GUIDEBOOK TO THE WELDON SPRING AREA, ST. CHARLES COUNTY, AND GEOLOGY AND UTILIZATION OF INDUSTRIAL MINERALS IN ST. LOUIS COUNTY, MISSOURI

ASSOCIATION OF MISSOURI GEOLOGISTS
34th Annual Meeting and Field Trip
September 25 and 26, 1987
St. Charles, Missouri

Sponsored by the
Missouri Department of Natural Resources
Division of Geology and Land Survey
Rolla, Missouri
and the
U.S. Department of Energy
Weldon Spring, Missouri

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ROAD LOG

Weldon Spring Chemical Plant to the Community of Weldon Spring via August A. Busch Memorial Wildlife Area Including Lake 13, Lake 35, Lake 34, and Burgermeister Spring

by
David Hoffman and Peter Price

Mileage		
Dif.	**Cum.**	
-	0.0	Begin road log on Missouri Highway 94, at the main entrance gate to the Weldon Spring Chemical Plant. Proceed northeast on Missouri Highway 94 (east).
0.1	0.1	Cross old railroad right-of-way (now abandoned). Rail line served the TNT production plant during World War II.
0.1	0.2	Missouri Highway and Transportation Department maintenance yard entrance on left. Proceed straight ahead.
0.1	0.3	Road junction straight ahead. Curve to the right and stay on Highway 94.
0.4	0.7	Francis Howell High School campus on left. The older buildings were built during World War II as a box factory for the TNT plant. After the war the buildings were given to St. Charles County; they are currently part of the high school.
0.3	1.0	Junction Highway D. Turn left onto Highway D. August A. Busch Memorial Wildlife Area property is on both sides of Highway D. Lake 9 is on left.
0.3	1.3	North side of Francis Howell High School campus is on left.
0.4	1.7	Road junction. Proceed straight ahead. Busch Wildlife Area Lake 10 on left.
0.3	2.0	Drainage passes under road from left (south) to right (north). This drainage comes (from the left) from Frog Pond, on the northeast side of the Weldon Spring Chemical Plant. The drainage goes (to the right) to Busch Wildlife Area Lake 36 and then to Schote Creek. This drainage will be referred to as Frog Pond Branch (from its headwaters down to Schote Creek).
0.5	2.5	Drainage passes under road from left (south) to right (north). This drainage comes (from the left) from the west side of the raffinate pits and the Ash Pond area of the Weldon Spring Chemical Plant site and from small tributaries on the east end of the Weldon Spring Training Area (Army Reserve). This drainage, referred to as Sewage Lagoon Fork, named in honor of the sewage lagoon (which serves the Busch Wildlife Area Headquarters Area) near the mouth of the drainage where it drains into Schote Creek. Just upstream (to the south or left) of Highway D this

drainage loses all its flow into the subsurface, except during runoff from heavy rainfall. The subsurface at that point is permeable cherty clay residuum over karstic Burlington Limestone. Upstream of the loss zone the Burlington Limestone and residuum are covered by weakly permeable glacial till. Water-tracing tests show that the lost water reappears at Burgermeister Spring, approximately 1 mi northward. A short way upstream of Highway D, Sewage Lagoon Fork branches into three tributaries. The southeast tributary (which drains to the northwest) is referred to as Ash Pond Branch. It drains the northwest and central portion of the Weldon Spring Chemical Plant, including Ash Pond and the area north and east of the raffinate pits. This branch loses its flow to the subsurface above its junction with Sewage Lagoon Fork. The south tributary (which drains north) is referred to as West Raffinate Pit Branch. It drains the area on the west side of the Weldon Spring Chemical Plant, including the west side of the raffinate pits, and the extreme east end of the Weldon Spring Training Area. The southwest tributary (which drains northeast) is referred to as Ditch 4A. It drains an area near the east end of the Weldon Spring Training Area.

0.15	2.65	Junction with main entrance road to August A. Busch Memorial Wildlife Area. Turn right into Busch Wildlife Area, which is operated by the Missouri Department of Conservation.
0.1	2.75	End of entrance drive. Parking area. Turn left and proceed west through parking area.
0.05	2.8	Entrance gate. Proceed straight ahead.
0.1	2.9	Junction. Turn right on Busch Wildlife Area Road A. Ahden Knight Hampton Memorial Lake is on left.
0.05	2.95	Junction. Turn right onto gravel road toward Lakes 11, 12, 30 and 36. Maintenance yard is on right.
0.25	3.2	Waste stabilization (sewage) lagoon is on right.
0.05	3.25	Drainage passes under road from right (south) to left (north). This is the Sewage Lagoon Fork. Schote Creek is about 100 ft to the left (north). Sewage Lagoon Fork is normally dry at this point, as all flow is lost to the subsurface about 0.3 mi to the south, at about elevation 580 to 590 ft M.S.L. Schote Creek is also normally dry at this point because of water loss to the subsurface. Schote Creek is at about elevation 560 to 570 ft M.S.L. in this area. Water lost in Sewage Lagoon Fork passes underneath the dry bed of Schote Creek and proceeds north another 0.7 mi to reappear on the surface at Burgermeister Spring, which is at about elevation 530 ft M.S.L. Enroute, the subsurface flow in the karstic Burlington Limestone passes underneath the ridge separating Schote Creek from Burgermeister Branch valley. This ridge has an elevation of from 590 to 620 ft M.S.L., which means the flow has to be about 50 ft below the surface where it passes under the ridge. Water-tracing tests show that the 1 mi subsurface travel time is less than 4 days.
0.1	3.35	Junction. Proceed straight ahead. The road to right goes to Lake 36, which was created by damming Frog Pond Branch, which drains the northeast side of the Weldon Spring Chemical Plant. The road to the left "ends" after about 200 ft at the edge of Schote Creek, which at that point is normally dry and

shows typical characteristics of losing streams commonly found in the Ozarks. Some of these characteristics include a non-graded streambed and poorly sorted sediments.

0.1 3.45 Drainage passes under road from right (south) to left (north). This is Frog Pond Branch, which drains the northeast side of the Weldon Spring Chemical Plant and has been dammed up to form Lake 36.

The dam for Lake 36 can be seen about 50 yd to the right (south). Frog Pond Branch normally does not have sufficient flow to keep Lake 36 full. Because the runoff into Lake 36 should greatly exceed evaporation, it is assumed that water is leaking from the bottom of Lake 36, a common occurrence in Ozark karst areas. The leaking water becomes part of the shallow karst groundwater system.

A leak in the drop inlet spillway system for Lake 36 allows a small flow of water to exit the spillway pipe, and thereby provides a small flow to Frog Pond Branch below the dam, even when the lake is not full. This flow stays on the surface to the mouth of Frog Pond Branch, which is about 0.1 mi to the north. Flow is lost into the subsurface as soon as it enters Schote Creek's dry channel.

0.3 3.75 Y-junction. Veer left toward Lakes 11, 12, and 30.

0.25 4.0 Y-junction. Veer left toward Lakes 11 and 12.

0.6 4.6 T-junction. Go left toward Lake 12 (road to the right goes to Lake 11).

0.25 4.85 STOP 1: FORMER LAKE 13.

Park at the end of the road by the dam for Lake 12. Do not block turn around area. Pull off into grass.

Walk west across crest of dam for Lake 12. At west end of dam for Lake 12 note that there is a dike running to the south that forms the west side of Lake 12. The basin for the former Lake 13 is on the west side of this dike. A small pond or swamp occupying a small portion of the Lake 13 basin may be seen just west of the dike.

Continue walking west along the crest of the dam for Lake 13 (this is collinear with the crest of the dam for Lake 12). After about 100 yd veer to the left and enter the dry basin of Lake 13, where a 50-yd-diameter clearing exists about 100 ft south of the dam. Near the center of the clearing (and by an isolated tree) is a compound double sinkhole.

Lake 13 is reported to have been built in the late 1950's, and to have filled and remained full for only a few months. One night the lake drained out through the newly formed sinkholes.

The current sinkholes are about 6 to 8 ft deep and about 15 to 20 ft in diameter. Only soil is exposed in the sides of the sinkholes. Water apparently still drains freely into the sinkholes and into the underlying karstic Burlington Limestone.

Return to cars.

-	4.85	Leave Lake 12 parking area by returning back along the road by which you entered.
0.25	5.1	Junction. Turn right (road straight ahead goes to Lake 11).
0.7	5.8	Junction. Proceed straight ahead (road to left goes to Lake 30).
0.2	6.0	Junction. Proceed straight ahead. Overgrown road to right is an abandoned county road that goes to and crosses Schote Creek at the head of Lake 35. STOP 2 is at the head of Lake 35 near where the bridge for this abandoned road crosses Schote Creek. STOP 2 is accessed via the road on the north (opposite) side of Schote Creek. On the left, just before the junction of the road to the left, is the site of the former Shaw residence. An old well here has been used for groundwater-level determinations. In addition, a new groundwater-monitoring well was installed here by the U.S. Geological Survey.
0.4	6.4	Junction. Proceed straight ahead (road to left goes to Lake 36.)
0.1	6.5	Waste stabilization lagoon on left.
0.25	6.75	T-junction with Road A. Turn right. You will drive across the crest of the dam for Ahden Knight Hampton Memorial Lake. The dip in the roadway marks where the road passes through the emergency spillway for the dam. The lake was formed by damming Schote Creek.
0.1	6.85	Cross junction. Turn right onto Road C toward Lakes 24, 34, and 35.
0.6	7.45	Junction. Turn right toward Lakes 24, 34, and 35 (road C goes straight ahead.)
0.2	7.65	Junction. Turn right (southeast) toward upper end of Lake 35. (Road straight ahead goes to Lakes 24, 34, and 35, lower end.) This road leading to the upper end of Lake 35 is the continuation of the abandoned county road mentioned at cummulative mileage 6.0.
0.15	7.8	STOP 2: SWALLET, OR SWALLOW HOLE, AT UPPER END OF LAKE 35.

Turn left into parking area at upper end of Lake 35 and park. Road straight ahead is closed to auto traffic; it is the continuation of the abandoned county road.

Walk southeast along the abandoned county road and cross the bridge over the upper end of Lake 35, which was formed by damming Schote Creek. Just after crossing the bridge, turn left (north) into the brush and weeds and head toward the easternmost finger of the upper end of Lake 35. It is about 100 ft from the road to the eastern finger of the lake. Proceed north along the eastern side of the finger for about 100 ft.

If the lake level is low, a swallet, or swallow hole, in the lake basin is exposed here. During high lake stages, the swallet drains water from Lake 35. During low stages of the lake (after the water level has lowered, due to this and other leakage areas) the swallet becomes isolated from the remainder of Lake 35 by higher ground about 50 yd to the north. During this condition, the swallet drains and the 4-ft-deep by 6-ft-diameter swallow hole is exposed. The visible swallow hole is entirely in alluvial soil with no bedrock exposed.

Reports from Department of Conservation personnel indicate that Lake 35 was built in 1961 and 1962 and has always had a leakage problem. The lake fills during rainy weather but water level drops when runoff stops. Leakage through the rock (Burlington Limestone) along the southeast side of the lake about 600-800 ft upstream of the dam has long been known or suspected. With time the leakage rate has increased. During the fall of 1986 the swallet at this stop first appeared.

After rainy weather the lake fills up and water flows out the spillway. After runoff stops and if there is no more rain, Lake 35 is reported to drop about 8 ft in 3 to 4 weeks; eventually the lake level will stabilize at about 12 to 13 ft below the spillway level. If these figures are correct and the surface area of Lake 35 is 50 acres (our estimate), then the average leakage rate for the first 8 ft of loss is between 7 and 10 ft^3 per second or about 3200 to 4300 gpm.

Water-tracing dye was injected in the swallet at the upper end of Lake 35. The dye was recovered in Burgermeister Branch valley below Lake 34, and in water entering the spillway for Lake 34. No dye was recovered from the stream entering Lake 34. This demonstrates that water is lost out of the bottom of Schote Creek valley, passes under the low ridge (approximately 30 ft higher than the full lake level for Lake 35) to the northwest, and resurfaces in Burgermeister Branch valley. Burgermeister Branch valley is about 30 ft lower in elevation than Schote Creek valley and about 0.5 mi to the northwest. The dye was detected at the spillway of Lake 34 between 3 and 6 days after injection. Elapsed time included travel time in the slow moving water of Lake 34.

Return to cars.

-	7.8	Leave parking area at upper end of Lake 35 by returning along the road by which you entered.
0.1	7.9	T-junction. Turn right toward Lakes 24, 34, and 35 (lower end). (Road to the left is the road by which you entered.) The overgrown road straight ahead is the continuation of the abandoned county road, which goes to Burgermeister Branch valley, near Burgermeister Spring, upstream of Lake 34. Burgermeister Spring is STOP 3 but will be accessed via a better road on the opposite side (west side) of Burgermeister Branch Valley.
0.1	8.0	Lake 24 on the left.
0.1	8.1	Y-junction. Veer right toward Lake 35 (lower end). (Branch to the left leads to Lake 34.)
0.3	8.4	Y-junction. Veer left toward Lake 35 dam. Road to right leads to Lake 35 boat ramp (middle part of Lake 35).
0.4	8.8	Junction. Go straight ahead to dam for Lake 34.
0.15	8.95	Loop at end of road and parking area for access to dam for Lake 34.
0.15	9.1	Junction. Turn right toward upper end of Lake 34.
0.1	9.2	Junction. Veer left (road to right leads to Lake 34 boat ramp).
0.3	9.5	Junction. Go straight ahead. Road to the right leads to upper end of Lake 34. Look to the right just before road junction. The orange pipe cap for a U.S. Geological Survey groundwater-monitoring well may be seen low in the grass.

0.05	9.55	Y-junction. Veer right. You have just completed a loop drive and are now retracing a portion on your route.
0.05	9.6	Lake 24 on right.
0.15	9.75	Junction with old county road. Proceed straight ahead.
0.2	9.95	T-junction with Road C. Turn right toward Lakes 22 and 23. (Road to the left is the road by which you entered.)
0.15	10.1	Drainage passes under road from left (south) to right (north). This is a tributary drainage to Burgermeister Branch. Burgermeister Spring is located at the mouth of this tributary.
0.2	10.3	Drainage passes under road from left (southwest) to right (northeast). This is Burgermeister Branch. Two springs are upstream of this road crossing. The perennial spring about 400 ft upstream will be referred to as Francis Howell Cemetery Spring; it rises through the gravel, sand, and silt of the streambed. The other spring is a wet weather spring about 75 ft upstream of the road which will be referred to as the Francis Howell Cemetery Wet Weather Spring; it issues from the left bank (east) of the valley.
		A water-tracing test showed that dye injected just west of the Weldon Spring Chemical Plant, in the West Raffinate Pit Branch, flowed to Francis Howell Cemetery Spring as well as Burgermeister Spring. The elevation at the injection site is about 600 ft M.S.L.; at Francis Howell Cemetery Spring, 543.8 ft M.S.L.; and at Burgermeister Spring, 532.3 ft M.S.L. Flow had to pass underneath Schote Creek valley, which has a bottom elevation of about 580 ft M.S.L. along the line between the injection and recovery points. Travel time for dye to traverse the 1 mi distance was less than 5 days.
0.1	10.4	T-junction. Turn right and stay on Road C toward Lakes 22 and 23.
0.2	10.6	Junction. Turn right toward Lake 22 (road straight ahead is Road C, which goes toward Lake 23).
0.15	10.75	Lake 22 on left and parking on right. Proceed straight ahead.
0.1	10.85	STOP 3: BURGERMEISTER SPRING
		Park in clearing just before road enters the woods. Road is closed to vehicle traffic beyond this point. This is the abandoned county road that was crossed previously.
		Walk down the abandoned county road to the south and east to Burgermeister Branch Creek. Cross it and turn right (southwest) into the woods, brush, and weeds. An unmaintained foot-path leads into the woods. Follow this path upstream along the east bank of Burgermeister Branch. After about 50 yd a tributary enters Burgermeister Branch from the left. Stay on the path that proceeds up this tributary. Within 50 ft is a U.S. Geological Survey stream-gaging station that gages the flow of Burgermeister Spring. The station consists of a calibrated aluminum weir and a water-level recorder.
		Cross below the wier and continue along the path. The path becomes more difficult to find and follow in this area. In about 50 yd the spring rise is

reached. A low concrete foundation is located in and around the spring rise. This is Burgermeister Spring, a perennial spring.

Two water-tracing tests have been conducted from on or near the Weldon Spring Chemical Plant to Burgermeister Spring. One test has been described at cummulative mileage 10.3. The dye injection point for the second test was in Ash Pond Branch, at about elevation 600 ft. Dye was recovered from Burgermeister Spring at elevation 523.3 ft M.S.L. The flow had to pass under Schote Creek valley where the valley bottom elevation is about 560 ft M.S.L. Travel time for the 1-mi distance between the injection and detection points was less than 4 days.

Adjacent to Burgermeister Spring is an intermittent spring referred to as the Burgermeister Wet Weather Spring (elevation 534.6 ft M.S.L.); it serves as an overflow when high flows are too large to be accommodated by Burgermeister Spring. Consequently, Burgermeister has a fairly constant flow of about 0.1 to 0.7 ft^3 per second (based on 1 year of gaging data), but Burgermeister Wet Weather Spring has a very erratic flow varying from long periods of zero flow up to 3.7 ft^3 per second (based on the same 1 year of gaging data).

To see Burgermeister Wet Weather Spring, continue up the tributary valley and the even fainter trail. After about 50 yd and on the opposite side of the valley (southwest side of the valley) the Burgermeister Wet Weather Spring is reached. Look for the U.S.G.S. water-level recorder used to gage flow in the spring rise basin.

Return to cars.

-	10.85	Leave parking area by returning along road by which you entered.
0.25	11.1	T-junction with Road C. Turn left to retrace route.
0.1	11.2	Junction. Proceed straight ahead (road to the left is Road C).
0.15	11.35	Junction with Road A. Proceed straight ahead (road to right is Road A leading to Lakes 3 and 4).
0.05	11.4	Francis Howell Cemetery on right.
0.1	11.5	T-junction. Turn left and stay on Road A.
0.25	11.75	Bunker 15. Bunkers like this were used during World War II to store TNT manufactured at the Weldon Spring Ordnance Works. They are widely spaced to prevent an explosion at one from causing explosions at others. There are 100 bunkers; all are on what is now the Busch Wildlife Area. Most are sealed shut, but a few are used for storage by the Department of Conservation.
0.1	11.85	Junction. Go straight ahead.
0.2	12.05	Cross junction and proceed straight ahead on Road A (road to the left is Road C). Cross Ahden Knight Hampton Memorial Lake Dam.
0.2	12.25	T-junction. Turn left to leave Busch Wildlife Area.
0.05	12.3	Entrance gate. Proceed straight ahead.

