The Geology of Kansas City, Missouri

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Introduction

This field trip is designed to introduce participants to the exposed rock section at Kansas City, Missouri and its environs (Fig. 1). All of the exposed rocks are sedimentary in origin and belong to the Pennsylvanian and Quaternary Systems.

The combined thickness of the exposed rocks is about 350 ft (107 m), measured from the bottom of the lowest valley to the top of the highest hill. Excellent exposures of Pennsylvanian strata can be observed in excavations for roads and highways. The excavations or "road cuts" as they are commonly called are in places 75 ft (23 m) high and several hundred feet long. The section of Pennsylvanian rocks consists predominately of limestone and shale with minor amounts of sandstone, coal, and conglomerate. Most of the Pennsylvanian strata belong to the Kansas City Group, Missourian Series. These lithologic types occur as "bundles" of strata that alternate in cyclical fashion throughout the section and are commonly called "cyclothems." Of most importance economically are the beds of limestone, in particular, the Bethany Falls. The industrial development of Kansas City is closely related to the exploitation of the 20-24 ft (6-7 m) thick "ledge" of Bethany Falls Limestone in quarrying and mining operations.

The Pennsylvanian bedrock is overlain by surficial deposits of Pleistocene and Holocene age. The surficial deposits include, glacial drift, loess, alluvium and soil. The glacial drift consisting of till and outwash (stratified drift) is of pre-Illinoisan age. It is variable in thickness and spotty in areal extent, but thicknesses of over 30 ft (9 m) occur locally. Glacial drift caps many of the higher hills in areas north of the Missouri and Kansas River but it has been removed by erosion along the valleys of the major tributary streams, and in most places south of the Missouri and Kansas River valleys. Deposits south of the major rivers, including downtown Kansas City, is evidence that glacial lobes pushed south of the present day channels of the Missouri and Kansas Rivers.

A cover of windblown silt (loess) is predominately of Wisconsinan age and overlies the glacial drift except in areas where the drift is absent. At these places, the loess rests on Pennsylvanian bedrock. The loess is thickest along the bluffs of the major river systems where it is 75 ft (23 m) thick.

The floodplains of the Missouri and Kansas Rivers are underlain by alluvium of sand and gravel of Late Pleistocene and Holocene age over 180 ft (55 m) thick in places.

Of special interest are small areas where structural blocks of Pennsylvanian strata bounded by high angle normal faults have moved downward many feet. These localized areas of pronounced structural disturbance contrast sharply with the surrounding region where the strata have been gently folded. The origin of the faulting in the "stable" interior of the North American Continent is a matter of debate. Also available for discussion is the paleogeographic setting in which some limestone beds thicken abruptly by addition of mounds of oolitic grainstone.

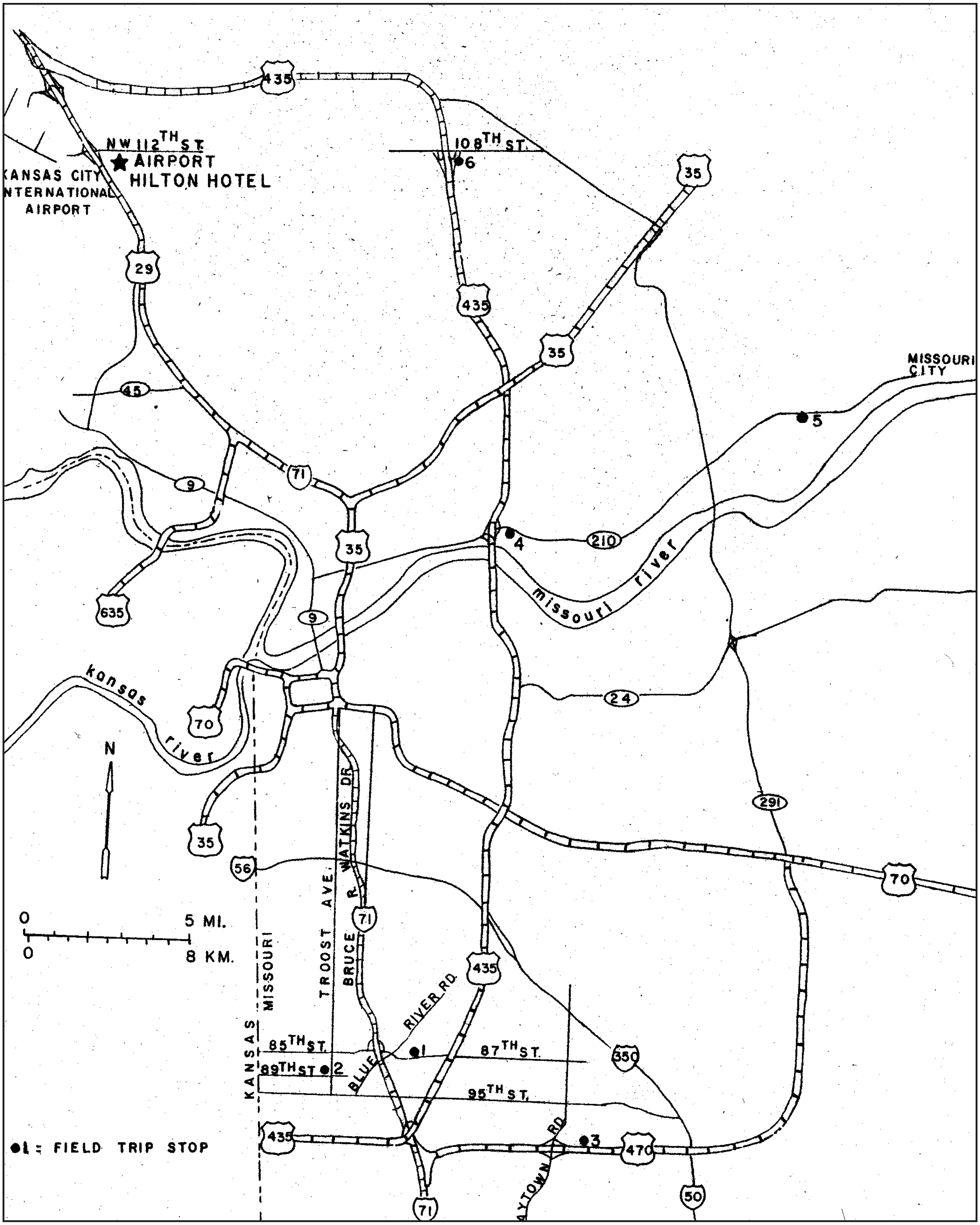


Figure 1. Guide to field trip stops in the greater Kansas City metropolitan area.

Route log for field trip (Fig. 1)

Miles
0.0 Leave parking lot at Airport Hilton Hotel
left (north) on Ambassador Drive
0.1 Stop light, 112th Street, turn left (west)
pass under I-29 overpass
0.4 Exit ramp to I-29 and Highway 71 south,
FOLLOW HIGHWAY 71 FOR 26.6 MILES, Highway 71
includes segments I-29, I-35 or I-70 for part of the route
3.0 Highway 152
5.0 Platte Woods city limits
8.4 I-635, stay on Highway 71 and I-29 south
9.3 Argentine Limestone Member exposed on both sides of Highway
9.4 Highway 169, City Limits of Kansas City
10.6 North Oak Traffic Way
11.2 I-35 north
13.2 North Kansas City
13.7 Armour Road, Highway 210 west
16.2 Paseo Bridge over Missouri River, the congested Downtown Loop,
Stay right on Highway 71 south, I-29 and I-35

The floodplain is underlain by 100-150 ft of alluvium that filled a channel eroded into Pennsylvanian age bedrock during the Pleistocene Epoch. Large diameter wells drilled into the alluvium are capable of producing 4000 gallons water per minute. An interesting feature is a deep narrow gorge that underlies the alluvium (Fig. 2). During construction of the Trans-Missouri River water tunnel samples from borings revealed that the deep narrow gorge was filled with glacial

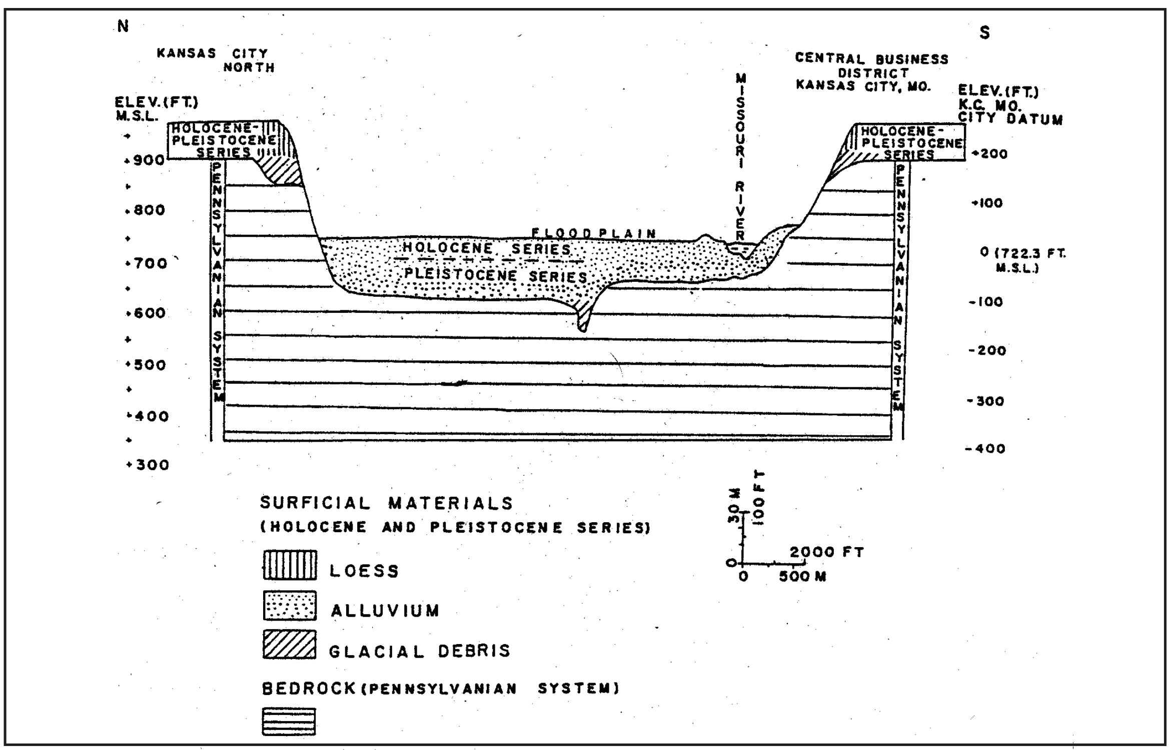


Figure 2. North-south cross profile of the Missouri River valley along the line of the Paseo Bridge in Kansas City, MO.

till. Glacial till was also encountered in the excavation for Interstate Highway 670 at one of the highest elevation in downtown Kansas City. The difference in elevation of the till in the deep gorge and the highest elevation in Kansas City is 400 ft, an indication of the minimum thickness of the ice lobe that filled the Missouri River Valley and advanced southward over the highest hills. This figure is based on the assumption that the till at both places was deposited by the same ice lobe (Gentile, 1994).

16.8 Continue south on Highway 71 and pass by Interstate 70 and Highway 24 west off-ramps

17.3 Continue south on Highway 71 and pass by I-70 east and I-635 west off-ramp
begin Bruce R. Watkins Drive a continuation of 71 Highway

20.9 Brush Creek, Swope Parkway, and Highway 56 exit to the University of Missouri Volker campus

24.5 Gregory road stoplight

26.1 Exit 85th-87th Streets and Blue River Road

26.2 85th Street, turn left, pass over Highway 71 overpass

26.3 Right on 87th Street, cross Blue River Bridge

26.4 Intersection with Blue River Road continue on 87th Street

26.5 STOP 1, Fireman's Memorial Section, park on grassy strip on left side of road

26.7 Retrace route to 85th Street, go west on 85th Street

28.6 Pass under Troost Avenue, overpass. Take on-ramp to Troost Avenue south

28.7 South on Troost Avenue

29.3 STOP 2, park in small turn-out on west side of Troost Avenue next to Westerville Limestone ledge about 500 ft north of intersection with 89th Street (Figure 10 and 11).

30.1 Continue south to intersection Troost Avenue and 95th Street (Bannister Road) left (east on 95th Street)

31.1 Bridge over Blue River Road
Exposure on high wall of abandoned quarry at 11 o'clock is in Bethany Falls and Winterset Limestone Members. The section from the Middle Creek Limestone to the Westerville Limestone is exposed in the quarry and along the hillside on the north side of 95th Street

32.1 Highway 71 overpass, continue east on 95th Street

32.6 I-435 overpass, continue east on 95th Street

33.8 Intersection Blue Ridge Road, continue east on 95th Street

34.5 Intersection James A. Reed, continue east on 95th Street

36.1 Intersection Raytown Road, right (south on Raytown Road)

36.9 STOP 3, park on west side of Raytown Road just before off-ramp to I-470 West

CAREFUL crossing Raytown Road, walk (east) for about 1000 ft along I-470 exit ramp to faulted outcrop (Fig. 16).

Off ramp from Raytown Road to I-470 west

37.1 Steeply dipping limestone and shale beds of Cherryvale Formation on right side of road. The beds are 50 ft lower here than at stop 3 and have moved downward along high angle faults as support was removed from below.
Continue west on I-470

39.7 Road cut, Cement City and Iola Limestones exposed on right side of I-470; entering the Grandview Triangle, under construction to remove a major bottle neck to the Highway system of Kansas City

40.1 Off-ramp to Highway 71 and I-435 north

40.6 On-ramp to I-435 north

CONTINUE NORTH ON I-435 FOR 26.2 MILES TO HIGHWAY 210 EAST EXIT

43.2 Westerville and Cement City limestones on both sides of I-435

43.9 Oldham Road Overpass, Winterset Limestone on both sides of I-435

44.5 Westerville Limestone

45.0 Winterset Limestone exposed along exit ramp to Gregory Road continue north on I-435

45.4 Cross-bedded limestone on left (west) side of road is a carbonate buildup in the upper part of the Westerville Limestone

45.5 Cement City Limestone exposed under 67th Street overpass

45.9 Winterset Limestone and Westerville Limestone exposed along exit ramp to 63rd Street. The upper part of the Westerville Limestone is a cross-bedded grainstone (carbonate buildup).

