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Open-file Report

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STUDIES IN PALEOECOLOGY OF THE WATHENA SHALE MEMBER OF THE LAWRENCE FORMATION (VIRGILIAN: U. PENNSYLVANIAN) OF EASTERN KANSAS

Compiled by

A. J. Robb, III

KANSAS GEOLOGICAL SURVEY

OPEN FILE REPORT 91-3

MAY 6, 1991

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INTRODUCTION

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Many aspects of the Upper Pennsylvanian cyclothems of Kansas have been extensively studied. These studies have often concentrated on the limestone formations or "bundles" within these sequences, neglecting the often stratigraphically thicker and more complex "outside shales" of Heckel, et al. (1979). These thick outside shales are generally interpreted as nearshore marine to terrestrial deposits (Heckel, et al. 1979), although detailed analysis of the depositional environments is rarely done. The Lawrence Formation (Shawnee Group: Virgilian) is one of these thick outside shales. As discussed by West (this report, p. 2), Stanton M. Ball (1964, p.158) named the upper portion of the Lawrence Formation, the strata between the Amazonia Limestone Member and the Toronto Limestone Member (Oread Formation), the Wathena Shale Member based on a section exposed in an abandoned quarry just south of the town of Wathena, Doniphan County, Kansas. In late March 1991, Chris Maples and I visited the type locality of the Wathena Shale Member, but were unable to locate the section due to heavy slumping and thick colluvial overburden in the quarry apparently described by Ball (1964). An attempt to locate a complete exposure of the upper part of the Lawrence Formation (= Wathena Shale Member) in nearby Doniphan County (Wathena area) failed to produce an acceptable location to view the section. Since the name was never published and described except in a doctoral dissertation by Ball (1964), this shale sequence remains informally named with a type section that is no longer accessible for study.

The contents of this open file report are the results of a graduate-level field paleoecology course jointly taught at the Kansas State University (KSU) and the University of Kansas (KU) in the Fall of 1990. The purpose of this field course was to study in detail the paleoecology of the Wathena Shale Member. As part of the course, class members selected a particular topic or faunal element within the Wathena to evaluate for later synthesis into a final analysis of the depositional environment of the unit. Brian Smith (KSU) studied the sedimentological aspects of the Wathena Shale Member. The macroinvertebrate fauna was studied by Jon Garbish (KU) and Kevin Krogstad (KSU). The microinvertebrates, particularly the ostracodes, were studied by George Hecht (KU). The flora was studied by Scott Hageman (KU) and Ken Ross (KSU). The vertebrate fossils were studied by Al Robb (KU), and the trace fossil assemblage by both Al Robb (KU) and Barbara Tilley (KSU). Ron West and Allan Archer directed the project at Kansas State University; Chris Maples, Roger Kaesler, and Howard Feldman supervised at the University of Kansas.

References Cited:

Ball, S.M., 1964, Stratigraphy of the Douglas Group (Pennsylvanian: Virgilian) in the northern Midcontinent region. Unpublished Ph. D. dissertation, University of Kansas, 490p.

Heckel, P.H., Brady, L.L., Ebanks, W.J., Jr., and Pabian, R.K., 1979, Fieldguide to Pennsylvanian cyclic deposits of Kansas and Nebraska. Kansas Geological Survey Guidebook, Series 4, 79p.

OBSERVATIONS ON THE WATHENA SHALE IN KANSAS

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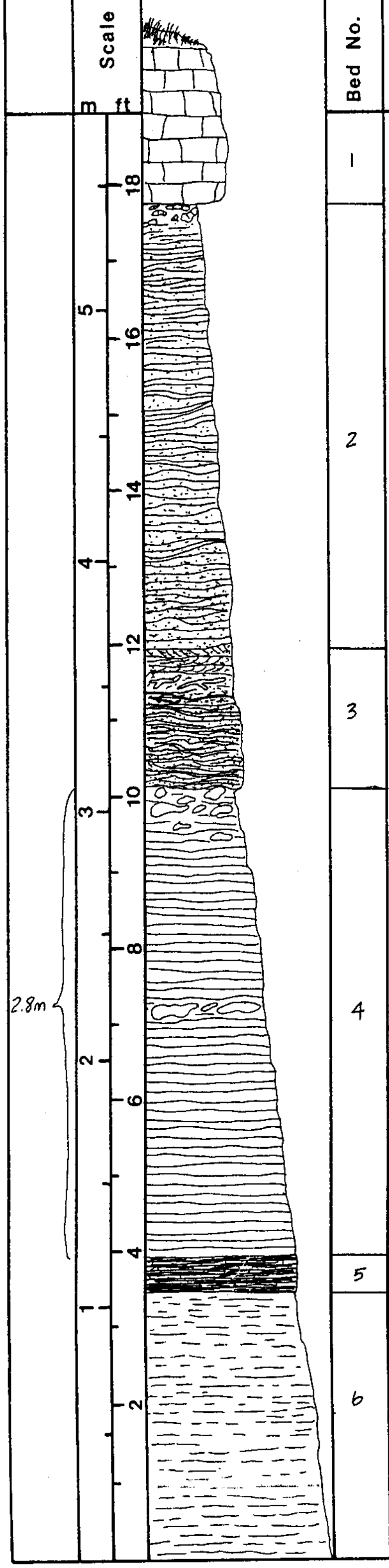
The attached five stratigraphic sections of the Wathena Shale are the results of the Fall 1990 Field Palaeoecology Class at Kansas State University, taught in conjunction with the same class (Field Palaeoecology) at the University of Kansas.

The Wathena Shale Member of the Lawrence Formation was described by S. M. Ball (1964). As originally proposed, the Wathena Shale Member consisted of the strata bounded by the Amazonia Limestone Member below and the Toronto Limestone Member (Oread Formation) above. As such, the Wathena is the uppermost member of the Lawrence Formation. Ball (p.158, 1964) designated the type section as an exposure (NE1/4, SW1/4, Sec. 33, T.3S., R.22E.) in an abandoned quarry along the Missouri River bluffs in Doniphan County, Kansas; about 0.6 mile south of Wathena, Kansas.

The purpose of this class project was to measure, describe, and interpret five exposures of the Wathena shale; two in Douglas Co., two in Coffey County, and one in Woodson County, Kansas. All students in the class were involved in the gathering of field data. Laboratory study of samples and specimens was divided based on the students interests with the final synthesis a joint effort. Brain Smith concentrated on the sedimentological aspects of the Wathena; while Barbara Tilley, Ken Ross, and Kevin Krogstad evaluated the trace, plant, and invertebrate fossils respectively.

Evidence from the five Wathena shale exposures studied suggest that the unit was deposited in a tropical esturary where the environments fluctuated in response to tidal and terrestrial influences. This interpretation was reported in a joint paper (authored by the eight students, four from KSU and four from KU) presented as a poster at the 1991 annual meeting of the South-Central Section of the Geological Society of America (held jointly with the Rocky Mountain Section of the Geological Society of America in Albquerque, New Mexico) in April 1991. A copy of the abstract of this paper is attached.

Ball, S. M., 1964, Stratigraphy of the Douglas Group (Pennsylvanian, Virgilian) in the Northern Midcontinent Region, unpublished doctoral dissertation, University of Kansas, 490p.



Locality Description: Roadcuts along both sides of road in SE1/4, NW1/4, Sec. 20, T.13S., R.19E., Douglas Co., Kansas; Lawrence West 7.5' Topographic Quadrangle, revised 1978.

Location: Clinton Lake Locality

Measured By:- B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks: 1 of 3

Description

Bed No.

1 Slabby calcarenite (packstone to wackestone), moderate yellowish brown, fossiliferous, crinoid, bivalve, and brachiopod fragments, fusulinids, lower contact sharp. Basal Toronto limestone.

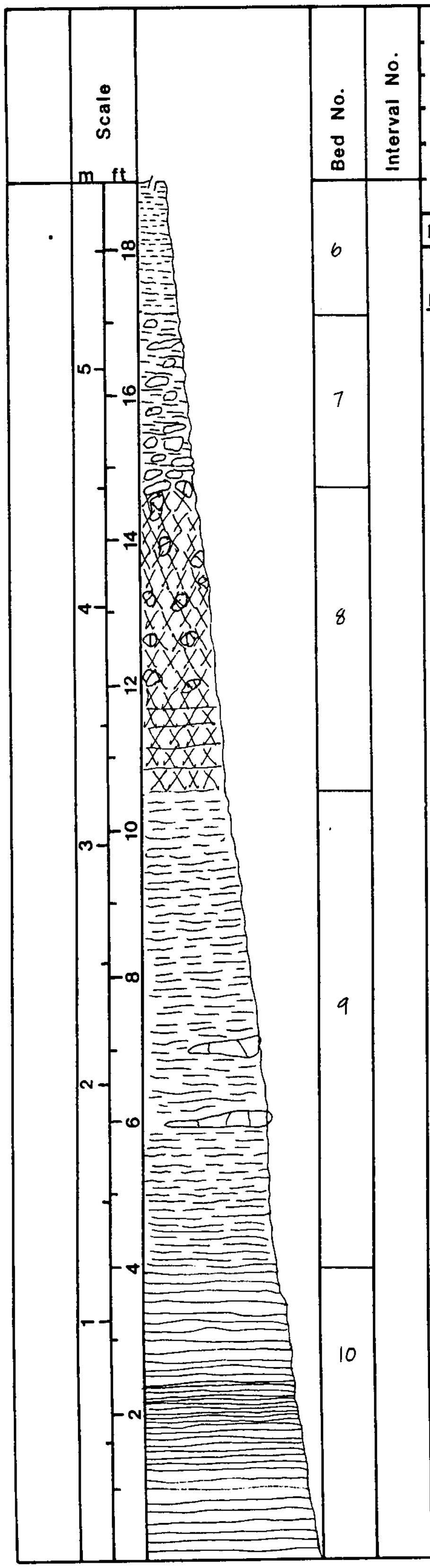
2 Sandy siltstone, 198cm thick, light gray, horizontal laminated to cross-bedded, some possible traces and tracks, calcareous, grain size decreases upward to clayey siltstone at sharp contact with overlying limestone, some horizontal burrows present, not as laminated near top, also, algal carbonate (not sandy carbonate) nodules present at upper contact.

3 Calcarenite, 33cm thick, gray, low angle cross-beds, upper contact gradational, lower contact sharp. Upper third of unit contains Isopodichnus, Planolites, Lockeia, Scolicia, Aulichnites, Uchirites, and pyrite filled burrows. Lower two-thirds of unit contains Asteriacites, Planolites, Uchirites, and Aulichnites.

4 Thinly laminated mudstone, 280cm thick, green-gray, some bioturbation, including Planolites, abundant siderite nodules in upper one meter, siderite layer 105cm above basal contact contains Dunbarella, clay content high, lower contact sharp marked by thin, ostracode rich, bed.

5 Blocky coal, 15cm thick.

6 Blocky mudstone, 173cm thick, olive green-gray, rooted at sharp upper contact with the coal, root casts sideritic.



Locality Description: Roadcuts along both sides of road in SE1/4, NW1/4, Sec. 20, T.13S., R.19E., Douglas Co., Kansas; Lawrence West 7.5' Topographic Quadrangle, revised 1978.

Location: Clinton Lake Locality

Measured By: ~~B. Smith~~, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks: 2 of 3

Description

Bed No.

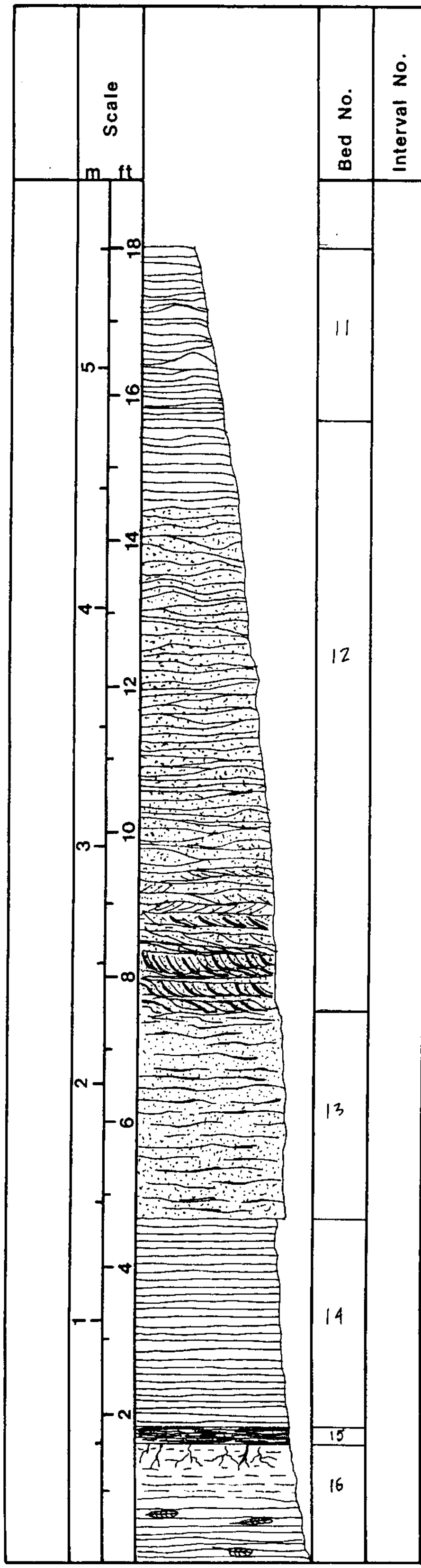
6 Blocky mudstone, 173cm thick, olive green-gray, rooted at sharp upper contact with the coal, root casts sideritic.

