KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 89-19

Guide to Mined-land Problems and Reclamation
in Southeast Kansas

by

Lawrence Brady
James McCauley
Larry Knoche
Rex Buchanan

KANSAS GEOLOGICAL SURVEY
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047

GUIDE TO MINED-LAND PROBLEMS AND RECLAMATION IN SOUTHEAST KANSAS

Kansas Geological Survey Open-file Report 89-19

by Lawrence Brady, James McCauley, Larry Knoche, and Rex Buchanan

This field trip focuses on past and present problems associated with coal and lead/zinc mining in southeast Kansas. Coal in the area is of Middle Pennsylvanian age and the lead/zinc ores were present in Mississippian age carbonates. Nearly 300 million tons of coal were mined by underground and surface-mining methods. There are about 50,000 acres of disturbed and reclaimed land by surface coal-mining and nearly 60,000 acres where coal was won by underground methods. We will view an active coal mine and see modern reclamation methods, areas with limited reclamation, and old areas with no reclamation. The route and stops on the trip are shown on the attached map. In the roadlog, directions for drivers are underlined.

The old lead/zinc mining area of Kansas, Oklahoma, and Missouri (the Tri-State) was the world's leading producer of zinc around 1920. During the life of the district there were over 4,000 mines, which produced 23 million tons of zinc concentrates and four million tons of lead concentrates. The mines and waste from milling of nearly 500 million tons of ore are conspicuous in this area. We will observe these areas by vehicle and stop several times to give you a feel for this old mining district. Problems of heavy metals in water and open shafts and large subsidence areas are common around Treece, Kansas; Picher, Oklahoma; and Galena, Kansas. We will visit these sites and discuss the problems and concerns that put these areas on the EPA Superfund list.

Rock units we will see in the roadcuts along U.S. Highway 69 in eastern Kansas range from the Stanton Limestone down through the Cherokee Group (Upper to Middle Pennsylvanian). Limestone units of the Warsaw Limestone and Keokuk Limestone, of Mississippian age, are present in the Galena, Kansas, and Joplin, Missouri, area. Stratigraphy of the area is shown in the attached cross section. In general, the rock units are progressively older as we travel south toward Oklahoma, or to the southeast into Missouri.

The roadlog for this field trip starts at the intersection of U.S. 59 and Kansas Highway 10. Much of the following is based on a field trip guide by Lawrence Brady, James McCauley, and Larry Knoche that was published by the Association of Engineering Geologists for their 31st annual meeting in Kansas City in October 1988. Significant parts of the roadlog south along U.S. 69 are based on geological correlation work by Jim McCauley as described in *Roadside Kansas* (Buchanan and McCauley, 1987, p. 223-243). Both the stretches along Kansas Highway 10 and U.S. 69 show information according to milepost markers, the small, green, rectangular signs on the righthand side of the road.

6.7	Along K-10, the Newman Terrace (el. 815 feet) is formed on the floodplains of the Kansas and Wakarusa rivers by the erosion of shales and soft sandstones in the Lawrence and Stranger formations.
7.0	Blue Mound (el. 1052 feet) is 2.3 miles to the south.
8.5	Oxbow lake, formed by the Wakarusa River, south of the highway.
9.1	Wakarusa River.
11.0	Eudora is north of the highway.
12.9	Stoner Limestone Member of the Stanton Limestone.
13.1	Vilas Shale overlain by the Captain Creek Limestone Member of the Stanton Limestone.
13.2	Captain Creek (el. 785 feet).
15.6-16.0	Stoner limestone.
16.1	Vilas Shale overlain by the Captain Creek limestone.
16.4	Eudora shale overlain by the Stoner limestone.
17.4	Captain Creek limestone.
18.0	DeSoto.
18.7	Kill Creek (el. 770 feet).
18.9-19.2	Captain Creek limestone, overlain by Eudora shale, overlain by the Stoner limestone, all members of the Stanton Limestone.
19.6-20.6	Captain Creek limestone.
21.0-21.2	The highway descends through members of the Wyandotte Limestone.
21.3	Camp Creek (el. 780 feet).
21.7	Cedar Creek.

22.4	Iola Limestone overlain by Lane Shale.
22.6-23.0	Wyandotte Limestone.
23.0	The Argentine limestone, overlain by the Island Creek shale, overlain by the Farley limestone, overlain by the Bonner Springs Shale.
23.5	Captain Creek limestone.
23.8	Stoner limestone.
23.9	Captain Creek limestone.
24.3	Plattsburg Limestone.
25.3	Intersection with Kansas Highway 7.
27.0	The Craig-Monticello natural gas storage area, where gas is stored in squirrel sands in the upper Cherokee Group at a depth that averages 582 feet.
27.1	Stanton Limestone.
27.3	Plattsburg Limestone.
27.6	Bonner Springs Shale.
27.8	Mill Creek.
28.2	Plattsburg Limestone overalin by Vilas Shale.
28.4	Stanton Limestone.
28.5	Plattsburg Limestone overlain by Vilas Shale.
29.1	Bonner Spring Shale overlain by Plattsburg Limestone.
29.4	Intersection with Interstate 435.

143.6 Intersection between I-435 and U.S. 69. Turn south on U.S. 69. The milepost numbering system along Kansas highways starts at 0 on the south and west borders of the state; the numbers grow larger as you travel north or east. As a result, the numbers along U.S. 69 grow smaller as we drive south.

142.6 Indian Creek.

141.6 Plattsburg Limestone on the east side of the highway.

140.7 Intersection of U.S. 69 and U.S. 169.

140.4 Lane Shale.

139.8 Tomahawk Creek. Lane Shale.

138.2-138.5 Plattsburg Limestone.

137.4 Negro Creek.

136.8 Plattsburg Limestone.

136.0 The stone in the quarry east of highway is the Wyandotte Limestone.

This limestone reaches a thickness of 60 feet in this area.

136.0-135.0 Wyandotte Limestone.

134.8 The Blue River, which flows northeast to the Missouri River.

134.7-134.3 Wyandotte Limestone.

133.9-132.9 Wyandotte Limestone.

132.2 Plattsburg Limestone.

131.7-131.5 Plattsburg Limestone.

129.7 Stanton Limestone and the Johnson-Miami county line.

128.3 Wea Creek.

127.4 Vilas Shale.

126.0 Christmas tree farm west of the highway and a turf farm to the east.

125.8 Plattsburg Limestone.

124.7-123.5 Wyandotte Limestone.