46.6 Cement City Limestone on curve under Highway 350 overpass

47.9 Eastwood Trafficway to the Raytown Road exit to the Sports Complex, a distance of 0.8 mile, the section includes the beds from the Cement City Limestone down to the Bethany Falls Limestone; the Westerville Limestone is about 20 ft (6 m) thick just north of Eastwood Trafficway, the upper part is a cross-bedded oolitic grainstone, and is one of the best developed carbonate buildups in the Kansas City area.

48.7 Raytown Road exit to Truman Sports Complex continue north on I-435

50.7 Interstate Underground Storage Facility in Bethany Falls Limestone to right

51.1 Brunson Instrument Company at 23rd Street and I-435

The Brunson Instrument Company occupies mined out space in the Bethany Falls Limestone. It is unique in that it is the first underground installation in the area in which the primary object was to use the mined out area. The move to the underground was completed in 1961 from a location in Downtown Kansas City where the calibration of precision instruments could take place only during the "dead" of night when vibrations and dust from traffic were at a minimum. At the present site work can continue around the clock because the underground is essentially vibration and dust free. The Brunson Instrument Company manufactures precision instruments for guided missile systems, polar research and lunar exploration. These instruments must measure accurately to eighty-millionths of an inch.

51.9 Sniabar Limestone to Winterset Limestone on right (east) side of highway; excellent exposure of the Sniabar Limestone, Elm Branch Shale and Middle Creek Limestone just before Winner Road exit ramp

52.7 Loess bank on south bluff of Missouri River on right (east) side of I-435 under Wilson Road overpass

53.3 Blue River Bridge

55.3 Cross I-435 bridge over Missouri River, enter Clay County

56.4 Take 55B exit to Highway 210 east

56.5 **STOP 4,** park on shoulder of Highway 210 about 1200 ft east from end of exit ramp onto Highway 210 (Fig. 24)

Continue east on Highway 210

57.1 Winterset Limestone to Block Limestone left (north) side of highway just west of railroad bridge. The Winterset includes and abundance of nodules and lenses of dark-gray chert.

57.3 Hunt-Midwest Subtropolis, numerous tunnels in the Bethany Falls Limestone lead into the underground developed in the bluff on the north side of the Missouri River. The Ameristar Gambling Casino is to the right on the floodplain along the Missouri River.

The Hunt-Midwest Subtropolis is the largest underground business complex in the world. Over 700 acres of floor space has been left after mining operations of the Bethany Falls Limestone. Underground space is leased by about 65 companies for warehousing, manufacturing, commercial, and office use. The majority of the leased space is for dry storage. Underground space is less expensive to rent than a conventional above ground warehouse. Several hundred people are employed underground. There are 3.5 miles (6 km) of road and 2 miles (3 km) of railroad tracks that can accommodate 150 rail cars at any one time.

The first foreign trade zone in the continental U.S. was established in the Hunt-Midwest underground in 1973. A Foreign-Trade Zone is a site where foreign and domestic materials are considered by the U.S. Customs Service to be in international commerce. This means that foreign or domestic goods may be brought into the Zone without formal customs entry or the payment of duty or excise and inventory tax. Goods brought into a Zone may be stored, manipulated, mixed with domestic and/or foreign materials, used in assembly or manufacturing processes or exhibited for sale.

Merchandise shipped out of the Zone into U.S. Customs territory is subject to duty. No duty is charged on waste materials. U.S. Customs duties are not levied on goods shipped to foreign nations. Foreign-Trade Zones offer many of the advantages of overseas plant locations without the risks of foreign investments. Zones enable business firms to take maximum advantage of the benefits of both domestic and foreign operations. The large available acreage of low cost underground storage space and the geographic location of Kansas City near the center of the nation are two major reasons why the first foreign trade zone was established here.

Continue east on Highway 210

58.0 For the next 5 miles (8 km) our route passes over the broad floodplain of the Missouri River

62.5 Highway 291 overpass. Continue east on Highway 210

63.3 Nebo Hill is straight ahead in the distance. The Winterset Limestone and Bethany Falls Limestone are exposed in face of the cliff. The Bethany Falls was mined by tunnels into the lower part of the cliff.
64.1 Cross Rush Creek bridge
64.2 Ascend Nebo Hill via Highway 210 road cut for the next 0.1 mile the highway passes through the section of Winterset Limestone through the Westerville Limestone. The upper Westerville is a cross-bedded oolitic grainstone.
64.9 **STOP 5**, park on south side of Highway 210, walk across grassy strip and down bank of small stream to exposure of diamicton (glacial till) along stream bank.
Retrace route to I-435
73.8 Exit ramp to I-435 north
Continue north on I-435, Worlds of Fun Amusement Park on right.
74.4 Argentine Limestone exposed in road cut along Randolph Road that parallels I-435
80.5 Spring Hill Limestone Member on both sides of the Highway
80.6 Exit ramp to 108th Street
80.7 **STOP 6**, park on side of exit ramp
80.8 Continue on exit ramp to 108th Street
Sharp left turn onto on-ramp and return to I-435 North
80.9 Continue north on I-435
89.3 Highway 169
91.0 Exit ramp to Skyview Drive
91.2 Skyview Drive
South on Skyview Drive
92.5 NE 108th Street, stop sign, turn right (west)
Continue west on 108th Street
93.3 Congress Avenue, stop sign
Right (north) on Congress Avenue
93.8 112th Street, turn left
Continue west on 112th Street
94.5 Ambassador Drive stop light, turn left (south)
94.6 Parking lot at Airport Hilton Hotel

END OF TRIP

Stop No. 1 – Fireman's Memorial Section, 87th Street and Blue River Road (Figs. 3-5)

The lower 95 ft (29 m) of the Kansas City Group (Pennsylvanian System) is exposed in an excavation for 87th Street for a distance of about 1,000 ft (305 m). Three thick limestone members are separated by relatively thin shale units and comprise a sequence of strata upon which most of the city is built. The limestone members are in ascending order: the Sniabar, Bethany Falls, and the Winterset (Fig. 4). The section is exposed in a series of benches. Each bench is successively higher than the preceding bench. The step-like pattern of rock removal is used to insure rock stability in deep excavations. The nose of a hill over 100 ft (30 m) high was removed to allow construction of 87th Street. Fortunately, the series of benches gives relatively easy access to the rock section. The section along 87th Street is representative of the sequence of strata that comprises the lower Kansas City Group throughout metropolitan Kansas City. (Figs. 5 and 6).

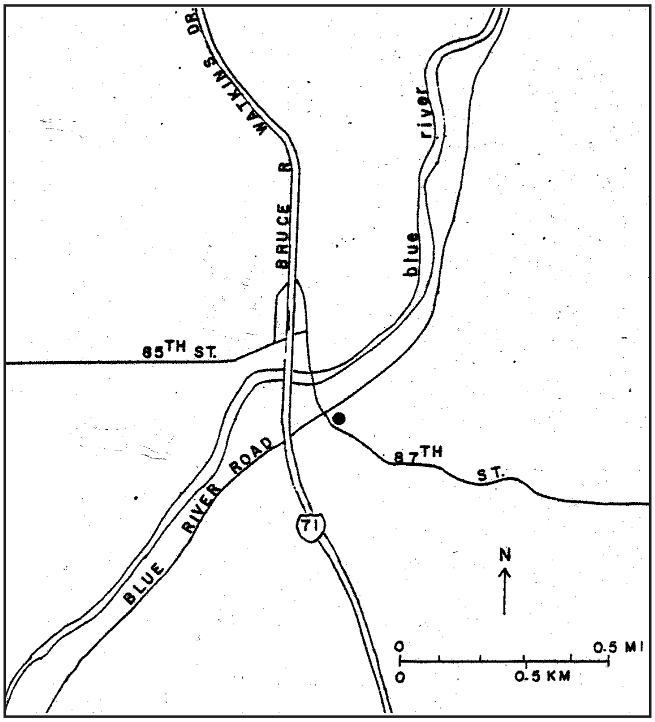


Figure 3. Location map of the 87th Street and Blue River Section (Stop 1 shown by •, Fireman's Memorial Section).

The physical properties of the Bethany Falls limestone are readily visible at this location, Figure 7. The Bethany Falls has been extensively quarried and mined throughout the Kansas City area since the 1880s. The industrial development of the city is closely related to the exploitation of the Bethany Falls Limestone, informally called the "Bethany Ledge" by quarrymen. Almost all of the underground space left after mining operations in metropolitan Kansas City is in the Bethany Falls Limestone.

The Middle Creek Limestone Member is abundantly fossiliferous with a variety of invertebrates. The most abundant fossils are the "twig-like" bryozoan *Rhombopora* but also common are brachiopods of the genera *Meekella*, *Derbyia*, and *Composita* (Fig. 8).

An interesting feature that is well exposed in the 87th Street excavation is the occurrence of two lens-shaped bodies of shale, each 60 to 100 ft (18 to 30 m) wide and with a maximum thickness of four feet (Fig. 9). The shale bodies are at the stratigraphic position of the upper part of the Sniabar Limestone but they are genetically related to the overlying Elm Branch Shale. The lens-shaped bodies of shale are interpreted to

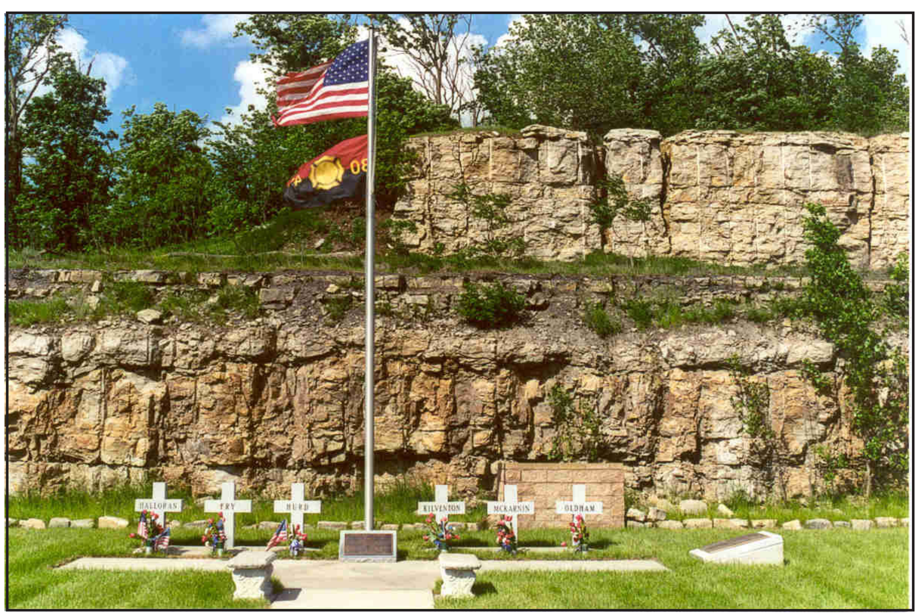
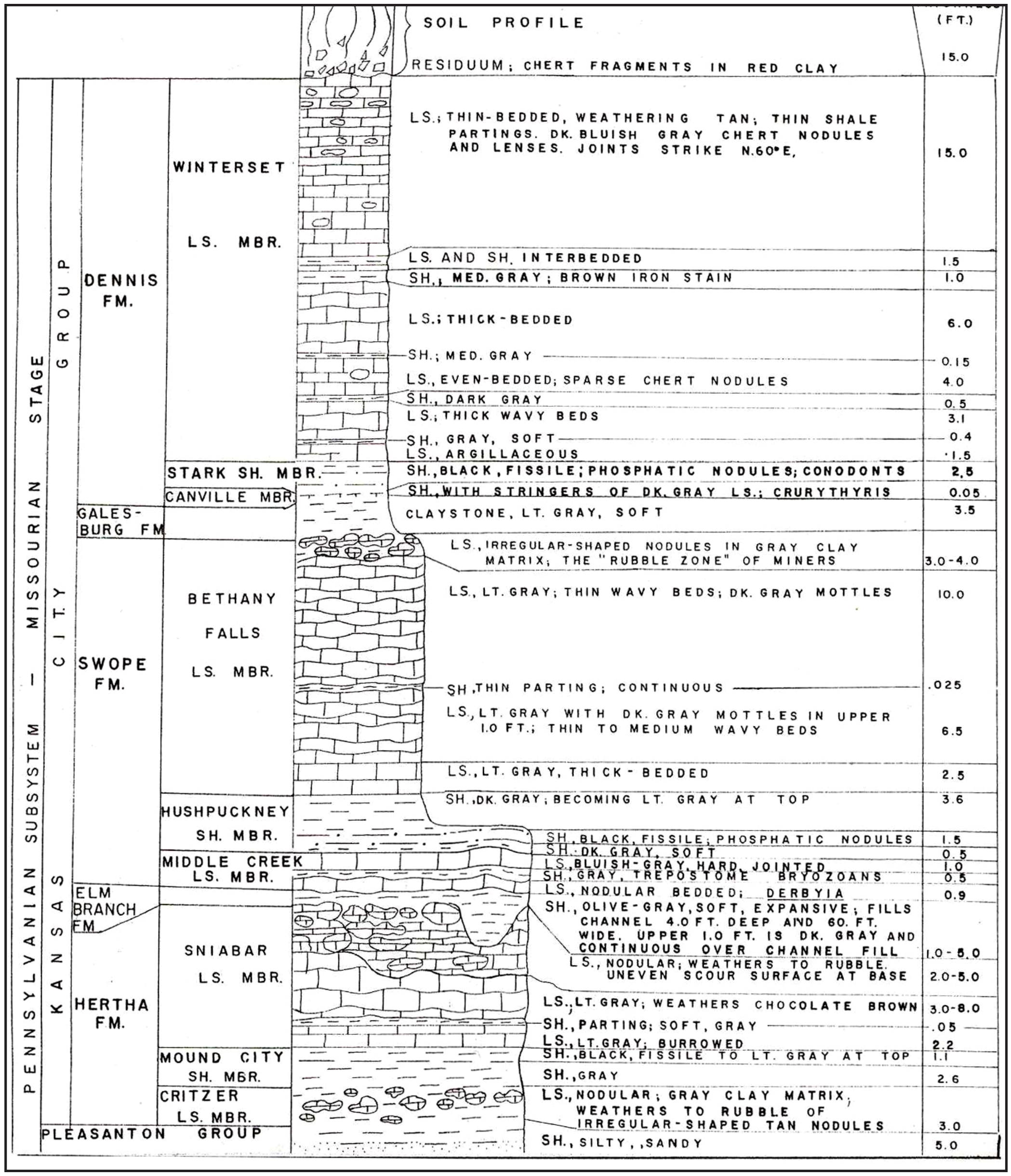


Figure 4. This memorial has been erected at the site of a former quarry. In November 1989, a fire ignited a tractor-trailer load of ammonium nitrate; the ensuing explosion resulted in the deaths of six fireman and extensive property damage to nearby buildings.