7 Mudstone, 72cm thick, green, dolomitized nodules, some unidentifiable trace fossils, contacts gradational.

8 Blocky mudstone, 137cm thick, mottled red and green, clay content high, calcareous nodules contain fossil fragments (mostly shell debris), some unidentifiable trace fossils present.

9 Thinly laminated to blocky mudstone, 208cm thick, calcareous nodular layers present 75cm below top containing: Composita, Crurithyris, myalinids, ramose bryozoans, Astartella, Phestia, with barnacle borings, Nuculopsis, Edmondia, some broken bone debris, Derbyia fragments, spiriferid fragments, and some probable horizontal and vertical burrows. These carbonate beds are probable Amazonia limestone equivalents.

10 Thinly laminated siltstone, 120cm thick, light gray, bioturbated with Planolites and Lockeia recognized, flaser bedded, laminations thicken upward from gradational lower contact, upper contact gradational.



Locality Description: Roadcuts along both sides of road in SE1/4, NW1/4, Sec. 20, T.13S., R.19E., Douglas Co., Kansas; Lawrence West 7.5' Topographic Quadrangle, revised 1978.

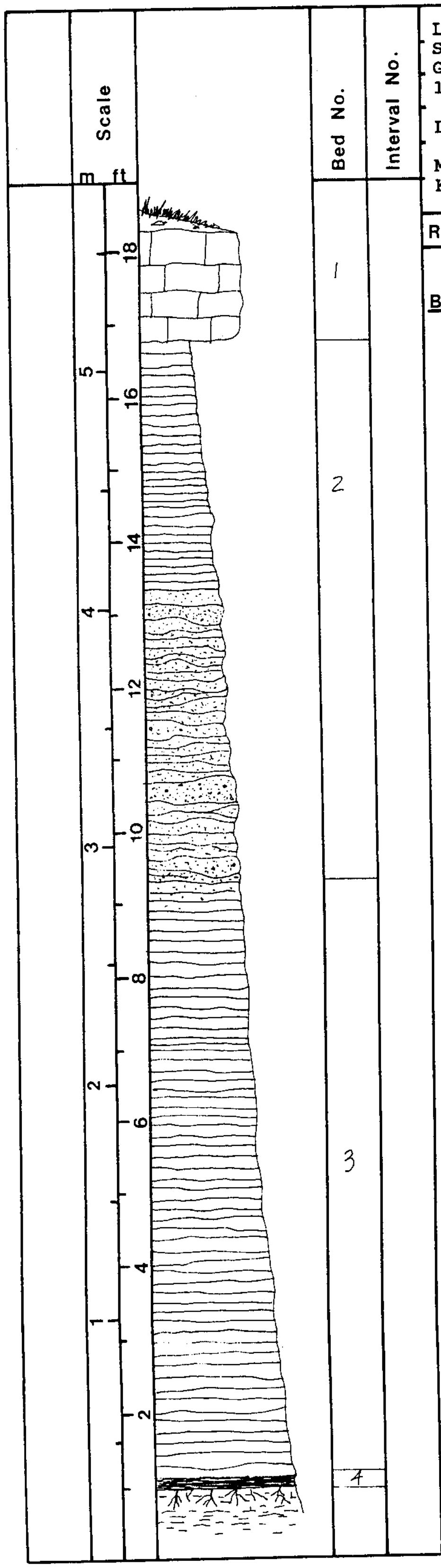
Location: Clinton Lake Locality

Measured By: B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks: 3 of 3

Description

Bed No.	
11	Flaser bedded sandy siltstone with clay drapes, 72cm thick, some bioturbation, clay content increases upward, bedding more horizontal near top, bioturbation decreases upward.
12	Fine grained silty sandstone, 254cm thick, gray, cross-beds and flaser beds, micaceous, organic debris deposited along cross-bed surfaces, and some possible horizontal burrows.
13	Massive micaceous quartz sandstone, 87cm thick, gray to tan, no bedding preserved, thin laminations of plant debris present.
14	Silty mudstone, 107cm thick, gray-brown, thinly laminated, _Planolites_.
15	Platy to blocky coal, 6cm thick.
16	Underclay with sideritic root casts, nodules, and discontinuous layers, base covered.



Locality Description: Center of South line of Sec. 11, T.14S., R.18E., Douglas Co., Kansas; Globe 7.5' Topographic Quadrangle, revised 1983.

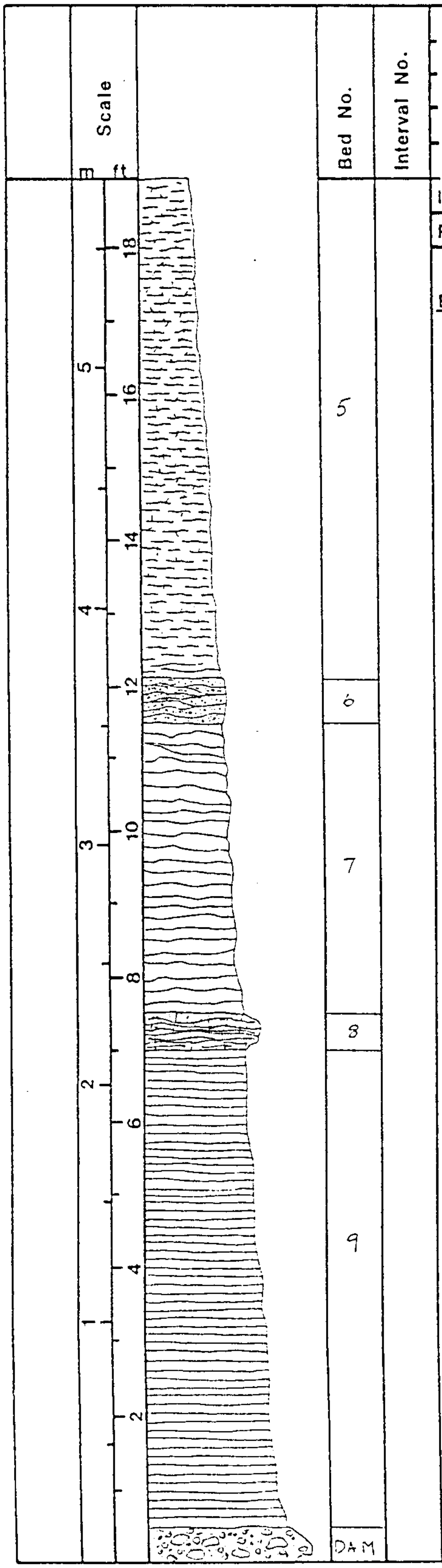
Location: Lonestar Lake Spillway

Measured By: B. Smith, B. Tilley, K. Ross, & K. Krogstad: Fall'90.

Remarks: 1 of 3

Description

Bed No.	
1	Slabby calcarenite (packstone to wackestone), moderate yellowish brown, fossiliferous; crinoid, bivalve, and brachiopod fragments, fusulinids, lower contact sharp. Basal Toronto limestone.
2	Thinly laminated siltstone, 228cm thick, gray-green, lower 122cm contains interbedded flaser micaceous sandstone lenses.
3	Finely laminated silty mudstone, 249cm thick, gray.
4	Thin blocky coal, 3cm thick.
5	Blocky mudstone, 218cm thick, purple brown gray.



Locality Description: Center of South line of Sec. 11, T.14S., R.18E., Douglas Co., Kansas; Globe 7.5' Topographic Quadrangle, revised 1983.

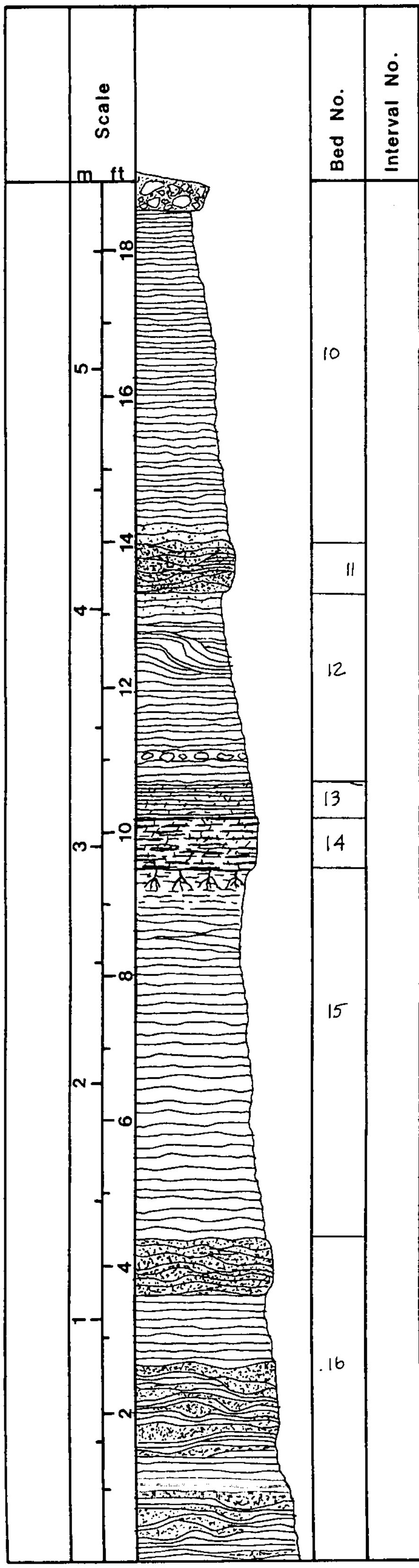
Location: Lonestar Lake Spillway

Measured By: B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks: 2 of 3

Description

Bed No.	
5	Blocky mudstone, 218cm thick, purple brown gray.
6	Flaser bedded sandstone, 20cm thick, <u>Asteriacites</u>.
7	Bioturbated gray mudstone, 120cm thick, horizontal laminations contain interbedded siderite deposits.
8	Cross-bedded calcarenite, 15cm thick, nodular, myalinids abundant. Probable Amazonia limestone equivalent.
9	Laminated to blocky mudstone, 200cm thick, gray, <u>Phestia</u> common.



Locality Description: Center of South line of Sec. 11, T.14S., R.18E., Douglas Co., Kansas; Globe 7.5' Topographic Quadrangle, revised 1983.

Location: Lonestar Lake Spillway

Measured By: B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks: 3 of 3

Description

B. No.

10 Sandy siltstone, 75cm thick, thin horizontal laminations with no fossils to highly bioturbated with Planolites, Lockeia Aulichnites and Isopodichnus?, medium light gray.

11 Flaser bedded sandstone, 20cm thick, Lockeia, Scalarituba, Scolichia? present and Planolites abundant.

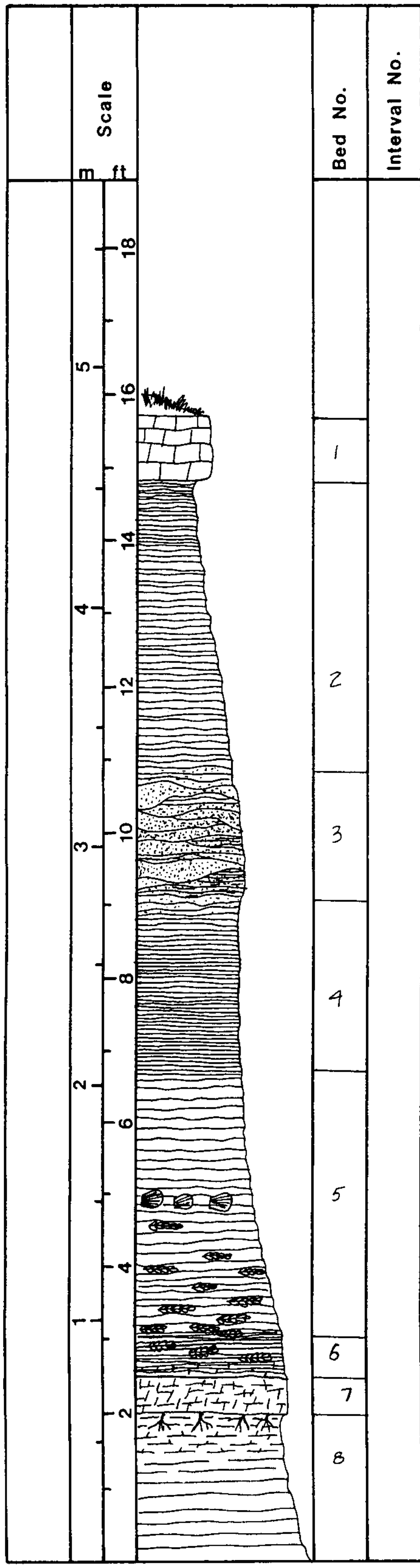
12 Siltstone, 80cm thick, light gray, horizontal to flaser laminations, sandstone lenses (2-3cm thick), current direction, measured 30cm above coal, varies from N60W to N80W, prominant siderite bearing layer (5-10cm above coal), nuculoid bivalves, Myalina, Aviculopecten common.

13 Shaly coal, 15cm thick, very dark gray, horizontally laminated, friable, disarticulated Annularia, Calamites, Cordaites, Neuropteris, Spenopteris, abundant, articulated Asterophyllites common, disarticulated Pecopteris common, Myalina, Aviculopecten common, fusain present, spirorbids common, upper and lower contacts gradational.

14 Blocky coal, 18cm thick, abundant disarticulated plant fragments, pyrite dendrites along blocky edges, upper contact gradational, lower contact sharp.

15 Sandy siltstone, 1.5m thick, light gray, finely laminated horizontal to flaser laminations, sandstone lenses present, highly bioturbated, rhizoliths present.