122.5 Wyandotte Limestone.

122.1 South Wea Creek.

121.8 Lane Shale overlain by the Wyandotte Limestone.

121.6 Louisburg.

121.8-120.4 Wyandotte Limestone.

119.8 A branch of South Wea Creek. Wea Creek is a notable name in the history of oil exploration in Kansas. Along its banks, about 0.5 miles east of Paola, a group of drillers put down the first wells in search of oil in Kansas. The wells were drilled in 1860 and produced mostly salt water with traces of oil. The Civil War brought a temporary halt to Kansas oil drilling, though it began again in 1865 in eastern Kansas. A field two miles west of here produced natural gas that was piped to Paola in 1884, making it the first city in Kansas to be supplied with natural gas.

Oil seeps have long been found in Miami County. The largest of these seeps, the Wea tar spring, was located about two miles west of here along South Wea Creek. George C. Swallow, the second director of the Kansas Geological Survey, predicted oil developments in Miami County and made the county the first in the state to undergo detailed geologic study by Survey staff members.

118.8-119.6 Wyandotte Limestone.

118.3 Wyandotte Limestone.

118.0 Wyandotte Limestone.

117.2 Louisburg oil field, discovered in 1927. It covers much of eastern Miami County and produces from wells 270 to 600 feet deep. The shallowest of those wells are in the Knobtown sandstone in the upper part of the Tacket Formation, which is exposed along U.S. 69 about 15 miles south of here.

116.6-116.4 Wyandotte Limestone.

113.3 Middle Creek.

113.2 Cherryvale Shale overlain by Drum Limestone.

112.3 Iola Limestone.

108.7-108.2 Dennis Limestone.

107.2 Swope Limestone.

105.4 Miami-Linn County line.

105.2-104.0 Dennis Limestone.

103.2 Swope Limestone.

103.0 Tacket Formation overlain by the Hertha Limestone. A coal dragline is visible to the southeast.

102.6 Tacket Formation.

102.4 Kansas Highway 152 runs to the east to the La Cygne generating station and the Midway Mine. The Pittsburg and Midway Coal Mining Company started their coal mining operations at the Midway Mine in Linn County in September, 1972. Coal is produced from the Mulberry coal bed (which averages 26" in thickness) in the Bandera Formation of Middle Pennsylvanian age. Overburden with thicknesses up to 110 feet (average about 50 feet) are uncovered with a 2570-W Bucyrus-Erie 110 cubic-yard dragline or with a 70 cubic-yard 8200 Marion dragline. Mining at Midway is within a few miles on both sides of the Missouri-Kansas line in Bates County, Missouri, and Linn County, Kansas.

With two operating pits, production from the mine generally ranges between 1.4 to 1.8 million tons annually. About 500 acres of land is mined and reclaimed each year to reach that production total. All of the coal produced at the mine is supplied to the #1 unit at the La Cygne Power Station that is owned jointly by the Kansas City Power & Light Company and the Kansas Gas and Electric Company. Coal is hauled directly by large trucks from the mine pits to the power plant stockpiles. The #2 unit at the

LaCygne Power Station burns coal hauled by unit train from the Powder River Basin in Wyoming.

High-volatile bituminous coal in rank, the Mulberry coal bed generally produces a lower quality coal than those coals mined in southeast Kansas. Sulfur content of the Mulberry coal burned in the power plant is approximately 5 percent, with an ash content of 25 percent, and a heat content near 9300 Btu/lb. (Energy Information Administration, 1987, p. 97). Because of equipment size and irregularities in the coal bed, a large amount of ash and consequently low heat values are present as inherent properties in the coal bed.

Pollution control at the #1 unit is maintained by use of seven wet limestone scrubber units.

Reclamation at the Midway Mine has been under study for several years. Experimental plots are being studied by P&M and Kansas State University to determine the effect of soil compaction by large earth-moving equipment, depth of overburden, and crop yield. Objective of the experimental plots is primarily to determine the optimum replacement-soil depth over shale soil to get the required yield for prime farmland. Rubber-tired earth movers cause increased soil compaction with each lift. Studies of crops produced on the plots are for four different soil thickness: 12" topsoil -- 0" subsoil; 12" topsoil -- 12" subsoil; 12" topsoil -- 24" subsoil; and 12" topsoil -- 36" subsoil.

In addition to crop and soil depth, the soil on half of the plots was deep-ripped to about 18" by bulldozer; the other half of the plots were left unripped. Researchers hope that, after four years of cropping on the experimental plots, a permanent plan for soil replacement in this area can be determined.

Geologic units easily observed in the highwall are the Mulberry coal, the Worland Limestone, and the Hepler Sandstone. See the generalized geologic column in Figure 2.

99.2 North Sugar Creek.

97.4-94.0 Marais des Cygne Waterfowl Area.

95.7 Trading Post.

95.6 Marais des Cygne River.

94.6 Big Sugar Creek.

91.0-89.0 Pleasanton.

89.1 Turn off to Papa John's Barbeque to the west. Mention of restaurants in this guide does not constitute a recommendation by the Kansas Geological Survey or any of its subsidiaries.

87.0 Mine Creek. The creek gets its name from a mine located near its banks about two miles to the northeast. This mine produced lead and zinc long before these minerals were discovered in the Tri-State district, but the exact date and identity of the miners is unknown. Indians told early settlers about the presence of lead ore, and the settlers found evidence of an old mine dump. Early French explorers or Indians may have opened this mine, and several mining ventures have since operated at this site, which is called Big Jumbo. One operation in 1901 produced 15 tons of high-grade lead ore, which was shipped to a refinery in the Argentine district of Kansas City, Kansas.

86.4 Hepler Sandstone Member of the Seminole Formation.

85.1 Swope Limestone.

84.8 Ladore Shale.

81.9 Quarry east of highway is in the Pawnee Limestone. The Altamont Limestone is exposed in the quarry walls.

80.6-80.3 Altamont Limestone with the three members--Amoret limestone, Lake Neosho shale, and Worland limestone.

80.1 Linn-Bourbon county line.

79 Bandera Shale.

78.2 Little Osage River.

77.8-77.4 Labette Shale (Anna shale located at the top).

