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FIELD TRIP TO THE KANSAS CRETACEOUS
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By

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FIELD TRIP TO THE KANSAS CRETACEOUS
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MEETS: McCollum labs parking lot

This two-day field trip focuses on rocks deposited during the Cretaceous Period, about 140 to 65 million years ago, in western and central Kansas (Figure 1). The first day will be spent in the Niobrara chalk along the Smoky Hill River in Gove and Trego counties. The Niobrara was deposited late in the Cretaceous, about 80 million years ago, when the western United States was covered by a sea (Figures 2 and 3) that was several hundred feet deep. The bottom of that sea was warm, dark, and relatively flat. The remains of single-celled animals that lived in the oceans would rain down on the ocean floor, forming a limy ooze at the rate of a fraction of an inch per year, eventually accumulating to thicknesses of as much as 750 feet. That ooze was the perfect medium to trap and preserve the animals that lived in and around the Cretaceous sea, including mosasaurs, plesiosaurs, fish, sharks, and pterodactyls. The first large vertebrate fossil to come out of the chalk was discovered in 1867 by the post surgeon at Fort Wallace, near the Colorado border. That set off a collecting spree in the 1870s that attracted paleontologists from around the world. Among their more notable finds was the discovery of *Hesperornis*, a toothed-bird fossil that was particularly important at the time because of the debate about Darwinian evolution. Today, the outcrop area (Figure 4) still attracts large numbers of fossil collectors, including commercial companies that take fossils from the Niobrara for sale to museums, scientists, and private collectors, both in the US and abroad. Casual collectors are far more likely to find trace fossils (burrows and borings; Figure 6) and invertebrate remains, including clams (inoceramids and oysters), cephalopods, and barnacles (Plate 1).

The second day of the field trip will be spent looking at rock units older than the Niobrara, mostly the Greenhorn Limestone (Figure 5) and the Dakota Formation. The Greenhorn includes the post-rock limestone, which was quarried and used by settlers for buildings and fenceposts throughout north-central Kansas. Invertebrate fossils of the Greenhorn generally are similar to those found in the Niobrara (Plate 2). The Dakota is composed mostly of shales and clays, though its most noticeable component is the red, crumbly sandstone that caps many of the hills in the Smoky Hill River valley. The main outcrop belt of the Dakota in Kansas is from Rice County to Washington County. The Dakota is present in the subsurface to the west, where it is sometimes used as a source of groundwater and could be an important replacement for dwindling water supplies from the overlying Ogallala Formation. Because of the uneven quality of water from the Dakota, the Survey is studying the unit to provide more information on its possible use as a water source. Invertebrate fossils from the Dakota and overlying Graneros Shale are shown in Plate 3.

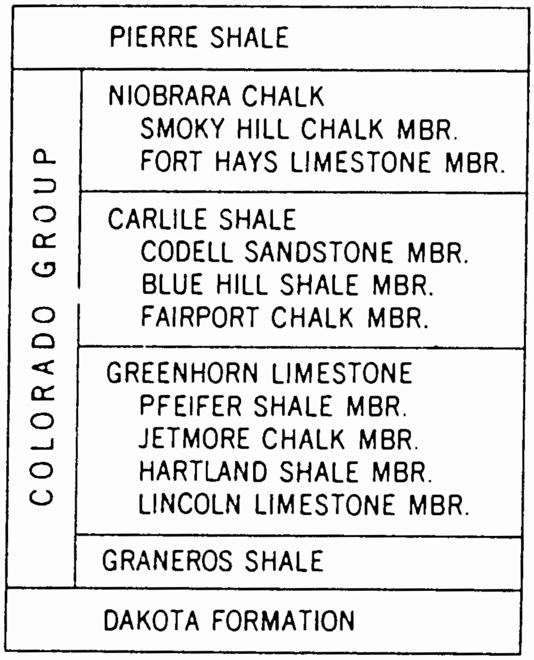


Figure 1.—Stratigraphic classification of Upper Cretaceous rocks in central and western Kansas (from Hattin, 1982).

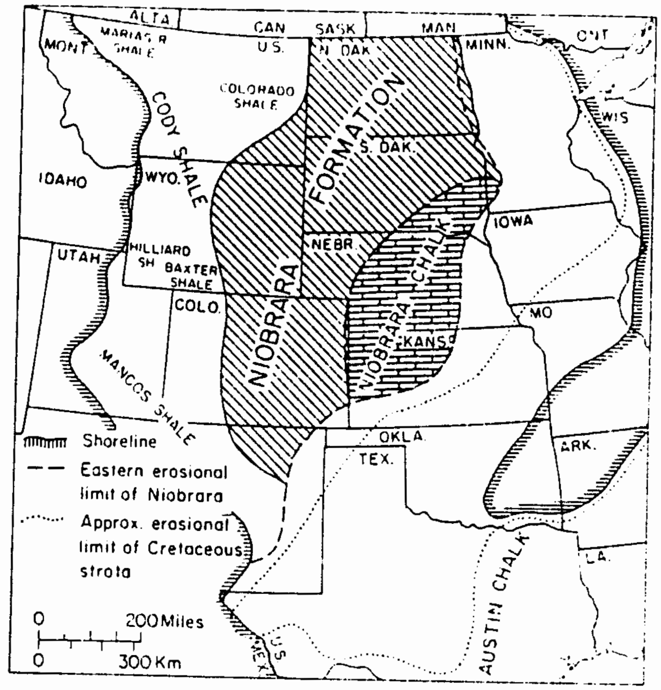


Figure 2.—Paleogeography during maximum extent of "Niobrara Sea," regional distribution of Niobrara Chalk, and nomenclature of laterally equivalent marine units (from Hattin, 1982).

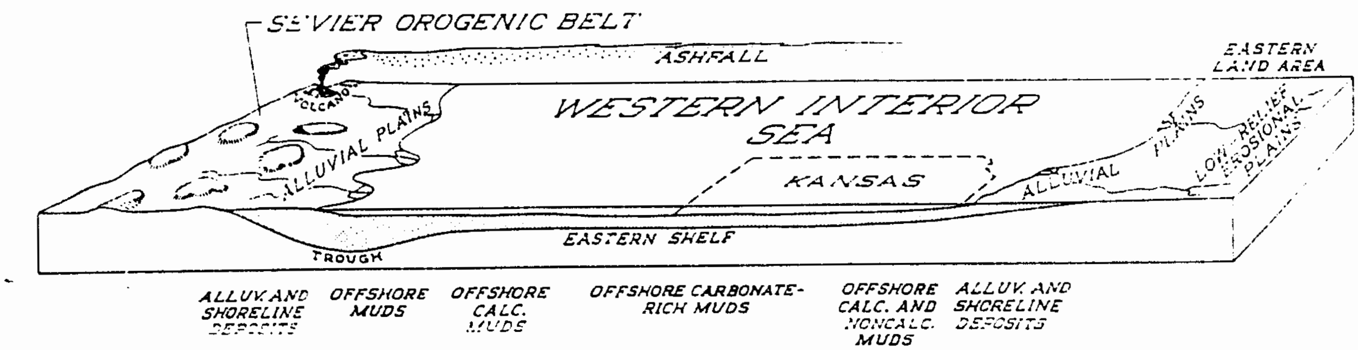


Figure 3.—Block diagram depicting a portion of the Western Interior basin and adjacent areas during deposition of the Niobrara Chalk (from Hattin, 1982).

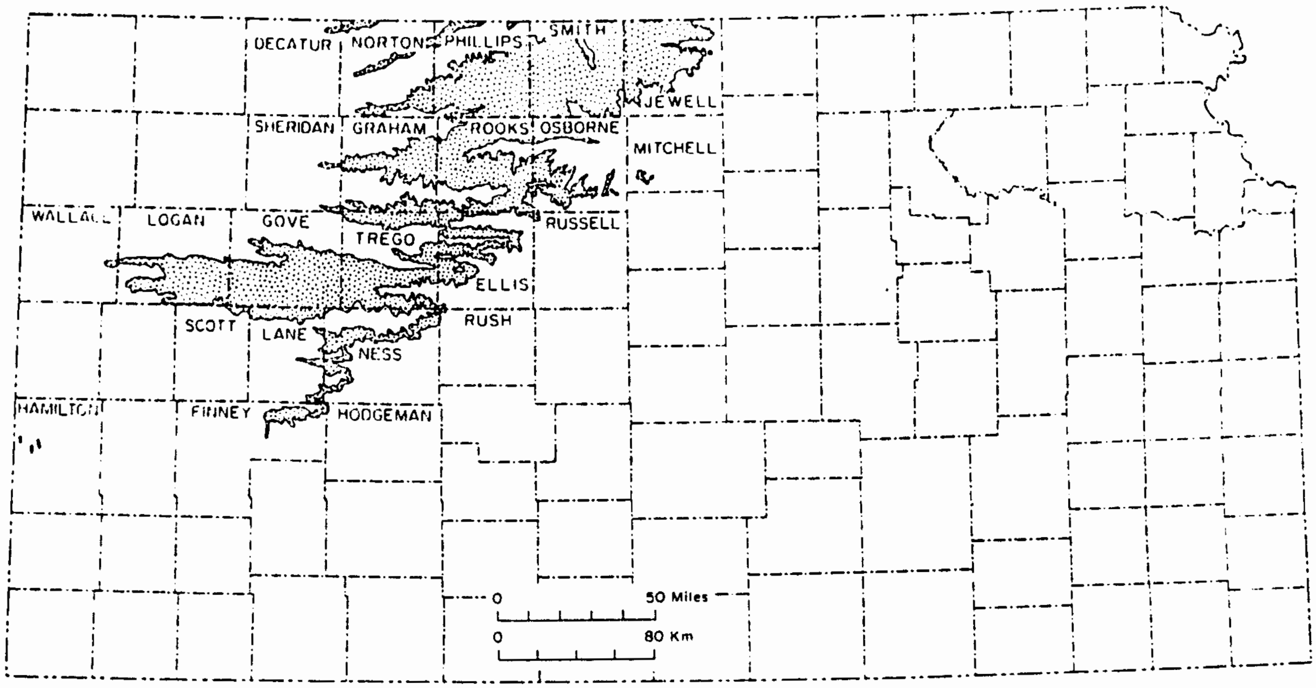


Figure 4.—Map of Kansas showing outcrop (stippled) of Niobrara Chalk (from Hattin, 1982).