16 Sandy siltstone, light brownish gray, finely laminated flaser bedforms dominant over horizontal laminations, contains more clay than overlying unit and grain size decreases upward, Planolites, Lockeia, and possible tool marks, contacts gradational, base convered.



Locality Description: Roadcut along south line of SW1/4, SW1/4, SW1/4, Sec.33, T.20S., R.17E., Coffey Co.,Kansas; New Strawn 7.5' Topographic Quardangle.

Location:

Measured By; B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks:

Description

Bed No.

1 Slabby calcarenite (packstone to wackestone) 30cm thick, moderate yellowish brown, fossiliferous, crinoid, bivalve, and brachiopod fragments, fusulinids, lower contact sharp. Basal Toronto limestone.

2 Siltstone to claystone, 175cm thick, grayish olive, grades from a calcareous siltstone at the base to a non-calcareous claystone at the top, horizontally laminated. A 25cm thick sandstone bed present at the base, flaser bedding present, highly bioturbated with possible crawling traces; Planolites and Cyzicus.

3 Fine grained lenticular sandstone, 25cm thick, micaceous, flaser bedding, bed is resistant to weathering, abundant ichnofossils; Planolites, unidentifiable crawling and burrowing traces abundant, Cyzicus? present, contacts distinct.

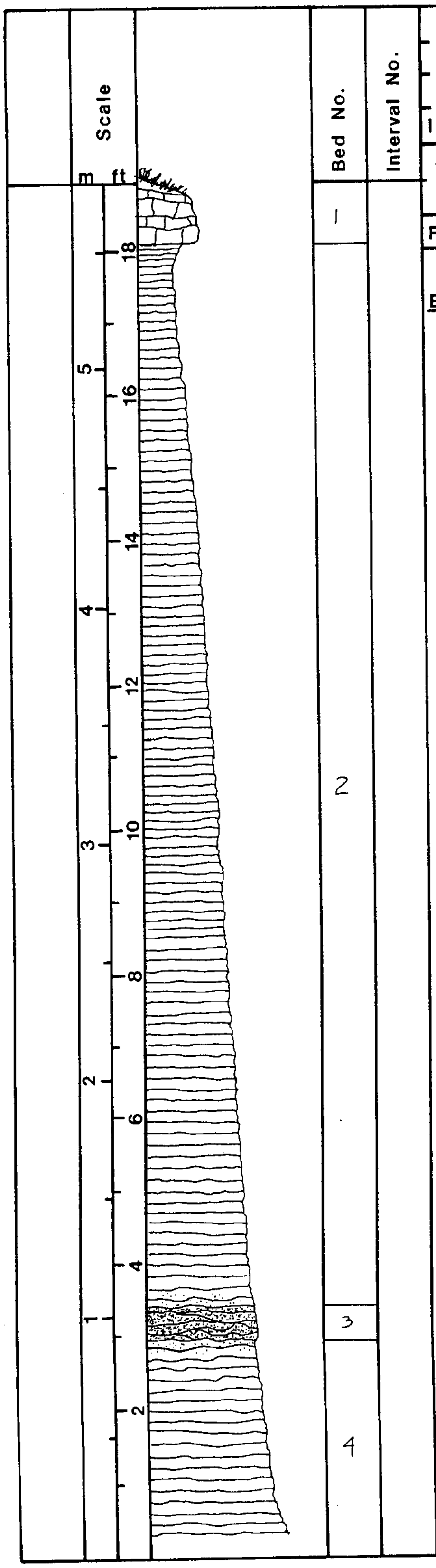
4 Silty mudstone, 75cm thick, light blue gray, finely laminated, no fossils, silt content increases upward, upper and lower contacts gradational.

5 Platy silty mudstone, 110cm thick, dark gray, finely laminated, laminations horizontal, lower 50cm; Myalina, Aviculopecten, and Spirorbis abundant, Orbiculoidea, Trigonoglossa common, (prominant myalinid bed 25cm above base), disarticulated Calamites, Neuropteris, Odontopteris, Pinnularia, Pecopteris, Sphenopteris abundant, articulated Cordaites common, disarticulated Mariopteris common, bivalves and spirorbids attached to some plant leaves, upper contact gradational, lower contact distinct.

6 Platy snaly coal, 20cm thick, very dark gray, friable, plant fossil diversity same as in unit 5, (articulated and disarticulated), Spirorbis attached to macerated plant fragments, upper contact sharp, lower contact gradational.

7 Blocky coal, 20cm thick, disarticulated plant fragments, Neuropteris, pyrite dendrites associated with plant fragments and along bed surfaces, logs found along upper contact, Planolites and some possible crawling traces, both contacts sharp.

8 Clay mudstone, medium dark gray, blocky in upper part, plant fragments penetrate mudstone, (underclay), siderite root casts and nodules abundant below blocky zone. Base covered.



Locality Description: Roadcut along the East line of NE1/4, Sec. 33, T.21S., R.16E, extending along roadcut near SE1/4, SE1/4, Sec. 28, T.21S., R.16E., Coffey Co., Kansas; Burlington 7.5' Topographic Quadrangle, revised 1979.

Measured By; B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks: 1 of 2

Description

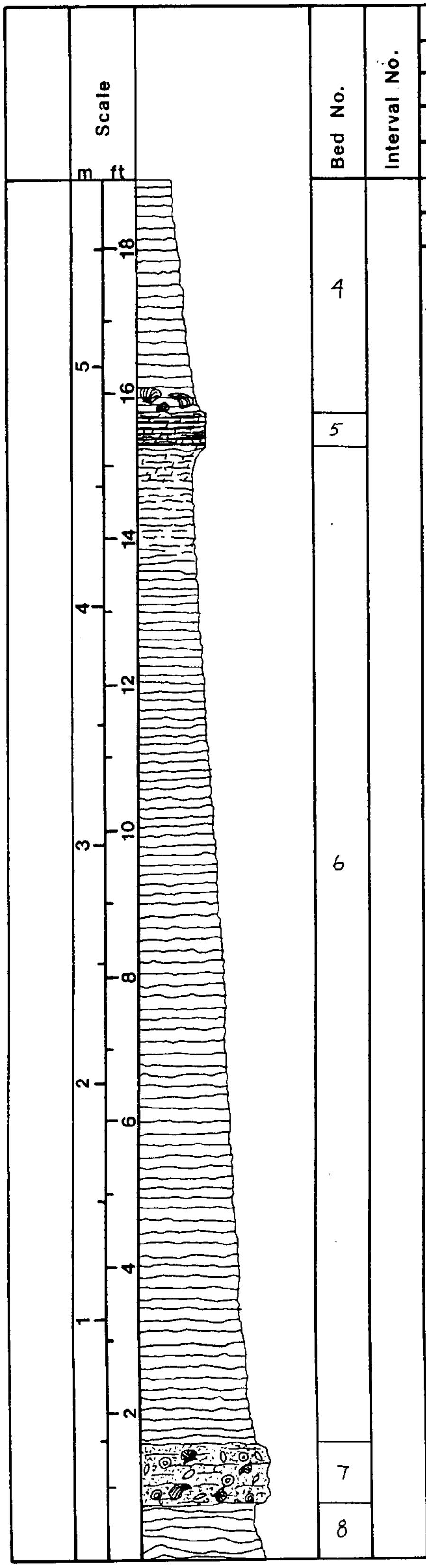
Bed No.

1 Slabby calcarenite (packstone to wackestone), 40cm thick, yellowish brown brachiopod fragments, fusulinids, lower contact sharp. Basal Toronto limestone.

2 Siltstone, 4.6±m thick, medium to dark brown, horizontally laminated throughout,blocky at upper contact, no fossils.

3 Sandstone, 10cm thick, fine to medium grained, light gray, micaceous, both horizontal and flaser bedding present, some highly bioturbated beds with Lockeia, Planolites, and Treptichnus?

4 Silty mudstone, 1.3m thick, blocky to platy, medium brown, prominent myolinid-rich bed at lower contact, Myalina abundant, Cyzicus, Spirorbis present, some trace fossils, including a few Planolites, contacts distinct.



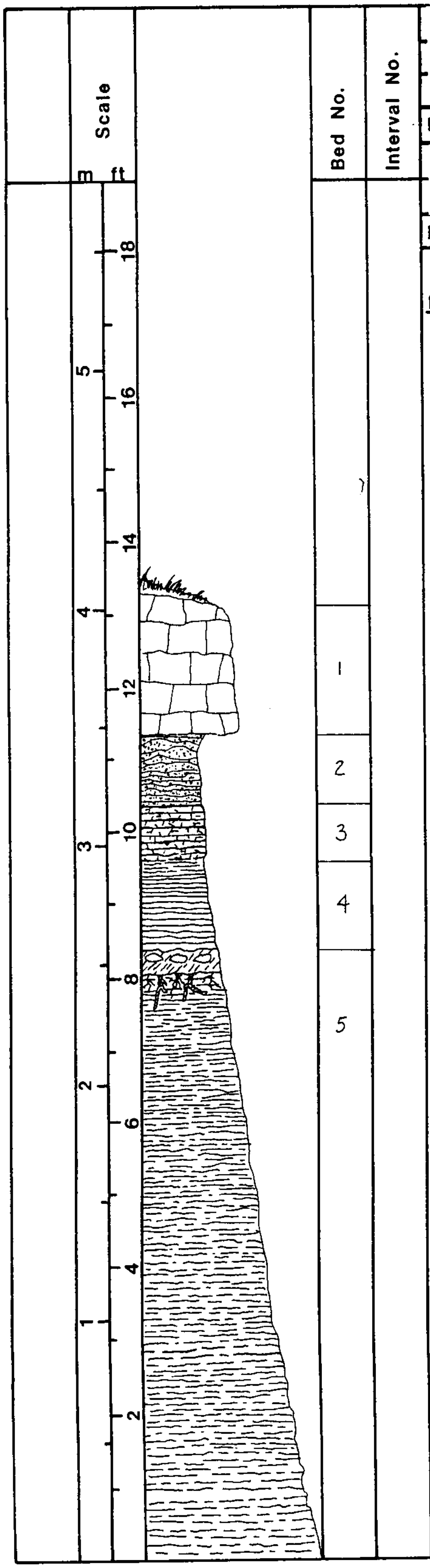
Locality Description: Roadcut along the East line of NE1/4, Sec. 33, T.21S., R.16E, extending along roadcut near SE1/4, SE1/4, Sec. 28, T.21S., R.16E., Coffey Co., Kansas; Burlington 7.5' Topographic Quadrangle, revised 1979.

Measured By; B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks: 2 of 2

Description

Bed No.	
4	Silty mudstone, 1.3m thick, blocky to platy, medium brown, prominent myolinid-rich bed at lower contact, <u>Myalina</u> abundant, <u>Cyzicus</u>, <u>Spirorbis</u> present, some trace fossils, including a few <u>Planolites</u>, contacts distinct.
5	Coal, 10cm thick, shaly to blocky, some pyrite, heavily weathered, plant fragments.
6	Clay mudstone, 4.0m thick, blocky, heavily weathered, siderite nodules present throughout and in veins, <u>Aviculopecten</u> common, <u>Spirorbis</u> common.
7	Slabby calcarenite, 24cm thick, light yellowish brown, fossiliferous brachiopods, bivalves; <u>Myalina</u>, <u>Aviculpecten</u>, <u>Orbiculoidea</u> abundant, fusulinids, crinoid fragments present. Probable Amozonia limestone equivalent.
8	Clay mudstone, olive brown, blocky, siderite nodules present, base covered.



Locality Description: Roadcut on the north side of U.S. Highway 54, near the midpoint of the South edge of SW1/4, Sec. 25, T.25S., R.13E., Woodson Co., Kansas; Toronto 7.5' Topographic Quadrangle, 1969.

Location:

Measured By: B. Smith, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

Remarks:

Description

Bed No.

1 Slabby calcarenite (packstone to wackestone), 65cm thick, thickness varies with underlying sandy unit, moderate yellowish brown, fossiliferous, crinoid, bivalve, and brachiopod fragments, fusulinids, lower contact sharp. Basal Toronto limestone.

2 Tidal creek or channel silt/sandstone, thickness varies from 28-71cm, fine horizontal laminations, highly bioturbated with Zoophycus, Planolites, and associated traces, Aviculopecten, Myalina, spiriferids common, Lepidodendron present, Calamites fragments associated with the lower contact organic layers associated with shell debris, channel strikes N40E, contacts sharp.

3 Blocky coal, 22cm thick, disarticulated plant matter, friable, pyrite and siderite veins present.

4 Carbonaceous shale, 37cm thick, dark gray, blocky to horizontally laminated, possible underclay at upper contact.

5 Blocky mudstone, 246cm thick, dark gray, numerous layers of siderite nodules to thin siderite beds, some horizontal burrows, prominent siderite layer traceable along outcrop, root structures filled with siderite penetrate into blocky mudstone from upper contact, highly weathered.

ABSTRACT FORM FOR ALL GSA MEETINGS IN 1991

Complete all sections ① through ⑨ below

① TYPE ABSTRACT COMPLETELY WITHIN THE BLUE LINES BELOW.

№ 9800

THE WATHENA SHALE MEMBER OF THE LAWRENCE FORMATION (VIRGILIAN: U. PENNSYLVANIAN) OF EASTERN KANSAS: A TIDAL ESTUARY

GARBISH[1], J.O., HAGEMAN[1], S.A., HECHT[1], G.D., KROGSTAD[2], K., ROBB[1], A.J., III, ROSS[2], K., SMITH[2], B., and TILLEY[2], B., Dept. of Geology, University of Kansas, Lawrence, 66045[1] and Dept. of Geology, Kansas State University, Manhattan, 66506[2].

