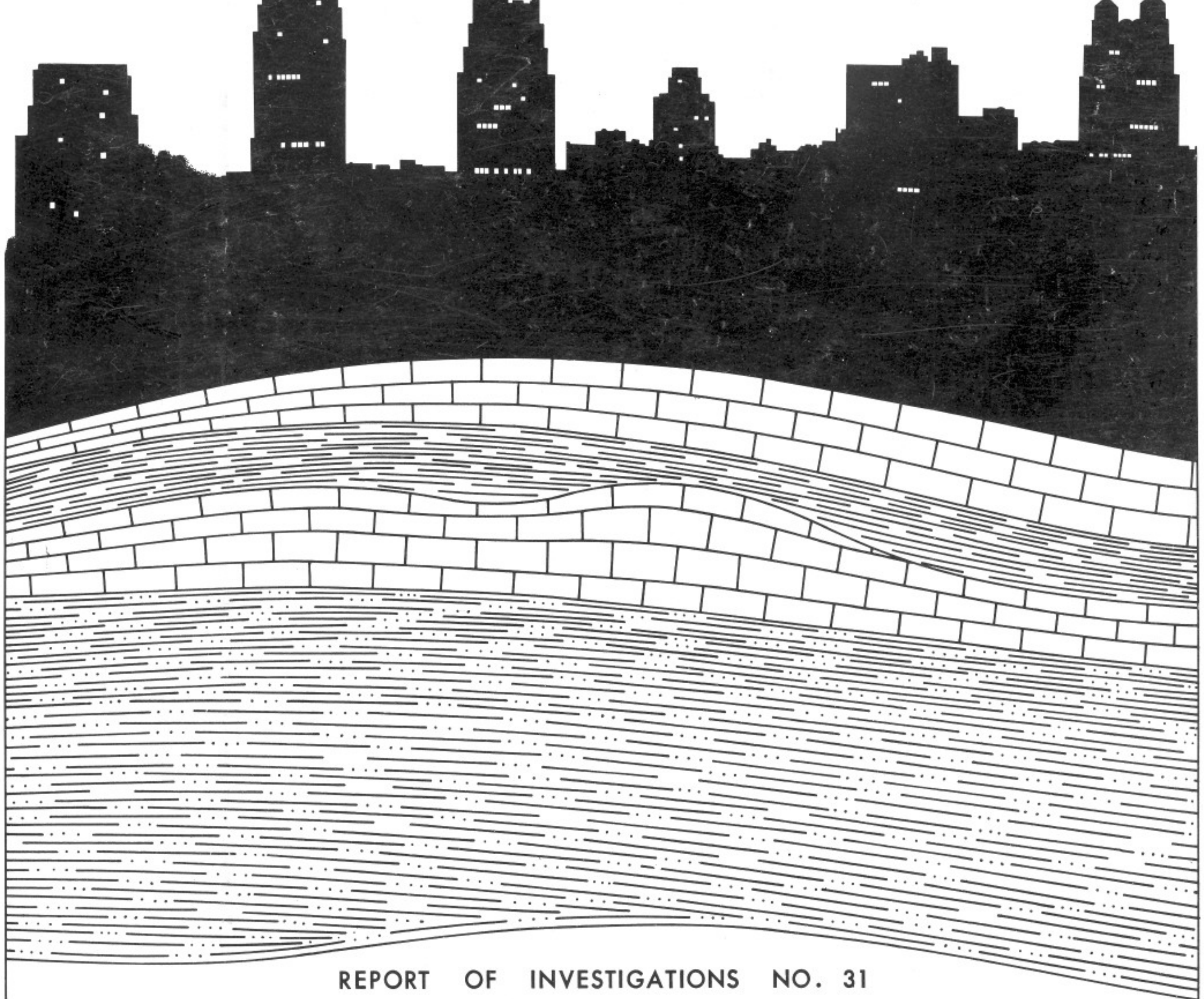
GUIDE BOOK

FIELD TRIP

RI 31

GEOLOGY of the KANSAS CITY GROUP at KANSAS CITY



REPORT OF INVESTIGATIONS NO. 31
NOVEMBER 1965

STATE OF MISSOURI DEPARTMENT OF BUSINESS AND ADMINISTRATION
DIVISION OF GEOLOGICAL SURVEY AND WATER RESOURCES
W C HAYES STATE GEOLOGIST AND DIRECTOR ROLLA MISSOURI

GUIDE BOOK

FIELD TRIP

Annual Meeting, 1965

Geological Society of America

THE GEOLOGY OF THE KANSAS CITY GROUP AT KANSAS CITY

by

ELDON J. PARIZEK *and* RICHARD J. GENTILE

REPORT OF INVESTIGATIONS NO. 31

1965

STATE OF MISSOURI
Department of Business and Administration
Division of
GEOLOGICAL SURVEY AND WATER RESOURCES
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Rolla, Missouri

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INTRODUCTION

Kansas City, Missouri, is located midway in a 150-mile-wide band of outcropping Pennsylvanian rocks that extends in a north-south direction through western Missouri and eastern Kansas. The beds exhibit a very gentle prevailing dip to the west-northwest. More than 300 feet of the Pennsylvanian beds are well exposed at Kansas City, comprising strata that are part of the lower Missourian Series, one of five series in the Pennsylvanian System of the Midcontinent. The Missourian Series is subdivided into four groups, named in upward order, the Pleasanton, Kansas City, Lansing, and Pedee. Most of the exposed sections at Kansas City are part of the Kansas City Group. In general, the Missourian Series contains an array of thick shale and limestone formations which separate assemblages of thinner alternating beds of limestone and shale. A disconformity which separates the Missourian Series from the Desmoinesian Series below occurs at the base of the Pleasanton Group. This break is denoted by the disappearance of typical Desmoinesian fossils and the introduction of new forms, among which the fusulinid, Triticites, is probably most significant. The upper boundary of the Missourian Series is along an unconformity at the base of the Tonganoxie Sandstone Member (Virgilian Series).

Although the initial geological observation in the vicinity of Kansas City was presumably in 1855 by G. C. Swallow, the first State Geologist of Missouri, it was not until 1873 that a systematic work was published on the Pennsylvanian rocks of Missouri. This work (Broadhead, 1873) includes a description of the strata in northwestern Missouri, the classification of beds into Lower, Middle, and Upper Coal Series, and contains a numerical designation for the distinct units. Some years later, the term "Kansas City Limestone" was given to the strata at Kansas City (Hinds, 1912). This was followed shortly by the classification of the Pennsylvanian "Series" of western Missouri into groups, formations, and members (Hinds and Greene, 1915). The latter contribution served for more than three decades as the standard terminology for Pennsylvanian deposits in western Missouri and was used in the first detailed geological investigation that included the Kansas City area (McCourt, 1917). Disagreement in the use of nomenclature and the correlation of certain Pennsylvanian units in the northern Midcontinent developed between some of the geological surveys in the ensuing years. In an attempt to resolve the problems a conference was held at Lawrence, Kansas, in May, 1947, at which Missouri, Kansas, Oklahoma, Iowa, and Nebraska were represented. Agreement was achieved and resulted in the adoption of nomenclature and correlations that have proved acceptable and are currently in use. The results of this conference were noted by Moore (1948), Greene and Searight (1949), and Moore (1949). The present classification of the Pennsylvanian rocks at Kansas City (Greene and Howe, 1952) closely follows the recommendations adopted at the conference.

Beds underlying the Kansas City area dip gently westward off the Ozark uplift and toward the Forest City Basin. The dips average 10 to 20 feet per mile. The region is characterized by east-facing escarpments held up by relatively resistant limestones in the Kansas City Group. One escarpment, the Bethany Falls, is particularly significant at Kansas City. The more gentle slopes and lowlands intervening between the escarpments are largely underlain with shales in the Pleasanton and Kansas City Groups. Loess and patchy deposits of glacial till often conceal the beds immediately north and east of the river.

The Kansas City Group, as defined at the Lawrence Conference, is formed of three subgroups, the Bronson, Linn, and Zarah, in upward order, and includes beds from the base of the Hertha Formation to the base of the Plattsburg Formation (Lansing Group). It includes 12 formations and 23 members in Missouri (Fig. 18). Names of the formations and members come mostly from Kansas localities, although several are from Missouri and two from southwest Iowa.

In general, the Kansas City Group at Kansas City is composed of alternating persistent limestones and shales. Black platy shales are present in association with several of the limestones. Sandstone is of minor importance in the sections at Kansas City but increases at the expense of limestones in southeastern Kansas. Coal beds are sparsely developed in the Kansas City Group at Kansas City.

The cyclic nature in sedimentation and rocks designated as a "cyclothem" is readily apparent in the Kansas City Group. The presence of cycles of cyclothems, termed megacyclothems, was first recognized by Moore (1936). Middle Pennsylvanian deposits in the northern Midcontinent region generally lack the complete sequence of units that constitute the idealized cyclothem which is more completely developed in the Illinois Basin. Moore (1936, pp. 29-33) believes that three types of cyclic sequences of deposits are distinguishable in the Pennsylvanian rocks in the northern Midcontinent: (1) cyclothems in the Wabaunsee Group (Virgilian Series), (2) megacyclothems in the Shawnee Group (Virgilian Series), and (3) somewhat less well defined megacyclothems of partial cycles within the Kansas City Group.

Four megacyclothems have been recognized in the Kansas City Group (Moore, 1949, pp. 78-79), each composed of two or three cyclothemic units. The letters B, C, and D were given to the cyclothem types. Readily distinguishable features characterize the B- and C- type cyclothems, but the D- type is less easily differentiated. The reader is referred to Moore (1949, pp. 77-82; 1957, pp. 77-83) for additional discussion and illustration of megacyclothems in the Kansas City Group.

ACKNOWLEDGMENTS

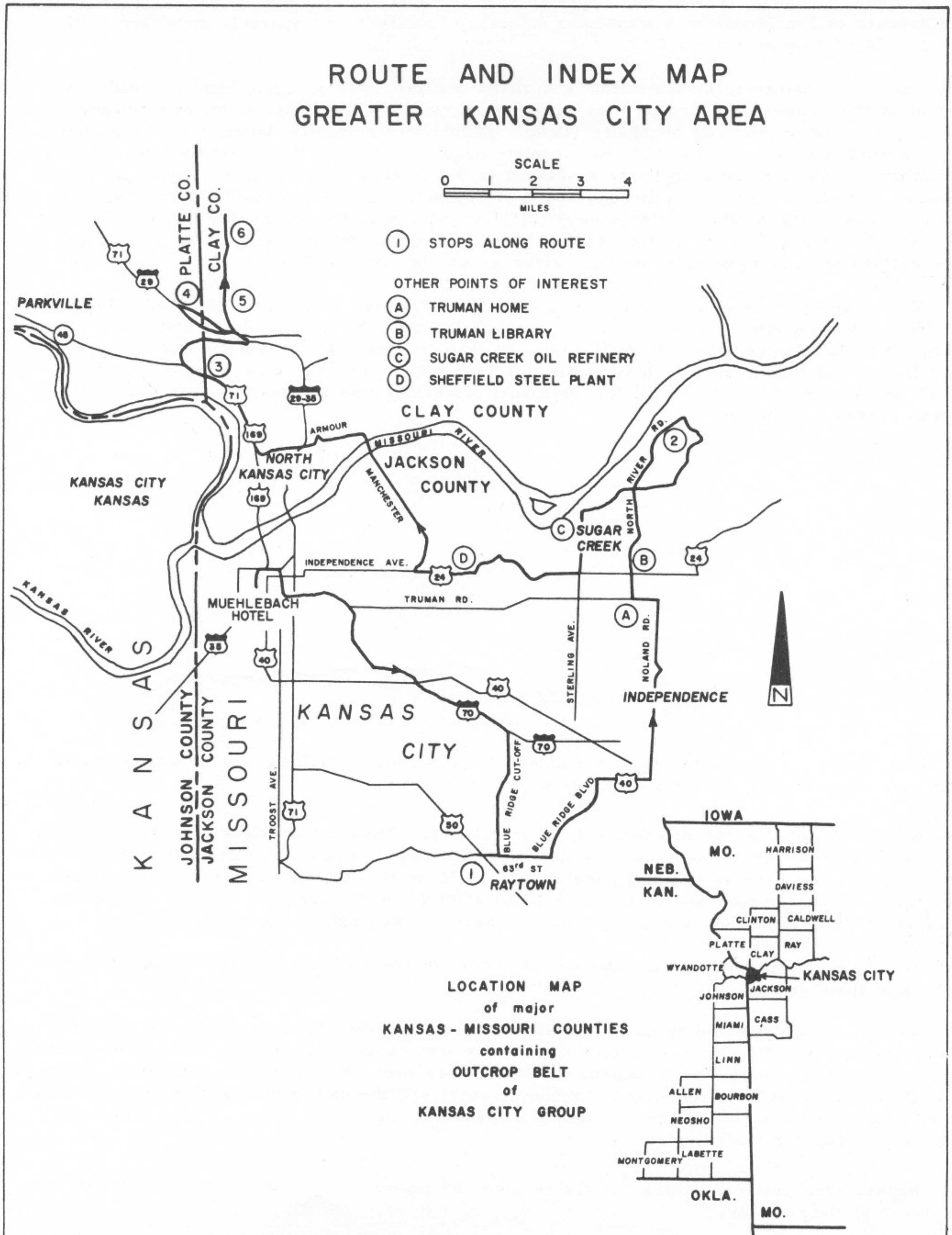
The leaders of this field trip are indebted to numerous individuals and organizations whose help and understanding have made this trip possible.

We are grateful to the management personnel of the Missouri Portland Cement Company, Kansas City Plant for allowing us to visit their operations. Dean Weixelman, Company Geologist supplied data used in compiling the stratigraphic section exposed in the quarry; Harry Gerleman, Plant Manager and J. E. Brown, Assistant Plant Manager volunteered information concerning plant processes and contributed the aerial photograph of the plant.

Also acknowledged is the management personnel of the McClain Quarry for allowing us access to their quarry.

We are deeply indebted to numerous staff members of the Missouri Geological Survey and Water Resources. Douglas Stark, Chief Draftsman was responsible for the drafting of illustrations and plates. Henry Groves photographed the rock exposures at most of the stops, John W. Koenig (now with the Continental Oil Company) supervised the editing of the manuscript. W. B. Howe contributed a measured section and photograph of one of the stops. Bonnie Happel and Glenda Otis typed the manuscript.

We are also grateful for the assistance given by numerous students of the University of Missouri at Kansas City.


ROUTE AND INDEX MAP
GREATER KANSAS CITY AREA
SCALE
0 1 2 3 4
MILES
1 STOPS ALONG ROUTE
OTHER POINTS OF INTEREST
A TRUMAN HOME
B TRUMAN LIBRARY
C SUGAR CREEK OIL REFINERY
D SHEFFIELD STEEL PLANT
PLATTE CO.
CLAY CO.
PARKVILLE
CLAY COUNTY
JACKSON COUNTY
NORTH KANSAS CITY
KANSAS CITY KANSAS
MISSOURI RIVER
KANSAS RIVER
ARMOUR
MANCHESTER
NORTH RIVER RD.
SUGAR CREEK
INDEPENDENCE AVE.
TRUMAN RD.
MUEHLEBACH HOTEL
STERLING AVE.
NOLAND RD.
INDEPENDENCE
KANSAS CITY
TROOST AVE.
BLUE RIDGE CUT-OFF
BLUE RIDGE BLVD
63rd ST
RAYTOWN
KANSAS
JOHNSON COUNTY
JACKSON COUNTY
MISSOURI
N
LOCATION MAP
of major
KANSAS - MISSOURI COUNTIES
containing
OUTCROP BELT
of
KANSAS CITY GROUP
IOWA
MO.
NEB.
KAN.
HARRISON
DAVIESS
CLINTON
CALDWELL
PLATTE
CLAY
RAY
WYANDOTTE
KANSAS CITY
JOHNSON
JACKSON
MIAMI
CASS
LINN
ALLEN
BOURBON
NEOSHO
MONTGOMERY
LABETTE
OKLA.
MO.

GEOLOGY OF THE KANSAS CITY GROUP AT KANSAS CITY

Saturday, November 6, 1965

Driving distance: 66.0 miles

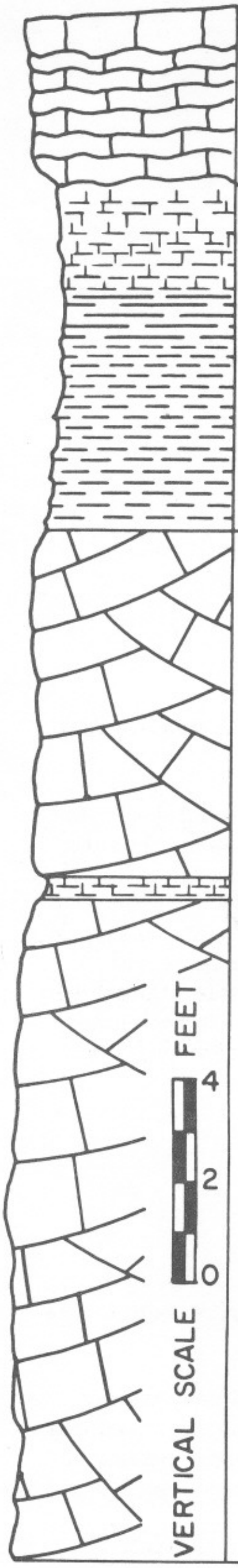
Departure time: 8:00 A.M. C.S.T.

Place: Muehlebach Hotel, Baltimore St. entrance

Road log prepared by Eldon J. Parizek[1] and Richard J. Gentile[2]

Mileage		
Cum.	Diff.	
0.0		Muehlebach Hotel.
		Proceed north to 10th Street and turn right.
0.8	0.8	Access road to Interstate 70.
		Veer right to enter Interstate 70.
6.6	5.8	Upper several feet of Winterset limestone, 3 feet of Fontana shale, and 1.5 feet of Block limestone exposed on both sides of road.
7.1	0.5	Even bedded upper Winterset limestone on right. Nodular and banded dark blue chert prominent. The siliceous limy layers (4 to 6 inches, average thickness) are separated by dark gray shale partings. The beds dip gently southeast.
7.5	0.4	Westerville limestone, Quivira shale, Cement City limestone, Chanute shale, Iola limestone, Lane shale, and the lower 8 feet of Argentine limestone are present on both sides of Interstate 70. Lower Chanute maroon shale and gray to olive-green Quivira and Lane shales are exceptionally well shown here because of the comparatively fresh road cuts. The colors will be much subdued once the beds have been weathered.
7.9	0.4	Blue Ridge Cut-off exit from Interstate 70.
		Bear right and enter Blue Ridge Cut-off.
8.9	1.0	CAUTION! Chicago, Rock Island, and Pacific Railroad crossing.
9.1	0.2	Bethany Falls limestone, and Galesburg-Stark shales are exposed behind the buildings on the left. Continue on Blue Ridge Cut-off.
9.3	0.2	Weathered gray to black upper Bethany Falls limestone on both sides of road. Large blocks of this unit are scattered downslope from the outcrops, a frequent condition in areas where the Bethany Falls is present. Some blocks measure 15 x 10 x 10 feet in size.
9.8	0.5	City limits of Raytown, Missouri, one of more than a score of incorporated municipalities that combine to form Greater Kansas City.

[1] Professor, University of Missouri at Kansas City, Kansas City, Missouri.
[2] Geologist, Missouri Geological Survey and Water Resources, Rolla, Missouri.



3'0"	Limestone, gray, finely crystalline, wavy bedded, weathers tanish buff; contains crinoid debris, brachiopods, echinoid spines, Campophyllum.	CEMENT CITY MBR.	DRUM FM.	LINN SUBGROUP	KANSAS CITY GROUP
7'0"	Shale, olive green, calcareous. Shale dark gray to black, calcareous, platy; underlain by 1 foot of light gray calcareous shale. Shale, olive green, calcareous.	QUIVIRA MBR.	CHERRYVALE FM.		
7'6"	Limestone, light gray, oolitic, cross-bedded; beds dip 12° S.10°-15°E.; weathers buff, oolites (¼-½ mm. diameter) decrease in number downsection; contains algae (Osagia and encrusting types), fenestellid bryozoans myalinid pelecypods, nautiloid cephalopods, and ostracodes.	WESTERVILLE MBR.			
0'6"	Shale, dark gray, calcareous.				
12'0"	Limestone, gray to dark gray, coarse-grained, algal, cross-bedded; beds 6 to 10 inches thick dip 12°-14° N.0°-5°E., thin shale seams in lower part; secondary calcite common in vugs and on bedding surfaces; contains Linoproductus, Juresania, Composita, and fenestellid bryozoans.				

