

GUIDEBOOK

UPPER CRETACEOUS STRATIGRAPHY
AND DEPOSITIONAL ENVIRONMENTS OF WESTERN KANSAS



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by
Donald E. Hattin
Indiana University
and
Charles T. Siemers
Cities Service Company
Assisted by
Gary F. Stewart
Oklahoma State University

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Upper Cretaceous stratigraphy and depositional environments of western Kansas

by Donald E. Hattin and Charles T. Siemers

Introduction

Objectives of the trip

Upper Cretaceous rocks of western Kansas are a treasury of fossils that has excited paleontologists for more than a century and has lured generations of enthusiastic collectors to concretion-strewn shale slopes and chalk badlands that break the monotony of the Great Plains. For decades, authors of historical geology and paleontology textbooks have embellished their chapters on the Cretaceous with illustrations of the mosasaurs, pterosaurs, cephalopods, bivalves, crinoids, and plant remains that have earned the Kansas Cretaceous a place of enduring fame in the annals of American paleontology. From early research concerned primarily with fossil collection and description in the 1800s, the study of these rocks evolved during the first half of the 20th century to a stage of mapping and description of strata that has now given way to studies devoted largely to petrogenesis, paleoecology, and refinements in biostratigraphy.

This field excursion is designed to acquaint participants with strata representing selected marine and nonmarine depositional environments of the Upper Cretaceous section in western Kansas and to afford opportunity for observing representative suites of body and trace fossils from most rock units. To this end, a group of excellent exposures has been selected for examination of a complete section extending from the upper part of the Dakota Formation upward into the lower part of the Niobrara Chalk. Additional exposures represent the middle and upper parts of the Niobrara and lower part of the Pierre Shale. At each stop, discussion will center on critical aspects of lithostratigraphy, biostratigraphy, paleoecology, and general depositional history of the exposed units.

Historical account

Classification of Cretaceous strata in the Western Interior region was accomplished first by Hall and Meek (1856, p. 405), who divided the Missouri River section of Nebraska into units numbered (ascending) 1 through 5. Geographic names based on places of typical exposure were published subsequently by Meek and Hayden (1861, p. 419), whose comprehensive tabulation included lithologic and paleontologic descriptions and thicknesses for each of the five formations. Assigned names were as follows:

- Formation No. 5—Fox Hills
- Formation No. 4—Pierre
- Formation No. 3—Niobrara
- Formation No. 2—Fort Benton
- Formation No. 1—Dakota

Cretaceous rocks were mapped in Kansas as early as 1857 (Hayden), but detailed study proceeded slowly as evident in a remark by Swallow (1866, p. 10), in his first annual report as State Geologist of Kansas, that the "...Cretaceous is represented rather largely, but no definite examination has been made to show its extent, as it lies mostly beyond the settlements. Chalk is said to have been found in it."

During the early 1870s, four expeditions led by O. C. Marsh and one by E. D. Cope entered the rich fossil field of western Kansas for the purpose of collecting vertebrate remains. From this work sprang a great volume of literature on fish, reptiles, and birds of the Niobrara Chalk, and a new generation of vertebrate paleontologists.

In 1872, Hayden published one of the first detailed accounts of Cretaceous rocks in Kansas following a train trip on the Union Pacific railroad, which included the area between Salina and Fort Wallace. Although

Hayden recognized Formations No. 1, 2, and 3 in this work, Mudge (1875, p. 111) claimed that the Benton Group (No. 2) appeared to be absent in Kansas and stated further, "Hostile Indians and an uninviting country have kept explorers from traversing the southwestern plains." Shortly thereafter, Mudge (1878) not only recognized the presence of the Fort Benton but included in it the Fort Hays Limestone (now a member of the Niobrara Chalk). During this period Meek examined some Kansas baculitids that Mudge claimed were collected from the Niobrara. Meek suspected that the specimens came from Formation No. 4 or No. 5 (Pierre or Fox Hills)¹ but Mudge persisted in his belief that the baculitid beds in question were Niobrara. Ultimately, beds containing these baculitids were referred to the Pierre Shale by Williston (1893).

During the last decade of the 19th century, considerable attention was focused upon the classification and description of Cretaceous rocks in western Kansas. Some rock-unit names proposed during this time were synonyms and were discarded (e.g., Lisbon for Pierre; Osborne for Fort Hays); some were nongeographic in origin (e.g., Bituminous Shale horizon for Graneros; *Hesperornis* beds for part of the Smoky Hill); and some stand to this day (e.g., Blue Hill; Lincoln). In 1896, G. K. Gilbert divided the Benton into three formations (Graneros Shale, Greenhorn Limestone, and Carlile Shale) on the basis of exposures in the Rocky Mountains foothills of Colorado. Logan (1899) recognized equivalent units in the Kansas Benton, but Gilbert's names for these units were first used in the state by Darton (1904, pl. 36). Subdivision of formations and naming of member units in the Kansas Upper Cretaceous took place rather haphazardly; one formal name was established as early as 1876 (Fort Hays Limestone) and the latest appeared in 1942 (Janssen Clay Member of the Dakota Formation).

In 1897 and 1898, under the direction of Erasmus Haworth, State Geologic Survey work in western Kansas culminated with publication of several major reports on the stratigraphy and paleontology of the Upper Cretaceous

rocks. Through the years of the present century, shorter paleontological papers have appeared steadily and treat a broad spectrum of vertebrate, micro- and macroinvertebrate, and both marine and nonmarine paleobotanical subjects, too numerous to list here.

The next stage of investigation occurred in the mid-twenties and thirties when the State Geological Survey published a number of geological reports concerned with counties lying across the Cretaceous outcrop. Among these detailed reports, those for Russell County (Rubey and Bass, 1925) and Wallace County (Elias, 1931) are especially notable. In more recent years, from about 1940 to date, brief summaries of Upper Cretaceous stratigraphy have accompanied a number of county reports concerned with geology and ground-water conditions within the Cretaceous outcrop in Kansas. Detailed stratigraphic reports have been published for the Dakota Formation (Plummer and Romary, 1942), Carlile Shale (Hattin, 1962), Graneros Shale (Hattin, 1965a), Greenhorn Limestone (Hattin, 1975a), Fort Hays Member of the Niobrara Chalk (Frey, 1972), Sharon Springs Member of the Pierre Shale (Gill, Cobban, and Schultz, 1972), and Smoky Hill Member of the Niobrara Chalk (Hattin, 1982). Other aspects of Cretaceous geology that have received attention in recent years include subsurface stratigraphy (Merriam, 1957a; Merriam and others, 1959), cyclic sedimentation (Hattin, 1964; Franks, 1975), cross stratification (Franks and others, 1959), chalk diagenesis (Scholle, 1977), sedimentology (Hattin, 1971; Siemers, 1976), regional unconformities (Hattin, 1968, 1975b), and mineral commodities ranging from chalk to uranium.

Interest in Upper Cretaceous rocks of western Kansas shows little sign of decline, despite decades of study by a legion of investigators. New fossil species are still being discovered, and many invertebrate species and trace-fossil assemblages remain undescribed. Studies of depositional environment and paleoecology are incomplete and offer continued challenge to present and future students of these fascinating strata.

¹ These baculitids were collected at a locality near McAllaster, Kansas. STOP 8 of this guidebook is in the Pierre Shale at McAllaster.

Physiography

Smoky Hills

Cretaceous rocks of Kansas are confined to the Great Plains physiographic province which, in the part of the state described in this guidebook, is divided into two contrasting sections, the Smoky Hills to the east and the High Plains to the west (figure 1). The two sections are separated by a prominent escarpment, which is capped by the Fort Hays Limestone Member of the Niobrara Chalk. During most of the first day of the field trip, we will be traveling across the Smoky Hills and during the second day we will be in the High Plains.

The Smoky Hills (figure 1) are composed of rocks belonging mainly to the Dakota Formation and lower part of the Colorado Group (table 1). The eastern

half of the section is characterized by hilly topography developed on shale and sandstone units of Cretaceous rocks older than the Greenhorn Limestone. Prominent hills are held up by sandstone bodies within the stratigraphically complex Dakota Formation. The distinctive topographic aspect of this part of the section prompted Schoewe (1949) to restrict use of the name "Smoky Hills" thereto and to use the term "Blue Hills" for the western part of the section. Along the route of this excursion, the most conspicuous development of Smoky Hills (restricted) topography is in the vicinity of STOPS 1 to 3.

The western half of the Smoky Hills section is bounded on the east by an escarpment capped by Greenhorn Limestone and on the west by the much bolder Fort Hays escarpment. Both features are most prominent along

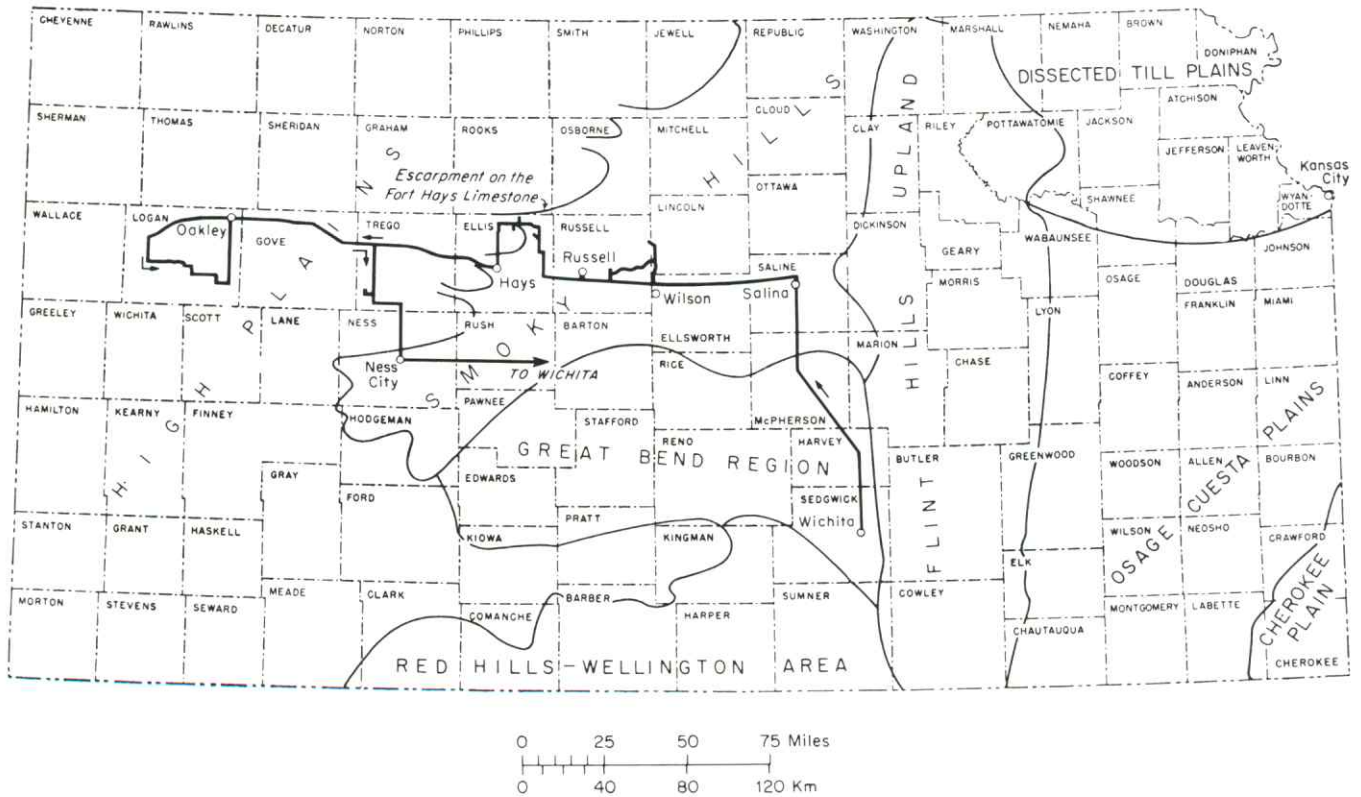


FIGURE 1—MAP SHOWING PHYSIOGRAPHIC DIVISION OF KANSAS (ADAPTED FROM FRYE, LEONARD, AND SCHOEWE, 1952); ROUTE OF FIELD TRIP IS INDICATED BY HEAVY LINE.

the Saline and Smoky Hill rivers and manifest progressively diminished relief away from these major stream courses. Upland topography is relatively flat where underlain by the upper part of the Greenhorn Limestone or lower part of the Carlile Shale, but toward the western edge of the Smoky Hills, steep slopes and local badlands are developed on younger parts of the Carlile in bluffs, buttes, and small mesas capped by the Fort Hays Limestone Member.

In the part of the Smoky Hills section that we will see, maximum relief is near 300 ft (91 m) along the Saline River and 150 ft (48 m) along the Smoky Hill River. Terraces underlain by Pleistocene alluvium are preserved along major stream courses and some tributaries but are more conspicuous in the valley of the Smoky Hill River. The upland surface is thinly veneered by Pleistocene loess.

High Plains

West of the Fort Hays escarpment, the High Plains section is underlain by Pierre Shale, Niobrara Chalk, Ogallala Formation, and various deposits of Pleistocene age (table 1). The uplands are, in general, monotonously flat owing largely to a widely distributed but discontinuous veneer of loess laid down during three episodes of eolian deposition that occurred during the Illinoian and Wisconsinan stages. Bedrock formations of Pliocene and Cretaceous age are exposed locally in the upland areas. Thousands of shallow depressions that dot the upland surface of the High Plains have been the subject of much discussion in the literature and have been attributed to the activity of buffaloes, wind, solution, compaction, and silt infiltration (Frye and Leonard, 1952, p. 203). In the western part of the region that we will cross during the second day, bedrock beneath the upland surface is largely that of the Ogallala Formation; farther east on the second-day route this formation is thin, patchy, or absent, and Niobrara beds form nearly all of the upland bedrock.

In the area of this trip, the High Plains surface is slashed by eastward- to southeastward-flowing streams of the Smoky Hill River drainage basin. The Smoky Hill River valley is 15 miles or more wide where it cuts into soft deposits of the Smoky Hill Chalk Member and Pierre Shale in Gove and Logan counties. The inner valley, including low-level, late Pleistocene terraces and Recent floodplain, ranges in width from 1/4 to 1 mi. In Logan and Gove counties, the outer parts of the valleys are characterized in many places by broad streamward-sloping, debris-veneered erosional surfaces that Frye and Leonard (1952, p. 27) called "flanking pediments." These surfaces are steepest at the valley edges, just below the upland margin, and downslope they flatten to near horizontality toward the inner valley, where they may merge with high-level terrace

deposits (Johnson, 1958; Hodson and Wahl, 1960, p. 13). Cretaceous rocks crop out in bluffs that separate these terrace deposits and the inner valley and also in areas where the outer valley slopes are not protected by flanking-pediment veneer. Exposures of the Smoky Hill Chalk Member are particularly susceptible to erosion by rain wash and streams, and in a number of places this unit has been carved into badlands with steep-walled canyons, natural bridges, and slender pinnacles. Where dissection of the upper parts of valley slopes has exposed lithified Ogallala beds that underlie the upland surface, that formation holds up steep cliffs.

During the afternoon of the second day, we will cross the eastern edge of the High Plains in an area where the Ogallala Formation has been stripped by erosion from all but the highest divides, where the unit remains as thin, discontinuous remnants nearly to the crest of the Fort Hays escarpment. Most of the area is underlain by the Smoky Hill, which is thinly veneered by Pleistocene loess. Upland areas underlain by Ogallala deposits are generally flatter than those underlain by Cretaceous rocks.

Development of present topography

Following final retreat of the Western Interior Sea, Cretaceous rocks in western Kansas were truncated during an erosional interval that produced, just prior to inception of Miocene-Pliocene deposition, broad plains of low relief across which drainage was generally eastward in the field-trip area (Johnson, 1958, p. 28; Frye and Leonard, 1952, p. 185). Major uplift in the Rocky Mountains region brought a flood of detritus that filled valleys and buried divides beneath a complex of coalescent alluvial plains; these deposits leveled the existing topography and formed the monotonous topography that remains little modified in undissected areas of the High Plains.

In the field-trip area, Pleistocene erosion and alluviation along the Smoky Hill River resulted in formation of terrace deposits at three major levels. The following summary of Pleistocene events in the area of the field trip is drawn from the work of Frye and Leonard (1952), Leonard and Berry (1961), and Bayne and Fent (1963).

Moderate initial dissection of the High Plains occurred during the Pleistocene Nebraskan Stage, during which time the streams deposited alluvium now preserved as a terrace remnant lying as much as 140 ft (46 m) below Pliocene deposits in the Smoky Hills of Russell and Ellis counties. Deep downcutting during Kansan time resulted in alluviation along channels now preserved beneath Illinoian sediments on a surface known as the Pfeifer

Terrace, which lies 30-40 ft (9.2-12.2 m) above the present floodplain in eastern Trego and western Ellis counties. This terrace has been traced from Ellsworth County, in the Smoky Hills, to as far west as Logan County in the High Plains. East of central Ellis County, the Kansan deposits occur as a separate terrace and lie topographically above Illinoian terrace deposits. Kansan deposits occur also along the Saline River valley in Ellis, Russell, and Lincoln counties. Valley broadening in Illinoian time is reflected in widespread sand, gravel, and silt deposits that form the surface of the Pfeifer Terrace. Remnants of a terrace of the same age are preserved along the Saline River valley to the north. Until Illinoian time, water of the Saline and Smoky Hill rivers in the field-trip area drained southeastwardly from the area, not into the Kansas River as at present. Headward erosion of the latter stream captured

the upper reaches of the southeastwardly draining system, and the Saline and Smoky Hill rivers became integrated as a part of the Kansas River drainage basin. Renewed downcutting and alluviation during the Wisconsin Stage produced low river terraces that are situated below the Illinoian terrace and lie only a few feet above the modern floodplain. Post-Wisconsin changes include cutting the present river channels into Wisconsin deposits or Cretaceous bedrock and development of the narrow floodplain.

Widespread deposition of loess during the Illinoian and Wisconsin stages has irregularly veneered the uplands, flanking pediments along stream courses, and older terraces, thus masking the relationships among these features in some areas and contributing to the extreme flatness of the High Plains surface.

Structure

Structural dip at the top of the Dakota Formation is approximately 7 ft (2.1 m) per mile to the northeast in the easternmost portion of the field-trip area, increasing westward in Ellis and Trego counties to approximately 10 ft (3.1 m) per mile to the north or slightly east of north. Still farther to the west, in Gove County, the dip is approximately 13 ft (4 m) per mile to the north and increases further to approximately 20 ft (6 m) per mile to the northeast in Logan County (see Merriam, 1957b). Major structural features reflected at this datum in western Kansas include, from east to west, the Salina basin, Cambridge arch, Western Kansas basin, and the eastern flank of the Las Animas arch (figure 2). According to Merriam (1963), the Salina basin and Cambridge arch are largely inherited from an earlier structural framework, the Western Kansas basin is a Mesozoic feature, and the Las Animas arch in Kansas is largely a post-Cretaceous feature. The Cambridge arch lies outside the area of this field excursion. Paleozoic structures in the area that are not reflected at the top of the Dakota include the Central Kansas uplift, which underlies our route in Ellsworth, Russell, Ellis, and Trego counties, and the Hugoton embayment, which embraces all of Kansas west of the Cambridge arch and Central Kansas uplift (Merriam, 1963, p. 178).

Named minor structures expressed in Cretaceous rocks in the field-trip area include the asymmetrical Fairport-Natoma anticline in northeastern Ellis County; the Pfeifer anticline of southeastern Ellis County, aligned with the Fairport-Natoma structure; Alanthus dome in southeastern Gove County; the domelike Hell Creek structure in southern Gove, southeastern Logan, and northeastern Scott counties; Elkader dome in southeastern Logan County;

Chalk Creek dome in southern Logan County; and Twin Buttes anticline in southwestern Logan County (Lupton and others, 1922; Jewett, 1951). Merriam (1963) also included the Ellsworth-Kanopolis anticline of northwestern Ellsworth County among minor structures reflected in Cretaceous rocks. The regional dip of the Cretaceous is further modified by numerous unnamed minor anticlines, synclines, and other structures that have been described by Lupton and others (1922), Rubey and Bass (1925), Bass (1926), Elias (1931), and Johnson (1958).

On a smaller scale, hundreds of normal faults that are best expressed in the Niobrara Chalk occur also in the Carlile and Pierre shales. In a small area of northwestern Ellis County, Bass (1926, p. 44) mapped 76 faults, nearly all of which are in the Smoky Hill Chalk Member. Maximum displacement observed by Bass is 80 ft (24.4 m), and the greatest length of trace among these faults is less than half a mile (1 km). Johnson (1958, p. 30) believed that displacement along similar faults in Logan County might exceed 200 ft (60 m) and mapped the trace of one fault, or closely spaced set of faults, that is nearly 3 1/2 mi (5.6 km) in length. The Pierre Shale lies in fault contact with the Niobrara Chalk in a number of areas in Logan and Gove counties. Most of the faults in the field-trip area have dips of $45^\circ \pm 10^\circ$, although some are nearly vertical, and are marked by coarsely crystalline masses of slickensided calcite that may be as much as 4-8 inches (10-20 cm) in thickness; however, brecciation has occurred along some fault planes. Dip on beds directly adjacent to such faults was found to be as high as 15° by Johnson (1958, p. 30) and 19° by Bass (1926, p. 45). These faults are not believed to be related to regional structure.

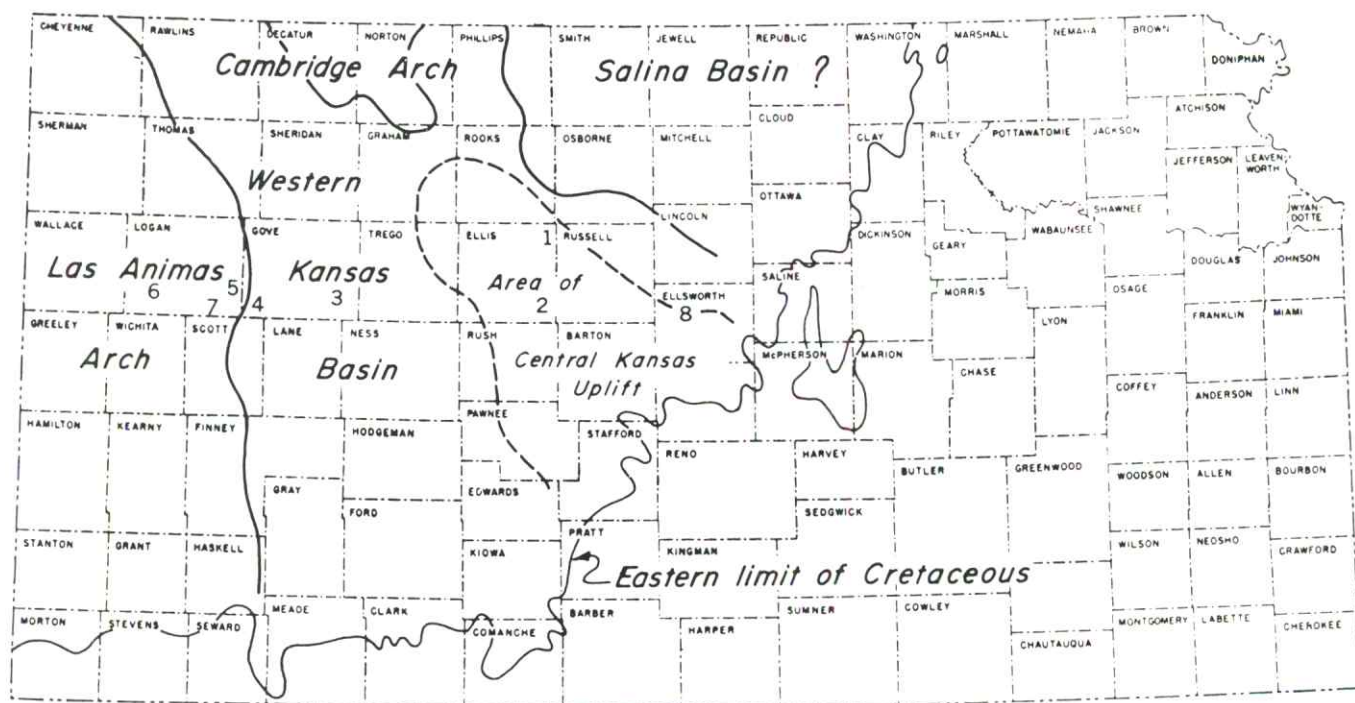


FIGURE 2—MAJOR STRUCTURAL FEATURES REFLECTED IN CRETACEOUS ROCKS IN THE FIELD-TRIP AREA. NAMED MINOR STRUCTURES ARE: 1) FAIRPORT-NATOMA ANTICLINE, 2) PFEIFER ANTICLINE, 3) ALANTHUS DOME, 4) HELL CREEK ANTICLINE, 5) ELKADER DOME, 6) TWIN BUTTES ANTICLINE, 7) CHALK CREEK DOME, 8) ELLSWORTH-KANOPOLIS ANTICLINE. ADAPTED FROM MERRIAM (1963).

In contrast to Cretaceous rocks, the Miocene/Pliocene Ogallala Formation is deformed only locally (Elias, 1931). Structure at the top of the “algal limestone” marking the top of the formation is characterized by “monotonously uniform east dip, which reflects none of

the major structural features in western Kansas” and averages approximately 15 ft (4.6 m) per mile between the Colorado state line and Mitchell and Lincoln counties (Merriam, 1963, p. 197).

General stratigraphy

Classification and characteristics of stratigraphic units that crop out in the field-trip area are summarized in table 1. Along the valley of the Smoky Hill River and its western tributaries, exposed Upper Cretaceous marine rocks reach an aggregate thickness of approximately 1,670 ft (590 m). Of this thickness, about 600 ft (183 m) are dark-gray noncalcareous shale belonging to the incompletely exposed Pierre Shale. The Colorado Group (Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Chalk) is approximately 1,060 ft (324 m) thick, of which 80% is limestone and chalk, 18.8% is dark-gray noncalcareous shale, 0.5% is quartzose sandstone and siltstone, and approximately 0.7% is bentonite. Sandstone locally comprising the uppermost 5 ft (1.5 m) of the Dakota Formation is probably also of marine origin. Along the Saline River valley, the Colorado Group is approximately 995 ft (303 m) thick, of which 74.5% is limestone and chalk, 21.6% is noncalcareous shale, a

maximum of 3.1% is sandstone and siltstone, and approximately 0.8% is bentonite. In addition, at least 30 ft (9.2 m) of sandstone and shale in the upper part of the Dakota Formation are locally of marine origin.

Cretaceous strata were truncated regionally by pre-Miocene erosion, then buried beneath Ogallala deposits which, at one place or another in the state, rest directly on every one of the Cretaceous formations. Pleistocene and Recent deposits rest on Cretaceous rocks in many places, especially along the valleys of larger streams where post-Pliocene erosion removed the widespread mantle of Ogallala sediments.

