GENETIC STRATIGRAPHY, DEPOSITIONAL ENVIRONMENTS, AND VERTEBRATE PALEONTOLOGY OF THE SPEISER SHALE (GEARYAN STAGE, LOWER PERMIAN SERIES) IN NORTHERN KANSAS

by

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B.S., University of Minnesota, 1986

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

(Geology)

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

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Co-major Professors

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ACKNOWLEDGEMENTS

I would like to express thanks to Drs. Ronald R. West and Hans-Peter Schultze who contributed in many ways to the completion of this thesis. I can truly say that both men gave generously of time and effort. Drs. M. D. Ransom, R. M. Busch, C. Oviatt, J. Day, G. R. Clark, II, R. J. Cuffey, P. C. Twiss, C. G. Maples, J. L. Graf, Jr., and S. Chaudhuri also made significant scientific, technical, or editorial contributions to this research project. I would also like to thank graduate students in the Department of Geology, Kansas State University, particularly Karl Leonard, for comments, suggestions, and technical help including identification of structures and fossil taxa. James McAllister and Brian Foreman, Museum of Natural History, University of Kansas, also contributed valuable information and ideas that improved the quality this thesis. I also acknowledge the financial support of the Kansas Geological Survey.

I owe my parents, Duane and Bonita Cunningham, special thanks for the encouragement and support over the years that made my education, both undergraduate and graduate studies, possible. I also thank Joan Cadillac, my best friend, for encouragement, support, and help of a thousand kinds, without which, this thesis would not have seen completion.

INTRODUCTION

General Statement

The Speiser Shale (Council Grove Group, Gearyan Stage, Lower Permian Series) (Figure 1), containing nonmarine to fully open marine mudrock and carbonate facies, underlies the geomorphologically prominent Wreford Limestone, and crops out in a narrow band stretching from southeastern Nebraska to northeastern Oklahoma (Figure 2).

Hattin (1957) described the lithostratigraphy of the Speiser Shale and the overlying Wreford Limestone. Most later workers who studied the stratigraphy of the Speiser Shale and Wreford Limestone (e.g., Lutz-Garihan and Cuffey, 1979) adopted the lithostratigraphic framework of Hattin (1957). Furthermore, in most paleontological studies of the Speiser Shale and Wreford Limestone (e.g., Lutz-Garihan, 1976, and Schultze, 1985), the distributions of fossil organisms were described relative to lithostratigraphic descriptive units identified by Hattin (1957).

Barrett (1989) differed from previous studies of the Speiser Shale and Wreford Limestone in that he approached this stratigraphic interval from a genetic stratigraphic perspective, and pursued his study with a methodology as outlined in Busch (1988) and Busch and West (1987). That

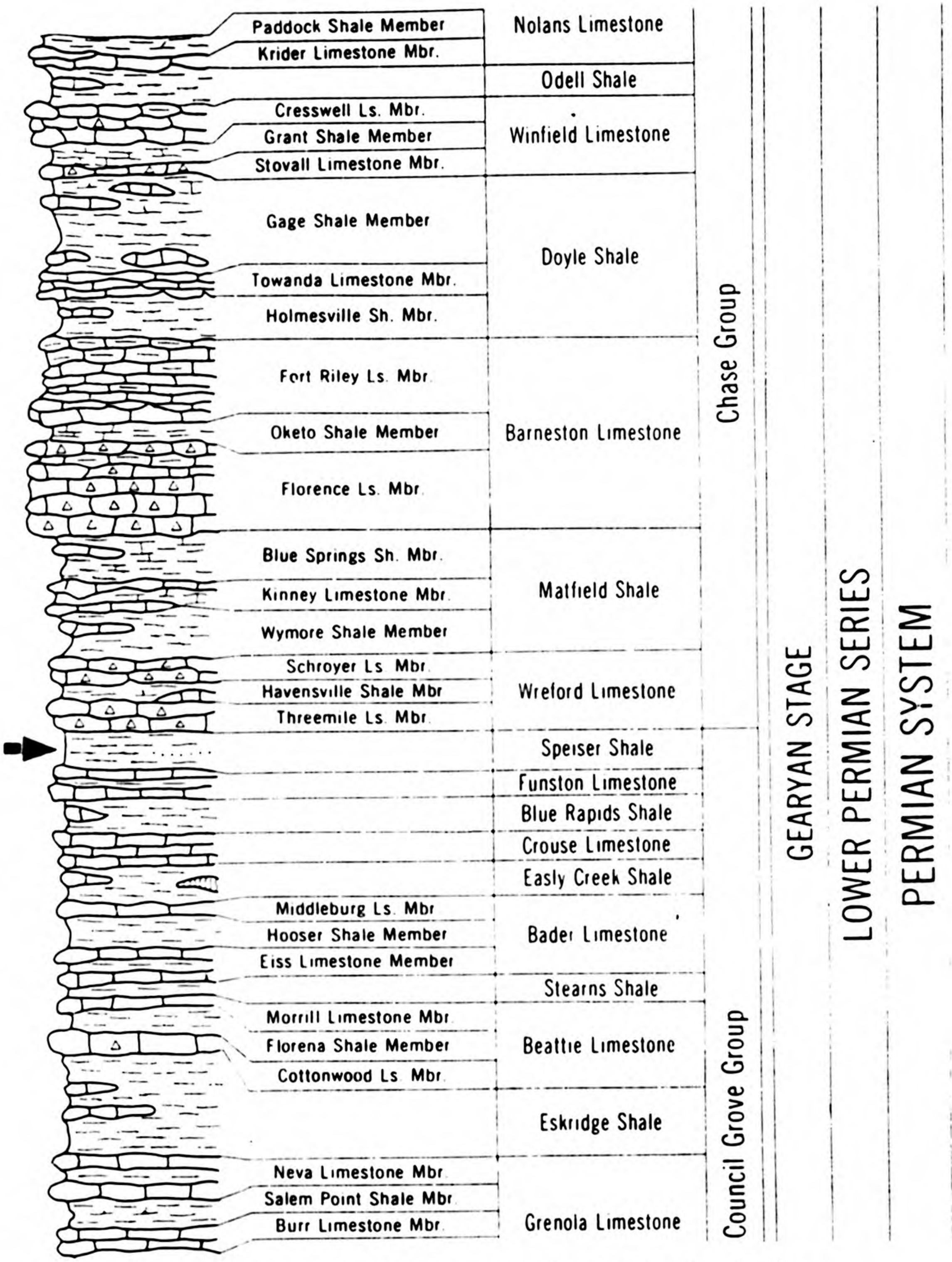


Figure 1. The formal stratigraphic context of the Speiser Shale (indicated by arrow). Triangles indicate the presence of chert mineralization (from Zeller, 1968).

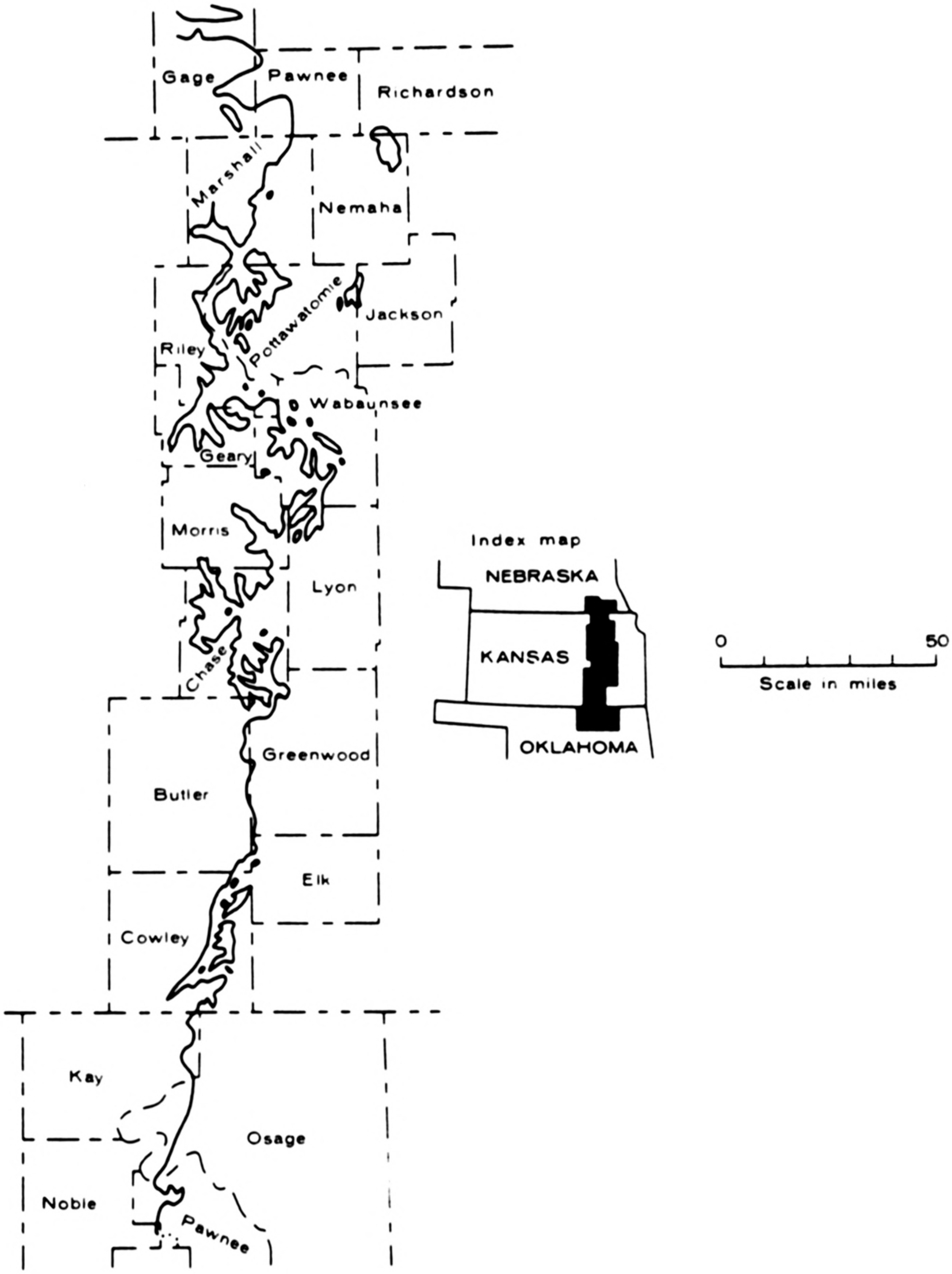


Figure 2. The outcrop pattern of the Wreford Limestone. The Speiser shale lies immediately below the Wreford Limestone (from Lutz-Garihan and Cuffey, 1979, p.3).

is, he attempted to identify and correlate hierarchal genetic (transgressive-regressive) units within the Speiser Shale and Wreford Limestone in a study area in northern Kansas.

Genetic stratigraphy is the science of resolving the temporal and spatial relationships of rock or sediment bodies through the identification and correlation of units that share a common origin or reflect a common influence. Correlation of the signatures of an event in earth history across and within facies, rather than the correlation of rock bodies on the basis of similarity of lithology (lithostratigraphy) or fossil content (biostratigraphy), distinguishes genetic stratigraphy from other branches of stratigraphy.

Hierarchal genetic stratigraphy (sensu Busch and West, 1987) ". . . relies upon definition of a nested hierarchy of distinct scales of deepening-shallowing units that are correlative at least intrabasinally and thus are regarded as transgressive-regressive units (T-R units)" (Busch, Rollins, and West, 1988, p.92).

In the present study, I utilized the methods of hierarchal genetic stratigraphy with the goal of refining previous knowledge of the stratigraphy and depositional environments of the Speiser Shale. In addition, I attempted to utilize these methods to understand the distribution of vertebrate fossils within the Speiser Shale in a study area in north-central Kansas (Figure 3).

Purpose of Study

The Speiser Shale contains a rich and diverse collection of fossil vertebrate assemblages. Body fossils of Osteichthyes (Acanthodii, Palaeoniscoidea, Platysomoidea; Dipnoi), Elasmobranchii (Xenacanthida, "cladodonts", petalodonts, and "bradyodonts"), Amphibia (Lepospondyli; Labyrinthodontia), and dipnoan (Gnathorhiza) and amphibian (Lysorophus) burrows have been found within this formation in Kansas (Schultze, 1985).

The principal scientific goals of this study were: 1) to identify and correlate hierarchal transgressive-regressive units within the Speiser Shale, and 2) to document and interpret the distribution of vertebrate body fossils and ichnofossils (burrows) within facies and hierarchal genetic units of the Speiser Shale in a study area in north-central Kansas (Figure 3).

An important part of this second goal was to document and interpret the distribution of lungfish (Gnathorhiza) and amphibian remains and burrows within the study interval. Previous workers had generally concluded that Permian amphibians and lungfish were nonmarine (lacustrine) organisms (Berman, 1976, Olson, 1956, 1971, 1972, 1977, Olson and Bolles, 1975; Romer and Olson, 1954). Schultze (1985), however, suggested that Gnathorhiza and some

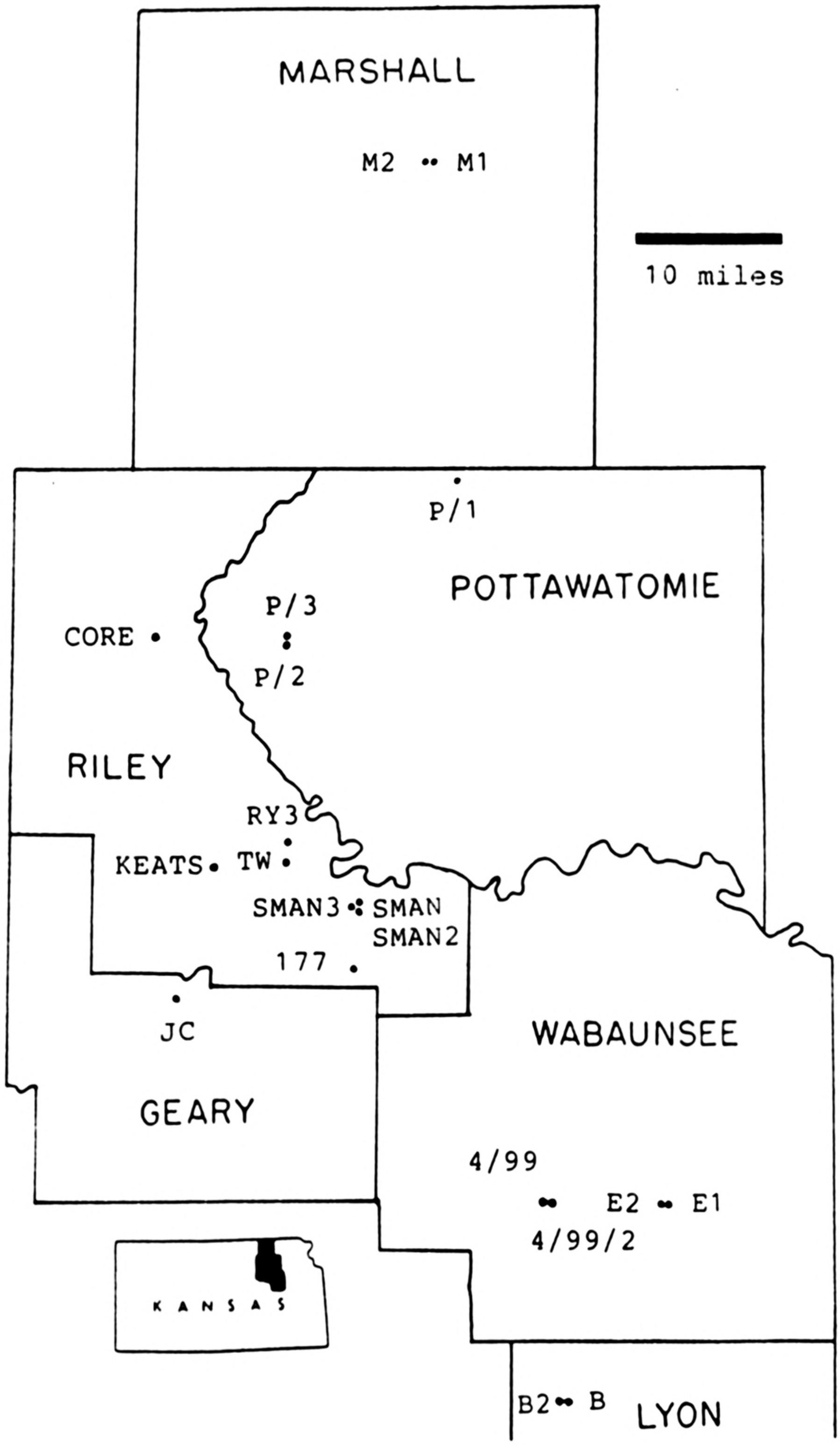


Figure 3. The study area with localities labelled.

Permian amphibians may have been salt water tolerant, and may have inhabited marginal marine paleoenvironments. For the purpose of this study, it was assumed that *Gnathorhiza* and the tetrapods of the Speiser Shale were nonmarine forms, and evidence was collected to confirm or deny this hypothesis.

PREVIOUS WORK

Formal and Cyclic Stratigraphy

Condra (1927) proposed the name Speiser Shale for mudrock and limestone units in the upper part of the Garrison shale (above the Crouse Limestone and below the Wreford Limestone). The Garrison shale was a lithostratigraphic entity containing the mudrock and limestone units above the Cottonwood Limestone and below the Wreford Limestone (Hattin, 1957). Condra and Upp (1931) redefined the Speiser Shale to include limestones and mudrocks above the Funston Limestone and below the Wreford Limestone, i.e., to the interval now referred to formally as the Speiser Shale. Moore (1936) elevated the subdivisions of the Garrison shale to the rank of formation. The type locality of the Speiser Shale is located in Speiser Township, Richardson County, Nebraska (Hattin, 1957).

The Lower Permian Series of Kansas is formally composed of two stages, the Gearyan Stage and the overlying Cimmarronian Stage (Zeller, 1968). The Gearyan Stage contains the Admire, Council Grove, and Chase Groups (in ascending stratigraphic order). Because the groups of the Gearyan Stage can not be confidently correlated lithostratigraphically with rock packages within the West

Texas Wolfcampian Series (O'Connor, 1963), the Gearyan Stage of Kansas bears a locally-derived (Geary County) name.

Roscoe and Adler (1983), however, correlated the Admire and Council Grove Groups with the Lower Wolfcampian, and the Chase Group with the Upper Wolfcampian of Texas. The Speiser Shale is the uppermost formation in the Council Grove Group, and is, therefore, probably correlative with rocks of the upper part of the Lower Wolfcampian of Texas.

Ross and Ross (1985) indicated that the Gearyan Stage is correlative with the upper Stephanian (Upper Carboniferous) and Autunian (Lower Permian) Stages of western Europe based on biostratigraphic (fusulinid) data. Johnson and Zidek (1981) reported that according to conventional usage of the Oklahoma Geological Survey, the ". . . Gearyan (Oklahoma, Kansas) corresponds to the Wolfcampian (Texas) and belongs in the Pennsylvanian" (p.526.).

For the purposes of this study, however, the Speiser Shale is considered to be Permian in age after Hattin (1957), Cuffey (1967), Newton (1971), Lutz-Garihan and Cuffey (1979), Schultze (1985), and others.

In addition to formal member, formation, and group designations, cyclic Permo-Carboniferous sequences in the Midcontinent have been grouped into cyclothems and megacyclothems, informal lithostratigraphic entities. The term cyclothem was defined by Wanless and Weller (1932) as the set of units that resulted from one cycle of sedimentation during the Pennsylvanian of the Midcontinent. Moore (1936) adopted a slightly different usage of the term and referred to each limestone-mudrock couplet of a cyclic sequence in the upper Paleozoic of Midcontinent as a cyclothem. Moore (1936) also coined the term "megacyclothem" for groups of limestone-mudrock couplets (up to five), and viewed megacyclothems as cycles of cyclothemic deposition.

Jewett (1933) noted the cyclicity of the sedimentary sequence of the "Big Blue Series" (Gearyan) of Kansas. Elias (1937) interpreted the "Big Blue Series" of Kansas in terms of cyclic sedimentation in response to cyclic fluctuations in sea-level. In this model, the deepest water generally corresponded to the carbonate-dominated part of the cycle. Elias (1937) constructed a depositional model for one ideal cycle of sedimentation in the Permian of Kansas (Figure 4), and Hattin (1957) interpreted the Wreford Limestone (and upper half of the underlying Speiser Shale) in terms of this model of an ideal cyclothem (Figure 5). Hattin (1957) agreed with Elias (1937) who interpreted the Wreford Limestone as reflecting two cycles of sedimentation (i.e., to contain two cyclothems). The upper half of the Speiser Shale, the Threemile Limestone Member, and the lower half of the Havensville Shale Member

	No.	Phases established chiefly on paleontologic evidence	Corresponding typical lithology
Regressive hemicycle	1.	Red shale.................	Clayey to fine sandy shale, rarely consolidated.
	2r.	Green shale................	
	3r.	Lingula phase..............	Sandy, often varved (?), rarely clayey shale.
	4r.	Molluscan phase...........	Clayey shale, mudstone to bedded limestone.
	5r.	Mixed phase............ – .	Massive mudstone, shaly limestone.
	6r.	Brachiopod phase..........	Limestone, flint, calcareous shale.
	7.	Fusulinid phase............	
Progressive hemicycle	6p.	Brachiopod phase..........	
	5p.	Mixed phase...............	Massive mudstone, shaly limestone.
	4p.	Molluscan phase...........	Clayey shale, mudstone to bedded limestone.
	3p.	Lingula phase	Sandy, often varved (?), rarely clayey shale.
	2p	Green shale................	Clayey to fine sandy shale, rarely consolidated.
	1.	Red shale.................	

Figure 4. An idealized cycle of sedimentation in the Permian of Kansas (from Elias, 1937, p.411).

	Fm.	Mbr.	Phase	Description
SCHROYER CYCLOTHEM	MATFIELD SHALE	Wymore shale	1 .	Red shale
			2r.	Green shale, ostracodes
	WREFORD LIMESTONE	Schroyer limestone	4r.	Algal limestone
			5r.	Calcareous shale, mixed fauna, *Derbyia* dominant
			6 .	Chert-bearing limestone, brachiopod-bryozoan fauna
		Havensville shale	5t.	Calcareous shale, mixed fauna, *Derbyia* dominant
			4t.	Molluscan limestone, *Aviculopecten*, *Septimyalina*
			3t.	Grayish-yellow mudstone, ostracodes
THREEMILE CYCLOTHEM			2 .	Green shale, ostracodes and sparse plant remains
			3r.	Grayish-yellow mudstone, ostracodes
			4r.	Molluscan limestone, *Aviculopecten*, *Septimyalina*
			5r.	Calcareous shale, mixed fauna, *Derbyia* dominant
		Threemile limestone	6r.	Chert-bearing limestone, brachiopod-bryozoan fauna
			6 .	Chalky limestone, *Fenestrellina*, corals
			6t.	Chert-bearing limestone, brachiopod-bryozoan fauna
	SPEISER SHALE		5t.	Calcareous shale, mixed fauna, *Derbyia* dominant
			4t.	Molluscan limestone, *Aviculopecten*, *Septimyalina*
			3t.	Grayish-yellow mudstone, ostracodes
			2t.	Green shale, ostracodes and sparse plant remains
			1t.	Red shale, charophytes
			0 .	Sandstone, unfossiliferous

Numbering corresponds to that of Elias (1937, p. 411) where applicable. t=transgressive phase, r=regressive phase. End members of hemicycles are not lettered. (Minor regressions and transgressions not shown).

Figure 5. The Wreford Limestone interpreted in terms of Elias'(1937) ideal cyclothem (from Hattin, 1957, p.106).

of the Wreford Limestone informally constitute the Threemile Cyclothem. Similarly, the upper half of the Havensville Shale Member and the Schroyer Limestone Member of the Wreford Limestone, and the Wymore Shale Member of the Matfield Shale are grouped into the Schroyer Cyclothem. Hattin (1957) informally combined the Threemile and Schroyer Cyclothems into the Wreford Megacyclothem.

For a more complete discussion of the history of cyclic sedimentation studies in the Upper Paleozoic of the Midcontinent, usage of terms applied to cyclic stratigraphy, and a detailed comparison of cyclothem and hierarchal genetic stratigraphy see Barrett (1989).

Fine-scale Lithostratigraphy and Depositional Environments

Hattin (1957) laid the foundation for modern studies of the Speiser Shale and Wreford Limestone. Later workers who studied the stratigraphy of this interval, such as Lutz-Garihan and Cuffey (1979), have generally adopted the lithostratigraphic framework developed by Hattin (1957). R. J. Cuffey developed a shorthand notation for referring to Hattin's (1957) descriptive subdivisions of the Speiser Shale and Wreford Limestone that he used extensively in the course of his field studies of this interval. This notation was described and utilized in Cuffey (1967), Lutz-Garihan (1976), and Lutz-Garihan and Cuffey (1979), and is given below for each of Hattin's (1957) descriptive units.

The lowest units in the Speiser Shale that were studied in detail by Hattin (1957) are the "red shales" of the "middle Speiser Shale," the mSp in Cuffey's notation. Hattin (1957) noted "shaly bedding," "blocky weathering," and the sandiness (quartz) and siltiness of these units, as well as their sparsely fossiliferous nature. He noted only charophyte oogonia (gyrogonites) at one locality in the middle Speiser Shale. Hattin (1957) interpreted the red mudrocks of the Speiser Shale to be subaerial deposits that formed on ". . . a broad, low alluvial plain bordering the Early Permian sea" (p.112). In his conclusion, he stated that the red color is due to ". . . oxidation of the soil from which the sediment was derived, by subaerial oxidation after deposition, or both" (p.113).

Lutz-Garihan and Cuffey (1979) interpreted the "red shales" of the middle Speiser Shale to be flood plain or tidal flat deposits.

Cubitt (1979) noted ". . . consistently high Fe oxide content. . ." (p.88) in the red and purple mudrocks of the Lower Permian Series of Kansas. However, the data Cubitt (1979) provided for two mudrock samples from the the middle Speiser Shale in Kansas showed "Fe oxides" to constitute only 3.8 and 2.1 percent (p.37) of samples, typical values for Lower Permian mudrocks from Kansas. About the red and purple mudrock facies, Cubitt (1979) wrote: "This facies represents, therefore, a locally important field unit, but at the same time is indistinguishable from other calcareous shales in terms of mineralogy and geochemistry" (p.88). Cubitt (1979) speculated that "Color variation recorded in the shales is a reflection of the iron content and/or organic content. Red colors arise from the presence of ferric oxide in the essential absence of organic materials whereas green shales are probably deposited with some organic material that reduces the red ferric ions to the ferrous state (Elias, 1937). The stratigraphic association of green shales immediately above and below red shales indicates this to be true" (p.88).

In the lower and middle parts of the Speiser Shale, " . . . green strata [mudrock] cyclically preceed and follow red shales where the latter are present" (Hattin, 1957, p.53). In his generalized, schematic presentation of the Speiser Shale, however, Hattin (1957) showed green shale only to overlie "red shale" of the middle Speiser Shale.

Lutz-Garihan and Cuffey (1979) also generalized the stratigraphy of the Speiser Shale and showed green shale, "lower lower upper Speiser shale" (lluSp), overlying red shale.

Hattin (1957) interpreted the green shales (presumably only the ones overlying the red-dominated part of the formation) to represent ". . . the product of sedimentation in the zone of marine deposition nearest shore" (p.113). He interpreted the salinity of the depositional environment to be brackish based on the ostracode-dominated fossil assemblage (Table 1). Lutz-Garihan and Cuffey (1979) also interpreted the green shales to represent shallow marine or intertidal paleoenvironments of brackish salinity.

Based on fossil content (Table 2), and position within what he interpreted to be a transgressive sequence, Hattin (1957) interpreted the "grayish-yellow mudstone" facies, the "upper lower upper Speiser Shale" (uluSp) in Cuffey's terminology and notation, to represent a brackish paleoenvironment ". . . next offshore from the area of green-shale accumulation" (p.113). Lutz-Garihan and Cuffey (1979) echoed this interpretation.

The molluscan limestone of Hattin (1957), the "middle upper Speiser Shale" (muSp) in Cuffey's terminology, with a smooth-shelled ostracode and mollusc (Bivalvia and Gastropoda) dominated fossil assemblage (Table 3) was interpreted by Hattin (1957) to have been deposited in marine water of ". . . more nearly normal salinity in an offshore zone where some turbulence resulted from wave activity" (p.113). Lutz-Garihan and Cuffey (1979) interpreted the molluscan limestone as representing fully marine or brackish paleoenvironments with water depths of 10 to 60 feet. Cuffey (1988, pers. comm.) stated that the

Table 1. List of fossil taxa identified in the green "shales" of the Speiser, Havensville, and Wymore Shales. Note that this is a composite list from similar lithofacies within three lithostratigraphic units (from Hattin, 1957, p.54).

Ostracodes
- *Bairdia* sp.
- *Bythocypris* sp.
- *Cavellina* sp.
- *Knoxina* sp.
- *Macrocypris* sp.
- *Paraparchites* sp.
- ?*Hollinella* sp.
- ?*Microcheilinella* sp.
- ?*Silenites* sp.

Mollusks
- Gastropods, high-spired

Vertebrates
- Fragmentary remains

Plants
- *Neuropteris* sp.
- Charophyte oogonia
- Seaweed impressions

Table 2. Composite list of fossil taxa identified in the grayish-yellow mudstones of the Speiser, Havensville, and Wymore Shales (from Hattin, 1957, p.55).

Plants
- Charophyte oogonia (s)

Foraminifers
- *Ammovertella* sp. (s)
- *Cornuspira* sp. (s)
- *Globivalvulina* sp. (c)
- *Orthovertella* sp. (s)

Annelids?
- Worm tubes (s)

Bryozoans
- *Septopora* sp. (s)

Brachiopods
- Productid spines (c)

Mollusks
- *Aviculopecten* sp. (s)

Ostracodes
- *Bairdia* sp. (c)
- *Bythocypris* sp. (s)
- *Cavellina* sp. (c)
- *Hollinella* sp. (s)
- *Kirkbya* sp. (s)
- *Knoxina* sp. (s)
- *Macrocypris* sp. (s)
- *Paraparchites* sp. (s)

Echinoderms
- Crinoid stems (s)
- Echinoid spines (s)
- Holothurian hooks (s)

Vertebrates
- Fragmentary remains (s)

Table 3. Composite list of fossil taxa identified in the molluscan limestones of the Speiser and Havensville Shales (from Hattin, 1957, p.58).

Plants	Mollusks
Osagia sp.	*Pseudomonotis* sp.
Foraminifers	*Aviculopinna* sp.
Nubecularia sp.	•*Aviculopecten* sp.
•*Ammovertella* sp.	•*Septimyalina* sp.
•*Ammodiscus* sp.	•*Pelecypods*, molds
Globivalvulina sp.	•Gastropods, tiny internal molds
Bryozoans	*Bellerophon* sp.
Fenestrate types	Ostracodes
Ramose types	?*Cavellina* sp.
Brachiopods	Ostracodes sp.
Productid spines	Echinoderms
Dictyoclostus sp.	Crinoid remains
Juresania sp.	
Lingula sp.	
Orbiculoidea sp.	

molluscan taxa of this facies (*e.g.*, pectenids) probably required normal marine salinity, however.

Above the molluscan limestone, Hattin (1957) noted a calcareous shale facies, the "upper upper Speiser Shale" (uuSp) in Cuffey's terminology, with a diverse marine fossil assemblage (Table 4). Hattin (1957) wrote: "The fauna of the calcareous-shale units is the most abundant and most varied taxonomically of any in the Wreford megacyclothem" (p.62). Hattin (1957) interpreted this facies as representing fully marine conditions ". . . where wave agitation was not strong" (p.113).

Above the calcareous shale facies of the "upper upper Speiser Shale" lies the base of the Threemile Limestone Member of the Wreford Limestone, in particular, a bed that Cuffey referred to as the "lower Threemile Limestone" (lWt).

Hattin (1957) believed that the cherty limestone facies was deposited in deeper, clearer normal marine water (farther from shore) than the calcareous shale facies. He interpreted the apparent lower diversity of the fossil assemblage (Table 5) of the cherty limestone facies of the Wreford Limestone to be a reflection of the relative difficulty of detecting taxa within a carbonate rock. Cuffey (1988, pers. comm.) also attributed the apparent relative decrease in taxonomic diversity in the cherty limestones of the Wreford Limestone to the fact that

Table 4. Composite list of fossil taxa identified in the calcareous "shales" of the Speiser Shale and Wreford Limestone (from Hattin, 1957, p.62).

Plants
- *Osagia* sp. (s)

Foraminifers
- *Ammovertella* sp.
- *Climacammina* sp. (s)
- Fusulinids, juveniles (s)
- •*Globivalvulina* sp.
- *Geinitzina* sp. (s)
- *Hyperammina* sp.
- *Tetrataxis* sp.
- ?*Orthovertella* sp. (s)

Corals
- *Aulopora* sp. (s)
- *Stereostylus* sp. (s)

Bryozoans
- Cyclostome, encrusting (s)
- •*Fenestrellina* sp.
- *Penniretepora* sp.
- *Polypora* sp.
- *Rhabdomeson* sp.
- •*Rhombopora* sp.
- *Septopora* sp.
- *Streblotrypa* sp. (s)
- Trepostome, encrusting (s)
- •*Thamniscus* sp.
- ?*Batostomella* sp. (s)
- ?*Leioclema* sp.

Brachiopods
- •*Chonetes* sp.
- •*Composita* sp.
- •*Derbyia* sp.
- •*Dictyoclostus* sp.
- •*Enteletes* sp.
- *Juresania* sp.
- *Lingula* sp.
- *Orbiculoidea* sp.
- *Petrocrania* sp.
- •Productid spines

Mollusks
- *Aviculopecten* sp. (s)
- *Aviculopinna* sp.
- *Euomphalus* sp.
- *Pseudomonotis* sp. (s)
- *Septimyalina* sp. (s)
- Gastropods, molds

Ostracodes
- *Amphissites* sp.
- •*Bairdia* sp.
- *Bythocypris* sp.
- •*Cavellina* sp.
- *Cornigella* sp. (s)
- *Ellipsella* sp. (s)
- *Healdia* sp. (s)
- *Hollinella* sp.
- *Kellettina* sp.
- *Kirkbya* sp.
- *Knightina* sp.
- •*Knoxina* sp.
- *Macrocypris* sp.
- *Monoceratina* sp.
- *Paraparchites* sp.
- *Roundyella* sp.
- *Silenites* sp.
- ?*Haworthina* sp. (s)

Trilobites
- *Ditomopyge* sp.

Echinoderms
- •*Delocrinus* sp.
- •Crinoid plates and stems
- •Echinoid plates
- •Echinoid spines
- Holothurian spicules, wheels (s) and hooks

Vertebrates
- Conodonts (s)
- •Fragmentary remains, plates, teeth, bones

Table 5. Composite list of fossil taxa identified in the cherty limestones of the Wreford Limestone (from Hattin, 1957, p.67-68).

Plants
- *Osagia* sp. (s)

Foraminifers
- *Ammodiscus* sp. (s)
- *Ammovertella* sp.
- *Schwagerina* sp. (s)

Bryozoans
- •*Fenestrellina* sp.
- *Penniretepora* sp.
- *Rhombopora* sp.
- *Septopora* sp.
- *Tabulipora* sp.
- *Thamniscus* sp.
- •Fenestrate and ramose types

Brachiopods
- *Chonetes* sp.
- •*Composita* sp.
- •*Derbyia* sp.
- •*Dictyoclostus* sp.
- *Enteletes* sp.
- *Orbiculoidea* sp. (s)
- •Productid spines
- *Wellerella* sp.

Sponges
- Sponge spicules

Corals
- *Stereostylus* sp.
- *Aulopora* sp. (s)

Mollusks
- *Aviculopecten* sp. (s)
- *Aviculopinna* sp. (s)
- Gastropods, small molds (s)
- *Septimyalina* sp. (s)

Trilobites
- *Ditomopyge* sp.

Ostracodes
- *Bairdia* sp.
- Ostracodes, indeterminable

Echinoderms
- *Delocrinus* sp.
- •Crinoid stems
- •Echinoid spines
- •Echinoid plates

Vertebrates
- Fragmentary remains

it is much easier to find fossils in mudrocks (through sieving) than in carbonate rocks.

Hattin (1957) stated that the nodular and bedded chert within the cherty limestone facies of the Wreford Limestone is of two types, concentrically-layered calcareous and non-calcareous, and that the non-calcareous chert is a "primary inorganic precipitate" (p.114) that precipitated directly out of sea water contemporaneous with the deposition of the enclosing limestone. Hattin (1957) envisioned masses of "unsolidified chert gel" (p.102) lying on the sea bottom. Hattin (1957) suggested, however, that ". . . the layering of the calcareous cherts seem to be of diagenetic origin and may be a liesegang [sic] phenomenon resulting from diffusion of silica ions through the deposit during compaction of the sediments" (p.103).

Barrett (1989) noted the presence of chert (length-slow) pseudomorphs after what were interpreted to be gypsum crystals and rosettes, and proposed a model (Table 6) to explain the presence of chert after evaporite in rocks with diverse open marine fossil assemblages. He stated that chert-bearing carbonate rocks within the Wreford Limestone were deposited in "normal marine environments," (p.169), and concluded that "Field and laboratory data indicate a diagenetic origin for the conspicuous nodular and bedded chert found within the Wreford Limestone. It is suggested that much of the chert formed as a result of evaporite

Table 6. Generalized model explaining the occurrence of chert within the Wreford Limestone. Parts I, II, III, and IV are not intended to be sequential. (from Barrett, 1989, p.169).

PART I: Deposition of a sixth-order T-R unit, T-R unit I.

1. Sediment accumulation in normal marine environments
2. Carbonate cementation to acclude porosity and Permeability

PART II: Deposition and diagenesis of chert-bearing sixth-order T-R unit, T-R unit II.

1. Sediment accumulation in normal marine environments
2. Infiltration of sediments by hypersaline pore fluids (due to coastal progradation and groundwater evaporation) with subsequent crystalization of evaporite minerals (i.e., euhedral-crystals, rosettes, and nodules of gypsum) producing primary lithification
3. Infiltration of pore fluids saturated with respect to silica:
   A. partial dissolution of evaporites
   B. precipitation of quartz polymorphs (e.g., chert) and final lithification

PART III: Deposition of superjacent sixth-order T-R unit, T-R unit III.

1. Sediment accumulation in normal marine environments
2. Compaction and cementation of T-R unit III

PART IV: Dissolution of evaporites in modern surface and near-surface intervals of the Threemile, removal of remaining gypsum has occured due to dissolution by late Cenozoic groundwater and surface water. Precipitation of minor amounts of alpha-quartz in fractures and crystal molds has occrred concomitant with this phase of alteration.

replacement. The evaporites themselves are secondary in origin, forming in the sediments after deposition and before compaction" (p.174). Barrett (1989) concluded that gypsum mineralization (cementation) in the cherty limestones of the Wreford Limestone produced primary lithification.

West, Barrett, and Twiss (1987) noted less chert in a core (Amoco Hargrave #1) from Riley County, Kansas through the Threemile Limestone Member of the Wreford Limestone than in outcrop and suggested that at least some chert mineralization may be a relatively recent, near-surface phenomenon (see Part IV in Table 6).

Barrett (1989) also noted that bryozoan and brachiopod fragments, respectively, were preferentially silicified in the cherty limestones of the Wreford Limestone. Barrett (1989) stated ". . . that the chert replacing the evaporite crystals in many instances (e.g., chert sample in [his] Figure 64) acted as a nucleus for further silicification of the surrounding limestone. The presence of numerous bryozoan and brachiopod shell fragments in the limestone surrounding chert nodules helped to facilitate this silicification process. In this way, the positioning of chert beds within the limestone is dictated by the presence of evaporites and biomoldic porosity" (p.168).

Hierarchal Genetic Stratigraphy

Genetic stratigraphy is the science of resolving the temporal and spatial relationships of rock or sediment bodies through the identification and correlation of units that share a common origin or reflect a common influence. The effects of an event such as a global climate change, or a eustatic rise and fall in sea level (a transgressive-regressive or T-R event) can sometimes be identified in several lithologic units in different geologic settings, as well as within a single facies of widespread geographic extent. Correlation of the signatures of an event in earth history across and within facies, rather than the correlation of rock bodies on the basis of similarity of lithology (lithostratigraphy) or fossil content (biostratigraphy) distinguishes genetic stratigraphy from other branches of stratigraphy.

Hierarchal genetic stratigraphy (*sensu* Busch and West, 1987) ". . . relies upon definition of a nested hierarchy of distinct scales of deepening-shallowing units that are correlative at least intrabasinally and thus are regarded as transgressive-regressive units (T-R units)" (Busch, Rollins, and West, 1988, p.92). The scale referred to is both temporal and physical (thickness). In this model, the nested hierarchy of deepening-shallowing Permo-Carboniferous units (Figure 6) reflect a nested hierarchy

HIERARCHY OF PERMO-CARBONIFEROUS T-R UNITS

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

Figure 6. Nested hierarchy of Permo-Carboniferous transgressive-regressive (T-R) units. An interpretation of the amount of time represented by each cycle of depostion is given for units of each order (from Busch and West, 1987, p.143).

of eustatic (or at least basin-wide) deepening-shallowing events (Figure 7).

Major sea-level fluctuations, which produce the first-, second-, and third-order units of Vail et al. (1977), may record tectonic processes such as changes in sea-floor spreading rates and relative intensities of global mountain-building processes (orogenies). For example, the rate of sea floor spreading affects the volume of hot, thermally-expanded submarine volcanic rock (and the large scale thermal bulge or welt submarine volcanic systems reside upon), and, therefore, the relative volume of sea water displaced up on to the continents (Pitman, 1978).

Fourth-, fifth-, and sixth-order transgressive-regressive units are different from the major first-, second-, and third-order units of Vail et al. (1977) in that the shorter-term cycles have been interpreted to record relatively minor eustatic transgressive-regressive events in response to glacio-eustatic sea-level fluctuations. Glacio-eustatic events are believed to be due to long-and short-term eccentricity, obliquity, and precession cycles (astrophysical cycles) and concommitant global climate change (Goodwin and Anderson, 1985). Fourth-order transgressive-regressive units represent 0.6 to 3.6 million years of depositional history. Fifth-order transgressive-regressive units represent approximately 300-

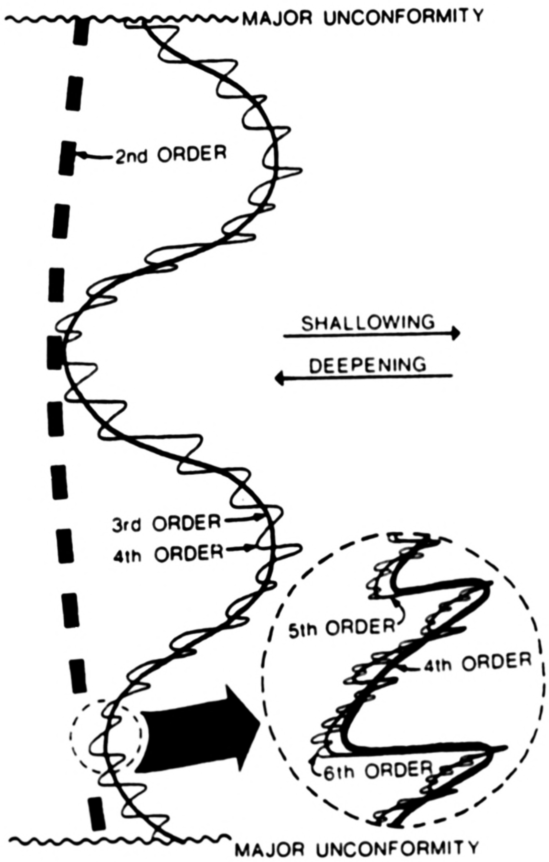


Figure 7. Graphic representation of the nested hierarchy of transgressive-regressive events responsible for the deposition of the nested hierarchy of transgressive-regressive units of Figure 6 (from Busch and West, 1987, p.146).

500,000 years of depositional history. Sixth-order transgressive-regressive units, or punctuated aggradational cycles (PACs) of Goodwin and Anderson (1985) reflect 50-130,000 years of depositional history (Busch and West, 1987). However, because T-R units are shallowing upward units, they are often unconformity-bounded. A distinction must therefore be drawn between the amount of time represented by the rock present within the bounding genetic surfaces (within the T-R unit) and the total time required to develop a sequence of hierarchal genetic units.

Goodwin and Anderson (1985) defined punctuated aggradational cycles (PACs) and discussed the PAC hypothesis (or model) of sediment accumulation (Figure 8). According to these authors, PACs are thin (1-5 meters thick), transgressive-regressive (T-R) sedimentary units that reflect a relatively rapid sea-level rise (a transgression, or punctuation event) and a subsequent relatively slow sea-level fall (regression). Furthermore, the transgressive bases of PACs are usually absent or relatively thin compared with the regressive part of the unit.