0.05	12.35	Turn right onto entrance drive.
0.1	12.45	T-junction with Highway D. Turn left (east).
1.65	14.1	T-junction with Missouri Highway 94. Turn left (east) toward St. Charles.
1.2	15.3	Junction (center of overpass) with U.S. Highways 40 and 61. Proceed straight ahead.
0.2	15.5	Weldon Spring on right (southeast). Spring is below road level along paved drainage ditch and is almost opposite junction of road to the left, which leads into village of Weldon Spring. A concrete stairway leads down from the highway shoulder to the spring.
		END OF THE FIELD TRIP
		PROCEED STRAIGHT AHEAD TO RETURN TO THE MOTEL FOR THE EVENING BANQUET AND MEETING IN ST. CHARLES.
3.5	19.0	Junction with Highway N. Proceed straight ahead on Missouri Highway 94.
7.3	26.3	Junction with on-ramp for Interstate Highway 70. Turn right (east) on I-70. Stay in right lane to exit at next interchange.
0.8	27.1	Exit I-70 at exit 229 (5th Street). Noah's Ark Motor Inn is straight ahead (east across 5th Street) at the end of the exit ramp.

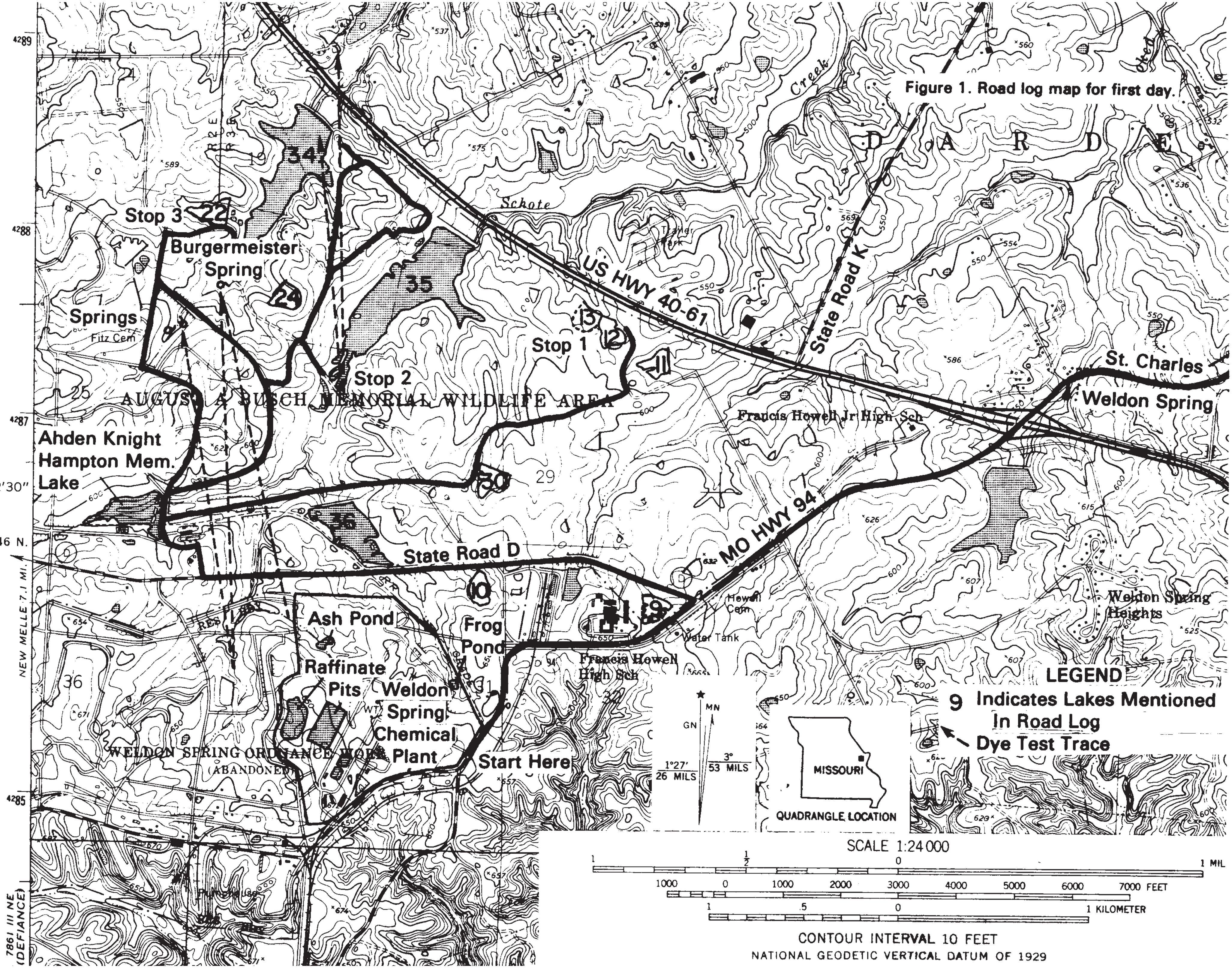

Figure 1. Road log map for first day.

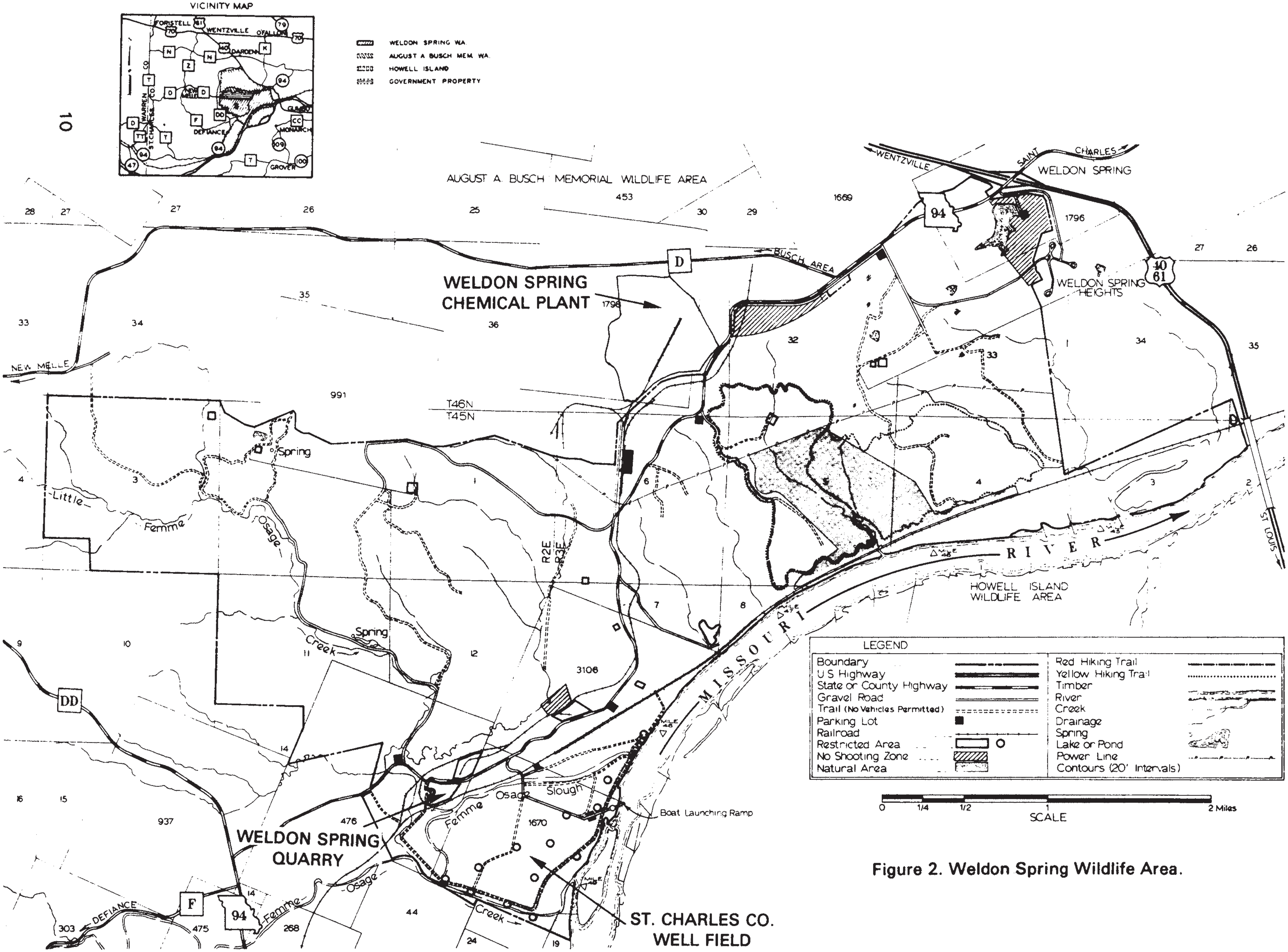

Figure 2. Weldon Spring Wildlife Area.

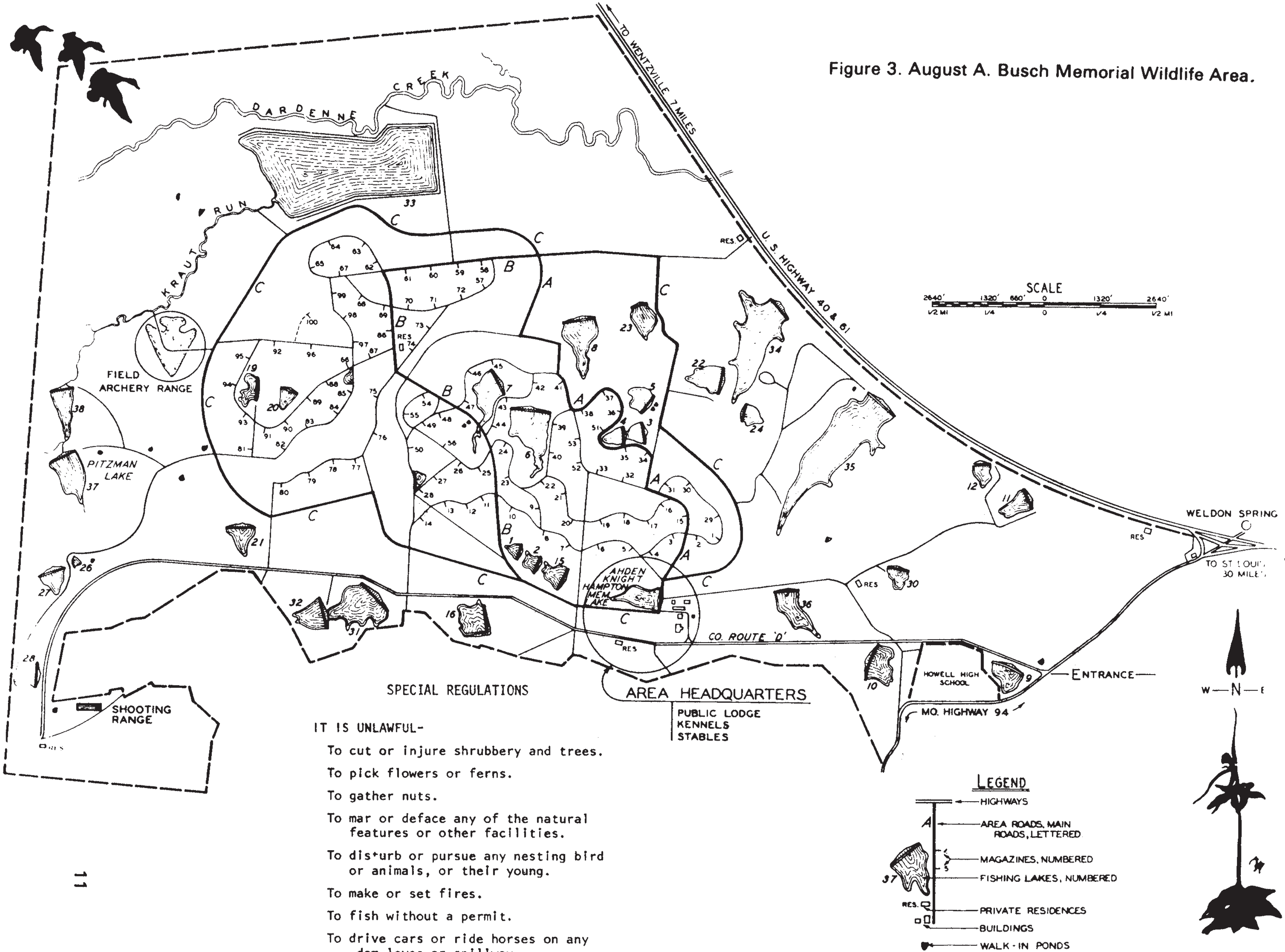

Figure 3. August A. Busch Memorial Wildlife Area.

SPECIAL REGULATIONS

IT IS UNLAWFUL-

To cut or injure shrubbery and trees.

To pick flowers or ferns.

To gather nuts.

To mar or deface any of the natural features or other facilities.

To disturb or pursue any nesting bird or animals, or their young.

To make or set fires.

To fish without a permit.

To drive cars or ride horses on any dam levee or spillway.

-Violators Will Be Prosecuted-

ROAD LOG FROM BUSSEN-JEFFERSON BARRACKS QUARRY (STOP 1) TO VIGUS NORTH QUARRY (STOP 2)

0.0	West on ramp to I-255 at Koch Road. St. Louis Limestone: lower 6-12 ft dolomitic; upper 15-30 ft fine-grained to crystalline limestone. Note irregular contact between two units. Believed to represent an erosional unconformity, because of surface features of underlying bed and deposition of additional beds at base of upper unit.
0.7	Jefferson Barracks exit.
1.0	Overpass.
1.3	St. Louis Limestone left.
2.0	Lindbergh Boulevard exit.
2.5-2.8	St. Louis Limestone on both sides.
2.9	I-55 north exit.
3.2	I-55 south exit. Take this ramp and drive south on I-55
3.6	St. Louis Limestone. Good exposures of limestone along south-bound entrance to I-55 and along I-55.
3.8-4.0	St. Louis Limestone (close to Salem in railroad).
4.1-4.3	St. Louis Limestone. Note solution and karst features along with dolomitization
4.6	St. Louis Limestone.
4.8	Butler Hill exit ramp.
5.4-5.6	St. Louis Limestone. Good section both sides.
5.9	Good exposures of St. Louis Limestone on both sides.
6.35	St. Louis Limestone-Salem Formation contact near mile post 194 on north-bound lane (fig. 9).
6.8	Meramec Bottom Road.
7.5	Meramec River.
8.1	Turn onto Hwy. 141 and drive west.
8.3	St. Louis Limestone on both sides; cross bedding; extremely coarse- and fine-grained texture.
8.7	Arnold Church Road.
9.1	St. Louis Limestone on left (south). Note shale pocket

9.6	Lonedell Road intersection.
9.7-10.3	Series roadcuts of very basal St. Louis Limestone, all of the Salem Formation, and the upper portion of the Warsaw Formation. Contact placed at bench level on left side of road. Contact is an irregular surface containing pockets of shale, quartz sand, and chert fragments. The basal St. Louis limestone contains several lithographic beds and a good section of cross-bedded calcarenite. The upper Salem is mostly fine calcarenite, somewhat dolomitic, and contains considerable chert; especially noticeable are several "bulls-eye" cherts. Of interest is the earthy, dolomitic appearance of the Salem. Lower Salem carbonates are characteristically even-textured calcarenites. Shale percentage increases dramatically toward base of hill. Note irregular contact between lower limestone and shale (fig. 10).
10.8	Contact between Warsaw and Salem Formations near top of hill. Contact is arbitrary, as no well-defined contact exists because of lateral lithologic changes.
11.4	Junction Hwys. 21 and 141. Continue west on Hwy. 141.
11.9	Roadcut is mostly Warsaw with Salem contact near top. Warsaw in this area appears atypically shaly as shale content decreases north and south (fig. 11).
13.4-13.6	Warsaw limestone and shale; cherty.
13.8-14.1	Salem Formation.
14.7	Salem Formation.
15.3	Gravois Road.
15.4	Turn right onto Hwy. 30 east.
15.6	Warsaw Formation.
15.7	Warsaw Formation. Salem Formation near top.
15.8	Meramec River.
17.3-17.8	Salem Formation. Roadcut to left contains bed of extremely coarse fossil debris. Note difference in lithology across highway. Note presence of "bulls-eye" cherts near upper part of section. Heavy chert unit near top of section.
18.1	Intersection of Hwy. 30 and I-270. St. Louis Limestone and Salem Formation contact on west-bound off-ramp from I-270 visible to right.
18.7-19.2	Salem Formation.
20.1	Exit I-270 to I-44. General area of figures 11, 12, and 13.
20.0	Entrance ramp to north-bound I-270, from west I-44.
20.6-20.9	Warsaw Formation. Contact with overlying Salem near top of hill.
21.0-21.5	Salem Formation.
21.8	Meramec Highland Quarry to right (fig. 14).
21.9	Salem Formation. Possible St. Louis Limestone at top near railroad bridge.

22.3 Salem Formation.

22.8 Dougherty Ferry Road.

23.0 Salem Formation.

Because of the lack of outcrops north of this area the road log stops at this point. We will proceed northward on I-270 until Dorsett Road, turn left (west), dine at Furrs Cafeteria, and then proceed to Vigus North for our final stop.

STOP 1
JEFFERSON BARRACKS QUARRY OF BUSSEN QUARRIES, INC.

Bussen Quarries, Inc. operates four quarries in the general St. Louis area, with the Jefferson Barracks quarry being the largest and most highly developed. The Jefferson Barracks quarry exposes nearly 200 ft of section, including the basal part of the Ste. Genevieve Limestone, all the St. Louis Limestone, and much of the Salem Formation. Overburden, mostly loess, approaches 15 ft thick.

Individual ledges from this quarry produce stone suitable for all types of aggregate and approximately 15 aggregate products are produced.

Two ready-mix concrete plants are located at this quarry. The largest, a portable plant operated by Bangart Brothers, has a daily capacity of 2000 yd^3. The other plant, owned by Westlake Quarry and Material Company, has a daily capacity of 700 yd^3.

Adjacent to the quarry, at the riverfront, is a sand dredge owned by St. Charles Sand Company and a processing plant owned and operated by Bussen Quarries. The dredge produces sand from the Mississippi River and has a daily capacity of 1500 tons. These facilities are used to produce fine aggregate (sand) for use in concrete and asphalt products.

At the north side of the quarry an underground mine is being developed for storage. One million ft^2 have been mined as is currently used by Bussen Quarries for dry storage of material unloaded at their river terminal. The planned underground storage at this site represents a secondary use of a mined area and is an economic asset to the company and the community.

STOP 2
VIGUS NORTH QUARRY

The Vigus North quarry of Fred Weber, Inc. is one of the largest aggregate quarries in Missouri and is the largest quarry in St. Louis County. Located on a 500-acre site, it is one of four quarries the company operates in the general St. Louis area. Rock has been quarried at this site since the turn of the century and with present reserves has a projected life of 50 years.

The quarry exposes over 200 ft of rock representing most of the St. Louis Limestone and the Salem Formation. The quarry floor is near the Warsaw Formation. Overburden with a maximum thickness of 70 ft is loess and Pennsylvanian clay and sandstone.

