GUIDEBOOK

TO THE HIGHWAY GEOLOGY OF ROUTE 79TR, HANNIBAL TO CLARKSVILLE.

PREPARED FOR ASSOCIATION OF MISSOURI GEOLOGISTS 17TH ANNUAL FIELD TRIP AND MEETING, SEPTEMBER 25-26, 1970.

SPONSORED BY DISTRICT 3, MISSOURI STATE HIGHWAY DEPARTMENT, HANNIBAL, MISSOURI

ROBERT W. PATTON, DISTRICT ENGINEER

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Ray G. Wagner

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Sponsored by the Missouri State Highway Department

District 3, Hannibal, Missouri

Robert W. Patton, District Engineer

(Some pages re-keyed in 2005 because of weak original)

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INTRODUCTION

The theme of this year's trip is the relationship of geology to highway construction and maintenance. This is the second Association trip on high-
way geology and the fourth to emphasize the problems encountered in engineering geology. The route follows Mo. Hwy. 79 (Map on back cover) from Hannibal to Clarksville, a distance of about 60 miles. The topography traversed by much of this portion of Hwy. 79 is quite rugged and many of the grades are constructed on mountain standards with some being as great as 12 percent.

The geologic section is one of alternating thick limestone and shale units which do not lend themselves to slope, cut, or roadbed stability and are the cause of major problems in construction and maintenance. The stops selected provide an opportunity to see both a complete section of the exposed bedrock in this part of Missouri as well as problems directly related to this geologic setting along new and old construction and stretches presently under construction. In addition to those along the highway, stops will be made at the Universal Atlas Cement Company shale pit, and both the limestone quarry and shale pit of the Dundee Cement Company. This trip will wind up with a tour of the Dundee plant.

The Dundee and Universal Atlas plants are two of the most modern cement plants in the United States. With a combined annual capacity of 10 to 12 million barrels of Portland cement, they have played a major part in the 60% plus increase in the Missouri cement production.

The premeeting Friday afternoon trip is to the Central Stone Company quarry at Huntington, Ralls County. The quarry, in the Kimmswick and Callaway limestone, is one of the larger in the state.

On behalf of the Association of Missouri Geologists, the Committee wishes to acknowledge and thank the following for their assistance and cooperation: Steven K. Griffiths, Plant Manager, Dundee Cement Company; Robert P. Jarrett, Plant manager, Universal Atlas Cement; Robert W. Patton, District Engineer; and Roger D. Hicks, District Materials Engineer, Missouri State Highway Department, District 3, Hannibal.

The field trip chairman wishes to thank James Martin, Missouri Geological Survey, for an assist in planning the trip and in preparation of the Guidebook; and James Williams, Missouri Geological Survey, for discussing the stratigraphy at Stops 1 and 3.

Stratigraphic sections for the Stops and selected references are appended.

GEOLOGIC SETTING

The route lies on the northeast flank of the Lincoln fold, on of the major structural features in Missouri. Entering the State near Winfield in Lincoln County, the axis trace of the anticline follows a rather sinuous path through Pike, Ralls, Marion, Shelby and Knox Counties, and thence onto the Iowa line. In Missouri the general trend of the axis of the structure is about N 45° W; maximum width is about 15 miles; length 160 to 170 miles; and the structural relief involved is approximately 1000 feet. The anticline is asymmetrical with steeper dips (10° to 15°) and faulting on the southwest flank. Dips on the northeast flank are gentile (5° or less) and there is no know faulting. The overall aspect of the Lincoln Fold is that of an uplift with superimposed anticlines and domes. Description of the structure are given in the 1941 (15th Annual Field Conference) and 1961 (26th Annual Field Conference) Guidebooks of the Kansas Geological Survey.

Surface and near-surface rocks along the route are sedimentary and represent the Ordovician, Silurian, Devonian and Mississippian Systems. The oldest rock unit exposed is the Middle Ordovician (Champlainian) Kimmswick; the youngest is the Mississippian and Pennsylvanian residuum, consisting of red cherty clays, reworked cherts, and shales. Pleistocene deposits of drift, alluvium, out-wash, and loess blanket most of the area.

Two major changes will be seen in the general stratigraphic sequence along the route from Hannibal to Clarksville. Both are within the interval between the Ordovician Maquoketa and the Devonian Louisiana formations. On the Mississippi River bluffs, north of the Salt River, the Devonian Grassy Creek – Saverton shale section reaches a maximum thickness of about 50 feet and is generally found directly overlaying the Ordovician Maquoketa shale, being separated from it by a thin (6" ±) sandstone and phosphatic pebble conglomerate. South of the Salt River exposures of the Grassy Creek – Saverton range from 3 to slightly over 10 feet, the average being about 5 feet. Throughout this area, the Devonian shale is separated from the Maquoketa by the Silurian Edgewood Formation.

Following is a general description of the principal rock units that will be seen along the route:

MISSISSIPPIAN SYSTEM

Osagean Series – Burlington Limestone: The Burlington, plus the overlying but seldom differentiated Keokuk Limestone, has the most widespread outcrop pattern of any formation in northeastern Missouri and caps most of the ridges and knobs along the field trip route. Thickness ranges upwards to 100 feet; the combined thickness of the Burlington and Keokuk ranges from 150 to 200 feet. Only those beds assigned to the Burlington will be seen. The Burlington is dominantly a massive, even-bedded, cherty gray, coarsely crystalline, crinoidal limestone. The basal 15 to 40 feet commonly contain less chert than the beds above, some of which may have 50% or more chert. The lower Burlington is quarried in this area for aggregates and aglime and by Universal Atlas for the manufacture of cement. A noncherty bed in the lower unit was mined by

Marblehead Lime Company and other lime plants in the area for the manufacture of quicklime.