Common macroinvertebrate fossils in Upper Cretaceous marine units of western Kansas are illustrated in figures 5-7, 10, and 11.

TABLE 1--STRATIGRAPHIC UNITS IN FIELD-TRIP AREA.
(following two pages)

TABLE 1--STRATIGRAPHIC UNITS IN FIELD-TRIP AREA.

SYSTEM	SERIES	STAGE	FORMATION	MEMBER	THICKNESS (METERS)	LITHOLOGY	TOPOGRAPHIC EXPRESSION
NEOGENE	PLEISTOCENE	Recent	Alluvium		0-21.4	Silt, sand, gravel	Present channel and flood plain; surface of lowest terrace.
		Wisconsinan	a. Low terrace well deposits (Brady Soil) b. Big-terrace well (Brady Soil) c. Peoria		a. 0-30.5	Silt, sand, gravel	Low terrace lying approximately 4.6 to 6.1 m above Smoky Hill and Saline Rivers.
					b. 0-8.2	Loess	Thin mantle on upland
					c. 0-15.3	Loess	Thin mantle on upland
		Illinoisan	(Sangamon Soil) Loveland			Loess; laminated sand and silt	Thin mantle on upland grading laterally into stream-laid deposits in upper part of Kansan-Illinoisan high-terrace complex.
			Crete		0-19.8	Sand and gravel	Widely distributed in dissected Kansan-Illinoisan high-terrace complex.
		Kansan	Sappa		0-13.7	Silt and sandy silt with lenses of sand, gravel, and volcanic ash (Pearlette ash bed)	Channel deposits truncated by overlying Illinoisan deposits in high-terrace complex.
			Grand Island		0-10.7	Sand and gravel	Basal part of channel deposit underlying the high-terrace complex.
		Nebraskan	Holdrege Fullerton		0-12	Gravel, sand, silt, clay	Channel deposits lying high on valley walls or on divides between major streams in Ellsworth, Russell and Ellis counties.
			Ogallala		0-69	Chiefly sand, with clay, silt, and gravel; in part lime-cemented to form "Mortar beds," in part cemented with silica to form "quartzite." Also contains some chert, bentonitic clay, volcanic ash, and limestone.	Loess-mantled cap rock of upland surface of High Plains. Outlying remnants cap divides in highly dissected areas. Exposed in steep bluffs and cliffs at upland margin along larger stream courses.
CRETACEOUS	GULFIAN	CAMPAIAN	Pierre Shale	Neokan Shale	52	Dark-gray shale with clay-ironstone and limestone concretions, phosphate nodules, and bentonite.	Canyons and slopes in valleys of larger streams; local badlands.
				Sharon Springs Shale	47	Dark-gray shale, organic-rich in upper part, with phosphate nodules, limestone concretions, calcareous septarian concretions, and many thin seams of bentonite.	Canyons and slopes in valleys of larger streams; commonly forms badlands.
		CONIACIAN-SANTONIAN	Niobrara Chalk	Smoky Hill Chalk	171-189	Olive-gray shaly chalk mostly weathering grayish orange and yellowish gray; many thin seams of bentonite. Where intensely weathered lacks shaly structure and forms resistant cap rock.	Canyons and badlands along valley walls of larger streams and small tributaries. Many rock pinnacles and monuments.
				Fort Hays Limestone	17-23	Light-olive-gray chalky limestone, mostly weathering pale grayish orange, yellowish gray, or nearly white.	Cliffs along valley walls of large streams. Cap rock on buttes, mesas, and low bluffs.

TABLE 1 (continued)

CRETACEOUS	GULFIAN	TURONIAN	Carlile Shale	Codell Sandstone	0-9.5	Light-olive-gray quartzose sandstone and siltstone, commonly streaked with shale, locally calcareous.	Lower part of cliffs held up by Fort Hays Member. Locally absent or too thin to be expressed physiographically.
				Blue Hill Shale	51.2-56.4	Dark-gray shale, very silty near top, with numerous zones of calcareous concretions and one or two zones of clay-ironstone concretions.	Gullied lower slopes of Fort Hays Escarpment; slopes of buttes and mesas capped by outliers of Fort Hays Member.
				Fairport Chalk	27.5-36	Olive-gray laminated shaly chalk with numerous beds of chalky limestone and marly chalk, and seams of bentonite. Lower part generally weathered yellowish gray to grayish orange.	Lower part typically underlies upland plain in western part of Smoky Hills. Along larger stream courses, especially near the Fort Hays Escarpment, member forms steep slopes and precipitous cutbanks. Local badlands.
		Greenhorn Limestone	Pfeifer Shale	6.4	Olive-gray to olive-black shaly chalk and chalky, commonly nodular or concretionary limestone; generally weathered yellowish gray to pale grayish orange.	Steep slopes, and locally cliffs, along valleys of larger streams.	
			Jetmore Chalk	6.1-6.4	Olive-gray to olive-black shaly chalk and chalky limestone, the latter commonly weathered yellowish gray to pale grayish orange.	Cliffs and steep bluffs along courses of larger streams.	
			Hartland Shale	8.8-10.7	Olive-gray to olive-black shaly chalk with scattered beds of chalk and chalky limestone and several conspicuous beds of bentonite.	Upper part: steep slopes below cliffs and bluffs held up by Jetmore Member. Lower part: gentle slopes, poorly exposed.	
	Lincoln Limestone		6.4-7.6	Olive-black shaly chalk, light-olive-gray to olive-gray chalk or chalky limestone, pale-yellowish-brown skeletal limestone and numerous seams of bentonite. Basal bed commonly conglomeratic.	Upper part: gentle slopes, poorly exposed. Lower part: cutbanks and cliffs along courses of large and some small streams.		
	GEMMANIAN	Graneros Shale	7.6-11	Dark-gray shale, quartzose sandstone, skeletal limestone, with a 0.3-m-thick bentonite bed near top.	Gentle grass-covered slopes. Best exposed in cutbanks along courses of larger streams.		
		Dakota Formation	Janssen Clay	about 15.3	Dark-gray silty carbonaceous shale, quartzose sandstone and siltstone, lignite, and mudstone.	Steep grass-covered but commonly gullied slopes, low bluffs, local badlands.	

Descriptions of Cretaceous units in field-trip area

Dakota Formation

The Dakota Formation is 200-300 ft (60-90 m) thick in the western half of Kansas and crops out extensively in the central and north-central part of the state; however, only the upper 100-150 ft (30-46 m) of the Dakota is exposed along the field-trip route. Although Dakota rocks are composed predominantly of nonmarine, variegated mudstones and channel-sandstone lenses, sedimentary deposits within the upper 30-40 ft (9.2-12.2 m) exposed in Russell County represent a transition from the nonmarine deposits below to the shallow-water marine deposits of the Graneros Shale above. These transitional deposits record deposition in an environmentally diverse, deltaic and marginal-marine setting during initial stages of the transgressive phase of the Greenhorn marine cycle (figure 3).

Several major facies of the upper part of the Dakota have been delineated by Hattin (1965b) and Siemers (1971, 1976). The six major facies of Siemers (1971) are 1) variegated nonmarine mudstones with thin siltstone and sandstone lenses, 2) crossbedded, elongate, trough-shaped fluvial sandstone bodies, 3) flat-bedded, elongate, tabular-shaped sandstone bodies, 4) lignite-bearing deposits, 5) sideritic clay-ironstone-bearing deposits, and 6) thin bioturbated and fossiliferous marine sandstone and shale beds near the top of the formation. The general relationships of some of the facies (which will be examined during the field trip) are illustrated in figure 4.

The major features of these facies and their interpretation are as follows:

Facies 1—Variegated mudstones with thin siltstone and sandstone lenses. The main lithologies of this facies are: a) blocky, kaolinitic mudstone and clay-

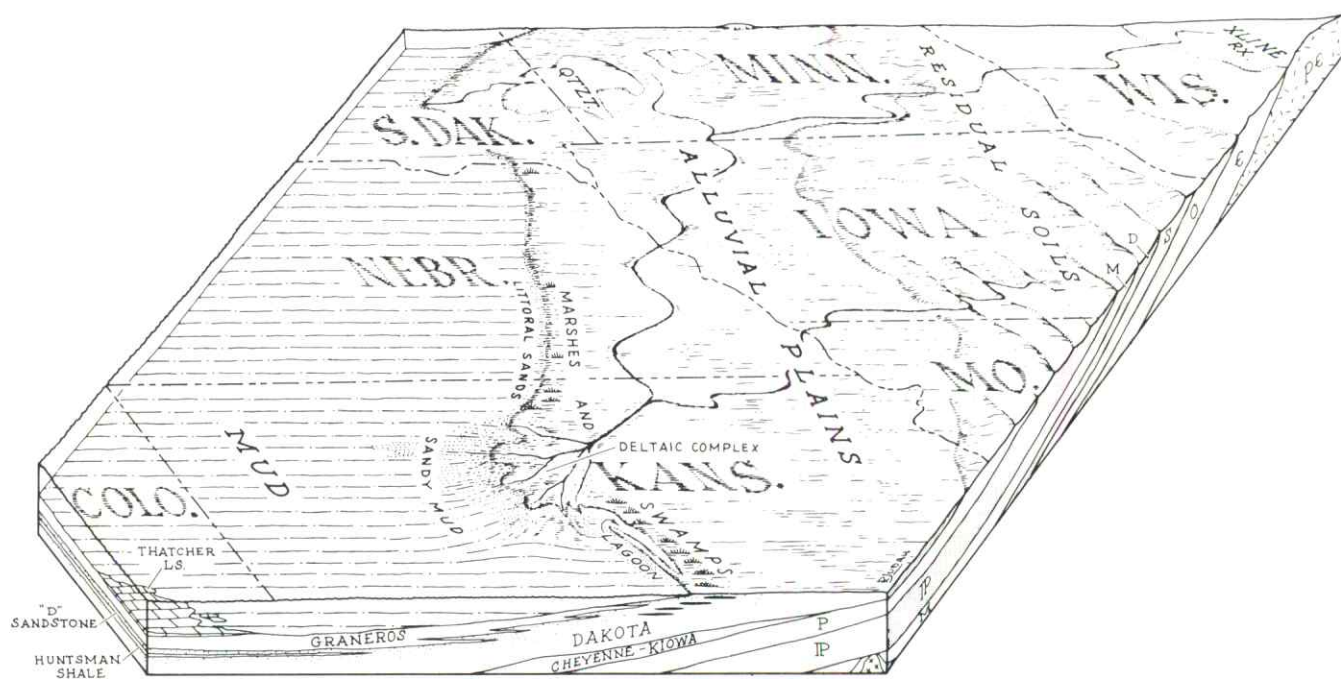


FIGURE 3—PALEOGEOGRAPHIC RECONSTRUCTION REPRESENTING CENTRAL KANSAS AND ADJACENT AREAS DURING DEPOSITION OF THE UPPER PART OF THE DAKOTA FORMATION AND LOWER PART OF THE GRANEROS SHALE (FROM HATTIN, 1967, P. 587).

stone, b) carbonaceous, blocky to shaly mudstone and claystone, and c) laminated clayey siltstone and thin lenses of laminated to cross-laminated sandstone. The mudstones and claystones are light greenish gray with yellowish to reddish-, greenish-, and brownish-colored mottles, probably resulting from the oxidation of siderite spherulites. The carbonaceous shaly beds form distinct dark-gray beds in many exposures. Chief fossils are plant remains, mainly leaves of deciduous trees. Terrigenous concretionary structures called "rhizocretions," which form around the roots and trunks of woody plants, are present locally. Burrow structures are conspicuously absent; only a single *Planolites*-like burrow was observed in this facies. The facies represents fluvial overbank deposits including probable shallow lacustrine and ephemeral-swamp deposition.

Facies 2—Crossbedded, elongate, trough-shaped fluvial sandstone bodies. These sandstones, along with those of Facies 3, have been discussed at length by Siemers (1976). The friable, yellowish-gray to orange-colored, trough crossbedded sandstone is very well sorted and fine grained. Strongly unimodal paleocurrent patterns are characteristic. Body fossils and trace fossils are conspicuous by their absence; plant debris is common but generally abraded and oxidized. Sandstone bodies are sinuous, elongate, broadly trough-shaped bodies as much as 59-72 ft (18-22 m) thick and 980-1,970 ft (300-600 m) wide, and at least one sandstone body (the Rocktown channel sandstone) has been mapped over a distance of nearly 30 mi (50 km). These sands are underlain by or pass laterally into the variegated mudstones of Facies 1 and usually are overlain by the flat-bedded sandstone of Facies 3. This sandstone facies represents active fill of fluvial channels; locally, the upper channel fill is fine-grained carbonaceous sediment representing abandoned inactive-channel fill.

Facies 3—Flat-bedded, elongate, tabular-shaped sandstone bodies. The laminated and ripple-bedded, very fine grained, well-sorted sandstones of this facies occur in units which cap the channel sandstones of Facies 2 and extend laterally to overlie mudstones of Facies 1 and in some areas rocks of Facies 4 and 5. Sandstone bodies are 20-30 ft (6-9 m) thick and 2,950-4,920 ft (900-1,500 m) wide. Paleocurrent patterns are bimodal to polymodal. Trace fossils are common and include *Planolites*, *Skolithos*, *Arenicolites*, and *Chondrites*. A brackish-water macroinvertebrate association dominated by *Corbicula* sp. and *Serpula* sp. was collected from these sandstones. This facies appears to represent late-stage sand deposition in delta distributaries and deposition of reworked sands during the Graneros transgression (figure 3).

Facies 4—Lignite-bearing deposits. Lithologies of this facies include matted ash-rich lignite seams interbedded with carbonaceous shales and thin discontinuous laminated beds of very fine grained sandstone, which

contains numerous vertical to subvertical reed molds. This facies generally overlies mudstones of Facies 1 and grades upward into the Graneros Shale. Fossils are scarce but include arenaceous foraminifera (Hattin, 1965a, b) in addition to the abundant plant debris and upright reed molds in the sandstone and siltstone beds. Siemers (1971) interprets this facies as the deposits of fresh to brackish-water swamps in a fluviodeltaic setting, whereas Hattin (1965b, 1977) suggests that these beds represent deposition in lagoons and adjacent marshes near the seaward margin of a coastal delta or along a nearby linear clastic shoreline.

Facies 5—Sideritic, clay-ironstone-bearing deposits. The main lithologies of this facies are: a) iron-stained olive-gray to olive-black sandy shale, b) bioturbated ferruginous siderite-cemented sandstone beds, and c) burrowed thin sideritic clay-ironstone seams and concretionary layers. Rocks of this facies occur in broad lenslike to sheetlike bodies that overlie variegated mudstones of Facies 1 or flat-bedded sandstones of Facies 3 and grade upward into the Graneros Shale. Laterally, the clay-ironstone facies appears to be adjacent mainly to Facies 3 sandstone units. Internally, the facies varies slightly in the abundance of siderite bands and in the type and abundance of body fossils and trace fossils. Where thin siderite seams are abundant, they contain burrow structures such as *Planolites*, *Polyupsilon*, *Arenicolites*, and *Rhizocorallium*, and macroinvertebrates are mainly the marginal-marine mussel *Brachidontes arlingtonanus* Stephenson, oyster *Ostrea* sp., and annelid *Serpula* sp. Where bioturbated ferruginous-sandstone beds are the main lithology, trace fossils are mainly *Planolites*, *Thalassinoides*, and *Teichichnus*, and the macroinvertebrates are represented by a more fully marine association including the mussel *Brachidontes* (mainly *B. filisculptus microcostae* Stephenson), oyster *Crassostrea soleniscus* (Meek), and several bivalves, including species of *Breviarca*, *Cymbophora*, *Geltena*, *Laternula*, *Parmicorbula*, *Tellina*, and *Volsella*. This facies appears to represent a range of depositional environments from brackish-water interdistributary bay to marginal-marine near-shore areas affected by nearby deltaic sedimentation.

Facies 6—Thin beds of bioturbated and fossiliferous sandstone and shale. These moderately well-sorted, fine- to very fine grained sandstones are laminated to ripple bedded and may contain abundant marine macroinvertebrate fossils and numerous trace-fossil taxa. The sandy shales are relatively more abundant than in Facies 3. The facies occurs between underlying nonmarine and marginal-marine strata and overlying marine strata of the Graneros Shale. Trace fossils include *Ophiomorpha*, *Thalassinoides*, *Skolithos*, *Planolites*, *Chondrites*, *Arenicolites*, and *Polyupsilon*, and the marine macroinvertebrate association, including the mussel *Brachidontes*, oyster *Crassostrea*, and numerous bivalves (see list for Facies 5

above), is well represented. These sands and shales represent near-shore-marine to shallow-marine environments.

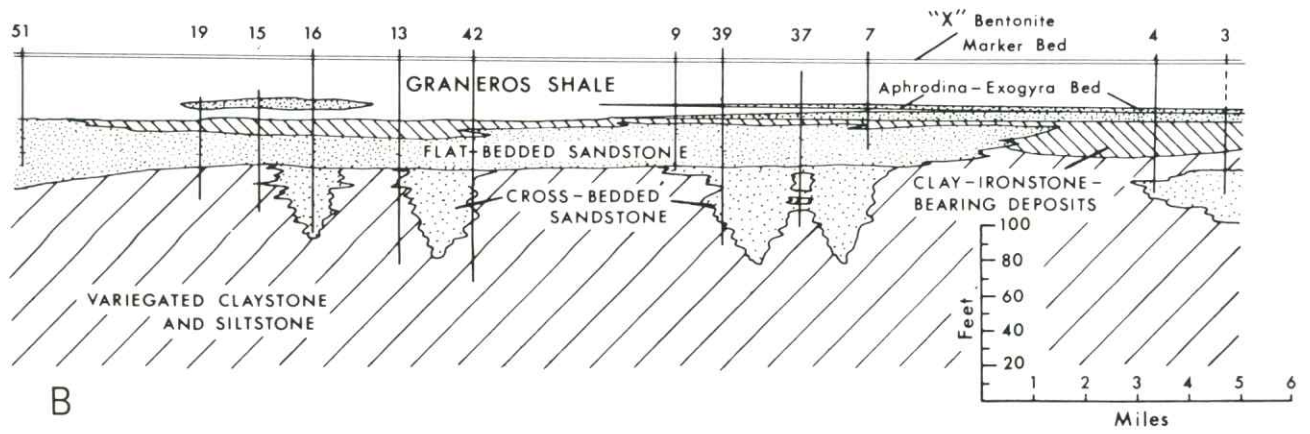
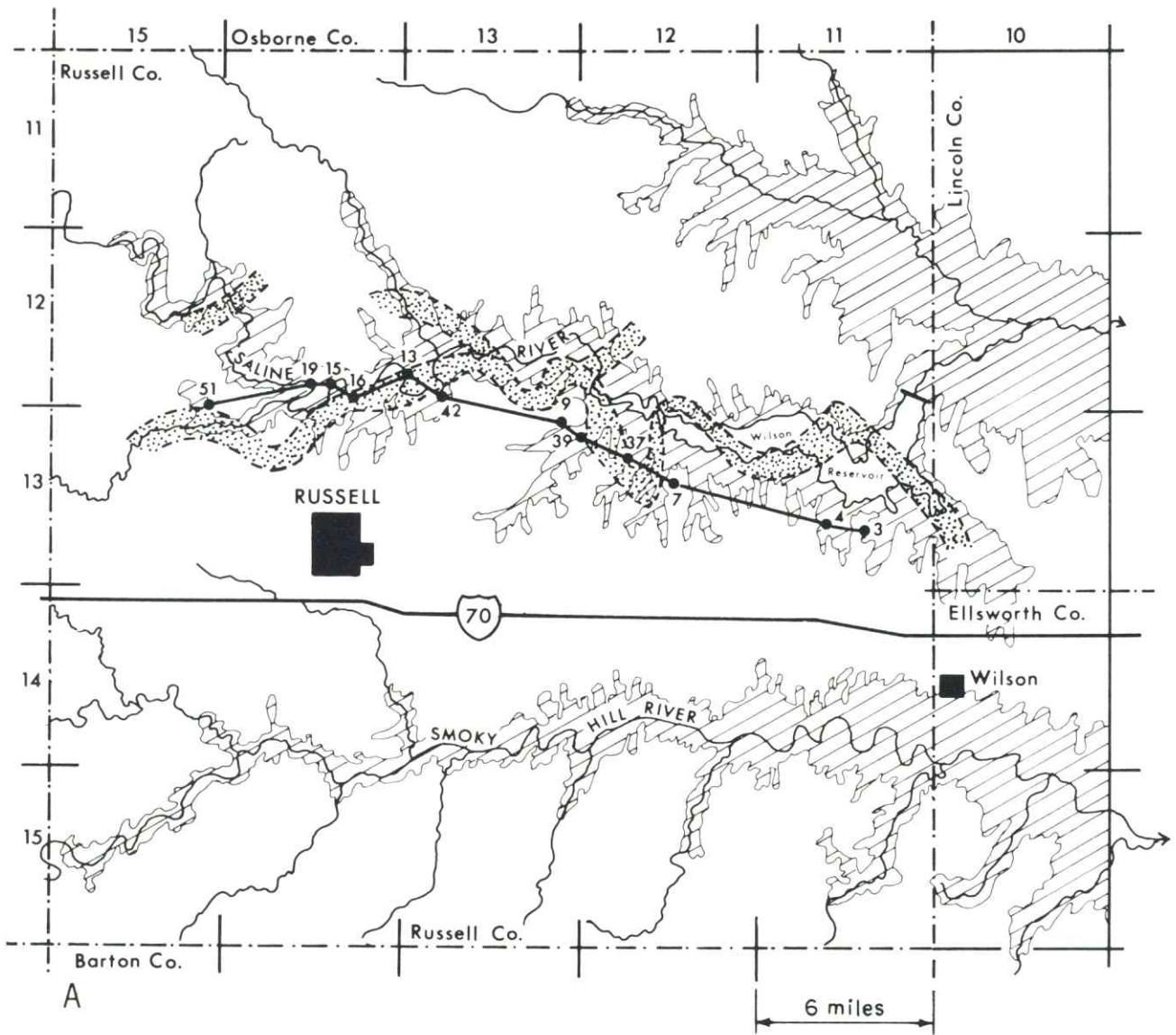
The variability of lithofacies in the upper part of the Dakota Formation in central Kansas is typical of a deltaic setting, which in this case has been preserved by a blanket of transgressive marine shale. The several distinct macroinvertebrate fossil associations (four recognized by Siemers, 1971) range from brackish-water to fully marine groups and relate well to the lithofacies. Trace-fossil abundance and diversity also correlate well with the lithofacies and body-fossil associations. Nonmarine and fluviodeltaic facies (Facies 1, 2, and 4) contain few biogenic structures other than reed molds and rhizocretions; however, marginal-marine facies (Facies 3 and 5) contain a greater variety of trace fossils, and the marine sands and shales (Facies 6) contain the greatest abundance and variety of trace fossils. Selected macroinvertebrate species of the Dakota Formation are illustrated in figure 5.

Graneros Shale

The nonuniform position of the Dakota-Graneros contact, as determined by reference to marker beds, reflects intertonguing of adjacent parts of two units. Complexly varied lithology in the upper part of the Dakota gives way upward to more uniform lithology in the lower part of the Graneros Shale. Everywhere in central Kansas, facies succession through the Dakota-Graneros transition suggests stratigraphically upward replacement of nonmarine and marginal-marine environments by broadly uniform, open-marine conditions. In some sections the sequence suggests transgression across linear clastic shorelines involving the marsh, shore-lagoon, and barrier-beach-shoreface environments. Other sections suggest spread of the open-marine environment across a delta platform, with Graneros shales, silts, and sands succeeding Dakota sediments of delta-front bars, drowned distributaries, interdistributary bays, or marshes.

In the immediate vicinity of the field-trip route, the Graneros Shale ranges from 24.9 to 36.4 ft (7.6-11.1 m) in thickness, averaging 31.5 ft (9.6 m) for nine complete sections in Russell, Ellsworth, and Lincoln counties. The lower part of the formation consists mainly of dark-gray silty-clay shale that is irregularly interlaminated with silt and fine sand and contains a few to several beds of thin-bedded, commonly cross-laminated, well-sorted, mostly noncalcareous quartzose sandstone. Concentrations of bone pebbles occur locally. Starved ripples, cross laminations, and small-scale sole markings are common evidence of current action, especially near the middle of the formation. Distribution and abundance of sand, silt, carbonaceous debris, and local bone beds suggest that deposition could have occurred in both outer delta platform-delta slope and in lower shoreface-offshore environments, depending upon whether the shoreline was deltaic or linear. Local shell conglomerate, extensive thin sand bodies enclosed in shale, and local bone beds all suggest reworking of a predominantly muddy bottom under shallow-water conditions. Near absence of calcareous beds, absence of ammonites, dominance of arenaceous foraminifers, rarity of planktonic foraminifers, and occurrence of *Lingula* in the lower part of the Graneros Shale all suggest brackish water that probably resulted from river discharge. The most common macroinvertebrates in this part of the formation are *Aphrodina lamarensis* (Shumard) and *Exogyra columbella* Meek; the strata have been assigned to the "*Callistina lamarensis* Assemblage Zone" by Hattin (1965a). The sparse fauna probably reflects inaccurately the original diversity of lower Graneros communities. In most beds only one or two species are represented, but an unusual coquina lens in southwestern Russell County includes, in addition to the common species, several forms not preserved elsewhere in the Graneros of Kansas: *Lispodesthes* sp. cf. *L. patula* Stephenson, *Ringicula* sp., *Fustiaria (Laevidentalium)* sp., and various unidentified bivalve molds.

FIGURE 4 (TO RIGHT)—LOCALITY MAP AND EAST-WEST CROSS SECTION OF SEDIMENTARY FACIES IN UPPER PART OF DAKOTA FORMATION, RUSSELL COUNTY, KANSAS. A) Dakota outcrop shown by ruled pattern; higher Cretaceous units (mostly Graneros and Greenhorn) lie in nonpatterned area. Approximate position of "latest" stage of channel-sand deposition of Rocktown channel sandstone shown by the stippled area. Positions of measured sections used in construction of the cross section shown below (figure 4B) indicated by numbered dots. (Map modified from Rubey and Bass, 1925, pl. III). B) Major sedimentary facies in upper part of Dakota Formation exposed in Saline River valley area. Crossbedded channel-sandstone body is crossed several times by section owing to meandering pattern of Rocktown channel sandstone. The flat-bedded sandstone subfacies shows an anomalously extensive occurrence owing to trend of cross section, which parallels approximate trend of sandstone body. Datum for section is "X" bentonite seam near top of Graneros Shale.