Selected ledges from this quarry produce high-specification aggregate acceptable to the MHTD for almost all uses. Approximately 20 products that meet various commercial, state, and local specifications are routinely produced by this quarry.

Ready-mix concrete and asphalt plants are on the quarry site and represent valuable end products of aggregate use. Today we will be touring and discussing the processing of rock from the quarry face through the crushing and screening plants, and we will observe and discuss the operation of an asphalt plant.

An integral part of the quarry is a solid-waste landfill operated by the same company. The landfill has operated since the early 1970's and has an annual capacity of 700,000 yds^3 of waste. It accepts only municipal solid waste and demolition materials. A gas field recovers methane gas and carbon dioxide produced by decomposition of the garbage. This gas is used to heat a greenhouse and to assist in the asphalt plant. The replacement value of the gas is estimated at $100,000 annually.

Some people may regard a major quarry such as this as the end or terminal use of a property. In this case, however, the quarry is but one use in a sequence from agricultural land, extensive mineral operation, landfill, and a subsequent unknown use. As an example, other landfills in the state when filled have been used as parks, "greenspace," and light commercial use.

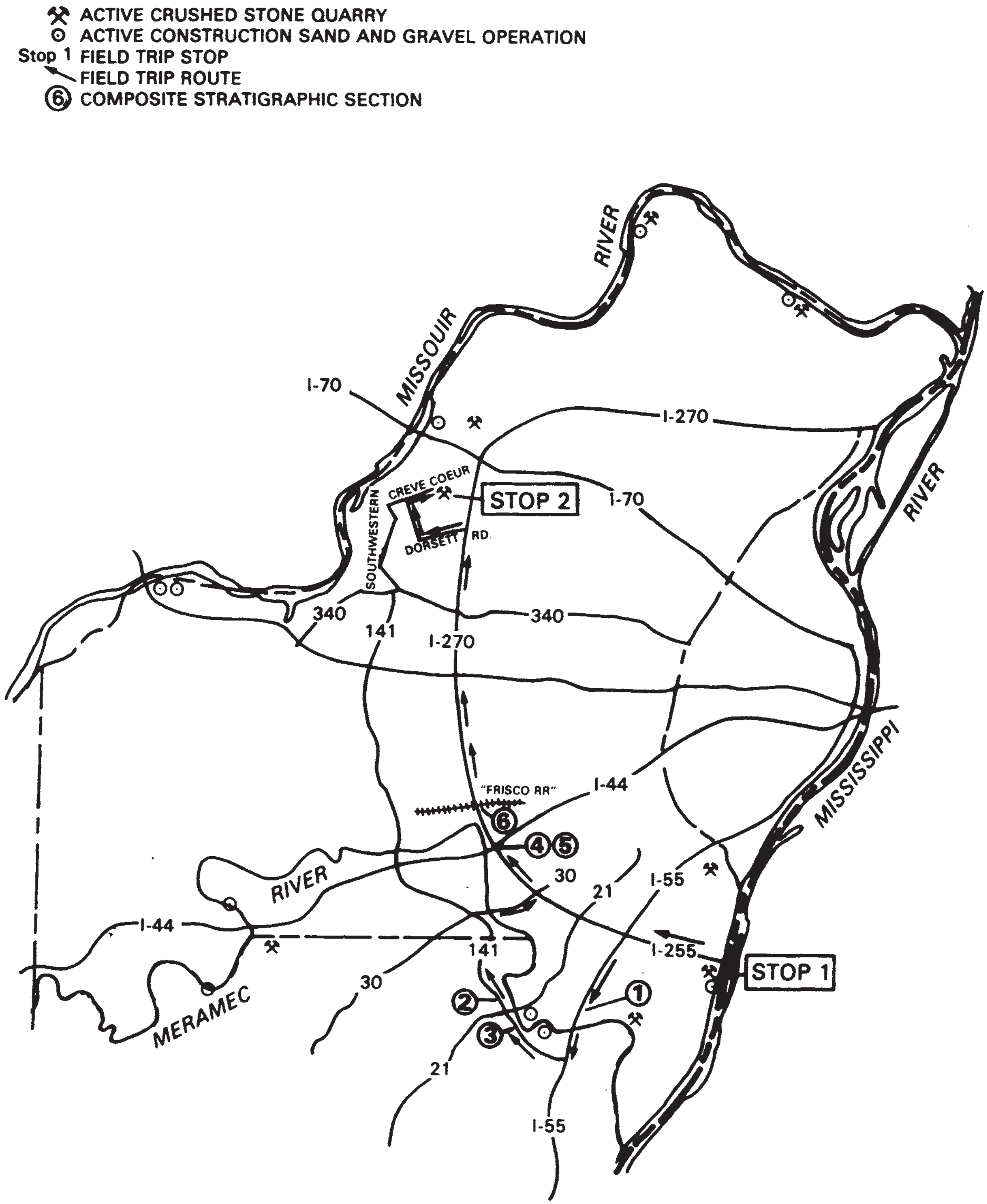

Figure 4. Location of active crushed stone quarries, sand and gravel operations, stratigraphic sections, and field trip route for second day.

GEOLOGIC SETTING OF ST. LOUIS COUNTY

(adapted from Lutzen and Rockaway, 1971, "Engineering Geology of St. Louis County, Missouri": Missouri Geological Survey, EGS 4)

St. Louis County is on the eastern border of Missouri, at the confluence of the Missouri and Mississippi Rivers. The county contains parts of two physiographic provinces: the west-county region, in the Salem Plateau of the Ozarks; the remainder is in the Dissected Till Plains. The topography, with the exception of the floodplains adjacent to the major rivers, varies from gently rolling to rugged; the greatest relief occurs in the west-county region and along the bluffs of the river valleys.

The topography of St. Louis County can be divided into four areas, each having similar landform characteristics, as outlined in figure 5. The floodplains of the Missouri, Mississippi, and Meramec Rivers are relatively flat or gently sloping plains made up of extensive alluvial deposits that fill deep bedrock valleys. There is little relief and slopes are generally less than 2 percent (2-ft fall through a distance of 100 ft). Included with this is the Florissant basin, a limited area of low relief in the northern part of the county. It is a flat lowland of what are believed to be Pleistocene lacustrine sediments (Goodfield, 1965). The second area, rolling uplands, includes more than 50 percent of the county and is formed by loess deposits that cover the more rugged bedrock topography. Most of this area is characterized by slopes of from 2 to 5 percent, although relief seldom exceeds 100 ft. The third and fourth areas, in southwestern St. Louis County, are characterized by rugged topography having slopes generally greater than 5 percent and occasionally greater than 10 percent; in many places the relief is more than 200 ft. Soils or other unconsolidated materials, which are generally shallow, overlie bedrock, exposures of which are common.

The bedrock geology in St. Louis County consists of essentially flat-lying sedimentary formations, mostly limestone and dolomite. Figure 6 is a very generalized geologic map of St. Louis County. A slight regional northeast dip is modified by several minor northwest-southeast-trending folds or flexures and by a broad irregularly shaped structural basin (Florissant basin) in northern St. Louis County. Ordovician to middle Pennsylvanian formations are exposed in St. Louis County. Figure 7 is a generalized geologic column. The Ordovician rocks include (from oldest to youngest) the St. Peter Sandstone; Joachim dolomite; and the Plattin, Decorah, and Kimmswick Formations. Most of the overlying Maquoketa Shale was removed by pre-Mississippian erosion. The Glen Park Limestone and Bushberg Sandstone (Devonian) were also largely removed at that time and exist only in isolated exposures. These formations are overlain by Mississippian rocks, including the Fern Glen Formation, Burlington-Keokuk Limestone (undifferentiated), Warsaw Formation, Salem Formation, St. Louis Limestone, and Ste. Genevieve Formation. As a result of post-Mississippian erosion, the contact between Ordovician through Mississippian formations and Pennsylvanian rocks is very irregular. The Pennsylvanian rocks, mostly shale with some limestone and sandstone, are included in the Cherokee, Marmaton, and Pleasanton Groups.

Almost all bedrock formations in St. Louis County are covered by extensive Pleistocene loess deposits derived from the Missouri River floodplain. The deepest loess, more than 50 ft thick, occurs along the bluffs of the Missouri River. As a general rule, however, these deposits thin southward and are seldom more than 5 to 10 ft deep along the ridgetops in the southwestern part of the county. Loess deposits on the adjacent hillsides have generally been removed or reworked by surface water.

A residuum (residual soil) derived from weathering of bedrock is developed where the loess is relatively thin. The residuum is mostly clay but includes the more resistant materials of weathered bedrock, mostly quartz sand and chert.

Stratified gravel, sand, silt, clay, and organic materials were deposited on the floodplains of the Missouri, Mississippi, and Meramec Rivers. These alluvial deposits are extensive, generally over 100 ft deep in the Mississippi and Missouri valleys and up to 60 ft deep in the Meramec valley. Less extensive deposits occur along Fee Fee, Bonhomme, and Creve Coeur Creeks. In many places, fine sand and silt, remnants of older alluvial deposits at higher elevations, remain as terraces on the valley slopes.

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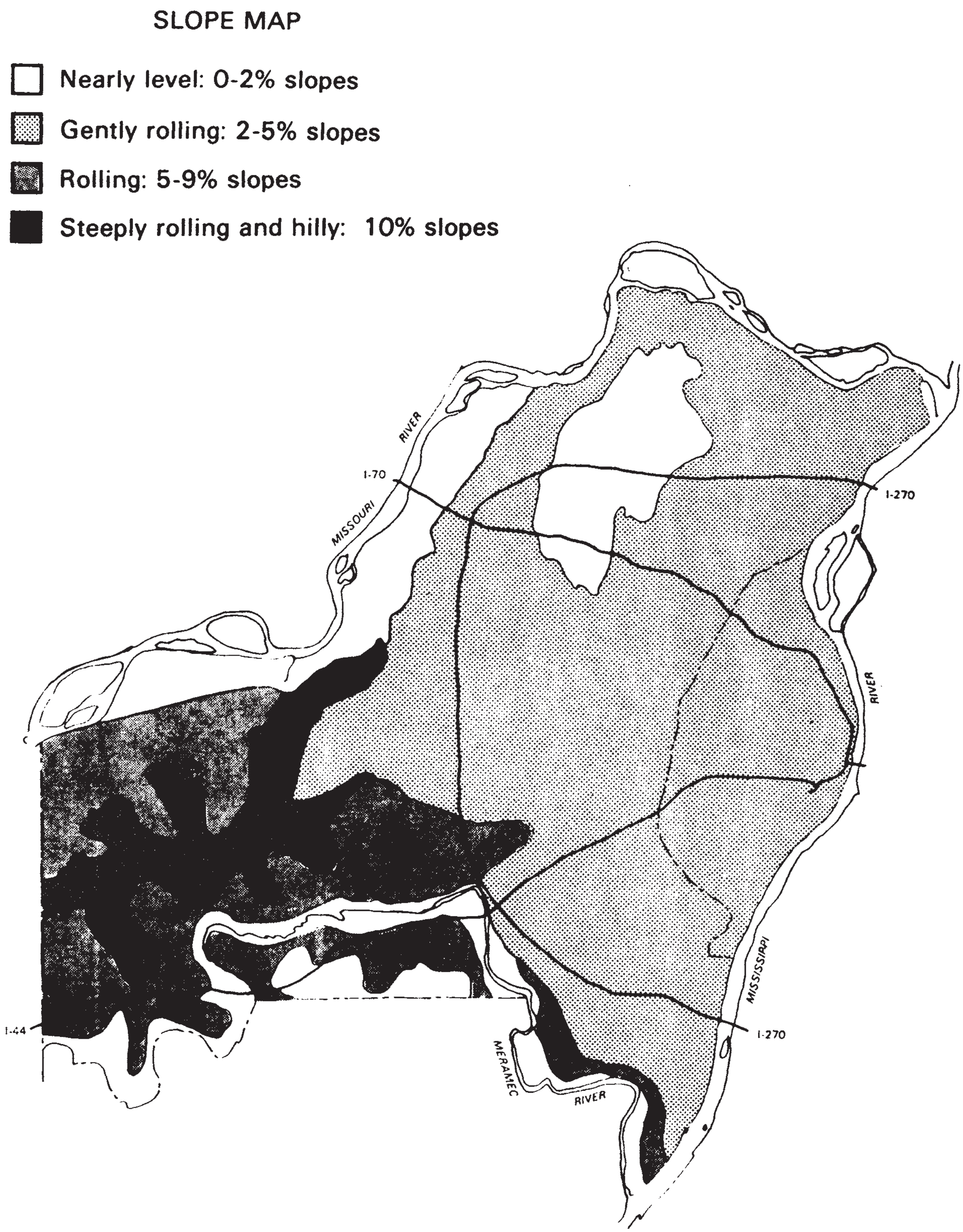

Figure 5. Slope map of St. Louis County.

LEGEND

Quaternary System

Qal Alluvium

Pennsylvanian System

Pp Pleasanton Group

Pm Marmaton Group

Pcc Cherokee Group including Cheltenham Clay

Mississippi System

Mm Ste.Genevieve and St.Louis Limestones and Salem and Warsaw Formations

Mo Keokuk and Burlington Limestones and Fern Glen Formation

Mk Bushberg Sandstone and Devonian Glen Park Limestone

Ordovician System

On Maquoketa Shale, Kimmswick Limestone, Decorah Formation, Plattin and Joachim Dolomite

Osp St.Peter Sandstone

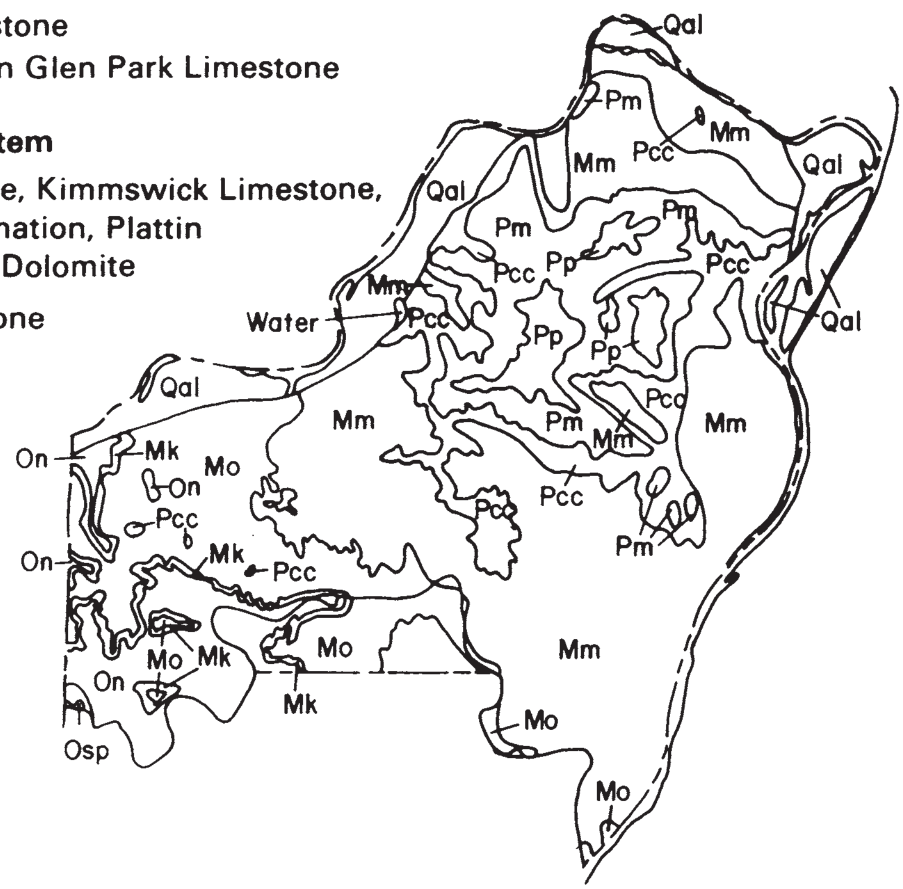

Figure 6. Generalized geologic map of St. Louis County.

System	Formation	Geologic Description	Thickness in Feet
Pennsylvanian	Pleasanton	Sandstone, channel-fill	0-100
	Marmaton	Shale; some limestone, minor sandstone	75
	Cherokee	Shale; with some clay and sandstone, very little limestone	50-150
	Cheltenham	Clay, plastic, refractory	0-25
Mississippian	Ste. Genevieve	Limestone, sandy, oolitic, coarsely crystalline, white	30-60
	St. Louis	Limestone, fine grained to lithographic, medium to massive bedded, white to gray breccia beds common	80
	Salem	Limestone, dolomitic, cherty, gray to light brown, becoming shaly at base	100-160
	Warsaw	Limestone and shale; limestone is coarse grained, crinoidal; upper portion is shaly	70-100
	Burlington-Keokuk	Limestone, coarse grained, olive-gray to brownish-gray, massive, crinoidal, cherty	200
	Fern Glen	Limestone and shale; grayish-green to red limestone; green to red shales, fossiliferous; upper unit cherty	60+
	Bushberg	Sandstone; yellowish-brown, fine to coarse grained, "dirty" appearance	5-50
Devonian	Glen Park	Limestone, oolitic, shaly, pale yellow, fossiliferous, contains quartz sand	0-30
Ordovician	Maquoketa	Shale, silty, calcareous	0-100+
	Kimmswick	Limestone, coarse-grained, massive, brownish-gray	25-125
	Decorah	Shale and limestone; interbedded, fossiliferous	25
	Plattin	Limestone, fine-grained to lithographic, gray to light tan, evenly bedded; burrowed appearance	80-150
	Joachim	Dolomite, argillaceous, shaly, yellowish-brown	60-125
	St. Peter	Sandstone, orthoquartzitic, grains medium size, rounded and frosted	50-150+

Figure 7. Generalized stratigraphic column, City and County of St. Louis.

MISSISSIPPIAN ROCKS OF THE ST. LOUIS AREA

Introduction

Mississippian rocks of the St. Louis area comprise five formations:

MERAMECIAN SERIES
- Ste. Genevieve Limestone
- St. Louis Limestone
- Salem Formation
- Warsaw Formation

OSAGEAN SERIES
- Keokuk Limestone

The first and last occur within restricted areas of eastern St. Louis County, whereas Warsaw through St. Louis form the prominent surface exposures through much of the region. The following is a brief discussion of these formations in the region of the City of St. Louis and eastern St. Louis County. Figure 8 is a generalized section of Meramecian rocks of the St. Louis area.

Keokuk Limestone

The Keokuk Limestone, the youngest formation of the Osagean Series, is exposed principally in the Meramec River Valley in eastern St. Louis County, but, along with the underlying Burlington Limestone (from which it is hard to differentiate), is widespread in central and western parts of the County. Primarily a fossiliferous fine- to medium-crystalline cherty limestone, the Keokuk is exposed beneath the I-44 bridge over the Meramec River, at the eastern edge of Fenton, and also north of there along the Meramec River bordering Kirkwood. At these sections, the Keokuk is overlain by basal Meramecian shales and limestones of the Warsaw Formation.

