KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 92-7

Fieldtrip Guidebook of Upper Pennsylvanian
(Virgilian and Missourian) Paleosols in Eastern Kansas

Held in conjunction with Paleosols Short Course
March 20-21, 1992

Department of Geology
University of Kansas

KANSAS GEOLOGICAL SURVEY
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047

FIELDTRIP GUIDEBOOK OF UPPER PENNSYLVANIAN (VIRGILIAN AND MISSOURIAN) PALEOSOLS IN EASTERN KANSAS

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Stop 1 Clinton Lake Spillway and Roadcut South of Clinton Lake Dam: upper Lawrence Shale and Oread Limestone

Location: SE1/4, NW1/4, sec. 20, T13S, R19E, Douglas County, Kansas

Contributors: *Lynn Watney, Bryan Stephens, and Howard Feldman*

Introduction

The gentle eastward-sloping upland surface in the vicinity of Lawrence is interrupted by several parallel northeasterly trending hills or cuestas resulting from differential erosion of slightly westward-dipping (approx. 25 ft./mi.) Pennsylvanian limestones and shales. Although local anticlines, synclines, and small faults may disrupt this shallow westerly dip, it provides for broad exposures of strata along valleys carved by rivers flowing east down regional slope. Mount Oread, the hill on which the University of Kansas rests, is capped by the Oread Limestone. The same strata are exposed here on the north face of the spillway near Clinton Lake dam on the Wakarusa River, 3.5 mi (5.5 km) west of Lawrence (fig. 1-1). The interval from the Plattsmouth Limestone down to the Amazonia Limestone Member of the Lawrence Shale is well exposed on the spillway wall (fig. 1-2). The measured section at this locality is provided in Fig. 1-3.

The Oread Limestone, originally described by Haworth (1894), consists, from base to top, of the Toronto Limestone, Snyderville Shale, the thin Leavenworth Limestone, the black Heebner Shale, the thick Plattsmouth Limestone, Heumader Shale, and Kereford Limestone. The Oread Limestone according to Moore (1936) is part of a megacyclothem, a succession of distinctive shale-limestone couplets repeated in several successive formations. Moore identified five limestone members in the idealized megacyclothem. The lower limestone is the Toronto, followed by the middle limestone (Leavenworth), the upper limestone (Plattsmouth), super limestone (Kereford), and finally the fifth limestone (Clay Creek) at the top of the cycle (fig 1-2). The inside or core shale is the Heebner Shale. Moore suggested that a marine transgression peaked during accumulation of the Plattsmouth Limestone based on abundance of fusulinids. The lower, super, and fifth limestones are not always present in a single megacyclothem, but are compositely expressed in the four late Missourian and early Virgilian megacyclothem successions.

Heckel (1977) describes a simpler cyclothem consisting of four components: the middle limestone, core shale, upper limestone, and outside shale. Maximum regression is associated with the outside shale (i.e., Kanwaka) and maximum transgression is recorded by the core shale (i.e., Heebner). The Toronto Limestone of the Oread Limestone (the lower limestone in Moore's megacyclothem classification) may represent an intermediate marine inundation separate from the transgression accounting for the Oread cyclothem (Troell, 1969). The upper surface of the Toronto has occasional solution fissures and piping filled with shale. Fragments of Toronto Limestone are also found infrequently at the base of the overlying Snyderville Shale. Together this suggests that the top of the Toronto was at least subjected to weathering and perhaps was subaerially exposed. The pattern of intermediate and major marine cycles is not unexpected, if these marine inundations are driven by glacial eustacy.

The presence and the extent of subaerial exposure due to relative sea level fall is also a key component relating to the mechanism affecting sedimentation. The individual paleosols observed in these cyclothems are often very extensive and can be traced laterally over the outcrop and into the subsurface. The magnitude and duration of sea level fall and the climatic conditions associated with the paleosol are critical components to interpretation of the cycles.

Channels and valley cuts are common throughout the Pennsylvanian section in the mid-continent. Mudge (1956) describes 27 occurrences of channels from the outcrops of Lower Permian and upper Virgilian strata. The incisions cut down as deep as 110 feet into underlying strata. Lins (1950) describes a valley filled by the Tonganoxie Sandstone in the Virgilian-age Douglas Group in the Lawrence area where it is up to 80 feet deep and approximately 20 miles wide. These valleys are now being considered as lowstand incised valleys filled during a succeeding rise in sea level. The combined period of marine inundation and lowstand events together suggest considerable fluctuations in relative sea level. During the incision an extensive emergent upland surface was developed over which paleosols formed.

A measured section (fig. 1-3) of the Clinton Spillway is provided for reference to the first stop at a cut in the upper Douglas Group. The section begins with a shale and claystone found below the Amazonia Limestone member of the Lawrence Formation. Several horizons appear to have undergone subaerial weathering including the upper portion of the claystone beneath the Amazonia which is red in color. The Amazonia Limestone although a marine limestone, contains an autoclastic breccia and other evidence of probable subaerial weathering. The underclay is developed below the Williamsburg Coal and above the Amazonia. Additional evidence of oxidation occurs in the shale above the coal.

The Williamsburg coal is one of several coals developed in the upper portion of the Lawrence Formation. This upper Williamsburg coal is the more laterally continuous. The Amazonia Limestone is lenticular in the area.

The paleosols at this locality display a range of thicknesses and structures. The paleosols are developed on both siliciclastic and carbonate substrates. What were the important factors that lead to the differences among these paleosols?

We will start at the lowest level and work upwards (Figure 1-4). The Lawrence Formation probably represents a sequence in the sense of the Exxon studies. This sequence starts with fluvial sands at the base, and proceeds upwards into muddy estuarine deposits and is capped by marine facies (or at least the most marine influence is at the top of the sequence). At this locality the upper Lawrence Formation was deposited in middle to upper estuarine and terrestrial environments. There are potentially three paleosols in the Lawrence at this locality. The first occurs below the lowest coal (the Lower Williamsburg Coal, unit 15). This interval is poorly exposed east of the road at road level. The second possible paleosol is a mottled red and green blocky mudstone with calcareous nodules (unit 8). The third paleosol is the underclay of the upper coal (the Upper Williamsburg Coal, unit 5).

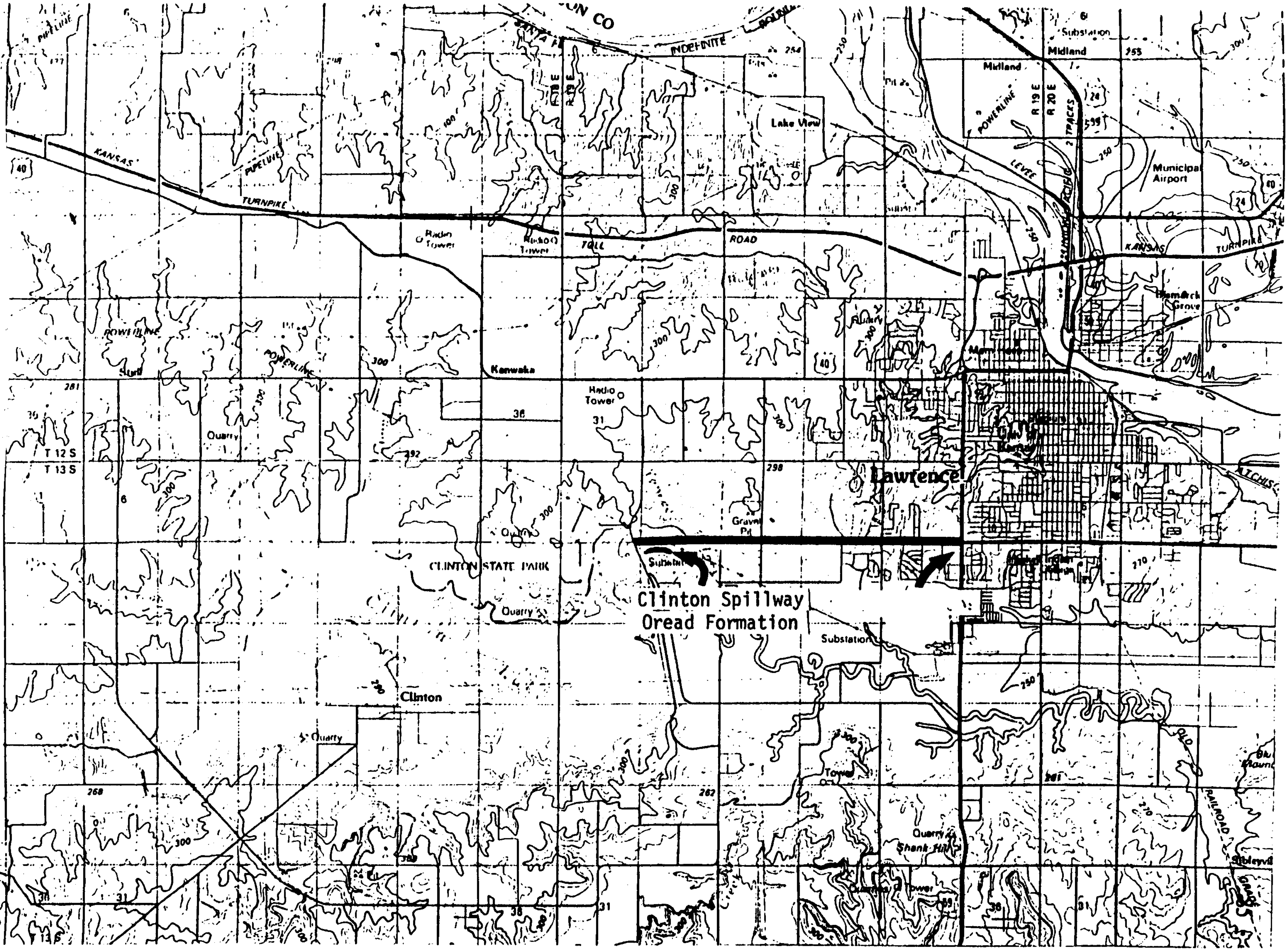


FIGURE 1-1

Index map showing site of exposure on Clinton Lake Spillway.

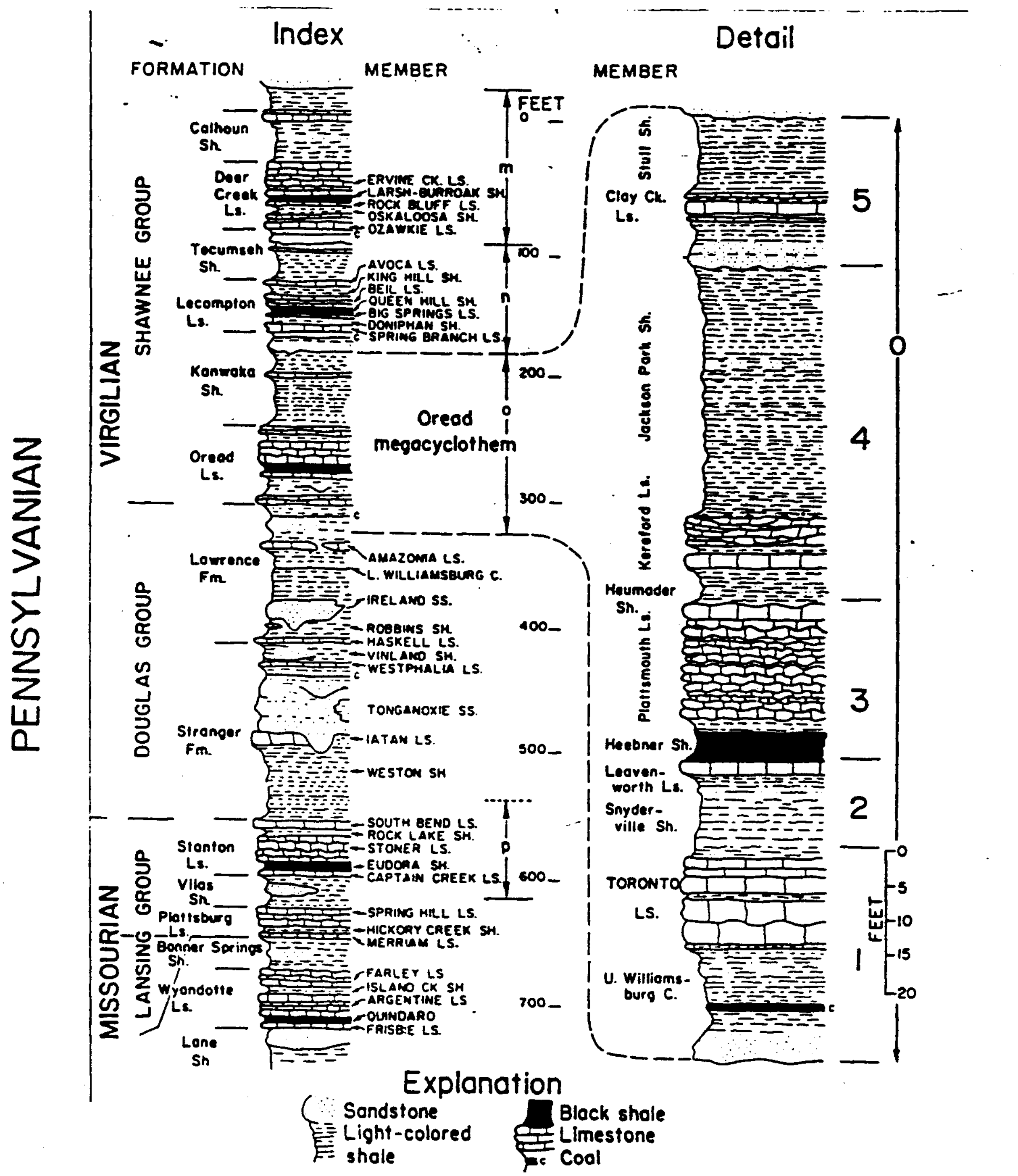
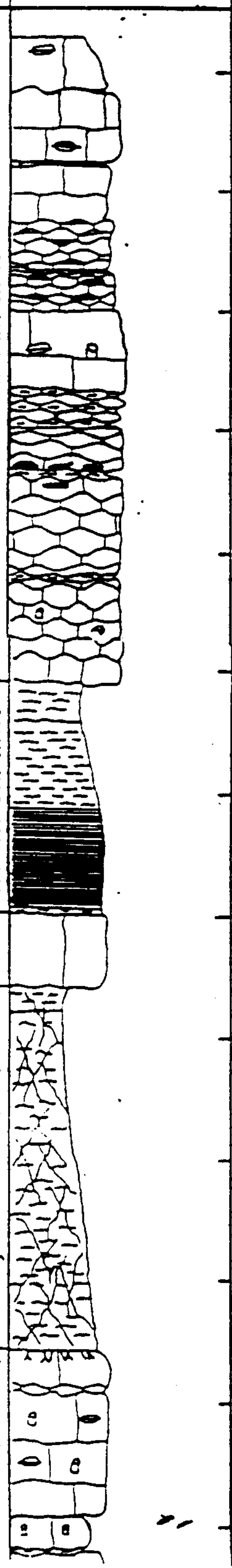


FIGURE 1-2 Stratigraphic position of the Oread Limestone and Oread megacyclothem (from Troell, 1969).