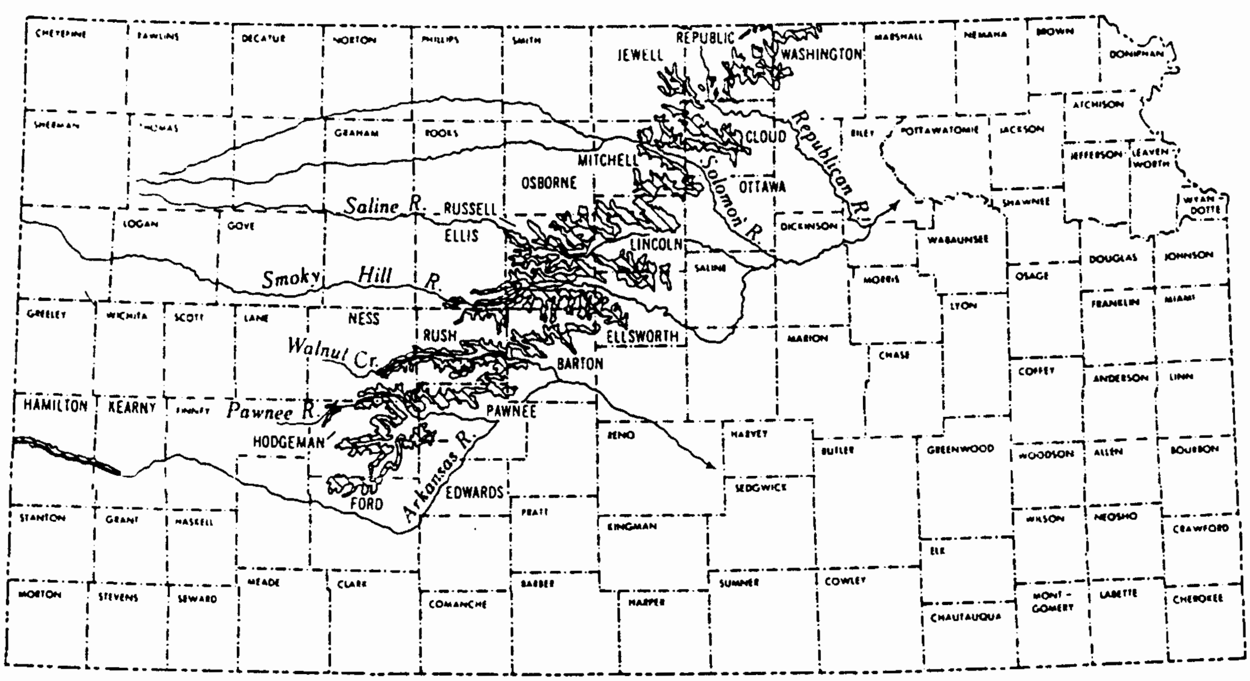


Figure 5.—Map of Kansas showing outcrop (diagonal striped) of Greenhorn Limestone (from Hattin, 1975).

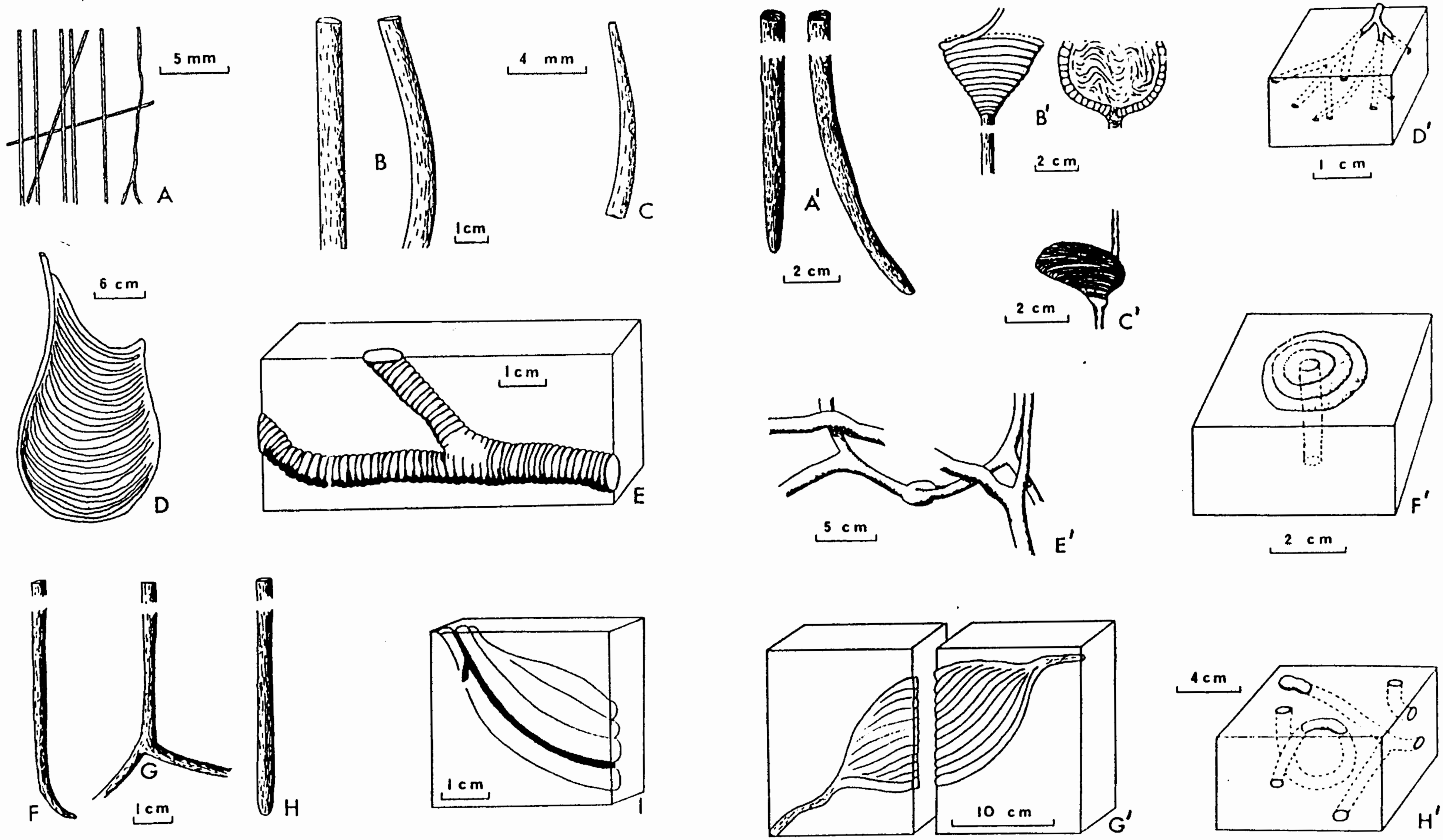
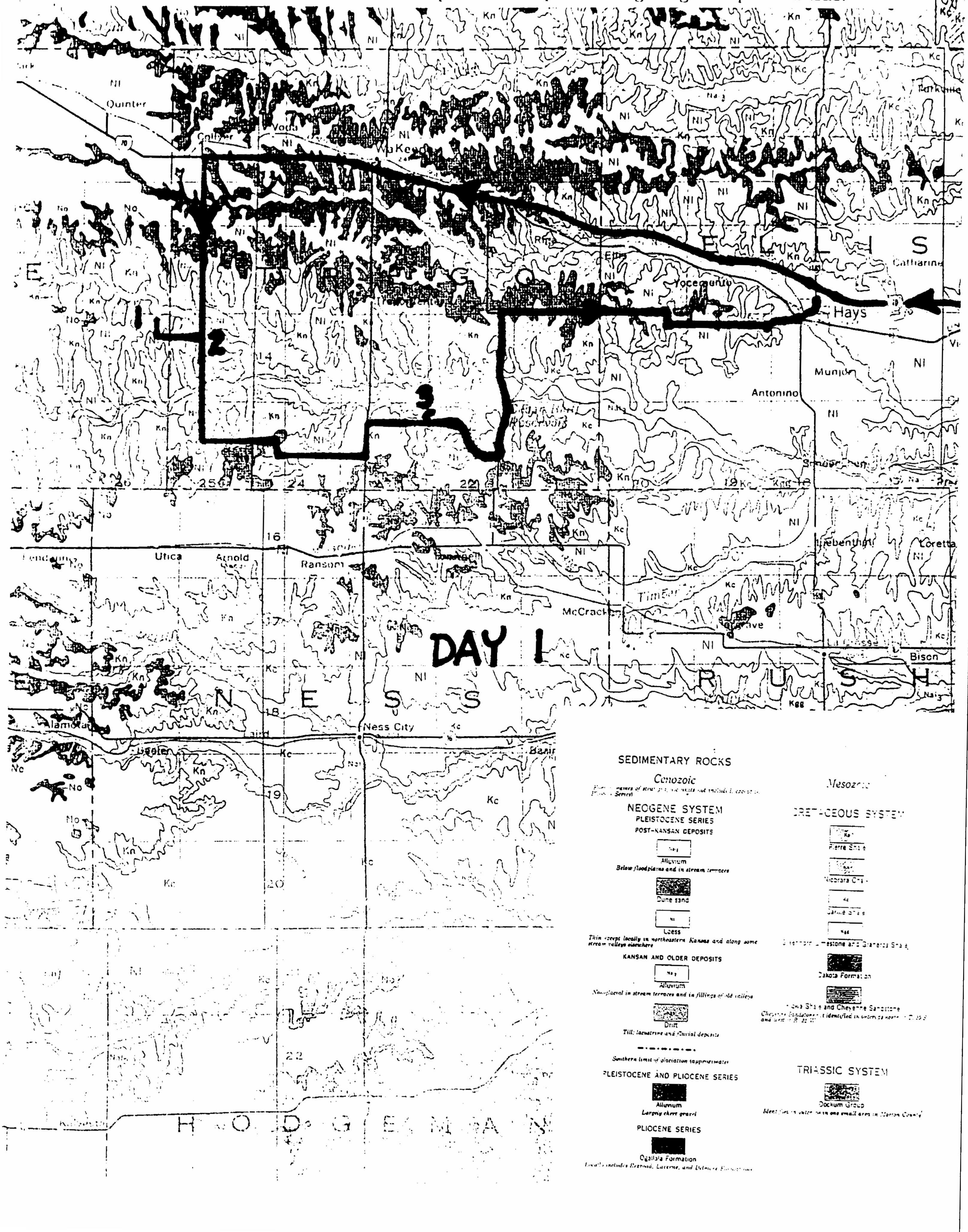


Figure 6.—Diagramatic reconstructions of trace fossils common in the Fort Hays Limestone Member of the Niobrara Chalk (from Frey, 1970); scales as indicated on each reconstruction. A. *Trichichnus linearis*. B. "Cylindrical shafts." C. "Scaphopod-shaped tube." D. *Zoophycos* ichnosp. E. *Arthrophycus*-like burrow. F-H. Mineral-filled burrows independent of other trace fossils. I. Secondary mineral-filled burrow coursing along primary spreite burrows. A'. *Cylindrichnus concentricus*. B', C'. ?*Rosselia* ichnospp. D'. *Chondrites* ichnosp. E'. *Thalassinoides* ichnosp.

Figure 7.—Stops for Day 1 of fieldtrip shown on portion of geologic map of Kansas.



DAY 1
(Figure 7)

0.0 Leave parking lot, and proceed north on U.S. Highway 59 to the West Lawrence entrance to the Kansas Turnpike. Head 270 miles west on Interstate 70 to the Collyer exit. Chapter 2 of **Roadside Kansas** provides a guide to the geologic features along the route. Take the Collyer exit, and go 10 miles south on the gravel road.

10.0 (mileage between roadlog entries)

10.0 (mileage between stops) At this point the road crosses the old Butterfield Overland Dispatch stagecoach route that ran from Atchison to Denver. Continue south.

