KANSAS GEOLOGICAL SURVEY
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Field Trip to Douglas, Franklin, Wabaunsee, and
Shawnee Counties, Northeastern Kansas

by

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Disclaimer

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0.0 Leave KGS back parking lot and turn south (left) on Constant Ave. and head toward Iowa Street (U.S. Highway 59).

0.3 Turn south (right) on Iowa.

0.5 At stop light, turn west (right) on 23rd Street/Clinton Parkway (Kansas Highway 10). The red brick building on the corner was once rural school #6.

1.5 Kasold Ave.

2.8 The Toronto Limestone Member of the Oread Limestone overlies the Lawrence Shale north of the road.

3.0 Wakarusa Drive, formerly known as Dragstrip Road.

3.1 The Plattsmouth Limestone Member of the Oread Limestone is exposed north of the road.

3.2 Toronto Limestone Member is exposed as we descend the hill.

3.6 Yankee Tank Creek.

3.7 Toronto Limestone Member.

3.8 The one-foot-thick limestone next to the road here is the Leavenworth Limestone Member of the Oread Limestone. Continue west to the end of the parkway.

4.5 T-intersection with E900 Road. Turn south (left).

4.8 STOP 1. The spillway at Clinton Lake provides an excellent introduction to the geology of eastern Kansas. The dam here was constructed on the Wakarusa River in the 1970s. The spillway is a means by which water can move out of the lake during times of extremely high water levels (though the water has never been that high). The bike path along the floor of the spillway was added in the 1990s as part of the construction of the South Lawrence Trafficway.

The spillway is an excellent place to view a cross section of the rock layers that are typical of this area. These interbedded limestones and shales were deposited during the Pennsylvanian Period of geologic history (also known as the Coal Age), about 300 million years ago. At that time, Kansas was near the equator, the climate was warmer, and a shallow sea advanced and retreated repeatedly across eastern Kansas.

At times the sea left behind minerals that eventually became limestone, the brown and tan rocks in the spillway. Limestone is made up of calcium carbonate, debris composed of sea shells and other marine life, and minerals that were deposited onto the shallow ocean floor. Some of those limestones contain fossils of the invertebrate animals that were common during the Pennsylvanian—corals, sponges, crinoids, etc. These creatures secreted calcium carbonate to form shells and other hard body parts that make up these limestones.

At other times the ocean deposited muds, which eventually formed shales, the softer, thinly layered rocks in between the limestones. Occasionally this area was at or slightly above sea level and sandstone was deposited by rivers, estuaries, or deltas. In fact, a layer of sandstone called the Ireland Sandstone is present a little deeper in the Lawrence Formation.

Although each rock layer here is only a few feet thick, these formations extend vast distances across Kansas and adjacent states. Geologists have given each of these rock layers a name, based on the location where it was first described. The limestones and shales here are part of the Oread Limestone (even though it includes more than just limestone) and the Lawrence Formation. The Oread Limestone is named after nearby Mount Oread, home of the University of Kansas, where the formation was first described by geologist Erasmus Haworth in 1894. The Lawrence Formation, which lies below the Oread (and is thus older), is named for the city of Lawrence.

Geologists have divided the rock layers in the Oread and the Lawrence down into smaller units called members, much the way that biologists divide a genus into smaller groups called species. The rock layer that is poorly exposed at the bottom of the spillway is called the Amazonia Limestone Member, named for the small town of Amazonia, north of St. Joseph in Andrew County, Missouri. Above the Amazonia are shales and mudstones that are also part of the Lawrence Formation. This part of the Lawrence Formation includes a thin coal layer called the Williamsburg coal bed, named for the small town of Williamsburg, Kansas. This coal layer is not visible at the spillway, but it is exposed in a road cut south of the dam. This part of the Lawrence Formation may have been deposited on the plain of an ancient delta, where local swamps had formed.

Above the Lawrence Formation is the Toronto Limestone Member of the Oread Limestone. The Toronto is a thick, light gray to brown limestone with a few fossils. Above the Toronto is the Snyderville Shale Member, which is gray, and above that is the Leavenworth Limestone. The Leavenworth is a thin layer of gray to brown limestone that was first described from exposures near the town of Leavenworth.

The next unit up is the Heebner Shale Member, one of the most recognizable rock layers in the spillway. The Heebner is very different from the Snyderville Shale and shales in the Lawrence Formation. The Heebner is very dark—black, in fact. It is fragile and thinly bedded, deposited in layers so thin that they resemble pages in a book. In places, the Heebner contains phosphate nodules, marble-sized rocks that are high in phosphate and are slightly radioactive. Geologists disagree about the conditions under which the Heebner was deposited. Some regard it as the kind of rock that was deposited where the Pennsylvanian sea was its deepest. Other geologists are less sure.

Above the Heebner Shale is the Plattsmouth Limestone Member of the Oread Limestone. The Plattsmouth is a wavy-bedded, gray to brown limestone. In places it contains chert (or flint) and fossils such as crinoids, corals, or single-celled, wheat-grain-shaped animals called fusulinids.