Data from six, widely-spaced exposures of the Wathena Shale Member in eastern Kansas supports an estuarine, tidally-influenced origin. The Wathena Shale is a typical outside shale of Upper Pennsylvanian cyclic sedimentary models. The interval studied includes a coal with a rooted underclay and overlying siliciclastic rocks. Directly above the coal, an organic-rich, platy mudrock grades upward into a sparsely fossiliferous, blocky mudrock. The coal, and overlying mudrock, contain large stem fragments and matted plant debris. Several centimeters upsection, the flora is dominated by well preserved pteridosperms, lycopods, and sphenopsids. The fauna includes spirorbid worm tubes, often attached to the leaves, small myalinid clams, and brackish and fresh-water ostracodes. Aviculopecten, a euryhaline clam, appears at this level and persist throughout the unit.

The upper siltstones are sparsely fossiliferous with tidal rhythmites evident in the non-bioturbated intervals. In a mudrock and siltstone interval approximately one meter above the coal, a predominantly marine fauna occurs including clams, brachiopods, crinoids, and bryozoan fragments. The microfossils of this interval include fish debris and near-shore to shallow shelf ostracodes. In a mudrock above this interval, conchostracans are present which suggest a return to a less saline (freshwater) environment. At several locations, a discontinuous, crossbedded, sandstone with an ichnocoenosis dominated by Planolites, occurs at the top of the Wathena. Additionally, the presences of Lingula in this interval suggests marine influence. Terrigenous and euryhaline components of the fossil assemblage, and sedimentological evidence for a tidal influence, support a fluctuating tropical estuarine depositional environment.

Results of a joint KU/KSU Field Palaeoecology course.

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- ☐ 7 geochemistry, aqueous
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- ☐ 13 global geoscience
- ☐ 14 history of geology
- ☐ 15 hydrogeology
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- ☐ 31 stratigraphy
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Address Dept. of Geology

Address University of Kansas

City/St/ZIP Lawrence, KS 66045

Country USA

Office Phone (913)864-4974 Home Phone ___________

If the speaker will be unavailable at these numbers during the 45 days following the abstract deadline, list phone numbers to be used instead.

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Macroinvertebrate Assemblages of the Wathena Shale Member

Jon O. Garbisch
University of Kansas - Dept. of Geology
120 Lindley Hall
Lawrence, KS 66045

Abstract

Macroinvertebrate specimens were collected from the Wathena Shale Member of the Lawrence Formation, from six sites in Kansas: three in the Lawrence area, in Douglas County; two from near Burlington, in Coffey County; and one west of Yates Center, in Woodson County. The majority of macroinvertebrates are found immediately above a coal, believed to be the Upper Williamsburg. The section in Lawrence, Kansas, next to the Kansas Geological Survey building, was the only one to contain a diverse and abundant marine fauna that includes; brachiopods, bivalves, bryozoa and crinoids. The other five sections contain a low-abundance, low-diversity assemblage of pectinids, myalinids, and orbiculoids, with one exception in the Woodson County section, where the brachiopod *Derbyia* is abundant. Conchostracans were also found at some of the Douglas County sections and the Coffey County sections. *Lingula* is found in the upper portion of the Wathena at one section in Douglas County.

Introduction

This project is part of a field paleoecology course given jointly at the University of Kansas and Kansas State University in the fall of 1990. The objective of the course is to interpret the paleontological information present in the Wathena Shale Member of the Lawrence Formation in east central Kansas. This report covers the taxonomy and the paleoecological interpretations of the macroinvertebrate fossils present. This report does not discuss the occurrence of *Spirorbis,* which is exclusively associated with plant fossils in the study interval.

Locations -- general paleontology, sedimentology and stratigraphy

Macroinvertebrate specimens were collected from six sites in Kansas: three in the Lawrence area, in Douglas County; two from near Burlington, in Coffey County; and one west of Yates Center, in Woodson County. The section in Lawrence, Kansas, next to the Kansas Geological Survey building, was the only one to contain a diverse and abundant marine fauna. The other five sections contain a low-abundance, low-diversity assemblage of pectinids, myalinids, and orbiculoids, with one exception in the Woodson County section, where the brachiopod *Derbyia* is abundant. Conchostracans were also found at some of the Douglas County sections and the Coffey County sections.

The Wathena Shale Member is a lithologically variable unit in the uppermost portion of the Lawrence Formation of the Shawnee Group (Virgilian, Pennsylvanian). The Lawrence Formation is exposed in a broad north-northeast to south-southwest outcrop belt across eastern Kansas. The Lawrence Formation includes the upper and lower Williamsburg coals and locally well-developed, associated underclays. The Wathena Shale Member consists of fine terrigenous clastics that vary from green-brown, pure clay to blue-gray, silty shale. Black, highly carbonaceous shales are often locally associated with the coals. Fine-grained, ripple-bedded sandstone bodies are locally present in the upper portion of the Wathena Shale Member. The inarticulate brachiopod *Lingula* often occur in these sandy intervals. Most of the macroinvertebrate fossils were collected from a shaly zone 0.0 to 0.5 meters above what is believed to be the upper Williamsburg coal. The conchostracan *Cyzicus* is restricted to a 0.5 meter zone approximately 2 meters above this upper coal. *Cyzicus* occurs most abundantly at the New Strawn location, but was also found in a similar interval by Keven Krogstad of Kansas State, in the other Coffey Co. section and in some of the douglas Co. sections. Conchostracans also occur at the base of the lower coal in the Clinton Lake section.

Discussion and Conclusions

The assemblages collected at the Survey Location and at the Woodson County location may indicate a marine environment of deposition. This is based on the presence of brachiopods and the general high diversity of the assemblages. The other four locations contain a low-diversity, low-abundance assemblage and suggest a depositional environment that was restricted, possibly brackish. The occurrence of conchostracans approximately a meter above the bivalve assemblages in these sections may indicate a change toward lower salinity or an environment of fluctuating salinity. The occurrence of *Lingula* in the sandstones yet higher in the sections suggests a return to more nearly normal marine conditions.

In a stratigraphic interval that includes marine sediments and coals one would expect a complex mosaic of depositional environments both laterally and vertically. The very flatness of the midcontinent region during the Virgilian probably allowed rapid changes in depositional environment with very small changes in climate and sealevel. Excluding the Survey and the Woodson County locations a general trend can be recognized for the 4 to 5 meters of section above the upper Williamsburg coal. A possible vertical succession of environments include a fresh water coal swamp, a gradual transition upward into less marine conditions, possibly fluctuating from brackish to fresh water and a return to a restricted marine condition as indicated by the lingulids. In the appendix are faunal lists and location information for the six sections starting from north to south. Significant taphonomic and paleoecological information is noted after each taxon.

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Appendix -- Faunal lists and location information

Survey Location -- a shallow pit in the Wathena next to the Kansas Geological Survey building in Lawrence, Kansas.

Composita sp.
Juresania nebraskensis (dissarticulated but apparently unabraided)
Aviculopectin sp. (possibly other genera of pectinids, many are fragmented)
Nuculoidea sp.
Phestia arata
Nuculopsis sp.
Monopteria sp. (this could be *M. longespina*)
Septimyalina sp.
Promytilus pottsvillensis ? (possibly a laterally compressed myalinid)
Aviculopinna sp.
bryozoan (two genera, one fenestrate and one branching)
crinoids (columnals 2 to 3mm, in diameter)

Clinton Lake Location -- a road cut in the Wathena located at the southern end of Clinton Lake dam, Douglas County, Kansas.

Dunbarella sp.
Septimyalina sp.
Lingula sp. (4 to 5 m above the upper coal in a sandstone)
gastropods (a possible juvenile *Pharkodonotus* and *Naticopsis* were found in the float; they may have weathered out of the overlying Toronto Limestone)
orbiculoids and nuculoids (reported by Kevin Krogstad of Kansas State)
conchostracans (found immediately below a lower coal in the Clinton section)

Lone Star Location -- an outcrop of the Wathena Shale in the spillway at Lone Star Lake, Douglas County, Kansas.

Phestia sp.

myalinids and pectinids (reported by Kevin Krogstad, also bivalves and arthropods are reported by others from concretions found in the shales and sandstones 0 to 3 m above the lower coal.)

New Strawn Location (Coffey County #1) -- a road cut approximately 10.5 miles (~17km) east of New Strawn, Kansas. (R17E T20S Sec 33 SW SW south edge)

Septimyalina sp.

bivalve or brachiopod fragments (the above are associated with plant fragments and *Spirorbis*)

Cyzicus ? (specimens are abundant but badly crushed and difficult to identify --the conchostracans occur in a 0.5 meter zone about 2 meters above the upper coal)

Trigonoglossa, pectinids and orbiculoids (reported by Kevin Krogstad of Kansas State)

Burlington Location (Coffey County #2) -- a road cut approximately 4 miles (~6.5km) east of Burlington, Kansas. (R16E T21S Sec 33 NW NW west edge)

myalinid fragments

Cyzicus, pectinids, and orbiculoids (reported by Kevin Krogstad of Kansas State)

Woodson County Location -- a road cut approximately 6 miles (~10km) west of Yates Center on U. S. highway 54.

Aviculopectin sp.

Septimyalina sp.

(The above are found in a silty to sandy lag deposit 10 to 50 cm thick with coal chips, between the upper coal and the Toronto Limestone)

Derbyia sp. (in a shale, laterally associated with the above sediments -- all are crushed)

Neospirifer and possible nuculoids (reported by Kevin Krogstad at Kansas State)

ONTOGENY AND PALEOECOLOGY OF *GEISINA GREGARIA* (ULRICH AND BASSLER) 1906, A NEARSHORE, POSSIBLY EURYHALINE OSTRACODE SPECIES FROM THE UPPER PENNSYLVANIAN OF THE MIDCONTINENT.

HECHT, George D., and KAESLER, Roger L., Department of Geology, Museum of Invertebrate Paleontology, and Paleontological Institute, The University of Kansas, 120 Lindley Hall, Lawrence, KS 66045

Geisina gregaria (Ulrich and Bassler) 1906, as its name implies, typically occurs in great abundance on bedding planes of Upper Pennsylvanian shales and mudstones of the Midcontinent. Species of *Geisina* are found in carbonaceous shales with a carbon content between 2 and 8 percent and in other terrigenous rocks with abundant plant fossils. *G. arcuata* (Bean) 1836, a species that is closely similar to *G. gregaria*, has been interpreted as having browsed on floating and detrital plant material. In spite of this species's abundance in rocks from some nearshore, brackish-water environments, the ontogeny of *G. gregaria* has not been studied. The ontogeny may be important for understanding the phylogenetic relationships between closely related species.

The Wathena shale, an informally described stratigraphic unit at the top of the Virgilian Lawrence Formation, has yielded abundant, very well-preserved specimens of *G. gregaria* from several localities in northeastern Kansas. At one locality near Clinton Lake in Douglas County, *G. gregaria* comprised more than 99 percent of the fauna. An ontogenetic sequence was preserved that included adults and at least four instars. In such samples from brackish-water environments, where *G. gregaria* is the dominant species, the posterodorsal spine that is characteristic of *Geisina* is much more prominent on the valves of instars than on adults. In samples with an ostracode fauna that is typical of terrigenous, nearshore-marine environments, adults have a quite prominent spine that is more anteriorly located and that may be curved in a posterior direction.

PALEOECOLOGICAL IMPLICATIONS OF THE VERTEBRATE TAXA AND ICHNOCOENOSIS OF THE WATHENA SHALE MEMBER OF THE LAWRENCE FORMATION (VIRGILIAN: U. PENNSYLVANIAN) IN EASTERN KANSAS

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ABSTRACT

The vertebrate fauna and trace fossil assemblage of the Wathena Shale Member of the Upper Pennsylvanian (Virgilian) Lawrence Formation in eastern Kansas were studied to evaluate their paleoecological implications. Vertebrate fossils of the Wathena Shale appear to be restricted to specific layers with lateral limits within the unit. Teeth of the xenacanthid shark *Orthacanthus* along with uncommon, indeterminate, palaeoniscoid remains (scales, bone) occur in a coalified shale directly below the lower coal of the Wathena. A single lungfish scale (cf. *Sagenodus*) was recovered from a concretion above the lower coal. Although both xenacanthid sharks and lungfish are generally interpreted as freshwater forms, brackish or marine occurrences of both taxa have been reported. The mudstone and shale interval directly above the upper coal contains teeth of the elasmobranch *Cladodus*, a coelacanth (cf. *Rhabdoderma*), as well as several indeterminate teeth, scales, and bones of palaeoniscoids. All of these taxa are generally interpreted as marine forms. Unfortunately, the low diversity and sometimes varied interpretations of environmental preferences for the vertebrate fauna limit their usefulness as environmental indicators. Associated invertebrate taxa with more definitive environmental preferences should be the most useful indicators of paleoenvironmental conditions.

The trace fossil assemblage, which includes *Asteriacites, Chevronichnus, Curvolithus, Isopodichnus,* cf. *Monomorphichnus, Phycodes, Planolites, Rhizocorralium, Taenidium,* and cf. *Thalassinoides* is restricted predominantly to the siltstone and sandstone beds in the upper portion of the member. This trace-fossil assemblage suggests a shallow, nearshore, brackish to marine environment of deposition with low to moderate influx of sediment. Overall, paleoecological implications of both groups are consistent with the interpretation of a terrestrial to marine transgression for the Wathena Shale.