Figure 5. Columnar section of the rocks exposed in the excavation for 87th Street at the intersection with Blue River Road.



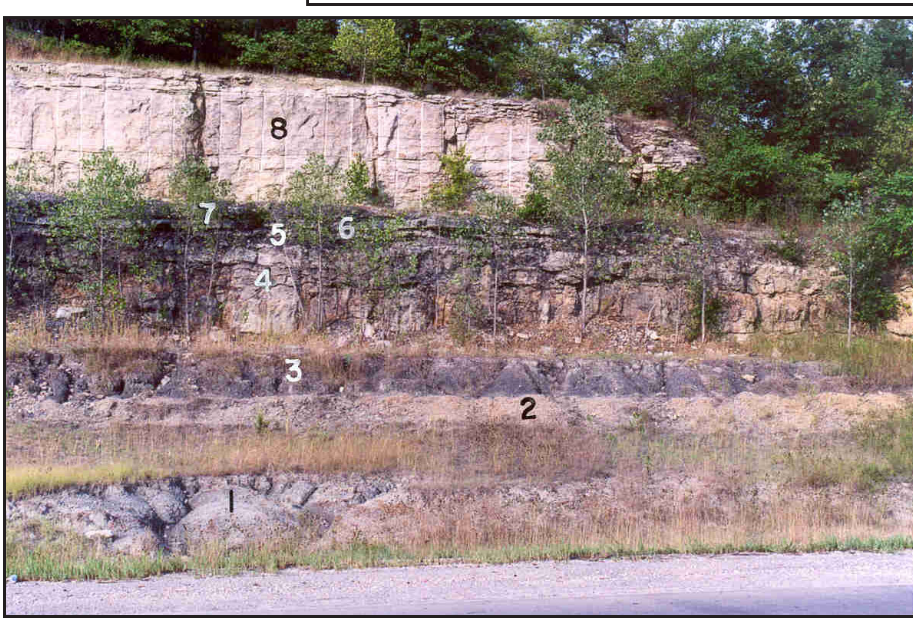


Figure 6. Sequence of beds forming the lower part of the Kansas City Group on the east end of 87th Street roadcut.
1. Upper Pleasanton Group, 2. Critzer Limestone Member, 3. Mound City Shale Member,
4. Sniabar Limestone Member, 5. Elm Branch Shale, 6. Middle Creek Limestone Member,
7. Hushpuckney Shale Member, 8. Bethany Falls Limestone Member,
9. Winterset Limestone Member. The Galesburg Shale, Canville Limestone Member, and the Stark Shale Member are not visible in the photograph.

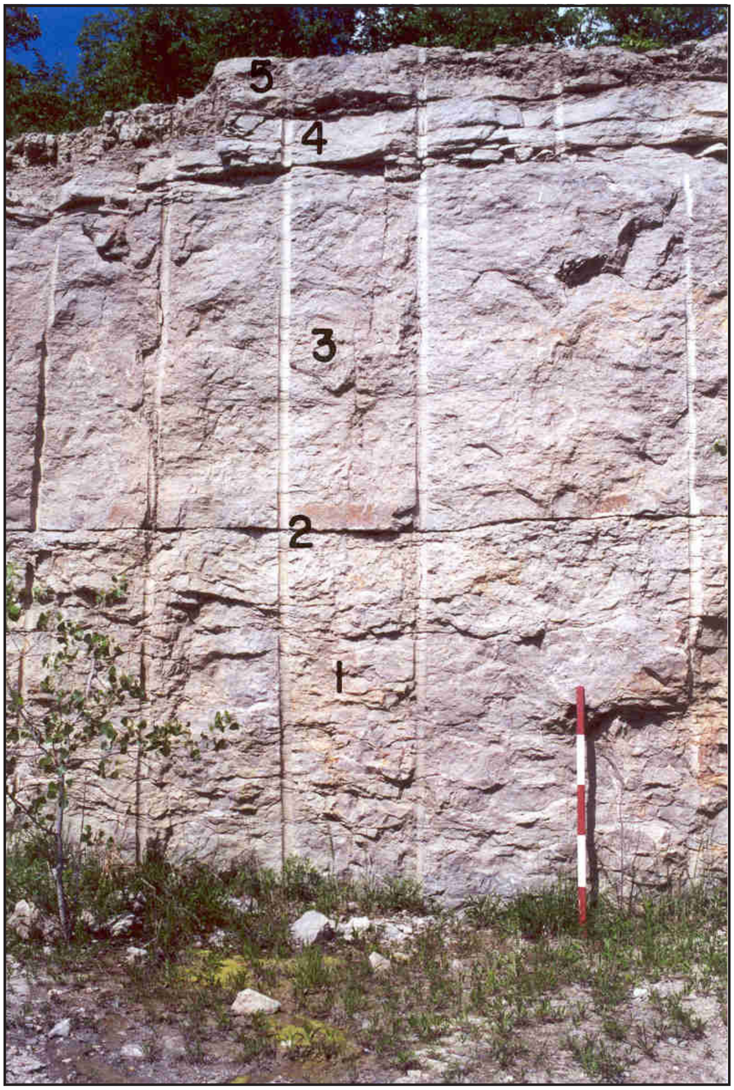


Figure 7. The facies of the Bethany Falls Limestone Member
1. Thick-bedded lower unit. 2. A thin shale parting that persists throughout the Greater Kansas City area. 3. Upper thin-bedded limestone unit; the thin wavy beds become well-developed only on weathered exposures. The limestone is light-gray with characteristic dark gray mottles.
4. Thick, even beds that are typically 4 or 5 ft (1.2 - 1.5 m) thick in most exposures and form a stable roof in underground mines. 5. Nodular limestone zone, informally known as the "peanut rock" by quarryman.

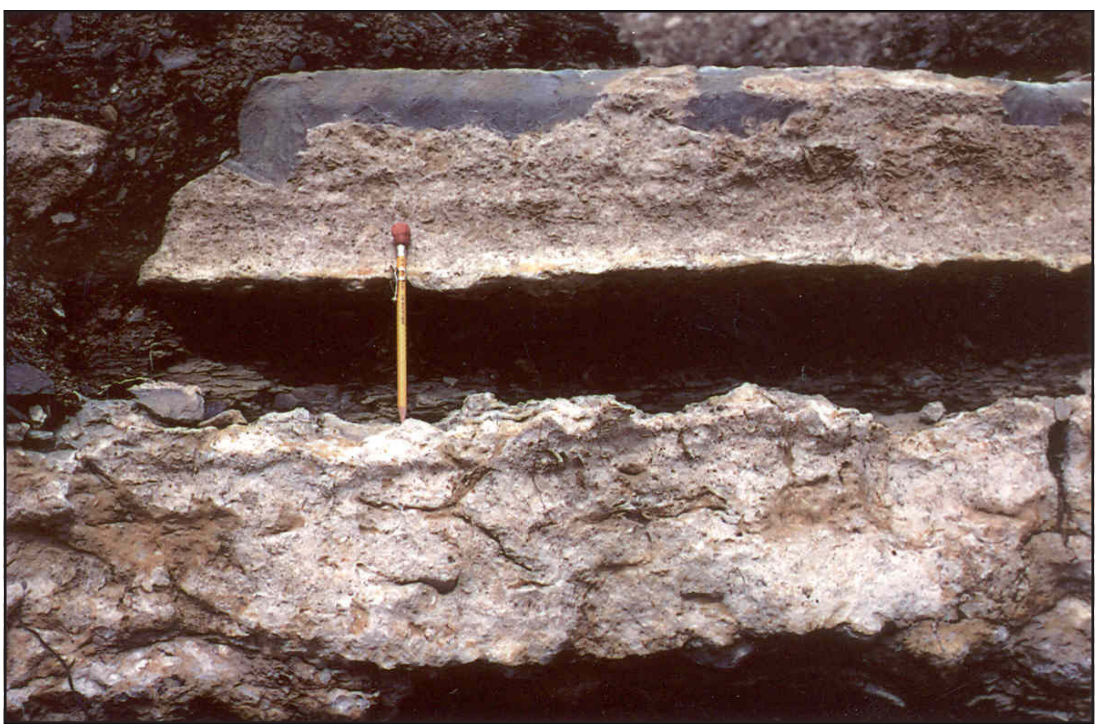


Figure 8. The Middle Creek Limestone Member is composed of two thin limestone beds separated by several inches (>10cm) of shale. The lower limestone bed and shale are two of the most fossiliferous beds in the Kansas City area.

Figure 9. Elm Branch Shale fills a tidal channel eroded into the top of the Sniabar Limestone Member. The Middle Creek Limestone Member (two thin even beds) is bowed-up over the Elm Branch Shale, an interesting phenomenon in the Greater Kansas City area. Thin beds of limestone or shale that overlie shale-filled tidal channels bow-upward several inches to a foot or more (>0.3 m). After several years they settle down and become horizontally inclined over the tidal channel fill.

have filled a tidal channel eroded into the upper part of the Sniabar Limestone. As the sea retreated across a broad carbonate platform, tidal currents eroded channels into the semiconsolidated sediments that comprise the upper few feet of the Sniabar Limestone. The channels filled with fine clastics of the Elm Branch Formation and represent the distal lobe of a delta system that prograded seaward over the emergent tidal flat. The Elm Branch, a predominately clastic unit, thickens toward the south-southwest in the direction of the source area in the Quachita-Marathon Region of Oklahoma and Arkansas (Wanless and Wright, 1978).

A contributing factor to the geographic location of the channels is the abnormal thickness of the Sniabar Limestone. At most places the Sniabar is six to eight feet thick (2-2.5 m), and is composed of thick beds of limestone that weather a chocolate brown. At the 87th Street location, the Sniabar is over 14 ft (4 m) thick. The lower one-half is similar in lithology and thickness to the Sniabar in most other areas of metropolitan Kansas City whereas the upper several feet has a nodular-like structure that is contributed to profuse growth of algae. These algal buildups have an areal extent of several acres to several square miles and have been recognized as forming the upper part of several limestone members of the Kansas City Group. The baffling action of sediment binding organisms such as algae may have produced carbonate buildups in intertidal and shallow subtidal areas that altered hydrologic processes. Currents forced to flow over these obstructions eroded channels into them. As the sea retreated, deltaic lobes of mud prograded seaward filling the tidal channels with mud. The flow direction of the channels in the 87th Street section was perpendicular to the face of the exposure and accounts for the lenticular shape when viewed in cross section.

The strata overlying the channel-fill deposits are arched to form small anticlines with about 12 in (30 cm) of displacement. The folding began shortly after the section was exposed in 1990 and is attributed to the removal of overburden. The release of pressure allowed the clay particles

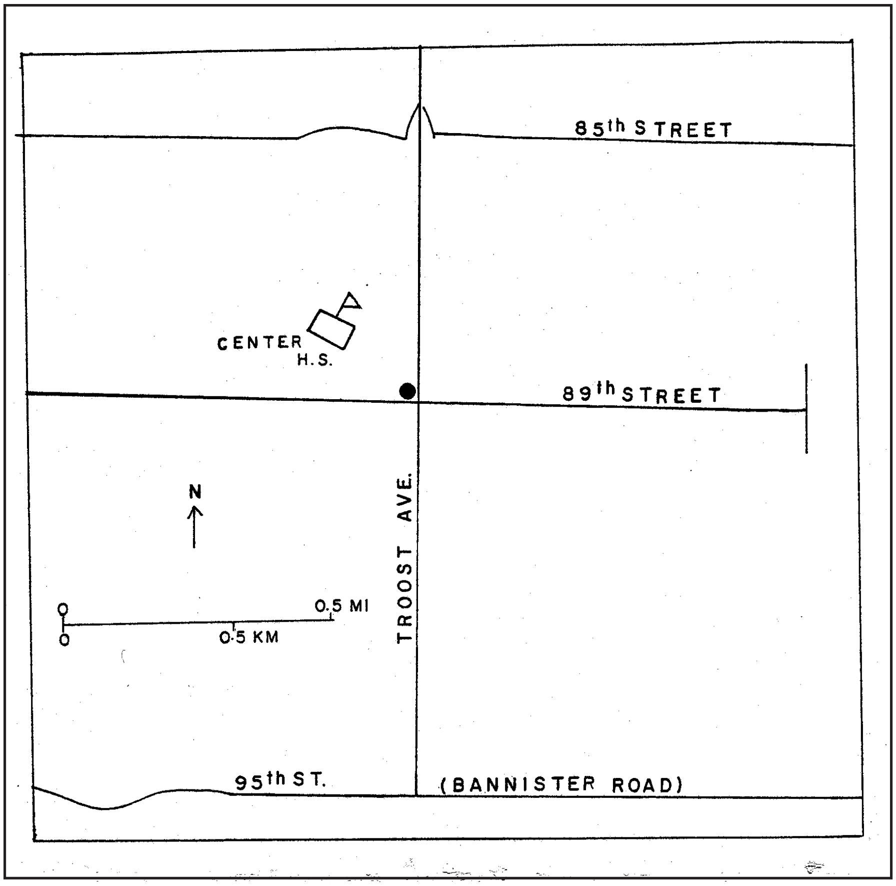


Figure 10. Location map of the 89th Street and Troost Avenue section shown by • (Stop 2).

to absorb water into the crystal lattice and to swell. The arching is particularly noticeable in the Middle Creek Limestone. The thin even beds of Middle Creek limestone were observed to be horizontally lying over the channel-fill deposits at the time the section was begin excavated after several years the bowed up anticlinal structures settle down and become horizontal again.