When viewed at the spillway, one obvious characteristic of these rock layers is their cyclicity. That is, the rocks here are deposited in a regular vertical sequence of limestone, shale, limestone, shale, etc. This sequence of rocks, which geologists call a "cyclothem," is found not only in the Oread Limestone and Lawrence Formation, but is repeated in rocks above and below these formations and throughout the Pennsylvanian. Geologists believe that this regular sequence of deposition is probably the result of fluctuations in sea level. As the sea levels deepened (in the range of tens of feet deep), limestone was deposited. As the seas shallowed, shale was deposited (except, perhaps, in the case of the Heebner, which some geologists believe represents the time when the ocean was at its deepest).

Geologists disagree, however, about the reasons for the change in those Pennsylvanian sea levels. The changing sea levels may represent times when polar ice caps were shrinking or growing. When the ice caps melted, sea levels rose, resulting in limestone deposition. At other times, when ice caps grew, sea levels went down and shale was deposited. There are other theories about the reasons behind the sea level change. Still, it is possible to look at the rock layers in the spillway as hard evidence of sea-level fluctuations in this long-ago ocean.

After this stop continue south across Clinton Dam.

5.5 Clinton Dam control structure. Like many of the streams in northeastern Kansas, the Wakarusa River was dammed by the U.S. Army Corps of Engineers in response to the disastrous flood that hit this area in 1951. The normal pool has an elevation of 876 feet above sea level, roughly 55 feet above the deepest part of the lake in the old channel of the Wakarusa. At flood pool, Clinton Dam can back up water to a point about 13 miles west of here, three miles into Shawnee County. The outlet releases water into a man-made channel that joins the natural channel of the Wakarusa about 0.7 miles southeast of here.

To the east on the horizon is Blue Mound, a prominent outlier that is capped by the Oread Limestone. The Wakarusa valley widens considerably downstream in contrast to the bluff-lined valley occupied by Clinton Lake. Clinton Dam is constructed in the area where the Wakarusa cuts through the resistant limestones that cap the Oread Escarpment. The rocks below are the Lawrence Formation and the Stranger Formation. These rocks are soft, composed mostly of shale and soft siltstone and sandstones, and in them the Wakarusa has been able to carve a wide valley eastward that merges with the Kansas River valley east of Lawrence.

6.1 Below the dam is Eagle Bend golf course. The abandoned natural channel of the Wakarusa is lined by trees and is just north of the club house and parking lot.

6.9 Leaving the dam we climb through the Toronto Limestone Member and then the Plattsmouth limestone.

7.1 After cresting the hill, descend through the Toronto Limestone Member on both sides of the road.

7.2 Multi-colored shale in the Lawrence Formation. The Williamsburg coal bed can be found in this exposure.

7.7 T-intersection with E1000 Road. Turn north (left).

8.2 N1200 Road. Turn east (right).

8.9 The road here climbs onto the Buck Creek terrace of the Wakarusa. This was the river's floodplain during the Illinoian Stage of the Ice Age. This glaciation occurred after the Kansan glaciation; no glacier entered Kansas during the Illinoisan, but the streams flowed at higher levels than they do today.

9.4 Washington Creek, the creek that feeds into and drains out of Lone Star Lake.

11.3 Junction with U.S. Highway 59. Turn south (right).

12.5 Here the highway skirts around the east slope of Shank Hill. With an elevation of 1,007 feet, it rises about 200 feet above the Wakarusa River. It is formed by an outlier of the Oread Limestone, which caps it and caps Mount Oread and the range of hills ahead of us to the south. Somewhere between Shank Hill and the hills ahead is the southernmost extent of glacial ice during the Kansan glaciation. We know this because glacial deposits are found on the crest of Shank Hill but are not present farther south. Part of Shank Hill has been quarried away and used in constructing a realignment of U.S. 59 in the 1970s.

13.7 Here the highway climbs onto the Oread Escarpment. Some limestone is poorly exposed in the cuts on the right side of the road. The Oread caps Mount Oread, its namesake, and the range of hills northeast of Lawrence that extend just west of Tonganoxie on up to Leavenworth.

15.2 Pleasant Grove, elevation 1,086 feet.

16.7 Here we cross the drainage divide, leaving the Kansas River drainage to the north and entering the drainage of the Marais des Cygnes River, which flows through Ottawa. Drainage to the south eventually flows into the Missouri by way of the Osage River east of Jefferson City. The divide is also the approximate trace of the Santa Fe Trail. The trails in eastern Kansas tended to follow drainage divides in order to avoid crossing the many permanent streams and rivers in this part of the state. Stream crossings were often the most difficult and hazardous aspects of travel on these early trails.

19.1 The Ireland Sandstone Member of the Lawrence Formation is exposed in this small creek east of the highway.

20.2 Intersection with U.S. Highway 56. Baldwin City is five miles east.

23.0 West Tauy Creek. This creek is named for John Tauy Jones, who was part Ottawa Indian and was instrumental in founding Ottawa University.

23.2 Enter Franklin County.

25.2 This road leads 4.5 miles west to the town of Centropolis.

29.2 At this crossroads, turn east on Sand Creek Road.

29.4 This railroad line was once active from Lawrence southward. Today part of this line is used by Midland Railroad, an excursion train that operates out of Baldwin.

29.7 STOP 2. This quarry is known informally as the Fogle Quarry, after a family who owned and operated it. The quarry was opened in 1967, and in 1998 it was purchased by Martin Marietta Aggregates, which owns a number of quarries in central and eastern Kansas. Today this is one of the largest quarries in the state, producing limestone that is used in asphalt, concrete, road gravel, and a variety of other purposes. The quarry employs about 30 people and estimates that it will produce about 200,000 tons of aggregate this year.