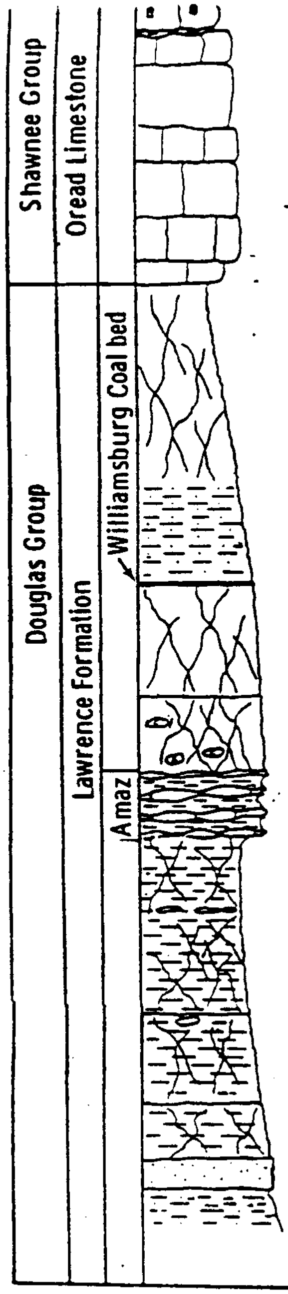
Measured Section of Clinton Spillway
Douglas Co., Kansas

Vertical Scale: 1 m



Group	Formation	Member	Sed. Struct.	Rock Name	Fossils Particles	Color Fresh/ Weathered	Grain Size	Diagenetic Features	Remarks
Shawnee Group	Oread Limestone	Plattsmouth Ls. Mbr.		fusulinid packstone					
				fusulinid packstone		brown-rusty orange			
				skeletal packstone		gray			
				algal packstone-wackestone		tan			thin wavy bedding shale interbeds
				cherty wackestone		gray		chert	
				fusulinid/crinoid packstone		gray-orange yellow			
				wackestone/packstone		rusty orange			rugose coral common
				skeletal packst.-wackestone		gray		(chert)	chert concentrated on bottom of bed
				skeletal packstone/wackestone		gray			whispy shale laminations
				skeletal packstone/wackestone		gray			whispy shale laminations
		Heebner Sh. Mbr.		clay shale		greenish yellow / dark gray brown	clay		softer and less platy than shale below
				black shale		black			hard platy phosphate nodules conodonts, sulfides 3 cm. soft shale at base
		Leav		Leavenworth Ls. wackestone		dark gray-brown			
Shawnee Group	Oread Limestone	Snyderville Sh. Mbr.		clay shale		dark gry-brn			
				clay shale		dark gray	clay		
		Toronto Ls. Mbr.		micrite		tan			tube-like structures at top of bed filled with shale, weather to tubes. pyrite
				crinoid/fusulinid packstone/wackestone		light gray			algal oncolites coated grains glauconite
				crinoidal wackestone		greenish gray			

FIGURE 1-3 Measured section of Upper Lawrence and Oread at Clinton Lake Spillway.

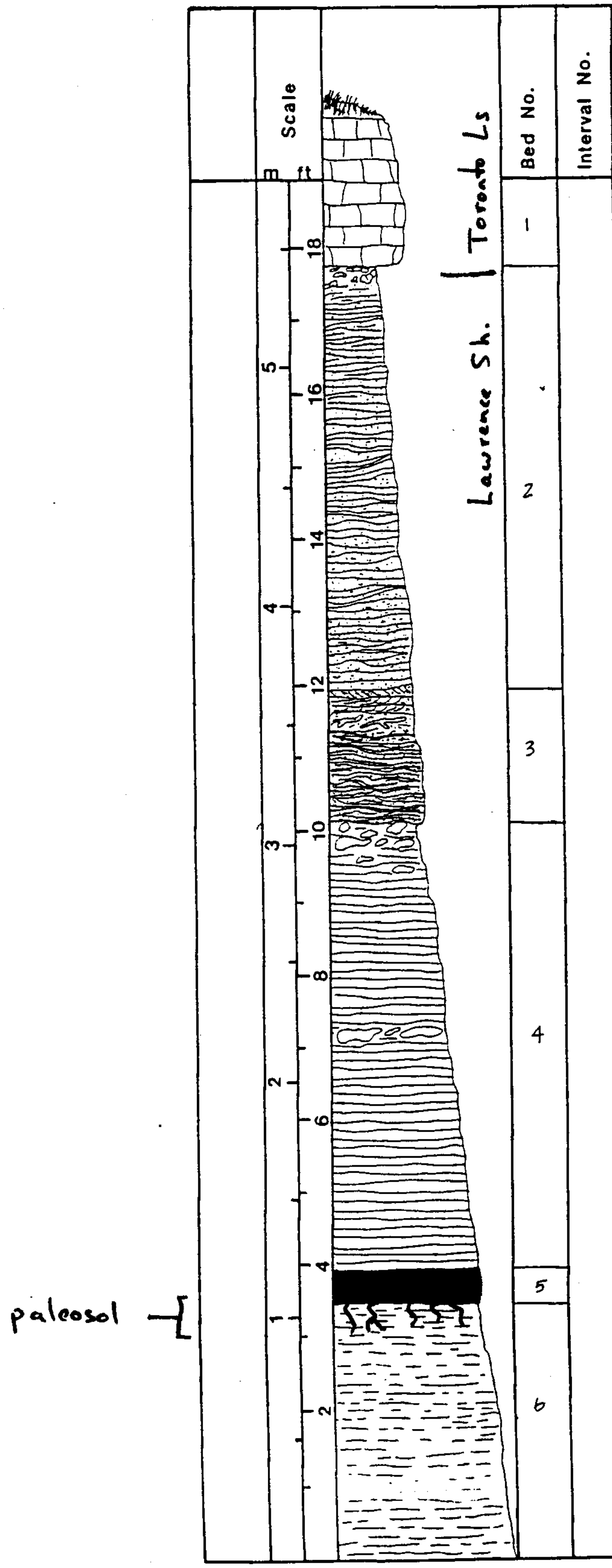


	crinoidal packstone/ wackestone		light greenish gray			whispy shale laminations
	skeletal packstone		light gray -orange yellow			iron stains
	skeletal wackestone		light gray			iron stains
	wackestone		light gray			
	mudstone/ clay shale		gray			thin (1 cm.) silty laminations weathering to yellow color
	coal smut		black			
	mudstone		greenish gray greenish gray with maroon mottling			clayey light brown calcareous nodules cylindrical and branching
	Amazonia Ls. Mbr. micrite, silty Ls. & clay shale		greenish gray/orange yellow			solution breccia sheet cracks fitted clasts
	slightly silty clay shale		greenish gray lt. gray			maroon lenses around iron rich nodules soft thinly laminated
	clay shale		red			some v. fine silt platy laminated
	clay shale		greenish gray			weathers blocky
	siltstone		pale green-gray			micaceous thinly laminated in places red, iron hardened burrows

KEY TO SYMBOLS

- brachiopods
- gastropods
- crinoids
- phylloid algae
- fusulinid forams
- bivalves
- rugose coral
- conodonts
- bryozoans
- oncolites
- coated grains
- vug
- pyrite
- shale interbeds
- burrows
- tubes
- shale interbeds
- phosphate nodules
- chert
- calcareous nodules
- iron rich nodules

FIGURE 1-4 Measured section of Upper Lawrence Shale and Lower Toronto Limestone south of Clinton Dam. Section measured by Kansas State University participants in joint K-State/KU Field Paleoecology Seminar (Fall 1990).



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 Sandstone ~~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.

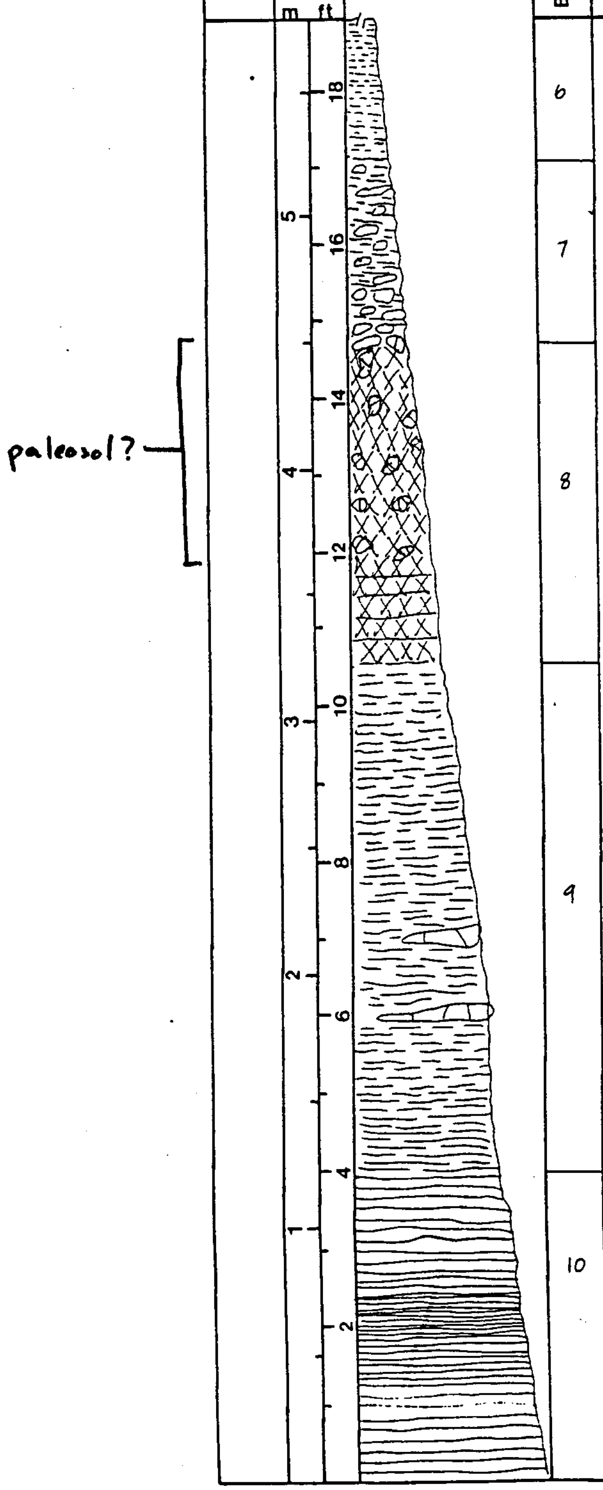
5 Blocky mudstone, 173cm thick, olive green-gray, rooted at sharp upper contact with the coal, root casts sideritic.