Fig. 1. STOP 1: Westerville-Cement City Section, McClain Quarry off James A. Reed Road; NW¼ SE¼ sec. 6, T. 48 N., R. 32 W., Jackson County, Missouri.

Mileage		
Cum.	Diff.	
11.1	1.3	Intersection of Blue Ridge Cut-off and 63rd Street Trafficway.
		Turn right. Enter Kansas City, Missouri.
11.5	0.4	Overpass of U. S. Highway 50.
		Pass beneath on 63rd Street. Westerville limestone, Quivira shale, and Cement City limestone exposed on both sides of street. Quarry in the Westerville limestone on right.
11.6	0.1	James A. Reed Road intersection with 63rd Street.
		Turn left on James A. Reed Road.
11.8	0.2	STOP 1: McClain Quarry.

Westerville, Quivira, and Cement City beds are exposed at this stop. The Westerville limestone is particularly interesting because of its abnormal thickness, fossil content and strong cross bedding. The outcrop is at the south margin of a limestone buildup (reef) that trends north-south in the Westerville. The Westerville is usually 4 to 6 feet thick at Kansas City; here and in several outcrops immediately north, it is as much as 21 feet.

Thick limestone in this region was first reported 48 years ago by McCourt (1917, p. 53) in a report on the geology of Jackson County. He mistakenly identified the limestone as the Drum (Cement City). The reef structure is elliptical in plain view, extending 3.4 miles to the north and is 1.75 miles across at its widest position (Fig. 2). The shape and areal extent agree closely with the Raytown anticline delineated principally from subsurface data (Clair, 1943, p. 59). The close relationship between the two seems to be more than coincidental. The Westerville thins to approximately 4 feet at the margin of the structure and pinches out locally a few miles to the southeast.

Thick Westerville sections at Kansas City contain massive to cross bedded, oolitic limestone in the upper half. Here such beds are separated by a thin calcareous shale from nonoolitic beds below. Reverse dip of the cross beds occurs at this point in the section. Oolites decrease in quantity downward in the upper Westerville and disappear below the shale parting. Stylolites exist throughout the section. The fossil content is large in the Westerville of this region. In addition to algal varieties and a great deal of fragmental crinoids, bryozoans, and unidentified forms, the following genera are present: Lophophyllidium, Composita, Juresania, Linoproductus, Echinoconchus, Hustedia, Neospirifer, Polypora, Fenestrellina, Myalina, Pecten, Lepetopsis, Trepospira, Titanoceras, Endolobus, Mooreoceras, Domatoceras, Ameura.

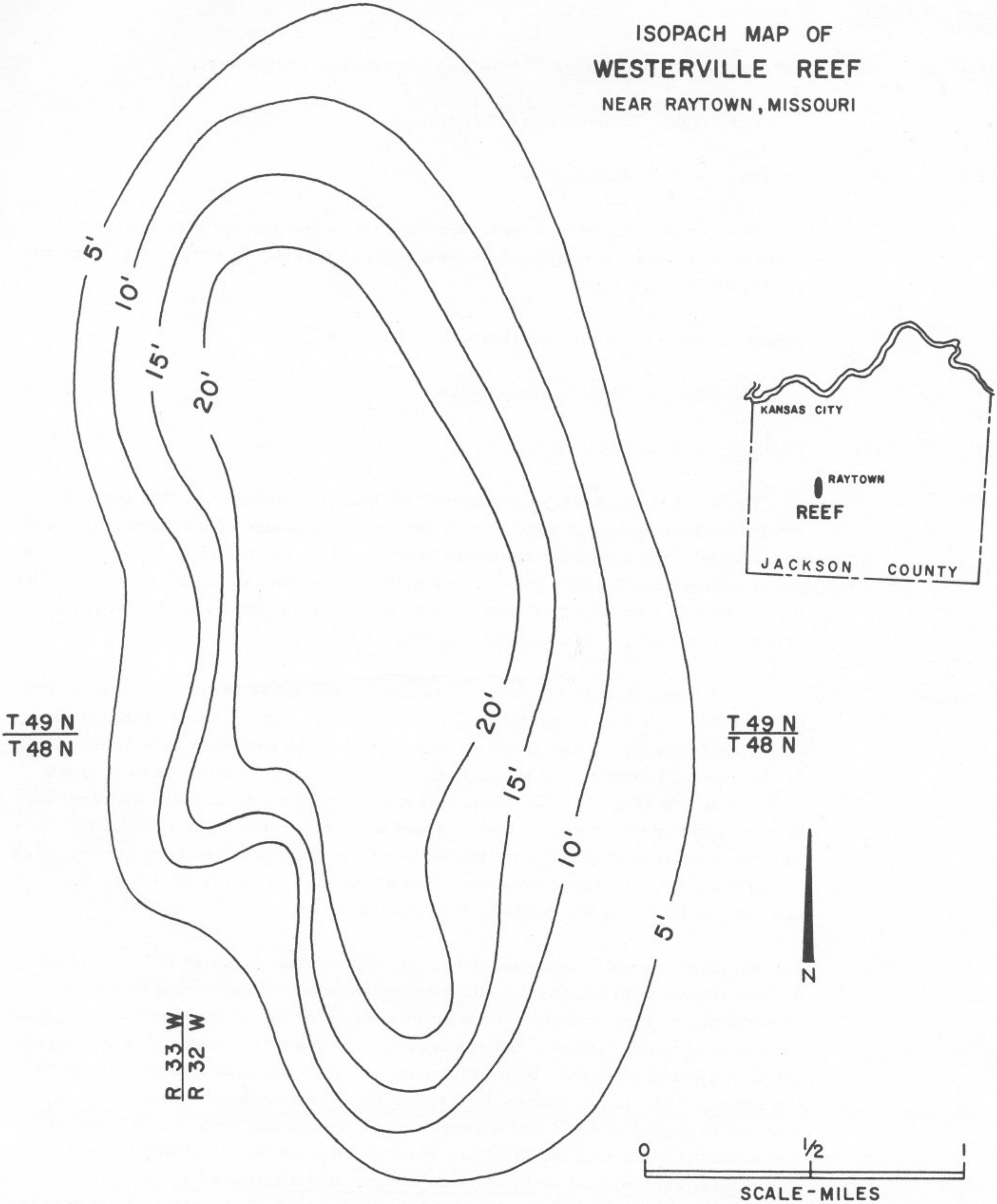


Fig. 2. Isopach map of the Westerville limestone.

Mileage

Cum. Diff.

For the most part, the overlying Quivira is olive-green, calcareous shale. It contains 8 inches of noncalcareous, dark platy shale midway in the section which is underlain by one foot of calcareous clay. The Quivira thickens marginally to the reef structure where the Westerville has thinned to a normal thickness. The lower 3 feet of Cement City limestone exposed at this quarry is thin and wavy bedded, typical of its appearance in weathered exposures. The beds are finely crystalline and contain crinoid fragments, echinoid spines, brachiopods, and the horn coral, Campophyllum. This coral occurs in a persistent zone and is useful in identifying the Cement City at Kansas City, because it does not occur in adjacent beds.

Fig. 3. STOP 1: Cross bedded, oolitic facies of the Westerville limestone exposed in McClain Quarry; NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 6, T. 48 N., R. 32 W., Jackson County, Missouri.

Mileage		
Cum.	Diff.	
12.0	0.2	Turn right on 63rd Street Trafficway from James A. Reed Road.
12.5	0.5	Intersection between 63rd Street and Blue Ridge Cut-off.
		Continue on 63rd Street.
13.1	0.6	CAUTION! Blue Ridge Boulevard joins 63rd Street from right.
13.5	0.4	Raytown, Missouri, business district.
13.6	0.1	Turn left on Blue Ridge Boulevard.
14.0	0.4	For the next 2 to 3 miles, the route closely follows the crest of the Blue Ridge anticline and former gas field, important in the Kansas City area 20 to 30 years ago. A shoestring sand whose trend agrees with the axis of the structure, is believed to exist here (Clair, 1943, pp. 94-102); this interpretation contrasts with shoestring sands in Kansas where accordance does not occur between the shape of buried sand bodies and associated structures (Bass, 1937, p. 56). Evidence strongly suggests that the Blue Ridge Shoestring sand formed as an off-shore bar (Clair, 1943, p. 99). The body curves for 7.25 miles in a northwest-southeast direction and is convex to the southwest. It is broader at the base and has secondary ridges which suggest that growth occurred in stages. The sand is more than 70 feet thick.
		The Blue Ridge gas field was opened in the early 1930's. It comprised three pools that were presumably related at depth. Production has been chiefly from the Squirrel sand (Lagonda) in the northwest and the Burbank horizon (Lower Cherokee) in the east and southeast part of the structure. Major production was obtained from the Burbank horizon. More than 70 producing wells were drilled in rapid succession along the Blue Ridge anticline, resulting in over-production and rapid decline in pressure. For the most part, production was depleted in a decade. Despite its short life, however, production from the Blue Ridge field reached nearly 2.2 billion cubic feet of gas.
16.2	2.2	Intersection of Blue Ridge Boulevard and Alternate U. S. Highway 40.
		Turn right.
16.3	0.1	Entering Independence, Missouri.

Mileage	
Cum.	Diff.

The early history of Independence pre-dates the Civil War. The city once was an important commercial center, serving as the starting point for wagon trains heading westward. It was also a netting for part of the Mormon War, and later became home for a President of the United States.

Independence, population 37,000, is now a national tourist center. The Truman Library and Truman Home are largely responsible for this tourist boom. The library in particular became a meeting place for scholars from all lands, who came to observe and study in this library and museum which chronicles the history of the American Presidency and houses the Presidential papers of Harry S. Truman.

Near the Independence City Hall is the Old Independence Courthouse, the oldest courthouse standing west of the Mississippi and now preserved because of its historical significance. Logs for it were hewn by a slave.

Cum.	Diff.	
17.0	0.7	Intersection of Alternate U. S. Highway 40 and U. S. Highway 40.
		Proceed east on U. S. Highway 40.
17.5	0.5	Intersection of U. S. Highway 40 and Noland Road.
		Turn left.
18.2	0.7	Interstate 70 overpass.
		Continue north on Noland Road.
19.1	0.9	Harry S. Truman High School on the right.
		The school was named for the 33rd President of the United States and dedicated by him in 1963.
21.6	2.5	Intersection of Noland Road and Truman Road (Missouri Highway 12).
		Turn left on Truman Road.
22.6	1.0	Intersection of Truman Road and Delaware.
		On the left corner of the intersection is the century old Harry S. Truman

Mileage	
Cum.	Diff.

Home surrounded by a high black iron fence. The home was known as the "Summer White House" during Mr. Truman's administration from April 12, 1945, until January 20, 1953. It was built in 1865 by Mrs. Truman's grandfather, George Porterfield Gates.

Fig. 4. Harry S. Truman Home, Independence, Missouri. This home was known as the "Summer White House" during former President Truman's administration from 1945 to 1953.

Turn right and proceed north on Delaware Street. Enter circle in front of Harry S. Truman Library, a facility established to preserve the books, papers, and historical mementos of the 33rd President and to make them available in a

Mileage	
Cum.	Diff.

setting suitable for study and research. The crescent-shaped building was dedicated July 6, 1957. It crowns a knoll adjacent to Slover Park and is built from Indiana limestone. In addition to facilities for the preservation and use of Presidential papers and other materials, the library has offices for the staff, a museum, photo laboratory, auditorium seating 250 persons, and offices for former President Truman and his staff.

Exhibits designed to the nature and history of the Presidents are featured in the library. Decorating the lobby wall opposite the main entrance is a large mural painting by the noted American artist and resident of Independence, Thomas Hart Benton, titled "Independence and the Opening of the West". The papers of former President Truman comprise approximately 5.5 million documents.

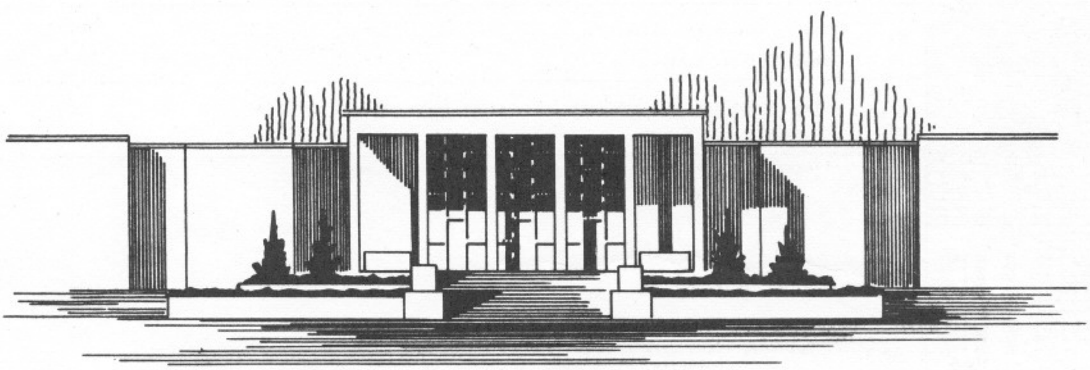


Fig. 5. The Harry S. Truman Library was dedicated in 1957 to preserve the presidential papers and other historical mementos of the 33rd president of the United States.

23.0 0.1 After completing circle in front of the library turn right on Highway 24.

23.3 0.3 Intersection of U. S. Highway 24 and River Road.

Turn right and proceed north on River Road. For the next 1.5 to 2 miles, the road extends along the crest of an upland formed primarily of loess and Argentine limestone.

25.4 2.1 Intersection with Kentucky Road.

Veer right and continue on Kentucky Road.

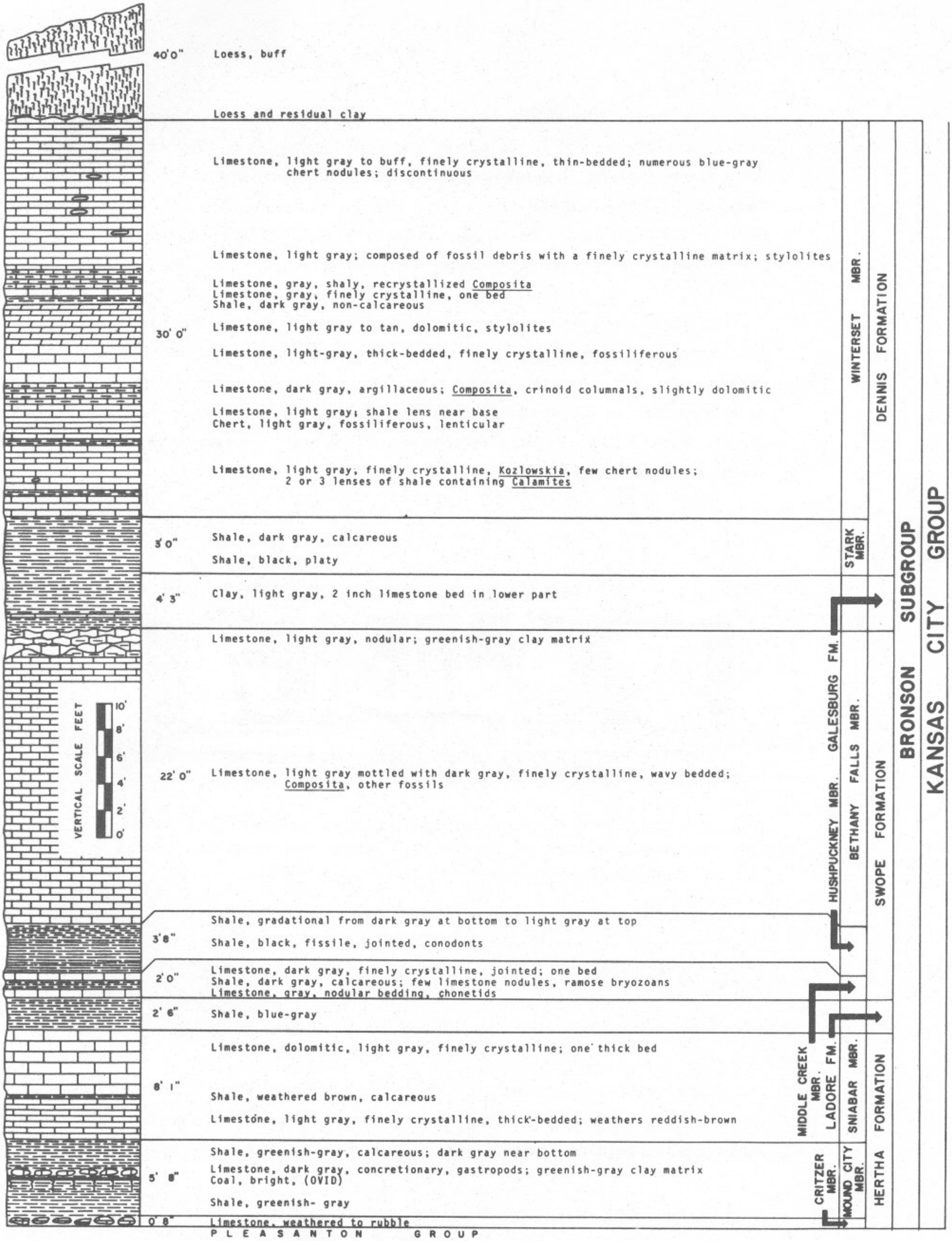


Fig. 6. STOP 2: Hertha-Winterset Section exposed in road cuts on both sides of Courtney Road and in quarry of Missouri Portland Cement Company, SE$\frac{1}{4}$ sec. 23, T. 50 N., R. 32 W., Jackson County, Missouri.

Mileage		
Cum.	Diff.	
26.1	0.7	CAUTION! STOP! Courtney Road joins Kentucky Road from the right.
26.4	0.3	Turn left on Courtney Road.
26.9	0.5	STOP 2: Missouri Portland Cement Company, Kansas City Plant. (Stop Leaders, Dean Weixelman, Company Geologist; Harry Gerleman, Plant Manager; and J. E. Brown, Assistant Plant Manager.)

Participants will leave buses and after viewing the lowermost Kansas City beds exposed in the road cut (Hertha, Ladore, Middle Creek and Hushpuckney) will enter the quarry to observe the Bethany Falls-Winterset section. Participants then will be transported by carryall through the mine. Buses will retrace the route and meet the participants at the plant entrance on the opposite side of the mine. Cement making processes in the plant will be discussed by Messrs. Gerleman and Brown.

LUNCH STOP AT PLANT ENTRANCE TO MINE

The lower part of the Kansas City Group is well exposed at this stop. The section includes beds from the base of the Kansas City Group (Critzer Member) to the top of the Winterset Limestone Member.

The Critzer Member is exposed at road level. It is the lowermost unit of the Kansas City Group and consists of a few inches of nodular limestone that weathers to rubble. The Critzer Member is overlain by the Mound City Member which is predominately shale but contains the thin but persistent Ovid Coal bed or horizon near the middle of the unit.

The Sniabar Member is exposed as two relatively thick beds of limestone separated by a thin shale parting. The limestone beds of the Sniabar Member are slightly dolomitic. Weathered surfaces are reddish-brown, a characteristic which aids in the identification of this unit in field studies.

The Middle Creek Member occurs in the shale interval between the top of the Sniabar limestone and the base of the Bethany Falls limestone and consists of two limestone beds, each less than a foot thick separated by an equal thickness of shale. The black, fissile shale of the Hushpuckney Member overlies the Middle Creek limestone.

