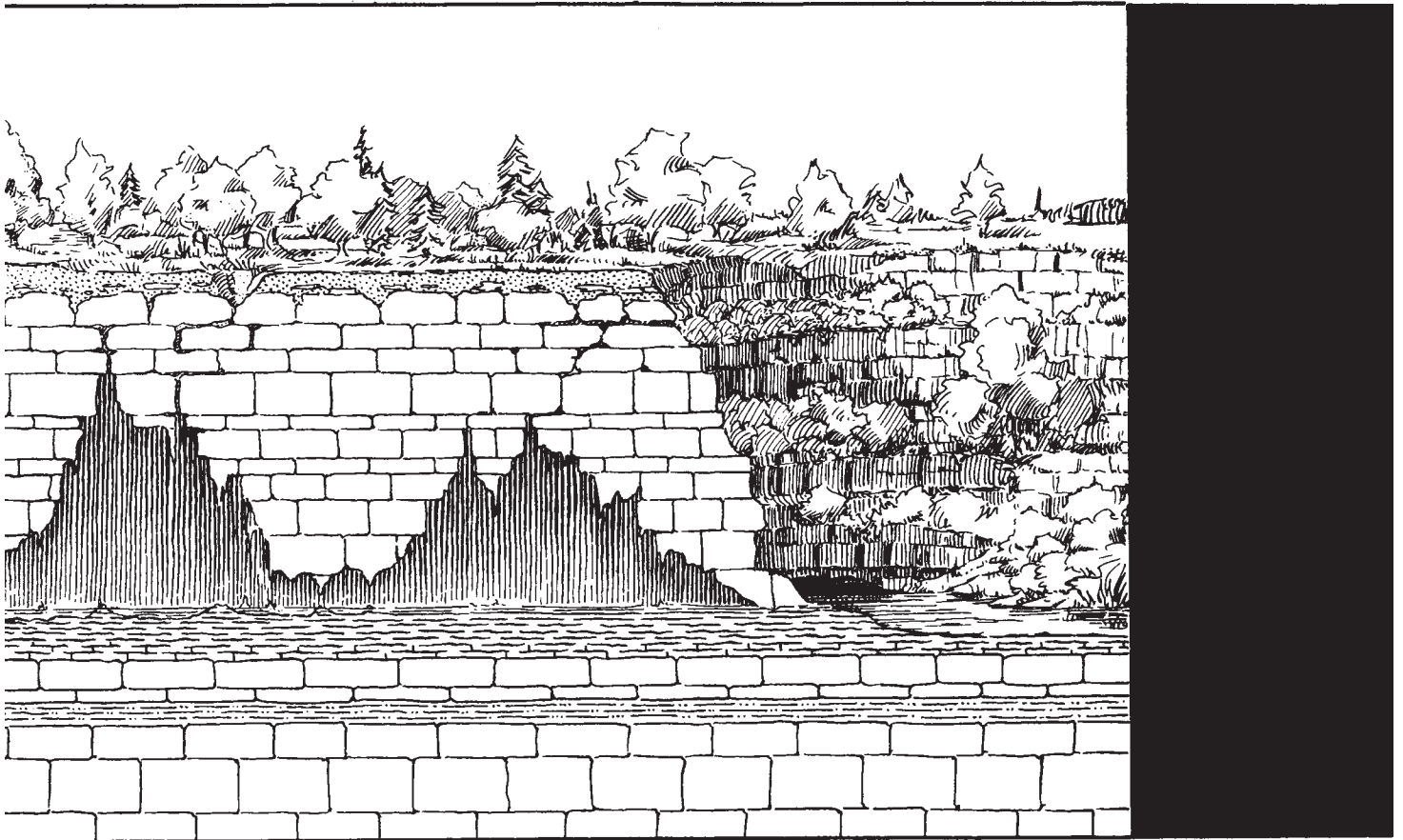


GUIDEBOOK of the

Karst Features and Stratigraphy of the Rolla Area



*ASSOCIATION OF MISSOURI GEOLOGISTS
NINETEENTH ANNUAL MEETING
ROLLA, MISSOURI
SEPTEMBER 29-30, 1972*



University of Missouri - Rolla

DEPARTMENT OF GEOLOGY AND GEOPHYSICS
DEPARTMENT OF MINING PETROLEUM, AND
GEOLOGICAL ENGINEERING - SPONSORS

ASSOCIATION OF MISSOURI GEOLOGISTS

19TH ANNUAL MEETING

SEPT. 29, 30, 1972

GUIDEBOOK to KARST FEATURES OF THE ROLLA AREA

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GUIDEBOOK TO KARST FEATURES
OF THE ROLLA AREA

Preface

This guidebook gives locations and describes some of the solution features as well as the stratigraphy of the Waynesville-Rolla-St. James area. Numerous sink holes, filled sinks, caves, and other solution features are to be seen in this area. At least 52 caves have been reported in Phelps County alone. The field trip log is designed to show some of the more accessible of these features in this area. There are two main logs and several optional side trips. The main logs are designated in the notes as STOPS West and STOPS East to indicate the Rolla-Waynesville and Meramec Spring -Rolla logs respectively.

Several short papers and notes which describe problems pertaining to the theme of the guidebook are included. A brief paper on the Indian dwellers of the Ozarks who utilized the caves is also included. There are no stops at caves. For information on the caves of the area and their location, the reader should refer to J Harlen Bretz's Missouri Geological Survey volume, "Caves of Missouri". A record of maps of caverns is being maintained at the Missouri Geological Survey and information about caves may also be had from members of the Spelunker's Club which is active on the UMR Campus.

The general stratigraphic column for the area is shown on page 5. A general description of the sink structures which are common in the area follows the geologic column as an introduction to the nature and origin of these features.

These notes were prepared by the local field trip committee. The committee wishes to acknowledge the help of Abd Borahay who assisted in measuring stratigraphic sections and made analyses of the clays and sandstones at Gray's pit. John Arseneau also assisted

with the mechanical analyses of the sandstones. The Missouri Geological Survey provided the insoluble residue analyses of the Roubidoux section at Waynesville (STOP 7). John Sullivan, Tom Eyermann and Richard Lance helped prepare the illustrations. Wealthy Spreng helped assemble and proof the manuscripts and Margaret Carey typed the script. The cover was designed by John W. Koenig. The cost of drafting and reproduction was in large part supported by funds of the V. H. McNutt Foundation at UMR.

_____ FIELD TRIP COMMITTEE

FILLED SINKS AND CIRCLE DEPOSITS
ROLLA AREA, MISSOURI

Introduction

More than 1000 roofless solution cavities filled with clay, shale, sandstone, coal, hematite, pyrites, galena, sphalerite, karite, and dolomite debris are reported by Bretz (1950) on the northern and western slopes of the Ozark Dome. He suggests three types of filled solution cavities in the calcareous rocks of the region: filled sink structures, circles and filled caves. Each type possesses its individual identifying features.

Filled Sinks

Three mechanisms for these subsidence structures have been proposed in the literature: 1) filling of former topographic sinks, 2) Collapse of roofs of former caves, and 3) Gradual solution of subjacent calcareous rocks with contemporaneous subsidence of existing cover rock to become the fill. Bretz's extensive review of the literature concludes with this statement (1950, p. 795):

".....except for meteoritic impact, every remotely logical idea for the origin of the Missouri filled sink structures has been suggested."

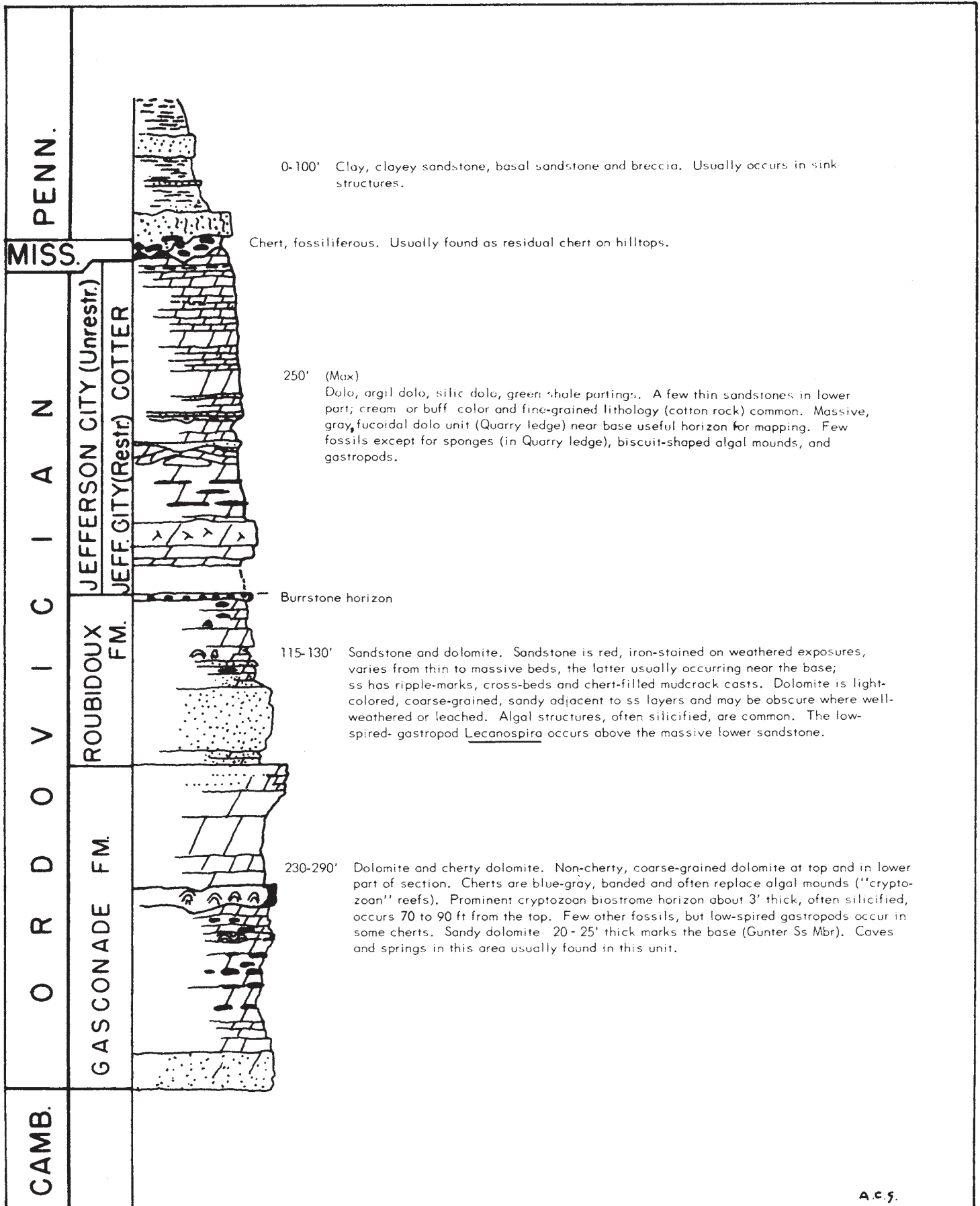
He concludes that there is no doubt of "consanguinity in the deformation of the fills and walls by subsidence of higher-lying materials into a solution-made cavity." He refutes the idea that pre-existing sinkholes had to be present to receive the various fill materials. Only slow subsidence under load into a contemporaneously forming cavity satisfactorily explains the known features. He suggests there is little or no evidence for tensional stress in this type structure.