73.9 Sandstone in Nowata Shale.

73.1-73.4 An unconformity occurs at the irregular contact between the Perry Farm shale and the Idenbro limestone members of the Lenapah Limestone below and the brown Helper sandstone above. The unconformity represents a gap in the geologic record during which sedimentation ceased and erosion occurred. Sedimentation resumed with the deposition of the Hepler sandstone. In places, the erosional surface at the base of the Hepler cuts completely through the underlying Idenbro limestone.

71.8 Wolverine Creek.

71.3 Pawnee Limestone is exposed in cuts for the next 1.3 miles.

68.7 Little Osage Shale Member over the Higginsville Limestone Member of Ft. Scott Limestone.

68.0 Fort Scott Limestone.

67.1 U.S. Highway 54.

66.6 Marmaton River.

66.2 **STOP 1** at the Fort Scott National Historic Site. Restored by the National Park Service, this is the site of the original fort, established in 1842 as an army base on the Indian frontier and situated on an old military trail that ran along the eastern edge of Kansas. The fort, named for Gen. Winfield Scott, was abandoned in 1855, then put back into service again during the Civil War and abandoned afterwards. Today the military barracks, parade grounds, and munitions-storage area are open to the public. We'll make a short stop here to pick up provisions and use the restroom.

65.2 Fort Scott Limestone. This unit is exposed in most cuts through Ft. Scott.

65.0 Fort Scott Limestone.

61.0 Kansas Highway 7.

59.3 Quarry on the east is in the Pawnee Limestone.

57.2 Strip mines on both sides of the highway are in the Mulky coal bed, generally about one foot thick.

55.6 Walnut Creek.

55.4 Strip mines to the west in the Bevier coal.

54.8 West Fork of Drywood Creek.

54.4 Crawford-Bourbon county line.

53.7 Most of the strip mines in this area were in the Bevier coal bed of the Cabaniss Formation.

52.4 Turn east on the road to Arcadia. Reclaimed land of Clemens Coal Company Mine #22 on the is on the north side of the county road. Drive two miles east, then turn south on county road just before the Mine #22 haul road. Mine #22 reclaimed land on both sides of the road. At the intersection about two miles south of the turn off from the Arcadia road is a location where Croweburg, Mineral, and some Bevier coal were mined when, in 1969, the Kansas reclaimed-land law went into effect (east side of the road about 200 feet). Drive five miles south.

STOP NO. 2

Croweburg Mine of Alternate Fuels, Inc.

This mine is an efficient mining and reclamation operation that mines three coal beds in the Cherokee Group. The large pit is a two-seam operation with mining of the Mineral coal at the bottom and the overlying Croweburg coal bed where present. The Croweburg coal crops within the present permit area. Bevier coal is mined from a separate pit in the western part of the permit area where the stratigraphically higher Bevier coal is present.

Bulldozers are used for mining the overburden in the Bevier coal pit and overburden down to the Croweburg coal. A Manitowoc 4600 dragline (7-yard bucket) is used to remove the shales between the Croweburg and Mineral coal beds (a thickness of 20-22 feet).

Coal from the mine, especially the Croweburg and Mineral coals, is trucked from the pit to the company plant for mechanical cleaning of the coal. Shipment is primarily by truck to power plants and cement plants in eastern Kansas and western Missouri. Coal is now being shipped under a new contract to the LaCygne power plant to blend with Mulberry coal.

Alternate Fuels, Inc., has been in operation since 1978. Their main area of mining has been in northern Crawford County, with most mining concentrated on the same three beds we see in this mine--the Mineral, Croweburg, and Bevier coal beds.

From this stop, go west two miles, then turn south on U.S. 69.

47.1 For the next eight miles to the south, from here to Frontenac, U.S. 69 passes over underground mines in the Weir-Pittsburg coal. They range from 75 to more than 200 feet below the ground.

46.4 Two miles to the east is Croweburg, a small mining town that gave its name to the Croweburg coal bed. The Croweburg, which occurs above the Mineral coal bed, has been strip mined throughout this area, though it is generally less than 15 inches thick around here. The Croweburg is found throughout the U.S., extending form central Oklahoma, through Kansas to Iowa, and eastward to eastern Pennsylvania and central West Virginia. The Croweburg coal and its eastern equivalent, the Colchester, represent one of the largest coal swamps that ever existed.

46.2 Follow US-69 around the west side of Arma and Franklin.

43.2 Kansas Highway 57.

41.1 Crawford County State Park, located on land mined for Mineral coal. The Kansas Department of Wildlife and Parks keeps a small herd of buffalo here.

39.1 Intersection with U.S. Highway 160.

38.1 Take US-69 west and south around Pittsburg.

37.4 Crawford County Historical Museum.

36.0 Cow Creek.

30.4 Junction of U.S. 69 and U.S. 160 (Crawford-Cherokee county line).

28.5 Turn west on K-103 toward Weir. Drive 7 miles west, then turn south on K-7. Drive two miles south on K-7, then turn west on K-102. Strip mines from the Mineral coal bed are on the north and south sides of the road. About 3.5 miles west of the K-7 and K-102 intersection is an abandoned pit that was used for washing coal. **STOP 3.**

Proceed west into the town of West Mineral. West of the town, turn south on county road toward large mining shovel.

STOP 4. Lunch and visit to "Big Brutus." Much of the strip-mined land south of this stop was mined as part of the Pittsburg and Midway Coal Mining Company Mine #19. A significant amount of the mining was done by "Brutus," a Bucyrus-Erie 1850-B shovel with a bucket capacity of 90 cubic yards. This large shovel was used in the mining operation from 1963 until 1974 when Mine #19 closed. At the time of its construction in 1962-63, this machine was the second largest mining shovel in existence.

Drive 1.5 miles south on county road from the "Big Brutus" site. Reclamation in this area was part of Mine #19 that resulted from mining the Mineral and Fleming coals under the old Kansas reclamation laws. mined under the old Kansas reclamation laws. Turn east on county road, drive 1.0 miles, then turn north on county road. Go 1 mile north, then turn east and make a loop through orphaned strip mines that have been developed for recreational use--mainly hunting and fishing--by the Kansas Department of Wildlife and Parks. Return to country road and proceed east 4.5 miles to K-7 and turn south. For about 3 miles south along K-7 from this intersection, there is subsidence in fields due to shallow underground coal mining.