PACs are bounded by genetic surfaces, transgressive surfaces that mark a shift from nonmarine facies to marine facies or from shallower (regressive) marine facies to deeper marine facies (Goodwin and Anderson, 1985), or in nonmarine rocks, climate change surfaces that mark a shift

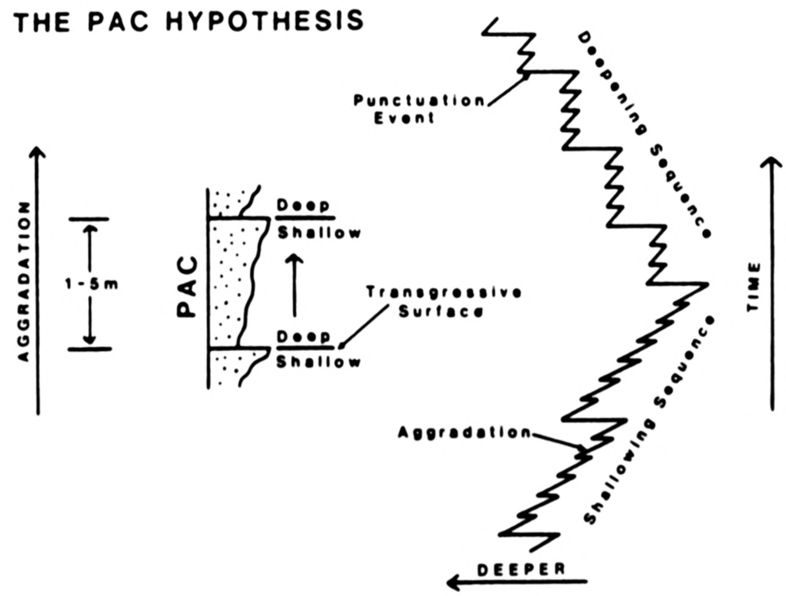


Figure 8. Generalized hypothesis of punctuated aggradational cycles (PACs). PACS, 6th-order transgressive-regressive units, are thin (1-5 m thick), shallowing upward units that reflect a relatively rapid transgression (punctuation event) and a gradual shallowing. PACs are the building blocks of shallowing PAC sequences (from Goodwin and Anderson, 1985, p.517).

from subaerial facies (paleosols or weathering profiles, for example) to more humid or subaqueous (nonmarine) facies (Busch, 1985).

Because PAC boundaries reflect climate change and, presumably, concommitant sea-level rise (i.e., allogenically-controlled events of widespread, at least basin-wide and perhaps world-wide, geographic influence) climate change surfaces are sometimes correlative with transgressive surfaces (Busch, 1985). PACs and PAC boundaries are, therefore, correlative across facies boundaries. Furthermore, PACs are believed by some to be bounded by isochronous genetic surfaces (Goodwin and Anderson, 1985). "The abrupt facies changes at PAC boundaries and the correlation of these surfaces for tens of kilometers (independent of lateral facies changes) provide the basis for interpreting PAC boundaries as isochronous" (p.519).

PAC's are, therefore, in the minds of some, time-stratigraphic units. Even though any one transgressive facies is not strictly isochronous over its geographic extent, PAC's may be time-stratigraphic units because they are not identified on the basis of lithology, but upon indications of an event that influenced sedimentation, eustatic sea-level rise or climate change. Events believed to be responsible for PACs, insolation variation due to astrophysical cycles, presumably, may be considered to be isochronous over a large, perhaps global, geographic extent.

In a hierarchal genetic study of the upper half of the Speiser Shale and the Wreford Limestone, Barrett (1989) identified and correlated sixth-order transgressive-regressive units or punctuated aggradational cycles (PACs). Furthermore, he demonstrated that these minor T-R units were nested to form fifth-order T-R units (Figure 9).

Based mostly upon fossil assemblage diversity and abundance (Figure 10), Barrett (1989) interpreted the sequence of green (lluSp) and grayish-yellow (uluSp) mudrocks to molluscan limestone (muSp), respectively, to be a transgressive sequence and to represent ". . . very shallow (possibly brackish) water (e.g., upper intertidal mudflats or lagoons) at the base; to shallow, relatively more open marine (e.g., lower intertidal) in the limestone . . . " (p.73). Barrett (1989) interpreted the molluscan limestone of Hattin (1957) to represent the transgressive apex of a punctuated aggradational cycle (PAC) (Figure 9).

Whereas Hattin (1957) and Lutz-Garihan and Cuffey (1979) interpreted the calcareous shale facies (uuSp) as representing one depositional environment with only minor geographic and vertical variations (within the area of the present study) in fossil assemblage composition, Barrett (1989) interpreted the lower part of this calcareous shale facies as regressive (upper intertidal), and the upper part

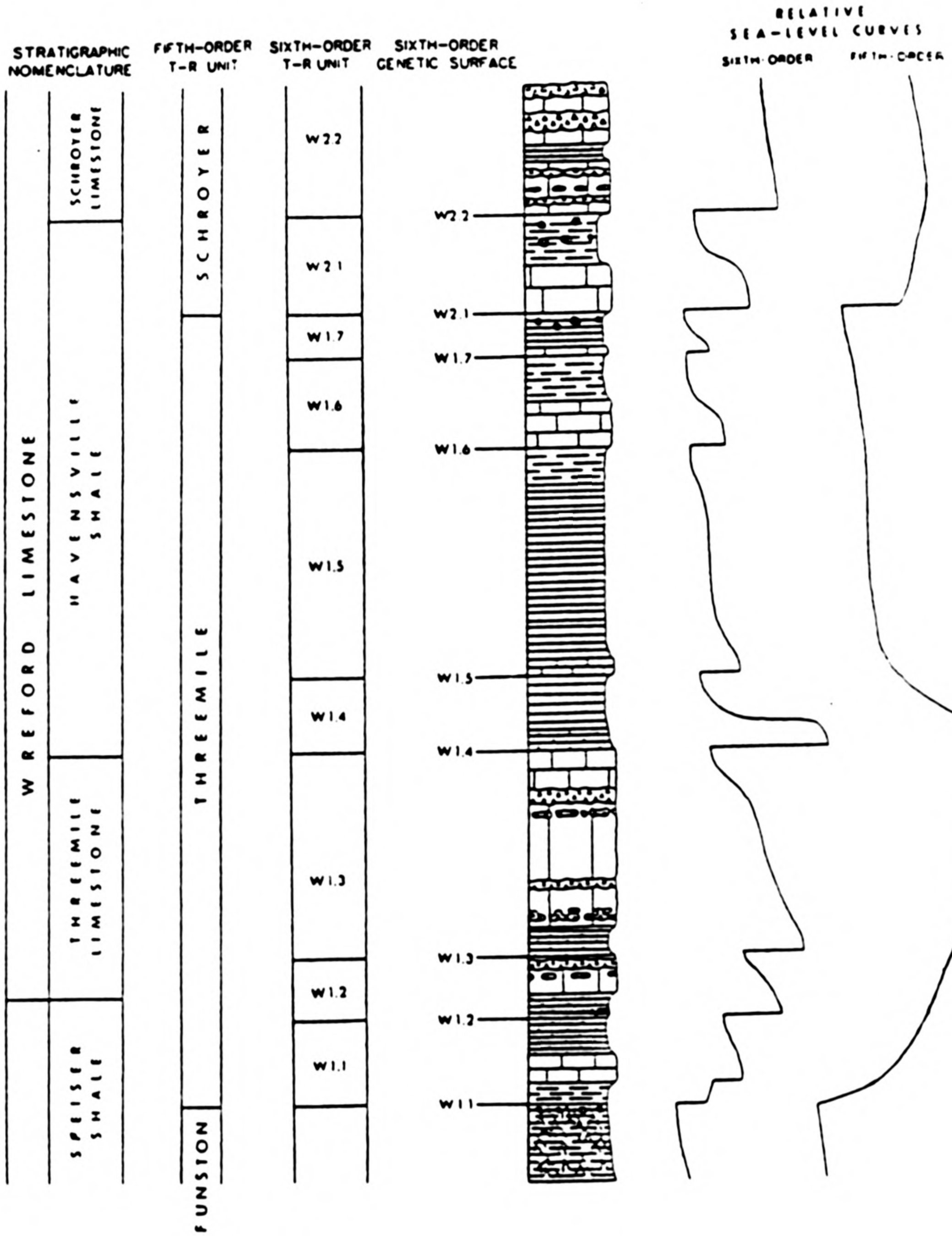


Figure 9. Hierarchal genetic and paleobathymetric interpretation of the Wreford Limestone showing calcareous shale deposition in response to deepest marine inundations (from Barrett, 1989, p.103).

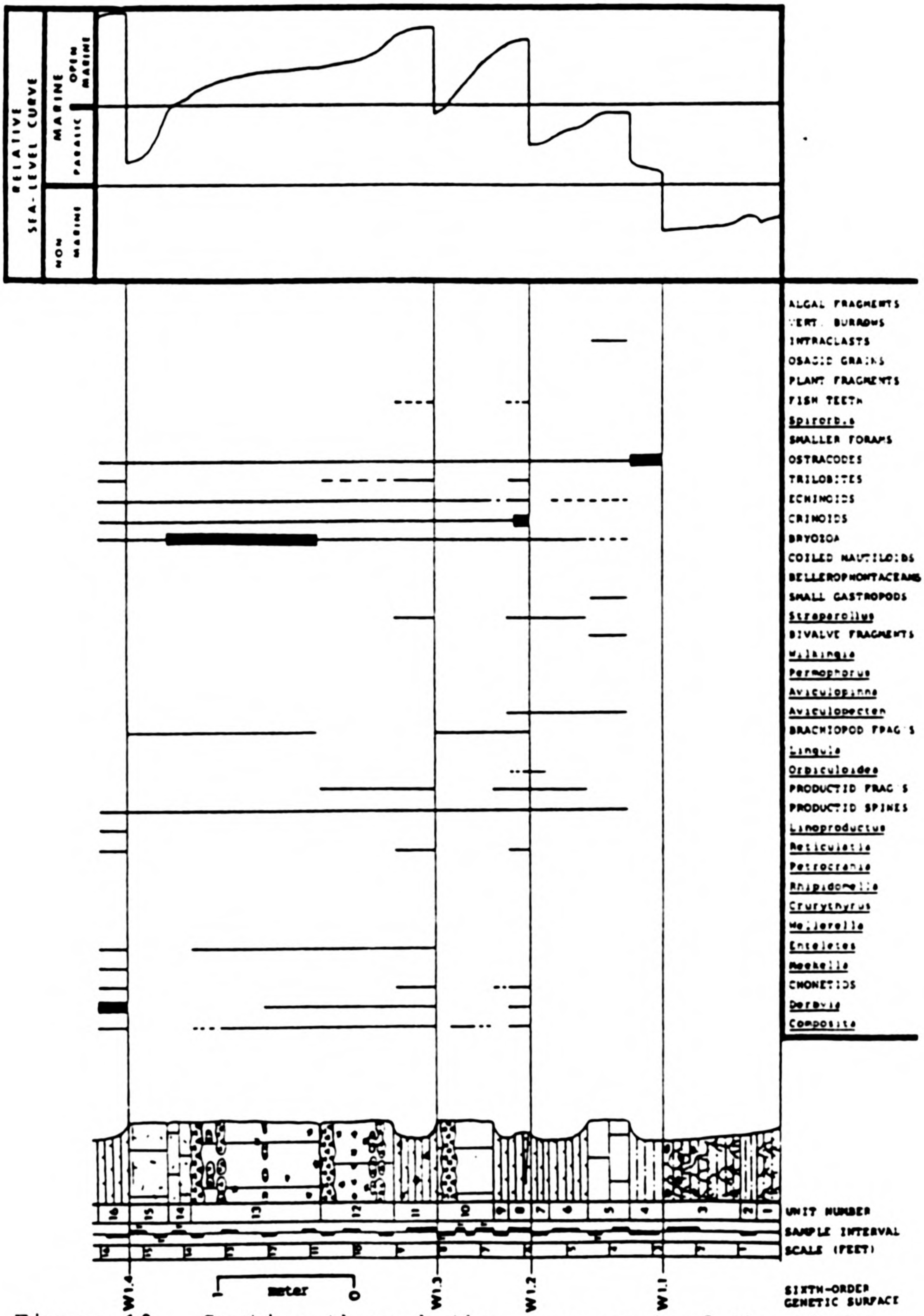


Figure 10. Section through the upper part of the study interval at locality GY3 of Barrett (1989) showing lithology, fossils present, and sea-level curve (from Barrett, 1989, p.66).

as transgressive, representing a transgressive apex, and regressive, respectively (Figures 9 and 10).

Barrett (1989) believed that the lowest cherty limestone bed in the Threemile Limestone Member of the Wreford Limestone (lWt) represents less open marine conditions than the most open marine part of the underlying calcareous mudrock (Figures 9 and 10). This opinion was based upon the lower diversity of marine invertebrates and the presence of gypsum crystal and rosette molds and chert pseudomorphs after gypsum rosettes in this bed.

Barrett's (1989) placement of PAC boundaries parallel to formational and member lithostratigraphic contacts (i.e., formal stratigraphic boundaries lie within the same PAC within the study area) and his construction of paleogeographic maps during "times" of maximum transgression and regression for each PAC he identified within the Wreford Limestone, suggest that he believed facies within the Wreford Limestone were, geologically speaking, isochronous or nearly isochronous over his study area. This is in marked contrast to Hattin (1957) who adhered to the widely-held notion that formations (lithostratigraphic entities) were diachronous, and who believed that facies within the Wreford Limestone were also diachronous.

Regional and Structural Setting

The Wreford Limestone and underlying Speiser Shale crop out in a narrow band stretching from southern Nebraska to northern Oklahoma (Figure 2). The Wreford Megacyclothem maintains a roughly constant thickness of about 65 feet in Kansas along this north-south traverse (Lutz-Garihan and Cuffey, 1979), but the Speiser Shale thickens to the south in southern Kansas and northern Oklahoma.

In northern Oklahoma, the Speiser Shale becomes interbedded with red channel sandstones suggesting that the Ouachita and Arbuckle structural and topographic highs served as sources of siliciclastic detritus during the deposition of the Speiser Shale and Wreford Limestone (Barrett, 1989). Similarly, in southern Nebraska the Speiser Shale becomes interbedded with channel sandstone deposits, and Newton (1971) suggested that this indicated a siliciclastic source area near this region. Wolfcampian rocks in Kansas increase gently in thickness southward and westward from the study area (Cook and Balley, 1975), and, in general, suggest deposition near the eastern margin of an epeiric sea.

Figure 11 shows the major structural features in the State of Kansas. Major structural elements within the study area are the Abilene anticline, the Nemaha anticline,

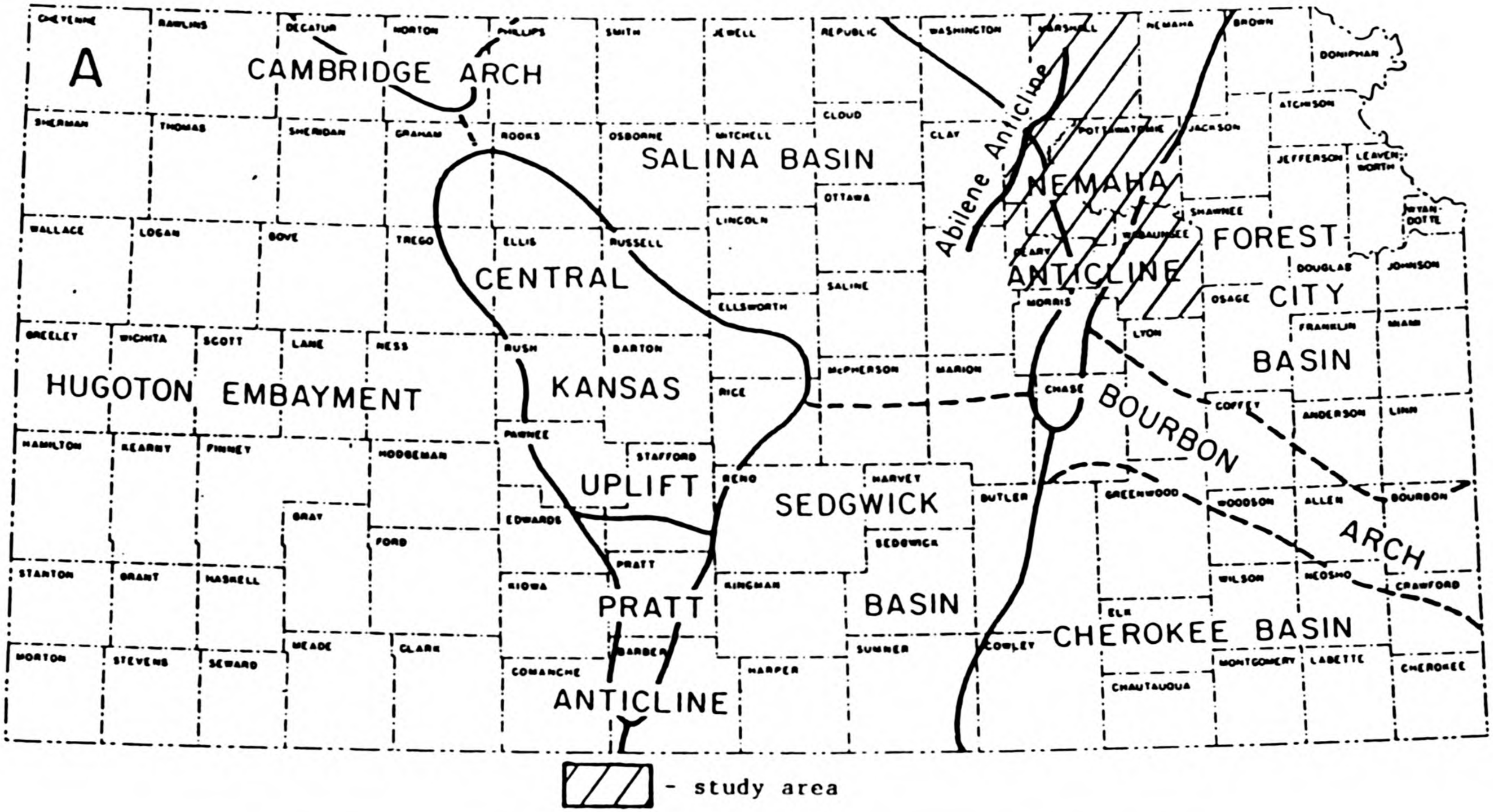


Figure 11. The major structural features of the state of Kansas (from, Shenkel, 1959).

and the Irving syncline (not shown on Figure 11) that lies between the aforementioned features. These structures all have a northeast-southwest trend, and have been interpreted to be, in part, a result of foreland deformation in response to the Ouachita orogeny (Berendson and Blair, 1986). Although these structures have experienced structural deformation throughout the Phanerozoic (Lee, 1954; Shenkel, 1959), most deformation took place near the end of the Mississippian Period (Shenkel, 1959; Berendson and Blair, 1986).

Overall, rocks of the study interval dip roughly 15-20 feet per mile to the west-northwest, and are part of the Prairie Plains monocline (Barrett, 1989).

Barrett (1989) stated that deposition of the Wreford Limestone in the study area was controlled, in part, by structural elements. If true, this would seem to indicate that deposition of the Speiser Shale was also influenced by these structures. Barrett (1989) cited Figure 12, a structural contour map of the upper contact of the Precambrian Eonothem in north-central Kansas and Figure 13, a structural contour map of the base of the Pennsylvanian Kansas City Group, and compared these figures to paleostructural contour maps on the bases of sixth-order T-R units (PACs) he identified within the Wreford Limestone in his study area (Marshall, Riley, Pottawatomie, Geary, and Wabaunsee Counties). Barrett (1989) used the top of

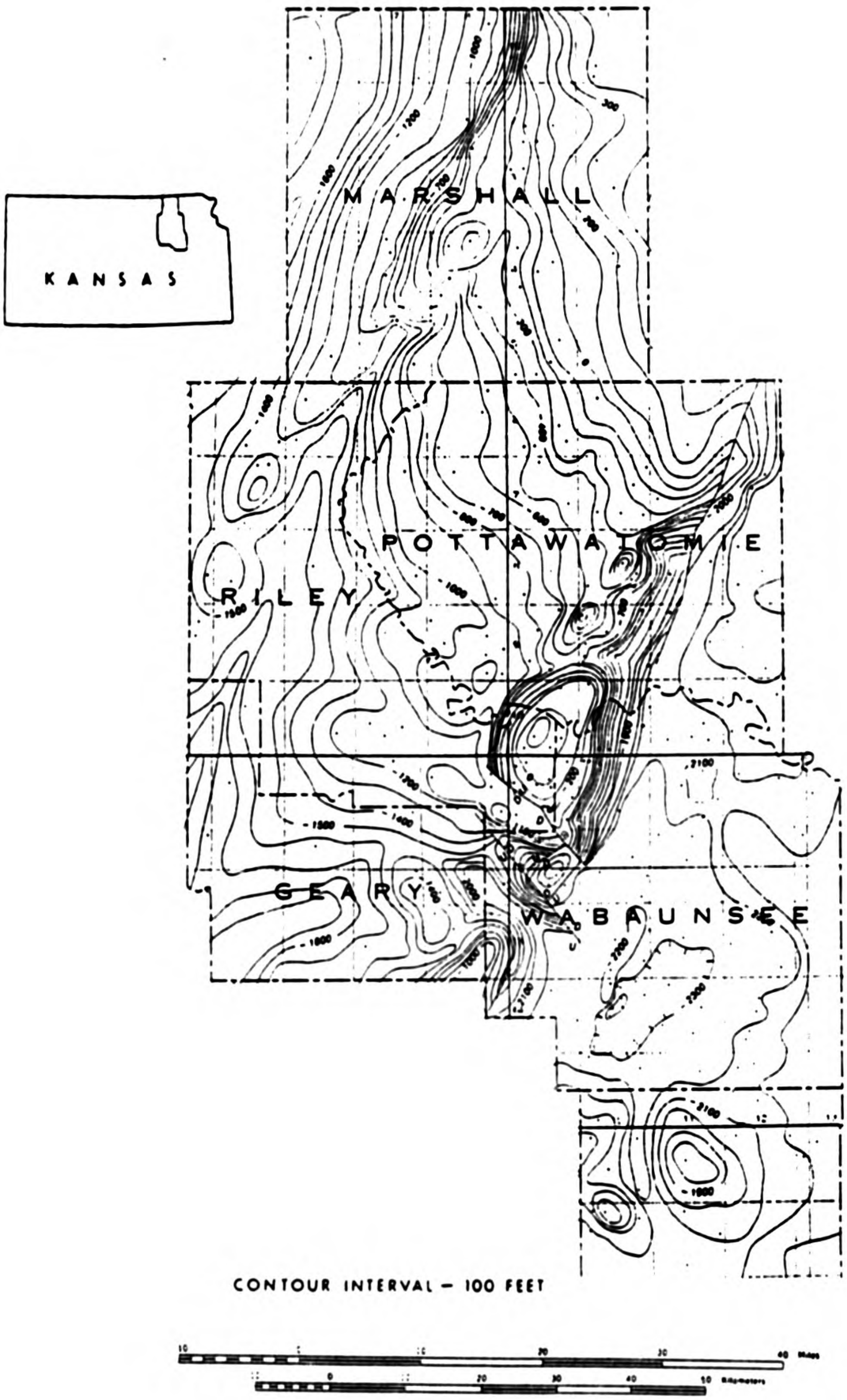


Figure 12. Structural contour map of the upper contact of the Precambrian Eonothem of Kansas within the study area (from Cole, 1976).

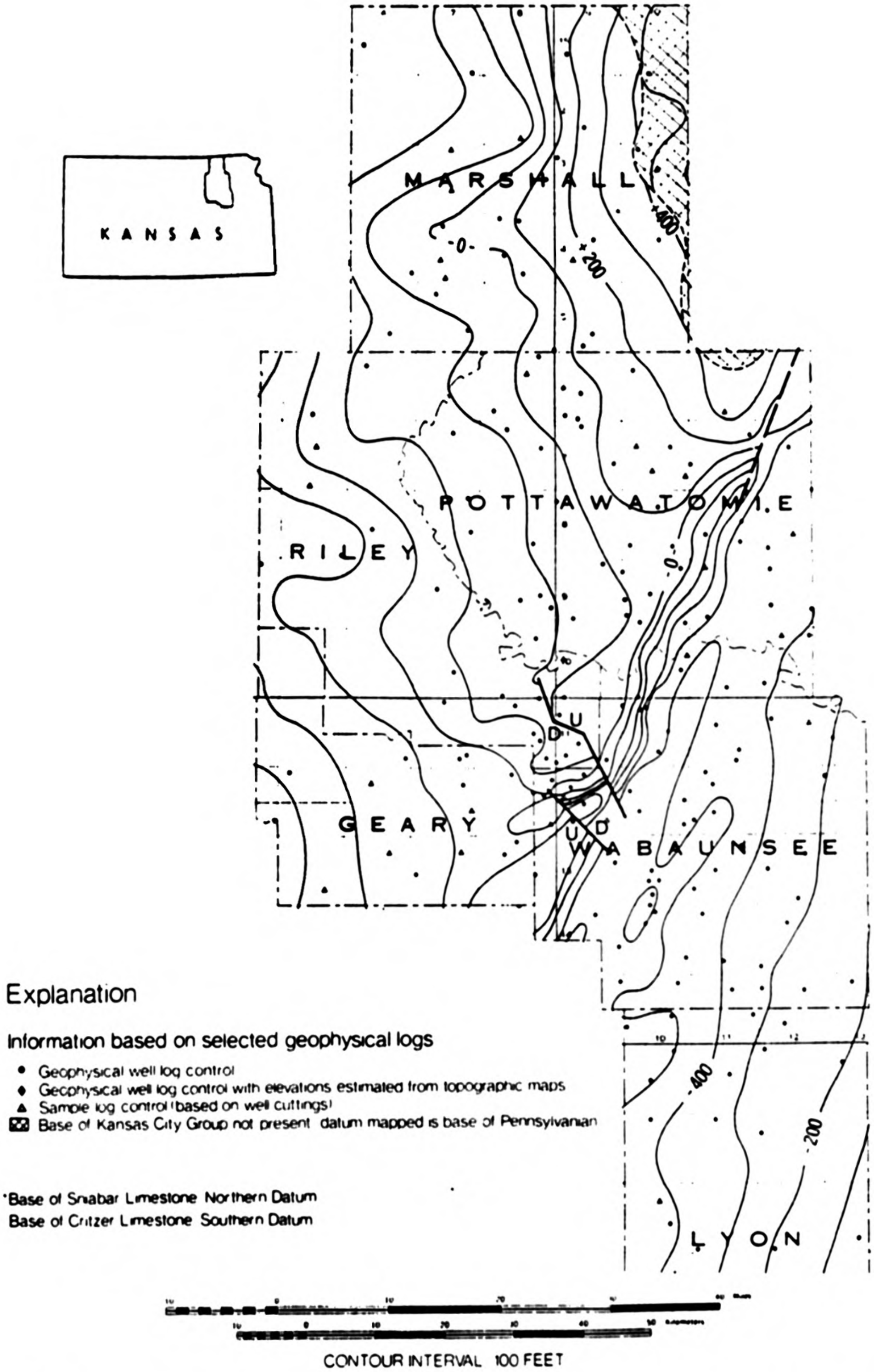


Figure 13. Structural contour map of the upper contact of the Kansas City Group (Upper Pennsylvanian) within the study area (from Watney, 1978).

his sixth-order T-R unit W1.3 as a paleosea-level datum to construct his paleostructural contour maps (see Figure 9 for the stratigraphic position of this T-R unit).

According to Barrett (1989) "These paleostructure contour maps show the same basic structural highs and lows, though less conspicuously, as those seen on present day structure contour maps for the top of the Precambrian basement rocks ([his] Figure 57) and the base of the Pennsylvanian Kansas City Group ([his] Figure 58)" (Barrett, 1989, p.154).

Barrett (1989) stated that sixth-order T-R units (PACs) that he identified in the Wreford Limestone generally thinned over structural highs, and thickened in structural lows indicating structural control on sedimentation during the deposition of this formation. Compare Figures 12, 13, and 14.

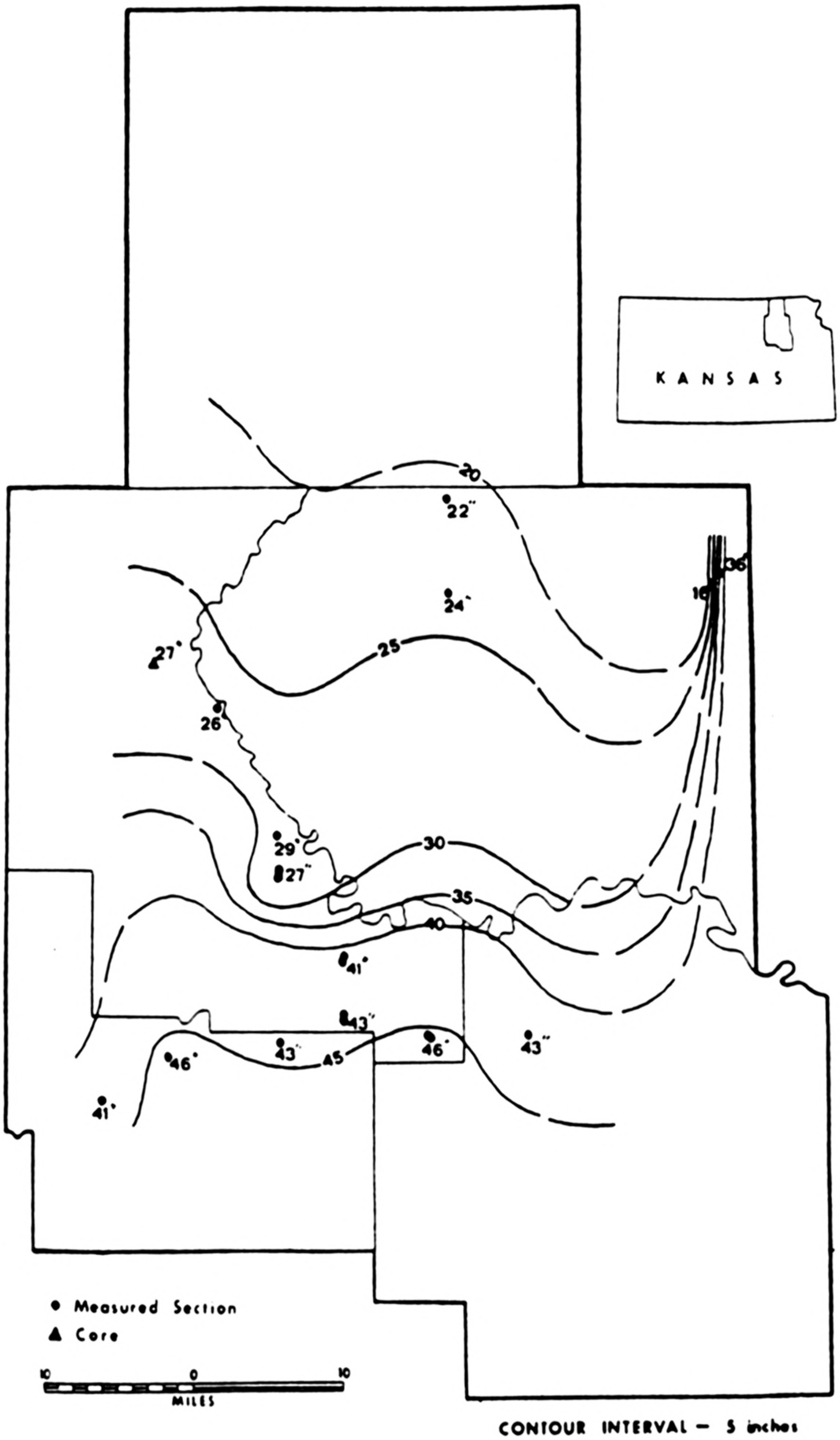


Figure 14. Isopach map for sixth-order T-R unit W1.2. Refer to Figure 10 for the stratigraphic position of this unit (from Barrett, 1989, p.120).

Vertebrate Paleontology

The Speiser Shale contains a rich and diverse collection of aquatic and semi-aquatic fossil vertebrate assemblages. Remains of Osteichthyes (Acanthodii, Palaeoniscoidea, Platysomoidea; Dipnoi), Elasmobranchii (Xenacanthida, "cladodonts", petalodonts, and "bradyodonts"), and Amphibia (Lepospondyli; Labyrinthodontia) have been identified from within this formal lithostratigraphic interval in Kansas (Schultze, 1985). In addition to body fossils, burrows attributed to and sometimes containing specimens of the lungfish *Gnathorhiza* and the serpentiform lepospondylous amphibian *Lysorophus* are known from this formation (Foreman and Martin, 1989). At one locality in the middle Speiser Shale (unit 2 of Locality E-1 of this study) the nectridean (Amphibia) *Diplocaulus* has also been found within burrows (Schultze, 1988, pers. comm.). Furthermore, the holotypes of the amphibians *Acroplous vorax* Hotton, 1959 (Labyrinthodontia) and *Euryodus bonneri* Schultze and Foreman, 1981 (Microsauria) were recovered from the Speiser Shale within the study area (the Keats locality, unknown horizon, and unit 2 locality E1, this study, respectively) (Schultze, 1988, pers. comm.).

Schultze (1985) described and interpreted the distribution of vertebrate remains within the Speiser Shale and Wreford Limestone (Wreford Megacyclothem). Within the Wreford Megacyclothem palaeoniscoid remains (mostly teeth and scales of at least four indeterminate species) and platysomid remains (mostly scales and phyllodont tooth plates and tooth plate fragments) are restricted to facies that show some marine influence. Similarly, acanthodian (presumably Acanthodes) remains are found only in marine facies of this interval. Acanthodes may have been euryhaline (catadromous or anadromous) because remains of this fish have been identified within other intervals in deposits interpreted to be of freshwater origin (Schultze, 1985). In the Wreford Megacylcothem, cladodont remains are restricted to open marine facies, whereas petalodonts and bradyodonts are restricted to marine facies, but show ". . . no consistent relationship to any specific marine environment" (Schultze, 1985, p.13). Indeterminate Elasmobranchii remains (dermal denticles, teeth, and prismatic cartilage fragments) are also restricted to facies that show some marine influence within the Wreford Megacyclothem. Figure 15 summarizes the distribution of vertebrate (and some invertebrate) remains within the Speiser Shale and overlying Wreford Limestone.

Schultze (1985) suggested that Gnathorhiza and the tetrapods present within the Speiser Shale may have been salt water tolerant, and may have been marine forms that occupied marginal marine paleoenvironments.

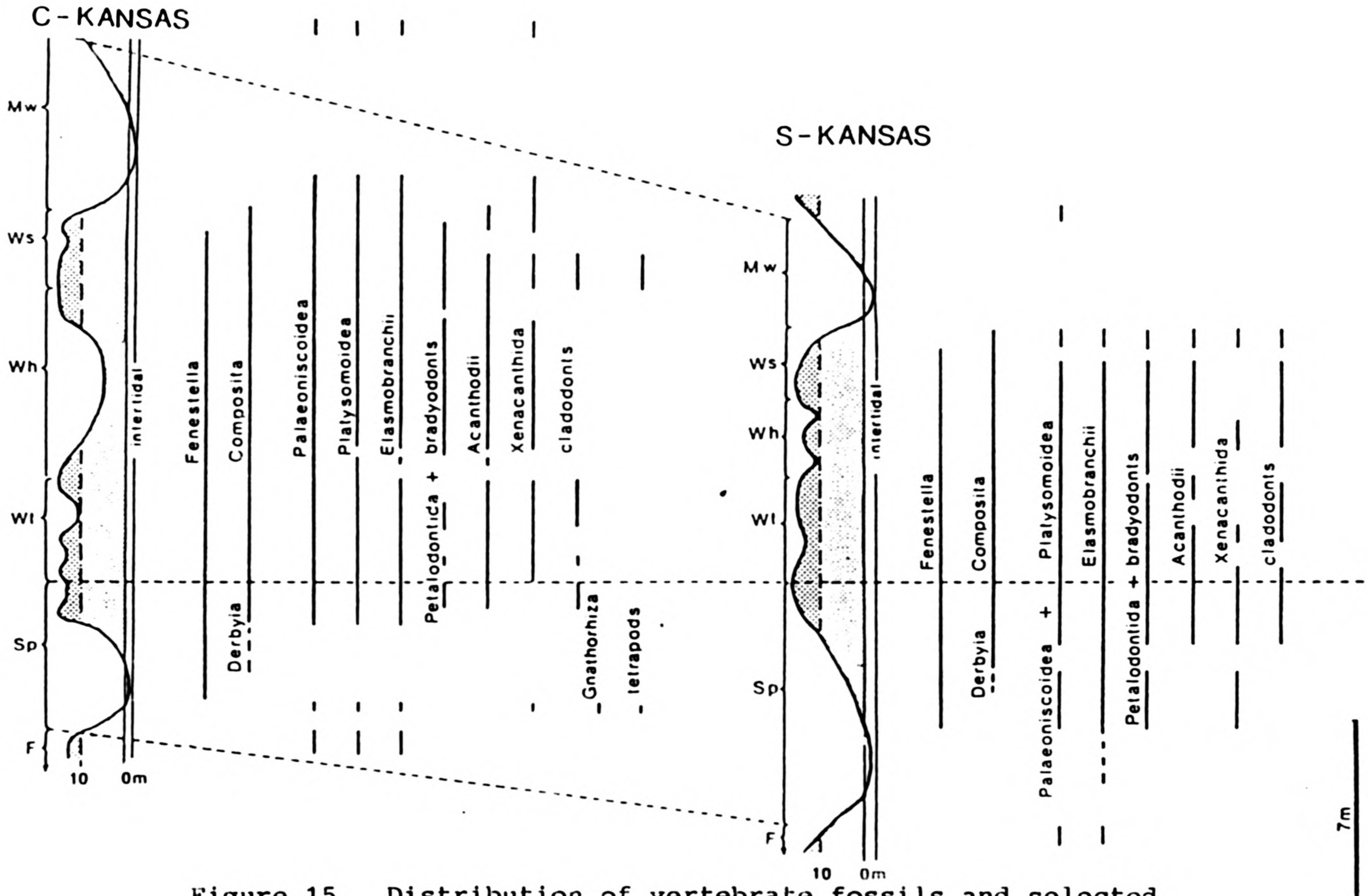


Figure 15. Distribution of vertebrate fossils and selected macroinvertebrate taxa within the Wreford Megacyclothem (from Schultze, 1985, p.12).

Schultze (1985) also suggested that Gnathorhiza may have burrowed to escape tidal changes of sea-level.

Based on the ecologies of modern lungfish and amphibians, however, Permian Dipnoi and Amphibia have generally been interpreted to be indicators of freshwater (lacustrine) paleoenvironments (Berman, 1976, Olson, 1956, 1971, 1972, 1977, Olson and Bolles, 1975; Romer and Olson, 1954).

Lepidosirenids, Protopterus (the African lungfish) and Lepidosiren (the South American lungfish), are freshwater fish. Besides occupying a variety of both lentic (standing) and lotic (running) water environments including seasonally wet swamps, marshes, and lakes, and permanent lakes and streams (Greenwood, 1987), Protopterus is known to aestivate (literally: to pass the summer in a dormant state) cocooned in burrows, and to occupy wet season breeding burrows of several geometries. The habits of Lepidosiren, on the other hand, are still largely unknown (Greenwood, 1987; Schultze, 1988, pers. comm.), although Carroll (1965) indicated that both Lepidosiren and Protopterus are known to aestivate. However, Lepidosiren paradoxa does occupy dry season burrows similar to those of Protopterus aethiopicus (Greenwood, 1987). The Australian lungfish, Neoceratodus, too, is generally a freshwater form, but unhealthy specimens have been reported from slightly brackish environments (Kirkland, 1987). With a few exceptions (including the frog Rana cancrivora), modern amphibians are salt water intolerant (Schultze, 1985).

Carroll (1988) indicated that Gnathorhiza from the Pennsylvanian and Permian of North America, and the Upper Permian of Europe, together with Lepidosiren, the South American lungfish, and Protopterus, the African lungfish, constitute the Family Lepidosirenidae. The inclusion of Gnathorhiza in the Lepidosirenidae, however, is based on the presumed aestivation of this genus (as evidenced by the presence of whole, articulated Gnathorhiza in burrows in nonmarine deposits that exhibit evidence of periodic aridity), not on close anatomical similarity (Schultze, 1989, pers. comm.). Marshall (1987) provided a phylogeny for the Dipnoi in which the lepidosirenids (Protopterus and Lepidosiren) were shown to be more closely related to the nonaestivating Neoceratodus (Australian lungfish) than to the gnathorhizids (Gnathorhiza and Monongahela). This suggests that the occupation of burrows (and aestivation?) by Gnathorhiza may only be ecologically analogous to these behaviors in lepidosirenids, and may not be common to these taxa because of close phylogenetic relationship (Schultze, 1989, pers. comm.).

Vertebrate burrows of at least two distinct morphologies are present within the study interval: 1) oblate flask-shaped burrows (Figure 16) sometimes containing and presumably made by Gnathorhiza (Foreman and

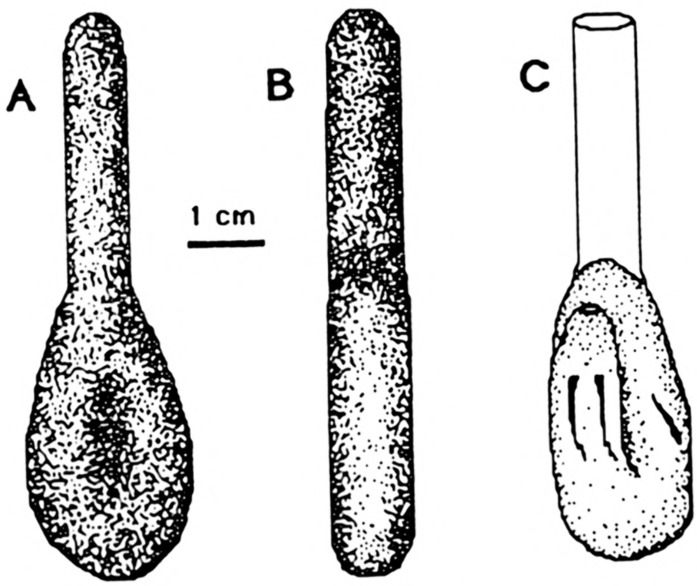


Figure 16. Generalized illustration of oblate flask lungfish (Gnathorhiza) burrow in two views (A; B), and the position of a lungfish inside such a burrow (C). Actual burrows of this type are often bent out of a plane. In the lateral view (B), the burrows usually appear j-shaped, and are not perfectly vertical as in the figure (from McAllister, 1987a, p.366).

Martin, 1989) that strongly resemble the aestivation burrows of Protopterus, the African lungfish (Figure 17), and 2) burrows of roughly ovoid cross section that maintain a nearly constant width vertically (cylinderical) of the Eskridge locality (locality E-1 this study) containing the amphibian Lysorophus. McAllister (1987b) discussed the burrows from this locality and wrote: "The Eskridge burrows have definite connections between the lower portion of the burrow and the unit above. This connection is not clearly delineated but seems to be approximately the same width or slightly smaller than the basal portion of the burrow. The burrows are fairly variable in size, ranging to depths of 9-28 cm and widths of 5-15 cm" (p.12).

Foreman and Martin (1989) provided lists of vertebrate taxa identified at four localities within the Speiser Shale. The middle Speiser Shale at the Bushong locality (locality B, this study) ". . . contains stream deposits rich in disarticulated bone" (Foreman and Martin, 1989, p.143). These deposits contain the disarticulated remains of Diplocaulus, Lysorophus, Acroplous vorax Hotton, 1959, Trimerorhachis, and Gnathorhiza (Foreman and Martin, 1989). Schultze (1985) interpreted these vertebrate-rich beds ". . . as the result of sweeping together (by storm?) of the burrow fauna from the seaside to the shore" (p.14). The middle Speiser Shale at the Eskridge locality (locality E-1, this study) contains a lacustrine mudstone

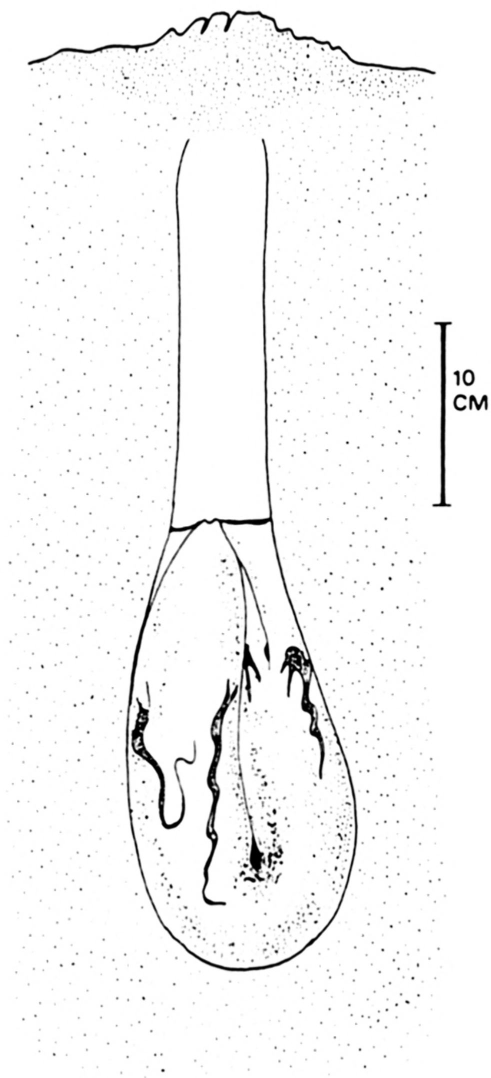


Figure 17. Ventral view of Protopterus annectens (African lungfish) cocooned in aestivation burrow. Cocoon cap is thick solid line; burrow cap is stippled densely (from Greenwood, 1987, p.165).