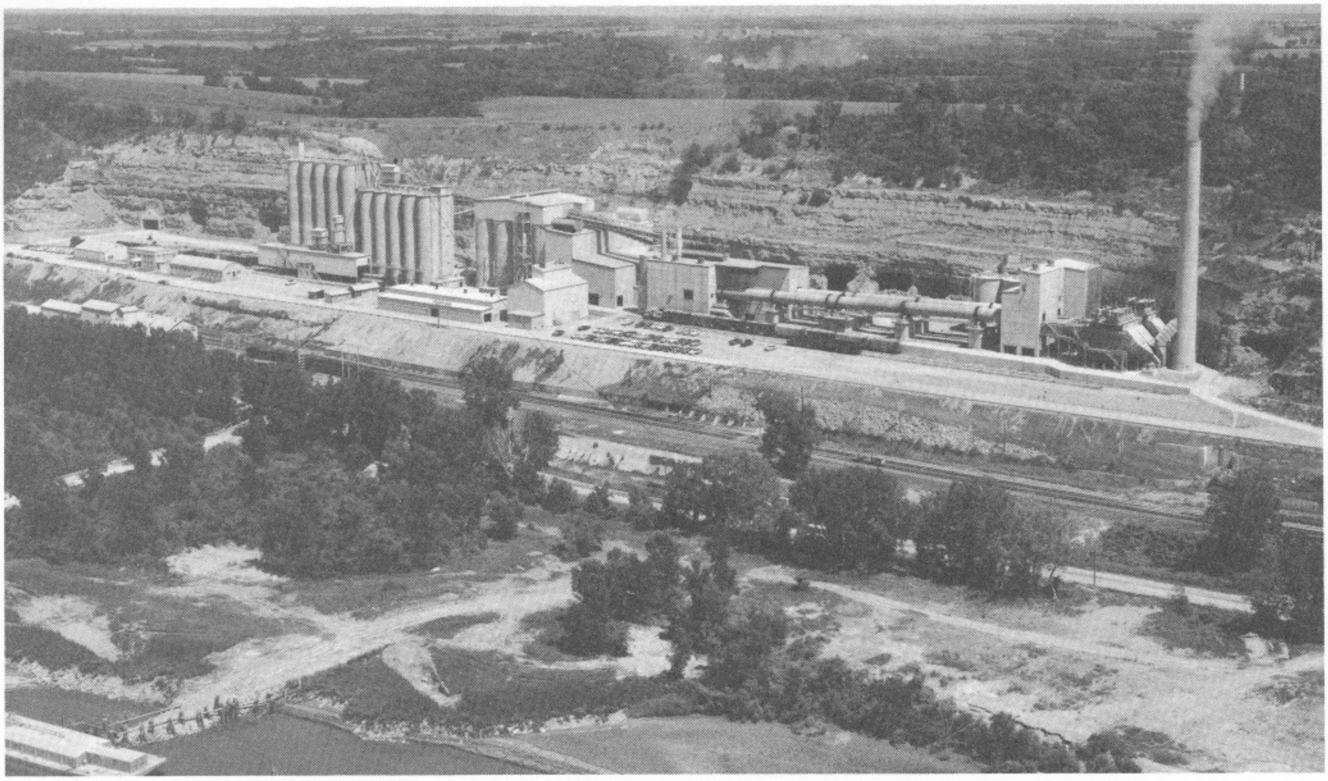


Fig. 7

The Kansas City plant of Missouri Portland Cement Company is located on the Missouri River about ten miles downstream from the center of Kansas City, Missouri. This is a dry process plant. The major raw materials are obtained by an open pit quarry and a mining operation in the bluff adjacent to the cement plant.

The raw materials, limestone and shale, are hauled to the crusher by 32 ton diesel trucks. The primary crusher is a 42 inch by 48 inch jaw crusher (150 HP) and the secondary unit is a 400 HP impactor mill. Crushing capacity of the system is 250 tons per hour of minus 5/8 inch product.

The crushed raw material and clinker is stored in silos which also serve as the mill feed bins. There are two banks of four silos each; one for raw mill material and the other for finish mill material. Each silo is 30 feet in diameter and 64 feet high above the conical steel hopper bottom. Each silo has a capacity of 1700 tons.

Raw grinding is accomplished in two mills each 10 feet 8 inches by 16 feet (900 HP and 800 HP). Each mill operates in closed circuit with a 16 foot air separator, producing 150 tons per hour of kiln feed. A gas fired furnace for each mill provides hot air for drying the raw materials in the air separator. Automatic continuous weighing feeders deliver the raw material for grinding in proper proportion. Subsequent testing and correction are done as required. There are six blending silos, each having a capacity of 1000 tons. This dry blending system is designed to homogenize the raw material to a degree comparable with wet blending systems.

There are two kilns, one 11 feet 3 inches by 350 feet and the other 12 feet by 350 feet. Draft is provided by 250 HP fans. The temperature of the kiln exit gases is reduced to 700° F by water sprays and atmospheric air before entering the dust collector and fan. All dust is collected by electrostatic precipitators and returned to the kilns either as a dry product or through a dust leaching system as a dust slurry.

Firing of the kilns is by either natural gas or coal. A unit coal pulverizer is provided. The clinker is cooled in inclined grate coolers. Full instrumentation is provided for the major operating factors of the kiln system.

The finish department consists of two two-compartment ball mills in closed circuit with 16 foot air separators. These mills are driven by 1250 HP and 1500 HP synchronous motors respectively. They have a total capacity of 420 barrels per hour.

This plant has a total capacity of 3,000,000 barrels per year. Storage capacity for finish cement is 300,000 barrels. Shipments are by rail, truck and barge. Cement is barged up the Missouri River to a cement terminal located at Omaha, Nebraska.

Missouri Portland Cement Company produces Portland cement in Type I, Type IA, Type II, Type III and masonry cement.

Mileage	
Cum.	Diff.

Two thick limestone beds are well exposed in the quarry of the Missouri Portland Cement Company. They are the Bethany Falls and Winterset Members. The lower 20 feet of the Bethany Falls is a light gray wavy bedded limestone of uniform lithology and chemical composition while the upper 2 or 3 feet is a nodular limestone which when penetrated in underground mining operations has a tendency to cave.

The Winterset Member consists of 30 feet of limestone containing numerous thin shale lenses. The upper part is silicious and weathers to angular pieces of light colored chert.

The Bethany Falls and Winterset limestones are separated by a few feet of shale, the upper part or Stark Member is a black fissile shale that is well exposed in the quarry face.

Forty feet or more of loess overlies the Winterset limestone at this locality.

27.6 0.7 More than 200 feet of the Kansas City Group outcrops along the hill road that leads to the front entrance of the plant. Included are beds from the Hertha Formation to the Argentine Member of the Wyandotte Formation. Thick loess caps the Argentine here. A short stop will be made near the top of the hill which extends for 0.7 mile so that participants can view the Iola-Argentine sequence and to permit picture taking of the excellent view of the Missouri River floodplain below.

28.0 0.4 Intersection of Kentucky Road and River Road.

Veer right on Kentucky Road.

28.7 0.7 Argentine limestone exposed on right.

29.1 0.4 Sugar Creek Refinery, American Oil Company Plant on the right.

The 450-acre Sugar Creek refinery processes crude oils from New Mexico, Oklahoma, Texas and Wyoming. It converts these crudes into gasoline and other petroleum products from liquefied petroleum gas to heavy asphalts. The plant employs nearly 600 persons.

Construction of the Sugar Creek refinery began early in 1904, and the

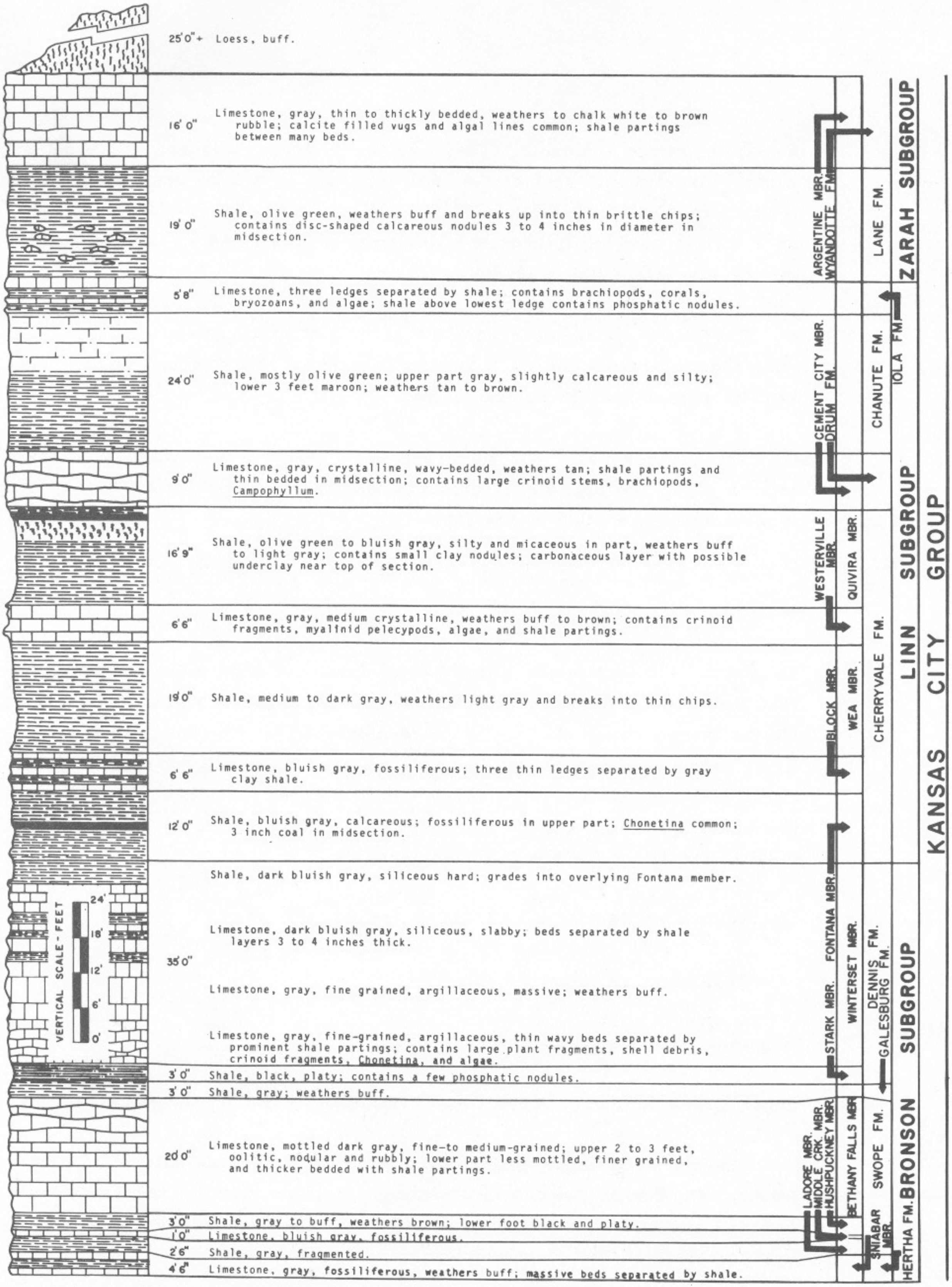


Fig. 8. STOP 2a: Sniabar-Argentine Section exposed in road cut along private road leading to Missouri Portland Cement Plant near Sugar Creek, SE¼ sec. 22, T. 50 N., R. 32 W., Jackson County, Missouri.

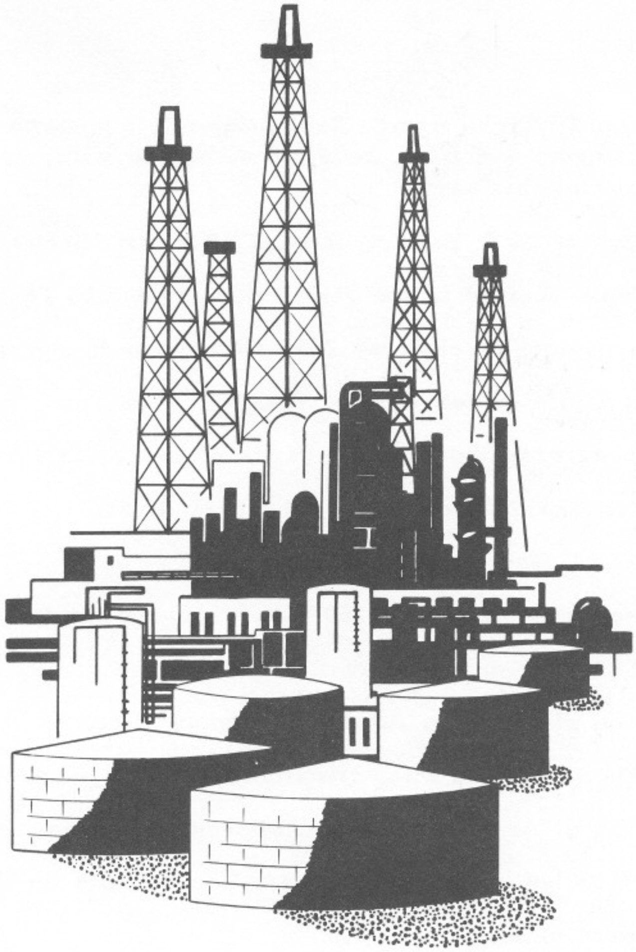


Fig. 9. The Sugar Creek Refinery of the American Oil Company converts crude oil into gasoline and other petroleum products.

Mileage		
Cum.	Diff.	
		first products were shipped from the plant by the end of that year. In the years that have followed, the refinery has undergone constant growth, innovation, and modernization and today is one of the most modern in the world. A battery of 60 Burton-Humphreys cracking stills are in operation. Average daily crude capacity is now 65,000 barrels (a petroleum barrel is 42 gallons) which makes Sugar Creek rank third among the 12 American oil refineries in the United States exceeded only by Whiting Indiana, and Texas City, Texas, in daily production.
		Automotive gasolines are the major products produced at the Sugar Creek refinery, but significant quantities of asphalts, heating oils, jet fuels, LP-gas, and petroleum coke are also produced. The products are shipped by pipeline, highway transport, and rail to serve 10 mid-western states.
30.0	0.9	Kentucky Road makes sharp turn to the left and becomes Sterling Avenue.
31.4	1.4	Intersection of Sterling Avenue and U. S. Highway 24 (Independence Avenue). Turn right.

Mileage Cum.	Diff.	
34.2	2.8	Sheffield Division, Armco Steel Corporation plant on both sides of the road. Steel, ingots and bars, rods, nuts, barbed wire, and field fence are manufactured at this plant.
35.5	1.3	Junction of U. S. Highway 24 and Missouri Highway 269.
		Bear sharply to the right on Highway 269 (Wilson Street).
36.3	0.8	Veer to right on Highway 269. (Chouteau Bridge Route).
36.7	0.4	Loess bluffs on left side of road.
37.0	0.3	Overpass crossing railroad yards of several major lines.
38.7	1.7	Chouteau Bridge across the Missouri River.
		Note loess bluffs in the distance.
39.4	0.7	Intersection of Highway 269 with Chouteau Road.
		Turn left on Chouteau Road.
39.7	0.3	Junction of Chouteau Road with Armour Road.
		Turn right and enter city limits of North Kansas City (population 5,600).
40.1	0.4	Junction of Armour Road and Missouri Highway 10.
		Bear left on Armour Road. Loess bluffs on the right.
41.1	1.0	Overpass of Interstate 35.
		Continue on Armour Road.
41.8	0.7	North Kansas City business district.
42.1	0.3	Junction of Armour Road and U. S. Highway 169 (Burlington Trafficway).
		Turn right.
42.7	0.6	Y - Junction of U. S. Highway 71 and U. S. Highway 169.
		Bear left on Highway 71.
44.3	1.6	Kansas City Concrete Company quarry and underground mine on the right.
		Operations are in the lower Kansas City Group.
44.5	0.2	Enter Riverside, Missouri (population, 1,315).
44.7	0.2	STOP 3: Section of Block limestone, below; Iola Formation above.
		The Block Member consists of several feet of interbedded thin limestone and shale. Brachiopods of the genera *Crurithyris*, *Chonetina* and *Kozlowskia* are very abundant.
		The two relatively thick limestone units that are well exposed in the quarry face are in ascending order the Westerville and the Cement City. These are separated by the Quivira Shale Member which contains a dark gray to black very persistent shale bed near the middle.

4' 0"	Limestone, light gray, finely crystalline. Archaeolithophyllum exposed on weathered surface as protruding thin wavy lines; large productids near top.	Raytown Mbr.	Iola Fm.
0' 2"	Shale, gray.	Muncie Creek Mbr.	Iola Fm.
0' 4"	Limestone, one bed, fenestellate bryozoans, small crinoid columnals.	Muncie Creek Mbr.	Iola Fm.
1' 0"	Shale, medium gray, Derbyia, chonetids.	Muncie Creek Mbr.	Iola Fm.
0' 4"	Shale, black, fissile, phosphatic concretions.	Muncie Creek Mbr.	Iola Fm.
1' 6"	Limestone, dark gray, finely crystalline, jointed, Osagia, Ottonosia, Archaeolithophyllum, pelecypods.	Paola Mbr.	Iola Fm.
1' 6"	Shale, dark gray, carbonized plant remains.		Chanute Fm.
4' 0"	Shale, dark gray; coalified remains of leaves, twigs, Calamites; abundant Myalina, Worthenia, Goniasma.		Chanute Fm.
5' 0"	Shale, light gray, silty.		Chanute Fm.
1' 0"	Limestone, composed predominately of algal debris (Corbin City? Mbr.).		Drum Fm.
0' 1"	Shale, gray.	Cement City Mbr.	Drum Fm.
8' 6"	Limestone, light gray; abundant shale lenses near middle; Composita, Kozlowskia.	Cement City Mbr.	Drum Fm.
2' 0"	Clay, greenish-gray.	Quivira Mbr.	Cherryvale Fm.
1' 0"	Shale, black, platy, small flattened phosphatic concretions.	Quivira Mbr.	Cherryvale Fm.
1' 0"	Clay, light gray.	Quivira Mbr.	Cherryvale Fm.
2' 0"	Limestone, light gray, finely crystalline.	Westerville Mbr.	Cherryvale Fm.
1' 4"	Limestone and shale interbedded.	Westerville Mbr.	Cherryvale Fm.
3' 0"	Limestone, light gray, cross-bedded; composed predominately of rounded fragments of foraminifera, echinoderms, algae and other fossil debris.	Westerville Mbr.	Cherryvale Fm.
2' 0"	Limestone, light gray; wavy bedding; algae.	Westerville Mbr.	Cherryvale Fm.
15' 0"	Shale, medium to dark gray.	Wea Mbr.	Cherryvale Fm.
0' 2"	Limestone, weathered brownish red; forms one-jointed bed; sideritic.	Block Mbr.	Cherryvale Fm.
2' 0"	Shale, dark gray, silty.	Block Mbr.	Cherryvale Fm.
0' 9"	Limestone, medium gray, weathered tan on exposed surface; thin-bedded; discontinuous; bioclastic.	Block Mbr.	Cherryvale Fm.
1' 4"	Shale, dark gray; abundant Kozlowskia, crinoidal debris.	Block Mbr.	Cherryvale Fm.
1' 3"	Limestone, medium gray, thin-bedded; forms a single ledge which is jointed into slabs; Crurithyris, Kozlowskia splendens, Archaeolithophyllum, ammovertellids, abundant small crinoid columnals.	Block Mbr.	Cherryvale Fm.
3' 4"	Shale, dark gray; top few inches a shaly limestone; very fossiliferous with Crurithyris, Chonetina, Kozlowskia, crinoidal debris.	Block Mbr.	Cherryvale Fm.
0' 6"	Limestone, medium gray, argillaceous.	Block Mbr.	Cherryvale Fm.

LINN SUBGROUP

KANSAS CITY GROUP

Fig. 10. STOP 3: Block-Iola Section exposed in abandoned quarry in bluff, north side of Highway 71 at Riverside; SW¼ SW¼ sec. 3, T. 50 N., R. 33 W., Platte County, Missouri.

Mileage	
Cum.	Diff.

Two contrasting lithologies comprise the Westerville Member in this area; a lower part which is composed predominately of cross-bedded bioclastic limestone and an upper part of finely crystalline, unfossiliferous limestone.

The Cement City Member is composed predominately of limestone with interbedded shale. A thin bed of algal limestone at the top occupies the same stratigraphic interval as the Corbin City Member in Kansas and may be the correlative of this unit.

The Chanute Formation includes in the upper part abundant plant remains and the gastropods Worthenia and Goniasma. These weather out and are abundant on the slopes.

The Iola Formation is exposed near the top of the quarry face and consists of two limestone beds and an intervening black, platy, shale bed a few inches thick. The upper limestone (Raytown) contains abundant algae Archaeolithophyllum. These protrude from the weathered surface as thin wavy structures.

45.3 0.6 Junction of Missouri 45 and U. S. Highway 71 (Business Route).

Veer right on Highway 71.

Fig. 11. STOP 3: Alternating sequence of limestone and shale beds constituting the stratigraphic interval from the Block Member to the Iola Formation exposed in quarry in bluff at Riverside; SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 3, T. 50 N., R. 33 W., Platte County, Missouri.

Mileage		
Cum.	Diff.	
45.7	0.4	Junction U. S. Highway 71 and U. S. Highway 169.
		Turn right on Highway 169.
47.5	1.8	Cloverleaf for junction of Interstate 29 and U. S. Highway 169.
		Continue beneath the overpass and turn right on access road leading to Interstate 29. Proceed on the right (north).
47.8	0.3	Y - Junction of Interstate 29 and U. S. Highway 169.
		Bear left on Interstate 29.
48.4	0.6	Thick and thin bedded Argentine limestone (Wyandotte Formation) exposed in vertical cuts on both sides of the highway.
48.7	0.3	STOP 4: Section of Lane shale, Frisbee limestone, Quindaro shale and Argentine limestone.