Kinderhookian Series – Hannibal Formation: The Hannibal is composed predominantly of interbedded shale and siltstone. The upper part is generally siltstones and sandy shales, whereas the lower is chiefly shale and silty shale. Irregular tubular markings, probably worm borings, and "rooster-tail" markings (Taonurus caudagalli) are common throughout the formation. Thickness of the Hannibal along the field trip route ranges from 50 feet at the north to slightly over 100 feet at the south.

Devonian

Upper Series – Louisiana Formation: The Louisiana is a rather distinctive unit in northeastern Missouri. It is typically a dense to lithographic limestone or dolomitic limestone which commonly weathers with a banded masonry wall appearance. The stone is hard and brittle and breaks with a conchoidal fracture, producing a talus of sharp edged fragments. Calcite-lined cavities are common throughout the formation. The unit is highly jointed and a number of joint-controlled caves have developed, the best known of which are Mark Twain (commercial) and Cameron caves. Thickness of the Louisiana ranges from about 60 feet at Hannibal to 30 feet at Clarksville; the maximum reported thickness, 67 feet, is in the area of Stop 2.

Upper Series – Saverton Formation: The formation is composed chiefly of bluish gray siltstone, silty shale and mudstone. The shale portion generally weathers to an unctuous silty clay. Maximum exposed thickness is in the area of Stop 3 where the unit is 14 feet thick. To the west and south, the unit thins. At Stops 5 and 6, the unit is 6½ feet and 2½ feet respectively.

Upper Series – Grassy Creek Shale: the Grassy Creek is a prominently jointed, dark gray to brownish black, spora bearing, fissile shale. Its outcrop is essentially coextensive with the overlying Saverton and there has been some question as to the validity of separating the two units into formations. On weathering, the Grassy Creek breaks down as shale fragments rather than as a clay mass. Reportedly, the formation reaches its maximum exposed thickness, about 50 feet, in the Saverton area. It thins southward and is only 3½ feet thick at Clarksville.

The base of the Devonian shale is marked by a persistent quartz sandstone and phosphatic pebble conglomerate. Thickness ranges from a few inches to as much as one foot. The name "Turpin" was proposed for this unit by Dr. Mehl (1961).

SILURIAN

Alexandrian Series – Edgewood Formation: The Edgewood is the principle Silurian unit in northeastern Missouri; however, locally the Sexton Creek is present in depressions on the Edgewood surface. In this area the Edgewood has been divided into two members: the Cyrene Limestone Member and the Bowling Green Dolomite member. A prominent and persistent oolite facies in the formation is termed the Noix. Only the Bowling Green Member and the Noix oolite facies will be seen (Stop 6).

Bowling Green Dolomite Member: The Bowling Green in the more prominent of the two Edgewood members throughout the northeast Missouri Silurian outcrop area. It is a massive bedded, prominently jointed dolomite. Vugs and veinlets filled with calcite and/or petroleum residue, and chert nodules are present locally throughout the member. Bluish gray on fresh surface, the unit typically weathers to a tan or yellow-brown color. Thickness ranges from a few feet to as much as 40 feet.

Cyrene Limestone Member: The Noix oolite, considered a facies of Cyrene, is the only lithology of this member that will be seen (Stop 6). Typically, the Cyrene is a gray, coarsely crystalline fossiliferous limestone that grades laterally into a blue-gray, argillaceous dolomitic limestone. The Noix is a distinctive white, somewhat fossiliferous, oolitic limestone. Thickness of the Cyrene ranges upwards to 20 feet; the Noix is generally 3 to 5 feet thick but locally thickens to nearly 10 feet.

ORDOVICIAN

Cincinnatian – Maquoketa Shale: In this area, the Maquoketa can be divided into two units; an upper shale, and a lower unit of interbedded shale, argillaceous limestone and siltstone. Typically, the shale is a bluish green to dark brown color and massive. The limestone and siltstone beds are generally 1 to 2 feet thick. Shales, limestones and siltstone are are locally fossiliferous. The average thickness of the Maquoketa along the route is 100 feet; however, nearly 145 feet was penetrated in a drill hole at the Universal Atlas cement plant at Itasco. The lower interbedded shale-limestone section makes up the bulk of the formation: the upper shale ranges from 10 to 40 feet in thickness. The bulk of the slides along Hwy. 79 from Louisiana southward are directly related to the upper Maquoketa shale. As a rule, slopes developed on the interbedded shale and flaggy limestone unit are stable.

Champlainian Series – Kimmswick Formation: There are no natural exposures of the Kimmswick along the route, and the unit will be seen in the Dundee Cement Company and Central Stone Company quarries. The formation is a coarsely crystalline, gray, medium to massive bedded, fossiliferous limestone. Chert nodules are present but not abundant. The weathered surface of the Kimmswick is pitted of "honeycombed" with tubular cavities. The characteristic fossil in the limestone is the "sunflower coral" Receptaculites. Thickness of the unit in this area ranges from 50 to about 125 feet.