2.5

12.5 Turn west.

2.7

15.2 Go north on the dirt road at the Castle Rock sign for one mile, then a short distance east to the scenic overlook. STOP 1. The elevation here is 2577 ft., the highest point on this field trip, and about 100 feet higher than the top of Castle Rock, which stands about 50 feet above the surrounding prairie. This bluff is capped by the Ogallala Formation, which is composed mostly of sand and gravels that eroded off the face of the Rocky Mountains and were washed out onto the Kansas plains about five to 10 million years ago. Here the Ogallala is in contact with the Smoky Hill Chalk Member of the Niobrara Chalk. The road continues south and east, to the bottom of the bluff, then north past the base of the bluff to Castle Rock. This east face is a maze of narrow canyons, hoodoos, and other erosional features, including a small cave near Cobra Rock. Castle Rock was an important landmark on the Butterfield Overland Dispatch stage route, marking the approximate halfway point between the Missouri River and Denver. Traces of the old stage route are still visible a short distance north of Castle Rock, and there was a Castle Rock station about two miles northeast of Castle Rock itself. A measured section of the bluff and adjacent erosional pinnacle directly south of Castle Rock is shown in Figure 8 and detailed on p. 9 (from Hattin, 1982). From Castle Rock, return south to the east-west section road, and head east.

2.7

2.7 Turn south.

0.5

3.2 STOP 2. Hike a short distance to the east to Wildcat Canyon, a maze of badlands in the Niobrara. Castle Rock and Monument Rocks, in far western Gove County, are probably the best known outliers of the Niobrara and have long served as collecting locations. This area is lesser-known, and thus a little less picked over, in terms of looking for fossils. Commercial collectors recently removed several large fish from this location, however invertebrate fossils generally are abundant (see Plate 1). A measured section is shown diagramatically in Figure 8 and detailed on p. 10 (from Hattin, 1982). The uppermost exposure at this locality is approximately 60 feet below the lowermost exposure at Castle Rock. From here, go south 6.5 miles.

6.5

6.5 Turn east.

3.0

9.5 Turn south.

1.0

10.5 Turn east.

8.8

19.3 Stop sign at U.S. Highway 283, which runs south to Ness City and Dodge City, and north to Trego Center, WaKenney, Hill City, and Norton. Turn north

2.0

21.3 Turn east.

4.0

25.3 Turn north to the Public Wildlife area.

1.1

26.4 Turn east, go up steep hill.

0.5

26.9 Turn north.

0.4

27.3 STOP 3. Cedar Bluffs. This sheer cliff has been carved from the Fort Hays Limestone Member of the Niobrara Chalk and is the source of the name for the lake below (or what remains of the lake; compare the present view with Plate 1, Figure 1). Cedar Bluff Reservoir was originally built for irrigation downstream in the Smoky Hill River valley. However, declining water tables—lowered by groundwater-based irrigation and conservation practices that have decreased runoff—have combined to reduce streamflow of many western Kansas streams, including the Smoky Hill, which feeds this lake. As a result, lake levels have dropped in several western Kansas reservoirs to levels well below those that were planned when the dams, such as Cedar Bluffs, were built. If this reservoir were at normal operating level, it would be a mile across and about 50 feet deep at the base of this cliff. Backtrack from Cedar Bluff to the east-west section road and then turn east.

1.0

1.0 Cedar Gorge, with exposures of the Fort Hays limestone.

2.0

3.0 Carlile Shale, the formation immediately below the Niobrara, is exposed in a roadcut west of the road. The Carlile consists of a chalky shale, bentonites, chalk, and fine-grained sandstones. Its maximum thickness is about 300 feet.

0.4

3.4 Page Creek.

1.1

4.5 Curve east and climb out of Goat Canyon through an exposure of the Fort Hays limestone.

1.6

6.1 Stop sign at Kansas Highway 147. Go north across Cedar Bluff dam.

10.1

16.2 K-147 curves to the west. Turn east on the gravel road.

12.0

28.2 Turn south for one mile.

1.0

29.2 Turn east.

8.8

38.0 Stop sign at junction with Alternate U.S. Highway 183. Turn east and pass by Old Fort Hays on the south and Frontier Historical Park and Fort Hays State University on the north. Go 1.5 miles east.

1.5

39.5 Junction with U.S. Highway 183 (Vine Street). U.S. 183 runs north to Rooks County, the only Kansas county named after a Civil War private. Turn north 1.3 miles to the Vagabond Motel. End of Day 1.

Bluff and adjacent erosional pinnacle directly south of Castle Rock, in SW¼ Sec. 4, T.14S, R.26W, Gove County, Kansas.

	SMOKY HILL CHALK MEMBER	Thickness m	cm
38.	Chalk, highly weathered, pale yellowish orange, soft, weathers shaly, gradational with overlying soil		21.4
37.	Bentonite, very dark yellowish orange (10YR5/6), somewhat silty, waxy		0.3
36.	Chalk, highly weathered, very pale orange to dark yellowish orange, fissile, apparently laminated, calcareous silty, much speckled throughout, weathers shaly		19.6
35.	Chalk, much weathered, grayish orange, apparently laminated, with poor to fair fissility, erodes to form smoothly curved cavernous surfaces, forms slopes, lichen-splotched. Rock contains numerous small solution vugs. Prominent gray line, parallel to bedding, 46.8 cm above base of unit. Limonite nodules occur in zone 9 cm thick, centered 16.8 cm above base. FOSSILS: *Pseudoperna congesta*, teleost scales and bones		91.1
34.	Bentonite, yellowish gray (5Y7/2), as thin film underlain by dark yellowish orange limonite		0.2
33.	Chalk, much weathered, pale yellowish orange, with traces of lamination, and fair fissility, calcareous silty, speckled throughout. Forms rounded, lichen-splotched ledge. Paper-thin ferruginous seam lies 6.7 cm above base. FOSSILS: *Inoceramus (Platyceramus) platinus, Pseudoperna congesta*, teleost scales and bones		35.0
32.	Bentonite, dark yellowish orange, silty, marked by small limonite nodules		0.3
31.	Chalk, weathered, very pale yellowish brown (10YR7/2) to pale orange pink (5YR8/2), tough, resistant, cliff-forming, with traces of stratification, breaks with fair degree of fissility, lichen-splotched, calcareous silty, speckled, with sparse solution vugs. Very thin seam of limonite, less than 0.1 cm thick, lies 6.2 cm above base. Unit contains smooth, vertical joints, forms caprock. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*, teleost bones and scales	1	2.3
30.	Bentonite, moderate yellowish brown, hard, brittle, very silty, waxy. Upper 0.6 cm of unit consists of limonitic bentonite. Unit hosts small limonite nodules, forms part of reentrant at base of unit 31		2.1
29.	Chalk, weathered, lower 1.56 m medium yellowish brown (10YR5/2) with local pale grayish orange (10YR8/4) horizontal banding, tough; upper 39.2 cm medium grayish orange (10YR6/4) and pale grayish orange (10YR8/4), lichen-splotched. Lower part apparently well laminated, with good fissility, weathers flaky. Upper part lacks obvious laminations, with good fissility, soft and punky, with unit 31 forms part of small vertical cliff. All rock calcareous silty, much speckled. Bed of limonite nodules, as much as 20 cm in diameter and 2.5 cm thick, lies 73 cm above base, marks very thin ferruginous seam. Second bed of limonite nodules, small, lies 52 cm below top of unit. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*, teleost scales and bones	1	95.2
28.	Chalk, partly weathered, light olive gray (5Y5/2), pale yellowish brown and very pale yellowish brown (10YR7/2), forms steep, cavernous slope. Unit not laminated in lowest 2.13 m, moderately well laminated in upper 31.2 cm. All rock is calcareous silty, speckled, has fair degree of fissility, weathers flaky. Middle part of unit weathers to lighter colors locally, and forms irregular, projecting ledges of hard, brittle yellow-colored chalk. Uppermost 27.5 m is distinctly darker colored than rest of unit, dark yellowish brown, probably organic rich, weathers distinctly shalier than rest of unit. Beds of small limonite nodules lie 48.8 cm and 80.5 cm below top, respectively. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*, teleost bones and scales	3	47.6
27.	Bentonite, yellowish gray, slightly silty, flaky, enclosed within lensing layers of limonite that include some jarosite and coarsely crystalline selenite. Where thickest, seam is bordered by crusts of crystalline selenite. Mineralized parts of unit form ledges on eroded slope. Where most mineralized the unit thickens to 6.4 cm		1.6
26.	Chalk, weathered, grayish orange to pale grayish orange (10YR8/4), soft, breaks blocky, burrow-mottled, not conspicuously speckled. FOSSILS: *Pseudoperna congesta*, teleost bones and scales		9.2
25.	Bentonite, dark yellowish orange, as very thin film at top of unit consisting mostly of crystalline selenite		0.9
24.	Chalk, weathered, pale grayish orange to very pale yellowish brown, breaks blocky, burrow mottled, not conspicuously speckled. FOSSILS: *Pseudoperna congesta*		10.7
23.	Bentonite, dark yellowish orange, slightly silty, brittle, in unit consisting predominantly of granular calcite		0.9
22.	Chalk, weathered, pale yellowish brown to grayish orange, tough, faintly bioturbated, calcareous silty, speckled throughout, forms pronounced, rounded shoulder on slope, weathers flaky, uppermost part weathers slabby. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*		29.6
21.	Bentonite, light brown (5YR5/6), silty, brittle, as minor component in seam consisting mainly of limonite and gypsum. Unit hosts sparse limonite nodules		0.6
20.	Chalk, partly weathered, medium olive gray (5Y5/1) to dark yellowish brown, surface dries to conspicuous light gray or very light gray. Rock very tough, somewhat granular, poorly stratified, more or less bioturbated, calcareous silty, speckled throughout. Unit forms smoothly convex, spally, buttressed slope where least weathered, lichen-coated caprock where highly weathered. Where most weathered, unit has fair fissility. Conspicuous shelly zone, 1.7 m thick, with abundant *I. (Platyceramus)*, lies 3.8 m above base of unit. Inoceramids and oysters common throughout unit. Dark line, 4 m above base of unit, marks position of small oblate spheroidal pyrite nodules. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta, ?Baculites* sp. (smooth mold frags?), *Stramentum haworthi, Zeugmatolepas* sp., coprolite, teleost scales	6	69.2
19.	Chalk and bentonite. Chalk medium olive gray (5Y5/1), very tough, not obviously laminated, bioturbated, shows some stratification, splits crudely parallel to bedding, calcareous silty, speckled throughout. Unit contains five subequally spaced bentonite seams occurring at base, 22.2 cm above base, 39.6 cm above base, 59.1 cm above base, and at top. Basal seam 0.6 cm thick, dark yellowish orange, consists solely of limonite and white powdery gypsum; probably a weathered bentonite. Second seam is 0.6 cm thick, dark yellowish orange, brittle, silty, waxy, with associated powdery gypsum. Third seam is 0.3 cm thick, consists mostly of limonite and granular calcite. Fourth seam 1.5 cm thick, dark yellowish orange, brittle, silty, consists mostly of limonite and gypsum, hosts limonite nodules. Uppermost seam is 0.6 cm thick, medium olive gray (5Y5/1) to dark yellowish orange, brittle, silty, as very thin film in seam consisting mostly of limonite and some powdery gypsum. Uppermost seam hosts limonite nodules, thicker where most extensively mineralized. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta, Inoceramus balticus?, Clioscaphites choteauensis, Baculites* sp. (smooth molds)		82.5
18.	Chalk, medium olive gray (5Y5/1), very tough, not laminated, poorly fissile, weathers shaly, calcareous silty, speckled throughout, upper part bioturbated. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*		55.2
17.	Ferruginous/gypsiferous seam, light brown (5YR5/6)		0.7
16.	Chalk, olive gray (5Y4/1), dark yellowish brown to medium olive gray (5Y5/1) where partly weathered, very tough, lower 40 cm with poor fissility, upper part with fair fissility, no obvious laminations, calcareous silty, speckled throughout, weathers shaly, upper 9.2 cm bioturbated. Lower part of unit with abundant fossils, litters slope with shelly debris. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta, Clioscaphites choteauensis, Inoceramus balticus, Baculites* sp. (smooth molds)		[illegible]
15.	Bentonite, yellowish gray (5Y7/2), soft, waxy, slightly silty, 0.2 cm thick, in unit consisting mostly of limonite and gypsum, which overlie the bentonite seam		1.0
14.	Chalk, olive gray (5Y4/1), tough, not laminated, poorly fissile, in part bioturbated, calcareous silty, speckled throughout. Lighter colored bed, 5 cm thick, bioturbated, lies 43.5 cm above base and forms conspicuous band on eroded slope. Unit abundantly fossiliferous, slope littered with shelly debris. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*		77.7
13.	Bentonite, moderate yellowish brown (10YR5/4), silty, waxy, soft. Unit hosts sparse limonitized marcasite nodules as much as 20 cm in diameter and 9 cm thick		0.7
12.	Chalk, light olive gray (5Y6/1) to olive gray (5Y4/1), tough, not obviously laminated, fissile, calcareous silty, speckled throughout, in part stained by iron oxide, weathers shaly. Bed of limonite nodules lies 53.8 cm below top. Upper 30 cm richly fossiliferous, litters slope with shelly debris. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*	1	17.5
11.	Bentonite, very dark yellowish orange. Unit consists mostly of white, powdery gypsum, which encloses a central seam composed mainly of limonite		1.2
10.	Chalk, light olive gray (5Y6/1) to medium olive gray (5Y5/1), tough, not obviously laminated, fissile, calcareous silty, much speckled throughout, weathers shaly. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*, teleost vertebrae		36.6
9.	Bentonite, light brown (5YR5/6). Unit dominated by granular gypsum in fresh exposure, limonite in weathered exposure, thickens locally to 1.5 cm, locally hosts large limonite nodules		0.5
8.	Chalk, olive gray (5Y4/1) to medium olive gray (5Y5/1), very tough, obscurely laminated, poorly fissile, calcareous silty, much speckled throughout, weathers shaly. Prominent dark bed, 6 cm thick, probably organic rich, lies 17 cm above base of unit. Some large inoceramids are partially surrounded by limonitized marcasite nodules. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*, coprolite	1	77.0
7.	Bentonite, dark yellowish orange, silty, brittle. Soft central bentonite is 0.3 cm thick, lies in center of seam dominated by limonite and gypsum		0.9
6.	Chalk, olive gray (5Y4/1), tough, not obviously laminated, moderately fissile, calcareous silty, much speckled throughout, weathers shaly. Some large inoceramids are partially surrounded by limonitized marcasite nodules. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*, coprolite, teleost scales	1	86.1
5.	Bentonite, pale grayish orange pink (5YR8/2), brittle, 0.6 cm thick, between seams of ferruginous gypsum		1.2
4.	Chalk, olive gray (5Y4/1) to light olive gray (5Y6/1), tough, poorly laminated, fissile, calcareous silty, much speckled throughout, weathers shaly. Seam of iron oxide, 0.2 cm thick, lies 2.5 cm below top of unit. Some inoceramid valves limonitized. FOSSILS: *I. (Platyceramus) platinus, Pseudoperna congesta*, coprolite, teleost bones	2	1.2
3.	Bentonite, grayish orange, underlain by crystalline selenite. Large inoceramid valve partially surrounded by limonitized marcasite nodule. FOSSILS: *I. (Platyceramus) platinus*		0.4
2.	Chalk, dark olive gray (5Y3/1) to medium olive gray (5Y5/1), tough, obscurely laminated, fissile, calcareous silty, much speckled throughout, weathers shaly. Some inoceramids are partially surrounded by large limonitized marcasite nodules. FOSSILS: *I. (Platyceramus) platinus, I.* [illegible], coprolite, teleost bones	1	26.2
1.	Bentonite, very light olive gray, mostly stained dark yellowish orange, very silty, as seam approximately 0.1 cm thick, in unit consisting mostly of limonite and granular gypsum		1.2
	Total thickness of measured section	26	86.2