This quarry consists of roughly a square mile that is either owned or leased by Martin Marietta. The company quarries limestone from several formations here, all of them older than the rocks at Stop 1. The floor of the quarry is formed on the Merriam Limestone Member of the Plattsburg Limestone. Above the Merriam, the company quarries limestone from the Spring Hill Limestone Member of the Plattsburg Limestone. The Spring Hill is a gray, fossiliferous limestone that ranges in thickness from about 20 feet here in northeastern Kansas to 88 feet where it crops out in southern Kansas.

The quarry also produces limestone from the Captain Creek Limestone, the Stoner Limestone, and the South Bend Limestone Members of the Stanton Limestone. At the top of the quarry is the Weston Shale Member of the Stranger Formation, which was quarried south of Ottawa at the Buildex Quarry. This shale was heated and the expanded form was used as an aggregate and as decorative stone. That quarry is no longer in operation.

The quarrying operation here consists of removing the overburden (soil and other material), blasting loose the limestone, hauling the resulting rock to be crushed, washed (in some cases), and sorted according to size and type. Eventually the overburden is replaced on the mined-out land and the land is reclaimed. Most limestone is broken up and used as aggregate, either directly as in gravel roads or mixed with asphalt to make macadam. Limestone is important in concrete construction both as a major component of cement and as an aggregate mixed with the cement.

Only limestone that meets standardized tests for durability and resistance to decomposition is used for highway construction. Finely ground limestone is used in agricultural and horticultural applications. Calcium carbonate is a buffer, which means it can help neutralize highly acidic or highly alkaline soils. This ability to neutralize acids makes calcium carbonate a major ingredient in over-the-counter antacid remedies.

After visiting the Fogle Quarry backtrack north on U.S. 59 to U.S. 56.

39.2 Intersection with U.S. 59 and U.S. 56. Proceed west (left). In the park here, there is an outcrop of the Ireland Sandstone Member, which has been highly eroded by a branch of Tauy Creek. In places the sandstone has large holes and steep bluffs that have been exposed by the creek. The Ireland, a massive, thick sandstone, was deposited in an old stream channel that cut across southern Douglas County and northern Franklin County during the Pennsylvanian Period, draining into a sea west of here. That river channel was as much as several miles wide and more than 100 feet deep so that the Ireland may be as much as 60 feet thick in places. In a location downstream from here, called Hole in the Rock, a particularly thick exposure of the Ireland is so highly crossbedded that the sandstone has a ropy, wavy appearance.

Where the Ireland is fairly close to the surface, it contains fresh water and is the source of water for many farms in this area, as well as for Baldwin City, four miles to the east, and several other towns along its trend. The name of the Ireland may be related to W.E. Ireland, a member of the Kansas Legislature from Yates Center, an area where the Ireland is also exposed. During one particularly troublesome legislative session in the 1930s, R.C. Moore reportedly named the Ireland after Ireland Creek, which was on the legislator's farm, in an attempt to improve the chances that the Survey's appropriation would be passed by the Kansas Legislature. Stratigraphic units are generally named after locations and not people.

39.7 West Fork of Tauy Creek.

40.4 Plattsmouth Limestone on the north side of the road.

41.1 Leavenworth Limestone in the creek bed south of the highway.

41.6 Leavenworth Limestone on both sides of the road. This rock layer is found throughout much of eastern Kansas and, except south of here in Franklin County, has a uniform thickness of between 1 and 2 feet.

42.7 Worden.

43.7 At this point, U.S. 56 passes over the Worden Fault, named for the small town 1.2 miles east of here. This fault, which is not visible from the highway, has been mapped southward to the Franklin County line and north of U.S. 56 a short distance, where it curves to the east and roughly parallels the highway all the way to Baldwin City. The fault apparently moved when the Oread Limestone, the surface rock here, was being deposited about 300 million years ago. This faulting may account for the absence of some members of the Oread in this vicinity, notably the Toronto Limestone Member. The Worden Fault is not considered tectonic in origin. That is, it was not caused by crustal movements associated with uplift and mountain building. Rather, it is apparently the result of sediment adjustment shortly after deposition. This adjustment may be caused by a thick body of sandstone, the Ireland, which fills a deep buried valley in this area. After sediments were deposited and buried by younger sediments, the sea water was squeezed out of them, and they became compacted. Some rocks, such as sandstones, compact much less than others, especially shales. Where two such rocks are near each other, as they are along the margin of the Ireland Sandstone Member, compaction occurs at different rates, and the sandstone compacts much less than does the adjoining shale. This differential compaction can lead to deformation and even to faulting, as in this case, in the overlying rocks.

44.7 The pond south of the road is actually an old quarry, probably in the Kereford Limestone, that has filled with water.

46.2 Globe. All that remains of Globe is a general store. It was originally called Washington, the first location in the state to be named after George Washington. Later the name was changed to Marion and finally to Globe. The county road here runs about three miles north to Lone Star Lake, built on Washington Creek, and on to Clinton Lake. Also, at about this point the highway crosses Eightmile Creek.

51.3 With an elevation of 1,200 feet, the hill south of the road is the highest point in Douglas County. About five miles to the north are two hills known as Twin Mounds. Their elevation, 1,108 feet, is somewhat lower than the elevation here, but they still stand about 100 feet above the surrounding countryside.