The olive-green Lane shale contains dark platy beds at road level which are not present in the Kansas City area south of the river. The thin Frisbee and

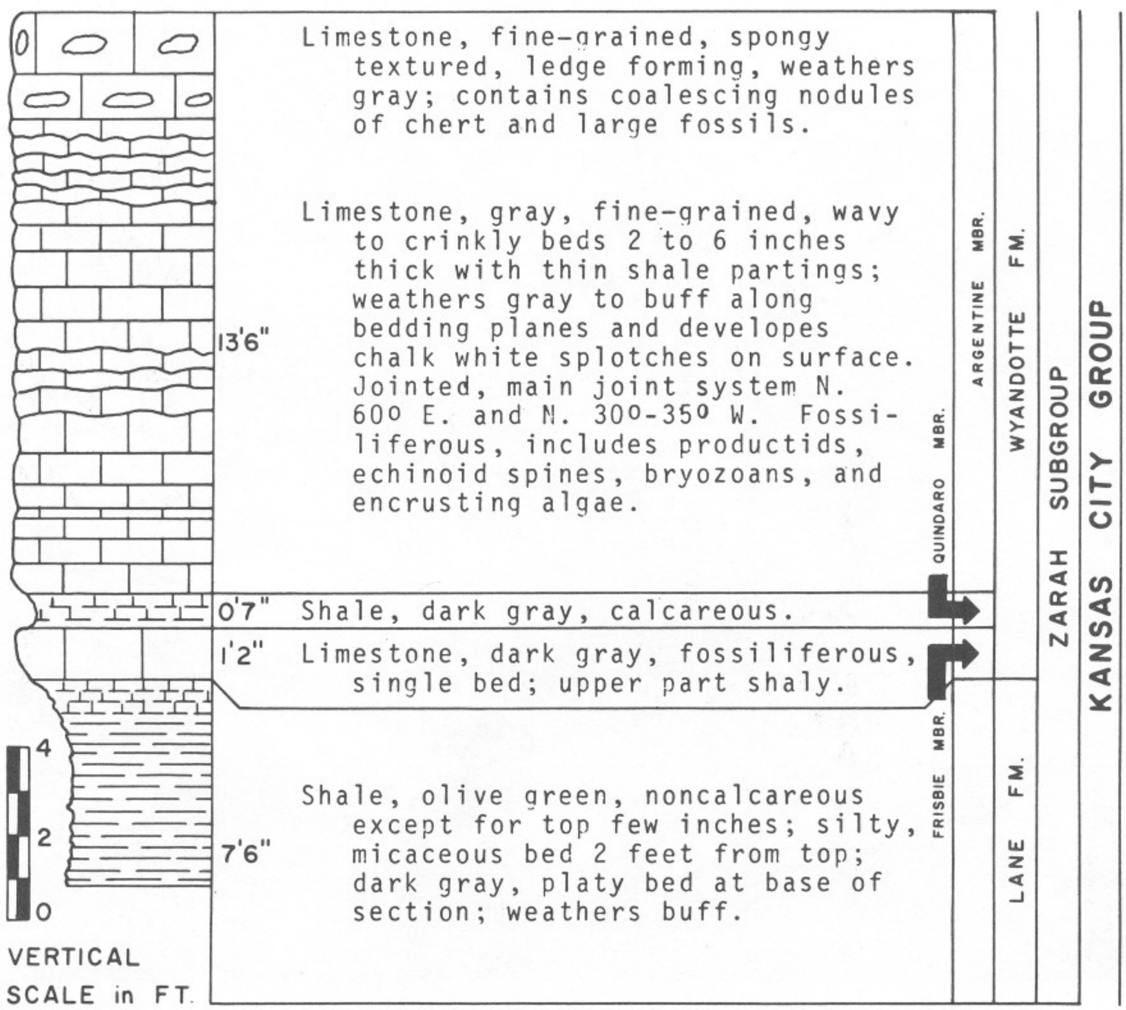


Fig. 12. STOP 4: Upper Lane-Argentine Section exposed along Interstate Highway 29, NW¼ SW¼ sec. 34, T. 51 N., R. 33 W., Platte County, Missouri.

Mileage	
Cum.	Diff.

Quindaro Members can be distinguished here, which usually is not the case for the lower Wyandotte at Kansas City. The Argentine limestone is somewhat thinner than in Kansas City south of the river. Crinkly to wavy bedding planes and shale partings characterize the Argentine in this region. The beds are siliceous near the top, and nodular chert is prominent in the ledge forming layers. Fractures cutting the limestones at this stop agree with the regional trends throughout the Kansas City area (N. 60° E. and No. 20° - 30° W.).

Fossils are often fragmented at this location, but large complete brachiopods, particularly productids, occur in the Argentine.

Cum.	Diff.	
49.4	0.7	Argentine limestone exposed on both sides of the highway beneath the overpass.
49.6	0.2	Decrease speed and cross over to the south bound lane of Interstate 29 (Business 71). Turn left to return to Interstate 29 Cloverleaf.
51.8	2.2	Interstate 29 Cloverleaf.

Turn right on Gladstone, Riverside exit.

Fig. 13. STOP 4: Typically bedded Argentine limestone exposed in road cuts along Interstate Highway 29; NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 34, T. 51 N., R. 33 W., Platte County, Missouri.

Mileage Cum.	Diff.	
51.9	0.1	Veer right on Gladstone exit to access road leading to Interstate 29.
52.1	0.2	Smithville turn-off to Interstate 29. Turn right and proceed north.
52.5	0.4	Y - Junction of Interstate 29 and U. S. Highway 169. Bear right on U. S. 169.
53.3	0.8	<u>STOP 5:</u> Section of Island Creek shale and Farley limestone.

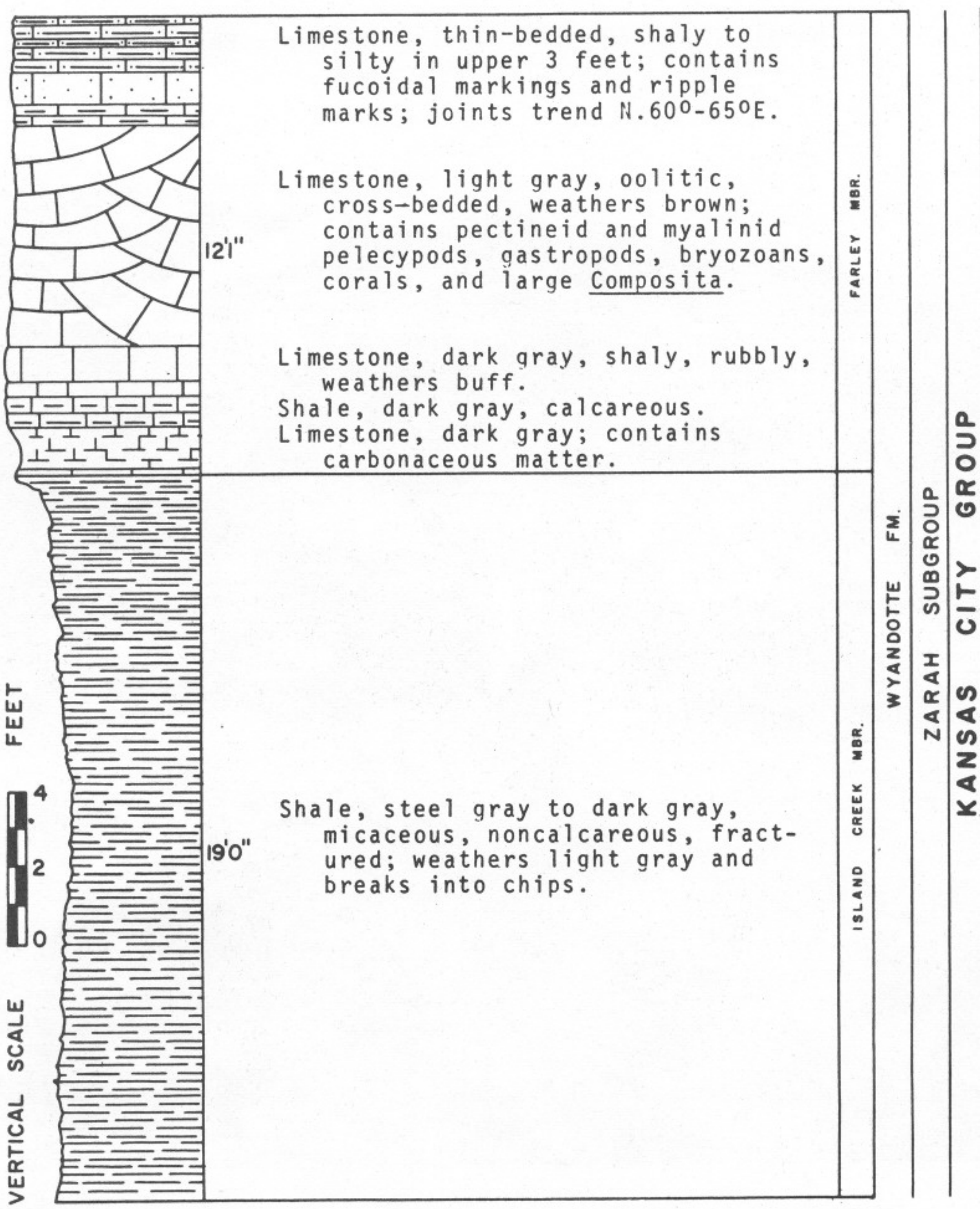


Fig. 14. STOP 5: Island Creek-Farley Section exposed in road cut along exit ramp, U. S. Highway 169 and Englewood Road, NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 34, T. 51 N., R. 33 W., Clay County, Missouri

Mileage

Cum. Diff.

The gray Island Creek shale below is noncalcareous and micaceous. It is sandy a short distance to the north. The Farley limestone is lithologically variable from the base upward in this area. The contact of the Farley and Island Creek is drawn at the base of a 5-inch bed of thin layered carbonaceous limestone overlain by shale. Cross bedded oolite forms the major portion of the middle Farley at this stop. Pectinoid and myalinid clams are common in the Farley here, although a number of other forms are present, for example, corals, brachiopods, bryozoans, and other molluscs.

Kansas (?) glacial drift overlies the upper Farley back from the face of the outcrop.

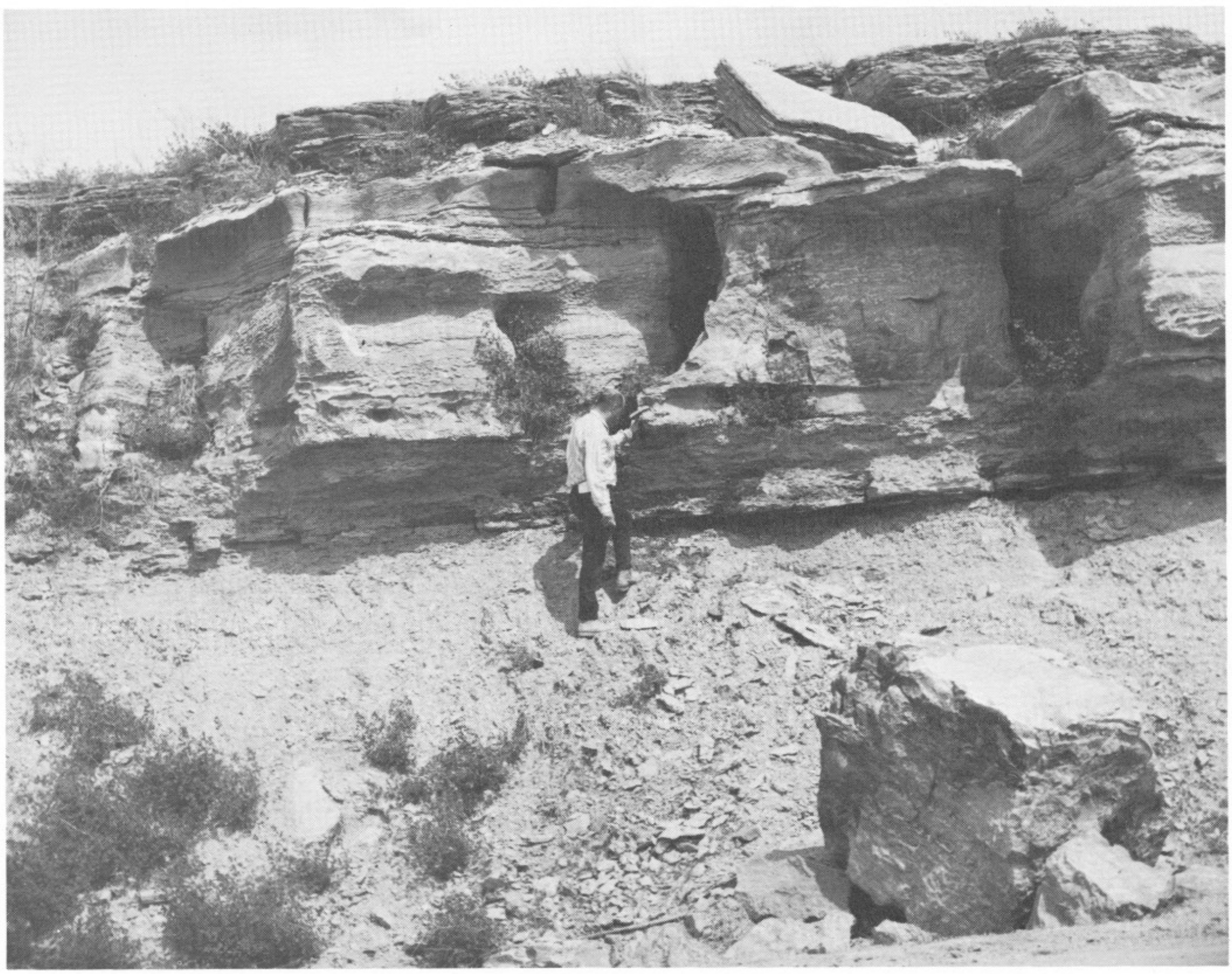


Fig. 15. STOP 5: Farley limestone and underlying Island Creek shale exposed in road cut along exit ramp, U. S. Highway 169 and Englewood Road; NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 34, T. 51 N., R. 33 W., Clay County, Missouri.

Mileage		
Cum.	Diff.	
		From STOP 5 continue on the Englewood exit road, cross the intersection and proceed north on the access road leading to the northbound lane of Highway 169.
54.6	1.3	STOP 6: Farley - Plattsburg (Lansing Group) section. (See Fig. 16, page 30).
		Shale is more conspicuous in the Farley here than at the previous stop. Twenty inches of calcareous shale separates lower oolite beds from non-oolitic layers above. The upper Farley is mainly shaly limestone capped by a ledge of Osagite (algal) limestone that has weathered reddish-brown. The oolite and upper algal ledge are rather fossiliferous; algae, clams, and bryozoans being most noticeable.
		The Bonner Springs shale becomes sandy near the middle of the exposure; the beds are calcareous and nodular near the top. The sandy fraction in the Bonner Springs is not as prominent at this stop as it is in many exposures immediately to the west of Kansas City. Massive sandstone several feet thick, which reaches 20 to 25 feet thick in some cases, is more often the rule.
		The 10 feet of strata above the Bonner Springs comprise the Merriam limestone (below) and the Hickory Creek and Spring Hill Members of the Plattsburg Formation (Lansing Group). The Merriam is a persistent algal limestone, ordinarily very fossiliferous. The thicker Spring Hill limestone carries much chert in Missouri and Kansas; it is layered and nodular here.
		The Plattsburg limestone is noticeably fossiliferous; algae, sponges, brachiopods, and clams being most common. Fusulinids, bryozoans, and shark teeth also occur in the Plattsburg at this stop. (See Fig. 17, page 31).
		To continue the route bear right on the 68th Street Gladstone exit preparatory to making a U-turn beneath the overpass. Take the access road leading to the southbound lane of U. S. Highway 169 and continue south, remaining on Interstate 29.
60.0	5.4	Junction of Interstate 29 and Interstate 35.
61.0	1.0	City limits of North Kansas City.
62.8	1.8	Paseo Toll Bridge.
		The new Paseo Bridge is the largest self-anchored suspension bridge in the world. '
63.7	0.9	In the distance on the left is Cliff Drive, a famous land mark overlooking the Missouri River. It is now a park area but was a favored site in the late 19th and early 20th centuries for the location of stately mansions of wealthier Kansas Citians. The Kansas City Museum now occupies one of these structures. The Argentine limestone underlies Cliff Drive and is continuously exposed along the southwest valley wall of the Missouri River. It is about 30 feet thick in this area.

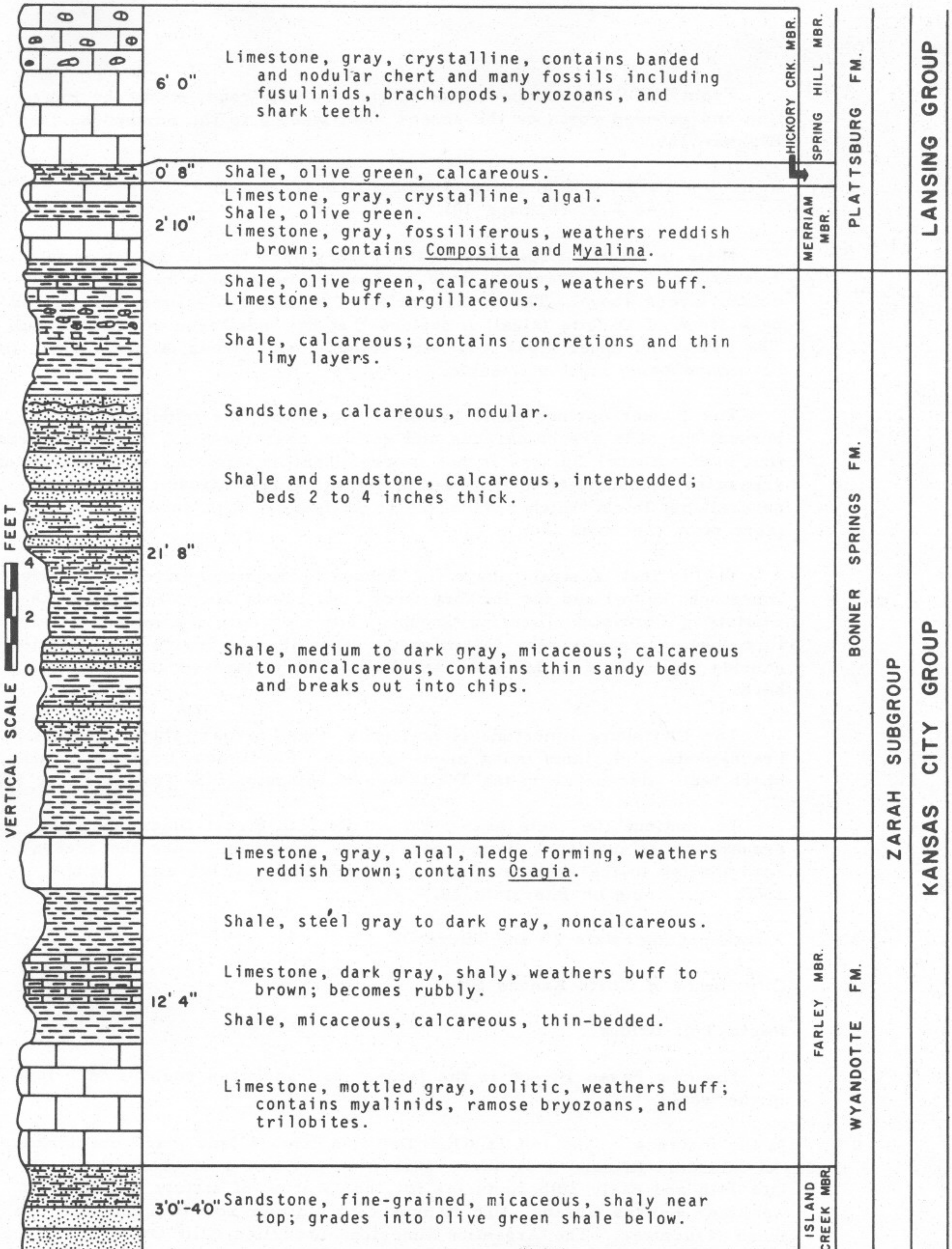


Fig. 16. STOP 6: Farley-Plattsburg (Lansing Group) Section exposed in road cut along northbound lane of U. S. Highway 169; SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 22, T. 51 N., R. 33 W., Clay County, Missouri.