Badlands and bluffs on west side of Hackberry Creek, in SW¼ Sec. 16, T.14S, R.25W, Trego County, Kansas.

SMOKY HILL CHALK MEMBER	Thickness m	cm
12. Chalky limestone, weathered, grayish orange, relatively hard, brittle, bioturbated, forms conspicuous, flat-topped bench. FOSSILS: *Inoceramus (Platyceramus) platinus, Pseudoperna congesta*		9.1
11. Bentonite, light brown (5YR5/6), ferruginous . . .		0.3
10. Chalk, weathered, grayish orange with streaks of yellowish gray (5Y7/2), soft, laminated, very well laminated in uppermost 15.3 cm, splits easily along bedding, calcareous silty, speckled throughout. Limonite nodules, widely spaced, occur in zones lying 61.0 cm, 76.3 cm, and 1.28 m below top of unit. Unit eroded locally so as to form steep face with three prominent ledges. FOSSILS: *I. (Volviceramus) grandis, Pseudoperna congesta*	2	16.5
9. Chalk, weathered, grayish orange, relatively soft, more or less well laminated throughout, calcareous silty, much speckled throughout, weathers shaly. Chalky limestone bed, grayish orange, relatively hard, brittle, 10.5 cm thick, bioturbated, ledge-forming, lies 42.7 cm above base of unit. Uppermost 18 cm of unit also harder than main body of unit, laminated, forms minor bench. Ferruginous seams, central one bentonite?, each less than 0.4 cm thick, lie 42.7 cm, 97.5 cm, and 1.83 m above base of unit. FOSSILS: *I. (Volviceramus) grandis, Pseudoperna congesta*	2	22.6
8. Chalk, weathered, grayish orange, relatively soft, well laminated, splits easily along bedding, calcareous silty, speckled throughout, weathers shaly, forms cavernous slope. Unit contains two prominent beds of chalky limestone, pale grayish orange (10YR8/4), bioturbated, ledge-forming. Lower bed is 18.3 cm thick and lies 1.30 cm above base of unit; upper bed is 15.2 cm thick, lies at top of unit, weathers into irregular slabs, forms prominent, flat-topped bench. Chalky limestones locally coated with lichens. Paper-thin ferruginous seams, light brown (5YR5/6), each less than 0.1 cm thick, lie 61.0 cm and 97.5 cm above base. Upper seam hosts small limonitized marcasite nodules. FOSSILS: *I. (Volviceramus) grandis, Pseudoperna congesta*.	2	28.7
7. Chalk and chalky limestone, weathered. Chalk is grayish orange to dusky yellow, relatively soft, more or less laminated, calcareous silty, speckled throughout, forms reentrants on steep faces, gradational with harder beds, weathers shaly. Chalky limestone is grayish orange to very pale orange, relatively hard, brittle, bioturbated, with sparse speckling. Uppermost hard bed lichen-splotched locally. Unit rich in inoceramid debris. Limonitized marcasite nodules, as large as 61.0 cm in diameter and 6.2 cm thick, lie in layers 73 cm and 1.19 m above base. FOSSILS. *I. (Volviceramus) grandis, Pseudoperna congesta. I. (Platyceramus) platinus, Durania maxima.* isolated lepadomorph cirriped plates, acrothoracican borings, *Portheus, Ptychodus*	2	89.6
6. Chalk, partly weathered, olive gray (5Y3/2) to light olive gray (5Y5/2), relatively soft, obscurely laminated, uppermost part bioturbated, calcareous silty, speckled throughout, weathers flaky. Layers of limonitized marcasite nodules lie at base and 58.0 cm above base of unit. Unit rich in inoceramid debris. FOSSILS: *I. (Platyceramus) platinus, I. (Volviceramus) grandis, Pseudoperna congesta, Stramentum haworthi, Zeugmatolepas* sp., acrothoracican borings, *Durania maxima,* teleost bones, lignitized log with *Teredolithus*. .	1	61.7
5. Chalk, olive gray (5Y4/1), in part weathered light olive gray (5Y5/2), tough, brittle, mostly well laminated, calcareous silty, speckled throughout, weathers flaky. Bioturbated chalk, in thin zones, especially 1.8 m above base, form light-colored bands on eroded slope, weather into small brittle chips. Ferruginous/gypsiferous seams, light brown (5YR5/6), each less than 0.2 cm thick, lie 6.88, 7.48, and 8.1 m above base. First and third seams host limonitized marcasite nodules as much as 45.7 cm thick and 9.1 cm thick. Granular gypsum seams, each less than 0.2 cm thick, lie 1.75 m above base and 88.5 cm below top of unit. Lower of these seams hosts limonitized marcasite nodules. Unit contains scattered limonitized marcasite nodules not associated with mineralized weathered bentonite? seams. Unit contains interval rich in inoceramid debris, approximately 60 cm thick, lying 6.08 m above base. FOSSILS: *I. (Platyceramus) platinus, I. (Volviceramus) grandis, Pseudoperna congesta,* acrothoracican borings	8	88.7
4. Bentonite, moderate yellowish brown (10YR5/2), very silty.		0.3
3. Chalk, olive gray (5Y4/1), light olive gray (5Y6/1), and medium light gray, relatively hard, softer where weathered, well laminated, splits evenly along bedding, slightly calcareous silty, speckled throughout, with conspicuous smooth vertical joints, weathers flaky. Bed of harder chalk, light gray, 21.4 cm thick, lies 24.4 cm above base, forms smoothly rounded shoulder on weathered surfaces. Ferruginous/gypsiferous seam, less than 0.2 cm thick, lies on top of harder bed. FOSSILS: *I. (Platyceramus) platinus, I. (Volviceramus) grandis, Pseudoperna congesta,* teleost scales	1	0.8
2. Bentonite, very pale orange to dark yellowish orange. Unit thickens locally to 4.9 cm by addition of ferruginous/gypsiferous seams at top and base. Unit locally hosts limonite nodules with rotten marcasite cores. Unit forms conspicuous reentrant on steep faces		2.5
1. Chalk, medium olive gray (5Y5/1) to olive gray (5Y4/1), grades upward to light olive gray (5Y6/1), tough, obscurely laminated, splits irregularly along bedding, slightly calcareous silty, speckled throughout, weathers flaky. Bed of bioturbated chalk, 20 cm thick, lying 21.3 cm below top of unit, granular, contains very small limonite nodules near base, forms light-colored band on weathered exposure, forms minor shoulder on eroded slope. Ferruginous/gypsiferous seam, less than 0.2 cm thick, lies on top of bioturbated chalk. FOSSILS: *I. (Platyceramus) platinus, I. (Volviceramus) grandis, Pseudoperna congesta,* teleost bones and scales.	1	98.3
Total thickness of measured section	23	19.1

Figure 8.—Graphical representations of measured sections from near Castle Rock (section A) and near Wildcat Canyon (section B); both from Hattin (1982).