51.6 Osage County/Douglas County line. Douglas County is named for Stephen A. Douglas, the abolitionist senator who is probably best remembered for his debates with Abraham Lincoln.

52.2 Ozawkie Limestone Member of the Deer Creek Limestone. Although fossils are abundant in a few outcrops of this limestone, they are generally sparse in most exposures.

52.9 Ervine Creek Limestone Member. Although this member of the Deer Creek Limestone is thin in this area, it thickens to more than 30 feet in southern Kansas, where it is quarried. It is also quarried north of here, between Topeka and Lawrence, near the town of Big Springs.

53.0 Rock Creek.

54.5 Overbrook. This town sits on a ridge, elevation about 1,200 feet, that serves as the drainage divide between the Wakarusa and the Marais des Cygnes rivers. However, Overbrook may be named after a town in Pennsylvania, as are nearby Scranton and Carbondale.

55.5 Topeka Limestone.

57.8 Plummer Creek.

58.7 Santa Fe Trail High School south of the road. Through much of its route in Kansas, U.S. 56 parallels the old Santa Fe Trail.

59.7 Osage County State Park and County Lake are directly south of here.

60.2 Strip pits, overgrown with trees, line both sides of the road on top of this hill. The coal that was mined in this area was from the Nodaway coal bed in the Howard Limestone. The swamps that produced these coal beds stretched across the entire north-south distance of Kansas and on into Oklahoma, Missouri, Nebraska, and Iowa. Geologists believe that these swamps bordered the coast line of the Pennsylvanian sea for several hundred miles. In general, it took about 10 feet worth of the organic material growing in those swamps to produce one foot of coal. In many cases the swamps produced coals that are overlain by limestones, indicating that the coal-forming swamps were close to sea level and were occasionally flooded by limestone-depositing sea waters. Geologists aren't sure if the swamps that formed the coal were in fresh or brackish water, but it seems clear that the limestones that covered the coals were deposited by seas, because of the marine fossils that are found in the limestone.

60.5 Intersection with U.S. Highway 75. Turn north (right). Where these two roads intersect is called Four Corners.

62.5 Just to the west is Carbondale, a former coal mining town. It is surrounded by abandoned strip mines, many of which are now filled with water. Carbondale was once known for its mineral springs, such as Merrill Mineral Spring, which brought salty and sulfate-bearing water close to the surface, where it was pumped into a large bath, which had a nearby pavilion. A hotel and sanitarium for the treatment of nervous disorders once operated near the spring. North of Carbondale 1.5 miles is an area that is still shown on maps as Mineral Springs. Here springs and shallow wells once produced mineralized water, which was bottled and shipped out for medicinal purposes.

63.9 Burys Creek.

65.3 Here the highway drops off a small escarpment held up by the Howard Limestone.

66.5 Shawnee County/Osage County line.

67.4 Limestones in the Topeka Limestone. We will see much better exposures of these rocks at our final stop.

67.7 Wakarusa River. The river bed elevation here is about 930 feet, about 54 feet above the normal conservation pool elevation of Clinton Lake. The small town of Wakarusa is about three-fourths of a mile west of here. During the Kansan Glaciation, considerable melt water was diverted down the Wakarusa River because the Kansas River was blocked by glacial ice.

68.1 Limestone and shale in the Topeka Limestone.

72.7 Here the highway cuts between two hills capped by the Bern Limestone, named for exposures near the small town of Bern in north Nemaha County. Scranton Shale is exposed in the road cut. The shale can be from 130 to 150 feet thick.

73.5 South Branch of Shunganunga Creek.

74.5 Kansas Turnpike.

75.5 Junction with Interstate 470. Take I-470 west.

77.5 Burnett's Mound, south of the highway. This hill is capped by the Bern Limestone and has an elevation of nearly 1,150 feet. Burnett's Mound is named for Abraham Burnett, a Pottawatomi chief who is buried near its base. Legend has it that this mound would protect Topeka from tornadoes because it is located southwest of the city, and tornadoes generally move from southwest to northeast. The mound did its job until 1966.

78.4 Shunganunga Creek. This Indian name may refer to a horse or small pony.

79.3 Take the 21st Street exit and go west on 21st to Wanamaker.

79.8 Go north on Wanamaker.

80.3 The Golden Corral and lunch. The first Golden Corral opened in Fayetteville, North Carolina, in 1973. Their motto is "Making Pleasurable Dining Affordable." Golden Corral has been rated number one in the buffet category by *National Restaurant News* for four years in a row. Franchises are available. After lunch, proceed south on Wanamaker to 21st Street.

81.0 Go west on 21st Street.

83.9 Go south on Kansas Highway 4. K-4 takes a meandering route from northeastern Kansas, through Topeka, across the Flint Hills, and through central Kansas, before terminating at its intersection with U.S. Highway 83, north of Scott City.

85.5 Blacksmith Creek. To the west, K-4 climbs through a saddle in the ridge separating Blacksmith Creek from Mission Creek just to the west. It has been theorized that when the Kansas River was blocked by ice, water flowed out of Mission Creek through the gap and on eastward into Shunganunga Creek and from there into the Wakarusa River and on east.

87.1 Mission Creek.

89.3 The prominent limestone cropping out above the highway to the north is the Tarkio Limestone Member of the Zeandale Limestone.