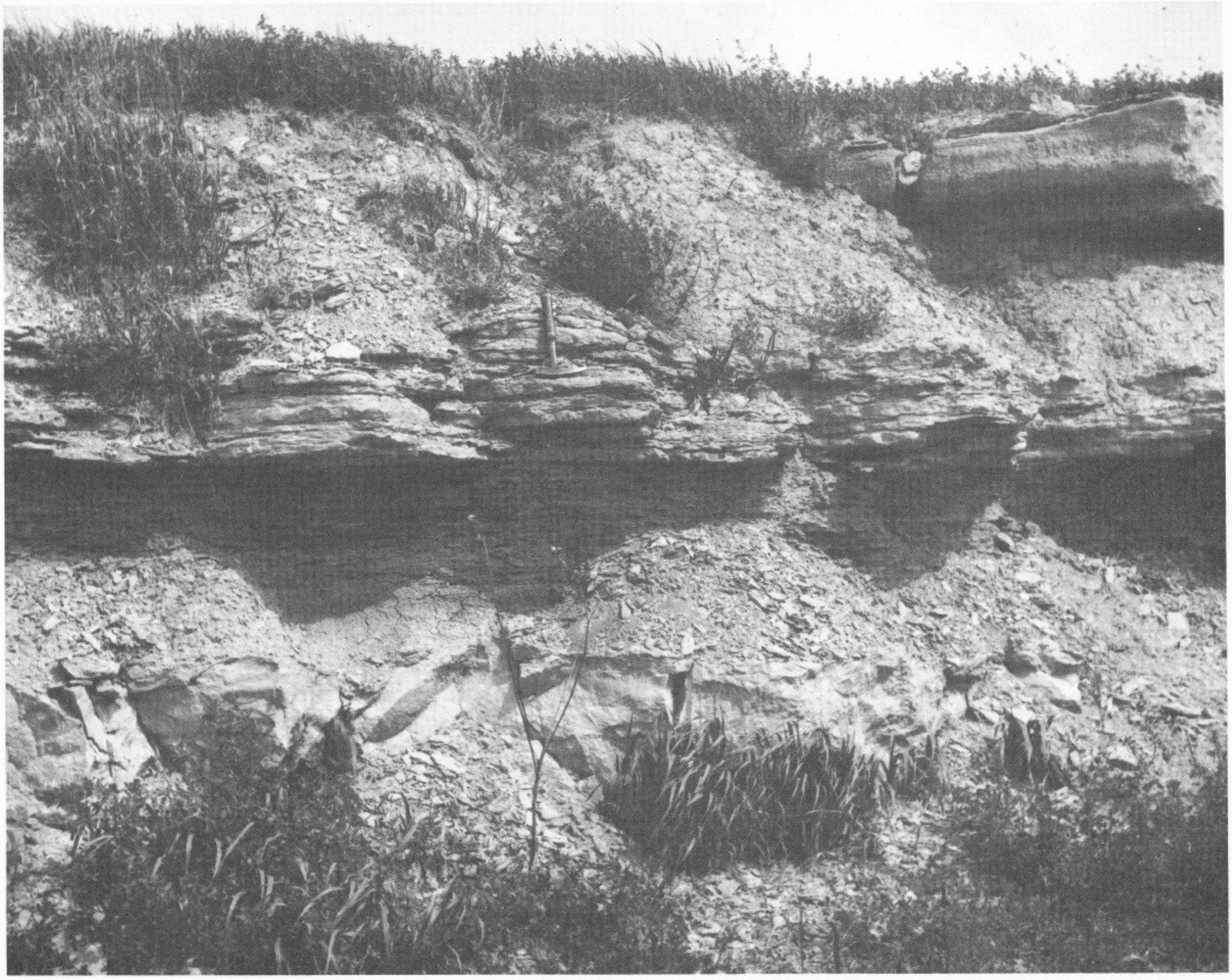


Fig. 17. STOP 6: Shaly facies of the Farley Member exposed in road cut along U. S. Highway 169; SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 22, T. 51 N., R. 33 W., Clay County, Missouri.

Mileage		
Cum.	Diff.	
63.9	0.2	Bear right on Interstate 35 - 70.
		The Cement City limestone, Chanute shale, and Iola limestone are exposed along the hill on the left just above the retaining wall.
64.5	0.6	Keep to the right on Interstate 35.
65.1	0.6	Delaware - Wyandotte exit road from Interstate 35 on the right.
		Leave the exit road and turn left on Delaware Street. Continue to 12th Street. Turn right to the Muehlebach Hotel. (66.0 miles)

END OF TRIP

STRATIGRAPHY OF THE KANSAS CITY GROUP

by

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INTRODUCTION

Rocks of the Kansas City Group are divided into three subgroups of unequal thickness that are named in ascending order the Bronson, Linn, and Zarah Subgroups. The cumulative lithology and the presence of good marker beds are the principal bases for subdivision. The Kansas City area is the type region for the group.

The Bronson Subgroup includes five formations which are in ascending order, the Hertha, Ladore, Swope, Galesburg, and Dennis Formations. The Hertha, Swope, and Dennis Formations consist predominantly of limestone, while the Ladore and Galesburg consist mostly of shale and clay. The aggregate thickness of the Bronson Subgroup is 65 to 85 feet at Kansas City. The Linn Subgroup, which is composed of the Cherryvale (oldest), Drum, Chanute, and Iola (youngest) Formations, consists largely of prominent shaly units that alternate with thinner but persistent limestones. Several lithologic units in the Linn Subgroup change thickness is short distances in and near Kansas City so that the total thickness of the subgroup varies between 65 and 100 feet. The Zarah Subgroup, composed in upward order of the Lane, Wyandotte, and Bonner Springs Formations, contains considerably more shale than limestone as only the Wyandotte includes important limestone beds. The limestones of the Wyandotte are comparatively thick at Kansas City but thin away from the city and disappear completely in northern Missouri and southeastern Kansas. In addition, sandstone is locally important in the uppermost Zarah at Kansas City. A generalized composite section is shown in Fig. 18.

BRONSON SUBGROUP

Beds of the Bronson Subgroup are dominated by three limestones which were originally named the "triple limestone" by Haworth (1895, p. 458). The name Bronson was given to this assemblage by Adams in 1904. The aggregate thickness of the beds varies between 65 to 100 feet, with approximately three-fourths of the layers being limestone. The limestones form a prominent northeast-southwest escarpment above the shale and sandstone of the Pleasanton Group in the vicinity of Kansas City.

Hertha Formation

The Hertha Formation is the basal unit of the Bronson Subgroup and is named from beds forming a minor escarpment near Hertha, Neosho County, Kansas, (Adams, 1903, p. 35). Two limestones separated by shale comprise the formation. The units are from oldest to youngest: The Critzer Limestone Member, Mound City Shale Member, and Sniabar Limestone Member.

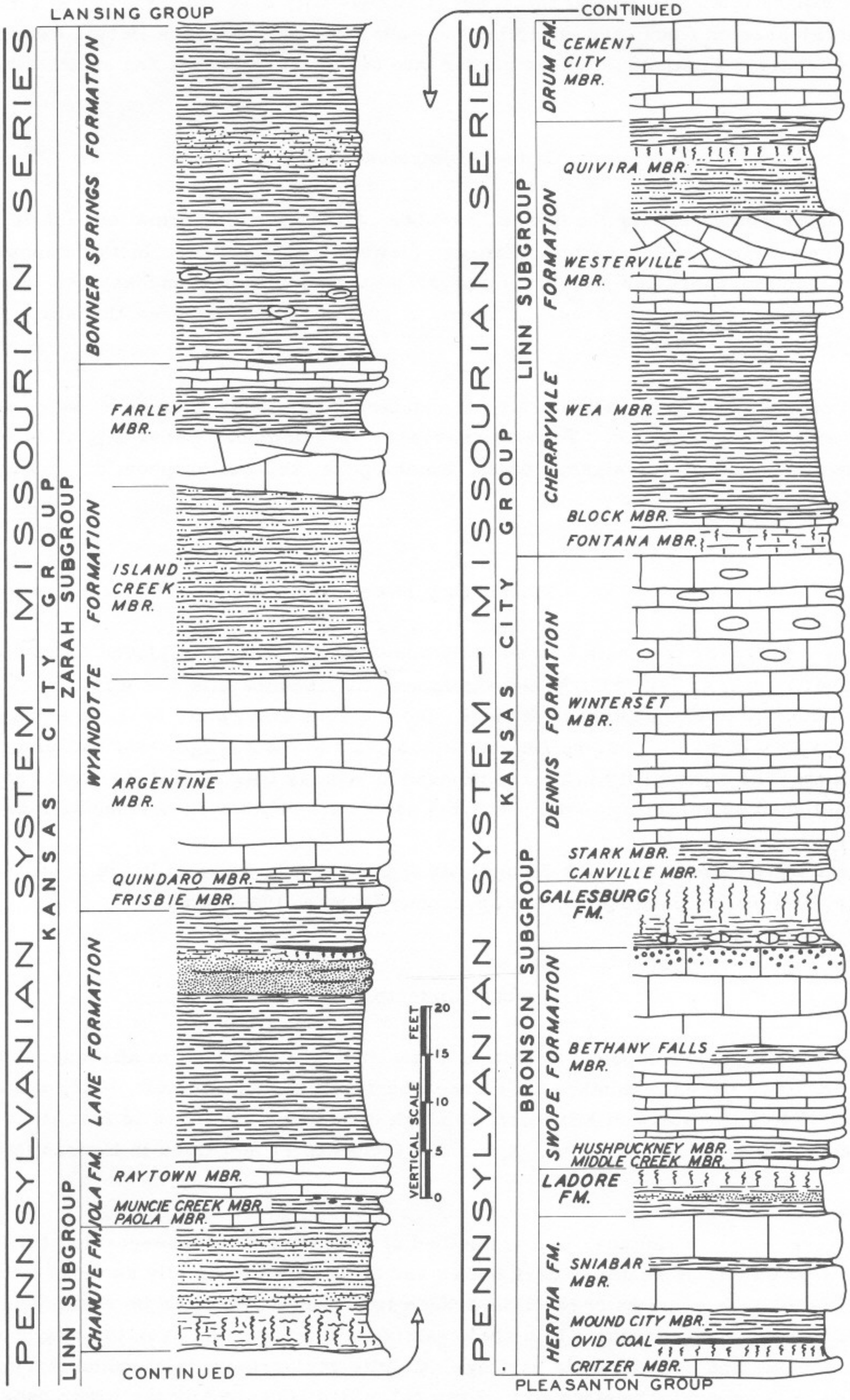

Fig. 18. Composite columnar section of the Kansas City Group (after Howe, 1961, p. 101).

The Hertha ranges from 1 to 30 feet thick, but at Kansas City it is usually 10 to 15 feet thick. It overlies the Pleasanton Group and underlies the Ladore Formation. The Hertha extends with little interruption from the Oklahoma-Kansas border into southeast Nebraska and southwest Iowa.

Critzer Limestone Member

The Critzer Limestone is the lowest member of the Hertha Formation. It is named for exposures near Critzer, Linn County, Kansas, (Jewett, 1932, p. 99). In the Kansas City area, the Critzer is often concealed or absent and at best is only a few inches to 2 or 3 feet thick. In parts of eastern Kansas, however, it forms a 10-foot rimrock above the shaly Pleasanton Group (Moore, 1949, p. 85).

The Critzer in Missouri is generally a nodular, ferruginous limestone which weathers into a lumpy, nondescript, tan rock. Travertine veneer is common. Generally, it is nonfossiliferous in Missouri but contains algae, corals, brachiopods, and bellerophontids in Kansas (Moore, 1949, p. 85).

Mound City Shale Member

The type locality for the shale immediately above the Critzer is at Mound City, Linn County, Kansas, (Jewett, 1932, p. 99). This shale, the Mound City Member, is 3 to 4 feet thick in Missouri and is 8 feet thick in eastern Kansas. It varies from a dark gray, platy shale to a gray or brown, calcareous clay shale which contains limestone nodules and plant fragments. A thin coal, the Ovid, is also present. The Mound City is poorly exposed at Kansas City so that its stratigraphic position is often established by referring to the overlying persistent Sniabar Limestone Member.

Fossils are best known from the Mound City in Kansas. Included in it are small horn corals, crinoid debris, chonetid brachiopods, and bryozoans (Moore, 1949, p. 80).

Sniabar Limestone Member

Usually the oldest well exposed limestone in the Bronson Subgroup in Missouri is the Sniabar, named from Sniabar Creek in southeast Jackson County, Missouri, (Newell, 1935, p. 25). Normally, the Sniabar is 3 to 6 feet thick in Missouri, although it thickens locally to 12 feet along the Big Blue River in the south part of Kansas City. It is a few inches to 11 feet thick in Kansas (Moore, 1949, p. 86).

In some exposures the Sniabar is a single bed of gray, fine to coarse-grained limestone that is spotted with iron oxide. It weathers dark brown and is referred to locally as "chocolate rock". Elsewhere, the Sniabar consists of two thin-bedded limestones separated by shale; a lower dense, fine-grained sequence with frequent thin shale partings, and an upper, even to wavy bedded limestone that may be nodular and contain shale partings. Calcite replacement is common throughout the Sniabar. The beds generally weather to a brown color, but occasionally the lower beds remain dark gray while the upper become reddish-brown. The Sniabar is dolomitic in some exposures.

Although the entire Sniabar is fossiliferous, fragmented to complete fossils largely comprise some layers 1 to 3 inches thick. Weathering accentuates the fossil content in such beds.

Table 1

Fossils Collected From the Sniabar Member at Kansas City

Coelenterata
- *Lophophyllum* sp.

Brachiopoda
- *Composita subtilita*
- *Chonetes granulifer*
- *Derbyia* sp.
- *Kozlowskia splendens*
- *Chonetina flemingi*
- *Hustedia mormoni*
- *Punctospirifer kentuckiensis*
- *Neospirifer latus*
- *Antiquatonia portlockiana*

Bryozoa
- *Fenestella* sp.
- *Fistulipora* sp.
- *Rhombopora* sp.

Echinodermata
- Echinoid spines and plates
- Crinoid ossicles

Arthropoda
- *Phillipsia* sp.

Protozoa
- Fusulinids

Plants
- Unidentified algae

Ladore Formation

Beds above the Sniabar and below the Swope Formation constitute the Ladore Formation, named from Ladore, Neosho County, Kansas, (Adams, 1904, p. 18). The beds of the Ladore vary considerably in lithology and thickness.

At Kansas City the Ladore comprises 1 to 5 feet of dark gray, fissile or crumbly shale that weathers gray to brown, or a similar thickness of steel gray clay shale which is usually obscured by wash from above. The basal Ladore often grades downward into algal limestone indistinguishable from the underlying Sniabar. The Ladore thickens to the east and north of Kansas City, containing 15 to 30 feet of medium-grained subangular sandstone and thin, nodular limestone. Sandstone is also an important component of the Ladore in Kansas where sections up to 70 feet thick occur in Neosho County (Moore, 1949, p. 87).

Fossils are scarce in the Ladore.

Swope Formation

The Swope Formation is named from Swope Park, Kansas City, Missouri, (Moore, 1932, p. 90), and is comprised, in ascending order, of the Middle Creek Limestone, Hushpuckney Shale, and Bethany Falls Limestone Members. The Swope crops out across northwestern Missouri and forms a prominent eastward-facing escarpment. It averages 25 to 30 feet in thickness at Kansas City.

Middle Creek Limestone Member

The lowest member of the Swope Formation is named the Middle Creek from exposures along Middle Creek, Linn County, Kansas, (Newell, 1935, pp. 26-27). It is a bluish gray, hard, fine-grained fossiliferous limestone which is broken into rectangular blocks by vertical joints. The beds weather to a buff color. The Middle Creek occurs as a single limestone bed 8 to 12 inches thick or as two beds separated by shale that total about 30 inches thick. The Middle Creek extends from southwestern Iowa to southeastern Kansas.

Table 2

Middle Creek Fauna at Kansas City

Brachiopoda	Bryozoa
Chonetes sp.	*Fistulipora* sp.
Composita subtilita	*Rhombopora* sp.
Meekella striatocostata	*Septopora* (?) sp.
Juresania nebrascensis	
Derbyia crassa	Echinodermata
Productid spines	Crinoid ossicles

Hushpuckney Shale Member

The Hushpuckney Shale Member is named for beds along Hushpuckney Creek in Miami County, Kansas, (Newell, 1935, pp. 26-27). Two dissimilar shales make up the complete Hushpuckney; dark fissile shale below and gray or buff, thin-bedded calcareous shale above. Gray phosphatic nodules may be present between the laminae in the dark fissile shale. The upper calcareous phase is micaceous and it weathers into small chips. The Hushpuckney is 4 to 5.5 feet thick at Kansas City but ranges from 2.5 to 6 feet in thickness.

Although fossils are uncommon in the Hushpuckney at most exposures, the brachiopods, *Composita*, *Crurithyris*, *Orbiculoidea*, and *Derbyia* do occur. Microfossils, primarily conodonts, are also present in the Hushpuckney.

Bethany Falls Limestone Member

Outcrops at the falls of Big Creek in Bethany, Harrison County, Missouri, were used by Broadhead (1866, p. 320) as the type beds for deposits now referred to as the Bethany Falls Limestone Member. The Bethany Falls, is one of several east-facing Pennsylvanian limestone escarpments in Missouri and Kansas, and also forms the cap rock of many topographic features in Jackson County, Missouri. The Bethany Falls extends from southwestern Iowa to the Kansas-Oklahoma borders, cropping out extensively at Kansas City where its thickness is 15 to 25 feet. Over its outcrop area, the Bethany Falls ranges from 12 to 30 feet thick. The Bethany Falls is the most extensively quarried Pennsylvanian limestone in western Missouri (Howe, 1961, p. 100).

Two distinct limestones characterize the Bethany Falls. A lower phase, usually 8 to 10 feet thick, is composed of fine- to coarse-grained gray to chalk-white limestone which weathers gray or tan. Stylolites and dendrites are often present, and shale partings separate many layers. Fossils are generally more common in the lower Bethany Falls. A thin calcareous shale separates the two phases of the Bethany Falls. The upper phase, averaging 10 to 12 feet thick, is formed of massive to thick-bedded limestone which is mottled or chalk-white and weathers gray to black. The mottled appearance of the upper Bethany Falls results from dark gray splotches on a lighter background. It is believed by some persons to indicate a development in association with algae. Oolites often occur in the upper Bethany Falls together with calcite veinlets, vugs, and dendrites. Usually the top 2 to 3 feet is nodular and lensing. Deep weathering of this portion develops a Bethany Falls residuum that superficially resembled unworked concrete. Large rectangular blocks of the upper Bethany Falls commonly are observed to have become separated from the main ledge in outcrops. Many are 8 to 10 feet thick and 10 to 20 feet in the other two dimensions. Initial separation occurs along prominent joints that have been enlarged by solution work of surface runoff and ground water. Actual separation is dependent to a large degree upon disintegration and decomposition of the lowermost portion of the upper Bethany Falls by water that moves along the shale parting. A shift in the center of gravity occurs in the beds above the shale parting as materials are removed unevenly at the base of the upper phase. Thus, the large rectangular blocks shift. Those moving away from the outcrop face begin a very slow gravitational downslope movement, which is interrupted by prolonged stable periods. Blocks that tilt inward have remained stationary along the step slopes, but continue to weather comparatively fast as surface runoff is concentrated along the depression at the inner edge of the blocks and the outcrop face.

Prickly pear cactus has an affinity for the Bethany Falls, apparently because the upper jointed phase quickly collects surface runoff and keeps the outcrops dry.

Fossils are common in most outcrops of the Bethany Falls, in fact, some of the beds can often be described as richly fossiliferous.

Table 3

Bethany Falls Fossils at Kansas City

Brachiopoda
- Juresania sp.
- Antiquatonia portlockiana
- Kozlowskia splendens
- Neospirifer kansasensis
- Neospirifer dunbari
- Punctospirifer kentuckiensis
- Derbyia crassa
- Composita subtilita
- Hustedia mormoni
- Chonetes sp.
- Chonetina flemingi

Bryozoa
- Polypora sp.
- Fenestella sp.
- Rhombopora sp.
- Fistulipora (?) sp.

Echinodermata
- Crinoid ossicles

Protozoa
- Fusulinids

Plants
- Algal varieties

Galesburg Formation

Shale beds immediately above the Swope Formation are designated the Galesburg Formation. The name originates from southern Neosho County, Kansas, (Adams, 1903, p. 36). The Galesburg is overlain by the Canville Limestone Member of the Dennis Formation in east-central Kansas and in Bates County, Missouri, however, in most other Missouri Counties the Canville is sparsely developed and the Galesburg is most often subjacent to the Stark Shale Member of the Dennis Formation. About 70 feet of nonfossiliferous grayish-brown clay and sandy shale form the Galesburg in eastern Kansas (Moore, 1949, p. 89). The beds thin extensively away from this area and at Kansas City are only 3 to 4 feet thick. The Galesburg is often partially concealed by vegetation and slope wash.