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

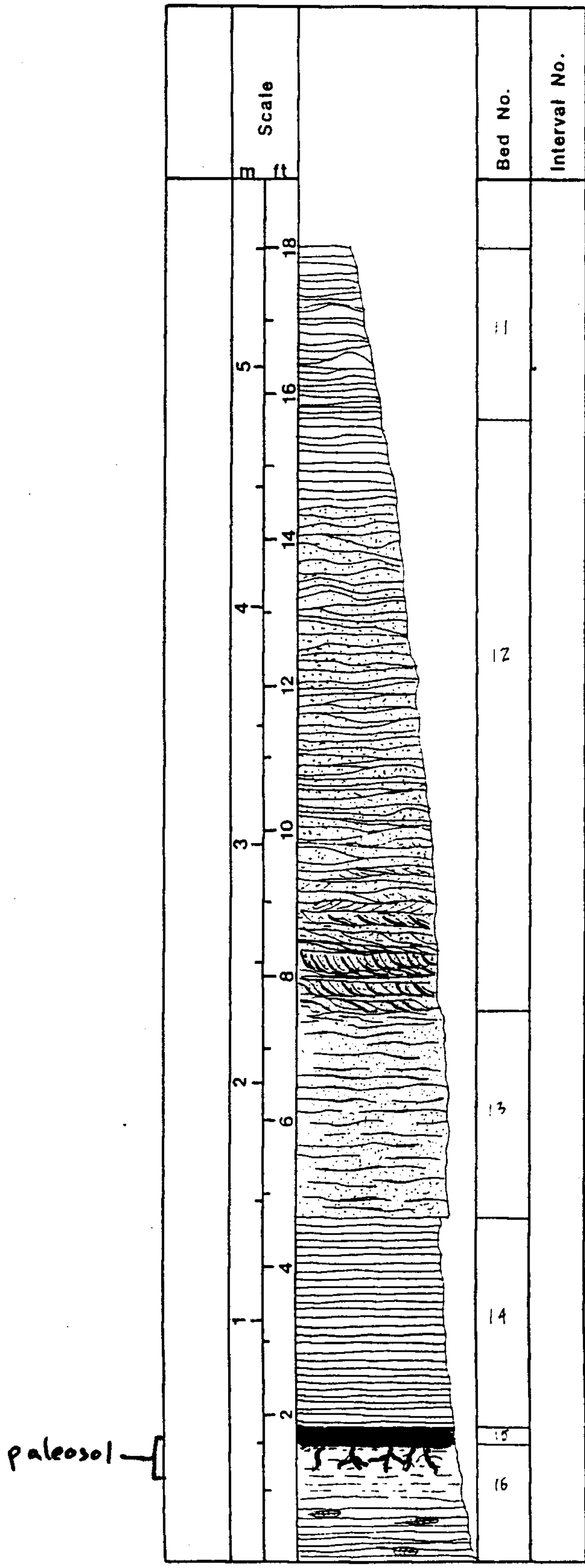
Measured By: ~~B. Smith~~, B. Tilley, K. Ross, & K. Krogstad; Fall'90.

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: <u>Composita</u>, <u>Crurithyris</u>, myalinids, ramose bryozoans, <u>Astartella</u>, <u>Phestia</u>, with barnacle borings, <u>Nuculopsis</u>, <u>Edmondia</u>, some broken bone debris, <u>Derbyia</u> 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 <u>Planolites</u> and <u>Lockeia</u> 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.

Stop 2 New Strawn quadrangle: upper Lecompton Limestone (upper King Hill Shale Member and lower Avoca Limestone member)

Location: midpoint between SW1/4, sec. 30 and SE1/4, sec. 25, T19S, R15E, Coffey County, Kansas

Contributor: *Janet Baker*

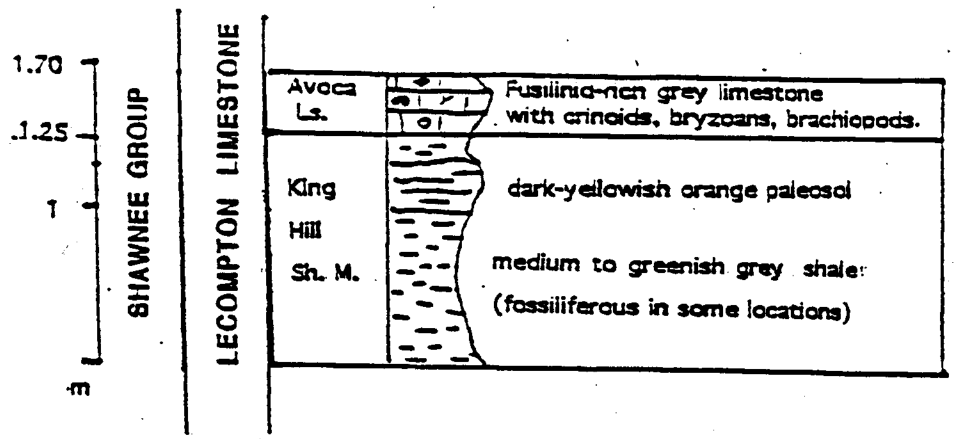
Introduction

The Lecompton Limestone is an example of a megacyclothem and includes an exposure surface with a possible fossil soil within the King Hill Shale Member. This dark-yellowish orange bed, referred to in previous literature as a "punky" or "rotton" interval, is useful in keeping one's place in the stratigraphic sequence because of its distinctive deep orange color and blocky and nodular appearance (note that, by definition, this is not a marker bed because it is not definitively isochronous). The exposure surface is nonfossiliferous and possesses features indicative of a paleosol. Field and hand-sample features include: 1) vertical prismatic fractures; 2) nodular and brecciated appearance; 3) large (> 10 cm) polygonal cracks resembling dessication cracks; 4) fenestral fabric; and 5) tubular root voids. Thin-section features include: 1) rhizoliths; 2) circumgranular cracking; and 3) alveolar texture.

Stratigraphy

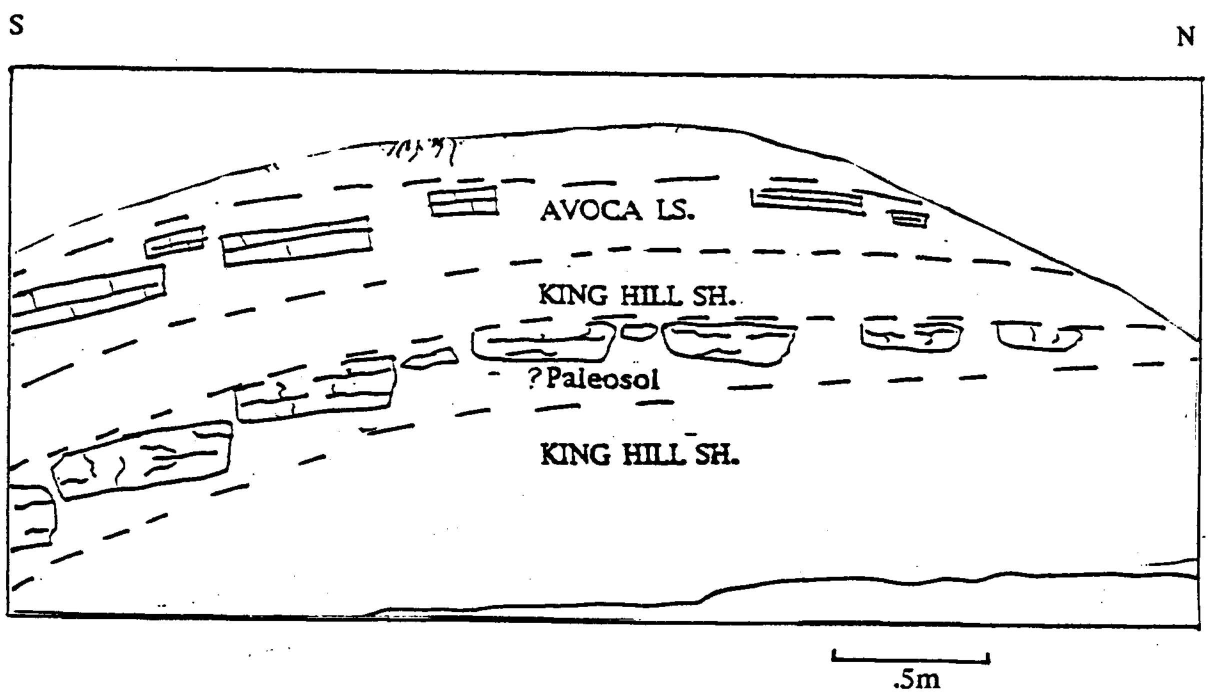
Upper Lecompton Limestone:
Avoca Limestone Member—Fusulinid-rich medium gray limestone with crinoids, brachiopods, gastropods, and bryozoans.

King Hill Shale Member—Medium gray to greenish-gray shale. Fossils recovered from other locations include charophytes (green algae), ostracodes, and gastropods (Lokke and Van Sant, 1966). ?paleosol—Dark yellowish orange blocky to nodular paleosol with light green horizontal and vertical veinlets.



Measured section of stop 2

FIGURE 2 Measured section and field sketch of exposure surface (?paleosol) in King Hill Shale Member at Stop 2.



Schematic Sketch of stop 2

Stop 3 Farlinville North quarry: Mid to upper Bethany Falls Limestone, Galesburg Shale, Canville Limestone, Stark Shale, lower portion of the Winterset Limestone

Location: E/2 SW sec. 34, T. 20 S., R. 23 E., Linn County, Kansas

Contributors: *John French, Lynn Watney*, and *Evan Franseen*

Introduction

Exposed at this stop are the upper portion of the Swope Limestone and the lower portion of the Dennis Limestone. Both units reside in the lower Kansas City Group and are lower Missourian in age. This location is a lower shelf setting about 55 mi (17 km) south-southwest of our next stop in Kansas City, in which the Swope and Dennis limestones are also present. Fig. 3-1 provides a map of the local area around Stop 3. A complex paleosol horizon is developed at the top of the Bethany Falls Limestone and overlying Galesburg Shale near the top of the quarry wall. Access is gained at various scree slopes. Also parts of the paleosol can be seen in fallen blocks.

The paleosol is developed at the top of the Swope Limestone, and according to our interpretation is a sequence boundary. This bounding surface is widespread, seen in outcrop and cores throughout the upper Midcontinent. Other aspects of interest at this stop include the sedimentologic and stratigraphic relationships associated with the shallowing-upward phase of Swope deposition (leading to development of the subaerial exposure surface) and the overlying marine flooding, condensed-section development, and initial shallowing-upward succession of the overlying Dennis Limestone (fig. 3-2, stratigraphic column).

Stratigraphy

The upper 13 ft (4 m) of the Bethany Falls Limestone is exposed in the lower wall of the quarry (figs. 3-2 and 3-3). The total thickness of the Bethany Falls is 23 ft (7 m) in a roadcut on Highway 7, located 1 mi (0.3 km) to the southwest of the quarry.

Here in the quarry the lower 7 ft (2.1 m) of the Bethany Falls is composed of light-gray to gray skeletal wackestone and packstone that is typically mottled. Parts of this unit have been altered to light-gray, chalky microspar; in places, fabric relationships suggest vertical piping of the fluids that were responsible for this alteration. The pipes become more numerous upwards toward the paleosol. The pipes are often shale filled within the upper meter of the Bethany Falls Limestone.

The upper 6 ft (1.8 m) of the unit consist of cross-stratified oolitic grainstone to packstone. The oolitic foresets overlie an apparently scoured surface at the top of the underlying finer-grained unit. Remnants of unfossiliferous, laminated lime mudstone have been observed at the top of the lower unit immediately beneath the oolite on the west wall of the quarry. The presence of this lime mudstone suggests that shallowing to a peritidal setting may have occurred prior to deposition of the oolite; evidence of subaerial exposure at this surface remains equivocal, however. Detailed petrography and carbon-isotope profiling in equivalent strata at other localities are yielding answers to these questions.

The Bethany Falls here is in a lower shelf setting than it is in the Kansas City area based on regional mapping. The evidence of pronounced subaerial exposure is even better developed in the higher shelf positions to the north.

Preliminary results of the study of the Bethany Falls Limestone in the surface and subsurface indicate that at least two oolite units are present at the top of the Bethany Falls Limestone just over 20 miles to the south-southwest. In that area the oolites are typically separated by 2- to 6-

foot-thick intervals of finer-grained lithologies; lithologic and isotopic evidence suggests that the deposition of each oolite was followed by a period of subaerial exposure. A detailed correlation of these interval events with the section in this quarry has yet to be made.

A discontinuous, brown micritic carbonate that is riddled with what appear to be root tubules occurs in the uppermost portion of the unit. Vertical pipes filled with greenish, shaly material are also ubiquitous in the upper few feet of the Bethany Falls Limestone. This piping is associated with vugs and cavities, many of which extend upward to the top surface of the unit (fig. 3-3). There is considerable small-scale (< 1 ft or 0.3 m) relief on this surface where it is exposed in the quarry, but no larger-scale solution features have been observed here. Abundant oomoldic porosity in the underlying upper Bethany Falls probably resulted from an influx of meteoric water during this exposure event. Coeval K-zone reservoirs in western Kansas typically produce from similar reservoirs where there is permeability (effective interconnected porosity). Further work is underway to understand the regional patterns and significance of this type of early diagenesis in the context of sequence stratigraphy and petroleum-reservoir development.

The Galesburg Shale overlies the Bethany Falls Limestone. It is a complex unit about 1.5 ft (0.5 m) thick. The basal portion of the Galesburg is a greenish blocky mudstone interpreted as the paleosol associated with post-Swope exposure. The upper part of the unit is a sandy siltstone that contains a limited marine fauna; it records the initial phase of the marine incursion that resulted in deposition of the Dennis sequence. The boundary between the Swope and Dennis sequences is placed at the top of the paleosol. A minor marine cycle (Mound Valley) is developed on the lower shelf to the south and is thought to represent a small rise in relative sea level. The depositional facies of this marine cycle at its updip limits is dominated by oolitic grainstones. This oolite is in places bounded above and below by a clay-rich paleosol. Evidence of the presence of this minor marine cycle at the base of the Galesburg Shale is equivocal in this quarry which is a little higher on the shelf, and the two subaerial exposure events that separate the marine unit farther basinward are thought to be superimposed in most places at this location. Perhaps this is the reason for the contrasting forms of paleosol development, i.e., an initial microkarst followed by patchy calcrete.