ROAD LOG

Mileage Cum.	Diff.	
		STARTING POINT: Hannibal Holiday Inn – Junction of U.S. 61 and City Route 61 (Market Street). Proceed east (3.2 miles) on City Route 51 to junction with Mo. Route 79 (Church and Third Streets). South (right) on MO. Hwy. 79 (0.5 miles) to Stop 1.
0.0	0.0	Route follows Bear Creek In the early 1900's five lime plants were active along Bear Creek in and near the city of Hannibal. Today only Marblehead Lime Company plant remains and it is on standby.
1.2	1.2	Gravel Deposit to left (north). This deposit, named the "Oakwood Gravels" and assigned to the Illinoian Stage by Heim (1954) consists of alternating layers of clayey crossbedded sands and gravels are highly oxidized and noncalcareous. The dominant rock-type in the gravel is chert. Igneous and metamorphic rocks, while present, are rare. Approximately 50 feet of gravel is exposed along the hillside. It is estimated that the deposit in excess of 100 feet in thickness below the present level of Bear Creek which occupies a pre-Pleistocene channel. The high percentage of Mississippian cherts, the presence of clay, and the poor sorting and rounding of chert fragments implies an origin of being derived locally from the residuum during periodic fluctuation of stream velocities. The "Oakwood gravels" have been used locally for many years as a fill material. For use as construction aggregates, it would be necessary to process the material to remove the high percentage of clay.
2.5	1.4	Bear right onto Church Street (City Route 61). Hwy. 61 follow Church Street.
3.2	1.6	Junction of Mo. Hwy. City Route 61 and Mo. Hwy. 79. Bear right (south) onto 79 and proceed south on overpass.
3.5	0.3	Hannibal shale overlying the Louisiana limestone to right (west).

Mileage Cum.	Diff.	
3.8	0.3	STOP 1. Center SW¼ SE¼, sec. 28, T. 57N., R. 4W., Hannibal Quadrangle.

This cut was originally designed for ¼:1 slopes through the Burlington limestone, 1:1 slopes with benches in the Hannibal siltstone and shale and ¼:1 slopes through the Louisiana limestone. All roch was to presplit. Flat slopes in the Hannibal were desirable to keep the shale from undercutting the siltstone and letting large blocks fall. The Hannibal backslope in this is composed of 12 % shale and 88% siltstone. Both the shale and the siltstone are very hard and the same color in fresh cores and backslopes and cannot be distinguished from each other. Since the shale and siltstone cannot be recognized in the new exposures, projects with excavations in the Hannibal formation are let as unclassified. From experience it is known that slopes in the Hannibal when placed on the normal rock slope of ¼:1 will have continual rock fall after a short period of time. In various areas of the District, the Hannibal is on slopes of ¼:1, ½:1, 1:1, and 1:1 with benches. As of now, it appears that the 1:1 with benches may be the best design.

Another problem in this area was the uncovering of many caverns in the Louisiana limestone. Although many holes were drilled in this area, none of these caverns, fissures and cracks were encountered in drilling operations. This is the area where, three years ago this past May, the three Hannibal boys were last seen. Openings to caverns in the backslope are sealed with concrete and openings under the roadway are filled with rock, talus and some soil.

4.3	0.5	The route is now crossing the former city dump of Hannibal. At one point the fill is 165 feet from the edge of the shoulder to the toe of the slope. At the time this was one of the highest fills in the state. The south side of the ravine was filled from top to bottom by debris which measured well over 200 feet in depth. The main part of the dump did not fall immediately beneath the roadbed proper but large pieces of junk such as washing machines, etc. had rolled into the valley. All loose rubbish was removed. The entire face of the dump was laid back on a 1½ to 1 slope and covered with a rockblanket. The toe of the slope and the turnout are built directly on top of the debris.

Mileage Cum.	Diff.	
		A large spring, which flowed from the toe of the dump, is running through the base of the rock fill on top of one of the siltstone layers in the Hannibal formation. A pack of wild dogs roamed these hills for many years and made the city dump their dining headquarters. These dogs were hunted and killed but were never eliminated until the city dump was abandoned. The dogs were known to attack other dogs who roamed into their territory and put the fear into anyone who came near their dens; however, they did not attack humans.
4.9	0.6	Road to Mark Twain Cave and Cameron Cave to right (west). These and many other caves in the area have developed along the joint pattern in the Louisiana Formation. In plan view these caves are a labyrinth of passageways and becoming lost is a simple matter.
5.7	0.8	STOP 2. NE¼, SW¼, SW¼, sec. 35, T. 67N., R. 4W., Hannibal Quadrangle. Exposed here are approximately 35' of Burlington limestone, 55' of Hannibal siltstone and shale and 40' of Louisiana limestone. Note the numerous joint planes, fissures and cracks. Some small caverns may also be seen along this backslope. Most of these were filled with red clay when first exposed. Many of the cracks have probably resulted from mine collapse. A proposed route on the top of the bluff was abandoned because of the numerous large collapse holes, some as much as 100' long and 8' to 10' wide. No doubt, these are due to mine subsidence. The river side of this bluff was talus covered and inaccessible to drilling equipment; therefore, all soundings were made with resistivity equipment. The main problem here is rock fall from the Hannibal Formation. Large cracks are rapid weathering of the shale due to excessive rainfall plus freezing and thawing has caused many tons of siltstone to fall, and you can see that many more tons are ready to come down. These backslopes were designed with ¼:1 slopes through the Louisiana limestone, Hannibal Formation and all talus. The Burlington limestone was not to be disturbed nor any talus, trees or brush between the top of the backslope and the right-of-way line. Early in construction, after much rainfall,