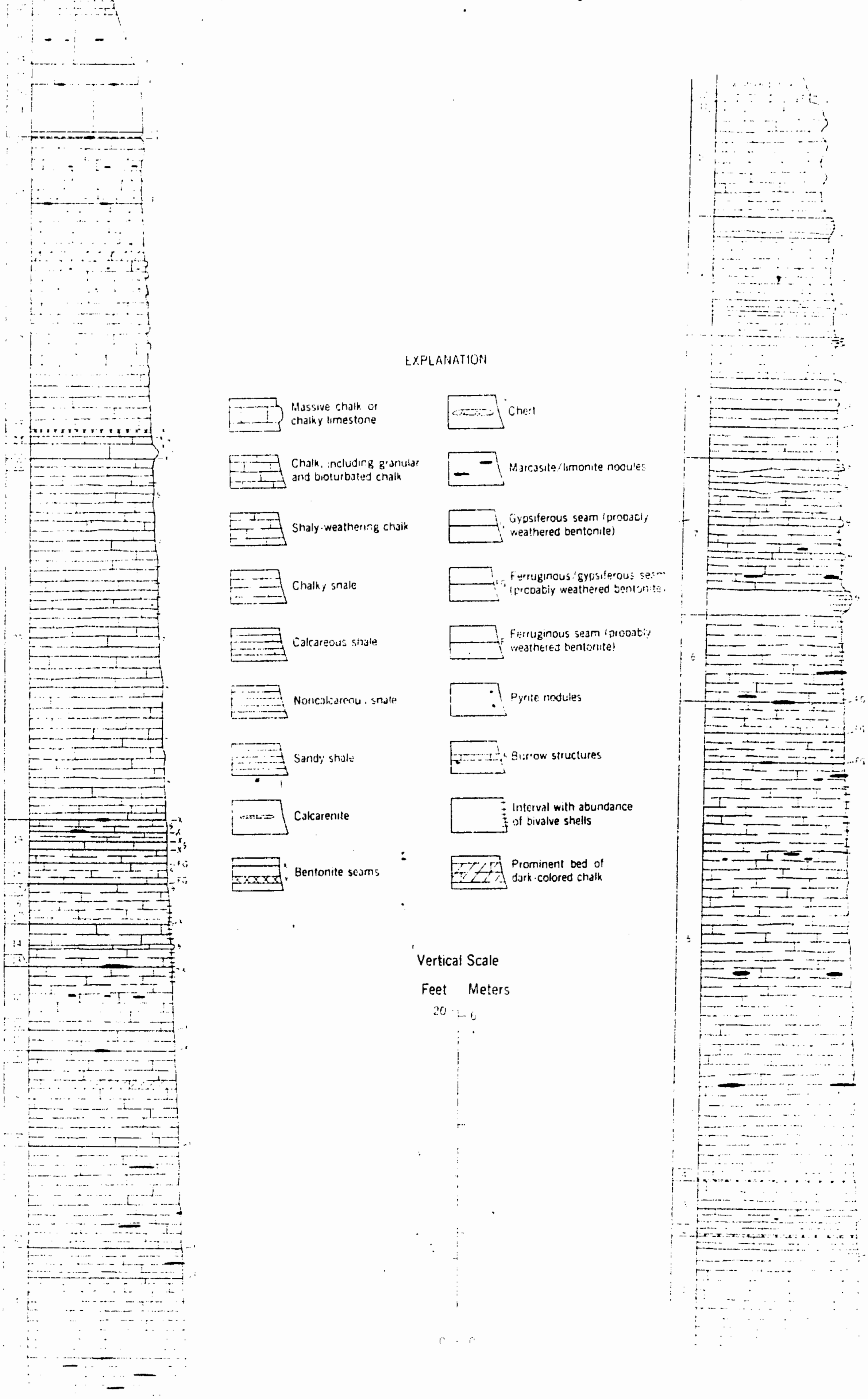


PLATE CAPTIONS

PLATE 1, Exposures and Invertebrate Fossils of the Smoky Hill Member (Modified from Hattin, 1982).—Figure 1: Cedar Bluff and Cedar Bluff Reservoir looking east from sec. 6, T15S, R22W; cliff is developed along a westward reentrant of the Fort Hays escarpment and is held up by the Fort Hays Member, Niobrara Chalk. Figure 2: Exterior view of the clam *Inoceramus (Volviceramus) grandis* (Conrad); note heavy incrustation by the oyster *Pseudoperna congesta* (Conrad); KUMIP153994 (~x1). Figure 3: Lateral view, cushed mold of the ammonoid *Baculites* sp.; note small encrusting oysters; KUMIP154022 (~1). Figure 4: Well-preserved barnacle *Stramenthum haworthi* (Williston); holotype KUMIP8323 (~x4). Figure 5: Right valve of large, nearly perfect clam *Inoceramus (Platyceramus) platinus* Logan; FHKSU2086 (~x0.1). Figure 6: Internal mold, left valve of the clam *Inoceramus (Cladoceramus) undulatoplicatus* Roemer; KUMIP153998 (~x1.3). Figure 7: Lateral view, internal mold of the ammonoid *Clioscaphites choteauensis* Cobban; KUMIP154023 (~x1).

PLATE 2, Invertebrate Fossils of the Greenhorn Limestone (Modified from Hattin, 1975).—Figure 1: Internal mold, right valve of the clam *Inoceramus prefragilis* Stephenson; KUMIP82152 (~x1.25). Figure 2: Internal mold, left valve of the clam *Mytiloides labiatus* (Schlotheim); KUMIP82188 (~x1.25). Figure 3: Cluster of small encrusting oysters, *Exogyra* aff. *E. boveyensis* Berquist, on the clam *Inoceramus* sp.; KUMIP82077 (~x0.6). Figure 4: Crushed internal mold of the ammonoid *Worthoceras vermiculum* (Shumard); KUMIP82116 (~x2.5). Figure 5: Flattened valve of clam *Camptonecthes* sp.; KUMIP82093 (~x2.5). Figure 6: Recrystallized shell of the gastropod *Cerithiella* sp.; KUMIP82141 (~x2.5). Figure 7: Calcitic internal mold of the ammonoid *Stomohamites* cf. *S. simplex* (d'Orbigny); KUMIP82081 (~x2.5). Figure 8: Latex cast, external mold of the ammonoid *Eucalycoceras* sp.; KUMIP82090 (~x1.25).

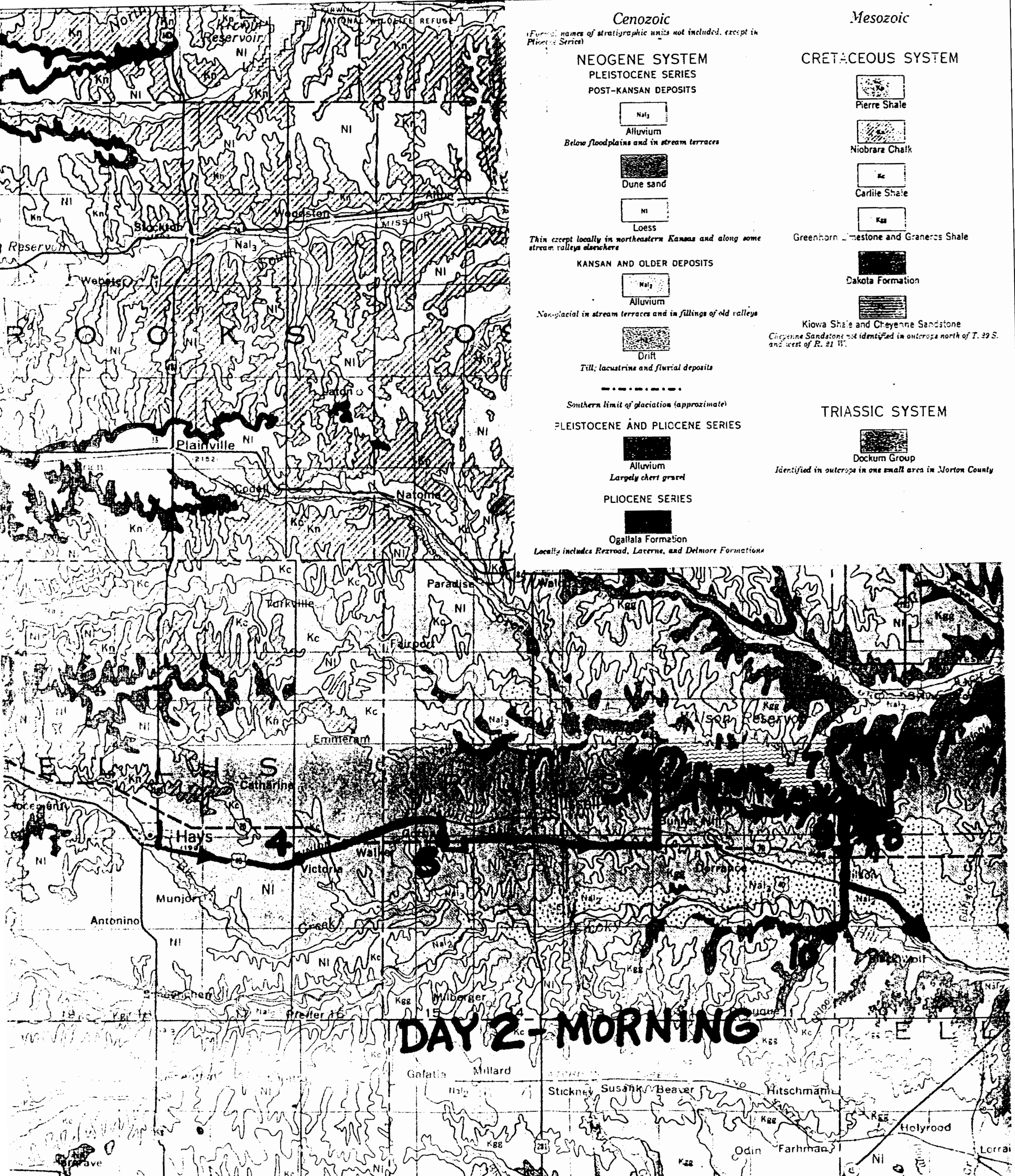
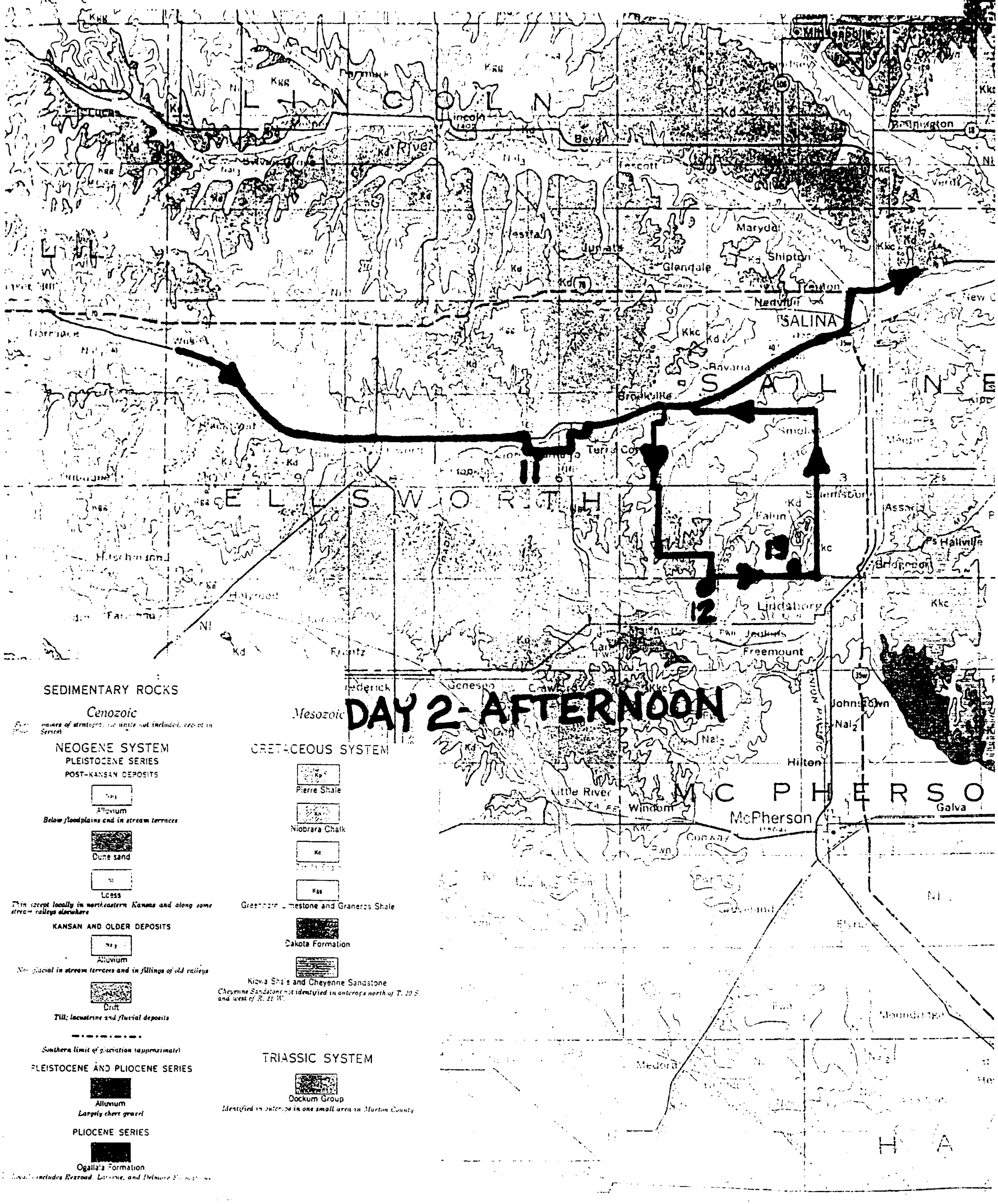