The Canville Limestone is a marine-flooding unit and represents a continuation of the major marine flooding associated with the overlying Dennis Limestone. Myalinid clams occur over the lower surface of the Canville Limestone. Bored spiriferid brachiopods and scattered fish plates mark the upper surface of the unit immediately beneath the Stark black shale. These features indicate reduced rates of sedimentation, which probably resulted from an increasing rate of base-level rise and the resulting deep-marine conditions unsuitable for carbonate producers.

Above the Canville Limestone lies the Stark Shale, the condensed section of the Dennis Limestone. This shale is for the most part black, fissile, phosphatic and rich in conodonts, some of which can be seen with a hand lens by the patient observer. Fragments of woody-plant material also occur in the Stark at this quarry. A gray, silty shale overlies the black shale. This interval becomes increasingly calcareous upwards, and brachiopods, bryozoa, and crinoids become common. A similar biota is found in the base of the overlying Winterset Limestone, which also contains phylloid algae.

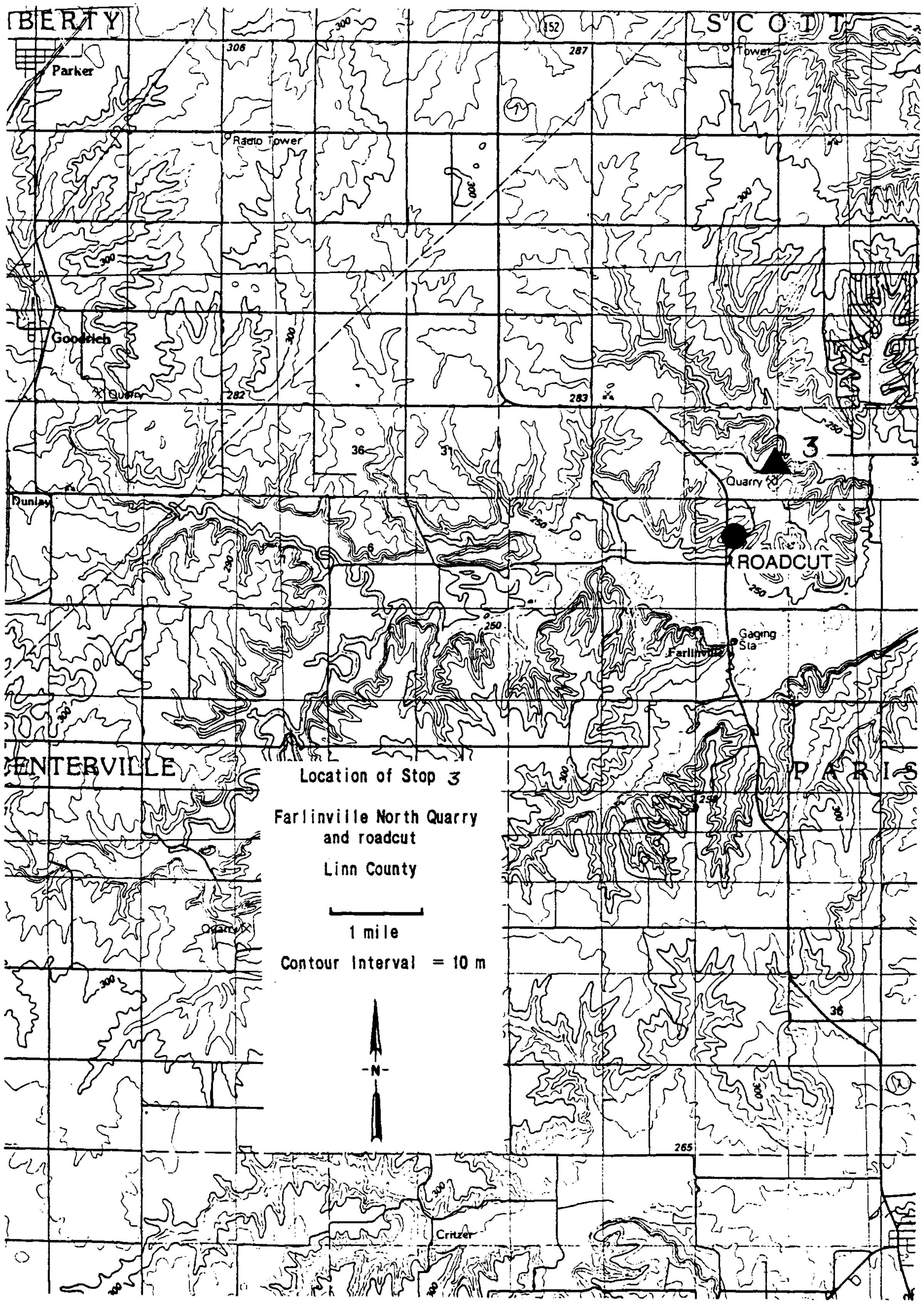


FIGURE 3-1 Location map for Stop 3 (Farlinville North quarry) and Farlinville roadcut in Linn County, Kansas.

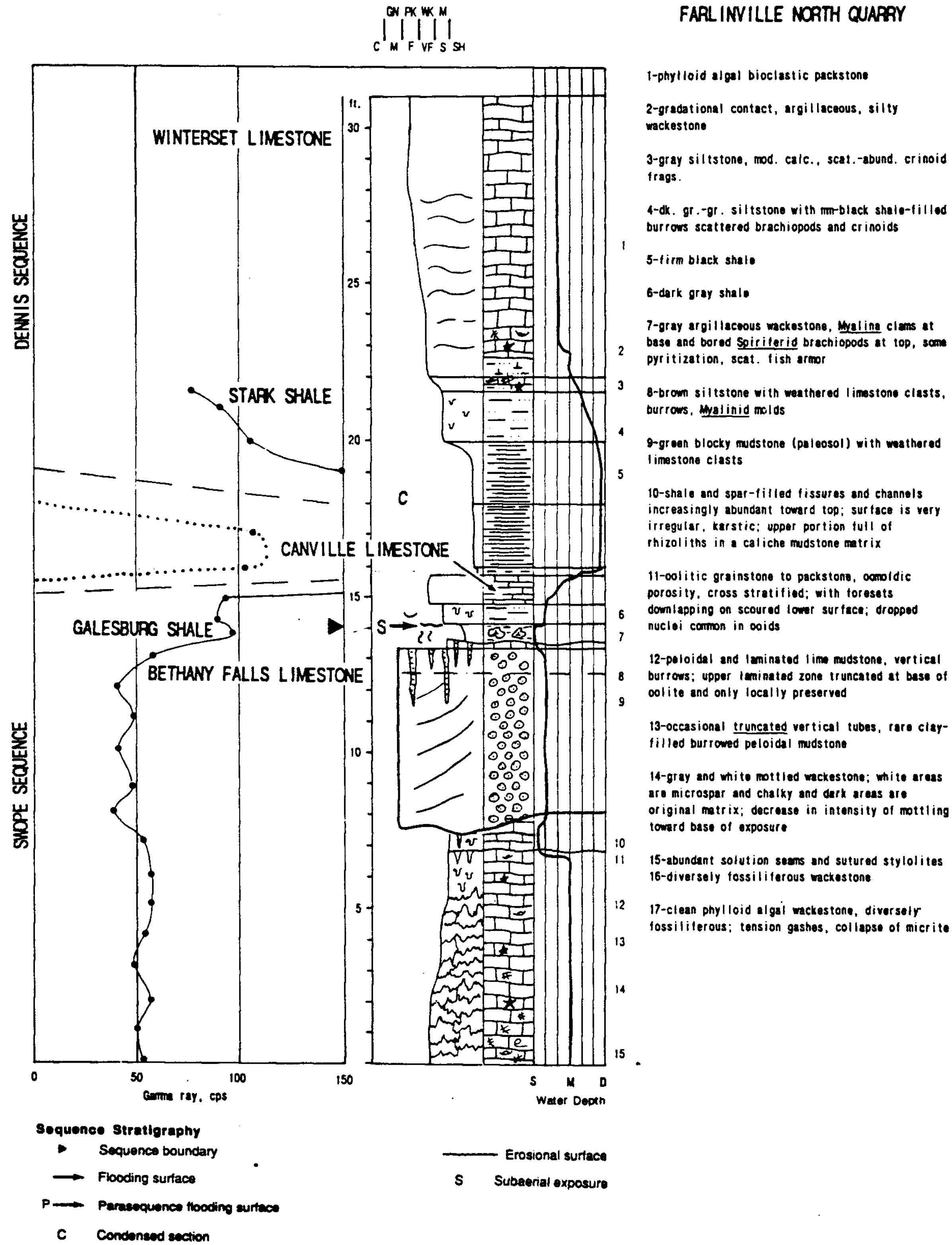
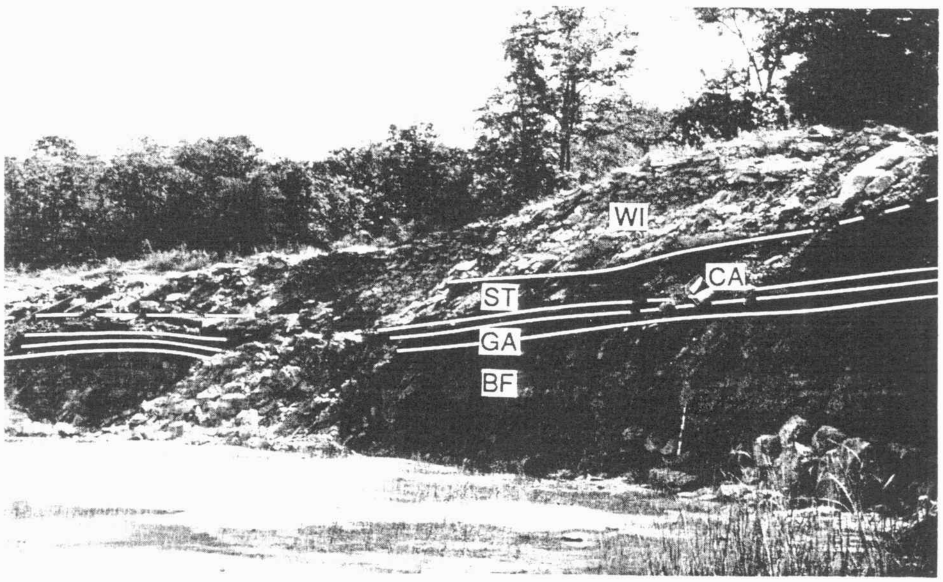


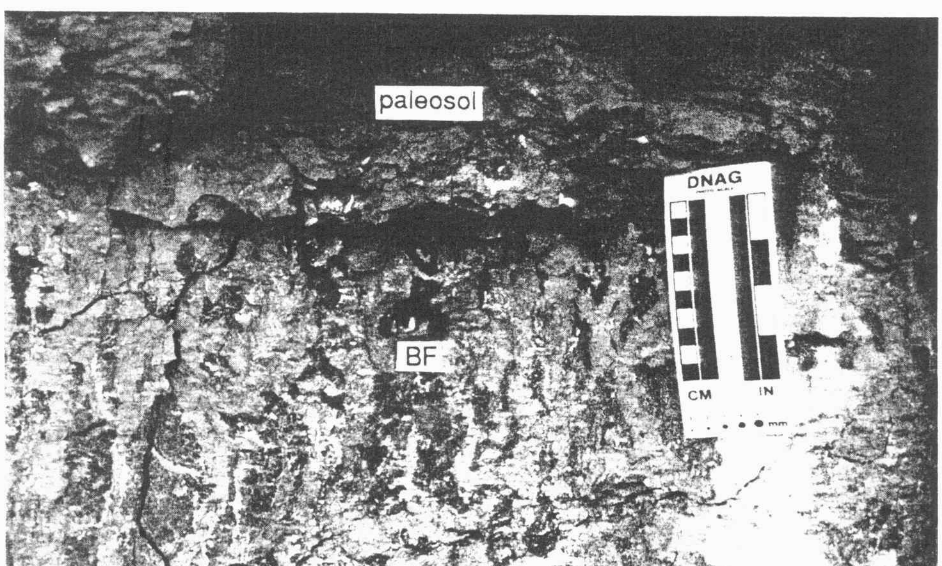
FIGURE 3-2 **Measured section of Farlinville North Quarry exposure at Stop 3. Section** includes gamma-ray profile and sequence-stratigraphic symbols. Bethany Falls Limestone Member of the Swope Limestone, Galesburg Shale, and Canville Limestone, Stark Shale, and lower portion of Winterset Limestone members of the Dennis Limestone are present along the walls of the quarry.

FIGURE 3-3 (A, B, and C) West wall of Farlinville North Quarry (A and B). Bethany Falls Limestone (BF), Galesburg Shale (GA), Canville Limestone (CA), Stark Shale (ST), and Winterset Limestone (WI) can be traced around quarry walls. **C) Close-up of top of Pennsylvanian subaerially weathered Bethany Falls (BF) and paleosol in lower Galesburg Shale. This paleosol forms the sequence boundary between Swope and Dennis sequences.**

A



B



C

Stop 4 Raytown section along I–435 just south of 350 Highway: Hertha, Swope, and Dennis cycles

Location: SW1/4, SW1/4, NW1/4, sec. 6, T48 N, R32 W, Jackson County, MO

Contributors: *Lynn Watney, John French,* and *Evan Franseen*

Introduction

This is a superbly exposed, continuous sequence of the lower Missourian rocks (including the Sniabar, Swope, and Dennis limestones) that are currently a major focus of investigation by the Kansas Geological Survey (figs. 4-1, 4-2). Familiarity with the variability of these units throughout most of Kansas allows us to put this important outcrop into a regional stratigraphic context.