INTRODUCTION

The Wathena Shale Member of the Upper Pennsylvanian (Virgilian: Douglas Group) Lawrence Formation constitutes the uppermost shale, sandstone, and coal interval that lies stratigraphically above the Amazonia Limestone Member. This upper shale, sandstone, and coal interval was informally named the Wathena Shale Member by Ball (1964). The Lawrence Shale, which lies stratigraphically just below the Toronto Limestone Member of the Oread Limestone, is a typical outside shale of the Upper Pennsylvanian cyclic sedimentary models (Heckel, 1986) and has generally been interpreted as a terrestrial to nearshore, marine, transgressive-shale sequence (Heckel, et al., 1979; Rutan, 1980; Heckel, 1986). For the purposes of this study, the Wathena Shale Member was measured and correlated at seven localities from northcentral Douglas County south into northern Woodson County, Kansas. Detailed descriptions of localities are provided in Appendix A.

Within the Wathena Shale Member, varied macro and microfaunas of both vertebrates and invertebrates exist. In addition, a diverse flora and trace-fossil assemblage is present. Thorough investigation has revealed that the vertebrate faunas consist exclusively of fish. The invertebrate fauna includes pelecypods, gastropods, brachiopods, branchiopods, ostracodes and annelids. The flora consists of a standard Upper Pennsylvanian coal forest assemblage including pteridosperms, lycopods, and sphenopsids. The trace fossils occur predominantly in the sandy intervals. These various assemblages appear to be restricted to specific zones with definite lateral limits within the unit. The purpose of this study is to examine in detail the vertebrate and trace fossil assemblage within the Wathena Shale Member of the Lawrence Formation in order to evaluate their paleoecological implications.

PREVIOUS STUDY

The vertebrate fauna of the Lawrence Formation has never been studied or described. Although numerous citations exist in literature concerning the vertebrate faunas of the Upper Pennsylvanian cyclothem units in Kansas, most of our knowledge of these faunas has been derived from their casual mention in other studies (Hattin, 1957; Moore, 1966; Toomey, 1964) or from the description of exceptional but isolated occurrences (Chorn and Schultze, 1988; Foreman and Martin, 1988; Gottfried, 1988; Hibbard, 1934; McAllister, 1988; Maisey, 1988; Schultze, 1988; Schultze and Chorn, 1988; Zidek, 1988a,b).

Tway (1979b) described the ichthyoliths, or microscopic fish remains, distributions from the Shawnee Group of eastern Kansas. Unfortunately, the stratigraphic interval for her study begins just above the Lawrence Formation in the Oread Limestone. Tway and Zidek (1982a,b; 1983) documented the great morphologic variability of Late Pennsylvanian ichthyoliths, many of which are from the Midcontinent including the rocks of Kansas. Zidek (1973, 1975) studied various upper Paleozoic fish fossils from Oklahoma, which are similar to those found in Kansas.

Trace fossils are locally common, primarily in the siliciclastic units of outside shales within the Upper Pennsylvanian cyclothems of eastern Kansas. These assemblages have been studied from several units including the Lawrence Formation. The ichnofauna of the South Bend Limestone Member (Stanton Limestone) was described and interpreted by Bandel (1967b). The trace fossils, particularly the limulid and isopod trails, of the Tonganoxie Sandstone Member (Stranger Formation) were described by Bandel (1967a). Hakes (1976a) described and evaluated the environments of deposition of four siliciclastic units within Upper Pennsylvanian megacyclothems in eastern Kansas. Hakes (1973, 1974, 1976b, 1985) used the trace-fossil assemblages to interpret the depositional environment of the Lawrence Formation. Hantzschel (1962) provided brief descriptions and citations for ichnotaxa in general.

PALEONTOLOGY

The vertebrate fauna (see Table 1) of the Wathena Shale Member of the Lawrence Formation consist exclusively of fish taxa. The ichnotaxa I recognized in the Wathena as well as additional ichnotaxa recognized by Barbara Tilley (Kansas State University) are listed in Table 2. Vertebrate systematics (see Appendix B) is based on the classification provided by Moy-Thomas and Miles (1979) and Carroll (1988). Illustrations of vertebrate fossils along with reconstructions of fish are provided in Appendix C. All vertebrate fossils were recovered from the Douglas County localities; samples from other locations were barren. Vertebrate specimens obtained during this study will be reposited in the Vertebrate Paleontology collection of the Museum of Natural History, The University of Kansas (KUVP). Trace fossils will be reposited at The University of Kansas Museum of Invertebrate Paleontology (KUMIP).

Key to vertebrate occurrences within the Wathena utilized in systematics:

Unit A--A 60-mm-thick coalified-shale bed directly below the lower coal bed

Unit B--Preserved within siderite concretions from a bed approximately 20 cm above lower coal

Unit C--Gray mudstone to shale interval, approximately 150 mm thick, directly above the upper coal bed

TABLE 1. Vertebrate taxa present in the Wathena Shale Member of the Lawrence Formation in eastern Kansas.

Class Chondrichthyes
- *Cladodus* sp.cf. *C. mortifer* Newberry and Worthen, 1866
- *Orthacanthus latus* Newberry, 1856
- Chondrichthyes indet.

Class Osteichthyes
- Palaeoniscoid indet.
- cf. *Rhabdoderma*
- cf. *Sagenodus*
- Osteichthyes indet.

TABLE 2. Trace fossil assemblage present in the Wathena Shale Member of the Lawrence Formation in eastern Kansas.

- cf. *Aulichnites**
- *Asteriacites*
- *Chevronichnus*
- *Curvolithus*
- cf. *Gordia**
- *Isopodichnus*
- *Locheia**
- cf. *Monomorphichnus*
- *Palaeophycus**
- *Phycodes*
- *Planolites*
- *Rhizocorralium*
- *Scolicia**
- *Taenidium*
- cf. *Thalassinoides*
- cf. *Treptichnus**
- *Uchirities**
- cf. *Zoophycus**

* Additional ichnotaxa recognized by Barbara Tilley (Kansas State University)

SYSTEMATIC PALEONTOLOGY

PHYLUM VERTEBRATA

CLASS CHONDRICHTHYES

SUBCLASS ELASMOBRANCHII

ORDER CLADOSELACHIDA

Genus *CLADODUS* Agassiz, 1843

Cladodus sp. cf. *C. mortifer* Newberry and Worthen, 1866

C. mortifer Newberry and Worthen, 1866, p. 00-00.

Specimens: KUVP

Discussion:

Recovered from this shark are some teeth, which possess a central blade averaging 3.0 mm in height surrounded on both sides by two smaller lateral cusps. The lateral cusps next to the main blade are smaller than the set of lateral cusps more distal on the root platform. Both the main blade and cusps are convex and plicated lingually. The root is slightly concave at the base and arches up, forming a triangular apron like platform that accounts for approximately one fifth of the total tooth height. It possesses a nutritive groove on the lingual side of the apron and two laterally symmetric pads on the labial face of the root. A single specimen with root structure and lateral cusp bases has been recovered along with several broken main blades and cusps.

It should be mentioned that species assigned to the genus *Cladodus* have for the most part been established based purely on morphology of isolated teeth without consideration of heterodonty or sexual dimorphism. The taxon has typically been used for teeth possessing a main central blade surrounded by lateral cusps, all of which may be coarsely plicated or grooved lingually. As a result of the artificial taxonomy of these fossils, this classification is ubiquitous and provides an indeterminate taxonomic assignment.

Therefore, Zangerl (1981) considered *Cladodus* a *nomen dubium* as defined by Chorn and Whetstone (1978).

Occurrence:

Unit C, Locality 1 (teeth)

ORDER XENACANTHIDA (PLEUROCANTHODII)

Genus *ORTHACANTHUS* Agassiz, 1843

Orthacanthus latus Newberry, 1856

O. latus Newberry, 1856, p. 99.

O. latus Newberry and Worthen, 1866, p. 59-60.

Specimens: KUVP

Discussion:

The only element of this shark recovered is a single tooth that exhibits two forked main blades, the largest of which is 5.0 mm long. These two blades are faintly serrated and diverge at approximately 45° but are recurved preferentially towards the commissure of the mouth. The smaller median blade (cusp), which is often present in xenacanthid shark teeth, was not observed on this specimen. Teeth of this species possess a relatively small, basal, root structure compared to other species in the genus and have tubercles projecting down from the root below the main blades. The specimen very closely resembles *O. lucasi* and was differentiated by its small size and reduced basal root structure. According to Zangerl (1981), teeth of *Orthacanthus* can be easily distinguished from those of *Xenacanthus* or *Pleuracanthus* by the presence of serrations. Although not recovered, spines of this genus are oval to circular in cross-section and possess parallel rows of denticles along the posterior edge.

Occurrence:

Unit A, Locality 2 (tooth)

Chondrichthyes indet.

A single placoid scale (KUVP) was recovered from Unit C at Locality 1. The crown of this shark scale is broadly trifercated and extends to the posterior above a diamond-shaped, apron like base. The surfaces of the scale are smooth and do not exhibit the furrowed pattern displayed by many placoid scales. This scale closely resembles ichthyoliths described by Tway and Zidek (1982a & b, 1983), which were tentatively assigned to elasmobranchs.

CLASS OSTEICHTHYES
SUBCLASS ACTINOPTERYGII
ORDER PALAEONISCIFORMES
Palaeoniscoid indet.

Specimens: KUVP
Discussion:

Both teeth and scales assignable to palaeoniscoid fish have been recovered. The teeth, which average 3 mm in length, are conical, striated, and taper to the characteristic acrodin tip present in all Actinopterygian teeth. Both smooth and elaborately sculptured scales of palaeoniscids are present. Scales are subrhombohedral to rhombohedral in outline and average 3.0 mm in length. Sculptured scales have numerous lateral grooves or furrows. Both varieties of scales have been found together in the same beds. Serrated scales or those with fringes were not observed.

Gardiner (1984) extensively discussed the morphology and interrelationships of the palaeoniscid fishes. The smooth variety of scales slightly resembles certain acanthodian scales (Denison, 1979; Schultze, 1985) but more closely resembles scales of palaeoniscids, a type of fish known otherwise to exist in the Wathena Shale.

As discussed by Moy-Thomas and Miles (1971) and Gardiner (1984), actinopterygian and particularly palaeoniscoid taxonomy is desperately in need of revision. Unfortunately, the most frequently preserved body elements (scales, teeth, and portions of the skull and dentition) are generally non-specific for taxonomic determination even to familial level. Several of the scales recovered very closely resemble scales assigned to the Carboniferous taxon *Australichthys* as illustrated by Gardiner (1967), but similar scale morphology cannot be used as the basis of specific identification. As a result, identification was not attempted for the samples from the Wathena Shale other that determination of palaeoniscid origin.

Occurrence:

Unit A. Locality 2 (scales)

Unit C, Locality 1 (teeth, scales)

SUBCLASS SARCOPTERYGII

ORDER CROSSOPTERYGII

SUBORDER COELACANTHIFORMES

GENUS *RHABDODERMA*

cf. *Rhabdoderma*

Specimens: KUVP

Discussion:

Scale fragments of this fish up to 3 mm long have been found. Although not found, complete scales are ovoid in outline and have two differently ornamented regions on the exterior face. The scales are approximately equally divided between a smooth surface on the anterior portion of the scale and a fine parallel grooved region posteriorly. No other elements of this taxon have been recovered from the Wathena. Hibbard (1933) and Echols (1963) report on coelacanthiform fish from the Pennsylvanian of Kansas. Moy-Thomas (1937) classified nearly all Carboniferous Coelacanthiformes into the single genus *Rhabdoderma*.

Occurrence:

Unit C, Locality 1 (scales)

ORDER DIPNOA

Genus *SAGENODUS*

cf. *Sagenodus*

Specimens: KUVP (specimen presently lost, fide J. Chorn)

Discussion:

A single scale of this lungfish has been recovered from within a concretion; but, unfortunately, it was not available for study and description. Scales assignable to *Sagenodus* are ovate with the anterior side truncated. The scales have an ovoid sculptured portion in the center surrounded by a smooth sometimes striated field along the margins.

Unfortunately, only a single scale of this dipnoan has been recovered; the characteristic dentary elements have not been observed. Hay (1900) described numerous dipnoan taxa, including several *Sagenodus* species, based exclusively on scale morphology. However, Romer and Smith (1934) demonstrated that scale taxonomy is invalid for these fish. Watson and Gill (1922) provided an extensive discussion of dipnoan comparatively anatomy. Williston (1899) described the species *Sagenodus copeanus* from the Upper Pennsylvanian of Kansas. The taxon *Sagenodus* is the most common and widely distributed lungfish in Carboniferous and Permian deposits globally (Chorn and Schultze, 1988)

Occurrence:

Unit B, Locality 3 (scale)

Osteichthyes indet.

Numerous indeterminate fragments of fish bone and scale were observed in Units A and C at Localities 1 and 2. These fragments are likely to be indeterminate remains of the known taxa present, although they may belong to yet unrecognized forms. Some of these fragments can be identified anatomically; and possible fin rays, skull elements, and gill-raker bones have been recognized.

DISCUSSION

The vertebrate fauna of the Wathena consists of a relatively low diversity assemblage represented by sparse and fragmental remains. The interpretations of paleoenvironmental preference for these taxa are varied, and the state of preservation in many instances suggests that the specimens may have been transported. In addition, environmental interpretations based on fish, particularly those documented by sparse occurrences, must be considered with caution due to the great mobility and seasonal migration observed in modern populations.

Cladodont shark remains, represented by *Cladodus* sp. cf. *C. mortifer* in the Wathena fauna, have been almost exclusively reported from marine deposits (Carroll, 1988; Zangerl, 1981). The body design and morphology of the teeth suggest that these sharks were aggressive, hunting predators much like many modern sharks. Carroll (1988) and Moy-Thomas and Miles (1971) reported that the diet of similar sharks consisted mainly of other fish and possibly some invertebrates.