(McAllister, 1987b) deposit that thickens to the east (from about 10 cm to 1 m) and contains the remains of sphenacodonts (Reptilia), Diplocaulus, Euryodus bonneri Schultze and Foreman, 1981, Lysorophus, Acroplous vorax Hotton, 1959, and Gnathorhiza (Foreman and Martin, 1989). Articulated specimens of Lysorophus and Diplocaulus within burrows are also known from this locality (McAllister, 1987b; Schultze, 1988, pers. comm.). The Junction City Locality (locality JC, this study) contains the remains of Gnathorhiza ". . . closely packed in estivation burrows" (Foreman and Martin, 1989, p.143) and Diplocaulus remains. Foreman and Martin (1989) wrote that the remains of these vertebrates can be found in ". . . a thick calcareous mudstone near the middle of the exposure" (p.143). Workers have found the remains of Lysorophus, Diplocaulus, Acroplous vorax Hotton, 1959 (holotype), Trimerorhachis, and Gnathorhiza at the Keats locality (locality KEATS, this study). Unfortunately, the precise horizons from which specific vertebrate taxa have been collected at this locality have not been recorded (Schultze, 1988, pers. comm.).

METHODS OF INVESTIGATION

General Statement

In the present study, I utilized the methods of hierarchal genetic stratigraphy with the goal of refining previous knowledge of the stratigraphy and depositional environments of the Speiser Shale. In addition, I attempted to utilize these methods to understand the distribution of vertebrate fossils within the Speiser Shale in north-central Kansas.

Procedures

Seventeen exposures of the Speiser Shale (and descriptive units immediately above and below, if present and exposed) were measured and described in the field using a hand held measuring tape and/or stadia rod and Brunton compass. Lithology, structures, and fossil content were noted for each descriptive unit at each locality. In addition, one core (Amoco Hargrave #1) through the study interval was examined and described in detail. Data from these eighteen localities are presented in the Appendix. Two other localities (SMAN3 and B2) were examined more briefly in the field. The general location of each measured section is shown in Figure 3. More precise descriptions of the location of each locality accompany measured section descriptions in the Appendix.

The Speiser Shale is composed predominantly of mudrocks with minor carbonate and sandstone facies. Mudrocks were assigned a rock name from the classification scheme presented in Blatt, Middleton, and Murray (1980) based on the criteria listed in Table 7. Carbonate rocks were assigned a Dunham (1962) rock name, and sometimes a Folk (1962) rock name if it was judged that doing so would aid the reader's understanding of the rock type. In addition, all carbonate rocks were classified according to Archie's (1952) textural classification (Table 8) because this author's scheme provided an effective method of describing and communicating the type of matrix porosity present and the overall appearance of the rock.

All descriptive units within the study interval were assigned a color from the Geological Society of America Rock Color Chart (1979).

Contacts between all descriptive units were noted and recorded as being either gradational, somewhat gradational, or sharp. Although recognition criteria of these three contact types are somewhat subjective, sharp contacts mark lithologic transitions that take place within a vertical distance of several millimeters, and gradational contacts mark transitions that take place over centimeters to tens of centimeters of vertical section. Designation of a somewhat gradational contact was generally reserved for

Table 7. Mudrock classification with recognition criteria (from Blatt, Middleton, and Murray, 1980, p.382).

Ideal size definition	*Field criteria*	*Fissile mudrock*	*Nonfissile mudrock*
$> \frac{2}{3}$ silt	Abundant silt visible with hand lens	Silt-shale	Siltstone
$> \frac{1}{3} < \frac{2}{3}$ silt	Feels gritty when chewed	Mud-shale	Mudstone
$> \frac{2}{3}$ clay	Feels smooth when chewed	Clay-shale	Claystone

Table 8. Carbonate classification based on matrix texture and porosity (from Archie, 1952, p.280)

Texture of Matrix	*Appearance of Hand Sample*	*Appearance under Microscope 10× to 15×*
Type I Compact Crystalline	Crystalline, hard, dense, sharp edges and smooth faces on breaking. Resinous	Matrix made up of crystals tightly interlocking, allowing no visible pore space between crystals, commonly producing "feather edge" on breaking due to fracturing of clusters of crystals in thin flakes
Type II Chalky	Dull, earthy or "chalky." Crystalline appearance absent because small crystals are less tightly interlocked, thus reflecting light in different directions, or made up of extremely fine granules or sea organisms. May be siliceous or argillaceous	Crystals, less effectively interlocking than the foregoing, joining at different angles. Extremely fine texture may still appear "chalky" under this power, but others may begin to appear crystalline Grain size for this type is less than about 0.05 mm. Coarser textures classed as Type III
Type III Granular or Saccharoidal	Sandy or sugary appearing (Sucrose). Size of crystals or granules classed as: Very fine = 0.05 mm. Fine = 0.1 mm. Medium = 0.2 mm. Coarse = 0.4 mm.	Crystals interlocking at different angles, generally allowing space for considerable porosity between crystals. Oölitic and other granular textures fall in this class

The visible pore size may be classed as follows.

Class A: No visible porosity under about 10-power microscope or where pore size is less than about 0.01 mm. in diameter
Class B: Visible porosity, greater than 0.01 but less than 0.1 mm.
Class C: Visible porosity, greater than 0.1 mm., but less than size of cuttings
Class D: Visible porosity as evidenced by secondary crystal growth on faces of cuttings or "weathered-appearing" faces showing evidence of fracturing or solution channels; where pore size is greater than size of cutting

situations in which the lithologic contact appears blurred and diffuse, and in which the lithologic transition takes place over a few centimeters. Additional adjectives, such as iron oxide-stained or wavy were also added to contact descriptions.

During the course of study, two kilogram samples of selected descriptive units were collected for recovery of fossils. This was accomplished by disaggregation and wet sieving. Samples were disaggregated by soaking them in tap water. The entire two kilogram sample of all mudrock units from locality TW were wet sieved (through 35 and 140 standard mesh size brass sieves with 500 and 105 micron openings or 0.0197 and 0.00410 inch openings, respectively), and the recovered fossil taxa (vertebrate and invertebrate) were identified. 500 gram subsamples were taken from the 2 kilogram mudrock samples collected at other localities because most or all of the taxa identified in two kilogram samples (from locality TW) were found in one quarter (by volume) of each residue. Furthermore, a similar number of taxa were identified in correlative descriptive units regardless of whether two kilogram or 500 gram samples were processed. In all, the mudrocks of four localities (localities TW, P/1, 4/99, and B) were completely or extensively sampled and processed, and selected samples from a number of other localities (e.g., localities P/2; SMAN; RY3) were collected and processed.

All mudrock units that were sampled, disaggregated, sieved, and picked are indicated by an asterisk to the right of the graphic sections in the Appendix.

Samples (500 gram) of selected carbonate descriptive units were dissolved in a 15% solution (by volume) of acetic acid. The insoluble residues were then sieved (through standard mesh size brass screens of sizes 35 and 140, respectively), and the fossil remains removed. Acid-insoluble biogenic constituents of these residues consisted mostly of conodonts and vertebrate skeletal debris, siliceous sponge spicules, and arenaceous foraminiferids.

Samples were collected throughout the entire thickness of the descriptive unit being sampled (i.e., trench or channel samples were collected). This sampling strategy was adopted because: 1) the great majority of descriptive units present within the study interval in the study area are relatively thin (less than one foot thick), and 2) many descriptive units are heavily bioturbated (rooted or burrowed). These processes tend to homogenize units, and little vertical variation of fossil content within units was expected. Descriptive units thicker than one foot (30 cm), however, were generally divided vertically into three sample intervals (subunits). The subunits were processed separately.

Descriptions of the majority of carbonate descriptive units were further supplemented with data from polished slabs and/or petrographic thin sections.

Fossil taxa were identified using a number of references including Benson _et al_. (1961), Schultze (1985), and others. Some taxa that I was unable to identify were identified by Dr. Ronald R. West, Department of Geology, Kansas State University, or Dr. Hans-Peter Schultze, Department of Systematics and Ecology, University of Kansas.

Identification and Correlation of T-R Units

Changes in fossil assemblage composition, lithology, and types of sedimentary structures present were used to interpret changes in sea-level within the study interval. Furthermore, the presence of root casts and slickensides within the study interval enabled me to recognize intervals that were subjected to subaerial (nonmarine) conditions. In the context of associated marine units, descriptive units exhibiting root casts and slickensides were used to make interpretations of sea-level history. Criteria used to recognize T-R units are discussed below.

Although PACs are identified on the basis of paleontologic or lithologic criteria, correlation of T-R units must be done relative to marker beds (laterally persistent, distinctive facies assumed to record the same paleoenvironment over their geographic extent) (Busch, 1988, pers. comm.). For the purpose of this study, the top of the Funston Limestone, a thin molluscan limestone near the top of the Speiser Shale (molluscan limestone of Hattin, 1957), and the lowest limestone bed in the Threemile Limestone Member of the Wreford Limestone were selected as marker beds, and PACs were identified relative to them over the study area.

Changes in Fossil Assemblage Composition.--Paleoecological studies of marine sequences have revealed that "The total fauna has usually been demonstrated to increase in diversity from nearshore to offshore, following a gradient from high physiological stress, or from low stability to high stability" (Rollins and Donahue, 1975, p.260). Mollusc-dominated communities, on the other hand, often exhibit a diversity gradient that is the reverse of that of other marine invertebrates, i.e., they decrease in diversity away from shoreline (Rollins and Donahue, 1975). In this study, increases in diversity of marine organisms were used to infer increases in depth of marine water. Facies dominated by marine mollusc fossils were interpreted to reflect shallower, more restricted marine paleoenvironments than those dominated by brachiopods, bryozoans, and echinoderms.

In addition, within the study interval the presence of some taxa was interpreted to suggest terrestrial (nonmarine), or more or less open marine conditions. Figure 18 illustrates relative distribution of some marine

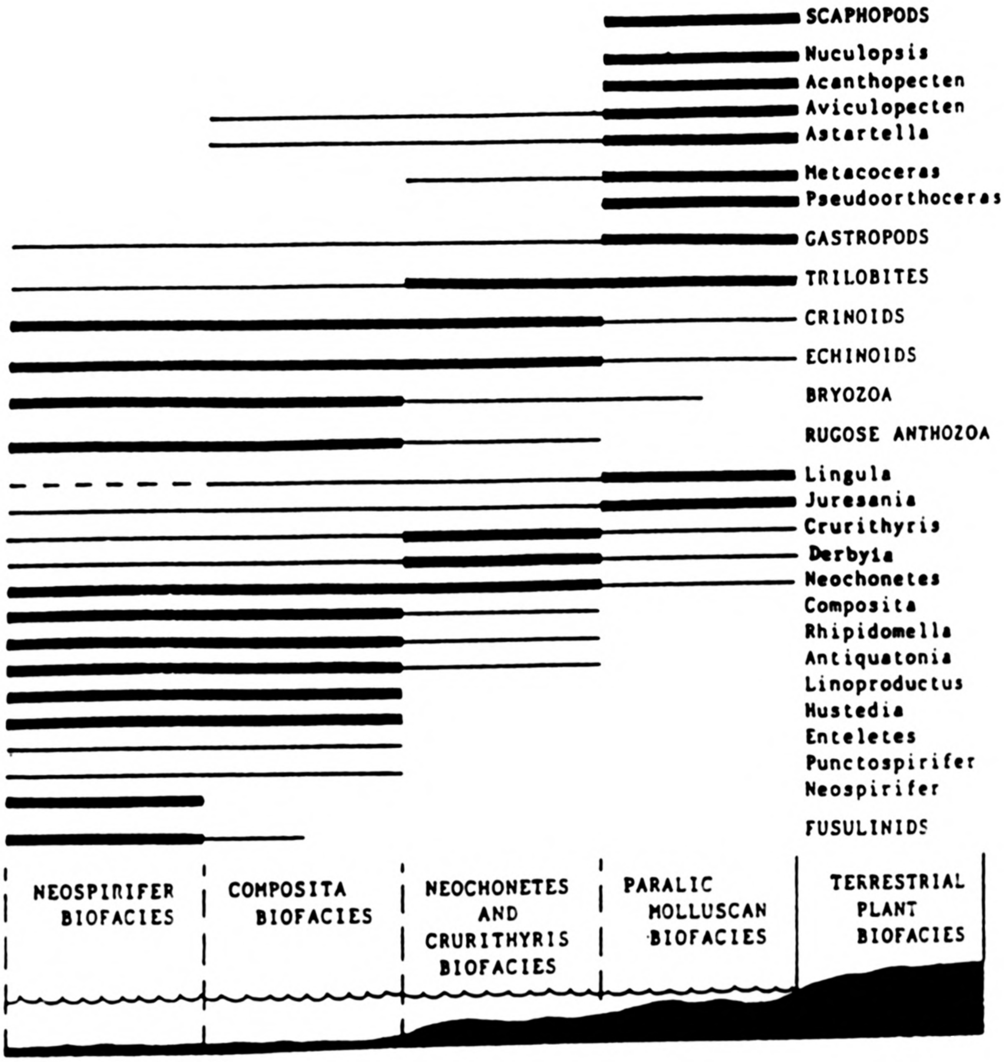


Figure 18. Biofacies zonation and interpretation of relative water depth along a late Paleozoic coastline based on fossil assemblage composition (from Barrett, 1989, p.58).

invertebrate taxa with respect to a late Paleozoic shoreline. Presence of marine invertebrate taxa listed in this figure was used to interpret relative marine water depths.

Lithology.--Differences in lithologic composition (i.e., mudrock versus limestone) have been interpreted to reflect changes in water depth within Permian cyclothemic sequences of the Midcontinent (e.g., Elias, 1937). Generally, the carbonate-dominated parts of these cyclic sequences have been interpreted as representing sedimentation in response to the deepest marine inundations. Likewise, within the marine parts of these sequences that contain mudrock and limestone facies, the limestones have usually been interpreted as representing the deepest water facies (e.g., Hattin, 1957).

The basis for this interpretation has been the observation that these limestones contain less terrestrially-derived clay, silt, and sand than the interbedded marine mudrocks. Because of this, the limestone was interpreted to have been deposited farther offshore (see Hattin, 1957).

Difference in lithology (i.e., mudrock versus carbonate) was not used to infer relative water depth or salinity during the present study because Brett and Baird (1985) suggested this to be a poor indicator of sea-level within shallow shelf sequences. However, in the present study, presence of evaporitic minerals (or evidence of the previous existence of evaporite minerals, gypsum crystal and rosette molds and chert pseudomorphs after gypsum rosettes) provided evidence of sea-level and other paleoenvironmental conditions. Figure 19 shows the distribution of evaporites within modern tidal flat environments.

Sedimentary Structures.--Cross bedding, ripple marks, hummocky topography, birdseye and fenestrae, laminations, and intraclasts were used to interpret paleoenvironmental conditions. Figure 19 shows the distribution of sedimentary structures relative to water depth in marine depositional environments.

Root Casts and Slickensides.--"Even if there are no other indications of ancient soil formation, root traces are evidence that the rock was exposed to the atmosphere and colonized by plants, and thus a soil by almost anyone's definition (Buol and others, 1980; Retallack and others, 1984)" (Retallack, 1987, p.1-2). Slickensides ". . . form in surface soils of clayey texture with shrinking and swelling of clay on wetting and drying" (Retallack, 1987, p.9). In the present study, root casts and slickensides were taken to be evidence of subaerial exposure.

Root casts and slickensides are often associated with red descriptive units in the middle Speiser Shale. Krynine (1949; 1950) indicated that hematite, the cause of

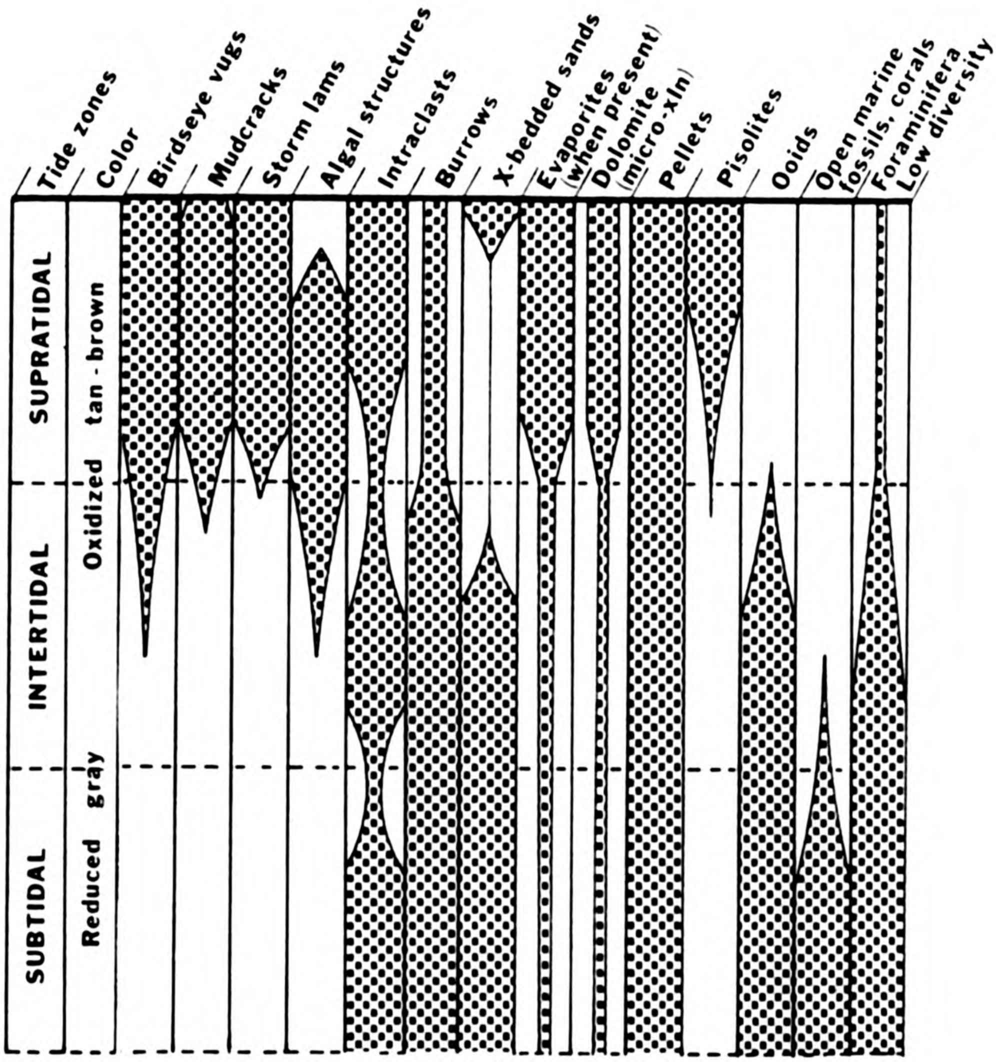


Figure 19. Distribution of structures, minerals, and fossils within tidal flat sub-environments (modified from Shinn, 1983, p.209).

some red color, was formed in tropical soils under conditions of heavy rainfall that leached more soluble soil constituents, and that transportation of red, hematite-rich sediments into the basin where they were preserved was the dominant mechanism of redbed formation. Walker (1967), on the other hand, indicated that ". . . hematite pigment in many red beds, particularly those associated with evaporites and aeolian sandstones, formed after deposition in hot semiarid or arid climates" (p.353), and that the color is therefore diagenetic (secondary) and resulted from in situ alteration of iron-bearing grains (e.g., hornblende and biotite). Alternatively, "Iron is the element most commonly oxidized in a soil or weathering environment, and the oxidation products give the altered material the characteristic yellowish brown to red colors. In soils and in many other weathering environments, the common oxidizing agent is oxygen dissolved in the water involved in the weathering reactions" (Birkeland, 1984, p.72).

Because geochemical and petrographic analyses of mudrocks were not performed during the course of this study, redness of descriptive units within the middle Speiser Shale could not, in general, be attributed specifically to compositional differences between depositional units, diagenetic effects, or pedogenic or weathering processes. Therefore, red color of descriptive units was not used to recognize units that had undergone subaerial exposure.

RESULTS

General Statement

Relatively closely-spaced localities TW and RY3 (Figure 3) were selected for detailed description and discussion because of the excellent exposure of the Speiser Shale in road cuts at these localities. Furthermore, at locality RY3 whole, articulated, coiled Gnathorhiza, presumably in burrows, are present in a well-exposed mudstone unit within the lower middle Speiser Shale. This occurrence was discovered during the course of study, and has not been described in the geological literature. Parts of the Speiser Shale at localities B, E1, and E2 will also be described and discussed in detail because of the significant occurrences of vertebrate remains at these locations. The above localities will be interpreted and discussed later in the context of data from other localities (principally, localities M1, P/2, KEATS, SMAN, 4/99) in the study area. See the Appendix for descriptions of all the above localities.

In the following discussions, descriptive units will be referred to by a series of hyphenated letters and numbers. The first set of letter(s) and/or numbers refers to the locality. The number following the hyphen refers to the descriptive unit at that particular locality. Units are numbered from bottom to top at each locality. For example, unit RY3-5 is the fifth descriptive unit from the bottom of the measured section at locality RY3. Thickness of each descriptive will generally be given in parentheses with each description.

Description of Locality RY3

The Funston Limestone, Speiser Shale, and Threemile Limestone Member of the Wreford Limestone are all well exposed at locality RY3. Unit RY3-1 is the upper part of the Funston Limestone. The lower Speiser Shale was subdivided into five descriptive units, units RY3-2 through RY3-6. The middle Speiser Shale was subdivided into eight descriptive units, units RY3-7 through RY3-14. Units RY3-15 through RY3-26 constitute the upper Speiser Shale, and unit RY3-27 is the lowest bed in the Threemile Limestone Member of the Wreford Limestone.

Unit RY3-1 (39 cm), the uppermost part of the Funston Limestone and stratigraphically the lowest unit described at this locality, is a vertically-burrowed (Skolithos?) wackestone with brachiopod spines and fragments, Knightina (Ostracoda), Ammovertella, spirorbids, high-spired gastropods, and vertebrate skeletal debris including acanthodian (presumably Acanthodes) scales, palaeoniscoid scales, and phyllodont (platysomid) tooth plate fragments. At locality RY3, the upper Funston Limestone exhibits a sharp upper contact.

Unit RY3-2 (34 cm) is a laminated, calcareous, light olive gray mudstone that contains well-preserved Neuropteris and Cordaites fronds (with and without attached spirorbids) on virtually every bedding plane. Also present in this unit are darwinulids (Ostracoda), palaeoniscoid teeth and scales, platysomid? scales, and indeterminate elasmobranch dermal denticles (including an undescribed? type of teardrop-shaped denticle). Unit RY3-2 grades upward into the overlying unit.

Unit RY3-3 (21.5 cm) is a calcareous, light olive gray mudstone with spirorbid fragments, Straparollus-like gastropods (marine gastropods), smooth-shelled ostracodes, and palaeoniscoid teeth and scales. Unit RY3-3 exhibits a sharp lithologic contact with the overlying limestone.

Unit RY3-4 (23 cm) is a biointramicrudrite with algally-laminated intraclasts, spirorbids, and algal-coated Globivalvulina. This unit weathers as one conspicuous, well-defined bed, and exhibits a sharp upper contact.

Units RY3-5 (17 cm) and RY3-6 (16) are massive, calcareous, olive gray and dusky yellow green mudstones, respectively, barren of invertebrate or vertebrate fossils. Unit RY3-6 has a gradational upper contact.

Unit RY3-7 (38 cm) is a grayish red, calcareous, massive, rooted, mudcracked (the upper surface) mudstone containing whole, articulated Gnathorhiza specimens.

The lungfish are in a coiled position similar to that exhibited by Protopterus in aestivation burrows. Gnathorhiza specimens are mantled by greenish (reduction?) halos, and appear to be encased in the lithology of unit RY3-7, not the overlying unit. Unit RY3-7 exhibits a deepening of red color upward.

Unit RY3-8 (28 cm) consists of interbedded light olive gray, argillaceous limestone and calcareous mudstone. The limestone interbeds of this unit are mudcracked, intraclastic, and contain acanthodian scales and phyllodont tooth plate fragments. In addition, one possible fragmentary specimen of an Ammovertella-like foraminiferid, and one Gnathorhiza toothplate fragment were found in samples of this unit. Mudstone interbeds were found to be calcareous and to contain acanthodian scales, phyllodont tooth plate fragments, and one specimen each of an indeterminate, crushed smooth-shelled ostracode and a palaeoniscoid tooth.

Unit RY3-9 (39 cm) is a massive, calcareous, dusky yellow green mudstone that becomes reddish upward due to increasing density of dusky red mottling. This unit exhibits a sharp upper contact

Unit RY3-10 (89 cm) is a relatively thick, massive, calcareous, pale olive mudstone with a slight reddish cast and a sharp upper contact.

Unit RY3-11 (7.5 cm) is a relatively hard, calcareous and rooted, yellowish gray mudstone with a sharp upper contact.

Unit RY3-12 (8 cm) is a thin, grayish yellow green, rooted mudstone with a sharp upper contact.

RY3-13 (35.5 cm) is a rooted mudrock unit that is pale red at the base and gradually becomes a deeper grayish red at the top. Unit RY3-14 (30 cm) is very similar to the underlying unit and exhibits an identical vertical variation in color.

Units RY3-15 through RY3-22 are relatively thin (see Appendix for thicknesses), massive, calcareous, mudrock units with sharp contacts (except the contact between units RY3-17 and RY3-18) of a variety of colors, including pale yellowish green, grayish red, grayish olive, pale olive, grayish olive, yellowish gray, grayish olive, and yellowish gray, respectively. Units RY3-18 through RY3-22 exhibit root casts or mottling or both, and unit RY3-22 contains smooth-shelled ostracodes.

Unit RY3-23 (30 cm), the molluscan limestone of Hattin (1957), is a medium-grained, moderately-sorted, angular skeletal wackestone to packstone with horizontal burrows (*Planolites*), *Aviculopecten* fragments and ostracodes. This unit exhibits a gradational upper contact.

Units RY3-24 through RY3-26 constitute the calcareous shale facies of Hattin (1957), and are mudstones containing the remains of marine invertebrates such as *Derbyia*, *Aviculopecten*, *Neochonetes*, *Orbiculoidea*, ramose and fenestrate bryozoans, and *Straparollus*-like gastropods.

Unit RY3-27 (36 cm), the lowest bed in the Threemile Limestone Member of the Wreford Limestone, is a yellowish gray, coarse, moderately-sorted, angular skeletal wackestone to packstone with echinoid spines, crinoid columnals, *Composita* and productid fragments, and ramose bryozoan and bivalve fragments. A 20 cm-thick horizon of coalescive chert beds is present within this descriptive unit.

Description of Locality TW

At locality TW, most of the middle and the entire upper Speiser Shale are well exposed in a road cut. The Threemile Limestone Member of the Wreford Limestone also crops out at this locality. Units TW-1 through TW-12 are units of the middle Speiser Shale, and units TW-13 through TW-18 constitute the upper Speiser Shale. Unit TW-19 is the lowest bed in the Threemile Limestone Member of the Wreford Limestone.

Unit TW-1 (25 cm) is a rooted, blocky, slightly calcareous, blackish red mudstone with slickensides and a sharp upper contact. One *Thamniscus* (Bryozoa) fragment, one smooth-shelled ostracode specimen, and a minor amount of fine-sized indeterminate invertebrate skeletal debris was found in the residue of unit TW-1.

Unit TW-2 (10 cm) is a calcareous, massive, dusky yellow green mudstone with a minor amount of fine-sized indeterminate invertebrate skeletal debris and a gradational upper contact.

Unit TW-2 grades vertically into unit TW-3 (14 cm), a calcareous, rooted, blocky grayish red mudstone. Unit TW-3 was found to contain a smooth-shelled ostracode specimen, and indeterminate fine skeletal debris (possibly brachiopod fragments).

Unit TW-4 (8 cm) is a calcareous, dusky yellow green mudstone with slickensides, abundant root casts, grayish red mottles, and a sharp upper contact.

Unit TW-5 (28 cm) is a calcareous, massive, dusky yellow green mudstone that grades vertically into unit TW-6 (18 cm), a massive, calcareous, rooted, blackish red mudstone that becomes slightly orangish upward. The upper contact of the latter unit is sharp.

Unit TW-7 (18 cm), a calcareous, purplish, mottled mudstone, grades upward into unit TW-8 (20 cm), a calcareous, dominantly reddish brown, mottled mudstone with root casts and a sharp upper contact.

Unit TW-9 (14 cm) is a calcareous, grayish green mudstone with circular green mottling and a sharp upper contact.

Unit TW-10 (10 cm) is a slightly calcareous, dusky yellow green mudstone with root casts, slickensides, and a sharp upper contact.

Unit TW-11 (48 cm) is a calcareous, blocky, greenish gray mudstone barren of identifiable body fossils. This unit contains slickensides, root casts, and exhibits a gradational upper contact with the overlying reddish mudrock unit.

Unit TW-12 (9 cm) is a calcareous, rooted?, grayish red purple mudstone containing sparse (two specimens were observed in a two kilogram sample) indeterminate (brachiopod?) spines. This unit exhibits a gradational upper contact.

Unit TW-13 (24 cm), a pale olive mudstone with a sharp upper contact, is more fossiliferous (greater diversity and much greater abundance) than the underlying unit, and contains brachiopod spines, Ammovertella, smooth-shelled ostracodes, and possibly plant fragments.

Unit TW-14A (8 cm) is a laminated pale olive mudstone with plant fragments, spirorbid fragments, and smooth-shelled ostracodes. Unit TW-14B (18 cm) is of similar lithology and contains echinoid spine fragments, Ammovertella, charophyte oogonia, plant fragments, smooth and ornamented ostracodes, spirorbid fragments, possible phyllodont tooth plate fragments and acanthodian scales? Unit TW-14B exhibits a sharp upper contact.

Unit TW-15 (25 cm) (molluscan limestone of Hattin, 1957) is an argillaceous, bivalve ostracode wackestone with

Aviculopecten and Septimyalina fragments, algal filaments, whole high-spired gastropods, ramose bryozoan fragments, echinoderm fragments, abundant smooth-shelled ostracodes (Cavellina?), palaeoniscoid teeth, phyllodont tooth plate fragments, and Planolites (up to 4 cm in diameter). A single cavusnathid (Conodonta) platform element was also found in the residue of this unit. Also present in unit TW-15 are granule-sized micritic intraclasts. Hummocky and oscillation ripple-marked bedding surfaces are present in the lower part of the unit.

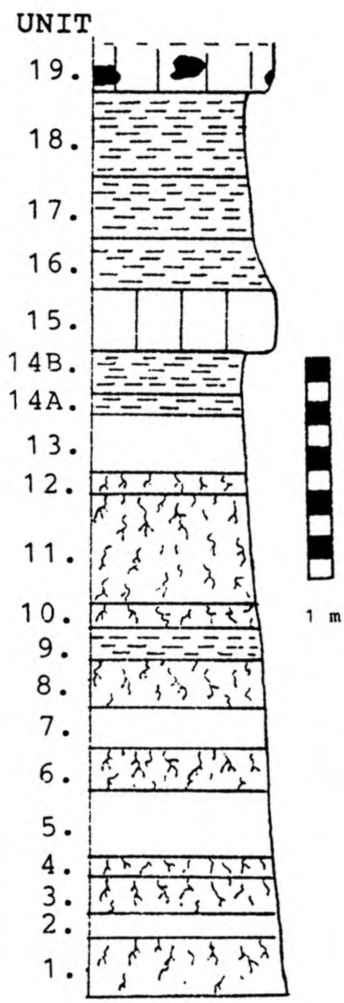
Unit TW-16 (22 cm) is a (burrow?) mottled, yellowish gray, calcareous mudstone containing a possible mixed marine/nonmarine fossil assemblage that is more diverse than the underlying unit. Marine elements in the assemblage include siliceous sponge spicules, holothurian sclerites, foraminiferids (Ammovertella, Globivalvulina, and Tetrataxis), brachiopod and echinoid spines, crinoid plates, and marine ostracodes including Knightina, Kellettina, and Bairdia, and the brachiopods Composita and Derbyia. Vertebrate remains are sparse in unit TW-16: only one fragment of a phyllodont tooth plate was found. Probable nonmarine elements of the assemblage include charophyte oogonia, plant fragments, and Whipplella (Ostracoda, Cypridacea). The upper contact of this unit is sharp and iron oxide-stained.

Unit TW-17 (27 cm), a calcareous, light olive gray mudstone, contains a diverse fossil assemblage similar to that of the underlying unit including arthropod, brachiopod, bryozoan, echinoderm, poriferan, mollusc, conodont, and vertebrate remains. Lacking, however, are nonmarine indicators, except possibly plant fragments. Vertebrate remains were found to be more common in this unit than the underlying unit, and acanthodian scales, a palaeoniscoid tooth, indeterminate Elasmobranchii dermal denticles, and a phyllodont tooth plate fragment were identified. Unit TW-17 grades into the overlying unit.

Unit TW-18 (39 cm) is a highly fossilferous, light olive gray (with fine to medium, medium dark gray motting) calcareous mudstone. This unit contains whole Neochonetes valves and fragments, whole articulated Reticulatia (large) in non-life position, whole articulated Composita and Derbyia (small), whole crushed Wellerella, Lingula, Orbiculoidea, and Petrocrania (attached to Lingula) fragments. This unit also contains whole and fragmented Ditomopyge, a variety of fragmented ramose and fenestrate bryozoan taxa including Leioclema and Fenestella, crinoid and echinoid skeletal debris, and ostracodes including Hollinella and Bairdia. Also present are whole Aviculopecten valves and fragments, whole articulated Edmondia (small), indeterminate bivalve fragments, foraminferids, whole high-spired gastropods, and a variety of vertebrate skeletal debris including complex dermal denticles of indeterminate Elasmobranchii, Cladodus-type teeth, acanthodian (presumably Acanthodes) scales, and palaeoniscoid teeth. Unit TW-18 exhibits a sharp upper contact.

Because of its thickness, unit TW-18 was divided into three sample intervals. In addition, a separate sample of the upper one centimeter of this unit was collected because Barrett (1989) reported that the upper part of this unit is sparsely fossiliferous, and generally contains a relatively low diversity of fossil invertebrates within the study area. Disaggregation of this series of samples did not confirm Barrett's (1989) findings: unit TW-18 contains a fossil assemblage of fairly uniform diversity (Figure 20), and is here treated as a cohesive lithological and genetic entity--with one qualification. The lowest part of this unit, sample TW-18A, contains a relatively high abundance and diversity of phosphatic particles, notably inarticulate brachiopod fragments and vertebrate skeletal elements and debris.

Unit TW-19 (20 cm) (basal Threemile Limestone Member of the Wreford Limestone) is an argillaceous, medium-grained, moderately-sorted, angular to rounded carbonate mudstone to wackestone with whole crushed Composita, whole articulated Crurithyris (silicified), Wellerella fragments (silicified), whole and fragmented Ditomopyge, bivalve fragments, whole high-spired gastropods, ramose and



SAMPLE TW-	14A	14B	15	16	17	18A	18B	18C	18U*	19
ANNELIDS										
Spirorbids	X	X		X					X	
indet. tubes							X		X	
ARTHROPODS										
Ostracodes										
Amphissites					X	X	X	X		
Bairdia				X	X	X	X	X	X	
Cavellina						X				
Hollinella					X		X			
Kellettina				X	X			X	X	
Knightina				X	X	X	X	X		
Knoxina							X			
Whipplella				X						
indet. smooth	X	X	X	3X	X		X	X		
indet. ornamented		X		X	X			X	X	X
Trilobite										
Ditomopyge						F	F	WA	F	WA
BRACHIOPODS										
Composita				AF			WA	WV	WA	WA
Crurithyris										WA
Derbyia				WV	F	F	WA	WA	WV	
Enteletes						F				
Lingula					F	F	F			
Neochonetes					WV	WV	WV	WV		
Orbiculoidea					F	F				
Petrocrania							X			
Reticulatia							WA			
Wellerella						WA		F		F
indet. chonetid				WV	WV				WV	
indet. productid				WV	WV	F	F	WV	F	S
BRYOZOANS										
fenestrate				F	F	F	F	F	F	F
Leioclema				F		F	F	F	F	
Penniretepora					F	F	F	F	F	
Polypora								F	F	
Thamniscus				F	F	F	F	F		
indet. encrusting						X	X	X		
indet. ramose			F	F	F			F		F
CONODONTS										
Cavusgnathus platform			X							
indet. platform			X		X	X		X		
indet. ramiform						X				
ECHINODERMS										
crinoid columnals					W	W	W	W	W	W
crinoid plates				W	W	W	W	W		
echinoid spines		F		W	W	W	W	W	W	W
echinoid plates				W	W	W	W	W	W	
holothurian sclerites				W	W	W	W	W		
indet.			F							
FORAMINIFERIDS										
Ammodiscus										X
Ammovertella		X	X	X						X
Globivalvulina				X						X
Tetrataxis							X	X	X	
MOLLUSCS										
Gastropods										
high-spired			W	3W		W	W		W	W
low-spired				2W		W				
Pelecypods										
Acanthopecten				F	F	F			F	
Aviculopecten			F		WV	F	WV	WV	F	
Edmondia				WA	WA	WA		WA		
Septimyalina			F						F	
indet.			F	F						F
PLANTS										
Charophytes		X		X						
Osagia										X
vascular plants F										
SPONGES										
Siliceous spicules				X	X	X	X	X		X
Amblysiphonella-like						X		X		
TRACE FOSSILS										
Planolites			X							
Pellets					X	X				
VERTEBRATES										
acanthodian scales		X			X	X	X	X		X
Cladodus-type teeth				.		X	X			
indet. Elasmobranch denticles					X	X	X		X	X
phyllodont tooth plate fragments		X	X	X	X				X	
palaeoniscoid teeth			X			X			X	X
palaeoniscoid scales									X	X
tetrapod bones			F							

EXPLANATION OF SYMBOLS
AF-articulated, but fragmented
F-fragments
S-spines
W-whole
WV-whole valves
WA-whole, and articulated
X-present
#-number of indeterminate taxa
18U*-upper 1 cm of unit TW-18C

Note: Symbols refer to most complete observed occurrence of macrofossil taxa. Presence/absence noted for microfossils and for very delicate macrofossils (susceptible to breakage during sieving). Data based on field observation and sieve analyses.

Figure 20. The distribution of fossils in the upper Speiser Shale at locality TW.

fenestrate bryozoan fragments, siliceous sponge spicules, echinoid and crinoid debris, productid spines, and an abundance of unidentifiable invertebrate skeletal debris. Vertebrate remains identified in this unit include acanthodian scales, palaeoniscoid scales and teeth, and indeterminate elasmobranch dermal denticles. Although whole, articulated brachiopod specimens were observed, most macroinvertebrate remains are fragmentary within this unit (and descriptive units correlative with it). Furthermore, no whole specimens of any macroinvertebrate taxon were noted in life position within the lowest descriptive unit in the Threemile Limestone in the study area.

Irregular and discontinuous yellowish gray and light gray laminations 2 to 5 mm thick, lensoidal skeletal wackestone to packstone stringers (placers?) up to 3 mm thick and 5 cm long (usually present in the yellowish gray laminae), chert nodules, discontinuous algal laminations and Osagia?-coated grains with foraminiferids such as Globivalvulina? serving as nuclei, and ripple-marked? and/or hummocky surfaces are also present within unit TW-19. Although they were not observed at this locality, gypsum crystal and rosette molds (and chert pseudomorphs after gypsum rosettes) were noted in correlative descriptive units at other localities by Barrett (1989) and during the course of the present study.

Description of a Vertebrate-bearing Bed in the Middle Speiser Shale at Localities E1 and E2

Localities E1 and E2 occur along the same outcrop in a road cut in Wabaunsee County, Kansas (Figure 3). At locality E2, the upper Funston Limestone up through the molluscan limestone of Hattin (1957) is well exposed. At locality E1, 91 meters to the east of locality E2, part of the middle Speiser Shale is well exposed in a University of Kansas, Museum of Natural History excavation pit. The occurrence of a vertebrate-bearing bed in the middle Speiser Shale is briefly described here to provide background for later discussion. For a more complete description of these localities, see the Appendix.

During the course of study, only three descriptive units were examined in detail at locality E1. All are part of the middle Speiser Shale.

Unit E1-1 (38 cm) is a calcareous, dark reddish brown mudstone with slickensides, root casts, and dusky yellow green mottles. It also contains vertically-elongate to subequant nodules of the overlying lithology. Some of these nodules contain vertebrate skeletal elements. Tetrapod skeletal elements were also observed within the lithology of unit E1-1.

Unit E1-2 (86 cm) is a light greenish gray, argillaceous carbonate mudstone with root casts and slickensides. This unit contains whole specimens of

Lysorophus (McAllister, 1987b) as well as Diplocaulus (Schultze, 1988, pers. comm.) in vertical burrows. Figure 21 shows an amphibian in a burrow from this locality. The remains of sphenacodonts (Reptila), Euryodus bonneri Schultze and Foreman, 1981, Acroplous vorax Hotton 1959, and Gnathorhiza are also present in this unit (Foreman and Martin, 1989).

Unit E1-3 (56 cm) is a brownish gray argillaceous carbonate mudstone at the base and gradually becomes a mudstone of the same color upward. This unit contains root casts and slickensides.

Unit E1-2 is correlative with unit E2-8 (16 cm) (Figure 22), a greenish gray, argillaceous carbonate mudstone with root casts and vertebrate skeletal elements within vertical cyclinderical vertebrate burrows. The latter, however, is much thinner. Furthermore, a few miles to the west (at localities 4/99 and 4/99/2) this descriptive unit is absent from the middle Speiser Shale.

Description of the Lower Part of the Middle Speiser Shale at Locality B

The middle and part of the upper Speiser Shale are well exposed in a road cut at locality B (Figure 3). The lower part of the middle Speiser Shale is described briefly here to provide background for later discussion. For a more complete decription of the Speiser Shale at this

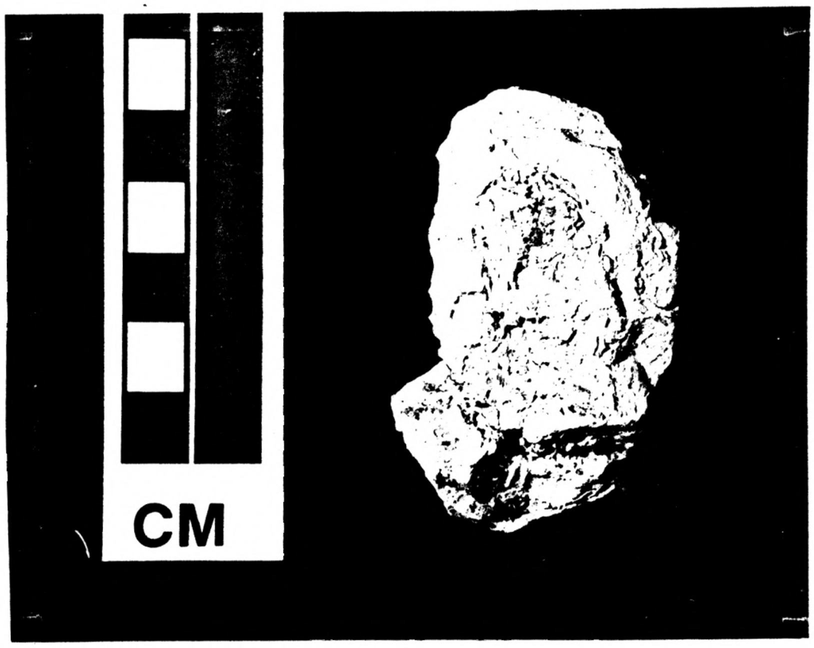


Figure 21. Cross section of vertical cylinderical (ovoid cross section) burrow containing amphibian bones from unit E1-2 (Eskridge locality). The up direction is out of the photograph toward the viewer. Lysorophus is presumed to have produced burrows of this geometry.