The units exposed at this location will be described in ascending order. For the sake of brevity, only salient features of the individual units are mentioned. These comments will hopefully foster further discussion. The stratigraphic relationships of these units is best understood by reference to the measured section (fig. 4-2).

Stratigraphy

The Mound City Shale is the lowermost unit exposed here. The upper portion is exposed beneath a small waterfall a few hundred feet downstream of the main outcrop. The Mound City is a widely correlative, relatively deep-water deposit that represents the condensed section within the Sniabar sequence. The portion that is visible here consists of a few centimeters of alternating black shale and dark-gray shale that contains *Chondrites*. This alternation may reflect fluctuations in bottom-water oxygenation that occurred in this relatively high-shelf setting; basinward (to the south) a black, phosphatic facies is well-developed in the Mound City.

The Sniabar Limestone is the high-stand deposit of the Sniabar depositional sequence. At this location, as well as at most locations to the south, it is primarily a relatively open- marine phylloid-algal and skeletal wackestone. Scattered clusters of rugose corals that appear to be in growth position are found in this unit near the bridge adjacent to this stop.

The upper portion of the Sniabar exhibits abundant evidence of subaerial exposure. Depressions along the surface of the unit are layered with laminated calcrete. Chalky microcrystalline caliche that contains clasts of laminated calcrete occurs along the upper few centimeters of the Sniabar, in direct contact with the presumably open-marine skeletal wackestone. In addition, rhizolith systems 3–5 cm (1.2–2 inches) in diameter made up of calcrete as well as mm-sized tubules penetrate extensively through much of the Sniabar Limestone. Some beds within the Sniabar appear more altered than others. Associated in situ brecciation and micritization of the host carbonate is pervasive, with multiple episodes of subaerial exposure possible. Internal dissolution and calichification of the unit apparently occurred while only the upper part was exposed, in similar fashion to observed diagenesis of Pleistocene carbonate rocks in south Florida and the Bahamas (H. Wanless Jr., personal communication, 1988).

Although it is only 9 ft (2.7 m) thick here, the Sniabar Limestone forms a carbonate-bank complex up to 90 ft (27 m) thick roughly 120 mi (190 km) to the southwest of here in association with thinning of the underlying Pleasanton siliciclastic platform.

The Elm Branch Shale is about 2.5 ft (0.8 m) thick and consists of an unfossiliferous gray mudstone succeeded upward by a coaly stringer, fossiliferous shale, and a thin carbonate. A sequence boundary between the Sniabar and Swope limestones is placed at the coaly stringer, which marks the initial marine incursion. The lower gray mudstone may be a paleosol, but no diagnostic criteria for subaerial exposure have been found.

The Middle Creek Limestone is about 2 ft (0.6 m) thick and is a dark-gray to gray phylloid-algal wackestone. The Middle Creek is the regionally extensive marine-flooding unit near the base of the Swope sequence. Brachiopods, bryozoans, and corals that are commonly bored occur at and near the base of the unit. Patches of phylloid algae that appear to be in growth position are also common in the Middle Creek Limestone.

The Hushpuckney Shale is the black, phosphatic, highly radioactive condensed section within the Swope sequence. It can be correlated from this location into Oklahoma, Iowa, and eastern Colorado, everywhere maintaining its black, phosphatic character except on major positive features of the shelf such as on portions of the Central Kansas and Nemaha uplifts. Gamma ray logs shown in Figure 4-3 show the radioactive character and continuity of the Hushpuckney and overlying Stark shales. Uranium concentrations in this shale vary locally from 20 to 200 ppm (Coveney, 1985). Enrichment of other metals is common in the Hushpuckney Shale as shown by analyses from Iowa and Missouri, including a location near this exposure.

The Hushpuckney Shale is an excellent marker bed that represents one of the most significant glacial-eustatic inundations in the midcontinent (Figure 4-4, Boardman and Heckel, 1989). The transition from Middle Creek Limestone to black Hushpuckney Shale is typically knife-sharp, in contrast to transitional changes at the bases of other condensed sections. The upper portion of the Hushpuckney Shale consists of gray shale that is transitional with the overlying Bethany Falls Limestone. Occurring within this transition are dark-shale-filled burrows that have tentatively been identified as *Zoophycos*. Although it is a common trace fossil in many marine settings, *Zoophycos* tends to be more common in some relatively deep-water (Ekdale and Bromley, 1984) or poorly oxygenated (Savrda and Bottjer, 1987) settings.

In contrast to the Hushpuckney Shale, the overlying Bethany Falls Limestone reflects deposition in relatively shallow, open-marine to very shallow, apparently restricted-marine conditions. The basal bed is made up of nonargillaceous light-gray skeletal wackestone that contains abundant blue-green-algal-coated skeletal grains and scattered phylloid algae as well as scattered worms and tubular foraminifera. Above that, the Bethany Falls consists of an interval of relatively open-marine phylloid-algal and skeletal wackestone that passes upward into virtually unfossiliferous lime wackestone to mudstone.

The rather abrupt transition from the presumably deep-water Hushpuckney Shale upward into algal limestone with essentially no intervening deep-shelf carbonates appears to represent a period of shallowing during which carbonate sedimentation was inhibited. Renewed carbonate accumulation may be related to high-stand progradation of the carbonate platform from the north (landward).

In many places to the south of this location the upper Bethany Falls Limestone consists of oolitic grainstone that is similar to the reservoir facies in coeval strata in central and western Kansas. This was seen at the last stop in the Farlinville quarry. However, at this stop the upper portion of the Bethany Falls Limestone is a rubbly, brecciated unit that contains abundant mm-sized tubular rhizoliths. This surface is believed to record the effects of prolonged subaerial exposure and as stated earlier can be traced in outcrops and cores across the northern midcontinent shelf.

The distinct mottling as well as localized in situ brecciation, both of which extend down into the Bethany Falls, are also believed to be associated with subaerial exposure. The mottling, which is characteristic of the Bethany Falls, appears to be related to the infiltration of meteoric water during the exposure event. Nollsch (1983) found that the dark mottles were microspar and that the lighter areas were less-altered micrite. He noted that the dark microspar was isotopically lighter in both carbon and oxygen than the micrite and suggested that these variations were due to meteoric diagenesis. Heckel suggests that the microspar nodules reported by Steinen (1982) in lime mud on Andros Island in the Bahamas are analogous to the mottles in the Bethany Falls. Steinen (1982) attributed the development of the Holocene nodules to meteoric phreatic diagenesis.

The Galesburg Shale at this location is a blocky mudstone less than 3 ft (1 m) thick that is covered in most places. It represents a period of extended soil formation during the exposure event that terminated deposition of the Swope Limestone (Schutter and Heckel, 1985). Southward (basinward) in Kansas this unit thickens into a lithologically heterogeneous siliciclastic package that attains thicknesses of more than 130 ft (40 m) near the Oklahoma border. These sediments were derived in large part from the Ouachita mountain front to the south. Major clastic wedges made up of fluvial-deltaic and density-current deposits filled much of the lower shelf and basin during this episode leaving the upper shelf emergent. Some sediment bypassing across the northern shelf is also indicated including small incised channels cut into the underlying Bethany Falls Limestone.

The Stark Shale is the condensed section within the Dennis Limestone. In most places south of this location a marine flooding unit, the Canville Limestone, is present above the Galesburg, but at this relatively high shelf position it is poorly developed or absent. The Hushpuckney and Stark shales and associated marine-flooding units are widely correlative intervals that can be traced southward into the detrital-sedimentary pile in Oklahoma 300 mi (483 km) distant and over 400 mi (644 km) west across the carbonate shelf into western Kansas.

The Winterset Limestone is the internally complex upper Dennis carbonate unit. It has tentatively been divided into three parasequences (minor sequences) at this location; about 50 mi (80 km) to the south near Jingo this unit consists of at least three and probably four minor cycles (Watney et al., 1985). Some of these minor shallowing-upward units may be due to eustatic pulses, while others may be entirely local in origin. Note the occurrence of the thicker medial shale and the parasequence boundary it overlies and the *Composita* brachiopod bed below the cross-stratified oolitic grainstone. Note also that the oolitic unit is only 6 ft (1.8 m) thick here while in Stop 6 the equivalent deposit is up to 13 ft (4 m) thick. Autogenic processes controlled thickness and facies variations within this parasequence.

The *Composita* bed is continuous and uniform in thickness along this exposure. The brachiopods are commonly coated with blue-green algae, with the coatings being thicker in the upper part of the bed. Upward-oriented geopetal fabrics are common. Sediments in this bed may have been transported by storm currents and later coated during day-to-day current activity. Subsequently, this bed was covered by cross-stratified skeletal and oolitic sand. Uncoated brachiopods and other skeletal debris accumulated at the toes of foresets.

The platy mudstone on top of the oolitic grainstone contains lenticular beds of sharp-based marine grainstone containing wood fragments. This is tentatively interpreted as an event bed that was deposited in a peritidal setting.

The Fontana Shale consists of platy, laminated mudstone near the base, passing upward into more radioactive gray shale. The upper boundary of the Dennis sequence is placed in that transitional interval.

The Block Limestone is a very fossiliferous marine-flooding unit of the Cherryvale sequence.

The Westerville Limestone exposed at the top of this roadcut is a phylloid-algal wackestone overlain by cross-stratified oolitic and skeletal grainstone. This unit thickens to over 20 ft (6 m) of grainstone locally around Raytown, 0.5 mi (0.8 km) to the east, and can be seen across I-435 from high points on this exposure; there it is a thicker cross-stratified grainstone. The Westerville may be equivalent to the Drum oolite at Independence, Kansas. The Cherryvale sequence, of which the Westerville is a part, apparently consists of five distinct shoaling-upward units in an 80-ft (24-m)-thick section in the Amoco Cox core in Haskell County in southwestern Kansas. While the Cherryvale is a thick unit here and in southwestern Kansas, the Cherryvale marine inundation reached only as far as the northwestern Kansas shelf.

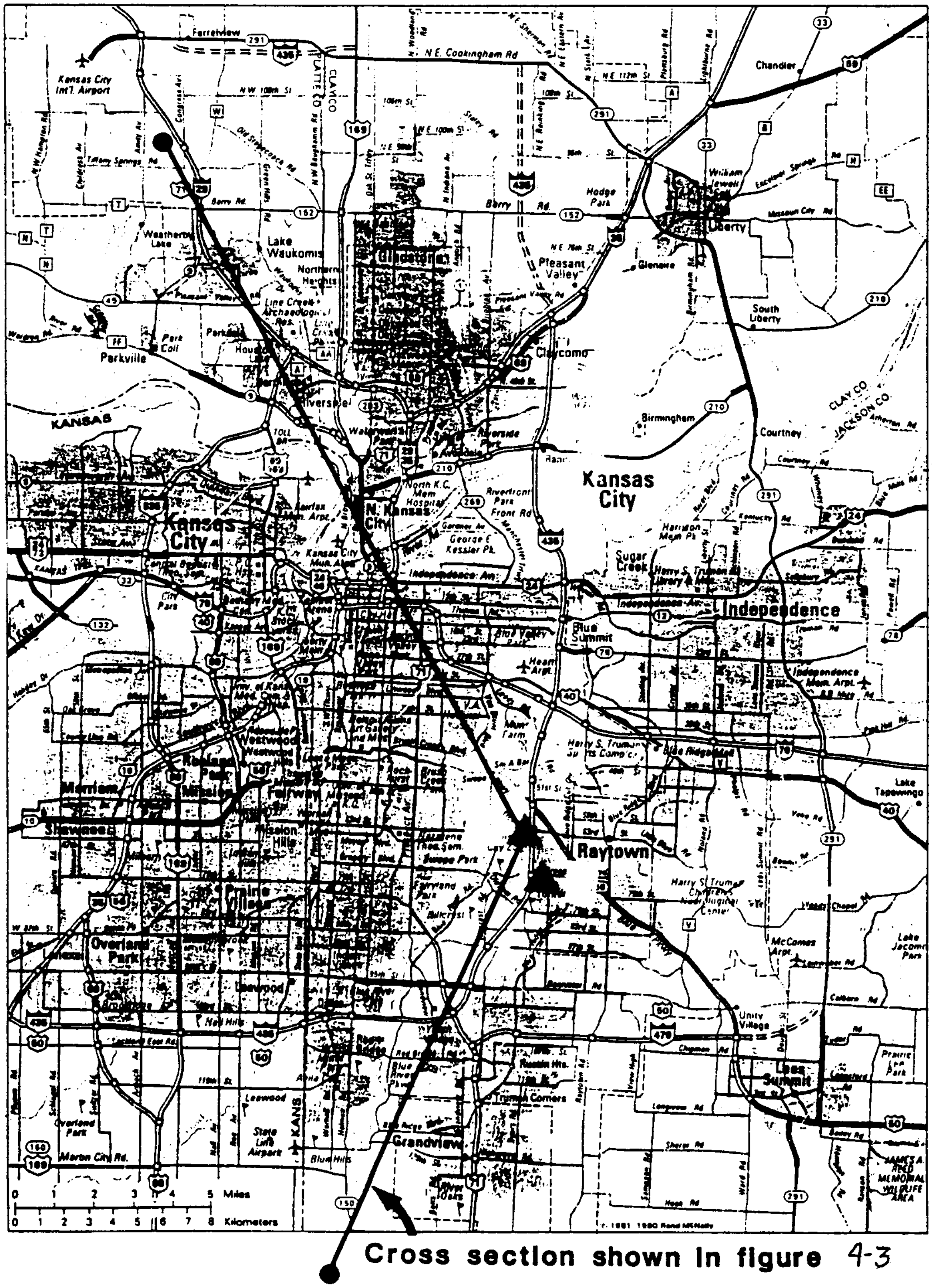


FIGURE 4-1 **Index map showing locations of Stop 4 and locations of well logs used in constructing cross section of fig. 4-3.**

