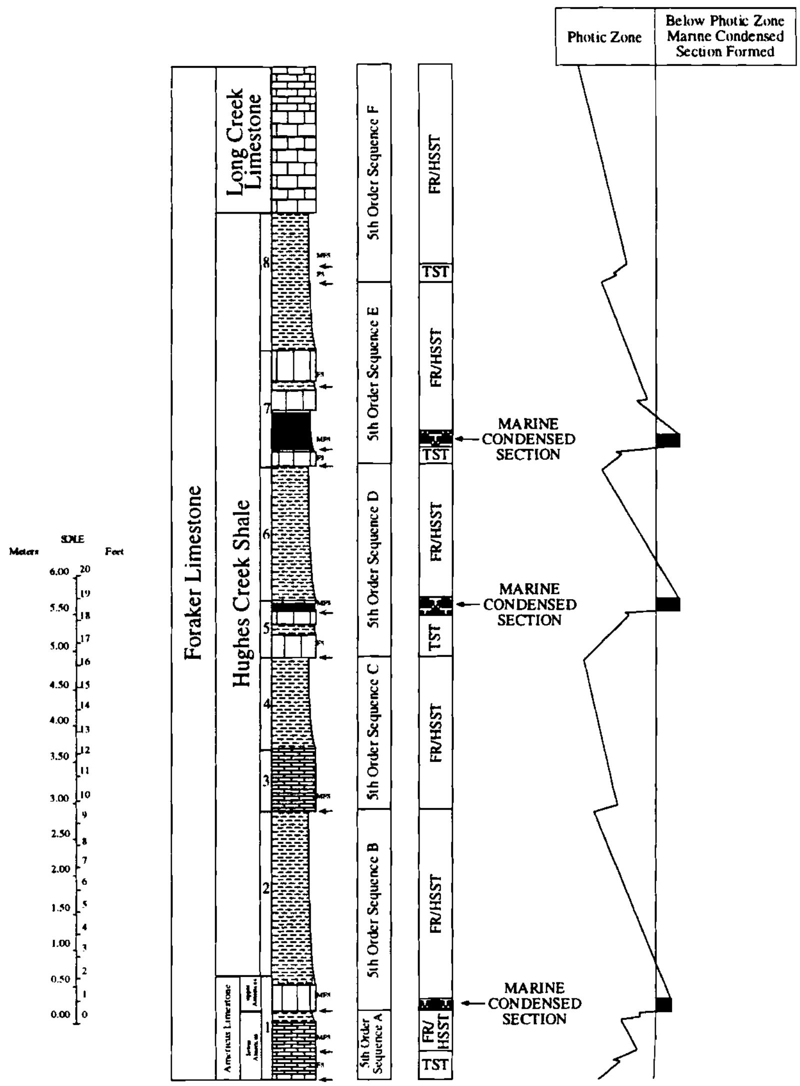


Figure 25

State: Kansas **County:** Wabunsee

Locality Description:
Location is near Paxico on interstate 70. The exposure reveals the entire Foraker limestone and provides an excellent opportunity to sample and measure.

Interval measured is the Foraker limestone

UNIT DESCRIPTIONS

1	31 inches (.79 meters)	Lower Americus Limestone: medium gray limestone, crinoids, some fusulinids. wackestone.
	9 inches (.23 meters)	Lower Americus Limestone: medium gray shale, crumbly, contains *Streptognathodus* conodont fauna.
	12 inches (.30 meters)	Upper Americus Limestone: medium gray limestone, crinoids, fusulinid, dense, hard. wackestone
2	92 inches (2.34 meters)	Hughes Creek Shale: light gray to medium light gray shale, silty at bottom and parts of middle.
3	32 inches (.81 meters)	Hughes Creek Shale: medium gray limestone, ostracodes, crinoids, wackestone.
4	48 inches (1.21 meters)	Hughes Creek Shale: medium gray shale.
5	12 inches (.30 meters)	Hughes Creek Shale: gray limestone, wackestone.
	8 inches (.20 meters)	Hughes Creek Shale: medium to medium dark gray shale.
	6 inches (.15 meters)	Hughes Creek Shale: medium to medium dark gray limestone, *Streptognathodus* conodonts, marine condensed section. wackestone
	6 inches (.15 meters)	Hughes Creek Shale: dark gray to black shale, *streptognathodus* conodonts, phosphate.
6	70 inches (1.78 meters)	Hughes Creek Shale: medium gray shale, silty, crinoids, fusulinids.
7	6 inches (.15 meters)	Hughes Creek Shale: dark gray limestone. wackestone
	22 inches (.56 meters)	Hughes Creek Shale: very dark gray to black shale, phosphate, *Streptognathodus* conodont fauna, wackestone
	28 inches (.71 meters)	Hughes Creek Shale: medium gray limestone, fusulinids abundant, crinoids, small 4 inch gray shale parting 12 inches from base. wackestone
8	73 inches (1.85 meters)	Hughes Creek Shale: gray to slightly olive shale, some silt and tan coloration in areas.

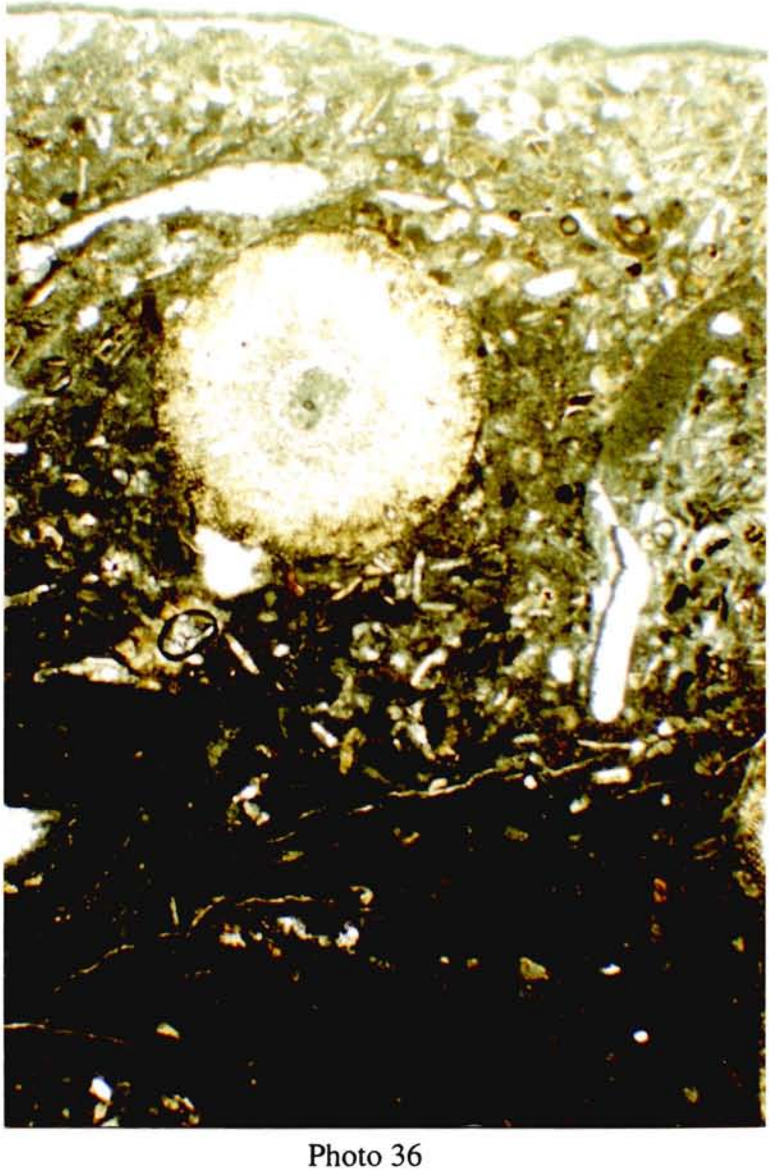


Photo 36

Paxico Americus Limestone Member

Wackestone, fossil content primarily echinoderm (crinoid).

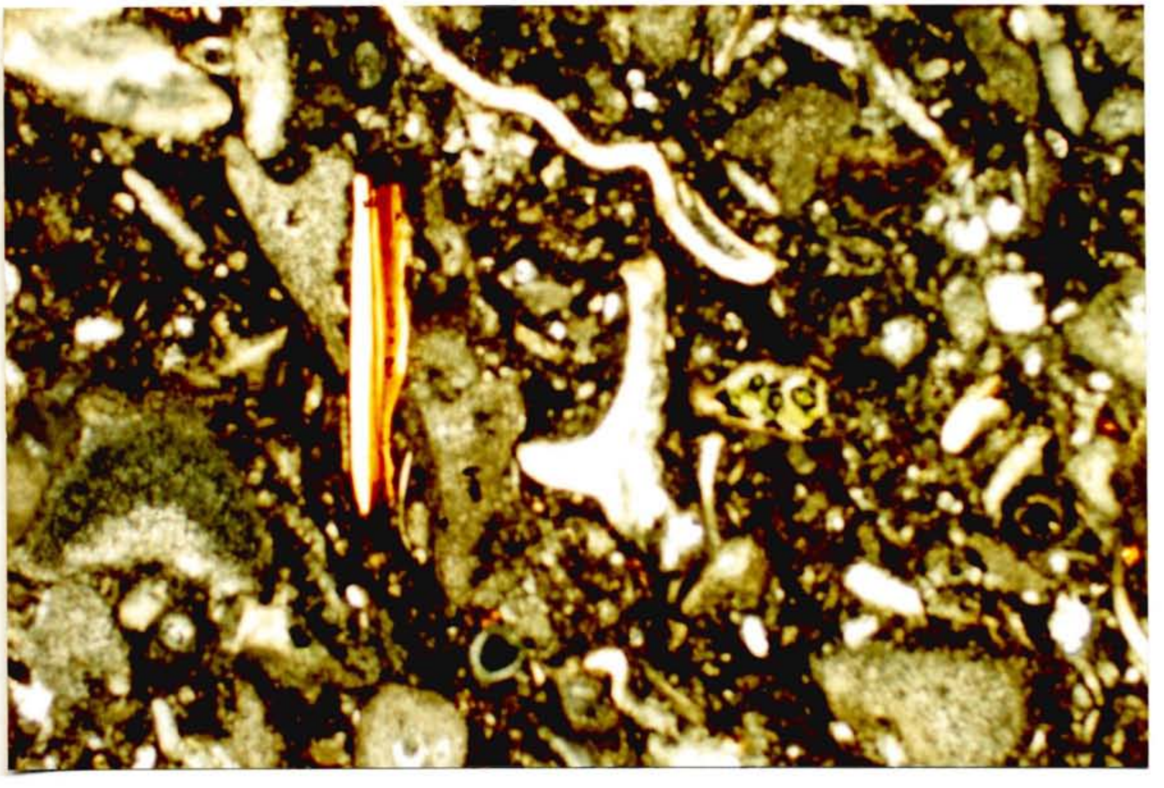


Photo 37

Paxico Americus Limestone Member

Marine condensed section, phosphate is the amber/caramel grain (likely a conodont), glauconite is the green grain, fossil content includes echinoderm, brachiopod, measured section unit 1, (shale parting), wackestone.

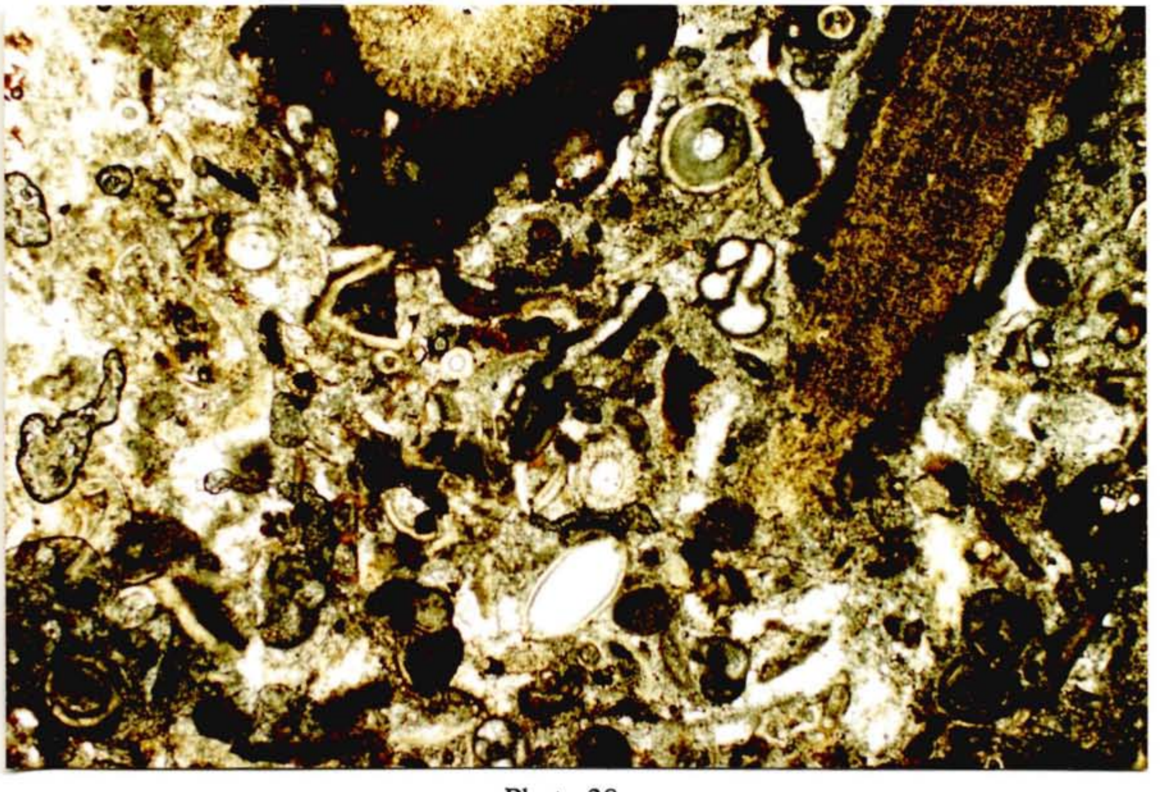


Photo 38

Paxico Hughes Creek Shale Member

Wackestone, measured section unit 3, fossil content includes ostracode and echinoderm.

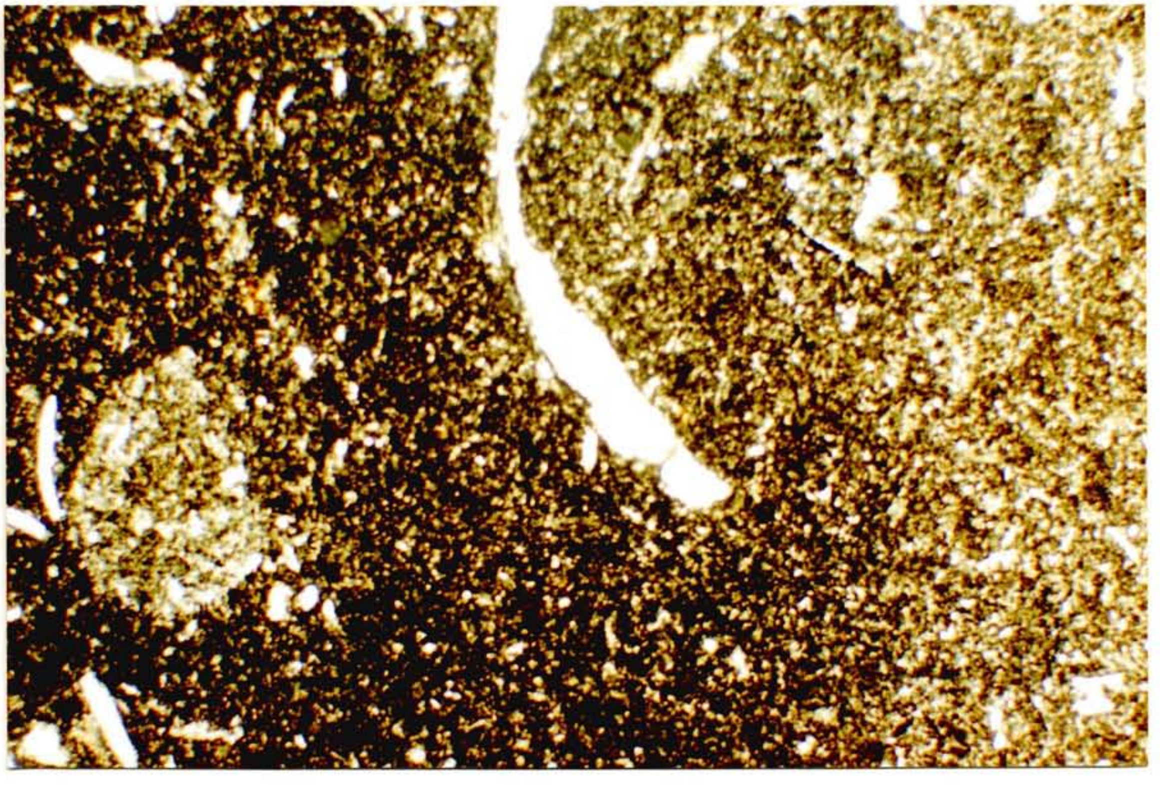


Photo 39

Paxico Hughes Creek Shale Member

Wackestone, measured section lower ledge unit 5, echinoderm and brachiopod.

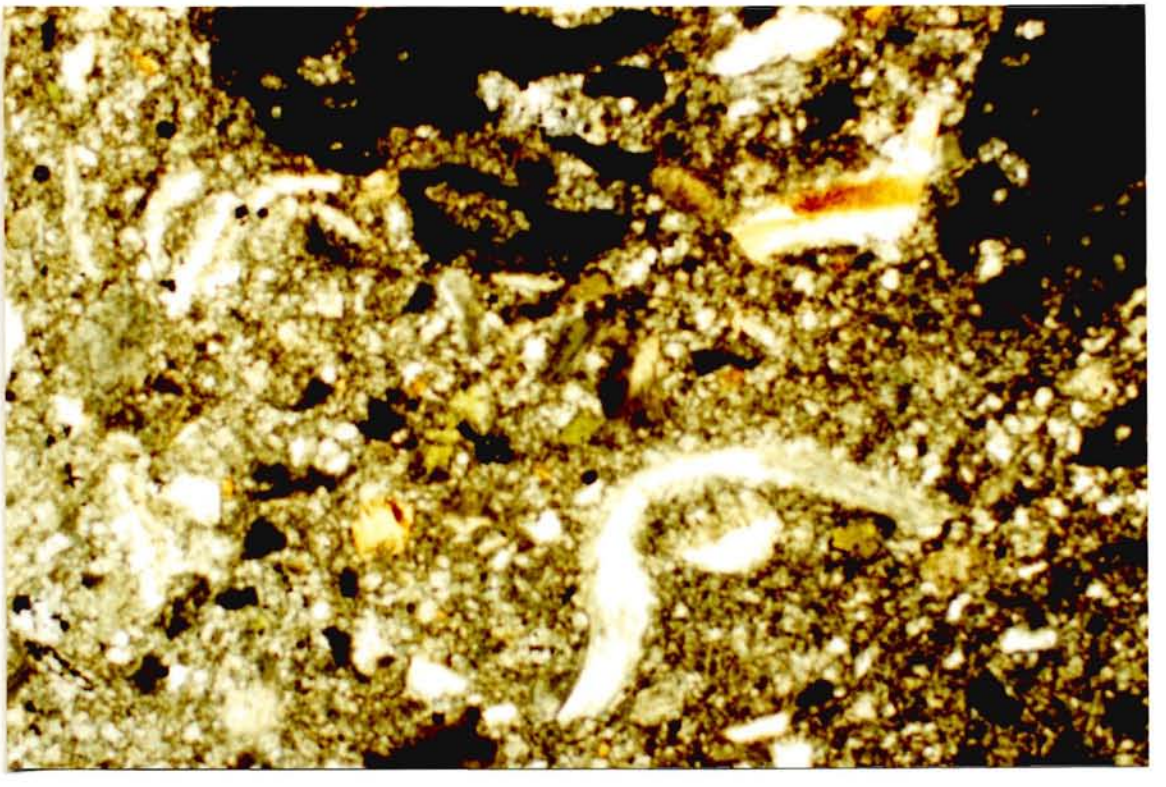


Photo 40

Paxico Hughes Creek Shale Member

Marine condensed section, measured section unit 5, phosphate is the caramel/amber grains brachiopod fragments, wackestone.

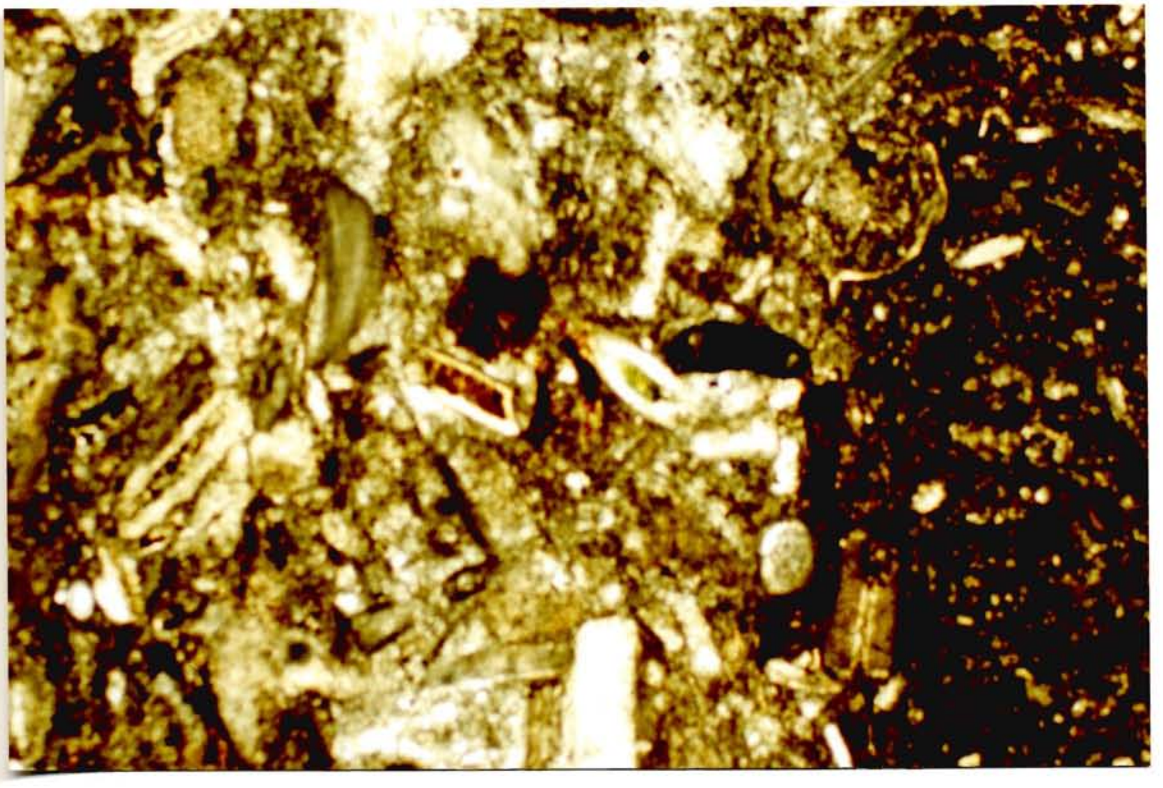


Photo 41

Paxico Hughes Creek Shale Member

Marine condensed section, measured section unit 7, phosphate is the caramel/amber grains echinoderm fragments, wackestone.

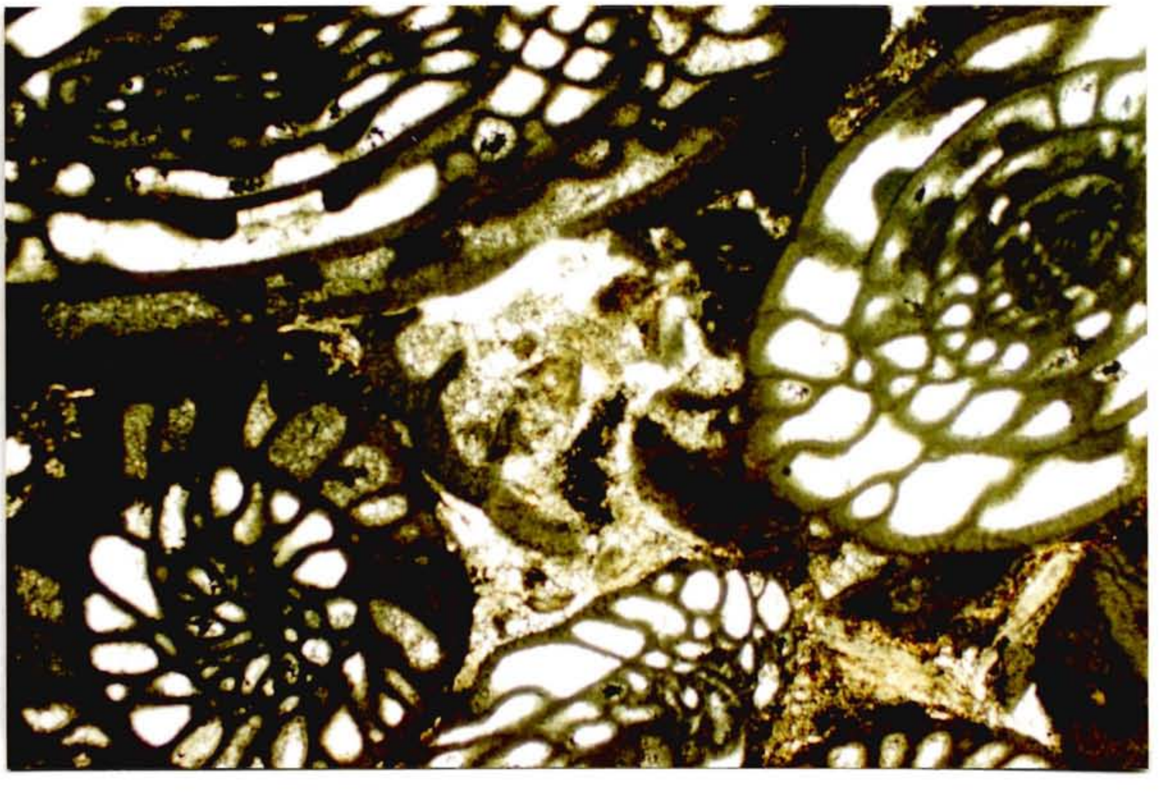


Photo 42

Paxico Hughes Creek Shale Member

Wackestone, measured section upper unit 7, fusulinids.

Photo 43

Paxico Entire Outcrop

Taken along I-70, Overview of Paxico locality, author (5' 7 1/4") for scale.

Photo 44

Paxico Americus Limestone Member

Taken along I-70, Americus Limestone Member, hammer on upper ledge, distinct shale parting near end of hammer.

Photo 45

Paxico Hughes Creek Shale Member

Taken along I-70, Crumbly limestone is L.S. 3.

Photo 46

Paxico Hughes Creek Shale Member

Taken along I-70, L.S. 5.

Photo 47

Paxico Hughes Creek Shale Member

Taken along I-70, Upper limestone, L.S. 7.

Photo 48

Paxico Long Creek Limestone Member

Taken along I-70, Outcrop of the Long Creek Limestone Member.

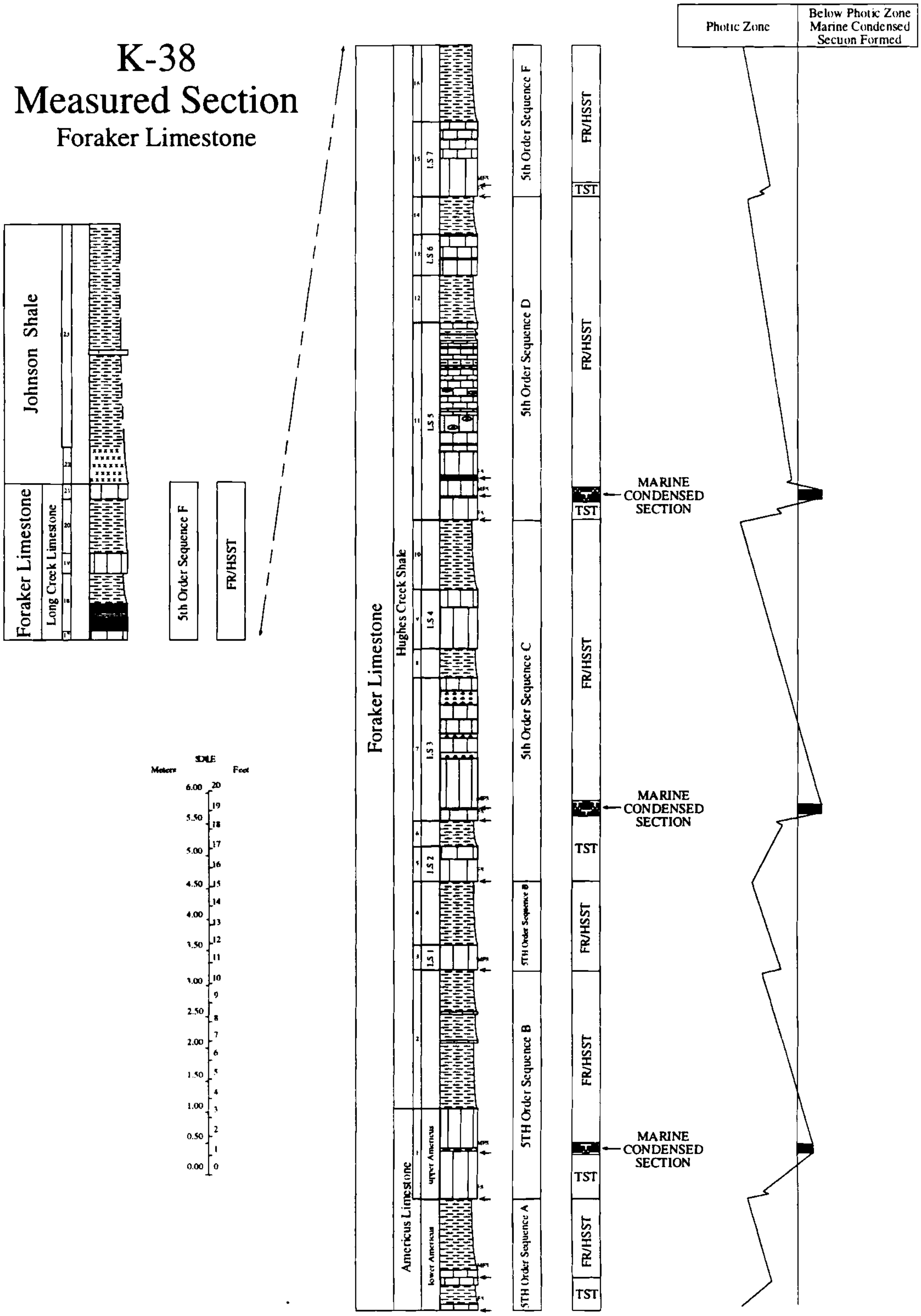

K-38
Measured Section
Foraker Limestone
Foraker Limestone
Long Creek Limestone
Johnson Shale
5th Order Sequence F
FR/HSST
SCALE
Meters
Feet
Foraker Limestone
Americus Limestone
lower Americus
upper Americus
Hughes Creek Shale
LS 1
LS 2
LS 3
LS 4
LS 5
LS 6
LS 7
5TH Order Sequence A
5TH Order Sequence B
5TH Order Sequence B
5th Order Sequence C
5th Order Sequence D
5th Order Sequence F
TST
FR/HSST
MARINE CONDENSED SECTION
Photic Zone
Below Photic Zone Marine Condensed Section Formed

Figure 26

State: Kansas **County:** Cowley

Locality Description:
Location is a road cut on highway 38. This locality provides excellent exposure of the Foraker Limestone.

Interval measured is the Foraker Limestone

South Line 21 T32S R8E

UNIT DESCRIPTIONS

1	30 inches (.76 meters)	Upper Americus: light gray limestone. some areas a medium dark gray crust has formed encoating the rock, fusulinids, echinoderms, ostracodes, bryozoa, crinoids, and brachiopods are present in small amounts. wackestone.
	4.5 inches (.11 meters)	Upper Americus: dark yellowish orange shale, similar fossil content. *Streptognathodus* conodont fauna.
	25 inches (.64 meters)	Upper Americus: medium dark gray to medium light gray limestone, wackestone, weathers to a pale yellowish orange, some bluish-gray chert is present, fusulinids, crinoids, productina and chonetidina brachiopods.
2	103 inches (2.62 meters)	Hughes Creek Shale: dark yellowish brown to moderate yellowish brown shale, interbedded with two thin lenticular gray (slightly yellowish) limestones, brachiopod fragments, some fusulinids
3	20 inches (.51 meters)	Hughes Creek Shale: medium gray to light gray limestone, weathers to grayish orange, some areas have a medium dark gray crust, crinoids, brachiopods, bryozoa, echinoderms, some algae, minor amounts of hematite, wackestone.
4	49 inches (1.24 meters)	Hughes Creek Shale: dark yellowish brown shale.
5	13 inches (.33 meters)	Hughes Creek Shale: light gray limestone, weathers to grayish orange, fusulinids, echinoderm, crinoids, bryozoa. minor amounts of hematite, wackestone.