Circle Deposits: Bretz (p. 823, *ibid*) notes that "circle deposits have been clearly differentiated by all writers from filled sink-deposits." He follows Mather's (1946) suggestion that "the term 'circle deposit' be applied only to solution cavities (1) filled with broken rock which has accumulated by the spalling and caving of walls and roof rock, (2) circular in ground plan and cone- or bell-shaped in cross section, and (3) without rim rock." He then states that a circle is a collapse-formed cave, filled with its own country rock debris. They may contain red tallow clay. Outward dipping fractures in the wall rock of tensional origin contrast with the sheared and slickensided fractures of filled sink walls.

Filled Caves: Bretz (p. 826, 1950) define a limestone cave as a "roofed solution cavity large enough to admit the human body." He cites examples of caves in the Ozark region which ceased growing when the "fill of red clay derived from surface residuum obliterated them as open cavities." A few contain undeformed Pennsylvanian sediments, but most of them are filled or partly filled with red or tallow clay, with or without sulfide ores and barite. Joint bedding planes appear to have controlled the moving ground water which formed them.

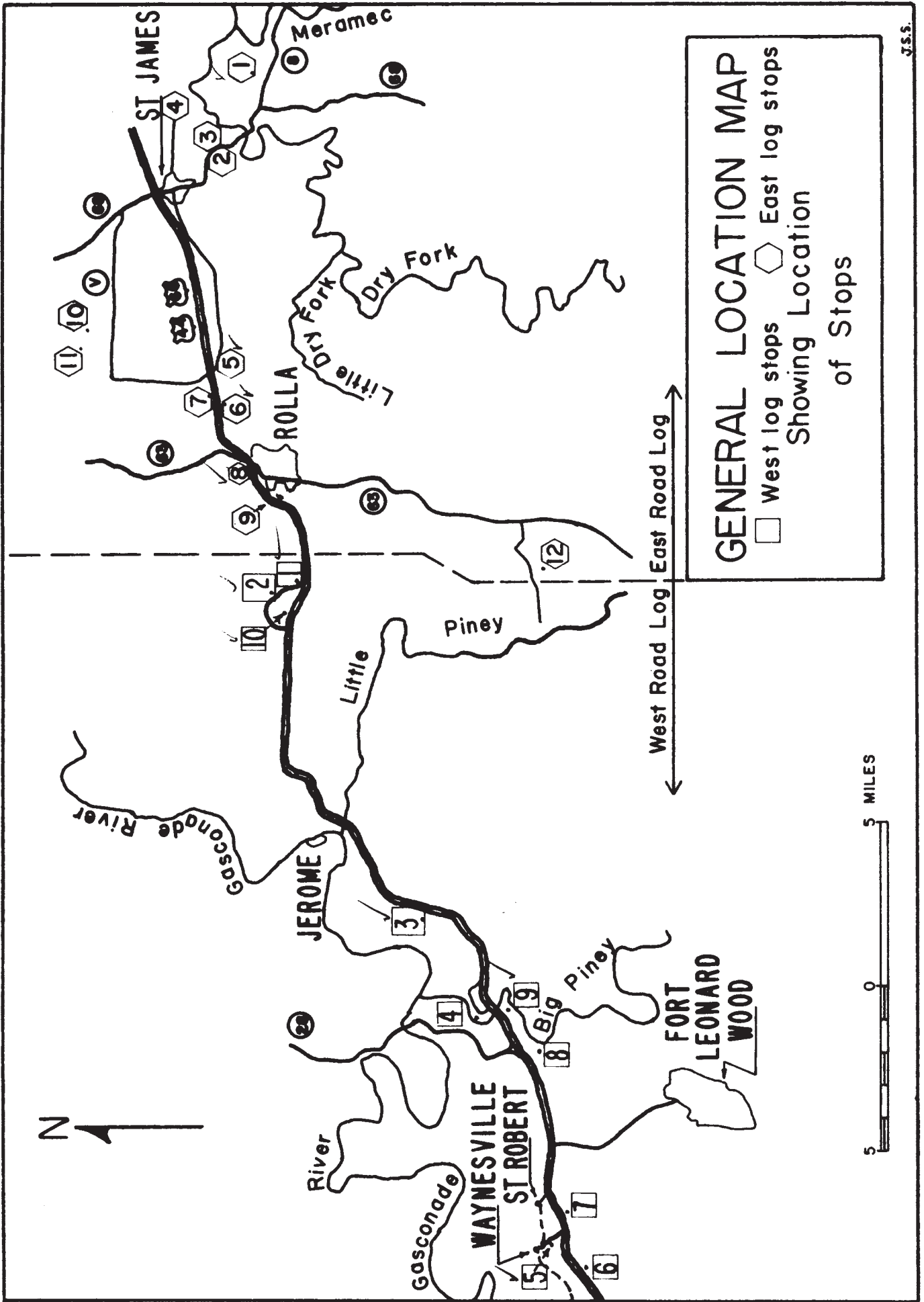
GUIDEBOOK AREA

Several filled sinks and at least one circle deposit occur in the area of the field trip. Some partly filled caves are also known, but will not be reviewed. Excellent cross-sectional views of filled sinks are exposed on road cuts along Highway I-44 within the guidebook area. Many other examples are present in the surrounding area. Examples of filled sinks and one circle deposit are described at the stops and in short notes which follow the road logs.



A.C.5.

General Section for the guidebook area.



WEST ROAD LOG

by

Thomas R. Beveridge and Nolan B. Aughenbaugh

Miles
Start

0.0 Head west onto I-44 at Highway E overpass. Exposures of Jefferson City (unrestricted) dolomites here and next interchange.

0.8 Bear right up interchange ramp, STOP, and turn right and then left onto north westbound service road.

1.3 to 1.55

"Quarry Ledge" dolomite in low cut on the left and in Holiday Inn area to the south. Cullison (1944, pp. 13-19 and figures 1 & 2) proposed that the "Quarry Ledge" be called the School Mine Ledge, because it crops out conspicuously at the experimental mine of the (then) Missouri School of Mines and Metallurgy, but the proposed name, despite its merits, has had difficulty in winning recognition because the older appellation had become so well established. This ledge of pitted dolomite was very popular in the past for dimension stone and may be seen in many of the older buildings in Rolla and surrounding areas. It is also a most convenient unit for field mapping in the area because the top of the Roubidoux Formation is approximately 25-30 feet below it. Long-abandoned quarries to the south of this outcrop where

the Holiday Inn now stands furnished much of the stone used in the area. Cullison, in the same publication, proposed that the Jefferson City be raised to the rank of group and divided into two formations, the Rich Fountain and the unconformably overlying Theodosia, but complete acceptance of this proposal has likewise not been reached. Overlying the Jefferson City is the Cotter Formation which in general tends to be more thin-bedded than the Jefferson City and contains sandstone units of considerable lateral extent. The stratigraphy of the Cotter has been described by Cullison (1930) and Grawe and Cullison (1931). Because exposures are poor and fossils are scarce over great areas of the Ozarks, the Cotter and the Jefferson City are often lumped together in field mapping under the single name of Jefferson City.

- 1.65 Lower Jefferson City and upper Roubidoux dolomites to the left.
- 2.0 Roubidoux Sandstone cut. Joints trend N 60° W. Some cross-bedding and ripple marks. Heller (1954) has discussed the stratigraphy and paleontology of the Roubidoux. In isolated exposures it is not always easy to differentiate Roubidoux sandstones from those of the stratigraphically higher Cotter Formation. In addition to being a widespread aquifer, the Roubidoux has long been used for dimension stone. In the Rolla area, two to three sandstone units are prominent; near Waynesville, dolomite predominates.

- 2.7 Old Corral Farm to right. This farm is so-named because it was the site of a corral for the Union cavalry. Rolla was a railhead during the Civil War and Fort Wyman at the south edge of town was in a very strategic location for control of the Ozarks. Several thousand troops were based in Rolla and in the valley we are now descending. Encampments extended down this valley past what is now Newburg, taking advantage of the numerous springs and good grazing.
- 3.05 Abeam stone spring house of Martin's Springs on south service road. This is a Gasconade-Roubidoux contact spring. In 1935, after an unusually heavy rain, it had a flow of 1.3 second feet or 584 gpm (Beckman and Hinchey, 1944 p. 92).
- 3.3 STOP 1. ROUBIDOUX-GASCONADE CONTACT. The contact between the crystalline Gasconade Dolomite and overlying sandstones of the Roubidoux is expressed as an uneven surface and truncation of the Gasconade is evident in this cut. Lee (1913, pp. 33-34) considered the contact "unconformable in the Rolla quadrangle". Regional evidence for a marked unconformity is cited by McCracken (1952, pp. 60-62).

The Gasconade is the main host for karst features in this area, whereas the Eminence wins the hospitality awards in the Big Spring area to the southeast.

Across the valley to the west, the upper Roubidoux is relatively low. A fault? Solution slumping?

3.5 Cross low-water bridge, a triumph of design economy and simplicity common in the Ozarks. Water goes under with normal flow; over after a heavy rain. Generally the flow drops in a relatively short time after a heavy rain and a bit of a wait eliminates expensive construction. You are now on the Old Wire Road, so-named because the main telegraph line between St. Louis and Fort Smith, Arkansas followed it prior to and during the Civil War. The wire was used mainly by the Union forces as far west as Springfield, but maintenance was a problem because of Rebel cut-ups.

Roubidoux sandstones crop out in ditches along the hill slope.

3.8 Bear right.

4.45 T-junction; continue straight ahead

4.7 Bear left.

4.8 STOP 2 EXCELLENT EXPOSURE OF THE "QUARRY LEDGE."

Note how fond cedars (junipers) are of dolomite. Concentration of cedars is often an indicator of carbonates at or very near the surface in the Ozarks. Local dip is here reflected by the cedars following, in part, the dip slope of the "Quarry Ledge."

The pines at this stop are an ecological anomaly. They generally prefer acid sandy soils and are not indigenous.