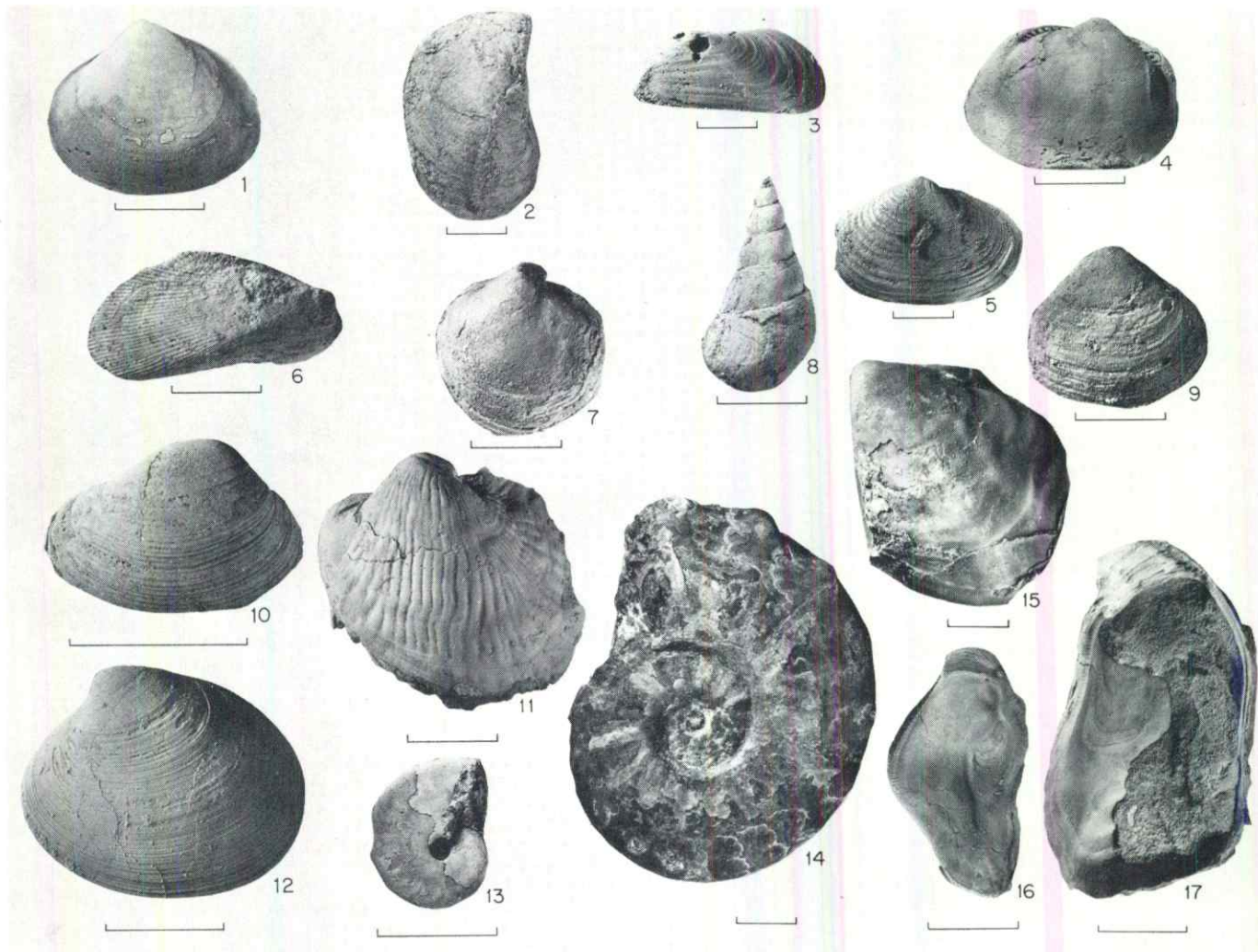


FIGURE 5—REPRESENTATIVE SPECIES OF MACROINVERTEBRATE FOSSILS OF THE DAKOTA FORMATION (1-9) AND GRANEROS SHALE (10-17) IN THE FIELD-TRIP AREA. Bar scales equal 1 cm. 1, *Geltena subcompressa* Stephenson, inflated form; 2, *Crassostrea soleniscus* (Meek); 3, *Volsella tarrantana* Stephenson; 4, *Breviarca (Sanoarca) grandis* (Stephenson); 5, *Laternula virgata* Stephenson; 6, *Brachidontes filisculptus microcostae* Stephenson; 7, *Exogyra* cf. *E. levis* Stephenson; 8, *Anchura* sp. G. of Stephenson (1952); 9, *Cymbophora spooneri* Stephenson; 10, *Parmicorbula? hillensis* Stephenson; 11, *Exogyra columbella* Meek; 12, *Aphrodina lamarensis* (Shumard); 13, *Borissiakoceras reesidei* Morrow; 14, *Acanthoceras amphibolum* Morrow; 15, *Inoceramus rutherfordi* Warren; and 16-17, *Ostrea beloiti* Logan.

The upper part of the Graneros comprises dark-gray silty-clay shale that commonly includes a few to several thin beds of calcareous sandstone in the lower part and thin beds of skeletal limestone in the upper part. The shale is weakly calcareous locally. Ripple marks and cross laminations are common features of the calcareous sandstone beds, and bone-pebble conglomerate is known locally. The X-bentonite marker bed lies near the top of the Graneros at most localities (Hattin, 1965a; 1968). Upward increase in number of planktonic foraminifers, appearance of ammonites in the upper part of the Graneros, and general upward increase in calcium carbonate content of the rocks suggest that salinity increased progressively as Graneros deposition proceeded. Carbonaceous matter and quartzose sand and silt are generally less abundant than in the lower part of the formation, reflecting decreased deltaic influence during deposition of the upper part of the Graneros. These beds are broadly analogous to bottomset beds of modern deltas or to the offshore muds of modern linear clastic shorelines. Chief macroinvertebrates in upper Graneros strata are *Ostrea beloiti* Logan, *Acanthoceras amphibolum* Morrow, *Inoceramus rutherfordi* Warren, and *Borissiakoceras reesidei* Morrow. Dominance of the first of these prompted Hattin (1965a) to assign these beds to the *O. beloiti* Assemblage Zone. At some localities oysters are concentrated in thin biostrome-like beds, many of which are actually current-accumulated shell hash set in calcarenite matrix. Fossils of the Graneros Shale are illustrated in figure 5.

Greenhorn Limestone

Lincoln Member

Basal beds of the Lincoln Member consist generally of crossbedded and cross-laminated skeletal and locally conglomeratic limestone that lies with sharp stratigraphic contact and abrupt lithologic contrast upon beds of the *Ostrea beloiti* Assemblage Zone across much of Kansas. At the southern end of the central Kansas outcrop, however, these basal Lincoln strata lie on older beds of the *Aphrodina lamarensis* Assemblage Zone. The unconformity separating the Graneros and Greenhorn formations has been shown to be diachronous (Hattin, 1968) and usually involves omission of one assemblage zone. At this stratigraphic break, nondeposition and local erosion of the upper part of the Graneros was followed by renewed deposition in a shallow-water zone of considerable turbulence that gave rise to relatively coarse-grained skeletal rocks that form the base of the Lincoln Member. Diachroneity of the contact and development of skeletal grainstones directly above it resulted from eastward to northeastward migration across the area of an offshore

high-energy belt (Shaw, 1964; Irwin, 1965) that shifted laterally during the transgressive half of the Greenhorn marine depositional cycle. *Ostrea beloiti* is locally concentrated in great numbers in the basal Lincoln beds, and *Exogyra columbella*, possibly reworked from the lower part of the Graneros, occurs sparingly. Molds of ammonites, probably including *Calycoceras canitaurinum* (Haas), *Dunveganoceras* sp. cf. *D. pondi* Haas, and *Stomohamites* sp. cf. *S. simplex* d'Orbigny, occur locally in the basal Greenhorn. These beds mark the first occurrence in Kansas of *Inoceramus prefragilis* Stephenson, which is host locally to *Exogyra* aff. *E. boveyensis* Bergquist, characterized by its small size and broad attachment surface. Initial turbulence during early Greenhorn deposition gave way to quieter conditions far from the eastern shoreline, and beds of laminated olive-black chalk accumulated under conditions generally unfavorable to bottom-dwelling infauna or epifauna. Scattered flattened valves of *I. prefragilis*, molds of the small ammonites *Eucalycoceras* sp. and *Desmoceras* (s.l.) sp., and, in one locality, excellently preserved *Stramentum moorei* Hattin, comprise nearly the entire fauna in the middle part of the Lincoln. Over much of central Kansas, Lincoln deposition terminated with accumulation of a zone of skeletal limestone lenses composed chiefly of *Inoceramus* remains and probably represented a brief return to depths shallow enough to permit occasional reworking of bottom deposits by wave action. Concentration of debris originally scattered widely through the sediment resulted from this renewed turbulence. *Inoceramus prefragilis* is the only common macroinvertebrate species in these beds. Species referable to *Inoceramus ginterensis* Pergament occur sparsely in middle and upper parts of the Lincoln Member. Selected Lincoln species are illustrated in figure 6. In Kansas, the Lincoln Member has an average thickness of 23 ft (7 m).

Hartland Member

This member consists predominantly of laminated olive-black marly to chalky shale with scattered beds of lighter-colored, burrow-mottled chalky limestone as much as 0.9 ft (0.27 m) thick and contains several beds of bentonite. Some of the chalky-limestone beds are demonstrably time parallel because they maintain a uniform relationship to marker bentonites. Four of these bentonite beds are traceable throughout the Kansas outcrop and westward to the southern Rocky Mountains of Colorado and New Mexico. The member is 29-32 ft (8.8-9.8 m) thick in the field-trip area. During Hartland deposition, environmental conditions were generally inhospitable to benthic forms of life, possibly owing to the highly fluid substrates, to the smothering effect of fine-grained sediment, to poor circulation, or to all of these factors. The burrow-mottled chalky-limestone beds are believed to

Jetmore Member

have accumulated during periods of slower sedimentation when very little terrigenous detritus reached the area (Hattin, 1971). Such beds are generally more richly fossiliferous than the intervening chalk-shale units and usually are thoroughly bioturbated. Selected fossils of the Hartland Member are illustrated in figure 6.

Inoceramus prefragilis Stephenson dominated the benthic macroinvertebrate fauna through much of Hartland deposition, although earliest members of the *Mytiloides labiatus* (Schlotheim) lineage characterize the uppermost part of the member in central Kansas. The *Sciponoceras gracile* Assemblage Zone occupies a small stratigraphic interval (see figure 18) lying below the middle of the member and consists of three widespread chalky-limestone beds and the intervening chalky-shale beds. A bentonite marker bed lies between the first two of these beds.

Major components of this assemblage are *Inoceramus pictus* Sowerby, *Phelopteria* sp. A, *Cerithiella* sp. A., *Sciponoceras gracile* (Shumard), *Worthoceras vermiculum* (Shumard), *Allocrioceras annulatum* (Shumard), *Euomphaloceras septemseriatum* (Shumard), and *Metoicoceras geslinianum* (d'Orbigny). Less common members of the assemblage include *Calycoceras* sp. cf. *C. naviculare* (Mantell), *Hemiptychoceras reesidei* Cobban and Scott, *Pseudocalyoceras dentonense* (Moreman), *Scaphites brittonensis* Moreman, and *Worthoceras gibbosum* (Shumard).

Benthic macroinvertebrates are more diverse in this zone than elsewhere in the Greenhorn and suggest more favorable bottom conditions. This interpretation is supported by evidence of benthic foraminifers, which are relatively abundant in the zone and sparse or absent in the remaining part of the formation (Eicher and Worstell, 1970). Above the *Sciponoceras gracile* Assemblage Zone, macroinvertebrate fossils other than inoceramids are rare, but a few molds of *Tragodesmoceras bassi* Morrow and *Watinoceras* cf. *W. reesidei* Warren have been recorded locally. Species of the *S. gracile* Assemblage Zone are illustrated in figure 6.

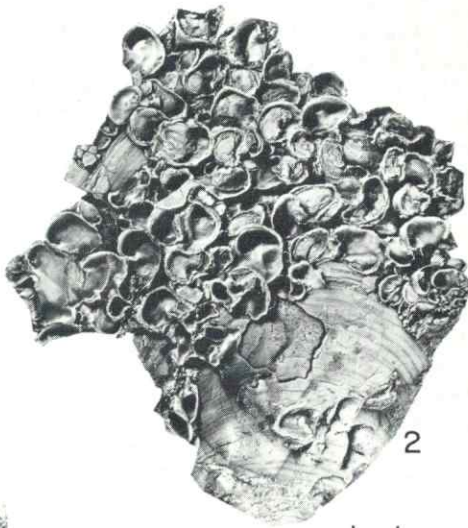
The Jetmore Member is 20-21 ft (6.1-6.4 m) thick in the field-trip area and is similar lithologically to the Hartland but contains more numerous (13), more closely spaced, mostly thicker, and more prominent beds of chalky limestone. The chalky-limestone beds are dark olive gray where fresh but commonly are weathered to some shade of orange. The chalky-limestone beds appear to be time parallel because of uniform position with respect to marker bentonites and were generated essentially in the same manner as those in the Hartland. The lower 10 of these limestone beds can be traced as far to the southwest as El Vado, New Mexico, and the upper four are recognizable as far to the northwest as the Black Hills. As in the Hartland, the limestone beds are generally more fossiliferous than the intervening chalky-shale beds. The conspicuously burrowed character of nearly all of these limestones suggests periods of slower deposition that favored development of an extensive mobile infauna, which produced abundant burrow structures. These limestone beds have mostly gradational contacts and lack evidence of hardground development. The upper half of the member contains a profusion of inoceramid remains, which seemingly reflects optimum conditions for growth of inoceramid bivalves. This part of the Jetmore is characterized by shell fragments and very thin lenses of skeletal limestone that indicate occasional stirring of bottom sediments by currents or waves. During this time interval, generally better circulation and reduced settling rates of fine-grained muds fostered establishment of a limited epifauna including *Pycnodonte kansasense* Bottjer, Roberts, and Hattin, sparse stalked cirripeds, and very rare *Discinisca* sp. Some larger inoceramid valves are covered by considerable numbers of the small pycnodont, which is best represented between the ninth and tenth beds of chalky limestone.

The Jetmore stratigraphic interval embracing the first six chalky-limestone beds is characterized by *Watino-*

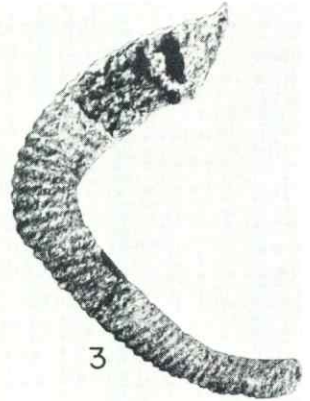
FIGURE 6 (TO RIGHT)—REPRESENTATIVE SPECIES OF MACROINVERTEBRATE FOSSILS FROM THE LINCOLN (1-6) AND HARTLAND (7-13) MEMBERS OF THE GREENHORN LIMESTONE IN THE FIELD-TRIP AREA. Bar scales equal 1 cm. 1, *Ostrea beloiti* Logan; 2, *Exogyra* sp. aff. *E. boveyensis* Bergquist; 3, *Stomohamites* sp. cf. *S. simplex* (d'Orbigny); 4, *Calycoceras canitaurinum* (Haas); 5, *Eucalycoceras* sp. B of Hattin (1975a); 6, *Inoceramus prefragilis* Stephenson; 7, *Worthoceras vermiculum* (Shumard); 8, *Metoicoceras whitei* Hyatt; 9, *Inoceramus pictus* Sowerby; 10, *Cerithiella* sp. A of Hattin (1975a); 11, *Phelopteria* sp. A of Hattin (1975a); 12, *Sciponoceras gracile* (Shumard); and 13, *Pseudocalyoceras dentonense* (Moreman).



1



2



3



4



5



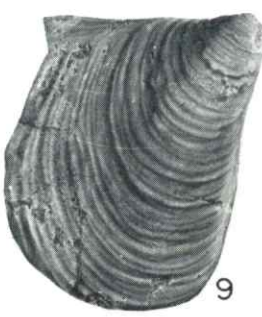
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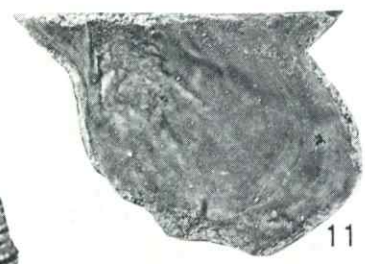
8



9



10



11



13



12



ceras cf. *W. reesidei* Warren and inoceramids of the *Mytiloides labiatus* (Schlotheim) lineage. Less common forms include *Baculites* sp. cf. *B. yokoyamai* Tokunaga and Shimizu, *Tragodesmoceras bassi* Morrow, *Discinisca* sp., and *Anomia* sp. The remainder of the member is characterized by *Mytiloides mytiloides* (Mantell), *Mammites nodosoides* (Schlüter), *Tragodesmoceras bassi* Morrow, and *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu. Selected Jetmore species are illustrated in figure 7.

The Jetmore Member of central Kansas represents far-offshore shelf deposition that occurred approximately at the peak of transgression during the Greenhorn cycle of sedimentation, at depths probably between 300 to 600 ft (90-180 m). These beds contain less terrigenous detritus than the beds below (Hattin, 1971) and suggest even greater distance to the shorelines than during Hartland deposition (figures 8 and 9).

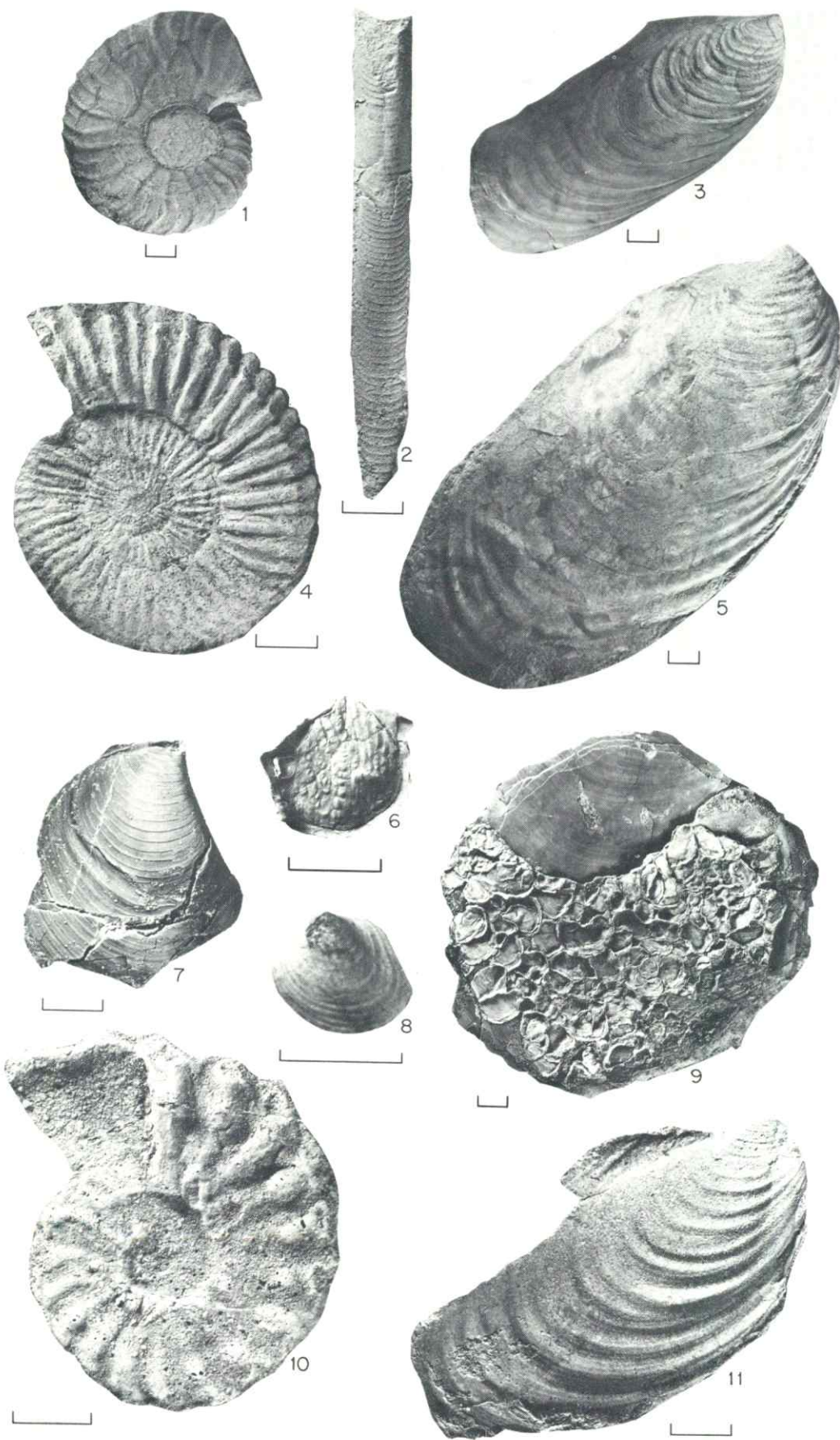
Pfeifer Member

The Pfeifer consists chiefly of chalky shale and chalky limestone but differs from the Jetmore in having numerous irregular, discontinuous, shell-rich concretionary beds of chalky limestone (lower 2/3) or layers of oblate, spheroidal chalky-limestone concretions (upper 1/3). Flat chalky-limestone beds, including the Fencepost limestone bed at the top, are scattered through the member and are believed to be time parallel because of consistent relationships to Pfeifer bentonite markers. The flat beds of limestone have some traces of bioturbation and are believed to have originated in the same manner as those in the Jetmore. Significance of the Fencepost bed to early settlement of the Plains is the subject of a fascinating book by Muilenberg and Swineford (1975). The Pfeifer is 21 ft (6.4 m) thick in the field-trip area. Depositional conditions that prevailed during the latter half of Jetmore time continued little changed during accumulation of the Pfeifer. Shaly chalk in the lower two-thirds of the member contains a profusion of inoceramid valves, which commonly host specimens of *Pseudoperna bentonensis* (Logan). Concentrations of shelly debris and the presence

here of epizoans such as *Pseudoperna* and scalpellid cirripeds suggests that the sea floor was swept irregularly by bottom currents. The layers of shelly debris were sites of concretionary addition of calcium carbonate, which explains the irregular shape and distribution of such limestones. In the upper third of the member, layers of chalky-limestone concretions contain fewer fossils than the other limestone beds and formed by carbonate-mud cementation around one or more whole inoceramid valves or around other fossils, including large logs. Early diagenetic origin is manifested by in-the-round preservation of contained fossils and bending of adjacent shaly chalk layers around the concretions as a result of compaction. In central Kansas, the Pfeifer Member includes some of the purest carbonate strata of the Greenhorn depositional cycle and is interpreted as having been deposited during the transgressional peak.

The lower third of the Pfeifer Member contains a fossil assemblage that is broadly similar to that in the upper part of the Jetmore Member. However, *Mammites nodosoides* is absent, *Tragodesmoceras bassi* is questionably represented, and *Pseudoperna bentonensis* replaces *Pycnodonte kansasense* as the principal epizoan on inoceramid valves. This assemblage is in the upper part of the *Mytiloides mytiloides* Range Zone. The remainder of the Pfeifer, from bed 46 of figure 18 through the Fencepost limestone, contains the first specimens of *Collignoniceras woollgari* (Mantell), *Inoceramus cuvieri* Sowerby s.s., and a broad form of the *M. labiatus* lineage that is referable to *M. subhercynicus* (Seitz). A sparse fauna of epizoans includes *Pseudoperna bentonensis* and two species of stalked cirripeds. Selected Pfeifer species are illustrated in figure 7. The lithostratigraphy, biostratigraphy, sedimentary petrology, and depositional environment of this and other members of the Greenhorn Limestone in Kansas have been treated extensively by Hattin (1975a).

FIGURE 7 (TO RIGHT)—REPRESENTATIVE SPECIES OF MACROINVERTEBRATE FOSSILS FROM THE JETMORE (1-6) AND PFEIFER (7-11) MEMBERS OF THE GREENHORN LIMESTONE. Bar scales equal 1 cm. 1, *Tragodesmoceras bassi* Morrow; 2, *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu; 3, 5, *Mytiloides mytiloides* (Mantell); 4, *Watinoceras* cf. *W. reesidei* Warren; 6, *Pycnodonte kansasense* Bottjer, Roberts and Hattin; 7, *Inoceramus cuvieri* Sowerby s.s.; 8, *Anomia* sp. A of Hattin (1975a); 9, *Pseudoperna bentonensis* (Logan) on a valve of *I. cuvieri*; 10, *Collignoniceras woollgari* (Mantell); and 11, *Mytiloides mytiloides* (Mantell) trans. to *M. subhercynicus* (Seitz).



Carlile Shale

Fairport Member

Although the Fairport Member has been classified historically as a member of the Carlile, the unit is genetically related, both faunally and lithologically, to the Greenhorn Limestone. Furthermore, the lowermost part of the Fairport is indistinguishable from the Pfeifer Shale Member of the Greenhorn, suggesting need for upward shift of the existing Pfeifer-Fairport boundary. Additionally, the Fairport fulfills all qualifications for formational status and is, therefore, inappropriately ranked as a member (Hattin, 1962, p. 20). In the area of this field trip, the Fairport ranges in thickness from 90 to 118 ft (27.5-36 m).

The Fairport consists chiefly of olive-gray to dark-olive-gray chalky to marly shale with beds of chalky limestone in the lower part and beds of marlstone in the middle and upper parts. Lenses of skeletal limestone composed largely of inoceramid bivalve debris are scattered throughout the middle and upper parts. Terrigenous detritus constitutes as little as 15% of the chalky shale, increasing to as much as 50% of the rock in the uppermost part of the member. As in the Greenhorn Limestone, many of the widespread layers of chalky limestone and marlstone of the Fairport have a uniform relationship to marker bentonites across the west-central Kansas outcrop and are thus believed to be essentially time parallel. Variations in the rate of deposition of terrigenous detritus against a gradually diminishing "background" accumulation of carbonate mud are responsible both for the alternation of chalky limestone and chalky shale in the lower part of the member and the increasingly impure carbonate strata stratigraphically upward in the member. Clearly, the Fairport reflects deposition during regressive movement of the closest shoreline. Following a period of almost no wave or current impingement on the sea floor during latest Pfeifer and early Fairport deposition, wave or current action swept the bottom regularly during later Fairport time and concentrated shelly debris into the abundant skeletal limestone lenses that now characterize middle and upper parts of the member.

In the lower part of the Fairport, the only common benthic macroinvertebrates are *Inoceramus cuvieri* Sowerby s.s. (throughout) and (in ascending order) *Mytiloides subhercynicus* (Seitz), *M. hercynicus* (Petrascheck), and *M. "latus"* (Sowerby) (sensu Hattin, 1962). The first of these reached very large size and commonly hosted clusters of *Pseudoperna bentonensis*. In this part of the section substrates were highly fluid and circulation was probably poor, just as in parts of the Greenhorn that lack evidence of current or wave activity; at any one horizon, diversity of benthic organisms was correspondingly low.