	7 inches (.18 meters)	Hughes Creek Shale: pale yellowish orange to grayish orange limestone, somewhat sandy texture. Fusulinids, brachiopods, small amount of coral and hematite, wackestone.
6	7 inches (.18 meters)	Hughes Creek Shale: pale yellowish orange to grayish orange marl of limestone-shale, fusulinids.
	5 inches (.13 meters)	Hughes Creek Shale: grayish orange to dark yellowish orange shale.
7	7 inches (.18 meters)	Hughes Creek Shale: light gray limestone, solitary corals, fusulinids, brachiopods, bryozoan, crinoids, echinoderm. Fusulinid packstone to wackestone.
	2 inches (.05 meters)	Hughes Creek Shale: medium gray limestone, weathered look, *Streptognathodous* conodont fauna, wackestone
	98 inches (2.49 meters)	Hughes Creek Shale: light gray limestone, solitary corals, fusulinids, interbedded with distinct bluish gray chert beds with abundant fusulinids, brachiopods, bryozoans, crinoids, echinoderms, wackestone.
8	20 inches (.51 meters)	Hughes Creek Shale: dark yellowish orange shale.
9	42 inches (1.07 meters)	Hughes Creek Shale: very light gray to light gray limestone, weathers to a medium gray. Ostracodes, echinoderm, fusulinids, brachiopods, wackestone.
10	51.5 inches (1.31 meters)	Hughes Creek Shale: moderate yellowish brown to dark yellow-orange shale.
11	21 inches (.53 meters)	Hughes Creek Shale: light gray to pale yellowish orange limestone, weathers dark gray, fusulinids, ostracodes, bryozoa, algae, ,echinoderm, trilobite fragments. wackestone
	1 inch (.03 meters)	Hughes Creek Shale: pale yellowish orange limestone, preferentially weathered, has grainy texture. *Streptognathodus* conodont fauna, wackestone.
	25.5 inch (.65 meters)	Hughes Creek Shale: very pale orange limestone, weathers to an olive gray, some fusulinids, crinoids, bryozoa, wackestone.
	45 inches (1.14 meters)	Hughes Creek Shale: very pale orange limestone weathers to a medium gray, crinoids, coral, brachiopods, and fusulinids, has blue- gray chert concretions with fusulinids, wackestone.
	3 inches (.08 meters)	Hughes Creek Shale: Medium blue-gray chert, fusulinids.
	16 inches	Hughes Creek Shale: pale yellowish

	(.41 meters)	orange limestone, wackestone, weathers to an olive gray, abundant fusulinids. also crinoids and coral.
	13 inches (.33 meters)	Hughes Creek Shale: dark yellowish orange to moderate yellow brown shale.
	4 inches (.10 meters)	Hughes Creek Shale: light gray to yellowish gray limestone, fusulinids, crinoids, echinoderms. minor amounts of hematite, wackestone.
12	35 inches (.89 meters)	Hughes Creek Shale: moderate yellowish brown shale.
13	30 inches (.76 meters)	Hughes Creek Shale: yellowish gray to very pale orange limestone, weathers to an olive gray, crinoids, bryozoa, fusulinids, brachiopods, some algae.wackestone
14	28.5 inches (.72 meters)	Hughes Creek Shale: gray slightly tan shale, crinoids, brachiopods.
15	55 inches (1.40 meters)	Hughes Creek Shale: medium gray limestone,
16	57 inches (1.45 meters)	Hughes Creek Shale: light gray shale
17	8 inches (.20 meters)	Long Creek Limestone: medium gray limestone
18	19 inches (.48 meters)	Long Creek Limestone:gray shale with limestone stringers
	23 inches (.58 meters)	Long Creek Limestone: gray shale calcareous, silty.
19	14 inches (.36 meters)	Long Creek Limestone: light gray limestone, weathers to a yellowish pale orange.
20	40 inches (1.02 meters)	Long Creek Limestone: gray shale, blocky
21	12 inches (.30 meters)	Long Creek Limestone:medium gray limestone, dense

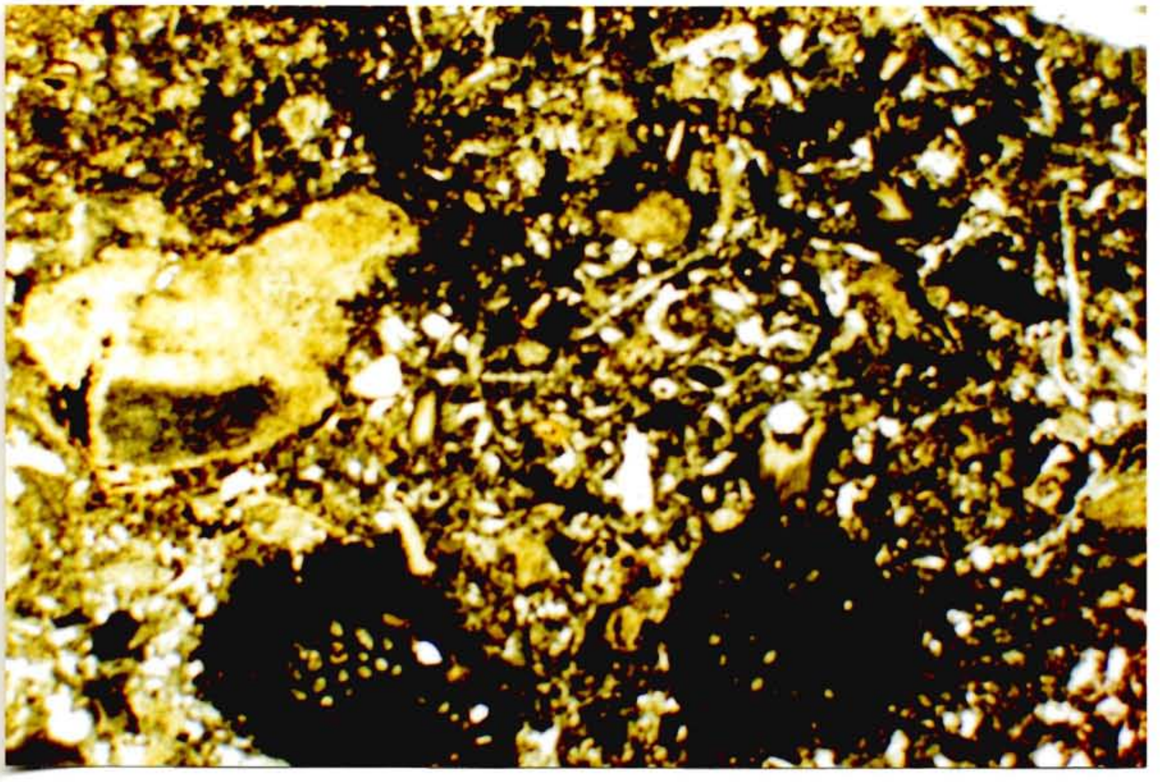


Photo 49

K-38 Americus Limestone Member

Wackestone, measured section lower limestone ledge unit 1, fossil remains include, fusulinid, echinoderm, brachiopod.

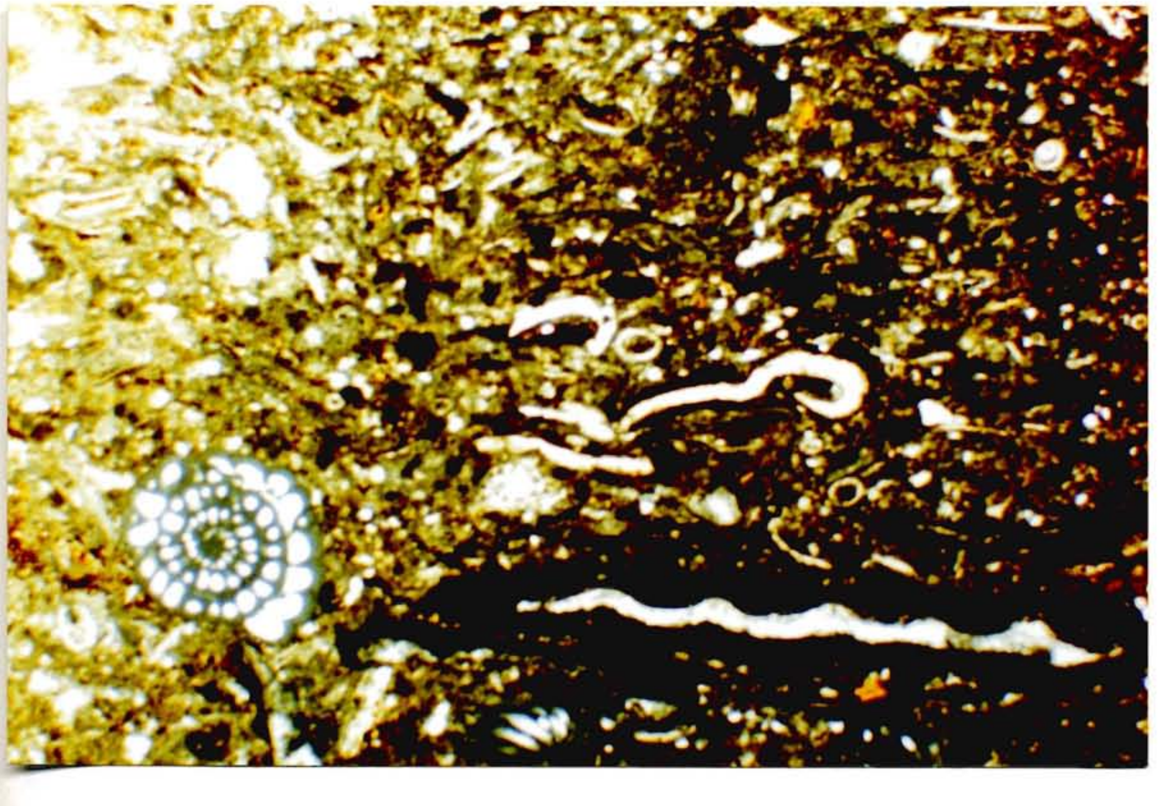


Photo 50

K-38 Americus Limestone Member

Wackestone, measured section upper part of the lower limestone ledge unit 1 near condensed section, fossil remains include, fusulinid, echinoderm, brachiopod, and trilobite, caramel/amber grains are phosphate.

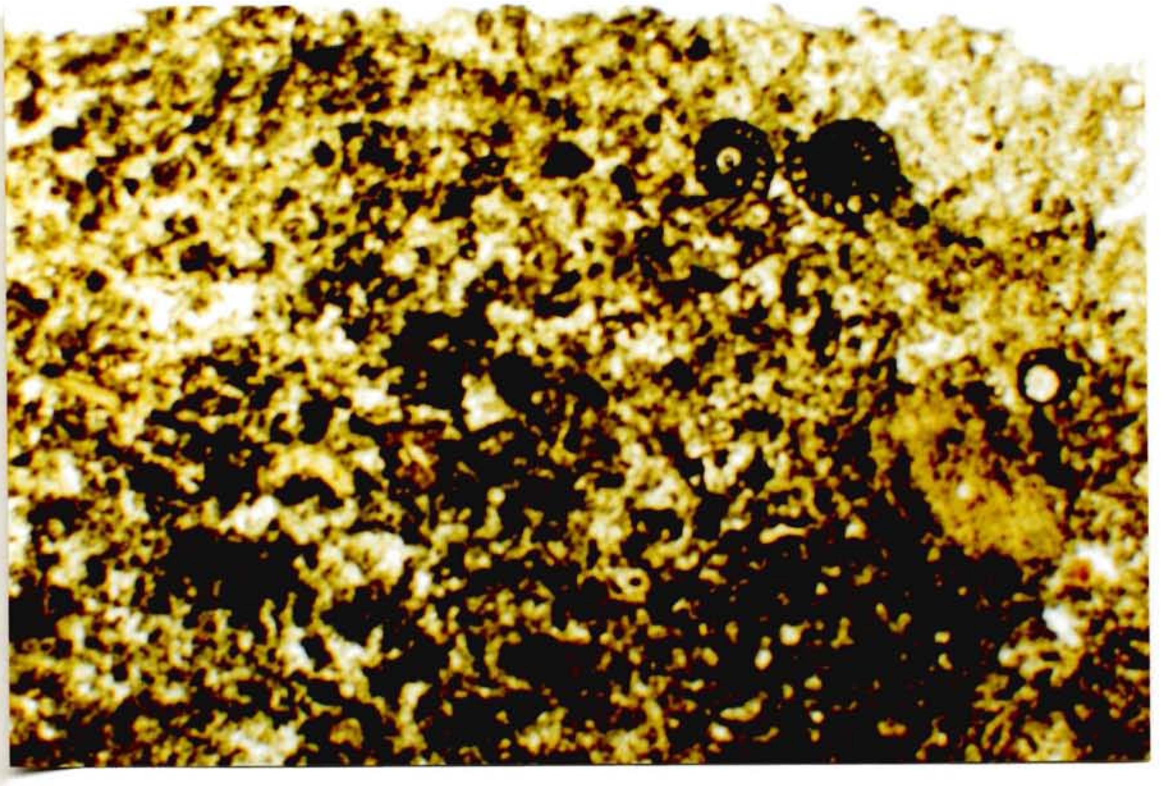


Photo 51

K-38 Americus Limestone Member

Wackestone, measured section upper limestone ledge of unit 1, fusulinid, echinoderm fossil fragments.

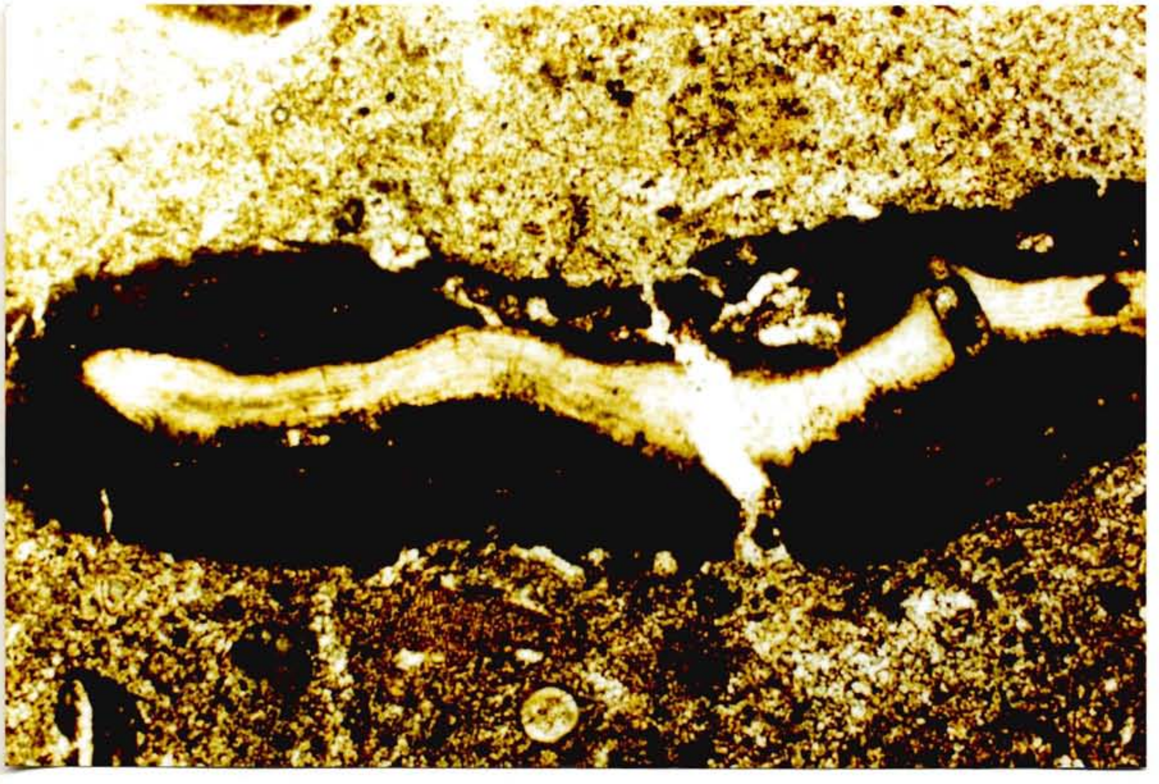


Photo 52

K-38 Hughes Creek Shale Member

Wackestone, measured section unit 3, fusulinid, brachiopod fragment encrusted in algae (center), echinoderm.

Photo 53

K-38 Hughes Creek Shale Member

Wackestone, measured section unit 5, fusulinids.

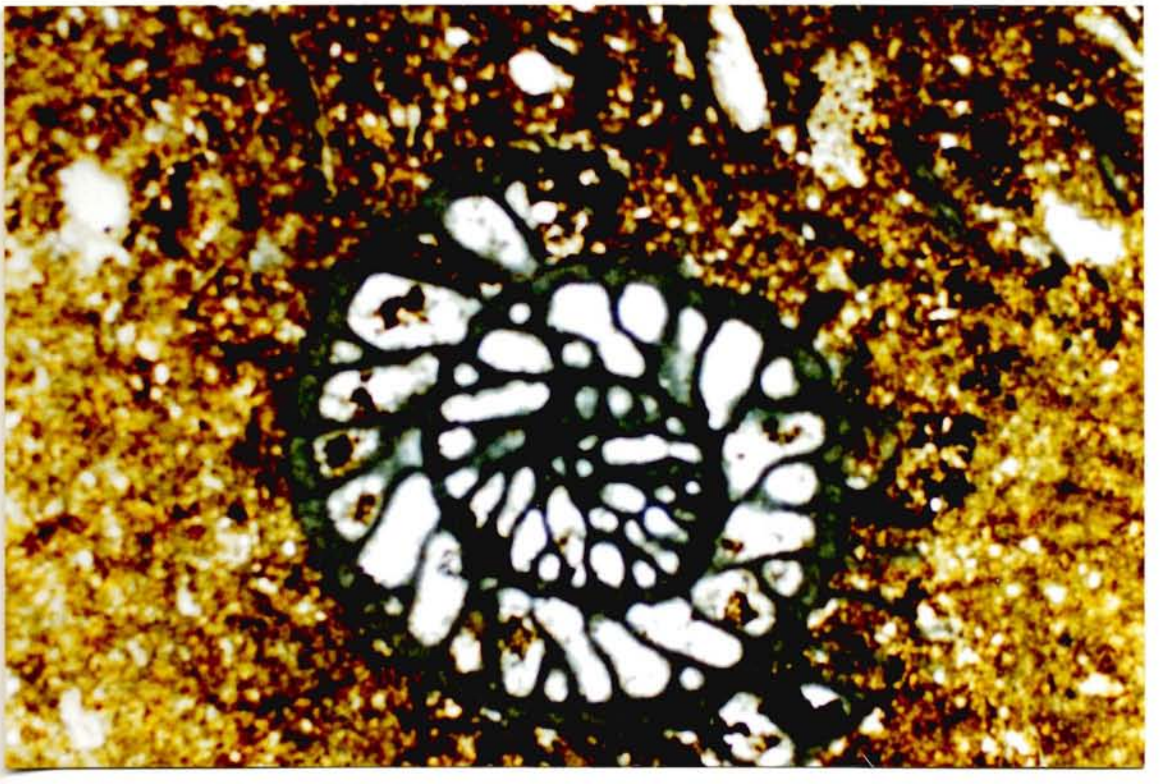


Photo 54

K-38 Hughes Creek Shale Member

Wackestone, measured section below marine condensed section lower unit 7, fusulinid.

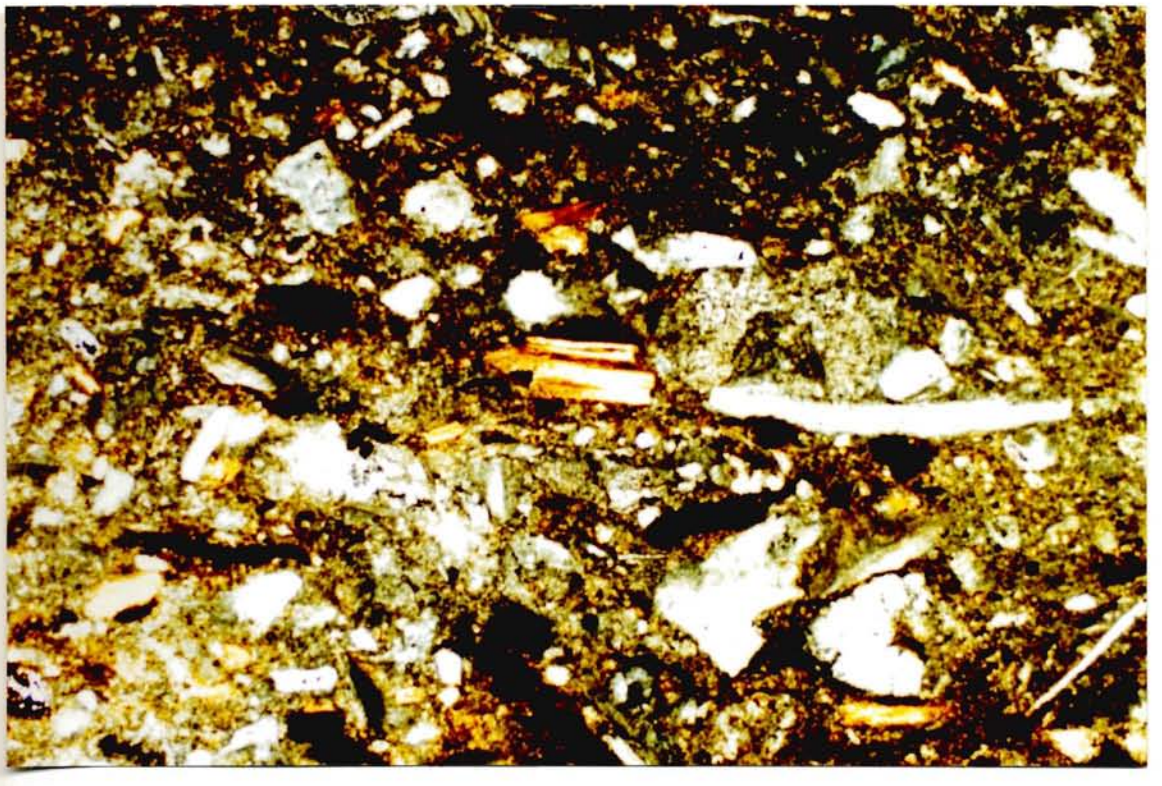


Photo 55

K-38 Hughes Creek Shale Member

Marine condensed section, measured section unit 7, amber/caramel grains are phosphate (likely conodonts), identified fossils include echinoderm, brachiopod, wackestone.

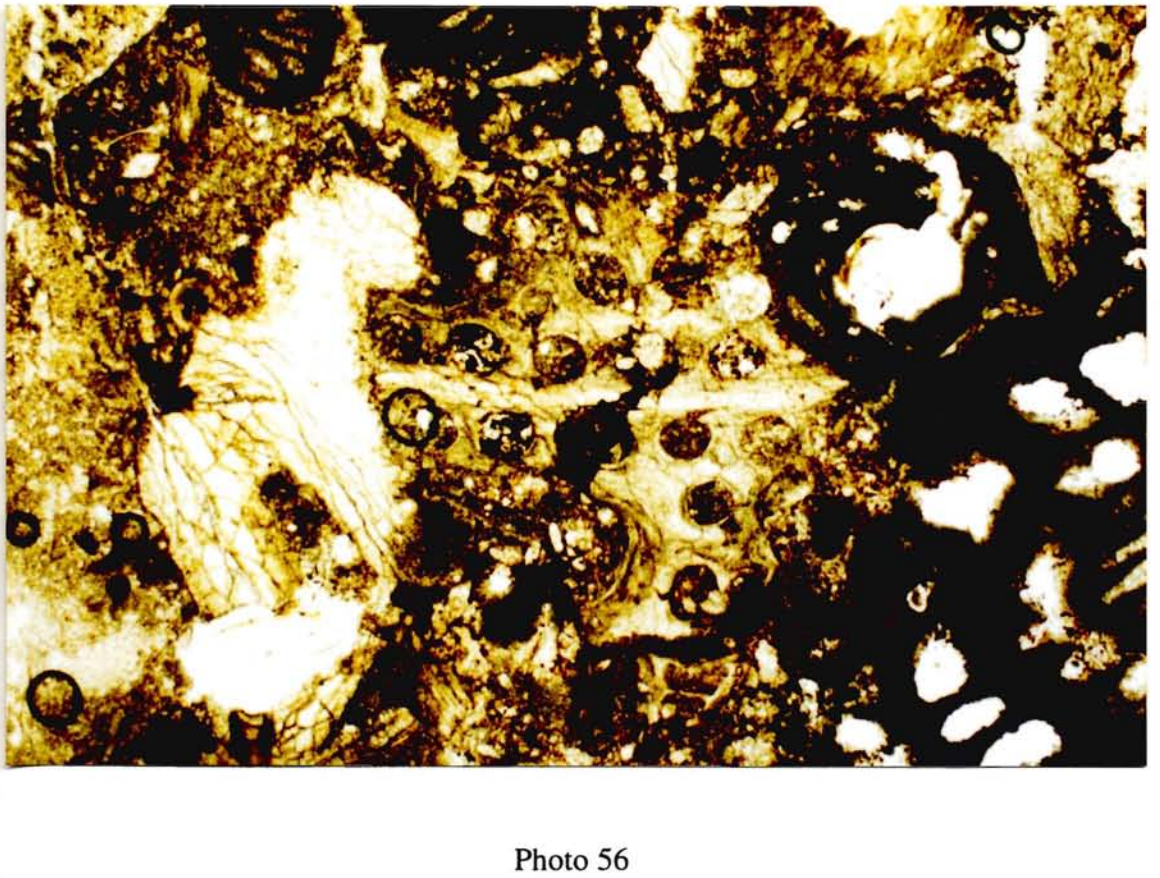


Photo 56

K-38 Hughes Creek Shale Member

Wackestone, measured section upper unit 7, identified fossils include coral, fusulinid, echinoderm.

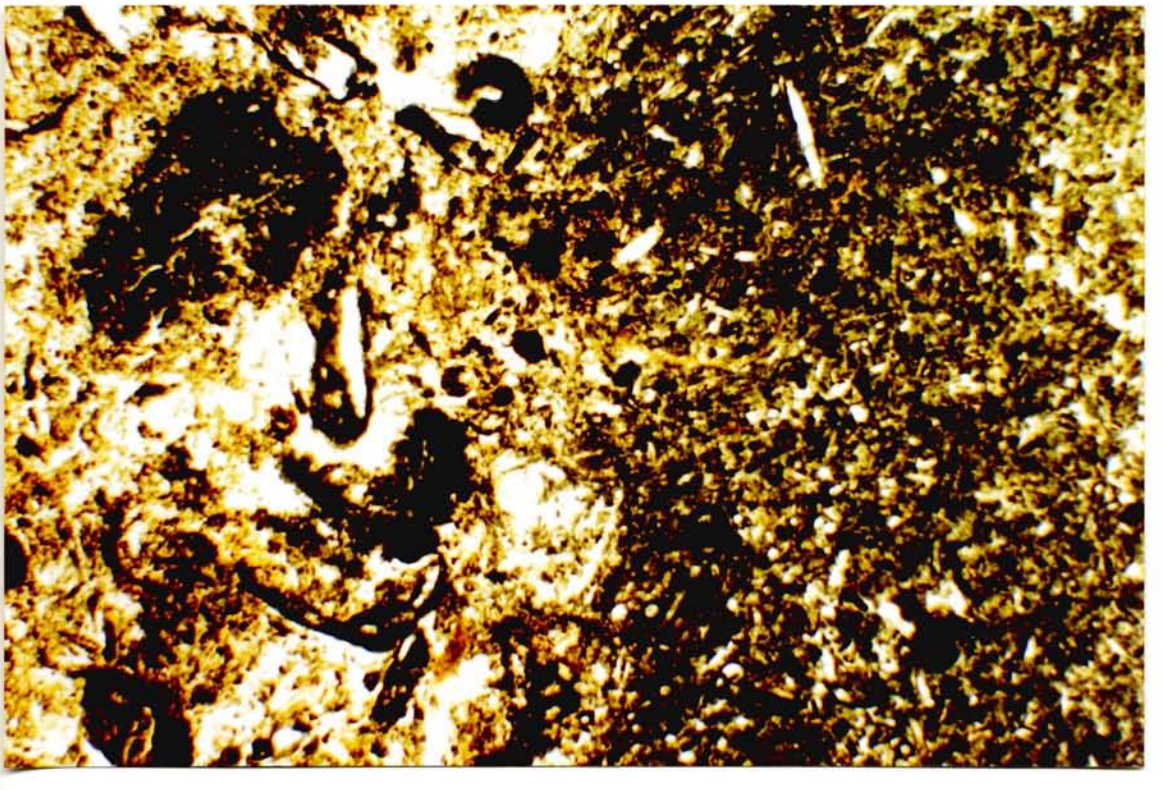


Photo 57

K-38 Hughes Creek Shale Member

Wackestone, measured section unit 9, identified fossils primarily echinoderm.

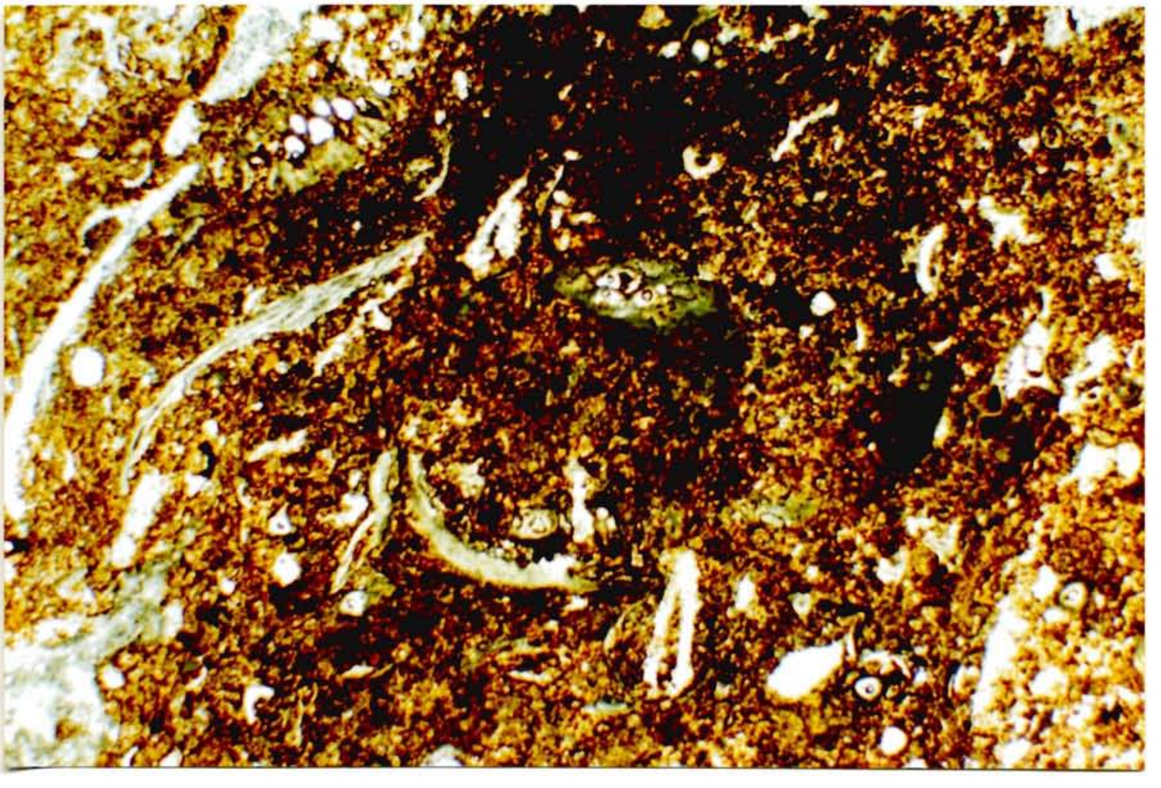


Photo 58

K-38 Hughes Creek Shale Member

Wackestone, measured section basal unit 11 below condensed section, identified fossils coral, echinoderm, and brachiopod fragments.

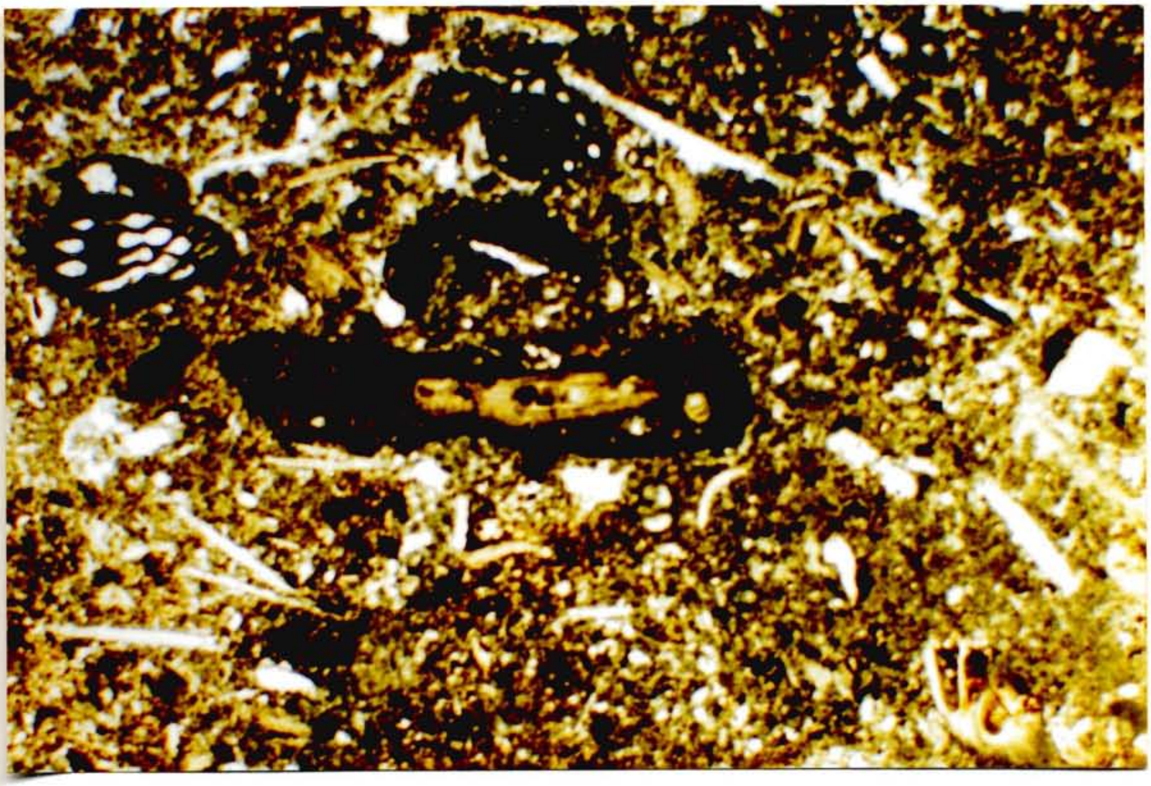


Photo 59

K-38 Hughes Creek Shale Member

Wackestone, measured section unit 11 just below condensed section, identified fossils fusulinid, echinoderm, and ostracode fragments.

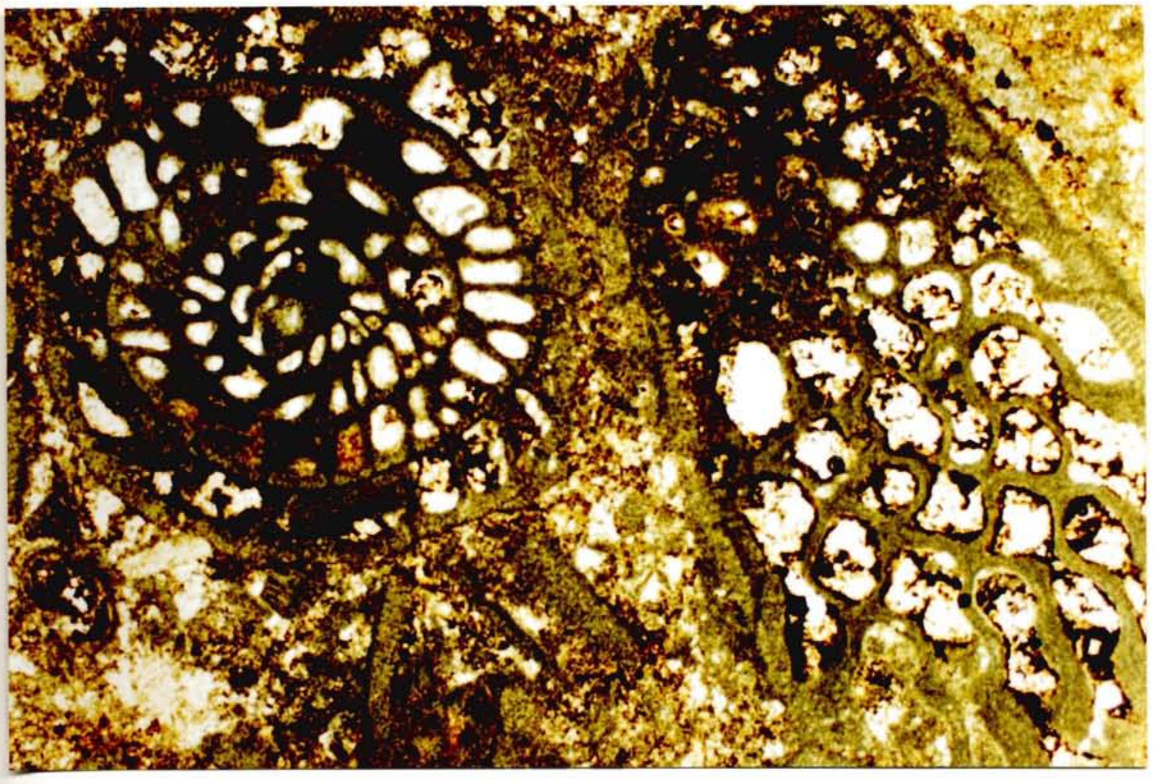


Photo 60

K-38 Hughes Creek Shale Member

Wackestone, measured section middle unit 11, identified fossils fusulinid, coral.