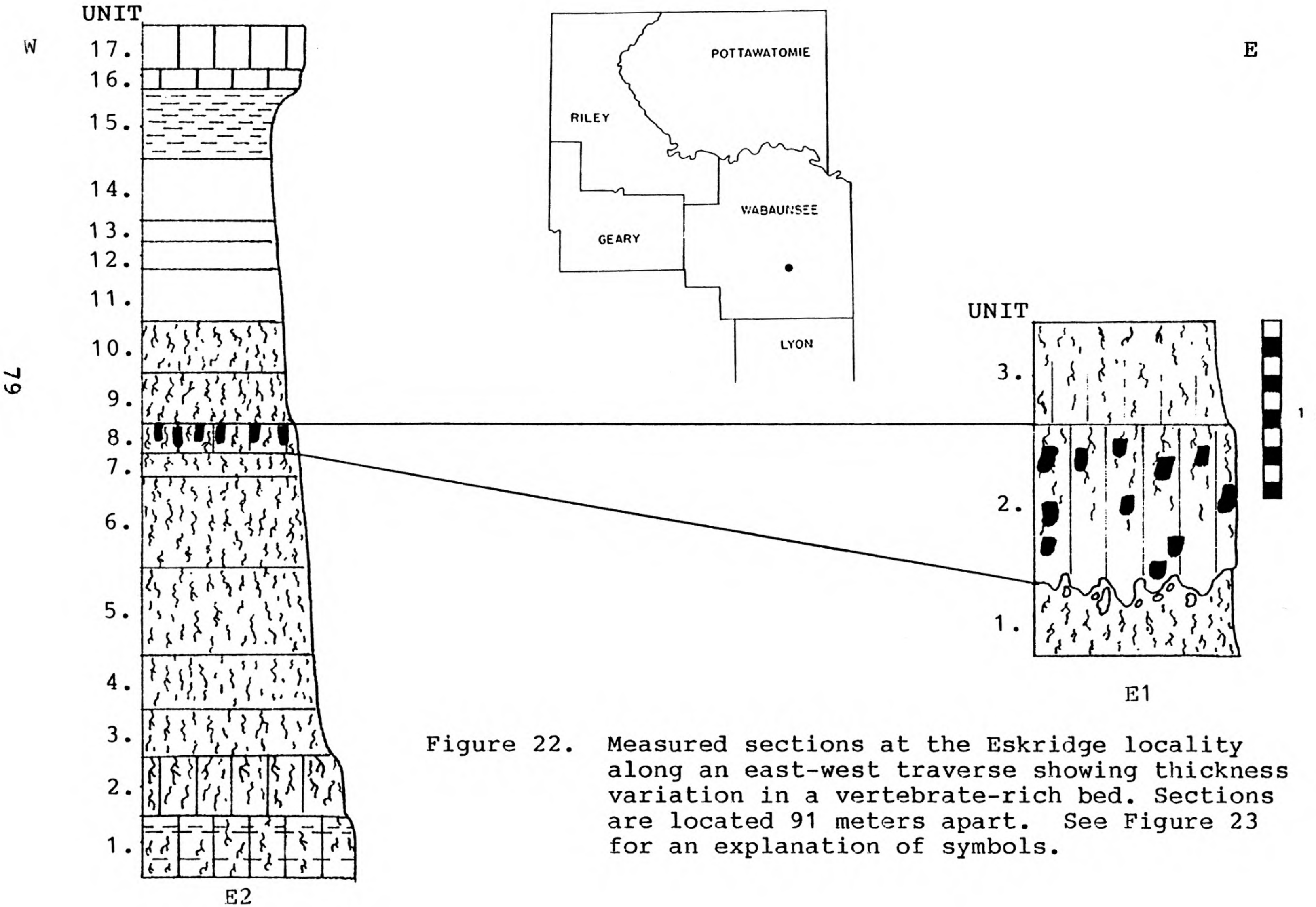


Figure 22. Measured sections at the Eskridge locality along an east-west traverse showing thickness variation in a vertebrate-rich bed. Sections are located 91 meters apart. See Figure 23 for an explanation of symbols.

locality, see the Appendix.

Unit B-1 (57 cm) is a calcareous, grayish olive mudstone with dark reddish brown root casts, slickensides, limestone (carbonate mudstone) nodules and a sharp upper contact. It contains spirorbids, indeterminate ostracodes (cyprids?), and indeterminate vertebrate skeletal debris.

Unit B-2 (2 cm) is a very coarse, moderately-sorted, subangular to rounded lithic wacke. Lithic clasts in this unit are of two types, carbonate mudstone and mudstone. Dissolution of a carbonate mudstone clast from unit B-2 in a mild solution (15% by volume) of acetic acid showed it to be over 96% soluble mineral (calcium carbonate) by weight. The matrix of this unit is a light olive gray mudstone with sparse vertebrate skeletal debris, similar to the lithology of the mudstone clasts.

Unit B-3 (17 cm) is a calcareous, light olive gray mudstone with fine cross-laminations, indications of hummocky paleotopography, and vertebrate skeletal debris and plant fragments.

Unit B-4 (17 cm) is a laminated and cross-laminated light olive gray calcareous mudstone with mudcracks, intraclasts, and vertebrate bone-rich laminations. Sandstone from above fills mudcracks in the upper surface of this unit.

Unit B-5 (2 cm) is a medium to coarse, moderately-sorted subangular to rounded, bone lithic wacke similar in appearance to unit B-2. Unit B-5, however, contains much more vertebrate debris that occurs as disarticulated elements and fragments. Some vertebrate skeletal elements are whole and relatively unabraded, and others are fragmentary and abraded.

Unit B-6 (27 cm) is a grayish olive, calcareous mudstone with very light gray laminations 0.1 to 1.1 cm thick and mudcracks. It contains horizontal burrows (Planolites) up to 3.5 cm in diameter that are filled in with sandstone from the overlying descriptive unit.

Unit B-7 (9 cm) is a cross-bedded, medium to coarse, moderately to poorly-sorted, subangular to rounded bone lithic wacke similar in appearance to unit B-5. Four ripple-marked surfaces were identified within this descriptive unit. This unit contains abundant disarticulated vertebrate remains. The remains of Diplocaulus, Lysorophus, Acroplous vorax Hotton 1959, Trimerorhachis, and Gnathorhiza are present in this descriptive unit (Foreman and Martin, 1989).

Unit B-8 (14 cm) is a calcareous, light olive gray mudstone. This unit contains sandstone lenses with vertebrate skeletal debris up to 1.5 cm thick and horizontal burrows (Planolites) up to 2 cm in diameter. The upper surface of this unit is mudcracked and the mudcracks are filled in with sandstone from above.

Unit B-9 (3 cm) is a cross-bedded sandstone similar to unit B-7.

Unit B-10 (16 cm) is an argillaceous carbonate mudstone. This unit contains vertebrate skeletal debris, plant fragments, and root casts, and exhibits a sharp upper contact.

Unit B-11 (11 cm) consists of interbedded pale red carbonate mudstone and calcareous mudstone with vertebrate skeletal debris. Unit B-11 has a sharp upper contact.

DISCUSSION

General Statement

For the purposes of discussion, the study interval has been subdivided into three parts. The lower part of the study interval (upper Funston Limestone, and lower and lower middle Speiser Shale) consists of marginal marine (intertidal to supratidal) and nonmarine (lacustrine) facies. Two transgressive-regressive units (PACs) are present throughout most of the study area in this stratigraphic interval. The upper middle Speiser Shale constitutes the middle part of the study interval and displays evidence of subaerial exposure (root casts and slickensides) and contains sparse, highly fragmentary and abraded, and possibly allochthonous, marine invertebrate skeletal debris. Presumably, this part of the Speiser Shale records a period of relatively low sea-level. The upper Speiser Shale and lower Threemile Limestone Member of the Wreford Limestone, the upper part of the study interval, record a return to marine conditions within the study area.

Interpretation of Descriptive Units

Lower Part of Study Interval.--Unit RY3-1 (upper Funston Limestone) is a vertically-burrowed (*Skolithos*?) skeletal wackestone containing a low diversity of marine invertebrates that is interpreted to represent an intertidal depositional environment. At locality SMAN, several miles to the south of locality RY3 (Figure 23), the upper part of the Funston Limestone is cross-bedded and vertically-burrowed (within sets of cross beds). Farther to the south, at locality 4/99 (Figure 23), this interval is laminated and contains a fossil assemblage similar to unit RY3-1. Although there are minor lithological variations in the upper Funston Limestone within the study area, this interval, in general, contains a low diversity of marine invertebrates and contains sedimentary structures common on tidal flats, and is interpreted to represent an intertidal depositional environment of widespread geographic extent.

Unit RY3-2 (lower Speiser Shale) contains abundant specimens of probable nonmarine organisms, vascular plants and darwinulids, and I interpret unit RY3-2 to record a lowering of sea-level relative to the underlying unit. Unit RY3-3 may represent a depositional environment similar to that of unit RY3-2, possibly a terrigenous supratidal zone. Marine influence is suggested by the presence of Straparollus-like gastropods in unit RY3-3.

Unit RY3-4, an intraclastic limestone containing foraminiferids, may record the return of slightly more marine (intertidal to supratidal?) conditions within the study area. Unit RY3-4 correlates with unit SMAN-5, an intraclastic carbonate that overlies a thin (4 cm thick) green mudstone (unit SMAN-4) overlying a rooted mudstone (unit SMAN-3) (Figure 23). Unit 4/99-5 (also interpreted to be correlative with unit RY3-4), interbedded mudstone and laminated carbonate mudstone containing arenaceous foraminiferids, overlies a mudstone containing only plant fossils (unit 4/99-4). On the basis of these facies changes over the study area, a transgressive surface (PAC boundary) is interpreted to exist at the base of units RY3-4, SMAN-5, 4/99-5, and all units genetically correlative with them within the study area, and is labelled T1 on Figure 23.

Mudstone units RY3-5 and RY3-6 may record a lowering of sea-level relative to the underlying unit. This intrepretation is made on the basis of a decrease in diversity and abundance of marine organisms over the study area in this interval.

Unit RY3-7 contains whole, articulated lungfish (Gnathorhiza), root casts, and mudcracks. The fish occur in a coiled position similar to that exhibited by Protopterus in aestivation burrows (see Greenwood, 1987). The Gnathorhiza in this unit are, therefore, interpreted to be in burrows, possibly aestivation burrows. The Gnathorhiza specimens are mantled by greenish (reduction?) halos, but seem to be surrounded by the lithology of unit RY3-7, not the overlying highly fossiliferous unit. Presence of Gnathorhiza is interpreted to indicate subaqueous conditions (except during aestivation). The root casts and mudcracks are interpreted to indicate subaerial exposure. Subaerial indicators, coupled with the localized occurence of whole, articulated Gnathorhiza, suggest that unit RY3-7 may be an ephemeral lacustrine deposit that was burrowed into by lungfish, and colonized by plants upon drying.

Unit RY3-8, interbedded intraclastic mudcracked limestone and mudstone containing phyllodont tooth plate fragments and acanthodian scales, may record a return to marine (supratidal) conditions over the study area. At locality SMAN, unit SMAN-11 (interpreted to be genetically correlative with unit RY3-8) contains brachiopod spines and fragments, spirorbids, phyllodont tooth plate fragments, and three types of cyprideacean ostracodes, including Carbonita and Whipplella which may be of freshwater origin (Lane, 1964; Benson et al., 1961). Unit 4/99-7, a probable supratidal gypsiferous boxwork limestone containing echinoid spines, is interpreted to correlate with descriptive units RY3-8 and SMAN-11 (Figure 23).

The lower middle Speiser Shale at locality B (Figure 23) contains rounded, sometimes cross-bedded, lithic sandstone deposits rich in the disarticulated remains of amphibians (Diplocaulus, Lysorophus, Acroplous vorax, and Trimerorhachis) and lungfish (Gnathorhiza). These deposits contain the remains of organisms that may have been exhumed from nonmarine, possibly lacustrine, facies (similar to units RY3-7 or JC-4) by the same minor transgressive event responsible for the deposition of genetically correlative supratidal descriptive units SMAN-11 and RY3-8. Units B-2, B-5, B-7 and B-9 (as well as sand and gravel-rich laminae within mudstone units B-3, B-4 and B-8) are here interpreted to be event beds, tempestites (in most cases probably reworked) or ordinary tidal laminae (in the case of the laminations), within an intertidal to supratidal sequence (units B-2 through B-9). Evidence that this interval (units B-2 through B-9) experienced marine influence include the presence of a number of sedimentary structures common on tidal flats including cross-bedding (units B-7 and B-9), laminations (units B-4 and B-6), mudcracks (unit B-4), and hummocky paleotopography (unit B-4).

Sandstone deposits of the type mentioned above are relatively localized compared to some other units in the study interval (especially open marine mudstones and carbonates), and were observed at only two closely-spaced localities, localities B and B2. These unusual lithic sandstone units contain blackish to brownish rounded carbonate mudstone clasts. The source of the dark-colored carbonate mudstone is enigmatic: no rock of similar lithology was observed in the study area, although such clasts were observed throughout the middle Speiser Shale at several localities including M1 and KEATS.

Unit RY3-8 and all correlative descriptive units present within the study area are interpreted to reflect widespread intertidal to supratidal conditions during deposition of this part of the Speiser Shale. Therefore, a transgressive surface (PAC boundary), designated T2, is interpreted to exist between units RY3-7 and RY3-8, and at the bases of units 4/99-7, SMAN-11, B-2 and all other units genetically correlative with them within the study area. Transgressive surface T2 is labelled on Figure 23.

Data from this study suggest the presence of two transgressive-regressive units (PACs) in the lower and lower middle Speiser Shale over much of the study area (Figure 23). In the southeastern part of the study area (locality E2), however, these two PACs are apparently absent from this interval (Figure 24). This is interpreted to be evidence of a minor topographic high (and as a result reduced marine influence) in that part of the study area (i.e., in the immediate vicinity of locality E2).

Middle Part of Study Interval.--Units RY3-9 and RY3-10 (middle Speiser Shale) may record a lowering of sea-level relative to the underlying marginal marine unit (unit RY3-8). This interpretation is based on a decrease in the abundance and diversity of marine fossils within the study area.

Units RY3-11 through RY3-21 are calcareous mudstone units (except unit RY3-11 which is an argillaceous carbonate mudstone). Most of these units also contain root casts (except units RY3-15 through RY3-17) and exhibit sharp upper contacts (except unit RY3-17).

Root casts in units RY3-11, RY3-12, RY3-13, and RY3-14 may be due to subaerial exposure at the upper contact of the latter unit. Questionable exposure surfaces are, therefore, labelled above units RY3-11, RY3-12, and RY3-13 on Figure 23. An exposure surface was more confidently placed at the sharp upper contact of unit RY3-14 because several overlying units (unit RY3-15

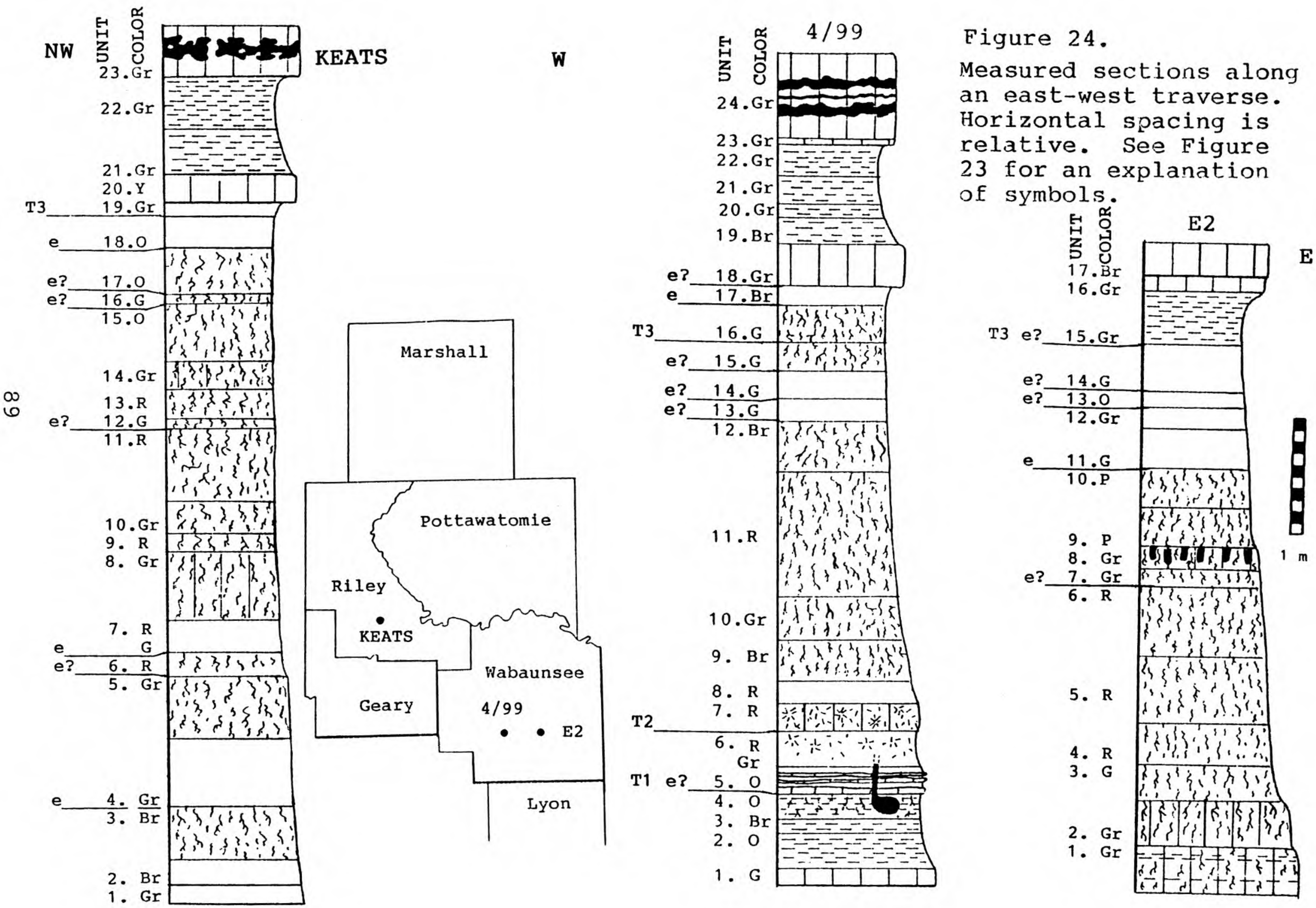


Figure 24.
Measured sections along an east-west traverse. Horizontal spacing is relative. See Figure 23 for an explanation of symbols.

through unit RY3-17) display no evidence of subaerial exposure or rooting.

Units RY3-18 through RY3-21 also contain root casts, and questionable exposure surfaces have been labelled at the upper contacts of units RY3-18, RY3-19, RY3-20, and RY3-21 on Figure 23. Exposure surfaces at the tops of units RY3-18, RY3-19, RY3-20 are considered questionable because root casts in these units may be due to subaerial exposure above or at the upper contact of unit RY3-21. The exposure surface at the upper contact of unit RY3-21 is considered questionable because the overlying unit (unit RY3-22) exhibits evidence of marine influence and the upper part of this unit may have been reworked by a minor transgressive event (T3).

The depositional environments represented by units RY3-9 through RY3-21 are difficult to assess because root casts are the only fossils present. Root casts indicate only that these deposits were subjected to subaerial processes, and do not suggest any specific depositional environment.

Presence of root casts in association with thin descriptive units with sharp contacts may be indicative of episodic deposition with intervening periods of exposure and plant colonization. Presence of *Gnathorhiza* in possible aestivation burrows (and slickensides) in the middle Speiser Shale suggest periodically wet/dry conditions. Rainfall events may have eroded ancient soils and other deposits and redeposited sediment from them locally. It is speculated that some thin descriptive units of the middle part of the study interval may be tempestites (inundites?) or localized ephemeral lacustrine facies (mudrock and carbonate), the result of ponding of water after heavy periodic rains.

Thickness patterns suggest that units RY3-9 through RY3-21 should be correlative with the middle (mSp), lower lower upper (lluSp), and upper lower upper (uluSp) Speiser Shale at nearby locality TW. Confident correlation, however, proved problematic.

At locality TW, units TW-1 through TW-12 are within the middle part of the study interval. Presence of root casts and slickensides within unit TW-1 provide evidence of subaerial exposure. Furthermore, an increase in the density of root casts near the sharp upper contact of this blackish red mudstone unit suggests that this contact may have been subaerially-exposed, and an exposure surface has been labelled above this unit on Figure 23.

Schutter and Heckel (1985) interpreted Missourian mudrock units containing slickensides-bounded structures (blocky texture) from the Midcontinent to be paleosols, specifically fossil Vertisols that formed under hot, semiarid (25-100 cm of rainfall annually), seasonally-wet conditions. However, lithified Permian paleosols (generally mudstones with root casts) encountered during this study were not classified according to Soils Taxonomy (Soil Survey Staff, 1987) because when studying such deposits ". . . important procedures for field identification and description, such as structure and texture assessement are difficult, if not impossible, to perform satisfactorily" (McSweeney and Fastovsky, 1987, p.49-50). For example, for a soil to be classified as a Vertisol, it must, in addition to other characteristics, have cracks ". . . at a depth of 50 cm that are at least 1 cm wide . . ." (Soil Survey Staff, 1987, p.58). Furthermore, mudrocks within the study interval have undergone diagenetic processes (lithification) and Soils Taxonomy does not address such changes.

As noted earlier, unit TW-1 contains marine invertebrate skeletal debris. The sparse, generally abraded, marine invertebrate skeletal debris present in this unit, and some other mudstone units within the middle Speiser Shale, may have been transported by wind or storms, or may have been derived from older sediments. Available evidence is insufficient to decide between these possiblities.

The vertical transition from a green mudstone (unit TW-2) to a red mudstone with root casts and slickensides (unit TW-3) to a mottled mudstone with root casts and slickensides (unit TW-4) may indicate subaerial exposure at the sharp upper contact of unit TW-4, and an exposure surface has been labelled on the top of unit 4 on Figure 23.

Mottling of localized descriptive units in the middle Speiser Shale suggests periods in which soils were soggy, perhaps after heavy periodic rains. "Poor water drainage and the accompanying low oxygen content, in the presence of organic matter, leads to reducing conditions in a soil" (Birkeland, 1984, p.146). "A fluctuating water table can produce very colorful horizons in which the drab colors that characterize reduced conditions are mixed with bluish black of manganese compounds and the bright yellows and reds of oxidized iron compounds" (Birkeland, 1984, p.147). When conditions in a soil fluctuate between reducing and oxidizing, iron and manganese can alternate between being mobile (in the reduced state) or precipitated (in the oxidized state). "The result can be a net loss of iron and manganese, but also with local iron and manganese enrichment in the brightly-colored mottles. The position of mottles help indicate the position of the water table" (Birkeland, 1984, p.147).

Unit TW-5 is green at the base and grades vertically up into unit TW-6, a red, rooted, and mottled mudstone.

The sharp upper contact of unit TW-6 has been interpreted to have been subjected to subaerial conditions, and is labelled as an exposure surface on Figure 23.

Unit TW-7, purplish mottled unit, lies above the sharp upper contact of the underlying unit. Unit TW-7 grades vertically into unit TW-8, a mottled, dark reddish brown unit with root casts. The sharp upper contact of unit TW-8 has been interpreted to have been subjected to subaerial conditions, and an exposure surface has been labelled above unit TW-8 on Figure 23.

The sharp contact between units TW-9 and TW-10 may be depositional. The presence of root casts and slickensides in unit TW-10, however, suggest subaerial exposure at the sharp upper contact of this unit, and an exposure surface is labelled at the top of unit 10 on Figure 23.

Unit TW-11, a rooted greenish gray mudstone with slickensides that becomes purplish upward, grades upward into a mottled, grayish red purple unit with root casts (unit TW-12).

Upper Part of Study Interval.--In contrast to the middle part of the study interval, the upper Speiser Shale and lower Threemile Limestone Member of the Wreford Limestone are remarkably uniform throughout the study area, and are characterized by laterally persistent marginal to open marine facies.

Unit RY3-22 exhibits some evidence of marine influence (smooth-shelled ostracodes), and may represent a terrigenous supratidal facies. As a result, a transgressive surface (PAC boundary), T3, has been labelled at the base of unit RY3-22 (Figure 23). This transgressive event may have truncated the upper surface of unit RY3-21, a rooted mudstone, so this contact is labelled as a transgressive surface and as a questionable exposure surface on Figure 23.

Within this part of the Speiser Shale there is an increase in the abundance and diversity of marine invertebrate fossils over the study area. Units TW-13 and TW-14 (together genetically correlative with unit RY3-22) contain a greater diversity and abundance of marine fossils than unit TW-12, a rooted mudstone. The fossil assemblage of unit TW-14 is a mixed one: charophyte oogonia and plant fragments suggest a terrestrial (nonmarine) influence, but echinoid spines and Ammovertella are of marine origin. This unit is probably a transgressive supratidal to intertidal terrigenous facies. Transgressive surface T3 is interpreted to exist at the base of unit TW-13 (Figure 23).

As in the case of the unit below, unit TW-15 (molluscan limestone of Hattin, 1957) which is genetically and lithologically correlative with unit

RY3-23, contains possible nonmarine fossils (tetrapod bone fragments) in addition to marine taxa, so the assemblage of this unit may be a mixed one. I interpret this unit as representing a very shallow subtidal to low intertidal marine depositional environment. Because the molluscan limestone lies below a facies containing a more diverse marine fossil assemblage, exhibits a fairly consistent pattern (within the study area) of fining upward, and contains a mollusc and smooth-shelled ostracode-dominated (presumably eurytopic) fossil assemblage, I interpret this to be a transgressive facies.

Units TW-16, TW-17, and TW-18 (all of which together constitute the calcareous shale facies of Hattin, 1975), which are correlative with units RY3-24 through RY3-26, are characterized by diverse marine fossil assemblages, and are interpreted to represent a shallow marine environments. Unit TW-18 is the most diverse, and possibly the most open marine (deepest) facies within the study interval, and may represent shallow subtidal conditions. The abundance of fragmented skeletal remains within units of the calcareous shale facies suggests depositional conditions above wave base.

The calcareous shale facies of Hattin (1957) probably represents transgressive to transgressive apical conditions of a 6th-order scale transgressive event (T3) within the study area, and is interpreted here to generally be a cohesive genetic and lithological entity within the study area. However, the basal part of unit TW-18 contains a relatively high diversity and abundance of phosphatic particles, mostly inarticulate brachiopod fragments and vertebrate skeletal debris.

Perhaps this accumulation of phosphatic skeletal grains is tempestic in origin, and similar to the accumulations of the remains of storm-killed and transported organisms described by Antia (1979). Noteworthy, is that in the well core (locality CORE), the lower contact of unit CORE-23 (interpreted to be correlative with the lower contact of unit TW-18) is demarcated by a sharp lithologic contact, the presence of intraclasts (clay pebbles), and an increase in fossil abundance. Perhaps a storm event left different signatures at different localities within the study area.

The lowest bed in the Threemile Limestone Member of the Wreford Limestone (e.g., unit RY3-27 and TW-19) is interpreted to represent shallower marine conditions than the calcareous shale facies of Hattin (1957). Multiply algal-coated grains (indicating repeated rolling), sedimentary structures, and the prevalence of broken, scattered skeletal fragments within this unit suggest that the depositional environment of the lower Threemile Limestone was very shallow and subject to agitation, and that some skeletal grains may have been transported. Presence of gypsum crystal and rosette molds suggest arid intertidal to supratidal conditions similar to those reported by Shinn (1983) from the Persian Gulf. On tidal flats of the Persian Gulf Shinn (1983) noted that gypsum ". . . occurs as large isolated rosettes several centimeters across. Such crystals are randomly scattered throughout the intertidal and algal mat zone underlying the anhydrite" (p.199). He also noted that gypsum rosettes increase in size and abundance landward on these arid tidal flats.

A minor amount of gypsum also occurs in the Speiser Shale in the core (locality CORE). This gypsum occurs as very thin veins at angles to bedding, and is interpreted to be secondary.

Interpretation of Depositional Sequence

The upper Funston Limestone, the Speiser Shale, and the lower Threemile Limestone Member of the Wreford Limestone provide data that is consistent with the hierarchal genetic stratigraphic depositional model of Busch and West (1987). Minor sea-level rises and falls represented by PACs appear to be superimposed on larger-scale sea-level fluctuations (presumably fifth-order T-R events) responsible for the larger scale alternation of limestone (Funston Limestone)/mudrock (Speiser

Shale)/Limestone (Threemile Limestone Member of the Wreford Limestone). During periods of relatively higher sea-level, such as during deposition of the Wreford Limestone, sea-level did not drop to low enough levels to allow the development of soils during regressive phases of PAC deposition (see Barrett, 1989).

The intertidal upper Funston limestone shallows upward into shallower marine or nonmarine facies of the lower Speiser Shale. The lower Speiser Shale contains two laterally persistent, minor transgressive-regressive units (PACs) that shallow into facies that have been subjected to subaerial exposure. These two PACs may be a shallowing PAC sequence, or part of a shallowing PAC sequence.

The middle part of the study interval is interpreted to record a period of relatively low sea-level, perhaps at the fifth-order temporal scale, and consists of descriptive units that can not be correlated (genetically or lithologically) over the study area. Some localities, such as locality TW, are characterized by a large number of descriptive units, many with sharp contacts. Localities such as 4/99 exhibit fewer, thicker descriptive units with gradational contacts (Figure 23).

It is speculated that differences in localities characterized by many thin descriptive units and those characterized by fewer, thicker units may be due to minor differences in paleotopography and concommitant differences in ancient weathering and soil-forming processes. Rooting and other forms of bioturbation in ancient soils may have, in some cases, disturbed stratification and generated thicker, more homogeneous subaerial deposits. Localities characterized by fewer descriptive units may have been subjected to more vigorous weathering processes, and may have been located on minor, localized paleotopographic highs. Localities characterized by large numbers of thin descriptive units with sharp contacts may have been located in paleotopographic lows that were subject to more frequent inundation after rains.

The thickness of the entire Speiser Shale at the most northerly locality (locality M1 in central Marshall County) is 5.73 m. At locality 4/99, far to the south, the Speiser Shale is 5.05 m thick. Likewise, east-west variations of the entire Speiser Shale (Figure 24) are interpreted to be minor, but show a slight thickening to the west which is consistent with Wolfcampian isopach trends for the Midcontinent (see Cook and Balley, 1975).

Changes in thickness of the Speiser Shale on the order of less than a meter over significant lateral distance suggests deposition over generally flat terrain. There is, however, some evidence of minor local paleotopographic differences within the study area, including the absence of two PACs at locality E2 and the presence of localized lacustrine facies within the middle Speiser Shale. Overall deposition of the Speiser Shale seems to have been controlled or dictated by its structural setting, a relatively stable, flat-lying part of the Midcontinent with topographic highs to the north and south that served as source areas for siliciclastic sediments. Localized minor changes in thickness of specific facies within the middle Speiser Shale over the study area are interpreted to reflect local (autogenic) control on deposition including ponding of water in minor topographic lows and concommitant deposition of localized lacustrine facies, tempestic scouring events, and other surficial processes.

Rainfall events yielding large rainfalls in short amounts of time over areas with fine-grained sediments (and presumably low infiltration capacities), over low topographic gradients would be expected to cause Horton overland flow (Oviatt, 1988, pers. comm.), not channel flow. This is consistent with the observed absence of stream channels within the middle Speiser Shale in the study area. It is possible that stream channels may have flowed perpendicular to the outcrop pattern of Permian rocks in Kansas. Such a drainage pattern would make discovery of channels less likely.

The upper Speiser Shale provides evidence of transition to open marine facies within a thin stratigraphic interval (rapid transgression at PAC boundary T3?). The upper Speiser Shale shallows upward into the cherty intertidal to supratidal facies of the lower Threemile Limestone Member of the Wreford Limestone.

Distribution of Vertebrate Remains

Palaeoniscoids, Platysomids, and Acanthodians.--Palaeoniscoid, platysomid, and acanthodian remains are known from both freshwater and marine deposits (Schultze, 1985). However, palaeoniscoid, platysomid, and acanthodian remains are consistently associated with open marine invertebrates in the upper Funston Limestone, the upper part of the Speiser Shale, and the base of the Threemile Limestone Member of the Wreford Limestone within the study area. The remains of these fish are also present in intertidal to supratidal rocks of the lower and lower middle Speiser Shale (e.g., unit RY3-8). In these marginal marine deposits, palaeoniscoid, platysomid, and acanthodian remains are sometimes found in association with such fossils as brachiopod fragments, *Straparollus*-like gastropods, arenaceous foraminiferids, darwinulids, cyprids, spirorbids, and vascular plants.

The available evidence suggests that these fishes probably inhabited marine environments during at least part of their life cycles. Deposits within the study interval that were interpreted to be nonmarine (lacustrine) on the basis of other evidence are devoid of palaeoniscoid, platysomid, and acanthodian remains.

Elasmobranchs.--Elasmobranch remains, mostly dermal denticles and teeth, are restricted to the lower Speiser Shale, upper Speiser Shale, and the lower Threemile Limestone Member of the Wreford Limestone within the study area. Indeterminate Elasmobranchii remains (dermal denticles) are present in the intertidal to supratidal facies of the lower Speiser Shale and the Threemile Limestone as well as the open marine facies of the upper Speiser Shale. Cladodus-type teeth are restricted to open marine calcareous mudstone facies of the upper Speiser Shale.

Lungfish and Tetrapods.--Lungfish (Gnathorhiza) remains and burrows (Figure 25) and tetrapod remains and burrows (Figure 21) are generally restricted to the middle Speiser Shale, although one tetrapod bone fragment was identified in the upper Speiser Shale (molluscan limestone) at locality TW (unit TW-15).

Gnathorhiza burrows (oblate flasks) were observed at several localities within the lower middle Speiser Shale (e.g., mudrock units P/2-3, JC-2, and RY3-7). However, at some localities Gnathorhiza burrows are absent from this part of the Speiser Shale (e.g., descriptive units

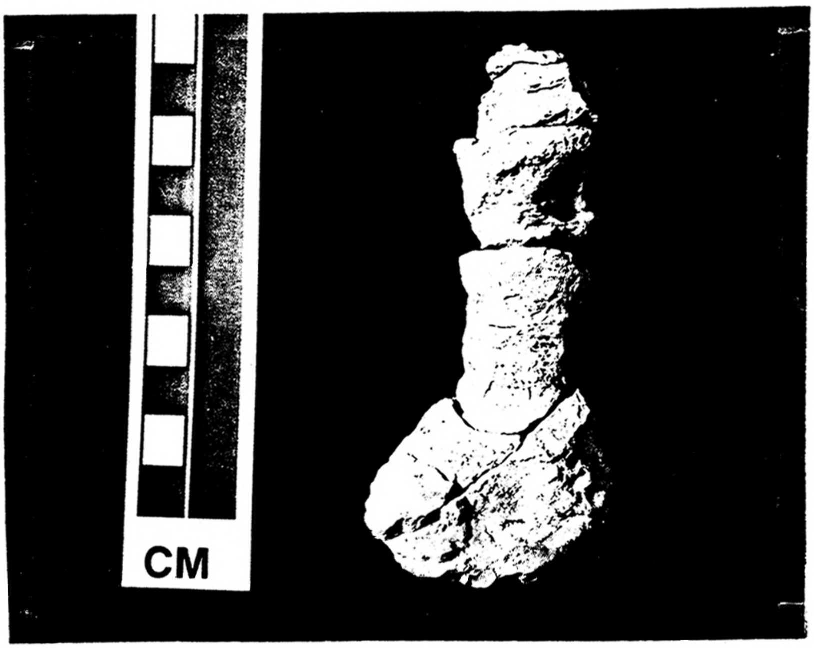


Figure 25. Gnathorhiza burrow of oblate flask morphology. Specimen from unit JC-2 (Junction City locality).

at localities M1, M2, and SMAN). On the basis of this evidence, it seems likely that conditions conducive to presence of burrowing *Gnathorhiza* were localized.

The Eskridge localities (E1 and E2) exhibit some of the best evidence that *Gnathorhiza* and the tetrapods (including *Lysorophus*, *Diplocaulus*, *Euryodus*, and *Acroplous*) inhabited periodically-dry (seasonally-dry?) lacustrine paleoenvironments during deposition of the middle Speiser Shale. Unit E1-2, a massive, well-sorted carbonate mudstone containing body fossils of the aforementioned vertebrate taxa, as well as articulated *Lysorophus* and *Diplocaulus* in burrows, is bounded above and below by paleosols. Furthermore, this unit thins dramatically to the west, and is absent from the middle Speiser Shale at localities 4/99 and 4/99/2, just a few miles west of the Eskridge localities. The limited geographic extent of this deposit suggests that the environment of deposition was a small lake or pond.

In contrast, at localities B1 and B2 the disarticulated remains of lungfish and amphibians occur in great abundance in localized intertidal to supratidal lithic sandstone deposits of the lower middle Speiser Shale. Likewise, at locality RY3 a *Gnathorhiza* tooth plate fragment was found in a supratidal descriptive unit in the lower middle Speiser Shale.

Such occurrences of disarticulated tetrapod and lungfish remains within marine units of the Speiser Shale seem to be best explained by exhumation of skeletal remains from older nonmarine (lacustrine?) deposits during minor (sixth-order) transgressive events. Justification for this interpretation hinges on the observation that whole, articulated Gnathorhiza and amphibians in burrows are known only from localized deposits associated with subaerial (nonmarine) indicators such as root casts and slickensides, whereas tetrapod and lungfish remains that occur in marine units of the Speiser Shale are disarticulated and/or fragmentary. Furthermore, such an interpretation is consistent with the stratigraphic occurrence of lungfish and tetrapod remains within the lower middle Speiser Shale. For example, at locality RY3, an isolated Gnathorhiza tooth plate fragment was noted in a supratidal descriptive unit that lies immediately above a mudstone containing whole, articulated coiled Gnathorhiza in presumed burrows.

In addition to Gnathorhiza and Lysorophus burrows, two other types of burrows were observed during the course of this study. Cylinderical flask-shaped burrows with rounded terminations (Figure 26) were found in the lower middle Speiser shale at locality P/2. No skeletal remains were found within any of the burrows of this morphology, so assignment to a particular organism is speculative. However, these burrows may have also been

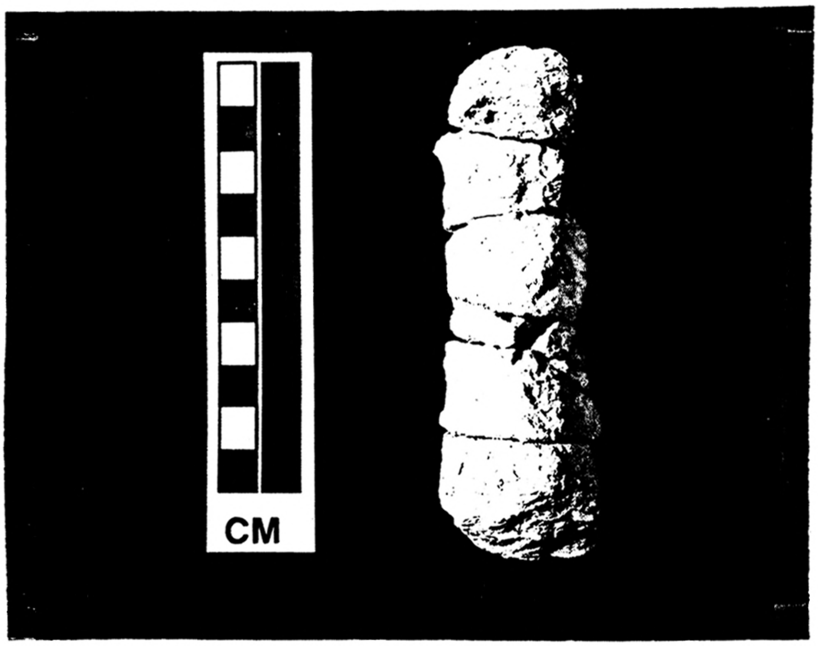


Figure 26. Vertical cylinderical flask-shaped burrow of enigmatic origin from unit P/2-1. Burrows of this type were observed in the lower middle Speiser Shale only at locality P/2 during the course of study.

produced by _Gnathorhiza_: they resemble lungfish burrows illustrated in Olson and Bolles (1975, p.275) and McAllister (1987a) (Figure 27). In addition, a previously undescribed, relatively large burrow consisting of a cylinderical neck reaching down to a rounded chamber was observed at locality 4/99. This burrow type is herein referred to as "stomach-shaped" because of its similarity in form to the human stomach (Figure 28). Only one specimen of the latter burrow type was noted during the course of this study and it was not associated with body fossils. This burrow type bears a morphological similarity to the ichnogenus _Gastrochaenolites_. _Gastrochaenolites_, however, is a much smaller trace fossil produced by invertebrates (bivalves).

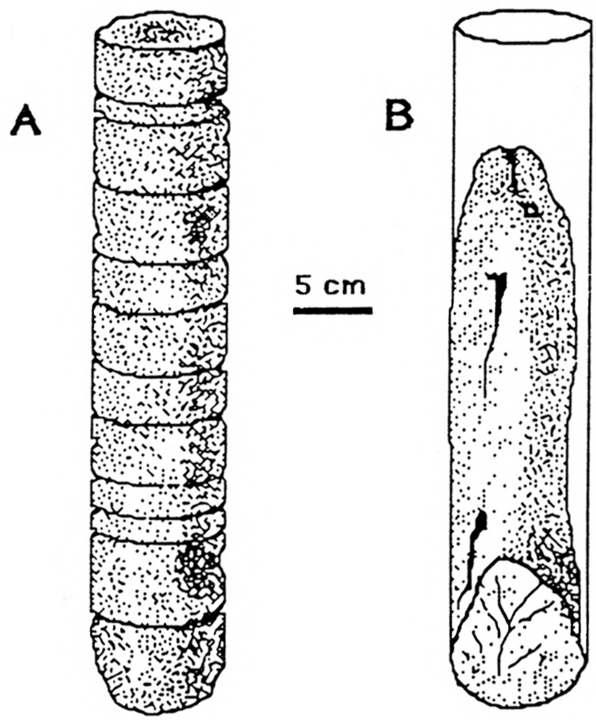


Figure 27. Generalized illustration of external form of weathered cylinderical lungfish burrow (A), and the position of lungfish within a burrow of this form (B) (from McAllister, 1987a, p.366).

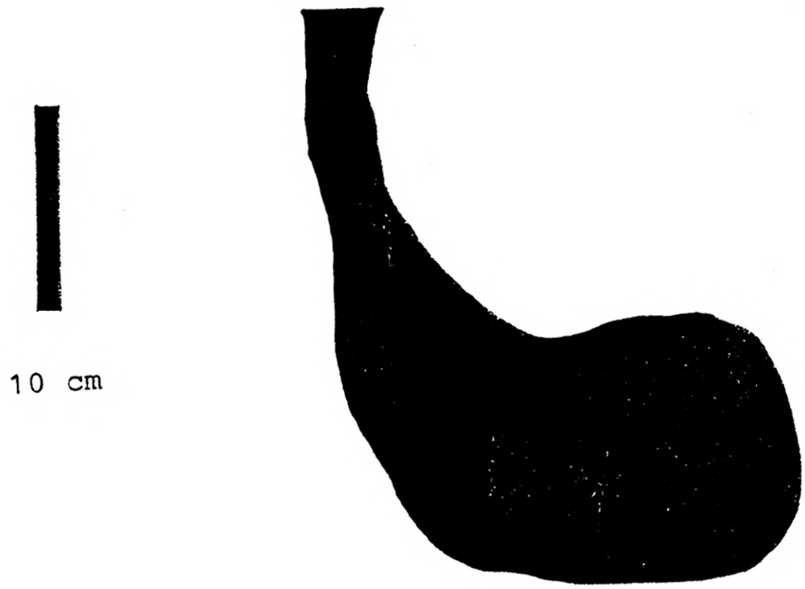


Figure 28. Stomach-shaped burrow of enigmatic origin from locality 4/99 (burrow cuts units 4/99-4 and 4/99-5). Only one specimen of this burrow type was observed during the course of study. The single specimen was inadvertantly dissected in the course of trenching section 4/99. The burrow outline was traced onto a plastic sheet, and reduced on a photocopier machine. The details of the three dimensional morphology of this burrow type are unknown. No skeletal debris was associated with the burrow. About 0.275 times natural size.