Parts of the Fairport containing an abundance of skeletal limestone lenses (i.e. middle and upper parts of the member except for the upper few feet) represent better circulation of bottom waters and probably shallower depths. Here is developed, for these chalky-carbonate strata, a relatively diverse suite of epizoans, including *Pseudoperna bentonensis* in enormous numbers, *Serpula tenuicarinata* Meek and Hayden, *Stramentum elegans* Hattin, and two species of bryozoans. These epizoans are mostly attached to large valves of *Inoceramus cuvieri*, or to one another. Their numbers reflect clearly improved circulation in the benthic environment and sufficient removal of settling mud to permit growth of several epizoan generations. The uppermost few feet of the member lack skeletal limestones and diverse epizoans, and the benthic fauna is dominated by a sulcate inoceramid, *Inoceramus* n. sp. aff. *I. flaccidus* White.

Fairport cephalopods include the ubiquitous *Collignoniceras woollgari*, sparse *Scaphites patulus* Cobban extending through the upper three-fourths of the member, and very rare specimens of *Actinocamax manitobensis* (Whiteaves) below the middle of the Fairport. From a high level in the Jetmore, diversity and abundance of planktonic foraminifers decreases irregularly upward through the Fairport Member (Eicher and Worstell, 1970, p. 276). Some common Fairport species are illustrated in figure 10.

Blue Hill Shale Member

The Blue Hill Shale Member ranges in thickness from 168 to 185 ft (51-56 m) in the field-trip area. The member consists chiefly of dark-gray silty-clay shale that weathers flaky and is sandy near the top. Zones of septarian limestone concretions characterize most of the member and clay-ironstone concretions occur in two zones in the lower half of the unit. Fine-grained noncalcareous sediment in the Blue Hill represents influx of terrigenous detritus associated with the regressive part of the Greenhorn depositional cycle; this regression is first reflected in the increase of land-derived sediment in the upper part of the Fairport. Blue Hill lithology and the low diversity of benthic forms suggest turbid water and a soft mud bottom that was inhospitable to most bottom-dwelling forms. The most successful benthic macroinvertebrates were large platter-shaped specimens of *Inoceramus cuvieri*, which are common in the lower part of the member, and *Inoceramus flaccidus* White, which possessed greatly inflated valves dorsally and coarse concentric rugae that apparently were adaptations to a reclining life habit on highly fluid substrates. These inoceramids commonly hosted small numbers of ostreid bivalves, possibly *Pseudoperna bentonensis*. Gastropods are represented by five or six genera, but specimens are preserved only locally in the

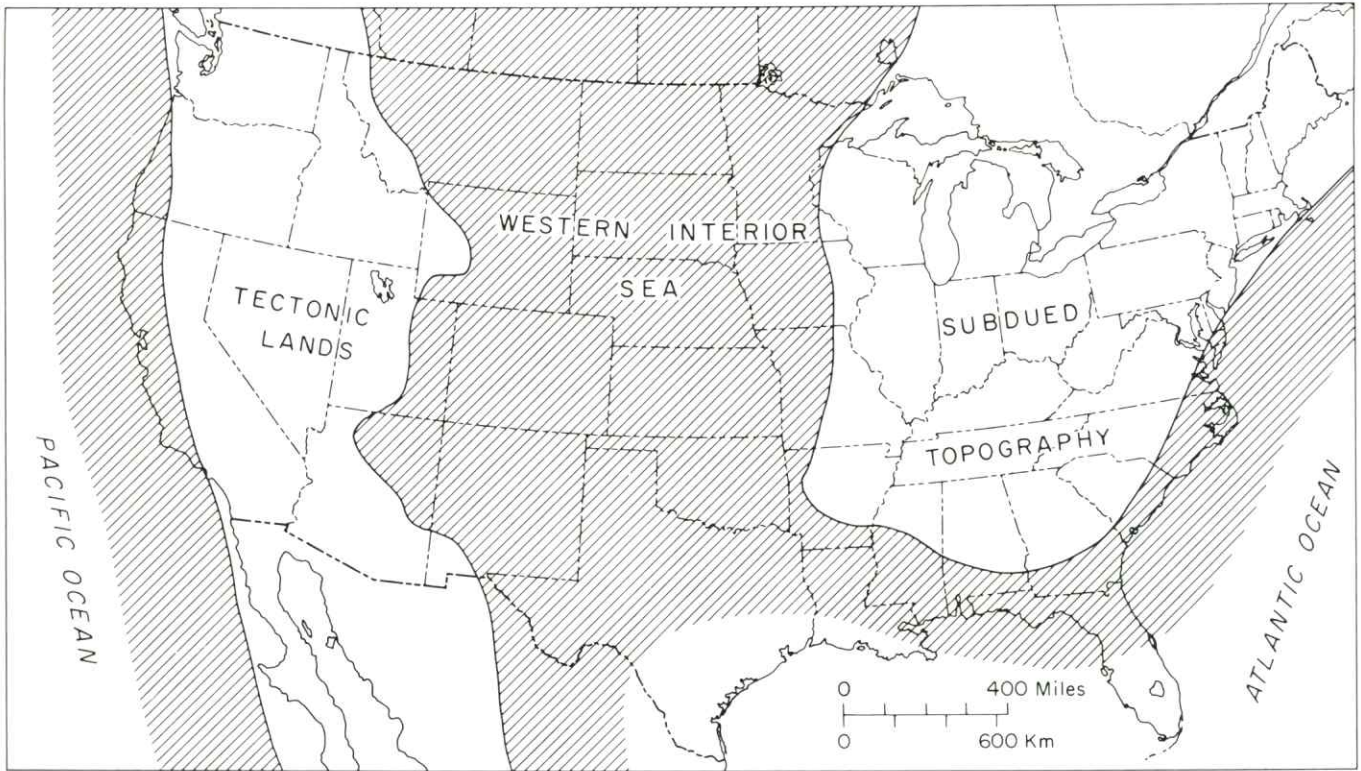


FIGURE 8—PALEOGEOGRAPHIC MAP OF UNITED STATES DURING GREENHORN TRANSGRESSIONAL MAXIMUM (EARLY TURONIAN). Map modified from Williams and Stelck (1975).

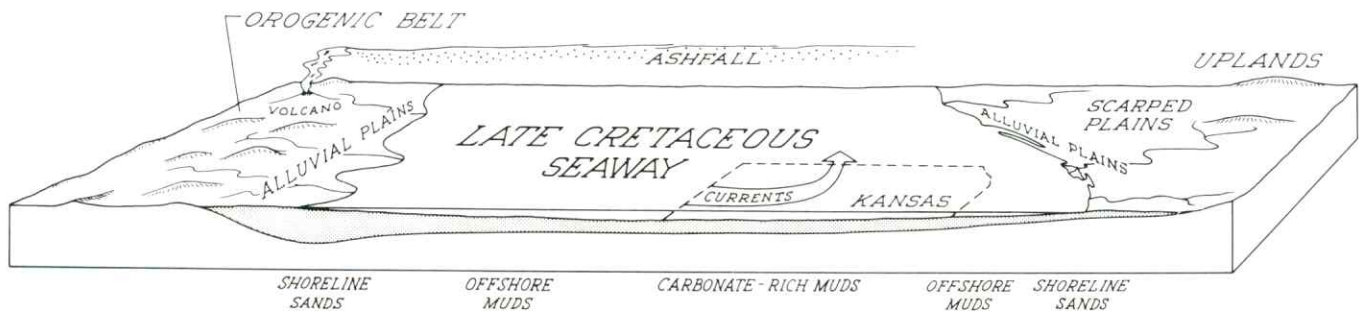


FIGURE 9—BLOCK DIAGRAM DEPICTING SCHEMATICALLY A PORTION OF WESTERN INTERIOR SEA DURING DEPOSITION OF GREENHORN LIMESTONE AND NATURE OF BORDERING LAND AREAS. Shaded portion indicates Upper Cretaceous sediments (modified from Hattin, 1975a).

section, especially in clay-ironstone concretions. The most common forms are *Bellifusus willistoni* (Logan) and *Tessarolax* sp. "*Lucina*" *juvenis* Stanton and *Yoldia* spp. also are distributed sparsely in the member. Ammonites include *Prionocyclus hyatti* (Stanton), *Scaphites carlilensis* Morrow, *Scaphites arcadiensis* Moreman, *Proplacenticerus pseudoplacenta* (Hyatt), and *Binneyites aplatus* (Morrow). The first two ammonite species are known to range essentially throughout the member. The remaining ammonite species are preserved only in limited stratigraphic intervals, especially near the middle of the Blue Hill. Most of the Blue Hill Member is virtually devoid of fossils, but in some thin shale units, and in certain concretion zones, the fauna is abundantly represented and even beautifully preserved. Present distribution of the fauna thus seems to be at least partly a function of preservational processes. Selected species of Blue Hill fossils are illustrated in figure 10.

The Blue Hill was deposited during continuation of the long slow regression that is displayed so well in the Fairport Member. Towards the top of the Blue Hill the quantity of terrigenous sand and silt increases markedly, small-scale oscillation ripple marks have been recorded in cross-laminated siltstone, and fish-tooth conglomerates are known locally. This evidence heralds the onset of shallow-water conditions and an end to the Greenhorn cycle of deposition. The Blue Hill Member is much thicker than the Graneros Shale but has much the same stratigraphic distribution of lithotypes as the latter unit, only in the reverse order of occurrence. Lithologically, the Greenhorn cyclothem is remarkably symmetrical in central Kansas.

Codell Sandstone Member

In the field-trip area, the Codell ranges from 5.7 to 31 ft (1.7-9.5 m), but over much of northern Kansas it is less than 1 ft (0.3 m) thick. At some localities in the southern part of the west-central Kansas outcrop, the Codell is not recognizable. The member is gradational vertically and laterally with upper beds of the Blue Hill. The Codell consists mostly of well-sorted fine quartzose sand and coarse quartzose silt. It contains small quantities of feldspar and a limited suite of stable heavy minerals. Silty shale occurs in the Codell in some sections. At most localities, the Codell is extensively bioturbated. Well-defined bedding or crossbedding is preserved only locally. Fossils are rare and preserved poorly in west-central Kansas, consisting of a few shark teeth, clam molds, and a small foraminiferal assemblage dominated by arenaceous species. Codell sediments represent return to the central Kansas area of shallow-water conditions during general retreat of the sea along the eastern shoreline. Intensive bioturbation of the sands in most sections suggests slow sedimentation, which was followed ultimately by a long period of nondeposition; renewed deposition began with

the Niobrara cycle of sedimentation. The lacuna separating the Carlile and Niobrara has been shown (Hattin, 1975b) to expand progressively from westernmost Kansas northeastward to northeastern Nebraska. In the former area the youngest Carlile fossils are from the zone of *Prionocyclus wyomingensis* Meek and the oldest Niobrara fossils are from the zone of *Inoceramus erectus* Meek. In northeastern Nebraska, however, youngest Carlile fossils are from the zone of *Collignoniceras woollgari* (Mantell) and the oldest Niobrara fossils are from the zone of *Volvicceramus grandis* (Conrad). Hattin (1975b) has shown that both the top of the Carlile and base of the Niobrara are diachronous and also that the major facies of the two formations have diachronous contacts. In northeastern Nebraska, sea-floor scour has removed any trace of the Codell so that basal beds of the Fort Hays Member lie with sharp contact on noncalcareous shale of the Blue Hill Member.

Niobrara Chalk

Fort Hays Limestone Member

The Fort Hays Limestone Member is 55-75 ft (16.8-22.9 m) thick in the field-trip area, the latter figure being near the maximum for the west-central Kansas outcrop. The unit is characterized by thick to very thick beds of relatively resistant chalky limestone that is light gray to medium gray or light olive gray where fresh but more commonly is weathered yellowish gray, grayish or pale grayish orange, or nearly white. The rock is mostly homogeneous micrograined carbonate rock composed largely of micrite and microspar, foraminifera, and calcareous nannoplankton remains, but with locally abundant *Inoceramus* prisms and shell fragments of inoceramid and ostreid bivalves. Except for the sandy basal bed, the rock is composed of 88-98% calcium carbonate (Runnels and Dubins, 1949, p. 17). Very thin beds of clayey chalk or bentonite separate many of the limestone beds. Most Fort Hays beds have uniform thickness for considerable distances, but channel-like features have resulted in local thickening of beds, especially at or near the base of the member (Hattin, 1965b; Frey, 1972, p. 49).

The Fort Hays is characterized throughout by thorough bioturbation of limestone beds as well as shaly partings. In a thorough and detailed study of Fort Hays trace fossils, Frey (1970) recognized approximately 20 discrete kinds of burrows among which such forms as *Teichichnus*, *Planolites*, *Chondrites*, and various mineral-filled burrows are the most common. Despite widespread bioturbation of most beds, thinly laminated to gently cross-laminated chalky limestone has been recorded sparingly in the member.

The Fort Hays contains benthic macroinvertebrates of limited diversity consisting principally of large, more-or-less bowl-shaped, relatively thick-shelled inoceramids. In westernmost Kansas, lower beds of the Fort Hays contain *Inoceramus erectus* Meek, but in the field-excursion area the oldest undoubted zone is that of *I. deformis* Meek. Upward in the section, forms representing *I. (Cremnoceramus) inconstans* (Woods), *I. browni* Cragin, *I. schloenbachi* Böhm, and *I. (C.) koeneni* Müller appear in succession, but gradation between some of these forms and difficulty of collecting anything other than internal molds places constraints on exact placement of range-zone boundaries at this writing. The bowl-like shape of most Fort Hays inoceramids apparently is an adaptation for life on substrates that were fluidized by intense activity of a highly mobile infauna. All of these western Kansas species are host to clusters of *Pseudoperna congesta* (Conrad). Ctenostomatous bryozoa, sessile foraminifera, acrothoracican cirripeds, and *Serpula tenuicarinata* Meek and Hayden are less common epizoans on the large inoceramids. Isolated clusters of the rudist *Durania* occur sparingly in the Fort Hays. Lower beds of the member generally contain specimens of *Pycnodonte aucella* (Roemer), regardless of the inoceramid zone to which those beds belong. Rare specimens of *Lopha falcata* (Morton) occur in the lower part of the Fort Hays locally (Miller, 1968, p. 33), and the species has been collected by the writer in Hamilton County, Kansas. Representative species of Fort Hays macroinvertebrates are illustrated in figure 11.

The Carlile-Niobrara unconformity has been described above, and the details of lithostratigraphy adjacent to the unconformity have been documented by Hattin (1975b). During regression that produced this unconformity, the sea floor was eroded, but unequivocal evidence of subaerial erosion is lacking. Abundance of sand in the basal Fort Hays represents reworking of Codell sands during the Niobrara transgression. Local channeling of uppermost Carlile strata has been reported by Hattin (1965b) and Frey (1972, p. 49). The regionally differing nature of uppermost Carlile strata between westernmost Kansas and northeastern Nebraska reflects variation in duration and/or intensity of sea-floor scour that helped to produce the northeastwardly widening lacuna described by Hattin (1975b). Following a prolonged interval of nondeposition and sea-floor scour, renewed subsidence or eustatic sea-level rise once again permitted permanent sediments to accumulate on the broad, flat eastern shelf of the Western Interior Sea. However, the eastern shoreline was so remote that terrigenous detrital influx was small. Thus, relatively pure far-offshore carbonates comprise initial deposits of the second Late Cretaceous sedimentary cycle in Kansas.

Frey (1970) concluded that Fort Hays deposition occurred slowly in well-circulated, gradually deepening

waters and that the sediment remained soft and yielding until late in diagenesis. Current action, manifest in channel-like features, cross laminations, and local skeletal limestone lenses, occurred only during deposition of the lower part of the member. By the time Smoky Hill deposition commenced, the sea was deeper and the bottom waters were less well aerated than during accumulation of the Fort Hays sediments. The Fort Hays-Smoky Hill contact has been shown by Hattin (1975b) to be diachronous toward the northeast in Kansas and Nebraska. This diachroneity is borne out also by lithostratigraphic and biostratigraphic relations along the same contact in the Pueblo area of Colorado (Scott and Cobban, 1964).

Smoky Hill Chalk Member

The Smoky Hill Chalk Member ranges approximately from 560 to 620 ft (171-189 m) in thickness in the field-trip area. The unit is dominated by light-olive-gray to olive-gray chalky shale that is speckled by nearly white spheroidal calcareous fecal pellets (Hattin, 1975c). The pellets are composed almost exclusively of coccoliths. The chalky shale is commonly weathered grayish orange to pale yellowish orange, or dark yellowish orange or very pale yellowish orange, or yellowish gray. During intense weathering the rock loses its obvious bedding features and becomes harder and more massive. Most of the rock is more or less evenly laminated, but scattered through the member are thin zones of bioturbated chalk or tough, granular, nonlaminated chalk that form prominent markers, which are especially evident on little-weathered slopes. The thickest interval of granular chalk is equivalent to the middle chalk unit of Scott and Cobban (1964). This bed forms the hard, lichen-splotched caprock on many erosional pinnacles and promontories in highly eroded areas of the Smoky Hill outcrop. Massive, weathered beds of other stratigraphic intervals locally hold up steep cliffs near the summits of many bluffs. Beds of massive chalk that lie near the base, middle, and top of the Kansas section are correlative with the lower limestone, middle chalk, and upper chalk units, respectively, that are recognized at Pueblo, Colorado, by Scott and Cobban (1964). Bentonite seams are prominent features of the member and can be used to construct Smoky Hill composite sections (Hattin, 1976; 1982).

Smoky Hill strata contain benthic epifaunal invertebrate communities of low diversity. This, combined with the paucity of bioturbated zones, suggests that Smoky Hill waters were deeper and less well-circulated than those in which the Fort Hays sediments were deposited. Principal substrates for attachment of epizoans consisted of large, heavy-shelled, bowl-shaped and giant-sized, platter-shaped species of inoceramids. *Volvicceramus grandis* (Conrad) represents the first of these growth forms and is usually encrusted heavily by one or more

generations of *Pseudoperna congesta* (Conrad). This form ranges through the lower 164 ft (50 m) of the member. A nearly smooth early form of *Inoceramus* (*Platyceramus*) *platinus* Logan, *I. (Cladoceramus) undulatoplicatus* Roemer, and *I. (P.) platinus* s.s. occur successively in the member and because of their snowshoe shape were admirably adapted to maintaining position on watery and oozy substrates. All of these species are host to *P. congesta*, with heavy encrustations occurring commonly on the exterior surfaces of both valves in paired specimens. This phenomenon parallels that seen among large specimens of *I. cuvieri* in the Fairport Member of the Carlile Shale. The only other nearly ubiquitous benthic invertebrates were acrothoracican cirripeds. Less common, smaller inoceramids include, in ascending order of occurrence, *I. (P.) cycloides* Wegner, *I. (Endocostea) balticus* Böhm, and *I. (E.) simpsoni* Meek. These forms do not usually host large numbers of epizoic oysters. Cephalopods are conspicuous in the Smoky Hill only in certain intervals. The common forms are *Clioscaphtes vermiformis* (Meek and Hayden), *C. choteauensis* Cobban, and a large, smooth unnamed species of *Baculites*. The last of these commonly hosts a few specimens of epizoic *P. congesta*. *Stramentum haworthi* (Williston) is a common epizoan locally on specimens of *C. choteauensis* and *Baculites* sp. and occurs sparingly on *I. (P.) platinus* and rarely on *P. congesta*. Rudists of the genus *Durania* are scattered through most of the member. These usually hosted a small epizoic fauna consisting of *P. congesta*, acrothoracicans and, rarely, lepadomorph cirripeds. Rare cuttlefish, belemnites, and free-swimming crinoids were elements of the nektonic fauna during Smoky Hill deposition. The crinoids apparently occur in local, very thin lenses within the zone of *C. choteauensis*. The foraminiferal fauna is dominated by planktonic species. A detailed listing of Smoky Hill species was compiled by Miller (1968). Representative species of Smoky Hill macroinvertebrates are illustrated in figure 11.

In a general way the lithology and faunal makeup of the member can be compared with that of the Fairport Member of the Carlile Shale. Each unit represents the regressive carbonate phase of the respective depositional cycle, but the Smoky Hill lacks the profusion of skeletal limestone lenses that is so characteristic of the Fairport.

The Smoky Hill Member is renowned for its content of marine vertebrate fossils. Species of mosasaurs, plesiosaurs, giant turtles, pterosaurs, birds, teleosts, and sharks are the principal forms and abound in some parts of the section. Fish preserved inside larger fish, bones found in coprolites, teeth of shell-crushing sharks, and teeth marks found on invertebrate shells are the kind of evidence that can be used to reconstruct details of food webs in the faunas that occupied this part of the Western Interior Sea.

Deposition of Smoky Hill sediments was relatively rapid, at least in the less pure chalks that lack

bioturbation. Tall, cone-shaped specimens of *Pseudoperna congesta*, found in the same beds with short, encrusting forms, apparently were attached to small shell fragments. The form is assumed to reflect rapid upward growth that was necessary to prevent burial as the substrate sank into watery or oozy mud. Oysters attached to baculitids are nearly all small, suggesting growth on empty conchs that were buried shortly after attachment of epizoans. The same is true of *Stramentum haworthi* that are attached to *Clioscaphtes choteauensis*. *Inoceramus* valves encrusted by large numbers of oyster spat are presumed to have been dead at or soon after the time of epizoic attachment and were buried before the oysters grew very large. In contrast, *Inoceramus* shells heavily encrusted by thick-shelled adult oysters were alive during oyster growth and remained unburied for lengthy periods. On such inoceramid valves, second- and third-generation oysters are attached commonly to oysters of earlier generations.

Toward the top of the member, quartz silt becomes increasingly evident in Smoky Hill sediments, and the chalky shale gives way gradually to calcareous shale in the uppermost few feet of the Smoky Hill. A fascinating chapter in Cretaceous history came to an end with the major influx of terrigenous detritus into western Kansas at the advent of Pierre Shale deposition. This sediment denotes approach to western Kansas of the eastern shoreline during a long, slow regressional episode on the eastern shelf of the Western Interior Sea.

Pierre Shale²

The Pierre Shale crops out only in seven western Kansas counties where erosional truncation has reduced original thickness to about 1,400 ft (427 m). The formation consists largely of dark-gray to medium-gray clay shale that contains gray- to brown-weathering limestone concretions, rusty- to dusky-red-weathering ironstone concretions, and numerous thin layers of white or gray bentonite. Elias (1931) described in detail the Wallace County exposures where the lower one-half or less of the Pierre is represented. This part of the Pierre was divided by Elias into four members (ascending): Sharon Springs Shale Member, 155 ft (47.3 m); Weskan Shale Member, 170 ft (51.9 m); Lake Creek Shale Member, 200 ft (61 m); and Salt Grass Shale Member, 60 ft (18.3 m).

Sharon Springs Shale Member

The Sharon Springs Shale Member, the type section of which is at McAllaster Buttes, Stop 8, consists of a poorly exposed soft lower part and a well-exposed harder upper part. The lower part, which forms half or more of the member, is a dark-gray soft shale that contains

² Section on Pierre Shale modified from Cobban, in Hattin (1965b).

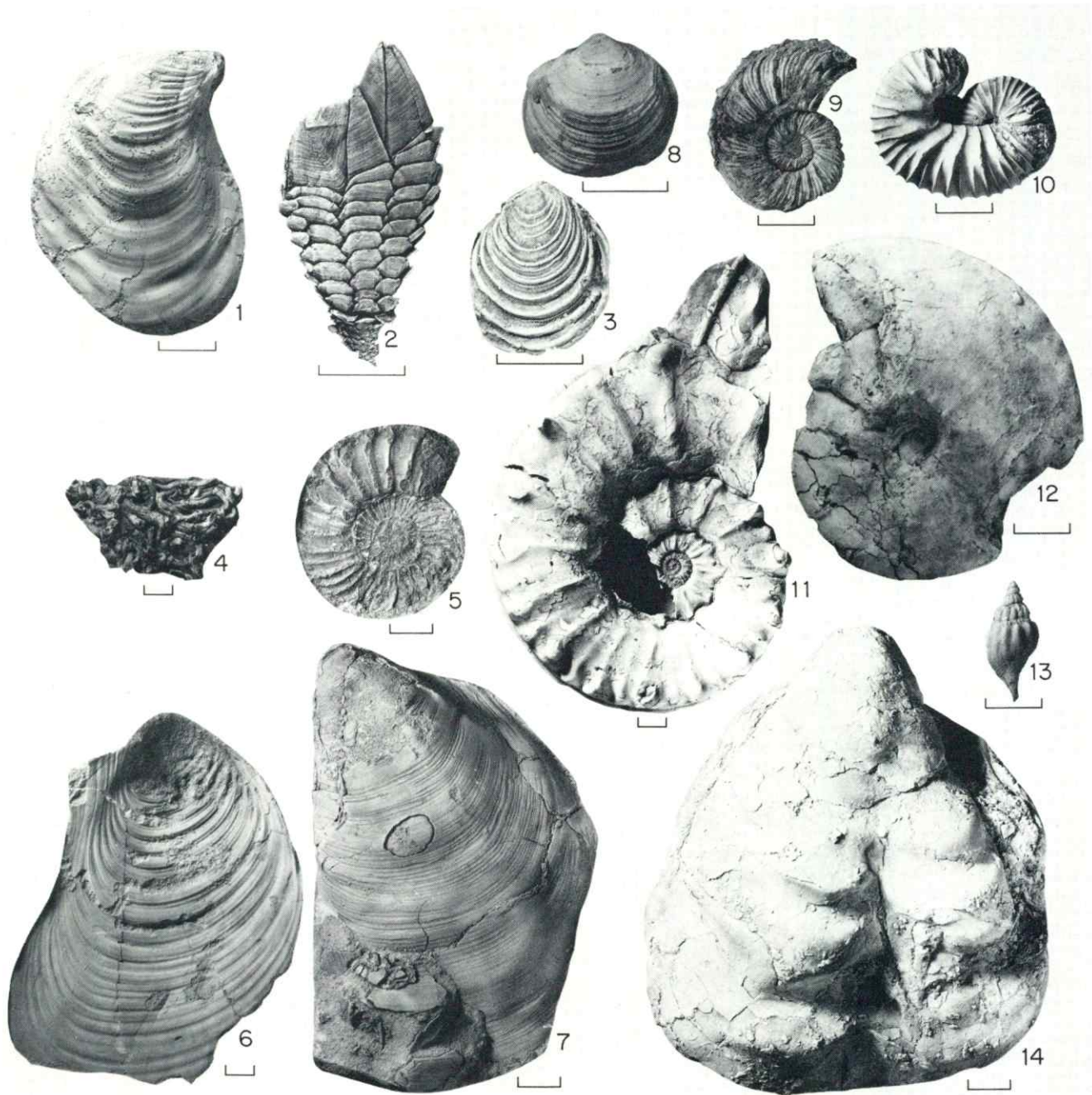


FIGURE 10—REPRESENTATIVE SPECIES OF MACROINVERTEBRATE FOSSILS FROM THE FAIRPORT (1-7) AND BLUE HILL (8-14) MEMBERS OF THE CARLILE SHALE IN THE FIELD-TRIP AREA. Bar scales equal 1 cm. 1, *Inoceramus* n. sp. aff. *I. flaccidus* White; 2, *Stramentum elegans* Hattin; 3, *Mytiloides "latus"* (Sowerby) (sensu Hattin, 1962); 4, *Serpula tenuicarinata* Meek and Hayden; 5, *Collignonicerias woollgari* (Mantell); 6, *Mytiloides subhercynicus* (Seitz); 7, *Inoceramus cuvieri* Sowerby s.s.; 8, "*Lucina*" *juvenis* Stanton; 9, 11, *Prionocyclus hyatti* (Stanton); 10, *Scaphites carlilensis* Morrow; 12, *Proplacenticerias pseudoplacenta* (Hyatt); 13, *Bellifusus willistoni* (Logan); and 14, *Inoceramus flaccidus* White.

ferruginous concretionary beds and a few thin layers of bentonite. Fossils are scarce; a few of the concretionary beds contain *Baculites obtusus* Meek and species of *Inoceramus* and *Pteria*. This part of the Sharon Springs will not be seen on this excursion. The upper part of the member, which crops out extensively at McAllaster Buttes, is a resistant, organic-rich, buttress-forming brownish-gray shale that contains hard limestone concretions, soft phosphatic concretions, and thin layers of bentonite. The upper part contains a bed of very large, closely spaced septarian limestone concretions, which contain thick veins of pale-brown calcite and, less commonly, crystals of barite. Fossils are rare in the upper part of the Sharon Springs although one concretion contained an abundance of *Baculites asperiformis* Meek. Vertebrate fossils, including numerous remains of small fish, giant turtles, plesiosaurs, and mosasaurs are common in the Sharon Springs Member. Gill, Cobban, and Schultz (1972) have described in detail the lithologic and stratigraphic character of the member in western Kansas.