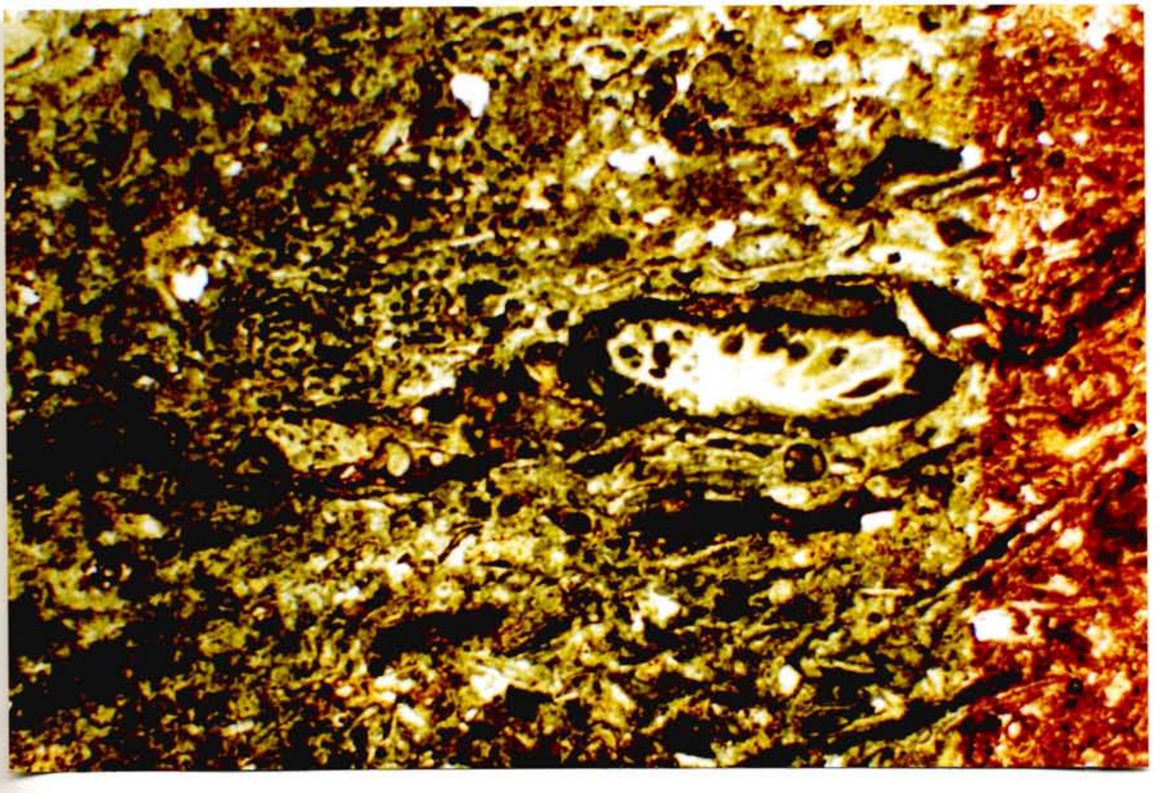


Photo 61

K-38 Hughes Creek Shale Member

Wackestone, measured section unit 13, identified fossils coral, some algal coated debris.

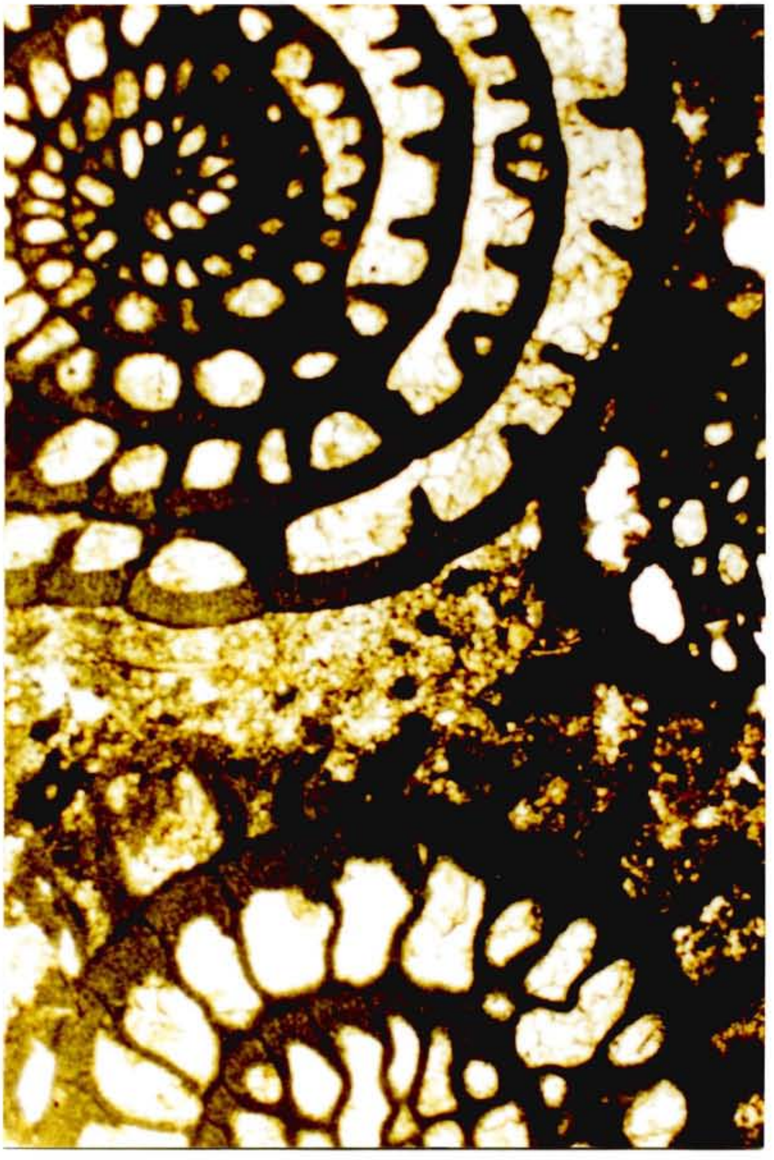


Photo 62

K-38 Long Creek Limestone Member

Wackestone, measured section unit 19, fusulinids.

Photo 63

K-38 Americus Limestone Member

Taken from Kansas State Highway 38, Americus Limestone Member with distinct shale parting.

Photo 64

K-38 Americus Limestone Member

Taken from Kansas State Highway 38, close up view of the distinct shale parting in the Americus Limestone Member .

Photo 65

K-38 Hughes Creek Shale Member

Taken from Kansas State Highway 38, Clipboard rests on the top of the Americus Limestone Member, hammer indicates L.S. 1 of the Hughes Creek Shale Member.

Photo 66

K-38 Hughes Creek Shale Member

Taken from Kansas State Highway 38, Large limestone is L.S. 3 of the Hughes Creek Shale Member, clipboard for scale sets on L.S. 2.

Photo 67

K-38 Hughes Creek Shale Member

Taken from Kansas State Highway 38, Close up of the carbonate marine condensed section in L.S. 3 of the Hughes Creek Shale Member, the condensed section is the rough weathered (2 inch thick) band between the blue handle and head of the hammer.

Photo 68

K-38 Hughes Creek Shale Member

Taken from Kansas State Highway 38, Massive limestone is L.S. 5

Photo 69

K-38 Hughes Creek Shale Member

Taken from Kansas State Highway 38, L.S. 6.

Photo 70

K-38 Long Creek Limestone Member

Taken from Kansas State Highway 38, Middle limestone ledge of the Long Creek Limestone Member.

Shidler Spillway Measured Section

Foraker Limestone

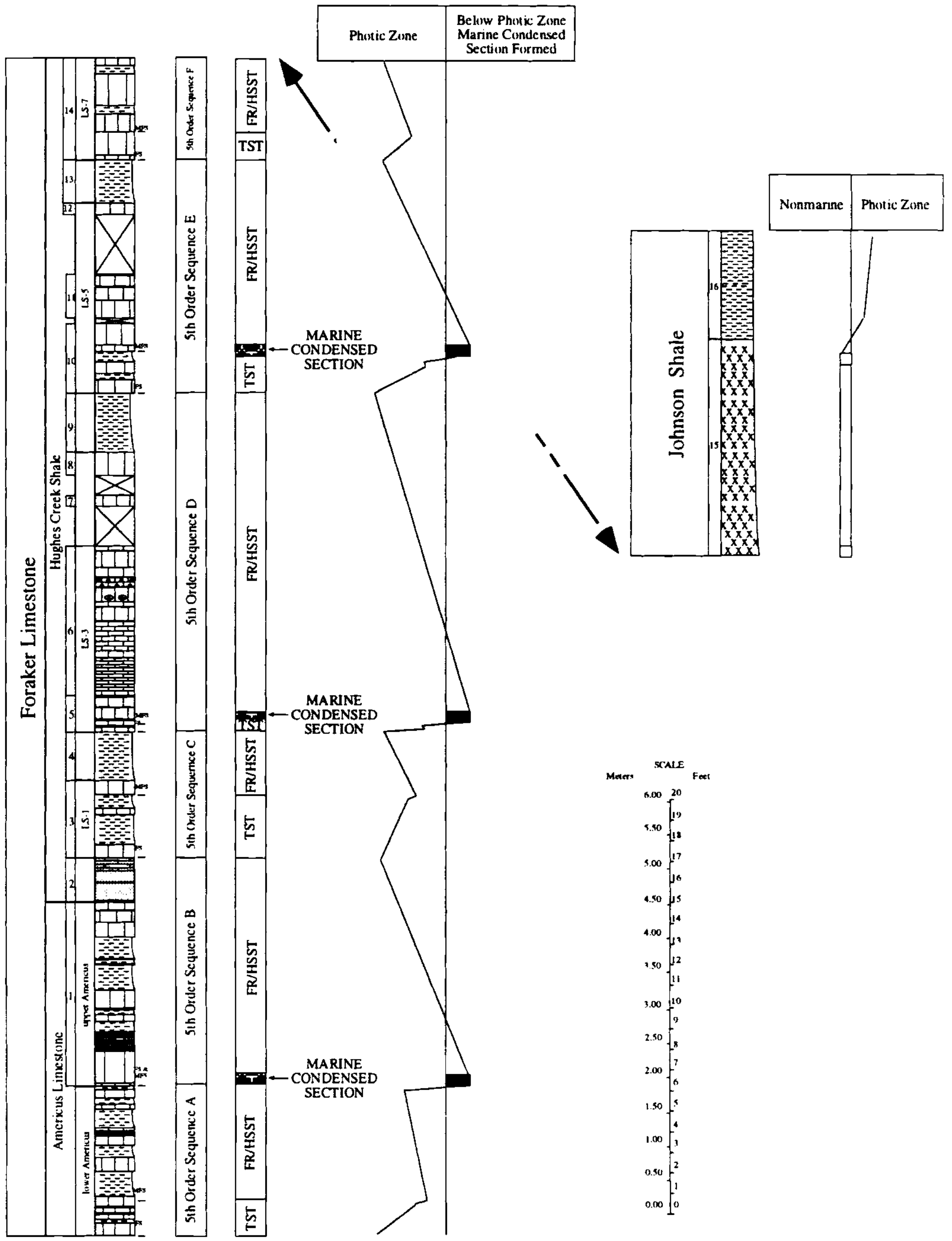


Figure 27

State: Oklahoma **County:** Osage

Locality Description:

Location is the lake Shidler spillway and adjacent roadcut on Oklahoma State Highway 18. The best Foraker exposures are at the spillway, contact between the Johnson shale and Red Eagle limestone can be located at the roadcut with minimal trenching.

Burbank quadrangle T26N R6E, NW1/4, Sect 10

Interval measured is the Foraker limestone and Johnson shale

UNIT DESCRIPTIONS

1	18 inches (.46 meters)	Upper Americus Limestone: medium gray limestone, fusulinids, basal 2 inches contains *Streptognathodus* conodonts, marine condensed section.
	12 inches (.30 meters)	Upper Americus Limestone: dark gray to black shale, limy, crinoids, brachiopods.
	6 inches (.15 meters)	Upper Americus Limestone: Medium dark gray shale.
	3 inches (.08 meters)	Upper Americus Limestone: medium gray limestone.
	4 inches (.10 meters)	Upper Americus Limestone: medium to medium dark gray shale.
	10 inches (.25 meters)	Upper Americus Limestone: medium dark gray limestone, crinoids.
	28 inches (.71 meters)	Upper Americus Limestone: medium dark gray limy to silty shale, crinoid fragments.
	17 inches (.43 meters)	Upper Americus Limestone: medium light gray limestone, brachiopods, crinoids.
2	24 inches (.61 meters)	Hughes Creek Shale: sandy to silty shale light gray slightly yellowish.
3	6 inches (.15 meters)	Hughes Creek Shale: medium light gray limestone
	16 inches (.41 meters)	Hughes Creek Shale: medium gray
	3 inches (.08 meters)	Hughes Creek Shale: medium light gray limestone, fusulinid.
	8 inches (.20 meters)	Hughes Creek Shale: medium gray, somewhat claey
	10 inches (.25 meters)	Hughes Creek Shale: medium light gray, crinoids.
4	27 inches (.66 meters)	Hughes Creek Shale: moderate yellowish brown shale.

5	6 inches (.15 meters)	Hughes Creek Shale: pale to yellowish orange limestone, weathered inch contains Streptognathodus conodonts, marine condensed section.
	12 inches (.30 meters)	Hughes Creek Shale: weathered to a pale yellowish orange limestone, crinoids.
6	86 inches (2.18 meters)	Hughes Creek Shale: medium light gray limestone, weathers to a pale yellowish orange, crinoids, brachiopods, fusulinids.
7	6 inches (.15 meters)	Hughes Creek Shale: medium light gray limestone.
8	13 inches (.33 meters)	Hughes Creek Shale: medium light gray limestone.
9	33 inches (.84 meters)	Hughes Creek Shale: medium to medium light gray shale, fusulinid, crinoid.
10	6 inches (.15 meters)	Hughes Creek Shale: medium gray limestone, weathers to a pale orange.
	4 inches (.10 meters)	Hughes Creek Shale: gray shale
	5 inches (.13 meters)	Hughes Creek Shale: medium light gray limestone, weathers to a pale orange.
	7 inches (.18 meters)	Hughes Creek Shale: gray shale
	3 inches (.08 meters)	Hughes Creek Shale: weathered orange medium light gray limestone, *Streptognathodus* conodont fauna, marine condensed section.
	12 inches (.30 meters)	Hughes Creek Shale: light gray limestone, weathered to a pale orange, crinoid fragments.
11	24 inches (.61 meters)	Hughes Creek Shale:
12	7 inches (.18 meters)	Hughes Creek Shale: light gray limestone, fusulinids.
13	23 inches (.58 meters)	Hughes Creek Shale: gray shale
14	24 inches (.61 meters)	Hughes Creek Shale: medium gray limestone
	6 inches (.15 meters)	Hughes Creek Shale: gray shale
	14 inches (.36 meters)	Hughes Creek Shale: massive medium gray limestone.
	6 inches (.15 meters)	Hughes Creek Shale: gray shale
	6 inches (.15 meters)	Hughes Creek Shale: medium gray limestone, weathers to a pale orange.

15	126 inches (3.2 meters)	Johnson Shale: dusky red, blocky mudstone, some areas shale, root traces evident.
16	63 inches (1.60 meters)	Johnson Shale: gray shale some areas brown, marine, some sparse fossils.

Photo 71

Shidler Americus Limestone Member

Wackestone, measured section unit 1 near marine condensed section, amber/caramel grains are phosphate, identified fossils fusulinid, echinoderm, brachiopod, and ostracode.

Photo 72

Shidler Americus Limestone Member

Wackestone, measured section upper limestone ledge unit 1, fusulinid.

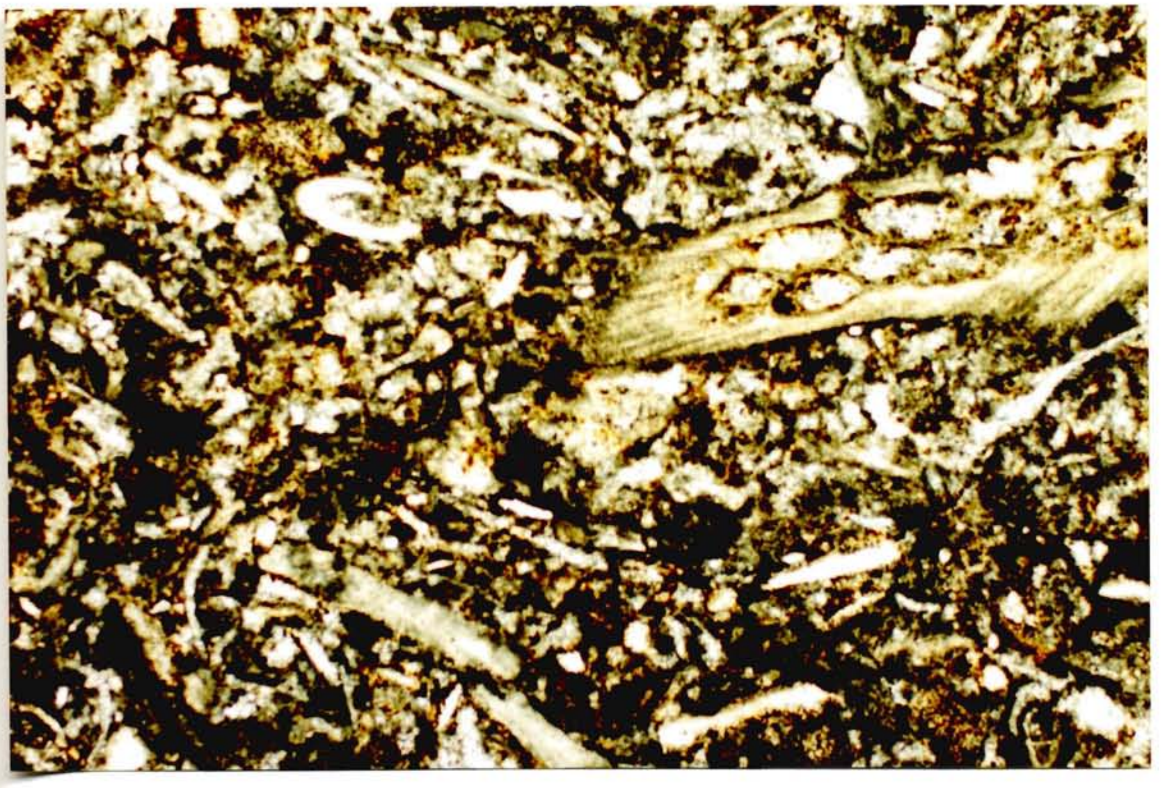


Photo 73

Shidler Hughes Creek Shale Member

Wackestone, measured section unit 3, identified fossil content coral, brachiopod, ostracode, echinoderm, trilobite.

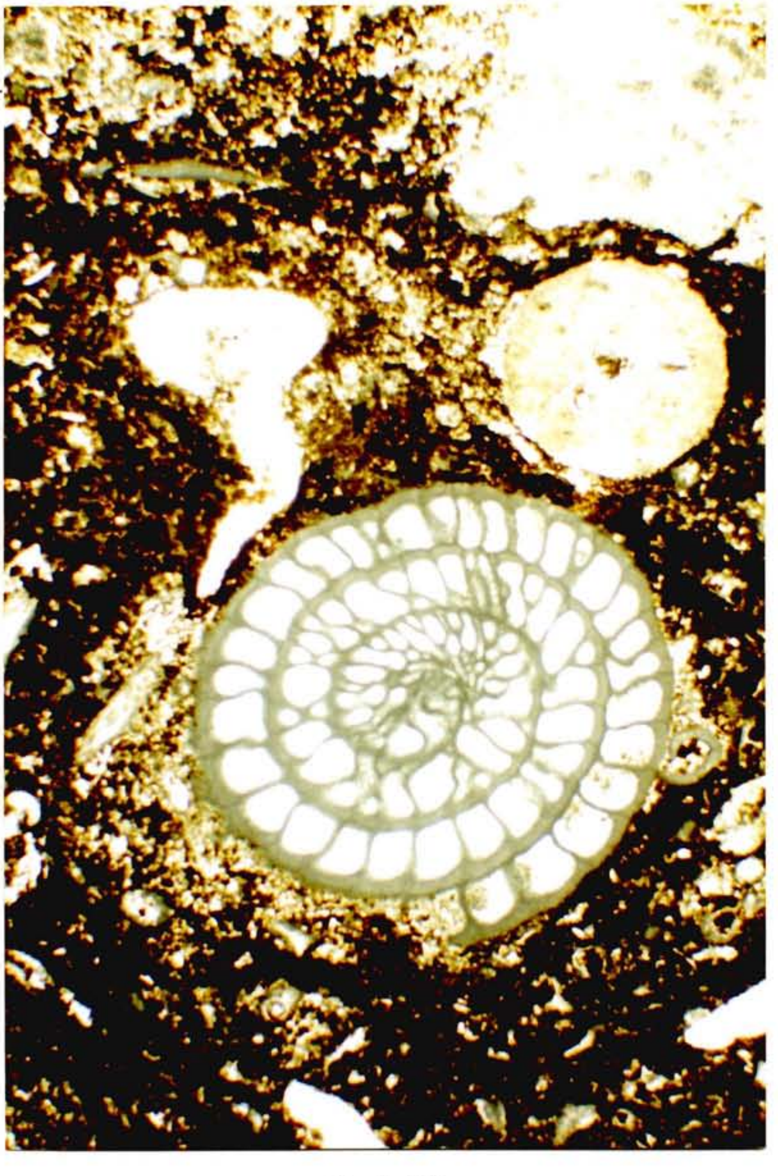


Photo 74

Shidler Hughes Creek Shale Member

Wackestone, measured section upper unit 3, identified fossil content fusulinid, echinoderm, trilobite.

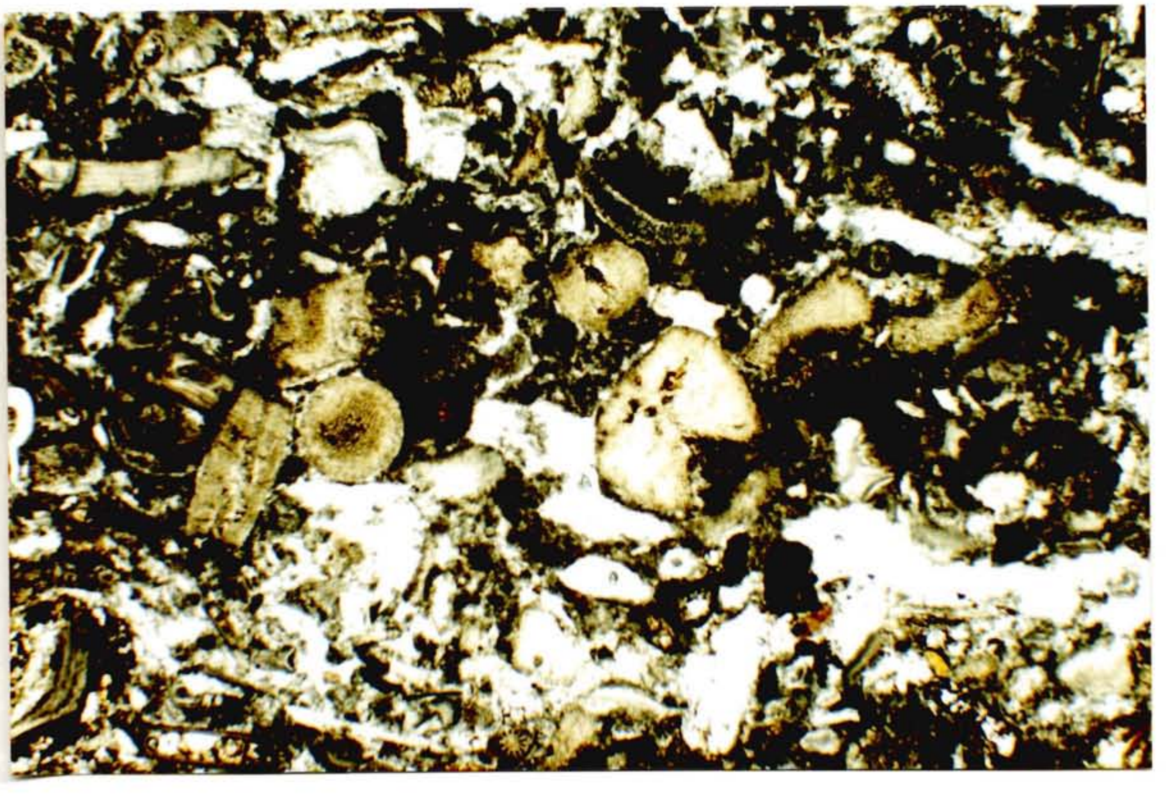


Photo 75

Shidler Hughes Creek Shale Member

Wackestone, measured section unit 6, identified fossil content brachiopod, echinoderm, trilobite.

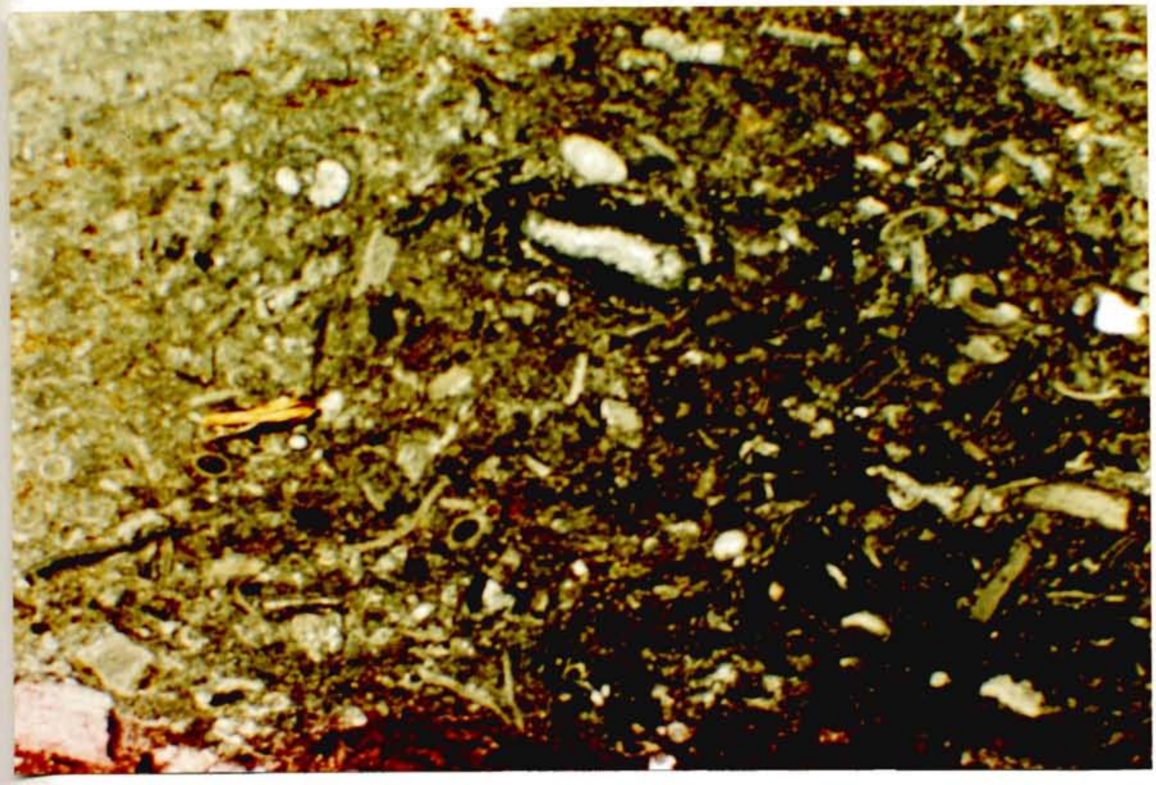


Photo 76

Shidler Hughes Creek Shale Member

Marine condensed section, measured section unit 10, caramel/amber grains are phosphate (likely conodonts), echinoderms.

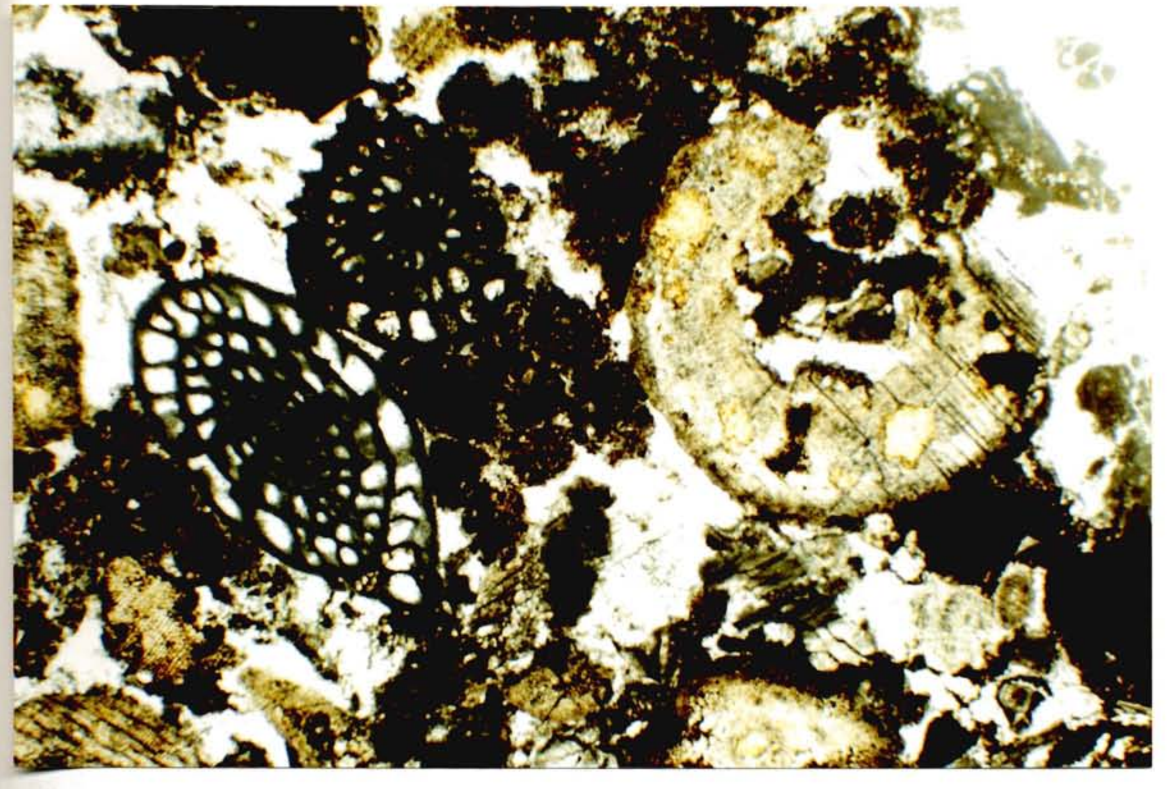


Photo 77

Shidler Hughes Creek Shale Member

Wackestone, measured section upper unit 10, fusulinids, echinoderm fragments.

Photo 78

Shidler Hughes Creek Shale Member

Wackestone, measured section unit 14, identified fossil content fusulinids, echinoderm fragments.

Photo 79

Shidler Spillway Americus Limestone Member

Taken at the spillway, Overview showing the Shidler Spillway, the Americus Limestone Member makes up the majority of this photo, from the pool at the base to the uppermost waterfall ledge.

Photo 80

Shidler Spillway Americus Limestone Member

Taken at the spillway, Upper Americus Limestone Member, limestone ledge the hammer sets on is the uppermost limestone in the Americus Limestone Member.

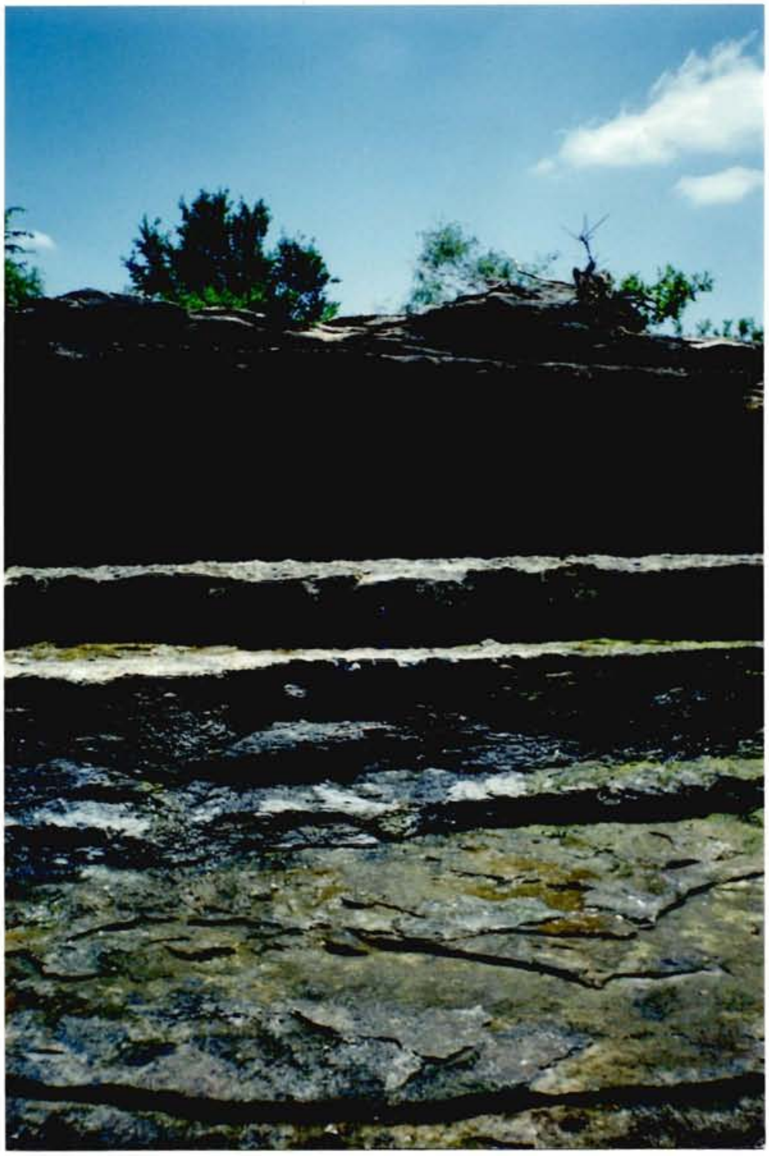


Photo 81

Shidler Spillway Hughes Creek Shale Member

Taken at the spillway, Hammer sets at the two upper limestone ledges of L.S. 1.

Photo 82

Shidler Spillway Hughes Creek Shale Member

Taken at the spillway, Top of the spillway, this is L.S. 3.

Photo 83

Shidler Spillway Hughes Creek Shale Member

Taken above the spillway, Hammer rests on part of L.S. 5.