CONCLUSIONS

Conclusions reached during the course of this study can be summarized as follows:

1) The lower part of the study interval (upper Funston Limestone, lower and lower middle Speiser Shale) consists primarily of marginal marine (intertidal to supratidal) and some nonmarine (lacustrine) facies. Two sixth-order transgressive-regressive units, or punctuated aggradational cycles (PACs), can be identified and correlated within this part of the study interval over most of the study area.

The middle part of the study interval contains localized mudrock and carbonate descriptive units that show evidence of subaerial exposure (root casts and slickensides). Exposure surfaces can be recognized within the middle Speiser Shale. These surfaces can not, however, be correlated between localities.

Thin, localized descriptive units of the middle Speiser Shale with sharp, apparently depositional contacts may have been the result of heavy rains that eroded ancient soils and other deposits and redeposited sediments from them locally. Localized lacustrine facies may reflect ponding after periodic (seasonal?) rains.

The upper part of the study interval is characterized by open to marginal marine mudrock and carbonate facies. One sixth-order transgressive-regressive unit (PAC) was identified within this stratigraphic interval. The lowest bed in the Threemile Limestone Member of the Wreford Limestone reflects the regressive depositional phase of this PAC, and shallowing to intertidal to supratidal conditions.

2) The results of this study are generally consistent with the hierarchal genetic stratigraphic model of sediment accumulation (sensu Busch and West, 1987). The lower Speiser Shale is part of a shallowing PAC sequence that shallows into the subaerially-exposed deposits of the middle Speiser Shale. The upper Speiser Shale and the lowest bed in the Threemile Limestone Member of the Wreford Limestone constitute the lowest PAC of the overlying 5th-order T-R unit. Data from this study, therefore, support the idea of a nested hierarchy of T-R units that shallow upward upon regression, and further, that transgressions (e.g., transgressive event T3) are characterized by achievement of open marine facies within a thin stratigraphic interval (rapid transgression?).

3) Palaeoniscoid, platysomid (phyllodont), and acanthodian remains are restricted to facies that show some marine influence within the study interval. These fish are interpreted to have lived in marine environments for at least some part, and possibly all, of their life

cyles. Phyllodont, acanthodian, and palaeoniscoid remains, mostly teeth and scales, can be found in subtidal through supratidal facies within the study interval.

Elasmobranch (Cladodus-type, and indeterminate) are also restricted to facies that show evidence of marine influence. Indeterminate Elasmobranchii remains (mostly dermal denticles) occur in subtidal through supratidal facies within the study interval. Cladodus-type remains, however, are restricted to the most open marine, subtidal facies of the upper Speiser Shale.

Whole, articulated dipnoan (Gnathorhiza) and amphibian specimens and burrows are restricted to facies that show little or no evidence of marine influence, possibly periodically (seasonally?) dry lakes. In some cases, nonmarine, probably lacustrine, facies, rich in lungfish (Gnathorhiza) and tetrapod skeletal remains, were overstepped by sea-level during minor (sixth-order) transgressive events. In these cases, exhumed, and therefore allochthonous, disarticulated Gnathorhiza and tetrapod remains are preserved in transgressive intertidal to supratidal deposits of the lower middle Speiser Shale.

Vertebrate burrows of at least two distinct morphologies were noted within the study interval. Oblate, flask-shaped burrows sometimes containing and presumably made by *Gnathorhiza* are present in what are interpreted to be ephemeral lacustrine deposits. Burrows of roughly ovoid cross section that maintain a nearly constant width vertically (cylinderical) that contain the lepospondylous amphibian *Lysorophus* are also present in what are interpreted to be lacustrine deposits. In addition, two other burrow types of enigmatic origin were observed within the study interval: a) cylinderical, flask-shaped burrows with rounded terminations, and b) a relatively large burrow consisting of a rounded chamber and a cylinderical tube reaching down to the chamber.

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APPENDIX

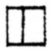
Explanation of Symbols

Lithology

 massive or blocky nonfissile mudrock

 platy nonfissile mudrock

 sandstone

 limestone

 gypsum

 chert

Trace Fossils

 root casts

 olate flask-shaped burrows (Gnathorhiza)

 vertical cylinderical burrows (Lysorophus)

 vertical cylinderical flasks (enigmatic)

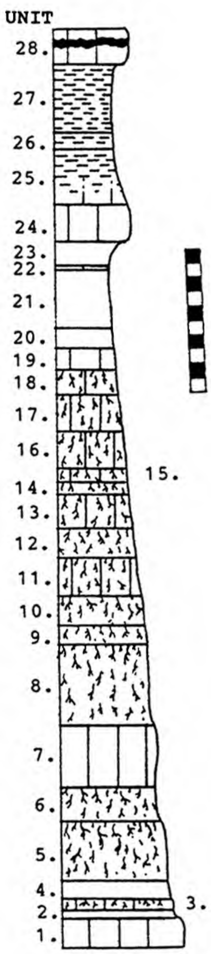
 stomach-shaped burrow (enigmatic)

Other

*--unit sampled

Note: Sections are arranged from north to south (See Figure 3). Carbonates are classified after Archie (1952) (See Table 2). For example, a designation of IA/B would describe a carbonate rock with a resinous matrix (I) that is mostly free of visible porosity (A), but contains a relatively minor number of pores greater than 0.01 mm in diameter but less 0.1 mm in diameter (B). The scale next to each section represents 1 meter.

Locality: M1
Location: South road cut on U.S. 36, 1.9 miles west of the intersection with K-99, SW1/4, SW1/4, SE1/4, Sec.30, T.2 S., R.9 E., Marshall Co., KS.
Units: Funston Limestone (unit 1), Speiser Shale (units 2-27), and Threemile Limestone Member of the Wreford Limestone (unit 28).
Notes: Measured by Christopher R. Cunningham (October, 1988). Most of interval was covered and exposed by digging.



3. Argillaceous limestone: light brownish gray 5 YR 6/1 with abundant dusky yellow green 5 GY 5/2 root casts; well-sorted carbonate mudstone; I/IIIA; with smooth-shelled ostracodes; massive?; slickensides; sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 7 cm thick.

2. Mudstone: dusky yellow green 5 GY 5/2; noncalcareous to slightly calcareous along upper and lower contacts; sandy; blocky; platy to crumbly weathering; slickensides; dark yellowish orange 10 YR 6/6 iron oxide staining; smooth-shelled ostracodes; black carbonaceous (plant?) fragments; medium quartz sand grains; upper contact sharp; 4 cm thick.

1. Limestone: pinkish gray 5 YR 8/1 (weathers medium gray N5 with dark yellowish orange 10 YR 6/6 iron oxide staining); fine, well-sorted, angular mudstone to wackestone; I/IIA with scattered subvertical burrow C; dolomitic?; slightly argillaceous; with Ammovertella?, subvertical burrows up to 2 mm in diameter and 2.5 cm in length; smooth-shelled ostracodes including Bairdia?, algal fronds up to 2 mm in diameter, and discontinuous algal laminations up to 0.5 mm thick; 1 fenestra? 3 mm long; slickensides with clay films from above?; upper contact sharp; 18 cm examined.

8. Mudstone: dark reddish brown 10 R 3/4 (at base) to blackish red 5 R 3/2 (at top) finely to coarsely and diffusely mottled with olive gray 5 Y 5/1; slightly calcareous; very silty; sandy; massive; dark reddish brown 10 R 3/4 root casts; dark yellowish orange 10 YR 6/6 and black iron oxide staining; 1 oxide-stained calcarous nodule 3 cm in diameter (I/IIA) near top (same color as unit); upper contact gradational (diffuse); 57 cm thick.

7. Argillaceous limestone: grayish olive 10 Y 4/2 (at base) to pale olive 10 Y 6/2 with light brownish gray 5 YR 6/1 cast (at top); well-sorted mudstone; IA; massive?; upper part of unit with nodular weathering; lower part of unit with flaggy (3 cm average thickness) to nodular weathering; unit lightens in color upward; becomes less argillaceous upward; dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 oxide staining; slickensides with dusky yellow green 5 GY 5/2 clay films; upper 13 cm slightly chalky (I/IIA) with columnar peds with elliptical cross-sections (7 cm x 3 cm average dimensions) pale red 10 R 6/2 to moderate brown 5 YR 4/4 oxide staining (increases upward); upper contact sharp; 41 cm thick.

6. Mudstone to siltstone: grayish olive 10 Y 4/2; calcareous; sandy; very silty; blocky; smooth-shelled ostracodes?; fine to granule-sized, rounded to subangular light brownish gray 5 YR 6/1 grains; dark yellowish orange 10 YR 6/6 iron oxide staining; dusky yellow green 5 GY 5/2 root casts and clay films on slickensides; dark yellowish orange 10 YR 6/6 iron oxide coatings on some slickensides; upper contact sharp; 23 cm thick.

5. Mudstone (at base) to siltstone (at top): grayish red 10 R 4/2 with a slight orange cast with dusky yellow green 5 GY 5/2 root casts; calcareous; sandy; massive; hard; becomes siltier and harder upward; very fine to silt-sized mica grains; black iron oxide staining; upper contact somewhat gradational; 40 cm thick.

4. Mudstone: grayish olive 10 Y 4/2; calcareous; sandy; massive; rounded to subangular fine to very coarse light brownish gray 5 YR 6/1 grains; chalky, whitish calcareous nodules up to 5 mm across; sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact gradational; 13 cm thick.

13. Argillaceous limestone to mudstone: pale olive 10 Y 7/2 with olive gray 5 Y 5/2 to dark reddish brown 10 R 3/4 root casts; calcareous, sandy, blocky; hard mudstone to massive carbonate mudstone (IA); coarse dusky yellow green 5 GY 5/2 mottles along lower contact; columnar peds 8 cm long and up to 4.5 cm in diameter; slickensides; nodular to platy weathering; smooth-shelled ostracodes?; becomes more argillaceous and more densely rooted upward; upper contact gradational; 23 cm thick.

12. Siltstone: grayish red 10 R 4/2; noncalcareous to slightly calcareous; sandy; blocky; hard; slickensides; diffuse, fine to coarse light olive gray 5 Y 5/2 mottling and root casts; dusky yellow 5 Y 6/4 iron oxide staining; joints; upper contact gradational and irregular; 20 cm thick.

11. Argillaceous limestone to mudstone: pale olive 10 Y 6/2 with fine to coarse grayish red 5 R 4/2 mottling and root casts; calcareous, sandy, hard and massive mudstone to carbonate mudstone (IA); platy to nodular weathering; dark yellowish orange 10 YR 6/6 iron oxide staining; becomes more argillaceous, friable and oxide stained and developes a grayish red 5 R 4/2 cast upward; black oxide? staining; upper contact somewhat gradational; 25 cm thick.

10. Mudstone: grayish red 5 R 4/2 with fine light olive gray 5 Y 5/2 mottling and root casts; very slightly calcareous; sandy; massive to nodular; black oxide? staining; grayish red 5 R 4/2 root casts; rounded granules with dusky yellow green 5 GY 5/2 reduction halos; iron oxide-stained subequant to vertically-elongate calcareous nodules (I/IIA) up to 3 cm in diameter with root casts of same colors as unit; upper contact gradational; 20 cm thick.

9. Mudstone: coarsely and distinctly mottled with dusky yellow green 5 GY 5/2 and blackish red 5 R 3/2; calcareous (green mottles more calcareous); sandy; massive; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining/mottling; fine to coarse rounded light brownish gray 5 YR 6/1 grains; iron oxide-stained, chalky (IIA), oblate calcareous nodules up to 3.5 cm in diameter with dusky yellow green 5 GY 5/2 root casts; blackish red 5 R 3/3 root casts; smooth-shelled ostracodes?; upper contact gradational; 13 cm thick.

18. Argillaceous limestone to mudstone: pale greenish yellow 10 Y 8/2 with pale olive 10 Y 6/2 root casts and coarse to very coarse light brownish gray 5 YR 6/1 to grayish red 5 R 4/2 mottles; calcareous, sandy, blocky, hard mudstone to carbonate mudstone (IA); mudcracks? in-filled with pale olive 10 Y 6/2 mudstone; slickensides; columnar peds? with elliptical cross sections up to 2 cm in diameter; upper contact somewhat gradational and irregular; 16 cm thick.

17. Argillaceous limestone to mudstone: finely and diffusely mottled with light brownish gray 5 YR 6/1 and light olive gray 5 Y 6/1; calcareous, sandy, blocky, hard mudstone to carbonate mudstone (IA); minor bench former; slickensides; light brownish gray 5 YR 6/1 and dusky yellow green 5 GY 5/2 root casts; possible columnar peds up to 3.5 cm in diameter; dark yellowish orange 10 YR 6/6 iron oxide staining; platy to nodular weathering; upper contact sharp; 24 cm thick.

16. Argillaceous limestone to mudstone: grayish red 10 R 4/2 to dark reddish brown 10 R 3/4 finely to coarsely and diffusely mottled with light olive gray 5 Y 5/2 becoming coarsely mottled with pale olive 10 Y 6/2 in the upper 1/3 of unit; calcareous, sandy, blocky to nodular mudstone to carbonate mudstone (IA); slickensides; olive gray 5 Y 3/2 root casts; upper contact gradational; 25 cm thick.

15. Argillaceous limestone: pale olive 10 Y 6/2 with light olive gray 5 Y 5/2 root casts and scattered diffuse fine to coarse grayish red 5 R 4/2 mottling and root casts; carbonate mudstone (IA); dark yellowish orange 10 YR 6/6 iron oxide staining; massive; blocky platy to nodular weathering; slickensides; upper contact sharp and irregular; 9 cm thick.

14. Mudstone: grayish red 10 R 4/2 with fine to coarse light olive gray 5 Y 5/2 mottles and root casts; noncalcareous to slightly calcareous; sandy; blocky; slickensides; upper contact sharp; 7 cm thick.

23. Mudstone: pale olive 10 Y 6/2 with fine, diffuse sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide mottling; calcareous; sandy; blocky coarse to very coarse, rounded to subangular light brownish gray 5 YR 6/1 grains; ostracodes?; coarse to granule-sized (up to 4 mm in diameter) dark yellowish orange 10 YR 6/6 grains; upper contact sharp; 15 cm thick.

22. Argillaceous limestone: yellowish gray 5 Y 7/2 with fine thread-like dark yellowish orange 10 YR 6/6 iron oxide? staining/ mottling; well-sorted carbonate mudstone with charophyte oogonia?; argillaceous; I/IIA/C; massive; white spar-lined, eye-shaped voids; upper contact sharp; 3 cm thick.

21. Mudstone: light olive gray 5 Y 6/2; calcareous; sandy; massive; weathers platy; smooth-shelled ostracodes; with fine sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; coarse to very coarse, rounded light brownish gray 5 YR 6/1 grains; black oxide staining on splitting planes; upper contact sharp; 40 cm thick.

20. Mudstone: grayish olive 10 Y 4/2 with very diffuse and faint light brownish gray 5 YR 6/1 mottling that decreases upward; calcareous (markedly less than below); sandy; massive; thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 13 cm thick.

19. Argillaceous limestone to mudstone: finely to coarsely and diffusely mottled with light brownish gray 5 YR 6/1 and light olive gray 5 Y 6/1 to pale greenish yellow 10 Y 8/2; calcareous, sandy, blocky; hard mudstone to carbonate mudstone (IA); slickensides; grayish olive 10 Y 4/2 and coarse to very coarse angular to subrounded grains (from above?); fine, sometimes thread-like pale red 5 R 6/2 oxide staining; upper contact gradational; 15 cm thick.

26. Mudstone: light olive gray 5 Y 5/2 with fine to coarse, diffuse dark yellowish orange 10 YR 6/6 iron oxide staining/mottling; calcareous; sandy; platy to flaggy; with Orbiculoidea fragments, echinoid spines, crinoid columnals, Derbyia fragments, smooth-shelled and ornamented ostracodes, pectenid bivalve fragments, ramose and fenestrate bryozoan fragments, chalky secondary carbonate fracture fill 1 mm thick at the top; minor bench former; upper contact sharp; 11 cm thick

25. Argillaceous limestone (at base) to mudstone (at top): basal 8 cm--very light gray N8 with dark yellowish orange 10 YR 6/6 iron oxide staining; very coarse, poorly-sorted, angular mudstone to wackestone; IA; fragments of large Derbyia, Hollinella, whole articulated small bivalves (Edmondia?), large Aviculopecten fragments, whole high-spired gastropods, crinoid columnals, Permophorus? fragments, indet. ostracodes; dark yellowish orange 10 YR 6/6 intraclasts as below; upper part of unit--dusky yellow 5 Y 6/4 with fine dark yellowish orange 10 YR 6/6 iron oxide staining; calcareous, sandy, platy to flaggy mudstone; with Orbiculoidea fragments, whole articulated Derbyia (convex up), fragments of large productids, whole Aviculopecten valves; unit becomes less fossilerous and more iron oxide-stained upward; upper contact sharp; 38 cm thick.

24. Limestone: yellowish gray 5 Y 7/2 (weathers grayish orange 10 YR 7/4); medium to coarse, moderately-sorted, angular to subrounded intraclast skeletal wackestone; I/IIA; argillaceous with smooth-shelled ostracodes, high-spired gastropod fragments, Ammovertella, Ammodiscus, large, thin-shelled bivalve fragments; intraclasts of 2 lithologies, grayish orange 10 YR 7/4 to dark yellowish orange 10 YR 6/6 micrite? and yellowish gray 5 Y 7/2 carbonate mudstone to skeletal wackestone intraclasts of rounded flat pebble morphology up to 2 cm long; chaotic, jumbled, bioturbated? texture; basal 6 cm with flaggy splitting and bedding (3 beds of variable thickness averaging 2 cm thick with undulose surfaces); upper portion of unit massive; upper contact gradational; 25 cm thick.

28. Limestone: yellowish gray 5 Y 7/2 with discontinuous laminations up to 3 mm thick (more argillaceous) and fine mottling of medium light gray N6 (weathers grayish orange 10 YR 7/4); fine to medium, moderately-sorted, angular to subrounded, skeletal wackestone with crinoid columnals, brachiopod spines and fragments, ramose bryozoan fragments; much indet. invertebrate skeletal debris; chert bed 14 cm from base and 6 cm from top; chert medium light gray N6 to whitish, noncalcareous to slightly calcareous, with whitish skeletal fragments; upper contact sharp; 24 cm thick.

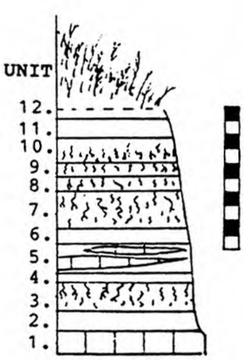
27. Mudstone: dusky yellow 5 Y 6/4 finely to coarsely and diffusely mottled with light olive gray 5 Y 5/2; dark yellowish orange 10 YR 6/6 iron oxide staining; calcareous; sandy; platy; with smooth-shelled and ornamented ostracodes, ramose and fenestrate bryozoan fragments, *Aviculopecten* whole valves and fragments, *Derbyia* fragments, whole productid brachial valves, crinoid columnals, upper contact sharp; 46 cm thick.

Locality: M2
Location: North road cut on U.S.36, 2.1 miles west of the K-99/U.S.36 intersection, SW1/4, SE1/4, SW1/4, Sec.30, T.2 S., R.9 E., Marshall Co., KS (Beattie Quadrangle, 1966).
Units: Funston Limestone (unit 1) and Speiser Shale (units 2-12).
Notes: measured by Christopher R. Cunningham (November, 1988); most of unit was covered and exposed by digging; upper part of interval weathered.

4. Mudstone: pale olive 10 Y 6/2; calcareous; sandy; massive; nodular weathering; very fine dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 5.5 cm thick.

3. Mudstone: slightly lighter than yellowish gray 5 Y 7/2 with a slight olive cast; calcareous; sandy; chalky texture; splintery to platy weathering; pale olive 10 YR 6/2 root casts; sparser grains as in unit 2; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 19 cm thick.

2. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; massive; platy to flaggy weathering; scattered fine to coarse, subangular to rounded, calcareous, moderate orange pink 5 YR 8/6 to light brown 5 YR 6/2 grains; upper contact sharp; 12 cm thick.



1. Limestone: pinkish gray 5 YR 8/1 (weathers yellowish gray 5 Y 7/2); fine, well-sorted carbonate mudstone; I/IIA; argillaceous; laminated (laminae averaging about 0.2 mm thick); scattered fine to coarse spar; dolomitic?; fine indet. invertebrate skeletal debris; platy (averaging 6 mm thick) splitting (weathering); fine dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 15 cm examined.

10. <u>Mudstone</u>: pale greenish 10 Y 8/2 with pale olive 10 Y 6/2 root casts in basal 5 cm to coarsely mottled with olive gray 5 Y 3/2 and finely to coarsely and very diffusely mottled with grayish red 5 R 4/2 in middle 7 cm to dusky yellow green 5 GY 5/2 with a slight yellowish cast in upper 4 cm; dark yellowish orange 10 YR 6/6 iron oxide staining in upper part of unit; calcareous; sandy; massive?; crumbly weathering; upper contact sharp; 16 cm thick.

9. As unit 7 except with olive gray 5 Y 3/2 root casts; calcareous; upper contact gradational; 9 cm thick.

8. <u>Siltstone</u>: pale olive 10 Y 6/2 with a slight pale red 10 R 6/2 cast; calcareous; sandy; massive; crumbly weathering; dusky yellow green 5 GY 5/2 and dark yellowish orange 10 YR 6/6 root casts; dark yellowish orange 10 YR 6/6 to dark reddish brown 10 R 3/4 iron oxide staining; upper contact sharp and slightly irregular; 9.5 cm thick.

7. <u>Siltstone</u>: finely to coarsely and diffusely mottled with grayish red 10 R 4/2 and grayish olive green 5 GY 3/2; noncalcareous; sandy; blocky; slickensides with grayish olive green 5 GY 3/2 coatings; joints with dark yellowish orange 10 YR 6/6 iron oxide staining; dark reddish brown 10 R 3/4 root casts?; upper contact sharp; 25 cm thick.

6. <u>Mudstone</u>: light olive gray 5 Y 5/2; calcareous; sandy; blocky; slickensides; basal 2 cm with dark yellowish orange 10 YR 6/6 iron oxide staining; scattered dusky brown 5 YR 2/2 and dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact gradational; 10 cm thick.

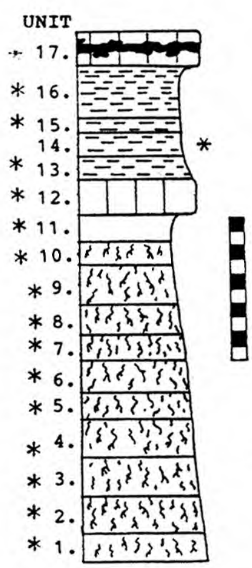
5. <u>Argillaceous Limestone and mudstone</u>: irregular lensoidal bodies of slightly more brown than very pale orange 10 YR 8/2 well-sorted carbonate mudstone (micrite) up to 12 cm thick (IA/C/D to IIA/C/D); C pores with slit-shaped cross sections (0.2 mm by 5 mm in diameter), parallel to splitting; D vugs slit-shaped to irregular with fine to granule-sized, bead-shaped, secondary calcite growths lining voids; dusky yellow 5 Y 6/4 to grayish red 5 R 4/2 iron oxide staining; and non-indurated grayish yellow 5 Y 8/4 mudstone with abundant modern root casts; calcareous; sandy; dark yellowish orange 10 YR 6/6 iron oxide staining; (Recent weathering/groundwater/root bioturbation alteration?); upper contact sharp; 19 cm thick.

12. Mudstone: pale olive 10 Y 6/2; calcareous; sandy; massive; grayish red 5 R 4/2 iron oxide staining; upper contact weathered; 5 cm examined.

11. Mudstone: grayish red 5 R 4/2 finely and diffusely mottled with light olive gray 5 Y 5/2; calcareous; sandy; blocky; slickensides; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact somewhat gradational; 13 cm thick.

Locality: P/1
Location: East side of roadcut on K-99, NW1/4, SW1/4, Sec.3, T.6 S., R.9 E., Pottawatomie Co., KS (Frankfort SW Quadrangle, 1969).
Units: Speiser Shale (units 1-16) and Threemile Limestone Member of the Wreford Limestone (unit 17).
Notes: interval measured by Christopher R. Cunningham (June, 1988); interval was mostly covered and exposed by digging.

2. Mudstone: finely to coarsely and diffusely mottled with dusky yellow green 5 GY 5/2 and grayish red 5 R 4/2; calcareous; sandy; massive; nodular to crumbly weathering; mottle size decreases upward from 5 cm at the base to an average of 3 mm at the top; unit dominated by green at the base, becoming redder toward the top (upper contact placed where green becomes dominant again); grayish red 5 R 4/2 root casts; dark yellowish orange 10 YR 6/6 iron oxide staining; mottles become more diffuse upward; scattered hard calcareous nodules up to 3.8 cm in diameter; rounded, argillaceous, calcareous clasts up to 1 mm in diameter; upper contact gradational, irregular; 25.5 cm thick.



1. Mudstone: grayish red 5 R 3/2 with fine to coarse light olive gray 5 Y 5/2 mottling; calcareous; sandy; blocky; platy to flaggy to crumbly weathering; dark yellowish orange 10 YR 6/6 iron oxide staining; blackish to orangish, rounded calcareous grains up to 2 mm in diameter--some surrounded by dusky yellow green 5 GY 5/2 reduction halos; slickensides with black carbonaceous staining; upper 10 cm nodular with relatively hard, calcareous nodules up to 3.8 cm across (some nodules vertically elongated); root casts of 2 constituent rock colors in nodules; upper contact gradational; 28 cm exposed--bottom covered.

7. <u>Mudstone</u>: dusky yellow green 5 GY 5/2 finely to coarsely mottled with grayish red 5 R 4/2; calcareous; sandy; massive; with fine, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide mottling/staining; black carbonaceous debris; dusky yellow green 5 GY 5/2 root casts; denser concentration of red mottling than above or below; upper contact gradational; 18 cm thick.

6. <u>Mudstone</u>: slightly lighter than pale yellowish brown 10 YR 6/2 with a slight greenish cast to pale olive 10 Y 6/2; dusky yellow green 5 GY 5/2 to pale olive 10 Y 6/2 root casts; calcareous; sandy; blocky to nodular--slightly blockier at base, slightly platy toward the top; dark yellowish orange 10 YR 6/6 iron oxide staining; slickensides associated with dusky brown 5 YR 2/2 coatings/staining; upper contact gradational; 20.5 cm thick.

5. <u>Mudstone</u>: pale olive 10 Y 6/2 to dusky yellow green 5 GY 5/2 with very diffuse fine grayish red 5 R 4/2 mottling; calcareous; sandy; massive; joints with dark yellowish orange 10 YR 6/6 iron oxide staining; dusky yellow green 5 GY 5/2 root casts; black carbonaceous debris (plant fragments?); unit redder near base; upper contact gradational--drawn where overlying unit becomes harder; 18 cm thick.

4. <u>Mudstone</u>: dusky yellow green 5 GY 5/2 with fine to coarse grayish red 5 R 4/2 mottling and root casts (more green than below, redder than above); calcareous; sandy; blocky; dusky yellow green 5 GY 5/2 root casts; dark yellowish orange 10 YR 6/6 iron oxide staining; joints with dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 staining; slickensides; upper contact gradational; 25.5 cm thick.

3. <u>Mudstone</u>: finely to coarsely mottled with dusky yellow green 5 GY 6/2 and grayish red 5 R 4/2 (mottles more distinct than below); calcareous; sandy; massive; platy to flaggy weathering; lower 7.5 cm dominated by green, becomes redder upward; grayish red 5 R 4/2 root casts; dark yellowish orange 10 YR 6/6 iron oxide staining; black carbonaceous (plant?) fragments; rounded, red, calcareous grains (some with red halos) up to 1 mm in diameter; upper contact gradational and placed where becomes more green again; 25.5 cm thick.

12. <u>Limestone</u>: yellowish gray 5 Y 7/2 (weathers dusky yellow 5 Y 6/4 to dark yellowish orange 10 YR 6/6 due to iron oxide staining); fine, moderately well-sorted, angular? packstone (biomicrite); I/IIIA; argillaceous; with ostracodes, whole pectenid bivalves in upright (life?) position, pectenid bivalve fragments, <u>Ammovertella</u>, phyllodont tooth plate fragments, palaeoniscoid teeth, horizontal burrows up to 7 mm in diameter; thinly-bedded (3 mm) (platy splitting) in basal and upper 2.5 cm with irregular, hummocky or ripple-marked surfaces, rest of unit massive (bioturbated?) and exhibits blocky splitting; upper contact gradational; 23 cm thick.

11. <u>Mudstone</u>: pale olive 10 Y 6/2; calcareous; slightly sandy; massive to platy (weathering?); fine dusky yellow 5 Y 6/4 to dark yellowish orange 10 YR 6/6 mottling; with 1 productid spine, 1 indet. smooth-shelled ostracode, 1 charophyte oogonium; joints with sometimes thread-like dusky brown 5 YR 2/2 and dark yellowish orange 10 YR 6/6 staining; black carbonaceous debris; sand-sized highly oxidized pyrite grains; upper contact sharp; 18 cm thick.

10. <u>Mudstone</u>: similar to unit 9 except: more platy (weathering?); softer; more dusky yellow 5 Y 6/4 to dark yellowish orange 10 YR 6/6 iron oxide mottling/staining; with 1 echinoid spine, 1 crushed, indet., smooth-shelled ostracode; upper contact gradational; 16.5 cm thick.

9. <u>Mudstone</u>: light olive gray 5 Y 6/2 with fine to coarse dusky yellow 5 Y 6/4 to dark yellowish orange 10 YR 6/6 iron oxide mottling and root casts; calcareous; sandy; massive to platy (weathering); with 1 abraded indet. bryozoan fragment; medium sand-sized highly oxidized pyrite grains; platiness and black carbonaceous debris preferentially associated with slightly more olive root casts and fine to coarse root(?) mottling; upper contact gradational; 26.5 cm thick.

8. <u>Mudstone</u>: pale olive 10 Y 6/2; calcareous; sandy; massive; joints with dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 coatings/staining; with brachiopod spines, large spirorbid? fragments; fine dusky yellow 5 Y 6/4 iron oxide mottling; fine carbonaceous plant? debris; mudcracks?; 0.2 mm-thick discontinuous laminae of gypsum (satin spar); dusky yellow green 5 GY 5/2 root casts and fine mottling (some rooted areas platy); medium-grained, euhedral quartz grains; upper contact gradational; 18 cm thick.

15. Mudstone: dusky yellow 5 Y 6/4 with fine to coarse medium gray N5 mottling; dark yellowish orange 10 YR 6/6 iron oxide staining (unit more brownish in color overall than below); calcareous; sandy; platy to flaggy; with Bairdia, Paraparchites?, horizontal burrows up to 7 mm in diameter, crinoid plates and columnals, echinoid spines, ramose bryozoan fragments; myalinid? bivalve fragments, whole, articulated Edmondia?, 1 low-spired and 1 planispiral gastropod, siliceous sponge spicules, Neochonetes valves, Derbyia? valves, Orbiculoidea fragments, Lingula fragments, brachiopod spines and fragments, 1 conodont element, acanthodian scales, palaeoniscoid scales, 2 indet. Elasmobranchii dermal denticles, pellets?, black carbonaceous debris, upper contact gradational; 9 cm thick.

14. Mudstone: yellowish gray 5 Y 7/2 to dusky yellow 5 Y 6/4 with fine to coarse medium gray N5 mottling; dark yellowish orange 10 YR 6/6 iron oxide staining; calcareous; sandy; platy to flaggy; with Knightina, Hollinella, Tetrataxis, whole Aviculopecten, ramose bryozoan fragments, echinoid spines and plates, crinoid columnals and plates, inarticulate brachiopod fragments, whole Neochonetes valves, productid spines and fragments and brachial valves of juveniles?, 1 conodont element, acanthodian scales, 1 broken indet. Elasmobranchii dermal denticle, indeterminate vertebrate? skeletal debris; black carbonaceous fragments; upper contact gradational; 15 cm thick.

13. Mudstone: yellowish gray 5 Y 7/2 with fine to coarse dark yellowish orange 10 YR 6/6 iron oxide mottling/staining (staining increases upward); calcareous; sandy; platy; black, carbonaceous (pyritic?) debris; with Hollinella, Knightina?, Bairdia, Cavellina?, Paraparchites?, Ammodiscus, Ammovertella, Globivalvulina?, spirorbids, high-spired, planispiral, and low-spired gastropods, indeterminate bivalve fragments (large, thin-shelled); indet., abraded ramose bryozoan fragments, productid spines and fragments, Composita fragment. echinoid spines and plates, crinoid plates, palaeoniscoid tooth; upper contact gradational; 15 cm thick.

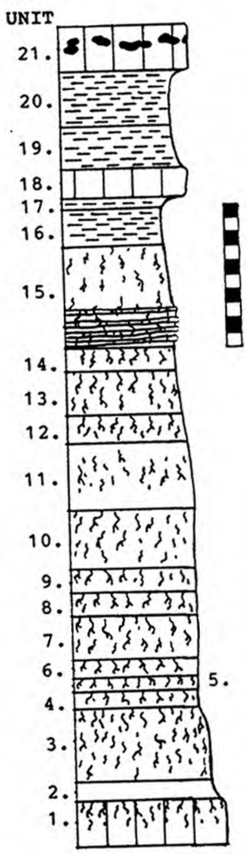
16. Mudstone: dusky yellow 5 Y 6/4 finely to coarsely mottled with light olive gray 5 Y 5/2 to medium gray N5; calcareous; sandy; platy; friable; black carbonaceous debris; dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 staining on splitting/bedding planes; lower 1/3 (sample P/1-16A) with Hollinella, indet. textured ostracode, Bairdia, indet. smooth-shelled ostracodes (3 types), Ditomopyge fragments, globular 2-chambered foram, spirorbids, holothurian sclerites (hook and wheel), echinoid spines and plates, crinoid columnals and plates, siliceous sponge spicules, Leioclema fragments (including one encrusting a brachiopod spine), fenestrate bryozoan fragments, indet. ramose bryozoan fragments (several types), Acanthocladia?, high-spired gastropods, Aviculopecten fragments, indet. bivalve fragments, whole pedicle valve and internal mold of juvenile Composita, Derbyia fragments, whole Neochonetes valves, Lingula fragments, productid spines and fragments and brachial valves of juveniles, 9 conodont elements (all ramiform, including 1 prioniodinid element), acanthodian scales and spine? fragment, indet. Elasmobranchii dermal denticles, palaeoniscoid teeth, and shark tooth fragment (cladodont?); middle 1/3 (sample P/1-16B) with Amphissites, Hollinella, Bairdia, indet. ornamented ostracodes (1 with dorsal spine; 1 Knightina-like), Ditomopyge fragments, Tetrataxis, siliceous sponge spicules, spirorbids, crinoid columnals and part of articulated calyx, echinoid spines and plates, holothurian sclerite (hook), Aviculopecten fragments, Acanthopecten fragments, Straparollus-like gastropods, high-spired gastropods, planispiral gastropod, fenestrate bryozoan fragments, Leioclema fragments (including 1 encrusting productid spine), ramose bryozoan fragments (several types), Derbyia fragments and whole, articulated juveniles, Composita fragments and whole, articulated juveniles, chonetid valves and fragments, productid spines, fragments and whole brachial valves of juveniles, acanthodian scales, indet. Elasmobranchii dermal denticles, palaeoniscoid teeth; upper 1/3 (sample P/1-16C) less fossiliferous with Hollinella, Bairdia, Amphissites, Kellettina, Knightina, indet. ornamented ostracode, indet. smooth-shelled ostracode, Ditomopyge fragments, Globivalvulina, Tetrataxis, siliceous sponge spicules, holothurian sclerites (wheels), crinoid columnals and plates, echinoid spines and plates, spirorbids, Leioclema fragments, fenestrate

bryozoan fragments, ramose bryozoan fragments (several types), *Straparollus*-like gastropods, high-spired gastropods, whole articulated *Edmondia*?, *Aviculopecten* fragments, productid spines and fragments, fragments, whole *Neochonetes* valves, *Composita* valve, *Derbyia* fragments and small, whole articulated individuals, 5 conodont elements (3 ramiform; 2 platform), acanthodian scales, palaeoniscoid scale and teeth, indet. Elasmobranchii dermal denticles; upper contact gradational; 35.5 cm thick.

17. Limestone: light gray N7 to yellowish gray 5 Y 7/2 (weathers grayish orange 10 YR 7/4 to dark yellowish orange 10 YR 6/6); medium, moderately well-sorted, angular packstone (biomicrite); III/IA; argillaceous; with crinoid columnals, ramose and fenestrate bryozoan fragments, whole? high-spired gastropods, horizontal burrows up to 1 cm in diameter, productid spines, echinoid spines, ostracodes?, indeterminate brachiopod and bivalve fragments, much indeterminate invertebrate skeletal debris; upper 1 cm with platy splitting, rest of unit massive with blocky splitting; 7.5 cm thick chert bed 10 cm above the base; upper contact gradational; 23 cm thick.

Locality: P3
Location: West road cut of federal aid secondary highway, NW1/4, SE1/4, SE1/4, Sec.2., T.8 S., R.7 E., Pottawatomie County, KS (Olsburg NW Quadrangle, 1964).
Units: Speiser Shale (units 1-20) and Threemile Limestone Member of the Wreford Limestone (unit 21).
Notes: measured by C.R. Cunningham (September, 1988).

4. Mudstone: pale olive 10 Y 6/2 to dusky yellow green 5 GY 5/2 with dusky yellow green 5 GY 5/2 root casts; calcareous; sandy; massive; dark yellowish orange 10 YR 6/6 and dark reddish brown 10 R 4/6 iron oxide staining; vertebrate skeletal debris; siltier and sandier than units 5 and 6; upper contact sharp; 9 cm thick.



3. Mudstone: Reddish brown 10 R 4/4 (weathers pale red 10 R 6/2); calcareous; very silty; sandy; massive; harder than 2 (minor ledge former); dusky yellow green 5 GY 5/2 root casts; black oxide? staining; pale red 10 R 6/2 coalescive micrite nodules up to 3 cm in diameter; upper contact sharp; 48 cm thick.

2. Mudstone: light olive gray 5 Y 6/1 to dusky yellow green 5 GY 5/2 (weathers greenish gray 5 GY 6/1); calcareous; sandy; blocky; vertebrate skeletal debris; slickensides; black carbonaceous fragments; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 12 cm thick.

1. Argillaceous limestone: pinkish gray 5 YR 8/1 (weathers moderate orange pink 5 YR 8/4); well-sorted mudstone; I/IIA with minor amount of gypsum crystal moldic B and C; abundant slickensides; whitish to light olive gray 5 Y 6/1 root casts; minor amount (less than 2%) of fine to coarse spar; nonbedded, massive; vertebrate skeletal debris; upper contact sharp; 31 cm thick.

10. Mudstone: finely to coarsely mottled with pale olive 10 Y 7/2 and pale red 10 R 6/2 (red dominates in middle 1/3; green dominates in upper and lower 1/3's) (weathers pale red 10 R 6/2); calcareous; sandy; blocky to platy to flaggy (weathering?); dark yellowish orange 10 YR 6/6 associated with slickensides; dusky yellow green 5 GY 5/2 and dark reddish brown 10 R 3/4 root casts; black carbonaceous fragments (plant?) and staining; upper contact sharp; 40 cm thick.

9. Mudstone: olive gray 5 Y 4/1 with grayish red 10 R 4/2 root casts and fine to medium mottling (weathers greenish gray 5 G 6/1); noncalcareous; sandy; blocky; slickensides; harder than above or below; moderate yellowish brown 10 YR 5/4 iron oxide staining; upper contact gradational; 15 cm thick.

8. Mudstone: finely to coarsely mottled with pale olive 10 Y 6/2 and pale red 10 R 6/2 to grayish red 10 R 4/2; calcareous; sandy; dusky yellow green 5 GY 5/2 root casts; platy (weathering?) to blocky; slickensides; black carbonaceous(?) staining; upper contact sharp; 15 cm thick.

7. Mudstone: grayish red 5 R 4/2 finely to coarsely and very diffusely mottled with olive gray 5 Y 4/1 (weathers pale red 10 R 6/2); red becomes more dominant upward; noncalcareous; sandy; blocky; dusky yellow green 5 GY 5/2 root casts; slickensides; black staining; harder than above and below; upper contact gradational; 29.5 cm thick.

6. Mudstone: light olive gray 5 Y 6/1; calcareous (more than unit 5; less than unit 4); sandy; brownish gray 5 YR 4/1 root casts; becomes whitish and slightly chalky and crumbly upward; pinkish gray 5 YR 8/1, chalky-weathering micrite nodules up to 7 cm in diameter; upper contact sharp; 12 cm thick.

5. Mudstone: dark greenish gray 5 GY 4/1 with fine, diffuse dark reddish brown 10 R 3/4 root casts and mottling; slightly calcareous; very silty; very sandy; blocky to nodular; poorly-developed slickensides; vertebrate skeletal debris; harder and blockier than units 4 and 6; upper contact gradational; 11 cm thick.

15. Interbedded limestone and mudstone: limestone--light brownish gray 5 YR 6/1 with fine dusky yellow 5 Y 6/4 to dark yellowish orange 10 YR 6/6 iron oxide mottling; well-sorted mudstone; IA; dusky yellow green 5 GY 5/2 root casts; slickensides; moderate yellowish brown 10 YR 5/4 iron oxide staining; massive, non-bedded; smooth-shelled ostracodes?; irregular, nodular, and discontinuous up to 7 cm thick; mudrocks--pale olive 10 Y 6/2 with fine, dusky yellow 5 Y 6/4 to dark yellowish orange 10 YR 6/6 iron oxide mottling; calcareous; sandy; blocky to platy (weathering); relatively low silt content; dusky yellow 5 Y 6/4 to dusky yellow green 5 GY 5/2 root casts; slickensides; smooth-shelled ostracodes?; unit dominated by 4 prominent limestone beds in lower 1/2 (minor ledge-former); upper contact somewhat gradational; 71 cm thick.

14. Mudstone: pale olive 10 Y 6/2; calcareous; sandy; relatively low silt content; blocky to crumbly to platy (weathering?); dusky yellow green 5 GY 5/2 root casts; slickensides; dusky brown 5 YR 2/2 to dark yellowish orange 10 YR 6/6 on splitting planes, joints and slickensides; vertebrate skeletal debris?; prevalent Recent root bioturbation; upper contact sharp 15 cm thick.

13. Mudstone: grayish red 10 R 4/2 (at base) to pale red 10 R 6/2 (at top) (weathers pale red 10 R 6/2); calcareous; sandy; blocky; joints with black and moderate yellowish brown 10 YR 5/4 staining; dusky yellow green 5 GY 5/2 root casts; weathers platy; black carbonaceous? fragments and staining; slickensides; upper contact sharp; 30 cm thick.

12. Mudstone: pale olive 10 Y 72 (weathers light greenish gray 5 GY 8/1); developes a slight reddish cast upward; calcareous; sandy; dusky yellow green 5 GY 5/2 (at base) to olive gray 5 Y 4/2 to dark reddish brown 10 R 3/4 (at top) root casts; massive to platy to flaggy (weathering?); upper contact sharp; 19 cm thick.

11. Mudstone: upper and lower 1/3 between grayish red 10 R 4/2 and moderate reddish brown 10 R 4/6; middle 1/3 pale red 5 R 4/2 with slight greenish cast (weathers pale reddish brown 10 R 5/4 in upper and lower 1/3; pale red 10 R 6/2 in middle 1/3); calcareous; sandy; blocky; weathers platy; dusky yellow green 5 GY 5/2 to pale olive 10 Y 6/2 root casts and fine mottling; slickensides; joints with black staining; upper contact sharp; 47 cm thick.

19. Mudstone: light olive gray 5 Y 6/1 with scattered fine to coarse olive gray 5 Y 3/2 mottling; calcareous; sandy; platy; fossil abundance decreases upward; with whole Aviculopecten valves, Ditomopyge pygidium, productid spines, echinoid spines, ramose bryozoan fragments, Derbyia fragments, smooth-shelled ostracodes, whole productid brachial valves (Juresania?), indeterminate bivalve fragments, 1 crinoid columnal, whole Neochonetes valves; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 31 cm thick.

18. Limestone: light brownish gray 5 YR 7/1 (weathers pale yellowish orange 10 YR 8/6 to grayish orange 10 YR 7/4); coarse to very coarse, moderately to poorly-sorted, subrounded to angular, skeletal intraclast wackestone to packstone (at base) to medium to coarse, moderately to poorly-sorted, rounded to angular intraclast skeletal wackestone; I/IIIA; argillaceous intraclasts micritic, grayish orange 10 YR 7/4, and up to 3 mm in diameter; basal 5 cm with platy splitting; upper part massive; with smooth- shelled ostracodes (Cavellina?), whole, high-spired gastropods (in upper part of unit), vertical (up to 3 mm in diameter), subvertical (up to 5 mm in diameter), and horizontal (up to 1 cm in diameter) burrows, Ammovertella, bivalve fragments; scattered yellowish gray 5 Y 7/2 carbonate mudstone to wackestone intraclasts with rounded edges and flat pebble morphology up to 2 cm long in upper part of unit; upper contact gradational; 21 cm thick.