Weskan Shale Member

The Weskan Shale Member consists of soft, dark-gray clay shale that has numerous concretions and many beds of bentonite, some of which are 0.5-1 ft (0.15-0.3 m) thick. The lower part contains thin, ferruginous, concretionary layers and small worm-burrowed phosphatic nodules. The upper part is characterized by many beds of light-gray, hard, dense, limestone concretions. Well-bedded elongated limestone concretions mark the base of the member. The limestone concretions contain specimens of *Inoceramus*, *Pteria*, and *Anomia*, as well as fragmentary ammonite remains. The Weskan contains rare, irregular, concretionary masses of *Nympholucina*-bearing limestone similar to that which comprises teepee buttes in the Pierre Shale of Colorado. Only the basal part of the Weskan is exposed at the McAllaster Buttes.

Lake Creek Shale Member

The Lake Creek Shale Member is a dark-gray, flaky-weathering clay shale that has many thin concretionary ferruginous layers that impart a rusty appearance to the outcrops. The member contrasts with adjacent members in near absence of large limestone concretions. Baculitids, chiefly *B. reesidei* Elias, are common. A wide variety of invertebrates, especially species of inoceramids, scaphites, and *Serpula*, were reported by Elias (1931), and remains of large fish and mosasaurs have been recorded from the Lake Creek.

Salt Grass Shale Member

The Salt Grass Shale Member is a gray clay shale containing limestone concretions, thin ferruginous concretions, and a few thin layers of bentonite. Irregular bodies of *Nympholucina*-bearing limestone occur in the lower and upper parts of the Salt Grass. The most abundant fossil is *Baculites eliasi* Cobban, but several species of scaphites, *Inoceramus*, and other bivalves have been recorded.

The Pierre Shale of western Kansas was deposited several hundred miles from the western shore of the Western Interior Sea and an unknown distance from the eastern shore. The formation is very thin relative to time-equivalent strata farther west in central Colorado. During much of Pierre time, depositional rates were probably slow in Kansas and were especially slow during deposition of zones containing an abundance of phosphatic concretions. Paucity of fossils in many of the rocks may be a reflection of slow deposition, but diagenetic removal of skeletal carbonates probably occurred on a large scale.

Late Cretaceous cyclic sedimentation in western Kansas

Formations in the upper part of the Dakota Formation and lower part of the Colorado Group record deposition during the first Late Cretaceous marine-sedimentation cycle. The stratigraphic succession is an asymmetrical cyclothem composed of nine facies including, in ascending order: (1) flat-bedded sandstone, carbonaceous and commonly clayey siltstone and sandstone, and generally silty and clay-ironstone-bearing gray shale, represented by the uppermost parts of the Dakota

Formation; (2) gray, noncalcareous silty or sandy shale with sandstone beds, represented by the lower part of the Graneros Shale; (3) gray, mostly noncalcareous silty shale with beds of calcareous sandstone and skeletal limestone and local septarian concretions, represented by the upper part of the Graneros Shale; (4) dark-olive-gray marly and chalky shale that contains abundant beds and lenses of skeletal grainstone; (5) dark-olive-gray chalky shale and chalky limestone containing relatively little terrigenous

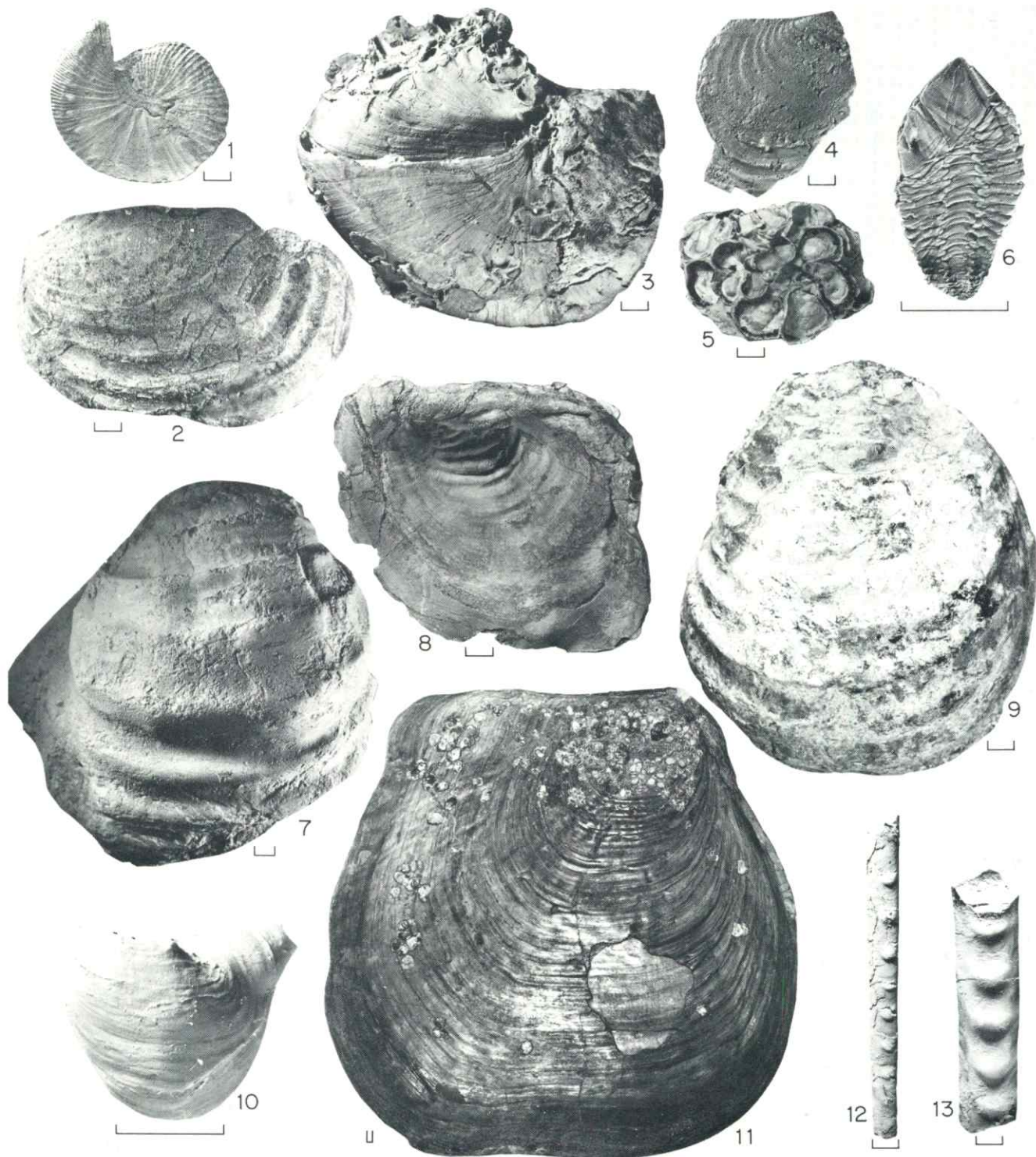


FIGURE 11—REPRESENTATIVE SPECIES OF MACROINVERTEBRATE FOSSILS FROM THE NIOBRARA CHALK (1-11) AND PIERRE SHALE (12, 13). Bar scales equal 1 cm. 1, *Clioscaphtes choteauensis* Cobban; 2, *Inoceramus (Cremnoceramus) inconstans* Woods; 3, *Inoceramus (C?) koeneri* Müller; 4, *Inoceramus (Endocostea) balticus* Böhm; 5, *Pseudoperna congesta* (Conrad); 6, *Stramentum haworthi* (Williston); 7, *Inoceramus browni* Cragin; 8, *Volviceramus grandis* (Conrad); 9, *Inoceramus deformis* Meek; 10, *Pycnodonte aucella* (Roemer); 11, *Inoceramus (Platyceramus) platinus* Logan; and 12-13, *Baculites asperiformis* Meek. Figures of *B. asperiformis* furnished by W. A. Cobban; figure of *I. (P.) platinus* courtesy of Myrl V. Walker.

detritus, represented by the Hartland, Jetmore, and Pfeifer members of the Greenhorn Limestone and by the lower part of the Fairport Chalk Member of the Carlile Shale; (6) dark-olive-gray chalky to marly shale that contains abundant lenses of skeletal grainstone, represented by the upper three-fourths of the Fairport Member, Carlile Shale; (7) gray, noncalcareous silty shale with septarian concretions, represented by most of the Blue Hill Shale Member, Carlile Shale; (8) gray, locally concretionary, noncalcareous silty or sandy shale with thin sandstone beds, represented by the uppermost part of the Blue Hill Shale Member; and (9) siltstone and sandstone, commonly argillaceous and thoroughly bioturbated, represented by the Codell Sandstone Member of the Carlile. Macroinvertebrate fossils are everywhere abundant only in phases (3) through (7). Further subdivision is unwarranted in the Kansas section, but for equivalent strata farther west in Colorado, Kauffman (1967, 1969) has proposed a cyclic model that has several additional phases.

Sequence, sedimentary structures, and fossils in these beds suggest successive, gradational changes from nearshore, shallow and mostly brackish-water environments of deposition in facies (1) and (2) to far-offshore deposition in deeper waters of normal or near-normal salinity in facies (5) and return to nearer shore, shallower water deposition through phases (7) to (9). The regressive half of the cyclothem is much thicker than the transgressional half.

Cretaceous rock units above the Carlile Shale in western Kansas represent parts of two additional Late Cretaceous cycles of sedimentation in the eastern portion of the Western Interior Sea. Niobrara strata represent maximum transgression (Fort Hays) and initial deposits of a protracted regression (Smoky Hill) that are analogous to facies (5) of the first cyclothem. Basal shales of the Pierre are analogous to facies (7) of that cyclothem. Transgressive rocks of this second cycle of sedimentation are unrepresented in Kansas for reasons outlined in an earlier section of this guidebook but are represented, at least in part, farther to the west and northwest in Colorado and the Black Hills.

The Sharon Springs Shale Member of the Pierre Shale includes an organic-rich interval that represents a third transgressional maximum. Above this interval, clay-rich shales of the Pierre represent an extended period of slow, regressive sedimentation that apparently proceeded, more or less uninterrupted, for the remainder of Pierre deposition and are broadly analogous to facies (7) of the first cyclothem. Regressive facies (8) and (9), if ever deposited in Kansas, have been entirely removed by pre-Miocene erosion. It should be noted that in other regions of the Western Interior, west of Kansas, the Pierre Shale and Fox Hills Sandstone and equivalent beds contain evidence of an additional cycle of sedimentation (Bearpaw cycle) not preserved in Kansas (Weimer, 1960).

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ROAD LOG FOR APRIL 13, 1977

Leaders: Donald E. Hattin (Indiana University)
and Charles T. Siemers (Cities Service Company)

Assisted by Gary F. Stewart (Oklahoma State University)

Miles

- 0.0 Intersection of I-70 and K-232.
Proceed north on K-232.
- 0.5 Low escarpment (left) capped by Greenhorn Limestone.
- 0.8 Ascending Greenhorn escarpment.
- 1.3 Poor exposures of Greenhorn Limestone, both sides of highway.
- 1.5 Entering Lincoln County. Valleys on both sides of highway dissect Greenhorn escarpment; escarpment well developed on left (9:00-11:00). Approximate position of Graneros-Greenhorn contact at first break in slope below top of escarpment. Dakota Formation present in valley floors.
- 2.2 Descending Greenhorn escarpment. Low exposures of Greenhorn Limestone on both sides of highway.
- 2.5 Base of Greenhorn Limestone; Graneros shale poorly exposed below Greenhorn.
- 2.9 Low mound on right (3:00) capped by sandstone in Dakota Formation; at 2:00 in near distance flat-bedded sandstone overlies variegated mudstone in Dakota (continental sedimentary facies).

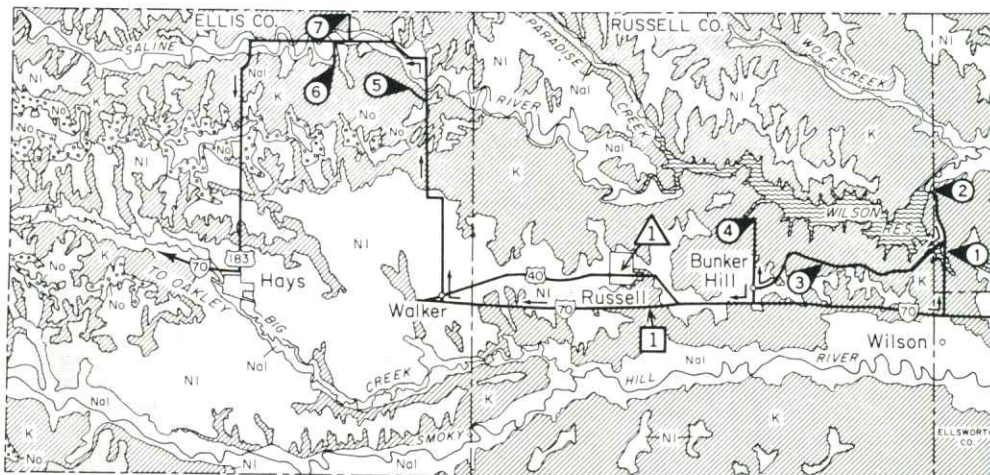


FIGURE 12—MAP SHOWING ROUTE OF FIRST DAY OF FIELD TRIP (APRIL 13, 1978). GEOLOGY MODIFIED FROM GEOLOGIC MAP OF KANSAS (1964).

- 3.2-3.5 Dakota Formation (fluvial continental facies) exposed in low cuts on both sides of highway. Trough crossbedded channel sandstone and variegated floodplain mudstone complexly interrelated here.
- 4.1 **STOP 1.** Dakota Formation—fluvial facies. See graphic section (figure 14) and photographs (figures 14 and 15).
- 4.5 Dakota Formation (fluvial facies) exposed on both sides of highway. Variegated mudstone with thin lenticular sandstone beds is overlain by flat-bedded sandstone which caps crossbedded channel facies and extends laterally so as to also overlie floodplain facies.
- 4.9 Dakota (fluvial facies) exposed on right.
- 5.3 Greenhorn Limestone exposed poorly on left.
- 5.4 Intersection with Farm Access Road 918 (FAS 918), to Hell Creek Bridge, on left; continue straight ahead. Greenhorn Limestone on left, just beyond intersection.
- 6.0 Top of Greenhorn Escarpment. Corral on left; view of Wilson Reservoir on left.
- 6.7 Entering Russell County; begin descent of Greenhorn escarpment. Greenhorn Limestone well exposed in cuts on both sides of highway to mileage 7.3
- 7.3 Graneros Shale exposed poorly in gully on right.
- 7.4 Dakota Formation exposed in gully on right. Variegated mudstone and lenticular sandstone bodies.
- 8.1 **STOP 2.** Dakota Formation—clay-ironstone facies. See graphic section (figure 16).
- 8.3 Wilson Dam. Turn around at roadside park and retrace route to FAS 918.
- 11.3 Intersection with road leading to Hell Creek Bridge (FAS 918). Turn right and proceed westward towards bridge. Greenhorn Limestone exposed in cuts on both sides of road at intersection. Road descends section from Greenhorn Limestone through Graneros Shale, into Dakota Formation.
- 11.5 Dakota sandstone poorly exposed in valley on right.
- 11.55 Dakota exposed in roadcuts on both sides of road. Clay-ironstone facies with thin lenticular sandstone beds.
- 11.65 Dakota exposed in roadcut on right. Variegated and carbonaceous mudstone and thin lenticular sandstone-fluvial facies.
- 11.9- Hell Canyon Bridge. Rocktown channel sandstone (informal member) of Dakota well exposed along west side
- 12.2 of reservoir at west end of bridge.
- 12.2 Variegated floodplain mudstone of Dakota exposed along both sides of road.

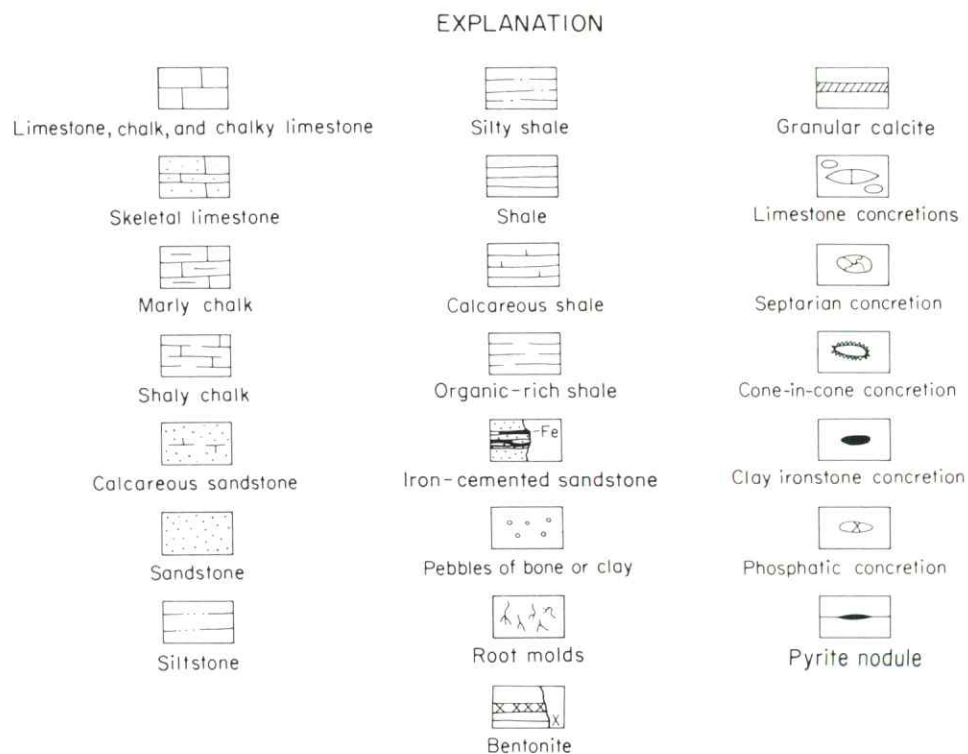


FIGURE 13—EXPLANATION OF SYMBOLS USED IN GRAPHIC SECTIONS.

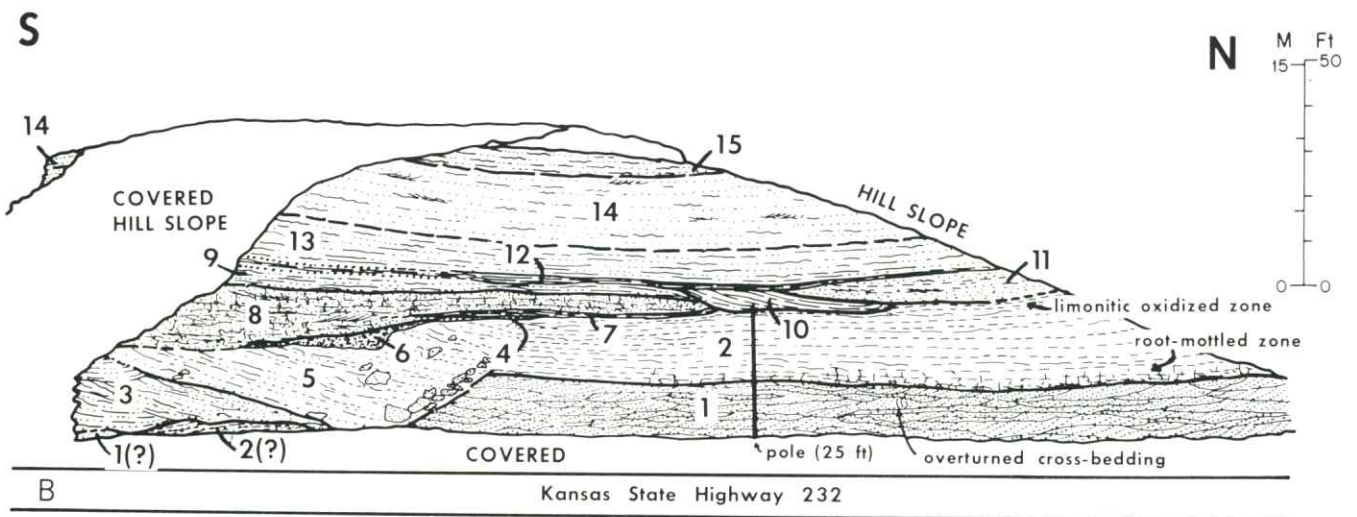


FIGURE 14—PHOTOGRAPH AND LITHOLOGIC SKETCH OF DAKOTA STRATA EXPOSED AT STOP 1. This exposure illustrates complex relationships of lithologic units in nonmarine fluvial channel and floodplain facies and marginal-marine deltaic facies in the upper part of the Dakota Formation. In general, unit 1 represents active-channel; units 2-6 represent complex floodplain and partly abandoned channel-filling processes; units 7-12 probably represent complex mixed-fluvial to marginal-marine deposition in deltaic environment; and units 13-15 may represent marginal-marine sand deposition across a deltaic surface during the initial phase of Graneros transgression. Elsewhere, Graneros Shale commonly overlies units such as 14 and 15 but has been stripped off here. Discordant surface labeled 4 is a spectacular feature of this exposure and may represent faulting of unit 5 against units 1 and 2 prior to deposition of unit 6. This surface may, however, be an erosional scarp of some sort, as indicated by numerous large exotic siltstone blocks in close proximity to discordant surface in shale of unit 5.

Main features of the lithologic units delineated follow:

UNIT 1--Trough crossbedded, medium- to fine-grained, yellowish-gray to grayish-orange, friable sandstone; plant and wood debris and root mottling at top; main exposure as much as 7 ft (2.1 m) thick; also possible small exposure of unit at lower left of cut.

UNIT 2--Blocky, variegated (yellowish- to reddish-gray) mudstone with abundant oxidized siderite (?) pellets, plant debris and root mottling; main exposure as much as 12 ft (3.7 m) thick; also probably exposure of same unit near lower left of road cut.

UNIT 3--Complex wedge-trough crossbed sets of interlaminated sand and carbonaceous shale; unit as much as 9 ft (2.7 m) thick.

SURFACE 4--Prominent discordant surface separating units 1 and 2 from unit 5; in upper part where surface brings dark-gray shale of unit 5 against yellowish-gray mudstone of unit 2, the surface appears to be a fault with small drag folds in the shale; near top the surface has strike orientation of N 37° E and dip of approximately 60° SE; in lower part, where separating unit 1 and 4, this surface is lined with limonitic sandy rubble and has an orientation of N 45-65° E and dip of 23-28° SE; shale appears drag folded against sandstone.

UNIT 5--Interlaminated carbonaceous silty shale and clayey siltstone with large exotic blocks of dense siltstone; laminae steeply inclined (15-20°) northward and truncated against discordant surface 4; siltstone blocks display irregular bedding and contain pyrite nodules and carbonized plant debris; as much as 17-18 ft (5.2-5.5 m) exposed.

UNIT 6--Discontinuous, highly ferruginous, sandy conglomeratic rubble layer with sandstone and mudstone clasts and abundant carbonized wood

fragments; unit truncates discordant surface (4) below; as much as 2 ft (0.6 m) thick.

UNIT 7--Thin, discontinuous black carbonaceous shale with abundant fine plant debris; wedges out southward and is truncated by unit 10 to north; 0-2 ft (0-0.6 m) thick.

UNIT 8--Fine-grained, well-sorted sandstone unit with abundant carbonized wood fragments and abundant root molds; unit thickens to about 10 ft (3.1 m) southward where covered and thins northward to about 3 ft (0.9 m) where it is truncated by unit 10.

UNIT 9--Interlaminated yellowish sand and dark-gray shale; as much as 2 ft (0.6 m) thick; truncated by unit 10.

UNIT 10--Brownish-black, carbonaceous silty shale overlying units 2, 7, 8, and 9; truncated by units 11 and 12; as much as 4.5 ft (1.4 m) thick.

UNIT 11--Very friable, yellowish-gray sand containing carbonaceous wood fragments; 0-4.5 ft (0-1.4 m) thick.

UNIT 12--Black, carbonaceous shale layer; relatively continuous across cut, thins northward over unit 11.

UNIT 13--Thin-bedded and wavy-bedded sandstone with interlaminated shale; sharply overlies unit 12 and grades upward into unit 14; 10-11 ft (3.1-3.4 m) thick.

UNIT 14--Flat-bedded sandstone unit, which caps hill; small-scale crossbedding and wavy bedding present; possible small burrow structures sparsely represented; unit 16 ft (4.9 m) thick.

UNIT 15--Interbedded silty sandstone and clayey siltstone with silty shale caps exposures; plant debris common; contains sparse *Planolites?* burrows and a possible *Teredolithus* unit; as much as 5 ft (1.5 m) thick.