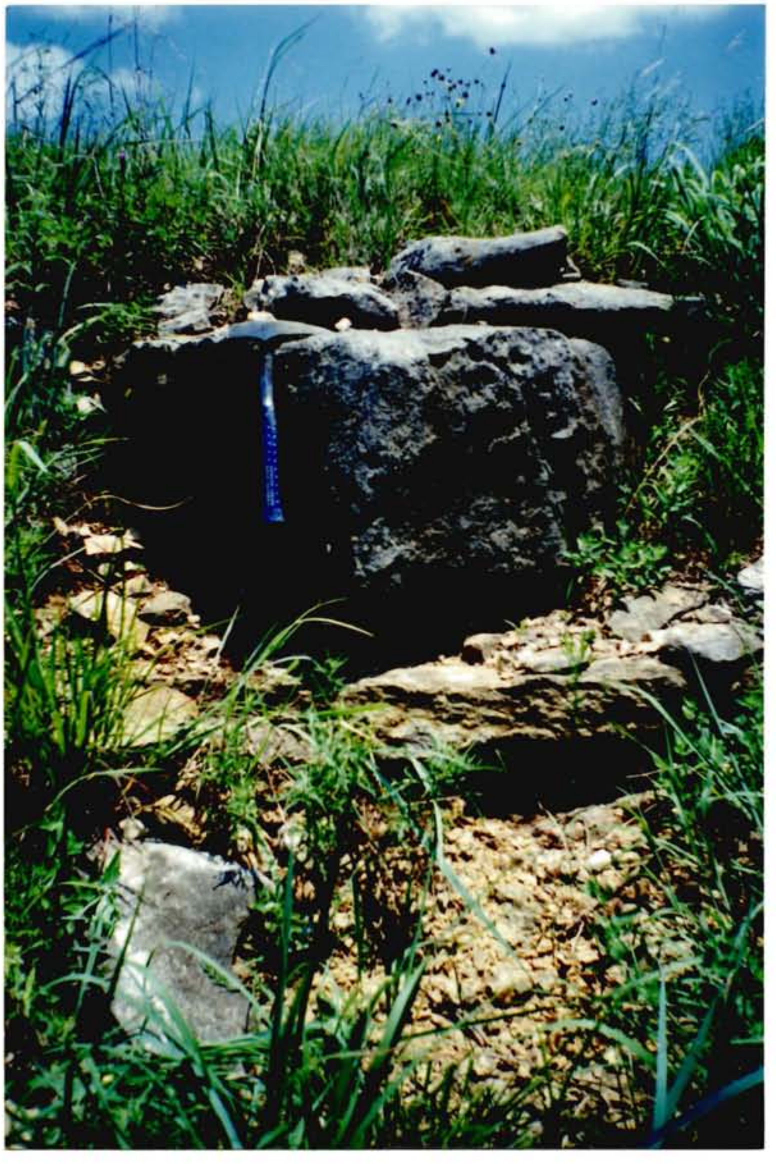


Photo 84

Shidler Spillway Hughes Creek Shale Member

Taken above the spillway, Large limestone ledge in upper half of L.S. 7.

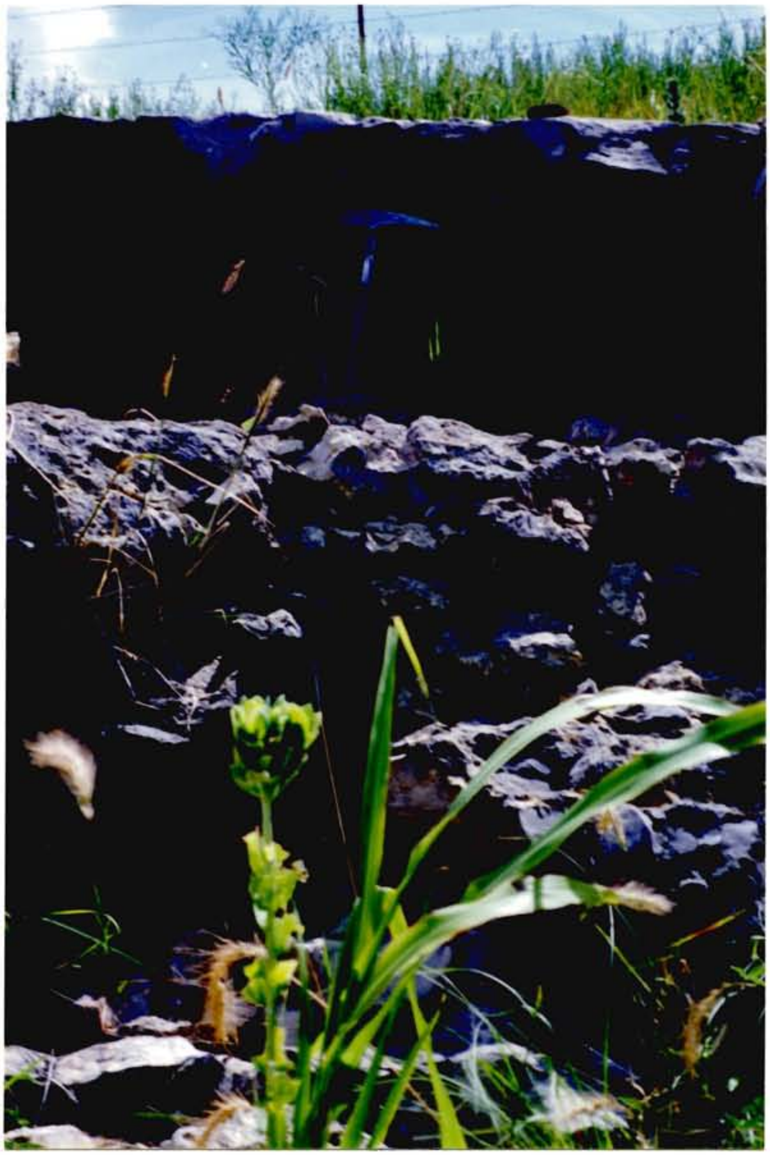


Photo 85

Shidler Spillway Hughes Creek Shale Member

Taken along Highway 18, Same limestone as previous photo, upper L.S. 7, this is from the roadcut along highway 18.

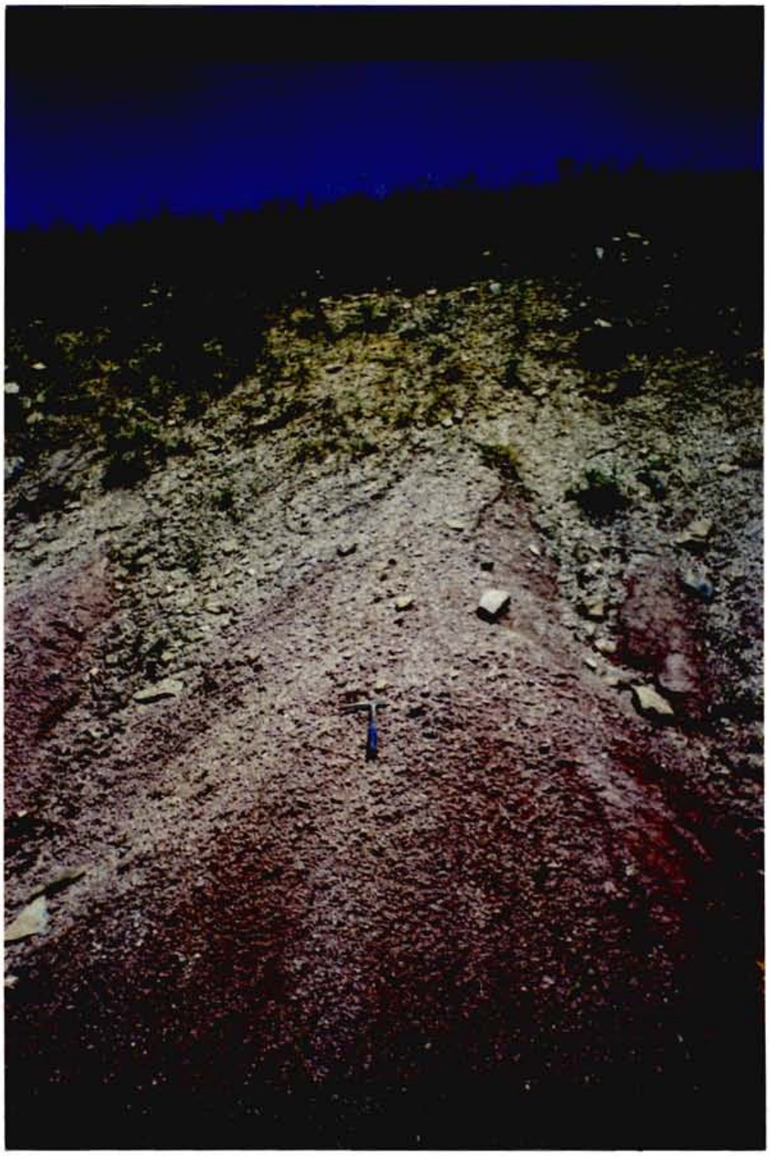


Photo 86

Shidler Spillway Johnson Shale

Taken along Highway 18, The contrast of the red to gray in the Johnson Shale.

Photo 87

Shidler Spillway Red Eagle Limestone

Taken along Highway 18, Hammer sets on one of the three basal limestone stringers of the Red Eagle Limestone, below is the brown to gray Johnson Shale.

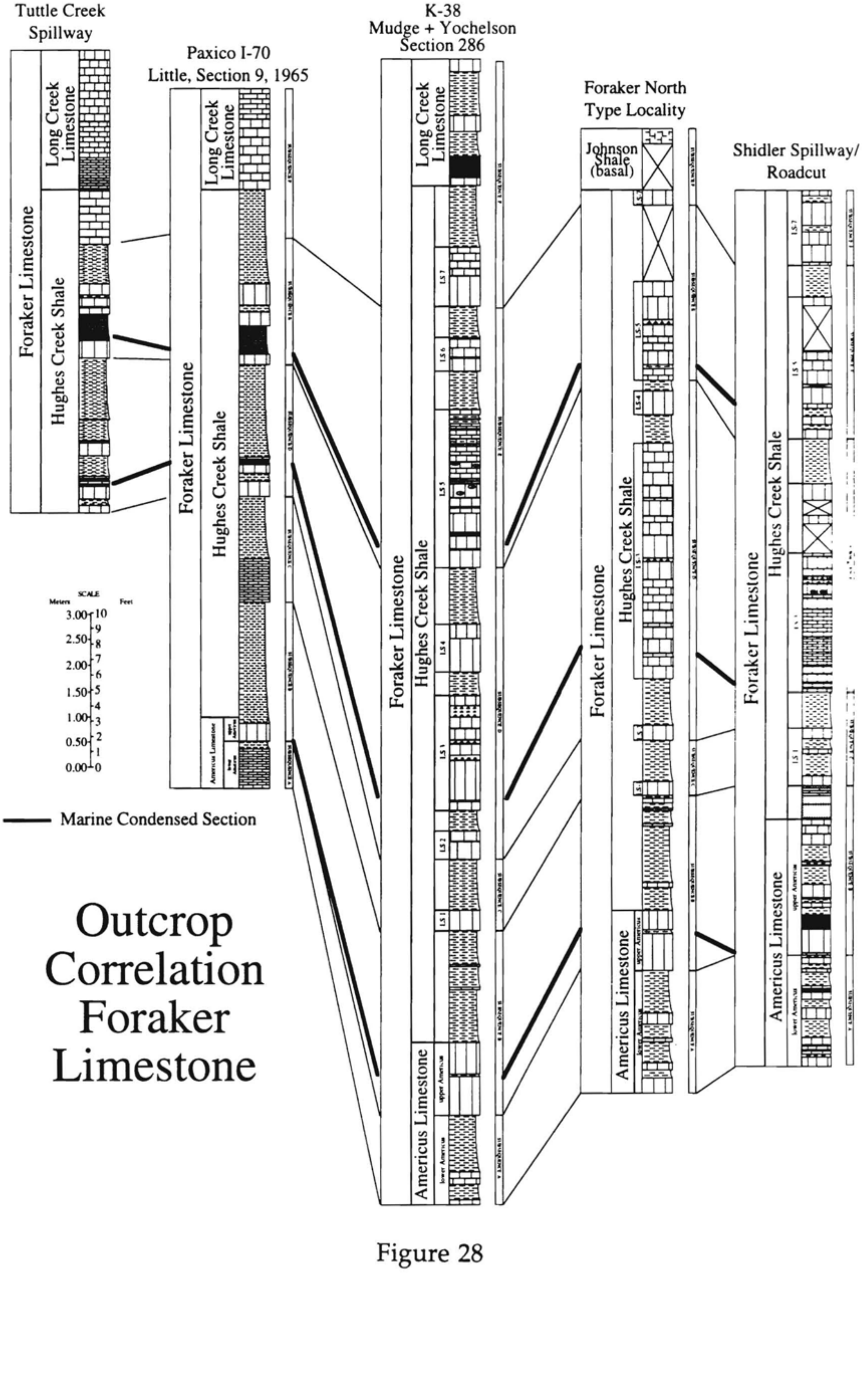

Tuttle Creek Spillway
Paxico I-70 Little, Section 9, 1965
K-38 Mudge + Yochelson Section 286
Foraker North Type Locality
Shidler Spillway/ Roadcut
Foraker Limestone
Long Creek Limestone
Hughes Creek Shale
Americus Limestone
Johnson Shale (basal)
SCALE
Meters
Feet
Marine Condensed Section
Outcrop Correlation Foraker Limestone

Figure 28

<u>Red Eagle Limestone</u>

In 1936 N.W. Bass correlated the Glenrock Limestone, Bennett Shale, and Howe Limestone of southern Nebraska to the Red Eagle Limestone of southern Kansas and northern Oklahoma. By 1937 Elias described the Red Eagle Limestone as a single cycle bounded by the Johnson Shale at the base and the Roca Shale at the top. Elias also proposed that the maximum depth of the cycle occurred during the Fusulinid phase in the Glenrock Limestone and reached depths somewhere between 160-180 feet (figure 29). O'Connor and Jewett correlated the Red Eagle from northern to southern Kansas (Figure 30). The northern Red Eagle was predominantly shale, southern outcrops were dominantly limestone. The correlation of individual members to the north was relatively simple, however to the south the members became virtually indistinguishable. The Glenrock Limestone Member was correlated based on *Orbiculoidea* fragments in the top crust. The correlation of the Bennett Shale Member was done with the *Orbiculoidea* brachiopods as well and the fusulinid zones at the base and top of the member. The Howe Limestone Member was correlated based on faunal and lithologic differences from the underlying Bennett Shale.

McCrone (1963) did extensive paleoecologic and lithostratigraphic analysis of the Red Eagle Limestone from southern Nebraska, through Kansas, into northern Oklahoma. McCrone agreed that the Johnson Shale and Roca Shale were the Bounding units of the Red Eagle Cycle, as well as the correlation of the Bennett Shale Member by O'Connor and Jewett (figure 31). McCrone did, however, propose some changes in interpretation. He proposed 3 sea level fluctuations within the Red Eagle, one in the Glenrock Limestone Member that matched Elias', a second at

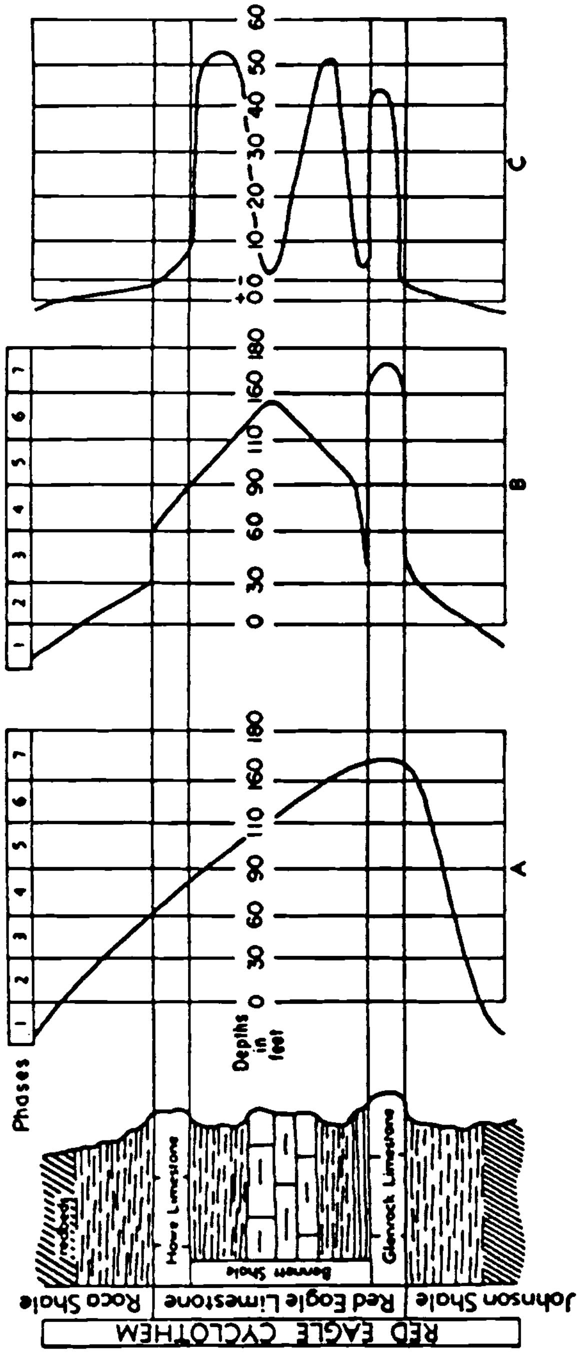


Figure 29
Interpreted depths of deposition for the Red Eagle Limestone
A-Elias 1937, B-Depths adjusted according to Elias, C-McCrone
(McCrone 1963)

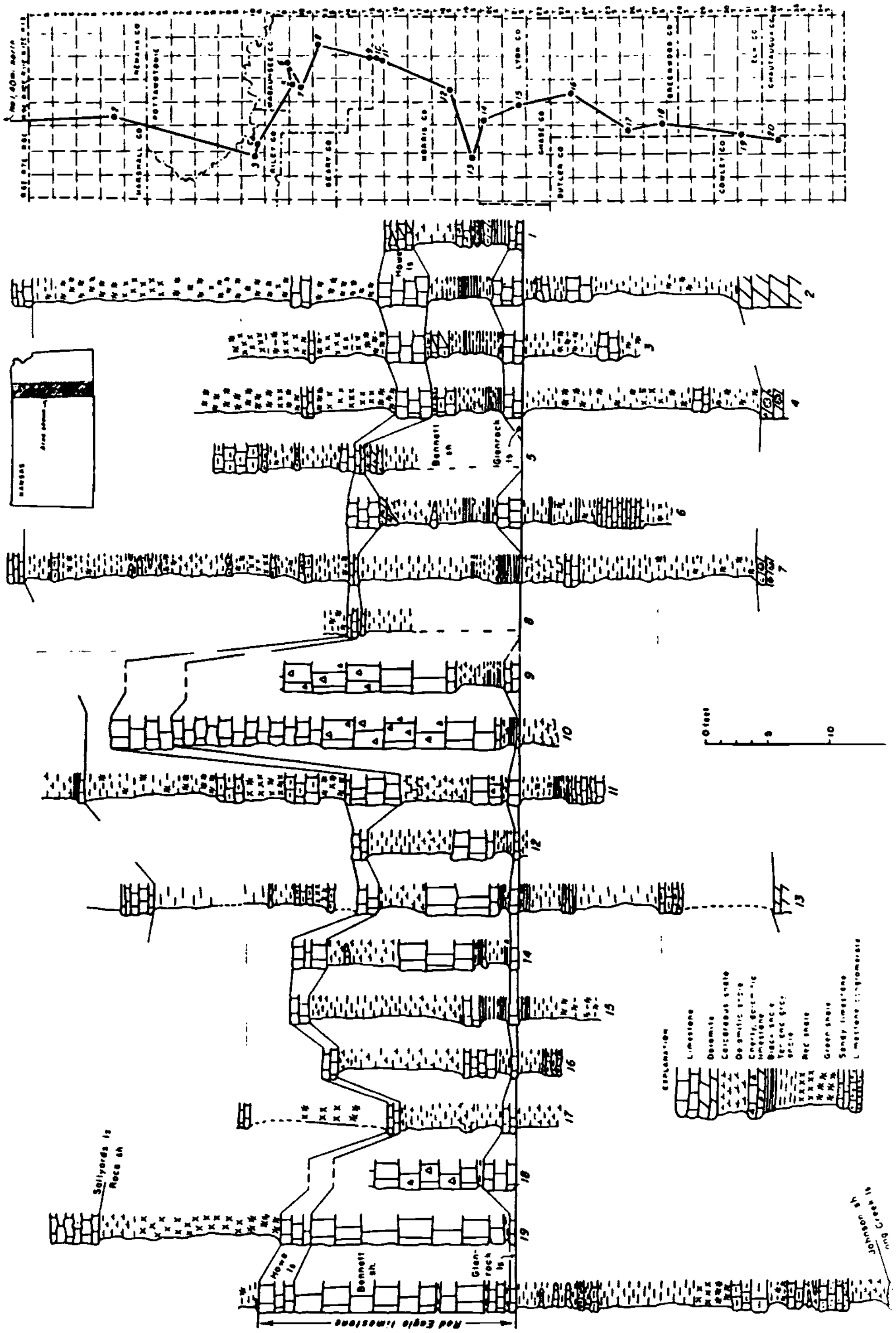


Figure 30
O'Connor and Jewett Red Eagle correlation (1952).

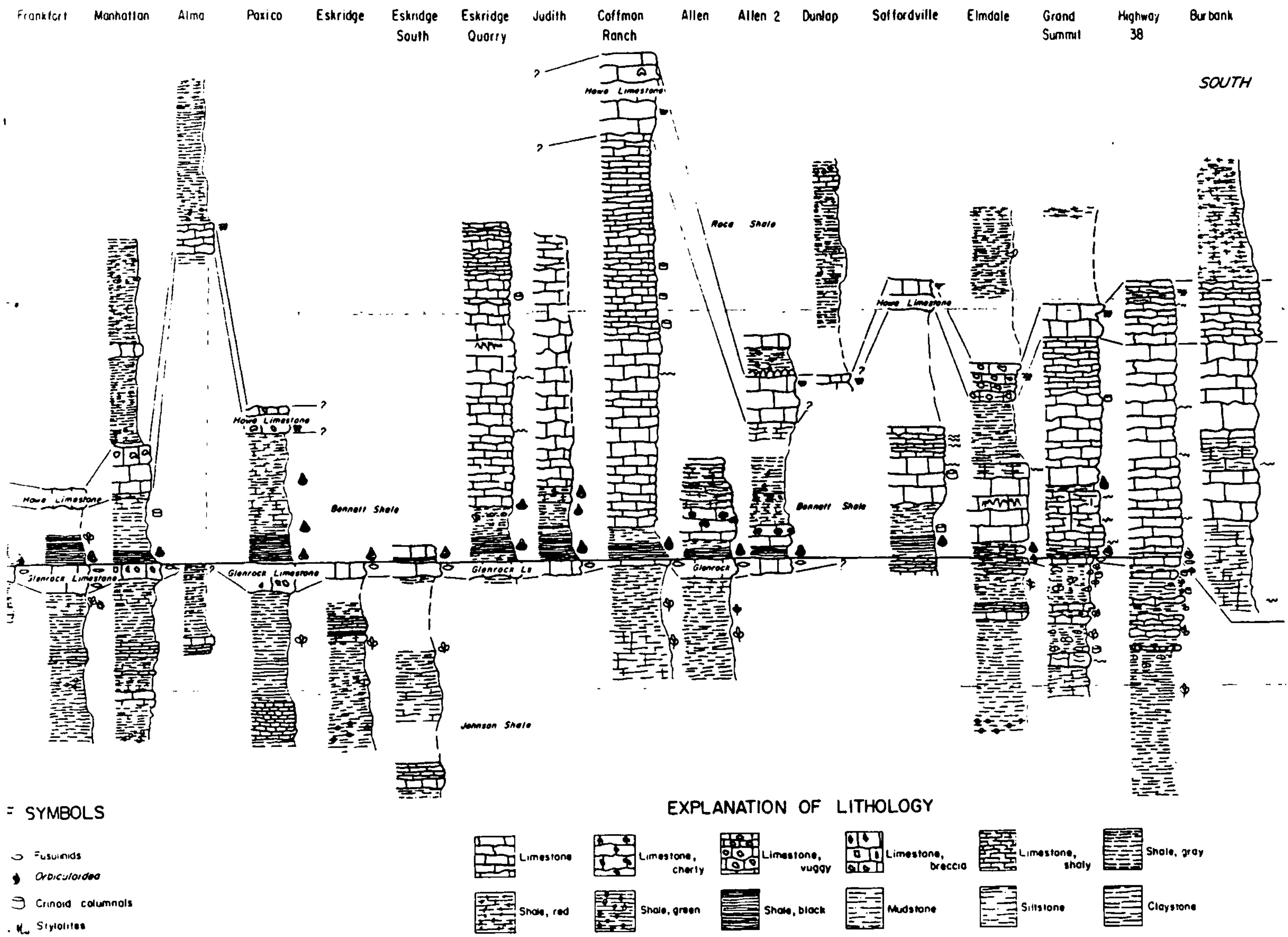


Figure 31
McCrone Red Eagle correlation (1963).

the Base of the Bennett Shale Member, and the third at the top of the Bennett Shale Member just below the Howe Limestone Member. He also suggested a shallower depositional environment, 50-60 feet maximum depth (see figure 18, tables 1 and 2).

Mudge and Yochelson did extensive work on the Red Eagle Limestone, complete with correlations as well as sedimentation and paleoecology. Their correlation of the Red Eagle from Nemaha county to Cowley County Kansas was exquisite, showing 24 measured sections. Their work also declared the Red Eagle Limestone as "A typical cyclothem of the Council Grove group of the Permian"(p.102). The measured section appears as figure 32, Mudge and Yochelson's interpretation is as follows.

> "In interpreting the cyclothem the fusulinid limestone (phase 7) very likely represents the maximum depth of water, if fusulinids indicate deep water. Assuming that they do, then a regression followed. During the regression, shale (phases 6 and 5) and the upper limestone (phase 4) were deposited. Phase 4 is very likely a relatively shallow water deposit. The deposition of the ostracode zone at or near the top of this limestone bed indicates that shoaling conditions existed. After deposition of phase 4 the basin began to subside and fill with shale." (Mudge and Yochelson 1962 p.102)

The initial flooding of the Red Eagle Sequence begins in the Johnson Shale. The Johnson Shale is generally a light gray to light brown shale with gray to green mudstone And some medium gray lenticular limestone. It also contains a distinct blocky dusky red zone, with root traces and caliche nodules. This zone is interpreted as an ancient soil and can be traced in outcrop from Manhattan Kansas to Ralston Oklahoma. Locally lag deposits of Chonited brachiopods are also present in gray shale just below the Red Eagle Limestone.

Unit of the Red Eagle cyclothem	Elias' depth of deposition, feet	Elias' phase	No.
Roca Shale			
medial red shale	0	Red shale	1
lower greenish shale	0-30	Green shale	2r
Red Eagle Limestone			
Howe Limestone Member	60-90	Molluscan phase	4r
Bennett Shale Member			
upper gray shale	90-110	Mixed phase	5r
medial limestone	110-160	Brachiopod phase	6
lower gray shale	90-110	Mixed phase	5p
basal black shale	30-60	*Lingula* phase	3p
Glenrock Limestone Member	160-180	Fusulinid phase	7
Johnson Shale			
upper greenish shale	0-30	Green shale	2p
medial red shale	0	Red shale	1

Table 1
Elias' (1937) depositional model of the Red Eagle Sequence (McCrone 1963)

Units of the Red Eagle cyclothem	Depth of deposition, feet	Phase (after Elias, 1937)	pH	Typical temperature, °F	Salinity, °/oo	Oxygenation	Turbidity	Circulation	Current velocity, cm/sec.
Roca Shale									
medial red shale	high intertidal	1		>70	?>37	oxidizing conditions	turbid	?restricted	
lower greenish-gray shale	low intertidal	2r		<65	<30		turbid	free	
Red Eagle Limestone									
Howe Limestone Member	0-10	4r	>7.5	>70	?>37	oxidizing conditions	clear	free	>10
Bennett Shale Member									
upper gray shale	10-50+	5r	8.0-8.2	>72	35-37		turbid	free	
medial limestone	0-50+	6	8.0-8.2	>70	35-37	oxidizing conditions	clear	free	
lower gray shale	10-50+	5p	8.0-8.2	>70	35-37		turbid	free	
basal black shale	0-10	3p				low oxygen	turbid	restricted	
Glenrock Limestone Member	10-40+	7	8.0-8.2	>70	35-37	oxidizing conditions	clear	free	
Johnson Shale									
upper greenish-gray shale	low intertidal	2p		<65	<30		turbid	free	
medial red shale	high intertidal	1		>70	?>37	oxidizing conditions	turbid	?restricted	

Table 2
McCrone's summary of interpreted conditions during Red Eagle deposition (1963)

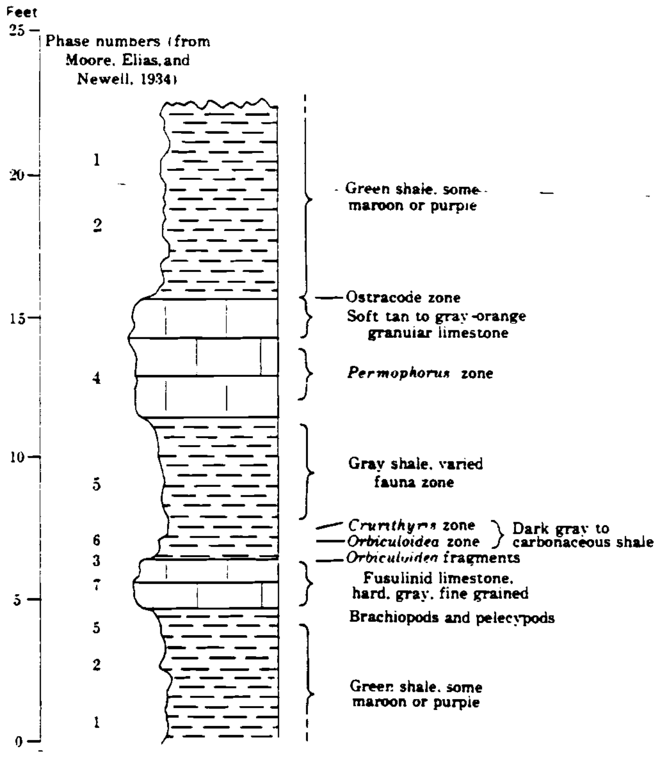


Figure 32
Typical Council Grove Cyclothem, Mudge and Yochelson (1963).

The thickness of the Johnson Shale varies from approximately 20 feet (6.10 meters) in Manhattan Kansas to approximately 15 feet (4.57 meters) at the Burbank Quarry and thins as it continues south to Ralston.

The general trend of the Red Eagle is for the exposures to be more clayey to the north. The northern exposures of the Red Eagle Limestone can easily be divided into it's specific members: Glenrock Limestone Member, Bennett Shale Member, and Howe Limestone Member. To the south the recognition of individual members is, in most cases, not feasible. The correlation of the Red Eagle Limestone was based on microfaunal conodonts, and marine condensed sections, as well as lithologic observations.

The Glenrock Limestone Member is 2 feet 3 inches (.69 meters) thick at the Tuttle Creek locality in Manhattan, Kansas. The Glenrock Limestone Member can be divided into three separate lithologies. The bottom inch is a very light to light gray intraclastic mudstone. Above that is 2 feet (.61 meters) of light gray limestone with rare fossils and Thalassinoides burrows. The top two inches contain fusulinids and abundant articulate brachiopods, as well as an omission surface evidenced by a hardground, indicating a minor hiatus in deposition with little to no erosion.

The Bennett Shale Member at Tuttle Creek in Manhattan Kansas is 4 feet (1.22 meters) thick and can be divided into three separate lithologies. The basal foot is a black phosphatic shale marine condensed section that contains Orbiculoidea, Curithyris, and Lingula brachiopods. The middle 3 feet 5 inches (1.04 meters) is a dark gray shale with abundant inarticulate brachiopods and minor shark debris. The upper 5 inches (.13 meters) is a medium to light gray carbonate, with abundant fossil remains and is interpreted as a lag deposit.

At the Tuttle Creek locality (figure 33, photos 88-99) in manhattan Kansas the Howe Limestone Member is 3 feet 10 inches (1.17 meters) thick and is capped by mound stromatolites. The Howe Limestone Member can be divided into two lithologies. A lower very pale orange limestone, with fusulinids, productids, crinoids and bryozoa, that is a wackestone. The upper is a very pale orange limestone, with coated grains and ostracodes and is a packstone. The two lithologies are separated, 3 feet 2 inches (.97 meters) from the base, by a thin minor marine condensed section that appears as a preferentially weathered two inch bed.

As you trace the Red Eagle Limestone to the south the three members, Glenrock Limestone, Bennett Shale, and Howe Limestone become indistinguishable, forming a massive limestone. At the southern Kansas locality K-38, (figure 34, photos 100-104) the Red Eagle Limestone is approximately 12 and 1/2 feet (3.81 meters) thick. The basal 2 feet (.61 meters) are interbedded fossiliferous limestones and shales, topped by 1 and 1/2 feet (.46 meters) of algal limestone. The rest of the section is limestone with occasional shale stringers.

In northern Oklahoma, Burbank Quarry, the Red Eagle is approximately 36 feet (10.97 meters) thick. The basal foot is thin interbedded limestones and shales, this is topped by 11 feet (3.35 meters) of algal limestone. One foot above the algal limestone is a foot thick shale parting, that is topped by massive gray marine limestone approximately 24 feet (7.32 meters) thick.