Mileage Cum.	Diff.	
		the talus and trees started creeping down hill and this has continues to date. At one point during construction, several thousand tons of talus let go and trapped a shovel operator inside his cab. He was buried to the waist and had to be dug out.
5.9	0.2	Entrance to the abandoned underground shale mine of Universal Atlas Cement Company to right (west). The backslope and flat bottom ditch of the highway is over the abandoned shale mine. The main entry is approximately 25 to 75 feet right and roughly parallel to our center line for about 1900 feet. This entry is 8 feet wide with 25 individual rooms drifted south. Each room is 300 feet long, 30 feet wide and 20 feet high. The drifts, on 50 foot centers, are connected by 8 foot cros-cuts. Mules pulling cars on rails brought the shale to the surface. The road ditch is 62 feet above the roof of the mine. This interval consists of approximately 24 feet of Louisiana limestone and 38 feet of Grassy Creek-Saverton shale. A large bricked airshaft was removed during construction and the shaft was sealed. These mines were opened in the early 1900's, abandoned in the middle 1940's, and are now flooded.
6.1	0.2	Entrance to Universal Atlas Cement Division of United States Steel, Hannibal Plant. The present facility is the third plant built at this site. Construction of the original plant began in 1901. It was completed in 1903 and dismantled in the early 1930's. In 1903 a second plant was begun and completed in 1905. this plant was dismantled 1965-66. Construction of the present single-kiln process plant was begun in 1965 and the 620 feet kiln was placed on stream in April, 1965. with the exception of the primary crusher, all plant operations are computer controlled. An on-line X-ray analyzer makes feed analyses which are transmitted to the computer. Raw materials used in the manufacture of cement are the Burlington limestone and the Saverton-Grassy Creek-Maquoketa shales. In the past, only the basal low chert Burlington (30 to 40 foot face) was quarried; however, with the present plant, a thicker interval – 40 to 80 foot face – is quarried and separated in the raw mill into a high silica and low silica slurry. These are stored separately and blended with the shale slurry to make the proper kiln feed. Cement shipments are made by truck, rail and barge.
6.2	0.1	Universal Atlas barge loading dock to left (east).
6.4	0.2	New cement plant to right (west).

Mileage Cum.	Diff.	
6.8	0.4	Remains of old plant to right (west).
7.1	0.3	Ilasco.
7.3	0.2	Turn right (west) onto gravel road at south end of overpass.
7.4	0.1	STOP – Quarry haul road, watch for trucks. Turn left (west).
7.6	0.2	Keep bearing left.
8.1	0.5	STOP 3. NE¼, NE¼, sec. 10 & 11, T. 56N., R. 4W., Hannibal Quadrangle. Universal Atlas shale pit. The universal Atlas shale pit provides the best exposure in the area of the Louisiana – Saverton – Grassy Creek – Maquoketa contacts. With the exception of a thicker Saverton interval (14' +), which is about twice the average thickness, the exposure is typical of the geologic section along the Mississippi River bluffs north of the confluence of the Salt River. Note here that the Grassy Creek overlies the Maquoketa, being separated from it by a 2" to 6" sandstone and phosphatic pebble zone. Although this is the general relationship in the area, intervening Silurian strata are present locally where they appear to occupy erosional depressions of channels on the Maquoketa surface. RETRACE ROUTE TO HWY. 79.
8.9	0.8	Junction with Mo. Hwy. Turn right (south) on 79.
9.7	0.8	Universal Atlas limestone quarry in the Burlington to the left (east).
10.1	0.4	Burlington limestone in roadcut.
12.4	2.3	STOP 4. Center W½, SW¼. sec. 18, T. 56N., R. 3W., Hannibal Quadrangle. The steps in the Hannibal Formation are accidental but have had a tendency to stabilize the cut slope. This was due to some freak happening during blasting operations. The contractor drilled all of the cut through the Hannibal and shot it at the same time. When all the loose material had been hauled away the backslope looked as you see it now. This could never have been done if we had wanted it to look like this. In time, of course, these small benches will weather. You can see that weathering has already taken its

Mileage Cum.	Diff.	
		toll. The south end of this cut shows how the finished slope was to have looked. A large spring runs under the approximate center line of the fill area immediately to the south of us. This water is running into a porous bed of crushed limestone about 3 feet thick. Perforated drains pick up this water and carry it to a 10 inch pipe which has an outlet on the east side of the roadway. This spring is mostly a wet weather one, but does run some water most of the year. The lower brown bed of the Burlington Limestone is a good collecting area for crinoids, blastoids, brachiopods, and bryozoa.
13.0	0.6	Junction Mo. Hwy. 79 and State Rd. N. Town of Saverton and U.S. Lock & Dam No. 23 to the left (east). Maquoketa shale exposed along the south bank of creek. In the gully behind the farmhouse to the southeast of the junction, the Silurian Edgewood (Cyrene and Noix oolite facies) is present overlying the Maquoketa shale. This is the northernmost outcrop of Silurian known, and it appears to occupy an erosional depression or channel on the Maquoketa surface.
14.0	1.0	Roadcuts in glacial drift.
14.5	0.5	Louisiana – Saverton contact to right (west)..
15.8	1.4	Fools Creek. Lower Maquoketa shale and limestone flags exposed in bed and bank of creek.
16.1	0.3	Former natural slide area in Upper Maquoketa shale.
16.2	0.1	STOP 5. NE¼, SW¼, sec. 33, T. 56N., R. 3W., Barry Quadrangle. We have just driven over an area which was originally a very large natural slide in the Maquoketa shale. The weathered shale was undergraded from ditch line to ditch line to solid shale, which was about 12 feet below the present roadway grade. The excavated area was then backfilled with shot Louisiana limestone obtained from this cut. This made a large French Drain between the shale and roadbed. The drainage system was covered with compacted, weathered shale to shed surface water. All the undergrade shale has been wasted on the side of the valley to the west. You will notice by looking at the top of the shale backslope to your right (east) that something has happened there. A slide developed soon after this backslope was completed. Memphis soil, loessial in origin, has moved over the shale and many cubic yards had to be removed. The roadway on this side of the darw is also built over