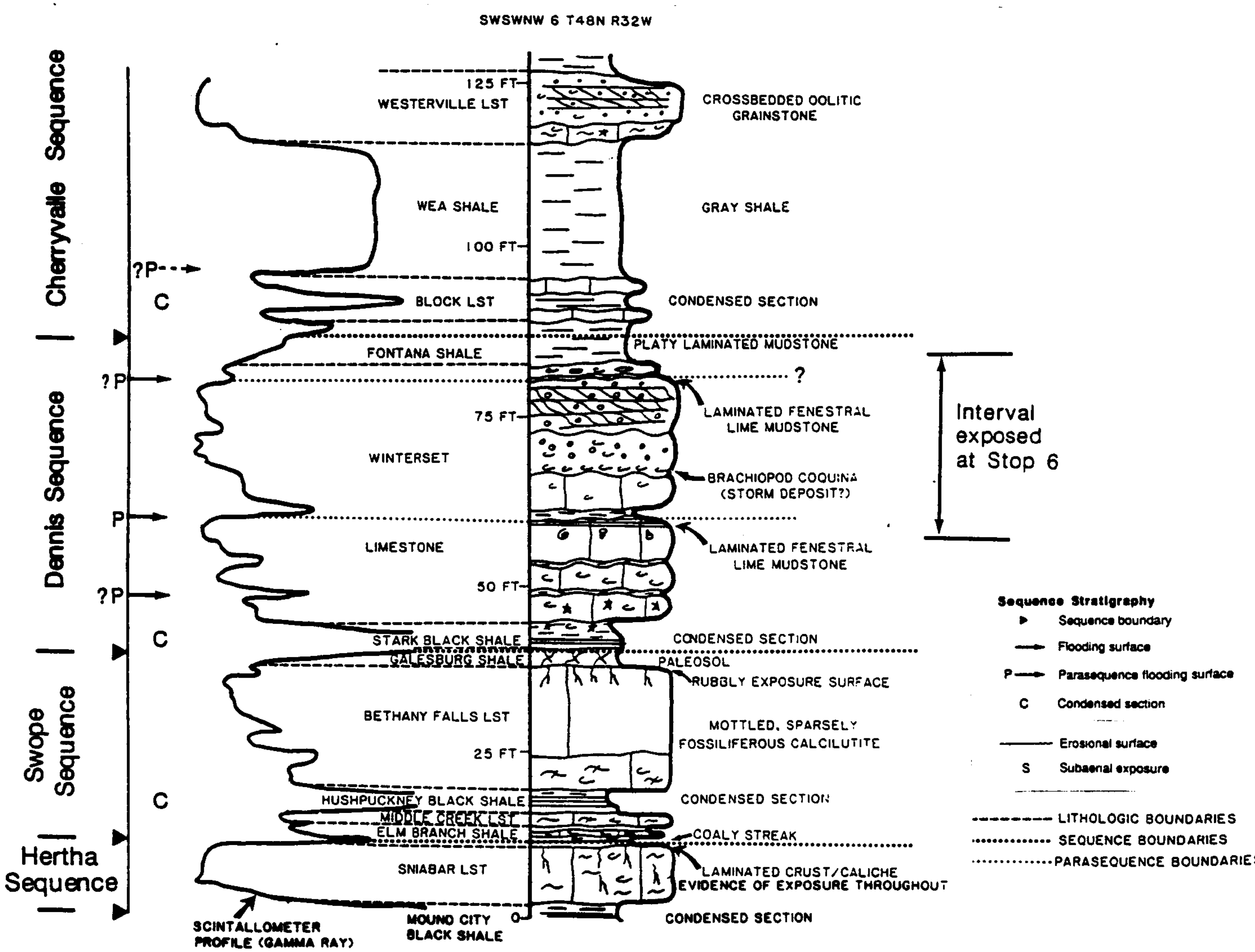


FIGURE 4-2 **Measured section of Stop 4 (Raytown) accompanied by gamma scintillometer profile (recording every 1 to 2 ft). Formations listed down middle of** diagram. Sequence-stratigraphic terms are indicated on the left.

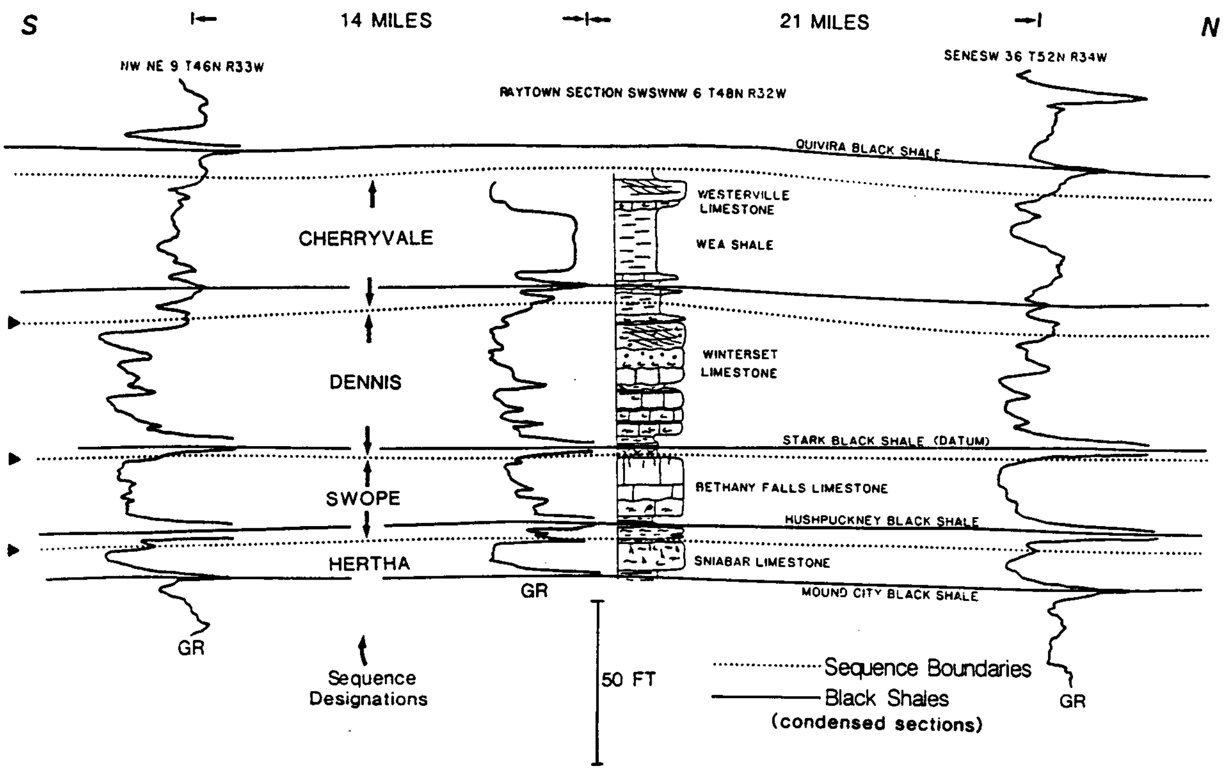


FIGURE 4-3 **North-south stratigraphic gamma-log cross section (Stark Shale Datum) from wells in vicinity of Stop 4 (index map in fig. 4-1). Correlations based on gamma-ray character of lithologic units. Sequence boundaries are established with lithologic information carefully correlated to gamma profiles.**

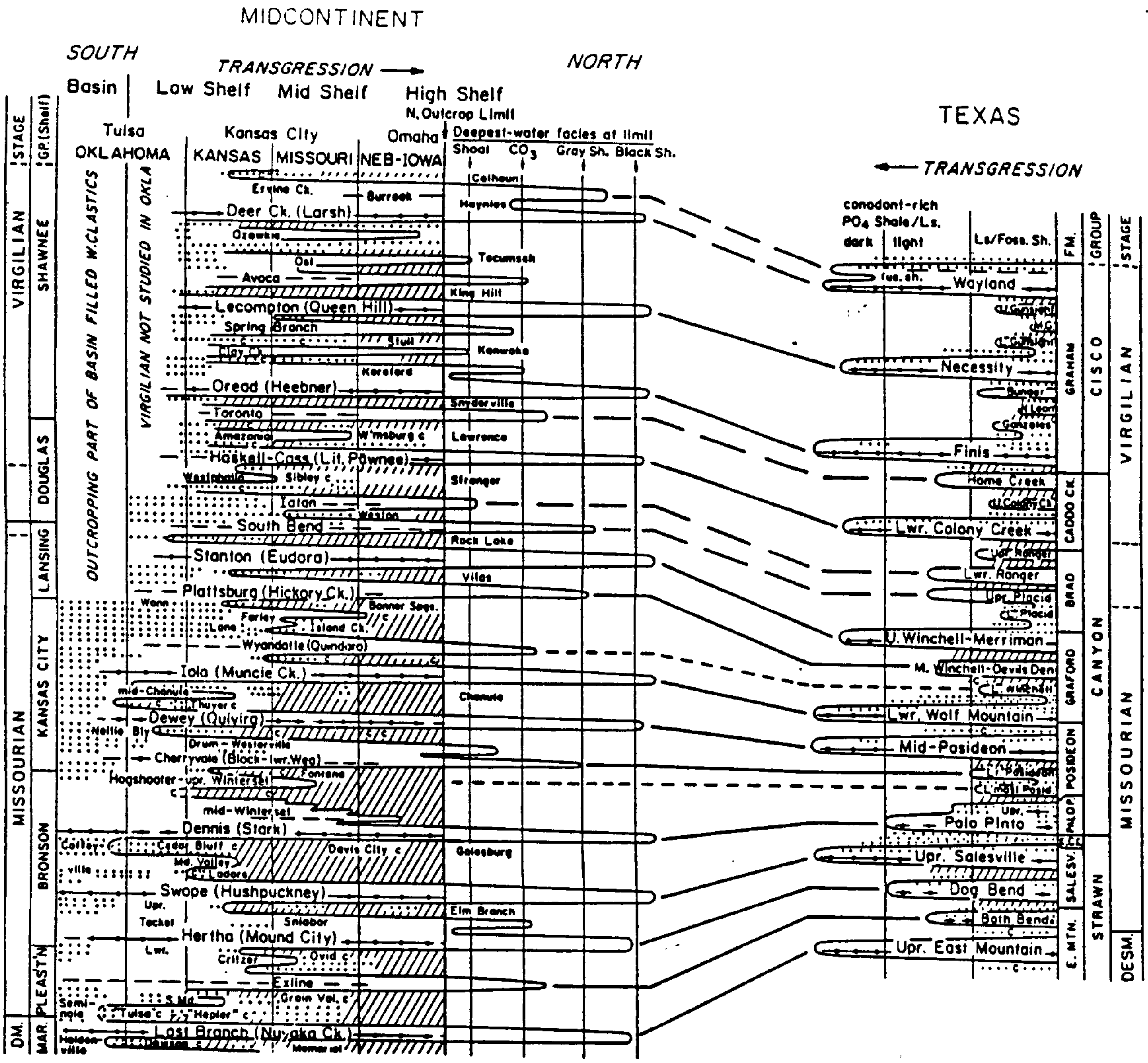


FIGURE 4-4 Glacial-eustatic sea-level curves for early Upper Pennsylvanian succession in north-central. Texas and mid-continent correlated using biostratigraphy. Curves depict maximum inundations based on occurrence of black shale and low stand based on extent subaerial exposure (Boardman and Heckel, 1989).

Stop 5 I–435 south of Holiday Road exit

Location: Center sec. 6, T. 12 S., R. 24 E., Johnson County, Kansas

Contributors: *Paul Enos, Lynn Watney*, and *Evan Franseen*

Introduction

The measured section of the interval seen here (Fig. 5-2) was obtained on the east roadcut across from this stop (fig. 5-1D). Fig. 5-3 provides three photos illustrating the paleosol developed at the top of the Bonner Springs Shale, the focus of Stop 5.

The Bonner Springs Shale and the overlying Plattsburg Limestone are typically developed along this roadcut. The Bonner Springs Shale is 25.3 ft (7.7 m) thick. The Plattsburg Limestone consists of the 2.3-ft (0.71-m)-thick Merriam Limestone Member, the 20-cm (8-inch)-thick Hickory Creek Shale Member, and the 14.6-ft (4.44-m)-thick Spring Hill Limestone Member. A series of channel forms are found near the top of the Bonner Springs Shale at and near this stop. Maximum dimensions of sandstone lenses within the channels are 1 to 2 m (3.3–10 ft) thick and about 100 m (330 ft) in apparent width.

An objective of this stop is to examine two paleosols developed at the top of the Bonner Springs Shale, a lower maroon zone and a capping calcareous paleosol. These paleosols are cut out in a small incised shale and sandstone filled channel-form several miles north of here at the intersection of I-435 and I-70 described previously in Watney et al. (1989). The capping paleosol, although sporadic, is widespread above the maroon zone. It's surface is a sequence boundary between the Plattsburg Limestone (above) and the Wyandotte Limestone (below).