17. Mudstone: greenish gray 5 GY 6/1 with fine light olive brown 5 Y 4/2 mottling; calcareous; sandy; platy to flaggy; hard; smooth-shelled ostracodes; vertebrate skeletal debris; grayish red 10 R 4/2 iron oxide staining; black carbonaceous (plant?) fragments; upper contact sharp; 7 cm thick.

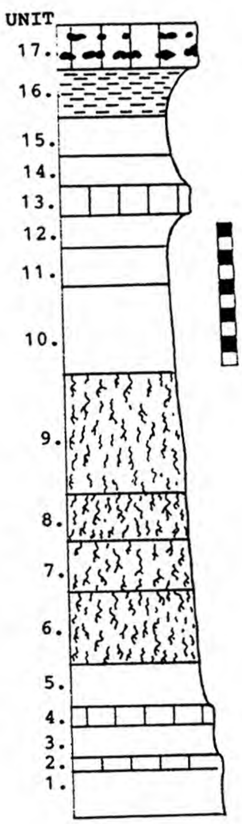
16. Mudstone: finely to mediumly mottled with greenish gray 5 GY 6/1 and dusky yellow 5 Y 6/4 to dark yellowish orange 10 YR 6/6; calcareous; sandy; blocky to platy (weathering?); slickensides; smooth-shelled ostracodes; black carbonaceous (plant?) fragments; dusky brown 5 YR 2/2 to black oxide? staining on splitting planes; overall, much browner in color than 17; upper contact sharp; 25 cm thick.

21. Limestone: yellowish gray 5 Y 7/2 with fine medium light gray N6 mottling (disturbed laminae?) (weathers grayish orange 10 YR 7/4); fine to medium, moderately well-sorted, angular to subrounded skeletal wackestone with scattered packstone stringers up to 3 mm long and 3 cm thick; I/IIIA; argillaceous; with crinoid columnals, Ammodiscus, ramose and fenestrate bryozoan fragments, brachiopod spines, brachiopod? fragments; zone of medium light gray N6 to whitish, noncalcareous to slightly calcareous coalescive chert nodules 10 cm above base and 6 cm below top with whitish skeletal fragments; upper contact somewhat gradational; 31 cm thick.

20. Mudstone: light olive gray 5 Y 5/2 finely to coarsely mottled with olive gray 5 Y 3/2 (weathers yellowish gray 5 Y 8/1); darker in color than 19; calcareous; sandy; platy to flaggy; harder than below; with crinoid columnals, inarticulate brachiopod fragments and whole Orbiculoidea valves, whole Neochonetes valves, whole Aviculopecten valves, smooth-shelled ostracodes, echinoid spines, productid spines and fragments, whole Reticulatia brachial valves; abundant vertebrate skeletal debris near base; abundance of coarse invertebrate skeletal fragments decreases upward (fines upward); upper contact sharp; 38 cm thick.

Locality: P2
Location: West road cut of federal secondary highway, SW 1/4, NE1/4, NW1/4, Sec.23, T.8 S., R.7 E., Pottawatomie County, KS (Olsburg NW Quadrangle, 1964).
Units: Speiser Shale (units 1-16) and Threemile Limestone Member of the Wreford Limestone (unit 17) (the upper part of the Funston Limestone is exposed about 30 meters north of the measured section).
Notes: Approximately upper 1/3 of section is weathered; parts of section were covered and exposed by digging; measured by Christopher R. Cunningham (September, 1988).

3. Mudstone: slightly lighter and more greenish than light olive gray 5 Y 6/1 (weathers slightly lighter); calcareous; sandy; massive to platy (weathering?); dusky brown 5 YR 2/2 (pyritic?) staining on splitting planes; oblate flask-shaped vertical vertebrate (Gnathorhiza) burrows (as at Junction City locality) and vertebrate skeletal debris; black thread-like staining; upper contact sharp; 19.5 cm thick. (very similar in appearance to unit 1).



2. Argillaceous limestone: light gray N7 (weathers to slight light brownish gray 5 YR 6/1 cast); well-sorted mudstone; I/IIA; indet. cylinderical vertical burrows (could identify only in cross-section) and whole? vertebrate specimens oriented parallel to splitting; indet. smooth-shelled ostracodes; upper contact sharp; 8 cm thick.

1. Mudstone: slightly lighter and more green than light olive gray 5 Y 5/2 (weathers pale olive 10 Y 7/2); calcareous; very sandy; massive; joints with pale red 5 R 6/2 iron oxide staining; contains indet. vertical, cylinderical flask-shaped burrows, and vertebrate skeletal debris; top of 12 cm-long, well-preserved burrow 4.5 cm below top of unit; fine, faint, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; unit becomes harder and lighter in color upward (possible result of moisture content--base of unit in creek bed); upper contact sharp; 32 cm exposed--bottom covered.

8. Mudstone: dusky yellow green 5 GY 5/2 finely to coarsely mottled with grayish red 5 R 4/2 (dominantly green, becomes more red upward); slightly calcareous; sandy; hard; massive; blocky; green root casts; abundant slickensides; basal 5 cm slightly more friable and platy; upper contact sharp; 31 cm thick.

7. Siltstone: grayish red 5 R 4/2 with abundant fine to medium dusky yellow green 5 GY 5/2 root? mottles and root casts; noncalcareous to slightly calcareous; sandy; hard; massive; blocky; abundant slickensides; upper contact sharp; 35 cm thick.

6. Siltstone: basal 21 cm between grayish red 10 R 4/2 and moderate reddish brown 10 R 4/6; upper 29 cm grayish red 10 R 4/2 (weathers pale reddish brown 10 R 5/4); blocky to crumbly texture--basal 21 cm blockier; slightly calcareous at base becoming more calcareous upward; sandy; slickensides; whitish, chalky-weathering micrite nodules up to 3 cm across and fine to coarse pale olive 10 Y 6/2 to dusky yellow green 5 GY 5/2 root? mottling in upper 29 cm of unit--greenish mottles more calcareous than rest of unit; dusky yellow green 5 GY 5/2 root casts throughout; blackish, rounded granule-sized grains; upper contact gradational; 50 cm thick. (contact between upper and lower portion of unit sharp).

5. Mudstone: light olive gray 5 Y 5/2; calcareous; sandy; blocky to platy (weathering?); pinkish gray 5 YR 8/1 chalky micrite nodules (IIA) up to 2.5 cm in diameter--some stacked, some coalescive; slickensides; rounded to angular granule sized clasts of different lithologies including blackish, orangish, and moderate yellow green 10 GY 6/4 (chloritic?) grains; upper contact sharp; 30 cm thick.

4. Argillaceous limestone: pinkish gray 5 YR 8/1 (weathers pale red 5 R 6/2 to light brownish gray 5 YR 6/1); well-sorted mudstone; I/IIA; massive; dark yellowish orange 10 YR 6/6 to moderate yellow 5 Y 7/6 iron oxide staining; indet. vertical burrows and vertebrate skeletal debris; ledge former; dusky brown 5 YR 2/2 (pyritic?) staining within and at surface of unit; upper contact sharp; 13.5 cm thick.

13. Limestone: yellowish gray 5 Y 7/2 (weathers dusky yellow 5 Y 6/4); medium to coarse, moderately-sorted bivalve fragment, smooth-shelled ostracode wackestone (biomicrite); I/IIA; argillaceous; with whole high-spired gastropods, phylloid algal wisps, indet. smooth-shelled ostracodes; Ammodiscus, indet. bivalve fragments (some algal-coated), horizontal burrows up to 1.5 cm in diameter (slightly lighter, less fossiliferous micrite burrow fillings); subrounded dark yellowish orange 10 YR 6/6 micritic intraclasts up to 2 mm in diameter; chaotic allochem orientation (bioturbational?); basal 4 cm with flaggy splitting (upper part of unit massive) and at least 2 irregular hummocky surfaces--beds average 2 cm in thickness, although variable; upper contact sharp and irregular; 20 cm thick.

12. Mudstone: light olive gray 5 Y 5/2 with fine, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide mottling; noncalcareous to very slightly calcareous; sandy; massive; smooth-shelled ostracodes; basal part of unit with modern? whitish, friable, chalky to powdery, granular calcium carbonate, geodes, and crusts (due to surface weathering or groundwater?); upper contact sharp; 22 cm thick.

11. Mudstone: dusky yellow green 5 GY 5/2 with fine, sometimes thread-like, diffuse light olive brown 5 Y 5/6 mottling; noncalcareous to slightly calcareous; sandy; massive; blocky to crumbly texture; abundant slickensides; harder than 10; smooth-shelled ostracodes; carbonaceous debris and coatings on slickensides; upper contact sharp; 25 cm thick.

10. Mudstone: pale olive 10 Y 6/2; calcareous; sandy; massive to platy (weathering?); dark yellowish orange 10 YR 6/6 iron oxide staining; joints with black carbonaceous staining; smooth-shelled ostracodes; upper contact gradational; 59 cm thick

9. Mudstone: dark reddish brown 10 R 3/4 with dusky yellow green 5 GY 5/2 root casts, fine mottling and horizons; horizons less silty and sandy with sharp wavy contacts; horizons 4, 0.5, and 18 cm thick 23, 33, and 36 cm above base of unit; calcareous; sandy; massive; joints throughout; 82 cm thick; upper contact sharp; 82 cm thick. (green horizons due to gleying?)

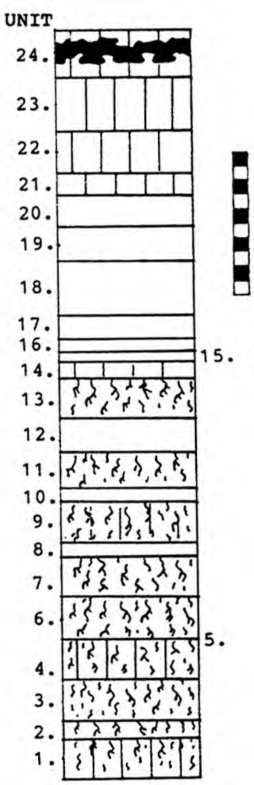
17. _Limestone_: yellowish gray 5 Y 7/2 with a slight brownish gray 5 YR 6/1 cast finely to coarsely mottled (bioturbational?) with medium gray N5 (density of gray mottling decreases upward) (weathers dark yellowish orange 10 YR 6/6); medium to coarse, moderately-sorted angular wackestone to packstone (biomicrite) with discontinuous packstone stringers up to 5 mm thick; argillaceous; with ramose and fenestrate bryozoan fragments; productid spines and fragments, crinoid columnals and plates, echinoid spines, indet. smooth-shelled ostracodes, _Ammodiscus_, indet. bivalve fragments, and _Globivalvulina_; zone of whitish-weathering, non-calcareous, fossiliferous coalescive chert nodules 5 cm below the top and 8 cm above the base upper contact somewhat gradational; 31 cm thick.

16. _Mudstone_: light olive gray 5 Y 5/2 (darker than below); calcareous; sandy; platy to flaggy (harder than unit below); harder at base; more brownish toward top (modern weathering effect?); very fossiliferous with _Orbiculoidea_ fragments, _Derbyia_ fragments; crinoid columnals, productid spines and fragments, and whole _Neochonetes_ valves; vertebrate skeletal debris including palaeoniscoid scales common near the base; upper contact sharp; 33 cm thick.

15. _Mudstone_: light olive gray 5 Y 5/2 to light olive brown 5 Y 5/6 (more brownish cast than 14); calcareous; slightly sandy; less silt and sand than 14; massive? to slightly crumbly (weathers slightly platy); friable; dark yellowish orange 10 YR 6/6 iron oxide staining; black carbonaceous debris; echinoid spines and plates, smooth-shelled ostracodes, productid spines, highly abraded/corroded ramose bryozoan fragments and indeterminate invertebrate skeletal debris; rounded calcareous granules (highly abraded/corroded invertebrate skeletal debris; upper contact sharp; 26 cm thick.

14. _Mudstone_: dusky yellow 5 Y 6/4; calcareous; sandy; friable; slightly platy (weathering?) to crumbly; fine dark yellowish orange 10 YR 6/6 iron oxide mottling; smooth-shelled ostracodes, highly abraded/corroded ramose bryozoan fragments and echinoid spines, productid spines, and black carbonaceous debris; abundant highly abraded/corroded indeterminate invertebrate skeletal fragments; rounded calcareous granules (abraded/corroded skeletal fragments?) upper contact sharp; 20 cm thick.

Locality: CORE (Amoco Production Company #1 Hargrave core)
Location: NE1/4, NE1/4, NE1/4, Sec.32, T.7 S., R.6 E., Riley Co., KS (Randolph Quadrangle, 1964).
Units: Speiser Shale (units 1-23) and Threemile Limestone Member of the Wreford Limestone (unit 24).
Notes: measured by Christopher R. Cunningham (July, 1988); top of core description at 324 feet 11 inches.



5. Gypsum (satin spar): fracture filling?; contacts sharp; 1 mm thick.

4. Dolomitic limestone: pale red 5 R 6/2 with fine to coarse moderate orange pink 10 R 7/4 mottling in upper 6.5 cm; dolomitic mudstone (calcilutite); I/IIIA; argillaceous; olive gray 5 Y 3/2 root casts; mudcracked? in upper part of unit; brecciated patches throughout; Skolithos?; with indet. invertebrate skeletal debris, bivalve fragments?, and ostracodes; massive?; upper part of unit brecciated with overlying unit infilling fractures; irregular fractures with gypsum; upper contact gradational; 27 cm thick.

3. Mudstone: dark reddish brown 10 R 3/4 with dusky yellow green 5 GY 5/2 root casts; calcareous; sandy; massive; upper contact gradational (due to root bioturbation?); 28.5 cm thick.

2. Mudstone: grayish olive green 5 GY 3/2 with dusky yellow green 5 GY 5/2 lensoidal clasts up to 1.5 cm long and root casts; calcareous; sandy; angular limestone clasts (as below) up to 3 cm long in lower 3/4 of unit; lower 4 cm of unit fragmented calcareous black mudstone with slickensides; upper contact gradational; at least 12.5 cm thick.

1. Limestone: yellowish gray 5 Y 7/2 with a slight greenish cast; well-sorted mudstone (calcilutite); I/IIIA; argillaceous; rhizobrecciated?; pale olive 10 Y 6/2 root casts; upper contact sharp; upper 27 cm examined.

11. Mudstone: grayish red 10 R 4/2; calcareous; sandy fine, faint, and diffuse dusky yellow green 5 GY 5/2 mottling and root casts; fractured texture?; upper contact gradational?; 23.5 cm thick.

10. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; upper part of unit fractured with overlying unit filling interstices; pyritic; fractured texture-fractures generally horizontally oriented and stained lighter dusky yellow green or grayish red 5 Y 4/2; upper contact gradational; at least 9 cm thick.

9. Mudstone to argillaceous limestone: olive gray 5 Y 5/1 with brownish gray 5 YR 4/1 and grayish olive green 3/2 root casts; calcareous, sandy, relatively hard mudstone to carbonate mudstone; fractured texture--generally horizontally oriented, irregular fractures stained slightly greenish or brownish gray 5 YR 4/1; upper contact sharp and irregular; 28 cm thick.

8. Mudstone: finely to coarsely and diffusely mottled with duskly yellow green 5 GY 5/2 and grayish red 5 R 4/2; fractured texture; dark reddish brown 10 R 3/4 horizon with diffuse contacts 1 cm thick 5 cm from top; upper contact sharp--top of unit brecciated; 10.5 cm thick.

7. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; grayish green 10 GY 5/2 root casts; coarse diffuse grayish red 5 R 4/2 mottling; fractured texture; fractures with grayish green 10 GY 5/2 and grayish red 5 R 4/2 staining; ostracodes; upper contact gradational; 27 cm thick.

6. Mudstone with limestone nodules: mudstone--olive gray 5 Y 3/2 finely to coarsely and diffusely mottled with blackish red 5 R 2/2; slightly calcareous; sandy; dusky yellow green 5 GY 5/2 and light olive gray 5 Y 6/1 root casts; micaceous; limestone nodules---slightly lighter than yellowish gray 5 Y 8/1 with slight olive cast; carbonate mudstone; argillaceous; dusky yellow green 5 GY 5/2 root casts; lumpy; fractured texture; nodules up to 8 cm long and 3 cm in diameter--generally with long axis vertical; upper contact gradational; 29.5 cm thick.

18. <u>Mudstone</u>: dusky yellow green 5 GY 5/2; calcareous; sandy; finely disseminated pyrite along irregular fractures; upper contact sharp?; 35.5 cm thick.

17. <u>Mudstone</u>: finely to coarsely and diffusely mottled with dusky yellow green 5 GY 5/2 and dusky red 5 R 3/4; calcareous; sandy; finely disseminated pyrite; upper contact somewhat gradational; 15 cm thick--end of core run.

16. <u>Mudstone</u> <u>and</u> <u>gypsum</u>: mudstone--dusky yellow green 5 GY 5/2; calcareous; sandy; fine dusky red root? mottling; at least 7.5 cm thick; gypsum (satin spar) --6 mm thick; unit 9 upper contact ?; thickness approximately 8 cm (core fragmented).

15. <u>Mudstone</u>: blackish red 5 R 2/2; calcareous; sandy; pyritic; upper contact gradational; 6 cm thick.

14. <u>Limestone</u> <u>breccia</u>: light greenish gray 5 GY 8/1 with dusky yellow green 5 GY 5/2 and blackish red 5 R 2/2 fracture fillings (red fracture fillings from above); argillaceous carbonate mudstone; I/IIA; clasts angular, from sand-sized to 2 cm in diameter; root? bioturbated; upper contact sharp, irregular, 10 cm thick.

13. <u>Mudstone</u>: blackish red 5 R 2/2 with a slight greenish cast; calcareous; sandy; becomes more greenish downward (at base dusky yellow green 5 GY 5/2 with maroonish cast and blackish red 5 R 2/2 root casts); unit projects into overlying unit--result of root bioturbation?; fractured texture; blackish red 5 R 2/2 root casts?; upper contact sharp; 26 cm thick.

12. <u>Mudstone</u>: grayish red 5 R 4/2; calcareous; sandy; fine, faint, and diffuse greenish mottling or blebs?; 0.1-0.2 mm thick algal? laminations; non-calcareous horizon 2 cm thick 2.5 cm above base that lacks laminations; brownish gray 5 YR 4/1 to grayish red 5 R 4/2, flat, angular to rounded laminated clasts up to 2 cm long and 2 mm thick (due to desiccation and reworking?; fractured texture?; upper contact gradational; 22. 5 cm thick.

22. Argillaceous limestone: dark gray N3, coarse, poorly-sorted, rounded wackestone (biomicrite); IA; very argillaceous; becomes less fossiliferous upward; with bivalve fragments (in all orientations including vertical), ostracodes, brachiopod spines and fragments, crinoid columnals, foraminiferids, ramose bryozoan fragments?; highly fossiliferous intraclasts? up to 2.5 cm in diameter; upper contact sharp; 29.5 cm thick.

21. Limestone: light olive gray 5 Y 6/1 coarse, moderately-sorted, angular ostracode bivalve wackestone (biomicrite); I/IIA; argillaceous; with biserial foraminiferids, bivalve fragments, ramose bryozoan fragments (in upper 2 cm), ostracodes, indet. foraminiferids, and phylloid algal wisps in basal 2 cm of unit; dolomitic; discontinuous medium gray N5 argillaceous partings up to 2 mm thick that increase in frequency toward the top; upper contact gradational; 13.5 cm thick.

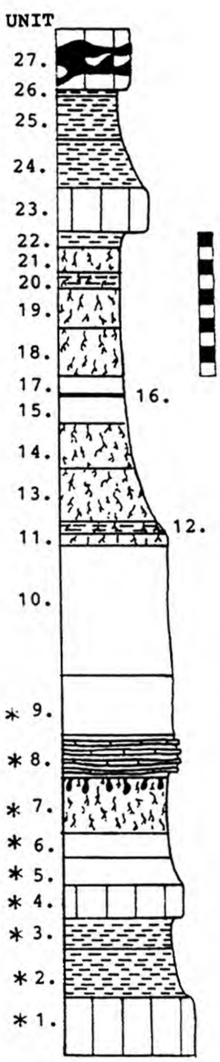
20. Mudstone breccia: light brownish gray 5 YR 6/1 to dark greenish gray 5 GY 4/1 with greenish gray 5 GY 6/1 subrounded to angular, sand-sized to 3 cm in diameter clasts; calcareous; dolomitic?; sandy; pyritic; becomes darker and greener toward the top; 1 to 3 mm-thick gypsum beds 2 cm from the base; basal 5 mm of unit continuously, thinly (0.1-0.5 mm) laminated; discontinuous, disrupted laminations throughout unit; upper contact sharp, irregular (due to clasts); 21 cm thick.

19. Mudstone: light greenish gray 5 GY 8/1; slightly calcareous; dolomitic?; sandy; brecciated; discontinuous, irregular dusky yellow green 5 GY 5/2 partings up to 1 mm thick and blebs up to 4 mm in diameter; patches of algally?-laminated dusky yellow green 5 GY 5/2 with sand-sized to 1 cm in diameter poorly-sorted, angular to subrounded, light greenish gray 5 GY 8/1 clasts, upper contact sharp?; 23.5 cm thick.

24. _Limestone_: light olive gray 5 Y 6/2, medium (at base) to fine (at top), moderately- to poorly-sorted, rounded wackestone (biomicrite); II/IA; argillaceous; with dark gray N3 discontinous, argillaceous, wavy laminations up to 1 mm thick; with crinoid columnals, productid fragments, bivalve fragments, sponge spicules?, whole high-spired gastropods, echinoid spines; fines upward; zone of coalescive chert beds 17 cm thick 7 cm from top; upper contact gradational; 32 cm thick.

23. _Argillaceous_ _limestone_: dark gray N3, very argillaceous, sandy, coarse, poorly-sorted, angular wackestone (biomicrite); IA; with crinoid columnals, brachiopod spines and fragments, ramose bryozoan fragments?, _Aviculopecten_? fragments, ostracodes, vertebrate skeletal debris; platy; lower contact sharp with flat, rounded clasts of underlying lithology up to 1.5 cm in diameter; intraclasts throughout; lower 21 cm more fossiliferous; fossils concentrated in lensoidal stringers and blebs up to 3 mm thick (placers or compaction features?); upper contact gradational; 36.5 cm thick.

Locality: RY3
Location: 0.1 miles west of the intersection of K-113 and US-24, SE1/4, SW1/4, SW1/4, Sec. 23, T. 9 S., R. 7 E., Riley Co., KS (Keats Quadrangle, 1947-55).
Units: Funston Limestone (1), Speiser Shale (2-26), and Threemile Limestone Member of the Wreford Limestone (27).
Notes: measured by Christopher R. Cunningham (June,1988); parts of section covered and exposed by digging.



3. Mudstone: light olive gray 5 Y 5/2; calcareous; slightly sandy; platy; moderate yellowish green 10 GY 6/4 waxy clay mineral present near base (chlorite?); contains smooth-shelled ostracodes, whole Straparollus-like gastropods, spirorbid fragments, palaeoniscoid teeth and scales; indet. vertebrate skeletal debris, and coprolites up to 2.5 cm long; upper contact sharp; 21.5 cm thick.

2. Mudstone: dominantly light olive gray 5 Y 5/2 with brownish black 5 YR 2/1 and dark yellowish orange 10 YR 2/1 beds (up to 5 cm thick), laminations and fine to coarse mottles; calcareous; slighty sandy; platy; with well-preserved Neuropteris, Pecopteris?; Cordaites fronds, spirorbids (spirorbids free and attached to plants); w/ Darwinula, Bairdia? (one fragmented specimen), palaeoniscoid teeth and scales, platysomoid? scales, and indet. Elasmobranchii dermal denticles; unit darker toward base; upper contact gradational; 34 cm thick.

1. Limestone: grayish orange 10 YR 7/4 (weathers slightly lighter to dark yellowish orange 10 YR 6/6); fine to medium, moderately to moderately well-sorted, angular wackestone (biomicrite); II/IA/B with scattered vertical burrow moldic C; argillaceous; with smooth-shelled ostracodes, Knightina, Ammovertella, spirorbids, high-spired gastropods, brachiopod spines and fragments, acanthodian scales, phyllodont tooth plate fragments, palaeoniscoid scales; upper contact sharp; 39 cm examined.

8. Interbedded argillaceous limestone and mudstone: mudstones--light olive gray 5 Y 3/2 (weathers greenish gray 5 GY 6/1); calcareous; sandy; mudcracked; with phyllodont tooth plate fragments, acanthodian scales, 1 palaeoniscoid tooth, 1 crushed, broken, indet. smooth shelled ostracode; upper part of unit with nodular weathering; limestones--yellowish gray 5 Y 8/1 (weathers same); well-sorted very fine calcarenite to coarse calcilutite; IIIA; mudcracked with scattered subrounded intraclasts of same lithology up to 1 cm long; with indet. bivalve fragments?, phyllodont tooth plate fragments, acanthodian scales, 1 Gnathorhiza tooth plate fragment, 1 Ammovertella- like foram?; massive; mudcracked; 4.0, 3.0, 1.0, and 1.0 cm-thick limestone beds 4.0, 13, 16, 20, and 21 cm above base; slightly lighter 2 mm-thick mudstone laminations throughout unit; upper contact sharp; 28 cm thick.

7. Mudstone: grayish red 5 R 4/2 (at base) to dark reddish brown 10 R 3/4 (upper 13 cm) faintly and diffusely mottled with grayish green 10 GY 5/2 (lower part of unit weathers pale red 5 R 6/2; upper part weathers grayish red 4/2); calcareous; sandy; massive; grayish green 10 GY 5/2 root casts; upper part of unit contains whole Gnathorhiza in burrows (oblate flasks); upper 1 cm of unit whitish; upper contact sharp and mudcracked; 38 cm thick.

6. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; massive; lightens in color upward; upper contact gradational; 16 cm thick.

5. Mudstone: olive gray 5 Y 3/2; calcareous; slightly sandy; upper 6 cm with yellowish brown cast, platy (weathering?), siltier, with fine, irregular to thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; 1 cm from top 5 mm-thick whitish, calcareous (micritic) bed (fracture filling?); upper contact sharp; 17 cm thick.

4. Limestone: finely to mediumly mottled with slightly more brown than yellowish gray 5 Y 7/2 and dark gray N3; light brownish gray 5 YR 4/1 (weathers pale yellowish brown 10 YR 6/2); poorly-sorted, subrounded biointramicrudite; I/IIA; argillaceous; algal-coated algally? wavy microlaminated intraclasts up to 5 mm in diameter (flat pebble morphology); w/ smooth-shelled ostracode fragments, 1 possible algal-coated Globivalvulina?, spirorbids; indeterminate vertebrate skeletal debris; upper contact sharp; 23 cm thick.

16. Mudstone: grayish red 5 R 4/2 (weathers slightly lighter); calcareous; sandy; massive; nodular weathering; dusky yellow green 5 GY 5/2 root casts and fine to medium (root?) mottling; upper contact sharp; 1.5 cm thick.

15. Mudstone: pale greenish yellow 10 Y 8/2 with fine to medium, sometimes thread-like dusky yellow green 5 GY 5/2 root casts and mottling; medium yellowish brown 10 YR 5/2 mottling; calcareous; massive; upper contact sharp; 18 cm thick.

14. Mudstone: pale red 5 R 6/2 (at base) to grayish red 5 R 4/2 at top; calcareous; slightly sandy; massive; silt content increases upward; 10 cm-thick greenish zone 8 cm from top; greenish root casts throughout; upper contact sharp; 30 cm thick.

13. Mudstone: pale red 5 R 6/2 at base becoming grayish red 5 R 4/2 at top; calcareous; slightly sandy; massive; silt content deacrease upward; greenish root casts; upper contact sharp; 35.5 cm thick.

12. Mudstone: grayish yellow green 5 GY 7/2 with fine to medium dark reddish brown 10 R 3/4 root casts and mottling; calcareous; slightly sandy; upper contact sharp; 8 cm thick.

11. Calcareous mudstone to argillaceous limestone: yellowish gray 5 Y 7/2 with fine dark reddish brown 10 R 3/4 root casts and mottling; calcareous; sandy; hard (ledge former); weathers platy; upper contact sharp; 7.5 cm thick.

10. Mudstone: pale olive 10 Y 6/2 (with a slight reddish cast); calcareous; relatively low silt content; massive; weathers platy to nodular; upper contact sharp; 89 cm thick.

9. Mudstone: grayish yellow green 5 GY 7/2 becoming reddish upward (the result of increased density of fine, thread-like dusky red 5 R 3/4 root(?) mottling; calcareous; slightly sandy; unit contains interbedded lighter mudstone laminae ranging from 2 to 5 mm in thickness; becomes siltier upward; nodular to slabby weathering; upper contact sharp (an exposure surface?); 39 cm thick.

22. Mudstone: yellowish gray 5 Y 7/2 (weathers slightly lighter); calcareous; sandy; platy weathering; with smooth-shelled ostracodes; upper contact sharp; 10 cm thick.

21. Mudstone: grayish olive 10 Y 4/2 (weathers slightly lighter); calcareous; relatively low silt content; slightly sandy; massive; fine, thread-like yellowish brown 10 YR 5/2 root casts and mottling; upper contact sharp; 16 cm thick.

20. Mudstone: yellowish gray 5 Y 7/2 (weathers slightly lighter); calcareous; slightly silty; platy; dusky yellow green 5 GY 5/2 root casts; fine yellowish brown 10 YR 5/2 mottles; upper contact sharp; 11 cm thick.

19. Mudstone: grayish olive 10 Y 4/2 (weathers slightly lighter); calcareous; relatively low silt content; massive; lightens in color upward; yellowish brown 10 YR 52 root casts; upper contact sharp with dark yellowish orange 10 YR 6/6 iron oxide staining; 26 cm thick.

18. Mudstone: pale olive 10 Y 6/2 (weathers slightly lighter); calcareous; relatively low silt content; massive to platy (weathering); fine to medium yellowish brown 10 YR 5/2 mottling; dark yellowish orange 10 YR 6/6 iron oxide staining on splitting planes; dusky yellow green 5 GY 5/2 root casts; upper contact sharp with dark yellowish orange 10 YR 6/6 iron oxide staining; 33 cm thick.

17. Mudstone: grayish olive 10 Y 4/2 (weathers slightly lighter); calcareous; massive; relatively low silt content; slabby to nodular weathering; upper contact gradational; 12 cm thick.

27. _Limestone_: yellowish gray 5 Y 8/1 (weathers grayish orange 10 YR 7/4); coarse; moderately-sorted, angular wackestone to packstone (biomicrite); IIIA; with echinoid spines, crinoid columnals, _Composita_ fragments, ramose bryozoan fragments, indeterminate productid and bivalve fragments; zone of coalescive chert beds 20 cm thick 10 cm from the base; upper contact sharp; 36 cm thick.

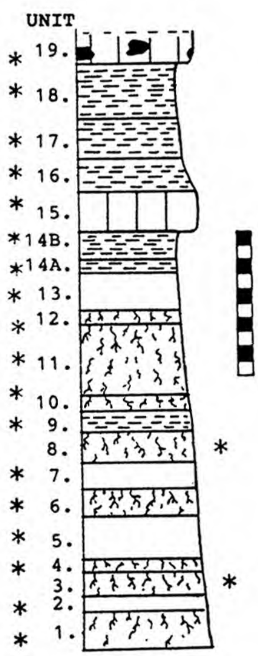
26. _Mudstone_: similiar to unit 25; with ostracodes, productid fragments; crinoid columnals, and _Aviculopecten_ fragments; upper contact sharp; 4.5 cm thick.

25. _Mudstone_: pale olive 10 Y 6/2 (weathers yellowish gray 5 Y 8/1); calcareous; hard; platy; sandy; more fossiliferous than below with crinoid columnals and plates, ostracodes, whole _Straparollus_-like planispiral gastropods, echinoid spines; whole _Orbiculoidea_ valves, _Aviculopecten_ fragments, ramose bryozoan fragments, _Neochonetes_ valves, and _Derbyia_ fragments; upper contact gradational; 27.5 cm thick.

24. _Mudstone_: yellowish gray 5 Y 7/2 (slightly more brownish than below) (weathers slightly lighter); calcareous; sandy; hard; platy to flaggy; with ostracodes, _Aviculopecten_ fragments, echinoid spines, indet. bivalve fragments, fenestrate bryozoan fragments; inarticulate brachiopod fragments, and vertebrate skeletal debris; upper contact gradational; 30 cm thick.

23. _Limestone_: lower 8 cm--dusky yellow 5 Y 6/4 (weathers grayish orange 10 YR 7/4); medium, moderately-sorted, angular wackestone to packstone (biomicrite); III/IA; argillaceous; platy; sandy; with horizontal burrows up to 4 cm in diameter, ostracodes, and indeterminate invertebrate and vertebrate skeletal debris; upper 22 cm of unit--yellowish gray 5 Y 7/2 (weathers grayish orange 10 YR 7/4); coarse, moderately-sorted, angular wackestone (biomicrite); III/IA; argillaceous; with bivalve (_Aviculopecten_?) fragments, ostracodes; vertebrate skeletal debris including palaeoniscoid teeth, and horizontal burrows averaging 7 mm in diameter; upper portion of unit mostly massive (bioturbated?); some evidence of hummocky bedding surfaces and 2.5 cm-thick beds; upper contact gradational; 30 cm thick.

Locality: TW
Location: East side of road cut on K-113, 1.0 miles north of the intersection of K-113 and Kimball Street; NE1/4, NE1/4, NW1/4, Sec.2, T.10 S., R.7 E., Riley Co., KS (Manhattan Quadrangle, 1982).
Units: Speiser Shale (units 1-18) and Threemile Limestone Member of the Wreford Limestone (unit 19).
Notes: measured by Christopher R. Cunningham (June, 1988).



3. Mudstone: grayish red 5 R 4/2 (weathers pale brown 5 YR 5/2); calcareous; slightly sandy; blocky; slickensides with moderate yellow 5 Y 7/6 to dark yellowish orange 10 YR 6/6 iron oxide staining; carbonaceous (plant?) fragments; dusky yellow green 5 GY 5/2 root casts; with indet. smooth-shelled ostracode (*Paraparchites*?), and indet. invertebrate skeletal debris; upper contact irregular (due to root bioturbation?); 14 cm thick.

2. Mudstone: dusky yellow green 5 GY 5/2 (weathers light olive gray 5 Y 5/2); calcareous; slightly sandy; massive; moderate yellow 5 Y 7/6 to dark yellowish orange 10 YR 6/6 thread-like iron oxide staining throughout; sand-sized, friable, carbonaceous, possibly pyritic grains (plant fragments?); indet. vertebrate and invertebrate skeletal debris; upper contact gradational; 10 cm thick.

1. Mudstone: blackish red 5 R 2/2 (weathers grayish red 5R 4/2); slightly calcareous; slightly sandy; blocky; relatively hard; slickensides; greenish root casts (particularly abundant in upper 5 cm); thread-like moderate yellow 5 Y 7/6 to dark yellowish orange 10 YR 6/6 iron oxide staining throughout; with *Thamniscus* fragment, 1 smooth-shelled ostracode, and indet. invertebrate skeletal debris; upper contact sharp; 25 cm exposed--bottom covered.

9. Mudstone: grayish green 10 GY 5/2 (weathers yellowish gray 5 Y 7/2); calcareous; slightly sandy; platy; fine to medium dusky yellowish green 10 GY 3/2 circular (root?) mottling that is preferentially? associated with platiness; friable, carbonaceous, possibly pyritic, sand-sized grains (plant fragments?); upper contact sharp; 14 cm thick.

8. Mudstone: dark reddish brown 10 R 3/4 (weathers moderate reddish brown 10 R 4/6); calcareous; slightly sandy; friable; platy; greenish root casts and fine mottling; upper contact sharp; 20 cm thick.

7. Mudstone: approximately grayish red purple 5 RP 4/2; becoming greener upward (weathers pale yellowish brown 10 YR 6/2); medium to coarse dusky yellow green 5 GY 5/2 mottling in upper 7.5 cm; fine to medium blackish red 5 R 2/2 (root?) mottling in lower part of unit; calcareous; slightly sandy; massive; weathers platy; friable, sand-sized carbonaceous, possibly pyritic grains (plant fragments?); upper contact gradational; 18 cm thick.

6. Mudstone: blackish red 5 R 2/2 (weathers pale red 10 R 6/2); calcareous; slightly sandy; massive; weathers platy; becomes orangish upward; greenish root casts; becomes more massive upward; subtle greenish fine to medium (root?) mottling; with indet. spines (brachiopod?) and ostracodes; upper contact sharp; 18 cm thick.

5. Mudstone: dusky yellow green 5 GY 5/2 at base gradually becoming more reddish upward (weathers yellowish gray 5 Y 7/2); calcareous; slightly sandy; massive; thread-like moderate yellow 5 Y 7/6 to dark yellowish orange 10 YR 6/6 iron oxide staining; weathers to thicker blocks than overlying unit; root casts; friable, fine sand-sized, carbonaceous, possibly pyritic grains (plant fragments?); upper contact gradational; 28 cm thick.

4. Mudstone: dusky yellow green 5 GY 5/2 coarsely mottled with grayish red 5 R 4/2 (weathers light olive gray 5 Y 5/2); calcareous; slightly sandy; blocky; greenish root casts; moderate yellow 5 Y 7/6 to dark yellowish orange 10 YR 6/6 iron oxide staining along slickensides and in fine to medium mottles; friable, sand-sized, carbonaceous, possibly pyritic grains (plant fragments?); upper 3 mm red 5 R 2/2 and iron-stained; upper contact sharp; 8 cm thick.

13. Mudstone: pale olive 10 Y 6/2 finely mottled with dark yellowish orange 10 YR 6/6 (weathers yellowish gray 5 Y 7/2); calcareous; sandy; scattered platiness (weathering feature?); calcareous nodule 2.5 cm across; friable carbonaceous, possibly pyritic, sand-sized grains (plant fragments?); with brachiopod spines, smooth-shelled ostracodes, and Ammovertella; upper contact sharp; 24 cm thick.

12. Mudstone: grayish red purple 5 RP 4/2 with medium to coarse grayish yellow green 5 GY 7/2 and fine, sometimes thread-like grayish yellow 5 Y 7/2 mottling; calcareous; sandy; massive to platy (weathering); friable, carbonaceous, possibly pyritic, sand-sized grains (plant fragments?); yellowish root casts?; friable carbonaceous (plant?) debris concentrated along splitting planes; with 2 brachiopod spines; upper contact gradational (bioturbational?); 9 cm thick.

11. Mudstone: greenish gray 5 GY 4/1 with a slight maroonish cast that becomes more pronounced upward; upper 8 cm approximately grayish red purple 5 RP 4/2 with fine to medium greenish gray 5 G 6/1 mottles; fine dusky yellow 5 Y 6/4 mottling throughout, although more pronounced at base and top of unit; calcareous; sandy; blocky; scattered platiness (weathering feature); iron oxide staining preferentially associated with slickensides and root casts; carbonaceous (plant?) fragments along slickensides and splitting planes; fine dark green circular (root?) mottling preferentially? associated with platiness; friable, sand-sized, carbonaceous, possibly pyritic grains (plant fragments?); upper contact gradational and irregular (bioturbational?); 48 cm thick.

10. Mudstone: dusky yellow green 5 GY 5/2 (weathers yellowish gray 5 Y 7/2); slightly calcareous; slightly sandy; blocky; dusky yellowish green 10 GY 3/2 root casts; slickensides; carbonaceous (plant?) fragments; fine, circular dusky yellowish green 10 GY 3/2 (root?) mottling; scattered platiness throughout unit (weathering feature?); thread-like dark yellowish orange 10 YR 6/6 to moderate yellow 5 Y 7/6 iron oxide staining, and subtle, fine dusky yellow 5 Y 6/4 mottling; with indet. invertebrate skeletal fragment; upper contact sharp; 10 cm thick.

15. Limestone: yellowish gray 5 Y 7/2 (weathers grayish yellow 5 Y 8/4) fine, moderately-sorted, subrounded ostracode biomicrite (wackestone); III/IA with scattered B and C which is commoner near base; argillaceous; bedding and splitting (platy to flaggy) thickness increases upward from 2 mm to 4 cm; with smooth-shelled ostracodes, Aviculopecten fragments, Septimyalina fragments, Ammovertella, phyllodont tooth plate fragments, palaeoniscoid teeth, 1 Cavusgnathus Pa element, echinoderm fragments, tetrapod limb bone fragments, ramose bryozoan fragments, whole high-spired gastropods; Planolites up to 4 cm in diameter in lower part of unit, and indet. bivalve fragments; granule-sized micrite intraclasts; some beds with hummocky or oscillation ripple-marked surfaces; upper contact gradational and irregular; 25 cm thick.

14B. Mudstone: pale olive 10 Y 6/2 with fine moderate yellow 5 Y 7/6 to dark orangish yellow 10 YR 6/6 iron oxide mottling (becomes more yellowish upward); calcareous; sandy; coarsens upward; platy; with smooth and ornamented ostracodes, Ammovertella, charophyte oogonia, spirorbid fragments, fragment of phyllodont tooth plate, acanthodian scale fragment, and echinoid spine fragments; indications of 0.5-1 mm thick grayish laminations (disturbed by bioturbation?); friable carbonaceous (plant?) fragments; upper contact sharp; 18 cm thick.

14A. Mudstone: pale olive 10 Y 6/2 with fine moderate yellow 5 Y 7/6 to dark yellowish orange 10 YR 6/6 iron oxide mottling; calcareous; sandy; platy; friable; 1-2 mm thick grayish laminations; friable carbonaceous (plant?) fragments; with smooth-shelled ostracodes and spirorbid fragments; upper contact gradational (14A slightly darker than 14B); 8 cm thick.

17. Mudstone: light olive gray 5 Y 5/2 with fine dusky yellow 5 Y 6/4 mottling (more densely mottled than 16); calcareous; sandy; platy; calcareous nodules up to 2.5 cm in diameter; with Bairdia, Kellettina, Knightina, Amphissites, Hollinella, large indet. bairdiid, indet. ornamented ostracode, Ditomopyge fragments, echinoid spines and plates, crinoid columnals and plates, Acanthopecten fragments, Aviculopecten valves and fragments, whole articulated Edmondia?, Thamniscus fragments, Penniretepora fragments, fenestrate bryrozoan fragments (Fenestella?), indet. highly-branched ramose bryozoan fragments, siliceous sponge spicules, holothurian sclerites (hooks), 2 platform conodont elements, whole Neochonetes valves and fragments, Orbiculoidea fragments, Lingula fragments, Derbyia fragments, whole valves small ribbed chonetid, productid spines, fragments and whole small valves, acanthodian scales, phyllodont tooth plate fragments, indet. elasmobranchii dermal denticles, 1 palaeoniscoid tooth, pellets?; friable, carbonaceous, possibly pyritic sand-sized grains (plant fragments?); gypsum nodules up to 0.5 cm in diameter; upper contact gradational; 27 cm thick.

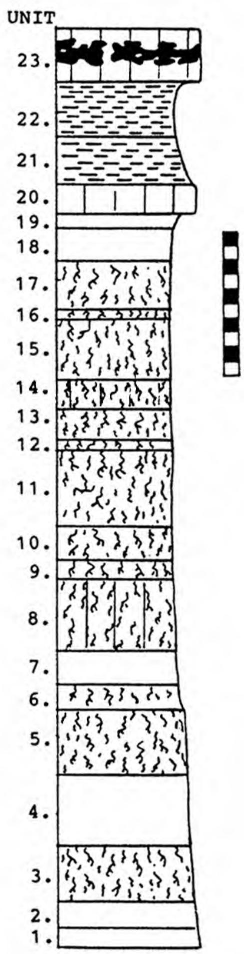
16. Mudstone: yellowish gray 5 Y 7/2 with fine to medium dusky yellow 5 Y 6/4 mottles; calcareous, sandy; calcareous nodules; platy; friable; friable, carbonaceous, possibly pyritic sand-sized grains (plant fragments?); with Bairdia, Kellettina, indet. ostracode (Paraparchites?), Whipplella, Knightina, indet. textured Hollinella-like ostracode, indet. large bardiid, 2 indet. smooth-shelled ostracodes (1 cyprid?; 1 darwinulid?), echinoid plates and spines, crinoid plates, whole articulated bivalves (Edmondia?), indet. bivalve fragments, Acanthopecten fragments, spirorbids, Ammovertella, Globivalvulina, Tetrataxis, siliceous sponge spicules, whole high-spired gastropods (3 types), low-spired gastropods (2 types), Thamniscus fragments, Leioclema fragments, fenestrate bryozoan fragments (Fenestella?), indet. highly-branched ramose bryozoan fragments, 1 articulated, fragmented Composita, whole Derbyia pedicle valves, small ribbed chonetid valve, productid spines, fragments and whole small branchial valve, holothurian sclerites (hooks and wheels), charophyte oogonium, and 1 phyllodont tooth plate fragment; upper contact sharp and iron-stained (dark yellowish orange 10 YR 6/6); 22 cm thick.