The lithostratigraphic characteristics and conodont data from this study of the Red Eagle Limestone was compiled to create a north to south correlation. (figure 35)

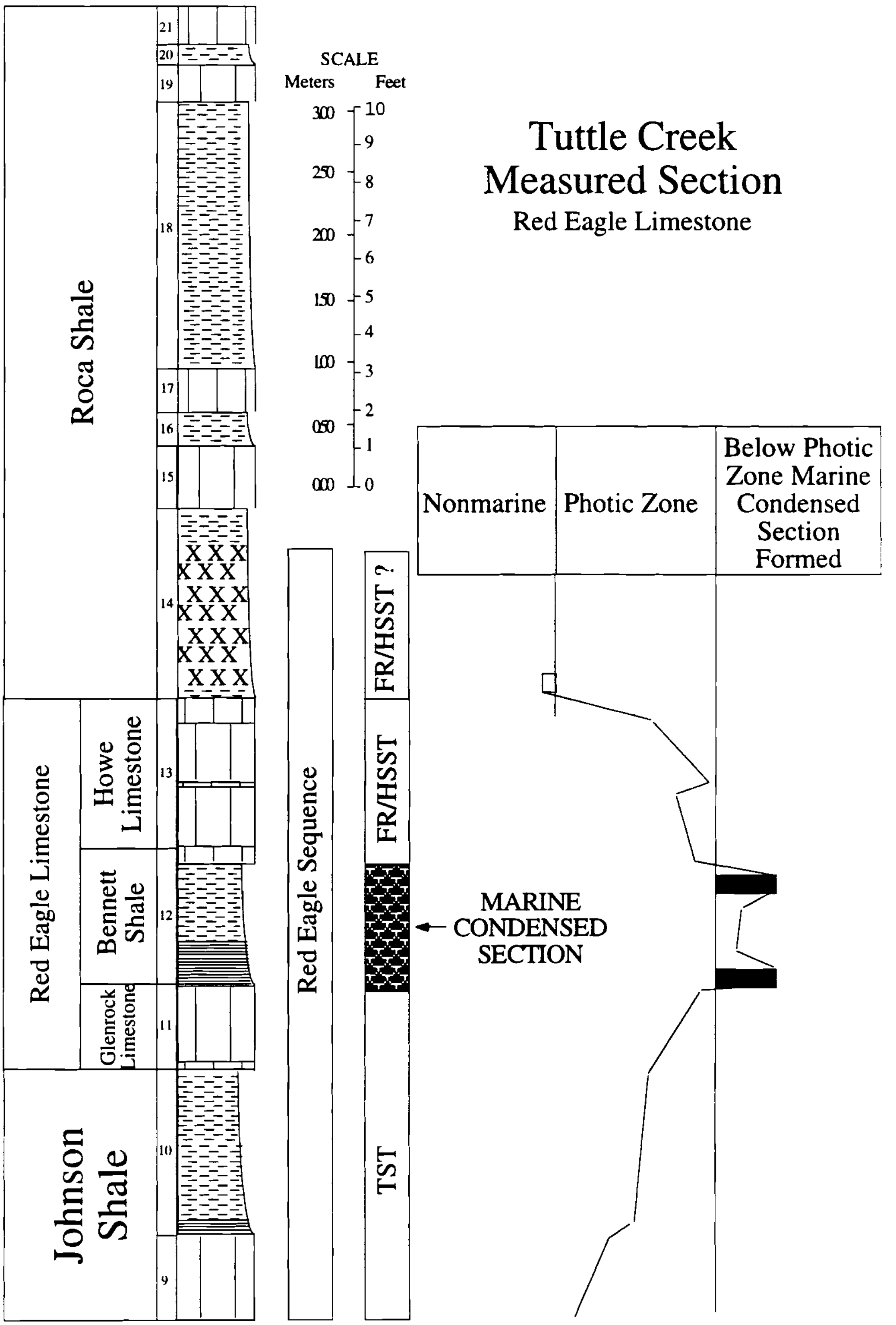

Tuttle Creek
Measured Section
Red Eagle Limestone
SCALE
Meters
Feet
300
250
200
150
100
050
000
10
9
8
7
6
5
4
3
2
1
0
Roca Shale
Red Eagle Limestone
Howe Limestone
Bennett Shale
Glenrock Limestone
Johnson Shale
21
20
19
18
17
16
15
14
13
12
11
10
9
Red Eagle Sequence
FR/HSST ?
FR/HSST
TST
MARINE CONDENSED SECTION
Nonmarine
Photic Zone
Below Photic Zone Marine Condensed Section Formed

Figure 33

State: Kansas **County:** Pottawatomie

Locality Description:
Location is the Tuttle Creek Spillway. Recent flooding (1994) has removed the topsoil exposing exquisite outcrops for sampling and measuring.

Interval measured is the Red Eagle Limestone and Roca Shale

UNIT DESCRIPTIONS

9	26 inches (.66 meters)	Johnson Shale: light olive gray, horizontally laminated limestone.
10	53 inches (1.35 meters)	Johnson Shale: dark gray at base grading up through medium gray at top, silty, four layers of silt that grade out up section, Chondrities like burrows, uppermost bioturbated.
11	27 inches (.69 meters)	Glenrock Limestone: bottom inch is a very fine grained mudstone, very light gray in color, it is overlain by light gray intraclastic packstone, with ostracodes, minor amounts of pyrite, fragments of brachiopods and/or mollusks, foraminifera -fusulinids- increase in abundance towards the top. The top 2 inches shows *Thassaloinides* burrows.
12	46 inches (1.17 meters)	Bennett Shale: bottom 36 inches is a black fissile shale with abundant orbiculoid brachiopods, it is packed with *Streptognathodus* conodonts. Above there is 6 inches of a dark gray shale and 4 inches of a medium gray limestone with abundant shark debris, and brachiopods, with abundant *Streptognathodus* conodonts.
13	46 inches (1.17 meters)	Howe Limestone: very pale orange limestone, wackestone, ostracodes, fusulinids, brachiopod, crinoid, and trilobite fossils are found, the fusulinids are abundant in the upper 23 inches.
14	52 inches (1.32 meters)	Roca Shale: green to dusky red blocky mudstone paleosol.
15	14 inches (.36 meters)	Roca Shale: light gray hard dense limestone
16	4 inches (.10 meters)	Roca Shale: gray green silty shale.
17	20 inches (.51 meters)	Roca Shale: light gray slight greenish, blocky hard dense limestone.

18	77 inches (1.96 meters)	Roca Shale: gray to gray green shale, some silt, blocky.
19	16 inches (.41 meters)	Roca Shale: gray slightly tan limestone, dense.
20	9 inches (.23 meters)	Roca Shale: silty dark gray shale, limestone nodules.
21	17 inches (.43 meters)	Roca Shale: gray dense hard limestone.

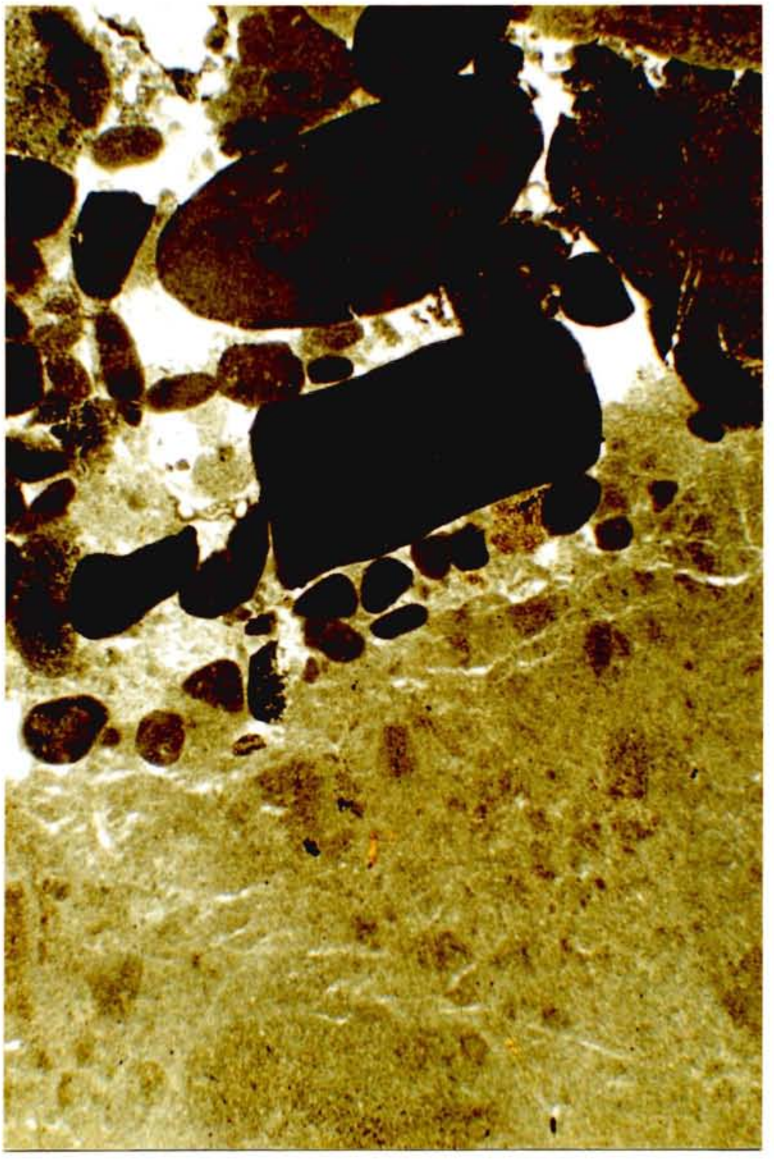


Photo 88

Tuttle Creek Glenrock Limestone Member

Mudstone intraclastic packstone boundary, measured section basal unit 19.

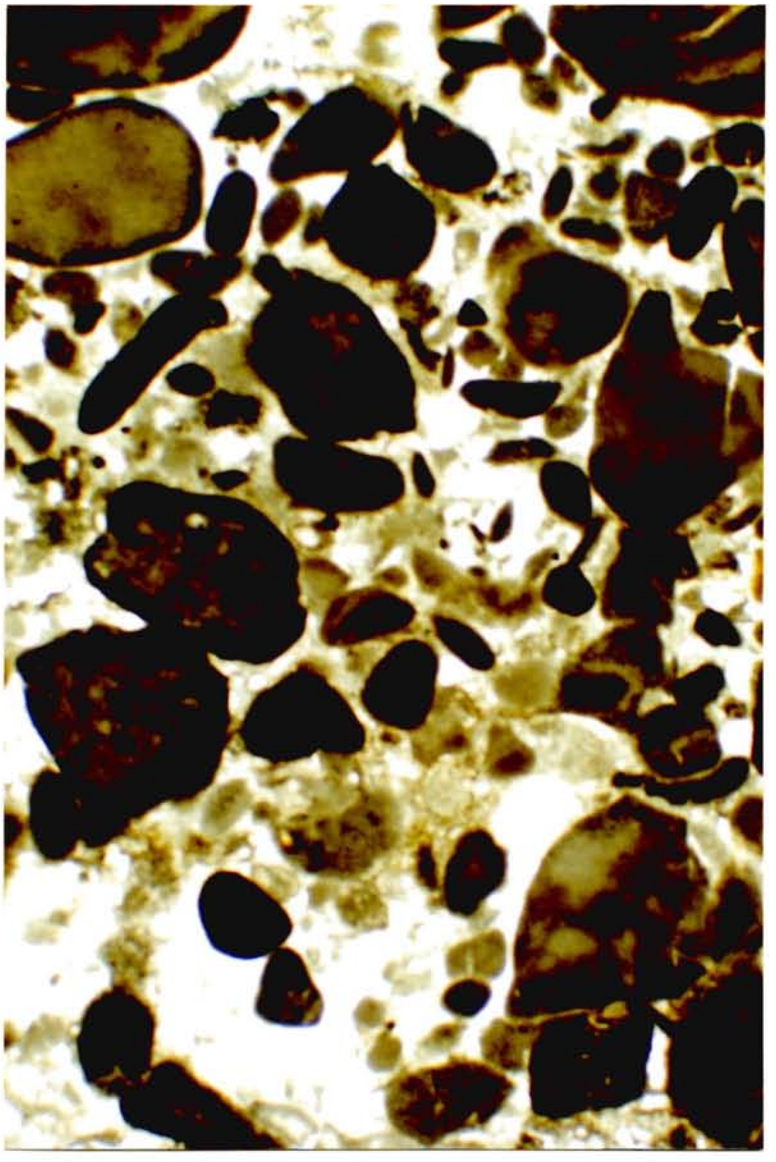


Photo 89

Tuttle Creek Glenrock Limestone Member

Intraclastic packstone, measured section lower unit 19.

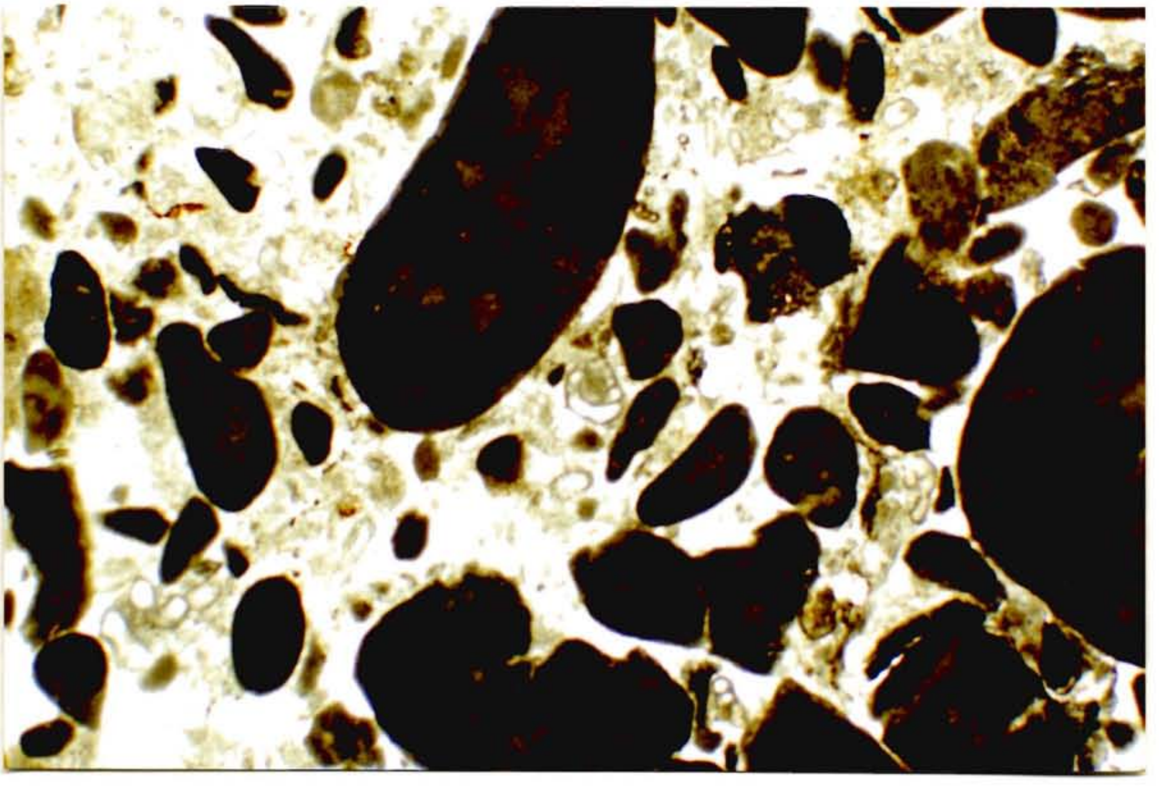


Photo 90

Tuttle Creek Glenrock Limestone Member

Intraclastic packstone, measured section middle unit 19, fusulinids.

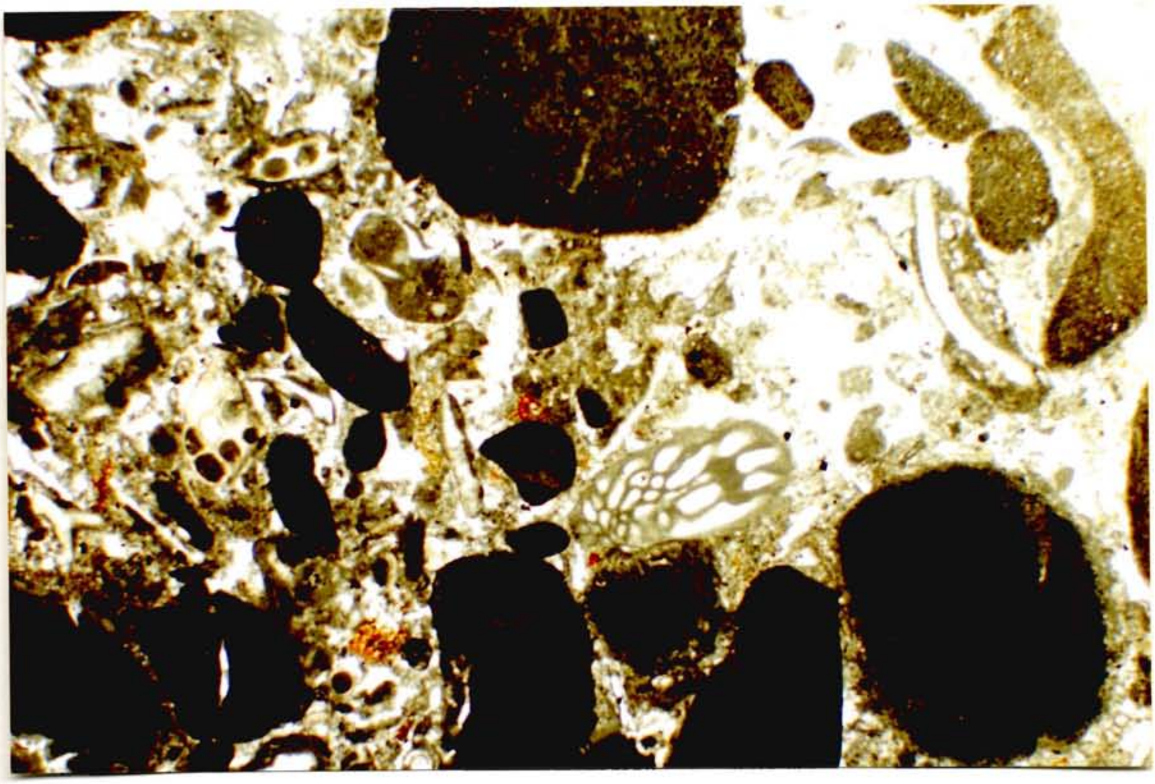


Photo 91

Tuttle Creek Glenrock Limestone Member

Intraclastic packstone, measured section middle unit 19, small foraminifera (center).

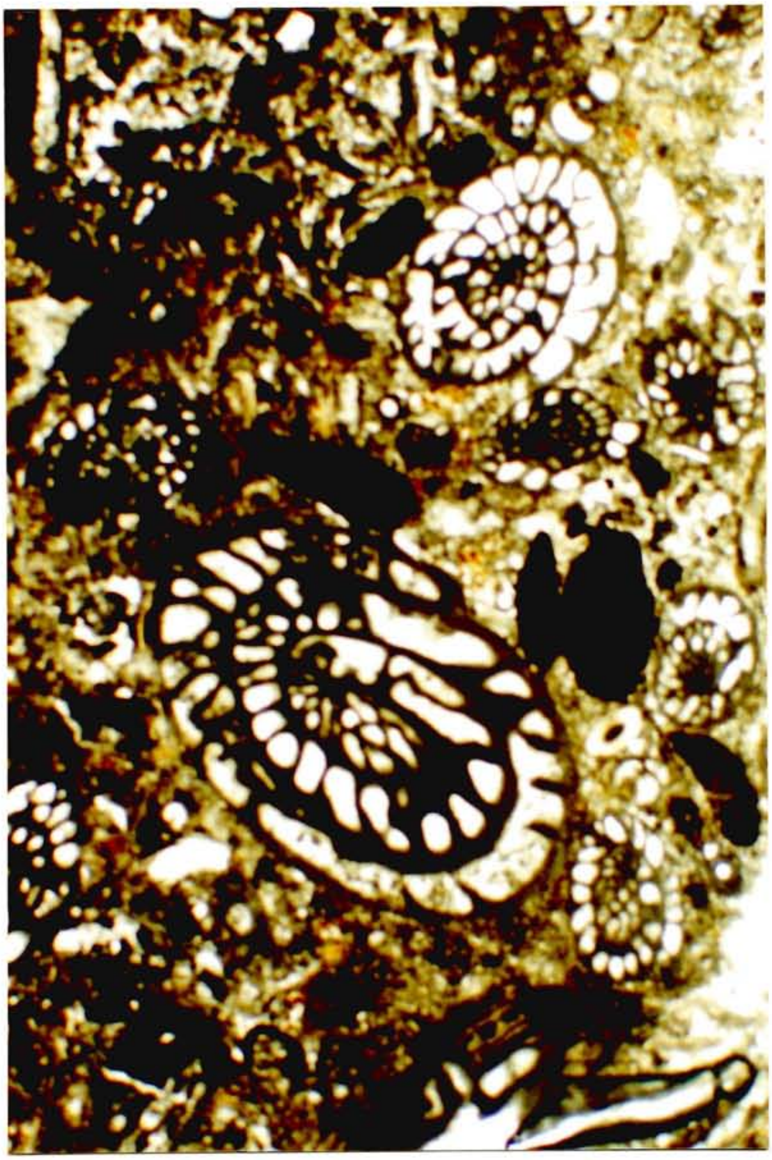


Photo 92

Tuttle Creek Glenrock Limestone Member

Intraclastic packstone, measured section upper unit 19, identified fossil content coral, brachiopod fragment.

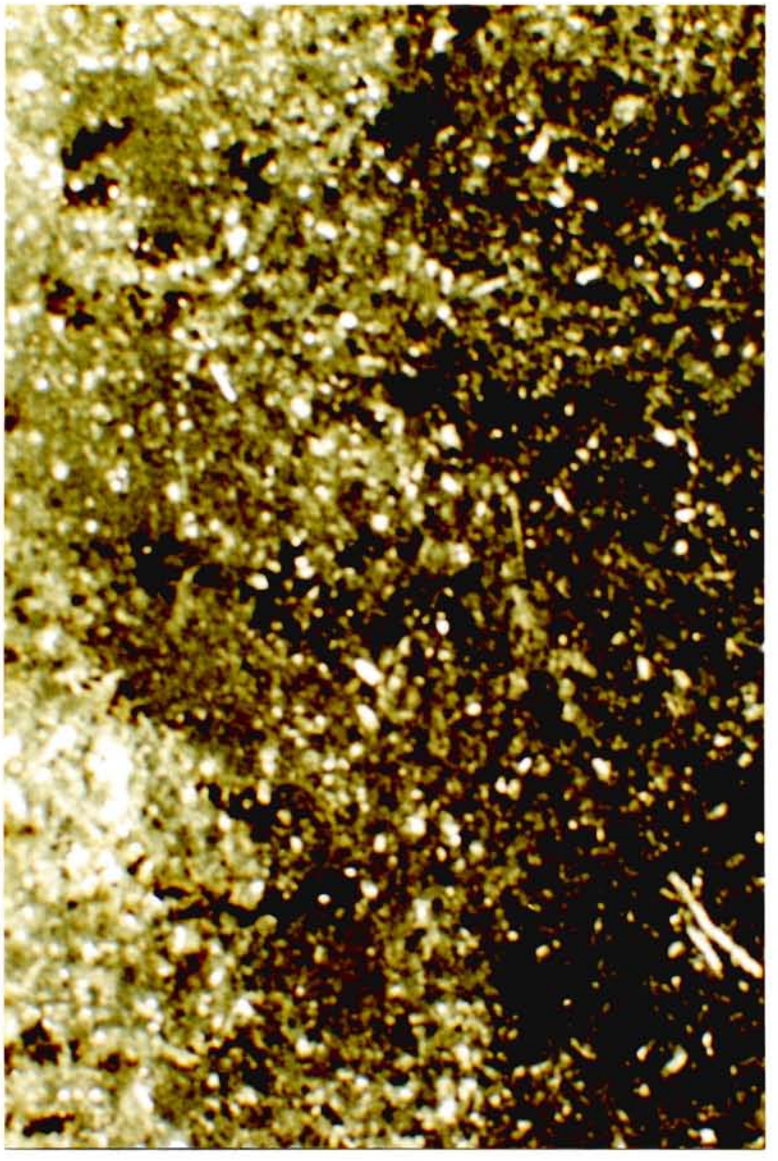


Photo 93

Tuttle Creek Howe Limestone Member

Wackestone, measured section lower unit 20.

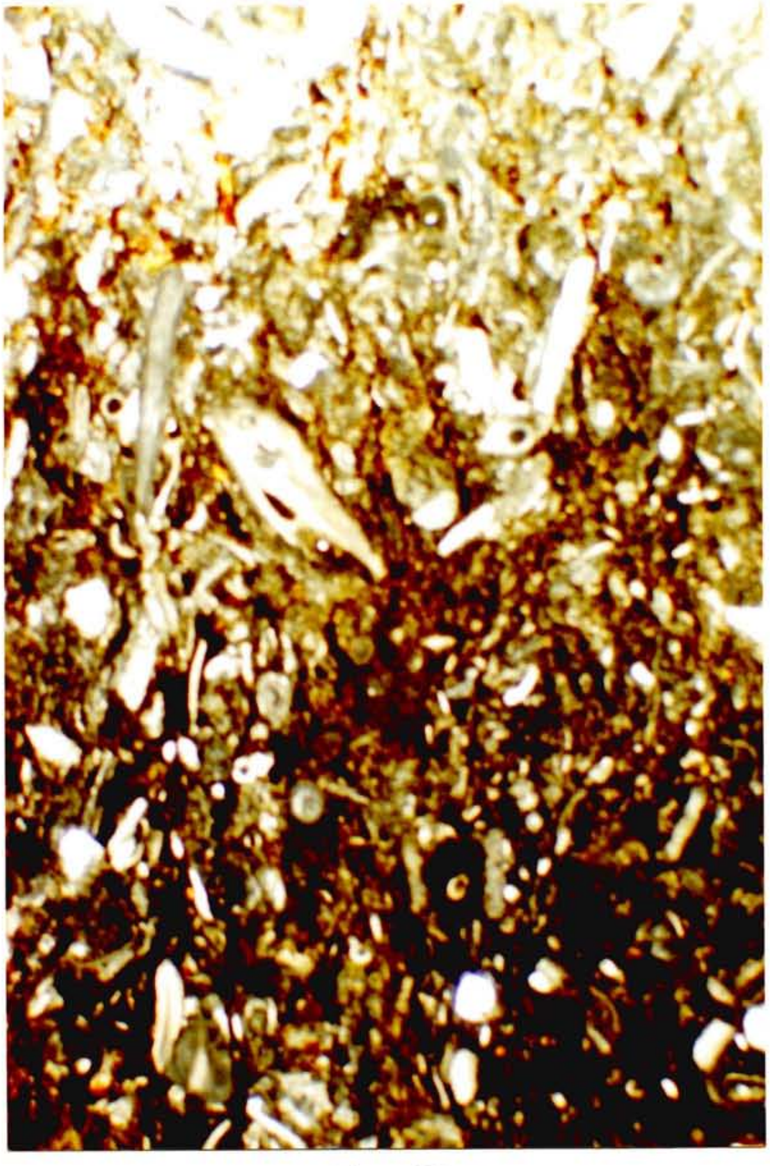


Photo 94

Tuttle Creek   Howe Limestone Member

Wackestone, measured section middle unit 20 minor marine condensed section, amber/caramel colored grains are phosphate (likely conodonts).

Photo 95

Tuttle Creek Howe Limestone Member

Wackestone, measured section upper unit 20, identified fossil content echinoderm, brachiopod (and spines).

Photo 96

Tuttle Creek Johnson Shale

Taken at Tuttle Spillway, Johnson Shale, contact with the Glenrock Limestone Member (uppermost limestone ledge in photo) of the Red Eagle Limestone.

Photo 97

Tuttle Creek Glenrock Limestone Member

Taken at Tuttle Spillway, Photo shows the burrows at the top of the Glenrock Limestone Member.

Photo 98

Tuttle Creek Bennett Shale and Howe Limestone Members

Taken at Tuttle Spillway, Contact of the Bennett Shale and Howe Limestone, the light gray carbonate at the contact is the uppermost Bennett Shale..

Photo 99

Tuttle Creek Bennett Shale Member

Taken at Tuttle Spillway, Burrows in the gray carbonate at the top of the Bennett Shale Member.

K-38 Measured Section

Red Eagle Limestone

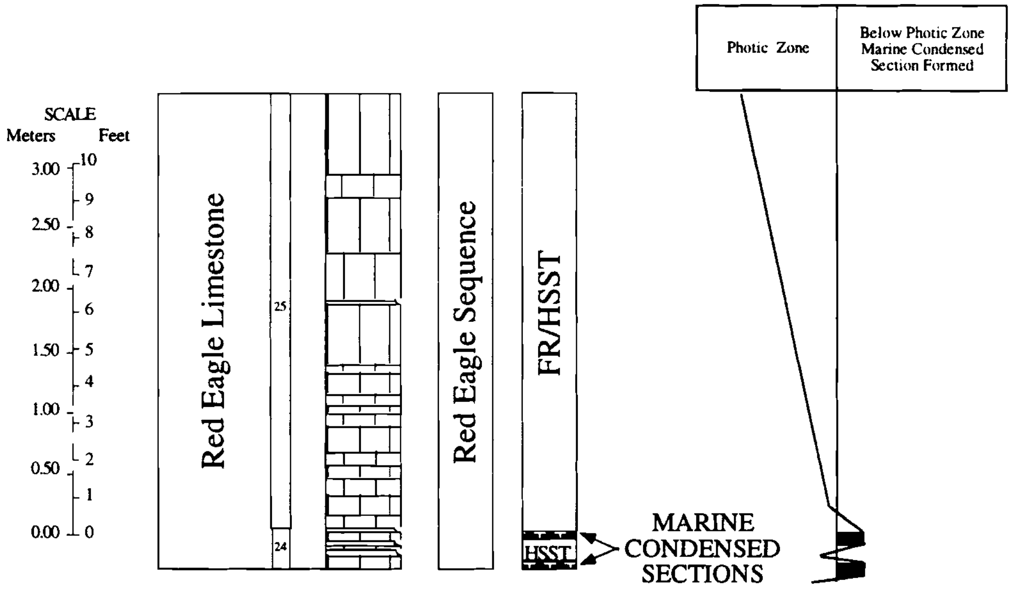


Figure 34

State: Kansas **County:** Cowley

Locality Description:

Location is a road cut on Kansas State highway 38. This locality provides excellent exposure of the Red Eagle limestone

Interval measured is the Red Eagle Limestone

South Line 21 T32E R8E

UNIT DESCRIPTIONS

24	1 inch (.03 meters)	Red Eagle limestone: bottom 1 inch is a medium light gray limestone, abundant *Streptognathodus* conodonts, some glauconite, phosphatic debris, fragmented brachiopods and crinoids. wackestone.
	17 inches (.43 meters)	Red Eagle limestone: medium light gray limestone wackestone with interbedded shale, brachiopods, crinoids.
	3 inches (.08 meters)	Red Eagle limestone: limestone-shale-limestone, abundant *Streptognathodus* conodonts, some glauconite and phosphatic debris. wackestone medium gray in color.
25	108 inches (2.74 meters)	Red Eagle limestone: very light gray to medium light gray limestone, wackestone, brachiopods, bryozoa, coral, algae, ostracodes, minor amounts of hematite.

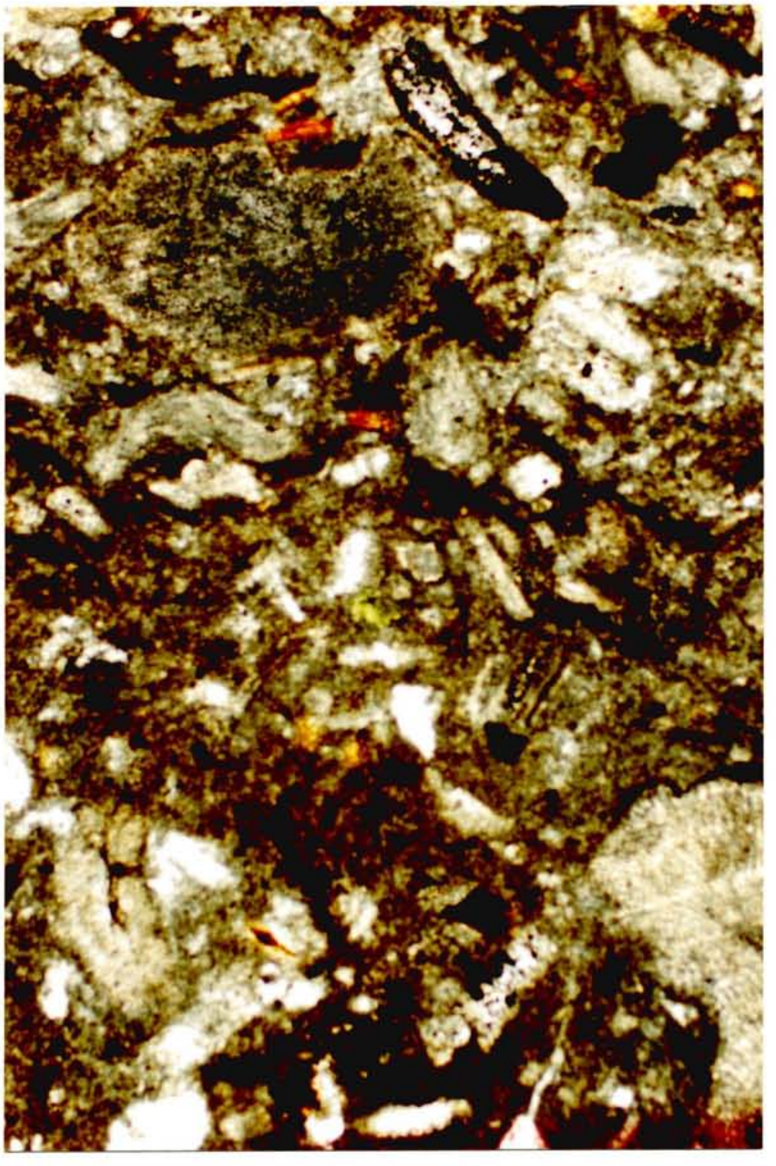


Photo 100

K-38 Red Eagle Limestone

Marine condensed section, measured section unit 24, amber/caramel grains phosphate (likely conodonts), green grains glauconite, identified fossil content echinoderm wackestone.

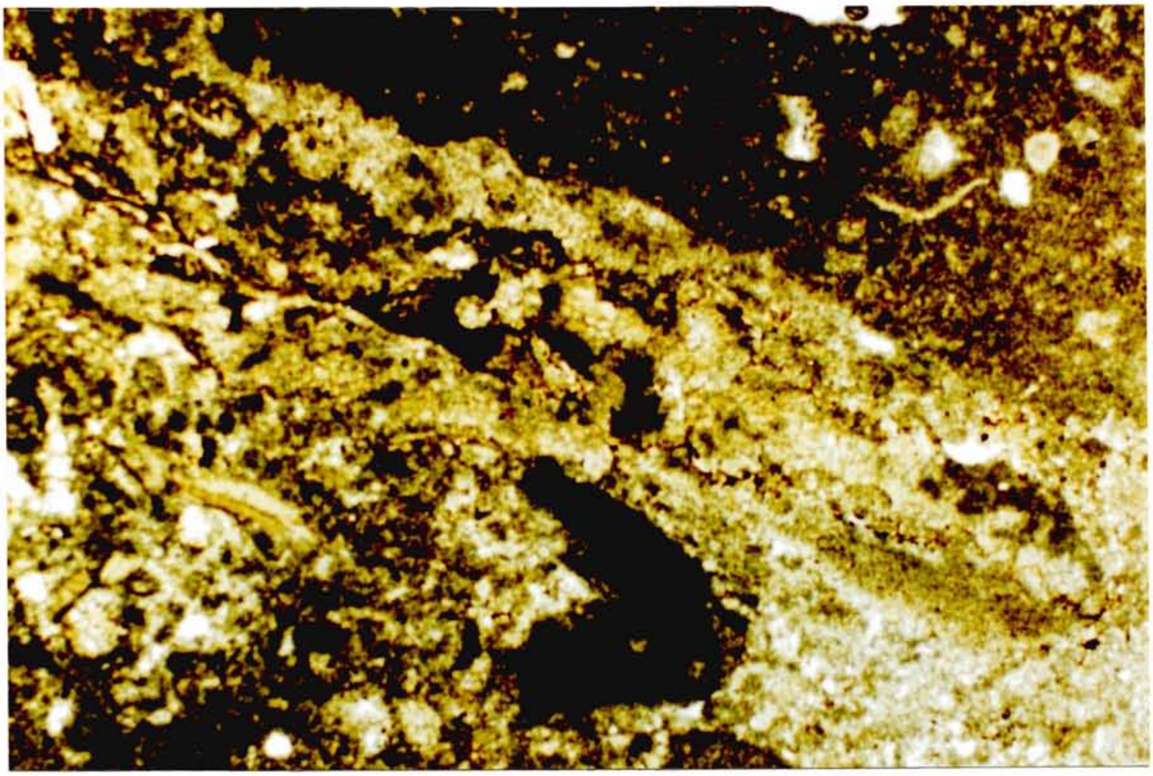


Photo 101

K-38 Red Eagle Limestone

Wackestone, measured section 24 inches (.61 meters) from base of unit 24, identified fossil content brachiopod, algae, foraminifera, echinoderm.