The capping paleosol has been described as an argillaceous, nodular, yellow-weathering limestone within the top meter of the Bonner Springs Shale. This limestone unit, which overlies the maroon shale, was described in part as "marlite" by Newell (1935, p. 68). It is nodular and locally conglomeratic in appearance, with fragments of calcareous mudstone or argillaceous limestone. Vertical prismatic fractures are scattered near the top of this limy interval. The calcareous zone grades down into nodular calcareous mudstone that locally contains large woody fragments, including *Calymites*, root casts, and U-tubes with poorly developed spreiten.

At several localities, the yellow-weathering carbonate unit extends down vertical fractures, interpreted as syndepositional desiccation cracks (Harris, 1985). The general V-shaped downward extension of the filled cracks and their irregular surface traces indicate large polygons resembling desiccation cracks, rather than a joint set. The best evidence that they are penecontemporaneous with deposition is at another location, where a V-shaped fracture fill of skeletal wackestone 10 cm (4 inches) deep is nested in a V-shaped zone of yellow-weathering carbonate that extends downward more than a meter. The skeletal wackestone was evidently deposited during marine flooding associated with Merriam Limestone deposition.

The nodular and brecciated appearance of the yellow-weathering carbonate is probably due to displacive crystal growth, enhanced compaction of the shale around semi-lithified carbonate, and growth of plant roots. Thin sections of the carbonate zone indicate microcrystalline calcite with scattered fragments of dense brown micritic calcite that are surrounded by circumgranular cracking. This texture is common in caliche. Rhizoliths (downward branching, clay-filled tubules) are also scattered through the unit. Prismatic fractures are probably ped surfaces, common in soils as illustrated by Retallack (1988) in Fig. 4-2.

Caliche, rhizoliths, vertical columnar peds, oxidation, and a gleyed (reduced, clay-rich) soil horizon define a well-developed paleosol. The complexity of the paleosol reflects changes in moisture level that probably resulted from changes in climate during falling sea level.

A typical section of the Merriam Limestone, Hickory Creek Shale, and Spring Hill Limestone overlies the Bonner Springs Shale at Stop 5. In some places the Bonner Springs Shale does not contain this paleosol due to local erosion. The thick preservation here may be related to a topographic low formed as the underlying sandstone channel subsided.

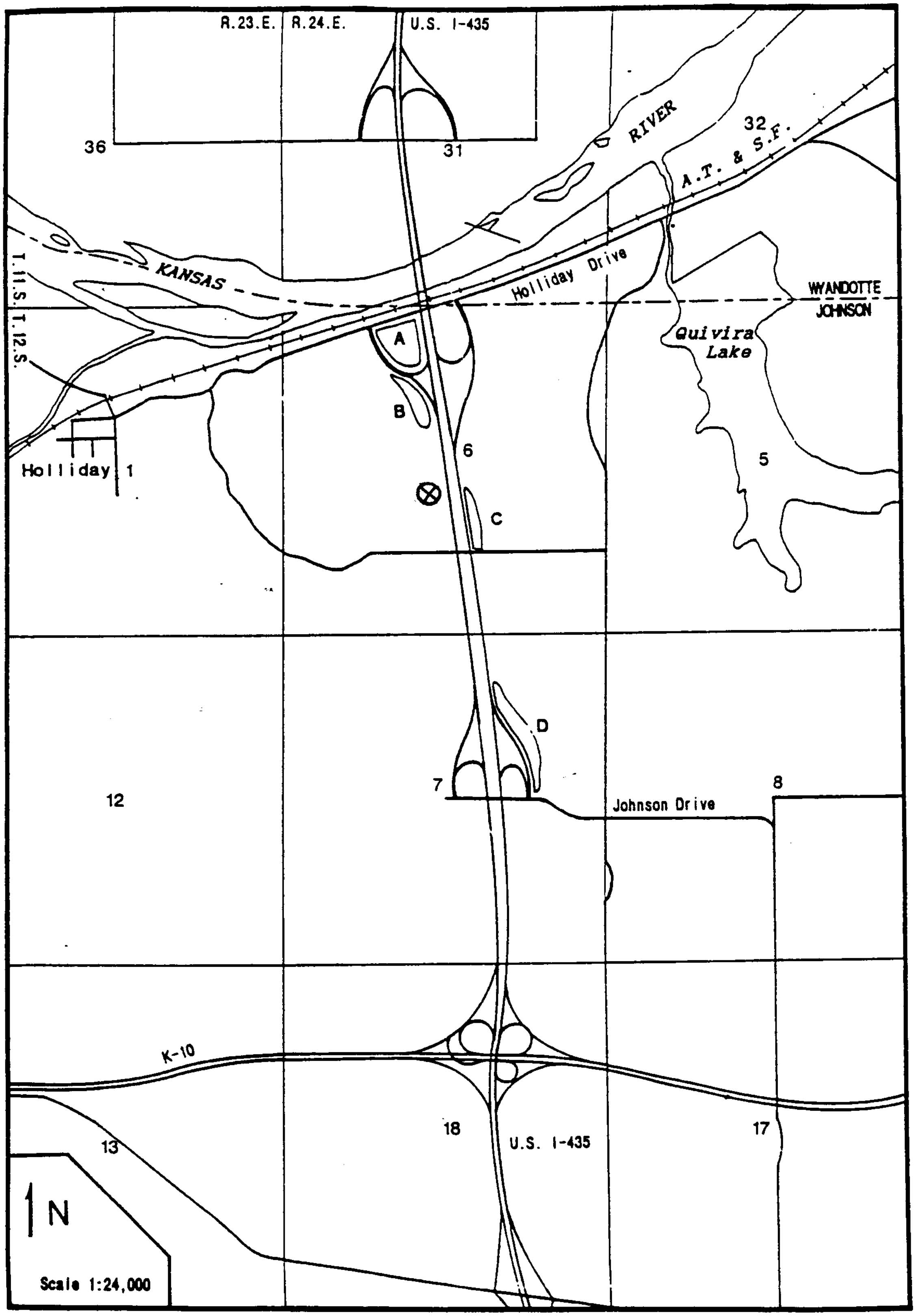


FIGURE 5-1 Location map of Stop 5 and sites A, B, C, and D used in preparing measured section provided this stop. (Fig. 5-2 from Johnsgard, 1984).

a

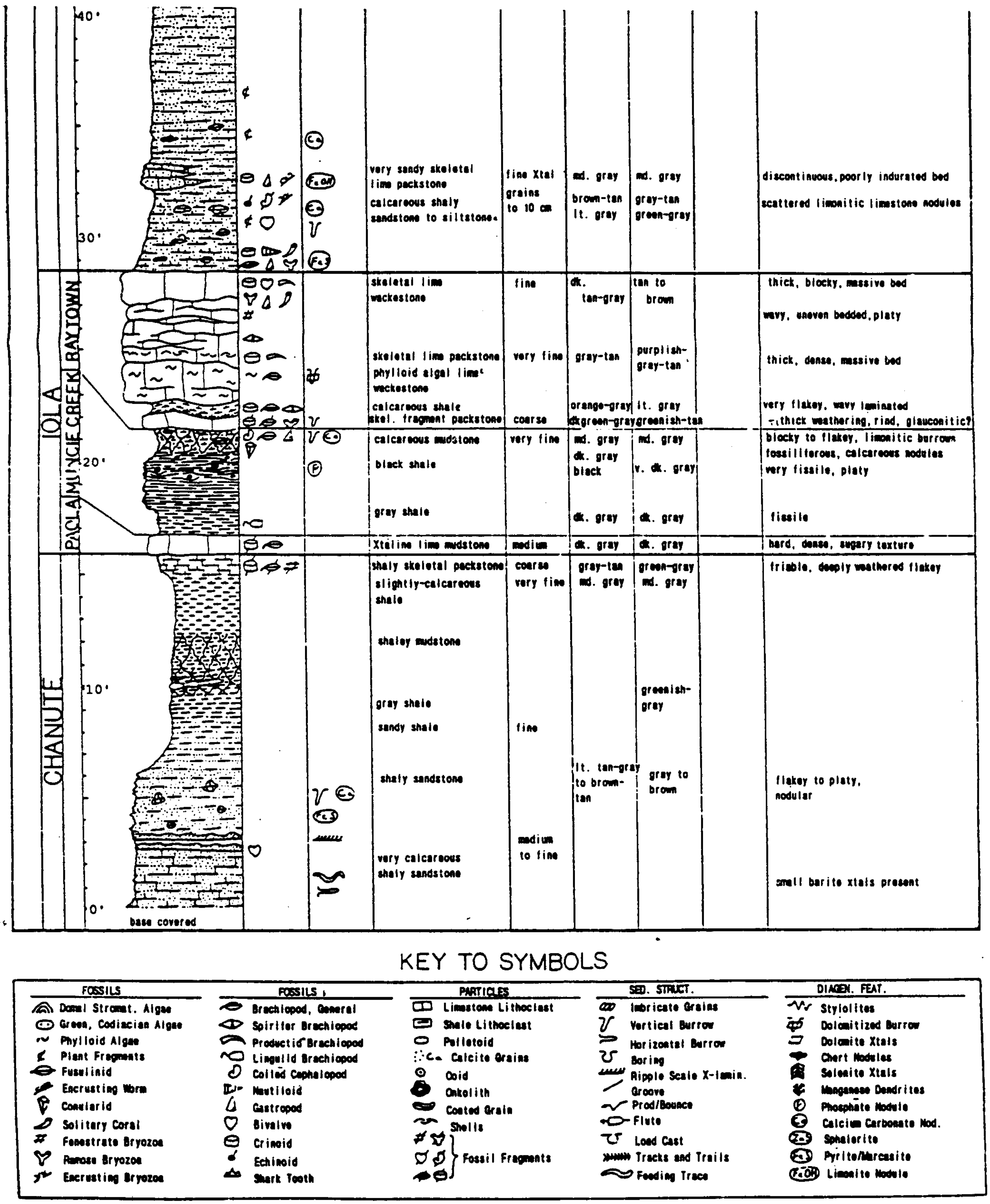
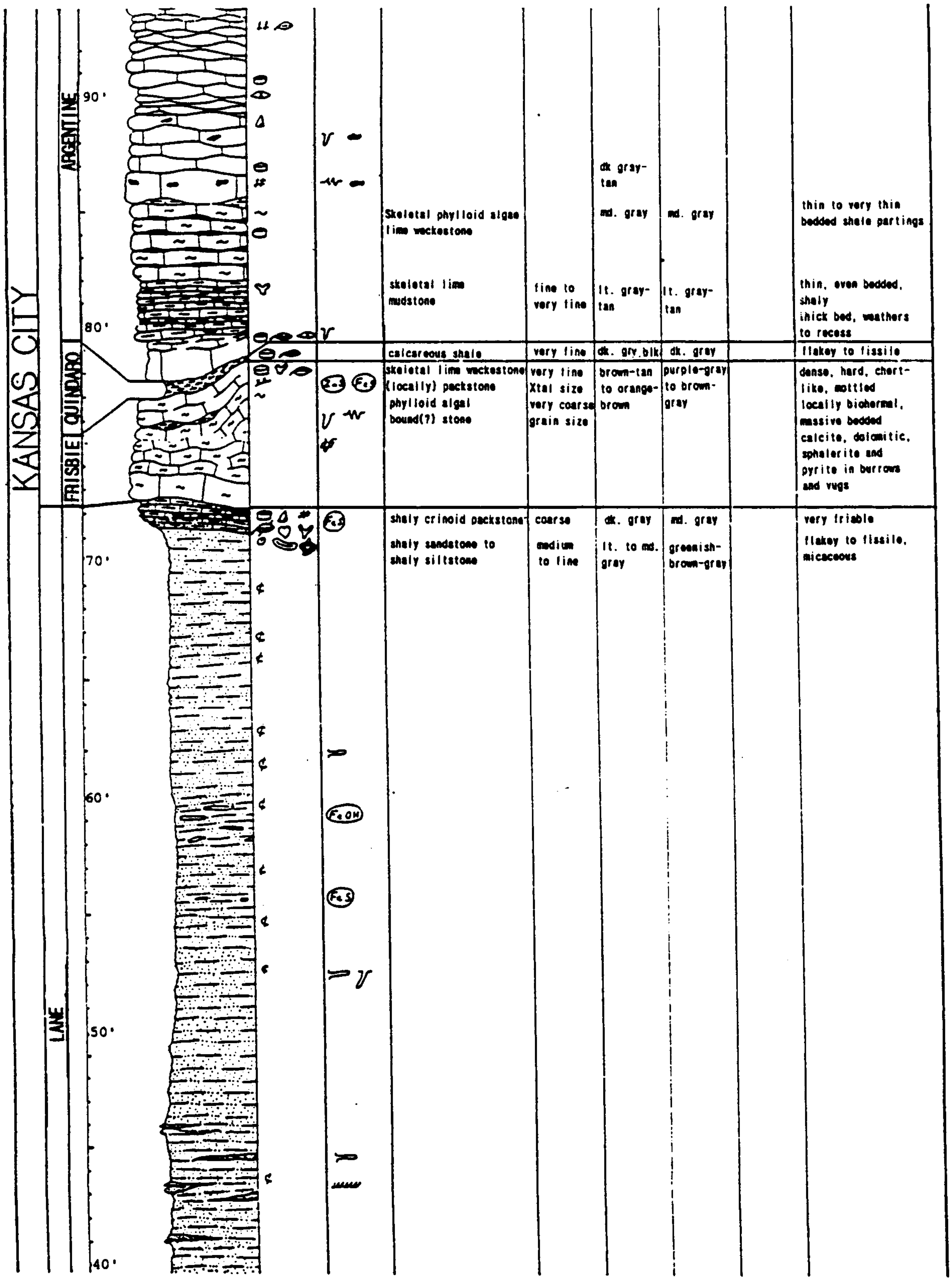
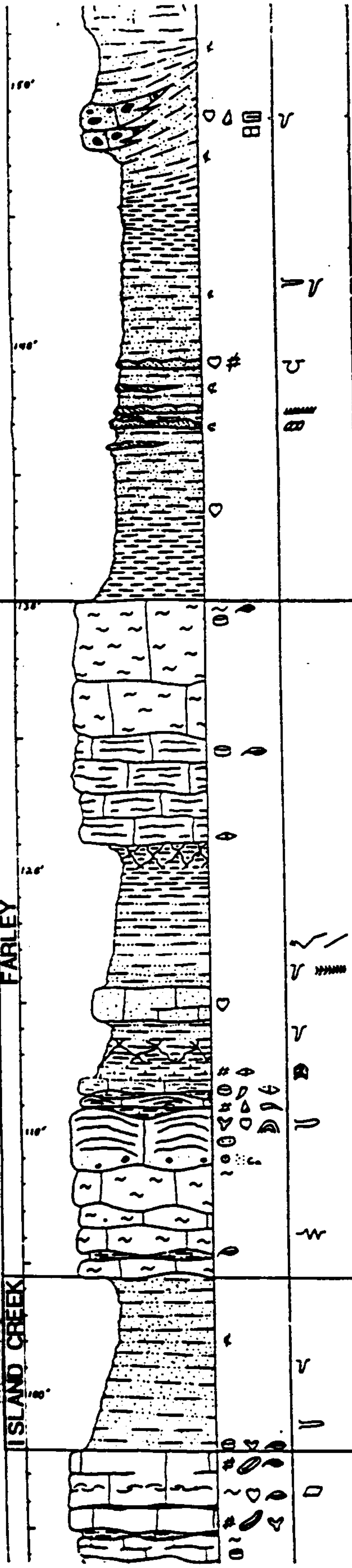