12 Intersection of K-7 and US-69 at Columbus. Continue south.

2.2 Intersection with U.S. Highway 166. Go 2 miles west, one south, then 0.5 miles east to **STOP 5.** Here we'll look at remedial control structures to prevent Tar Creek from being captured by collapsed mine workings north of road. See text on EPA and KDHE control of heavy metals in the water of the Pitcher-Treece area. The Tri-State mining district of southwest Missouri, southeast Kansas, and northeast Oklahoma was one of the major mining areas of the world. For one hundred years (1850-1950), the district produced 50 percent of the U.S. zinc and ten percent of the U.S. lead production (Gibson, 1972, p. 401).

The first commercial ore discovery in the district was made in southwest Missouri around 1838, and the first discovery in Kansas was in 1870 at Galena. Stewart (1986, p. 16) describes the peak years of production (in the 1920's) when there were more than 11,000 underground miners in the area with perhaps three times that amount in support work and industries. Production of the ore was mainly from Mississippian rocks present at or near the surface. Important mining was from the Boone Formation carbonates.

The general method of mining Tri-State ores was by underground mining using room and pillar methods. However, the occurrence of ore bodies near the surface in the eastern part of the district resulted in some mining companies trying open-cut mining methods, especially in the Galena area and in Missouri.

North and west of the Galena field, the Cherokee Group of shale, sandstone, and coal beds of Middle Pennsylvanian age overlie the ore-bearing carbonates of Mississippian age. The Cherokee Group becomes progressively thicker northwest from the Galena area due to the regional northwest dip of the rocks and the increase in surface elevation in a west and north direction. With increase in Cherokee thickness, the deeper mines were in the western part of the Tri-State, with the Foley Mine one mile north of Treece, Kansas, being the deepest mine in the Tri-State district with a shaft depth of 480 feet.

Sphalerite and galena were the commercial ore minerals mined in the district. McKnight and Fischer (1970, p. 101) list marcasite and pyrite as commonly occurring with the ores, and the common gangue minerals include jasperoid, dolomite, calcite, and occasionally quartz or barite. A detailed discussion of the mineralogy of the Tri-State district is covered by McKnight and Fisher (1970, p. 101- 124), Brockie, Hare and Dingess (1968, p. 414, 416-417), and Hagni (1962, 1982, 1986).

Forms of the ore bodies have been described by Brockie, Hare and Dingess (1968) as assuming three basic shapes: (1) irregular, relatively narrow, long ore "runs" of varying heights; (2) circular "runs," and (3) flat-lying, generally tabular bodies called "sheet ground" that cover large areas. The most important type of ore body shape in the district was the elongate "long runs."

In addition to the lead and zinc produced in the Tri-State, the district was also an important source of cadmium and germanium that are produced as by-products of the lead/zinc smelting process. Germanium is produced by the Eagle-Picher Industries, Inc., of Quapaw, Oklahoma, and is only one of two domestic producers of primary germanium.

Following the mining of various sub-districts in the Tri-State, large pumps that were used to lower the water below the mining level were shut down and the water allowed to seek static level. With this rise in water, marginal metal reserves were lost. This fact was discussed by McKnight and Fischer (1964, p. 101) in describing the Picher field area of Oklahoma and Kansas as being so extensive and interconnected that the cost of pumping them out again would be prohibitive when balanced against the tonnage and grade of the remaining reserves.

The last operating mine in the Tri-State district was the Swalley Mine located just west of Baxter Springs that was operated by the Eagle-Picher Industries, Inc. This mine closed in 1970 and along with it came the last pumpage of water from the mining district.

The quantity of water required to be pumped from the field for mining was enormous. Ruhl and others (1949, p. 27) describe the volume of water pumped in the Oklahoma-Kansas portion of the district alone as totaling over 36 million gallons a day in 1947. This volume of water was handled by 63 pumping plants, with 28 of this total located in Kansas in the Picher field area.

Problems Resulting from Mining in the Tri-State

In the early 1980's, the U.S. Bureau of Mines became interested in determining the physical hazards associated with the old mining areas. The Bureau of Mines, in cooperation with the state geological surveys, conducted detailed studies in each state. In Missouri the study was conducted by McFarland and Brown (1983), in Kansas by McCauley, Brady, and Wilson (1983), and in Oklahoma by Luza (1983). A summary article of the hazards of the Tri-State was recently published by Dressel, McFarland, and Brown (1986). These studies showed that there are more than 1,500 open mine shafts and nearly 500 subsidence collapse features in the Tri-State.

Since the main areas of the Tri-State to be observed on this field trip are in the Treece and the Galena areas of Kansas, a summary of the surface hazards in these areas is presented mainly from the report by McCauley, Brady, and Wilson (1983). Information on the environmental hazards due mainly to the presence of heavy metals in the surface water and groundwater is mainly from Fuerst (1986) and recent releases of the U.S. Environmental Protection Agency.

Surface Hazards, and Subsidence Problems

Treece

A total of 97 mine hazards were found in the Treece area and most (79) are open shafts. Although there are only 17 surface collapses in this area of intense mining, some of these features are quite large. The largest collapse in the Treece area occurs along the course of Tar Creek in section 2, T.35S., R.23E. This collapse is 230 feet by 430 feet and is about 60 feet deep. Another large collapse is present in section 11, T.35S., R.23E. that is about 180 feet in diameter and is filled with water to within 40 feet of the surface. Its total depth is unknown, but the mine workings are about 300 feet deep. A third large collapse is present in section 7, T.35S., R.24E. This oblong-shaped collapse is 150 feet by 300 feet and is 60 feet deep. It occurs within 300 feet of U.S. highway 69 and is over mine workings that are 300 feet deep. Shallow subsidence occurs just to the southeast of this large collapse that might indicate its direction of growth.

The remainder of the 97 hazards found in the Treece area are the hazardous shafts. Sixty-two of the hazardous shafts are collapsed. Some of these appear to have been filled at one time, but further collapse and settlement of the fill has again made them hazards. These shafts are generally less than 30 feet deep and are thimble-shaped. However, a large number of shafts are collapsed and appear to never have been filled and usually have water in the bottom. Depths have been estimated as high as 200 feet. These collapsed shafts are usually funnel-shaped at the top with diameters of 20 to 40 feet. Recent cave-ins found in the field indicate that many of these collapsed shafts are still growing outward. Most of these shaft openings are surrounded by brush and trees that conceal the potential hazard until it is closely approached.

The remaining 18 hazardous shafts are open but not collapsed, and reach depths up to 200 feet. These shafts are usually rectangular in cross-section with wood cribbing and often have concrete collars.