- 12.5 Exposure on left displays carbonaceous shaly mudstone with steeply (20-25°) inclined bedding (upper-channel fill?) overlain by flat-bedded sandstone cap, which is in turn overlain by ferruginous sandstone of the Dakota.
- 12.6 Flat-bedded fluvial sandstone of Dakota exposed on left.
- 12.7 Dakota (fluvial facies) exposed along both sides of road.
- 12.8 Crossbedded fluvial sandstone of Dakota overlain by rubbly ferruginous sandstone.
- 12.9 Intersection of FAS 918 and Wilson State Park road (right). Continue west on FAS 918.
- 13.3 Dakota (fluvial facies) exposed poorly on both sides of road.
- 13.6-13.7 Cuts on both sides of road expose crossbedded fluvial sandstone of Dakota.
- 14.0 Crossbedded channel sandstone of Dakota in small cuts on both sides of road.
- 14.3 Farmhouses on left constructed of stone from Fencepost limestone bed of Greenhorn Limestone.
- 14.5 Intersection with country road. Continue west on paved road.
- 14.6 Corral on right. Dakota sandstone (fluvial facies) exposed in low cuts on both sides of road.
- 15.1 Begin ascent of Greenhorn escarpment. Dakota floodplain mudstone poorly exposed on left.
- 15.2-15.4 Deep roadcut on left. Upper part of Graneros (with X-bentonite marker bed) at base of exposure. Lincoln, Hartland, and lower part of Jetmore members of Greenhorn Limestone well exposed.
- 15.45 Cuts on both sides of road expose Lincoln Member of Greenhorn. Lowermost part of Hartland Member exposed at top of cut on left.

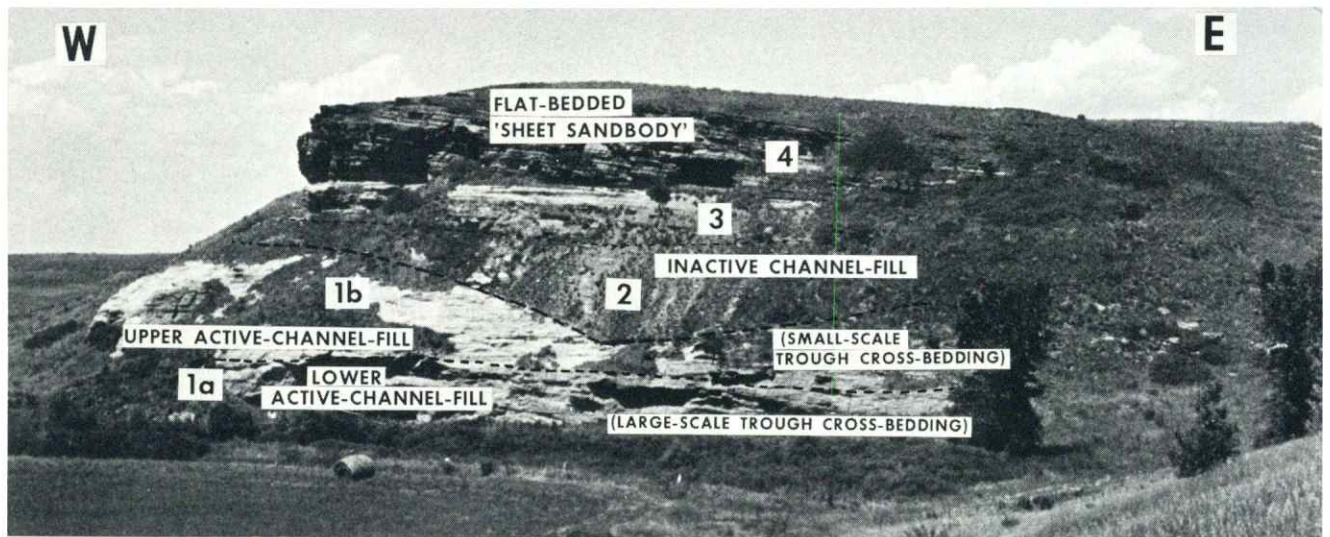
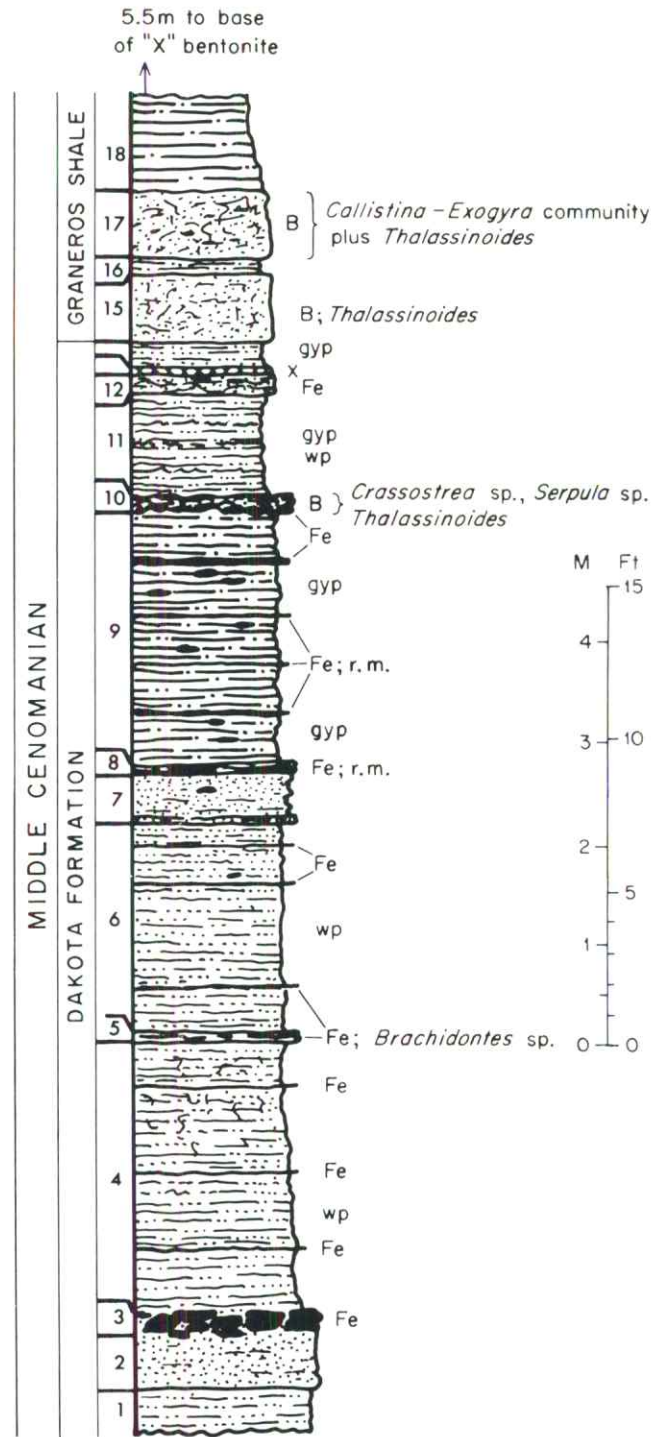


FIGURE 15—SPECTACULAR 100-FT (30-M)-THICK SECTION OF UPPER PART OF DAKOTA FORMATION EXPOSED AT STOP 1. Units 1a and 1b represent active channel-fill of Rocktown channel sandstone body; unit 1a is characterized by large (1-3 ft (0.3-0.9-m) high and 5-15 ft (1.5-4.6-m) across) trough features and medium- to fine-grained sand with mudstone clasts and limonitized wood and plant debris; unit 1b is characterized by relatively small-scale (0.5-1.5-ft (0.15-0.46-m)-thick) trough crossbed sets and fine- to very fine grained sand. About 15 ft (4.6 m) of unit 1a is exposed; unit 1b is as much as 25 ft (7.6 m) thick. Sandstone body of unit 1 is truncated by carbonaceous silty claystone and shale (interlaminated with siltstone and clayey sandstone) of unit 2, which represents inactive fill of an abandoned channel; plant debris and root mottling is common. Unit 2 is as much as 25 ft (7.6 m) thick. Unit 3 is a root-mottled, carbonaceous sandy siltstone (as much as 16 ft (4.9 m) thick) of somewhat indeterminate origin but possibly related to units 8-12 (figure 14) exposed in nearby cut. Unit 4 is same as unit 14 in nearby cut (figure 14); as much as 31 ft (9.5 m) of flat-bedded sandstone is exposed here. The very fine grained sandstone contains abundant iron-stained plant debris, sparse burrows, and *Teredolithus* borings in wood; ripple-bedding and small-scale trough crossbed sets are abundant, especially in upper part of exposure.

- 15.7 Dakota exposed in roadcut on left. Rubbly, fossiliferous, ferruginous sandstone and silty shale (shallow marine facies) of upper Dakota overlain by lowermost part of Graneros Shale.
- 16.0 Low roadcuts in Dakota (fluvial facies).
- 16.1 Roadcuts in fluvial facies of Dakota.
- 16.2 Ferruginous, crossbedded fluvial sandstone of Dakota exposed in valleys on both sides of road.
- 16.5-16.6 **STOP 3.** Shallow marine facies of Dakota Formation, overlain by complete section of Graneros Shale and lower beds of Lincoln Member, Greenhorn Limestone. See graphic section (figure 17).
- 17.1-17.4 Long roadcuts in carbonate section expose most of Lincoln Member of Greenhorn Limestone through lower part of Fairport Member of Carlile Shale.
- 17.5 Cuts, both sides of road, expose lower part of Fairport Member, Carlile Shale.
- 17.6-17.8 Roadcuts expose carbonate section extending from lower part of Fairport Member, Carlile Shale, downward to upper part of Lincoln Member, Greenhorn Limestone.
- 18.1 Cuts on both sides of road expose upper part of Graneros Shale and most of Lincoln Member of Greenhorn.
- 18.3 Roadcut on right exposes most of Lincoln Member and lower part of Hartland Member, Greenhorn Limestone.
- 18.4 Roadcut on right exposes Hartland Member and most of Jetmore Member, Greenhorn Limestone.
- 18.5 Roadcut on right exposes upper part of Hartland Member and lower part of Jetmore Member, Greenhorn Limestone.
- 18.6 Cuts on both sides of road expose upper part of Jetmore Member and Pfeifer Member of Greenhorn and basal part of Fairport Member, Carlile Shale.

FIGURE 16 (TO RIGHT)—GRAPHIC COLUMN OF UPPER DAKOTA AND LOWER GRANEROS STRATA EXPOSED AT SPILLWAY OF LAKE WILSON (STOP 2). At this locality sideritic clay-ironstone-bearing sandy shales and ferruginous sandstones in upper part of Dakota Formation represent marginal-marine brackish lagoon or interdistributary-bay deposition. Fine-grained wood and plant debris (labeled **wp** on column) and root molds (**r.m.**) are common. One specimen of *Brachidontes* sp. and several specimens of *Crassostrea* sp. and *Serpula* sp. were collected from beds indicated. Burrow mottling (**B**) and distinct *Thalassinoides* burrows occur in uppermost part of Dakota (bed 10) and lower yellowish sandstone beds of Graneros Shale (beds 15-17). Gypsum (**gyp**) is abundant on outcrop as weathering product.

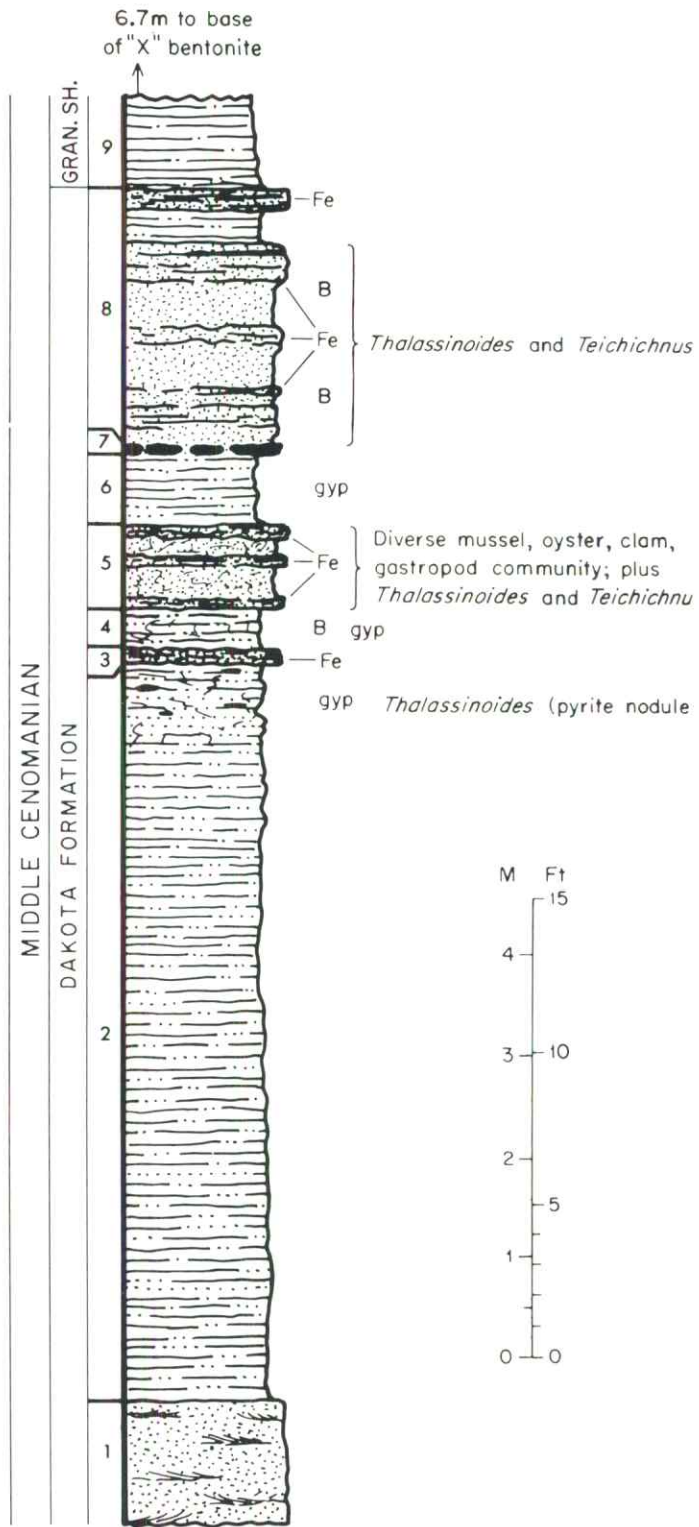


- 18.7 Crossroad. Road on right leads to Minooka Park. Proceed straight ahead.
- 18.8 Low cuts on both sides of road expose uppermost Pfeifer Member of Greenhorn and lowermost Fairport Member of Carlile.
- 18.9 Low roadcut on right exposes uppermost part of Pfeifer Member, Greenhorn Limestone, and lowermost part of Fairport Member, Carlile Shale.
- 19.1 Low cuts on both sides of road expose small portion of lower Fairport Member, Carlile Shale.
- 19.2 Weathered exposure, portion of lower part of Fairport Member, Carlile Shale.
- 19.4- Long, deep roadcut exposes lower 15-20 ft of Fairport Member of Carlile, and Pfeifer Member, Jetmore
- 19.5 Member and uppermost part of Hartland Member of Greenhorn.
- 19.6 Fluvial channel sandstone facies of Dakota Formation well exposed at bottom of draw on right.
- 19.7- Deep cuts on both sides of road expose upper half of Hartland Member and Jetmore and Pfeifer members
- 19.8 of Greenhorn.
- 19.9 Cuts on both sides of road expose upper part of Jetmore Member and lower part of Pfeifer Member, Greenhorn Limestone.
- 20.0 Cuts on both sides of road expose Pfeifer Member of Greenhorn and lower part of Fairport Member, Carlile Shale.
- 20.1 For next 1.4 mi, road crosses upland surface underlain by Fairport Member of Carlile.
- 21.1 Cuts on both sides of road expose uppermost part of Pfeifer Member of Greenhorn and lowermost part of Fairport Member of Carlile.
- 21.2 View right toward upper reaches of Wilson Reservoir.
- 21.3 Cuts on both sides of road expose Pfeifer, Jetmore, and Hartland members of Greenhorn.
- 21.5- Cut on right side of road exposes Lincoln Member of Greenhorn, Graneros Shale, and uppermost part of
- 21.6 Dakota Formation.
- 21.8 Small excavation at right exposes floodplain mudstone facies of Dakota.
- 21.9 In next 0.2 mi, several low roadcuts expose Pleistocene slope deposits.
- 22.2 View right (1:30) of channel-sandstone facies of Dakota on hill slope.
- 22.3 Old excavations on left expose mudstone facies of Dakota.
- 22.4- Cuts on both sides of road expose Dakota (floodplain facies with crossbedded channel sandstone, overlain by
- 22.7 shallow marine facies), entire Graneros Shale interval, and Lincoln, Hartland, Jetmore, and Pfeifer (lower part) members of Greenhorn.
- 22.8- Cuts along both sides of road expose lower part of Fairport Member of Carlile Shale, Greenhorn Limestone,
- 23.1 and upper part of Graneros Shale.
- 23.2 Channel sandstone facies of Dakota exposed on hill slope on right.
- 23.4 Roads converge at end of pavement. Proceed straight ahead on gravel road.
- 23.5 Cut on left exposes floodplain facies of Dakota overlain by flat-bedded fluvial sandstone facies of Dakota.
- 24.1 Low roadbank on right exposes Quaternary terrace deposits.
- 24.4 Cut bank on intermittent stream at left (3:00) exposes flat-bedded fluvial sandstone facies of Dakota.
- 24.8 Low roadcut on right exposes Quaternary terrace deposits.
- 24.9- Low roadcut on right with poor exposures of Graneros Shale.
- 25.0
- 25.2- Long, deep roadcut on right exposes Lincoln (upper part), Hartland, Jetmore, and Pfeifer members of
- 25.4 Greenhorn Limestone and basal part of Fairport Member, Carlile Shale.
- 25.5 For next several miles, road crosses upland surface underlain by lower part of Carlile Shale.
- 25.6 Low roadcuts expose a highly weathered portion of the Fairport Member, Carlile Shale.
- 26.0 Low cuts on both sides of road expose part of lower portion of Fairport Member, Carlile Shale.
- 26.2 Low roadbank on left exposes part of lower portion of Fairport Member.
- 26.6 Converging roads, with cemetery at left. Proceed straight ahead.
- 26.9 Low banks on both sides of road expose part of lower portion of Fairport Member, with many oysters.
- 27.0 Side road left. Proceed straight ahead.
- 27.5 Intersection of gravel road and Bunker Hill-Luray road. Turn right (north) on paved road.
- 28.2 Lower part of Fairport exposed in roadside ditch on right. (*Inoceramus cuvieri*, *C. woollgari*, burrows, *Pseudoperna*, "pink lime" exposed here).
- 28.8- Upper part of Pfeifer Member and lower part of Fairport Member exposed in long roadcut. Fencepost lime-
- 28.9 stone bed conspicuous in middle part of section.
- 29.0 Upper two-thirds of Hartland Member and lower part of Jetmore Member exposed on right in cutbank of intermittent stream. Roadcut ahead is in upper part of Pfeifer and lower part of Fairport.

FIGURE 17 (TO RIGHT)—GRAPHIC COLUMN OF UPPER DAKOTA AND LOWER GRANEROS STRATA EXPOSED AT STOP 3. Sideritic clay-ironstone cemented sandstone units in uppermost part of Dakota here contain abundant macroinvertebrate body fossils and the trace fossils *Thalassinoides* and *Teichichnus*. Diverse macroinvertebrate assemblage listed below was collected from bed 5 and is indicative of nearshore-marine setting. Identified taxa include:

- Brachidontes filisculptus* (Cragin)
- Brachidontes filisculptus microcostae* Stephenson
- Brachidontes* sp.
- Breviarca (Sanoarca) grandis* Stephenson
- Crassostrea soleniscus* (Meek) (short variety)
- Cymbophora spooneri* Stephenson
- Exogyra* sp.
- Geltena subcompressa* Stephenson
- Laternula virgata* Stephenson?
- Parmicorbula rupana* Stephenson?
- "*Tellina*" *dugansensis* Stephenson
- "*Tellina*" cf. "*T.*" *stabulana* Stephenson
- "*Tellina*" sp.
- Volsella tarrantana* Stephenson
- Anchura* sp.
- Lingula subspatulata* Hall and Meek (?)

Thalassinoides burrows are preserved as pyrite nodules in shale of upper part of unit 2 and as ferruginous burrows in sandstone units 5 and 8, which are intensely burrow mottled (B). Well-developed *Teichichnus* burrows also are common in units 5 and 8; many specimens grade into *Thalassinoides* structures, illustrating variability of such form ichnogenera.



- 29.1 Upper part of Pfeifer Member, Greenhorn Limestone, in low cuts on both sides of road.
- 29.4 Note use of stone posts in fences on both sides of road.
- 29.7 Side road on right marks top of Bunker Hill section. Reboard bus here after STOP 4.
- 30.2 **STOP 4.** Base of Bunker Hill section (Graneros Shale). On foot, ascend hill through entire thickness of Greenhorn Limestone. See graphic section (figure 18).
- 30.7 Reboard bus at top of hill. Proceed south on Bunker Hill-Luray road.
- 32.9 Junction with road (left) to Minooka Park. Proceed straight ahead.
- 33.6 Grade crossing at Union Pacific Railroad at north edge of Bunker Hill, Kansas.
- 34.8 Junction of Bunker Hill-Luray road with I-70. Turn right (west) onto I-70.
- 35.8 Upper part of Jetmore in low roadcut.
- 38.6 Russell exit at US-40. Proceed on I-70.
- 40.5 Roadside rest area. Lunch stop. For next several miles, highway crosses upland surface underlain by upper part of Greenhorn Limestone and lower part of Fairport Member, Carlile Shale. After lunch proceed west on I-70.
- 42.8 US-281 interchange on I-70. Proceed west on I-70. Oil wells are in northern edge of Hall-Gurney field. This field, discovered in 1931, has produced nearly 130 million bbls from the Cambrian-Ordovician, Upper Pennsylvanian, and Lower Permian.
- 43.8 Oil field on both sides of highway is part of Russell oil field, producing from rocks of the Arbuckle Group (Cambrian-Ordovician) and the Kansas City and Lansing groups (Pennsylvanian) on the Central Kansas uplift. For next several miles, route crosses loess-veneered Cretaceous rocks.
- 46.9 Russell (Balta Road) exit. Proceed west on I-70. From here to next exit, road passes through the Gorham oil field. This field, discovered in 1926, has produced approximately 87 million bbls from the Arbuckle, Upper Pennsylvanian, and Lower Permian.
- 52.0 Gorham interchange. Proceed west on I-70.
- 53.0 Entering Ellis County.
- 54.7 Walker interchange. Leave I-70.
- 54.8 Junction of exit ramp and county road. Turn right (north) towards Walker, Kansas.
- 55.5 Intersection of county road and US-40 in Walker. Proceed straight (north) on country road. (If roads are wet, alternate route will be followed west to Victoria, thence north to Saline River valley, thence southeast to STOP 5 via Saline Valley Road). For next several miles, route crosses loess-covered Carlile Shale.
- 57.8 Crossroad. Hills on horizon to north are capped by Fort Hays Limestone Member of Niobrara Chalk.
- 61.8 "T" intersection. Turn left (west).
- 62.8 Crossroad. Turn right (north). The numerous small oil fields between Walker and STOP 5 were discovered after World War II. Production is largely from the Arbuckle and/or Upper Pennsylvanian.
- 63.4- Ascending Fort Hays escarpment. Codell Sandstone Member of Carlile Shale, exposed in ditches at mile 63.5,
63.6 consists of soft argillaceous siltstone. Extensively burrowed chalky limestone in ditch on left at mile 63.6 is basal part of Fort Hays Limestone Member, Niobrara Chalk.
- 64.4 Fort Hays Member exposed on both sides of road.
- 64.5 Codell-Fort Hays contact exposed in pasture on right.
- 64.6 Large septarian concretions in pasture on right are in upper part of Blue Hill Shale Member of Carlile Shale.
- 64.7 View across Sweetwater Canyon toward Fort Hays escarpment at 11:00.
- 65.0 Blue Hill, Codell, and Fort Hays exposed in pasture on right. View left to Fort Hays escarpment.
- 65.3 Small hill in pasture on left is slump block capped by limestone of the Fort Hays.
- 65.5 Zone of grayish-orange to dark-yellowish-orange septarian concretions is in middle part of Blue Hill Shale Member.
- 65.7 Steep hill shortly west of road capped by limestone of the Fort Hays showing normal lithology at south end and on flanks of hill. Steeply south-dipping limestone at north end of hill apparently has been altered by ground-water action. Anomalous dip has resulted from slump-block tilt and/or frost action.
- 66.3 Crossing stream in Sweetwater Canyon. Bench on right underlain by Fairport Chalk Member of Carlile Shale and thinly veneered by loesslike silt. Fresh exposure of Fairport at left rear (7:00).
- 66.6 View ahead across Saline River valley to bluffs on north side of valley. Good view of Fort Hays escarpment at 10:00.
- 66.8 Crossroad at Blue Hill School.
- 66.9 Weathered Fairport exposed in Sweetwater Canyon on right.
- 67.4 Weathered Fairport exposed in roadside ditch on right.
- 68.2 Middle part of Fairport exposed in roadside ditch on right. *Inoceramus*, *Pseudoperna*, *Stramentum*.