In the Kansas City area, the Galesburg is gray or dark gray, blocky shale with poorly defined bedding. The beds weather tan or buff. Upper layers are slightly carbonaceous and possess a few plant fragments. Mica, iron oxide stains, and pellet size nodules occur along some bedding planes.

At best, the Galesburg is only sparingly fossiliferous. A few small brachiopods are present in the top 2 inches in a few localities.

Dennis Formation

The name "Dennis limestone" was originally given to beds overlying the Galesburg Shale and underlying the Cherryvale shale (Adams, 1903, p. 36). It was withdrawn in favor of the name "Winterset" limestone in 1912, but reintroduced as a formation name in 1932 to include the following members: Canville Limestone (oldest), Stark Shale, and Winterset Limestone (youngest). The type locality is at Dennis, Labette County, Kansas, (Jewett, 1932, p. 102).

Although Canville limestone crops out widely in eastern Kansas, it occurs sparingly at Kansas City and most other parts of Missouri. Two inches of dark blue, fossiliferous Canville limestone occurs near Pleasant Hill (Lohrengel, 1964, p. 53), and a few thin, hard, coarse-grained, fossiliferous Canville beds are present near Tarsney in eastern Jackson County (Kinerney, 1961, p. 58).

Stark Shale Member

The Stark Shale Member includes beds overlying the Canville and underlying the Winterset Limestone Members. In Missouri the Canville is seldom present and the Stark rests directly on the Galesburg Formation. The type area is near Stark, Neosho County, Kansas, (Jewett, 1932, p. 102). The Galesburg -- Stark contact is ordinarily established at the initial appearance of black fissile shale in the Stark. Because outcrops are usually poor and partially concealed, this can not always be done. The Stark is 2 to 4 feet thick at Kansas City and elsewhere in Missouri but may be thicker in parts of Kansas.

The Stark is composed of two phases, a lower, dark, platy shale with sporadic phosphatic nodules along the bedding and an upper, black, brown, or gray clay shale that weathers into flat chips. Fossils are scarce, but a few megafossils have been reported from the Stark (Moore, 1949, p. 91).

Winterset Limestone Member

The Winterset Limestone, is named from exposures of alternating limestones, shales and sandstones near Winterset, Madison County, Iowa, (Tilton and Bain, 1897, pp. 517-519). It is widely exposed in and near Kansas City and extends southwesward into Neosho County, Kansas. The Winterset is 20 to 35 feet thick at Kansas City and nearly 50 feet thick in eastern Jackson County. It is one of the thickest Pennsylvanian limestones in Missouri. A comparable development occurs in eastern Kansas.

Lithology, texture, and bedding vary in the Winterset. The beds range from a few inches to several feet thick. The rock is gray to bluish-gray, frequently oolitic near the top, and possesses algal veins and vugs lined with calcite. White or blue nodular and banded chert, mostly concentrated in the upper half is diagnostic of the Winterset. The associated limestone layers are generally hard, dark blue, and siliceous. Winterset soils contain much chert float. Shale is also important in the Winterset. In some cases, thin shale partings separate individual beds, and in places the middle Winterset contains shale beds up to 2 feet thick.

Fossils occur throughout the Winterset. Brachiopods and bryozoans are the most conspicuous. Plant remains are also locally prominent in the shale beds.

Table 4

Winterset Fossils in the Greater Kansas City Area

Brachiopoda
- Composita subtilita
- Derbyia crassa
- Dictyoclostus americanus
- Hustedia mormoni
- Echinochoncus semipunctatus
- Juresania nebrascensis
- Linoproductus missouriensis
- Neospirifer latus
- Neospirifer dunbari
- Kozlowskia splendens
- Chonetes sp.
- Crurithyris sp.

Echinodermata
- Crinoid ossicles

Protozoa
- Fusulinids, including
  - Triticites sp.

Bryozoa
- Fenestella sp.
- Rhombopora sp.

Coelenterata
- Lophophyllum sp.

Mollusca
- Myalina sp.
- Aviculopinna sp.

Arthropoda
- Ameura major
- Phillipsia sp.

Plants
- Leaves, Calamites

LINN SUBGROUP

Formations of the middle Kansas City Group comprise the Linn Subgroup; established at the Lawrence Conference in 1947. Shale dominates this subgroup which is named from Linn County, Kansas, (Moore, 1948). Several persistent limestones and lesser amounts of sandstone are also included. Formations making up the Linn Subgroup are, from oldest to youngest; the Cherryvale, Drum, Chanute, and Iola. The thickness of the Linn Subgroup at Kansas City ranges from 65 to 110 feet because of considerable variation in certain units.

Cherryvale Formation

At the type area of the Cherryvale Formation in Montgomery County, Kansas, (Newell, 1935, p. 34) the beds are blue-gray clays and silty shales. Northward the shale is partially replaced by two persistent limestones, the Block Limestone Member and Westerville Limestone Member. The Cherryvale averages 60 feet thick in Kansas. It is 45 to 50 feet thick in the Kansas City area (Greene and Howe, 1952, pp. 14-15) but locally increases to an aggregate thickness of 80 feet. The increased thickness is largely contained in two members, the Block and Westerville. The Cherryvale Formation is composed of the Fontana Shale (oldest), Block Limestone, Wea Shale, Westerville Limestone, and Quivira Shale (youngest) Members.

Fontana Shale Member

Shales superjacent to the Dennis Formation constitute the Fontana Shale Member which was named from beds near Fontana, Miami County, Kansas, (Newell, 1935, p. 19). The beds extend northward into southwestern Iowa. The Fontana is 2 to 5 feet thick in the vicinity of

Kansas City, but increases to 10 to 15 feet thick in northern Missouri and to 25 feet thick in Linn County, Kansas, (Moore, 1949, p. 94).

The beds are clayey to silty, grayish-green, micaceous shales which contain calcareous nodules and are ferruginous or calcareous near the base. A thin coal seam occurs in the middle Fontana in the Kansas City area.

The Fontana regularly contains the small brachiopod, *Chonetina flemingi*, near the top. Ohterwise, the beds are sparsely fossiliferous at Kansas City.

Block Limestone Member

The Block Limestone Member overlies the Fontana Shale and is a hard, bluish-gray, fine-grained limestone that is named from a small settlement in Miami County, Kansas, (Newell, 1935, p. 35). The member extends from Linn County, Kansas, into southeastern Iowa. Although 3 to 8 feet thick in Kansas, the Block is generally thinner at Kansas City where 1 to 2 feet is the common thickness. However, at Longview Farm and Lees Summit, several miles southeast of Kansas City, the Block consists of alternating limestones and shales with a total thickness of 15 feet.

The Block is richly fossiliferous, particularly in the areas where the unit is thick.

Table 5

Fossils Collected From the Block Limestone at Kansas City

Brachiopoda
- *Composita* subtilita
- *Chonetes*
- *Crurithyris* sp.
- *Derbyia crassa*
- *Kozlowskia splendens*
- *Neospirifer dunbari*

Coelenterata
- *Lophophyllum* sp.

Echinodermata
- Crinoid ossicles

Protozoa
- Fusulinids

Bryozoa
- *Fistulipora* sp.
- *Polypora* sp.
- *Fenestella* sp.

Mollusca
- *Astarte*
- *Pharkidonotus*

Plants
- *Calamites*

Wea Shale Member

Beds along Wea Creek, Miami County, Kansas, constitute the type section of the Wea Shale Member that overlies the Block Limestone (Newell, 1935, p. 38). The Wea is between 10 to 40 feet thick near Kansas City. Normally the beds are partly calcareous, green or gray shales that weather lighter in color. Ferruginous claystone nodules occur in many localities and are useful in identifying isolated exposures. The Wea weathers into thin chips that veneer the shaly slopes. It is nonfossiliferous.

Westerville Limestone Member

The Westerville Limestone Member is persistent from Kansas City northward into Iowa and is named from exposures near Westerville, Decatur County, Iowa (Bain, 1898, pp. 276-277). The member thins and disappears south of Kansas City, and although it is present in some parts of eastern Kansas it disappears south of Miami County, Kansas.

The Westerville consists of two dissimilar, wavy-bedded limestone beds which are separated by calcareous shale. The upper limestone is absent in many localities. The lower Westerville, usually 3 to 4 feet thick, is a dense, texturally variable, gray limestone which is frequently siliceous near the top. It is known locally as the "Bull ledge."

The upper Westerville is a gray oolitic commonly cross bedded, limestone known as the "Kansas City oolite." It has been quarried for building stone at Kansas City. The upper Westerville is unusually thick and fossiliferous near Raytown, southeast of Kansas City. There the member is over 20 feet thick, largely because of the thick oolitic upper beds. The oolite thins north of Kansas City and is often absent.

The Westerville is moderately to richly fossiliferous. The lower beds contain large productids, crinoid debris, and bryozoans. The upper Westerville includes algal varieties, brachipods, ostracods, fenestellid bryozoans, pelecypods, and large nautiloid cephalopods.

Table 6

Westerville Fauna at Kansas City

Brachiopoda
- Composita subtilita
- Dictyoclostus americanus
- Neospirifer dunbari
- Echinoconchus sp.
- Punctospirifer kentuckiensis
- Juresania sp.
- Hustedia mormoni
- Derbyia crassa
- Linoproductus sp.
- Productid spines

Coelenterata
- Lophophyllidium sp.

Echinodermata
- Crinoid ossicles

Arthropoda
- Ameura major

Protozoa
- Fusulinids

Bryozoa
- Fenestella sp.
- Fistulipora sp.
- Polypora sp.
- Polypora elliptica

Mollusca
- Myalina sp.
- Pecten sp.
- Lepetopsis parrishi
- Trepospira discoidalis
- Titanoceras ponderosum
- Endolobus forbesianus
- Mooreoceras normale
- Domatoceras lasallense

Arthropoda
- Ostracoda

Quivira Shale Member

The youngest member of the Cherryvale Formation is the Quivira Shale, named from Quivira Lake, near Holliday, Johnson County, Kansas, (Newell, 1935, p. 43). It ranges from 1 to 15 feet thick in Missouri, although at most places in Kansas City it is 7 to 10 feet thick.

Usually the beds are gray or olive green, calcareous shale. In some areas, however, the beds are dark and platy. Dark clay nodules are locally common. Several inches of dark carbonaceous shale occur midway in many Quivira sections, underlain by 1 to 3 feet of possible underclay.

At best the Quivira is sparsely fossiliferous. The inarticulate brachiopods, Orbiculoidea and Lingula, are reported from some Quivira outcrops (Moore, 1949, p. 96).

Drum Formation

Two thin limestones exposed along Drum Creek, Montgomery County, Kansas, make up the type section of the Drum Formation (Adams, 1903, p. 37). They overlie the Cherryvale Shale and are named the Cement City Member (Dewey of Kansas) and the Corbin City Member. The latter (upper) member is thin or missing at Kansas City. Thin shale separates the two limestones. The Drum Formation extends from Oklahoma to southwestern Iowa.

The beds are fine grained, crystalline, wavy-bedded limestone with crinoid debris and other fossil matter. Some exposures are partially oolitic. The thickness of the Drum averages 5 feet in Kansas and 6 to 10 feet in Missouri.

Cement City Limestone Member

The Cement City Limestone Member is the only member of the Drum Formation that is well developed near Kansas City. It is named from a small community in eastern Jackson County, Missouri, (Hinds and Greene, 1915, p. 7).

The Cement City is 3 to 12 feet thick in Missouri, although it is regularly 6 to 8 feet thick at Kansas City. The layers are composed of gray, crystalline limestone. The Cement City weathers to a buff color and develops prominent wavy beds. A zone of Campophyllum torquium occurs regularly near the top. It is useful in correlation. In addition, the Cement City limestone at Kansas City contains a variety of small brachiopods -- Composita, being conspicuous -- lacy and branching bryozoans, large crinoid stems, and numerous spines and plates.

Chanute Formation

Shale and sandstone next above the Cement City form the Chanute Formation. The name comes from beds near Chanute, Neosho County, Kansas, (Haworth and Kirk, 1894, p. 109). The Chanute ranges from 10 to 100 feet thick in Kansas. At Kansas City the beds are 15 to 35 feet thick, although the average is 20 to 25 feet.

The Chanute is a variable sequence of clay or sandy shale, siltstone, sandstone, and coal. The beds are generally gray or bluish-gray when fresh and weather to a light gray or brown. Several feet of maroon shale and warty lime nodules occur in the lower Chanute at Kansas City. The Thayer coal occurs in southeastern Kansas where it is 2.5 feet thick in some places (Schoewe, 1944, p. 97). A thin Chanute coal also occurs in northern Missouri but does not occur at Kansas City. A disconformity is present below the Chanute in southeastern Kansas, the basal beds being in juxtaposition with the Dennis in some road cuts (Moore, 1949, p. 100).

Sandstone forms an appreciable part of the Chanute Formation in Missouri and particularly in Kansas. The Chanute is divided into two members in southern Kansas, the Noxie Sandstone Member below, underlying the Thayer coal and ranging from 40 to 75 feet in thickness, and the Cottage Grove Sandstone Member above, ranging from 2 to 50 feet in thickness (Moore, 1949, p. 101). The Cottage Grove Member forms a prominent escarpment in northeastern Oklahoma (Oakes, 1940, p. 63). At most places in Kansas City sandstone forms but a small part of the Chanute sections. The beds are calcareous in some places and alter to a silty limestone which contains abundant marine fossils.

Plant remains, for example Calamites, normally constitute the chief fossil material in the Chanute. In the calcareous Chanute sandstone at Kansas City, however, invertebrate fossils become locally significant. Included in the limestone layers are the brachiopods; Composita subtilita, Linoproductus sp., and Wellerella; the bryozoans, Fenestella, and Fistulipora; small pectinoid clams; gastropods; crinoid ossicles; and echinoid spines.

Iola Formation

Two limestones with an intervening shale lie directly above the Chanute Formation at Iola, Kansas, (Haworth and Kirk, 1894, p. 109). The beds total 40 feet thick and are divided into three members of the Iola Formation; the Paola Limestone Member below, Muncie Creek Shale Member, and the Raytown Limestone Member above. The three members occur at and near Kansas City and altogether are only 6 to 10 feet thick. The limestones are usually fine grained, gray or bluish-gray, and exhibit conspicuous algal veins in the upper layers. The middle shale member consists of two phases, lower black, platy beds and upper gray, argillaceous beds. Ubiquitous small phosphatic nodules occur in the shale. The Iola extends from south-central Iowa to northern Oklahoma.

Paola Limestone Member

The bluish-gray Paola Limestone, named from Paola, Miami County, Kansas, (Newell, 1935, pp. 51-54), is a seemingly uninterrupted 1 to 2-foot layer of hard, fine-grained limestone, usually fractured and moderately fossiliferous. It extends from Oklahoma into southwestern Iowa and southeastern Nebraska. The Paola weathers to a gray color and becomes rubbly in the upper few inches. Fresh beds indicate that the upper Paola is initially uneven or pitted, particularly if the superjacent Muncie Creek Member is thin. In such areas, Muncie Creek nodules are firmly embedded in the upper Paola, augmenting the uneven condition of the top layer.

Fossils are concentrated in the upper few inches of the Paola. The small brachiopod, Composita, and crinoid fragments make up the bulk of the material.

Muncie Creek Shale Member

Muncie Creek in southern Wyandotte County, Kansas, is the type locality for the Muncie Creek Shale Member, of the Iola Formation (Newell, 1935, pp. 51-55). Its geopraphic distribution parallels that of the underlying Paola Limestone. It is 1 to 3 feet thick at Kansas City and at most outcrops in Missouri and Kansas.

The Muncie Creek typically contains a lower, black, platy shale and an upper, gray or buff, clayey shale. Characteristic of these shale types and enhancing the value of the Muncie Creek as a marker bed are persistent, round, phosphatic nodules that lie along the bedding planes. The nodules average 1 to 2 inches in diameter and have dark interiors and buff to white weathered exteriors. Fragments of bryozoans, pelecypods, ammonoids, arthropods, fish brain casts, and plants were the nuclei of growth for many nodules.

Raytown Limestone Member

The upper member of the Iola Formation is the Raytown Limestone, named from exposures at Raytown, Jackson County, Missouri, (Hinds and Greene, 1915, p. 27). The Raytown is 6 to 8 feet thick in the type area and at Kansas City but increases to 35 feet near Paola, Kansas. It extends from Oklahoma to southwestern Iowa.

Several thick beds of fine- or medium-grained, light gray, algal limestone form the Raytown which is known to quarry operators as the "Calico ledge". It weathers to a buff or tan color. The massive layers display wavy surfaces with thin shale partings. Fossils are usually common in the upper Raytown.

Table 7

Fossils of the Raytown Limestone at Kansas City

Brachiopoda
- Composita subtilita
- Juresania nebrascensis
- Kozlowskia splendens
- Echinoconchus sp.
- Dictyoclostus americanus
- Linoproductus sp.
- Neospirifer dunbari
- Punctospirifer kentuckiensis

Coelenterata
- Lophophyllum sp.

Bryozoa
- Rhombopora sp.
- Fenestella sp.

Mollusca
- Worthenia sp.

Echinodermata
- Delocrinus missouriensis
- crinoid ossicles

ZARAH SUBGROUP

The Zarah Subgroup, named from the village of Zarah, Johnson County, Kansas, (Moore, 1949, p. 107) includes units from the top of the Iola Formation to the base of the Plattsburg Formation of the Lansing Group. In ascending order, the beds make up the Lane, Wyandotte, and Bonner Springs Formations. These formations are 125 to 150 feet thick at Kansas City but are thinner in northern Missouri, largely from thinning of the Argentine Limestone Member of the Wyandotte Formation. The aggregate thickness of the Zarah Subgroup in Kansas is about 100 feet.

The Wyandotte Formation thins and disappears southwest of Kansas City, whereas, the Lane Formation thickens. Disappearance of the Wyandotte gives rise in some localities to an indivisible shale section from the Lane into the Bonner Springs Formation which is referred to in Kansas as the "Lane-Bonner Springs Shale".

Lane Formation

Shales and Sandstones that are the lowermost beds in the Zarah subgroup constitute the Lane Formation, from Lane, Franklin County, Kansas, (Haworth, 1895, p. 277). The Lane ranges from 5 to 35 feet thick near Kansas City to over 100 feet in Kansas. It extends from southeastern Kansas into southeastern Nebraska and southwestern Iowa.

The Lane is composed largely of gray or bluish-gray clays, silts, and micaceous shales, although light brown friable sands occur in some sections of the upper lane. A thin coal occurs north of Kansas City. Lane exposures may also possess disc-shaped septarian nodules, some of which are 12 to 16 inches across. The Lane beds become light gray or buff upon weathering and break into small chips that mantle the slopes.

Generally speaking the Lane is nonfossiliferous. However, unusually well preserved crowns and stems of the crinoids Aesiocrinus, Eupachycrinus, Graphiocrinus, and Delocrinus, were unearthed at the turn of the century in construction projects in downtown Kansas City. A few plant fossils have also been reported from the Lane.

Wyandotte Formation

The Wyandotte Formation consists of three limestone and two shale units of variable thickness that occur in alternating sequence directly above the Lane Formation. The type area is along the Kansas River in Wyandotte County, Kansas, (Moore, 1932, p. 15). The Wyandotte thins and disappears south of Miami County, Kansas, but can be traced northward into southwestern Iowa and southeastern Nebraska. Members of the Wyandotte Formation are the Frisbie Limestone (below), Quindaro Shale, Argentine Limestone, Island Creek Shale, and Farley Limestone (above). The Frisbie and Quindaro Members are poorly exposed or locally missing in much of the Kansas City area. The aggregate thickness of the Wyandotte is 60 feet. Members vary in thickness throughout the outcrop area. For example, the Argentine increases from 3 to 60 feet within a few miles in eastern Kansas and from 1 to 35 feet in Missouri.

Frisbie Limestone Member

The basal member of the Wyandotte Formation is the thin Frisbie Limestone, named from exposures at Frisbie, Johnson County, Kansas, (Newell, 1935, p. 59). The Frisbie is often concealed or difficult to recognize at Kansas City where it is a single 1 to 3-foot bed of hard, gray to dark gray limestone or thin limestone layers with interbedded calcareous shale. The Frisbie weathers light gray to buff in color.

The Frisbie at Kansas City contains crinoid ossicles, bryozoans, brachiopods, small horn corals, and calcite veinlets that are apparently of algal origin.