Xenacanthid sharks, represented by *Orthacanthus latus* in the Wathena fauna, are predominantly considered to be freshwater forms (Zangerl, 1981), although they have been reported from marine deposits (Tway and Zidek, 1983; Schultze, 1985; Zidek, 1988b; Schultze and Chorn, 1988). Therefore, these fish may have possessed both a freshwater and brackish to marine tolerance. Again, body form and tooth morphology suggest that these sharks were predators of smaller fish.

Although primarily marine forms, palaeoniscids have been found in rocks considered both freshwater and marine in origin (Carroll, 1988; Moy-Thomas and Miles, 1971; Schultze, 1985). Therefore, these fish cannot be used as environmental indicators. Schultze (1985) reports a strictly marine distribution within a Lower Permian megacyclothem (Wreford) in Kansas for palaeoniscids of a variety similar to those found in the Wathena Formation. Palaeoniscid fish are considered to be predators of smaller fish and relatively soft-shelled invertebrates (Carroll, 1988; Moy-Thomas and Miles, 1971).

Although the lungfish *Sagenodus* has traditionally been considered to be a freshwater variety (Hay, 1900), Schultze and Chorn (1988) suggested that it may have tolerated brackish or marine environments based on its occurrence in marginally marine Upper Pennsylvanian rocks at Robinson, Kansas. According to Chorn and Schultze (1988), *Sagenodus* probably ate aquatic plants and shelled invertebrates.

Overall, the frequency and diversity of the microscopic fish remains (ichthyoliths) that in other Upper Pennsylvanian units are numerous, was suprisingly low. Unfortunately, many of the isolated microscopic fish remains recovered from Upper Pennsylvanian sediments cannot be assigned taxonomically. Tway (1979a, 1984) devised a numerical coding system that artificially classified these ichthyoliths based on element morphology. In an attempt to overcome this artificial taxonomic classification, Tway, et al. (1985) proposed using a cluster analysis of ichthyolith assemblages.

The low diversity and varied interpretations of environmental preference for the vertebrate fauna limits their usefulness as environmental indicators. In addition, the preservation of much of the vertebrate sample suggests that the specimens may have been transported prior to final deposition. Therefore, associated invertebrate taxa of more definitive environmental preferences should prove to be the most useful indicators of paleoenvironmental conditions.

As a special note, Unit A at Locality 2 contains numerous chonchostracan branchiopods (cf. *Cyzicus*) that superficially resemble fish scales. The phosphatic valves of these crustaceans are round to subcircular in outline and have concentric furrows. These fossils originally suggested that this lithounit (Unit A) was a bone bed as defined by Antia (1979). These chonchostracans can be differentiated from fish scales based on their external morphology, particularly with respect to their slight convexity.

The presence of trace fossils within the Wathena Shale Member is dependent on both the depositional environment, which has an affect on the biota present, and the parent lithology which effects preservation. Bathymetry, currents, rates of sedimentation, salinity, and aeration all affect trace-producing biota. As a result of lithology, nearly all of the trace fossils observed in the Wathena were present in the siltstone and sandstone lenses in the upper portion of the member. Other traces occurred either in concretions or as poorly preserved, infilled burrows in siltstone.

The bed in the Wathena that contain the most abundant trace fossils is a silty, micaceous, sandstone interval between the upper coal and the Toronto Limestone Member of the Oread Limestone. At Locality 2, it is approximately 2.5 mm above the upper coal and 1.0 meters below the base of the Toronto Limestone. It is lenticular and has ripples at some locations. Ripple and flaser bedforms and numerous tool and drag marks suggest strong currents at some localities.

The absence of body fossils from the sandstone, except for a single sample containing chitinophosphatic lingulid brachiopod shells, is peculiar. This is probably the result of the thin shells of the biota as well as the destructive effects of diagenic dissolution in the relatively coarse-grained siltstone and sandstones.

The burrows may be the result of sediment influx requiring upward movement, or erosion necessitating a downward movement. Bower (1961) briefly discussed the sources and formational processes of Upper Pennsylvanian siliciclastic units (Tonganoxie Sandstone and Ireland Sandstone) in eastern Kansas, but provided no estimates of rates of sedimentation. Concretions with a septarian internal structure occur in several horizons approximately 3 meters above the lower coal at Locality 3. These concretions may be rhizolith structures resulting from a plant root nucleus.

The ichnocoenosis of the Wathena is certainly the result of a varied biota that may have included bivalves, brachiopods, gastropods, echinoderms, and annelids. According to Hakes (1976a, p. 21), Seilacher (1953) interpreted *Asteriacites* traces to be predominantly of ophiuroid origin, although some asteroid traces may be among the assemblage. Hakes (1976a) suggested that *Asteriacites* traces could be good indicators of shallow-water despite the varied bathymetric range of modern asteroids andophioroids. He also pointed out that modern starfish and brittlestars inhabit not only marine environments but can also tolerate brackish conditions.

The presence of numerous kinds of trace fossils suggests a varied biota capable of inhabiting a fluctuating environment. Similar trace-fossil assemblages in the Tecumseh Shale and Stull Shale Member (Kanwaka Shale) were interpreted by Hakes (1976a) as representing a shallow-water marine to brackish biota. In addition, the presence of the inarticulate brachiopod *Lingula* in the trace-fossil-bearing unit indicates a brackish to marine environment but excludes freshwater or hyposaline environments. Based on the ichnocoenosis and overall sedimentologic setting, a shallow, nearshore, brackish to marine environment of deposition with low to moderate sediment influx is suggested for the siliciclastic units near the top of the Wathena.

ACKNOWLEDGMENTS

Research was undertaken as part of a graduate-level field paleoecology seminar jointly sponsored by the University of Kansas and Kansas State University. This seminar was directed by Chris Maples and Howard Feldman (Kansas Geological Survey), Roger Kaesler (University of Kansas), and Allen Archer and Ron West (Kansas State University). Samples were processed for microfossils by George Hecht. Hans-Peter Schultze and John Chorn provided assistance with the identification of vertebrate fossils. Roger Kaesler and Chris Maples provided helpful comments to improve this manuscript.

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APPENDIX A. Study Locations

Locality 1. Trench between Parker Hall and Natural Resources Storage Facility (Core Storage) during construction of the latter. (This locality has been backfilled and is no longer accessible).
NE $^{1}/_{4}$, SW $^{1}/_{4}$, sec. 2, T. 13 S., R. 19 E., Douglas County, KS

Locality 2. Roadcut, west side of county road
E $^{1}/_{2}$, NW $^{1}/_{4}$, sec. 20, T. 13 S., R. 19 E., Douglas County, KS

Locality 3. Spillway at Lonestar Dam
Center, south line, sec. 11, T. 14 S., R. 18 E., Douglas County, KS

Locality 4. Roadcut on county road
SW $^{1}/_{4}$, SW $^{1}/_{4}$, sec. 33, T. 20 S., R. 17 E., Coffey County, KS

Locality 5. Roadcut on county road
NW $^{1}/_{4}$, NW $^{1}/_{4}$, sec. 33, T. 21 S., R. 16 E., Coffey County, KS

Locality 6. Roadcut, north side of U.S. 54
midpoint, south edge, SW $^{1}/_{4}$, sec 25, T. 25 S., R.13 E., Woodson County, KS

Locality 7. Roadcut, north side of U.S. 54
south edge, SE $^{1}/_{4}$, SE $^{1}/_{4}$, sec. 25, T. 25 S., R. 13 E., Woodson County, KS

APPENDIX B. Systematic Classification Of Vertebrate Taxa

PHYLUM VERTEBRATA

CLASS CHONDRICHTHYES (Cartilaginous Fishes)

Subclass Elasmobranchii (Sharks)

Order Cladoselachida

Cladodus cf. *C. mortifer* Newberry and Worthen, 1866

Order Xenacanthida (Pleurocanthodii)

Orthacanthus latus Newberry, 1856

CLASS OSTEICHTHYES (Bony Fish)

Subclass Actinopterygii (Ray-Finned Fish)

Order Palaeoniscoidea

Palaeoniscoid indet.

Subclass Sarcopterygii (Lobe-Finned Fish)

Order Crossopterygii

Suborder Coelacanthiformes (Coelancanths)

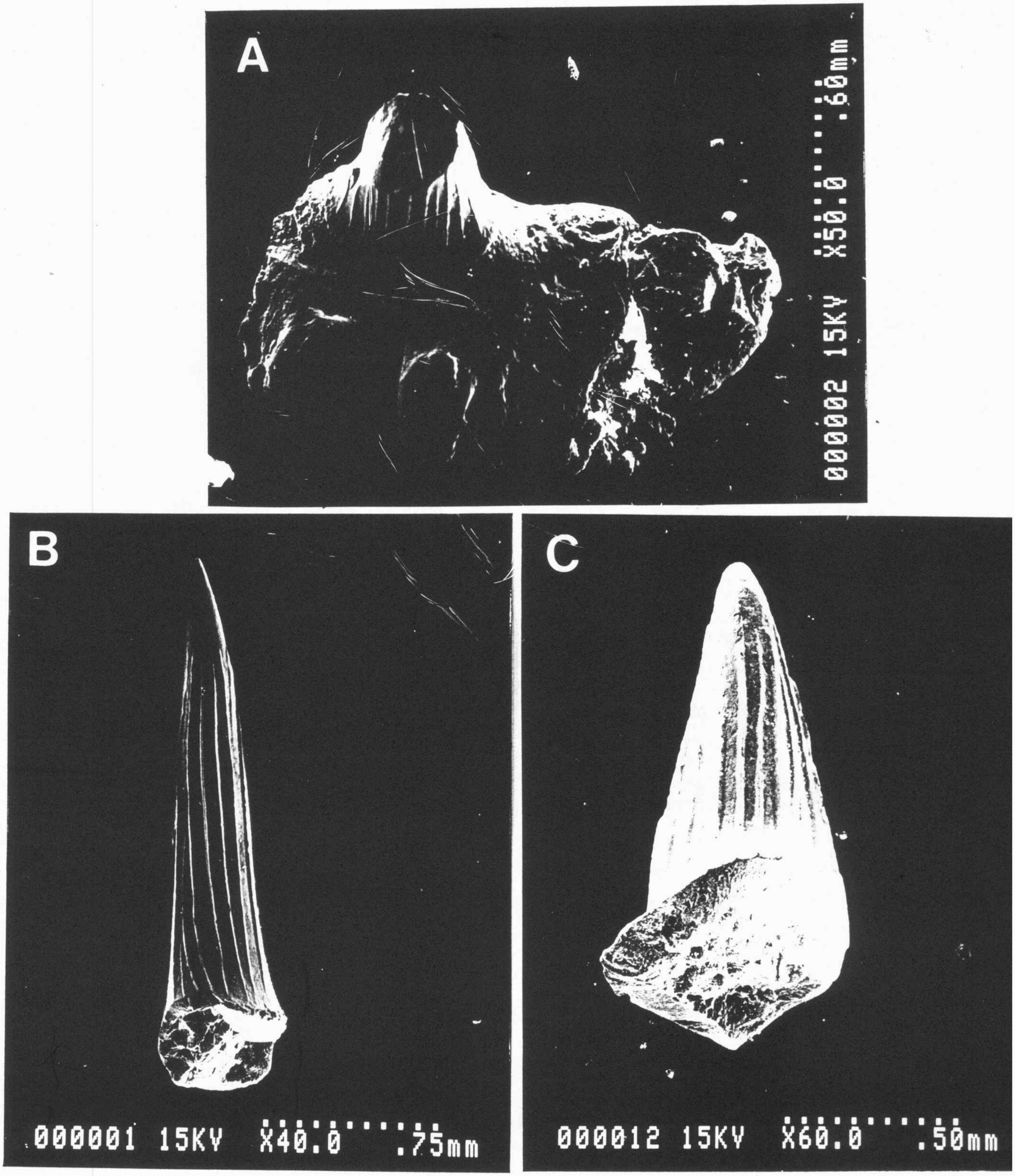
cf. *Rhabdoderma*

Order Dipnoi (Lungfish)