Mileage Cum.	Diff.	
		a slide area. Weathered Maquoketa shale has moved downhill carrying some Grassy Creek shale along with it. In this case the slide was toward the draw and our fill butted directly into the hillside. All we did here was remove all the loose weathered shale and build our fill directly over the solid shale. Exposed here are the contacts between the Louisiana limestone, Saverton siltstone and shale and the Grassy Creek shale. The type locality for the Saverton shale is just a few miles northwest of here. Here the Saverton is 6½ feet thick. The upper half is a gray siltstone, rather hard in the fresh state, but breaks with a subconchoidal fracture. The lower half is a sandy shale. Black Grassy Creek shale is a hard fissile shale which breaks into very thin slabs. It is usually more resistant to weathering than other shales in northeast Missouri. This shale very seldom weathers down into a structure-less mass but holds together in thin platy slabs. The Louisiana limestone at this location seems to have an abundance of calcite-filled vugs. You will notice that most of the calcite is clear.
16.5	0.3	Burlington – Hannibal contact.
18.2	1.7	Burlington Limestone.
19.0	0.8	Scenic overlook – Roadside Park.
19.1	0.1	Burlington – Hannibal contact to left (west).
19.4	0.3	Junction Mo. Hwy. 79 and State Road T. Continue straight ahead (south) on Hwy. 79.
20.8	1.4	Has your car lost power??? It's not that extra load or 28¢ gasoline but one of the 12% grades on this stretch of road.
22.3	1.5	Burlington – Hannibal contact. This roadcut is Stop 9 (NE¼, SW¼, sec. 12, T. 55N., R. 3W., Barry Quadrangle) in the 1961 K.G.S. Guidebook (M. G. S. RI-27).
22.8	0.5	Junction Mo. Hwy. 79 and State Road TT. Continue on 79.
23.3	0.5	A slide developed here during the extremely wet period this past spring. This section of Hwy. 79 has been in use for more than 15 years and the hillslope was considered relatively stable. The slide, principally in weathered Maquoketa and Grassy Creek talus, extended across both lanes and for a distance of about 200 feet beyond. The road was closed for 3 weeks and several thousand

Mileage Cum.	Diff.	
		yards of shale, stone and debris were removed. The slide developed after several weeks of heavy rainfall along the talus – Maquoketa shale contact.
24.8	1.5	Salt River. For the next 5 miles, the route will be on the Salt River floodplain.
26.6	1.8	Stop sign! Junction Mo. Hwy. 79 and State Rd. B. Continue south on Route 79.
31.0	4.4	Junction Mo. Hwy. 79 and State Road YY and AD. Continue ahead on Route 79.
33.9	2.9	Crossing Grassy Creek. Maquoketa shale exposed along south bank of creek to west.
35.7	1.8	Burlington limestone in cut to right; old underground limestone quarry to left (east).
36.9	1.2	Louisiana. Junction of Mo. Hwy. 79 and U.S. Highway 54. Turn left (east) onto 79 and 54.
37.1	0.2	Four-way stop. Turn right (south) and continue on Hwy. 79.
38.3	1.2	Clinton Springs. A short distance to the south of the spring is a small mine in the Noix oolite which at this locality is about 10 feet thick. Reportedly, the limestone was used in the manufacture of putty.
39.4	1.1	Hercules Chemical Works. Buffalo Knob ahead.
39.7	0.3	Buffalo Creek. Slide area in the Maquoketa shale and talus for next ½ mile.
43.8	4.1	Slide area in Maquoketa shale and talus for next ½ mile.
45.4	1.6	Entrance to Dundee Cement Company to right. Barge, rail and truck loading facilities to the left (east).
45.8	0.4	Junction Mo. Hwy. 79 and State Rd. N. Continue ahead (south) on Hwy. 79. Pinnacle Hill ahead.
47.0	1.2	Bear left (east) onto turn-off (old Hwy.) to roadside park.

Mileage Cum.	Diff.	
47.3	0.3	STOP 6. Pinnacle Hill, N½, SW¼, SW¼, sec. 9, T.53N., R. 1E. Nebo Quadrangle. Lunch Stop.

The road was originally built in 1939 over a natural bench composed of Maquoketa shale. It was not paved until May, 1941, due to backslope slides and has had a continual history of settlement and slides ever since. Talus was removed from the side of the bluff on at least two occasions to relieve pressure. In 1958 a 6 inch underdrain was laid under the west ditch line approximately 10 to 15 feet deep to catch water which was moving through the talus and shale and under the roadway. This pipe ran a good stream of water but the roadway continued to move toward the river. Patching of the pavement was a weekly operation. In places there was as much as 40 inches of oil mat and no indication of the concrete pavement. Drilling of holes always showed the same results; several feet of wet weathered shale and then hard, dry shale. The slide plane was never found. In 1961 the settlement, movement and cracking was so severe that it was evident that the roadway probably could not be held by patching much longer. It was then decided to relocate the road toward the bluff and to put the roadway on solid Maquoketa shale. While investigations were being made, a large spring which we had heard about for years from local residents, was sought out and found. This spring had been feeding water through the talus since the original road was built. Due to the steepness of the terrain, all soundings were made with resistivity equipment. It was established that the proposed relocation would be on solid shale and away from the slide plane. No solid rock would be involved in the excavation other that some large boulders incorporated in the talus. Blasting was to be held to a minimum. Plans proceeded and the contract was let in the summer of 1961. There was no evidence of problems until all excavation was completed and the first course of asphalt had been laid. At this time the Maquoketa shale directly below the Bowling Green dolomite started weathering out by the bushels. As the exposed surface of shale dried, it slaked and a steady stream of shale fragments rolled down the backslope. In a short period, it had undercut the Bowling Green dolomite several feet and the first large dolomite block fell. As the blocks came down, they were broken with a headache ball and the fragments were cast on the shale slope. This soon became an impossible task. The decision was made to let them accumulate on the slope to protect the Maquoketa shale from the elements and reduce slaking. As you can see, this is just about completed and in most area the contact is either covered or most of the slope is no longer exposed.