Warsaw Formation

In the area under study the Warsaw Formation consists of slabby bluish-gray very fossiliferous finely crystalline argillaceous limestone interbedded with fissile to blue-gray blocky shale. The shale content varies; it is most abundant in the region between Manchester Road and I-55, but thick shale beds characterize the formation throughout the region. The base of the Warsaw is marked by the lowest shale beds; the contact with the underlying Keokuk Limestone is relatively easy to detect. The upper contact with the Salem Limestone, however, is regionally transitional: a calcarenitic limestone with "typical" Salem characteristics interbedded with Warsaw shale. Agreement has not been reached on where to place this contact. Several choices are available:

1) The base of the lowest calcarenitic "Salem" limestone
2) The top of the highest "Warsaw" shale
3) A transition zone between the two formations.

The Warsaw Formation is well exposed in roadcuts on I-44, at the junction with I-270, where both the lower and upper parts of the formation are exposed, and in roadcuts on Missouri Highway 141 between I-55 and Missouri Highway 30 (Gravois Road), where the shale of the Warsaw is well developed and the interbedded nature of Warsaw shale and Salem limestone is prominent.

Limestone of the Warsaw Formation is also exposed in the roadcuts on I-44, at the Meramec River bridge, and on Highway 141.

Salem Formation

The Salem Formation is mostly a brown to gray, partially dolomitic, fine to medium grained, often cross-stratified, calcarenite. Some portions of the Salem are nearly a coquina of fossil debris. Grain size of the limestone beds is usually very uniform, differing from the less uniform limestone of the Warsaw Formation and the generally much finer-grained to lithographic St. Louis Limestone. The Salem can be described as "sucrosic," (sugary) in appearance. Some thin (1-3 ft) dolomitic shale beds are interbedded with the limestone. The dolomitic limestone beds weather to a slabby appearance.

The most distinctive forms of chert in the Salem Formation are concentrically banded gray to tan and light-gray subspherical "cannon ball" or "bulls-eye" chert nodules. They are prominent in the upper third to fourth of the formation; their presence can be used to distinguish uppermost Salem from basal beds of the overlying St. Louis Limestone.

Many calcarenitic limestone beds, particularly in the lower part, where they are interbedded with bluish to gray shale, are lenticular. Because of this, designating the lowest calcarenite as the base of the Salem is futile, in as much as such a "contact" "moves" up and down the section in a single exposure. The shale beds also appear to be lenticular, and placing the "contact" at the uppermost shale produces the same result. Perhaps the interbedded limestone and shale should be designated as the *"Warsaw-Salem transition zone."*

The upper boundary of the Salem Formation with the St. Louis Limestone is somewhat easier to decide, but it is not always well-defined. The St. Louis Limestone is "typically" very light gray, nearly white, sublithographic to lithographic, and interbedded with tan fine-grained dolomite. Exposures on I-270 show a zone of interbedded calcarenitic and lithographic limestone that renders absolute placement of the boundary in question — another "transition zone." Unless a complete succession is available, actual placement of this contact may be questionable. Several light-gray lithographic limestone beds are present, but it is difficult to recognize the precise one in exposures, unless a relative complete succession is present.

The Salem Formation is extensively exposed in roadcuts on I-270, from north of the junction with I-55, to Manchester Road, and on Highways 30 (Gravois Road) and 21 (Tesson Ferry Road). A nearly complete succession of Salem is on Highway 141, just west of the junction with I-55 at Arnold, and at the junction of I-44 and I-270.

St. Louis Limestone

Characteristically, the lithology of the St. Louis Limestone is a very light-gray, nearly white lithographic limestone, which may be oolitic and cross-stratified, but lacks quartz sand. Limestone occurs in even beds and, less frequently, in thick zones of brecciated limestone that are collapse breccias resulting from removal of anhydrite by solution. Several prominent dolomite zones occur in the St. Louis Limestone; some chert is present, usually as small nodules and discontinuous beds. Both the St. Louis and upper Salem are extensively quarried in the St. Louis area. Shales of the upper Warsaw ("transition zone") usually "floor" larger quarries.

The overlying Ste. Genevieve Limestone is a cross-stratified fine-grained oolitic sandy (quartz) limestone. It is usually readily distinguishable from the St. Louis Limestone, because it contains quartz and is more oolitic and generally of a more clastic character.

The St. Louis Limestone is exposed over much of the metropolitan area, but most formed exposures are covered by construction. It is exposed on parts of I-270, south of I-55, and on I-44 and I-55, east of I-270.

Ste. Genevieve Limestone

The St. Genevieve Limestone is characteristically a cross-stratified light-gray oolitic limestone that contains quartz sand. It occurs only in a few places and is usually not very thick. It is present in a small area south of I-255, near Telegraph Road (Bussen Quarry), and in the Ft. Bellefontaine Quarry in the extreme northern part of the City of St. Louis.

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Thompson, T.L., 198, Paleozoic succession in Missouri, part 4, Mississippian System: Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 70, 182 p.

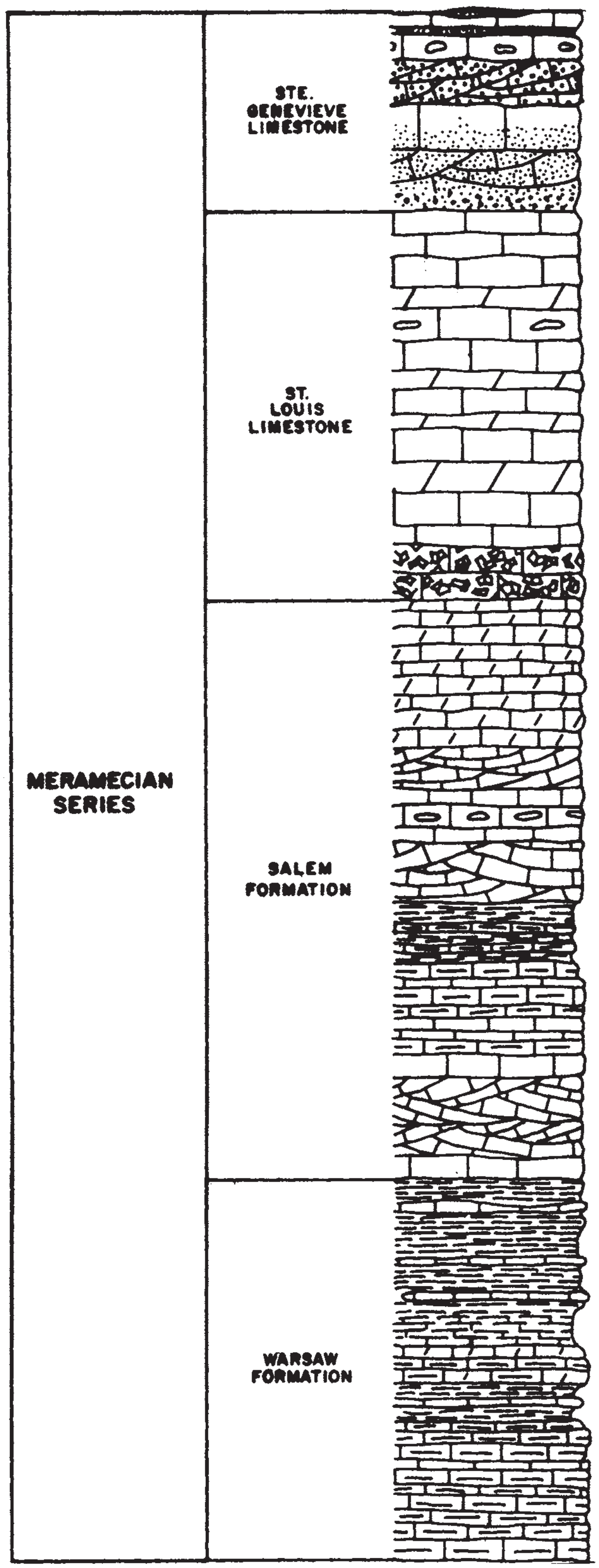
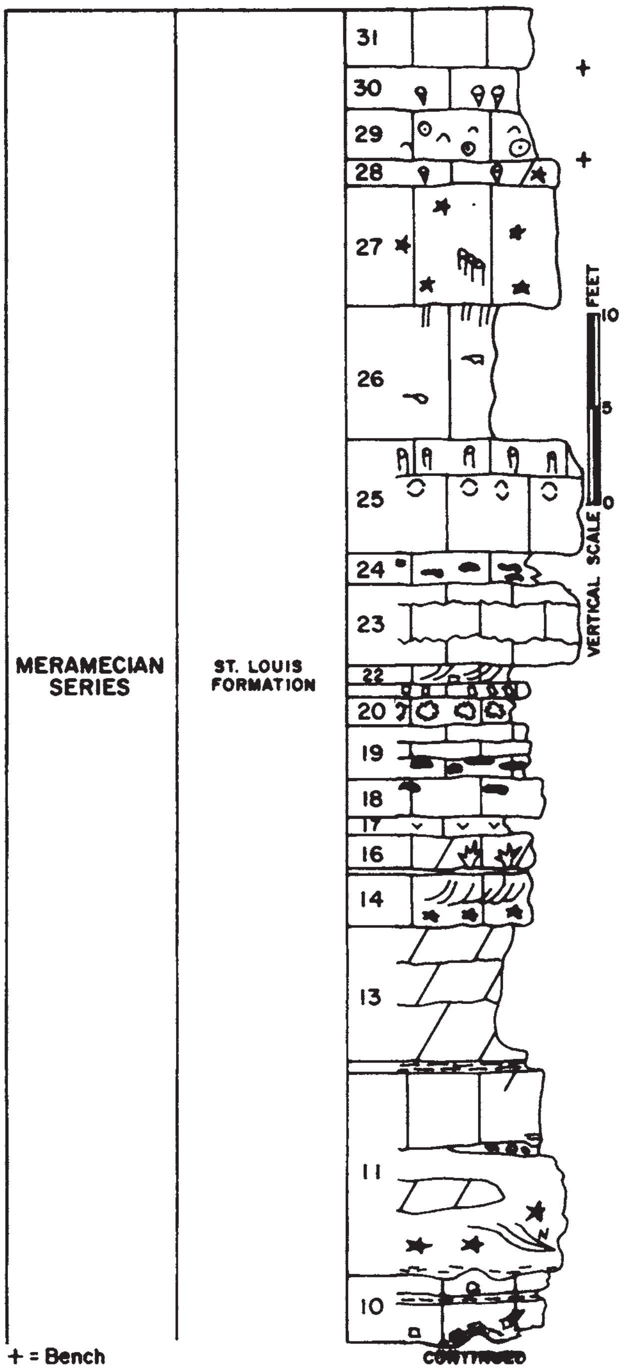


Figure 8. Generalized section of the Meramecian rocks of the St. Louis area.



31. Limestone, (calcarenite), with numerous *Camarotoechia*.
30. Limestone (calcarenite), with lithostrotionid corals at top.
29. Limestone (calcarenite), oolitic, very light gray, contains irregular chert and siliceous areas.
28. Limestone, dolomitic, light-brown, fine-grained, fossiliferous (small horn corals, lithostrotionids, debris); chert nodules at base.
27. Limestone (calcarenite), very light-gray, oolitic, uneven, medium bedding; thin, tripolitic chert in lower half; echinoid debris, lithostrotionids.
26. Limestone, brown, crumbly, recessive; worm-burrows(?) at top.
25. Limestone (calcarenite), oolitic; parts have fine-grained matrix; *Composita* and lithostrotionids.
24. Limestone, dolomitic(?), light-brown, mottled with light-gray limestone, yellow-gray base; top laminated, which may represent an algal mat structure.
23. Limestone (lithographic), weathers light-gray.
22. Limestone (lithographic), locally fossiliferous, brecciated at base; laterally becomes breccia up to 5 ft thick.
21. Limestone (lithographic), light-gray with LLH algal structures at top.
20. Limestone, sparry, irregularly layered; basal layer fine grained; several chert layers.
19. Limestone (calcarenite), gray; contains long flat, yellow-white chert nodules with black centers.
18. Limestone (calcarenite), gray, coarser at base, laminae show where well weathered.
17. Limestone, slightly dolomitic, light-brown, medium-grained, very vuggy.
16. Limestone with dolomitic limestone at top and base, tan; contains the alga *Spongiostromata*.
15. Limestone (calcarenite), very thin-layered.
14. Limestone (calcarenite), light-gray, medium-grained, cross-bedded, weathered surface speckled with crinoid columnals. *Syringopora* at base.
13. Dolomite, tan, medium-grained, argillaceous at base; conspicuous marker in the exposure on both sides of highway. Cavernous.
12. Shale, dark, platy, grades into overlying dolomite.
11. Limestone (calcarenite), light-gray, coarse-grained with upper few feet finer grained; several impersistent shale partings; crinoid debris weathers out. Conspicuous dolomite lens in upper part.
10. Lithographic limestone at base, locally brecciated; coarse-grained limestone containing lithographic clasts above; beds separated by thin shale.

Figure 9. Composite stratigraphic section No. 1, I-55 North of Meramec River (A.C. Spreng, 1987).

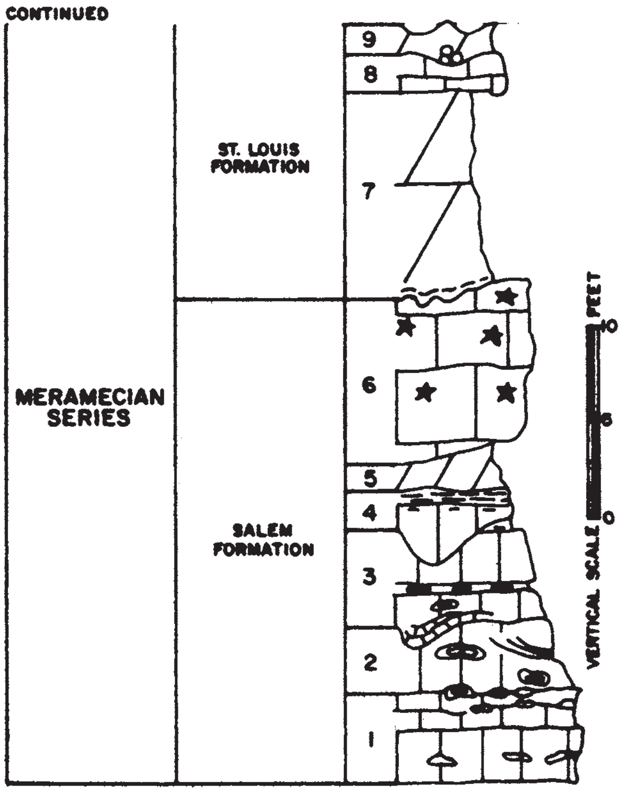


Figure 9. (continued)

9. Dolomite, steel-gray, locally brecciated.
8. Limestone, light-gray, sublithographic to lithographic. Lowest lithographic limestone in this section.
7. Dolomite, tan; two beds, sometimes with intervening shale; recessive weathering, cavernous at top.
6. Limestone (calcarenite), massive with uneven top.
5. Dolomite containing clasts; dull, smoky-gray; single bed; uneven top.
4. Limestone (calcarenite), generally buff weathering with laminated chert at base; shale at top and base.
3. Limestone (calcarenite), light-tan, numerous cherty bands; lower beds truncated against unit 2.
2. Limestone (calcarenite), light-tan, massive, laminated and cross-laminated; bulls-eye chert at base and middle. Good marker.
1. Limestone (calcarenite), light-gray, thin- to medium-bedded; cherty and siliceous layers shown.

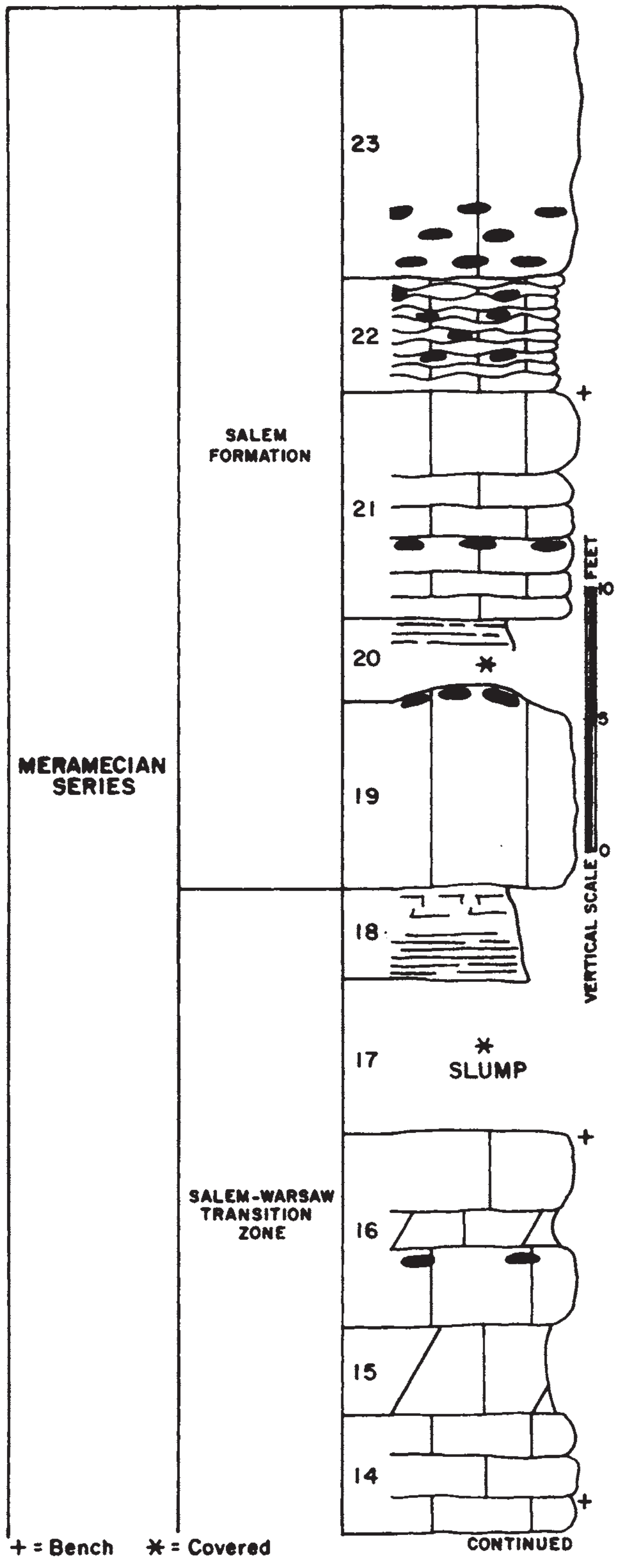


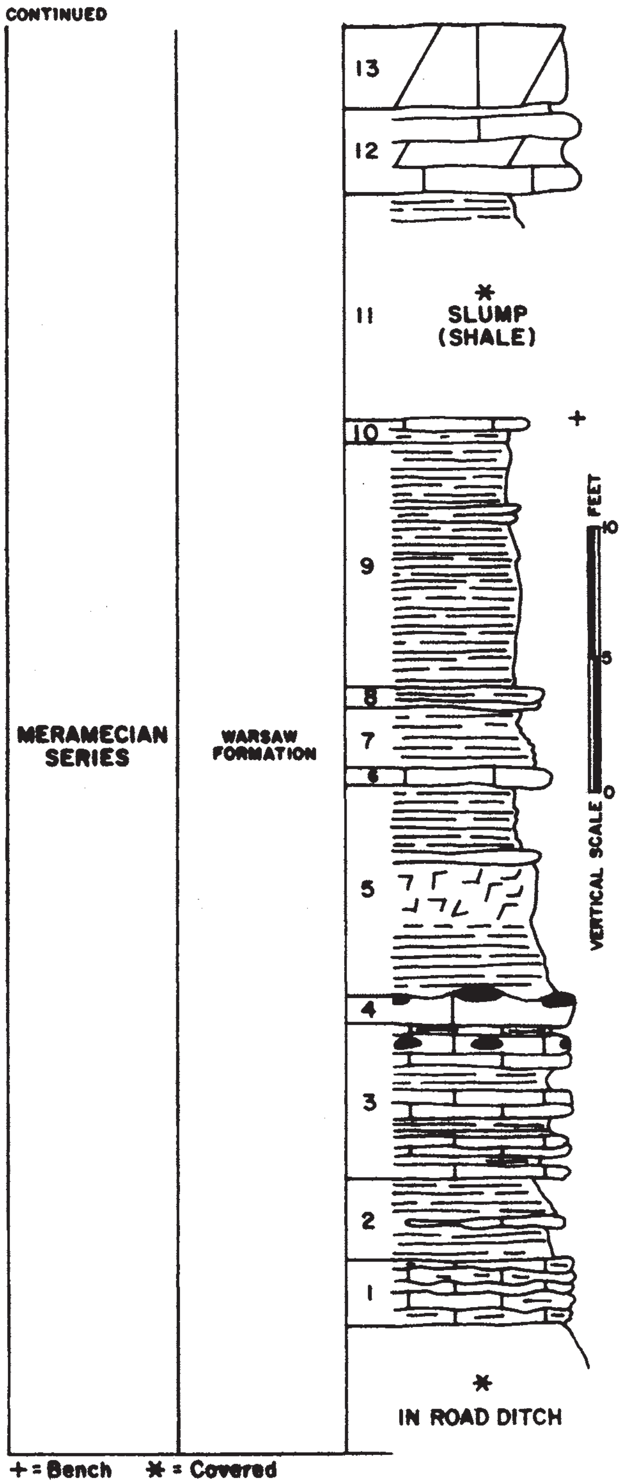
Figure 10. Composite stratigraphic section No. 2, Sugar Creek, Highway 141.