Figure 9.—Stops for Day 2 (morning) of fieldtrip shown on portion of geologic map of Kansas.

Figure 10.—Stops for Day 2 (afternoon) of fieldtrip shown on portion of geologic map of Kansas.



DAY 2—Morning
(Figure 9)

Leave Vagabond Motel, headed south on U.S. 183 for 1.0 miles.

1.0 8th Street. Turn east, onto old U.S. Highway 40. Before the construction of I-70, U.S. 40 was the primary route from Kansas City to Denver.

4.3

5.3 The town of Toulon.

4.8

9.1 Victoria. Turn north, cross the Union Pacific tracks and the North Fork of Big Creek.

0.6

9.7 STOP 4. St. Fidelis Church, the Cathedral of the Plains. This church was built of fencepost limestone, the uppermost bed of the Greenhorn Limestone, between 1908 and 1911. Backtrack to old U.S. 40 and continue east.

3.8

3.8 Pass under Interstate 70.

0.7

4.5 The town of Walker. Immediately south is St. Ann church, which is also built out of fencepost limestone.

3.0

7.5 The town of Gorham. About nine miles north of Gorham is the Fairport oil field. Discovered in 1923, it was 120 miles north and west of previous production in Kansas, and thus heralded expanded oil and gas production in the state. The field's discovery was based on surface mapping of an anticline in the fencepost limestone. The nearby Gorham oil field was discovered in 1926, and it has resulted in the production of nearly 100 million barrels of oil, most of it from the Arbuckle, and Upper Pennsylvanian and Lower Permian formations that are 2400 to 3400 feet deep.

3.2

10.7 Turn south on gravel road.

1.5

12.2 STOP 5. Below this overpass, on I-70, are several sinkholes that were caused by the dissolution of the Hutchinson salt bed, about 1500 feet below ground. That dissolution was probably caused by improperly installed oil wells, or wells whose casing corroded, allowing water to enter the wells and dissolve away the underground salt, creating subsidence at the surface. The Witt sink is visible to the west of the overpass; the Crawford sink is immediately east of the overpass, at milepost 179; the Roubach is east of the Crawford sink; and a fourth, new sink, is east of the Roubach. The Crawford and the Witt sinks have been subsiding at the rate of about 6 inches per year since I-70 was built. This has necessitated raising and rebuilding the roadbed, so that the dips caused by the subsidence don't cause a traffic hazard. The subsidence is also putting stress on bridge at this overpass. While the subsidence is continuing, its rate has decreased during the past few years. Seismic surveys that the KGS ran here in the early 1980s indicate that there is little chance of a catastrophic collapse at this location. From the Crawford sink, continue south on the gravel road.

0.5

0.5 Turn east on the gravel road.

2.0

2.5 Turn north on the gravel road.

0.5

3.0 Take the east-bound entrance to I-70 at milepost 181. Drive east for 6.2 miles. Notable features on the way include Fossil Creek (mp 182.8), the Russell oil field (mp183.8), drilling equipment from the Russell oil field museum (mp184.8), and the Russell exit, U.S. Highway 281 (mp 185). See **Roadside Kansas** for more description.

6.2

9.2 Rest area. Following the rest stop, continue east on I-70 for 5.8 miles. The Hall-Gurney oil field, which has produced more than 137 billion barrels of oil since its discovery in 1931, is visible here. These oil fields are in the central Kansas uplift, a subsurface feature that underlies north-central Kansas. The central Kansas uplift is one of the most densely drilled geologic provinces in the U.S.

5.8

15.0 Bunker Hill exit. Take the crossroad north. Just north of the exit is the Bear House Cafe, once the home of a caged bear. Several years ago, then-heavyweight boxing champion Muhammad Ali was driving across Kansas when he developed car trouble here and was forced to spend the day waiting for parts to arrive. He passed the time entertaining customers at this restaurant.

1.0

16.0 Bunker Hill. This town is home to public television station KOOD and the Bunker Hill Cafe, a well-known eatery in central Kansas.

3.7

19.7 STOP 6. This long roadcut exposes the entire Greenhorn Limestone, from the Lincoln limestone member, up to the Hartland shale, to the Jetmore chalk, to the Pfeifer shale, to the fencepost limestone at the top. Hattin and Siemers (1978, p. 40) for a cross section of this location. Walk south up the hill to the vans, where we reload and head south for 2.3 miles.

2.3

2.3 Turn east on gravel road for 1.0 miles. Hattin's guidebook contains a log for this route; however, it covers the route from east to west, so it's a little confusing. Hattin also contains paleontologic and stratigraphic descriptions of the rock units exposed in this area.

1.0

3.3 Turn north.

1.3

4.6 Long, deep roadcut on the north exposes the upper part of the Lincoln limestone, and the Hartland, Jetmore, and Pfeifer members of the Greenhorn, and the base of the Fairport Chalk Member of the Carlile Shale.

1.3

5.9 A small spring is fenced north of the road. It probably issues from the Dakota Formation.

0.5

6.4 Fork in the road. Go east.

0.2

6.6 Channel sandstone in the Dakota exposed on the hill to the north.

0.4

7.0-7.3 Cuts along both sides of the road expose the lower part of the Fairport Member of the Carlile, the Greenhorn Limestone, and the upper Graneros Shale.

2.8

10.1 Deep cuts on both sides of the road expose the upper half of the Hartland, Jetmore, and Pfeifer members of the Greenhorn.

0.3

10.4 Long, deep roadcut exposes the lower 15-20 feet of the Fairport and the Pfeifer, Jetmore, and uppermost Hartland.

0.6

11.0 Crossroad. Continue east, through numerous roadcuts in the Greenhorn.

2.2

13.2 Shallow-marine facies of the Dakota Formation, overlain by the complete section of Graneros Shale and lower beds of the Lincoln Member of the Greenhorn.

2.0

15.2 Crossroad. Continue east.

0.9

16.1 Cuts on both sides of the road expose crossbedded, fluvial sandstone in the Dakota.

0.7

16.8 Wilson State Park road. Continue north.

1.3

18.1 Hell Canyon Bridge. Rocktown channel sandstone of the Dakota is well exposed at the west end. Continue east through several Dakota outcrops.

0.6

18.7 Stop sign. Junction with Kansas Highway 232. Turn north.

0.6

19.3 Top of the Greenhorn escarpment, elevation 1770. This is about 250 feet above the normal pool elevation in Wilson Lake. This lake was built by the Army Corps of Engineers on the Saline River. The natural salinity in the river is compounded by evaporation from the lake's surface, making the water in this lake slightly saline.

0.7

20.0 Begin descent of Greenhorn escarpment through several Greenhorn roadcuts.

1.4

21.4 STOP 7. Wilson Dam floodway and exposures of clay-ironstone facies in the Dakota Formation. The Dakota Formation is mostly made up of non-marine sandstones, clays and shales that were deposited in the delta of a Cretaceous river that drained to the west, or as beach deposits along the ocean that the river drained into. However, in places, such as this one, the Dakota sandstones and shales were deposited in a brackish lagoon or bay. Pyrite and gypsum are present in the Dakota here. The Dakota here is capped by the Graneros Shale, which was probably deposited in a open marine situation. Page 36 in Hattin shows a cross section of this stop. Continue 0.2 miles north to the roadside park, then head east on Kansas Highway 181.

1.2

1.2 Deep roadcut through Greenhorn Limestone and Graneros Shale.

3.0

4.2 Crossroads. Turn south on gravel road.

5.3

9.5 Crossroads. Turn west.

0.5

10.0 STOP 8. Park at the crest of the hill. Just north of the road is the Hanzlicek ash pit. This ash was deposited in the Pleistocene. It came from erupting volcanoes to the west, perhaps in northern New Mexico or the Yellowstone area, and was carried into Kansas by winds. Originally deposits were thin and uniform, but they became concentrated in irregularities in the terrain, blown into drifts at the heads of canyons or washed by runoff into streams or lakes. Continue east on gravel road.