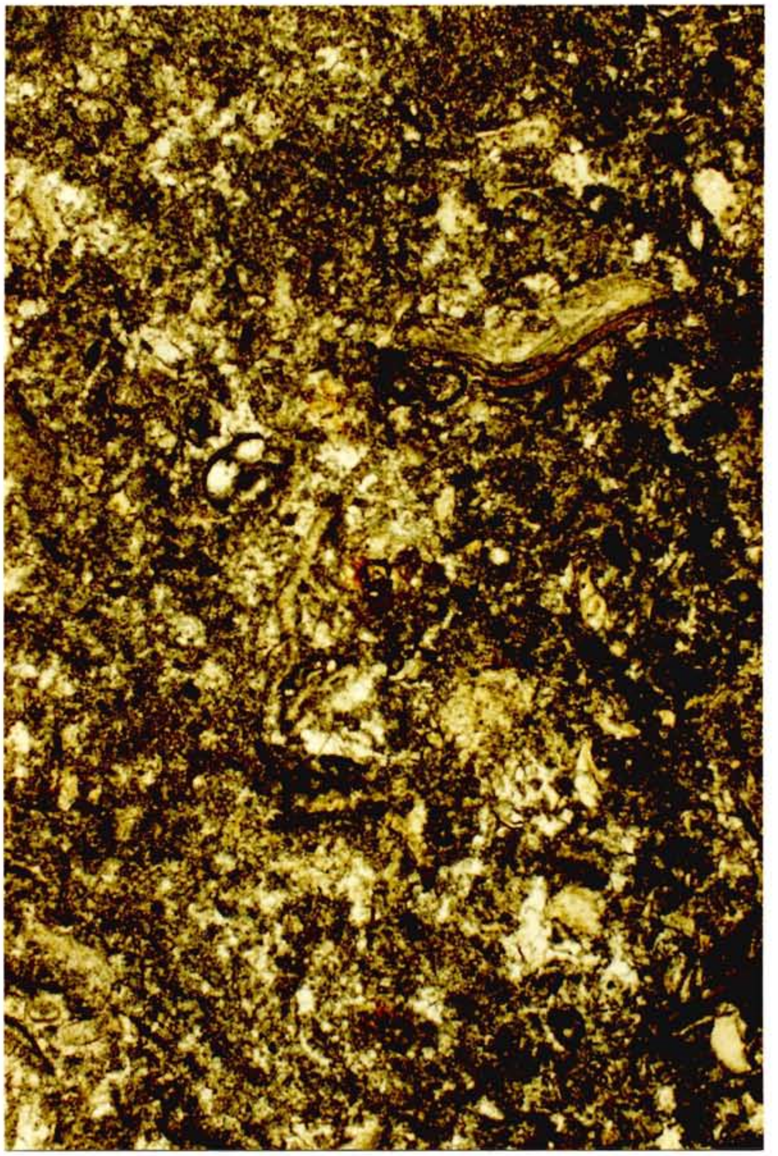


Photo 102

K-38 Red Eagle Limestone

Wackestone, measured section unit 25, identified fossil content ostracodes.

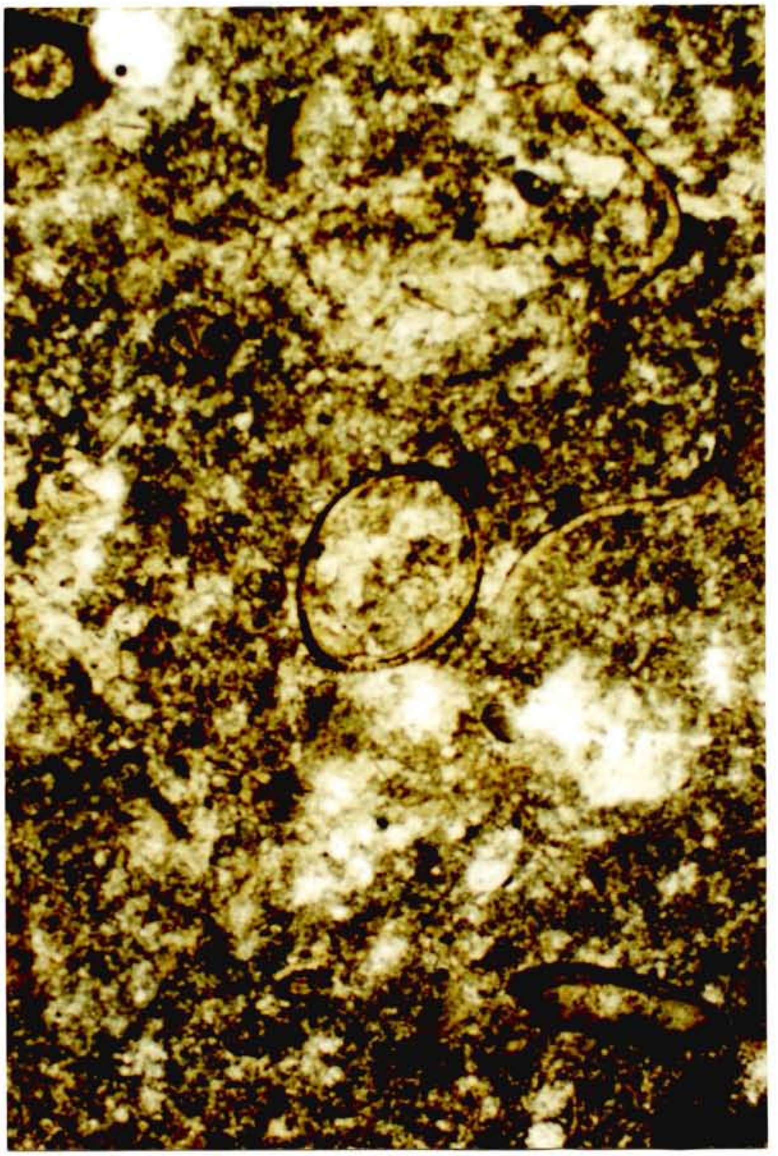


Photo 103

K-38 Red Eagle Limestone

Wackestone, measured section uppermost unit 25.

Photo 104

K-38 Red Eagle Limestone

Taken along Kansas State Highway 38, The lowermost shale in the photo is the Johnson Shale, the massive block including the crumbly limy shale at the base is the Red Eagle Limestone..

Correlation of Red Eagle Limestone

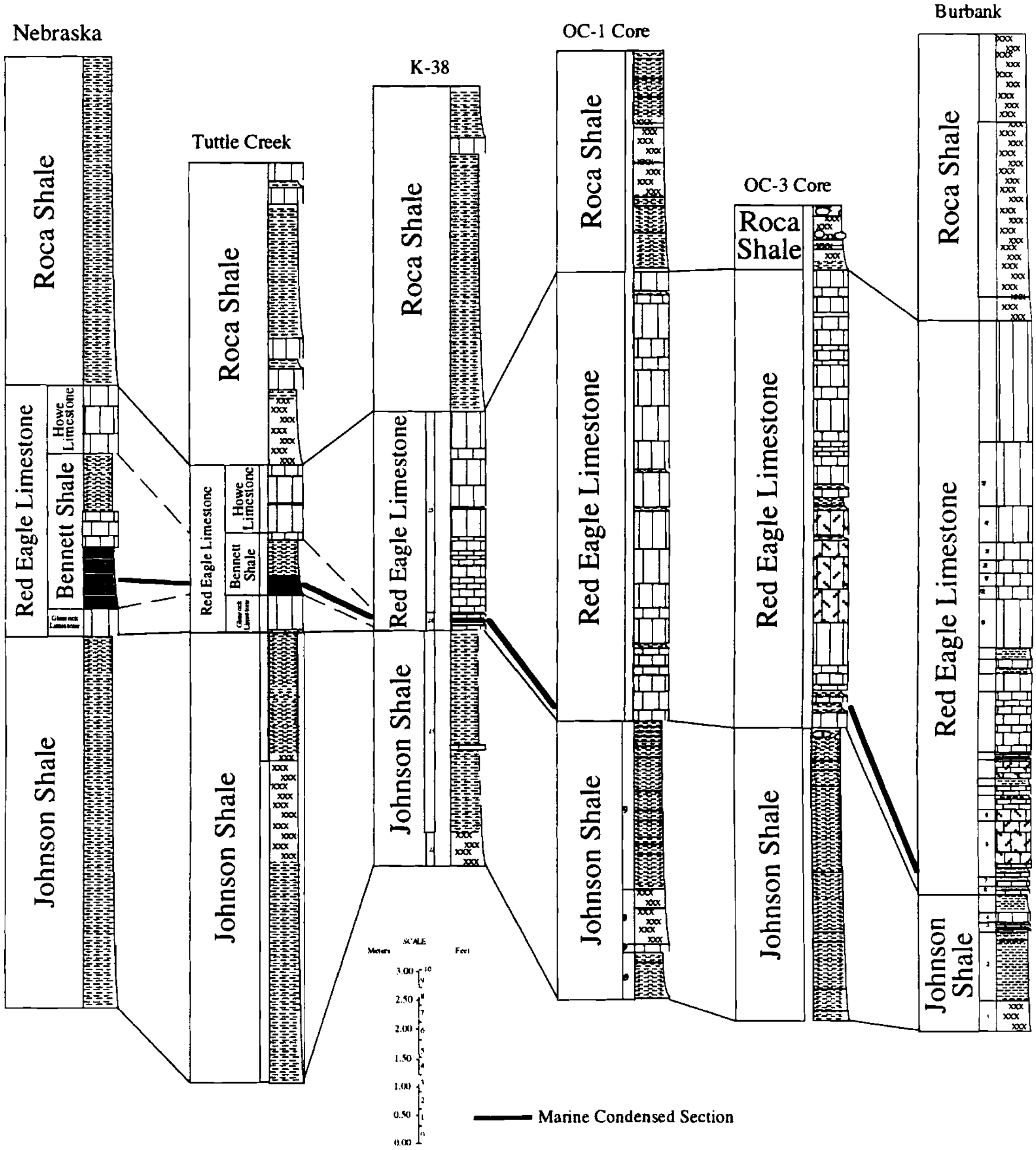


Figure 35

The History Of The Permian Boundary

The exact location of the Pennsylvanian Permian boundary of the North American Mid-continent is highly disputed among geologists.

The first reference of Permian fossils in Kansas was made by Swallow in 1858, this was followed shortly by the first placement of the Pennsylvanian Permian boundary. Swallow and Hawn (1858) placed the boundary in the Council Grove Group at the base of the Neva Limestone. The boundary came into dispute in 1859 when Meek and Hayden preferred the term "Permo-Carboniferous" claiming the work by Swallow and Hawn had insufficient paleontological and lithologic data to accurately place the boundary. Further disagreement was shown by Prosser who originally placed the boundary near the Cottonwood Limestone, only to move it himself, in 1902, to the base of the Wreford Limestone. In 1903 Adams, Girty, and White, believed a lithologic and color difference in the limestones of the Admire Group and the Americus and Foraker would aid in placing the boundary.

Based on the fusulinid *Paraschwagerina*, Beede and Kniker (1924) suggested the base of the Neva Limestone as the boundary location. In 1931 King, based on the first appearance of the amminoid *Uddenittes*, suggested the boundary be placed at the Americus Member. Moore, who originally supported the boundary at the Americus Member in 1932, working with Moss (1934) moved the boundary to a massive channel sandstone at the base of the Admire Group. Romer (1935) working with vertebrate fossils, proposed a boundary above the Carlton Limestone of the Sumner Group. Schuchert (1935) working with brachiopods, decided the boundary would have to be placed based on the decisions of a commission. White (1936) working with plants, noted the Americus as Permian and suggested a lower boundary. This plant correlation was shunned by Moore, Elias, and Newell, and maintained that lithologic difference between the Virgilian and Big Blue series should be the determining factor. Elias (1937a) cited the first occurrence of the "true Permian type cycle" at the Five Point Limestone in the Admire as sufficient evidence to place the boundary at the base of the Admire Group. Kellett (1943) working with ostracodes in the Permian agreed with the base of the Admire as the boundary.

In 1962 Mudge and Yochelson felt the boundary location was based on incomplete faunal evidence, cephalopods, bryozoans, and conodonts, had not been consulted. They suggested the current boundary, at the base of the Admire, should be retained until more research and correlations with the Russian type area had been conducted.

In addition to the confusion and disagreement of a suitable location for the Pennsylvanian Permian boundary, the names of the rocks themselves have been disputed. Originally the rocks of the Permian were referred to as the "Big Blue Series", this included the Admire, Council Grove, and Chase groups. Moore (1951) replaced the Big Blue Series with the West Texas time-stratigraphic terminology calling it "Wolfcampian". Branson (1960) favored replacing Wolfcampian with "Lyon Series" in Oklahoma, Kansas, and Nebraska as they are not correlatable with the West Texas section. (The Lyon Series was never widely used) O'Connor (1963) suggested the term "Gearyan Stage" in place of Wolfcampian, this term was not widely accepted either. In 1983 the North American Commission on Stratigraphic Nomenclature and the Kansas Geological Survey have agreed to use the West Texas nomenclature and abandon all others ". . . until global boundaries are formally established" (Barrs 1990).

Since this decision Ross and Ross (1987) have created a stage called "Bursum" in an effort to correlate the North American boundary with the former Soviet Union boundary. The Carboniferous-Permian boundary stratotype is located in a stratigraphic section at Aidaralash Creek, northern Kazakhstan.(Bogoslovskaya et al. 1995) The section contains "abundant and well preserved amminoid, fusulinacean, and conodont faunas" with a "profound" change in amminoid fauna.

CONODONTS

General Characteristics of the Conodont

This study utilized conodont elements, first named and described by Pander (1856), as the primary paleoecologic indicator of sea-level fluctuation and depositional environment. The conodont is an extremely useful stratigraphic tool for several reasons: 1. worldwide distribution in marine strata, 2. restricted lateral and vertical distribution within the marine environment for specific genera, 3. not independent of facies changes within sedimentary environment, 4. rapid diversification and a long stratigraphic range, upper Cambrian to late Triassic (Stearn and Carrol 1989)(Sweet 1988).

Conodonts were dominantly soft bodied organisms, and as a result rarely preserved in entirety. Our understanding of what the Conodont appeared as during its life is derived primarily from 1 Silurian *Panderodus* specimen from Wisconsin, described by Mikulic et al. (1985a, 1985b) and Smith et al. (1987) and 4 Scottish Namurian specimens described by Briggs et al. (1983) and Aldridge et al. (1986). The Scottish specimen have provided the most insight (figure 36). The material that was originally organic has been preserved as a brownish crystalline substance with overlying patches of pale blue mineral. Although the specimens have been compressed and altered during preservation an interpretation of the living conodont can be made. The Conodont was an elongate and worm like organism, 40 -42 mm long and 1.2 - 1.8 mm wide.

> "One end of one specimen, interpreted as a cephalic lobe, is slightly expanded, bilobed, and includes an essentially complete natural assemblage of conodont elements, which are oriented with their long axes transverse to that of the specimen as a whole. The

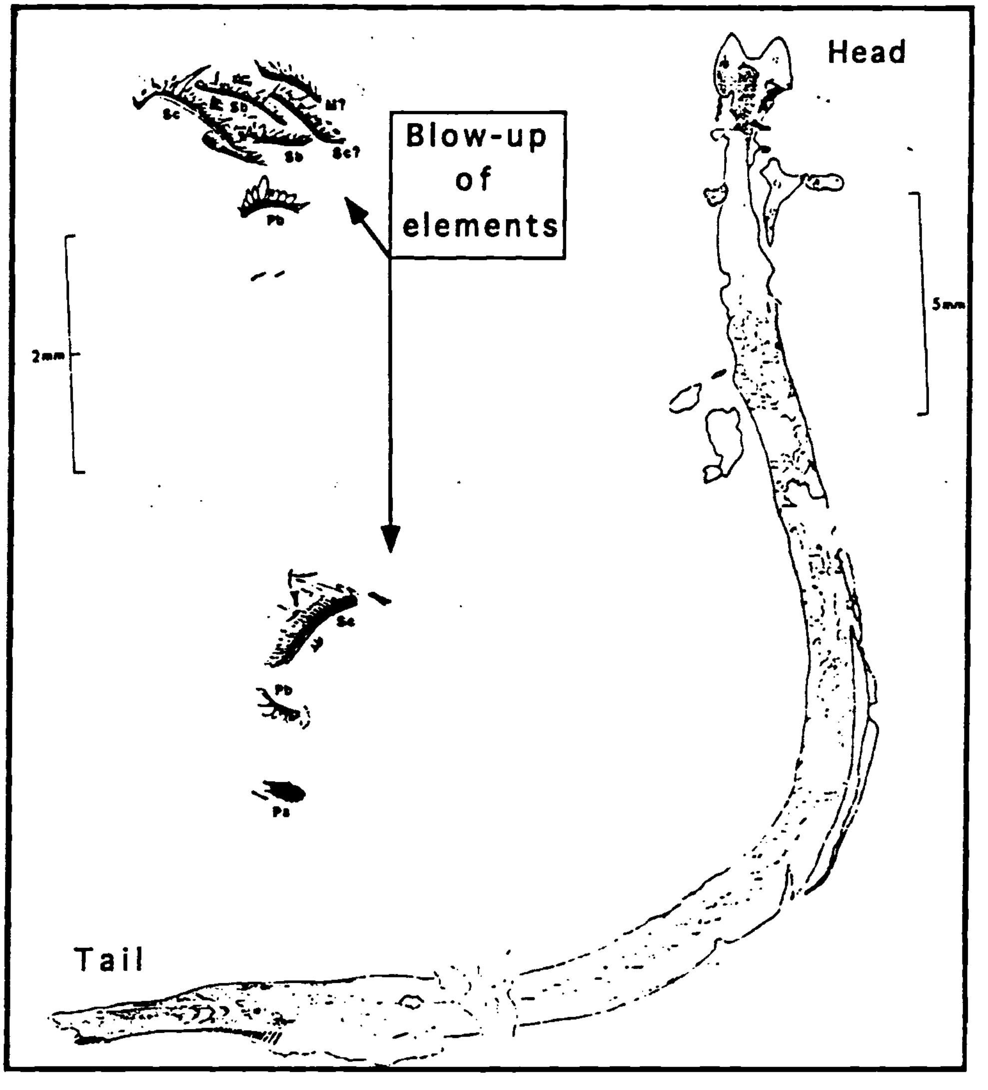


Figure 36
Scottish Conodont, artist rendering (Briggs et al. 1983)

> opposite end, interpreted as the tail and shown more or less clearly in two specimens tapers to a bluntly rounded point and bears marginal sets of short, posteriorly directed, fringelike impressions interpreted to be the rays of fins surrounding the periphery of the tail.
>
> A pair of dark spots in the posterior part of the cephalic lobe of one of the Scottish specimen may represent eyes, and a series of posteriorly opening V-shaped impressions characterize what are interpreted to be the sides of at least the posterior parts of all four specimen." (Sweet p.170)

Composition

The first attempt at determining the composition of conodont skeletal elements was by C.H. Pander in 1856, in this first analysis he concluded that they were calcium carbonate. Five years later J. Harley made the claim that the conodonts were composed of phosphate (the primary constituent) and carbonnate of lime. Opposition to the theories of Harley was made public by G.J. Hinde in 1879 when he claimed that Harley's specimens were not conodonts, and were composed of carbonate of lime. In 1926 P. V. Roundy asserted, based on his research, that conodont elements ". . .appear to be a phosphatic carbonate of lime." By 1932 Stauffer and Plummer claimed that ". . . conodont teeth are probably chiefly calcium phosphate."

In 1944 Samuel Ellison, a doctoral student of Branson and Mehl, used x-ray analysis to determine that conodont elements are composed of a member of the apatite isomorphous group. The significance is that conodonts elements are comparatively heavy (2.84 to 3.10) and less soluble in acetic, formic, and citric acids than their surrounding carbonate matrix. This allows conodont elements to be separated by soaking samples in acid for extended periods of time, a distinct advantage over many other fossils.

A more current and thorough work on conodont element composition is a paper by H. Pietzner et al.(1968). Their paper concluded the following formula for the composition of the mineral matter in conodont elements.

$$Ca_5 Na_{0.14} (PO_4)_{3.01} (CO_3)_{0.16} F_{0.73} (H_2O)_{0.85}$$

This mineral was interpreted as Francolite,

> ". . . a carbonate apatite in which the OH and CO_3 ions substitute for phosphate and do not occupy lattice positions as they do in hydroxy-apatites. Traces of at least 39 other chemical elements have been identified in various places in the hard parts of conodonts. . ."

Conodont Affinities

The conodonts have had reason to be associated with most major phyla, and even have been considered their own, at one time or another. The theories, both accepted and dismissed, should be discussed in this study.

Prior to Panders publication in 1856, it was believed by Murchison, Barrande, and Carpenter that conodonts were some part, perhaps tip ends, of the trilobite carapace. Although this claim was never followed up it first associated the conodonts with the arthropods. Shortly after Pander's publication Owen (1860) claimed conodonts were ". . . spines, hooklets, or denticles, of naked molluscs or Annelids." Later Harley (1861) and Simpson (1875) proposed conodonts were crustacean remains. This theory was discarded as the conodont assemblages are not equivalent to the spines that rim crustacean carapaces. The strongest and most influential (affecting the work of Zittel and Rohon, 1886; Scott, 1934; DuBois, 1943; Rhodes, 1954) of these early interpretation of conodont affinities was that of Owen who hypothesized they were annelids. This hypothesis was dealt a blow in the mid 1950's when Rhodes noted that annelids were unable to secrete calcium phosphate, the chemical composition of conodonts. The demise of this hypothesis was furthered by Clark in 1981 who showed the fossil jaws of polychaete annelids have a fundamentally different internal structure.

Owen also proposed in his 1960 paper that the conodonts could be the radular teeth of a mollusk. This proposal was embraced by Morse (1875), James (1884), and Loomis (1936) who compared coniform conodont elements to the radular elements of living gastropods. This proposal was countered by Rhodes who noted that mollusk teeth are almost entirely chitonous and show considerable amounts of wear, unlike the conodont elements. In Clark et al. 1981, Muller, on a suggestion from Yochelson closed the debate by bringing to light the fact that mollusks are not equipped physiologically to secrete phosphatic hard parts, and therefore would be a poor choice to associate with the conodonts. Recently (1986) this association with the mollusks has been revered by Tillier and Cuif, citing that the Scottish conodonts resemble living aplacophorans, and through X-ray microdiffraction and microprobe analysis have concluded their teeth and mandibles include calcium phosphate.

Three papers (Nature 27 April 1995) have associated conodonts with vertebrates. Gabbott and others have new evidence of large eyeballs and eye muscles, with fossilized muscle fibers resemble those that have been found in much younger fossil fishes. Purnell has solidified the biting function of the conodont, by noting wear facets on the tip of cusps. He also concludes conodonts were macrophagous, with that, the notion the earliest vertebrates could have been conodonts. While the argument of conodont affinity is not over, Philippe Janvier, an opponent of the vertebrate theory has decided "Considering this and other evidence for the vertebrate affinity of the conodonts that has accumulated over the past ten years, I think it is time for me to stop playing the Devil's advocate against this theory."

Environmental Distribution and Interpretation of Conodonts

The primary works on interpretation and distribution of conodonts by Baesemann (1973) and Heckel and Baesemann (1975) have produced a theoretical model of conodont distribution within upper Pennsylvanian megacyclothems. The maximum conodont abundance (more than 100 specimens per kilogram) and diversity occurs ". . . near the lower middle of the limestone formation, specifically in the black shale member and commonly in the adjacent parts of the two limestone members as well." (Heckel and Baesemann 1975). This is referred to as the core of the megacyclothem. These cores are dominated by *Streptognathodus* conodonts. This maximum abundance of conodonts ". . . suggests deeper water or slower sedimentation, or both." (Heckel and Baesemann 1975).

The outside shales of a megacyclothem are characterized by a low abundance (less than 10 specimen per kilogram) and diversity of conodonts. These outside shales are dominated by a species of *Adetognathus* and or *Idiognathodus*.

The limestone members that lie between the core and outside shales have transitional conodont abundance (5 to 50 specimens per kilogram) and diversity. The parts close to the core tend to be dominated by *Streptognathodus* while those further away from the core are dominated by *Adetognathus*.

From this a theoretical model (figure 37) showing conodont distribution in the upper Pennsylvanian megacyclothems of eastern Kansas was constructed by Heckel and Baesemann (1975). A simplified model showing *Streptognathodus, Idiognathodus, Gondolella, Sweetognathus* and *Adetognathus* conodonts was constructed by Heckel and Baesemann (1984) (figure 38) and later updated by Boardman and Nestell (1993) (figure 39). This model is adapted, focusing on the *Streptognathodus* and *Adetognathus* conodonts used in this study.

The model consists of five distinct conodont biofacies. In order from non marine deepening to open marine they are; 1. no conodonts in a non marine environment, or marginal marine environment 2. *Adetognathus* conodonts in a shallow water near shore environment, with molluscs, low diversity foraminifera (Boardman and Nestell, 1993) 3. *Streptognathodus* and *Adetognathus* conodonts mixed in an intermediate zone, 4. a *Streptognathodus* dominated zone indicating an open marine environment with corals, fusulinids, brachiopods, sponges, and bryozoans. (Boardman and Nestell 1993), 5. a basinal deep water zone with no associated conodonts.

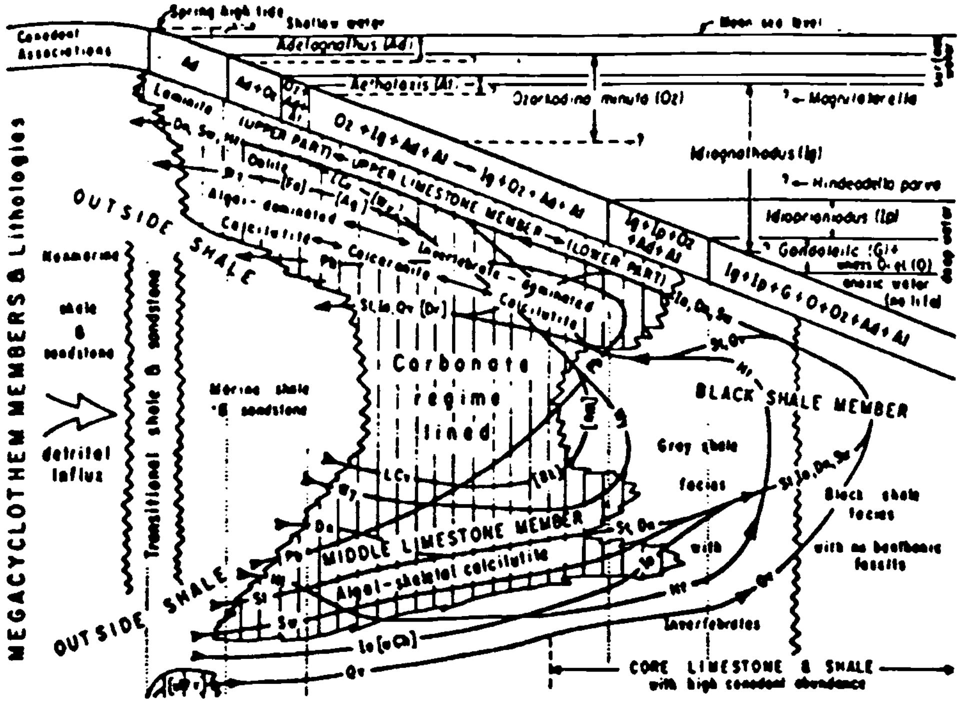


Figure 37
Reconstruction of probable living depth zones of eastern Kansas conodonts, and relations of resulting conodont associations to megacyclothem members
(Heckel and Baesemann 1975).

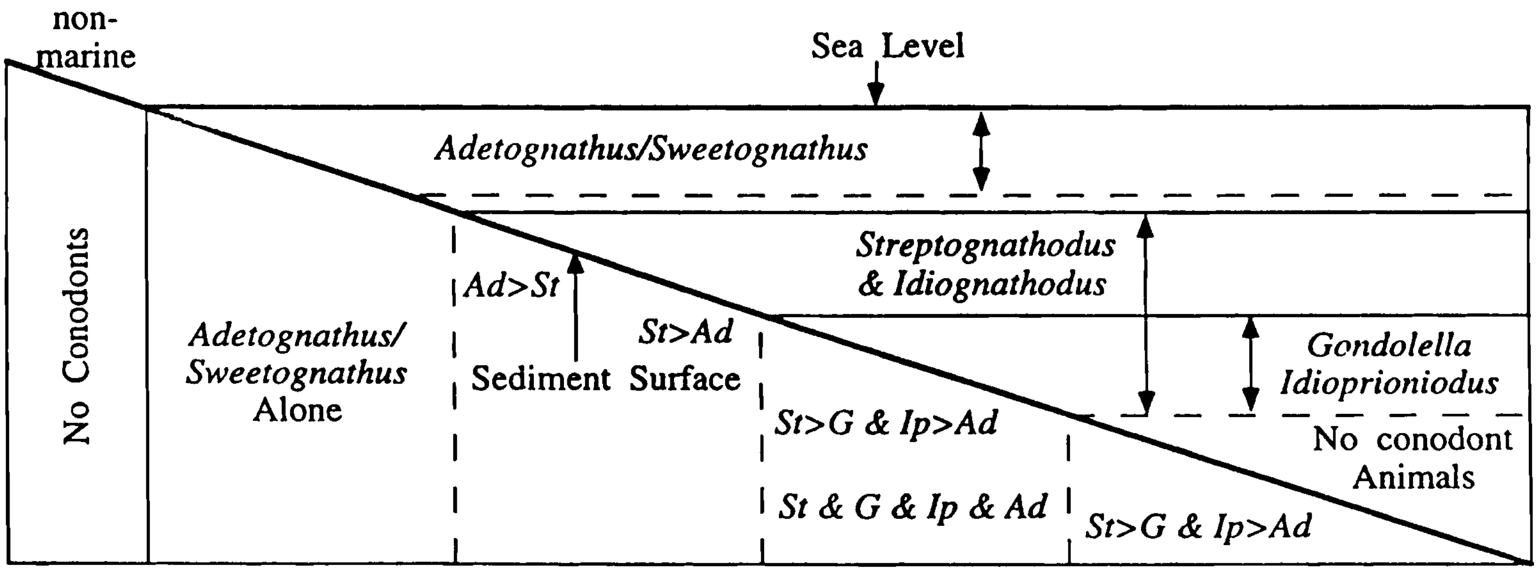


Figure 38
Theoretical conodont distribution (pelagic life mode)
(Heckel and Baesemann 1975).

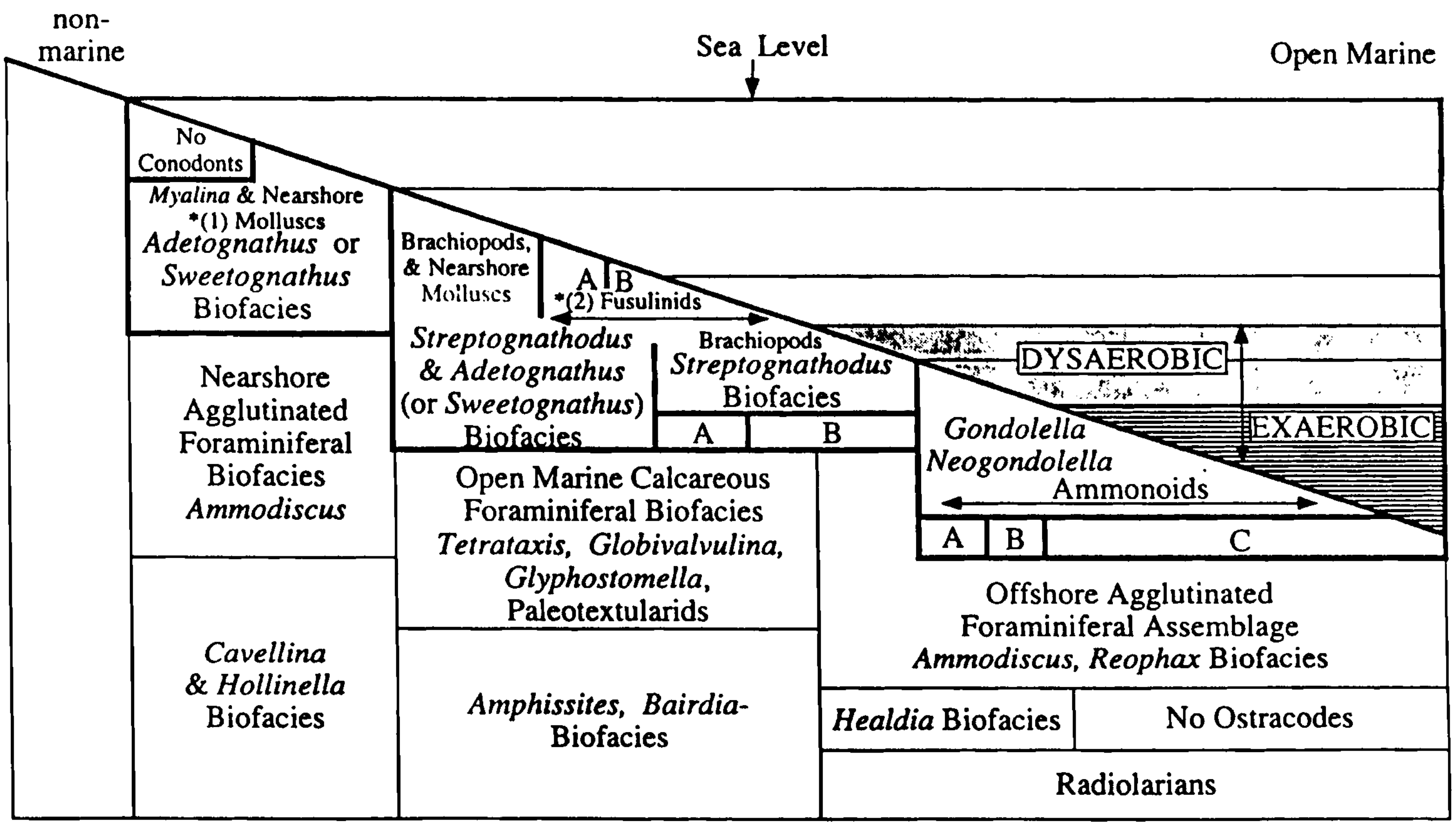


Figure 39
Boardman and Nestell model (1993).

Conodont Data

The following charts (chart 1-5) indicate the distribution of the *streptognathodus* (offshore) and *adetognathus* (nearshore, marginal marine) conodonts from sampled outcrop localities in this study. The units listed correspond to the units on the measured section from the particular locality. The marine condensed sections are indicated by significant increases in the *streptognathodus* conodont fauna. The graphical representation illustrates the condensed sections best, although the data is somewhat difficult to read accurately. The actual numbers are on a table (table 3-7) directly following each chart.