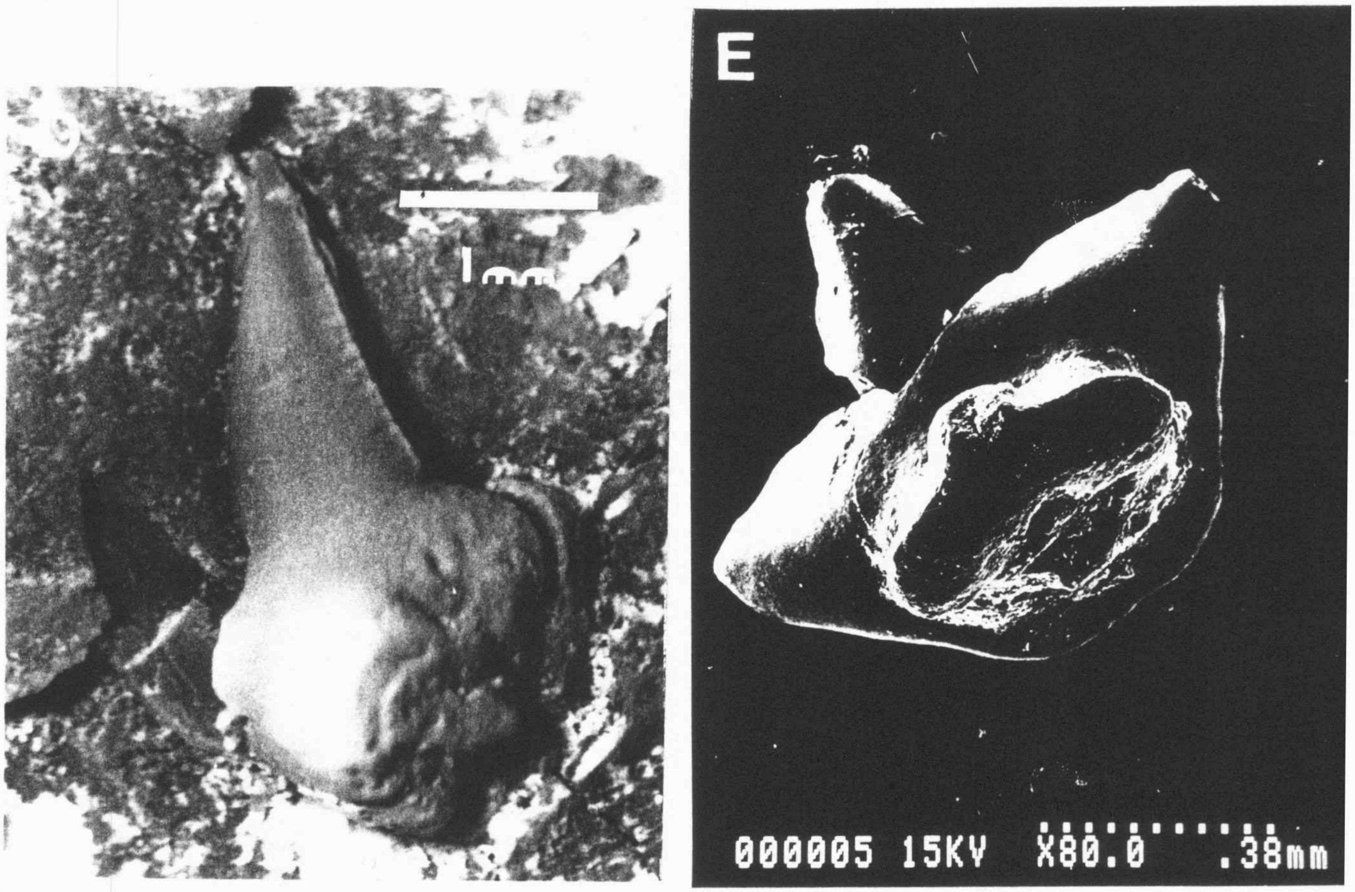
cf. *Sagenodus*

APPENDIX C.

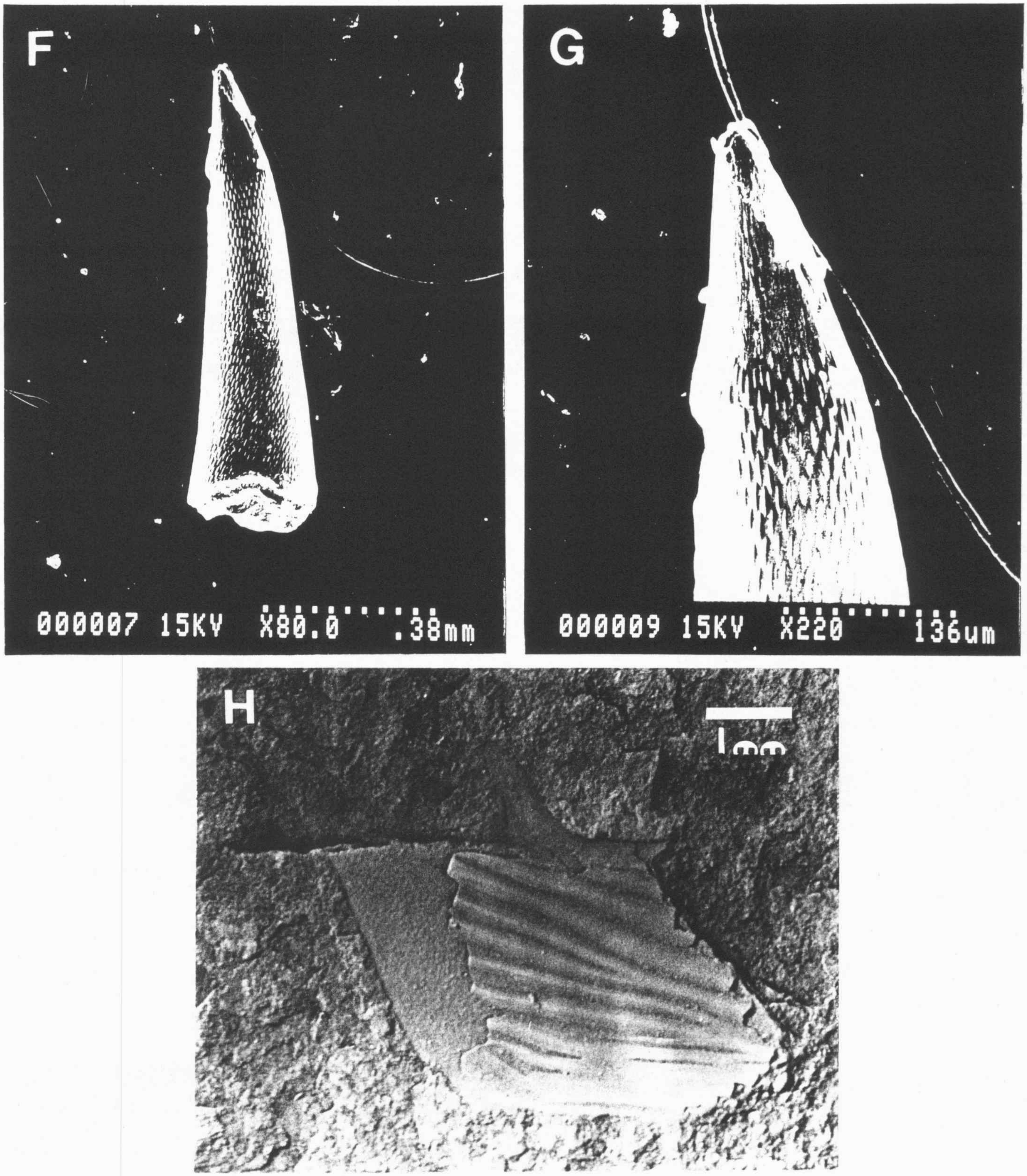
Illustrations of vertebrate fossils and fish reconstructions.



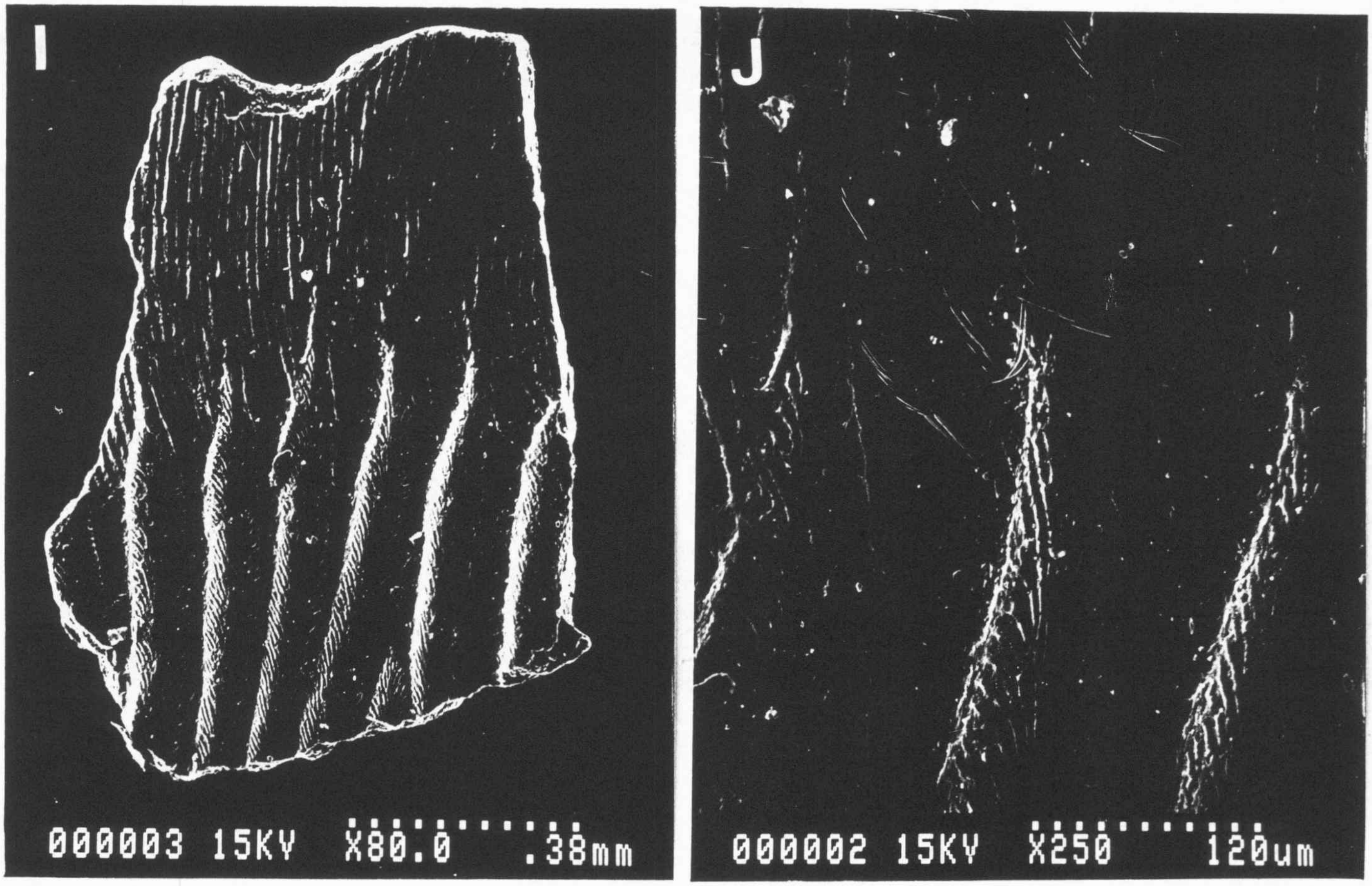
SEM photomicrographs of Chondrichthyan (shark) remains from the Wathena Shale Member. A-C, *Cladodus*. A, Tooth root. B, Central tooth blade. C, Lateral denticle (cusp).



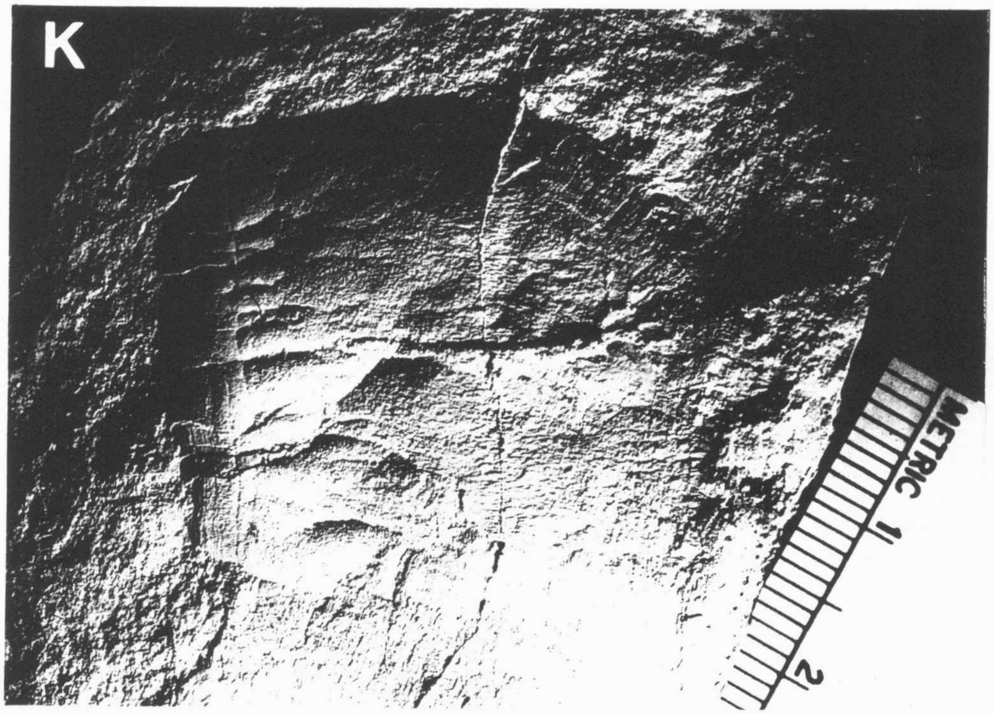
SEM photomicrographs of Chondrichthyan (shark) remains from the Wathena Shale Member. D, *Orthacanthus* cf. *O. latus* tooth. E, Placoid scale.