18. Mudstone: light olive gray 5 Y 5/2 with fine dusky yellow 5 Y 6/4 mottling, and fine to medium medium dark gray N4 mottling; calcareous; sandy; platy; basal 13 cm (sample TW-18A) with Bairdia, Cavellina?, Amphissites, Knightina, Ditomopyge fragments, echinoid spines and plates, crinoid columnals and plates, holothurian sclerites (hooks), conodont elements (2 platform; 4 ramiform), siliceous sponge spicules, chambered sponge resembling Amblysiphonella, Orbiculoidea fragments, Lingula fragments, whole Neochonetes valves and fragments, whole articulated crushed Wellerella, Enteletes fragments, Derbyia(?) fragments, productid spines and fragments, whole high-spired and low-spired gastropods, Aviculopecten fragments, Acanthopecten fragments, whole, articulated Edmondia?, Thamniscus fragments, Leioclema fragments, Penniretepora fragments, fenestrate bryozoan fragments (Fenestella?), indet. bryozoan encrusting on chonetid fragment, acanthodian scales, indet. Elasmobranchii dermal denticles from mouth cavity or gills (and other), Cladodus-type teeth, palaeoniscoid teeth, pellets?; middle 13 cm (sample TW-18B) with Amphissites, Knightina, Knoxina?, large, indet. smooth-shelled ostracode fragments, Hollinella, Bairdia, Ditomopyge fragments, echinoid spines and plates, crinoid spines and plates, holothurian sclerites (hooks), siliceous sponge spicules, Aviculopecten valves and fragments, high-spired gastropods, annelid tube, Tetrataxis, Thamniscus; Leioclema; Penniretopora?; and fenestrate (Fenestella?) fragments, indet. bryozoan encrusting on productid fragment, whole, articulated small Composita, Neochonetes valves and fragments, large (up to 5 cm across) whole (in non-life position) and fragmented Reticulatia, Lingula fragment with attached Petrocrania, Derbyia fragments and whole, articulated small individuals, productid spines and fragments, acanthodian scales, indet. Elasmobranchii dermal denticles, 2 Cladodus-type teeth; upper 13 cm (sample TW-18C) with Amphissites, Kellettina, Knightina, Bairdia, large indet. bairdiid, whole and fragmented Ditomopyge, indet. textured ostracode, echinoid spines and plates, crinoid columnals and plates, holothurian sclerites (hooks and wheels), 1 platform conodont element, siliceous sponge spicules, chambered Amblysiphonella-like sponge, Tetrataxis, Aviculopecten valves and fragments, whole, articulated Edmondia?, Thamniscus; Leioclema; Penniretepora?; Polypora?; indet. highly branched

bryozoan; indet. encrusting on whole, crushed Derbyia adult; fenestrate (Fenestella?) fragments, whole pedicle valve small Composita, whole, articulated small and large Derbyia and fragments, Neochonetes valves and fragments, Wellerella? fragments, productid spines, fragments, and whole small branchial valve; and acanthodian scales; upper 1 cm of unit with Bairdia, Kellettina, indet. reticulate ostracode, Ditomopyge fragments, echinoid spines and plates, crinoid columnals, spirorbids, Tetrataxis, non-coiled annelid tube?, whole high-spired gastropod, Acanthopecten fragments, Aviculopecten fragments, Septimyalina? fragments, Polypora?; Penniretepora?; Leioclema?; fenestrate bryozoan (Fenestella?) fragments; whole valve indet. ribbed chonetid, pedicle valves small Derbyia, whole, articulated, crushed Composita, productid (large) fragments, indet. Elasmobranchii dermal denticles (complex), palaeoniscoid tooth and scale fragment, phyllodont tooth plate fragment; upper contact sharp; 39 cm thick.

19. Limestone: medium, moderately-sorted, angular to rounded biomicrite (mudstone to wackestone) with irregular, somewhat indistinct, discontinuous yellowish gray 5 Y 7/2 and medium light gray N6 laminations approximately 2 to 5 mm thick (weathers dusky yellow 5 Y 6/4); II/IA with scattered B and C gypsum crystal molds?; argillaceous; with lensoid wackestone to packstone stringers (placers?) up to 3 mm thick and 5 cm long (placers usually in yellowish gray laminae; discontinuous algal laminae; algal-coated forams including *Globivalvulina*; possible ripple-marked surfaces; with ostracodes, whole and fragmented trilobites, echinoid spines, crinoid columnals, *Ammodiscus*, *Ammovertella*, siliceous sponge spicules, fenestrate and ramose? bryozoan fragments, productid spines?, whole, crushed *Composita*?, whole high-spired gastropods, indet. bivalve fragments; silicified *Wellerella* fragments, whole, articulated silicified *Crurithyris*, palaeoniscoid scales and teeth, acanthodian scales, indet. Elasmobranchii dermal denticles; scattered chert nodules up to 8 cm in diameter; 20 cm thick.

Locality: KEATS
Location: stream cut of Kitten Creek, NW1/4, SE1/4, Sec.36, T.9 S., R.6 E., Riley County, KS (Keats Quadrangle, 1947-1955).
Units: Speiser Shale (units 1-22) and Threemile Limestone Member of the Wreford Limestone (unit 23).
Notes: measured by Christopher R. Cunningham (November, 1988); interval mostly covered and exposed by digging; introduced to outcrop by Dr. Hans-Peter Schultze.



4. Mudstone: light olive gray 5 Y 5/2; calcareous; sandy; massive to platy (weathering?); vertebrate skeletal debris; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 to dusky yellow 5 Y 6/4 iron oxide staining; fine dusky yellow green 5 GY 5/2 mottling; upper contact sharp (although lithologies above and below very similar); 48 cm thick.

3. Siltstone: dark reddish brown 10 R 3/4 with pale olive 10 Y 6/2 root casts and fine to coarse mottling; calcareous; sandy; very hard; massive; upper contact sharp; 36 cm thick.

2. Mudstone to siltstone: finely and diffusely mottled with dark reddish brown 10 R 3/4 and light olive gray 5 Y 5/2; slightly calcareous; sandier than unit 1; massive; slightly platy weathering; becomes redder upward; upper contact gradational; 17 cm thick.

1. Mudstone: slightly lighter and more greenish than light olive gray 5 Y 5/2; calcareous; sandy; massive to nodular; slightly platy weathering; faint, diffuse, fine light brownish gray 5 YR 6/1 to dark reddish brown 10 R 3/4 mottling; vertebrate skeletal debris; upper contact gradational; 12 cm examined.

10. Argillaceous limestone: light olive gray 5 Y 6/1 with grayish red 5 R 4/2 root casts; well-sorted carbonate mudstone; I/IIA; finely to coarsely and very diffusely mottled with grayish red 5 R 4/2 in basal 2/3, becoming more dominantly greenish upward; scattered fine dusky yellow green 5 GY 5/2 mottling; upper contact somewhat gradational; 22 cm thick.

9. Mudstone to siltstone: grayish red 10 R 4/2 with light olive gray 5 Y 6/1 and dark reddish brown 10 R 3/4 root casts; calcareous; sandy; massive; upper contact slightly gradational; 12 cm thick.

8. Argillaceous limestone: very light gray N8 with a slight olive cast with pale brown 5 YR 3/2 root casts and very diffuse, faint mottling (weathers light brown 5 YR 6/4); well-sorted carbonate mudstone; I/IIA; massive; density of root casts increases in upper part of unit; platy to flaggy splitting; upper contact gradational; 49 cm thick.

7. Mudstone (at base) to siltstone (at top): basal 7 cm dusky yellow green 5 GY 5/2; basal 1.5 cm discontinuously laminated (0.1 to 1.0 mm thick) with dusky yellow green 5 GY 5/2 and pale olive 10 Y 6/2; unit becomes grayish red 5 R 4/2 finely and diffusely mottled with light olive gray 5 Y 6/1 upward; calcareous; sandy; calcareous, fine to very coarse, subrounded to rounded pinkish gray 5 YR 8/1 and light brownish gray 5 YR 6/1 clasts on lamination bedding planes (mostly associated with pale olive laminations) and scattered throughout massive part of unit; upper contact gradational; 23 cm thick.

6. Mudstone to siltstone: grayish red 5 R 4/2 becoming dark reddish brown 10 R 3/4 upward with fine, very diffuse dusky yellow green 5 GY 5/2 mottling and root casts throughout; slightly calcareous; sandy; hard; massive; upper contact sharp; 17 cm thick.

5. Mudstone: yellowish gray 5 Y 7/1 to greenish gray 5 G 6/1 (moderate brown 5 YR 3/4 to 5 YR 4/4 iron oxide staining on weathered surfaces); slightly calcareous to calcareous; sandy; massive and hard; conchoidal fracture; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; spar-filled veins up to 3 mm thick; minor bench-former; upper 5 cm less indurated, platy to crumbly (weathering?) mudstone with dusky yellow green 5 GY 5/2 root casts and smooth- shelled ostracodes; upper contact sharp; 43 cm thick.

17. Mudstone to siltstone: pale olive 10 Y 6/2; calcareous; sandy; massive to platy (weathering); fine to thread-like dark yellowish orange 10 YR 6/6 iron oxide staining (more than 15); dusky yellow green 5 GY 5/2 root casts; upper contact gradational; 33 cm thick.

16. Mudstone to siltstone: dusky yellow green 5 GY 5/2 to greenish gray 5 GY 6/1 with fine light olive brown 5 Y 5/6 and fine to coarse diffuse brownish gray 5 YR 4/1 mottling (dusky brown 5 YR 6/6 oxide staining on weathered surfaces); noncalcareous; very sandy; massive; dusky yellow green 5 GY 5/2 root casts; upper contact sharp; 5 cm thick.

15. Mudstone to siltstone: pale olive 10 Y 6/2 with dusky yellow green 5 GY 5/2 root casts; calcareous; sandy; massive to platy (weathering); moderate brown 5 YR 4/4 to dusky brown 5 YR 2/2 iron oxide staining on splitting planes; angular clasts of above lithology up to 1 cm long; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 41 cm thick.

14. Argillaceous limestone to mudstone: light greenish gray 5 GY 8/1 with pale olive to dusky yellow green 5 GY 5/2 root casts; well-sorted carbonate mudstone (II/IA) to mudstone; sandy; massive; fine to coarse, pinkish angular grains; upper contact gradational; 20 cm thick.

13. Mudstone to siltstone: grayish red 10 R 4/4 with pale olive 10 Y 6/2 to dusky yellow green 5 GY 5/2 root casts; calcareous; sandy; massive; upper contact gradational; 21 cm thick.

12. Mudstone: dusky yellow green 5 GY 5/2 with scattered fine to coarse grayish red mottles (dusky yellow green 5 GY 5/2 root casts in mottles); calcareous; sandy; massive to nodular; vertebrate skeletal debris; upper contact gradational; 6.5 cm thick.

11. Mudstone to siltstone: grayish red 10 R 4/2 with pale olive 10 Y 6/2 root casts and very diffuse to distinct fine to coarse mottles; calcareous; sandy; massive; band of dark yellowish orange 10 YR 6/6 iron oxide staining up to 5 mm thick approximately 1 cm below upper contact; upper contact sharp, irregular (root bioturbational?); 52 cm thick.

21. Argillaceous limestone to calcareous mudstone: yellowish gray 5 Y 7/2 finely to coarsely and diffusely mottled with medium gray N5 (weathers yellowish gray 5 Y 7/2 to pale olive 10 Y 6/2); very coarse, poorly-sorted, angular wackestone (biomicrudite); I/IIA; bedding thickness averages 5 mm?; flaggy to platy splitting; with whole Aviculopecten valves, whole Derbyia pedicle and brachial valves (convex up); large productid fragments and spines; crinoid columnals, indet. ostracodes, whole Permophorus valves, ramose bryozoan fragments, large, whole articulated bivalves (pinnid?) in upright (life?) position; becomes more argillaceous and friable upward; density of mottling increases upward; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact somewhat gradational; 32 cm thick.

20. Limestone: grayish yellow 5 Y 7/2 finely to coarsely (burrow?) mottled with light olive gray 5 Y 5/2 (weathers pale yellowish brown 10 YR 6/2 to dark yellowish orange 10 YR 6/6); medium to coarse, moderately to poorly-sorted, subrounded to subangular lithic skeletal wackestone; argillaceous; III/IA; with smooth-shelled ostracodes, Ammovertella, large (up to 25 cm long) pinnid? fragments; ramose bryozoan fragments; indet. bivalve fragments, whole high-spired gastropods; Planolites up to 7 mm in diameter, whole? pectenid bivalve valves; intraclasts dark yellowish orange 10 YR 6/6 and up to 6 mm long; allochems more densely concentrated in lensoid stringers; shell fragments in all orientations; generally massive texture with stringers; upper contact sharp; 19 cm thick.

19. Mudstone to siltstone: yellowish gray 5 Y 7/2; calcareous; sandy; slabby to platy (weathering); coarse sand-sized pale olive 10 Y 6/2 grains; indet. smooth-shelled ostracodes; fine to thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; black carbonaceous staining and fragments; upper contact sharp; 9 cm thick.

18. Mudstone to siltstone: pale olive 10 Y 6/2 with fine to coarse, diffuse dark yellowish orange 10 YR 6/6 iron oxide mottling; calcareous; sandy; massive; platy (weathering) with iron oxide staining on splitting planes; dusky brown 5 YR 2/2 plant? fragments; upper contact sharp?; 22 cm thick.

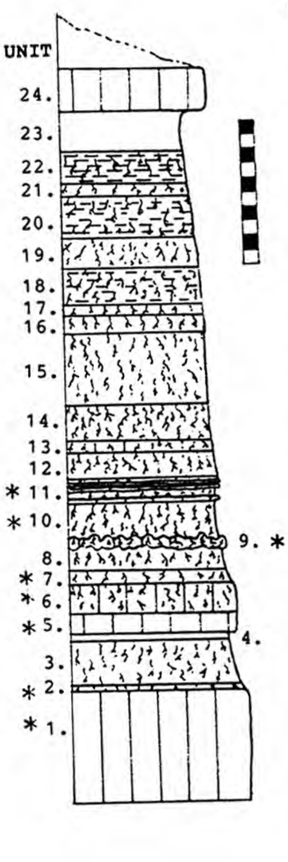
23. Limestone: yellowish gray 5 Y 7/2 with medium gray N5 stringers up to 2 mm thick that decrease in abundance upward (weathers grayish orange 10 YR 7/4 to dark yellowish gray 10 YR 6/6); medium to coarse, moderately to poorly-sorted, subangular to subrounded skeletal wackestone; III/IA; argillaceous; with brachiopod spines, crinoid columnals, 1 large productid pedicle valve (convex up); ramose and fenestrate bryozoan fragments; compacted Planolites?; echinoid spines; some allochems concentrated in discontinuous packstone stringers up to 3 mm thick; irregular zone coalescive chert of variable thickness averaging 13 thick 17 cm above base of upper contact sharp; 37 cm thick.

22. Mudstone: finely to coarsely mottled with yellowish gray 5 Y 7/2 and medium gray N5 (weathers yellowish gray 5 Y 7/2 to pale olive 10 Y 6/2); calcareous; sandy; basal 5 cm platy to splintery with abundant inarticulate brachiopod fragments (Orbiculoidea?), whole Straparollus-like gastropods, whole Derbyia valves, and crinoid columnals; middle 7 cm more slabby splitting (minor ledge-former) with abundant, conspicuous crinoid columnals and large calyx plates, (1 large, partially-articulated crinoid calyx); some bedding planes paved with Aviculopecten valves; upper part of unit decrease in large, conspicuous, identifiable fossil fragments (fines upward) with plant fragments; whole crushed Wellerella; upper contact sharp; 36 cm thick.

Locality: SMAN
Location: East road cut on K-177, NW1/4, SW1/4, NW1/4, Sec.33, T.10 S., R.9 E., Riley Co., KS (Manhattan Quadrangle, 1982).
Units: Funston Limestone (unit 1); Speiser Shale (units 2-24).
Notes: measured by Christopher R. Cunningham (June, 1988); most of interval was covered and was exposed by digging; introduced to locality by Dr. Hans-Peter Schultze.

3. Mudstone: dusky yellow green 5 GY 5/2; slightly calcareous; slightly sandy; slightly lighter green root casts; more massive than below; nodular weathering; upper contact sharp; 29 cm thick.

2. Mudstone: grayish olive green 5 GY 3/2; slightly calcareous; massive to platy (weathering?); fine to coarse dark yellowish orange 10 YR 6/6 iron oxide mottling on splitting planes; slightly lighter green root casts; less silty than above; fine yellowish brown 10 YR 5/2 mottling; upper contact gradational; 4 cm thick.



1. Limestone: white N9 to grayish orange pink 10 R 8/2 (weathers moderate brown 5 YR 3/4); coarse, poorly-sorted, angular bivalve gastropod pellet? packstone (biopelmicrite to biopelsparite), II/IIA with scattered vertical burrow C (upper 45 cm); basal 32 cm finer grained, with slightly better sorting, II/IIIA; slightly argillaceous; with high-spired gastropods, smooth-shelled ostracodes, smooth, unornamented bivalve fragments, and pellets?; highly oxidized, fine to medium pyrite grains decrease in abundance upward; bimodal grain size distribution?--very coarse and medium in upper 45 cm; upper 17 cm massive with blocky to slabby splitting, and Skolithos up to 2 cm long; between 32 and 60 cm above base cross-bedded, with foresets up to 5 mm thick (large scale, low angle dunes up to approximately 1.5 m in length?); Skolithos up to 2 cm long (burrow density increases downward); basal 32 cm massive? with platy to slabby splitting (up to 4.5 cm thick); upper contact sharp; 77 cm examined.

9. Argillaceous limestone: light brownish gray 5 YR 6/1 to pale olive 10 Y 6/2 with pale olive 10 Y 6/2 fracture fillings and/or root casts (dusky brown 5 YR 2/2 and dark yellowish orange 10 YR 6/6 iron oxide staining on weathered surfaces); carbonate mudstone; I/IIA; rhizobrecciated texture; nodular; upper contact sharp; up to 10 cm thick.

8. Mudstone: grayish green 10 GY 5/2 (with a reddish cast); slightly calcareous; sandy; massive; slightly more greenish root casts; upper contact sharp; 15 cm thick.

7. Mudstone: dusky yellow green 5 GY 5/2; noncalcareous to calcareous (nodules); sandy; massive to platy (weathering?); less silt than above; sometimes thread-like dark yellowish orange 10 YR 6/6 to dark reddish brown 10 R 3/4 iron oxide staining on splitting planes; pale olive 10 Y 6/2 to whitish chalky (IIA) oblate to irregular micritic carbonate nodules up to 7 cm in diameter; indeterminate vertebrate skeletal debris; slightly darker green root casts; upper contact gradational; 9 cm thick.

6. Argillaceous limestone: yellowish gray 5 Y 8/1 with slight olive cast (weathers pale red 5 R 6/2); fine, moderately-sorted intraclastic smooth-shelled ostracode biomicrite (mudstone); IA; argillaceous; dusky yellow green 5 GY 5/2 root casts; light brownish gray 5 YR 6/1 algally? microlaminated, irregular, subrounded to subangular intraclasts up to 5 mm in diameter; abundant disseminated pyrite and/or oxide mineralization; thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; massive?; generally blocky weathering; upper 6 cm weathers nodular; upper contact gradational; 20 cm thick.

5. Limestone: yellowish gray 5 Y 8/1 with a slight olive cast (weathers pale red 5 R 6/2); fine, moderately-sorted intraclastic smooth-shelled ostracode biomicrite (mudstone); IA; argillaceous; as above except platy to flaggy splitting; moderate brown 5 YR 3/4 iron oxide staining on splitting planes; upper contact sharp; 13 cm thick.

4. Mudstone: pale greenish yellow 10 Y 8/2; calcareous; sandy; massive thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 4 cm thick.

13. Argillaceous limestone to calcareous mudstone: pale red 5 R 6/2 with fine to medium dusky yellow green 5 GY 5/2 mottling and root casts; sandy; hard; nodular; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact gradational; 7.5 cm thick.

12. Mudstone: grayish red 10 R 4/2; slightly calcareous; sandy; massive; greenish root casts; upper contact sharp; 18 cm thick.

11. Interbedded argillaceous limestone and mudstone: limestones--poorly-sorted, smooth-shelled ostracode biointramicrudite; IA; pale brown 5 YR 5/2 generally subrounded to subangular algally? microlaminated flat pebble intraclasts with vertical burrows less than 1 mm in diameter; intraclasts up to 3.5 cm in diameter; micritic matrix pale yellowish brown 10 YR 6/2; w/ *Bairdia*, spirorbids, indet. brachiopod fragment, indet. ostracode with pitted surface (cypridacean?), and phyllodont tooth plate fragment; ostracodes spar-filled; dark yellowish orange 10 YR iron oxide staining on weathered surfaces; weather dark yellowish orange 10 YR 6/6 to moderate yellowish brown 10 YR YR 5/4; mudstones--pale olive 10 Y 6/2 with moderate red 5 R 5/4 root casts and fine diffuse mottling; calcareous; sandy; massive; with indet. smooth-shelled ostracode, *Carbonita*?, *Whipplella*?, spirorbid fragments, brachiopod spines, and phyllodont tooth plate fragment; fine to very coarse rounded light brownish gray 5 YR 6/1 grains; 4, 2 and 3 cm-thick limestone beds 0.0, 7, and 11 cm above the base; upper contact gradational; 16 cm thick.

10. Mudstone: slightly more gray than greenish gray 5 GY 6/1 w/ reddish brown 10 R 4/4 to light brownish gray 5 YR 6/1 root casts; noncalcareous to calcareous (nodules); sandy; massive to nodular; with 1 specimen broken, indet. smooth-shelled ostracode, and 1 specimen *Whipplella*?; indurated, subequant to vertically-elongate yellowish gray 5 Y 7/2 to slightly brownish or whitish micritic calcareous nodules up to 5 cm in diameter; possible columnar peds up to 2 cm in diameter; rhizobrecciated texture; upper contact sharp; 23 cm thick;

20. Mudstone: light olive gray 5 Y 5/2 with fine to coarse grayish red 10 R 4/2 mottling; calcareous; sandy; platy to crumbly weathering; dark reddish brown 10 R 3/4 and slightly greenish root casts; upper contact sharp; 28 cm thick.

19. Mudstone: grayish red 10 R 4/2 with indistinct medium to coarse greenish gray 5 GY 6/1 mottling and root casts; dark reddish brown 10 R 3/4 root casts; calcareous; sandy; massive; becomes more massive downward and redder upward; upper contact gradational; 19 cm thick.

18. Mudstone: dusky yellow green 5 GY 5/2 with scattered coarse grayish red 10 R 4/2 mottles; grayish olive green 5 GY 5/2 root mottling; dusky yellow green 5 GY 5/2 and dark reddish brown 10 R 3/4 root casts; calcareous; platy (weathering); upper contact sharp; 24 cm thick.

17. Mudstone: dark reddish brown 10 R 3/4 with scattered coarse dusky yellow green 5 GY 5/2 mottles; calcareous; sandy; blocky; brownish root casts; slickensides; upper contact gradational; 7 cm thick.

16. Mudstone: dark yellowish green 5 GY 5/2 with scattered coarse dark reddish brown 10 R 3/4 mottles and root casts; noncalcareous to slightly calcareous; sandy; massive; upper contact gradational; 11 cm thick.

15. Mudstone: blackish red 5 R 2/2; noncalcareous to slightly calcareous; sandy; blocky; slickensides; reddish brown 10 R 4/4 root casts; with fine to very coarse (up to 30 cm long) rounded dusky yellow green 5 GY 5/2 mottles; upper contact irregular (due to large mottles) and gradational; 48 cm thick.

14. Mudstone: dark reddish brown 10 R 3/4; calcareous; sandy; massive; weathers platy to nodular; fine to coarse grayish green 10 GY 5/2 mottling and root casts; calcareous nodules up to 7.5 cm across with root casts; becomes greener upward due to increased density of root casts; fine to coarse dark yellowish orange 10 YR 6/6 iron oxide mottling in upper part of unit; upper contact sharp; 24 cm thick.

24. _Limestone_: yellowish gray 5 Y 7/2 (weathers dusky yellow 5 Y 6/4 to pale yellowish orange 10 YR 8/6); fine, moderately well-sorted, angular smooth-shelled ostracode, foraminiferal wackestone; II/IIIA; argillaceous; with algal filaments, _Ammovertella_, _Ammodiscus_, _Globivalvulina_, smooth-shelled ostracodes including _Bairdia_ and _Cavellina_?, bivalve fragments; discontinuous, irregular pale olive 10 Y 6/2 argillaceous partings up to 1 mm thick; massive, blocky in upper part of unit; platy splitting at base; upper contact absent; approximately 30 cm thick.

23. _Mudstone_: grayish olive 10 Y 4/2 with fine dusky yellow 5 Y 6/4 mottling; calcareous; crumbly--highly weathered; slickensides (Recent?); whitish calcareous stringers 0.5 to 1 cm thick in lower 1/2 of unit; smooth-shelled ostracodes(?); upper contact sharp; 27 cm thick.

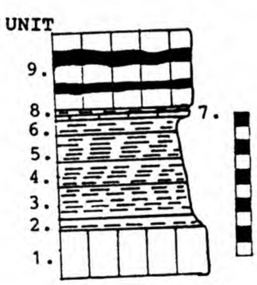
22. _Mudstone_: finely mottled with dusky yellow green 5 GY 5/2, dusky yellow 5 Y 6/4, and dark reddish brown 10 R 3/4; root casts of constituent rock colors; calcareous; sandy; blocky to platy (weathering); slickensides; upper contact sharp; 22 cm thick.

21. _Mudstone_: dusky yellow green 5 GY 5/2; noncalcareous; sandy; blocky; slickensides; medium to coarse grayish red 5 R 4/2 mottling; dark reddish brown 10 R 3/4 root casts; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact gradational; 7 cm thick.

Locality: SMAN2
Location: East road cut on K-177, 2.3 miles south of the intersection of K-177 and K-18, NW1/4, SW1/4, NW1/4, Sec. 33, T.10 S., R.8 E., Riley Co., KS (Manhattan Quadrangle, 1982)
Units: Speiser Shale (units 1-8) and Threemile Limestone Member of the Wreford Limestone (unit 9).
Notes: measured by Christopher R. Cunningham (July, 1988).

2. Mudstone: yellowish gray 5 Y 7/2 with fine to coarse dark yellowish orange 10 YR 6/6 iron oxide mottling; dusky brown 5 YR 2/2 mottling/staining on bedding/splitting planes (plant debris?); calcareous; sandy; platy to nodular; with fragments of large bivalves (pinnids?) oriented parallel to perpendicular to bedding; whole *Aviculopecten* valves; ostracodes; productid spines; 2 mm-thick horizontal burrows; less iron oxide staining than above; upper contact gradational; 8 cm thick.

1. Limestone: yellowish gray 5 Y 8/1 (weathers grayish yellow 5 Y 8/4 to pale yellowish orange 10 YR 8/6); medium, moderately-sorted, angular ostracode bivalve biomicrite (wackestone to packstone); III/IA; argillaceous; with ostracodes, indeterminate bivalve fragments, whole? gastropods, horizontally to vertically oriented pinnid? fragments; 1 phyllodont tooth plate fragment; micrite intraclasts up to 2 cm in diameter; horizontal burrows from 1 to 4 cm in diameter; upper 5 cm finely to coarsely mottled with medium gray N5, very argillaceous, and platy; bedding and splitting range from 5 mm to 6 cm (platy to slabby splitting); two 2 cm-thick sandy argillaceous partings with mollusc fragments, ostracodes, and vertebrate skeletal debris 2 and 10 cm from base; lower contact sharp; upper contact somewhat gradational; 33 cm thick.



7. Limestone: pinkish gray 5 YR 8/1 (weathers grayish yellow 5 YR 8/4); coarse, moderately- to poorly-sorted, angular biomicrite (wackestone to packstone); III/IA; argillaceous; with echinoderm fragments, trilobite(?) fragments, Neochonetes fragments, whole Crurithyris valves, fragments of large bivalves, productid spines, vertebrate skeletal debris; upper contact sharp; 2 cm thick.

6. Mudstone: finely to coarsely mottled with medium light gray N6, grayish yellow 5 Y 8/4, and dusky yellow 5 Y 6/4 (weathers yellowish gray 5 Y 7/2); calcareous; sandy; platy; hard; with ostracodes, Acanthopecten? fragments; whole Straparollus-like gastropods; productid spines, Derbyia fragments, crinoid columnals; less fossiliferous than below; upper contact sharp; 9 cm thick.

5. Mudstone: dusky yellow 5 Y 6/4 with faint fine to coarse medium gray N5 mottling, and fine to coarse dark yellowish orange 10 YR 6/6 iron oxide mottling; calcareous; sandy; platy; hard; with Neochonetes valves, whole articulated Composita, crinoid columnals, inarticulate brachiopod fragments, Aviculopecten valves, large whole productids (Reticulatia?) in non-life position, ostracodes, whole Derbyia valves up to 4.5 cm in diameter, upper contact gradational; 18 cm thick.

4. Mudstone: finely to coarsely mottled with medium dark gray N4 and yellowish gray 5 Y 7/2, with fine to coarse dark yellowish orange 10 YR 6/6 iron oxide mottling; calcareous; sandy; with whole Neochonetes valves, crinoid columnals; Derbyia fragments; vertebrate skeletal debris, whole and fragmented Orbiculoidea, ostracodes; whole nuculid? bivalves; upper contact gradational; 16 cm thick.

3. Mudstone: light olive gray 5 Y 6/1 with fine to coarse dark yellowish orange 10 YR 6/6 iron oxide mottling; fine to coarse dusky brown 5 YR 2/2 mottling/staining on bedding/splitting planes (plant debris?); calcareous; sandy; hard; platy to nodular; more yellowish toward the top; irregular spar-lined D voids; with plant fragments, whole Straparollus-like plansipiral gastropods, Derbyia fragments, Aviculopecten? fragments, echinoid spines; upper contact gradational; 22 cm thick.

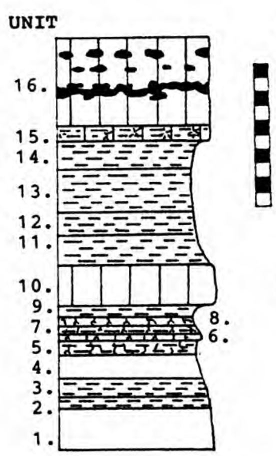
9. Limestone: yellowish gray 5 Y 8/1 (weathers grayish orange 10 YR 7/4); coarse, moderately-sorted angular biomicrite (packstone); IIIA; argillaceous; cross-bedded?; with bivalve fragments up to 8 cm long; ramose and fenestrate bryozoan fragments, whole *Composita*?, whole *Crurithyris*, indeterminate brachiopod fragments, echinoid spines, productid spines, indet. Elasmobranchii dermal denticles; blocky splitting; 6 cm and 12 cm thick chert beds 12 and 32 cm from the base, respectively; upper contact sharp; 52 cm thick.

8. Mudstone: finely to coarsely mottled with medium gray N5 and dusky yellow 5 Y 6/4 (weathers yellowish gray 5 Y 7/2); calcareous; sandy; hard; degree of induration varies laterally; unit thins to a parting on outcrop scale (10's of feet); with vertebrate and invertebrate skeletal debris, productid spines, bivalve fragments, ostracodes; gypsum crystal and rosette molds (crystal molds up to 0.5 cm long); upper contact sharp; 2.5 cm thick.

Locality: 177
Location: East side of roadcut on K-177, 6.0 miles south of the intersection of U.S.24 and K-177, SW1/4, NW1/4, NW1/4, Sec.16, T.11S., R.8E., Riley Co., KS (Swede Creek Quadrangle, 1947-1955).
Units: Speiser Shale (units 1-15) and Threemile Limestone Member of the Wreford Limestone (unit 16).
Notes: measured by Christopher R. Cunningham (June, 1988); interval was mostly covered and exposed by digging.

4. Mudstone: grayish olive green 5 GY 4/2; noncalcareous to slightly calcareous; sandy; massive; crumbly to nodular; fine to medium, diffuse, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; fine olive gray 5 Y 3/2 root(?) mottling; joints with dusky brown 5 YR 2/2 and dark yellowish orange 10 YR 6/6 iron oxide coatings/staining; upper contact gradational; 15 cm thick.

3. Mudstone: finely to coarsely and diffusely mottled with light olive brown 5 Y 5/6 and dusky yellow green 5 GY 5/2; calcareous; sandy; platy to nodular weathering; highly oxidized, pyritic, carbonaceous dusky brown 5 YR 2/2 to moderate brown 5 YR 4/4 (plant?) fragments; highly oxidized, sand-sized pyrite grains; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact sharp; 11.5 cm thick.



2. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; platy; fine light olive brown 5 Y 5/6 to dark yellowish orange 10 YR 6/6 mottling; black carbonaceous debris and staining; fine sand-sized highly oxidized pyrite grains; upper contact gradational; 6.5 cm thick.

1. Mudstone: greenish gray 5 GY 5/1; calcareous; sandy; massive; relatively hard; developes maroonish cast downward; fine dark yellowish orange 10 YR 6/6 iron oxide mottling; upper contact gradational; 28 cm exposed--bottom covered.

9. <u>Mudstone</u>: alternating light olive brown 5 Y 5/6 to yellowish gray 5 Y 7/2 and olive gray 5 Y 3/2 laminations averaging 0.5 mm thick; calcareous; sandy; platy; with plant fragments, and ostracodes; dark yellowish orange 10 YR 6/6 iron oxide mottling on bedding/splitting planes; slickensides; upper 2 cm coarser with rounded, flat pebbles up to 2 cm long--this part of unit stained dark yellowish orange 10 YR 6/6 with iron oxide; grayish orange 10 YR 7/4 coprolites up to 7 mm long; fine light olive brown 5 Y 5/6 mottling--due to disturbance of laminae by burrowing?; upper contact gradational; 7.5 cm thick.

8. <u>Mudstone</u>: light olive gray 5 Y 5/2 with fine olive gray 5 Y 3/2 mottling and root casts; calcareous; sandy; massive; black carbonaceous plant fragments; black coal parting 2 mm thick, 1.3 cm from the top; mudstone with ostracodes (<u>Bairdia</u>?); upper contact sharp; 6.5 cm thick.

7. <u>Mudstone</u>: light olive gray 5 Y 5/2 with fine, diffuse olive gray 5 Y 3/2 mottling and root casts; calcareous; sandy; platy to flaggy; dark yellowish orange 10 YR 6/6 iron oxide staining; fine, diffuse light olive brown 5 Y 5/6 mottling; fine black carbonaceous debris; with ostracodes (<u>Bairdia</u>?) upper contact gradational; 6.5 cm thick.

6. <u>Argillaceous limestone</u>: approximately pale olive 10 Y 6/2 to yellowish gray 5 Y 7/2 with fine to coarse dark yellowish orange 10 YR 6/6 to dusky yellow 5 Y 6/4 iron oxide mottling; dusky yellow green 5 GY 5/2 to light olive gray 5 Y 5/2 root casts(?); medium, moderately-sorted, angular ostracode wackestone to packstone (biomicrite); IA; very argillaceous; platy--bedding averages 1 mm(?); with ostracodes (<u>Bairdia</u>?) (some ostracodes disarticulated and fragmented), spirorbids, <u>Pseudomonotis</u> fragments, and vertebrate skeletal debris including Elasmobranchii dermal denticles, upper contact sharp; 4 cm thick.

5. <u>Mudstone</u>: light olive brown 5 Y 5/6 with fine and diffuse light olive gray 5 Y 5/2 root casts and mottling; calcareous; sandy; platy to flaggy; with ostracodes and ostracode valve fragments, indeterminate invertebrate skeletal debris; carbonaceous plant fragments; fine diffuse blackish mottling; flat, rounded intraclasts up to 1 cm long; blackish root casts?; upper contact sharp; 9 cm thick.

13. Mudstone: medium gray N5 finely to coarsely mottled with yellowish gray 5 Y 7/2 to dusky yellow 5 Y 6/4; calcareous; sandy; hard; platy to flaggy; weathers nodular; with crinoid columnals (and 1 articulated pinnule), Orbiculoidea fragments, whole Neochonetes valves, large whole Derbyia, whole Aviculopecten, nuculid bivalves (whole valves), Wilkingia (whole?--poorly preserved), whole Composita, echinoid spines, ostracodes, whole Crurithyris; indications of 1-3 mm-thick laminations (of constituent rock colors) that were disturbed by bioturbation?; upper contact gradational; 29 cm thick.

12. Mudstone: yellowish gray 5 Y 7/2 (weathers pale olive 10 Y 6/2); calcareous; sandy; hard; platy to flaggy; weathers nodular; with whole and fragmented Aviculopecten, Wilkingia? fragments; echinoid spines, ostracodes; Derbyia? fragments, ramose bryozoan fragments, and productid fagments; scattered fine to medium and diffuse medium gray N5 mottling; dark yellowish orange 10 YR 6/6 iron oxide staining; upper contact gradational; 15 cm thick.

11. Mudstone: finely mottled with yellowish gray 5 Y 7/2 and medium gray N5 (weathers yellowish gray 5 Y 7/2); calcareous; sandy; hard; platy to flaggy; weathers nodular; dark yellowish orange 10 YR 6/6 iron oxide staining; with whole Aviculopecten, ramose bryozoan fragments, ostracodes?, whole? Wilkingia?, productid spines and fragments, whole, articulated Composita?, whole Crurithyris?, and echinoid spines; upper contact gradational; 20 cm thick.

10. Limestone: yellowish gray 5 Y 7/2 to grayish yellow Y 8/4 finely to coarsely and diffusely mottled with medium gray N5 to light gray N7 (weathers grayish orange 10 YR 7/4; fine, moderately-sorted angular intraclast bivalve ostracode wackestone (intrabiomicrite); I/IIA; argillaceous; yellowish gray 5 Y 8/1 (weather dark yellowish orange 10 YR 6/6) rounded micrite intraclasts upt to 1.5 cm in diameter; with ostracodes, Aviculopecten fragments, and foraminiferids?; bedding and splitting thickness increases up--except upper 2.5 cm, which is platy; in basal 1/2 of unit individual beds of variable thickness from .1 mm to 1 cm; platy to slabby splitting; bedding surfaces irregular and undulose; basal portion of unit more argillaceous; upper contact irregular, sharp; 28 cm thick.

16. Limestone: yellowish gray 5 Y 8/1 with very faint and diffuse fine to coarse light gray N7 to dark gray N3 mottling that is more pronounced in the lower 5 cm of the unit (weathers grayish orange 10 YR 7/4); fine to medium, poorly-sorted, angular wackestone to packstone (biomicrite); I/IIA with scattered gypsum crystal and rosette moldic C--C more common toward the base; argillaceous; with echinoid spines and plates, large ramose and fenestrate bryozoan fragments, whole articulated Wellerella, whole Aviculopecten valves, crinoid columnals, trilobite fragments?, Composita? fragments, and indeterminate brachiopod and bivalve fragments; indications of 1-3 mm-thick gray laminations that have been disturbed by bioturbation?, particularly in the lowermost 5 cm of the unit; cross-bedded? in middle part of unit; blocky (upper) to platy to slabby (lower) splitting; 6 cm-thick chert bed 18 cm from the base; chert nodule horizons 34 and 52 cm above the base; upper contact sharp; 61 cm thick. (lower 18 cm sampled--diversity appears same throughout unit).

15. Calcareous siltstone to argillaceous limestone: yellowish gray 5 Y 7/2 to dusky yellow 5 Y 6/4 finely to coarsely mottled with medium gray N5; calcareous; sandy; platy to flaggy mudstone to coarse, poorly-sorted, angular carbonate mudstone to wackestone (I/IIA/C--C gypsum crystal molds); with gypsum crystal molds; dark yellowish orange 10 YR 6/6 iron oxide staining; less fossiliferous than below; with ostracodes, plant fragments, Aviculopecten fragments, Derbyia? fragments, crinoid columnals and plates, Composita? fragments; whole Enteletes valve on basal surface; upper contact sharp; 10 cm thick.

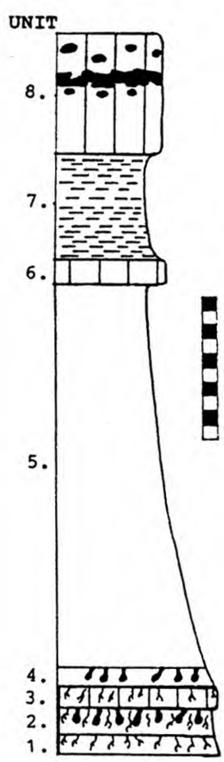
14. Mudstone: finely to coarsely mottled with olive gray 5 Y 3/2 and light olive gray 5 Y 5/2 (weathers dusky yellow 5 Y 6/4); calcareous; sandy; darker and more friable than unit 15; mottling may be the result of disturbance of 1.5 mm-thick laminations by burrowers; dark yellowish orange 10 YR 6/6 to dusky yellow 5 Y 6/4 iron oxide staining; with echinoid spines and plates, crinoid columnals, whole and fragmented Aviculopecten, ramose and fenestrate bryozoan fragments, whole Enteletes valve, trilobite fragments, whole Composita, whole Straparollus-like gastropods, Derbyia fragments, Reticulatia fragments, ostracodes?, inarticulate brachiopod fragments, upper contact gradational; 18 cm thick.

Locality: JC
Location: South road cut on I-70 approximately 4 miles east of Junction City, KS, NE1/4, Sec.34, T.11S., R.6E., Geary Co., KS (Ogden Quadrangle, 1978).
Units: Speiser Shale (Units 1-8) and Threemile Limestone Member of the Wreford Limestone (unit 9)
Notes: measured by Christopher R. Cunningham (July, 1988); interval covered and exposed by digging.

5. Covered interval: 265 cm thick.

4. Mudstone: grayish olive green 5 GY 3/2; noncalcareous to very slightly calcareous; sandy; blocky; slickensides; *Gnathorhiza* burrows (oblate flasks) with and without body fossils; upper contact sharp; 12 cm thick.

3. Limestone: light brownish gray 5 YR 6/1 with fine to coarse greenish gray 5 G 6/1 mottles and root casts; moderately-sorted angular mudstone with fine to very coarse indeterminate invertebrate skeletal debris; nodular to lensatic(?), with nodules/lenses up to 10 cm long; nodules/lense surrounded by above lithology; dark yellowish orange 10 YR 6/6 to light brown 5 YR 5/6 iron oxide staining of fractures in limestone; upper contact gradational; 12 cm thick.



2. Mudstone: finely to coarsely mottled with grayish red 5 R 4/2 and pale olive 10 Y 6/2; calcareous; very sandy; massive; weathers platy; limestone (as unit 3) nodules up to 3.5 cm in diameter in upper 8 cm of unit; dusky yellow green 5 GY 5/2 root casts; fine dusky brown carbonaceous (plant?) debris; *Gnathorhiza* in burrows (oblate flasks); lungfish specimens relatively large; upper contact gradational; 18 cm thick.

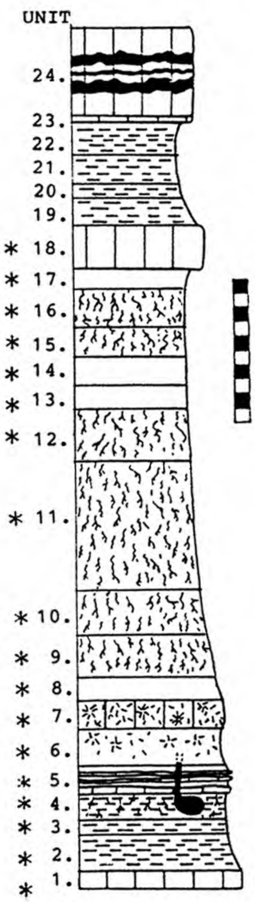
1. Mudstone: grayish red 5 R 4/2 with dusky yellow green 5 GY 5/2 root casts; calcareous; very sandy; massive; upper contact gradational; 14 cm exposed--bottom covered.