Tidal channels several hundred feet long have been uncovered in quarry operations for limestone as the overburden is removed at other locations in metropolitan Kansas City. Sediment filled channels in the upper part of limestone units, and similar in appearance to the ones exposed in the excavation for 87th Street, are a common occurrence in the rock section. Unfortunately, these features are rarely observed in plain view and only occasionally in cross-sectional profile because they are removed with the quarried rock.

Figure 11. Westerville Limestone Member, northwest corner of East 89th Street and Troost Avenue, Kansas City, MO.

Stop No. 2 – Westerville Limestone on Troost Avenue

The Westerville Limestone Member throughout most of the Kansas City area is about 3 to 5 ft (0.9-1.5 m) thick. It is even bedded with beds ranging in thickness from 6 in. to 1 ft (2.5-5 cm) and was referred to by local stone masons as the "Bull Ledge" because it was difficult to work (Fig. 12). However, in localized areas of a few acres to several square miles the thickness increases to 20 ft (6 m) by addition of an upper unit that is a cross-bedded, oolitic grainstone and very fossiliferous (Figs. 13 and 14). These areas of increased thickness are referred to as carbonate buildups. The location of several carbonate buildups are shown on Fig. 15.

A carbonate buildup is defined as a carbonate rock that is thicker than, and different from, laterally equivalent strata, and probably stood above the surrounding sea floor during some or all of its depositional history (Jackson, 1997, p. 96). In addition to the carbonate buildup at this stop, they occur in Kansas City

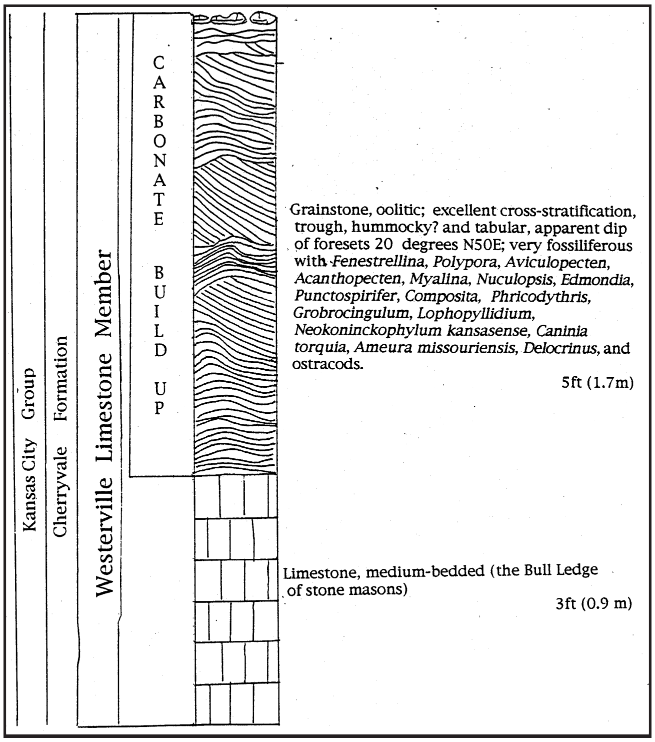


Figure 12. Graphic section of the east 89th Street and Troost Avenue carbonate buildup in Westerville Limestone Member.

Figure 13. Carbonate buildup (above 2.5 ft [0.8 m] interval on stadia rod) consists of very fossiliferous, cross-bedded oolitic grainstone. The lower 2 ft (0.6 m) is even-bedded limestone and is slightly fossiliferous. It is persistent throughout the Kansas City area whereas the upper carbonate buildup occurs only locally.

Figure 14. Tabular cross-bedding in upper part of Westerville Limestone Member.

along the south bluff of the Missouri River; at the Missouri Rock Company quarry 1 mile (1.6 km) west of Missouri City; along the south bluff of the Kansas River just northeast of Holiday in Johnston County, Kansas; at the Lafarge Cement Company quarry at Sugar Creek. The largest carbonate buildup is at Raytown at the junction of Highway 350 and I-435. The carbonate buildup at Raytown covers an area of about 6 mi^2 (Parizek and Gentile, 1965, p.10). Several quarries once produced building stone from the Raytown carbonate buildup, referred to by Parizek and Gentile (1965) as a "reef." The cross-bedded, oolitic grainstone from the carbonate build-up at Raytown and other quarries in Kansas City was known commercially as the "Kansas City oolite." Many of the buildings on the Volker Campus, University of Missouri-Kansas City are constructed of this stone.

Carbonate banks are abundantly fossiliferous. Over 100 species of invertebrates were collected from the carbonate build-ups in the Kansas City area (McCourt and others, 1917, p. 53). Of particular interest to amateur paleontologists are the specimens of the planispirally coiled nautiloid cephalopod *Domatoceras*, many over 1 ft (0.3 m) diameter. In former times, hundreds of specimens of *Domatoceras* were collected by curious quarrymen who stacked them in piles that sometimes attained a height of several feet, and they took some of them home to be used as door stops. Also, of interest were specimens of the trilobite *Ameura missouriensis*.

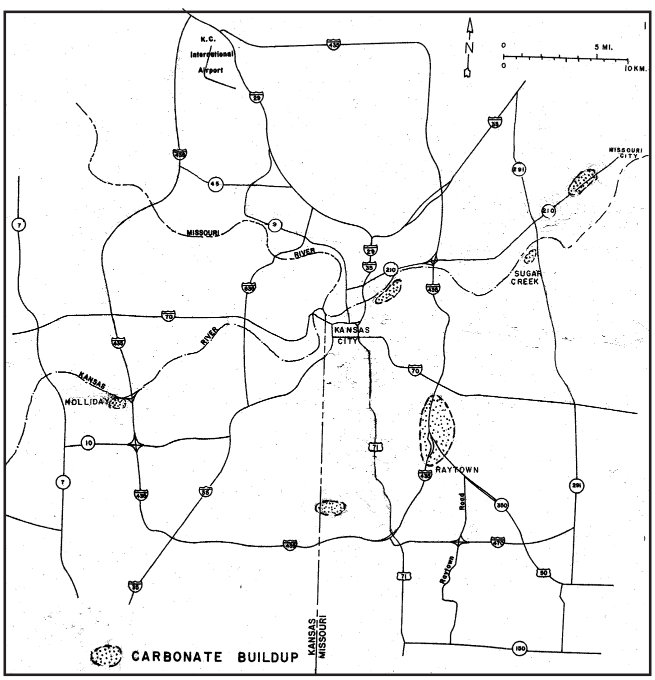


Figure 15. Location map of carbonate buildups in the Westerville Limestone Member in the Greater Kansas City area.

A modern day analog of the carbonate build-ups in the Kansas City area are the "dunes" of oolitic sand that are moving across the shallow water carbonate shelf on the Grand Bahama Bank off of Andros Island in the Caribbean Sea. However, there are some differences. Around the fringes of carbonate build-ups the oolitic limestone is interbedded with shale, an indication that mud was being transported into the shallow Pennsylvanian seas. The "dunes" of oolitic sand in the Caribbean are devoid of clastic mud.

Stop No. 3 – I-470 and Raytown road section and fault

A "textbook example" of normal faulting is well exposed in the thick limestone members of the lower Kansas City Group in the road cut at the I-470 exit at Raytown Road (SW 1/4, NW 1/4, sec. 33, T. 48 N., R. 32 W.), Jackson County, Missouri. Lee's Summit, 7.5' minute Quadrangle (Figs. 17-19). Park along Raytown Road north of the bridge over I-470 and walk east along the access road and onto the grassy strip of right-of-way about 200 ft (60 m) wide on the north side (westbound lane) of I-470. The section, with faults, is exposed about 1000 ft (300 m) east of Raytown Road. The section of Pennsylvanian strata exposed along I-470 is shown in Figure 20. The strata along the route are faulted at several locations. Figure 17 shows two of the faults shortly after they were exposed in a highway excavation in 1976. Fault scarps have been removed and the roadbed graded. The faulting

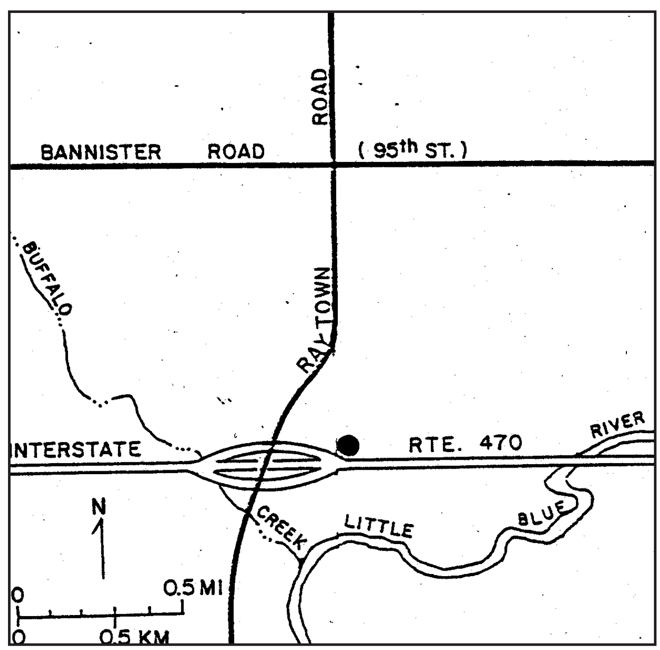
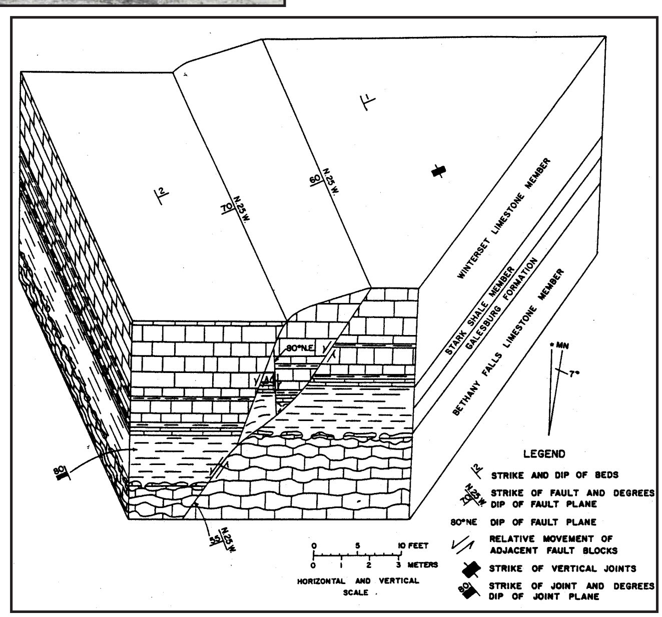


Figure 16. Location map of Interstate Route 470 and Raytown Road section and faulting shown by •.

Figure 17. Photograph of exposure in 1976 showing two small normal faults (below arrows in upper part of photo) in the north (westbound) lane of Interstate Highway 470, east of the Raytown Road Bridge, Jackson County, Missouri. Fault scarps have been removed and the road bed graded. The ledge of limestone at road level is the Bethany Falls.

Figure 18. Close-up of fault shown on the right (northeastern side) of Figure 17.

Figure 19. Block diagram showing interpretation of the fault shown in Figure 18.



does not extend into the thick covering of unconsolidated loess and soil. The faults shown in Figure 17 form the sides of a northwest-trending structural block about 200 ft (60 m) wide. Figure 19 is a detailed sketch of the fault on the northeastern side of the block.

The Bethany Falls Limestone Member of the Swope Formation, exposed at road level, is a light-gray, finely crystalline limestone mottled with dark-gray spots or blotches. The upper two or three feet (0.5-1 m) consist of limestone nodules in a greenish-gray matrix.