Quindaro Shale Member

The Quindaro, 3 to 40 inches of nonfossiliferous shale, overlies the Frisbie Limestone and underlies the Argentine Limestone. In some localities it is gray and calcareous; elsewhere, it is black and platy. This member is named from Quindaro Lake, Wyandotte County, Kansas, (Newell, 1935, p. 59).

Argentine Limestone Member

The Argentine Limestone is extremely variable in thickness and appearance. It is more than 35 feet thick at Kansas City but thins to less than one foot in northern Missouri. It is 30 to 60 feet thick in Kansas localities and decreases within a short distance to 2 to 3 feet thick. It is part of a limestone "buildup" that extends northeastward through eastern Kansas and northwestern Missouri. The geographic extent of the Argentine is from southeastern Kansas into southwestern Iowa and southeastern Nebraska. It is named from the Argentine district, Kansas City, Kansas, (Newell, 1935, pp. 59-60).

The color of Argentine Limestone varies from light gray to bluish-gray. The texture is fine- to coarse-grained. In some exposures, the bedding is massive with shale occurring in only minor amounts. Elsewhere, the Argentine Limestone is thin-bedded and shale partings occur along most bedding planes, particularly in the lower part. The limestone is cherty in many localities, the chert being nodular and banded. The chert weathers chalk white to brown in color and gives rise to a surface rubble. Algal lines and partly filled calcite vugs also characterize this member. The Argentine has been extensively quarried in eastern Kansas, and in a few cases the openings are now used for underground storage of perishable products where operations have ceased.

The Argentine contains a considerable suite of fossils, consisting primarily of brachiopods, bryozoans, echinoid debris, and algae.

Table 8

Argentine Fauna at Kansas City

Brachiopoda
- *Composita subtilita*
- *Chonetes* sp.
- *Juresania nebrascensis*
- *Kozlowskia splendens*
- *Kozlowskia wabashensis*
- *Punctospirifer kentuckiensis*
- *Chonetina flemingi*
- *Derbyia crassa*
- *Linoproductus* sp.
- *Neospirifer dunbari*
- Productid spines

Bryozoa
- *Fenestella* sp.
- *Polypora* sp.
- *Rhombopora lepidendroides*

Coelenterata
- *Lophophyllum* sp.

Echinodermata
- *Delocrinus subhemisphericus*
- *Brachial actus*
- Crinoid ossicles

Mollusca
- *Myalina* sp.
- *Worthenia* sp.

Island Creek Shale Member

Variably thick shales that overlie the Argentine Limestone and underlie the Farley Limestone are named the Island Creek Shale Member, from Island Creek, Wyandotte County, Kansas, (Newell, 1935, p. 60). The beds are more than 40 feet thick at the type locality, which represents the maximum development of the Island Creek in Kansas and Missouri. The beds thin to a mere parting or are completely absent in some localities in Johnson County, Kansas. South of the river at Kansas City, the Island Creek is represented by thin soil that caps a few hills. Northward, however, it is as much as 30 feet thick in Platte and Clay Counties.

Normally the Island Creek is a blue to steel-gray, noncalcareous clay shale, that weathers into small light gray to buff chips which cover the slopes. Fine-grained, micaceous sandstone occurs in the upper Island Creek north of the Missouri River, whereas in Kansas almost the entire Island Creek is represented in places by fine-grained massive sandstone, (More, 1949, p. 110). The Island Creek extends from eastern Kansas into northern Missouri and southeastern Nebraska. It is nonfossiliferous throughout its outcrop area.

Farley Limestone Member

The Farley Limestone, youngest member of the Wyandotte Formation, is often represented by two limestones and an intervening shale. It is named from Farley, Platte County, Missouri, (Hinds and Greene, 1915, p. 29) and extends from east-central Kansas into northwestern Missouri. A single thin exposure occurs in Kansas City south of the Missouri River, but north of the river it crops out extensively and ranges from 5 to 30 feet thick, although averaging 10 to 15 feet. In Kansas, the Farley varies from about 1 to 40 feet thick throughout its development.

The lower Farley limestone is a gray, thin- to medium-bedded limestone which may be mottled, oolitic, and occasionally cross-bedded. It is very fossiliferous. The shale separating the lower and upper Farley is a few inches to a few feet thick. It is gray to olive in color, thin-bedded, calcareous, and occasionally silty and micaceous. The upper limestone is variable in thickness, composition, and paleontology. It may occur as shaly, micaceous, rubbly limestone, as a single ledge of gray, cross-bedded, algal to oolitic limestone, or as breeciated, cross-bedded limestone that weathers reddish-brown in color.

Algae and molluscs are the most conspicuous fossils in the Farley, myalinid pelecypods being particularly prominent. Several other invertebrate types are also present in the Farley.

Table 9

Fossils in the Farley Limestone of the Greater Kansas City Area

Coelenterata
- *Lophophyllidium* sp.

Brachiopoda
- *Juresania nebrascensis*
- *Juresania symmetrica*
- *Antiquatonia portlockiana*
- *Linoproductus* sp.
- *Echinoconchus semipunctatus*
- *Composita subtilita*
- *Crurithyris planoconvexa*

Bryozoa
- *Rhombopora crassa*
- *Polypora* sp.
- *Polypora elliptica*

Mollusca
- *Aviculopecten* sp.
- *Aviculopinna* sp.
- *Lima retifera*
- *Pharkidonotus* sp.
- *Bucanopsis* sp.

Arthropoda
- *Ameura major*

Plants
- Algal varieties

Bonner Springs Formation

The uppermost beds in the Zarah Subgroup of Missouri and Kansas form the Bonner Springs Formation which overlies the Wyandotte Formation and underlies the Plattsburg Formation of the Lansing Group. The Bonner Springs is composed mostly of shale, but lenticular to massive sandstone occurs in many thick exposures. The formation name comes from Bonner Springs, Wyandotte County, Kansas, (Newell, 1935, p. 65) where the maximum thickness of 45 feet is attained. It is 20 to 40 feet thick north of the Missouri River.

The Bonner Springs is primarily green to buff, thin-bedded shale. Clay ironstone layers, mica, and sandstone concretions occur in the Bonner Springs, the concretions measuring up to 3 feet across. Plant fragments are usually the only fossil material recovered from the Bonner Springs. The fragments tend to occur in the sandy beds.

The Bonner Springs crops out from southeastern Kansas into northern Missouri. Where the subjacent Wyandotte Formation has pinched out in south eastern Kansas, the Bonner Springs-Lane contact is indistinguishable.

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ECONOMIC MINERAL COMMODITIES OF THE KANSAS CITY AREA

by

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INTRODUCTION

Kansas City is underlain almost entirely by rocks belonging to the Kansas City Group of the Pennsylvanian System. These strata occur in cyclical sequences or cyclothems and consist of relatively thick units of limestone and shale with minor amounts of sandstone, underclay, and coal. The total thickness of the group is approximately 250 feet with limestone accounting for about half of the total thickness.

An important factor in the growth of Kansas City into an industrial center has been the exploitation of the large reserves of readily accessible, beds of high quality limestone belonging to the Kansas City Group.

The total value of the mineral production, (water not included), in the Kansas City area* in 1963 was $22,423,186. Limestone in its various uses such as portland and masonry cement, lime, aglime, concrete aggregate, riprap, roadstone, and dimension stone accounted for over 90 percent of the total mineral production. Moreover, almost all limestone production was and still is from the relatively thick limestone beds of the Kansas City Group.

In addition to limestone, the mineral resources of the Kansas City area include sand and gravel, clay and shale, sandstone, oil and gas, and water. Areas of active exploitation of mineral resources in 1963 are indicated on Plate 1.

Sand is produced by several companies by dredging the Kansas and Missouri Rivers and by exploiting Pleistocene terraces and channel fills. Sand and gravel accounts for about 5 percent of the total mineral production. It is used chiefly for construction purposes.

Clay and shale are being mined in Jackson and Platte Counties, Missouri, and Wyandotte County, Kansas. The material is used in the manufacture of portland cement, brick, and lightweight aggregate.

A small amount of oil and gas is produced in Johnson County, Kansas, and in Jackson and Platte Counties, Missouri. All production is from the upper Cherokee, Marmaton, and Pleasanton Groups of the Pennsylvanian System.

The total value in 1963 of oil and gas from wells in the Kansas City area was less than $150,000. Most of the production was in Johnson County, Kansas, where 46 oil wells and 56 gas wells produced 29,908 barrels of oil and 273,002 million cubic feet of gas. In 1963 the market production of natural gas increased 173 percent and oil production 121 percent over 1962.

In Jackson County, Missouri, two oil pools, the Boten and Longview, produced 3,400 barrels of petroleum from 21 wells. The Belgium Bottoms oil pool in southern Platte County produced 500 barrels of petroleum in 1963.

Thin beds of coal occur in the Marmaton and Cherokee Groups which underlie the area at depth, but the coal beds are considered to be of no commercial value at the present time.

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* Production figures have been calculated on a 5 county basis and include Jackson, Clay and Platte Counties, Missouri, and Johnson and Wyandotte Counties, Kansas. In this report these 5 counties are designated as the Kansas City area.

PLATE I

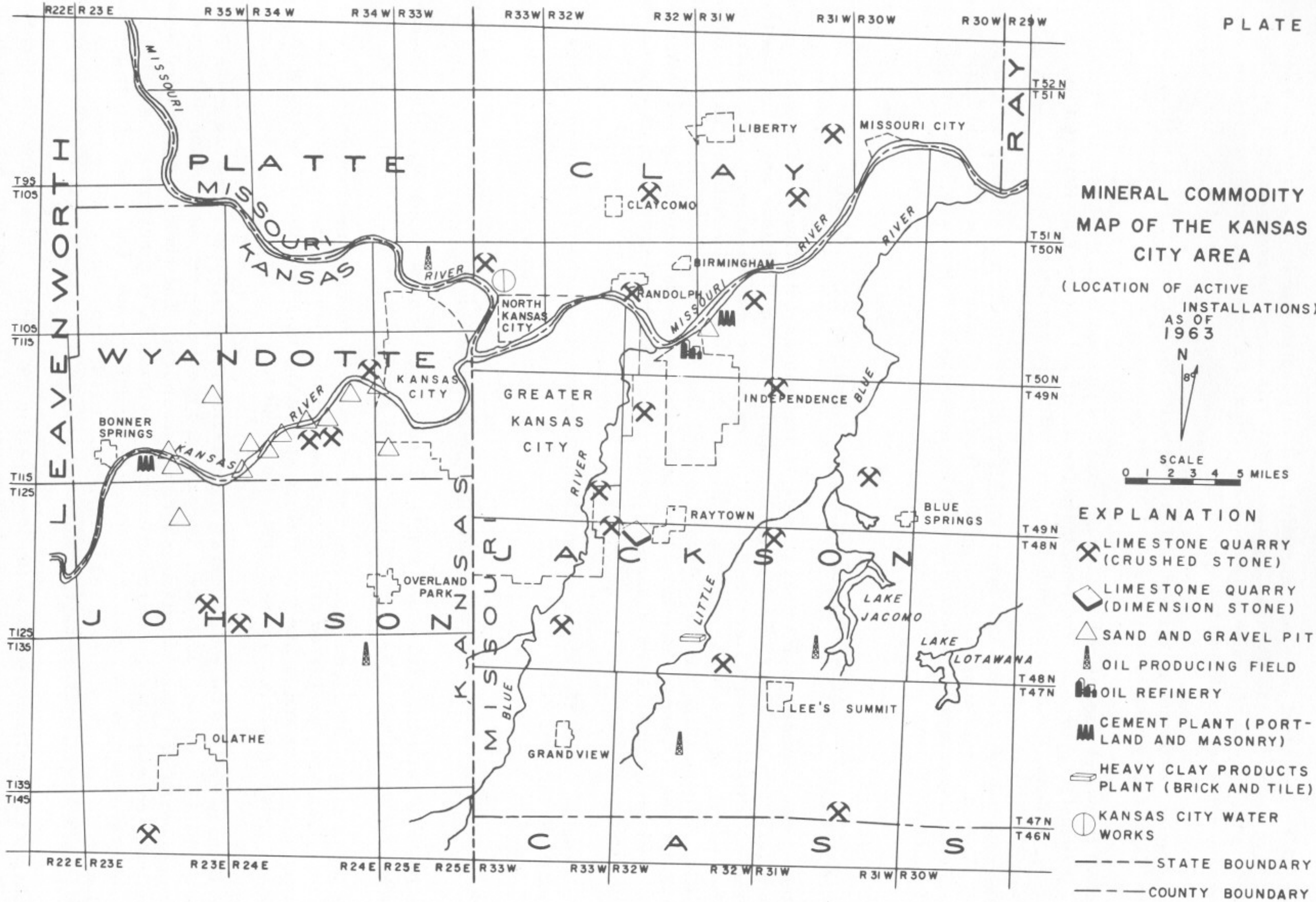

Plate 1. Mineral Commodity Map of the Kansas City Area.

Sandstone is quarried for riprap in Platte County, Missouri.

Water is an important mineral commodity and will continue to have a profound effect on the economic development of the Kansas City area. Water is unique in comparison with other minerals because of its migratory and renewable characteristics. Its economic value, therefore, cannot be readily measured from a value added approach.

The combined daily use of surface and ground water for municipal, industrial, and agricultural use in the Kansas City area is well over one billion gallons.

Much of the water used in the Kansas City area is pumped from the Missouri River. Most of it is used for industrial purposes, the remainder for municipal purposes by Kansas City, Missouri, Kansas City, Kansas, and the many suburban areas of these two cities.

Large supplies of ground water are available from the alluvium of the Kansas and Missouri River valleys. Moderate supplies are available from the alluvium of the Blue and Little Blue River valleys. According to available records, wells in the Missouri River valley alluvium have average yields of about 1,000 gpm.

LIMESTONE BEDS OF THE KANSAS CITY GROUP

Fifteen named limestone members occur in the Kansas City Group. These range in thickness from less than an inch to 55 feet. The majority of the limestone units are too thin or of quality too poor to be utilized economically. Seven of the members have been quarried and used for a variety of purposes. They are in ascending order: the Bethany Falls, Winterset, Westerville, Cement City, Raytown, Argentine, and the Farley Limestone Members. Only the Bethany Falls and Argentine Members have been quarried extensively in recent years. In some areas the overlying or underlying shale is used along with the limestone in the manufacture of the portland cement.

A brief summary of the physical and chemical properties, and the economic aspects of these members follows.

Bethany Falls Limestone Member

The Bethany Falls Limestone is a single massive ledge in most exposures. The thickness of the member varies between 15 and 24 feet, averaging about 20 feet.

The lower part of the member is composed of gray, crystalline limestone beds a few inches to a foot thick which when weathered exhibit irregular bedding planes. The limestone in the upper part is a mottled gray color and is finely crystalline and locally may be oolitic. The top of the member consists of a mass of poorly cemented limestone nodules.

The Bethany Falls is the most extensively quarried Pennsylvanian limestone in the Kansas City area and probably in western Missouri. Underground mining is particularly common where the thickness of overburden makes surface mining uneconomical. The rock is well adapted to underground mining, consequently most production of the Bethany Falls limestone in the Kansas City area is from underground mines which utilize the room and pillar plan. The lower 12 feet of the Bethany Falls Member is commonly mined, and the upper part is left to form a stable roof. Haphazard mining practices in some instances have dangerously penetrated the uppermost nodular part.

A chemically analyzed sample of the lower part of the Bethany Falls at the Missouri Portland Cement Plant near Independence tested 95.29 percent $CaCO_3$, 1.50 percent $Mg\ CO_3$, 2.00 percent $Fe_2\ 0_3$ and $Al_2\ 0_3$, and 3.30 percent $Si\ 0_2$. Loss of ignition was 41.74 percent.

The Bethany Falls Limestone is particularly suitable for use as crushed stone, because the silica and shale content is relatively low as compared with the limestone of the Winterset and Argentine Members.

Winterset Limestone Member

The Winterset Limestone is gray, thin, evenly-bedded, and has numerous shale partings. The member commonly contains an abundance of dark gray chert in its upper part. The average thickness of the Winterset is about 30 feet in the Kansas City area.

The lower part of the Winterset has been quarried in tandem with the Bethany Falls, particularly in places where the intervening shale of the Galesburg Formation is of reduced thickness or can be utilized with the limestone in cement manufacture.

In former times, limestone of the Winterset Member was used in the Kansas City area for building stone, siding, veneer, and curbing.

Westerville Limestone Member

The Westerville Limestone Member of the Cherryvale Formation varies considerable in thickness and lithology throughout the Kansas City area. The thickness of the member is from 6 to 21 feet. The lower 2 to 4 feet is a relatively uniform and even bedded limestone which has been called the "Bull Ledge" because it is difficult to work in quarrying operations. The limestone in the upper part of the member is commonly oolitic and very fossiliferous -- the variation in thickness occurs chiefly in this part of the member. The upper part has been called the "Kansas City Oolite" and is quarried as dimension stone and as rubble. This part of the member is locally absent or represented by limestone nodules.

In the vicinity of Raytown in Jackson County where the Westerville thickens to about 21 feet, it is currently being quarried. The stone at this location is cross bedded and oolitic. It is light gray and when quarried retains its light color.

The Westerville stone has been very popular in Kansas City where it has been used in many public and private buildings. Examples of its use are found on the campus of the University of Missouri at Kansas City where it is used in the gymnasium, Law Building and other buildings. It was also used in the construction of the Liberty Memorial in Kansas City. The stone used in these buildings was quarried in Johnson County, Kansas, but at the present time the only production of dimension stone is from Jackson County, Missouri.

Cement City Limestone Member

The Cement City Limestone Member of the Drum Formation is about 9 feet thick, although in places it attains a thickness of 13 feet. The lower 2 feet is a massive bed of fine crystalline, bluish gray limestone which is somewhat argillaceous. The upper 7 feet or more consists of gray, thin-bedded to wavy bedded limestone which sometimes resembles the Argentine limestone. A thin bed of partially oolitic limestone locally is present near the top of the member.

The Cement City Limestone is known as the "Building Ledge" in the vicinity of Kansas City. In former times it was the most extensively quarried stone in the city. It supplied building stone and rubble for the rustic masonry of the bungalow-type house construction which was so common about the turn of the century. The lower 2 feet was used for the curbing.

Raytown Limestone Member

The Raytown Limestone Member of the Iola Formation is about 5 to 7 feet thick in the Kansas City area. The member consists of a massive ledge of gray to brown limestone. The weathered stone has a rough appearance.

The Raytown derives its local name "Calico Rock" from its mottled appearance. The numerous large productid brachiopods and the brecciated appearance of the rock produce a characteristic spotted appearance in both weathered and fresh exposures. Joints and fissures are filled with pink to gray calcite which imparts a variegated color to the rock.

The Raytown Limestone was an important quarry ledge, especially in Kansas City. It was mostly used for rubble and crushed rock.

Argentine Limestone Member

The Argentine Limestone Member of the Wyandotte Formation is generally the thickest limestone in the Kansas City area. The observed thickness ranges from 15 to 55 feet but commonly it is between 20 and 30 feet thick.

Irregular bedding characterizes the Argentine limestone. Individual beds range from 0.1 to 1.0 feet in thickness and the bedding surfaces are wavy. This limestone is second only to the Bethany Falls in economic importance.

In most exposures, the Argentine limestone is from 90.0 to 95.0 percent $CaCO_3$.

Farley Limestone Member

The Farley Limestone Member of the Wyandotte Formation is extremely variable in thickness and lithology. Depending on location it may be exposed as one limestone bed over 20 feet thick or represented by 2 or 3 beds of limestone separated by shale. The limestone beds appear to thicken at the expense of the interbedded shale. Where the Farley limestone is in thick beds, it is from 95.0 to 98.0 percent $CaCO_3$; a suitable purity for quicklime manufacture. Until recently, quicklime producing plants have not been successful in the Kansas City area. Selective quarrying seems to be the major factor in eliminating many of the problems which caused eventual shutdown of earlier operations.

Quicklime is made by heating crushed limestone to a critical temperature to drive off CO_2 to produce a product rich in CaO (quicklime).

MAJOR USES OF LIMESTONE IN THE KANSAS CITY AREA

Portland and Masonry Cement

The manufacture of portland and masonry cement amounted to over 11 million dollars in 1963 or approximately 50 percent of the total mineral production of the Kansas City area. Two large cement plants are currently in operation. They are Missouri Portland Cement Company's Kansas City plant at Independence, Jackson County, Missouri, and the Lone Star Cement Corporation at Bonner Springs, Wyandotte County, Kansas.

The Missouri Portland Cement Company is the larger producer with an annual capacity of well over 3,000,000 barrels. The Bethany Falls limestone and the shale beds of the Ladore Formation, Hushpuckney Member, Galesburg Formation, Stark Member and upper Winterset Member are utilized as raw materials. The Lone Star Cement Corporation is quarrying the Argentine and Farley limestones and shale from the overlying Bonner Springs.