FIGURE 5-2 (A, B, C, D) Measured section of Lansing and Upper Kansas City groups at Johnson Drive and Holliday Drive interchanges prepared by Johnsgard (1984).

b

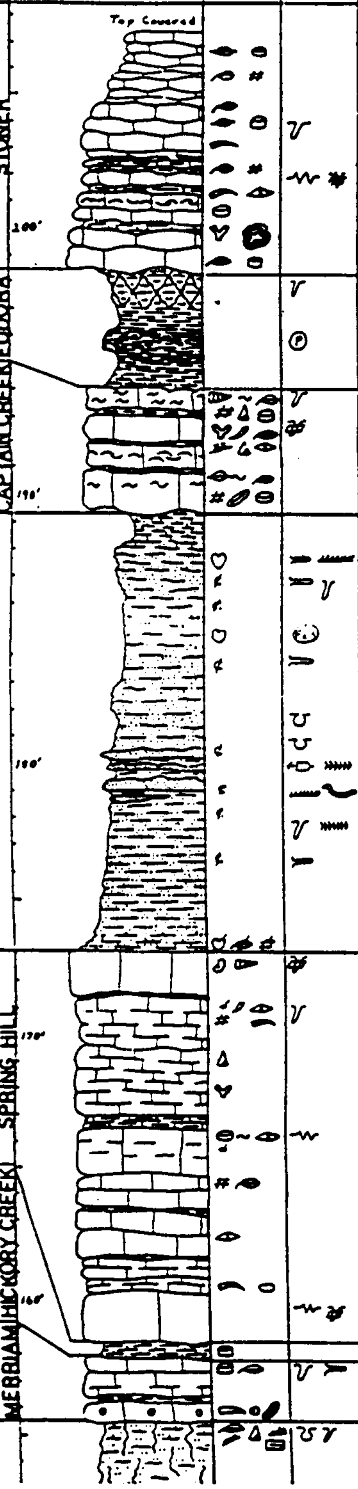

KANSAS CITY
ARGENTINE
FRISBIE
QUINDARO
LANE
90'
80'
70'
60'
50'
40'
dk gray-
tan
md. gray
md. gray
Skeletal phylloid algae
lime wackestone
thin to very thin
bedded shale partings
skeletal lime
mudstone
fine to
very fine
lt. gray-
tan
lt. gray-
tan
thin, even bedded,
shaly
thick bed, weathers
to recess
calcareous shale
very fine
dk. gry blk
dk. gray
flakey to fissile
skeletal lime wackestone
(locally) packstone
phylloid algal
bound(?) stone
very fine
Xtal size
very coarse
grain size
brown-tan
to orange-
brown
purple-gray
to brown-
gray
dense, hard, chert-
like, mottled
locally biohermal,
massive bedded
calcite, dolomitic,
sphalerite and
pyrite in burrows
and vugs
shaly crinoid packstone
coarse
dk. gray
md. gray
very friable
shaly sandstone to
shaly siltstone
medium
to fine
lt. to md.
gray
greenish-
brown-gray
flakey to fissile,
micaceous

C



Unit	Lithology	Grain size	Fresh color	Weathered color	Remarks
BONNER SPRINGS	shaly sandstone	fine	md. gray	pink-gray	platy to fissile
	sandy lithoclastic mollusc lime packstone	very coarse	md. brown	lt. gray	blocky, limonitic single channel(s) shaped bed
	shaly sandstone	fine	md. gray	md. gray to lt. gray	platy, fissile
	sandy shale	very fine			
	gray shale				
	shaly sandstone	fine			
	ripple laminated shaly sandstone	medium to coarse		lt. gray	very micaceous
	shaly sandstone	fine		md. gray	
	sandy shale gray shale	very fine			fissile, shaly
FARLEY	skeletal phylloid algae lime wackestone to packstone	very fine	gray-tan	pale pink-tan	thick bedded, massive
	stromatolitic(?) skeletal lime wackestone	fine	tan-gray	md. tan	vague laminations
	shaly mudstone gray shale	very fine	md. gray	md. gray	fissile, flakey
	shaly siltstone				platy, micaceous
	shaly sandstone	fine			
	lime mudstone	medium	gray-brown	pinkish-brown	single, persistent bed
	shaly sandstone	fine	md. gray	lt. gray	flakey to fissile
	shaly mudstone	very fine			
	calcareous shale	fine	dk. brown	lt. brown	wavy to nodular
	stromatolitic skeletal lime wackestone	medium	orange to tan-gray	orange-tan	bedded, domal stromatolitic(?) laminae
	phylloid algal lime mudstone	fine	pink-tan to gray	pale pink-gray	sparse ooids & calcite grains
WYANDOTTE ISLAND CREEK	shaly sandstone	very fine	lt. gray	lt. gray	flakey
	coated grain packstone	very fine Xtal size	tan-gray	brown-tan	3 even, distinct beds
	skeletal wackestone	very coarse grain size			shells w/calcite, dolomite Xtals
	coated grain packstone skeletal lime mudstone	very fine		gray-tan	wavy bedded, "clay seams" present

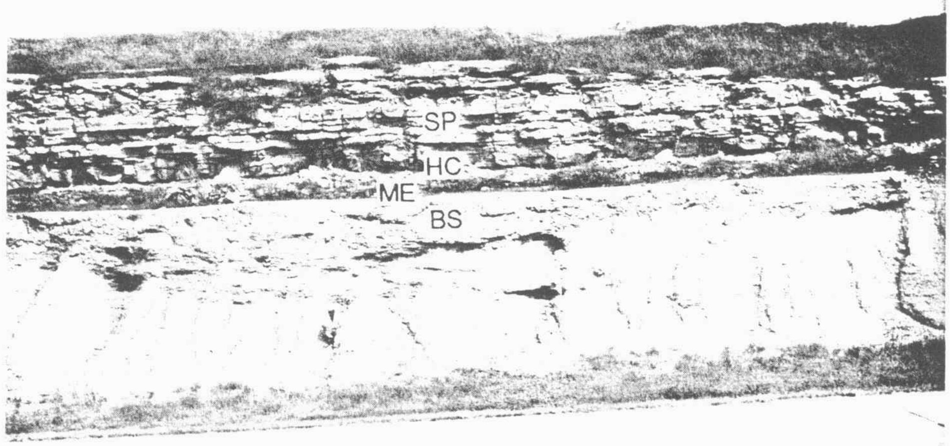
d



Group	Formation	Member	Rock name	Crystal or Grain Size	Color: Fresh	Color: Weathered	Sample and/or Photo #3	Additional Remarks
LANSING	STANTON	STONER	Skeletal lime wackestone	fine to medium	tan-gray	brown-tan to orange		slabby to platy
								iron stained, ferruginous very wavy bedded
			shaly lime wackestone					
					gray-tan	orange-tan		
		EUDORA	blocky mudstone	very fine	lt. gray-orange	orange-tan		blocky, mottled
			gray shale		dk. gray	md. gray		flakey to fissile
			black shale		black	dk. gray		platy, very fissile
			gray shale		gray-tan	lt. gray		
		CAPTAIN CREEK	skeletal lime wackestone	fine	brown-tan	brown-tan		
			skeletal lime mudstone	very fine				dense; 4 even, distinct beds
			skeletal coated grain lime wackestone	fine	lt. gray -tan	purple-tan		
	VILAS		calcareous shale	very fine	tan	tan		flakey, fissile
			wavy laminated shaly sandstone	medium to fine	lt. gray md. gray	md. to lt. gray		wavy laminated, bioturbated very micaceous, carbonaceous
			ripple laminated shaly sandstone	fine	lt. tan-gray	greenish-lt. gray		slabby, even bedded, platy N 85 degrees W (ripple marks)
			very sandy shale	very fine	lt. gray	v. lt. gray		platy, fissile, very micaceous
			sandy calcareous shale	fine	lt. brown	brown-tan		
	PLATTSBURG	SPRING HILL	mollusc lime wackestone	medium	lt. gray-tan	lt. brown		single, even bed
			very argillaceous lime wackestone		md. gray	orange-tan		thick bedded, massive to shaly weathers to many thinner beds "clay seams" abundant
			argillaceous skeletal lime wackestone	very fine medium	lt. brown lt. gray- md. gray lt. gray	lt. brown lt. tan-gray lt. tan-gray		thin, uneven beds thick bedded, "clay seams" present
			skeletal lime wackestone					
						md. gray		
					lt. brown md. gray	lt. brown md. gray-tan		uneven, wavy bedded
		HICKORY CREEK	calcareous shale	very fine	dk. gray	dk. gray		flakey
		MERRIAM	skeletal lime wackestone	fine	md. gray	lt. tan		
			oolitic skeletal lime wackestone	medium				
			calcareous siltstone	very fine	md. gray-brown	orange-brown		nodular, blocky, very limonitic
			shaly siltstone					
			sandy siltstone		lt. gray	lt. gray		flakey, micaceous

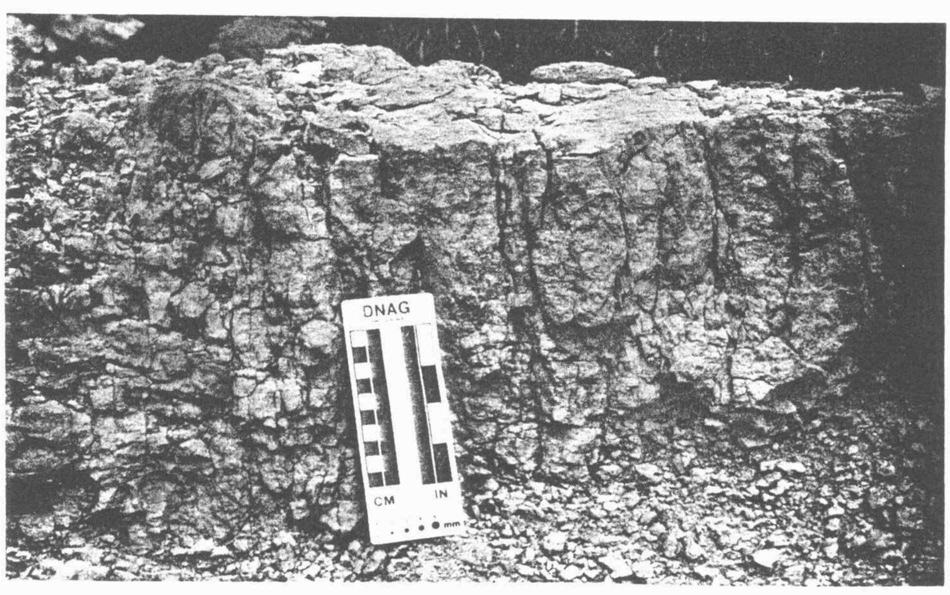
FIGURE 5-3

(A) West-facing exposure at Stop 5 (on highway median) showing BS, Bonner Springs Shale; ME, Merriam Limestone; HC, Hickory Creek Shale; SP, Spring Hill Limestone. Bonner Springs **Shale here is a typical section as** opposed to that seen at Stop 4. Paleosol is unusually thick in association with a lenticular sandstone located at the position of the letters, BS. Derek Herman provides a scale. (B and C) Paleosol developed near top of Bonner Springs Shale from west-facing slope in the highway median at Stop 5. Evan Franseen is taking a close-up photo of the paleosol shown in (C). Photo (C) shows ped surfaces, one of the diagnostic features of a soil.



A

B



C

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