The Bethany Falls is overlain by the Galesburg Formation, a medium gray claystone about 3 ft (1 m) thick. The Galesburg forms a seal that prevents water seepage into mined out areas. Above the Galesburg, the Dennis formation includes, in ascending order, the Canville

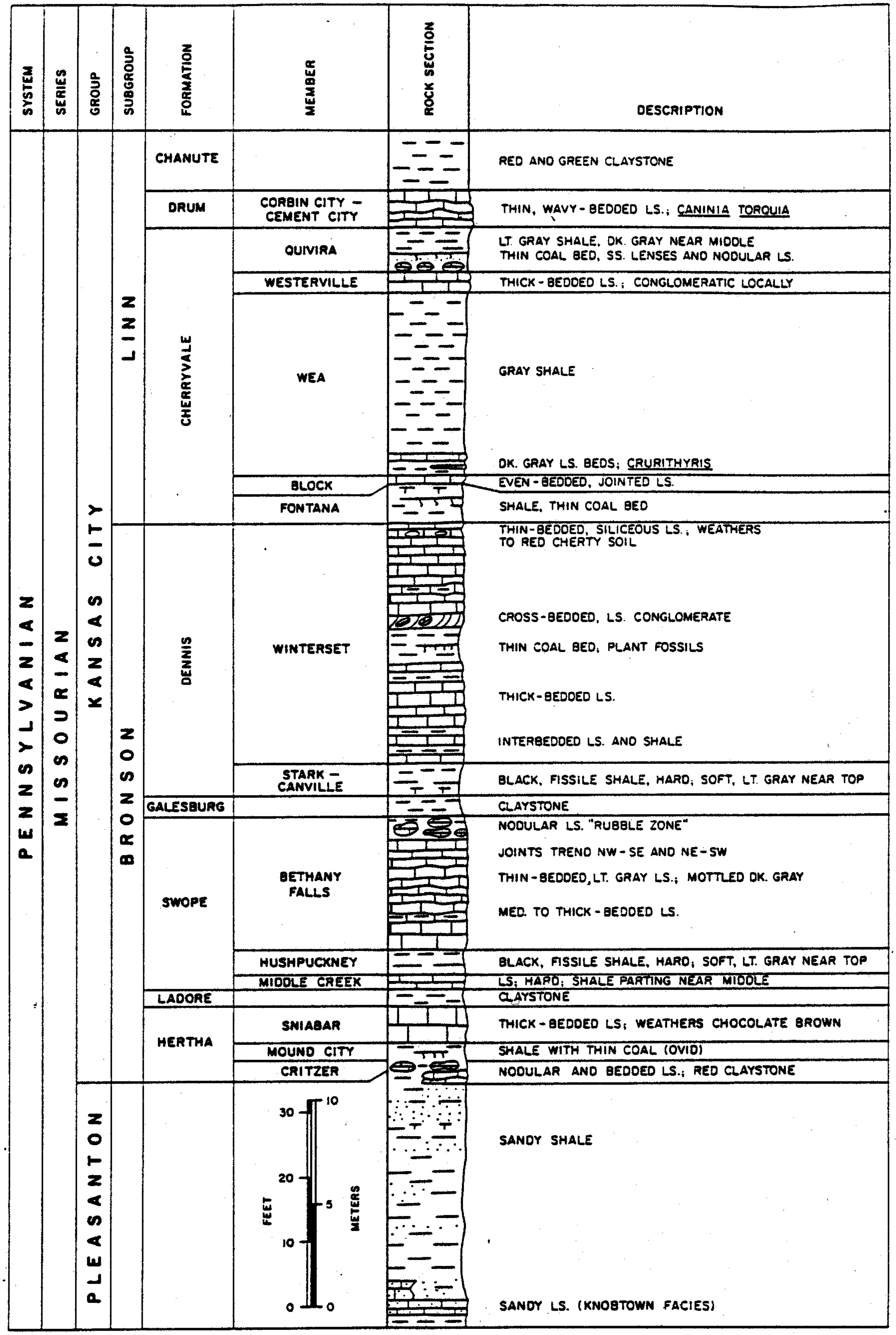


Figure 20. Composite stratigraphic column of the rocks exposed during construction of Interstate Highway 470 in the vicinity of Raytown Road.

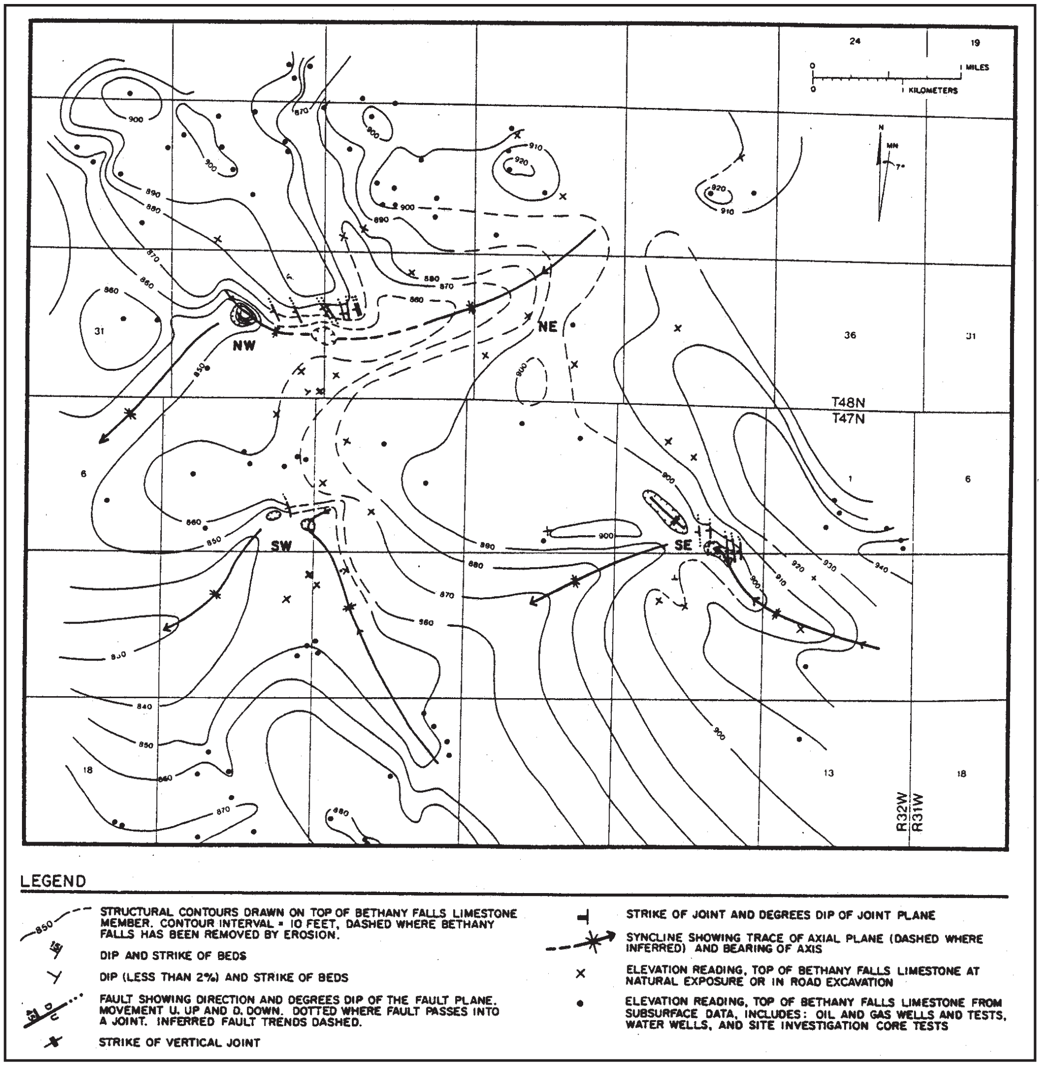
Member, represented by a thin bed of fossiliferous shale about an inch (2.5 cm) thick; the Stark Shale Member, about 4 ft (1.5 m) thick, the lower half is black fissile shale with abundant conodonts; and the Winterset Limestone Member, 30-40 ft (9-12 m) thick, the lower part interbedded with shale. At this stop the upper half of the Winterset is deeply weathered. Overlying the Winterset about 20 ft (6 m) of soil and loess form a grass covered slope.

The part of the section below the Bethany Falls Limestone Member shown in Figure 20 is exposed along Buffalo Creek west of Raytown Road. Beds overlying the Winterset are exposed in the roadbed excavation through a low hill west of Buffalo Creek, but the exposure is partially overgrown by vegetation. A series of ten northwest striking parallel faults were exposed in construction excavations for I-470 along a 4000 ft (1200 m) segment of the route from just west of Buffalo Creek to about 3000 ft (910 m) east of the Raytown Road Bridge (Fig. 23). The faults could be traced along the strike, perpendicular to roadway, for about 400 ft (120 m) across the area under construction until they become concealed by the regolith (Fig. 21). All are high-angle normal faults, the fault planes dipping southwest toward a deep structural depression along Buffalo Creek. They are step faults, the downthrown blocks on the southwest sides of several parallel faults; the strata between having moved downward step-wise in relation to the adjacent faults to the northeast.

The steeply dipping strata exposed in the bed of Buffalo Creek can be projected many feet below the level of the valley floor, as determined by the records of core-drill test borings. Moreover, in most places the hill slopes are normal to the fault strikes, therefore, the faulting is not the result of downhill creep by slump blocks toward the lower elevation of the valley. In addition to the faulting described along a segment of I-470 at Raytown Road, two more small faulted areas have been mapped and river alluvium conceals a fourth area of probable faulting in an area of about 20 mi^2 (52 km^2) designated the Longview Region by Gentile (1984a). The faults in all three of these areas appear to have formed by collapse of strata as support was removed from below and are obscure features that were formed during an earlier interval of geologic time because the faulting does not extend into the thick covering of unconsolidated surficial material of Late Pleistocene and Holocene (Recent) age, hence the name paleocollapse structures. These localized areas of crustal disturbance are situated to form the corners of an orthogonal-shaped area and are identified by geographic location: NW (northwest), SW (southwest), SE (southeast), and NE (northeast) on the structure map (Fig. 22). The paleocollapse structure along I-470 at Raytown Road is designated NW (northwest) (Fig. 23).

Figure 21. Upthrown block forms low escarpment across roadway, exposed during construction.

Figure 22. Structure map of the Longview region. Three paleocollapse structures have been recognized in the Longview region and are designated by geographic location SE (southeast), SW (southwest), and NW (northwest). A fourth area of probable faulting is designated NE (northeast).



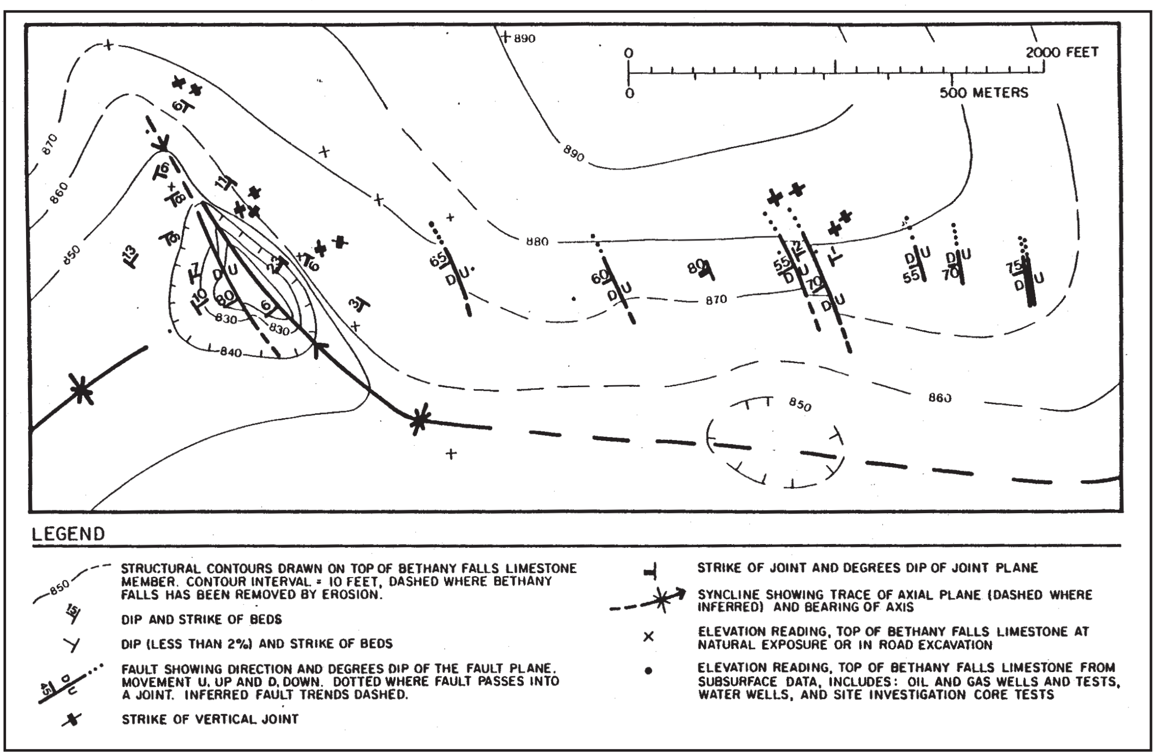


Figure 23. Detailed structure map of complex faulting exposed in excavations for construction of I-470 in fall and winter of 1976 (Geographic location NW).

Several faulted areas similar to those at the Longview Region have been recognized in western Missouri and northeastern Kansas (Gentile, 1984a). These areas contrast sharply with the relatively undisturbed nature of the bedrock surrounding them. The largest of these structures has been named the Belton Ring fault complex by Gentile, 1984b. It is a circular-shaped intensely faulted structure 3 miles (4.8 km) in diameter located about 8 miles (12.8 km) southwest of the faulting along I-470 at Raytown Road. In places the strata have been displaced over 150 ft (46 m) along a high angle faults.