90.0 Tarkio Limestone Member.

91.9 Mission Creek.

92.3 The highway crests a hill capped on either side by the Stotler Limestone.

93.9 Dover. This town was named by two families of settlers. One family said it was named for Dover, New Hampshire, while the other maintained it was named for Dover, England. Continue west on K-4, crossing Mission Creek on the west edge of town.

94.4 Wabaunsee County/Shawnee County line. Wabaunsee was a Pottawatomi chief whose name means "Dawn of Day." This is the only county in Kansas named for an Indian chief, though some towns (such as Satanta) are named for individuals and many counties (such as Shawnee and Osage) are named for tribes.

95.4 Turn south (left) near the electrical substation. Go one mile south.

96.4 Turn east (left) into the small park just before the bridge over Mission Creek. <u>STOP 3</u>. Echo Cliffs, which stand about 75 feet above the stream, are an excellent example of ancient river-channel deposits. Cycles of submergence and emergence, caused by changes in sea level, occurred many times during the Pennsylvanian here in the Midcontinent. When sea level fell, streams cut deep channels into previously deposited layers of limestone and shale. As channels meandered across the landscape, sand, silt, and claysized sediments were deposited, removed, and redeposited again and again, much as they are in a modern river like the Kansas River. Evidence indicates that channel cutting occurred in a freshwater environment when the ground was above sea level, and in most cases, the channels filled with nonmarine sandstones and shales. Some channel filling, however, may have taken place in a transitional setting, where marine and nonmarine environments met and tides affected sediment deposition. Much of the material filling the channel probably came from the uplands to the north and northwest.

The channel deposits at Echo Cliffs probably represent two separate channels. The first river channel developed about the same time the Plumb Shale was being deposited, cut down into rocks below the Plumb Shale. Later, a second river channel started in the Towle Shale and cut into the older Plumb Shale channel. A prominent layer of conglomerate (a rock composed of pebbles and rock fragments that have been cemented together) can be seen about two-thirds of the way up from the base of the cliff; this marks the base of the Towle Shale channel.

Plumb Shale Channel. About 48 feet of the Plumb Shale channel is exposed at Echo Cliffs. The Plumb channel fill is alternating layers of very fine grained micaceous (containing flakes of the mineral mica) sandstone, and micaceous siltstone and claystone. The entire deposit exhibits large-scale crossbedding. Crossbedding is a series of thin, inclined layers in a large bed of rock (usually sandstone) that is inclined at a distinct angle to the typically horizontal bedding surface. Formed by currents of water or wind, crossbedding is found in dune, stream channel, or delta deposits. The direction in which the beds are inclined usually indicates the direction the current of water or air was flowing at the time of deposition. In this case, the crossbedding was formed by water. Some sandstone crossbeds fill small channels cut into more massive beds. Carbonized leaf and wood fragments are common on bedding planes, giving the outcrop a streaked or banded appearance. Limonite (iron oxide) nodules are abundant, and the entire outcrop is stained with iron oxide. Calcium carbonate, iron oxide, and locally, barite cement the sand grains together.

Normally, the Plumb Shale is about 10 feet thick, but where deep channels develop, it can be up to 105 feet thick. The Plumb Shale channel at Echo Cliffs trends east to southeast and is probably not more than 1.5 miles wide.

Towle Shale Channel. The Plumb Shale channel is separated from the overlying Towle Shale channel by a limestone conglomerate. The conglomerate commonly forms a prominent ledge and breaks into large slabs. This conglomerate is 2-3 feet thick and consists of angular to subrounded fragments of local limestone and shale. Many of the limestone fragments are from the Brownville Limestone and Grayhorse Limestone Members of the Wood Siding Formation; evidence that shows this channel is younger than these units. In other words, sometime when the Towle was being deposited, channel downcutting eroded through the limestone layers in the Brownville and Grayhorse, and fragments of these limestones were broken off and carried downstream to be deposited within the conglomerate at a level lower than where they initially occurred. This not only dates the Towle channel as younger than the Brownville, it also shows the channel cannot be the same age as the Plumb because the Brownville and Grayhorse, which occur above the Plumb, hadn't been deposited when the Plumb channel was active.

At Echo Cliffs, the conglomerate is overlain by about 23 feet of very fine-grained micaceous sandstone that is interbedded with sandy siltstone. The Towle channel trends west to southwest. The channel is less than a mile wide and is about 85 feet deep. Normally, the Towle is only 10-20 feet thick in Wabaunsee County.

The channel sandstone in the Towle Shale Member is informally called the Indian Cave sandstone, referring to sandstone bluffs on the Missouri River in southeast Nebraska where this unit was first described that are locally called the "Indian Caves."

Pennsylvanian-Permian Boundary. At this location we are very close to the Flint Hills. The eastern boundary of the Flint Hills can be defined by rocks deposited during the Permian Period (about 290 million years ago), which are slightly younger than the Pennsylvanian rocks at Echo Cliffs. The Pennsylvanian and Permian rocks were deposited under similar conditions—that is, in shallow seas that fluctuated in depth. Because the rocks left behind by the Permian seas are similar to those deposited during the Pennsylvanian (alternating beds of limestone and shale), geologists have a difficult time deciding where the Pennsylvanian ends and the Permian begins. At one time, the boundary was placed at the base of the conglomerate in the Towle shale, so that everything above would have been considered Permian and everything below Pennsylvanian. In 1994, however, the Pennsylvanian-Permian boundary was moved, based on fossil evidence, much higher up in the geologic rock section. This means that all the rocks at Echo Cliffs are now considered Pennsylvanian, and you don't encounter Permian rocks (and thus the edge of the Flint Hills) until you go several miles west of here.