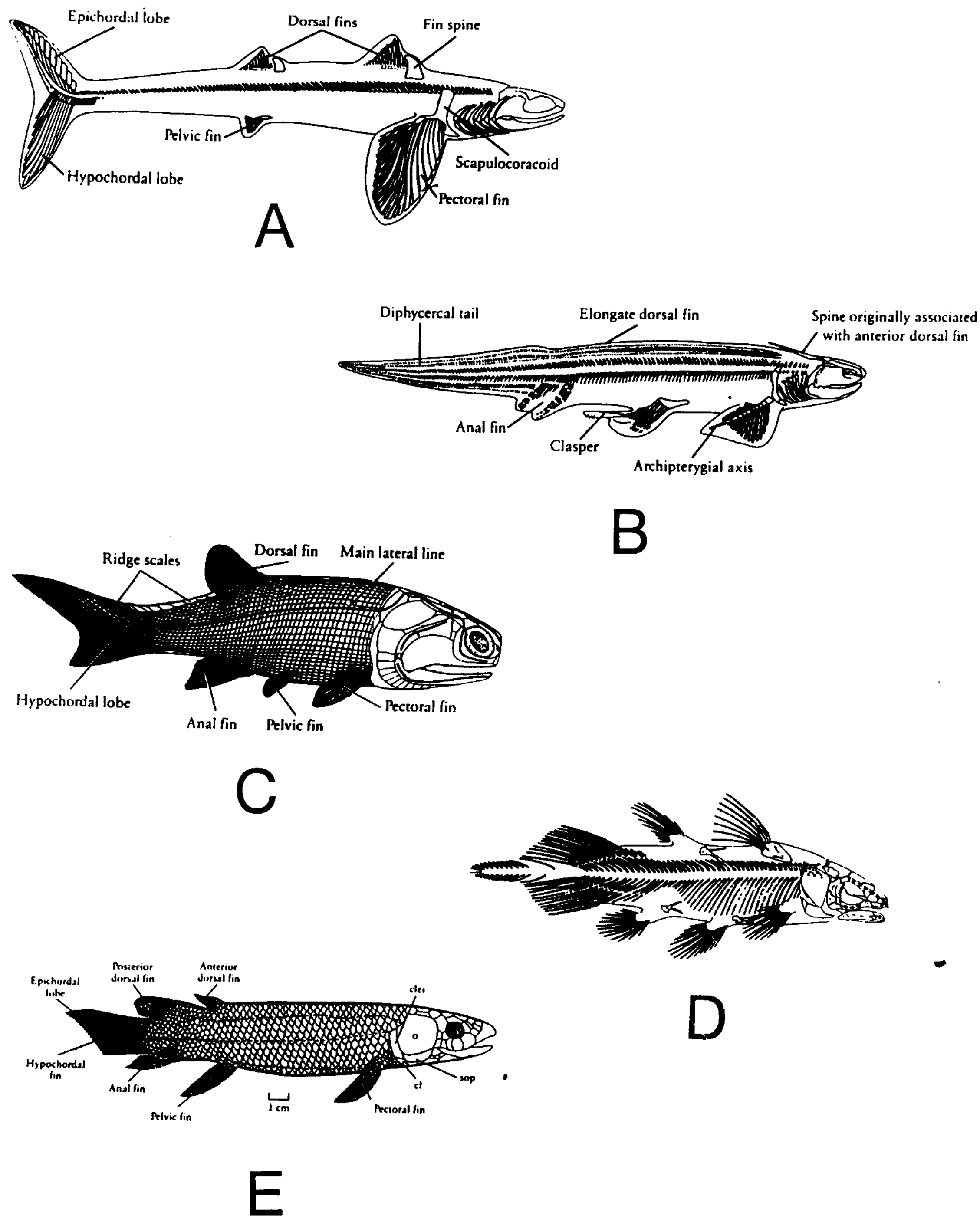
SEM photomicrographs of Osteichthyan (bony fish) remains from the Wathena Shale Member. F-H, Palaeoniscoidea indet. F, Tooth. G, Close-up of acrodin tip on tooth. H, Scale.



SEM photomicrographs of Osteichthyan (bony fish) remains from the Wathena Shale Member. I-J, cf. *Rhabdoderma*. I, Scale. J, Close-up of boundary between covered and uncovered scale fields.



Photomicrograph of Osteichthyan (bony fish) remains from the Wathena Shale Member. K, *Sagenodus* scale from the Calhoun Shale (Virgilian) at Hamilton Quarry, Greenwood Co., KS (The single specimen recovered from the Wathena Shale Member was unavailable for photographing).



Fish Reconstructions. A, Cladoselachid shark body form. B, Xenacanthid shark body form. C, Palaeoniscid body form. D, Coelacanth body form. E, Dipnoan body form. All figures smaller than natural size (from Carroll, 1988).

Paleoecology of Plant Fossils and Spirorbids in the Wathena Shale Member of the Lawrence Formation (Virgilian: Pennsylvainian) in Eastern Kansas

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INTRODUCTION

The Wathena Shale Member of the Lawrence Formation is overlain by the Toronto Limestone Member of the Oread Limestone and is underlain by the Amozonia Limestone Member of the Lawrence Formation (Fig. 1). The shale ranges in thickness from 12 to 54 meters. The Lawrence Formation consists of blue-gray and yellowish shale, tan sandstone, thin coals, limestone, and conglomerate that indicate a range of depositional environments.

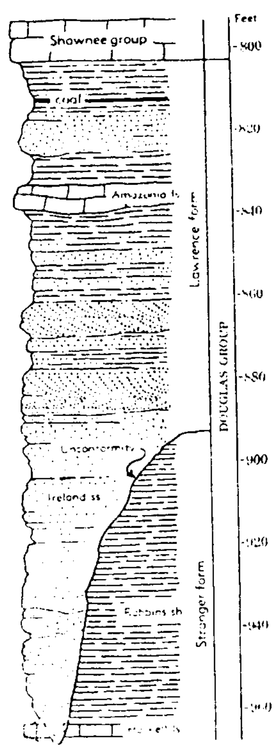

Figure 1. Stratigraphic cross sectoin of the Lawrence Formation (Moore et al., 1951).

METHODS

The Lawrence Formation is being studied in three counties. Douglas County contains three localites: Lonestar Lake spillway, Clinton Lake dam, and Kansas Geological Survey. Coffey County and Woodson County have two localites each, called localites one and two respectively. Each locality was measured, fossils were collected, and a stratigraphic sections were drawn.

RESULTS

Two types of fossils that have been found are plant fossils and *Spirorbis*. *Spirorbis*, a polyhaete annelid, has a characteristic, small, coiled tube that resembles a small gastropod (Moore et al., 1962). *Spirorbis* lives attached to a substrate. In Pennsylvanian strata it has been found attached to surfaces of lophyophyllid corals, fenestrate bryozoans, bivalves, and compressions of terrestrial plants (Condra & Elias, 1942).

Plant fossils and spirorbids were found at Lonestar Lake and Coffey County one, whereas only plant fossils were found at the Survey and Woodson County two. Plants and spirorbids were not found at the other localities. The spirorbids found with plant fossils were attached to them. The plant fossils that were collected are typical of a Pennsylvanian swamp environment that is associated with the formation of Pennsylvanian coals. The fossils include leaves (*Cordaites, Pecopteris, Calamites, Asterophyllites, Annularia, Sphenophyllum, Neuropteris, Lepidophylloides*) and bark (*Lepidodendron*).

Cordaites (Fig. 2-1) is a long, slender, stemless leaf covered with longitudinal veins with no distinct midvein. *Pecopteris* (Fig. 2-2) has small pinnules that are attached to the rachis by the entire base. The pinnules have lateral veins froming a midvein. *Calamites* (Fig. 2-3) is a tree like plant that has leaves in whorls. Two types of leaves are associated with *Calamites, Annularia* and *Asterophyllites* (Fig. 2-4, 2-5). *Annularia* leaflets are in a whorl and are of unequal length, and cup upwards around the stem. *Sphenophyllum* (Fig. 2-6) resembles *Calamites* but is smaller, and the whorled leaflets are wedge shaped. *Neuropteris* (Fig. 2-7) attaches to the rachis at a indistinct midvein. *Lepidophylloides* (Fig. 2-8) are grass like leaves that have a midvein and were attached to *Lepidodendron* trees (Fig. 2-9), which is a tree like plant with leaf scars (Gilespie et al., 1966).

DISSCUSSION

The plant fossils are typical of a Pennsylvanian coal-forming swamp, except for *Calamites*, which grew on Carboniferous mud flats, and *Sphenophyllum*, which grew as a shrubby plant, a vine, or in water

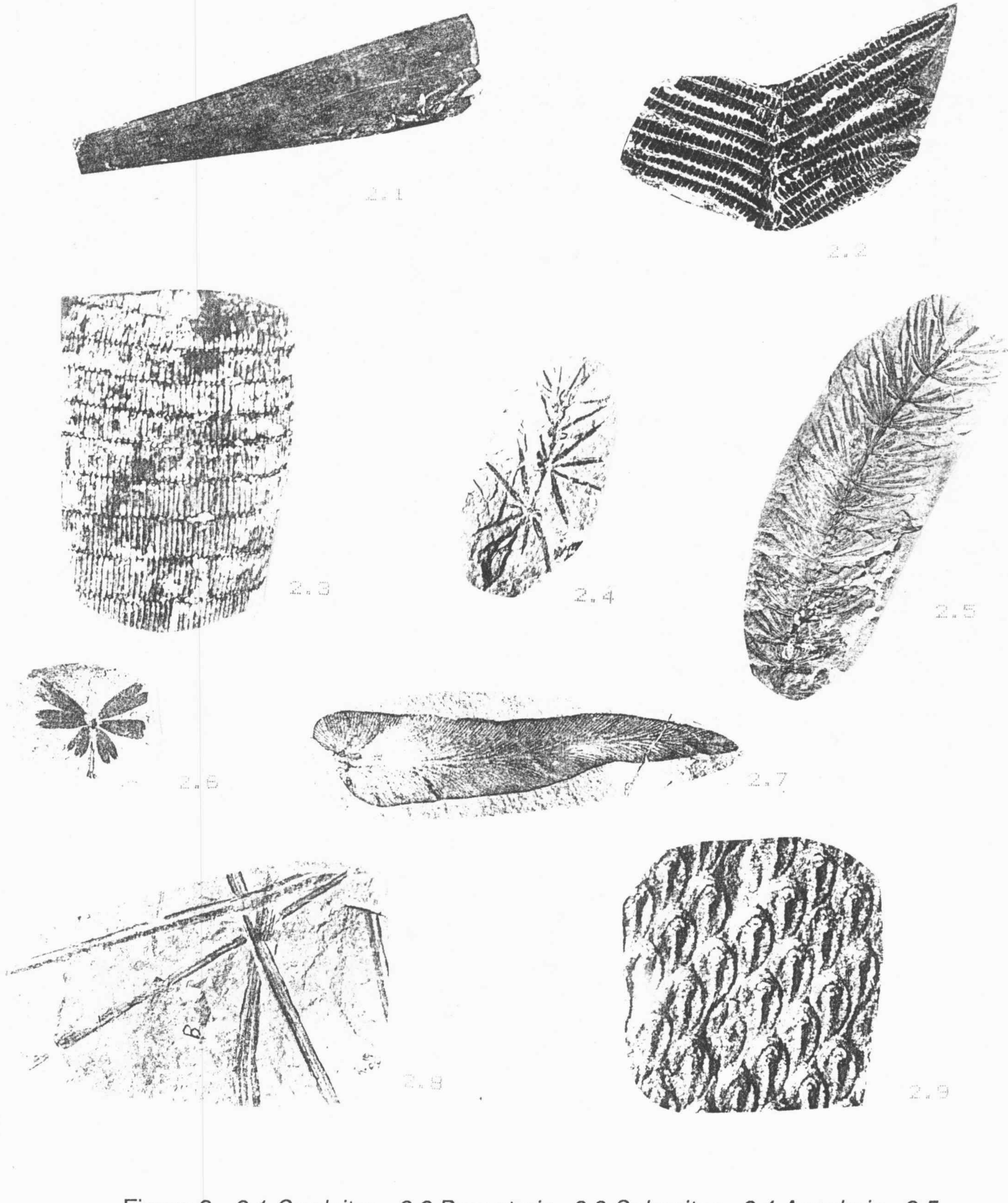

Figure 2. *2.1 Cordaites. 2.2 Pecopteris. 2.3 Calamites. 2.4 Annularia. 2.5 Asterophyllites. 2.6 Sphenophyllum. 2.7 Neuropteris. 2.8 Lepidophylloides. 2.9 Lepidodendron.* (From Gillespie et al., 1966).

(Gillespie et al., 1966).

Because the plant fossils are from terrestrial or swampy environments, the plant debris found with the spirorbids probably fell from the plants into the water. Spirorbids then attached themselves to the plant debris. Spirorbids probably attached to the undersides of vegetation (Ivany et al., 1990) and lived in freshwater to brackish envrionment (Etheridge, 1880).

Spirorbids were found on *Cordaites*, *Neuropteris* and *Pecopteris* leaves. The spirorbids on the *Cordaites* occur 15 cm above the lower coal at the Lonestar Lake spillway. The spirorbids were not found on any of the other plant fossils at Lonestar. Spirorbids are aboundant on *Cordaites, Neuropteris* and *Pecopteris* within 15 cm above the coal at Coffey County one.

The Survey locality had plants in the 15 cm interval above the coal, but spirorbids wer not present. It is possible they were present but were not found, perhaps due to the short time the locality was exposed.

CONCLUSION

The coal and 15 cm interval above the coal at Lonestar Lake, Coffey County one, and the survey represent an environment where an abundance of vegetation collected to form peat that later turned to coal. The plant fossils in the 15 cm interval were buried as the peat had been, but they were preserved as scattered debris with spirorbids attached to some. The spirorbids and plant debris were probably in a shallow, freshwater, or slightly brackish environment because the spirorbids attach to the leaves and the leaves grew in that type of environment.

ACKNOWLEDGMENTS

I wish to thank Dr. R.W. Baxter for his assistance in identifying plant fossils and for providing references for this study. I also wish to thank Dr. J. Doveton for collecting and donating plant fossils from the Survey locality.

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