5.64 T-junction; bear left.

5.9 T-junction; bear right onto slab of original Highway 66.

6.4 STOP. Bear right (west) onto Highway 66-I-44.

7.4 Roubidoux Sandstone on right.

7.8 Roubidoux Sandstones on right.

- 8.7 "Quarry Ledge" on right.
- 12.2 Roubidoux residuum on left.
- 12.5 Gasconade dolomites on left.
- 12.9 Town of Arlington at 3 o'clock low.
- 13.1 Cross Little Piney River.
- 13.7 First (most easterly) building on north service road is former Arlington School. In the front yard is a flowing artesian well.
- 13.8 Orange well head to right of our lane is also a flowing artesian well. Springs and artesian wells in this area and upstream in this valley (Tater Hollow) suggest some local structure and Spreng (oral communication) reports a fault with more than 20 feet of displacement in the Gasconade and Roubidoux Formations which form the ridge to the right.
- 14.0 Bear right off I-44 onto ramp.
- 14.2 T-junction; STOP; bear left onto service road (old Highway 66).
- 14.4 Interchange junction; continue straight ahead up hill on service road. Gasconade dolomites in cut on right.
- 14.75 Slumped Roubidoux sandstones on right. Roubidoux crops out intermittently to top of hill.
- 15.9 Buildings faced with Roubidoux to right.
- 16.6 Powellville. Main building faced with ripple-marked Roubidoux sandstone and blocks of Northview (Kinderhookian) siltstone with well-developed worm burrows and cauda-galli ("rooster tail") markings. The type section of the Northview is near the namesake town on I-44 ten miles this side of Springfield, Missouri and the stone is definitely a xenolith in terms of local dimension stone.

17.15 Turn right onto Boiling Spring road.

17.4 STOP 3. CONICAL AND SLAUGHTER SINKS (SW 1/4 Sec. 34, T.37 N., R.10 W., Phelps County).

Conical Sink on south (left hand) side of road and Slaughter Sink one tenth of a mile north of road. The bottom of Conical Sink is 100 feet below road level. Walk north over Roubidoux sandstone slabs to Slaughter Sink. This sink is 175 feet deep measured from the northwest rim, and approximately a quarter of a mile in maximum diameter. The elevation of the bottom of the sink is approximately 816 feet above sea level, or 145 feet above the Gasconade River. It is of interest to note that the log of the Powellville well half a mile north and slightly east of this sink had a static water level of 807 feet above sea level at the time it was drilled. The log of the Powellville well No. 2 is as follows:

Location - NE 1/4, SE 1/4, NW 1/4, Sec. 34, T.37 N., R.10 W., curb elevation 1019, logged by R. D. Knight, 1954.

Roubidoux residuum	0 to 55 feet
Roubidoux Formation	55 to 100 feet
Upper Gasconade	100 to 165 feet
Lower Gasconade	165 to 360 feet
Gunter member of Gasconade	360 to 385 feet
Eminence	385 to 412 feet (T.D.)

This well has 94 feet of casing and yielded 10 gallons per minute.

Slaughter Sink is developed in the Gasconade Formation, as is Conical Sink. The upper rim is Roubidoux which has been breached through collapse as the Gasconade was

dissolved. King Sink, which is very similar in size, scenic virtues, and geologic setting, is seven miles south and slightly east of Slaughter. It is located in the SW 1/4 Sec. 36, T.36 N., R.10 W. These sinkholes are of interest to botanists because asylum flora are often preserved in the uncultivated bottoms. Slaughter and Conical Sinks are along a line trending slightly east of north as shown on the Dixon 7 1/2 minute quadrangle.

The U. S. Forest Service has purchased property including these two sinks and Powellville.

RETURN TO CARS and proceed westward on road to Boiling Spring.

17.95 Take fork to right.

18.3 Onyx Cave is on the left hand side of the road a short distance southeast of Boiling Spring. This cave has been discussed by Bretz (1957 pp. 411-412). A 126-foot shaft was opened in the early 1900's for the mining of cave onyx. This shaft, with large slabs of the cave onyx lying around it, is a short distance to the left of the road. The project was not economically feasible and met the fate of similar projects in other onyx caves of which Bretz names six in Missouri.

As an additional stop, one may drive 0.5 miles farther to Boiling Spring, NW 1/4, Sec.33, T.37 N., R 10 W., Pulaski County. Flow measurements by Beckman and Hinchey, (1944, p. 63) were 65 second-feet or 42,000,000 gallons per day. This spring, which boils up from the right edge of the Gasconade is undoubtedly part of a Conical-Slaughter Sink-Onyx Cave karst complex and the plumbing system deserves geophysical

and tracer dye study.

A study of subterranean drainage of the Gasconade River by the late Harry C. Bolon (reprinted in this publication p. 77) demonstrates the Stygian characteristics of this river, a characteristic shared by many Ozark streams.

Turn around at Onyx Cave. Return to service road.

- 19.35 STOP. Turn right onto service road.
- 19.7 First and Main Streets, Clementine, Missouri.
- 20.25 Bear left to interchange.
- 20.3 Bear right onto ramp and onto I-44
- 21.9 BEAR RIGHT OFF HIGHWAY onto loop of Old Highway 66.
- 22.3 Hooker Church on right.
- 22.8 In suburban Hooker area.
- 23.6 STOP 4. Gravel operation in the Big Piney valley and long-range view of the Gasconade - Roubidoux contact in west bluff of the Big Piney River, NW 1/4, Sec.7,T.36 N.,R.10 W., Pulaski County.

This is an excellent opportunity to see the variation of vegetation with underlying soil and rock types. The Gasconade forms the essentially vertical bluffs with the Roubidoux contact being represented by a much more gentle slope. Sycamores are prominent in bottom lands or wherever moisture is readily available, and cedars are especially fond of the bare dolomite which occurs at the top of the Gasconade Formation. Pine trees grow well on the sandstones of the Roubidoux, although where the pine has been cut oaks tend to take over. The Big Piney River received its

name, as did the Little Piney, from the original pine forests on the Roubidoux sandstone in the upper drainage area of these streams to the south.

Truncated spurs are especially well-developed in many of the Ozark streams and an excellent example of one may be seen straight ahead.

24.2 STOP and turn right on U. S. Highway 66.

NOTE: Should time be a problem, we will cross both lanes of the highway and follow the old loop of Highway 66 (which is now Highway V) past the town of Devil's Elbow for a distance of 1.4 miles from this stop sign to STOP 8.

24.5 Cross Big Piney River. To the left a short distance upstream on the right bank of the Big Piney is a remnant of a pre-Civil War fill for the Southwest Branch of the Pacific Railroad (now the Frisco). When the railroad was continued west from Rolla after the war, the routing was changed at Arlington to climb the ridge to Dixon 15 miles to the north. Cuts and fills for the old route can be traced from Arlington to the Fort Wood area.

24.8 Gasconade dolomites draped with the broad-leafed creeper, KUDZU, on the left.

25.1 Fill in valley to right was added after the shoulder was lost as a result of a slide in the original fill.

30.3 BEAR RIGHT off interchange and follow City Route to Waynesville.

31.6 Roubidoux sandstones on both sides.

31.9 Gasconade dolomites on right.

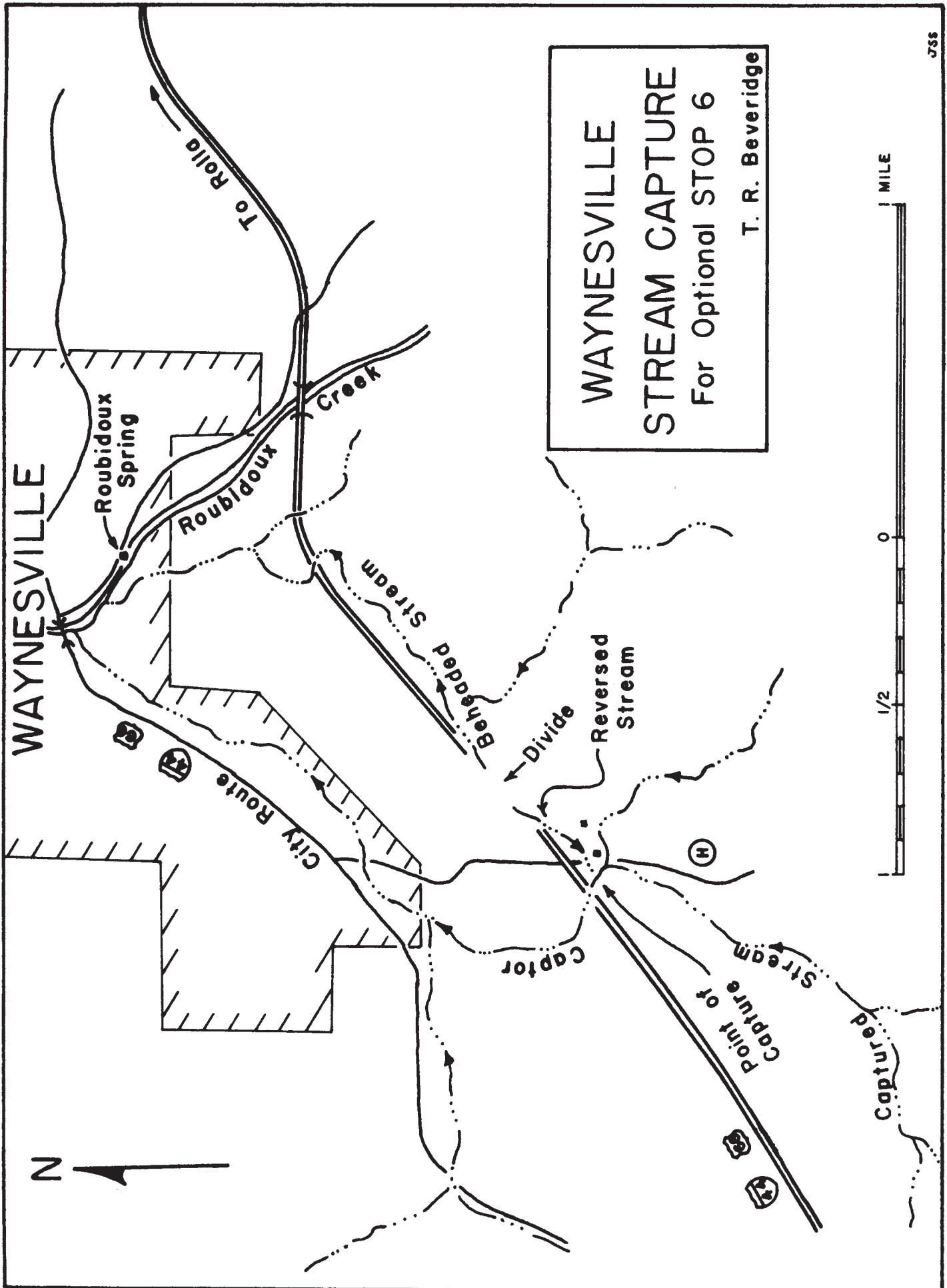
- 32.1 Cryptozoan chert to right.
- 32.3 Cryptozoan chert to right. Continue through main business district of Waynesville.
- 32.65 TURN LEFT off street onto gravel road this side of bridge. Follow gravel road along bluff.
- 32.9 STOP 5 . ROUBIDOUX SPRING, (NE 1/4,Sec.25,T. 36N., R. 12 W. Pulaski County).