Backtrack to K-4.

97.4 Turn east (right) on K-4.

98.4 Turn north (left) on the county line road.

99.9 The pastures in this area are littered with numerous hard, pink boulders of Sioux quartzite. This rock was previously sandstone that was fused into blocks of solid quartz over a billion years ago in the area around Sioux Falls, South Dakota. They were carried into Kansas by the Kansan glacier about 600,000 to 700,000 years ago. These foreign boulders, called erratics by geologists, are tell-tale markers of the presence of glacial ice during the Pleistocene and can be used to mark the extent of the glacier because only the immense force of moving ice is capable of carrying rocks this big any appreciable distance. Glacial deposits are not found a short distance south of here, so we are very near the terminus of the Kansan glacier.

102.5 STOP 4. Shoffner gravel pit. Pull into the driveway on the west side of the road, just south of Vassar Creek. This gravel pit operated until 1952. The rocks here are composed of rounded gravel, pebbles, cobbles, and boulders of limestone, chert, quartzite, and granitic rocks. These rocks are poorly sorted and some layers are cemented by calcium carbonate. The rounded nature of these rocks and their large size indicates that they traveled some distance in a strongly flowing river, yet we are five miles south and more than 150 feet above the nearest large river, the Kansas. The presence of relatively soft limestone pebbles and cobbles suggests that this material didn't travel very far. The occurrence of rocks foreign to this area, erratics, indicates that a glacier played a role in forming this deposit. This is a deposit of glacial drift left behind by the Kansan glacier roughly 700,000 years ago. Drift is a term that originated in Britain to describe the diverse mixture of rock and clay that covers much of that island. Early beliefs were that this material "drifted" in during the Great Flood of the Old Testament. We now know that continental glaciation formed these deposits yet drift persists as a name for them. Drift is a general term for deposits associated with glacial ice and includes river and lake deposits formed by the melting waters of a glacier. A deposit formed directly by glacial ice is known by a Scottish word, "till."

This deposit most likely formed when the Kansan glacier occupied the Kansas River valley, damming its southern tributaries, creating a temporary lake and diverting the drainage to upland areas such as this. Melt water from the glacier carried part of the huge, diverse sedimentary load from the glacier across present drainage divides and deposited it locally on some of the uplands, as in this location and in terrace deposits along some of the larger streams such as Shunganunga Creek and the Wakarusa River. Glacial drift covers a large part of northeastern Kansas, north of the Kansas River and east of the Big Blue River. Deposits of sand and gravel such as this make excellent aquifers because of the porosity and permeability provided by the coarse grain sizes. These deposits feed small springs that drain into Vassar Creek just down the hill, and drift-related aquifers are important groundwater resources in the glaciated region of Kansas. The gravel itself is an aggregate resource and this pit was operated to provide gravel for county roads.

Following this stop, return to the blacktop county line road and proceed north.

102.7 Vassar Creek.

103.8 West of the road is a center-pivot irrigation system. These are common sights on the High Plains where the underlying High Plains aquifer has abundant supplies of groundwater. These are also becoming common in eastern Kansas in some of the large stream valleys, such as the Kansas River, where the alluvial aquifer can supply the large amounts of groundwater necessary to feed one of these systems. But they are rare in upland areas such as this, because the bedrock of eastern Kansas has few good aquifers. However, glacial drift covers this area and in it are sands and gravels like the ones we saw at the last stop that contain enough groundwater to justify the installation of such a system.

105.5 Junction with Interstate 70. Go east (right). This is also the line between Wabaunsee and Shawnee counties. This was once part of a 900-square-mile Pottawatomi reservation that stretched 30 miles north and west from Topeka. A 120-square-mile reservation still exists about 15 miles to the north, in Jackson County. The Pottawatomi language has provided what is probably the best known Indian phrase in America—kemo sabe—which means "faithful friend" and was used by television's Tonto in reference to the Lone Ranger.

106.8 Willard Shale overlain by the Tarkio Limestone Member of the Zeandale Limestone. This Pennsylvanian limestone is gray but weathers to a deep yellow-brown and is characterized by an abundance of large fusulinids.

107.5 Vassar Creek.

107.9 Willard Shale, overlain by Zeandale Limestone.

108.3-108.6 Zeandale Limestone, named for a small town east of Manhattan. Zea is the Greek word for grain and that part of the Kansas River valley was known as the Zeandale Bottoms.

109.0 Willard Shale.

110.3 Mission Creek.

110.8 Here the road passes through a hill called Hickory Knob. Along the road, the Scranton Shale is overlain by the Bern Limestone.

110.8 Blacksmith Creek, a small creek that joins Mission Creek and drains into the Kansas River.

111.9 Emporia Limestone.

112.3 Auburn Shale, overlain by the Emporia Limestone.

112.6 K-4 interchange.

113.9 Burlingame Limestone Member of the Bern Limestone. Fusulinids and algal remains are common in this limestone, which ranges in thickness from 1 to 25 feet.