23. Limestone, calcarenite, fine- to medium-grained, very cross-bedded, prominent, large "bulls eye" cherts at base of unit, light-gray to light-brown, weathers to a vuggy, pitted surface. (10-12 ft)
22. Limestone, very weathered, cherty, forms prominent re-entrant with red soil. (5-8 ft)
21. Limestone, calcarenite, fine-grained at base becoming more coarse upward, "muddy", light-gray to light-brown, upper one-half massive appearance, minor amount of spherical chert. (8 ft)
20. Covered interval, shale exposed at top. (3 ft ±)
19. Limestone, calcarenite to "muddy" calcarenite, light-brown to gray, irregular base and top, massive appearance, somewhat lenticular, calcite-filled vugs common in lower half, occasional chert near top of unit. (6-8 ft)

Top of Warsaw-Salem transitional zone.

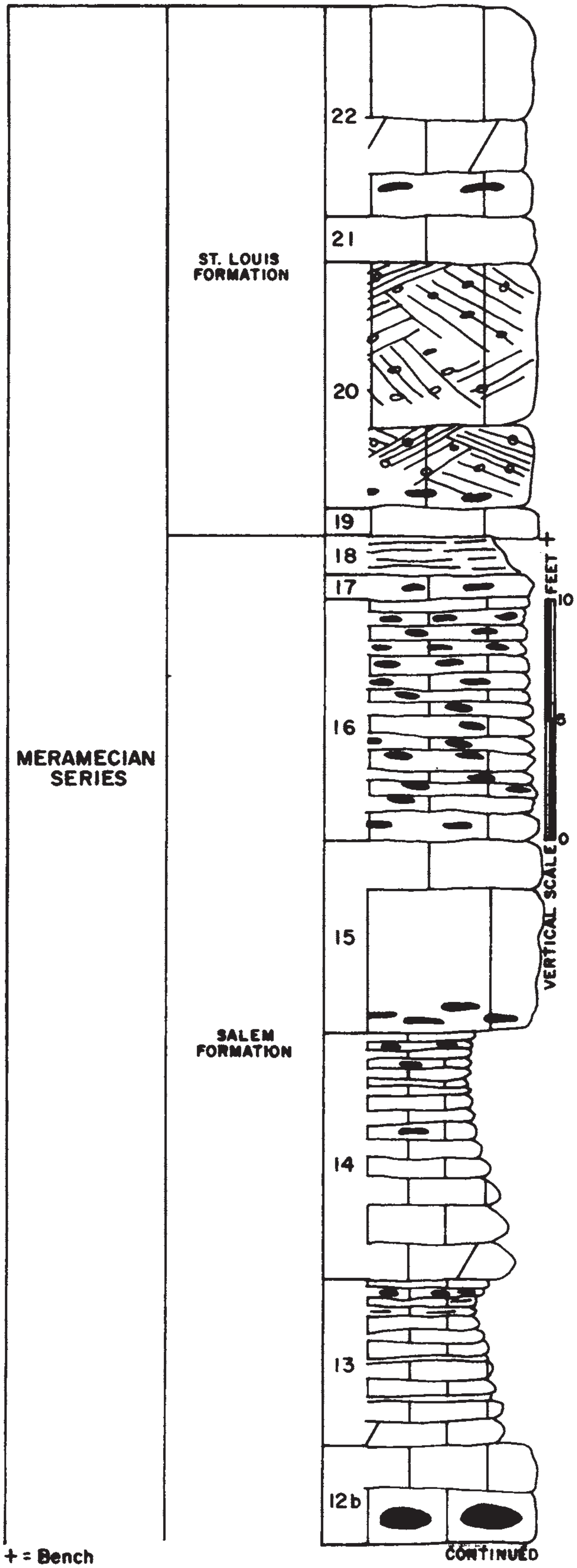
18. Shale, blue-gray at base to light-brown at top, fissile at base, blocky at top, weathered appearance, prominent re-entrant. (3 ft)
17. Covered interval. (6 ft ±)
16. Limestone, calcarenite, light-gray to light-brown, massive appearance, 1½ ft to 2 ft dolomitic zone near center of unit, minor amount dead white chert below dolomite. (6-8 ft)
15. Dolomite, very weathered, fine-grained, brown, forms prominent re-entrant, calcite masses common in lower part of unit, irregular, hacky, rough appearance. (3-5 ft)
14. Limestone, calcarenite, light-brown to gray, fine-grained, unit forms top of second bench on northeast side of road. (5 ft)

Base of Warsaw-Salem transitional zone.



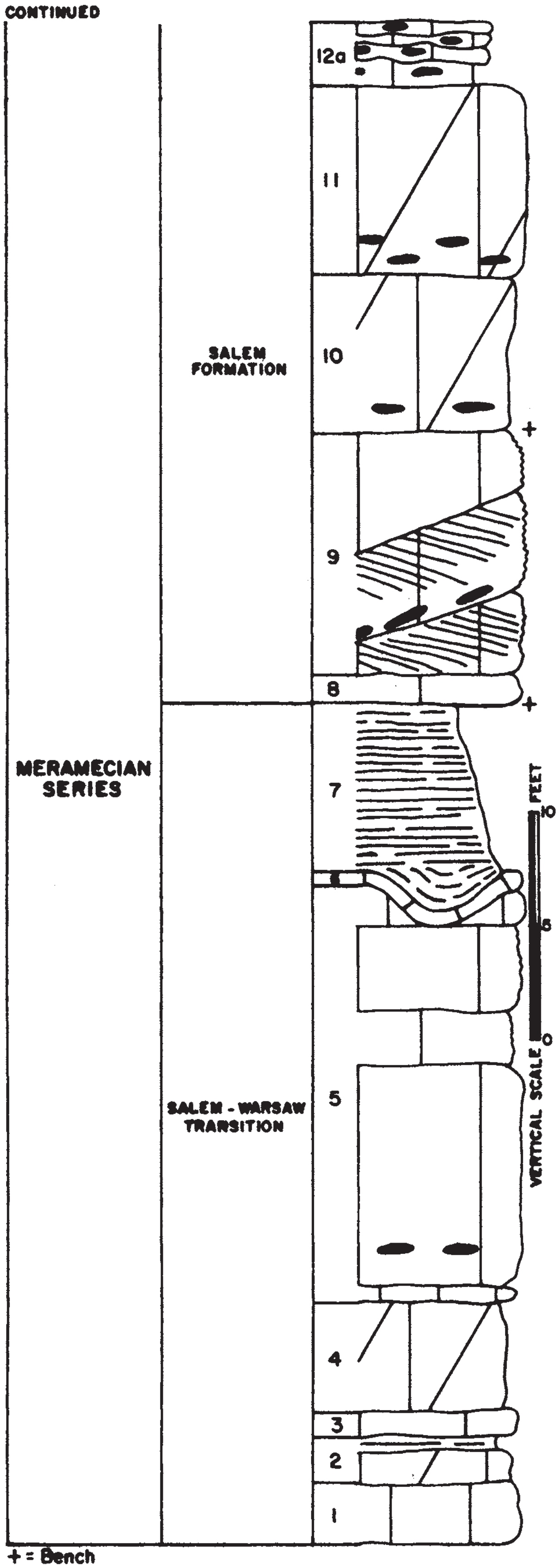
13. Limestone, calcarenite, "muddy", fossiliferous, with prominent calcite filled vugs, gives massive appearance. (3 ft)
12. Alternating beds of 1 ft ± nodular mudstone, waxy bedded, lenticular 3 in. shale unit at top. (3 ft 6 in.)
11. Poorly exposed section of shale and mudstone covered with slump from above units. (8 ft ±)
10. Limestone to mudstone, sparsely sandy yellow-brown to red-brown, 3 in. shale at base. (1 ft 6 in.)
9. Shale, light-gray, fissile to slightly blocky, 6 in. mudstone near top of unit. (8-9 ft)
8. Mudstone, blocky, calcareous, prominent bed, forms bench on southwest side of road. (6 in.)
7. Shale, light-gray, fissile to slightly blocky. (3 ft)
6. Limestone, like no. 4, medium-grained, fossiliferous, calcareous, forms prominent marker bed. (6 in.)
5. Shale, gray to light-gray, fissile with several blocky, very prominent, limestone beds, also contains massive calcareous mudstones. (8 ft)
4. Limestone, calcarenite, light-gray, fine- to medium-grained, single massive appearing bed with uneven top and bottom, very fossiliferous, irregular 2-3 in. siliceous chert bed at top of unit, chert often ferruginous, large calcite masses. (1 ft 6 in.)
3. Limestone, interbedded mudstone and thin shales, medium-grained, fossiliferous, irregular bedded, 2-3 in. waxy ferruginous chert unit in top limestone bed, thin shale zone forms top of unit. (6 ft)
2. Shale, gray, fissile, with a lenticular 6 in. limestone near center, limestone similar to unit no. 1. (3 ft)
1. Limestone, medium-grained, dark-gray calcarenite, argillaceous, waxy, shale partings up to 2 in., irregular bedding 2-8 in., very fossiliferous with crinoids common. (3 ft)

Figure 10. (continued)



22. Limestone, light-gray to light-brown, calcarenite, fine-grained, 2 ft "muddy" zone 2-3 ft from base, cherty. (8 ft)
21. Limestone, gray, dense to lithographic, mottled appearance. (2 ft)
20. Limestone, calcarenite, light-gray, fine-grained, oolitic, irregular chert bodies in lower part, cross-bedded. (8 ft)
19. Limestone, very fine-grained to lithographic, light gray. (1 ft 6 in.)
18. Shale, calcareous, light-gray to tan. St. Louis Formation. (1 ft 6 in.)
17. Limestone, calcarenite, dark-gray, cherty in lower part, fossil fragments. (1 ft)
16. Limestone, dolomitic, calcarenite, light-tan, thin-bedded, thin elongated chert, slabby, shattered appearance, forms pronounced re-entrant in lower part of unit. (10 ft)
15. Limestone, calcarenite, light-brown, fine-grained, with medium-grained lenses, very heavy chert at base, scattered elsewhere, massive appearance, cross-bedded, top forms slight re-entrant. (10 ft)
14. Limestone, calcarenite, dolomitic, similar to unit 13, massive "bulls-eye" cherts in middle of unit and upward. (8 ft)
13. Limestone, dolomitic, beds become thinner upward, shaly in upper 2 ft, top forms re-entrant, 1 in. thick interbedded siliceous zones, crystalline calcite vugs in lower bed. (7 ft)
12b. Limestone, calcarenite, very fine-grained, large "bulls-eye" chert nodules in 6 in.-2 ft beds, conchoidal fracture; light-gray, massive, dense appearance. (4 ft $\pm$)

Figure 11. Composite stratigraphic section No. 3, Highway 141 and Highway 21.



12a. Limestone, highly weathered, fractured sublithographic, cherty. (2 ft 6 in. ±)

11. Limestone, dolomitic, calcarenite, light-tan massive appearance, cherty at base, stylolites near top. (8 ft)

10. Dolomite, tan to light-gray, fine-grained, laminated appearance, forms re-entrant, chert bed at base of unit. (7 ft)

9. Limestone, calcarenite, light-gray to tan, fine-grained, cross-bedded, massive appearance, calcite-filled vugs common, chert nodules near base. (10 ft ±)

8. Limestone, light-gray to dark-gray, extremely fossiliferous, mud matrix cementing fossil fragments, lenticular. (1 ft 6 in.)

Top of Warsaw-Salem transitional zone

7. Shale, light-gray, blocky to fissile, irregular base, forms first bench. (4-8 ft)

6. Dolomite, tan, weathers to light-gray, mottled, earthy, forms continuous cap over unit 5. (6 in.-1 ft)

5. Limestone, calcarenite, brown, fine-grained, massive appearance, 2 ft dolomite bed 10 ft above base, dolomite unit weathered to light-gray with "punky" appearance, unit overlying dolomite is calcarenite similar to basal unit, top surface irregular. (13-17 ft)

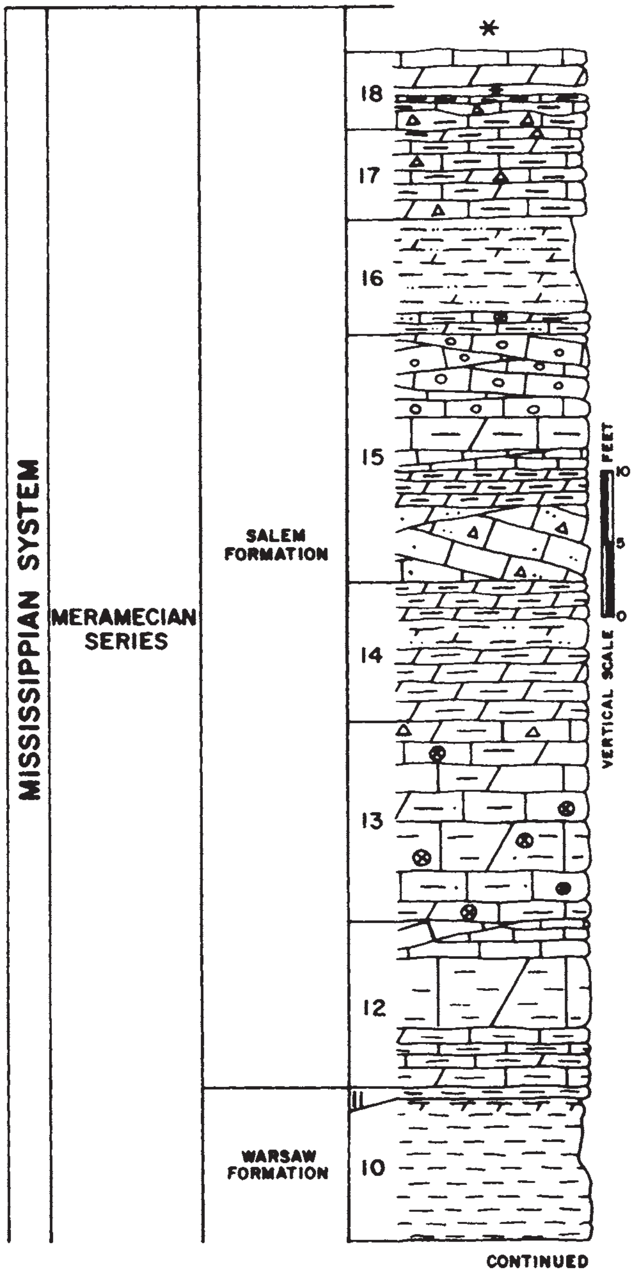
4. Dolomite, weathers to light-gray, very "punky" appearance, forms re-entrant, zone of calcite crystals near base. (4 ft)

3. Limestone, calcarenite, dark-gray, very coarse grained, irregular to cross-bedded, "muddy" at base. (1 ft 6 in.)

2. Limestone, dolomitic, light-brown, weathers to light-gray color, very fine-grained, "muddy", becoming shaly at top 6 in., argillaceous. (2 ft)

1. Limestone, calcarenite, light-brown to light-gray, fine- to medium-grained, large coral colony near base of unit on northeast side of road, fossiliferous. (2 ft 6 in.)

Figure 11. (continued)



18. Limestone, light-gray to buff; fragmental fossils, abundant brachiopods; lower part dolomitized, dark-brown, porous. (1 ft 9 in.)
17. Limestone, buff, dolomitic, argillaceous, slabby, wavy-bedded; brachiopodal wackestone to crinoidal-bryozoan packstone; bedded chert nodules in upper 2 ft; lower 5 ft appears shaly. (7 ft)
16. Shale, gray to brown, slightly silty, dolomitic, mostly inaccessible. Limestone, thin, dolomitic, at base; echinoderm wackestone to packstone; thickens laterally, calcite-filled vugs, skelmoldic porosity; abundant brachiopods, bryozoans. (7 ft)
15. Limestone, gray to buff, cross-bedded, fossil fragmental-superficial oolitic grainstone; large endothyrids, abundant brachiopods, crinoids, bivalves, corals; middle 2 ft partly dolomitized, argillaceous; light-buff, sandy and silty, with chert stringers in lower part. (14 ft 7 in.)
14. Dolomite, brown to buff, argillaceous; abundant bryozoans; silty shale, slightly dolomitic. (8 ft)

Section transferred to exposure at east end of bridge across I-270 on Cragwold Road.