This spring, in the Gasconade Formation, has recorded flows varying from 3,420,000 to 103,000,000 gallons per day. The low measurement was in August, 1934 during the drought; the high measurement was after a very high rain. The variable flow demonstrates the close relationship to a sink-hole and fissure recharge system.

Caverns above the spring may represent, in part, former orifices abandoned as erosion lowered the outlet.

Roubidoux Creek is, like the Gasconade, a "sinking" stream with alternating stretches of surface water and dry bed. The latter condition is created where the stream flows within the bed gravel or where it follows cavernous passages in the indurated rock. The original proper spelling of "Roubidoux" is Robidoux after the French explorer and entrepreneur. This spelling has been corrupted wildly with "Rabidoux" as another variation; local pronunciation tends to be "Ruby-Do."

- 33.9 TURN OFF TO OPTIONAL STOP 6 - MILEAGE NOT INCLUDED IN CUMULATIVE LOG.

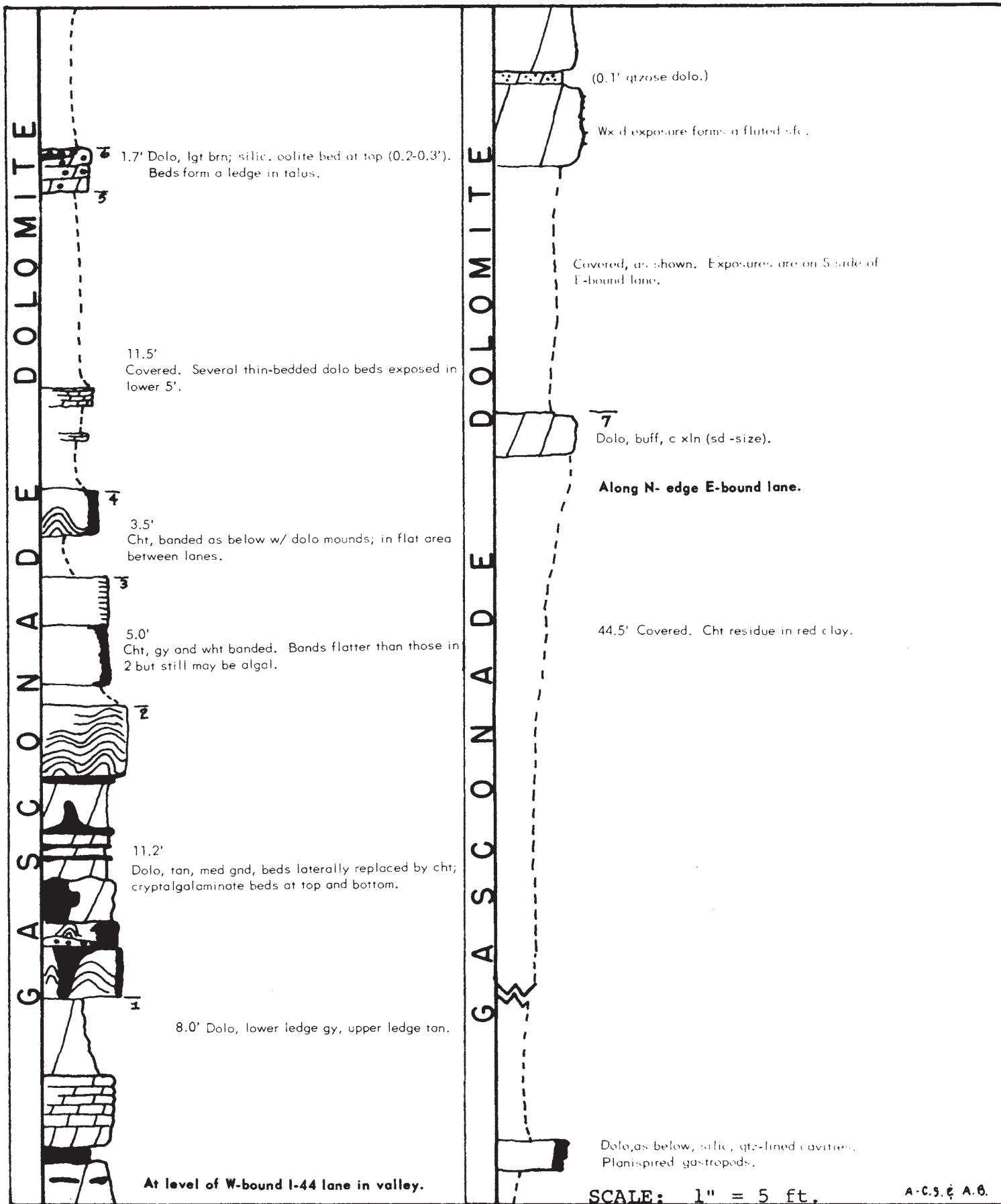


**WAYNESVILLE
STREAM CAPTURE
For Optional STOP 6**
T. R. Beveridge

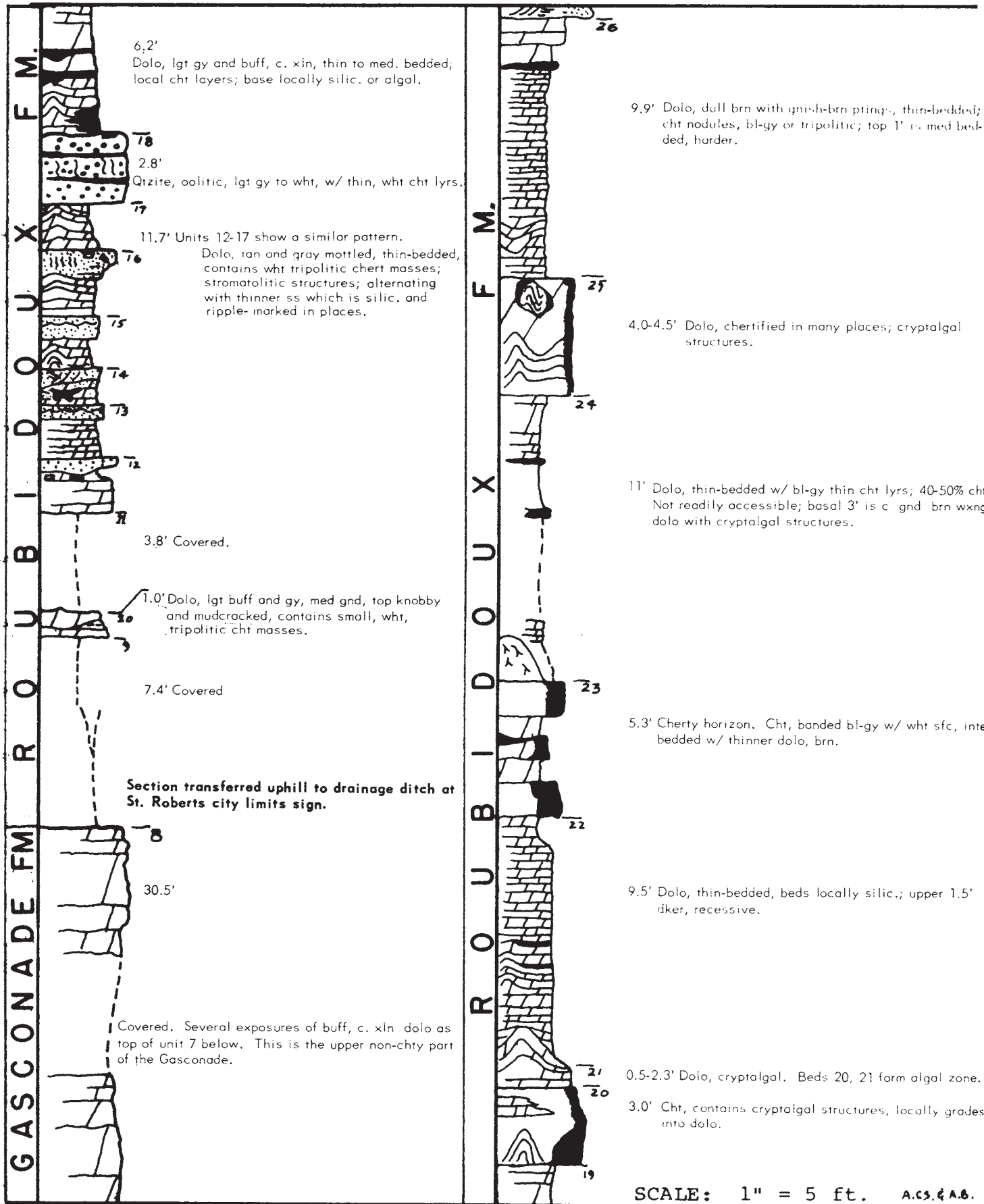
- STOP 6. Should one wish to study the stream capture as shown in the accompanying map, p. 17, turn right on I-44 and continue west for an additional 1.8 miles.
- 33.9* STOP. CAUTION! Cross to east-bound lane and turn left onto it.
- 34.0 Gasconade dolomites on right.
- 34.3 STOP 7. Gasconade dolomite which weathers to a sand of dolomite rhombs. Base of the Roubidoux in slope immediately above (see section, p. 19-22).
- 34.5 Roubidoux dolomites and sandstones in cut to right. The Roubidoux here contains a much higher ratio of dolomite than in the Rolla area and the sandstone beds do not weather to as brown a color. As a result, this exposure could be easily confused with Gasconade when one is cruising at 70 (or even much less).
- 34.75 Upper Roubidoux and lower Jefferson City dolomites. Cherchez le contact!
- 34.9 "Quarry Ledge" to left.
- 39.1 TURN-OFF TO OPTION STOP -- MILEAGE NOT INCLUDED IN CUMULATIVE LOG.

OPTIONAL ROUTE (STOP 8) Turn right onto gravel road. Follow it for 0.8 miles and turn right short of railroad tracks. Continue for 0.1 miles more and STOP. Residuum and highly polished gravel locality, NW 1/4, SW 1/4, NE 1/4, Sec. 24, T. 36N, R 11 W., Pulaski County.