RETRACE ROUTE TO JUNCTION OF MO. 79 AND STATE RD. N.

Mileage Cum.	Diff.	
48.8	1.5	Junction Hwy. 79 and State Rd. N. Turn left (west) on N.
50.5	1.7	STOP 7. QUARRY Office., Dundee Cement Company. Tour of the shale and limestone quarries.

Dundee Cement Company has three quarries. An abandoned temporary shale quarry, a temporary limestone quarry, and a permanent shale quarry.

The abandoned shale quarry is located 2½ miles from the plant and is in the Maquoketa Shale. This temporary quarry was so located because the overburden which had to be stripped was only ten feet thick. The upper level had a face of about 60 feet and the lower level a face of 40 feet. About 1,300,000 tons of shale were removed from this quarry in the 2½ years it was used.

The temporary limestone quarry is about 2½ ,lies from the plant and is in the Kimmswick limestone. This quarry was also located at this site because the overburden is only about 15 feet thick. The upper level has a 40 foot face and the lower level has a 33 foot face. During the 3 years it has been used, approximately 3,5000,000 tons of limestone have been extracted.

The permanent shale quarry, and eventually permanent limestone quarry, is now under development. It is located about 1/8 mile from the plant. The Maquoketa varies in thickness from 0 – 70 feet; however, the face height will probably average about 40 feet. A 120 foot face will be developed in the underlying Kimmswick limestone. The overburden averages 65 feet thick and is stripped with a dragline.

The extraction operation runs 3 shifts per day – 5 days a week. On weekends two endloaders feed the crusher from the stockpiles. All raw materials are extracted with four 35 ton. Trucks which are loaded by electric shovels.

PROCEED TO PLANT FOR TOUR OF THE CEMENT MANUFACTURING FACILITY.

The Dundee Cement Company's 7 million barrel, wet process, single kiln plant was placed on stream in May, 1965. The 760' × 25' kiln is the largest in the world. The raw mill (15' × 54') and two finish mills (15' × 49') are also of record size. The installation has the largest capacity of the six cement plants in Missouri; it is the largest capacity single kiln plant in the world; and ranks ninth among the more than 200 plants in North America.

This concludes the 17th Annual A.M.G. trip.

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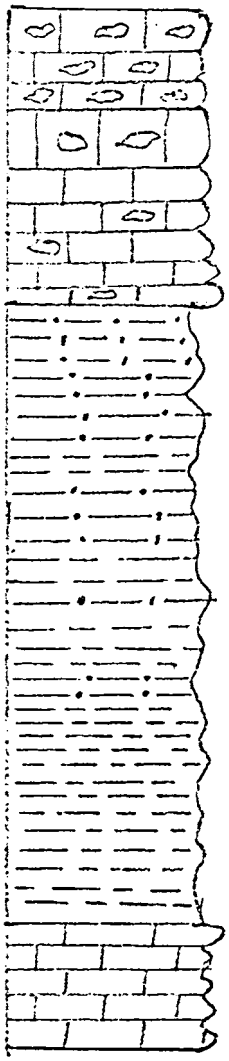
STOP 1

STRATIGRAPHIC SECTION

CENTER OF THE SW¼, SE¼, SEC. 28, T-57-N, R-4-W

MARION COUNTY



BURLINGTON (30’)
Limestone, coarsely crystalline; brown except for persistent light gray zone which is variable along Highway 79 roadcuts. Cherty throughout. The lower chert-free intervals are missing here.

HANNIBAL (65’)
Bluish gray silty shale and yellowish brown siltstone; siltstone beds more resistant and jointed.

LOUISIANA (12’ exposed)
Limestone, dolomitic, lithographic; light gray to yellowish brown. Weathers into small angular fragments.

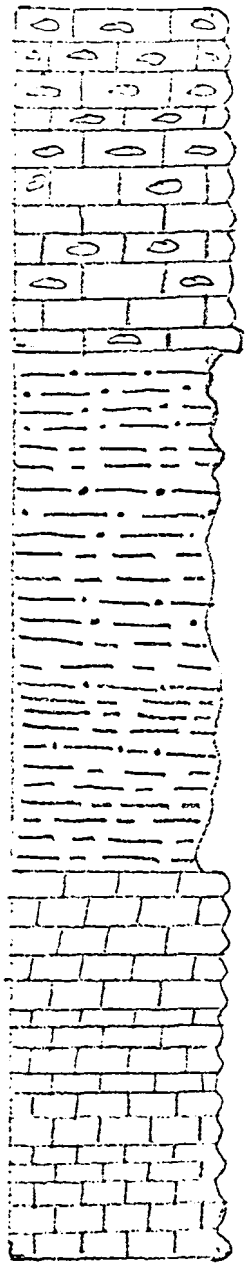
SCALE ½” = 10’

STOP 2

STRATIGRAPHIC SECTION

NE¼, SW¼, Sw¼, SEC. 35, T-67-N, R-4-W

MARION COUNTY



BURLINGTON (35’)
Limestone, coarsely crystalline; brown except for light gray zoned located at different interval than Stop 1; cherty throughout with no evidence of the two lower chert free zones typical of the area; massive beds are poorly jointed.

HANNIBAL (55’)
Siltstone and silty shale; bluish to brownish gray. Siltstone – shale sequence is regularly interbedded in contrast to more persistent and thicker shale zones to the west.

LOUISIANA (40’)
Limestone, dolomitic, Lithographic; light gray to yellowish brown, evenly bedded with uniformity of beds a common feature, well jointed, brittle fracture.

Ditch level; approximately 27’ covered.