0.5

0.5 Crossroads. Turn north.

1.0

1.5 Crossroads. Turn west for 1.0 miles.

1.0

2.5 Crossroads. Turn north.

1.0

3.5 Crossroads. Turn west.

0.8

4.3 Outcrops of Dakota sandstone.

0.7

5.0 Junction with K-232. Turn south.

0.3

5.3 Dakota Formation on both sides of the road.

0.4

5.7 STOP 9. Pull well off the west side of the highway to view the Dakota Formation exposed in this bluff above Hell Creek. The lower part of this bluff was deposited as a river channel and contains fossilized wood and plant debris. The upper part of the bluff is a fine-grained sandstone that is heavily cross bedded. Continue south on K-232.

1.3

1.3 Begin climb through the Greenhorn Limestone onto level upland.

2.7

4.0 Pass over I-70. Continue south.

1.7

5.7 Cross railroad tracks and turn west on first street, old U.S. 40.

0.3

6.0 Turn south at the second street, Michigan Street. Across the tracks is the Midland Hotel, used in filming the Peter Bogdanovich movie "Paper Moon," which featured Ryan and Tatum O'Neal, John Hillerman, Randy Quaid, and Madeline Kahn as Trixie Delight.

2.7

8.7 Cross the Smoky Hill River and take the first turn to the west.

0.6

9.3 Enter the gate on the south side of the road, which leads onto the Krause property. Follow narrow trail south past lignite mine dumps.

0.4

9.7 STOP 10. Walk a short distance up a wooded draw to an adit of an abandoned lignite mine. Lignite is the lowest rank of the three types of coal. The other two are bituminous, which is extensively mined in southeastern Kansas, and anthracite, the highest rank, which is mined primarily in Pennsylvania. Coals are ranked by the heat they produce when burned. Lignite when burned does not exceed 8500 b.t.u., whereas the coals of southeastern Kansas average 12,000 b.t.u. Lignite is sometimes called brown coal because of its color and woody appearance. High moisture content, averaging 30 to 40 percent (10 times more than the bituminous of southeast Kansas), also makes lignite less marketable than other coals. When exposed to weather, lignite crumbles or "slacks" easily, as can be seen in this outcrop.

This area is known as the Coal Creek mining district and was active from around 1890 until 1902. Most of the lignite mined here was burned locally for heating, with some burned to fire steam locomotives along the Kansas Pacific Railroad, now the Union Pacific, which crossed central Kansas. Six lignite seams can be found in the upper 17 feet of the Dakota Formation in a unit named the Janssen clay member. The largest seam is 20 inches thick and occurs between two siltstones. Some of the mines here in Russell County extended completely under the ridge east of here and opened on the other side of this hill, in Ellsworth County.

4.0

4.0 Follow the narrow trail south, bearing east, and climb onto a Greenhorn-capped ridge. Travel east, cresting the ridge, and descend the east side, curving north past more lignite mine dumps. Pass through the gate and return to the east-west gravel road where we started. Travel east, then north, retracing the route to the corner of Michigan and old U.S. 40 in Wilson. Turn east on old U.S. 40.

7.5

7.5 The town of Black Wolf is a short distance south of the highway. From here to Ellsworth the road follows the Smoky Hill River, which is just to the south.

7.5

15.0 Ellsworth.

0.7

15.7 Junction with Kansas Highway 14, which runs north to Lincoln and south to Lyons. Continue east on K-140.

3.5

19.2 Junction with Kansas Highway 111, which leads two miles south to the town of Kanopolis, the site of a salt mine in the Hutchinson salt member and a plant that manufactures brick out of clay from the Dakota Formation.

5.5

24.7 Outcrops of Dakota sandstone.

0.5

25.2 Crossroad. Turn south on the gravel road. The town of Carneiro is 0.5 miles to the east.

1.0

26.2 Turn east on gravel road. A clay pit in the Dakota, one of several in the area, is just southwest of this corner.

0.5

26.7 Just beyond Alum Creek is Mushroom Rocks State Park, STOP 11. Mushroom Rocks are concretions that have weathered out of the surrounding, softer Dakota Formation. If sliced and sauteed in butter, these rocks could garnish 500,000 T-bone steaks or up to 1,000,000 filets! Continue east on this gravel road.

2.5

2.5 Junction with Kansas Highway 141, which crosses the dam at Kanopolis Lake to the south. Go north.

1.5

4.0 Turn east on gravel road, just north of the railroad tracks.

1.0

5.0 The prominent sandstone hill north of the road is Buzzard Roost. Turn north just after passing it.

0.6

5.6 Junction with K-140. Turn east.

1.4

7.0 Sandstone concretions similar to those at Rock City, near Minneapolis, are weathering out of the hillside in the pasture south of the road.

3.8

10.8 West edge of Brookville. Take the gravel road south.

1.3

12.1 Turn west on Farrelly Road. This is the north boundary of the Smoky Hill Air Force Bombing Range, utilized by planes and pilots stationed at McConnell Air Force Base in Wichita.

1.0

13.1 Turn south on Sunnyside Road, which runs along the west edge of the bombing range.

3.5

16.6 The prominent hill 5.0 miles east is Soldier Cap Mound, elevation 1578 feet, compared to the road elevation of 1450. The hill was named for its resemblance to wool caps worn by Civil War soldiers.

4.7

21.3 At crossroads, take Sundgren Road east along the south edge of the bombing range.

4.0

25.3 Turn south on Soderborg Road at crossroad. The Swedish names in this area are the result of Swedish emigration to the Lindsborg-Marquette area. Dry Creek cemetery is on the northwest corner.

0.7

26.0 The Premier Cattle Feeders feedlot is on the east side of the road.

2.5

28.5 STOP 12. Buildex clay pit on the west side of the road. This quarry is in the Kiowa Formation; the shale mined here is heated and used for light-weight aggregate. A second Buildex plant is located south of Ottawa, in Franklin County. The Dakota here includes a form of gypsum called selenite, a sedimentary structure called cone-in-cone, and a thin layer of brachiopod and gastropod fossils. Leave the pit and head north on the north-south section road.

0.5

0.5 Turn east on the gravel road, Coronado Heights Road.

3.8

4.3 From this hill capped by the Dakota sandstone, Soldier Cap Mound is visible 8 miles to the north.

2.2

6.5 Turn north at crossroads and take the serpentine route to the summit of Coronado Heights, STOP 13, the southernmost of a series of hills called the Smoky Hill Buttes. This hill is capped by Cretaceous sandstone from the Dakota. Below the Dakota is the Kiowa Shale, also Cretaceous, which lies unconformably on shales of Permian age near the base of the Smoky Hill Buttes. This unconformity marks a large gap in the geologic record; rocks from the Jurassic and Triassic Periods are missing in this part of Kansas. Thus, more than 100 million years of geologic history passed with no physical record left for geologists to study. This butte gets its name from the Spanish explorer Coronado, who travelled as far north as central Kansas in search of the fabled land of Quivira in 1541. Though this hill is named after Coronado, there is no evidence that he got this far east in his travels. Return to the crossroads south of Coronado Heights and head east.

1.0

1.0 Those returning directly to Lawrence should continue east to Kansas Highway 4, which leads north to I-135, about 5.0 miles. I-135 leads north to I-70. Those wanting to go to the Brookville Hotel should turn north on Burma Road.

4.0

5.0 Hedberg Road, named after the family of noted geologist Hollis Hedberg, who was from the town of Falun, which is four miles to the west.

2.0

7.0 The small settlement of Salemsborg

3.0

10.0 Smolan, the home town of the once and possible future governor of Kansas, John Carlin.

2.0

12.0 Water Well Road. Turn west.

8.0

20.0 Turn north at the crossroad. Cross railroad tracks and turn west on Kansas Highway 140 just north of the tracks, about 0.1 miles.

1.7

21.7 Brookville. The hotel is north of the highway one block. Many of the buildings in Brookville are made of iron-cemented sandstone from the Dakota. Bon Appetit. Return to Lawrence by taking K-140 east to I-135, then north to I-70, and then east.

PLATE CAPTION

PLATE 3, Invertebrate Fossils of the Dakota Formation (1–9) and the Graneros Shale (10–17). All bar scales equal 1 cm (From Hattin and Siemers, 1978 [1987]).—Figure 1: Right valve of clam *Geltena subcompressa* Stephenson. Figure 2: Free-living oyster *Crassostrea soleniscus* (Meek). Figure 3: Right valve of the clam *Volsella tarrantana* Stephenson. Figure 4: Internal mold, left valve of clam *Breviarca (Sanoarca) grandis* (Stephenson). Figure 5: Left valve of the clam *Laternula virgata* Stephenson. Figure 6: Left valve of clam *Brachidontes filisculptus microcostae* Stephenson. Figure 7: Left valve of the oyster *Exogyra* cf. *E. levis* Stephenson. Figure 8: The gastropod *Anchura* sp. G of Stephenson (1952). Figure 9: The clam *Cymbophora spooneri* Stephenson. Figure 10: Left valve of the clam *Parmicorbula? hillensis* Stephenson. Figure 11: Left valve of the oyster *Exogyra columbella* Meek. Figure 12: Right valve of the clam *Aphrodian lararensis* (Shumard). Figure 13: The ammonoid *Borissiakoceras reesidei* Morrow. Figure 14: The ammonoid *Acanthoceras amphibolum* Morrow. Figure 15: Small inoceramid clam *Inoceramus rutherfordi* Warren. Figures 16, 17: Two examples of the oyster *Ostrea beloiti* Logan.