Mine depths in the Treece area range from 170 feet down to 480 feet. Many of the mines are 300 feet or more in depth.

From STOP 5, proceed east 0.5 miles then south one mile to the old company mining town of Treece. Continue south 0.25 miles through Treece to the stateline road, and proceed east to U.S. 69. Turn south and drive three miles through Picher and the heart of the Picher mining field. Go west 0.75 miles to a bridge and **STOP 6** at the confluence of Tar Creek on the west and a tributary, Lytle Creek, on the east. Just up stream a short distance on Lytle Creek is a spring that dumps a steady flow of mineralized water out onto the surface. The diversion structures at STOP 5 were designed to reduce contamination sources such as these.

Proceed one mile west, turn north and follow the paved road back to Picher and U.S. 69. Go north 1.5 miles to the state line and turn east, following the stateline road five miles to Alternative 69, formerly Route 66. Turn north and proceed through Baxter Springs, the first cowtown in Kansas, and continue four miles to Riverton. At 0.5 miles east of Riverton, cross the Spring River, which marks the western edge of Mississippian rocks in Kansas. East of the Spring River is the Kansas Ozarks.

One mile east of the Spring River is a roadcut in the Warsaw Limestone. Continue 0.5 miles to a county road and turn south. Go south one mile, then east one mile past several small prospect pits. Here you are near the southwest end of the Galena mining area. Continue north to several large mine collapses and **STOP 7**.

Proceed north to Kansas Highway 66 (old U.S. 66) and turn east, continuing into Galena. Turn north on Belvue and proceed to Hell's Half Acre and **STOP 8.**

Galena

A total of 599 mine hazards were found in the Galena area. This represents nearly two-thirds of all the mine hazards found in the Kansas study. Most of the mine hazards in the Galena area are located in seven sections: 11, 13, 14, 15, 22, 23, and 27 in T.34S., R.25E. A large number of mine hazards exist in this area because: 1) shafting was the primary means of exploration, 2) mining was restricted to 200-foot square lots, each one containing a shaft, 3) the deposits were close to the surface, and 4) ore-bearing pillars were routinely robbed. The result, 100 years after the heyday of mining in Galena, is six open adits, seven open pits, 209 surface collapses, and 377 hazardous shafts, many within the city limits of Galena.

Much of the mining in the Galena area is concentrated in a broad arc beginning near the Missouri state line east of Galena in sec. 13, T.34S., R.25E., and extending northwest to the Short Creek bottoms near the Main Street bridge in section 14, then sweeping south and southwest through sections 22, 23, and 27 and ending at the valley of Shoal Creek.

One particularly bad spot in Galena is in the southwest quarter of section 13 and the southeast quarter of section 14. Once the site of the Southside Mine, this area is today called "Hell's Half Acre" by local residents. This area visited on this field trip is a "moonscape" of rubble piles, collapsed mines, and open mine shafts. One of the largest of the 209 surface collapse features in the Galena area are two collapses that together form an opening about 600 feet long and 60 feet deep.

In some cases cave-ins have occurred where either an underground room was close to the surface or the spalling of the roof rock has brought the room close to the surface. In either case, part of the underground workings are exposed at the surface. McCauley (1983, p. 48) described visiting two cave-ins:

> Two such cave-ins were entered in the Southside Mine area in the company of Ralph Cure, a life-long Galena resident who is familiar with its many mine hazards. One mine was entered through surface collapse. This mine opening leads downward and then eastward.

From underground, the penetrations of three mine shafts could be seen through the ceiling. Another mine was entered through a surface collapse in section 14. This mine claimed the life of a boyhood friend of Mr. Cure's about 20 years ago. At that time the mine, according to Mr. Cure, was deeper, having since worked its way to the surface through a succession of roof falls. When this mine was entered in the late summer of 1981, three mine shafts could be seen penetrating what appeared from below to be a very thin roof. At this time Mr. Cure expressed surprise at how much higher the floor of this mine was in comparison to his last visit. It appeared that a large part of the ceiling had fallen in fairly recently. *The mine was vacated at this point and no other mines were entered* [italics added]. If deterioration and spalling of room ceilings is occurring in this mine room, similar conditions are probably occurring in other mine rooms as well. Thus, despite the age of the Galena mine workings, they have probably not reached stability and further mine cave-ins are a possibility.

Whereas most of the surface collapses in the Southside Mine area are dry and are generally less than 60 feet deep, surface collapses in the Short Creek valley of sections 14 and 15 usually contain water. However, three of the largest water bodies in this area are actually open-pit mines. Crane (1901, p. 189-190) states that open-pit mining in the Short Creek valley began in 1901 as the result of a mine cave-in. A study of multidate aerial photography, however, shows that much of the open-pit mining was conducted in the 1940's.

Water-filled surface collapses are also found in the northeast quarter of section 23. The largest of these features is 250 feet by 300 feet, appears to be quite deep and is known locally as the "Blue Hole" because of the vivid color of the water that fills it. Few of the other surface collapses in the Galena area contain water.

Of the 599 hazards in the Galena area, 377 are hazardous shafts and all but 11 are collapsed to some extent. The paucity of uncollapsed shafts in this area can be explained by the age of the shafts and the rotting away of cribbing over the years, and by the widespread occurrence of unconsolidated cherty gravels that mantle most of the outcrops. As a result, the 366 collapsed shafts in and around Galena have the characteristic appearance of inverted cones of loose cherty rubble at or near the angle of repose. These cones narrow down to small square craggy shafts cut through cherty limestone bedrock. The loose rubbly slopes surrounding these shaft-openings make them very hazardous. Since the material above the shaft is at or near the angle of repose, people walking along this slope may set off a small landslide of which they might inadvertently become a part.

According to mine maps, the working levels of most of the mines in the Galena area were shallow, generally less than 100 feet in depth. However, two mines south of Galena, the Hartford Mine in the southeast quarter of section 26, T.34S., R.25E. and the Clermont Mine in the southeast quarter of section 34, T.34S., R.25E., reached depths of 185 feet.

The mine shafts found in the field are estimated to be as deep as 80 feet; however, most are considered to be 30 to 50 feet deep. About half of the shafts contain water. The rough, jagged nature of the rock comprising the walls of these shafts makes them hazardous at any depth. A fall into one of these shafts would seemingly result in as much injury from glancing off the walls as from final impact with the bottom.