114.7 I-470 interchange. This road loops around the western and southern edges of Topeka before intersecting with the Kansas Turnpike and I-70.

114.9 The Kansas Museum of History, operated by the Kansas State Historical Society, opened in 1984 with exhibits related to the history of the state.

115.6 Exit for Wanamaker Road and U.S. Highway 75 By-pass South. The Kansas Museum of History and the Menninger Foundation are accessible from this exit.

116.1 North of I-70 is the Menninger Foundation, a nationally known center for the treatment of and research into psychiatric disorders. The main building, which is modeled after Independence Hall in Philadelphia, contains a collection of Sigmund Freud's papers.

116.6 On the hill to the north is Cedar Crest, the official residence of the governor of Kansas.

117.5 Interchange for U.S. Highway 75, which exits to the north and joins I-70 for a short distance to the west. The eastbound exit for Gage Boulevard and Gage Park is at this interchange.

117.8 Just north of I-70 is a view of the Kansas River. This is also the westbound exit for Gage Boulevard. One mile south is Gage Park and the Topeka Zoo.

119.1 Here I-70 crosses Ward Creek, which flows a short distance north and empties into the Kansas River. A dredge operates on the river here, suctioning sand and gravel from the bed of the river. The Kansas, or Kaw, drains almost all of northern Kansas, eastern Colorado, and most of Nebraska south of the Platte River. The Kansas begins at the confluence of the Republican and Smoky Hill rivers near Junction City and empties into the Missouri River at Kansas City. Other rivers that drain into the Kaw include the Solomon, Saline, Delaware, Blue, and Wakarusa. In all, the Kaw drains a watershed of more than 60,000 square miles, carrying an average of 4.75 million acre-feet of water each year. In northeastern Kansas, where groundwater supplies are rare, the Kansas is an important water source, and it is no accident that many of the state's major cities—Topeka, Lawrence, Kansas City—are perched on its banks.

120.9 The twin spires of St. Joseph's Catholic Church are visible south of the highway.

122.0 Tenth Ave. Exit. The Kansas Statehouse and other state office buildings are accessible from this exit. Construction on the Kansas Statehouse began in 1867, using the Fort Riley Limestone Member of the Barneston Limestone, quarried near Junction City. Construction began on the west wing in 1869, using Cottonwood Limestone Member of the Beattie Limestone, dug near Cottonwood Falls in Chase County. Located on a 20-acre square in the center of Topeka, the Statehouse features murals by John Steuart Curry. Since Kansas was organized as a territory in 1854, the legislature has met at four locations in addition to Topeka. The 1855 legislature, called the Bogus Legislature because many of its members were elected by proslavery Missourians, met at Pawnee in Fort Riley and at Shawnee Mission. Later legislatures met at Lecompton and Lawrence, before Topeka was voted the permanent state capital.

122.4 Shunganunga Creek.

122.7 Topeka Limestone.

123.9 Take U.S. 40/Deer Creek Parkway Exit (no. 364-B) and proceed north following Deer Creek. The Deer Creek Limestone was named for exposures along this stream.

124.9 Sixth Street. Turn east (right). This is also K-4 and U.S. Highway 40.

125.0 Deer Creek.

126.6 Turn north (left), taking K-4 north at the stoplight. Members of the Deer Creek Limestone are exposed at this intersection.

127.3 Shunganunga Creek flows through a man-made channel here. It once meandered across the Kansas River floodplain north of here through what is now Phillip Billard Municipal Airport. Shunganunga Creek flows into the Kansas River at Tecumseh a little more than a mile east of here.

128.2 This is the old natural channel of Shunganunga Creek. To the west is Billard Municipal Airport.

128.7 To the east are abandoned sand pits. The Kansas River is a primary source of quartz-rich sand and gravel in this part of Kansas. Sand and gravel are extracted by dredges that operate on the river and by dredges that operate in pits excavated in the river's floodplain. Environmental groups have opposed in-river dredging, although pit dredging is not without its potential environmental hazards. When pit dredging ends, a large hole is left in the floodplain, which fills with water. The surface of the water is the water table, representing the upper surface of the alluvial aquifer in that area. These abandoned pits are, in essence, windows to the aquifer, providing a direct pathway for potential ground-water pollution. Polluted aquifers are very difficult and costly to clean up.

129.2 The Kansas River. The river's elevation here is about 850 feet.

129.9 The highway crosses over the Union Pacific tracks and Indian Creek and climbs onto Calhoun Bluff. Below the highway are exposures of the Calhoun Shale, which contain fine sandstone in the area. This outcrop is the type locality of the Calhoun Shale. Near the top of the Calhoun Shale is an unnamed coal bed.

130.0 STOP 5. The road cut at the junction of K-4 and U.S. Highway 24 is an easy place to see and collect invertebrate fossils. Fossils are the ancient remains or evidence of once-living plants and animals, and invertebrates are animals without backbones. In Kansas, invertebrate fossils are much more common than vertebrate fossils. Even so, they represent only a tiny sampling of the animals that once inhabited this part of the earth, most of which lived and died leaving no visible trace. The fossils here give an idea of the variety of animals that lived in the Pennsylvanian seas, roughly 300 million years ago. Among the fossils found at this site are brachiopods, bryozoans, crinoids, gastropods (snails), bivalves (oysters, clams, scallops), and trilobites. The less familiar of these are described in more detail below.