The following paragraph discussed the probable origin of paleocollapse structures. Detailed geologic mapping indicates that these small structurally disturbed areas are located at the intersection of northwest and the northeast striking fold axes. The fold axes and the faults trend in the direction of the joint pattern. The regional pattern in western Missouri consists of two joint sets trending almost at right angles to one another (Hinds and Greene, 1915; Ward, 1968). The northwesterly trending set parallels the regional dip and the northeasterly set the regional strike. Consequently, the small structurally disturbed areas including the one at I-470 and Raytown Road are related to the major structural "grain" of the mid-continent. Gentile (1984a, b) has proposed that these small faulted areas formed when the Pennsylvanian strata collapsed into caverns enlarged by dissolution at the intersection of fracture zones almost perpendicular to one another in thick Mississippian limestones and dolomites underlying the region at depths of 600-800 ft (180-240 m). An extensive system of filled solution cavities is known to exist in Mississippian limestones throughout the Midcontinent. Moreover, these limestones are thick enough to account for the displacement recorded at the surface, using key marker beds in Pennsylvanian strata as datums. In comparison, the Pennsylvanian limestones are not thick enough, if removed by cavern development, to allow this much displacement. Recurrent vertical movements along fracture systems in Mississippian and older rocks caused by minor tectonic activity of blocks of Precambian basement rocks at a depth of 2100 ft (640 m) provided the routes of migration from acidic ground water engaged in cavern development. There structures did not form in modern times, because the faulting does

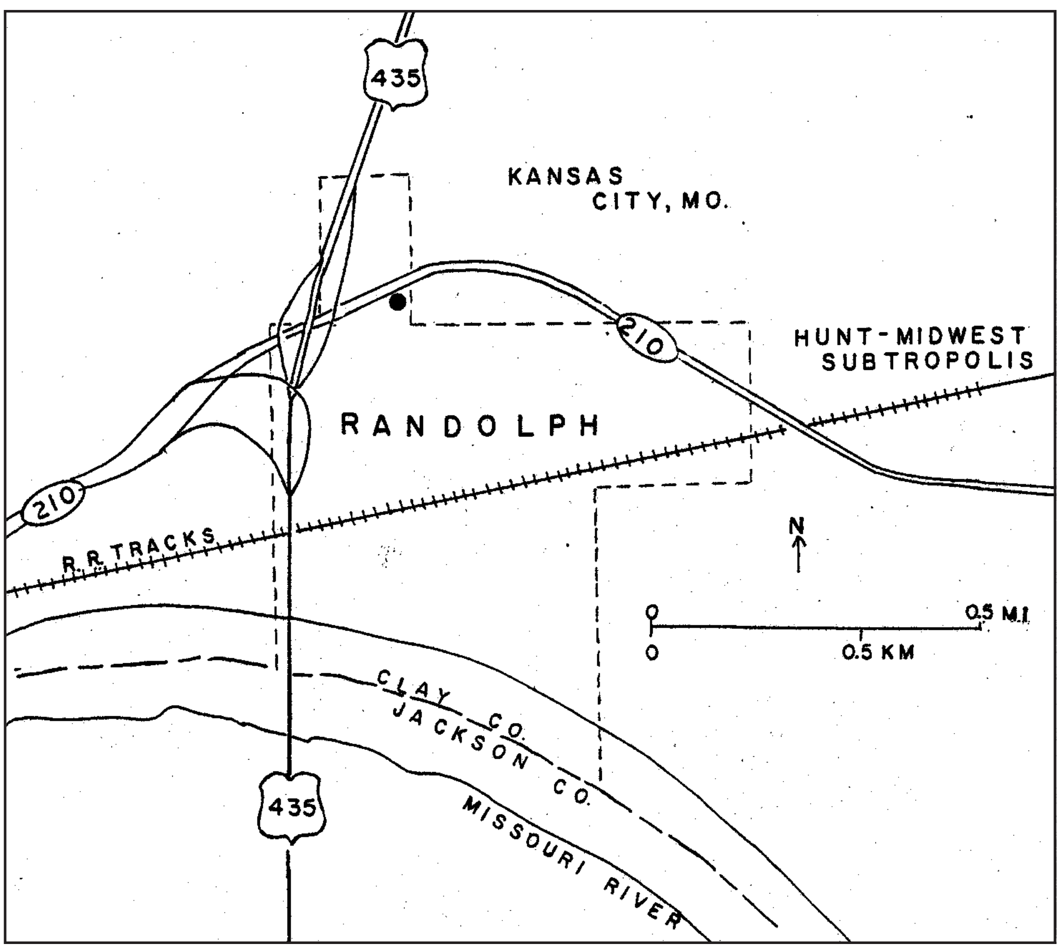


Figure 24. Location maps of Pleistocene outwash, diamicton and loess section shown by •. Road cut on south side of east bound lane of Highway 210, 0.2 mile (0.3 km) east of Interstate Highway 435 overpass; SE 1/4, SE 1/4, NE1/4, sec. 9, T. 50 N., R. 32 W.; Randolph, Clay County, Missouri. Liberty 7.5 ' quadrangle, 1990 edition (Stop 4).

not extend into the thick covering of unconsolidated Late Pleistocene and Holocene surficial materials.

Deep drill tests and detailed geophysical investigations, especially seismic reflection surveys are needed to determine subsurface structure.

Stop No. 4 – Glacial deposits at Highway 210 and I-435

This is the only recent exposure in western Missouri to show a well-developed paleosol between pre-Illinoian diamictons, and one of the best loess paleosol exposures of Late Wisconsian age in the region (Figs. 25-26; Table 1). The photograph, Figure 25, was taken in late 1999 shortly after the hill was excavated but most of the section including two or three paleosols are still visible.

The pre-Illinoian deposits consist of lenses of stratified drift (outwash) or valley train deposits intercalated with deeply weathered diamicton. The pre-Illinoian sediments are oxidized to shades of brown, yellowish-brown, reddish-brown and yellowish-orange and leached of calcium carbonate but patches of diamicton near the bottom at the western end of the exposure are light-gray, unoxidized and leached of calcium carbonate. The two units of glaciogenic sediment deposits are separated by a paleosol and are labeled A and B on Figure 26. The pre-Illinoian sediments are tentatively correlated with the lower and the upper tills of the Independence Formation, early middle Pleistocene. Correlation of the tills at this stop could be premature. There could be several tills in the Kansas City area and the two tills recognized at this stop may not necessarily correlate to two tills at another place. Rovey and Keene (1996) have shown that there are at least five tills in central Missouri and the tills here may correlate to any of these. Furthermore, the lowest till could be older then the Independence Formation (>780,000 yr B.P.) when tested by reverse magnetism. Obviously, age data is necessary to determine if the tills in the Kansas City area correlate with those in central Missouri or Kansas. Unique lithostratigraphic terms may be applied to the tills at Kansas City if neither correlation is applicable (Patrick Colgan, pers. comm., 2002). The importance of this section is the evidence for two glacial events separated by a significant interstadial or interglacial.

Ice-movement indicators suggest that glaciogenic sediments were deposited by a lobe originating in the Dakotas that advanced down the Missouri River lowland (Aber, 1991; Colgan 1999). The two interbedded tills and outwash labeled A and B at stop 4 probably represent two distal phases of glacial deposition recognized by Colgan (1999) along the pre-Illinoian glacial boundary near Kansas City (Fig. 27). Classification of pre-Illinoian stratigraphic units are shown in Figure 28. Davis (1971) placed unit A (Table 1) in the Medial Kansan Substage and unit B in the Late Kansan Substage. Revision of the standard classification system of the early and the middle Pleistocene units in the Midcontinent U.S. has been proposed by Richmond and Fullerton (1986), Morrison (1991), and Aber (1991). Glacial deposits formerly classified as Kansan have been reassigned to the informal time division pre-Illinoian and the name Kansan is abandoned.

The Yarmouthian Interglacial is represented by the Yarmouth paleosol that is developed on the pre-Illinoian deposits.

The Sangamon paleosol is developed on the deposits tentatively assigned to the Illinoian Glaciation. They consist of alluvium, possibly as a terrace deposit, and silt that may be reworked Loveland Loess (Fig. 26; Table 1, units 10-12). The Loveland Loess of the Illinoian Glaciation has not been recognized at this stop but has been reported from other places in the Kansas City area. The Sangamon paleosol is the most distinctive and widespread marker in the Pleistocene in west central Missouri. Two loess blankets overlie the Sangamon paleosol and are included in the Wisconsinan Glaciation. They are in ascending order the Peoria and the Bignell.

The section at Stop 4 along Highway 210 is an extension of the excavation for the I-435 and Highway 210 interchange in the late 1960's. Davis (1971) believed the exposure to be the most complete and extensive section of loess in Missouri. The most distinctive feature of the exposures is the large number of buried "soils" which can be seen. Most of the "soils" appear as dark bands in the outcrop. The dark color is, in part, caused by closely spaced shrinkage cracks which in turn are related to the clay content that is greater than adjacent less weathered loess (Davis, 1971).

The Missouri State Highway Department drilled 10 test holes to bedrock in the I-435 and Highway 210 interchange area. All except two of the holes penetrated from 10 to 25 feet (3-7.5 m), of weathered to unleached diamicton before entering bedrock. The hole nearest to the measured section described by Davis (1971) penetrated 20.8 feet (6.3 m) of till starting about 20 feet (6 m) below road level.

Figure 25. Paleosols in the Pleistocene section, excavation for Highway 210 about 0.2 mile (0.3 km) east of I-435; Randolph, Clay County.

Pre-Illinoan Stage

1. *Well-developed paleosol separating lower and upper Independence Formation*

Yarmouthian Interglacial

2. *Yarmouth paleosol developed on pre-Illinoian deposits*

Sangamonian Interglacial

3. *Well-developed Sangamon-paleosol developed on Illinoian? deposits*
4. *Paleosol separating Peoria loess Late Wisconsinan (20-15ka) and Bignell loess (Late-Wisconsinan-Early Holocene)*

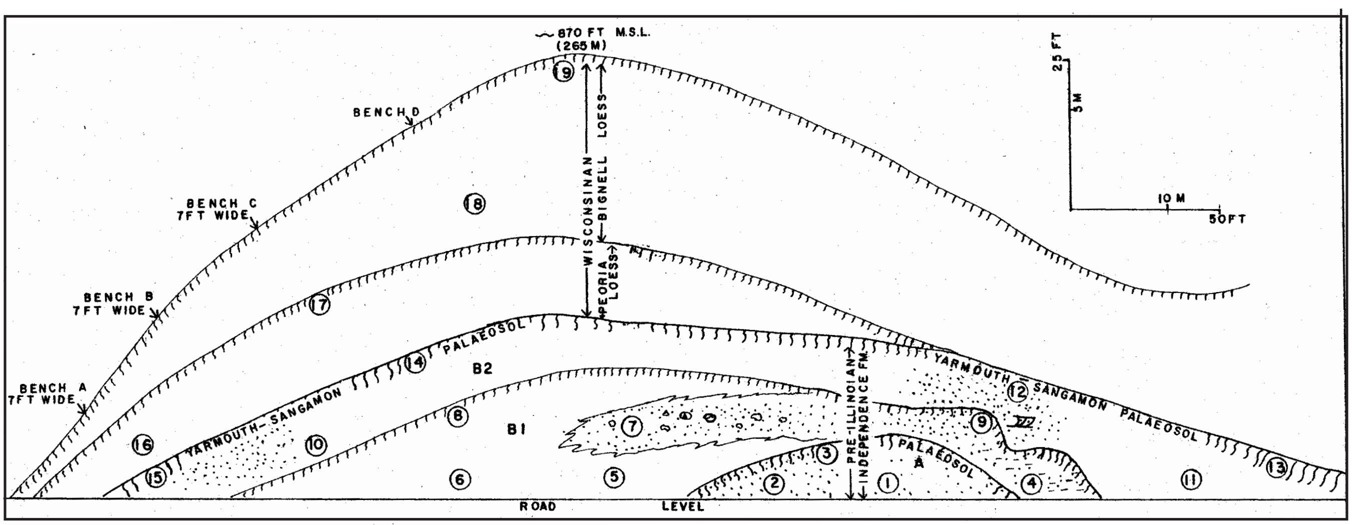


Figure 26. East-west cross section of the Pleistocene section along Highway 210 shown in Figure 25.

Pleistocene Series		Thickness in feet (m)
Wisconsinan Glaciation		
5.	Bignell Loess	
	Silt, light-brown 5YR 5/6*; slightly plastic	45 ft (14 m)
4.	Paleosol	
	Silt, clayey; sparse quartz grains, vertical shrinkage cracks	1 ft (0.3 m)
3.	Peoria Loess	
	Silt, moderate-brown 5YR 4/4; plastic	20 ft (6 m)
Yarmouthian-Sangamonian Interglacials		
2.	Paleosol (Yarmouth-Sangamon)	
	Silt, moderate reddish-brown 10 R 4/6; coarse sand grains to granules of chert, quartz; vertical joints, scales and "peels" upon drying	5 ft (1.5 m)
Pre-Illinoian Stage		
Independence? Formation		
1A.	Till (diamicton)	
	Clay, sandy, weathered reddish-brown; stone line at top, becoming yellowish-brown below; clasts of resistant erratics mostly Sioux quartzite, some vein quartz, granite that is weathering to grusss; locally derived chert; soft "powdery" calcium carbonate concretions derived from weathered limestone; lenses of gravelly, cross-bedded sandstone of stratified drift (outwash)	20 ft (6 m)
1B.	Till (diamicton)	
	Clay, silty, sandy, dark bluish-gray "fresh" unoxidized and unleached, minor amount of pebbles to boulder size; the "boulder clay" of early workers; the larger size fraction is mostly locally derived rounded to angular limestone boulders, cobbles etc., a few with glacial striations; pieces of angular black shale and chert; small percentage of erratics, mostly Sioux quartzite, some vein quartz, gneiss, granite, schist, pegmatite and sandstone; isolated lenses of cross-bedded gravelly sandstone	20 ft (6 m)

*Colors of moist samples were described with Standard Munsell Soil Color Charts (1975).

Table 1 Lithologic Description of Pleistocene Deposits Exposed along Highway 210 through Nebo Hill (Fig. 31).