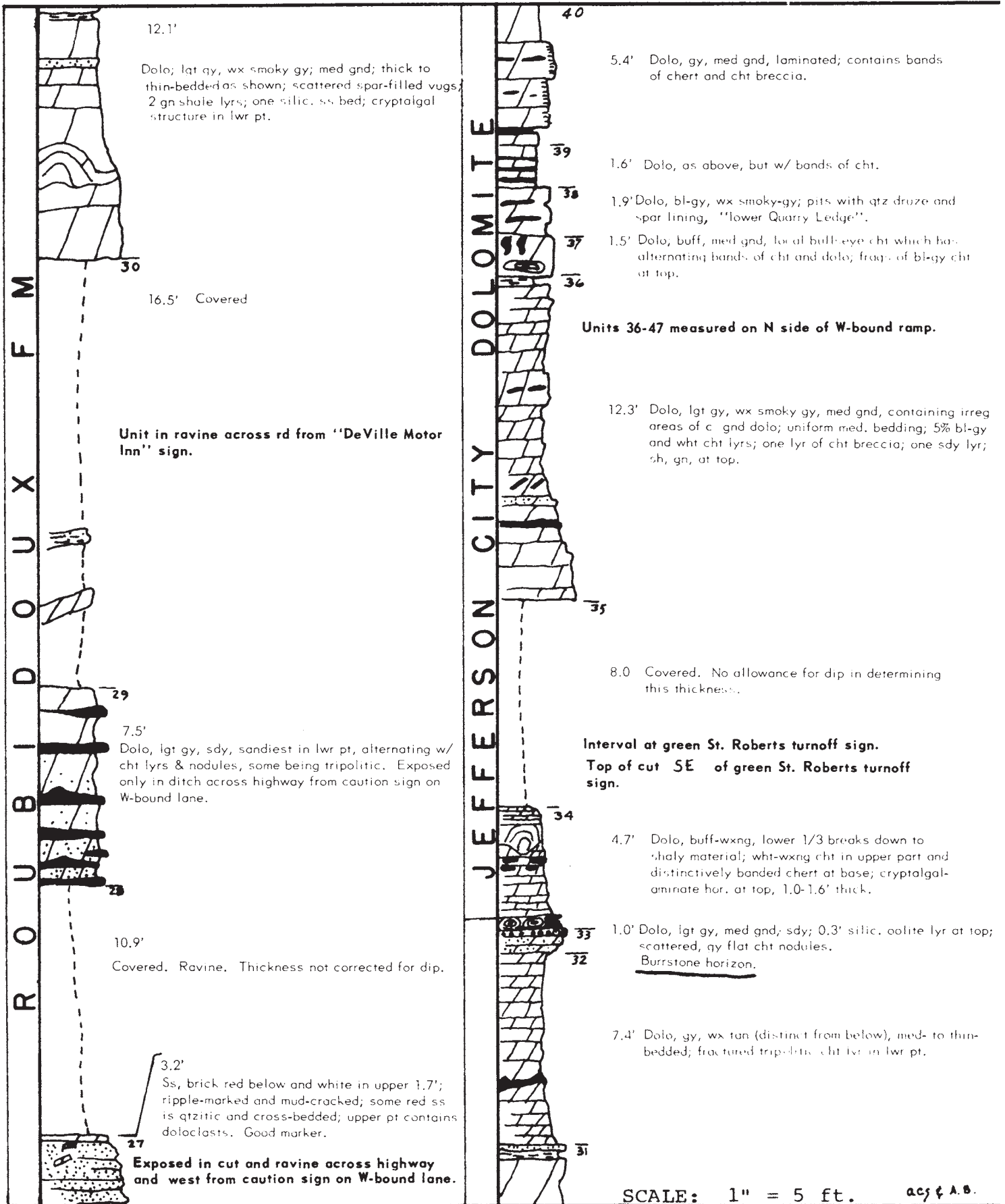
*Mileage does not include Alternate Stop 6



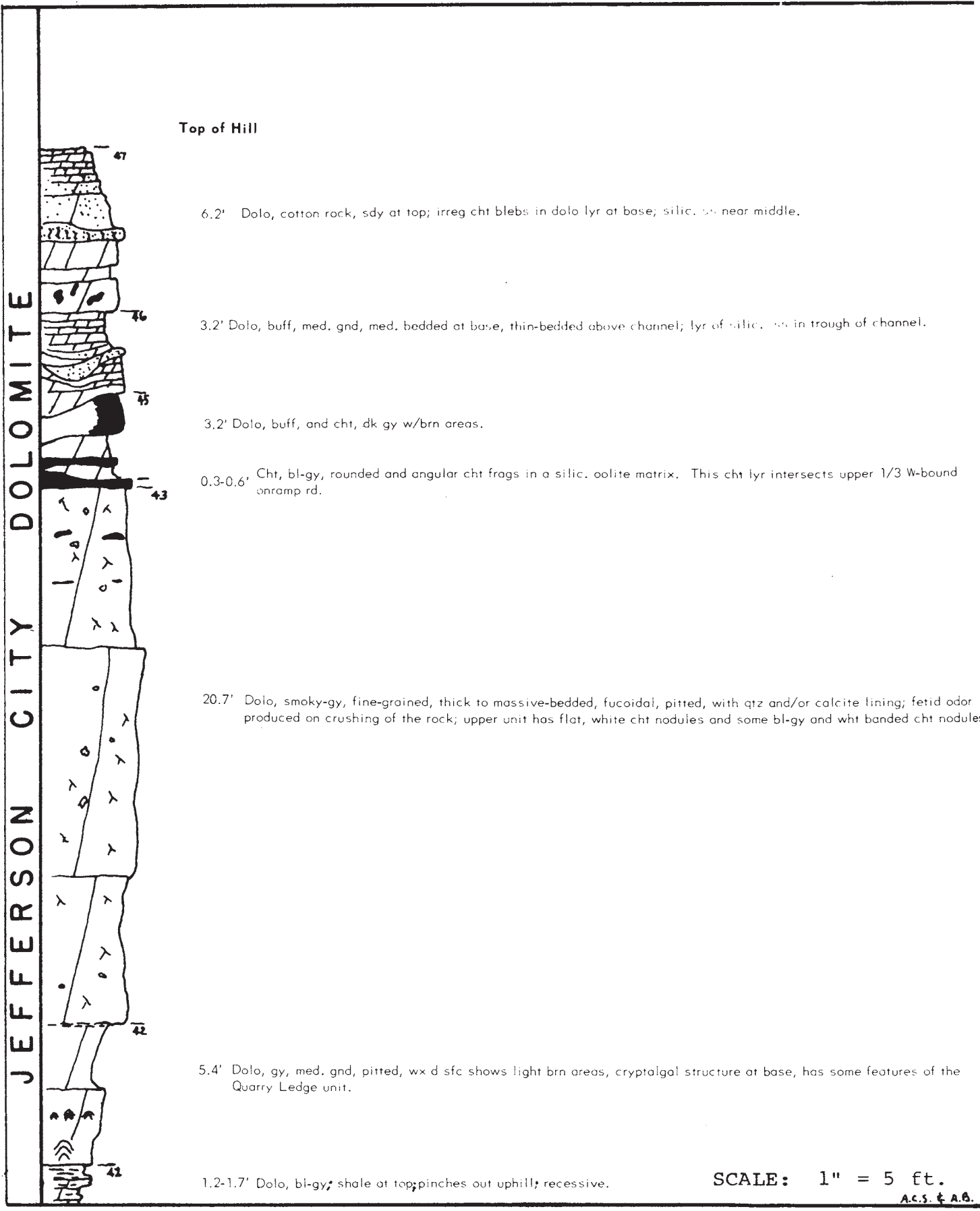
STOP 7 Stratigraphic Section, Waynesville-St. Roberts I-44 hill. Units 1-7 measured in ledges between lanes starting at valley level along W-bound lane; units 8-40, in successive cuts along south side of E-bound lane; units 41-47 (top) along on ramp to W-bound lane at top of hill.



STOP 7 Waynesville Section Cont'd.



STOP 7 Waynesville Section Cont'd.



Top of Hill

6.2' Dolo, cotton rock, sdy at top; irreg cht blebs in dolo lyr at base; silic. ss near middle.

3.2' Dolo, buff, med. gnd, med. bedded at base, thin-bedded above channel; lyr of silic. ss in trough of channel.

3.2' Dolo, buff, and cht, dk gy w/brn areas.

0.3-0.6' Cht, bl-gy, rounded and angular cht frags in a silic. oolite matrix. This cht lyr intersects upper 1/3 W-bound onramp rd.

20.7' Dolo, smoky-gy, fine-grained, thick to massive-bedded, fucoidal, pitted, with qtz and/or calcite lining; fetid odor produced on crushing of the rock; upper unit has flat, white cht nodules and some bl-gy and wht banded cht nodules

5.4' Dolo, gy, med. gnd, pitted, wx d sfc shows light brn areas, cryptalgal structure at base, has some features of the Quarry Ledge unit.

1.2-1.7' Dolo, bl-gy, shale at top; pinches out uphill; recessive.

SCALE: 1" = 5 ft.

A.C.S. & A.B.

The gravels on the right are very highly polished in the lower part of the exposure. Pebbles and cobbles with similar high polishes have been found in Ozark caves and in some of the more boisterous springs. Similar very highly polished material has been encountered in well cuttings in areas of "open ground" where sinkholes, caves, springs, and solution channels are common. The exact mechanics of polishing this material is not known, but in a spring environment it may be polished by running water, or in a cavernous environment by running water in conjunction with the very fine, unctuous, cave clays which might act as a jeweler's rouge.

To the left of these very highly polished pebbles is an exposure of unusually thick residuum and still farther to the left, or south, is a normal section of the Gasconade Formation. Roubidoux sandstones are preserved in the upper part of the residuum section and the cryptozoan chert reef is represented by large blocks of chert in the lower part. Shanghai Spring is a quarter of a mile to the south of this locality on the same side of the road.

Turn cars around and return to highway.

- 39.1* STOP and turn right on U. S. Highway 66.
- 39.25 BEAR RIGHT on Highway V.
- 40.0 Gravel operation visible to right in bottom lands of the Big Piney River.

*Mileage does not include Optional Stop 8.

40.2 Scenic pull out. Park cars here for stop 9.

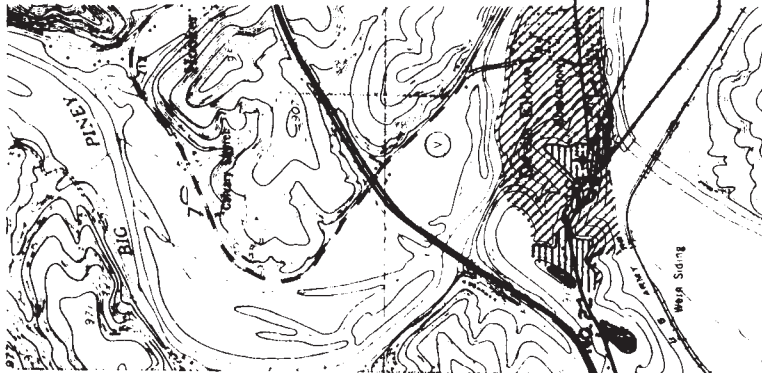
40.3 STOP 9. NW. 1/4, SE 1/4, Sec. 18, T.36N., R.10W., Pulaski County. Residual material in contact with pinnacles of Gasconade dolomite. This section has been studied in detail by K.H. Anderson, Subsurface Geologist of the Missouri Geological Survey. The accompanying diagram which he prepared shows that the 22 feet of residual material exposed represents approximately 260 feet of original bedrock section, including part of the Gasconade Formation, all of the Roubidoux Formation, and the lower part of the Jefferson City Formation.