SCALE ½” = 10’

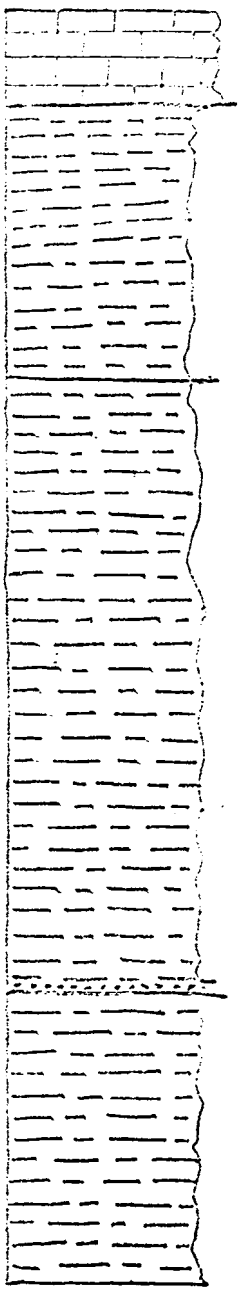
STOP 3

STRATIGRAPHIC SECTION

NE¼, NE¼, SEC. 10 & NW¼, NW¼, SEC. 11, T-56-N, R-4-W

RALLS COUNTY

UNIVERSAL ATLAS CEMENT CO. SHALE PIT



LOUISIANA (5’ exposed)
Limestone, dolomitic, gray to yellow brown, lithographic, well bedded.

SAVERTON (14’)
Upper 5½’ bluish gray siltstone, massive, argillaceous; lower 8½’ bluish gray shale, flaky.

GRASSY CREEK (32’)
Shale, dark gray with brown stains; fissile and joined; numerous resinous brown spores.

TURPIN SANDSTONE (2”) single irregular bed.

MAQUOKETA (15’)
Shale. Bluish gray, massive and breaks with conchoidal fracture. Contains massive beds of silty limestone, 1’ to 2’ thigh. Uppermost bed present at base of sandstone is fossiliferous.

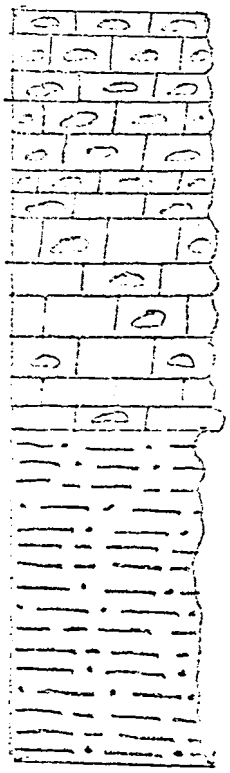
SCALE 1” = 10’

STOP 4

STRATIGRAPHIC SECTION

CENTER OF THE W½, SE¼, SEC. 18, T-56-N, R-3-W

RALLS COUNTY



BURLINGTON (43')
Limestone, coarsely crystalline; brown beds but light gray color of the more typical Burlington becoming more common; cherty throughout. The massive beds are poorly jointed.

HANNIBAL (34')
Siltstone and silty shale; bluish to brownish gray; regularity of siltstone and shale bedding is apparent.

Ditch line

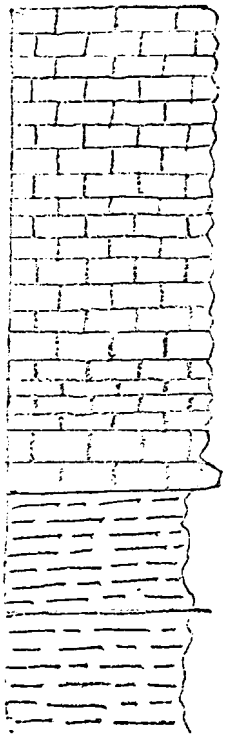
SCALE ½" = 10'

STOP 5

STRATIGRAPHIC SECTION

NE¼, SW¼, SEC. 33, T-56-N, R-3-W

RALLS COUNTY



LOUISIANA (25’)
Limestone, light gray, lithographic, jointed; uniform thin to medium beds distinguished by dolomitized yellow brown beds which give outcrop typical masonry wall appearance. Two massive beds at base are found at most exposures.

SAVERTON (6.6’)
Upper 3’ gray massive siltstone; lower 3’6” shale, flaky, with rounded clear quartz grains.

GRASSY CREEK (5’)
Shale, dark gray with brown stains, fissile, jointed.

Ditch line

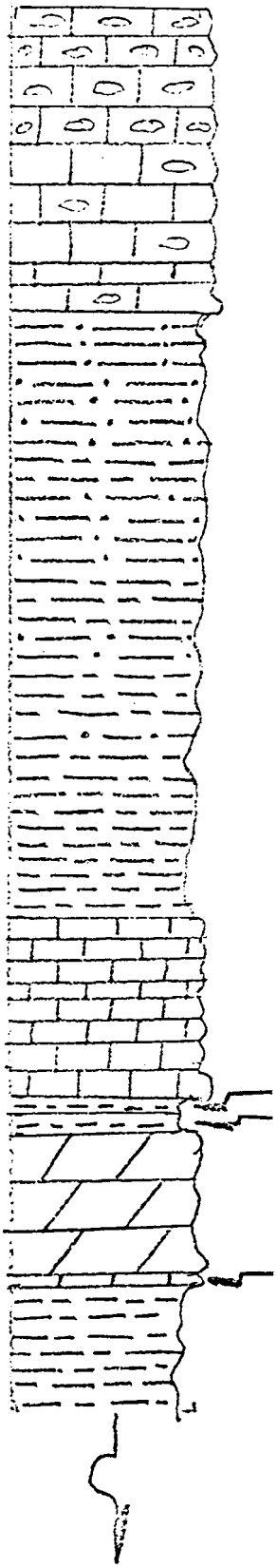
Scale 1” = 10’

STOP 6

STRATIGRAPHIC SECTION

N½, SW¼, SW¼, SEC. 9, T-53-N, R-1-E

RALLS COUNTY



BURLINGTON (50’)
Limestone, coarsely crystalline; cherty, massive.