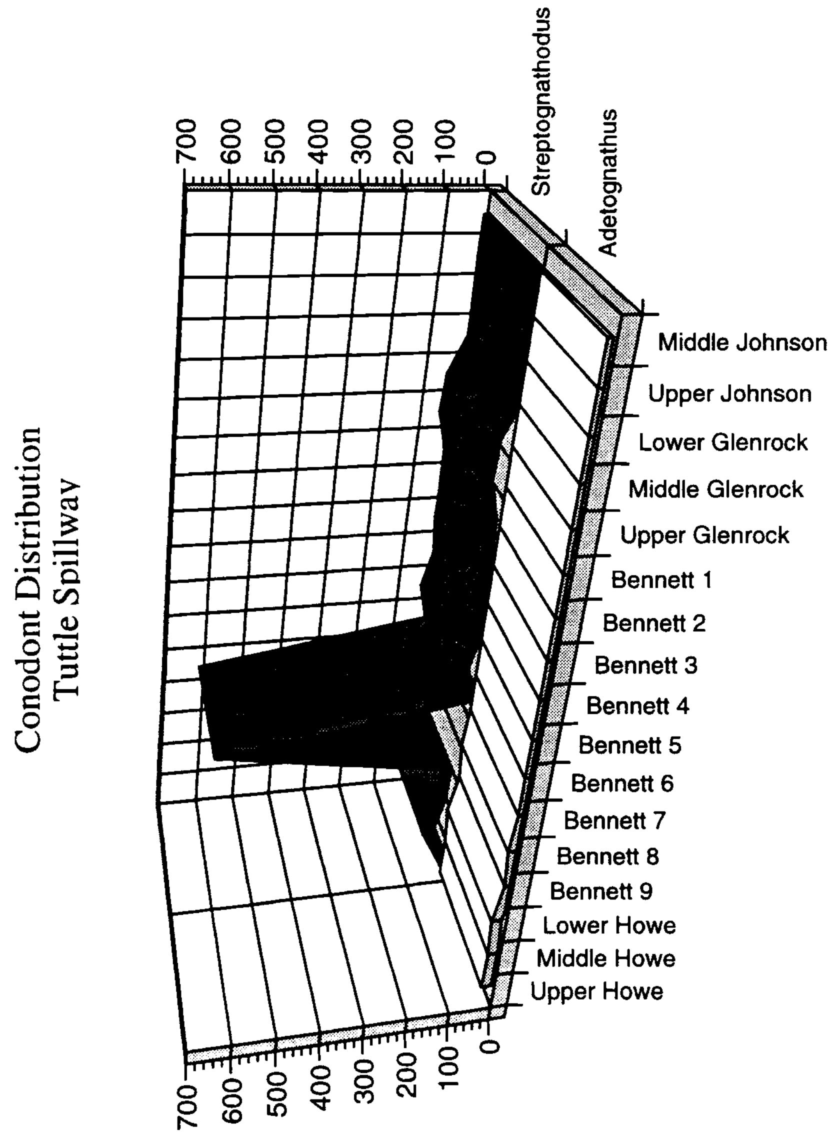

Conodont Distribution
Tuttle Spillway
Streptognathodus
Adetognathus
Middle Johnson
Upper Johnson
Lower Glenrock
Middle Glenrock
Upper Glenrock
Bennett 1
Bennett 2
Bennett 3
Bennett 4
Bennett 5
Bennett 6
Bennett 7
Bennett 8
Bennett 9
Lower Howe
Middle Howe
Upper Howe
0
100
200
300
400
500
600
700

Chart 1

	Label	A	B
Label		Streptognathodus	Adetognathus
1	Upper Howe	8	13
2	Middle Howe	61	11
3	Lower Howe	39	17
4	Bennett 9	36	0
5	Bennett 8	603	8
6	Bennett 7	10	0
7	Bennett 6	32	0
8	Bennett 5	11	0
9	Bennett 4	19	0
10	Bennett 3	19	0
11	Bennett 2	21	0
12	Bennett 1	45	0
13	Upper Glenrock	40	0
14	Middle Glenrock	0	0
15	Lower Glenrock	1	0
16	Upper Johnson	3	0
17	Middle Johnson	1	0

Table 3
Tuttle Creek Spillway Conodont Data

Conodont Distribution
K-38

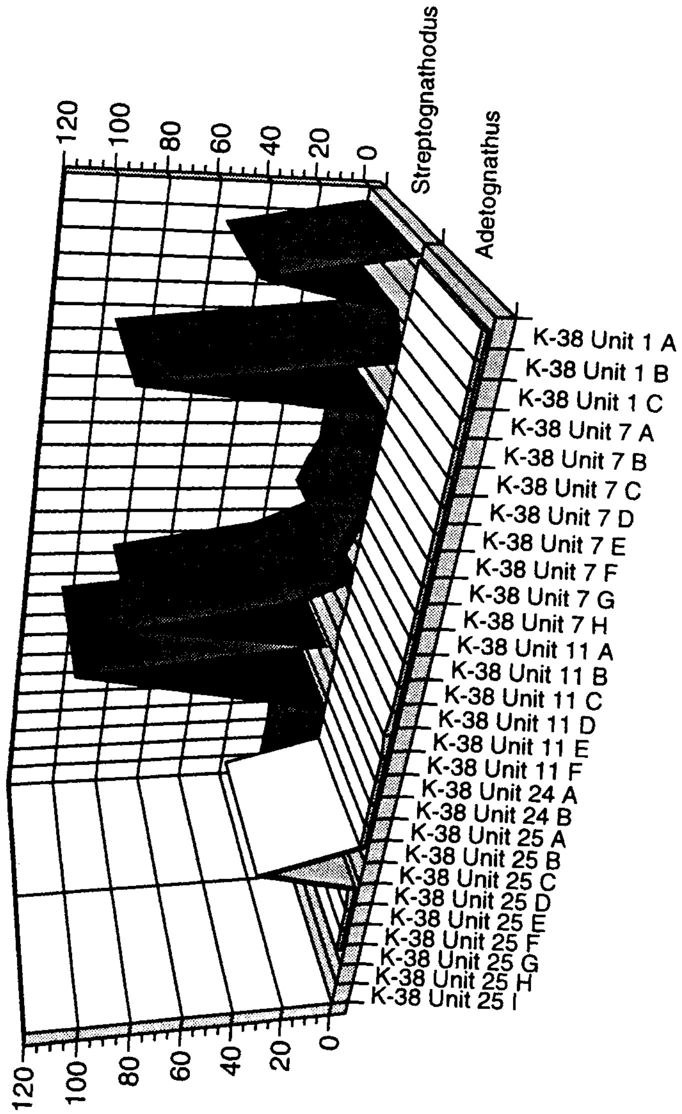


Chart 2

	Label	A	B
Label		Streptognathodus	Adetognathus
1	K-38 Unit 25 I	1	
2	K-38 Unit 25 H	0	
3	K-38 Unit 25 G	0	0
4	K-38 Unit 25 F	0	0
5	K-38 Unit 25 E	1	0
6	K-38 Unit 25 D	0	1
7	K-38 Unit 25 C	0	38
8	K-38 Unit 25 B	0	0
9	K-38 Unit 25 A	0	0
10	K-38 Unit 24 B	51	0
11	K-38 Unit 24 A	103	0
12	K-38 Unit 11 F	7	0
13	K-38 Unit 11 E	83	1
14	K-38 Unit 11 D	23	0
15	K-38 Unit 11 C	0	0
16	K-38 Unit 11 B	7	0
17	K-38 Unit 11 A	4	0
18	K-38 Unit 7 H	0	0
19	K-38 Unit 7 G	0	0
20	K-38 Unit 7 F	0	0
21	K-38 Unit 7 E	0	0
22	K-38 Unit 7 D	2	0
23	K-38 Unit 7 C	93	0
24	K-38 Unit 7 B	3	0
25	K-38 Unit 7 A	3	0
26	K-38 Unit 1 C	6	0
27	K-38 Unit 1 B	54	0
28	K-38 Unit 1 A	1	0

Table 4
K-38 Conodont Data

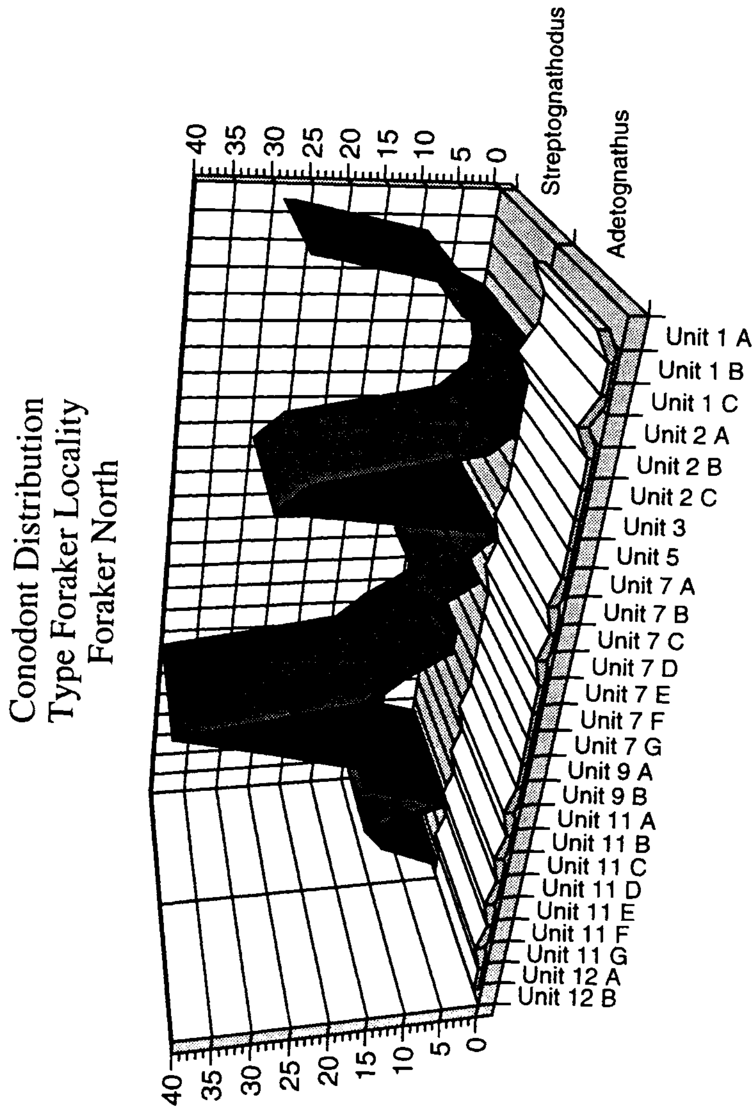

Conodont Distribution
Type Foraker Locality
Foraker North
Streptognathodus
Adetognathus
Unit 1 A
Unit 1 B
Unit 1 C
Unit 2 A
Unit 2 B
Unit 2 C
Unit 3
Unit 5
Unit 7 A
Unit 7 B
Unit 7 C
Unit 7 D
Unit 7 E
Unit 7 F
Unit 7 G
Unit 9 A
Unit 9 B
Unit 11 A
Unit 11 B
Unit 11 C
Unit 11 D
Unit 11 E
Unit 11 F
Unit 11 G
Unit 12 A
Unit 12 B
0 5 10 15 20 25 30 35 40

Chart 3

↘	Label	A	B
Label		Streptognathodus	Adetognathus
1	Unit 12 B	0	0
2	Unit 12 A	8	0
3	Unit 11 G	11	1
4	Unit 11 F	0	0
5	Unit 11 E	12	1
6	Unit 11 D	13	0
7	Unit 11 C	26	1
8	Unit 11 B	40	0
9	Unit 11 A	14	1
10	Unit 9 B	10	0
11	Unit 9 A	4	0
12	Unit 7 G	4	0
13	Unit 7 F	7	0
14	Unit 7 E	2	0
15	Unit 7 D	4	1
16	Unit 7 C	0	0
17	Unit 7 B	29	1
18	Unit 7 A	25	0
19	Unit 5	4	0
20	Unit 3	0	0
21	Unit 2 C	0	0
22	Unit 2 B	1	0
23	Unit 2 A	1	2
24	Unit 1 C	9	0
25	Unit 1 B	10	0
26	Unit 1 A	28	2

Table 5
Foraker North Conodont Data

Conodont Distribution
Shidler Spillway

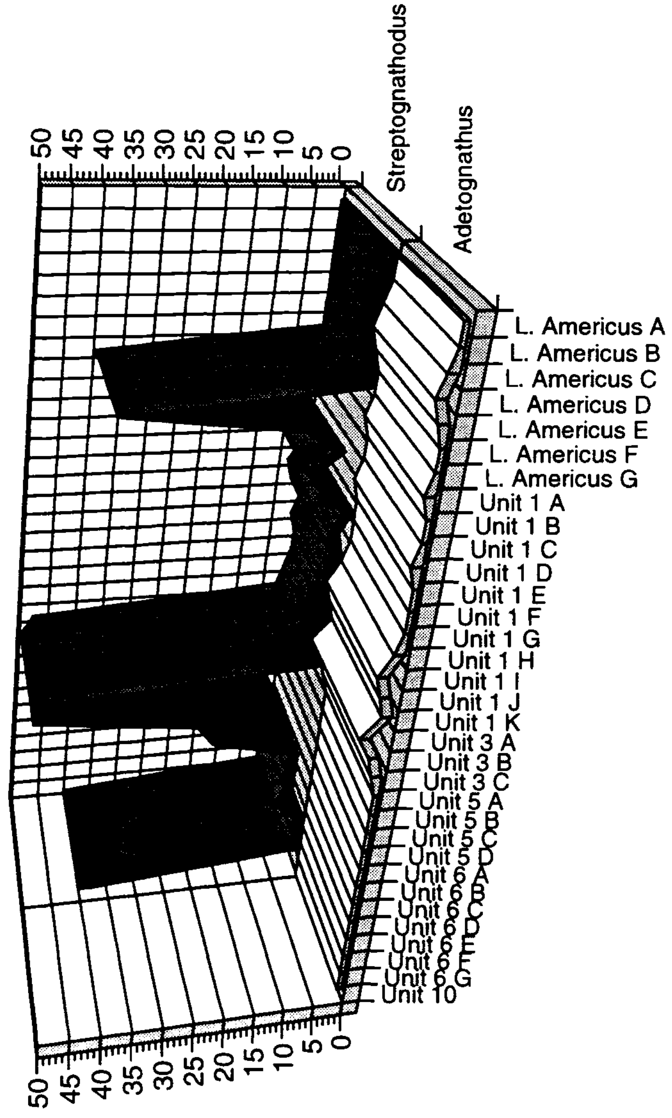


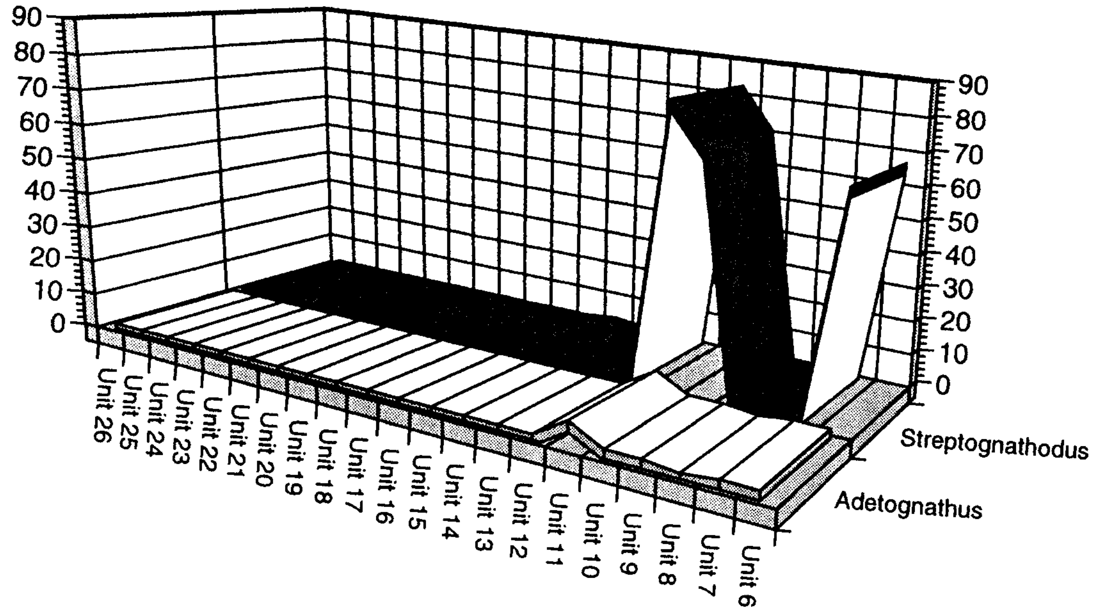
Chart 4

	Label	A	B
Label		Streptognathodus	Adetognathus
1	Unit 10	39	0
2	Unit 6 G	1	0
3	Unit 6 F	1	0
4	Unit 6 E	1	0
5	Unit 6 D	5	0
6	Unit 6 C	4	0
7	Unit 6 B	4	0
8	Unit 6 A	4	0
9	Unit 5 D	18	0
10	Unit 5 C	21	0
11	Unit 5 B	49	0
12	Unit 5 A	47	0
13	Unit 3 C	2	1
14	Unit 3 B	1	2
15	Unit 3 A	0	4
16	Unit 1 K	0	1
17	Unit 1 J	1	2
18	Unit 1 I	0	3
19	Unit 1 H	2	1
20	Unit 1 G	3	0
21	Unit 1 F	1	0
22	Unit 1 E	5	0
23	Unit 1 D	8	1
24	Unit 1 C	4	0
25	Unit 1 B	9	0
26	Unit 1 A	39	1
27	L. Americus G	0	0
28	L. Americus F	0	0
29	L. Americus E	0	1
30	L. Americus D	0	2
31	L. Americus C	0	1
32	L. Americus B	0	0
33	L. Americus A	0	0

Table 6
Shidler Spillway Conodont Data

Chart 5

Conodont Distribution
Principle Reference Section
Red Eagle Limestone
Burbank Quarry



	Label	A	B
Label		Streptognathodus	Adetognathus
1	Unit 26	0	0
2	Unit 25	0	0
3	Unit 24	0	0
4	Unit 23	0	0
5	Unit 22	0	0
6	Unit 21	0	0
7	Unit 20	0	0
8	Unit 19	0	0
9	Unit 18	0	0
10	Unit 17	0	0
11	Unit 16	0	0
12	Unit 15	1	0
13	Unit 14	0	0
14	Unit 13	0	0
15	Unit 12	0	0
16	Unit 11	81	6
17	Unit 10	69	1
18	Unit 9	0	1
19	Unit 8	0	0
20	Unit 7	0	1
21	Unit 6	65	1

Table 7
Burbank Quarry Conodont Data

HIERARCHICAL GENETIC STRATIGRAPHY: STRATIGRAPHY OF THE FORAKER LIMESTONE, JOHNSON SHALE, RED EAGLE LIMESTONE, AND ROCA SHALE

Transgressive - Regressive Units

Eustatic sea-level changes are the major controls in the distribution of lithofacies (Busch et al. 1987, Vail 1987). In all, six orders of transgressive - regressive units, each with it's own periodicity, have been identified (figure 40). The first three orders were described by Vail et al. 1977 (figure 41). The first order transgressive - regressive unit has a periodicity of 225 to 300 million years, the second order 20 to 90 million years, and the third order 7 to 13 million years. These are considered the major transgressive - regressive units, Busch and Rollins (1984)(figure 42) have introduced three minor transgressive - regressive units. The fourth order transgressive - regressive unit has a periodicity of 0.8 to 1.5 million years, the fifth order 300,000 to 500,000 years (Heckel's Kansas cyclothem) and the sixth order units are on a scale of tens of thousands of years (Heckel's minor transgressive - regressive sequences).

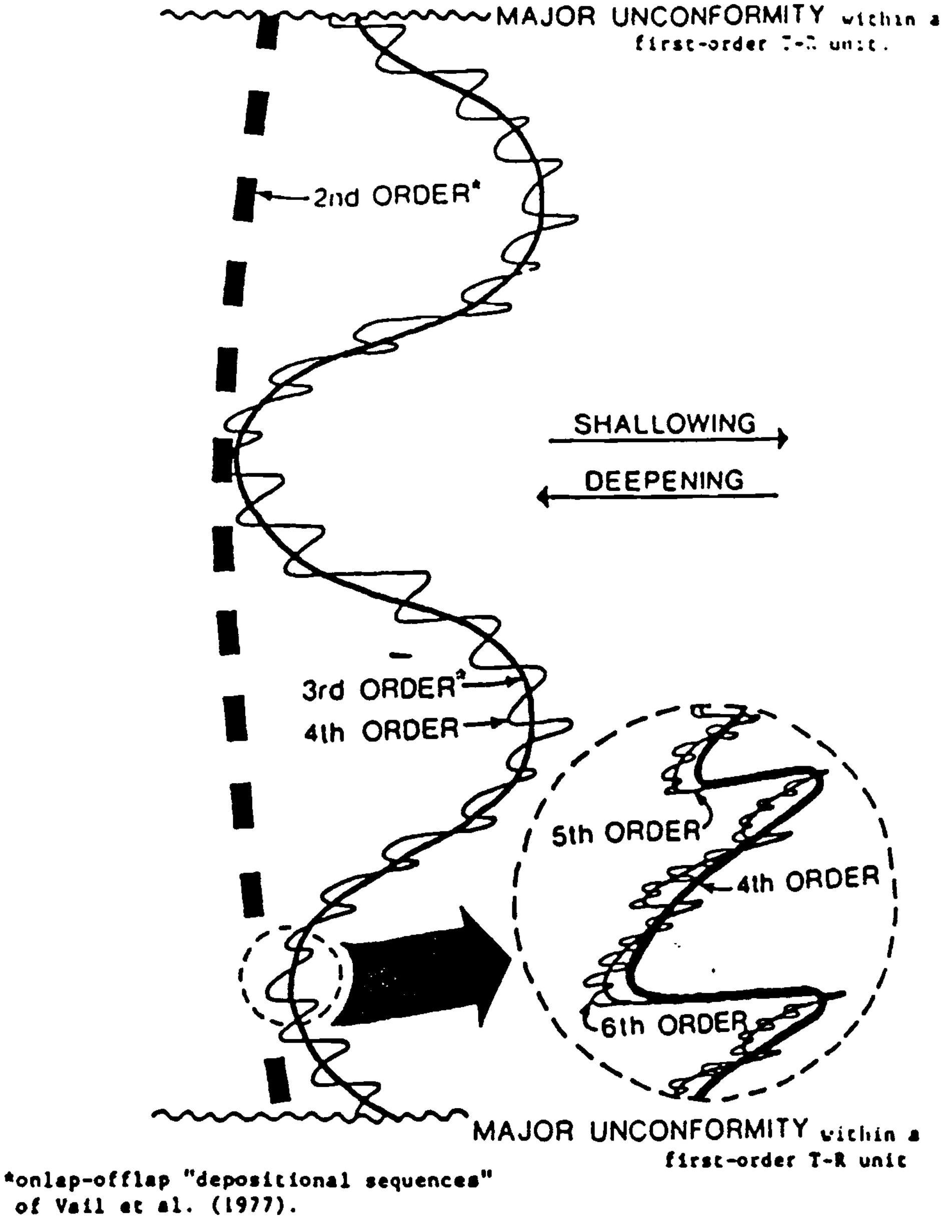


Figure 40
Hierarchy of transgressive-regressive units
(Busch and West 1987).

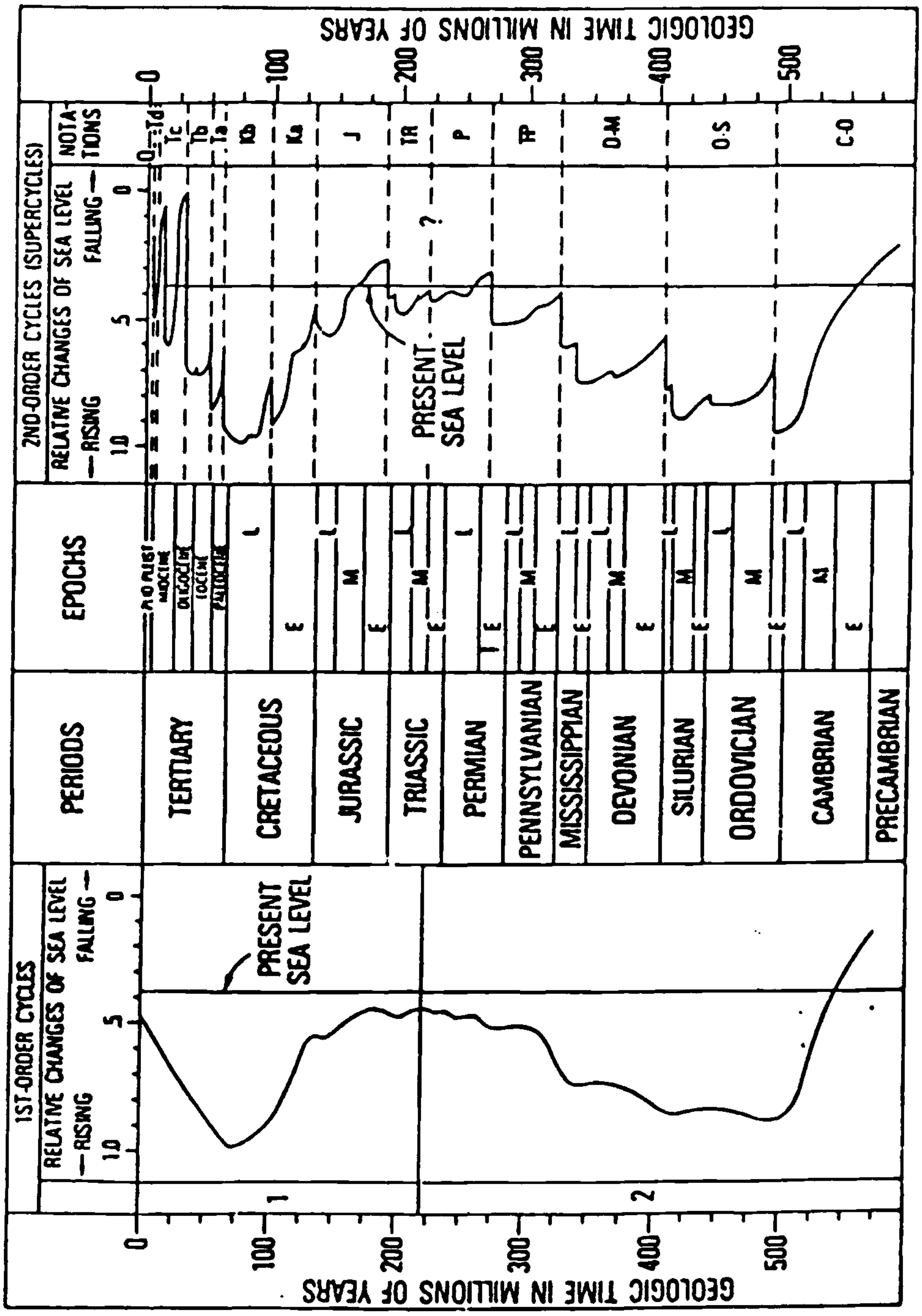


Figure 41
First and second order global sea-level cycles during the Phanerozoic
(Vail and Others 1977).

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

Figure 42
Hierarchy of Pennslyvanian-Permian transgressive-regressive units (Busch and Rollins 1984 and Busch and West 1987).

Allocyclicity Versus Autocyclicity

Transgressive - regressive sequences are the result of autocyclic processes, allocyclic processes, or a combination of both (Busch et al., 1985)(figure 43). Autocyclic processes are ones that operate in a specific depositional environment, such as delta lobe switching and channel migration. Because these environments are so specific, autocyclic processes tend to be local in scale. Allocyclic processes are ones that operate on processes that affect numerous depositional environments at the same time, such as eustatic sea-level change. As a result, allocyclic processes tend to be large (basin or global) scale.

All transgressive - regressive units are assumed to be potentially allocyclic. This assumption can be tested (proved or disproved) by correlating the genetic surfaces relative to "key" marker beds. Correlative transgressive - regressive units are also time stratigraphic units, because they represent specific intervals of a transgression and a regression (Bush and West, 1987) (Modified from Clark 1986).

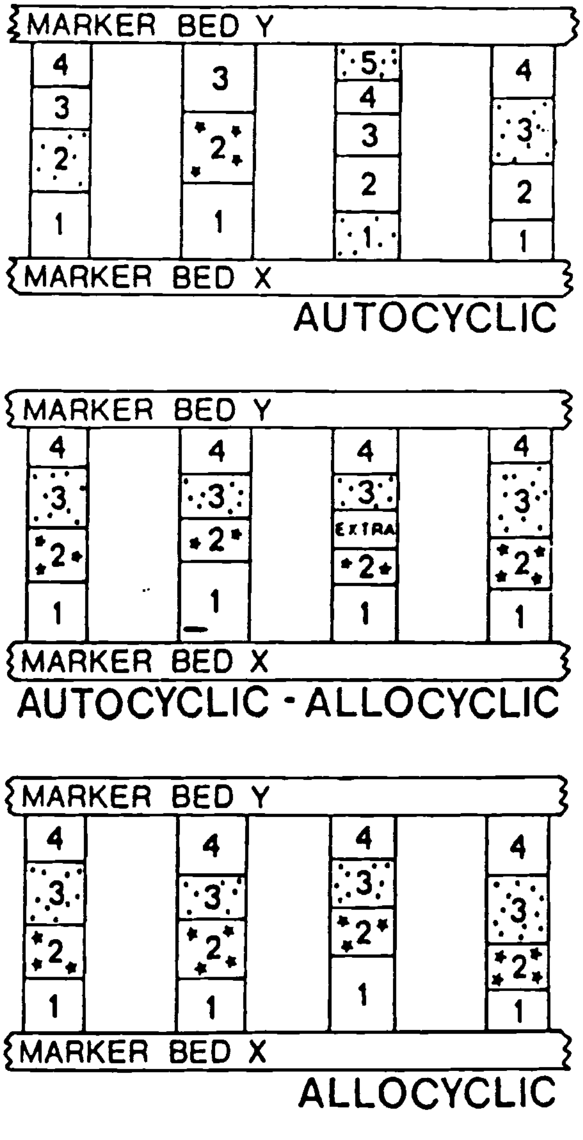


Figure 43
Relationship between autocyclic and allocyclic units
(Busch and West 1987).

5th Order Sequences

In the complex hierarchy of the Pennsylvanian - Permian mid-continent the Exxon sequence stratigraphic requires modification. A unit representing the cycles of sedimentation between sequences and parasequences is necessary. As a result the term 5th order sequence has been introduced (Boardman 1995). A 3rd order sequence would be the deposition of the entire Council Grove, a 4th order sequence would be the deposition of the entire Foraker Limestone. Fifth order sequences are provisionally used to discriminate widespread 2-5 meter subdivisions of a cyclothemic sedimentary sequence that are conformably bounded by flooding surfaces that may also posses attributes of a full fledged sequence with transgressive deposits, marine condensed sections, and forced regressions. These 5th order sequences usually contain meter and sub-meter flooding surfaces that delineate parasequences (Boardman 1995).

Cyclothems

Rocks from the mid-continent of Pennsylvanian - Permian age are interpreted based on the cyclic deposition of specific lithofacies. These successions of rocks are referred to as "Kansas cyclothems" (Heckel 1977)(figure 44). Kansas cyclothems adhere to a specific order, in ascending order: 1. thick, sandy nearshore to non marine "outside" shale; 2. thin transgressive "middle" limestone; 3. thin non sandy offshore "core" shale, commonly a fissile black shale; 4. thicker regressive "upper" limestone; 5. thick sandy nearshore to non marine shale (Heckel 1983).

The sandy nearshore to non marine outside shales ". . . represent the times of lowest sea-level stand at maximum regression between the marine inundations." (Heckel 1983). These outside shales contain a low conodont abundance and diversity. In areas where they are non marine, gray to red blocky mudstones with caliche and soil features are evident (Schutter 1983). The thin offshore core shales represent ". . . the times of highest sea-level stand at maximum marine inundation." (Heckel 1983). These core shales contain abundant and diverse conodont fauna, most in a phosphatic black fissile facies reflecting an anoxic sea floor established in deep water during maximum transgression (Heckel 1983). The middle and upper limestones were deposited under water that was either deepening or shallowing. The transgressive middle limestone is thin due to the short span of carbonate formation under deepening water, ". . . with clastics stranded progressively away from the site of deposition." (Heckel 1983). The regressive upper limestone tends to be a thick unit as carbonate formation is intensified in shallow water depths and ". . . detrital pulses from encroaching shorelines were brought readily to the site of deposition." (Heckel 1983).

In addition to the Kansas cyclothem Moore (1936) has modeled a megacyclothem for the upper Pennsylvanian (figure 45). It is a more complex model in that it adds 3 shale and 2 limestone units. In ascending order the ideal upper Pennsylvanian megacyclothem consists of: 1. outside shale, sandy, paleosol, underclay, or coal at the base, marine at the top; 2. lower limestone; 3. shale, unfossiliferous, blocky, locally red at the base, fossiliferous gray at the top; 4. thin middle limestone; 5. black shale "core"; 6. thick upper limestone; 7. marine to non marine shale; 8. super limestone; 9. thick outside shale, often with plant fossils; 10. thin fifth limestone; 11. outside shale, sandy, plant fossils, paleosol. (after Moore 1936) The middle and upper limestones are present in nearly all Pennsylvanian cyclothems, whereas the super, lower, and fifth limestone units occur with less frequency.

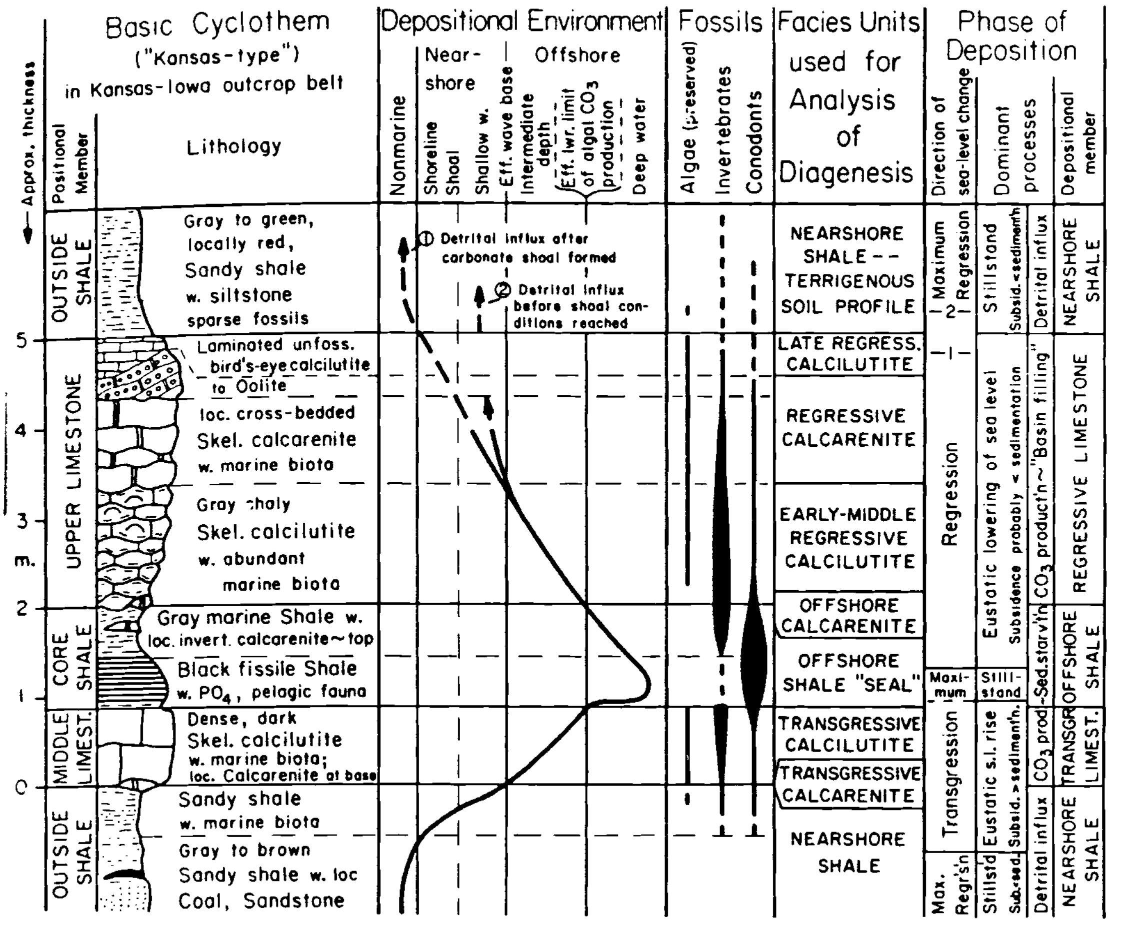


Figure 44
Basic Kansas cyclothem
(Heckel 1977).