This exposure represents a natural insoluble residue, and the residual material was compared with insoluble residues from a nearby well to determine the amount of original section. In addition to demonstrating how solution can remove tremendous amounts of carbonates, this exposure also shows how the insoluble material can retain much of its bedding as it is let down.

Such conditions create field mapping problems in parts of the Ozarks such as Dent County to the east of the Phelps County. In that county much of the surface rock is Roubidoux sandstone, yet where bedrock is exposed it may be as old as Eminence with all of the Gasconade dolomites as well as the original Roubidoux dolomites removed by solution. The problem is thus posed as to whether to map the area as Roubidoux because of the preponderance of Roubidoux sandstone material, or to depict the highest, preserved bedrock section which in some cases would be Eminence.

SECTION REPRESENTED
IN RESIDUUM (CENTER) LOG
CHEROKEE PIPELINE CO.
40N 7W SEC 5
MARIES CO., MO.

PENNSYLVANIAN
JEFFERSON CITY
ROUBIDOUX
UPPER GASCONADE
LOWER GASCONADE



AREAL LOCATION
OF
MEASURED SECTION
IN
RESIDUUM
T 36N R10W SEC 18

- RESIDUUM
- ROUBIDOUX
- GASCONADE
UPPER & LOWER

AVERAGE THICKNESSES
FROM 15 WELLS IN THIS AREA

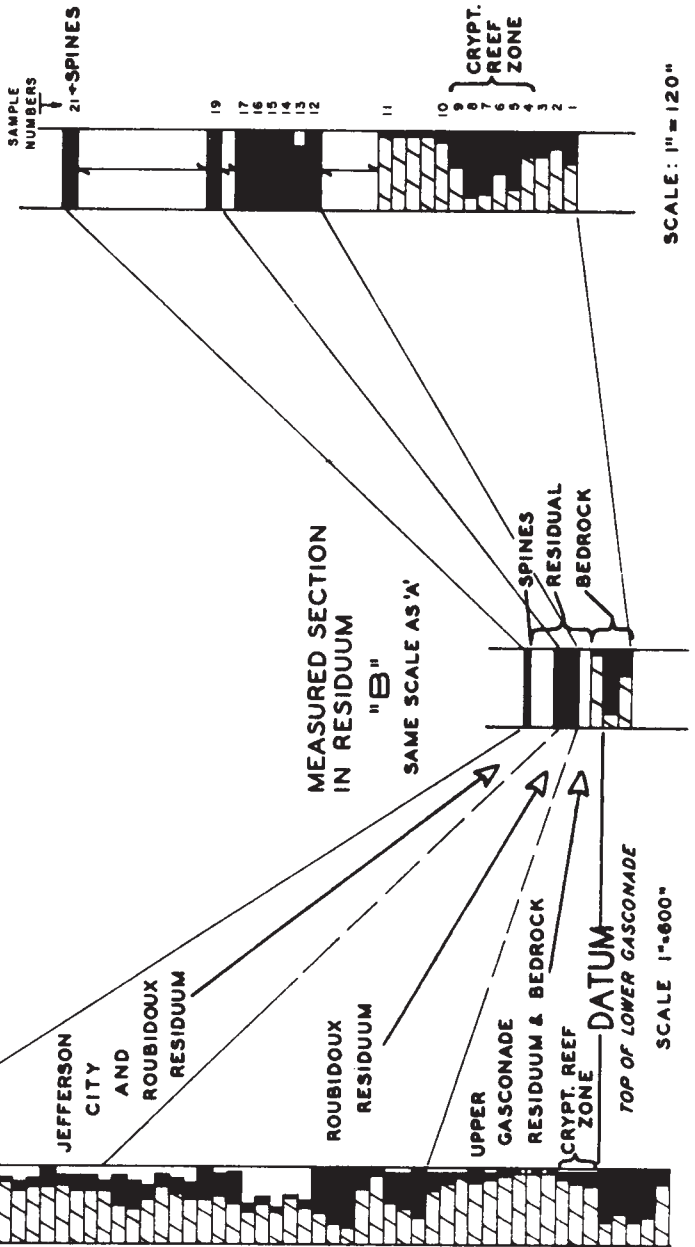
- JEFFERSON CITY
SPINE ZONE TO BASE 80'
- ROUBIDOUX 120'
- UPPER GASCONADE 60'

BY
K. H. ANDERSON

260' OF BEDROCK SECTION IN
LOG "A" REPRESENTED BY 22'
OF RESIDUUM IN LOG "B"

↑ SPINE ZONE IN JEFFERSON CITY FORMATION
HIGHEST ZONE RECOGNIZED IN RESIDUAL LOG

DETAIL OF
RESIDUUM SECTION "B"
SCALE: 5 TIMES "B"



MEASURED SECTION
IN RESIDUUM
"B"
SAME SCALE AS "A"

DATUM
TOP OF LOWER GASCONADE
SCALE 1"=600'

- DOLOMITE
- SANDSTONE
- SHALE
- CHERT

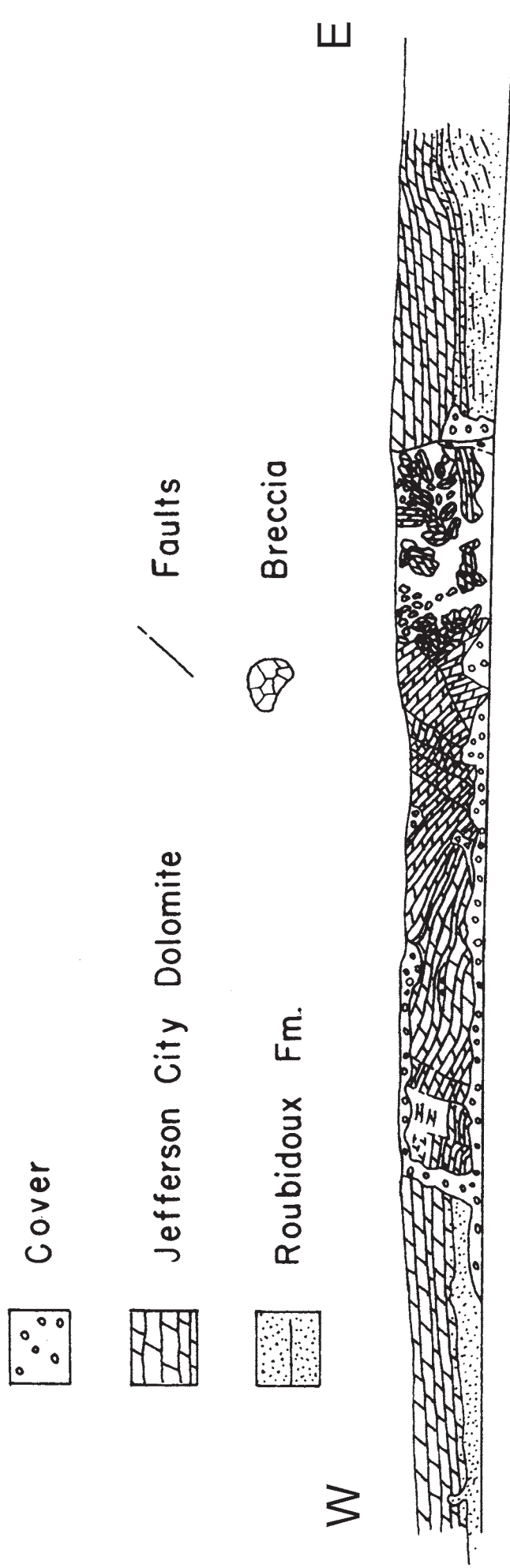
SCALE: 1"=120'

In one particular area the problem was solved by making two geological maps; one portrayed the youngest bedrock underlying the residual material, and the other map portrayed the rock at the surface whether it be residual or bedrock. In this particular case the geological mapping was requested by the Forest Service. The type of material at the surface was of importance because of ecological conditions for tree growth.

This stop also demonstrates a problem in engineering geology in areas of solution where the bedrock surface may be pinnacled.

- 40.4 Vertical Gasconade bluffs of the Big Piney straight ahead. In these bluffs to the right is the Devil's Sugar Bowl, a rock formation with a tall cylindrical sugar bowl surmounted by a conical shaped lid.
- 41.5 Town of Devil's Elbow to right. Devil's Elbow is so-named because of the sharp bend in the river at this point. Logs and ties were rafted down the Big Piney and Gasconade rivers and resulted in a very colorful breed of tie rafters renowned for their prodigious strength, ability to consume whiskey and fight, and knowledge of the Bible. Upstream from Devil's Elbow is a rock promontory called the Devil's Tea Table.
- 41.7 Cross Big Piney River and leave Devil territory.

- 42.1 STOP. Junction with J. S. Highway 66. Bear right onto eastbound lane.
- 42.5 Deep cut in the Gasconade. Contact with Roubidoux in bench near top.
- 46.9-47.0 Roubidoux to right.
- 48.1-48.5 Gasconade in cuts.
- 49.1 Gasconade quarry on right.
- 49.5 Cross Little Piney River
Gasconade in cuts to near top of grade where Roubidoux crops out.
- 53.8 Doolittle City Limit.
- 56.8 TURN RIGHT-CAUTION!
(Note: We are going to STOP 10 via the back road because of highway traffic. The exposure for this stop is 1.1 miles straight ahead on the main highway.)
- 57.6 Cross-bedded Roubidoux Sandstone on left.
- 57.7 Cabin on left built circa 1869, an excellent example of early Ozark construction.
- 58.5 Sewage treatment plant.
- 58.6 STOP 10 Collapse filling in sink development in the basal part of the Jefferson City Formation, SW 1/4, SW 1/4, Sec. 8, T 37 N., R. 8 W. Phelps County. This structure is visible on both sides of the road but is best studied on the north side where large blocks of the "Quarry Ledge" are easily identified. This is an excellent example of collapse



STOP 10. CROSS-SECTION ALONG I-44 AT MARTINS SPRING

P. D. Proctor & T. Eyermann

filling in a pre-existing sink hole. It could therefore, be called a "circle" (Mather, 1946, Bretz, 1950) according to Bretz's definition which is "a collapse-formed cave, filled with its own country rock debris." (p. 823). The visible portion of this circle structure is in the Jefferson City, of which a maximum of 23 feet is exposed in this cut. (See sketch on page 28)

Roubidoux sandstones in the first cut to the west show the tendency of formations to dip into the valleys in the Ozarks. This phenomenon which is probably in part the result of solution, poses a problem in field mapping of distinguishing tectonic dips from solution structures. Similar tendencies of the Roubidoux to follow the topographic slope (or vice versa?) may be seen for the next mile to the west. The Roubidoux-Jefferson City contact is at the contact of the highest thick sandstone bed with a nodular tripolitic white to smooth gray chert.