MIDDLE CENOMANIAN

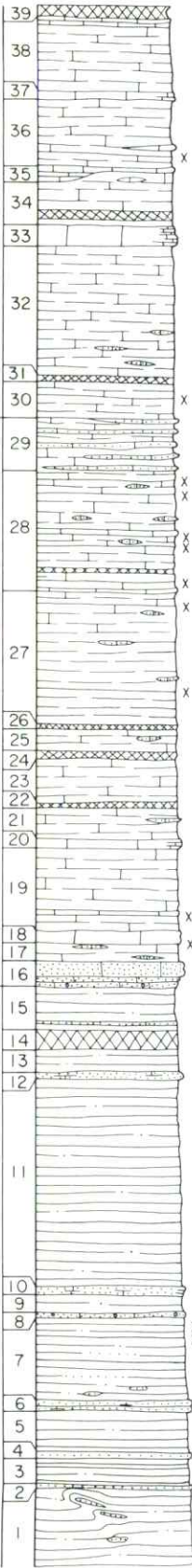
UPPER CENOMANIAN

GRANEROS SHALE

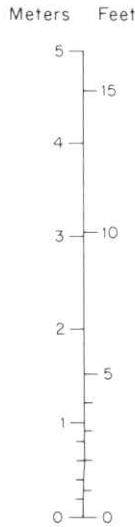
GREENHORN LIMESTONE

LINCOLN LIMESTONE MEMBER

HARTLAND SHALE MEMBER



- Ostrea beloiti* Loran
- Aphrodina lamarensis* (Shumard)
- Stomohamites* cf. *S. simplex* (d'Orbigny)
- Calycocheras*? *canitaurinum* (Haas)
- Exogyra* aff. *E. boveiensis* Bernhuist
- Inoceramus prefragilis* Stephenson
- Inoceramus ginterensis* Vermyert
- Stramentum moorei* Mattin
- Inoceramus* cf. *I. tenuistriatus* Hayao & Matsumoto ?
- Inoceramus rutherfordi* Warren
- Metiocheras whitei* Hyatt
- Kanabiceras septemstriatum* (Cragin)
- Sciponoceras gracile* (Shumard)
- Alloiocheras annulatum* (Shumard)
- Cerithiella* sp. A
- Worthoceras vermiculum* (Shumard)
- Phelepteria* sp. A
- Baculites* sp. (smooth)



LOWER TURONIAN

MIDDLE TURONIAN

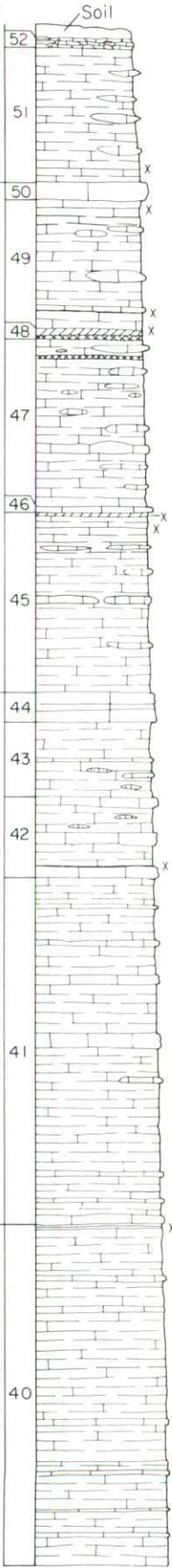
GREENHORN LIMESTONE

CARLILE SHALE

JETMORE CHALK MEMBER

PFEIFER MEMBER

FAIRPORT CHALK MBR.

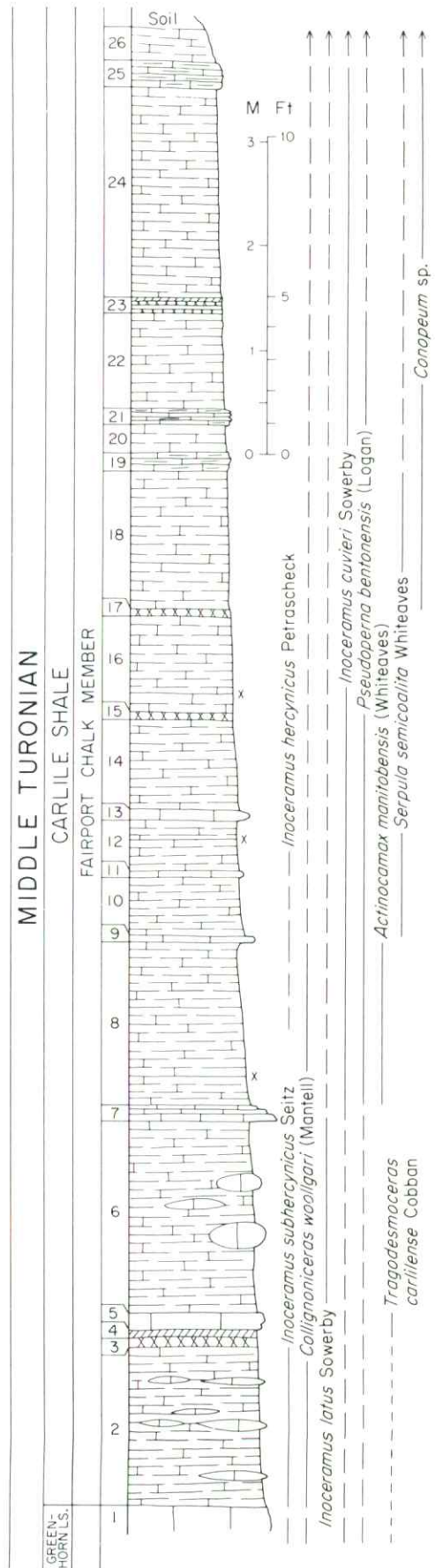


- Inoceramus prefragilis* Stephenson
- Mytiloides opalensis* (Eckse)
- Katinoceras reesei* Warren
- Tragodesmoceras bassi* Morrow
- Mammites nodosoides* wingi Morrow
- Baculites* Cf. *B. yokoyamai* Tokurajza & Shindzu
- Pseudoperma bentonensis* (Loran)
- Collignoniceras wooligari* (Zantell)
- Inoceramus cuvieri* Sowerby
- Mytiloides labiatus* (Schlotheim)
- Mytiloides subhircunicus* (Seitz)
- Anomia* sp. A
- Mytiloides* *Mytiloides* (Zantell)

- 69.0 Middle part of Fairport exposed in small canyon on right. *Inoceramus*, *Pseudoperna*, reptile bones near road.
- 69.2 Cattle guard on left. Turn left (west) into pasture and follow old lease road. Fort Hays escarpment straight ahead. Blue Hill Shale Member of Carlile is approximately 215 ft thick in this bluff.
- 70.2 Cattle guard and gate. Pull onto faint trail on right just past cattle guard.
STOP 5. Lower half of Fairport Member, Carlile Shale. See graphic section (figure 19).
 Turn around and retrace lease road to county road.
- 71.2 Cattle guard, turn left (north) on county road.
- 71.6 Roadcut and stream bank on right expose section from upper part of Jetmore to lower part of Fairport. Note ditch on hillside to left where Fencepost limestone was quarried.
- 71.7 Crossing Saline River.
- 72.8 Crossroad, proceed straight ahead.
- 73.3 Weathered Blue Hill Shale Member exposed in roadside ditch on right.
- 73.5-73.7 Weathered Fairport and high-level terrace gravel exposed in low roadcuts.
- 73.8 Road junction, turn left (west) and descend to lower level alluvial terraces of Saline River.
- 74.6 Road curves to north.
- 74.7 Sand and gravel of lower alluvial terrace exposed in roadbank on right.
- 75.1 Road junction. Turn left (west). For next half mile, route crosses lowest terrace of Saline River.
- 75.9 Terrace alluvium (sand, gravel) exposed in pit on left.
- 76.3 Terrace alluvium exposed in cuts on both sides of road.
- 76.4 Loessal soil in roadcut on right. High-level terrace alluvium exposed in pits at 10:00.
- 76.9 Terrace alluvium exposed in roadcut on left.
- 77.4 Crossing Saline River. Oil wells in vicinity are in Bemis-Shutts oil field. This field was discovered in 1928, has produced approximately 200 million bbls, and produces from the Arbuckle (Cambrian-Ordovician), Simpson (Ordovician), Kansas City-Lansing (Pennsylvanian), and Shawnee (Pennsylvanian).
- 77.6 Terrace alluvium exposed in roadcut.
- 78.7 Kaw Pipeline Company tank farm on right.
- 79.4 Crossroad, proceed straight ahead on Saline Valley Road.
- 79.6 High-level terrace alluvium exposed in low roadcut.
- 79.8 Middle part of Fairport exposed in ditch north of culvert (on right).
- 79.9 Exposure of high-level terrace alluvium.
- 80.0 High-level terrace alluvium exposed in small pit and roadcut on right.
- 80.1 View of low alluvial terrace ahead and to right. Floodplain on far right.
- 80.5 Lease road on left leading to Bemis oil field. Turn left onto Beach Ranch.
- 80.6 Cattle guard.
- 81.1 Blue Hill Shale Member of Carlile exposed in gullies on right. Exposure of Fort Hays Limestone Member straight ahead caps slump block.
- 81.5 Cattle guard.
- 81.8 Bridge.
- 81.9 "Y" in road. Turn right on secondary oil-field road.
- 82.1 **STOP 6.** Upper half of Fairport Member and lower part of Blue Hill Member, Carlile Shale. See graphic section (figure 20). Retrace lease road to Saline Valley Road.
- 83.6 Junction of lease road and Saline Valley Road. Turn right (east) on latter. Proceed to crossroad at mileage 79.4.
- 84.7 Crossroad. Turn left (north) across Saline River.
- 85.0 Crossing Saline River. Note Fort Hays escarpment ahead.
- 85.4 Ascending to level of high alluvial terrace.
- 86.2 Note pediment surface to right and left.
- 86.6 Base of King Hill. **STOP 7.** Upper half of Blue Hill Shale Member and full thickness of Codell Sandstone Member, Carlile Shale, overlain by lower half of Fort Hays Member, Niobrara Chalk. See graphic section (figure 21).
- 86.8 Reboard bus at top of hill and retrace route to lease road at Beach Ranch (mileage 80.5).
- 88.9 Crossroad just south of bridge across Saline River. Turn right on Saline Valley Road.

FIGURE 18 (TO LEFT)—GRAPHIC COLUMN OF UPPER GRANEROS, GREENHORN, AND LOWER FAIRPORT STRATA EXPOSED NORTH OF BUNKER HILL (STOP 4), NEAR CENTER OF WEST LINE SEC. 18, T. 13 S., R. 12 W., RUSSELL COUNTY, KANSAS. Section measured by Donald E. Hattin, 1962, 1964.

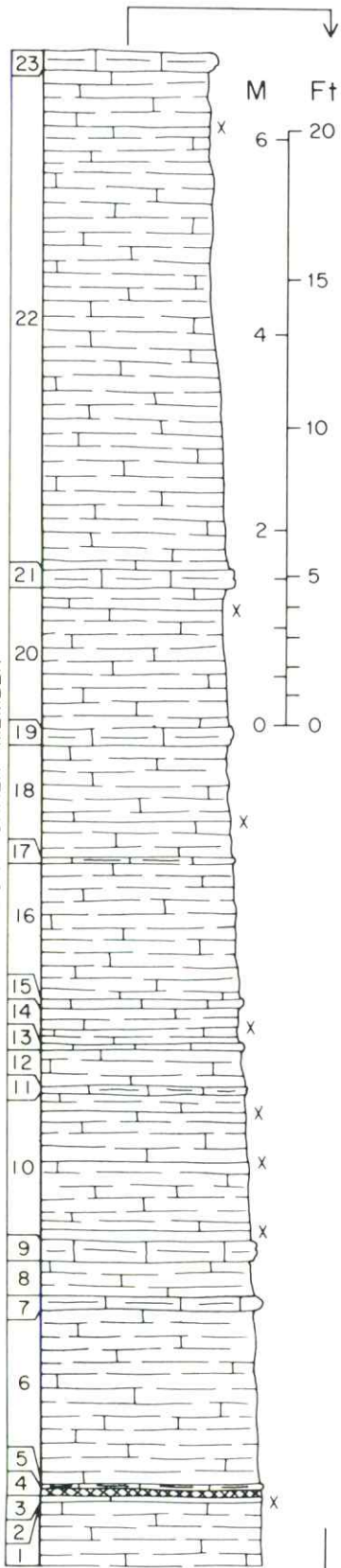
FIGURE 19 (TO RIGHT)—GRAPHIC COLUMN OF LOWER FAIRPORT STRATA EXPOSED ON CRISLER RANCH (STOP 5), SWSW SEC. 28, T. 11 S., R. 16 W., ELLIS COUNTY, KANSAS. Section measured by Donald E. Hattin, 1959.



- 90.0 Lease road leading to Bemis oil field. Proceed straight ahead on Saline Valley Road through cut in loess on both sides of road and cross Saline River.
- 90.1 View of modern floodplain of Saline River on both sides of road.
- 90.5 Entrance to Beach Ranch. Occupied for four generations, since 1883, by the Bemis family, the ranch changed ownership recently.
- 90.8 Blue Hill Shale overlain by high-level terrace alluvium in roadcuts.
- 91.4 Pits in terrace alluvium on both sides of road.
- 91.5 Crossing Saline River.
- 91.8 View south to Fort Hays escarpment, with exposures of Blue Hill, Codell, and Fort Hays.
- 91.9 Crossing Saline River.
- 92.2 Crossing low terrace of Saline River.
- 92.4 High-level terrace alluvium on left, south of hilltop. View ahead to low terrace.
- 92.9 Descend from low terrace to floodplain.
- 93.1 Cross Saline River. Terrace alluvium overlain by loess in cut on left just west of bridge.
- 93.3 Crossing floodplain of Saline River.
- 93.6 Crossing Saline River.
- 94.6 Terrace alluvium in roadcut.
- 94.7 Crossing low terrace of Saline River for next 0.6 mi.
- 95.4 Junction of Saline Valley Road and US-183. Turn left (south) on US-183. To north, where US-183 ascends north bluff of Saline Valley, upper part of Blue Hill, Codell, and Fort Hays are exposed in deep roadcut.
- 95.6 Crossing floodplain of Saline River.
- 95.8 Crossing Saline River.
- 95.9- High-level terrace alluvium poorly exposed in roadcuts.
- 96.0
- 96.2- Loessal soil in roadcut. Ahead, road ascends Fort Hays escarpment. Oil wells in vicinity are part of Bemis-
- 96.4 Shutts field.
- 96.9 Blue Hill shale overlain by (ascending) alluvium (chalky-limestone gravel), loess, and colluvium.
- 97.6- Upper part of Blue Hill, Codell, and lower part of Fort Hays in roadcuts on right. Note slumped rock.
- 97.9
- 98.2- Upper part of Blue Hill, Codell, and lower part of Fort Hays exposed in large roadcut on right. Normal fault near center of north part of cut has displaced Fort Hays downward (relatively) so that limestone lies opposite Codell. Low area between north and south parts of cut is a small colluviated valley with Fort Hays slumped to north at south side of old valley. Note channel-like structure near south end of cut.
- 98.3
- 98.4 Codell-Fort Hays contact exposed in roadcut on right.
- 98.5- Fort Hays Member exposed in cut on right. Fort Hays colluvium visible at north end of cut. Note river channel near south end of cut.
- 98.7
- 98.8- Fort Hays exposed in low roadcut. Ogallala Formation caps hill on west (right) side of highway.
- 98.9
- 99.5 Crossroad.
- 99.5- Ogallala Formation exposed in low roadcuts on both sides of road.
- 99.8
- 100.0 Smoky Hill Chalk Member of Niobrara Chalk exposed in low roadcut on left. *Volvicerasmus grandis* and *Pseudoperma congesta*.
- 100.5 Crossroad. For next several miles, highway crosses upland surface of High Plains.
- 100.6- Ogallala Formation in low roadcuts.
- 100.8
- 101.4 Ogallala Formation exposed in roadcut on left.
- 103.9 Weathered Fort Hays exposed in roadside ditch on right.
- 105.5- Fort Hays exposed in long low roadcut. Note soil profile developed at top of cut.
- 105.7
- 106.8 Loess exposed in low roadcut on left.
- 107.6- Much-fractured Fort Hays exposed in several roadcuts.
- 109.1
- 109.1 Descending Fort Hays escarpment.
- 110.0 I-70 overpass at north edge of Hays, Kansas. Dinner in Hays. After dinner, proceed to Oakley, Kansas, for overnight stop.

MIDDLE TURONIAN
CARLILE SHALE

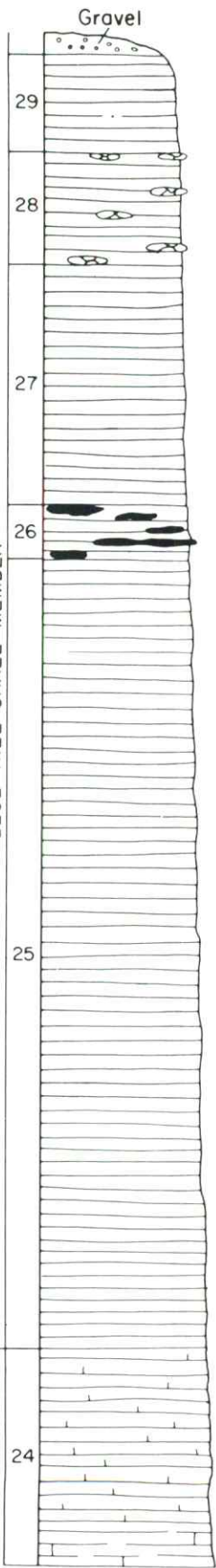
FAIRPORT CHALK MEMBER



- *Inoceramus latus* Sowerby
- *Pseudoperna bentonensis* Logan
- *Inoceramus cuvieri* Sowerby
- *Collignonicerus woolligari* (Mantell)
- *Stramentum elegans* Hattin
- *Serpula tenuicarinata* M & H
- *Actinocamax manitobensis* (Whiteaves)¹
- *Inoceramus n. sp. aff. I. flaccidus* White
- *Scaphites larvaeformis* M & H?¹

MIDDLE TURONIAN
CARLILE SHALE

BLUE HILL SHALE MEMBER



- *Inoceramus cuvieri* Sowerby
- *Inoceramus n. sp. aff. I. flaccidus* White
- *Inoceramus flaccidus* White
- *Collignonicerus woolligari* (Mantell)
- *Prionocyclus hyatti* (Stanton)

FIGURE 20 (TO LEFT)—GRAPHIC COLUMN OF UPPER FAIRPORT AND LOWER BLUE HILL STRATA EXPOSED ON BEACH RANCH (STOP 6), IN E1/2 SEC. 21, T. 11 S., R. 17 W., ELLIS COUNTY, KANSAS. Section measured by Donald E. Hattin. These species known here from single specimens.

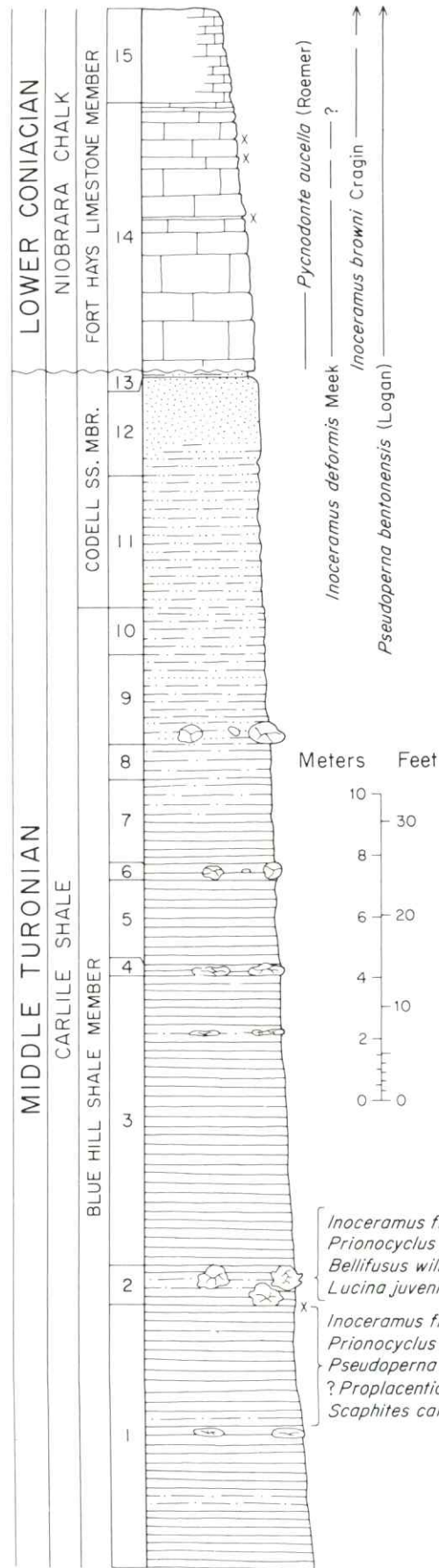


FIGURE 21 (TO RIGHT)—GRAPHIC COLUMN OF UPPER BLUE HILL, CODELL, AND FORT HAYS STRATA EXPOSED AT KING HILL (STOP 7), NE SEC. 3, T. 11 S., R. 17 W., ELLIS COUNTY, KANSAS. Section measured by Donald E. Hattin, 1959, 1964.

ROAD LOG FOR APRIL 14, 1978

Leader: Donald E. Hattin

Assisted by Charles T. Siemers and Gary F. Stewart

Miles

- 0.0 Junction of US-40 and US-83, Oakley, Kansas. Proceed westward on US-40. For next 27 mi, route crosses loess-veneered upland surface of High Plains.
- 8.3 Entering Monument, Kansas.
- 15.9 Entering Page City, Kansas.
- 17.8 Junction: K-25 turns south. Proceed straight on US-40.
- 18.4- Loess exposed in roadcut on left.
- 18.6
- 21.1 Entering Winona, Kansas.
- 23.5- Loess exposed in roadcut on left.
- 23.6

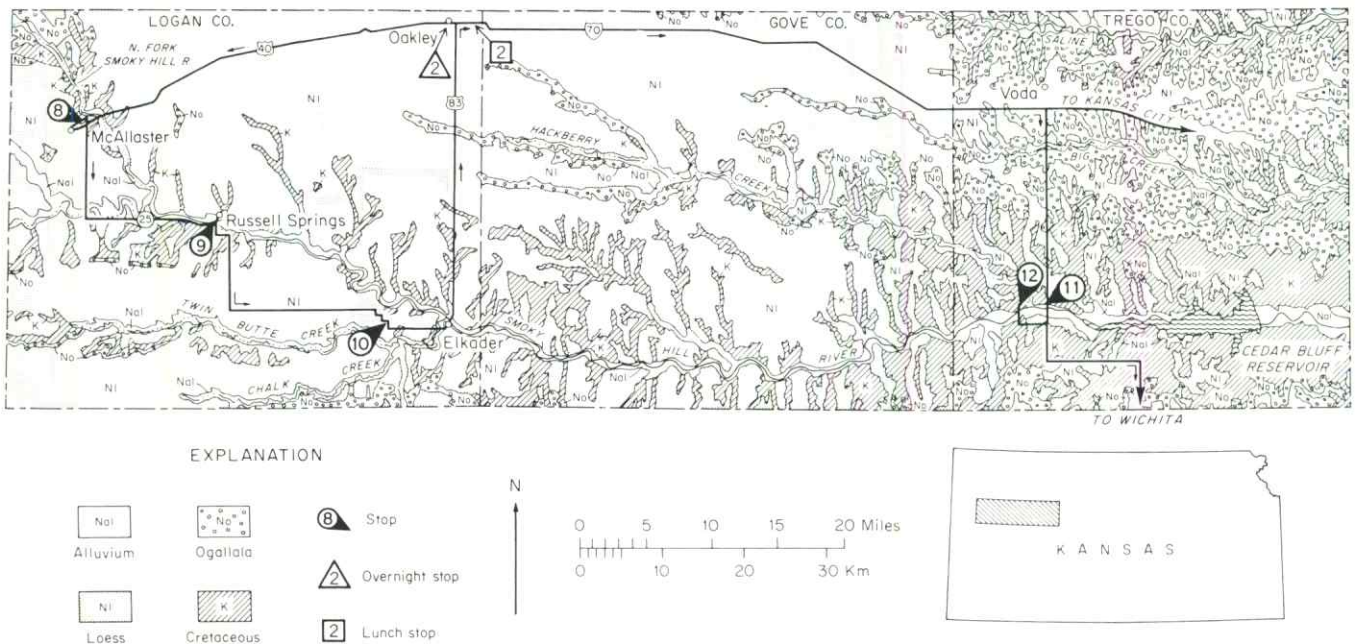
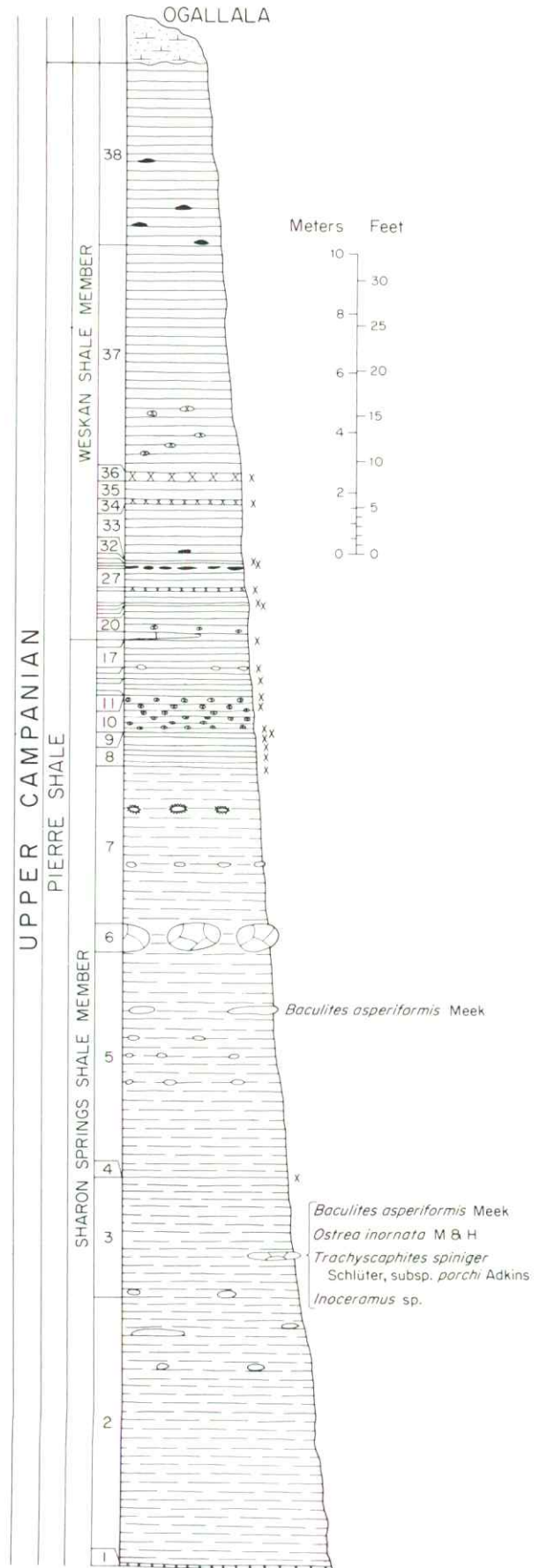


FIGURE 22—MAP SHOWING ROUTE OF SECOND DAY OF FIELD TRIP (APRIL 14, 1978). Geology modified from Geologic Map of Kansas (1964).