13. Limestone, brown to buff upper part, light-gray lower 7 ft 6 in., dolomitic, bryozoan-crinoidal wackestone to packstone, calcite-filled vugs and brown chert nodules; scattered solitary rugose corals; lower part slightly sandy, very argillaceous, with calcite-filled vugs, brachiopods, syringoporid corals. (12 ft)
12. Limestone, brown, dolomitic, massive in middle; upper 2 ft cross-bedded, lower 3 ft 6 in. very argillaceous; medium- to fine-grained, crinoidal bryozoan packstone to grainstone; brachiopods. (10 ft)
11. Shale and claystone, brown, blocky. (0 ft 6 in.)
10. Shale, greenish-gray to dark-gray, slightly sandy, glauconitic; fine selenite crystals on shale partings in upper 9 ft; dolomitic at top; crinoidal-bryozoan packstone in lower part, slabby. (10 ft)

Figure 12. Composite stratigraphic section No. 4, Meramec River to Cragwold Road.

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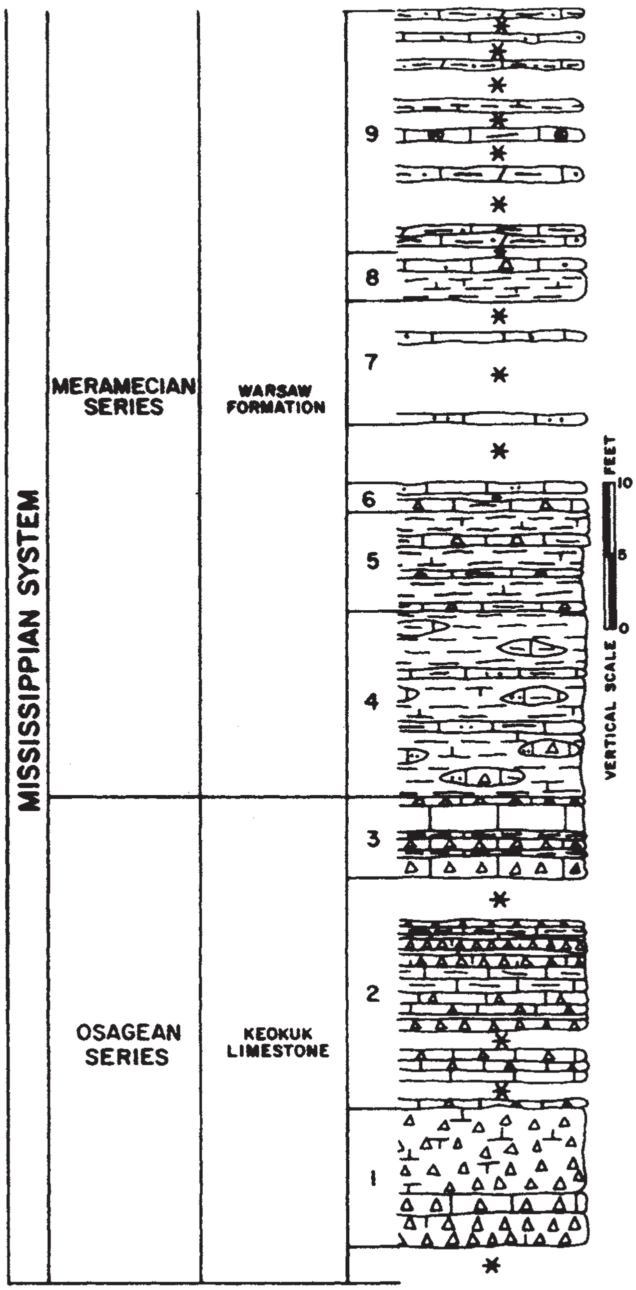


Figure 12. (continued)

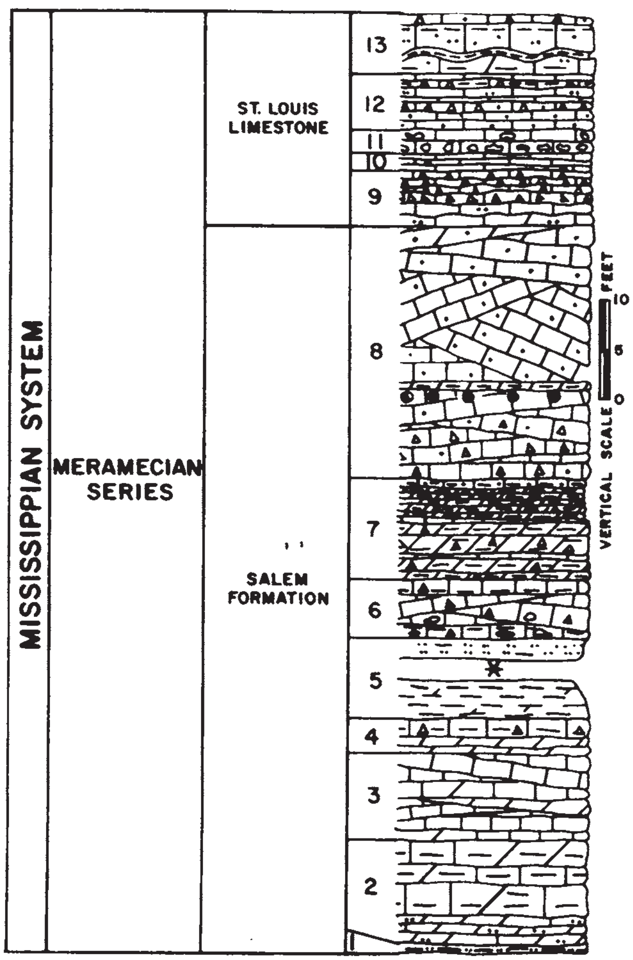
9. Limestone, buff to gray beds, bryozoan-crinoidal packstone, alternating with covered thin, argillaceous zones, probably shale. (13 ft)

Section continues in south side of gully near culvert.

8. Limestone, gray to buff, argillaceous, slightly sandy; crinoidal grainstone; small chert stringers, bryozoans; overlying 1 ft 6 in. buff, very calcareous shale. (2 ft 6 in.)
7. Limestone, slightly silty to sandy, medium- to coarse-grained; crinoidal-bryozoan packstone to grainstone; middle 4 ft 6 in. covered. (5 ft 6 in.)

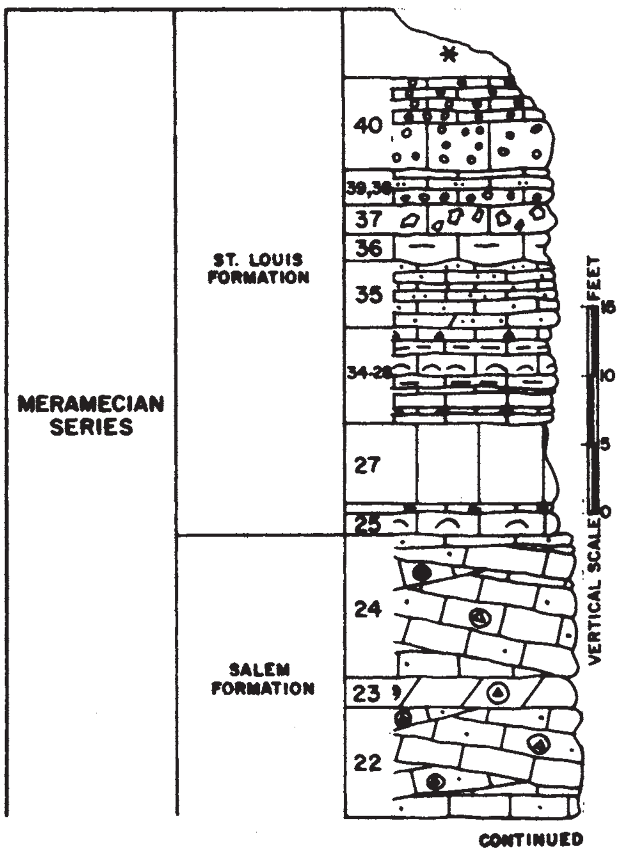
Rest of section from exposure at I-44 bridge over Meramec River.

6. Limestone, gray to buff, slightly sandy-silty, medium-grained; crinoidal-bryozoan packstone to grainstone; partly silicified; lower half covered. (1 ft)
5. Limestone and interbedded shale. Shale, buff, fossiliferous, calcareous. Limestone, light-gray to brown, partly silicified, argillaceous, coarse-grained, crinoidal-bryozoan packstone; light-gray to white chert nodules and stringers; brachiopods. (7 ft 6 in.)
4. Shale, dark-gray to buff, slightly calcareous, fissile; with interbeds and lenses of light-gray to buff, partly silicified, silty, coarse-grained limestone, crinoidal-bryozoan packstone; scattered chert lenses, brachiopods. (12 ft 10 in.)
3. Limestone, light gray to buff; fine- to medium-grained grainstone, abundant light- to dark-gray disseminated chert; interbedded buff, shaly packstone. (5 ft 5 in.)
2. Limestone, light-gray to buff, argillaceous, thin-bedded, shaly; abundant crinoids, fenestrate bryozoans, brachiopods; abundant light-gray chert, some bedded. (11 ft)
1. Limestone and chert. Limestone, light-gray, coarse-grained, crinoidal-bryozoan grainstone to packstone; chert light- to medium-gray, speckled, calcareous, with many small limy pockets. (10 ft)



13. Limestone, light-gray, slightly sandy, fine-grained; crinoidal-bryozoan packstone; scattered light-gray chert nodules; brachiopods; capping 5 ft of limestone, brown, earthy, dolomitic mudstone to banded, sandy-silty, ostracod wackestone, with partly shaly, jointed appearance. (5 ft 8 in.)
12. Limestone, light- to medium-gray, slightly silty; sandy in lower 2 ft; ostracod packstone to grainstone interlaminated with light-gray lithographic mudstone; thin bedded, argillaceous and buff banded chert nodules in upper part; buff to brown chert in lower part. (5 ft)
11. Limestone, light-gray, laminated; intraclastic packstone with mudstone intraclasts; less intraclastic and finer grained upwards. (2 ft)
10. Limestone, light-gray, thin-bedded, laminated; fine-grained packstone; chert sparse. (2 ft 3 in.)
9. Limestone, light-gray to brown, laminated, fine-grained packstone; dolomitic at base; abundant white chert nodules and stringers in upper 3 ft; appears knobby. (5 ft)
8. Limestone, gray to buff, sandy, cross-bedded, massive, fine- to coarse-grained; crinoidal-bryozoan grainstone; locally dolomitized and silicified at top; stylolites; brachiopods near top; 10 ft above base is 8 in. buff, fine-grained laminated dolomite, with shaly parting at top; lower 10 ft has light-gray to white banded chert, with cannonball chert nodules along upper surface and stylolites near base; lower 10 in. is brown limestone, with thin-bedded, sandy, argillaceous partings. (25 ft)
7. Dolomite, brown, argillaceous, earthy, medium-bedded in lower part, recessive and thin-bedded in upper; scattered "botryoidal" limestone layers, chert nodules. (9 ft 2 in.)
6. Limestone, buff, cross-bedded, fossiliferous packstone to grainstone; partly dolomitized; interbedded fine- to coarse-grained layers in lower part becoming coarse-grained at top; mudstone intraclasts in lower part; scattered gray chert nodules; argillaceous partings; abundant brachiopods, gastropods, rugose corals. (5 ft 5 in.)
5. Siltstone, brown, laminated, dolomitic; and shale, dark-gray, slightly dolomitic; 2 ft covered interval in middle of unit. (7 ft 10 in.)
4. Limestone and dolomite. Upper unit is limestone, gray to buff, argillaceous, fine- to medium-grained, fossiliferous packstone; buff chert nodules; corals, brachiopods. Lower part is dolomite, buff, earthy, of variable thickness. (3 ft 6 in.)
3. Limestone, buff to gray, fine- to coarse-grained, cross-bedded, crinoidal-bryozoan packstone; partly dolomitized; shaly parting at base, fine-grained dolomite lens in middle; rhynchonellid brachiopods. (8 ft 3 in.)
2. Limestone, brown to gray, argillaceous, medium- to coarse-grained wackestone to packstone; locally leached and dolomitized with pinpoint porosity; rhynchonellid brachiopods, crinoids, bryozoans, syringoporid corals, burrows. Lower part more dolomitic, fine-grained. (10 ft)
1. Shale, gray, blocky, silty. (1 ft)

Figure 13. Composite stratigraphic section No. 5, Dieterle Road.



St. Louis Limestone

40. Light-gray, medium-grained, fossil fragmental-superficial oolitic grainstone. (6 ft 3 in.)
39. Gray to buff, silty, fossiliferous packstone, shaly in upper part. (1 ft 3 in.)
38. Light-gray to buff, fossil fragmental-superficial oolitic grainstone. (1 ft 4 in.)
37. Intraclastic packstone, medium-grained matrix, light-gray chert nodules. (2 ft)
36. Buff, argillaceous mudstone to packstone, inaccessible. (2 ft)
35. Buff to brown, platy, sandy-silty, dolomitic packstone, top surface undulatory as seen in exposure across interstate; bryozoans, brachiopods. (4 ft 5 in.)

Section transferred north to base of Unit 35 under the railroad and Big Bend overpasses.

34. Wackestone as below, buff chert nodules. (1 ft)
33. Gray to buff, crinoidal wackestone to packstone, argillaceous partings; brachiopods, bryozoans, echinoid debris. (9 in.)
32. Gray to buff, stromatolitic boundstone grading up into fossiliferous wackestone. (1 ft 5 in.)
31. Buff, very argillaceous, crinoidal packstone, fissile weathering, abundant secondary quartz in top 0.2 ft, rubbly appearance. (8 in.)

Section transferred west to trench next to I-270 highway.

30. Gray to buff, fine-grained packstone. (1 ft 7 in.)
29. Gray to buff, stromatolitic boundstone. (4 in.)
28. Gray to buff, fine- to medium-grained wackestone to packstone. (7 in.)
27. Buff, slightly sandy, fine- to medium-grained crinoidal packstone, slabby at top. (5 ft 6 in.)
26. Light-gray, intraclastic packstone, matrix fine-grained and slightly sandy, intraclasts of silty mudstone. (5 in.)
25. Gray, fine- to medium-grained wackestone grading into stromatolitic boundstone. (1 ft 7 in.)
24. Buff, slightly sandy, highly cross-bedded, fine-grained grainstone, slabby near top, scattered buff cannonball chert nodules; brachiopods. (10 ft 2 in.)
23. Buff to brown, fine-grained dolomite, buff cannonball chert. (2 ft)

Figure 14. Composite stratigraphic section No. 6, Meramec Highlands Quarry.

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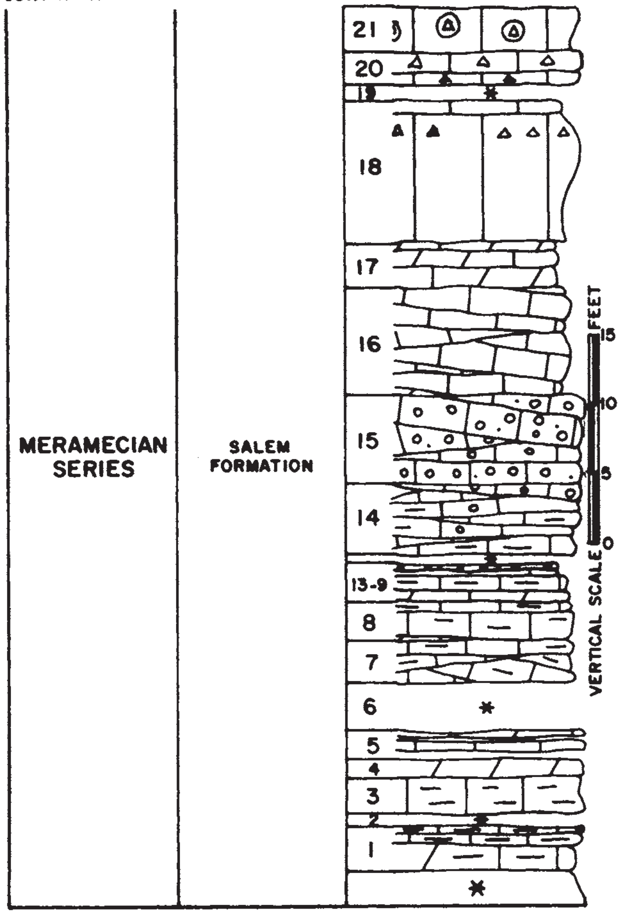

Figure 14. (continued)

22. Buff, slightly sandy, highly cross-bedded, fine-grained grainstone, buff cannonball chert nodules; scattered brachiopods. (7 ft 9 in.)
21. Buff to brown, earthy packstone, recessive, abundant buff cannonball chert nodules. (3 ft 5 in.)
20. Buff, fine-grained grainstone, abundant light-gray to buff chert nodules and lenses. (2 ft 3 in.)
19. Covered interval. (1 ft 2 in.)
18. Light-gray, fine- to medium-grained, crinoidal-bryozoan grainstone to packstone, chert nodules near top; brachiopods, rugose corals. (9 ft 9 in.)
17. Buff, porous, fine-grained, limy dolomite, abundant calcite-filled voids and scattered shell fragments. (3 ft 4 in.)
16. Buff to brown, cross-bedded, crinoidal-bryozoan grainstone; brachiopods; lower 0.7 ft, buff, fossiliferous, dolomitic wackestone lensing laterally into the grainstone. (7 ft 6 in.)
15. Buff to brown, slightly sandy, cross-bedded, fine-grained,· crinoidal-superficial oolitic grainstone to packstone, rugose corals, abundant endothyrids, brachiopods at top. (6 ft 2 in.)
14. Buff to brown, cross-bedded, medium-grained, crinoidal-bryozoan grainstone to argillaceous packstone, superficial ooliths, crumbly weathered surface; brachiopods, gastropods. (5 ft)
13. Covered interval. (9 in.)
12. Light-gray to buff, slightly sandy, crinoidal-superficial oolitic packstone. (2 in.)
11. Same as unit 9. (3 in.)
10. Buff, very argillaceous, brachiopodal wackestone, shaly partings. (1 ft 1 in.)
9. Buff, limy, fine-grained dolomite, skelmoldic porosity; fossil fragments. (8 in.)
8. Brown, argillaceous, medium-grained, crinoidal-bryozoan packstone; abundant brachiopods. (2 ft 4 in.)
7. Buff, argillaceous, cross-bedded, medium-grained packstone, dolomitized in upper part; brachiopods. (3 ft 4 in.)
6. Covered interval. (3 ft 5 in.)
5. Buff to brown, argillaceous, bryozoan-crinoidal packstone, skelmoldic porosity, partly dolomitized and covered. (2 ft 5 in.)
4. Buff, fine-grained dolomite, skelmoldic porosity; scattered fossil fragments. (6 in.)
3. Light-gray to buff, medium-grained, bryozoan-crinoidal grainstone to argillaceous packstone. (2 ft 7 in.)
2. Covered interval. (1 ft)
1. Buff to brown, argillaceous, medium- to coarse-grained, crinoidal-bryozoan packstone, partly dolomitized. (3 ft 1 in.)