Continue eastward toward Rolla after this stop.

- 59.0 Martin's Springs
- 60.5 Holiday Inn (Old "Quarry Ledge" quarry site).
- 61.05 YIELD SIGN.

END OF WEST ROAD LOG.

LUNCH STOP - MARAMEC SPRING PARK (NW 1/4, SE 1/4, Sec. 1,
T 37N, R 6W, Phelps County, Mo.)

Maramec Spring Park is owned by the James Foundation. Following the lead of state parks, a flat car rate is charged for admission to the park and its facilities. These are extensive and include grass covered recreational fields, tennis courts, facilities for volleyball, croquet and horseshoes, children's playground equipment, shelters and hiking trails. In addition, trout fishing, under state control, is permitted below Maramec Spring. Recent landscaping of trails and the extensive fish ponds for trout rearing make the area a most charming place.

Remnants of the old iron works of the James family can be seen in the lower picnic grounds of the park. Originally built in 1829, the plant ceased operation in 1876.

The Maramec Museum in the upper area of the park is well worth a visit (admission 25¢). Exhibits demonstrate features of Ozark karst topography, pioneer life in Missouri and the James iron works, the latter through the use of excellent scale model reproductions. These provide an accurate depiction of operational procedures in early iron production.

A member of the field trip committee, T. R. Beveridge, served as advisor in planning the museum.

The Spring

Maramec Spring surfaces at about 785 feet above sea level in a circular basin in the Gasconade Dolomite. Waters from the spring flow through a picturesque stream valley in the park and join the Meramec River about a mile away.

According to Beckman and Hinchey (1944, p. 95), water power from Maramec Spring was developed to serve the Maramec iron works which exploited the iron ore deposit about one-half mile west of the spring.

Source of the waters for Maramec Spring (*ibid*, p. 95) is thought to be an area south, west and southwest of the spring in the vicinity of Asher Hollow and Brown Hollow. Dry Fork to the southwest may contribute to the waters. In the upland area, surface rocks of the Roubidoux Formation and a thin veneer of residuum, both pervious to water

flow, may also be sources for the spring. Numerous sink holes are known in the same upland area. These may collect surface waters and divert them to interconnected subsurface channelways.

These same authors (p. 97) observe that direct channel connection from the surface to the subsurface is strongly suggested by the rapid response of the spring to heavy rainfall and also to conditions of drought. Shortly after heavy rains, turbid and even muddy waters rise at the spring.



MARAMEC SPRING

Maximum flow rate, according to Beckman and Hinchey (1944, p. 97), in the period 1927-28 was 420,000,000 gallons per day. A maximum flow rate of 36,200,000 gallons per day was recorded on August 1, 1934. In more recent measurements the U. S. Geological Survey and Missouri Geological Survey (1970) report an average daily discharge over a 14 year period (1903-1905, 1922-29, 1965-70) of just over 106,500 acre-feet per year or 95,000,000 gallons per day.

Chemical Composition

Continuing studies have been made of the chemical composition of the waters of the spring. In the table below, a part of the data is from the Beckman and Hinchey report; other data are from the more recent (1970) U.S. Geological Survey report.

TABLE I Partial Chemical Composition of Maramec Spring
Waters, Phelps County, Missouri

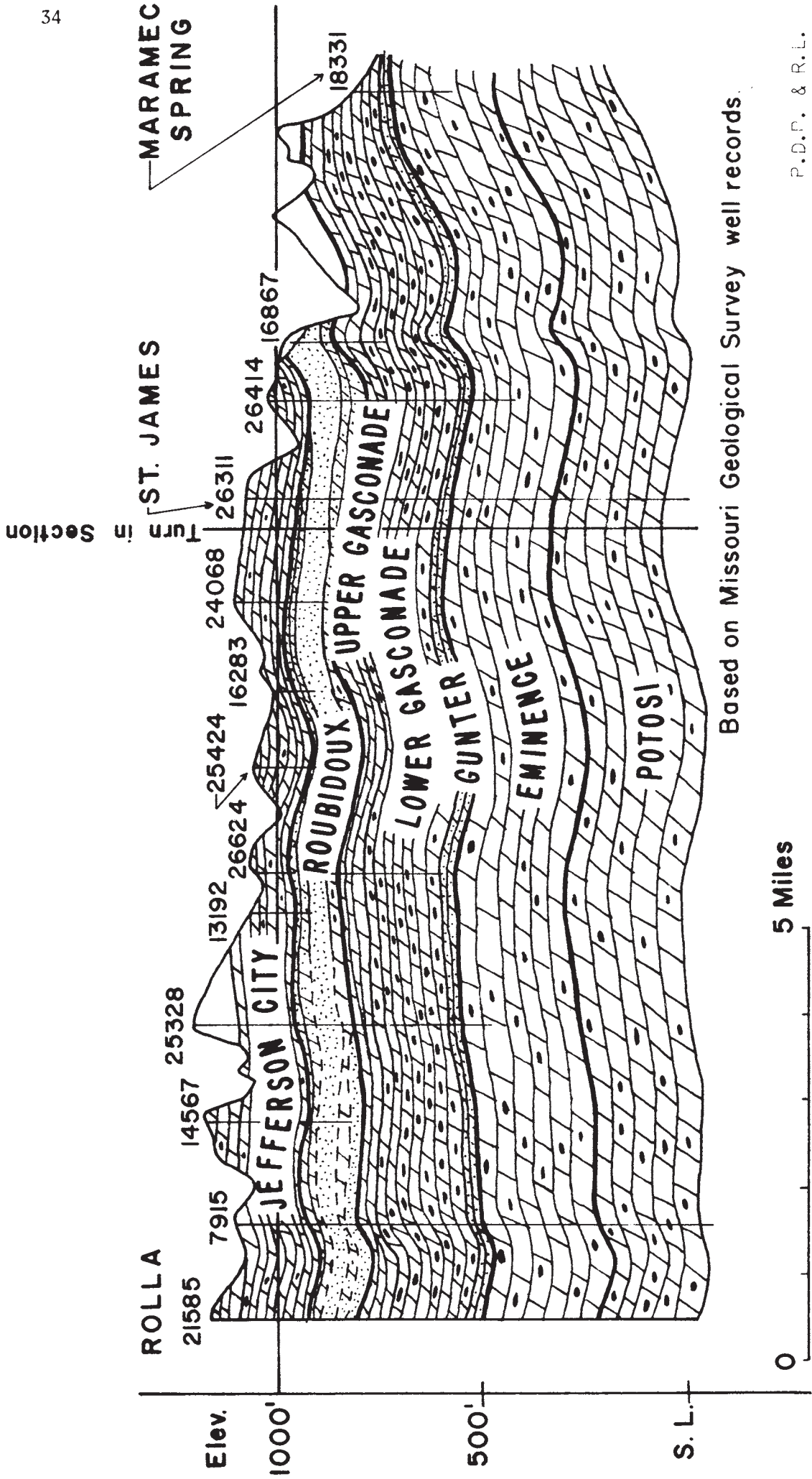
	<u>SiO₂</u>	<u>Fe</u>	<u>Mn</u>	<u>Ca</u>	<u>Mg</u>	<u>Na</u>	<u>CO₃</u>	<u>HCO₃</u>	<u>SO₄</u>	<u>Cl</u>	<u>NO₃</u>
1945*	6.2	0.87	-	30.2	17.9	3.3	8.4	163.1	2.7	2.4	1.73
1970-S**	6.7	63	10	21	12	2.0	-	118	8.2	2.6	9.0
1970-F**	9.1	90	4	34	17	2.4	-	204	3.8	3.7	3.9

*Beckman and Hinchey, 1944 in PPM

**U. S. Geological Survey, 1970 in mg/l except for Fe and Mn; these are in Ug/l and for spring (S) and fall (F) of the year.

Conversion of the spring (S) values from the table above for 1970 into short tons per day based on an average flow rate of 95,000,000 gallons per day, yields the impressive figures of 2.6 tons of silica; 8.32 tons of Ca⁺⁺; 4.76 tons of Mg⁺⁺; 0.8 tons of Na⁺; 3.25 tons of SO₄⁼; 1 ton of Cl⁻; 1.59 tons of NO₃⁻ per day. These become more meaningful if we take only Ca and Mg and convert these to volume of carbonate rock dissolved. Approximately 420 cubic feet of rock a day is taken into solution, or a block just over one mile long, five feet high and 500 feet wide in 100 years. In 1000 years at this same rate, a square mile of the area will have been lowered 5 feet. Grawe (p. 181, 1945) suggests the equivalent of a cavern of 5x5x104 feet long per day is dissolved at Big Spring where the discharge rate was 242,000,000 gallons per day. Equating his estimate to a 1000 year time period results in a block of about seven square miles being lowered by 5 feet.

NOTES



P.D.P. & R.L.

SUBSURFACE CROSS-SECTION ROLLA TO MARAMEC SPRING

EAST ROAD LOG

by

Paul D. Proctor and Alfred C. Spreng

Miles
Start

- 0.00 Junction Highway 8 and Maramec Spring Park turnoff. Elevation 789'. Quarry in Gasconade approximately 700' east at mouth of Asher Hollow.
- 0.10 Road cut. Former quarry in massive Gasconade Dolomite. Approximately 36' exposed. Top of section is 16' below cryptozoan biostrome, a useful mapping horizon in the area. The unit here exposed has little chert.
- 0.36 Reddish soil, chert fragments and layers and occasional outcrops of Gasconade Dolomite. The cryptozoan biostrome at 0.10 mile crops out in road cut; also white chert, some of which is oolitic.
- 0.80 Approximate base of the Roubidoux Formation in ditch on north side of Highway 8. Elevation 953'. Low outcrops of Roubidoux sandstone up gentle hill to west.
- 1.50 Junction Highway 8 and old Maramec Spring road. Turn right. Note slag fragments from old smelter in road fill. The oak and cedar trees east and south of the junction are indigenous. The short leaf pines (Pinus echinata) have been planted.
Proceed eastward (walk or drive) on old Maramec Spring road.
- 1.95 STOP 1 MARAMEC IRON ORE MINE (SW 1/4, SW 1/4, NW 1/4, Sec. 1, T. 37 N., R. 6 W, Maramec Spring 7 1/2' Quad.)