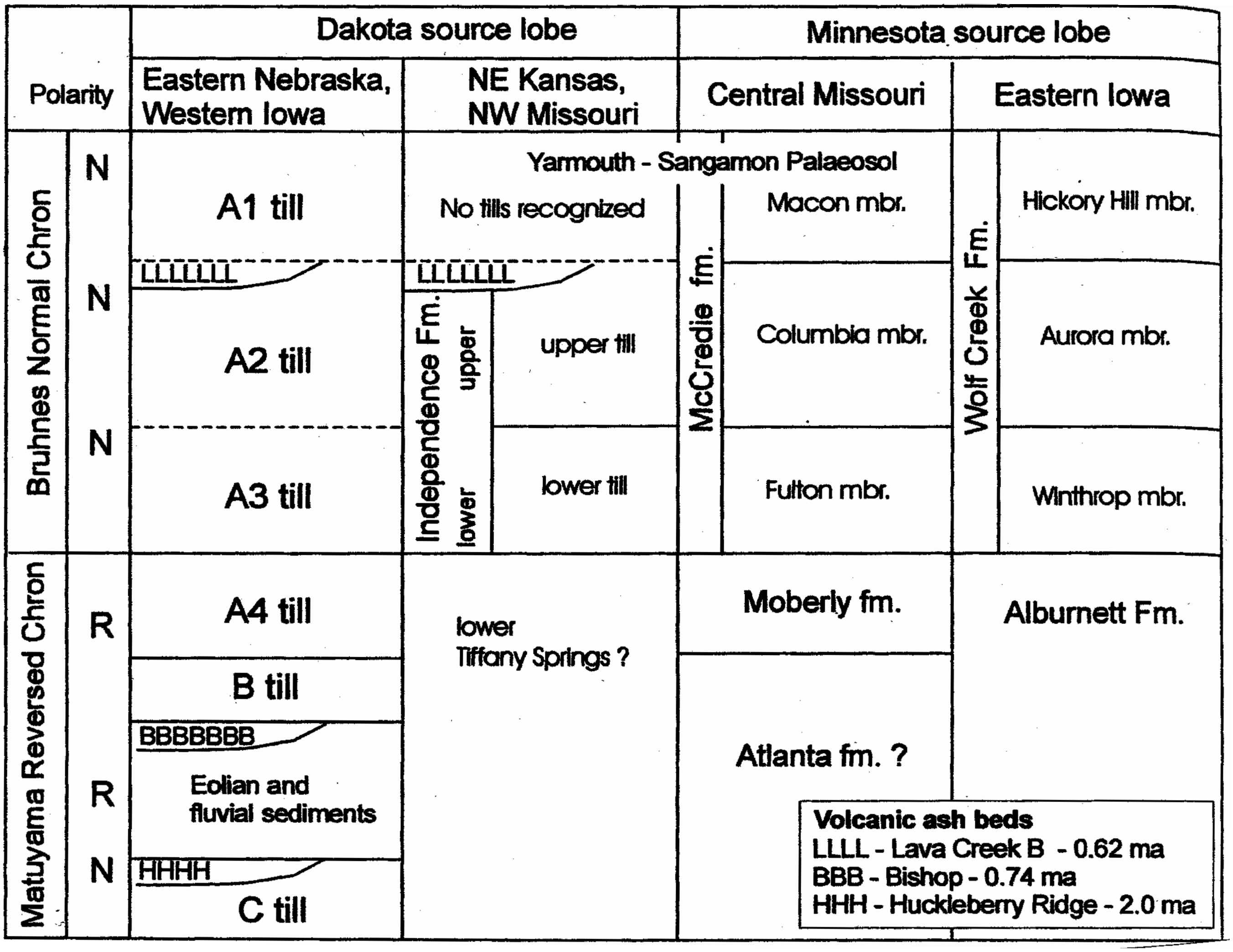


Figure 27. A summary of the pre-Illinoian stratigraphy of Iowa, Nebraska, Kansas, and Missouri (after Colgan, 1999).

Stop No. 5 – Nebo Hill glacial deposits

Nebo Hill is a loess-mantled promontory that juts out like a south-pointing finger onto the floodplain of the Missouri River (Fig. 28). Nebo Hill was occupied by Native Americans from at least 3000 BC until colonial times. A wealth of archeological materials have been collected from the hill. The most spectacular is the Nebo Hill lanceolate blade (a knife blade-like projectile point). Other artifacts include: three-quarter grooved axes, bifacial hoes, rectangular and oval manos, rectangular and flat celts, and fiber-tempered pottery.

Artifacts were collected from the hill for research purposes beginning in the 1940's but the major investigation was in 1975-76 by the University of Kansas Anthropology Museum under a contract awarded by the Missouri State Highway Commission to make an archeological investigation of Nebo Hill along the proposed right-of-way corridor for the relocation of Highway 210 (Reid 1983; 1984).

Till (diamicton) deposits in the Greater Kansas City area, including Nebo Hill are believed to be between 780,000 and 620,000 years old (early middle Pleistocene), and are probably time equivalent to the Independence Formation in northeastern Kansas (Figs. 29-31; Table 2). The age date is based on the radiometric dating of volcanic ash deposits in Kansas and paleomagnetism. Unoxidized and unleached till (dark bluish-gray "boulder clay") shows normal polarity when analyzed for remanent magnetism, and was probably deposited during the Brunhes normal polarity epoch. The primary carrier of remanent magnetism is magnetite (Colgan, 1992; 1998; 1999).

The finer fractions of the unoxidized and unleached till consists of 40% sand, 43% silt, and 17% clay based on an analysis of samples from Nebo Hill and several other localities in the Greater Kansas City area.

Note: 300 ft north of the culvert under Highway 210, along a cut bank of the stream, unweathered lodgement till is "plastered" under a ledge of Bethany Fall limestone.

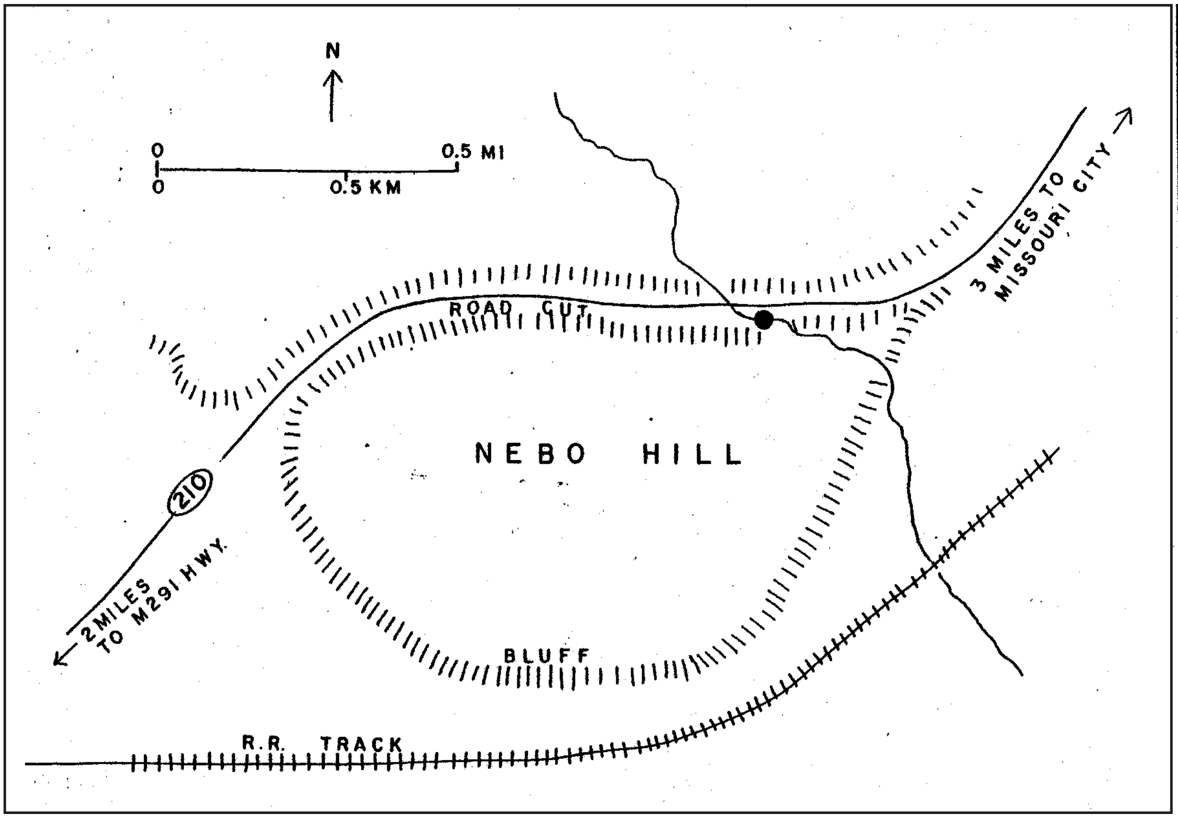


Figure 28. Location map of Highway 210 and Nebo Hill section by • (Stop 5). 3.3 miles (5.5 km) east of Junction Highway 210 and Highway 291, along an eastward flowing stream 200 ft south of Highway 210 at place where the stream passes through a culvert under the Highway. NE1/4, SE1/4, NE1/4, SE 1/4, sec. 23, T. 51 N., R. 31 W.; Kansas City, Clay County, Missouri; Missouri City 7.5 ' quadrangle. At this place about 10 ft (3 m) of unweathered glacial till is exposed at the bottom of a hill excavated through for location of Highway 210 in the 1980's. The upper part of the hill is covered by vegetation.

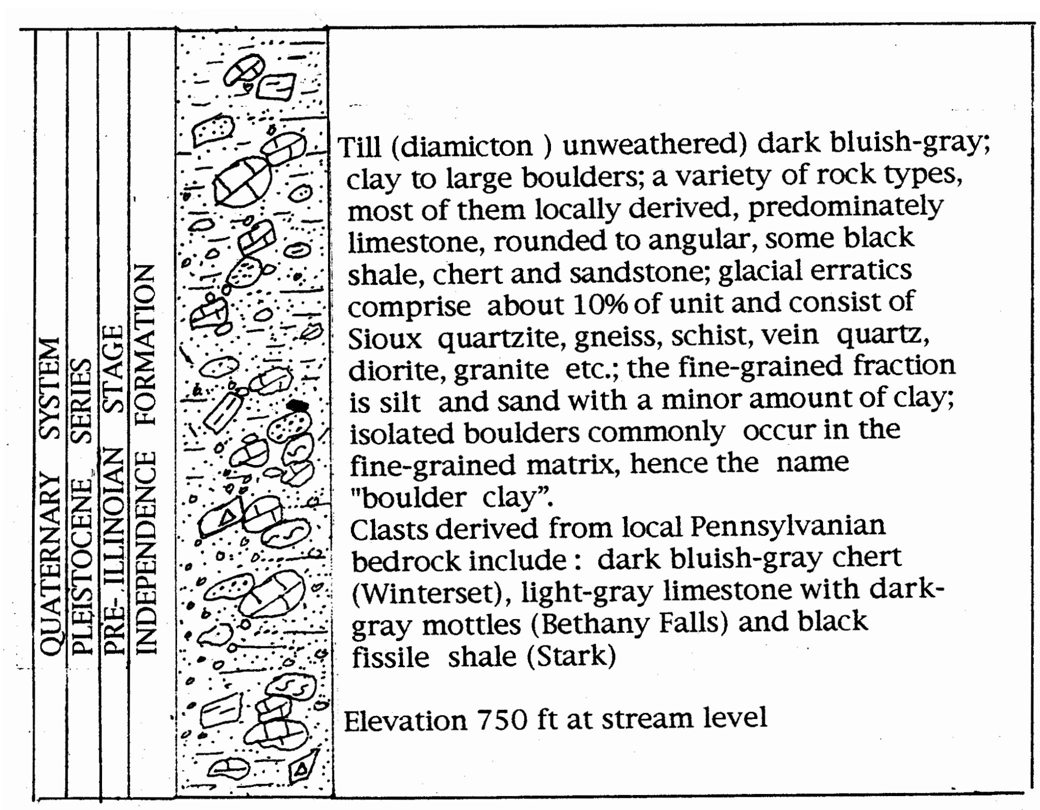


Figure 29. Graphic section of pre-Illinoian glacial till.

Figure 30. Unweathered pre-Illinoian glacial till, commonly called "boulder clay."

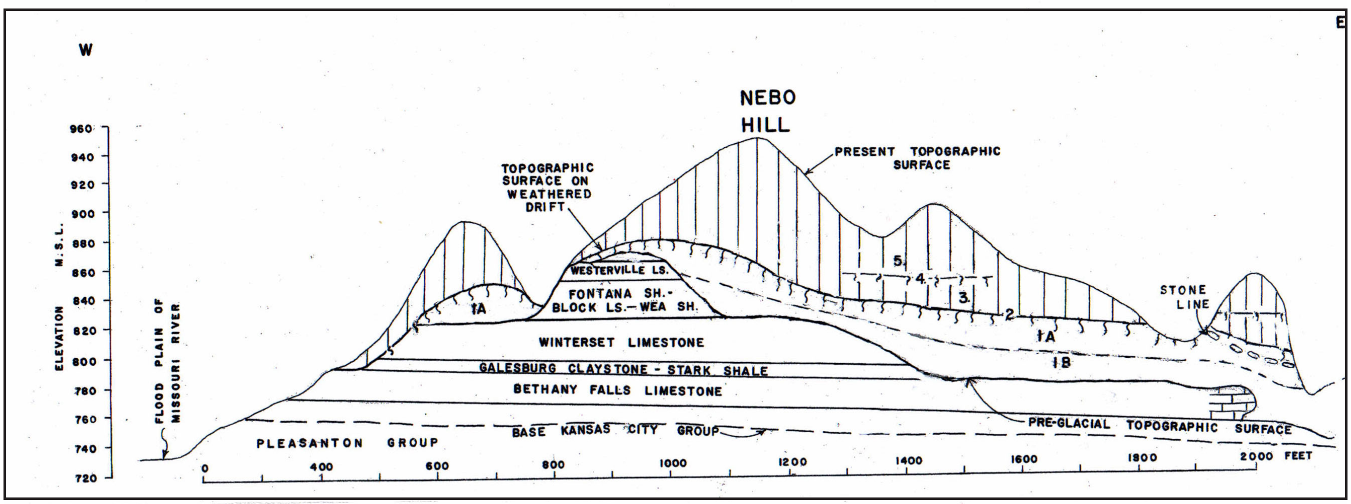


Figure 31. Cross section of Pleistocene – age deposits overlying bedrock in an excavation for Highway 210 through Nebo Hill, 3 miles (5 km) west of Missouri City, Clay County, MO.

Lithologic Description and Tentative Correlation of Pleistocene Units
Exposed in a section along Highway 210 (Fig. 26).