Two units here, the Holt Shale and Coal Creek Limestone Members of the Topeka Limestone, are particularly fossiliferous. The Holt Shale Member is a dark-gray, layered siltstone, about 2 feet thick. Fossils of brachiopods and bryozoans (see description below) are common in this member. The Coal Creek Limestone Member, which sits directly above the Holt Shale Member, is a light-gray or olive, silty limestone, about four feet thick.

In addition to the fossils at this site, you can see coal, exposed at the surface in the Calhoun Shale, the formation just below the Topeka Limestone. Pyritized wood is also found in the same vicinity as the coal, just above the coal layer in the Calhoun Shale.

Bryozoans are some of the most abundant fossils found in sedimentary rocks, and they are also widespread today, both in marine and freshwater environments. Bryozoans are small animals (just large enough to be seen with the naked eye) that live exclusively in colonies. Bryozoans are sometimes called moss animals—the name comes from two Greek words, *bryon* (moss) and *zoon* (animal)—because some bryozoans form colonies of bushy tufts that resemble mosses. Bryozoan colonies can also resemble colonies of some corals. Like corals, most bryozoans secrete external skeletons made of calcium carbonate, but unlike corals, bryozoans generally don't build reefs. Each bryozoan colony starts out with a single individual, called a zooid. Each zooid is essentially cylindrical and has a ring of tentacles that it uses to feed, drawing tiny plants and animals towards its mouth. As the first zooid begins feeding, it buds to form additional zooids, each of which has its own feeding tentacles. The new zooids also bud, forming the colony. Large colonies may consist of hundreds of thousands or even millions of zooids. Fossil bryozoan colonies come in a variety of shapes. Some bryozoans built colonies that grew from the seafloor in branching structures; these fossils look like something like twigs. Other species erected netlike frameworks, while still other spread like a crust on shells, rocks, plants, and even other bryozoan colonies. All of these types of bryozoan colonies can be seen at this site.

Brachiopods are marine animals that secrete a shell consisting of two parts called valves. Their fossils are common in the Pennsylvanian and Permian limestones of eastern Kansas. Brachiopods have an extensive fossil record. They first appear in rocks dating back to the early part of the Cambrian Period, about 545 million years ago, and were extremely abundant until the end of the Permian Period, about 250 million years ago, when they were decimated in the mass extinction that killed more than 90 percent of all living species and was the largest of all extinction events (larger than the major extinction at the end of the Cretaceous that killed off the dinosaurs). A distinctive feature of all brachiopods is that their valves are bilaterally symmetrical—that is, the right half is a mirror image of the left half. (Humans are also bilaterally symmetrical.) The bilateral symmetry of the individual valves differentiates brachiopods from clams and other bivalved mollusks, with which they are sometimes confused. Unlike brachiopods, clam valves are not bilaterally symmetrical; instead, the right and left valves are mirror images of each other. Brachiopod shells come in a variety of shapes and sizes. The outer surface of the valves may be marked by concentric wrinkles or radial ribs. Some brachiopods have prominent spines, but these are generally broken off and incorporated separately in the sediment.

Clams and other bivalves. Fossil clams are generally easy to recognize because they look a lot like the shells scattered along modern seashores. Clams and their relatives (oysters, scallops, mussels) are often called bivalves (or bivalved mollusks) because their shell is composed of two parts called valves. Like their living relatives, fossil bivalves come in many different shapes and sizes. Typically the right and left valves are symmetrical (in contrast to the bilateral symmetry of individual brachiopod valves), though some bivalves, such as oysters, have valves that are not symmetrical. In western Kansas, fossil clams found in younger rocks from the Cretaceous Period, are even more common. Some of these—the inoceramid clams from western Kansas—are huge, as much as 6 feet in diameter.

Crinoids are another animals that lived in the Pennsylvanian seas. Because they resemble plants, with feathery arms set atop a long stem, crinoids are sometimes called sea lilies. But they are definitely animals—relatives of starfish, sand dollars, and sea urchins. Crinoids appeared in the fossil record about 500 million years ago and still inhabit the world's oceans. Well-preserved fossils of entire crinoids have been found in the chalk of western Kansas (and are on display in museums around the country). Usually, what people find are pieces of the crinoid stem, which are shaped like little buttons and were used by Native Americans as beads. At this site, you might also find the crinoid calyx, the cup-like part that sat on top of the stem.

Trilobites are an extinct group of arthropods, relatives of insects, spiders, ticks, crabs, shrimp, lobsters, and numerous other organisms. They were exclusively marine organisms. Trilobites first appear in the fossil record in rocks deposited during the Lower Cambrian, about 540 million years ago. Although they were extremely abundant during their first 100 million years or so, by the Pennsylvanian and Permian Periods (when the surface rocks in eastern Kansas were deposited), trilobites were much less dominant. They became extinct, along with many other species, at the end of the Permian. The bodies of trilobites, like insects, have three parts: the head (or cephalon), the thorax, and the tail (or pygidium). Leg-like appendages attached to all three parts, but these are rarely preserved. Because of this, and the fact that trilobites have no living counterpart, paleontologists are hesitant to speculate about how trilobites lived. Trilobite pygidia are sometimes found at this site.

Following Stop 5, return to Lawrence via U.S. Highway 24.