HANNIBAL (100’)
Siltstone and silty shale; bluish gray, massive. Siltstone breaks into angular blocks; shale breaks with sub-conchoidal fracture into angular fragments.

LOUISIANA (30’)
Limestone, dolomitic, light gray with yellowish brown dolomitized beds.

SAVERTON (2’ 6”) bluish gray siltstone, massive.
GRASSY CREEK (3’ 6”) shale, dark gray, fissile.

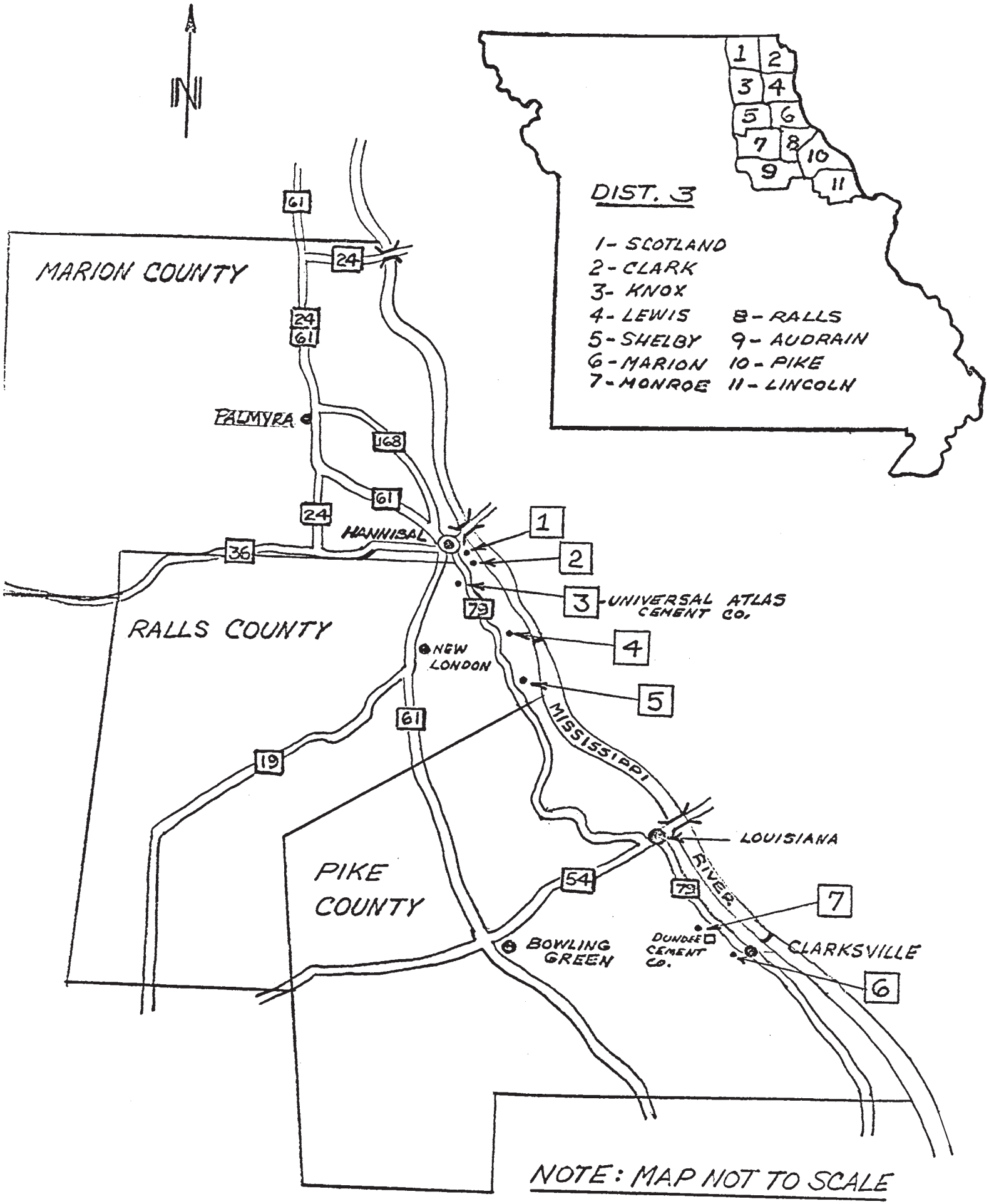
BOWLING GREEN (24’)
Dolomite, fine grained, yellow brown, massive, well jointed.

NOIX OOLITE (1’) facies of Cyrene Member

MAQUOKETA (20’ exposed)
Shale, bluish gray on fresh surfaces. Weathered shale has color tones of yellow and green; massive and breaks with conchoidal fracture.

Ditch line; 100+130’ covered.

SCALE ¼” = 10’


N
1 2
3 4
5 6
7 8 10
9 11
DIST. 3
1- SCOTLAND
2- CLARK
3- KNOX
4- LEWIS
5- SHELBY
6- MARION
7- MONROE
8- RALLS
9- AUDRAIN
10- PIKE
11- LINCOLN
MARION COUNTY
61
24
24
61
PALMYRA
168
61
24
HANNIBAL
36
RALLS COUNTY
1
2
3
UNIVERSAL ATLAS CEMENT CO.
79
4
NEW LONDON
5
MISSISSIPPI
61
19
LOUISIANA
RIVER
PIKE COUNTY
54
79
7
BOWLING GREEN
DUNDEE CEMENT CO.
CLARKSVILLE
6
NOTE: MAP NOT TO SCALE