Quaternary System

Pleistocene Series

Late Wisconsinan-Holocene (Recent) Stages

Unit 19, Modern soil developed on Bignell Loess

Wisconsinan Glacial

Unit 18, Loess (Bignell)

Silt, moderate brown 5 YR 4/4, non-calcareous; crumbles easily

Unit 17, Paleosol, poorly developed

Silt, moderate yellowish-brown 10 YR 5/4, clayey, plastic

Unit 16, Loess (Peoria)

Silt, moderate yellowish-brown 10 YR 5/4, clayey; sparse quartz sand grains to 0.25 mm diameter

Sangamonian Interglacial

Unit 13, 14 and 15, Paleosol, well-developed 3 to 4 ft (1 m) thick

Silt, moderate brown 5 YR 4/4, clayey; sparse clear speroidal quartz grains to 0.5 mm diameter; sand sized manganese nodules; vertical joints; scales and flakes off upon exposure (The Sangamon paleosol is the most intensely developed and the most widespread of the Pleistocene paleosols.

Illinoian Glacial

Unit 12, (valley train deposits? alluvium?)

Sand, yellowish brown 10 YR 5/4, cross-bedded, fine-grained, loose; very little clay

Unit 11 (alluvium?)

Sand, light olive-gray 5Y 6/1; poorly sorted, loose; clear angular to rounded quartz grains to 0.5 mm diameter; non-calcareous

Unit 10 (alluvium and reworked Loveland? Loess)

Silt, moderate brown 5YR 4/4; clear rounded to angular quartz grains to 0.5 mm diameter; sparse mica flakes; sand-sized manganese nodules

Yarmouthian Interglacial

Unit 9, Paleosol

Sand, moderate brown 5Y 4/4; silty, clayey, poorly sorted clear and milky quartz grains to 1.5 mm diameter; sand-sized brown to black manganese nodules

Unit 8, Paleosol, 1 ft to 2 ft (0.3 – 0.6 m) thick on west end of cut (unit 9)

Silt, moderate brown 5YR 4/4; poorly sorted clay to fine sand; clear and milky quartz grains to 0.125 mm diameter; sand-sized manganese nodules; vertical joints

Pre-Illinoian (Early middle Pleistocene)

Independence Formation (upper)

Unit 7, Stratified drift and deeply weathered diamicton?

Sand, gravel, lenticular with clasts of angular to rounded pink quartzite (Sioux), white and purple quartzite, chert and vein quartz to 5 cm diameter

Units 4, 5 and 6, Stratified drift

Sand, silty, moderate brown 5 YR 4/4 intercalated with moderate yellowish brown 10YR 5/4 laminae oriented at high angle; clear rounded quartz grains to 1 mm diameter; brownish black sand-sized manganese nodules; sparse mica flakes

Independence Formation (lower)

Unit 3, Paleosol, well-developed, 2 to 3 ft (0.6 – 0.9 m) thick

Sand, moderate brown 5YR 4/4; blotches of light-gray, non-calcareous coarse silt with clear quartz grains to 0.75 mm diameter; sand-sized manganese nodules

Unit 1 and 2, Stratified drift and deeply weathered diamiction

Sand, light, olive-gray 5Y 6/1 to moderate brown 5YR 4/4, silty, clayey; clear rounded quartz grains to 0.75 mm diameter

1. Classification of Pleistocene units modified after S.D. Davis in Bayne, 1971; Whitfield, J.W. in Thompson, M.L. 1995; and Colgan, 1999.
2. Color identification from Munsell Soil Color Chart and samples were tested moist.

Table 2

Stop No. 6 – Plattsburg Limestone at I-435 and 108th Street

At this stop the Plattsburg Limestone is well exposed. It consists of 3 members in descending order, Spring Hill Limestone, Hickory Creek Shale and the Merriam Limestone (Figs. 32-36).

Near the middle of the Spring Hill is a zone of the producticd brachiopod *Juresania* with the spines still attached to many specimens.

A diagnostic feature of the Spring Hill Limestone in the Greater Kansas City area is the presence of thin beds and nodules of dark bluish-gray chert. A persistent chert bed about 3 in. (8 cm) thick is well exposed in the lower one half.

The Hickory Creek Shale is light-gray with laminae of dark-gray to black shale.

The Merriam Limestone is over 4 ft (1.2 m) thick at this stop. The lower 2 ft (0.6 m) is a dark bluish-gray, thick-bedded limestone and is typical of most areas of western Missouri. The upper part is interbedded with shale, a feature that becomes more common as the unit thickens in a northwesterly direction. The Merriam Limestone is jointed into blocks of the size that make it and excellent stone for the construction of buildings in early Kansas City. It is now used primarily for decorative purposes.

A zone of the brachiopod *Composita* is near the bottom of the Merriam.

The Bonner Springs Member is mostly covered.

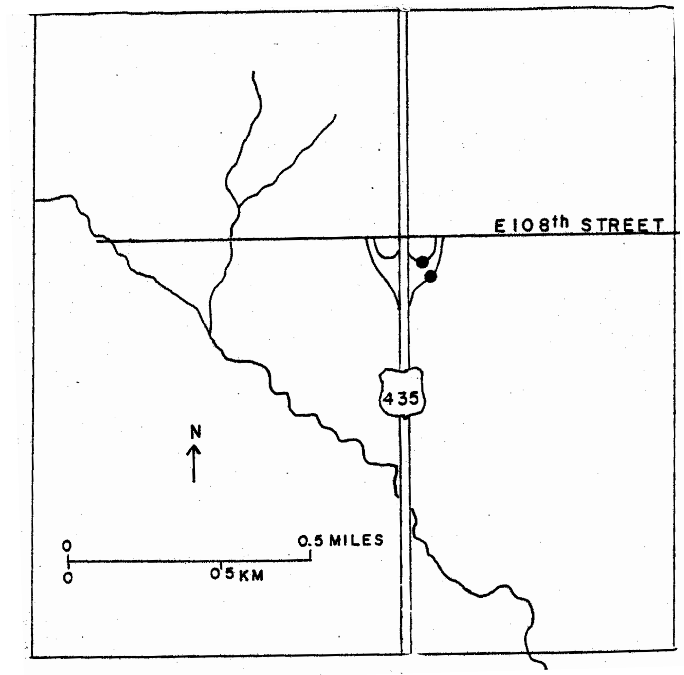


Figure 32. Location map at Interstate Route 435 and 108th Street section shown by • (Stop 6). Excavations on both sides off-ramp from Interstate Highway 435 to NE 108th Street; NW1/4, NW1/4, SW1/4, sec. 28, T. 52 N., R. 32 W.; 4 miles (6.5 km) southeast of Nashua, Clay County, Missouri; Nashua 7.5 ' quadrangle.

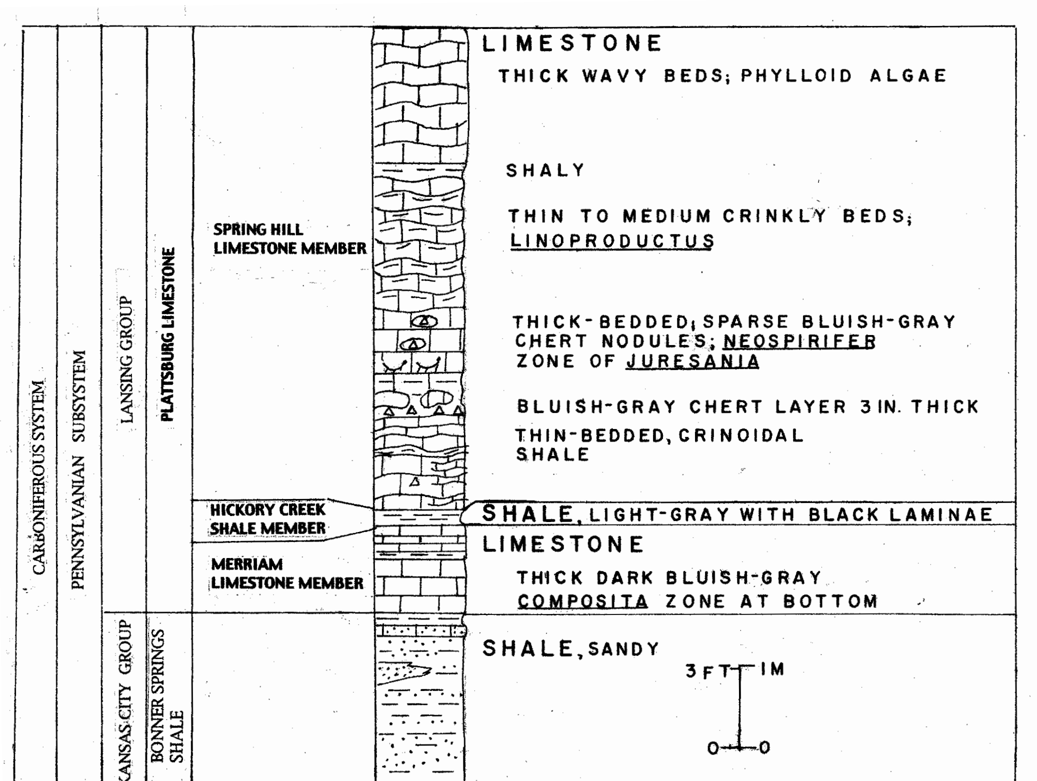


Figure 33. Graphic section of the Plattsburg Limestone in excavation for off-ramp from I-435 north to 108th Street.

Figure 34. Lower Plattsburg Formation. Merriam Limestone Member lower 4 ft (1.2 m) on stadia rod; Hickory Creek Shale Member top 1 ft (0.3 m), and the lower Spring Hill Limestone above stadia rod.

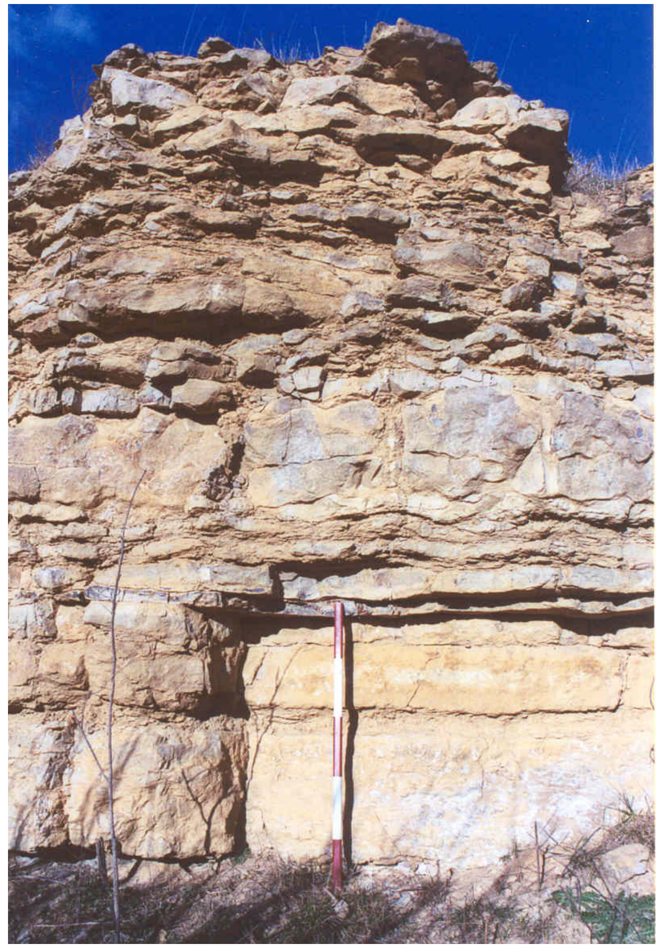


Figure 35. Spring Hill Limestone Member, Plattsburg Formation. A 3 in. (7.5 cm) thick layer of dark bluish-gray chert near top of stadia rod.

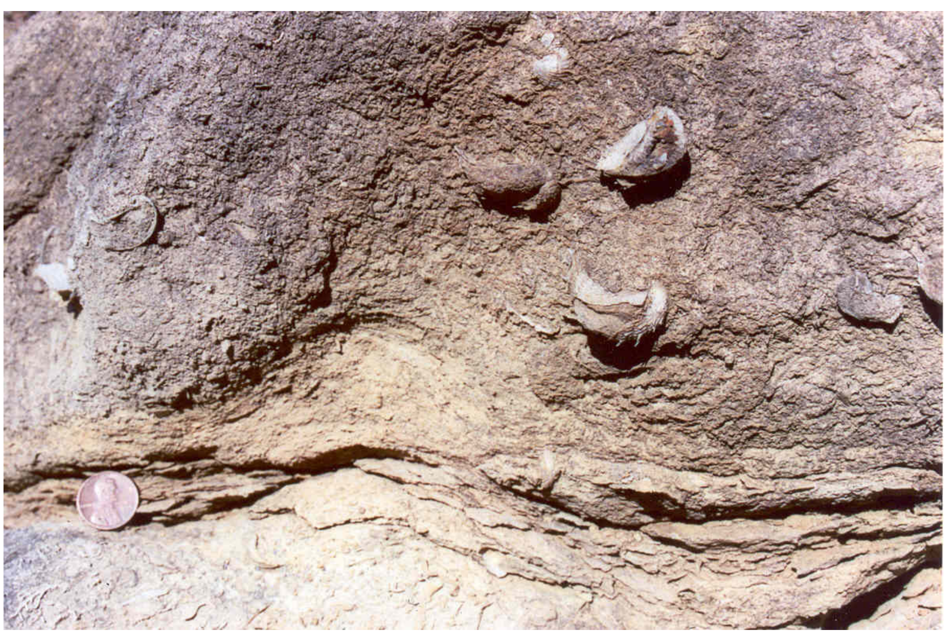


Figure 36. Zone on the productid brachiopod, genus Juresania *near middle of the Spring Hill Limestone Member.*

Acknowledgements

Patrick M. Colgan, Geology Department, Northwestern University, Boston, Massachusetts read the Pleistocene section of the guidebook and offered many helpful suggestions.

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