STRUCTURAL FEATURES OF ST. LOUIS COUNTY AND VICINITY

(adapted from McCracken, 1966, "The Structural Features of St. Louis County and Vicinity," in "Middle Ordovician and Mississippian Strata, St. Louis and St. Charles Counties, Missouri": Missouri Geological Survey, RI 34)

The St. Louis, St. Charles, and northern Jefferson County region incorporates part of a monoclinal structure dipping northeastward from the northwest flank of the Ozark uplift into the northern part of the Illinois basin. Dips average 55 ft per mile between Pacific, Missouri, and the Mississippi River at St. Louis. The monocline is interrupted by several anticlinal and synclinal structures trending northwest-southeast, the chief of which are the Eureka-House Springs anticline and the Dupo-Waterloo anticline. Northward, in southern Lincoln County, the Cap au Gres faulted flexure (Rubey, 1952) is a major structure in the region. Just south of the Cap au Gres structure is a sharp syncline (Troy-Brussels syncline of Rubey, 1952). North of the Cap au Gres structure the Lincoln fold plunges northwestward along a northwest-southeast axis. East of the Eureka-House Springs anticline and west of the Waterloo-Dupo anticlinal trend a somewhat poorly defined synclinal area that preserves Pennsylvanian rocks has been designated the St. Louis depression by Searight and Searight (1961). Fenneman's Cheltenham syncline, which preserves early Pennsylvanian fire clays, lies in the area of the St. Louis depression.

The Eureka-House Springs anticline, the westernmost of the two anticlinal structures crossing the St. Louis County area, is well developed between Eureka, Missouri (sec. 26, T. 44 N., R. 3 E.) and House Springs, Missouri (sec. 2, T. 42 N., R. 4 E). It seems to plunge to the southeast in Jefferson County and to the northwest, where it crosses the Missouri River on the St. Louis-Franklin County line at St. Albans, Missouri. A northwest extension appears as a window (fenster) of Ordovician strata along Dardenne Creek, in T. 46 N., R. 1 E., and as several windows of Kinderhookian strata and one of Devonian strata, to the northwest, in T. 46 N., R. 1 E., St. Charles County, south of Foristell. This structure was first described by Gleason (1935, p. 8), who stated that "...the Eureka Anticline passes through the town of Eureka in sec. 36, T. 44 N., R. 3 E., and continues through western St. Louis County with a general north-northwest trend...".

Engle (1939, p. 5), describes the Eureka-House Springs anticline in Jefferson County as an anticlinal structure in the House Springs area. His map shows the apex of the structure to pass through secs. 21, 26, W½ sec. 26, NE¼ sec. 34, W½ sec. 35, T. 43 N., R. 4 E., and through NE¼ sec. 2 and SW¼ sec. 1, T. 43 N., R. 4 E., and sec. 7, T. 42 N., R. 5 E. Later theses by Doman (1955) and Good (1948) describe the same area.

To the southeast and slightly en echelon to the east, the Valmeyer anticline of Illinois appears to cross the Mississippi and is associated with rock folds near Imperial, Missouri. The Eureka-House Springs and Valmeyer anticlines make up a northwest-southeast trending structure which may be related to basement faulting. Deep drilling information is not available and this relation cannot be substantiated at present.

The second major anticlinal trend, the Dupo-Waterloo anticlinal structure in Illinois, has been recognized as passing into Missouri near the Workhouse Quarry, at the foot of Meramec Street, in the City of St. Louis (Fenneman, 1911). It appears to die out northwestward near the Compton Hill Reservoir at Grand and Lafayette Avenues in the City of St. Louis; however, an anticlinal structure near 12th and Spruce Streets, described by Gleason (1934), is slightly en echelon to the east of the Dupo structure and reappears again to the north as the Florissant dome (McCracken, 1956). Cole (1961, p. 86-88) shows this to be a northwest-southeast linear structure extending from the Cap au Gres fault, southeast to below Waterloo, Illinois. Small quantities of oil and gas have been reported from wells in this structure in the City of St. Louis. Fenneman (1911) reports that three wells at the Welle-Boettler Bakery on the corner of Vandeventer Avenue and Forest Park Boulevard encountered brine, some gas, and little oil. For a 6-month period gas from one of the wells was used to heat the ovens of the bakery. The closed pressure was said to have reached 240 pounds per square inch. The pressure weakened until after one year only a little gas continued to escape. The well was then pumped, and produced about one barrel a day of heavy, black, ill-smelling oil. The oil and gas were probably from the Kimmswick Formation (Trenton), the same productive horizon in the Dupo, Waterloo, and St. Jacobs fields in Illinois, and in the Florissant field in north St. Louis County.

Fenneman also reported that wells at Tamm's Glue Factory, the Fruin-Bambrick Construction Company, the Union Brewing Company, and the Grone Brewery encountered slight amounts of gas and oil. In 1912, a well at the Mutual Brewery, at Boyle and Duncan Avenues, encountered gas at a depth of 700 ft.

The north end of the Dupo-Waterloo-Florissant anticlinal trend is terminated by the Cap au Gres fault, which greatly displaces early Ordovician to Pennsylvanian rocks. Worthen (1870) referred to the great fault at Cap au Gres as "the most remarkable disturbance of stratified rocks to be found within the limits of the state (Illinois)." He attributed the name Cap au Gres to French Voyageurs who named the outcrop of St. Peter Sandstone at the fault line the "sandstone headland." Potter (1873), in a report on the geology of Lincoln County, described a great fault crossing Lincoln County at the south of the anticlinal fold (Lincoln fold), in a W. 30° N. direction. Keyes (1894) later applied the name Cap au Gres to the fault. The structure was described by Virgil Cole (1961) as follows: "...Rubey (1952) described the east-west Cap au Gres faulted flexture as a narrow band of steeply dipping rocks and discontinuous faults. South of the fault zone, rocks of lower Paleozoic age are steeply upturned, whereas, north of the zone, beds dip gently downward into the fault. Rubey judged that the presence of a long, continuous fault could not be justified by surface work but recognized that the Cap au Gres Fault was one of the sharpest zones of rock deformation in Illinois. In his regional interpretation, Rubey showed that the fault is related to the Lincoln Fold, and that both the fold and fault are related to the Ozark Uplift. He concluded that the steep dips along the Cap au Gres Fault are not the result of drag folding along a normal fault, but are caused by horizontal compression or that the structural features might be accounted for by movements along a deep-seated reverse fault which did not reach the surface."

Cole (1961) further shows that the alignment of the Lincoln fold and Waterloo-Dupo anticline, which are Precambrian structures, parallels the major NW-SE structural trend of Missouri. Both features are offset by the Cap au Gres fault. In conclusion Cole states, "It seems possible then from the foregoing evidence to conclude that the Cap au Gres is a left lateral fault that has experienced movement of approximately 30 miles, offsetting the Lincoln Fold and the Dupo-Waterloo Anticline."

Statewide isopach and structural maps of pre-St. Peter Ordovician formations of Missouri by McCracken and McCracken (1965) show the probability of this relationship. Unpublished maps of the Cambrian of the area also show this relationship. The distribution of the Silurian, Devonian, and lower Mississippian formations along the Lincoln fold points to probable westward movement of the north side of the Cap au Gres fault. This may account for some of the difficulties in correlating these beds across the Cap au Gres structure.

South of the Cap au Gres structure, Rubey (1952) has described a syncline that preserves Pennsylvanian and Mississippian (Meramecian) rocks. The Pennsylvanian rocks preserved in this area; some small outliers near St. Charles, in St. Charles County, Missouri; and a rather large area in St. Louis County have been referred to the St. Louis depression by Searight and Searight (1961). Preservation of the Pennsylvanian in this area seems to be due to its general synclinal structure between the Eureka-House Springs trend and the Waterloo-Dupo-Florissant trend.

Fenneman (1911) described a syncline striking north-northwest to south-southeast passing near the southwest corner of Forest Park, City of St. Louis. This structure allowed the Cheltenham fire clay and other Pennsylvanian beds to be preserved along its axis. Mining of the Cheltenham fire clay has been entirely within this synclinal area. It is within the area described as the St. Louis depression.

Structurally, St. Louis County and adjacent parts of St. Charles and Jefferson Counties owe much to the Precambrian basement configuration. Limited control seems to point to variations in elevation and rock types at the Precambrian surface. Precambrian wells near Dupo, Illinois, and at the Florissant oil field show the Bonneterre Formation to be thick and resting on granite, and the Lamotte Sandstone to be absent. A well at the Insane Asylum, at 5800 Arsenal Street, St. Louis City, drilled in 1869, encountered a thicker section of Bonneterre that rested on Lamotte Sandstone. It was originally believed that the well bottomed in granite. In 1940 the author examined cuttings from this well and decided that it bottomed in Precambrian quartzite. Studies by the Illinois Survey (Grogan, 1950) indicated the well bottomed in Lamotte and did not reach Precambrian rocks. The author believes that the section below 3831 ft, which was logged by the drillers as "very hard red granite," is quite similar to Precambrian rocks encountered in the Wynne-McAlpine well, in sec. 20, T. 50 N., R. 12 W., Boone County, Missouri, and to rocks encountered in a deep well drilled at Clarinda, in Page County, Iowa. These wells encountered hard red Precambrian quartzite similar to the Sioux and Baraboo quartzites to the north. It would therefore appear that the structurally low well in St. Louis encountered metamorphosed basement sediments, whereas the structurally high wells encountered granite. This would suggest the probability of Precambrian basement fault block structures that are reflected in later Precambrian topography. In turn this would account for thinning of sedimentary units above structurally high areas and their thickening in structurally low areas. As deep drilling is expanded we should be able to pinpoint such block faulting. At present any fault locations must be very tentative.

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Construction Aggregates in the St. Louis Area
by A.W. Rueff

The St. Louis area is the largest producing and consuming area for construction aggregates in the state. In 1985 total aggregate production was valued at an estimated $26.5 million and included crushed stone, sand, and gravel. Of this figure approximately 70 percent was from crushed stone. This is the value of the aggregate at the plant site; estimates of the value of concrete, a mixture of fine and coarse aggregate, cement, and water, approach $50 million. Concrete usage alone represents only 10 to 15 percent of the total aggregate produced in the area. Added to this would be the value of asphaltic concrete and other materials produced directly from the aggregate. Another insight to the importance of construction aggregates is that they are the essential first step in the $1.8 billion annual construction market in the St. Louis standard metropolitan statistical area. The value of total aggregate production for the City and County of St. Louis from 1955 to 1985 is shown in figure 15. Fourteen aggregate operations are active at present and their locations are shown on the index map, figure 4. By comparision 27 aggregate operations were active in 1967.

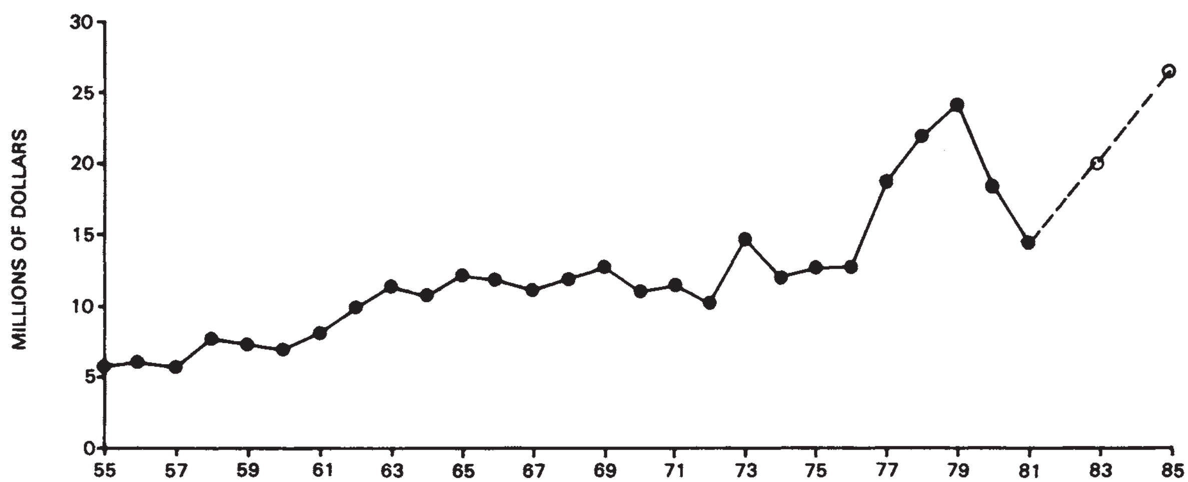

Figure 15. Value of crushed stone and construction sand and gravel (1955-85), City and County of St. Louis.

Crushed Stone

Crushed stone is one of the most valuable mineral products in the area, as it is for most of the state. In 1985, the latest year complete data are available, production was almost 6.5 million tons valued at $18.4 million. Annual production of crushed stone from 1955 to 1985 are shown on figure 16. The major use of crushed stone during 1985 was for construction aggregates; table 1 provides a complete breakdown by use for 1980, 1981, and 1983.

Economic stone resources in the City and County of St. Louis area are in the Plattin, Kimmswick, Salem, St. Louis, and Ste. Genevieve Formations. Of these units the most desirable for high-quality aggregate production are the Plattin, Kimmswick, St. Louis, and Ste. Genevieve Formations. These units produce stone suitable for portland-cement concrete aggregate and also cement manufacture.

TABLE 1

CITY AND COUNTY OF ST. LOUIS - STONE PRODUCTION BY USE

1983

Use	Tons	Value
Concrete Aggregate	332,888	$ 744,632
Bituminous Aggregate	271,328	475,727
Macadam Aggregate	1,799,731	3,463,686
Roadbase/Road Surface	500,167	1,255,040
Use Not Specified/Miscellaneous	2,374,584	7,510,758
	5,278,698	$13,449,843

1981

Use	Tons	Value
Aglime	30,758	$ 72,533
Concrete Aggregate	389,974	1,076,778
Bituminous Aggregate	831,187	1,825,857
Macadam Aggregate	1,073,432	1,867,155
Roadbase	1,170,266	2,807,570
Unspec. Aggregate/Surface	443,660	1,106,201
Riprap/Jetty/RR/Etc.	429,351	1,000,669
	4,368,628	$ 9,756,763

1980

Use	Tons	Value
Aglime	21,017	$ 45,291
Concrete Aggregate	499,654	1,355,997
Bituminous Aggregate	1,057,954	2,298,994
Macadam Aggregate	1,133,680	1,860,519
Roadbase	1,499,872	3,520,812
Unspecified Aggregate	503,736	1,104,351
Riprap/Jetty/Cement/RR	979,235	1,968,989
	5,695,148	$12,154,953

Other units quarried are generally not suited for high-specification aggregate use or for cement and lime manufacture, but find wide usage as base stone or surfacing. While a formation is commonly said to be suitable for a particular use, this does not mean that the entire formation is suitable; in most cases this refers only to selected "ledges." Furthermore, each site and ledge is a separate entity and must be continuously evaluated on its own properties.

Resources of high-quality stone are large in the St. Louis area; however, as in most urban areas, many prospective sites have been developed or otherwise "culturally nullified." Although unreclaimed stone operations can leave the landscape an eyesore and result in air and water pollution, these are solvable problems, many of which are met by existing State and Federal regulations; others can be anticipated by local planning authorities. We as the general public must recognize both the absolute necessity of this type of operation and that these operations must locate where there is suitable stone, not where locations might otherwise be convenient.

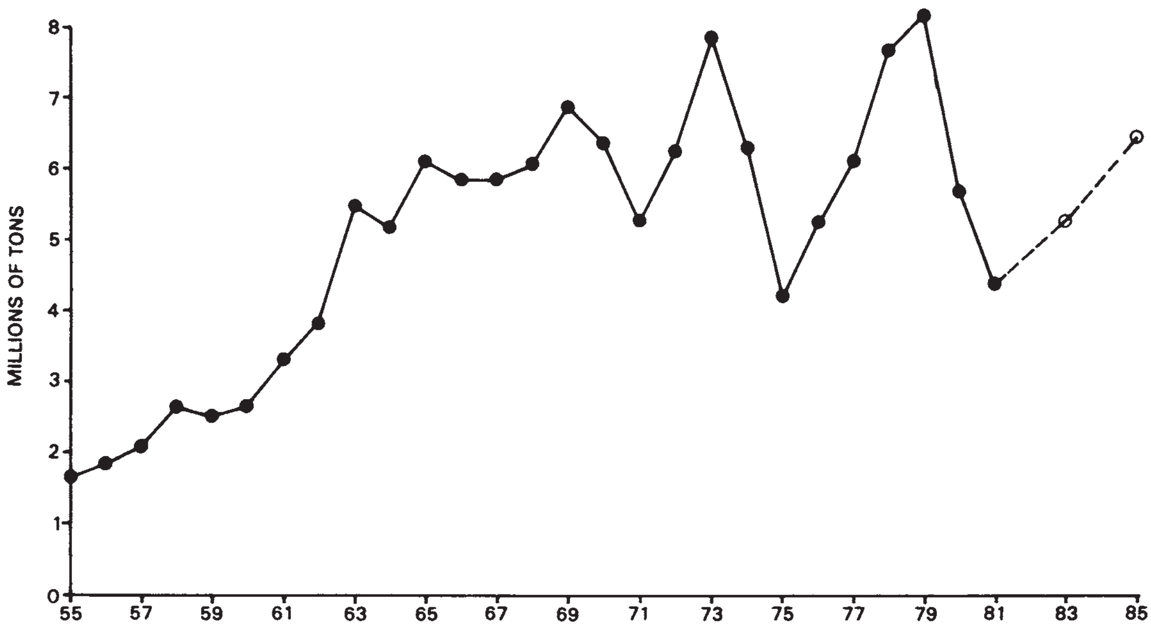

Figure 16. Crushed stone production (1955-85), City and County of St. Louis.

Construction Sand & Gravel

Construction sand and gravel resources are large but restricted to several major streams. In 1984, the latest year complete data are available, production was slightly over 3 million tons valued at almost $7.5 million. The major uses that year were concrete aggregate and concrete products. Other uses included fill, asphaltic concrete, and snow-ice control. Figure 17 shows the production of construction sand and gravel in the City and County of St. Louis for 1955 to 1985.

Two distinct types of material are produced in the area. In-channel deposits along the Missouri and Mississippi Rivers produce sand (fine aggregate) and account for about 55 percent of the total tonnage and 40 percent of the total value. Dredges on the two rivers pump sand into barges on which there is some washing and sizing. Later, the sand is transferred to stockpiles on shore. Material produced by the dredges can be summarized as follows: the sand fraction in both streams is quartz; the Missouri River sands are generally coarser and there is more silt. In addition, lignite, a deleterious material in finished concrete, is abundant in Missouri and Mississippi River sands. Sand from both streams is rounded; sizes range from minus #10 to plus #60.