The hazardous nature of the many mine shafts and surface collapses in the Galena area is tempered somewhat by the lack of heavy vegetation in most mining areas. The cherty rubble that blankets areas of former intense mining creates a substrate that is too sterile for most types of native vegetation. However, tall grasses grow in some areas where the mine waste is thin or absent and they can conceal open mine shafts.

Following the study of mine stability in the three states, the U.S. Bureau of Mines conducted a project to demonstrate a new approach to closing abandoned mine shafts in the Galena area (Dressel, McFarland, and Brown 1986, p. 51). The Bureau of Mines constructed eleven pyramid-shaped steel forms having bases eight to 12 feet square. The forms were placed pyramid point down into the shaft opening and filled with concrete. Dressel, McFarland and Brown (1986) report that after two years there was no settlement in the concrete plugs.

Surface and Groundwater Problems

In a summary article on environmental problems affecting public health in the Tri-State area, Fuerst (1986) outlined the problems that placed the Cherokee County area in Kansas and the Tar Creek area in Oklahoma on the U.S. Environmental Protection Agency's National Priorities List (NPL) or "Superfund" list. Both of the sites were added to the list because water in the area contained heavy metals from the old mine workings that could contaminate drinking water supplies. There was concern that the metal-laden water would enter shallow private water supplies and also public water supplies that use the deeper Ordovician Roubidoux Formation. Contamination of this deeper aquifer could be by abandoned deep water wells, open exploratory holes, and wells having faulty casings (Fuerst, 1986, p. 55).

Remediation of the problems in the Tar Creek area of Oklahoma and Kansas was the location and plugging of deep wells into the Roubidoux Formation and the diversion of surface water along Tar Creek drainages away from mine collapse areas where the surface water was captured.

Through the summer of 1986, 64 old water wells or open exploration borings that were drilled into the Roubidoux Formation were plugged in the Picher district of Oklahoma and Kansas by the Oklahoma Water Resources Board. Depth of the wells was 900 to 1200 feet (Fuerst, 1986, p. 58-59). Two diversion structures were built in Kansas to divert surface water from entering collapsed mines and going back to the main stream channel. One diversion structure was built in Oklahoma.

In 1983, the EPA added a 110-square mile area of Cherokee County, Kansas, to the National Priorities List. EPA divided the Cherokee County site into six subsites for individual investigation and remediation (Fig. 6). Of interest on this field trip are the Treece and Galena subsites that will be visited.

The largest subsite of the six areas is the Galena subsite that covers approximately 18 square miles. At the Galena subsite, the EPA has determined that metallic compounds containing lead, cadmium, zinc and other contaminants were being released into surface streams and shallow groundwater. Sources of the metals are old mine workings and the chat and waste rock piles on the surface that resulted from the mining and milling operations. The level of metal content in the water could cause deterioration of the environment and present a health hazard to those people who use shallow water-wells in the area (EPA, 1988a; EPA, 1987).

In response to these problems the EPA and the Kansas Department of Health and Environment (KDHE) have developed a preferred remedial action plan for the Galena area (EPA, 1988b) that consists of four parts: 1) The surface-mine wastes will be removed and treated, through milling and flotation, to remove the lead and zinc. This action will reduce the human exposure to the contaminants in the surface wastes and the migration of those contaminants to groundwater and streams. The metals removed from the wastes will be sold to help defray a portion of the costs. The tailings remaining after the removal of the metals will be disposed of in the mine voids; 2) surface drainage will be diverted around specific areas to prevent stream capture by mine shafts and subsidence. The planned diversions include re-establishing the Tributary A stream bed through Hell's Half Acre via a lined channel and channelizing Owl Branch in the Blue Hole area. Lined channels will eliminate surface water recharge to the groundwater system. A portion of Owl Branch will be diverted to Tributary C to reduce surface water flow through the mined areas. This basin is a primary contributor to the metals loading in Short Creek (see Fig. 7 for locations); 3) to reduce surface water ponding and infiltration to the subsurface mineral zones, the surface will be recontoured. The EPA is exploring the use of vegetation to stabilize the soils and control erosion of the recontoured surface; 4) and wells penetrating the Roubidoux aquifer will be examined. Abandoned wells will be plugged. Operating wells will be lined if remediation is necessary. This action will be taken to protect the Roubidoux aquifer from contaminant migration from the shallow aquifer.

The cost of this plan is estimated by EPA to be $5,800,000, with an annual operation and maintenance cost of $10,000.

<u>From STOP 8, proceed north on Smelter Hill road to the site of the old Eagle-Picher Smelter</u>. Note the lack of vegetation on the surrounding hills. <u>Turn west on the paved road ("old old U.S. 66") and continue west along the north edge of Hell's Half Acre to Main Street. Turn south. Continue south 2.5 miles to Schermerhorn Park and cave</u>. **STOP 9**. At the edge of the park is Schermerhorn

Cave. According to the Kansas Speleological Society, this cave extends 2,566 feet back into Keokuk Limestone. The KSS says the cave is home to eastern Pipistrelle bats, gray bats, grotto salamanders, cave salamanders, and dark-sided salamanders. This is a also a good stop to view native Ozark flora and fauna, but watch out for poison ivy and mosquitoes.

If time permits, we'll proceed to the south edge of Joplin and **STOP 10** at Grand Falls on Shoal Creek, about six miles upstream from Schermerhorn Park. The falls flow across the Grand Falls chert in the Reeds Spring and Elsey formations.

References Cited

Brichta, L.C., 1960, Catalog of recorded exploration drilling and mine workings, Tri-State zinc-lead district, Missouri, Kansas, and Oklahoma: U.S. Bureau of Mines IC7993, 13 p.

Brockie, D.C., and Hare, E.H., 1963, Geological tour of the Westside- Webber Mines in Guidebook to the geology in the vicinity of Joplin, Missouri, including Westside-Webber Mine (Guidebook to 10th annual field trip): Association of Missouri Geologists, p., 15-26.

Brockie, D.C., Hare, E.H., and Dingess, P.R., 1968, The geology of ore deposits of the Tri-State district of Missouri, Kansas, and Oklahoma, in Ridge, J.D. (ed.), Ore deposits of the United States, 1933-1967: American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, p. 400-430.

Buchanan, R.C., and McCauley, J.R., 1987, Roadside Kansas--A traveler's guide to its geology and landmarks: University Press of Kansas, Lawrence, Kansas, 365 p.