Portland Cement is the major product of these plants, and it accounts for approximately 98 percent of the total cement production, the remainder being predominately masonry cement.

Crushed Limestone

A total of 5,833,401 short tons of crushed limestone valued at $7,974,016 was produced by 17 companies in the Kansas City area in 1963. Nine of these companies are located in Jackson County, four in Clay County, and one in Platte County, Missouri, while Johnson and Wyandotte Counties, Kansas, each had three producers. The largest production was from Jackson County with 2,526,351 tons. Wyandotte County, Kansas, ranked second with 1,072,099 tons, and Clay County, Missouri, ranked third with 749,147 tons. Clay County was fourth among the Missouri counties in the production of crushed limestone which was the only mineral produced in the county. Value of output in Clay County rose 23 percent over the previous year because of high residential and industrial construction in the area. The largest tonnage of crushed limestone went for concrete aggregate and road metal.

UTILIZATION OF UNDERGROUND SPACE IN MINED-OUT AREAS

The extensive mining of the Bethany Falls Limestone in the Kansas City area has created a vast amount of underground space. It was soon realized that this space could be utilized for storage and other purposes. However, it was not until after the end of World War II that this possibility became a reality, and the underground space began to be converted to office, warehouse, and manufacturing use.

In 1963 a total of over 20 million square feet of space was available for rent under short or long term leases in Clay and Jackson Counties. Considerably more than double this amount of space is present in operating mines. In addition to Jackson and Clay Counties, Missouri, considerable space is available in underground mines in Wyandotte County, Kansas.

The average ceiling height in most of the mines is about 12 feet. The bays average 35 feet in width and are as long as 3,000 feet. Over 6 million square feet of floor space is available in one of the larger mines.

The temperature in the underground workings varies from 50 degrees Fahrenheit in winter to 65 degrees in summer. The humidity varies from 30 to 95 percent with an average of about 75 percent.

Space has been leased by a number of companies and individuals. Among them are toy manufacturers, tool and die makers, soils foundation engineer specialists, artists, air conditioning and refrigeration companies, food stores, petroleum companies, breweries, and the U.S. Government.

The Inland Cold Storage Company, Inc. of Kansas City, Kansas, occupies more than 6 million square feet. It is the largest freezer and cold storage facility in the world. Fifty-five trucks can be loaded or unloaded at one time. Two inside warehouse rail spurs accommodate 46 freight cars.

The Brunson Instrument Company, makers of precision instruments, occupies 140,000 square feet of underground space at 8000 East 23rd Street in Kansas City, Missouri. This plant was conceived by A. N. Brunson, president of the company, shortly after World War II and was put into production after 12 years of planning and alteration.

The general plan of the plant consists of six east -- west tunnels and seven north -- south tunnels, with pillars 15 feet wide and 90 feet long between tunnels. The entrance is a sheer cliff approximately 67 feet high which extends from the floor of the plant to the top of the face.

The following stratigraphic units are encountered in the interval from 24 feet below floor level to the top of the front face:

Overburden	3 ft. soil
Westerville Mbr.	13 ft. limestone
Wea Mbr.	1 ft. shale
Block Mbr	3 ft. limestone
Fontana Mbr.	2 ft. shale
Dennis Fm.	20 ft. limestone
Galesburg Fm	4 ft. shale
Swope Fm	21 ft. limestone
Ladore Fm.	4 ft. shale
Hertha Fm.	20 ft. limestone

The plant is located in an excavation in the basal 12 feet of the Bethany Falls Limestone. It is interesting to note that not a single roof bolt was required in plant construction.

The sewers for the Brunson plant are connected directly to the city sewers, and the water supply is furnished by the city. All sewer pipes are in the rock under the plant floor. Water pipes are also buried in the rock beneath the concrete floor. Seepage water which flows at the base of the pillars is removed by drains installed in the floor.

An underground plant is considered ideal for the manufacture of precision instruments such as theodolites, because vibration, dust, and noise are eliminated.

In the advent of nuclear war or other major disaster, the underground space in the Kansas City area could be utilized as shelters. The Missouri Civil Defense Agency estimates that sufficient underground space exists in Jackson County for over one million people at 30 square feet per person. Although this is sufficient space to house more than the entire population of Kansas City and its environs, most mines lack sanitation and ventilation facilities.

In most mined-out areas, the roof rock is firm and free from spalling, nevertheless, in a few of the early mines haphazard mining methods, particularly poorly spaced pillars, has resulted in the collapse of the overlying formations. In the winter of 1964-1965, caving of underground workings resulted in the destruction of 2 houses and the endangering of many more in Kansas City, Kansas. Collapse of the formations overlying the old mine workings has also occurred at Independence, Missouri, and along Manchester Avenue in Kansas City, Missouri.

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Fig. 1. Cryptozoon biomicrite facies (polished section)

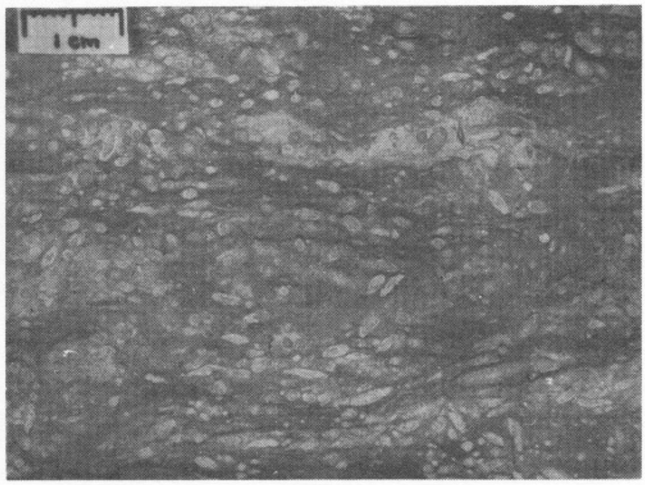

Fig. 2. Wedekindellina biomicrite facies (polished section)

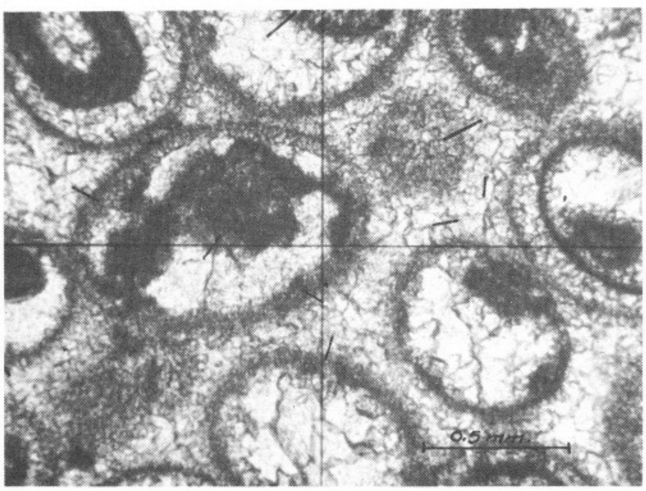

Fig. 3. Intraclastic oolite facies (thin section)

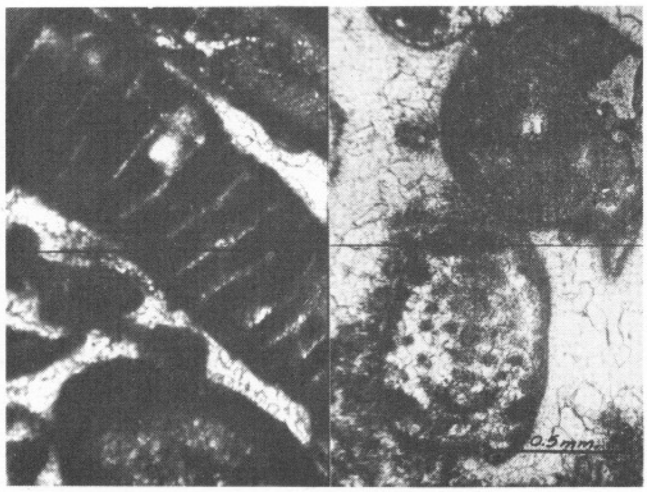

Fig. 4. Algal biosparite facies (thin section). Views of two different samples. Right shows Epimastopora and cellular algae; left, recrystallized Staffela (below) and gastropod.

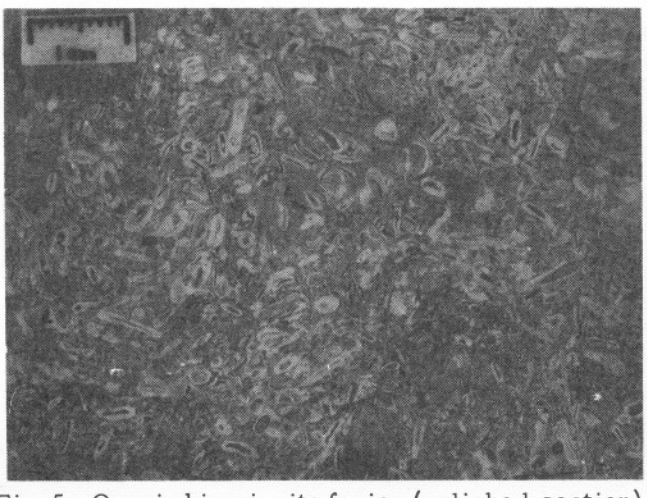

Fig. 5. Osagia biomicrite facies (polished section)

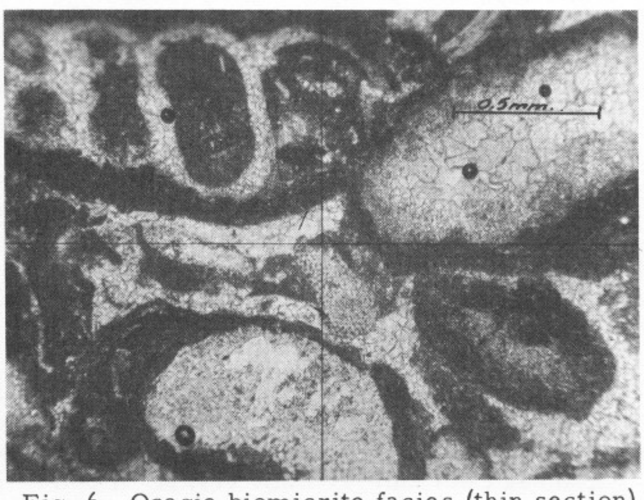

Fig. 6. Osagia biomicrite facies (thin section)

FACIES RELATIONSHIPS IN THE BETHANY FALLS LIMESTONE

by

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GENERAL STRATIGRAPHY AND SUBDIVISION OF FACIES

The Bethany Falls limestone constitutes the upper and principal member of the Swope Formation, Bronson Subgroup, Kansas City Group, Missourian Series, Pennsylvanian System. An excellent account of the evolution of nomenclature and the pertinent hierarchical subdivisions through this sequence is given by Moore (1935, p. 75-94). Moore (1949, p. 2028) and Howe (1961, p. 100) outline the current usage of stratigraphic terms.

Physical properties that adequately meet specifications for concrete aggregate made the Bethany Falls a prime objective of quarry operators. As a result, superb exposures occur from southwestern Iowa into central Kansas that allow close examination of the constituent facies and their interrelationships.

Although exceptional members exist, those thick limestones in the Kansas City Group that occupy cyclothemic positions equivalent to that of the Bethany Falls possess strong similarities in types, relative volumes, and geographic position of facies. The Bethany Falls may therefore serve as a model for the type of sediment that accumulated to form the major limestones of the Kansas City Group, as well as a model for interpreting conditions that existed during their deposition.

Based on field observations and statistical analyses of petrographic data, nine principal facies form the Bethany Falls Limestone. The Lower portion is composed of argillaceous, pyrite biomicrite facies; brachechino biomicrite facies; *Cryptozoon* biomicrite facies; and *Wedekindellina* biomicrite facies. *Osagia* biomicrite facies, algal biosparite facies, *Cryptozoon* biolithite facies, micrite facies, and intraclastic oolite facies form the upper Bethany Falls which is separated from underlying facies by a persistent shaly interval.

PETROGRAPHY AND DISTRIBUTION OF FACIES

Lower Bethany Falls Facies

At all localities, argillaceous pyritic biomicrite forms the basal 6 to 25 cm of the Bethany Falls. This facies is characteristically dark gray and is expressed as a single stratum. Whole and fragmented shelly fossils are abundant (average 27 percent of rock) and are composed either of calcite, or of replacing pyrite. Algae for the most part are absent. The volume of terrigenous mud decreases upward, as the facies is transitional between the underlying Hushpuckney Shale Member and the overlying biomicrites. The restriction of pyrite to this facies appears related to reducing conditions that prevailed during deposition.

The argillaceous pyritic biomicrite is succeeded either by brachechino biomicrite containing mostly fragments of brachiopods, echinoderms (dominantly crinoidal debris) and bryozoans scattered through a matrix of microcrystalline calcite and terrigenous mud or by *Cryptozoon* biomicrite (Figure 1). By far, these two facies form the bulk of lower Bethany Falls rocks, and differ from each other in their fossil assemblages and in the greater amount of argillaceous material in the brachechino biomicrite facies. Due to scarcity to rocks containing subequal volumes of algae and brachiopods plus echinoderms, it is concluded that the two types of sediment were generated under mutually exclusive conditions and should be separated into distinct facies.

Both biomicrite facies are brownish-gray to light gray, in thin to very thin-bedded strata (McKee and Weir, 1953, p. 383). Each bedding plane is undulose, and is marked by an anastomose network of argillaceous seams that abruptly cap each biomicrite stratum. The volume of terrigenous mud gradually decreases upward in the succeeding stratum.

The microcrystalline calcite matrices of both the Cryptozoon and brachechino biomicrites have been effected by solution and recrystallization. Growth of matrix grains to particles as large as 30 mu is widespread throughout the facies. Swirled or contorted matrices are visible in polished sections of some samples, and these associated with "nests" of angular, unabraded shelly fossil fragments and calcite spar-filled tubules are strong evidence for extensive organic reworking of the sediment. Microfissures and distorted algal mats are evidence for minor penecontemporaneous slumping.

Mutual interstratification of brachechino and Cryptozoon biomicrites of most localities results in very complex patterns of distribution for each facies. In general, the Cryptozoon biomicrite facies is well-developed in southwestern Iowa and northern Missouri.

A robust algae phase of the Cryptozoon biomicrite facies is present through north-central Missouri in Harrison, Daviess, Mercer, Grundy and Livingston Counties, and in south-central Iowa (Decatur and Wayne Counties).

This modified body is transgressive to the north. A similar robust Cryptozoon biomicrite in the overlying Winterset Limestone Member of the Dennis Formation and concomitant thinning of the underlying Hushpuckney Shale reveals strong persistent shoaling as the cause of this phase. Although some brachechino biomicrite may be found at almost any locality, it is best developed north of Kansas City, Missouri in an area 50 miles wide, elongated northwest-southeast.

Wedekindellina biomicrite (Figure 2) completes the lower Bethany Falls succession. Although this unit is very thin (maximum 30 cm) and restricted to the east central outcrop belt, isopach trends indicate that its pre-erosional extent and thickness were much greater. In these regions the thickness of the Wedekindellina biomicrite facies have been proportionally as thick as the similar Triticites biomicrite facies is in the overlying Winterset (maximum 250 cm).

Upper Bethany Falls Facies

At all localities, the upper Bethany Falls limestone exhibits an abrupt change in lithology from that of the upper part of lower Bethany Falls rocks. In most places a micrite facies is present, but elsewhere, intraclastic oolite lies directly on the medial shaly interval. Where micrite is present it is light gray, is essentially free of terrigenous mud, and contains few fragments of fossils common to the lower Bethany Falls. Ostracodes are the only organisms that do not undergo a decrease in percentage.

At some localities, particularly to the east, a micrite facies grades upward into intraclastic, pelletiferous or oolitic micrite and eventually gives way to the intraclastic oolite facies. At other localities, the basal, homogeneous micrite becomes mottled and contains scattered pellets. The volume of terrigenous mud increases progressively until it exceeds the volume of carbonate, and the sediment becomes typical of the overlying Galesburg Formation. Where intraclastic oolite succeeds basal micrite, it is in turn covered by argillaceous, mottled micrite.

The mottling is due principally to a variation in grain size. The calcite composing the dark mottles averages 20 mu in diameter whereas that in the surrounding interareas averages 10 mu in diameter. A core of spar may exist in some mottles, but these are not common. The cause for the variation in grain size is unknown, but may be related to organic activity.

Sections of upper Bethany Falls limestone composed entirely of mottled and pelletiferous micrite are restricted to southwestern Iowa and to the western portion of the outcrop belt in

Missouri. Scanty well data to the west indicate a continuation of the micrite facies into the subsurface.

The upper Bethany Falls is composed predominantly of the intraclastic oolite facies throughout the eastern part of the exposure belt in Missouri and Kansas. Great variations in thickness (0 to 5 m) and intricate interfingering with the micrite and other facies are characteristic. The products of solution, recementation, and recrystallization are widespread throughout the facies, and these processes have effected intraclasts and ooids alike. Ooids in the Bethany Falls show no radial structures and only rarely crude concentric structures (Figure 3). In this respect they are unlike ooids of the Winterset and other major limestones in the Kansas City Group. Many ooids are asymmetrical, having nuclei of carbonate mud or fossil fragments that occupy the periphery of sparry calcite-filled spheres (Figure 3). Those individual ooids with nuclei in the lower hemisphere probably were formed by solution-collapse process. Others with nuclei in different peripheral positions must have been produced by some mechanism other than simple solution-collapse.

In several localities through north-central Missouri the intraclastic-oolite facies is capped by a thin crust of Cryptozoon biolithite. This facies is sporadically developed, and at no exposures are the mats continuous. The geographic position of this facies coincides with that of the lower Bethany Falls robust Cryptozoon biomicrite phase.

Small isolated pods of Osagia biomicrite and algal biosparite are also present in places over the shoal. The latter facies (Figure 4) is characterized by abundant Epimastopora and other cellular algae in association with Staffela, and shelly fragments of diverse affinities. All detritus is well-rounded, abraded, and cemented by sparry calcite. Such sediment undoubtedly accumulated in very shallow water over the north-central Missouri shoal.

The Osagia biomicrite patches represent small extensions from the extensive parts of the facies in southwestern Iowa. The Osagia biomicrite facies is regressive southward, composing almost all of the upper Bethany Falls along the northern outcrop belt, but forming only the top few centimeters in northern Missouri. As a result, the facies interfingers with both the intraclastic oolite and micrite facies, and succeeds both in some areas.

Small biscuit-shaped colonies of Osagia are encrusted about fossil fragment nuclei (Figure 5). The resulting bodies are packed tightly and surrounded variously by sparry calcite cement and microcrystalline calcite. Some binding by algal fibers is indicated from thin section studies (Figure 6). The Osagia biomicrite facies grades into the overlying Galesburg Formation with increasing content of terrigenous mud.

BOUNDARIES BETWEEN MAJOR FACIES

Synchronous facies boundaries are mutually interpenetrating but sharp, thereby demonstrating the effectiveness of currents in mixing sediment produced in neighboring environments. Likewise, facies show abrupt vertical succession, although certain isochronal pairs (brachechino - Cryptozoon facies in the lower, and micrite-interclastic oolite facies in the upper Bethany Falls) alternate repeatedly at some localities.

Within the Bethany Falls, sparry allochemical rocks are restricted to the upper portion. These rocks formed from sediment deposited under turbulent conditions sufficiently vigorous to wash away the fine carbonate mud. Such turbulence is characteristic of shallow water conditions. As the lower Bethany Falls contains no sparites, the medial shaly interval may likely mark an abrupt, regional shoaling of the sea. This corresponds to the transgression-regression boundary within the idealized cyclothem as proposed by Weller (1957). This type of facies separation is exhibited by several other major limestones of the Kansas City Group, in particular the overlying Winterset. Although controls over sedimentation other than strand line migration might produce similar patterns, several lines of evidence to support control by water depth are apparent in some facies as discussed by Payton (1964).

COMPARISONS WITH OTHER MAJOR LIMESTONES

With the exception of expected differences in areal extents and geographic positions of various facies, other major limestones of the Kansas City Group show only small variations on the Bethany Falls model. These are expressed either as omissions of minor facies, and/or very local modifications of biomicrite by concentrations of corals or sponge spicules. As with the Bethany Falls, brachechino, Cryptozoon, and Osagia biomicrite; micrite; and intraclastic oolite form the bulk of the limestones in the Kansas City Group.

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