The Meramec River is the other major source of sand and the only source of gravel in the St. Louis area. Material from this stream is completely different from that from the Missouri and Mississippi Rivers. The sand fraction is quartz somewhat angular in shape, and lignite free. Gradation of the sand is generally more desirable for aggregate purposes than sand from the Missouri and Mississippi Rivers. In addition, minor amounts of flint occur in the coarser sand size ranges. The gravel fraction, mostly minus 1½", is over 90 percent rounded chert. Sand and gravel occur as in-channel bars and as alluvial fill under 10 to 15 ft of silt or clay. Most current production is from floodplain operations. Meramec River sand and gravel is a well-known high-quality aggregate and is widely used in ready-mix concrete.

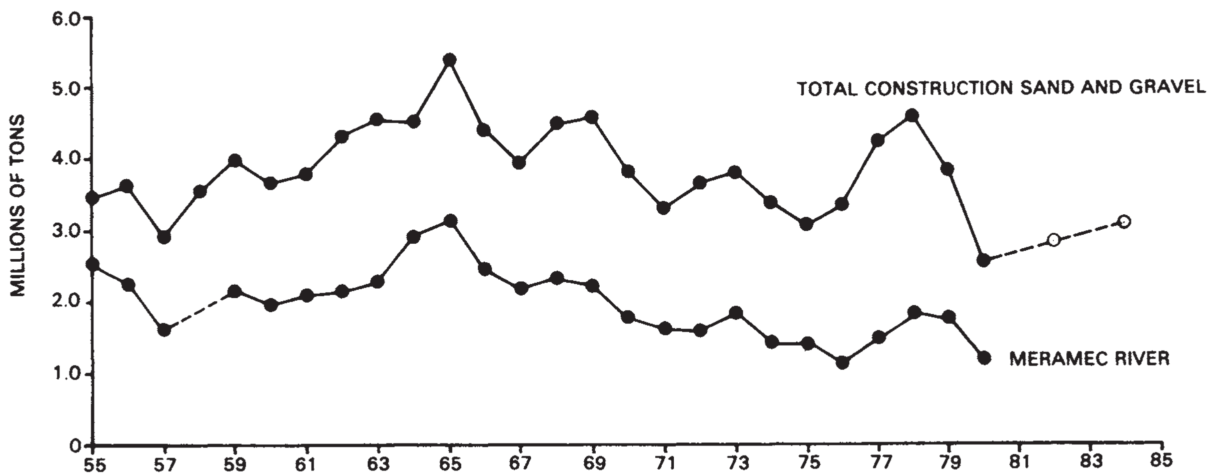

Figure 17. Construction sand and gravel production (1955-85), City and County of St. Louis.

MINERAL RESOURCES IN THE ST. LOUIS AREA

Cement

Cement, one of the most important and widely used construction materials, is the binding or cementing material known commercially as portland cement. Joseph Aspdin in 1842 patented a cement in England, which was a rather exact mixture of lime, silica, and clay burned to a specific temperature. As it resembled quarry rock from the Isle of Portland it was named portland cement. It was far superior to the haphazard blends it succeeded, and by the end of the century, this cement had virtually replaced all others.

The first portland cement manufactured in Missouri was at Prospect Hill, north of St. Louis, on the Mississippi River, in 1902. In 1909 another cement plant was opened in south St. Louis County, on Gravois Creek. Both plants are now closed, but Missouri ranks fifth nationally in cement production.

The cement formerly made in St. Louis was a mixture of St. Louis limestone, normally quarried at the plant, and silica and clay from the Pennsylvanian deposits that lie directly above the limestone. Cement manufacturing consists of blending these raw materials in the proper proportions, burning the mixture in a rotary kiln to the point of fusion to form Clinken, the addition of gypsum to retard setting, and fine grinding for shipment.

Petroleum and Natural Gas

In recent years the Florissant dome, the only geologic structure economically important as a petroleum source in this area, has become a boon to St. Louis residents and industry, because it stores the city's vast supplies of natural gas and propane. The gas is transported in pipelines, and the dome is used as a natural surge tank to contain fuel sufficient for the peak heating periods.

Exploration in the early 1950's for a natural reservoir for natural gas storage resulted in discovering oil in the Kimmswick Formation, in north St. Louis County, near the center of the dome. Further drilling disclosed the dimensions of the structure, the stratigraphic horizons that could hold gas, and the volume of the "bubble" that could be contained.

Crude petroleum is still produced from about 20 wells in the Kimmswick limestone at a depth of about 1000 ft in the Florissant oil field.

The St. Peter formation, a sandstone from 90 to 150 ft thick and 1500 ft deep, is porous enough to accept gas injection and, more importantly, there are thin shale "membranes" near the top of the formation that are impervious and can prevent gas from migrating upward.

Gas injection began in 1955 and continued until a maximum of approximately 31 billion ft^3 had been stored, a quantity more than adequate for current St. Louis needs, in as much as less than 10 billion ft^3 are used in a winter heating season.

Coal

Coal was first discovered in St. Louis very early in the 19th century, near the Oak Hill area of St. Louis. Two thin coal seams were discovered in the Cheltenham syncline; one was about 1.5

ft thick and another, 50 ft higher, about 4 ft thick. Interbedded with the coal were thick beds of shale or clay that were often mined with the coal. The coal was bituminous and of a quality to make it quite satisfactory as a fuel for industry at that time.

Several fortunes were made in this enterprise and numerous people employed. Coal was mined in the area for many years until improved transportation made the thicker, more easily mined coal of Illinois more practical. Until this century, coal was mined in conjunction with the refractory grade clays with which it was associated. Much coal still remains under south St. Louis at various depths in the Cheltenham syncline.

The amount of coal mined would be insignificant by today's standards, even if it had all been extracted. Measured by the needs of the young industry and the primitive transportation of 150 years ago, however, this natural resource had a tremendous impact on the growth and economy of St. Louis

Industrial Sand

Industrial, or silica sand, are terms used by the mineral industry for natural mineral aggregates consisting essentially of silica. The most common source of this material is quartz sand. Silica minerals are among the hardest of the common minerals; they are chemically inert and are fusible at high temperatures. Many of their important uses relate to these properties.

Statewide, the largest single use, slightly over 50 percent, is glass making. Other leading uses are metallurgical processing, abrasives, and general chemical purposes.

Chemical and physical properties of industrial sands must meet rigorous specifications, depending on the desired final product. Chemically, the most important specifications are for silica, iron, alumina, lime, magnesia, and alkalies. The more important physical properties are size gradation, grain shape, and uniformity of grain size; hardness, toughness, and strength are also important.

The source of almost all industrial sands produced in Missouri is the St. Peter Sandstone, which is present at the surface in a narrow, nearly continuous outcrop belt paralleling the Missouri and Mississippi Rivers in east-central Missouri. It is up to 100 ft or more in thickness but averages between 60 and 80 ft. It is a white, fireable, very pure quartz sandstone, the particles of which are fine- to medium-grained, well rounded and frosted. The formation commonly forms massive, gray-brown ledges in natural outcrops.

High-purity silica sand has been continuously produced from the St. Peter Sandstone since the early 1870's, when predecessors of Pittsburg Plate Glass began operations near Crystal City. The historic mine that formerly supplied sand for glass making at this plant closed in early 1983.

Production of industrial sand from mines in east-central Missouri has slowly and steadily declined since the mid-1970's. Perhaps the major reason for this decline is that several of the sand mines specialized in producing sand for plate- and window-glass and container-glass manufacturing, and they were adversely affected when technological improvements in the flat-glass industry and the substitution of other materials for container glass industry greatly affected those industries.

Clay and Shale

Resources of fireclay, common clay, and shale occur in the St. Louis area. They were mined for use in manufacturing refractory clay products, common brick and tile, and cement, but these resources are no longer mined in the area.

Fireclay production in Missouri began in the mid-1800's in the Cheltenham district of south St. Louis County. Later minor production was reported from the western part of the county. Plastic refractory clays were produced from the area between Forest Park and Tower Grove Park. The refractory clays were 2 to 12 ft thick and mining was underground. When more refractory clays were discovered elsewhere, they were shipped to the St. Louis area and blended with these plastic clays. With the depletion of most deposits in this area, the growth of plants outside it, and the encroachment of metropolitan St. Louis, this district is no longer active. All fireclay used in the St. Louis area today is imported from other places.

Production of common clay and shale for use in structural clay products began with the earliest settlements in the area. In 1891, for example, 50 brickyards operating 213 kilns manufactured 250,020,000 bricks valued at $2,262,947. The last operating brick plant closed in the late 1970's. Production of shale for in cement manufacture continued until the last cement plant closed in 1982.

TESTS FOR PROPERTIES IN CRUSHED STONE AGGREGATE FOR USE IN BUILDING AND ROAD CONSTRUCTION

by
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Crushed stone products have a wide range of applications in construction today and are grouped primarily by their physical and chemical properties, which are affected by the environment in which they will be expected to perform. The most common of these measures of rock quality which are used in Missouri for grouping are the following:

(1) Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine (ASTM C131). This test is performed by taking a dried aggregate sample separated into individual size fractions and recombining them by weight to make a specific graded sample. This sample is then placed in the Los Angeles Machine (a motorized steel drum with a lifter bar) with the proper number of steel balls for the graded sample. The drum and sample are rotated for 500 revolutions at 30 to 33 rpms. After the sample is processed, it is regraded and the weight loss is expressed in percent of loss. This test indicates how durable a stone will be (the lower the percent of loss the more durable the stone). The test also gives an indication of the amount of fines that will be produced in crushing operations (the higher the percent of loss, the more fines produced).

(2) & (3) Specific Gravity and Absorption of Coarse Aggregate (ASTM C127). The specific gravity is tested by bulk sample in a wire screen and, like all specific gravities, is a comparison of weight in air vs. weight in water (Wa/Wa-Ww). This test is important to the producer of concrete, because if the aggregate specific gravity is too low the rock will float to the top of the concrete mix in the finishing operation. An "*as received*" bulk specific gravity of like type stone also has an inverse correlation with water absorption capacity (the lower the specific gravity the higher the water absorption capacity).

The water absorption capacity, a measure of the stone's ability to absorb and hold water in the rock pores, greatly affects production of concrete and asphaltic concrete. The test is performed by soaking a sample for 24 hours then measuring the percent of loss between a surface-dried sample and a dry sample (Ww-Wd/Wd x 100). In asphaltic concrete, the higher the absorption, the more asphalt absorbed; the more asphalt required, the higher the production cost. In concrete, the higher the absorption, the more water the stone will remove from the mix, which means additional water must be added to prevent shrinkage cracks and to ensure adequate amounts of water for proper concrete hydration.

(4) Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate (ASTM C88). This test attempts to approximate the action of freeze-thaw action on the aggregate by growing chemical crystals in the rock pores to create internal pressure and deteriorate the stone. In this test, as in all soundness tests, the percent of loss is the measure of rock quality.

Other soundness tests which have been used are Unconfined Freeze-Thaw of Aggregate (AASHTO T103-78) in water or a 10 percent NaCl water solution, and the Copper-Nitrate Staining Method (Handbook of Concrete Aggregate: Ludmila Dolar-Mantuani). Of these two methods, the copper-nitrate staining method yields more useful information more quickly. For this test a sample is first separated into individual size fractions, each of which contains 200 pieces. The fractions of the sample are then placed in open containers for 16 hours and soaked in a 250 gram/liter copper nitrate solution. After processing, the sample is stabilized in a strong ammonia solution to fix the results. The test performs several functions:

1. It distinguishes between unstained silicate and stained carbonate particles or portions of particles such as porous limestone and porous chert.
2. It distinguishes between limestone and dolostone; calcite is dark blue and dolomite is light blue.
3. It shows the presence and amounts of impurities, which occur as unstained grains or areas on the surfaces of carbonate rock particles.
4. It helps to evaluate the quality of shales and sedimentary carbonate rocks that contain significant amounts of clay impurities by producing damage of various kinds and of varying degrees to the aggregate particle.
5. It reveals the depth of carbonation and distinguishes old carbonated cracks from recent uncarbonated cracks in concrete.
6. It reveals hidden fabric characteristics in apparently uniform carbonate rocks.

Advantages of the copper nitrate test over the sodium sulfate test, the most used test for soundness, and the magnesium sulfate test are the following:

1. The solution is easily prepared and is stable.
2. The elements in the solution are normally foreign to rocks used as concrete aggregate.
3. The test is based on particle count and is performed on 200 particles, the same number as used in petrographic examinations, thereby facilitating comparison of the two sets of results. On coarse aggregate fractions and rock specimens, it is usually applied to petrographically selected material.
4. The copper nitrate coating does not produce misleading shrinkage cracks on drying after a test; very fine shrinkage cracks are visible on the particles smaller than 300 μm when using magnifications greater than 50.
5. Type and degree of damage to impure carbonate rocks and shales seem to correspond to the harmfulness of these materials in concrete.
6. Damage is observed easily with a hand lens, an examination that is an essential part of the test. Most coarse aggregates are also examined petrographically before the test.
7. Damage occurs while particles are still immersed in solution and all material is available for examination.
8. Material is not handled before observation of the more pronounced damage.
9. The nitrate test can be performed in the field because it requires only the nitrate solution, concentrated ammonia, tap water, and containers.
10. The test takes very little time: 16 hours for the test proper, in contrast to 1 week for the sulfate test.

Other important tests for the discriminating quarry, concrete, and asphaltic concrete producer are the following:

(1) The Iowa Pore Test Index. This test uses a modified Press-Ur-Meter to determine pore size by pressure penetration of water under 35 psi pressure. The test uses a sample consisting of a 0.5- to 0.75-inch 9,000 gram oven-dried stone placed in the pore test equipment. After venting, the meter is filled to the O milliliter mark and the supply is closed. Air at 35 psi is then applied to the meter and a water level reading is taken after 1 minute. The amount of water injected during this first minute fills the aggregate's macropores and is referred to as the *primary load.* A large primary load is considered a beneficial limestone property. A well-developed macropore system may function in a manner similar to air entrainment voids in concrete paste. The primary load is not used in the pore index

result calculations. The water level is measured again after 15 minutes. The volume of water injected between 1 and 15 minutes is the *secondary load* and represents the amount of water injected into the aggregate's micropore system. A secondary load of 27 milliliters or more indicates a negative limestone property that correlates with a saturated aggregate's incapacity to withstand internal pressure from freezing. Studies have shown that pore sizes larger than 0.2 microns appear to be able to act as air entraining to aid freeze-thaw resistance. Pore sizes less than 0.04 microns are not affected greatly by freeze-thaw action. This test was developed by the Iowa Department of Transportation because of a severe D-cracking problem caused by the inability of some coarse aggregates to perform in cold winter environments. (Vernon Marks and Wendell Dubberke: Durability of Concrete and the Iowa Pore Index Test). An article in the Journal of the American Concrete Institute, July-August 1985/no. 4, Proceedings v. 82, page 453, *Comparison of aggregate pore characteristics as measured by Mercury intrusion porosimeter and Iowa pore index tests* (A. Shakoor and C. F. Scholer) drew the following conclusions:

1. Mercury intrusion porosimeter and Iowa's pore index tests provided reliable information about the influence of an aggregate's pore system on the aggregates freeze-thaw durability. There is a strong correlation between the expected durability factor and the pore index value.
2. The pore index tests can be used as a simpler, quicker, less expensive, and more representative replacement of the mercury intrusion porosimeter to identify aggregate potential for causing D-cracking, pitting, and pop-outs. It could be used as an acceptance test for production aggregate.

(2) Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method) (ASTM C586). This test is made on individual rock strata in a quarry from which aggregate is to be used in concrete. The test is made on a rock cylinder, 0.35" x 1.38" in size, soaked in 1-normal NaOH solution and checked at intervals for expansion. This expansion, when present, is caused by alteration of dolomite to brucite in rock where illites are present. Possible durability problems occur more commonly when calcite and dolomite percentages are about equal and small amounts of acid insoluble residue are present. These alkali-reactive carbonate rocks fall into two categories:

1. Early expanders, which are characterized by slow, steady growth and a slight weight decrease.
2. Late expanders, which are characterized by higher water absorption capacity, a steady decrease in size to a period of around 56 days, with a large increase appearing around the 84th day of measurement, and a greater weight decrease.

Hilton's work on "Expansion of Reactive Carbonate Under Restraint" indicates that certain porous argillaceous limestones, known to expand in alkali solutions, did not have sufficient internal textural rigidity to expand under a restraining force of about the same magnitude as would be found in concrete paste. Gillott and Swenson's work on the "Mechanism of the Alkali-Carbonate Rock Reaction" noted that late expanders may be prevented from expressing their expansion in concrete by the strength of more hydrated concrete of ages greater than 10 weeks. If the expansion is sufficiently slow, the concrete may adjust to the changing aggregate by creep and autogeneous healing. One further note should be made. Dolomitization is an uneven process. Entire beds in strata may be dolomitized evenly or the changes may take place only along certain cracks, fissures, bedding surfaces, or stylolites. One portion of a rock may be a pure micrite with no insolubles and another portion may contain veins and stylolites high in acid insolubles with included dolomite rhombs in a typical reactive texture. Reaction along stylolites was described by Ludmila Dolar-Mantuani.

(3) Atomic Absorption Analysis for Trace Elements and MgO:CaO Rations. This test determines the probability of an adverse reaction between the concrete aggregate and the total alkalies contained in the cement((K_2O x .658) = Na_2O)which may cause expansion in concrete. This test is performed by using a modified Yule method (Mantie and Beste, 1985) to put a 0.5 gram (±.0002 grams) sample in solution to a 1000µg/ml concentration. This sample is run on the AA machine for trace elements. An additional sample is made from the 1000µg/ml solution by adding a 2 percent La_2O_3 solution to a portion to make a 50µg/ml concentration. This sample is run on the AA machine for MgO and CaO.

Durability problems are most likely when calcite and dolomite percentages are about equal and there is some insoluble residue. This effect is increased as the total alkali content of the cement is increased. Durability is also decreased in concrete when the magnesium, iron, and sulfur contents are higher (excess pyrite and marcasite) in salt-treated concrete areas (Marks and Dubberke: The Relationship of Aggregate Durability to Trace Element Content, 1984). Marks and Dubberke used X-ray analysis to determine the compound compositions of the aggregates. There is strong evidence that the accelerated mechanism that causes durability failures with iron and sulfur present is of a chemical nature.

(4) Petrographic Analysis for Alkali-Formed Rims in Aggregate in Hardened Concrete. In a sawed concrete sample, positive and negative rims can be seen in or around the coarse aggregate in response to a reaction with the rock and cement paste. Positive rims are dark acid-resistant rims inside the aggregate. It is known that these rims are less soluble than either the interior of the aggregate or a very narrow layer of the aggregate in contact with the cement paste. Positive reaction rims are not accompanied by excessive expansion of test bars of concrete; however, they appear to be highly susceptible to freeze-thaw damage. Negative rims are limited to high-calcite rocks where insoluble residues are low. Tests have shown that expansion in concrete is at about the same percentage as rim growth in the aggregate. Exterior rims are produced by another form of reaction that forms in the mortar surrounding the aggregate.

In summary, every day, new and exciting research is being developed that helps the quarries, and concrete and asphaltic concrete producers deliver a higher quality product. This research enables producers to deliver problem free products at lower costs, with higher profits.