Crane, W.R., 1901, Methods of prospecting, mining, and milling in Kansas lead and zinc district: Kansas Geological Survey, v. 8, p. 177-387.

Dressel, W.M., McFarland, M.C., and Brown, J.C., 1986, Post-mining hazards of the Kansas-Missouri-Oklahoma Tri-State zinc-lead mining district in Guidebook to the geology and environmental concerns in the Tri-State lead-zinc district, Missouri, Kansas, Oklahoma: Guidebook to 33rd annual meeting and field trip, Association of Missouri Geologists, p. 47-54.

Energy Information Administration, 1987, Cost and quality of fuels for electric utility plants 1986: Energy Information Administration, DOE/EIA-0191(86), 223 p.

Environmental Protection Agency, 1987, Record of decision--operable unit remedial alternative selection, Cherokee County site-- Galena subsite, 27 p.

Environmental Protection Agency, 1988a, Fact sheet, Cherokee County site--Galena subsite, 2 p.

Environmental Protection Agency, 1988b, Proposed plan for groundwater and surface water operable unit, Cherokee County site--Galena subsite, 4 p.

Environmental Protection Agency, 1988c, Groundwater and surface water operable unit feasibility study--final draft, Cherokee County site--Galena subsite, 359 p.

Fuerst, A.C., 1986, Environmental hazards and corrective actions, associated with the Tri-State lead and zinc mining district, Kansas and Oklahoma; in Guidebook to the geology and environmental concerns in the Tri-State lead-zinc district, Missouri, Kansas, Oklahoma: Guidebook to 33rd annual meeting and field trip, Association of Missouri Geologists, p. 55-59.

Gibson, A.M., 1972, Wilderness bonanza--the Tri-State district of Missouri, Kansas, and Oklahoma: University of Oklahoma Press, Norman, Oklahoma, 362 p.

Hagni, R.D., 1962, Mineral paragenesis and trace element distribution in the Tri-State zinc-lead district, Missouri, Kansas, and Oklahoma: Ph.D. dissertation, University of Missouri-Columbia, 252 p.

Hagni, R.D., 1982, The influence of original host rock character upon alternation and mineralization in the Tri-State district of Missouri, Kansas, and Oklahoma, U.S.A.; in Amstutz, G.C., ElGoresy A., Frenzel, G., Kluth, C., Moh, G., Wauschkuhn, A., and Zimmermann, R.A. (eds.): Ore Genesis--The state of the art, Springer-Verlag, Berlin, p. 97-107.

Hagni, R.D., 1986, A summary of the geology of the ore deposits of the Tri-State district, Missouri, Kansas, and Oklahoma; in Guidebook to the geology and environmental concerns in the Tri-State lead-zinc district, Missouri, Kansas, Oklahoma: Guidebook to 33rd annual meeting and field trip, Association of Missouri Geologists, p. 30-46.

Luza, K.V., 1983, A study of stability problems and hazard evaluation of the Oklahoma portion of the Tri-State mining area (Contract J0100133, Oklahoma Geological Survey): U.S. Bureau of Mines OFR 76-83, 147 p.

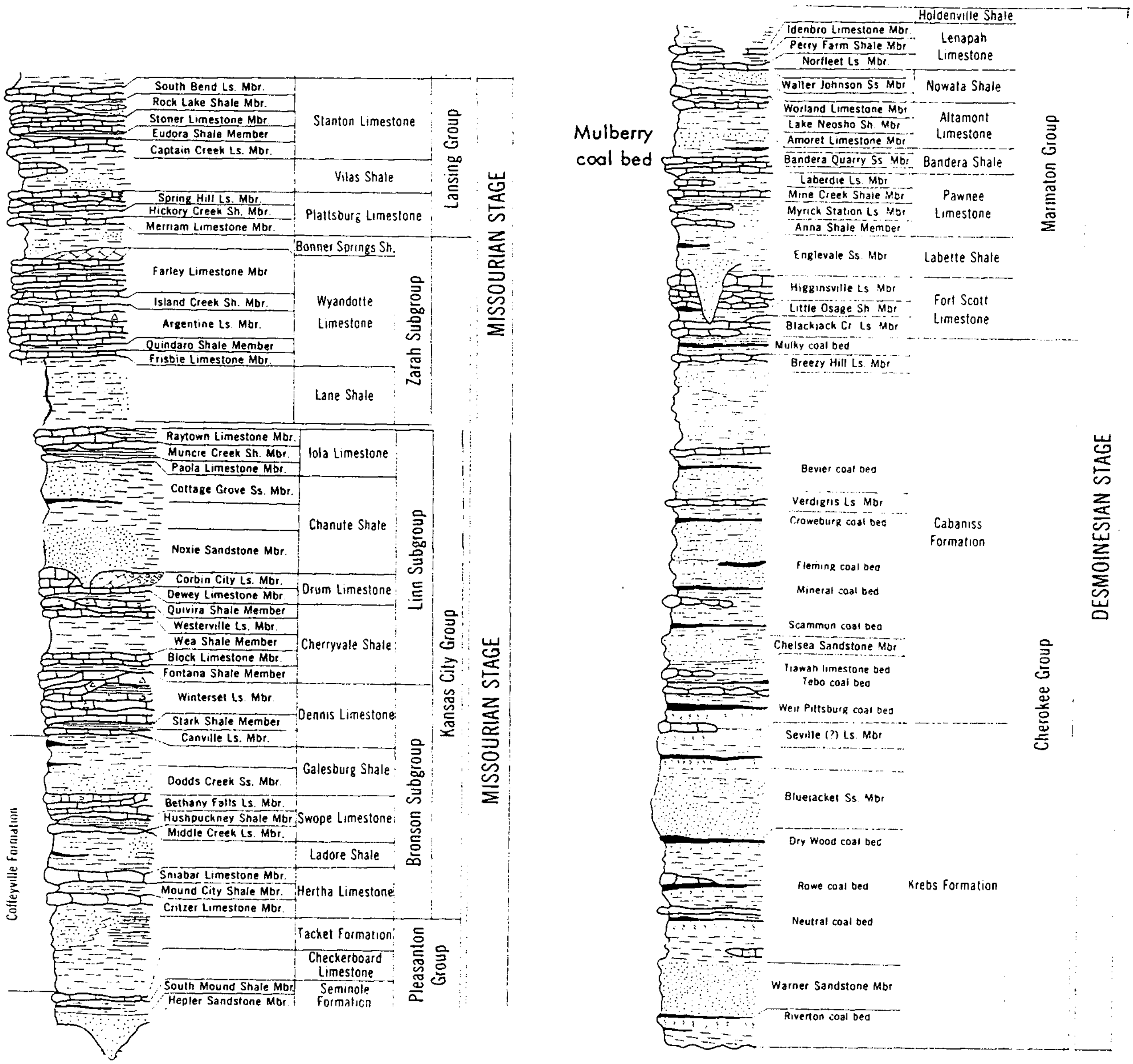
McCauley, J.R., Brady, L.L., and Wilson, F.W., 1983, Study of stability problems and hazard evaluation of the Kansas portion of the Tri-State mining area (Contract J0100131, Kansas Geological Survey): U.S. Bureau of Mines OFR 75-83, McFarland, M.C., and Brown, J.C., 1983, Study of stability problems and hazard evaluation in the Missouri portion of the Tri-State mining area (Contract J0100132, Missouri Department of Natural Resources, Division of Geology and Land Survey): U.S. Bureau of Mines OFR 97-83, 141 p.