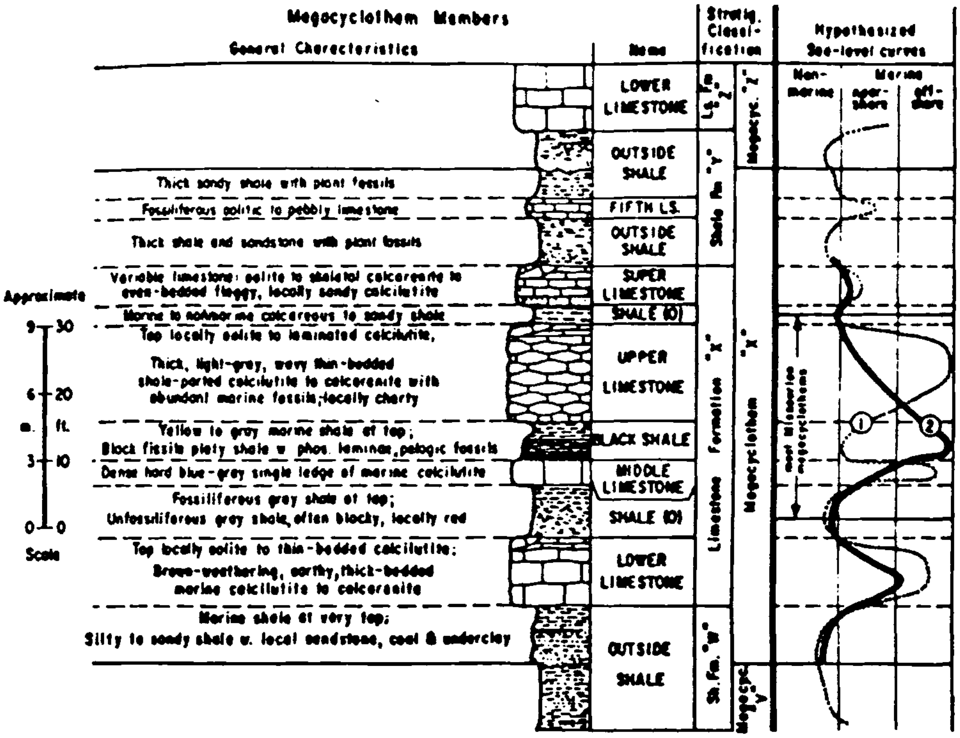


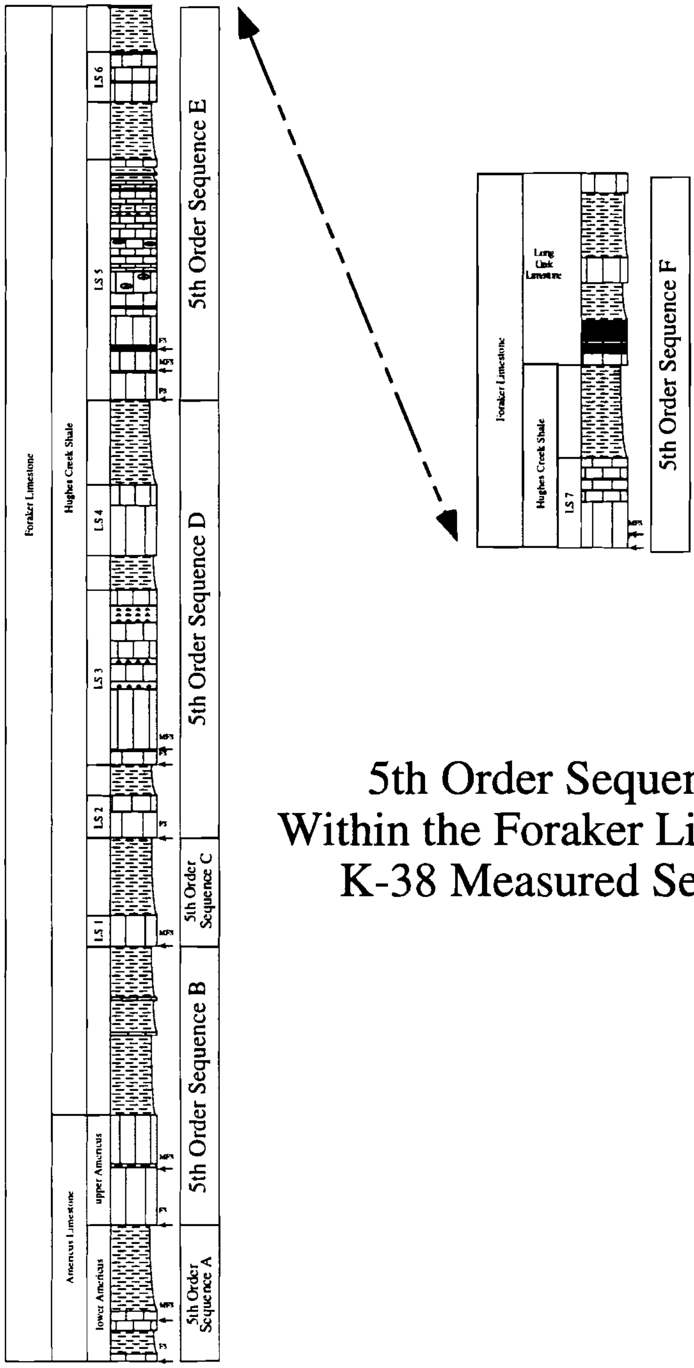
Figure 45
Ideal Pennsylvanian megacyclothem
(Heckel and Baesemann1975).

<u>Cyclothemic Interpretation</u>

This study primarily utilized conodont elements and distribution, as well as lithologic evidence for interpretation of deposition within the Foraker and Red Eagle Limestone. In comparison to previous interpretations, this study differs from Mudge and Yochelson's 1962 work, as they proposed the Foraker to be a two cycle event. Avers 1968 work proposed a six event Foraker, but based it on lithology and shale-limestone couplets.

The Foraker is in fact a sequence bound by paleosols, representing glacial episodes, with six transgressive regressive events (Figure 46). These events are classified as 5th order sequences. The initial flooding is represented by 5th order sequence A, and occurs as a minor transgression at the lower Americus Limestone. 5th Order sequence B occurs in the upper Americus and contains the major flooding event of the Americus Limestone, this was a maximum flooding, evidenced by a marine condensed section. 5th order sequence C, is the basal Hughes Creek flooding event. It is a shallow transgression followed by a regression. 5th order sequence D is the major flooding event of the lower Hughes Creek. Evidenced by a marine condensed section, this was a deep flooding with maximum depths below the photic zone. 5th order sequence E is the major flooding event of the upper Hughes Creek, also indicated by a marine condensed section, this was a maximum flooding event as well. 5th order sequence F is the final transgressive regressive event of the Foraker, and is a minor transgressive event terminating with the Johnson Shale paleosol (figure 47).

The Red Eagle sequence is one 5th order sequence, bound at the base by the Johnson Shale paleosol and at the top by the Roca Shale paleosol.



5th Order Sequences
Within the Foraker Limestone
K-38 Measured Section

Figure 46

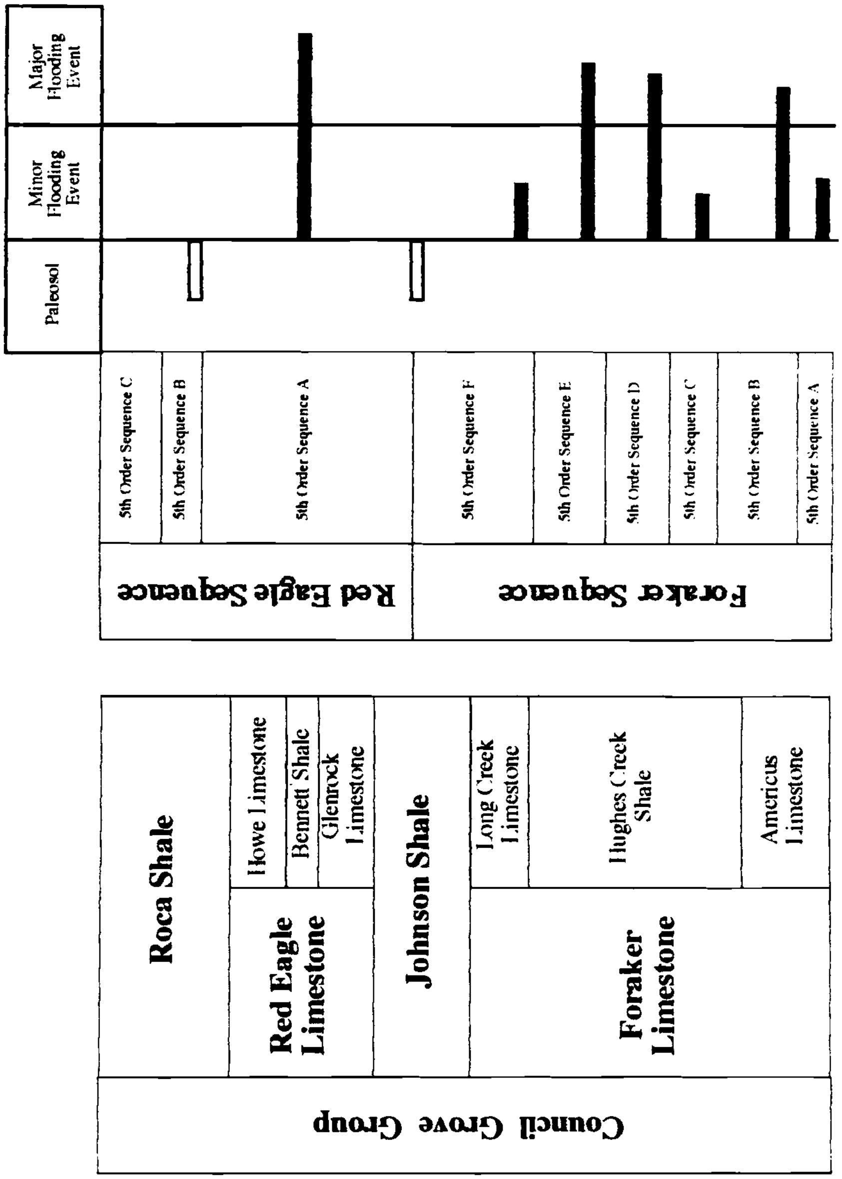


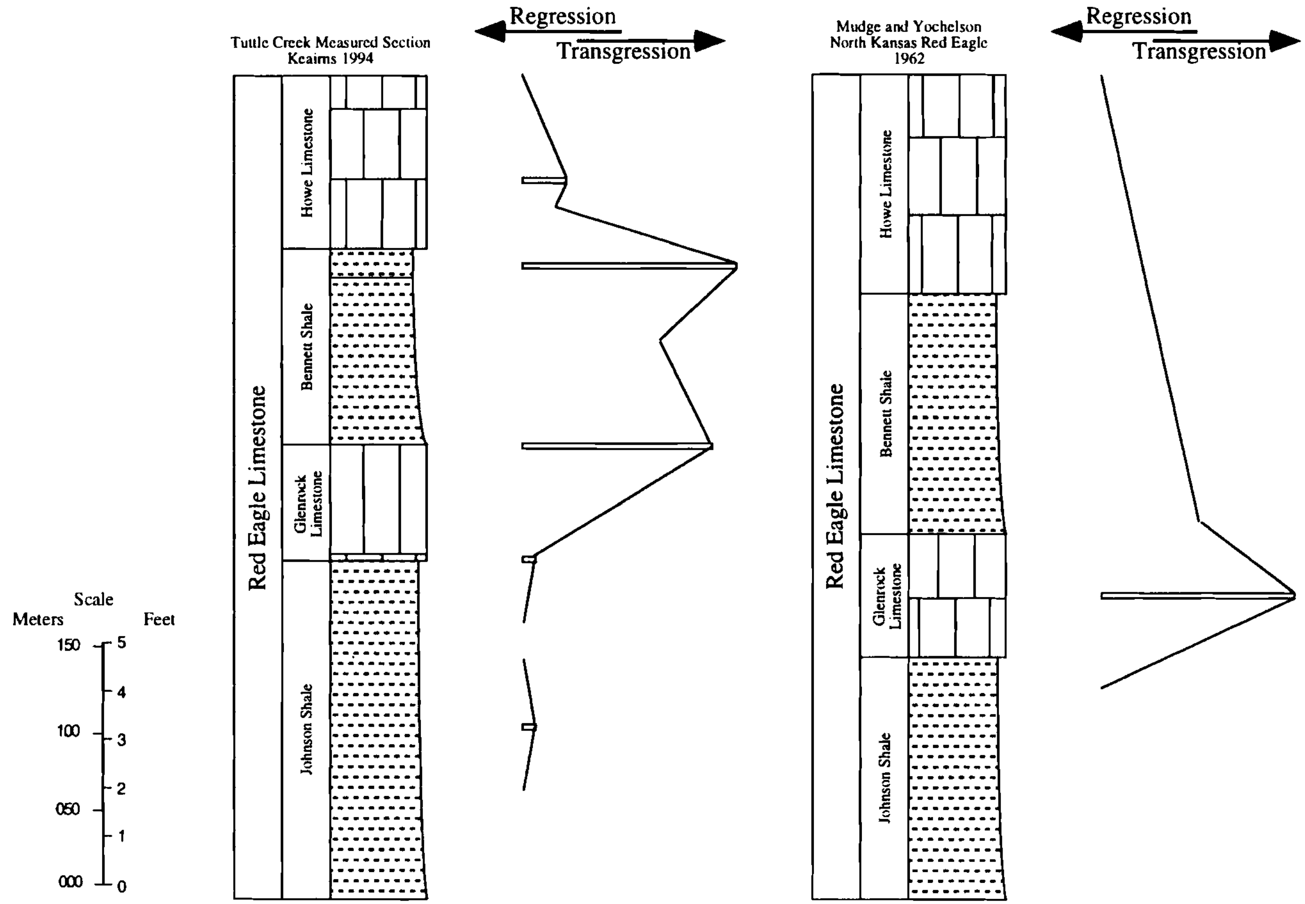
Figure 47
5th order sequences in the Foraker and Red Eagle Limestone

Previous work by Mudge and Yochelson (1962 p.102) have called the Red Eagle the typical Council Grove Cyclothem. In their interpretation they claimed that maximum water depth was during the fusulinid limestone (Glenrock), the Bennett Shale Member, along with the Howe Limestone Member were regressive, with the Howe being a relatively shallow water deposit. Microfaunal conodont analysis has lead me to a different interpretation of deposition (Figure 48).

The initial flooding of the Red Eagle Sequence occurs in the Johnson Shale and is relatively minor. Water depths increase as the Glenrock Limestone Member is deposited and the uppermost Glenrock and basal Bennett Shale Member show a significant flooding event. The Bennett Shale Member continues as a deep water deposit (instead of a regressive deposit) until the upper foot. The top foot of the Bennett Shale Member represents the maximum flooding event of the cycle, as evidenced by a tremendous offshore *Streptognathodus* conodont fauna. The Howe Limestone Member is deposited as a regressive limestone, showing a minor flooding event before continuing to shoal upwards. To the north, at Tuttle Spillway, the Howe Limestone Member is capped by large mound stromatolites, indicating an supra-tidal depositional environment.

Figure 48

Comparison of Mudge and Yochelson Red Eagle Cyclothem



Sequence Stratigraphic Nomenclature

"Sequence Stratigraphy is the study of rock relationships within a chronostratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or nondeposition, or their correlative conformities" (Van Wagoner et al. 1988). The fundamental unit of sequence stratigraphy is the sequence, a relatively conformable succession of genetically related strata bounded by unconformities and their correlative conformities (Mitchum, 1977). A sequence can be subdivided into systems tracts, linkages of contemporary depositional systems that are delineated on the basis of types of bounding surfaces, parasequence set distribution, position within a sequence, overall geometry, and facies associations (Van Wagoner et al. 1990).

There are four types of systems tracts recognized by Van Wagoner (1988) that comprise the principle units of sequences: lowstand, shelf margin, transgressive, and highstand systems tracts. (figure 49) In addition Henry Posamentier (1992) introduced the concept of forced regressions.

In categorizing the sequences of this study three systems tracts are utilized: transgressive, highstand, and forced regression. In ascending order the 5th order sequences have a thin transgressive systems tract (deepening of sea-level), a highstand systems tract (widespread deep water depth), followed by a forced regression (shallowing of sea-level). In some of the sequences a marine condensed section is formed. This occurs at the peak of the transgressive systems tract, and indicates maximum water depth.

The transgressive systems tract indicates an overall rise in sea level. The term was introduced and defined by Van Wagoner as follows.

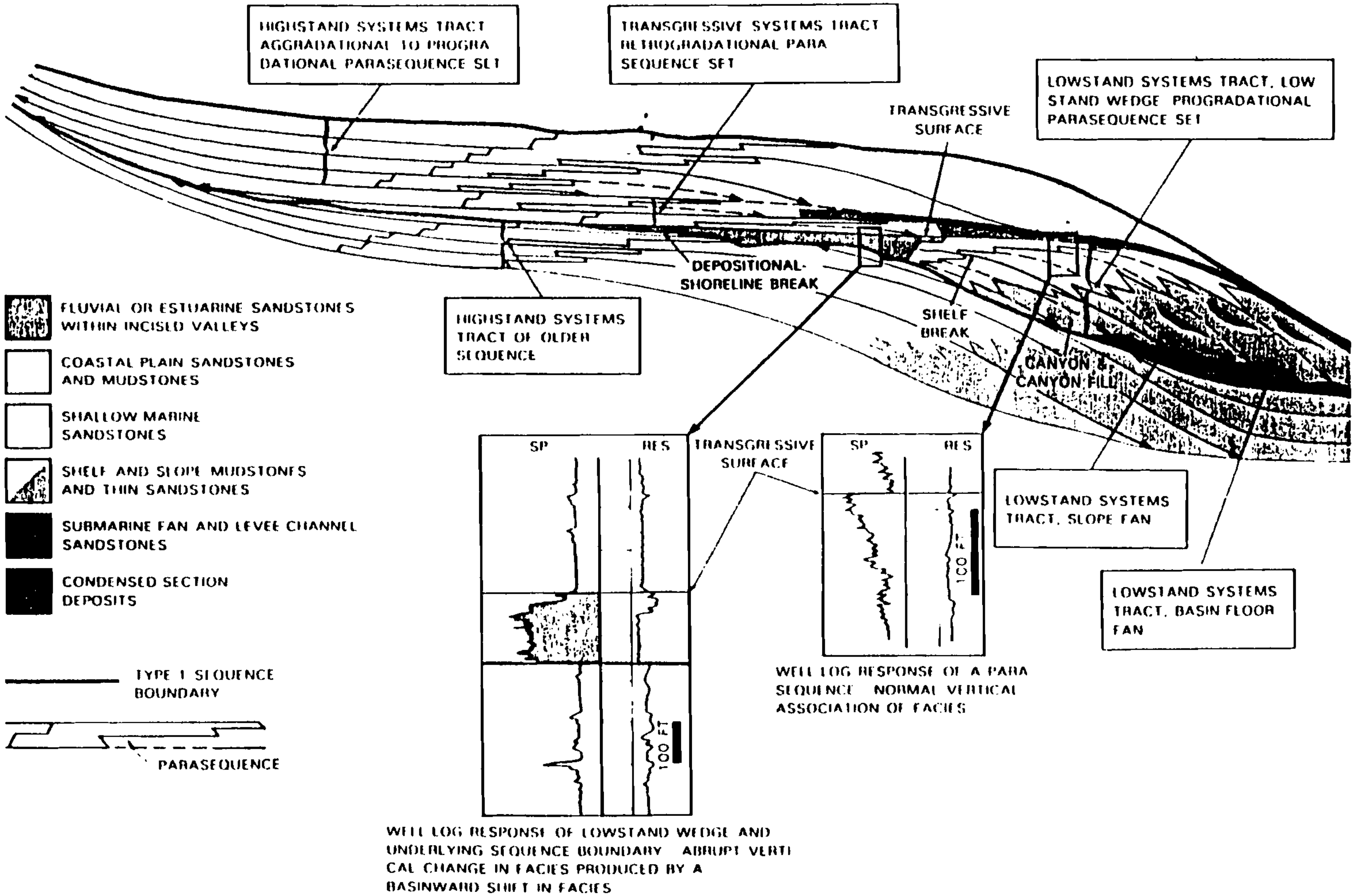


Figure 49
Principle units of sequence stratigraphy
(Van Wagoner et al. 1988).

The transgressive systems tract is the middle systems tract of both type 1 and type 2 sequences. It is characterized by one or more retrogradational parasequence sets. The base of the transgressive-systems tract is the transgressive surface at the top of the lowstand or shelf-margin systems tracts. Parasequences within the transgressive-systems tract onlap onto the sequence boundary in a landward direction and downlap onto the transgressive surface in a basinward direction. The top of the transgressive systems tract is the downlap surface. The downlap surface is a marine flooding surface onto which the toes of prograding clinoforms in the overlying highstand systems tract downlap. This surface marks the change from a retrogradational to an aggradational parasequence set and is the surface of maximum flooding. The condensed section occurs largely within the transgressive and distal highstand systems tracts." (Van Wagoner et. al. 1988)

The highstand systems tract indicates a time of widespread deep water deposition. It was introduced and defined by Van Wagoner as:

". . .the upper systems tract in either a type 1 or a type 2 sequence. This systems tract is commonly widespread on the shelf and may be characterized by one or more aggradational parasequence sets that are succeeded by one or more progradational parasequence sets with prograding clinoform geometries. Parasequences within the highstand systems tract onlap onto the sequence boundary in a landward direction and downlap onto the top of the transgressive or lowstand systems tract in a basinward direction. The highstand systems tract is bounded at the top by a type 1 or type 2 sequence boundary and at the bottom by the downlap surface."

The forced regression is "a seaward translation of facies and shoreline regression in a response to relative sea level lowering. . . independent of variations of sediment flux" (Posamentier 1992). This differs from the "normal" regression in that a normal regression "occurs in response to excess sediment flux relative to space available on the shelf (i.e. accommodation)" (Posamentier 1992)(figures 50-51).

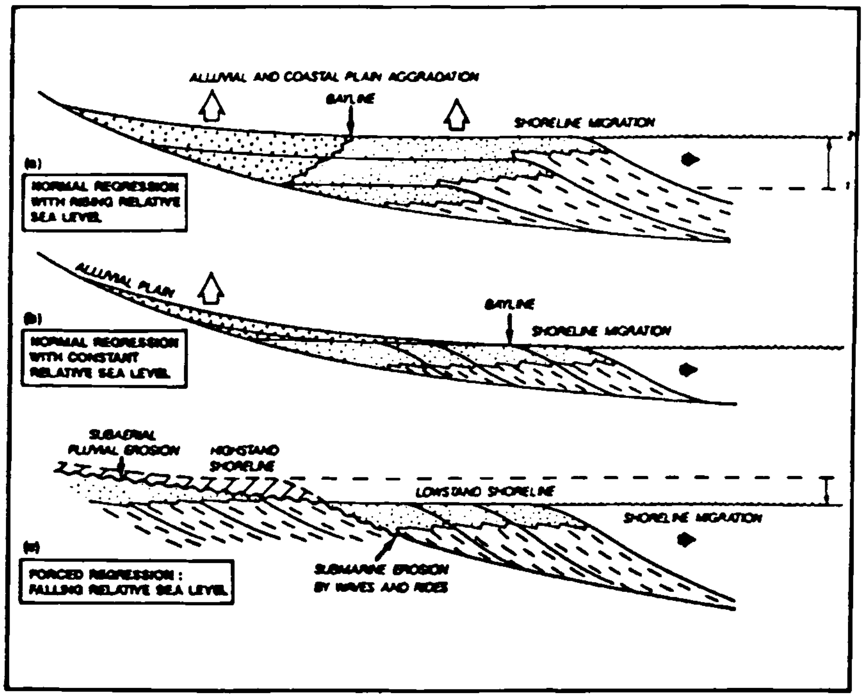


Figure 50
Forced Regression, showing varied relative sea-levels
(Posamentier 1992).

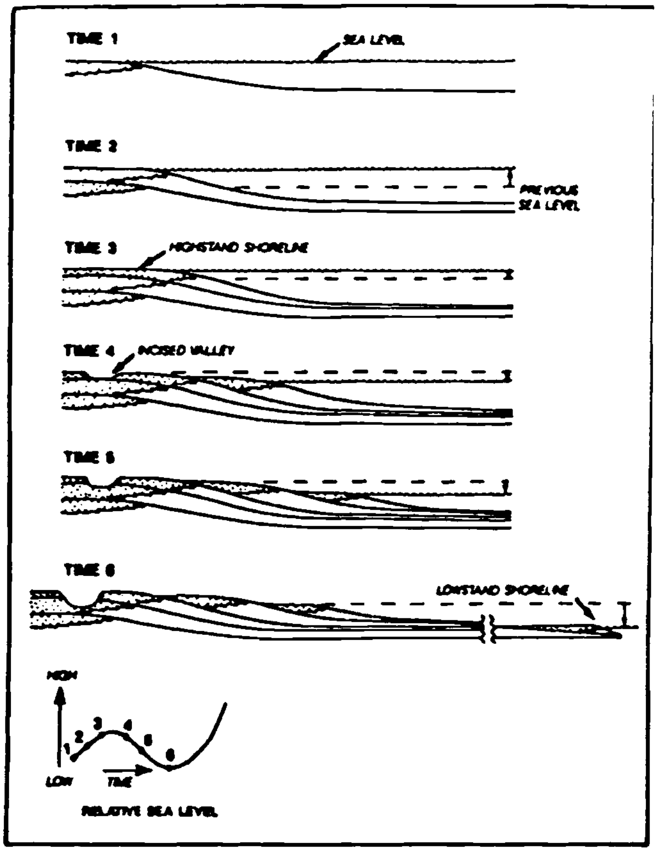


Figure 51
Forced Regression, relative sea-level vs. time
(Posamentier 1992).

General Characteristics of Marine Condensed Sections

Marine Condensed Sections are important in both regional and global stratigraphic correlation. They tie together the deep water open-ocean stratigraphy with the shallow water shelf landward stratigraphy. The ability to correlate these two depositional environments is invaluable. A condensed section is defined as

> ". . .thin marine stratigraphic units consisting of pelagic to hemipelagic sediments characterized by very low sedimentation rates. They are areally most extensive at the time of maximum regional transgression of the shoreline. Condensed sections are commonly associated with apparent marine hiatuses and often occur either as thin but continuous zones of burrowed, slightly lithified beds (omission surfaces) or marine hardgrounds. Condensed sections may also be characterized by abundant and diverse planktonic and benthic microfossil assemblages, authigenic minerals (glauconite, phosphorite, and siderite), organic matter, and bentonites, and may possess greater concentration of platinum elements such as iridium."
> (Loutit et al. 1988)

The condensed section occurs in the middle of a depositional sequence as a thin sedimentary unit that extends from the basin to the shelf. It is the result of a relative rise in sea-level coupled with an abrupt transgression of the shoreline (Loutit 1988). The condensed section occurs during times of maximum water depth in a depositional sequence, when the rate of eustatic rise and subsidence is at a maximum.

A typical marine condensed section from the Pennsylvanian Permian of the Mid Continent contains a large amount of phosphate, a abundant offshore *Streptognathodus* conodont fauna, and some amount of glaucony. In outcrop it appears as a thin (1 to 3 inch .03 to .08 meter) preferentially weathered zone within larger limestones, or it can occur in shales both black and gray. Microfaunal analysis is the only way to positively identify a marine condensed section.

Marine Condensed Sections Within the Red Eagle and Foraker Limestone

The Foraker Limestone contains three marine condensed sections. Each of these can be positively identified by an abundance of phosphatic remains, glaucony, and an abundant offshore *Streptognathodus* conodont fauna. The condensed sections within the Foraker are laterally correlatable from the northern most locality at Tuttle Creek to the southern most locality, Shidler Spillway. Typically the condensed sections of the northern (Paxico, Tuttle Creek) localities are within dark gray to black shales while the southern (K-38, Foraker North, and Shidler Spillway) condensed sections are within limestones. Explanation for the condensed sections occurring in differing lithologies is the depth of initial deposition. While the condensed section is being deposited in the deep basin (dark gray to black shales) it is simultaneously being deposited in the shallow marine shelf (limestone). This illustrates two major points, one: that the marine condensed sections are correlatable regardless of lithologic change, two: that the depositional basin lies to the north.

The Red Eagle Limestone contains two major marine condensed sections and one minor condensed section towards the top of the sequence. These condensed sections exhibit the same characteristics of those in the Foraker; laterally correlatable regardless of lithology, indicative of a northern located basin.

Sea-Level Curves

The Foraker Limestone contains six transgressive - regressive events, three of which are considered major. The three major flooding events occurred in 5th order sequences A, D, and E. These transgressions were large enough to produce carbonate marine condensed sections. The Red Eagle Limestone has three transgressive - regressive events, two of which were major. (figure 52) These two are believed to be the maximum flooding event of the Permian. To the north they are represented by thick black shales, and to the south by glauconitic carbonates.

Placement of The Pennsylvanian-Permian Boundary

Several factors converge to justify the placement of the Mid-Continent United States Pennsylvanian-Permian boundary at the base of the Red Eagle Limestone. Based on conodont research by Boardman, Nestell and Ritter (1994-1995), the identification of the conodont *Streptognathodus Nodulinaris* in the lower condensed section of the Red Eagle Limestone indicates it is correlatable with the Permian type locality in Kazakhstan, southern Ural Mountains. The Soviet boundary is secure, based on amminoid, fusulinacean, and conodont assemblages (Bogoslovskaya, 1995). Correlation between the two conodont faunas indicates this is the ideal location in order to keep a consistent world wide boundary.

SEA - LEVEL CURVE FOR THE FORAKER THROUGH RED EAGLE LIMESTONE, COUNCIL GROVE GROUP, OF THE MIDCONTINENT

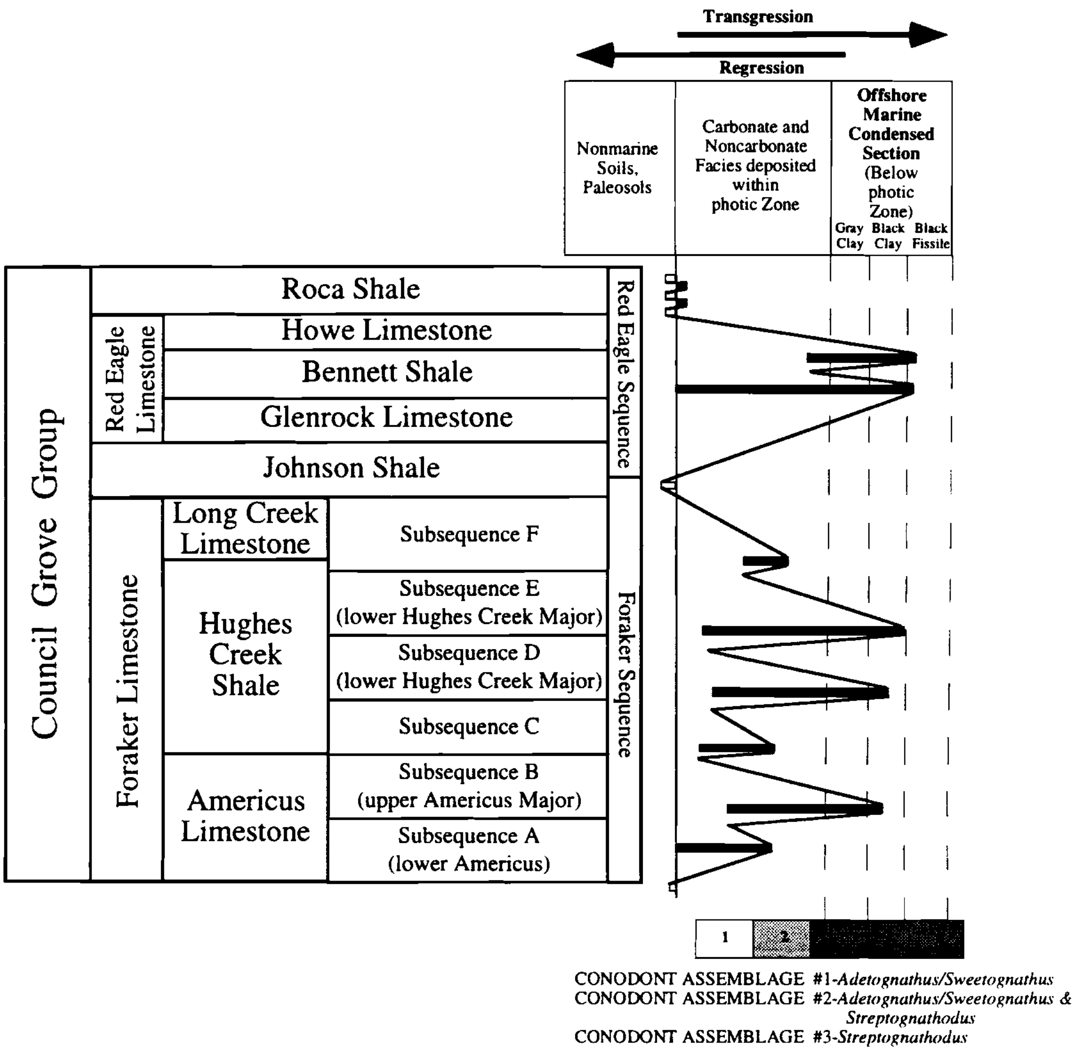


Figure 52.

CONCLUSIONS

Conclusion

The Foraker Limestone consists of six transgressive - regressive cycles of sedimentation that can be traced from northern Kansas to northern Oklahoma. Three of these cycles had sufficient water depths at or near highstand necessary to form marine condensed sections. These condensed sections are represented in the northern most localities by black shales, and in the southern sections by glauconitic and phosphatic carbonates. Both the northern and southern marine condensed sections are dominated by abundant off shore *Streptognathodus* dominated conodont fauna. All of these transgressive - regressive cycles are capped by marginal marine *Adetognathus* dominated conodont fauna.

The lower Johnson Shale is a blocky red mudstone/siltstone to fissile red shale interpreted to represent paleosols. These paleosols are representative of lowstand deposits. The upper Johnson Shale contains gray fossiliferous shales and thin fossiliferous limestones. These strata are interpreted as the initial flooding event of the Red Eagle Sequence.

In northern Kansas the maximum flooding event of the Red Eagle is represented by a black shale. In southern Kansas and northern Oklahoma this maximum flooding event is represented by phosphatic and glauconitic carbonates. These are highstand deposits and represent marine condensed sections characterized by abundant off shore *Streptognathodus* dominated conodont fauna.

The placement of the Pennsylvanian-Permian boundary, based on conodont assemblages of Boardman and others should be immediately below the Red Eagle Limestone. This correlates with the boundary position in the type Permian locality in the southern Ural Mountains.

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