- 25.1- Loess exposed in roadcut on right.
- 25.4
- 25.6- Loess exposed in roadcut.
- 25.8
- 26.5- Loess exposed in roadcut on right. McAllaster Buttes on horizon at 11:30.
- 26.7
- 27.1- Sharon Springs Shale Member of Pierre Shale, overlain by loess, exposed in roadcut. Excellent exposure of the
- 27.3 Sharon Springs in pasture north of highway.
- 27.6 Crossing North Fork of Smoky Hill River.
- 28.3- Stratified Pleistocene sand and gravel (Crete Formation) overlain by loess (Loveland Formation) in roadcut.
- 28.5 McAllaster Buttes at 1:00.
- 29.9 Entering McAllaster, Kansas.
- 30.2 Dirt road on right. Turn right.
- 30.3 Junction, dirt road and abandoned US-40. Turn right on old US-40 and enter pasture through wire gate.
- 31.3 North side of McAllaster Buttes. **STOP 8** (figure 23). Walk across pasture to extensive exposures of Pierre Shale. Proceed eastward to old US-40.
- 31.9 Crossroad. Turn right (south) on county road.
- 32.8 Junction county road and US-40. Cross US-40 and proceed south on Logan County Highway 391.
- 33.1 Pierre Shale exposed in low roadcut on right.
- 33.3- Loess exposed in roadbank on left. For next several miles, route crosses upland surface of High Plains.
- 33.5
- 36.5- Loess exposed in roadcut on left.
- 36.7
- 36.8 Loess exposed in roadbank on right.
- 38.0 Valley of Smoky Hill River marked by line of trees ahead.
- 38.5 Margin of low alluvial terrace.
- 39.2 Crossing Smoky Hill River, which is an intermittent stream in this area.
- 39.4 Upper part of Smoky Hill Chalk Member of Niobrara Chalk exposed in roadcuts. Chalk is overlain by sand, gravel, and loess of alluvial terrace. Note exposures of weathered Smoky Hill in bluffs on right at 2:30.
- 39.5 Smoky Hill overlain by thin loess veneer exposed in low roadcut.

FIGURE 23 (TO RIGHT)—GRAPHIC COLUMN OF SHARON SPRINGS AND WESKAN STRATA EXPOSED AT McALLASTER BUTTES (STOP 8), SE SEC. 13, T. 12 S., R. 37 W., LOGAN COUNTY, KANSAS. Section measured by James E. Gill, U.S. Geological Survey. Numbering corresponds to published section by Gill, Cobban, and Schultz (1972, p. 40).



- 39.9 Junction Logan County Highway 391 and K-25. Turn left (east) on K-25.
- 40.1 Pierre Shale exposed in small fault block and overlain by loess.
- 40.4 Crossing low alluvial terrace of Smoky Hill River.
- 41.0 Terrace alluvium overlain by loesslike silt exposed in roadcut on right.
- 41.2 Sloping surface on right is a flanking pediment.
- 41.3- Smoky Hill Chalk Member exposed in roadcut and mantled by loess. Chalk contains *Platyceramus* and
41.4 *Pseudoperna*.
- 41.6 Loess and terrace alluvium exposed poorly in cut on right.
- 41.9- Terrace alluvium exposed poorly in roadcut.
- 42.1
- 42.2 Crossing low alluvial terrace.
- 42.3 Smoky Hill Chalk Member exposed ahead and to left in cliffed bluff overlooking valley of Smoky Hill River.
Note anomalous dips owing to flexure. Brilliant coloration of weathered chalk is common in upper
part of Smoky Hill Member.
- 42.8- Smoky Hill Chalk Member, Pierre Shale, and loess exposed in long, deep roadcut. Normal fault at mile 43.0
43.1 dropped Pierre to level of Smoky Hill Member. Pierre overlain by thick deposit of loess.
- 43.3 Erosional pillar of Smoky Hill in pasture on right.
- 43.6 Gullied alluvial terrace on left.
- 43.8 Terrace alluvium exposed in arroyo on right. Just east is roadcut in loess overlain by alluvium (sand) of high-
level terrace. Note buried soil (dark) within loess.
- 44.0 Note relatively steep dip in exposure of Smoky Hill Member in bluff of Smoky Hill River at 10:00.
- 44.1 Weathered Smoky Hill overlain by (ascending) loess and terrace alluvium (sand), all exposed in roadside ditch
on right. Note buried soil (dark) in loess.
- 44.4 Terrace alluvium (sand) and silt (probably loess) exposed in low roadcut.
- 44.8- Smoky Hill Chalk Member, Pierre Shale, and loess exposed in roadcut. Pierre slope littered with large selenite
44.9 crystals.
- 45.2 Loess exposed in roadcut on right.
- 45.5 Crossing low alluvial terrace of Smoky Hill River.
- 47.9 Junction K-25 and Logan County Highway 407. Proceed on K-25.
- 48.8 Smoky Hill Chalk Member exposed in bluffs on right at 2:00.
- 48.9 Smoky Hill veneered by colluvium of small flanking pediment in low roadcut.
- 49.2 Smoky Hill Chalk Member and overlying alluvium well exposed in arroyo on right. Cap rock on cliff is
weathered Smoky Hill.
- 49.5 Top of small rise; pull onto small ramp on right. **STOP 9** (figure 24). Cuts directly ahead are terrace gravel
and sand veneered by colluvium of flanking pediment developed around badlands (Goblin Hollow)
that comprise STOP 9. In 1965, a modern bison skull was discovered in this colluvium. Walk south
from road into badlands through section in upper part of Smoky Hill Member.
Reboard bus and proceed eastward on K-25.
- 49.7- Smoky Hill Chalk Member, overlain by terrace gravel, sand, and silt, exposed in roadcut.
- 49.8
- 49.9 Junction, K-25 and county road. Turn sharp right (south) on county road. Town visible on left at junction is
Russell Springs, former seat of Logan County. Like other towns along Smoky Hill River, Russell
Springs declined in importance because the railroad and US-40, a major transcontinental route, were
built not along the river course, but to the north, on an interstream divide. The early stage and wagon
route, however, did follow the river.
- 50.7 Junction of county roads. Turn left (east).
- 51.4 Steep hill. Road descends to level of Quaternary alluvium in small tributary to Smoky Hill River.
- 51.7 Crossroad. Turn right (south) on county road. For most of next 18 mi, route traverses upland surface of High
Plains.
- 52.6 Small exposures of Smoky Hill Member in pasture on left (east).
- 54.7 Side road left. Proceed straight ahead. Brilliantly colored cliff in distance ahead and to left is much-weathered
Smoky Hill chalk, in upper third of member, along south bluff of Twin Butte Creek.
- 56.7 Junction of county roads. Turn left (east).
- 58.7 Side road left. Proceed straight ahead on High Plains surface.
- 61.7 Crossroad. Proceed straight ahead.
- 64.7 Side road left. Proceed straight ahead.

- 67.2 Road curves to right (south). Exposures of Smoky Hill Member visible at left of road and on distant side of Smoky Hill River.
- 67.7 Road curves to left (east). View ahead (1:00-2:00) of large badlands in Smoky Hill.
- 68.2 Road curves to right (south).
- 69.2 Road curves to left (east).
- 70.2 Road curves to right. Turn left onto unimproved ranch trail, keeping fence on left.
- 70.8 Gap in fence line. **STOP 10** (figure 25). Walk north to badlands that expose middle part of Smoky Hill Chalk Member. Turn around and retrace trail to county road.
- 71.4 Junction trail and county road. Proceed south (left) on county road.
- 71.9 Junction of county roads. Turn left (east) on Logan County Highway 474.
- 73.0 Smoky Hill exposed in badlands on right.
- 74.3 Loess exposed in roadcut.
- 74.4 High-level terrace alluvium (gravel) exposed in roadcut.
- 75.0 Bridge across Ladder Creek.
- 75.3 Junction Logan County Highway 474 and US-83. Turn left (north) on US-83.
- 75.8 Remains of Elkader, Kansas.
- 76.0 Bridge across Smoky Hill River.
- 76.2 Crossing low alluvial terrace of Smoky Hill River. Note stone post on right, marked B.O.D. 1865. This and several similar posts on other well-traveled north-south roads in the area mark the Smoky Hill Trail and route of the Butterfield Overland Dispatch, a stageline that served Smoky Hill River country from June 1865 to March 1866. The line was then sold to Holiday Overland and Express Company, and finally to The Wells Fargo & Co. Indian attacks and railroad construction to the north terminated stageline operations.
- 76.4- Smoky Hill Member, overlain by high-level terrace gravel, in roadcuts and natural exposures.
- 76.6
- 76.7- Smoky Hill Member exposed in low roadcut. Alluvium, overlain by pebbly silt (colluvium), exposed in roadcut
- 76.8 ahead on right.
- 77.7 Loess exposed in roadcut on right. Badlands cut into Smoky Hill Member in draw on left.
- 78.4 Abandoned schoolhouse on left. Road to right at large sign leads to erosional features in Smoky Hill Member known as "Monument Rocks" and "Sphinx."
- 79.0 Smoky Hill Member well exposed in miniature badlands on right.
- 79.1 Unconformity between Smoky Hill Member and Pleistocene loess exposed in roadcut on right.
- 79.2 Bridge across draw.
- 80.0 Smoky Hill Member exposed in many places in large draw on left.
- 81.2 Smoky Hill Member exposed in draw on right at 4:00.
- 81.7 Loess exposed in roadcut on right.
- 82.0 Side trail on right. Smoky Hill Member exposed in draw on both sides of highway.
- 83.2 Loess exposed in roadcut on right.
- 84.3 Bridge. Loess exposed in roadcut just south of bridge.
- 87.2 Crossroad. Proceed on US-83.
- 89.2 Ogallala Formation exposed in draw on right.
- 89.7- Ogallala Formation, overlain by Pleistocene alluvium (sand) and loess, exposed in deep roadcut.
- 89.9
- 90.0 Bridge.
- 90.8 Crossing loess-veneered upland surface of High Plains from here to Oakley.
- 92.9 Alluvium (sand), overlain by loess, exposed in roadcut. Ogallala Formation exposed in draw on left.
- 94.9 Loess exposed in roadcut.
- 97.6- Loess exposed in roadcuts.
- 97.7
- 97.9 Junction US-83 and 40 at Oakley. Turn right (east) on US-40. From here to Voda exit, route crosses loess-veneered upland surface of High Plains.
- 99.7 Roadside park.
- 99.9 Entering Gove County.
- 100.0 Junction US-40 and I-70. Turn right onto eastbound ramp of I-70.
- 120.1 Roadside park on I-70.
- 130.8 Loess exposed in roadcut on right.

FIGURE 24 (TO RIGHT)—GRAPHIC COLUMN OF SMOKY HILL STRATA EXPOSED AT GOBLIN HOLLOW (STOP 9), E1/2 SEC. 27, T. 12 S., R. 35 W., LOGAN COUNTY, KANSAS. Section measured by Donald E. Hattin and Gary F. Stewart, 1965.

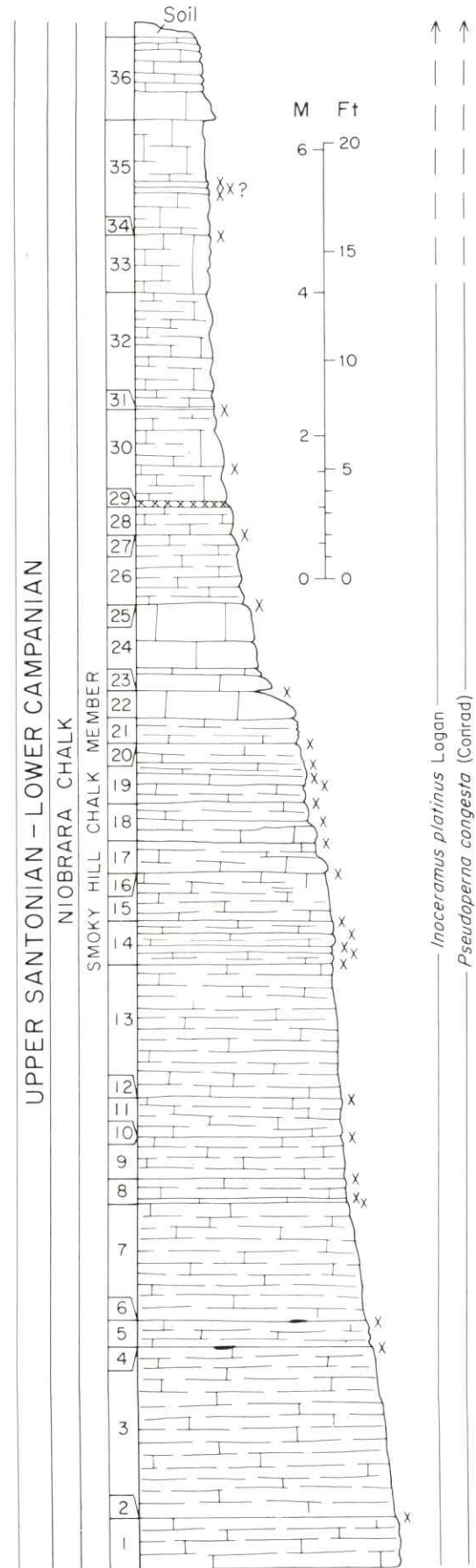


FIGURE 25 (TO RIGHT)—GRAPHIC COLUMN OF SMOKY HILL STRATA EXPOSED AT CHALK BLUFF (STOP 10), SW SEC. 25, T. 14 S., R. 33 W., LOGAN COUNTY, KANSAS. Section measured by Donald E. Hattin and Philip H. Heckel, 1965.

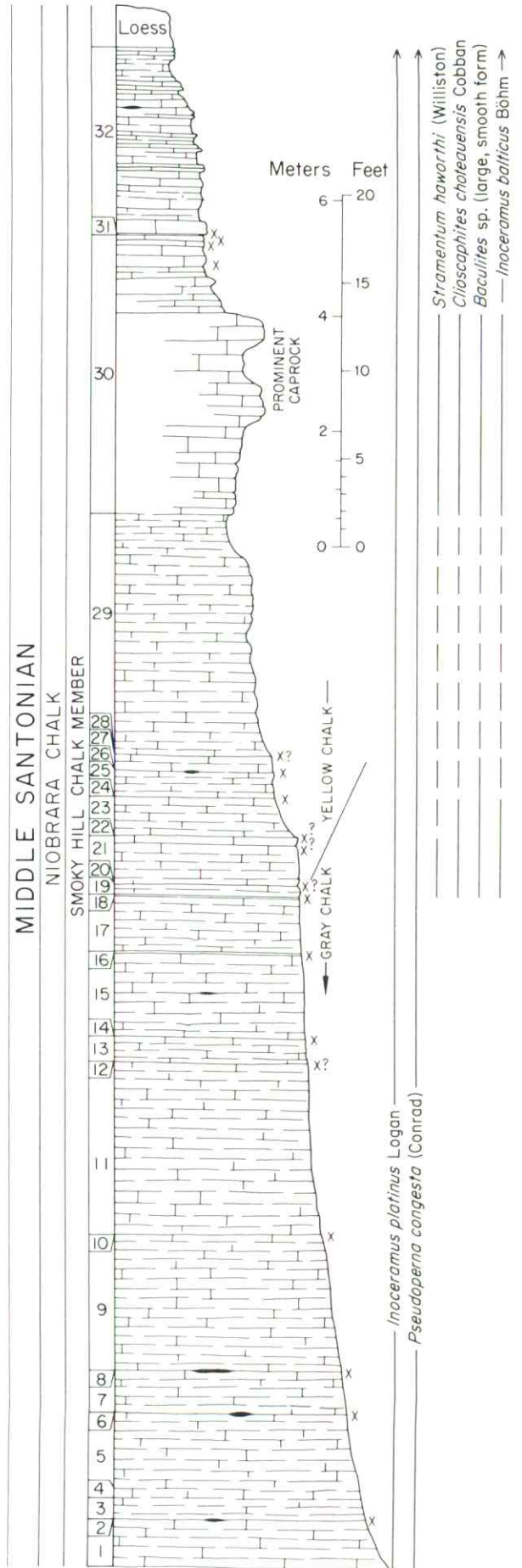
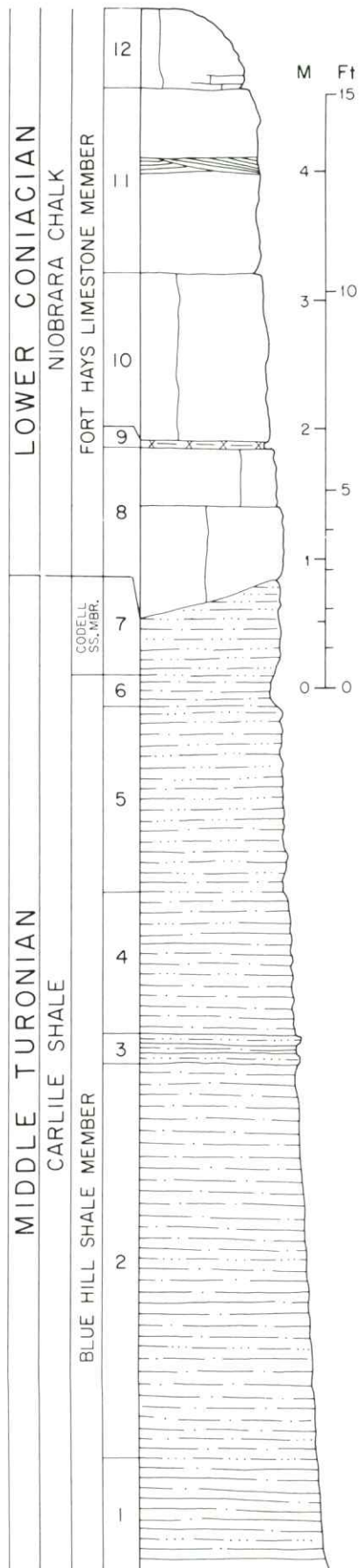


FIGURE 26 (TO RIGHT)—GRAPHIC COLUMN OF UPPER BLUE HILL, CODELL, AND FORT HAYS STRATA EXPOSED ON VODA ROAD, ON NORTH BLUFF OF SMOKY HILL RIVER (STOP 11), NW SEC. 29, T. 14 S., R. 24 W., TREGO COUNTY, KANSAS. Section measured by Donald E. Hattin and Gary Stewart, 1965.



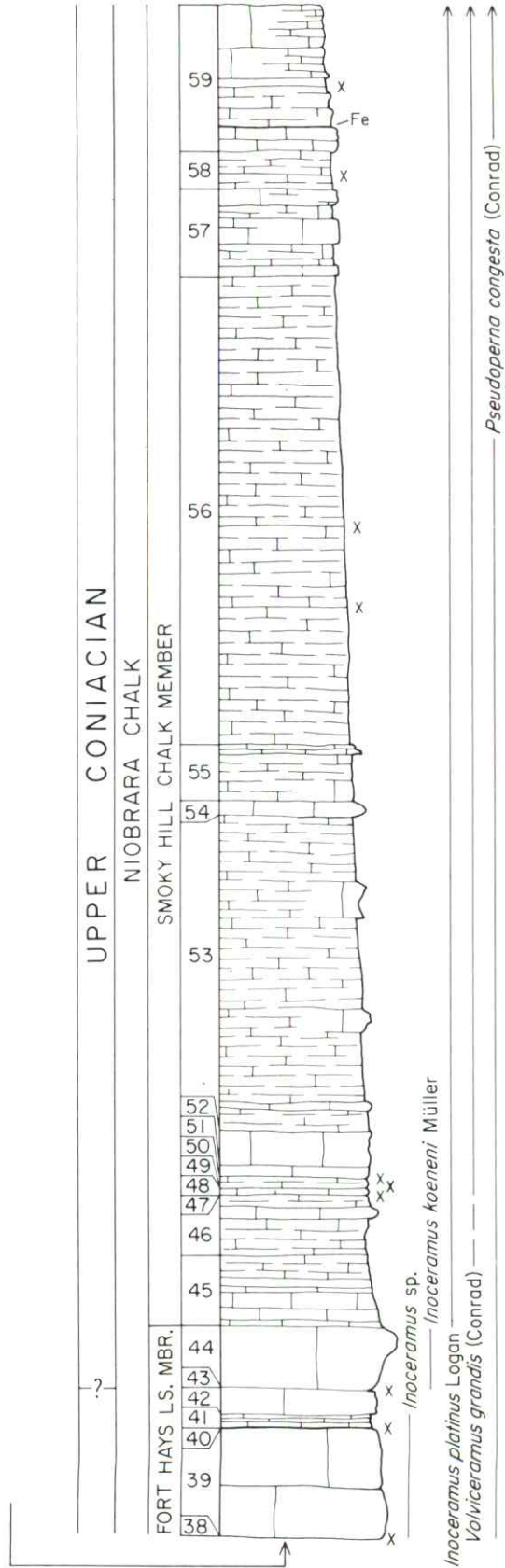
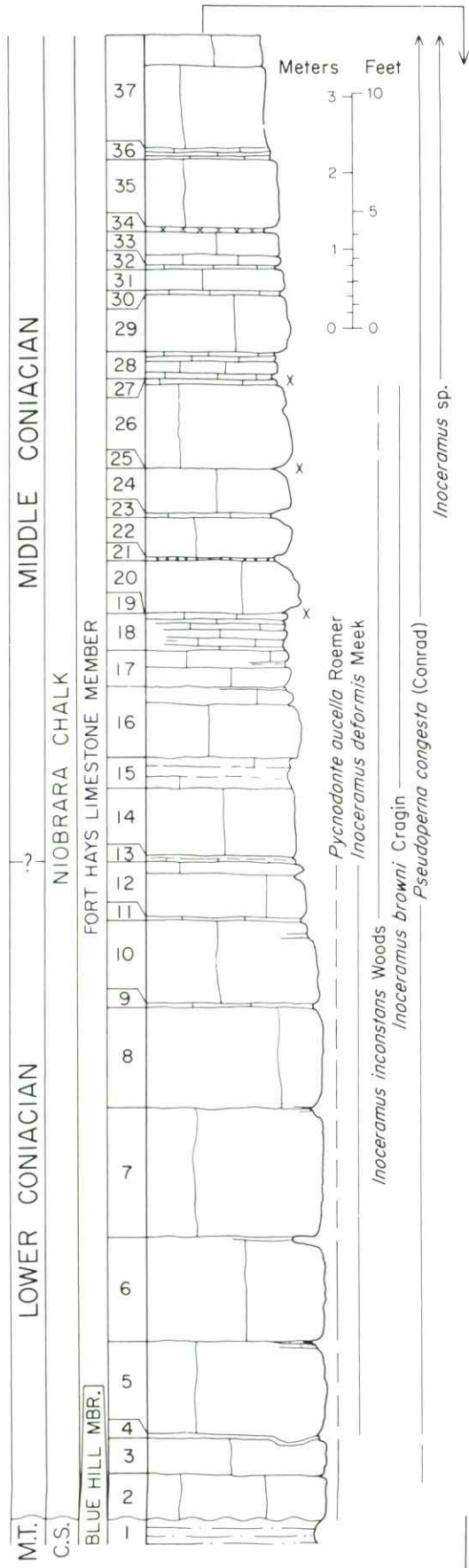
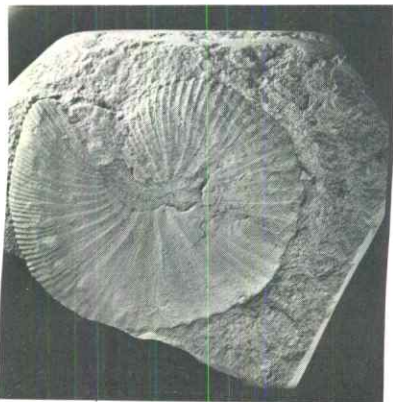


FIGURE 27 (TO LEFT)—GRAPHIC COLUMN OF ROCKS EXPOSED AT MOUTH OF HACKBERRY CREEK (STOP 12, O'TOOLE RANCH), SW SEC. 24 AND NW SEC. 25, T. 14 W., R. 25 W., TREGO COUNTY, KANSAS. Section measured by Donald E. Hattin and Craig Hatfield, 1962. C.S. = Carlile Shale; M.T. = Middle Turonian.

- 135.0 Loess exposed in roadcut on right.
 136.3 Entering Trego County.
 138.8- Loess exposed in roadcut on right.
 139.1
 140.9 Loess exposed in roadcut on left.
 141.6- Loess exposed in roadcut.
 141.9
 142.9 Voda interchange. Turn right onto exit ramp.
 143.0 Stop sign. Turn right (south) on Voda Road.
 145.1 Pleistocene alluvium and loess exposed in roadcut on left. Prominent buried soil (dark) about halfway between top and base of cut. Conspicuous filled burrow lies in and below soil zone. Irregular-shaped calcareous nodules abundant in zone below soil. Colluvium and scattered blocks of Ogallala lie at top of cut.
 145.7 Bridge across intermittent stream.
 145.8 Ogallala Formation exposed in roadside ditch on right and in graded bank on left.
 145.9 Roadcut in sand and gravel deposit derived from Ogallala Formation, which closely underlies upland surface in distance on right.
 152.4 Junction Voda Road and Trego County Highway 458. Proceed on Voda Road.
 156.4 Junction Voda Road and Trego County Highway 462. Proceed on Voda Road.
 156.7 View ahead to valley of Smoky Hill River.
 157.0 Top of bluff overlooking valley of Smoky Hill River. Smoky Hill Member exposed in roadcut on left.
 157.3- Fort Hays Member, overlain by colluvium, exposed in roadcuts on left.
 157.4
 157.5 Upper part of Blue Hill Shale Member, Codell Sandstone Member, and lower part of Fort Hays Limestone Member exposed in roadcut on left. **STOP 11** (figure 26).
 157.6 Intermediate-level alluvial terraces of Smoky Hill river visible on left.
 157.7 Floodplain of Smoky Hill River. Low-level terrace can be seen at right and right rear. Cross Smoky Hill River.
 157.9 Crossing margin of one of intermediate-level terraces. Blue Hill Shale Member exposed poorly in roadside ditch on right, beneath terrace alluvium. Note large septarian concretions in pasture on right.
 158.0 Terrace alluvium exposed in roadside ditch and roadbank on right. Note gravel pit in pasture on left. Pit is in the next-to-highest of four terraces that can be readily distinguished on the south side of the river at this point.
 158.3 Alluvial sand of high-level terrace exposed in roadcut on right.
 158.4 Crossroad. Turn right (west). For next 1.4 mi, route crosses surface of highest terrace of Smoky Hill River. Gently arched Fort Hays strata visible in bluff on north side of Smoky Hill River, on right.
 160.1 Fort Hays member exposed in roadside ditch and pasture on right.
 160.3 Fort Hays Member, overlain by terrace alluvium, exposed in roadside ditch on right.
 160.4 "T" intersection. Turn right (north). Fort Hays exposed in pasture and along road on right.
 160.6- Crossing low terraces and floodplain of Smoky Hill River. Cross Smoky Hill River.
 160.8
 160.9 Stop on north side of river. Cross fence and walk eastward to bluff at confluence of Hackberry Creek and Smoky Hill River. **STOP 12** (figure 27). Party will examine section along cliffs extending upstream for one-half mile along Hackberry Creek and in badlands above the cliffs.
 Follow ranch trail to wire gate. Cross fence and follow road south to waiting bus.
 160.9 Reboard bus and retrace route to Voda Road.
 161.4 County road junction, turn left (east).
 163.4 Junction of county road and Voda Road. Turn right (south) on Voda Road. Proceed to Garden City (dinner), Wichita (for plane connections), and Oklahoma City.

END OF ROAD LOGS



KANSAS GEOLOGICAL SURVEY
THE UNIVERSITY OF KANSAS
LAWRENCE, KANSAS 66046