McKnight, E.T., and Fischer, R.P., 1970, Geology and ore deposits of the Pitcher field, Oklahoma and Kansas: U.S. Geological Survey Prof. Paper 588, 162 p.

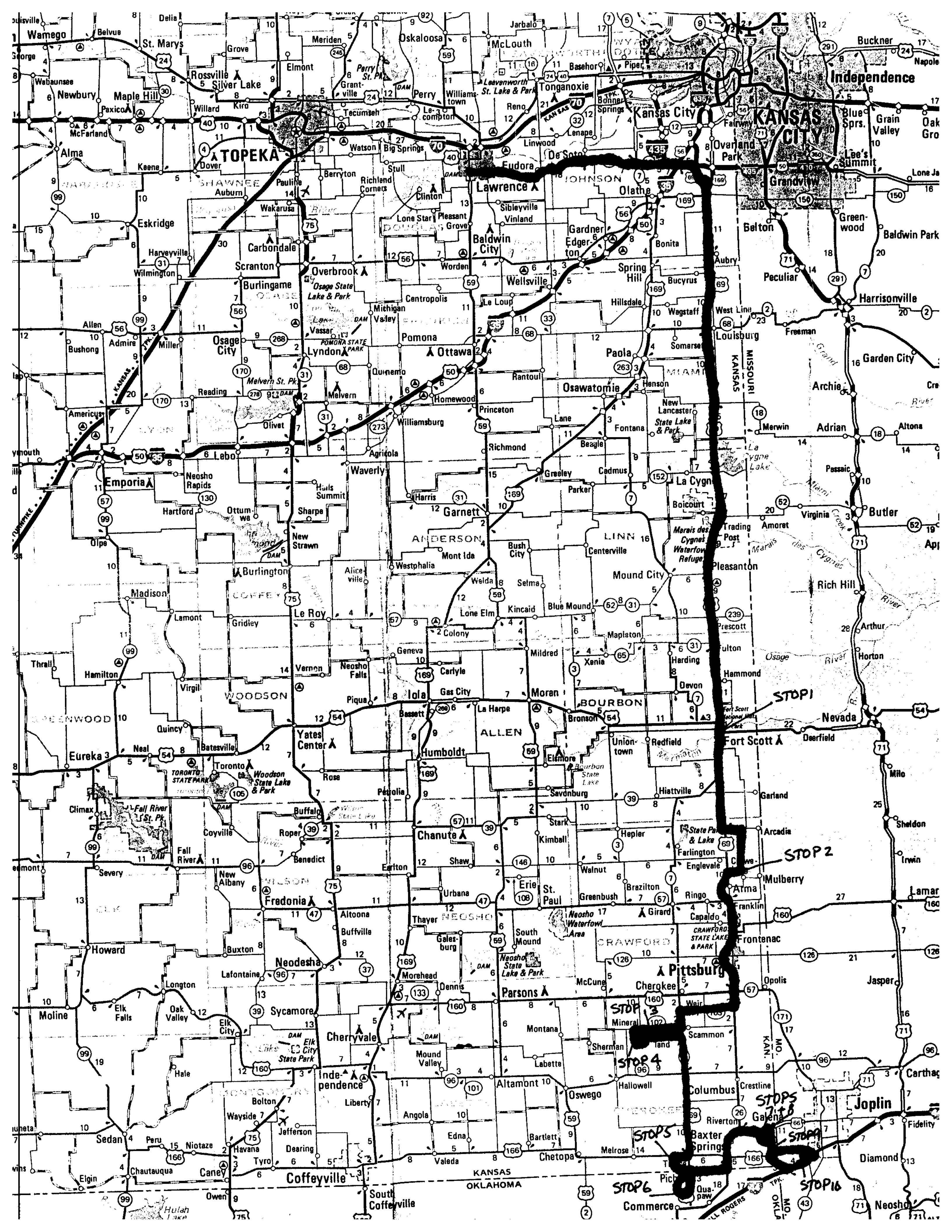
Ruhl, O., Allen, S.A., and Holt, S.P., 1949, Zinc-lead ore reserves of the Tri-State district, Missouri-Kansas-Oklahoma: U.S. Bureau of Mines RI 4490, 59 p.

Stewart, D.R., 1986, A brief description of the historical, ore production, mine pumping, and prospecting aspects of the Tri- State zinc-lead district of Missouri, Kansas, and Oklahoma; in Guidebook to the geology and environmental concerns in the Tri- State lead-zinc district, Missouri, Kansas, Oklahoma: Guidebook to 33rd annual meeting and field trip, Association of Missouri Geologists, p. 16-29.

Zeller, D.E., (ed.), 1968, The stratigraphic succession in Kansas: Kansas Geological Survey Bulletin 189, 81 p.



General stratigraphic sequence of Pennsylvanian rocks along field trip route [column modified from Zeller (1968)].



STOP1
STOP 2
STOP 3
STOP 4
STOP5
STOP6
STOPS 7+8
STOP9
STOP10
KANSAS
OKLAHOMA
MISSOURI
KANSAS CITY
TOPEKA
Lawrence
Olathe
Ottawa
Emporia
Garnett
Iola
Fort Scott
Pittsburg
Parsons
Chanute
Independence
Coffeyville
Columbus
Baxter Springs
Galena
Joplin
Nevada
Commerce