8. Limestone: yellowish gray 5 Y 7/2 (weathers grayish orange 10 YR 7/4); medium to coarse, moderately-sorted, subangular to subrounded, skeletal wackestone with packstone lenses up to 1 cm thick; I/IIA; argillaceous; massive?; with crinoid columnals, ramose and fenestrate bryozoan fragments, brachiopod spines and fragments, echinoid spines, Wellerella fragments, whole, articulated Composita, and broken, indet. invertebrate skeletal debris; possible compacted horizontal burrows up to 1 cm in diameter in-filled with carbonate mudstone; skeletal grains in all orientations including vertical (burrowed?); 7 cm thick chert bed 25 cm from top of unit; scattered chert nodules in upper 25 cm of unit and immediately below chert bed; chert medium light gray N6 with whitish silicified skeletal grains; upper contact gradational; 84 cm thick.

7. Mudstone: undescribed; platy; upper contact gradational; 70 cm thick

6. Argillaceous Limestone: finely mottled with yellowish gray 5 Y 7/2 and medium light gray N6 matrix with granule-sized micritic and mudstone intraclasts of variable color from dark yellowish orange 10 YR 6/6 to dusky brown 5 YR 2/2; coarse, poorly-sorted, rounded to angular skeletal lithic wackestone; I/IIIA; massive; with Ammovertella, Ammodiscus, smooth-shelled ostracodes, pectenid? bivalve fragments; lithoclasts concentrated in lensoid placers? up to 1 cm thick; hummocky irregular surfaces?; 16 cm thick; upper contact gradational.

Locality: 4/99
Location: South road cut on K-99, 3.0 miles east of the intersection of K-4 and K-99, SE1/4, SW1/4, Sec.31, T.13S., R.11E., Wabaunsee Co., KS (Alta Vista SE Quadrangle, 1971).
Units: Funston Limestone (unit 1), Speiser Shale (units 2-22), and Threemile Limestone Member of the Wreford Limestone (units 23; 24).
Notes: measured by Christopher R. Cunningham (June, 1988); section was covered and exposed by digging.



3. Mudstone: pale brown 5 YR 5/2; calcareous; slightly sandy; platy; with plant fragments, 1 palaeoniscoid tooth, indet. bone fragments, 1 whole, high-spired gastropod, and 1 indet., poorly-preserved ostracode valve; upper contact sharp; 10 cm thick.

2. Mudstone: pale olive 10 Y 6/2; calcareous; slightly silty; platy; friable, sand-sized, highly-oxidized pyrite grains; upper contact sharp; 23 cm thick.

1. Limestone: yellowish gray 5 Y 7/2 (weathers grayish yellow 5 Y 8/4); well-sorted mudstone with lighter, discontinuous, poorly-sorted wackestone laminations 0.1-5 mm thick; I/IIIA; argillaceous; upper 2.5 cm platy to flaggy splitting, more massive below; scattered disseminated dark reddish brown 10 R 3/4 to blackish pyrite grains; wavy, discontinous argillaceous partings; with spirorbids, whole small high-spired gastropods, masses of Ammovertella up to 1.5 cm long (masses hollow inside indicating dissolution of substrate), brachiopod spines and fragments, smooth-shelled ostracodes, phyllodont tooth plate fragments, palaeoniscoid scales and 1 tooth-bearing element; upper contact sharp; upper 8 cm sampled.

8. Mudstone: grayish red 5 R 5/4 finely to coarsely mottled with light olive gray 5 Y 5/2; unit highly weathered; calcareous; sandy (quartz); granular, with calcareous crusts and sand to granule-sized grains and blebs; calcareous nodules up to 1.5 cm across; upper 5 cm distinctly more grayish (light olive gray 5 Y 5/2), lower part of unit dominantly grayish red 5 R 5/4; upper contact sharp; 15 cm thick.

7. Gypsiferous limestone: very dark red 5 R 2/6; medium to coarsely recrystallized; granular texture; sandy (quartz); IIIA/C with scattered D; with 1 echinoid spine; gypsum crystals and rosettes; upper contact gradational; 19 cm thick.

6. Mudstone: yellowish gray 5 Y 7/2 with fine to medium grayish red 5 R 4/2 mottles at base, becoming grayish red 5 R 4/2 at top; calcareous; sandy; gypsum nodules (up to 2.5 cm across) and crusts; abundant calcite veins, crusts, and irregular sand to granule-sized blebs giving unit granular texture (possible weathering features?); unit generally friable, although parts indurated and calcite-cemented; with well-formed very fine to fine calcite rhombs; 1 indet., abraded/corroded ramose bryozoan fragment; upper contact gradational; 25 cm thick.

5. Interbedded mudstone and limestone: pale olive 10 Y 6/2; mudrocks--calcareous; platy; friable sand-sized pyritic grains; possible plant fragments; fine to coarse, sometimes thread-like dusky yellow green 5 GY 5/2 root(?) mottling; mudcracks; ostracodes?; limestones--very well-sorted mudstone (calcilutite); argillaceous; laminated (1-5 mm thick laminae); platy splitting; sand-sized pyritic grains, particularly common on bedding planes; with Ammovertella-like forams and ostracodes?; limestones become nodular toward top; basal 5 cm of unit apparently cut by neck of large enigmatic burrow; upper contact gradational; 18 cm thick.

4. Mudstone: pale olive 10 Y 6/2; calcareous; platy; friable sand-sized carbonaceous, pyritic grains (plant fragments?); plant fragments and impressions (Lepidophylloides?); possible fine dusky yellow green 5 GY 5/2 root mottling; slightly yellowish root casts?; cut by large, stomach-shaped burrow of enigmatic origin (burrow filled with mudstone: blackish red 5 R 2/2; slightly calcareous; platy; sandy; friable; contacts sharp); upper contact sharp; 18 cm thick.

14. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; massive; blocky; fine, sometimes thread-like moderate yellow 5 Y 7/6 to dark yellowish orange 10 YR 6/6 iron oxide mottling; pellets?; slickensides; blockier than below with more iron oxide staining; upper contact sharp with dark yellowish orange 10 YR 6/6 iron oxide staining; 18 cm thick.

13. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; massive; crumbly to blocky; slickensides; blockier than 12; fine, sometimes thread-like dark orangeish yellow 10 YR 6/6 to moderate yellow 5 Y 7/6 iron oxide staining; friable, sand-sized carbonaceous, pyritic grains (plant fragments?); blackish, rounded grains up to 1 mm in diameter; upper contact sharp with dark orangish yellow 10 YR 6/6 iron oxide staining; 15 cm thick.

12. Mudstone: dark reddish brown 10 R 3/4; calcareous; sandy; massive; blocky to slightly nodular; slickensides; dusky yellow green 5 GY 5/2 root casts; upper 1/3 of unit with grayish red 5 R 4/2 calcareous nodules up to 5 cm across with dusky yellow green 5 GY 5/2 root casts; middle 1/3 of unit (sample 4/99-12 B) with pellets?; upper 8 cm with fine to medium dusky yellow green 5 GY 5/2 mottles; upper contact gradational (bioturbational?); 38 cm thick.

11. Mudstone: grayish red 5 R 4/2; calcareous; sandy; massive; fine dusky yellow green root(?) mottling and casts; upper 1/3 of unit (sample 4/99-11C) with 1 sponge spicule and bivalve fragments in 140 mesh size residue); upper contact gradational (horizon with calcareous nodules up to 3.8 cm across at upper contact); 89 cm thick.

10. Mudstone: light olive gray 5 Y 5/2 with fine to medium grayish red 10 R 4/2 mottling; calcareous; sandy; massive; grayish red 10 R 4/2 root casts; indet. spine; becomes redder upward; friable; upper contact gradational; 30.5 cm thick.

9. Mudstone: dark reddish brown 10 R 3/4; calcareous; sandy (quartz); massive; calcareous nodules up to 2.5 cm in diameter; fine pale olive 10 Y 6/2 root mottling and casts; well-formed very fine to fine calcite rhombs; developes greenish cast upward; upper contact gradational; 28 cm thick.

18. Limestone: yellowish gray 5 Y 7/2 finely to coarsly and diffusely mottled with medium gray N5 (bioturbational?); fine to medium, moderately-sorted, angular smooth-shelled ostracode bivalve fragment wackestone (biomicrite); III/IA; argillaceous; bedding and splitting thickness increases upward (platy to slabby); in lower 8 cm bedding averages 2 mm in thickness; in upper portion of unit bedding averages 4 cm in thickness; bedding surfaces wavy and irregular; within beds grains disordered (bioturbated?); with pectenid bivalve fragments, smooth-shelled ostracodes, brachiopod spines, echinoid spines, Ammovertella, palaeoniscoid teeth and scales, phyllodont tooth plate fragments, crinoid arm plates, tetrataxid forams, indet. Elasombranchii dermal denticles; indet. sculptured fish scale; granule-sized, rounded dark yellowish orange 10 YR 6/6 micritic intraclasts; upper contact gradational; 30.5 cm thick.

17. Mudstone: moderate olive brown 5 Y 4/4; calcareous; sandy; blocky to crumbly; slickensides; fine, indistinct dark yellowish orange 10 YR 6/6 mottling; friable, rounded, argillaceous, calcareous grains up to 2 mm in diameter (rhizocretions?); smooth-shelled ostracodes?; upper contact sharp; 13 cm thick.

16. Mudstone: dusky yellow green 5 GY 5/2; slightly calcareous; sandy; massive; blocky; fine pale olive 10 Y 6/2 mottling and root casts; fine to coarse sometimes thread-like dark yellowish orange 10 YR 6/6 mottling/staining; fine dusky brown 5 YR 2/2 circular to irregular mottling/staining; slickensides; smooth-shelled ostracodes?; upper contact gradational; 25 cm thick.

15. Mudstone: dusky yellow green 5 GY 5/2 (slightly darker than above or below); slightly calcareous; sandy; massive; light olive gray 5 Y 5/2 root casts; fine dark yellowish orange 10 YR 6/6 mottling/staining--absent at base; rounded, friable calcareous argillaceous grains up to 3 mm in diameter (rhizocretions?); upper contact gradational; 20 cm thick.

22. Mudstone: finely to coarsely mottled with light olive gray 5 Y 5/2 and dusky yellow 5 Y 6/4; calcareous; sandy; platy to flaggy; with dark yellowish orange 10 YR 6/6 iron oxide mottling; with Derbyia fragments and whole valves, Aviculopecten fragments and whole valves, Enteletes fragments, echinoid spines, ramose and fenestrate bryozoan fragments, crinoid columnals, whole articulated Composita, and ostracodes?; upper contact gradational; 21.5 cm thick.

21. Mudstone: light olive gray 5 Y 5/2 with faint and diffuse dark yellow orange 10 YR 6/6 iron oxide mottling; calcareous; sandy; platy to flaggy; oxidized sand-sized pyrite grains; upper 2.5 cm finely to coarsely mottled with olive gray 5 Y 3/2; with whole, poorly-preserved Straparollus-like planispiral gastropods, ostracodes?, brachiopod spines?, productid fragments?, indeterminate bivalve fragments, Aviculopecten? fragments, crinoid columnals, whole, articulated and fragmented Orbiculoidea, and echinoid spines, upper contact gradational; 19 cm thick.

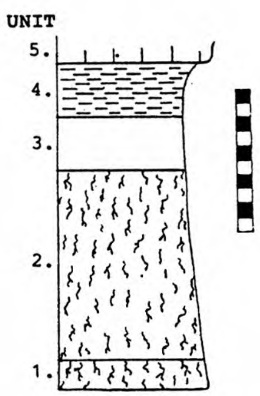
20. Mudstone: finely to coarsely mottled with olive gray 5 Y 3/2, yellowish gray 5 Y 7/2; dusky yellow 5 Y 6/4; calcareous; sandy; hard; platy to flaggy; dark yellowish orange 10 YR 6/6 iron oxide staining; with whole and articulated and fragmented Orbiculoidea; crinoid columnals, echinoid spines?, ostracodes?, whole Straparollus-like plansipiral gastropod?; gypsum rosettes; upper contact sharp; 9 cm thick.

19. Mudstone: light olive brown 5 Y 5/6; calcareous; sandy; platy to flaggy; relatively hard; nearly whole valves of Aviculopecten; fine to coarse medium dark gray N4 mottling near base; with whole valve of Neochonetes, inarticulate brachiopod fragments, and 1 whole valve of Orbiculoidea, echinoid spine and plate fragments, ostracodes?; upper contact gradational; 20 cm thick.

24. Limestone: yellowish gray 5 Y 8/1 (weathers grayish orange 10 YR 7/4 to pale yellowish orange to 10 YR 8/6) fine, moderately well-sorted subrounded wackestone (biomicrite); II/IIIA; slightly argillaceous; with whole, articulated and fragmented Composita, Wellerella? fragments, foraminiferids, echinoid spines, brachiopod spines?, indet. bivalve fragments, ramose bryozoan fragments; whole, articulated silicified Crurithyris, echinoid spines and plates, sponge spicules, acanthodian scales, whole high-spired gastropods, indet. elasmobranchii dermal denticles, Ammovertella, indet. Pa (1 specimen) and Pb or M (1 specimen) conodont elements, blocky splitting; (3) chert beds--7.5, 2.5, and 9 cm thick 17.5, 30, and 42 cm above the base, respectively; upper contact sharp; 62 cm thick.

23. Argillaceous limestone: transitional between units 22 and 24; finely to coarsely mottled with medium gray N5 and dusky yellow 5 Y 6/4 carbonate mudstone to wackestone; I/IIIA with scattered gypsum crystal moldic C; platy to flaggy splitting; ripple-marked surfaces; individual beds vary in thickness up to 1 cm; gypsum crystal molds; dark yellowish orange 10 YR 6/6 iron oxide staining; with indet. bivalve fragments, and invertebrate skeletal debris; upper contact gradational; 4 cm thick.

Locality: 4/99/2
Location: 0.7 miles east of locality 4/99, SW1/4, SW1/4, Sec.31, T.13 S., R.11 E., Wabaunsee Co., KS (Alta Vista SE Quadrangle, 1971).
Units: Speiser Shale (units 1-5).
Notes: measured by Christopher R. Cunningham (July, 1988); section weathered.



2. Mudstone with limestone nodules: mudstone--grayish red 5 R 3/2; slightly calcareous; sandy; blocky; dark reddish brown 10 R 3/4 root casts?; fine black carbonaceous debris; slickensides; limestone nodules--dusky yellow green 5 GY 5/2 to dusky yellow green 5 GY 5/2 finely to coarsely mottled with grayish red 5 R 4/2 (weather yellowish gray 5 Y 8/1 to light brownish gray 5 YR 6/1); argillaceous mudstone (calcilutite); III/IA; weather chalky; nodules elongate and up to 10 cm long; long axis usually vertical; associated with dark yellowish orange 10 YR 6/6 sometimes thread-like iron oxide staining; fine dark reddish brown 10 R 3/4 mottling and root casts; between 32 and 53 cm from base a denser concentration of nodules; unit 2 upper contact sharp; 132 cm thick.

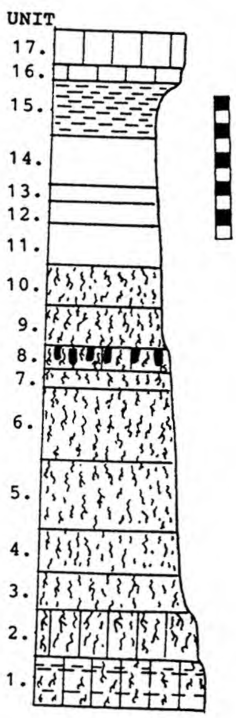
1. Mudstone: dark reddish brown 10 R 3/4; calcareous; sandy; blocky; with indistinct fine to coarse olive gray 5 Y 4/1 root casts and mottling; slickensides; joints with black and dark yellowish orange 10 YR 6/6 iron oxide coating/staining; fine dusky yellow green 5 GY 5/2 root casts and mottling; upper contact gradational; 20 cm exposed--bottom covered.

5. Limestone: very light gray N8 (weathers yellowish gray 5 Y 7/2 to grayish orange 10 YR 7/2) medium, moderately-sorted, rounded ostracode bivalve wackestone (biomicrite); I/IIIA; argillaceous; beds average 3.5 cm in thickness; bedding surfaces irregular, sculptured; with bivalve fragments, ostracodes, and horizontal burrows up to 2 cm in diameter; flaggy splitting; rounded, yellowish micrite intraclasts average 3 mm in diameter; upper contact absent; 12 cm present.

4. Mudstone: pale olive 10 Y 6/2 with some laminae slightly lighter; calcareous; sandy; platy; fine dark yellowish orange 10 YR 6/6 iron oxide staining; with ostracodes and plant fragments; fine to coarse dusky yellow 5 Y 6/4 mottling; laminated, 0.1 to 1 mm thick; fine dusky brown 5 YR 2/2 on bedding planes; upper contact sharp?; approximately 32 cm thick--unit highly weathered, especially upper 10 cm.

3. Mudstone: dusky yellow green 5 GY 5/2; calcareous; sandy; massive; crumbly to nodular weathering; joints with dark yellowish orange 10 YR 6/6 iron oxide staining; fine indistinct olive gray 5 Y 3/2 mottling toward top; with vertebrate skeletal debris, and ostracodes; rounded reddish grains to 2 mm in diameter; 4 mm-thick chalky calcareous parting 10 cm from the top--probable fracture filling; fine black mottling/debris; upper contact sharp; 36 cm thick.

Locality: E2
Location: North side of road cut on K-99 approximately 1.5 miles northwest of Eskridge, KS, SE1/4, Sec.36, T.13 S., R.11 E., Wabaunsee Co., KS (Eskridge Quadrangle, 1971).
Units: Funston Limestone (unit 1) and Speiser Shale (units 2-17).
Notes: measured by Christopher R. Cunningham (July, 1988); interval was mostly covered and exposed by digging; introduced to outcrop by Dr. Hans-Peter Schultze.



2. Brecciated limestone: finely to coarsely mottled with dusky yellow green 5 GY 5/2, dusky yellow 5 Y 6/4, and light brownish gray 5 YR 6/1; with fine to coarse dark yellowish orange 10 YR 6/6 to moderate yellow 5 Y 7/6 iron oxide staining/mottling that decreases downward; brecciated carbonate mudstone (as below); IA with scattered C and D porosity toward the top; angular limestone clasts up to 10 cm long; argillaceous; unit becomes more brownish (and more like underlying unit) downward; large dusky yellow green 5 GY 5/2 root casts that increase in abundance upward; fine dusky brown debris 5 YR 2/2; upper contact somewhat gradational; 33 cm thick.

1. Interbedded limestone and mudstone: limestones--pinkish gray 5 YR 8/1 well-sorted mudstone (calcilutite); IA; argillaceous; laminated--alternating 1 mm thick (lighter) and 0.2 mm-thick laminations; dusky yellow green 5 GY 5/2 root casts?; coarse, angular indeterminate invertebrate skeletal debris (bivalve fragments?); mudstones--light olive gray 5 Y 5/2; calcareous; platy; mudcracks?; fine to coarse grayish brown 5 YR 3/2 mottling on bedding/splitting planes; 2.0, 0.5, 0.5 cm-thick shale partings 10, 25, and 26.5 cm above the base, respectively; unit upper contact gradational; 33 cm examined.

7. Mudstone: light brownish gray 5 YR 6/1 (with slight greenish cast); calcareous; sandy; hard; blocky; darkens in color downward; dark reddish brown 10 R 3/4 and whitish root casts?;slickensides?; vertebrate skeletal debris; upper contact sharp; 13 cm thick.

6. Mudstone: between grayish red 5 R 4/2 and dark reddish brown 10 R 3/4; calcareous; sandy; massive nodular; becomes harder upward; fine light olive gray 5 Y 5/2 root mottling and casts; light olive gray 5 Y 5/2 limestone nodules to 3.5 cm in diameter; joints with dark yellowish orange 10 YR 6/6 staining and fine black carbonaceous debris; upper contact gradational; 50 cm thick.

5. Mudstone: finely to coarsely mottled with dusky yellow green 5 GY 5/2 and between grayish red 5 R 4/2 and dark reddish brown 10 R 3/4; calcareous; sandy; massive to nodular; joints with dark yellowish orange 10 YR 6/6 iron oxide staining and fine to coarse black carbonaceous debris; root casts of both constituent rock colors; 4 mm thick yellowish gray 5 Y 8/1 calcilutite bed with thread-like dark yellowish orange iron oxide staining 18 cm above base; upper contact gradational; 47 cm thick

4. Mudstone: finely to coarsely mottled with grayish red 5 R 4/2 and dusky yellow green 5 GY 5/2; root casts of both constituent rock colors; calcareous; sandy; massive to nodular (weathering); darker and more reddish than above unit; fine to medium dark yellowish orange 10 YR 6/6 iron oxide mottling; joints with dark yellowish orange 10 YR 6/6 iron oxide staining/mottling; 7 mm-thick calcilutite bed (as in unit 5) 5 cm below upper contact; upper contact gradational; 28 cm thick.

3. Mudstone: grayish olive green 5 GY 3/2 with fine to coarse dusky yellow green 5 GY 5/2 mottles and root casts; slightly calcareous; sandy; massive; blocky to nodular; fine to coarse indistinct brownish gray 5 YR 4/1 to dark reddish brown 10 R 3/4 mottling and root casts; slickensides with fine black carbonaceous debris; joints with dark yellowish orange 10 YR 6/6 staining; upper contact gradational; 25 cm thick.

12. Mudstone: greenish gray 5 G 6/1 with a slight maroonish cast; calcareous; sandy; massive; blocky; fine dark yellowish orange 10 YR 6/6 to moderate yellow 5 Y 7/6 iron oxide mottling; fine to medium dusky yellow green 5 GY 5/5 root(?) mottling; slickensides with dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 coatings; upper contact sharp with dark yellowish orange 10 YR 6/6 iron oxide staining; 15 cm thick.

11. Mudstone: dusky yellow green 5 GY 5/2 finely to very coarsely mottled with approximately grayish red purple 5 RP 4/2 (with a greenish cast); some mottles lensoidal in cross section and up to 30 cm long; slightly calcareous to non-calcareous; sandy; blocky; slickensides, some with dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 staining/mottling; upper contact gradational; 28 cm thick.

10. Mudstone: slightly lighter than grayish red purple 5 RP 4/2 and with a slight greenish cast finely and faintly mottled with pale olive 10 Y 6/2; calcareous; sandy; dark reddish brown 10 R 3/4 root casts; slightly harder and blockier than 9; slickensides; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 to moderate yellow 5 Y 7/6 mottling; moderate yellowish brown 10 YR 5/4 iron oxide staining on splitting planes; upper contact gradational; 30 cm thick.

9. Mudstone: slightly lighter than grayish red purple 5 RP 4/2 with a slight greenish cast; calcareous; sandy; blocky to platy (weathering); dark redddish brown 10 R 3/4 and olive gray 5 Y 3/2 root casts; dark reddish brown 10 R 3/4 (pyritic?) and dusky brown 5 YR 2/2 staining on some bedding/splitting planes; slickensides; less iron oxide staining than above; upper contact gradational; 27 cm thick.

8. Argillaceous limestone: greenish gray 5 GY 6/1 with slight maroonish cast (weathers grayish orange 10 YR 7/4); well-sorted carbonate mudstone; IA; sandy; hard; massive; blocky splitting; dusky yellow green 5 GY 5/2 root casts; vertebrate skeletal debris, and vertical vertebrate burrows with skeletal elements; ledge former; upper contact sharp; 16 cm thick.

17. Limestone: pale yellowish brown 10 YR 6/2 (weathers grayish yellow 5 Y 8/4 to pale yellowish orange 10 YR 8/6) medium to coarse, moderately-sorted, angular wackestone to packstone (biomicrite); III/IA; argillaceous; with whole high-spired gastropods, indet. bivalve fragments, echinoid spines(?), vertebrate skeletal debris, horizontal burrows up to 2.5 cm in diameter, and smooth-shelled ostracodes; individual beds vary in thickness from 2 mm to 3 cm; ripple-marked and irregular hummocky surfaces; platy to blocky splitting; upper part of unit weathered; 23 cm present.

16. Argillaceous limestone: yellowish gray 5 Y 7/2 moderately-sorted mudstone to wackestone; I/IIA; blocky (angular) to crumbly weathering; becomes more crumbly upward (weathering feature?); with indet. ostracodes and Ammovertella (a bedding plane near base of unit covered with ostracodes and ostracode fragments--overall bedding thickness could not be determined; peloids(?) or coprolites(?) up to 2 cm in diameter; fine to coarse black carbonaceous staining/debris; generally bioturbated(?) and massive(?); upper contact sharp; 11 cm thick.

15. Mudstone: light olive gray 5 Y 6/1 with fine to coarse, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide staining/mottling; calcareous; sandy; platy; light olive gray 5 Y 3/2 laminations up to 1 cm thick; some laminations with abundant smooth-shelled ostracodes; ostracodes on bedding planes; upper contact sharp; 36 cm thick.

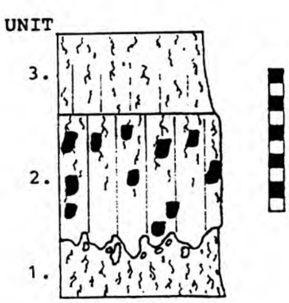
14. Mudstone: slightly more olive and lighter than dusky yellow green 5 GY 5/2; calcareous; slightly sandy; blocky; slickensides, some with dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 to black staining; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 iron oxide mottling; upper contact sharp; 33 cm thick.

13. Mudstone: finely to coarsely mottled with pale red 5 R 6/2 and pale olive 10 Y 6/2; calcareous; sandy; blocky; slickensides; with fine to medium dusky yellow green 5 GY 5/2 root(?) mottling; fine, sometimes thread-like dark yellowish orange 10 YR 6/6 to moderate yellow 5 Y 7/6 mottling and coatings on joints; dusky brown 5 YR 2/2 to black carbonaceous staining/mottling on slickensides; calcareous nodules averaging 2 mm in diameter; upper contact sharp; 11 cm thick.

Locality: E1
Location: 91 m east of locality E2, North road cut on K-99 approximately 1.5 miles northwest of Eskridge, KS, SE1/4, Sec.36, T.13 S., R.11 E., Wabaunsee Co., KS (Eskridge Quadrangle, 1971).
Units: Speiser Shale (units 1-3).
Notes: measured by Christopher R. Cunningham (September, 1988); University of Kansas, Museum of Natural History vertebrate locality; introduced to outcrop by Dr. Hans-Peter Schultze.

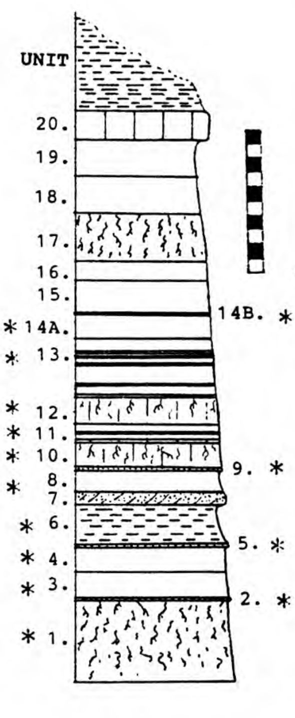
2. Argillaceous limestone: light greenish gray 5 GY 7/1 with fine to coarse, very diffuse light brownish gray 5 YR 6/1 mottling (weathers same, although exposure is new--KUMNH pit); well-sorted carbonate mudstone; IA; massive; platy to nodular weathering; dark reddish brown 10 R 3/4 to greenish gray 5 G 6/1 root casts; root casts more common toward the top; moderate brown 5 YR 3/4 to grayish orange 10 YR 7/6 oxide staining; scattered fine to coarse light olive gray 5 Y 3/2 mottling; vertical, cylinderical (ovoid cross-section) vertebrate burrows with specimens inside; some burrows packed with bone; some vertebrate skeletal elements clustered--indicating burrows were in-filled with sediment of similar grain size as that of surrounding matrix; upper contact sharp; 86 cm thick.

1. Mudstone: dark reddish brown 10 R 3/4 with fine to coarse dusky yellow green 5 GY 5/2 mottling and root casts; calcareous; sandy; blocky; slickensides; upper part of unit contains rounded vertically-elongate to subequant nodules of above lithology up to 18 cm long and 7 cm in diameter, some with vertebrate skeletal debris; unit 1 "projects" up into unit 2 (bioturbational?); dark yellowish orange 10 YR 6/6 iron oxide staining; greenish, rounded, micritic, indurated granules; upper contact irregular, sharp; 38 cm examined.



3. Argillaceous limestone (at base) to mudstone (at top): brownish gray 5 YR 5/1 (weathers very light gray N8 with a slight olive cast); calcareous; sandy; massive, well-sorted carbonate mudstone to mudstone; blocky to platy to flaggy weathering; lightens slightly in color upward; olive gray 5 Y 3/2 and dark reddish brown 10 R 3/4 root casts; dark yellowish orange 10 YR 6/6 iron oxide staining at surface and on splitting planes; slickensides; upper 24 cm with columnar peds up to 4 cm in diameter; upper contact somewhat gradational; 56 cm thick.

Locality: B
Location: North road cut of U.S.56, about 1 mile west of the turnoff to Bushong, KS, NE1/4, Sec.15, T.16 S., R.10 E., Lyon Co., KS (Bushong Quadrangle, 1971).
Units: Speiser Shale (units 1-21).
Notes: measured by Christopher R. Cunningham (June, 1988); interval was mostly covered and exposed by digging; introduced to outcrop by Dr. Hans-Peter Schultze.



3. Mudstone: light olive gray 5 Y 5/2; calcareous; sandy; weathers platy; hummocky paleotopography?; fine cross-laminations 0.1 to 1 mm thick; plant fragments and vertebrate skeletal debris; upper contact sharp; 17 cm thick.

2. Sandstone: upper very coarse, moderately-sorted, subangular to rounded lithic wacke; calcareous; matrix (approximately 20% of unit) light olive gray 5 Y 5/2 mudstone; micrite lithoclasts very pale orange 10 YR 8/2 to grayish orange 10 YR 7/4; and brownish gray 5 YR 4/1 to black; rounded grayish olive 10 Y 4/2 mudstone lithoclasts (as unit 1); matrix with sparse vertebrate skeletal debris?; lense?; upper contact sharp; up to 2 cm thick.

1. Mudstone: grayish olive 10 Y 4/2; calcareous; sandy; massive; blocky to nodular; developes a slight reddish cast upward; slickensides with dark yellowish orange 10 YR 6/6 iron oxide staining; fine dark reddish brown 10 R 3/4 mottling and root casts; upper 33 cm (sample B-1B) with vertebrate skeletal debris, spirorbid fragments, indet. ostracodes (cyprids?) with pitted surface texture; and calcareous nodules up to 2 cm in diameter that are concentrated in a band 23 cm from the top; upper contact sharp; 57 cm thick.

7. Sandstone: medium to coarse (coarsens slightly upward), moderately to poorly-sorted, subangular to rounded bone lithic wacke (micrite and mudstone lithoclast colors as in unit 2); cross-bedded?; 20-50% matrix (as in unit 2)--upper 3 cm more argillaceous, less well-indurated--result of reworking?; moderate reddish brown 10 R 4/6 to dark yellowish orange 10 YR 6/6 iron oxide staining; at least 4 ripple-marked surfaces within unit (individual coset thicknesses variable up to 3.5 cm); rounded mudstone intraclasts as in 2 up to 8 cm in diameter; vertebrate skeletal debris--some whole, relatively unabraded elements, some broken, abraded fragments; upper contact gradational, irregular and sculptured; up to 9 cm thick.

6. Mudstone: grayish olive 10 Y 4/2 with very light gray N8 laminae 0.1 mm to 1.1 cm thick; calcareous; sandy; platy; lighter laminations more calcareous than rest of unit; dark reddish brown 10 R 3/4 and dark yellowish orange 10 YR 6/6 iron oxide staining on bedding planes; horizontal burrows up to 3.5 cm thick filled with sandstone from above near top of unit; mudcracks and desiccation brecciation; upper contact sharp; 27 cm thick.

5. Sandstone: medium to coarse, moderately-sorted, subangular to rounded, bone lithic wacke (micrite and mudstone lithoclast colors as in unit 2); matrix (approximately 20% of unit) calcareous light olive gray 5 Y 5/2 mudstone; rounded flat yellowish micrite? and sandstone lithoclasts up to 0.75 cm in length; mudstone lithoclasts as in 2; upper part of unit muddier--reworked?; with fine to granule-sized vertebrate skeletal elements and fragments, some abraded and some relatively unabraded; upper contact somewhat gradational; up to 2 cm thick.

4. Mudstone: light olive gray 5 Y 5/2; calcareous; sandy; platy weathering; vertebrate skeletal debris; finely laminated (0.1 to 1 mm thick) and cross-laminated (some laminae coarser with vertebrate skeletal debris); hummocky paleotopography?; mudcracks and desiccation brecciation--sandstone from above filling mudcracks on upper contact of unit; 3 mm thick sandstone bed with vertebrate skeletal debris 12 cm from the top; lensoidal bone-rich lags?; yellowish to brownish micrite intraclasts up to 1 cm in diameter; 1 specimen indet. cyprid? with pitted surface texture; upper contact sharp; 17 cm thick.

12. Argillaceous limestone: yellowish gray 5 Y 7/2 to pale olive 10 Y 6/2; intramicrudite (intraclast packstone); intraclasts well-sorted carbonate mudstone, lensoidal in cross-section (compacted?), up to 1 cm long, and surrounded by argillaceous dusky yellow green 5 GY 5/2 stringers; shaly to platy splitting; dusky yellow green 5 GY 5/2 root casts?; mudcracked--extensive dessication brecciation; upper contact gradational; 18 cm thick; (unit highly weathered).

11. Interbedded limestone and mudstone: pale red 5 R 6/2; limestone--well-sorted mudstone (calcilutite); IA/C; argillaceous; with fenestrae? up to 1 cm long; (2) limestone beds 2.0 and 1.0 cm thick 0.0 and 6.0 cm above the base respectively; mudstone-calcareous; sandy; platy to crumbly weathering; fine to coarse dark reddish brown 10 R 3/4 mottling on bedding/splitting planes; with vertebrate skeletal debris; unit 11 upper contact sharp; 11 cm thick.

10. Argillaceous limestone: pale olive 10 Y 6/2; well-sorted mudstone; I/IIA/C; massive; nodular to platy (weathering); vertebrate skeletal debris; fenestrae? up to 1 cm long lined with dark brown spar; dusky yellow green 5 GY 5/2 root casts (rhizobrecciated texture?); dark reddish brown 10 R 3/4 carbonaceous (plant?) fragments; upper contact sharp; 16 cm thick.

9. Sandstone: similar to 7; cross-bedded--2 cosets--upper slightly thinner, lower muddier; matrix 20-40%; upper contact sharp; up to 3 cm thick.

8. Mudstone: light olive gray 5 Y 5/2; calcareous; sandy; platy weathering; vertebrate skeletal debris; upper 2 cm whitish, more calcareous with fenestrae? up to 1 cm long; sandstone lenses with vertebrate skeletal debris up to 1.5 cm thick; 2 cm in diameter horizontal burrow filled with sandstone from above; upper contact sharp and mudcracked (mudcracks filled with sandstone from above); 14 cm thick.

18. Mudstone: pale olive 10 Y 6/2 with fine to medium light olive brown 5 Y 5/6 root? mottling (slightly more brownish overall than 17); calcareous; sandy; blocky; weathers platy; black carbonaceous (plant?) debris on joints and on splitting planes; dark yellowish orange 10 YR 6/6 iron oxide staining on joints and splitting planes; slickensides; smooth-shelled ostracodes?; upper contact sharp and stained yellowish with iron oxides; 25 cm thick.

17. Mudstone: light olive gray 5 Y 5/2 with fine to medium light olive brown 5 Y 5/6 mottling and root casts; calcareous; sandy; massive; weathers platy; joints with dark yellowish orange 10 YR 6/6 iron oxide coatings and fine to coarse dusky brown 5 YR 2/2 staining/mottling; upper contact sharp with a concentration of dark yellowish orange 10 YR 6/6 iron oxide staining; 33 cm thick.

16. Mudstone: dusky yellow green 5 GY 5/2; calcareous; slightly silty; slightly sandy; massive; joints with dark yellowish orange 10 YR 6/6 and dusky brown 5 YR 2/2 staining/coatings; upper contact sharp; 14 cm thick.

15. Mudstone: pale olive 10 Y 6/2; calcareous; slightly silty; massive; lightens in color upward; upper contact sharp with dark yellowish orange 10 YR 6/6 iron oxide staining; 23 cm thick.

14B. Limestone: pale olive 10 Y 6/2; well-sorted mudstone (calcilutite); IA; upper contact sharp; 1.5 cm thick.

14A. Mudstone: dusky yellow green 5 GY 5/2; calcareous; slightly silty; massive; weathers platy; vertebrate skeletal debris?; upper contact sharp; 15.5 cm thick.

13. Interbedded mudstone and limestone: mudstone--grayish red 5 R 4/2 with scattered medium to coarse dusky yellow green 5 GY 5/2 root? mottling; calcareous; slightly silty; massive; weathers platy; joints with black carbonaceous coatings; nodular weathering at base; limestones--pale red 5 R 6/2 to light grayish olive 10 Y 4/2 (generally lighter in color than claystone); well-sorted mudstone (calcilutite); IA; (5) limestone beds 2.0, 1.0, 1.0, 1.5; 2.0 cm thick, 0.0, 9.0, 22.0, 27.0, 30.0 cm above the base respectively; birdseyes? in lowest limestone; unit 13 upper contact sharp; 39 cm thick.

21. Mudstone: finely to coarsely mottled with medium gray N5 and light olive gray 5 Y 6/1 with fine circular to thread-like dark yellowish orange 10 YR 6/6 iron oxide staining; calcareous; sandy; hard; platy; with smooth-shelled ostracodes, Aviculopecten fragments and whole valves, large productid spines, whole valves of large Derbyia, echinoid spines, and poorly-preserved bellerophontid?; 18 cm examined--top covered.

20. Limestone: finely to coarsely mottled with medium gray N5, light olive gray 5 Y 6/1, and dusky yellow 5 Y 6/4; fine, poorly-sorted, angular to rounded mudstone to wackestone (micrite to biomicrite); IA; argillaceous; with smooth-shelled ostracodes, echinoid spines, fragments of large (pinnid?) bivalves, Aviculopecten fragments, Septimyalina(?) fragments, Derbyia(?) fragments; platy to nodular; becomes more platy and more argillaceous upward; possible oscillation ripple-marked surfaces near base; upper contact gradational; 20 cm thick.

19. Mudstone: finely and faintly mottled with light olive brown 5 Y 5/6 and pale olive 10 Y 6/2; calcareous; sandy; massive; weathers crumbly to platy; fine black carbonaceous debris; with smooth-shelled ostracodes; upper contact sharp and stained dark yellowish orange 10 YR 6/6 with iron oxides; 24 cm thick.

GENETIC STRATIGRAPHY, DEPOSITIONAL ENVIRONMENTS, AND VERTEBRATE PALEONTOLOGY OF THE SPEISER SHALE (GEARYAN STAGE, LOWER PERMIAN SERIES) IN NORTHERN KANSAS

by

Christopher R. Cunningham

B.S., University of Minnesota, 1986

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

(Geology)

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

ABSTRACT

The methods of hierarchal genetic stratigraphy were utilized to understand the distribution of vertebrate fossils within the Speiser Shale (Council Grove Group, Gearyan Stage, Lower Permian Series) in northern Kansas. In the course of investigation, twenty exposures of the Speiser Shale in Marshall, Riley, Pottawatomie, Geary, Wabaunsee, and Lyon Counties, Kansas, were examined. Lithology, structures, and fossil content of each descriptive unit at each locality were noted and recorded in the field. In addition, samples of selected mudrock descriptive units were disaggregated and sieved for recovery of fossil specimens. Selected carbonate descriptive units were dissolved in an acetic acid solution, and were also sieved for recovery of fossil specimens. Results of the analysis of the distribution of facies and vertebrate and invertebrate remains within the Speiser Shale in north-central Kansas may be summarized as follows. 1) Sixth-order transgressive-regressive units, or punctuated aggradational cycles (PACs), can be identified and correlated with confidence only within parts of the study interval that show marine influence, i.e., the dominantly marginal marine lower and lower middle, and the marginal to open marine upper Speiser Shale. 2) Results of this study are generally

consistent with the hierarchal genetic stratigraphic model of deposition. 3) Palaeoniscoid, platysomid (phyllodont), acanthodian, and elasmobranch (Cladodus-type, and indeterminate) remains are restricted to facies that show some marine influence within the study interval. Phyllodont, acanthodian, indeterminate elasmobranch, and palaeoniscoid remains, mostly teeth and scales, were found in subtidal through supratidal facies within the study interval. Cladodus-type remains, however, are restricted to the most open marine, subtidal facies of the upper Speiser Shale. Whole, articulated dipnoan (Gnathorhiza) and amphibian specimens and burrows are restricted to facies that show little or no evidence of marine influence, possibly periodically (seasonally?) dry, lakes. In some cases, nonmarine, possibly lacustrine, facies rich in lungfish (Gnathorhiza) and tetrapod skeletal remains were overstepped by sea-level during minor (sixth-order) transgressive events. In these cases, exhumed, and therefore allochthonous, disarticulated Gnathorhiza and tetrapod remains are preserved in transgressive intertidal to supratidal deposits of the lower middle Speiser Shale.

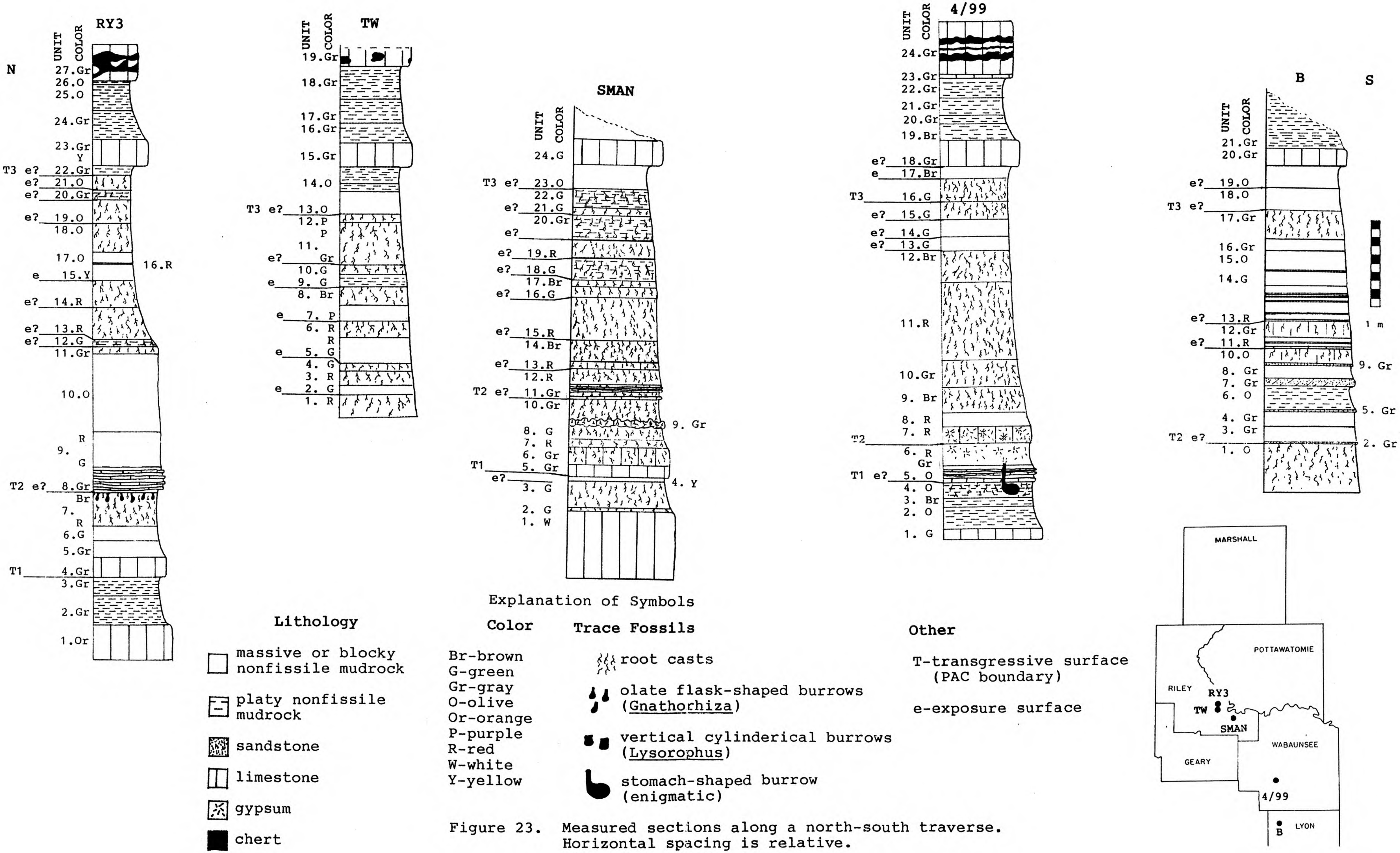


Figure 23. Measured sections along a north-south traverse. Horizontal spacing is relative.