REFERENCES

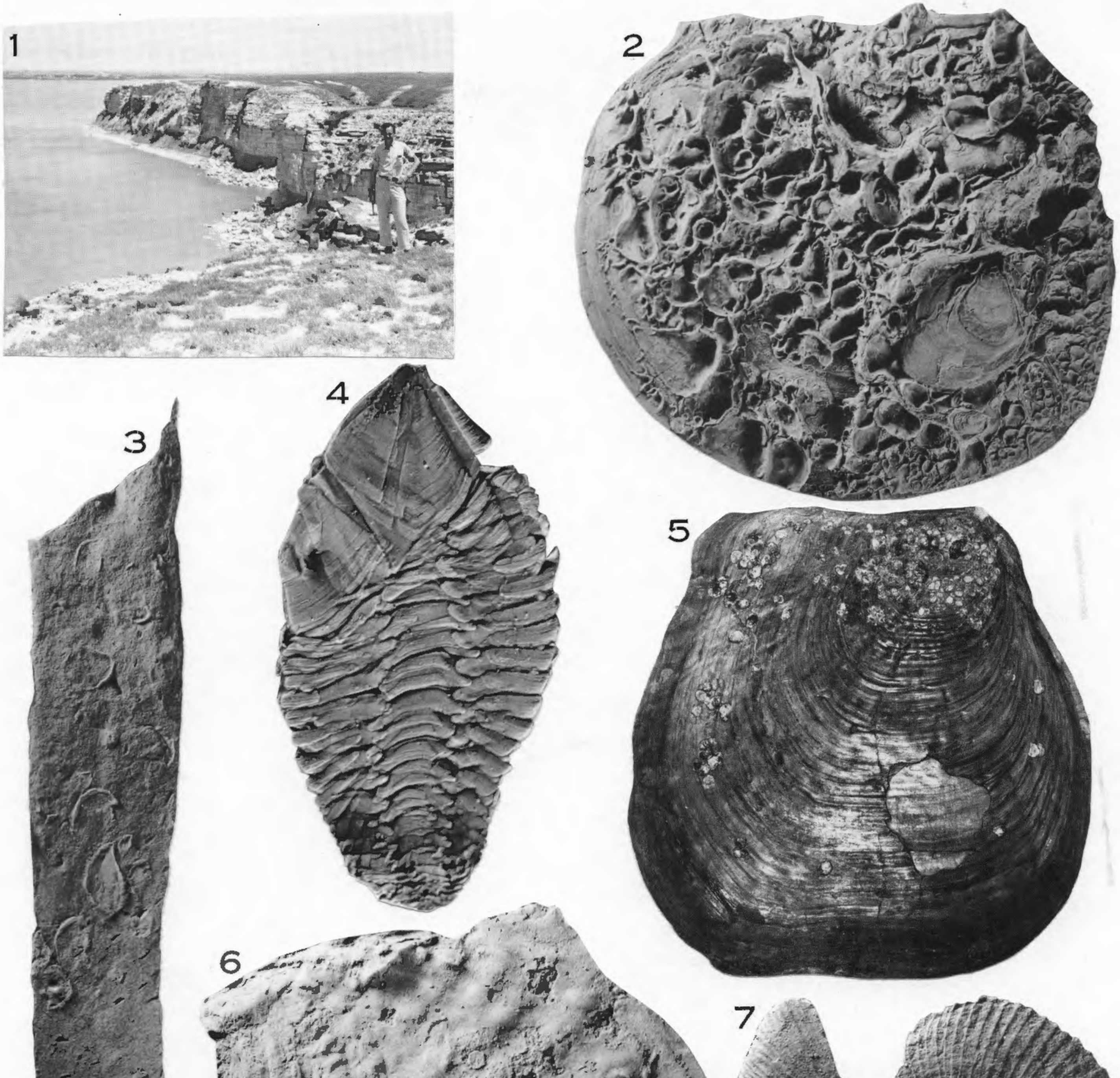
BUCHANAN, R. C., and J. R. McCAULEY. 1987. Roadside Kansas. University of Kansas Press, Lawrence, 365 p.

FREY, R. W. 1970. Trace fossils of Fort Hays Limestone Member of Niobrara Chalk (Upper Cretaceous), west-central Kansas. The University of Kansas Paleontological Contributions, Article 53 (Cretaceous 2), 41 p.

HATTIN, D. E. 1975. Stratigraphy and depositional environment of Greenhorn Limestone (Upper Cretaceous) of Kansas. Kansas Geological Survey Bulletin 209, 128 p. [reprinted 1979]

HATTIN, D. E. 1982. Stratigraphy and depositional environment of Smoky Hill Cahlk Member, Niobrara Chalk (Upper Cretaceous) of the type area, western Kansas. Kansas Geological Survey Bulletin 225, 108 p.

HATTIN, D. E., and C. T. SIEMERS. 1978. Upper Cretaceous stratigraphy and depositional environments of western Kansas. Kansas Geological Survey Guidebook Series 3, 55 p. [reprinted, with modifications, 1987]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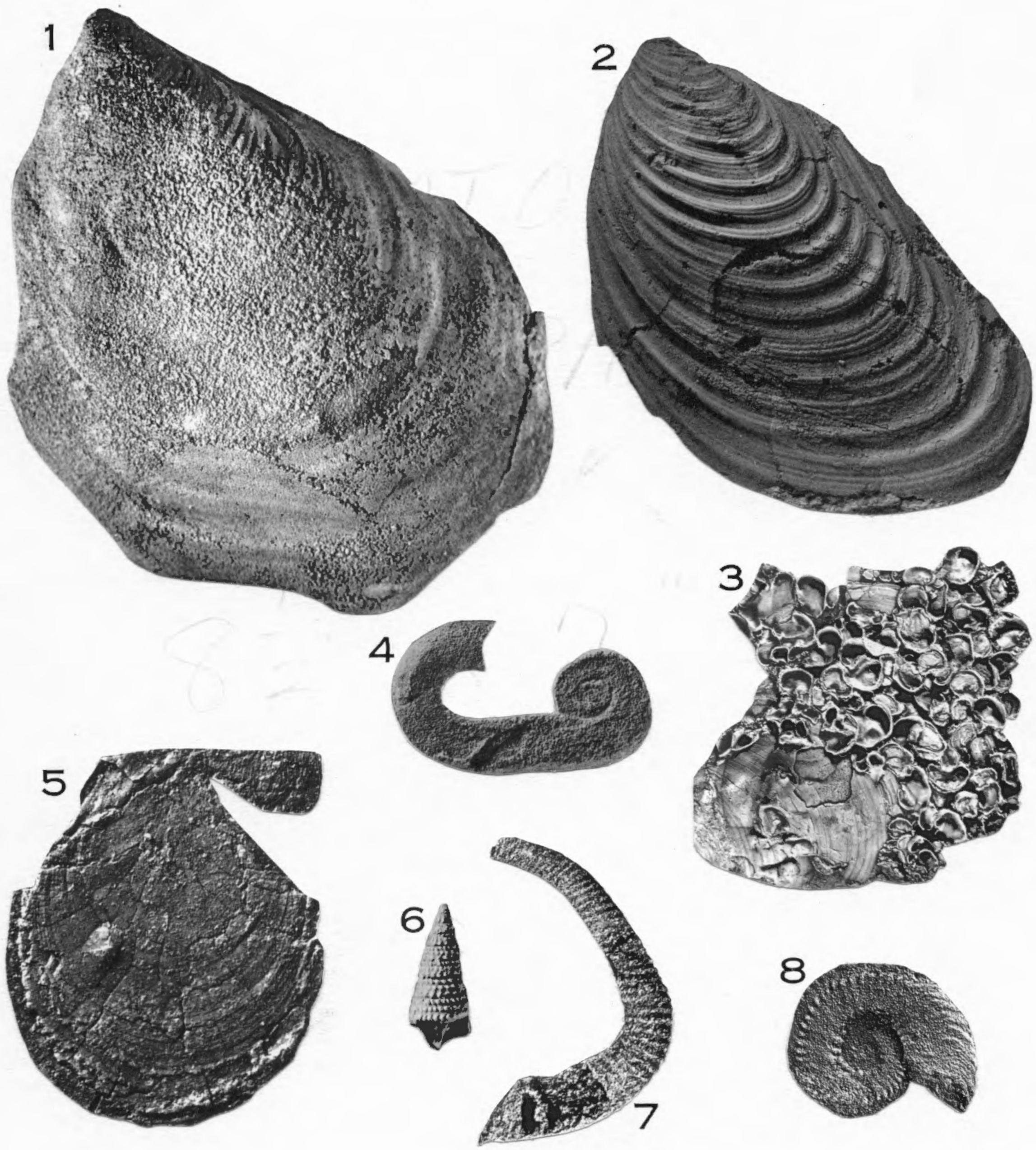
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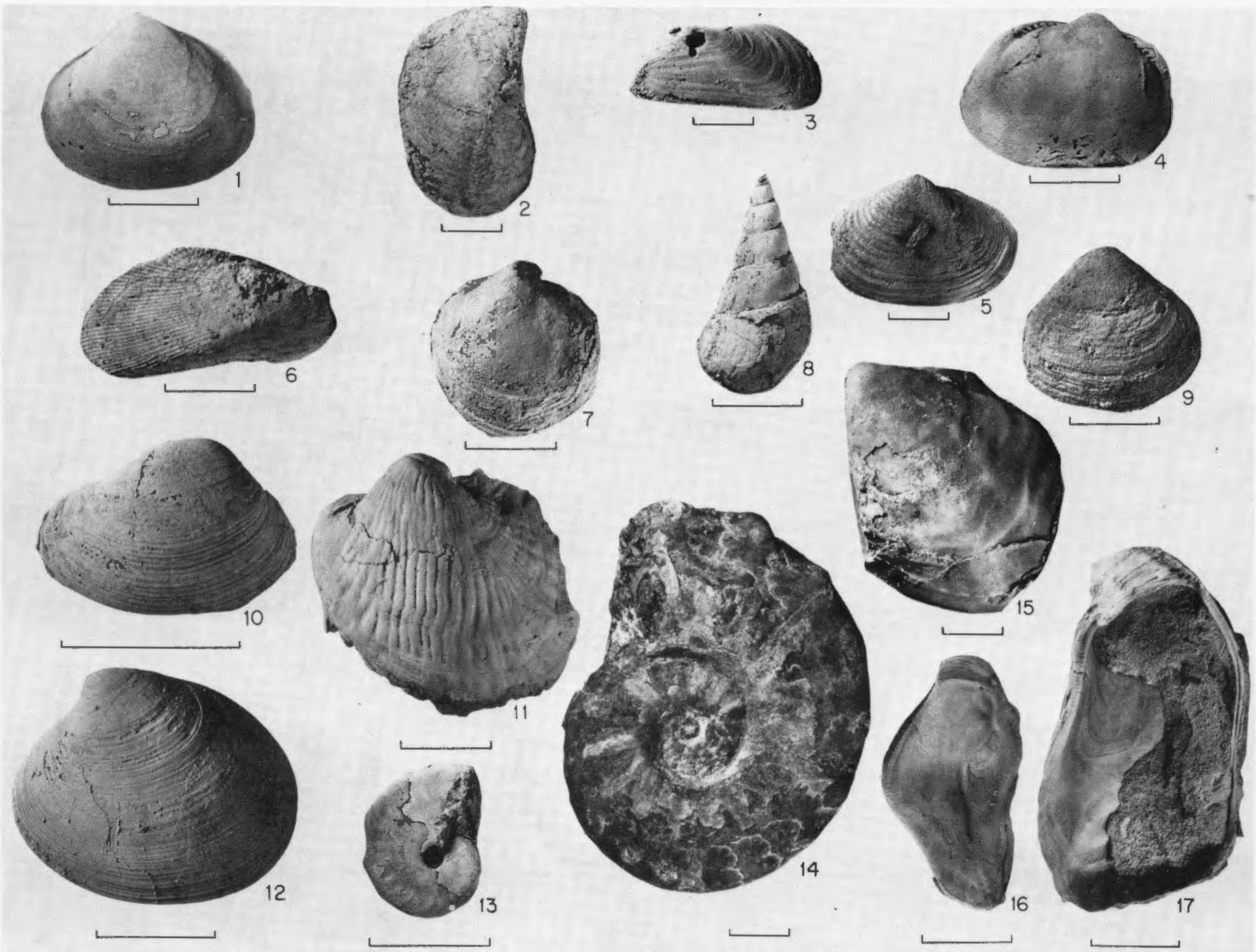
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