Visitors should obtain permission from Maramec Spring officials to enter the mine. The pit may also be approached from the other end of the road at the maintenance

building in Maramec Spring Park. According to Grawe (1945) this is one of the oldest and best known mines in Missouri. Originally it was worked by the Shawnee Indians as a source of paint. Thomas James, Jr. of Chillicothe, Ohio was guided to the deposit by these Indians. The purchase of the land from the government on June 14, 1825, was the beginning of the iron industry at Maramec Springs.

MARAMEC IRON ORE FILLED SINK-DEPOSIT

The Maramec iron ore deposit is about one half mile west of Maramec Spring in the SE 1/4, SW 1/4, NW 1/4, sec. 1, T. 37 N. R. 6 W. at an elevation of about 920 feet. The deposit has underlying Gasconade Dolomite, wall rock of Roubidoux Formation, possibly Jefferson City residuum and some Pennsylvanian strata. The Roubidoux Formation shows a centripetal dip toward the deposit of ten to twenty degrees which increases toward the mine area.

The original lenticular deposit consisted of boulder-sized specular hematite irregularly distributed through soft red hematite underlain by cherty clay (Schmidt, 1873). Grawe (1945) suggests that a center cone within the deposit, which rises to within 20 feet of the highest rim, is made up of a capping of "blocks of heavy chert breccia, while the body of the (pinnacle) consists of buff cherty clay, tripoli," and "probably represents broken roof rocks of the Jefferson City Dolomite which slumped into the sink structure sometime after the ore began to form." Red hematite was mined from below and around the cone.

Grawe's description for the mine (p. 425)
is appropriate:

"At the present time, the pit is somewhat ovoid in shape having a major northwest-southeast axis of about 250 feet. The bottom of the pit is now filled by slope wash, but the maximum depth from the lowest point in the pit to the highest point of the rim is about 75 feet. A cone-shaped mass of chert, clay and tripoli occupies a considerable part of the central part of the pit. The walls are covered by slope wash, but good exposures of the "rimrock" can be found, especially on the north wall".

While the exact production is unknown, Nason (1892) indicates that William James, son of the original owner, estimated a total production of 375,000 tons. The ore quality was considered good, consisting mainly of rounded and angular masses of specular hematite in "a soft purplish, soapy or greasy matrix." Iridescent hematite crystals and transparent quartz crystals occurred in some cavities in the specular hematite. Iron content of selected ore samples ranged from 53-68 percent; sulfur content to 0.13 percent (in soft paint ore) and silica to 14.7 percent.

Return to junction with Highway 8.

- 3.00 Outcrops of Roubidoux sandstone in cut just west of crest of hill and east of Buck's Lodge sign. Low outcrops of sandstone, some distinctly cross-layered, extend eastward along highway to Maramec Spring Country Store.
- 3.25 Contact of Roubidoux Formation and Gasconade Dolomite. Elevation 908'. Small ledges of Gasconade in wash north of highway at campsite.

3.50 Junction with Highway 68. These roads merge here and continue together into St. James. Area largely alluvium covered. Lower valley walls are in Gasconade Dolomite with exposures in the stream bed on west side of junction. Ripple marks trend N 15° E; joints N 20° E, N 57° E, N 60° - 70° W and N 2° W.

Continue on Highway 8 and 68.

3.70 Gasconade Dolomite north side of highway. Small algal biostrome exposed.

3.85 Small spring at road level north side of highway, (across from mail box), in Gasconade Dolomite.

4.20 East edge of Dry Fork Bridge. Gasconade Dolomite with abundant white chert in wash on south side of highway; probably cryptozoan reef horizon. Ripple marks exposed in dolomite with a wave length of 6" and trend of N 60° E. South along Dry Fork, about 300' on east side of the stream, are ledge outcrops of Gasconade Dolomite. The contact with the Roubidoux Sandstone is near the top of the hill further south at 920' elevation. A small cave and a small natural bridge about 30' long occur near the top of the Gasconade Dolomite.

4.65 Small ledges of Gasconade dolomite are on bank of ditch opposite house and right bend of Highways 8 and 68. Roubidoux Sandstone crops out to the west in the ditch at 855' elevation. This is a rather abrupt elevation change for the Gasconade-Roubidoux contact from the elevation at the 4.2 mile point. The change may be due to solution in the upper Gasconade or possibly to some structure in the area. Joints in the Gasconade Dolomite strike N 55° E, N-S, and N 35° E.

5.10 Roubidoux crops out north of road and in ravine.

- 5.20 STOP 2. INCIPIENT SINK STRUCTURE. NW 1/4, NW 1/4, Sec. 33, T. 38 N., R. 6 W., Meramec Springs Quad.

Large areas of Roubidoux crop out south of the highway. These possibly indicate a large, dish-shaped sink with centripetal dip of the Roubidoux sandstone. Excellent cross-bedding and some ripple marks are exposed. Joint development in the sandstone is conspicuous with a prominent set of N to N 15° E and less prominent sets of N 75° W and N 40° W.

Continue NW along Highway 8 and 68.

- 5.30 Pennsylvanian clays exposed on north side of highway.

- 5.65 TURNOFF TO OPTIONAL STOP 3 - MILEAGE NOT INCLUDED IN CUMULATIVE LOG.

Follow quarter section road to right one mile to natural bridge, also called the St. James natural tunnel. Road cut in possible residuum of Jefferson City Dolomite. A sink structure is suggested in excellent Roubidoux sandstone outcrops at road junction 1/4 mile west of the natural bridge. The contact of the Roubidoux Formation and Gasconade Dolomite is at the main ravine and tributary junction at an elevation of 840'. The natural bridge is cut in Gasconade Dolomite. Only minor chert is visible. This contrasts with the abundant chert to the south at Dry Fork Bridge and suggests possible solution removal of Upper Gasconade in the bridge area.

THE ST. JAMES NATURAL TUNNEL

Near the south line of the SW 1/4, NE 1/4, SW 1/4, Sec. 27, T. 38 N., R. 6 W., Meramec Spring Quadrangle is a tunnel in the Gasconade about 300' long and slightly S-shaped. At the upper end it is 15' high and 20' wide and is about twice as high and wide at the lower end. A small permanent stream flows through the tunnel, its source a spring; the upper part of the valley is ordinarily dry.

The tunnel evidently had its origin in a collapsed cave which once extended under a valley tributary to that of Dry Fork. It represents, according to Dake and Bridge (1923), an interesting case of stream capture through underground drainage.

The porous Roubidoux Sandstone lying above the very soluble Gasconade Dolomite makes an ideal situation for the development of underground drainage. Some of the water from the stream bed east of the tunnel found its way into the cave through joints. Eventually, as solution enlarged these joints, all of the water passed through to the cave, thus beheading the stream valley. Since capture, the steeper gradient of the valley once occupied by the cave has caused an intrenching to a depth of 20 feet. The intrenching may be due partially to the former presence of the cave beneath the valley and partially to erosion following capture.

- 5.80 State Highway Department building on north side of Highway 8 and 68. Pennsylvanian clays and sands on south side of highway.
- 5.90 Clubhouse, St. James Golf Course. Excellent view of topography to south. Crests of hills approximately 1000' elevation.
- 6.55 Intersection with hard surface road south. Abandoned clay pits about 1/4 mile south and 1/4 mile east. North across Highway 8 and 68, excavation for basement of new house is in Jefferson City residual sediments.
- 6.75 Inconspicuous outcrops of Pennsylvanian sediments, north side of highway.
- 6.85 St. James city limit sign.
- 7.35 Highway DD to right. Turn off to Boys Town of Missouri, 2 miles east.

OPTIONAL ROUTE TO STOP 4 (THIS MILEAGE IS NOT PART OF CUMULATIVE LOG)

Miles
Start

- 0.00 Junction. County road DD (Cartall St.) and Hwy 68
(Mile 7.35 on main road log.)
- 0.07 Jog in road.
- 0.4 to 0.8 Pennsylvanian sink(s). Sink fill and rimrock.
- 1.4 Conspicuous Roubidoux sandstone ledges in valley to left
(north).
- 1.7 Turn left into Boys Town.
- 1.8 Roubidoux sandstone ledge along road.
- 1.85 STOP 4. Bridge over tributary of Dry Fork Creek.
Gasconade Dolomite under bridge. Gasconade-
Roubidoux contact about 75 yards upstream.
- 2.1 Boys Town of Missouri.

BOYS TOWN OF MISSOURI

Boys Town of Missouri is the result of a vow made by William James of St. Louis who, after surviving a torpedoing off the coast of North Africa as a naval officer in World War II, as well as raids by Japanese bombers in the Pacific, resolved to "do something for somebody" if he survived.

After his discharge he heard a St. Louis judge comment that in Missouri there was "no place to send a boy in trouble except to a penal institution". James enlisted the help of eight other young businessmen who were also veterans of World War II and through donations of money, labor and materials, Boys Town was established. The first 12 boys were admitted in June, 1949. They lived in a refurbished hunting lodge and went to school in a renovated

garage. Since then over 1,000 neglected and delinquent boys have entered Boys Town of Missouri, some from as far away as Texas and Michigan. It is supported entirely by donations and graduated fees from referring sources.

Today there are six cottages on the rocky, tree covered slope of the campus. Each cottage houses 16 boys and a cottage couple. There is also a modern school building with a gym, workshop and 8 classrooms. On the grounds are an outdoor swimming pool, two baseball fields and room for a flag football or soccer field. Basketball and baseball teams from the school play teams from other schools and institutions. There are no fences on campus.

There is strong social work staff at Boys Town. The boys are normally allowed three two-week vacation periods a year plus other special vacation periods of shorter duration. Special outings or trips are arranged for those boys who cannot return home during these short vacation periods.

Retrace route to St. James

7.40 "Y" junction; half left on South Maramec Street.

7.60 Library to the left of Scioto Street.

LUCY WORTHAM JAMES LIBRARY

On February 8, 1953, the Lucy Wortham James Memorial Library was opened for the first time to the public. It was a gift from Mrs. Wortham James, granddaughter of the founder of St. James, who had willed that money be provided for support of a library

in her home town. The library was built on the site of her former home.

Because of its excellent care, the library looks as new today as it did on opening day nearly twenty years ago. The 80' x 30' main reading room with its leather topped tables, carpet, drapes, lamps and comfortable chairs gives the appearance of a living room in a fine home. The adult section has a fireplace over which hangs a portrait of Mrs. James. The children's reading room has chairs, tables, couches and benches grouped to invite and encourage reading. Beyond the stack room is a patio with bird feeders.

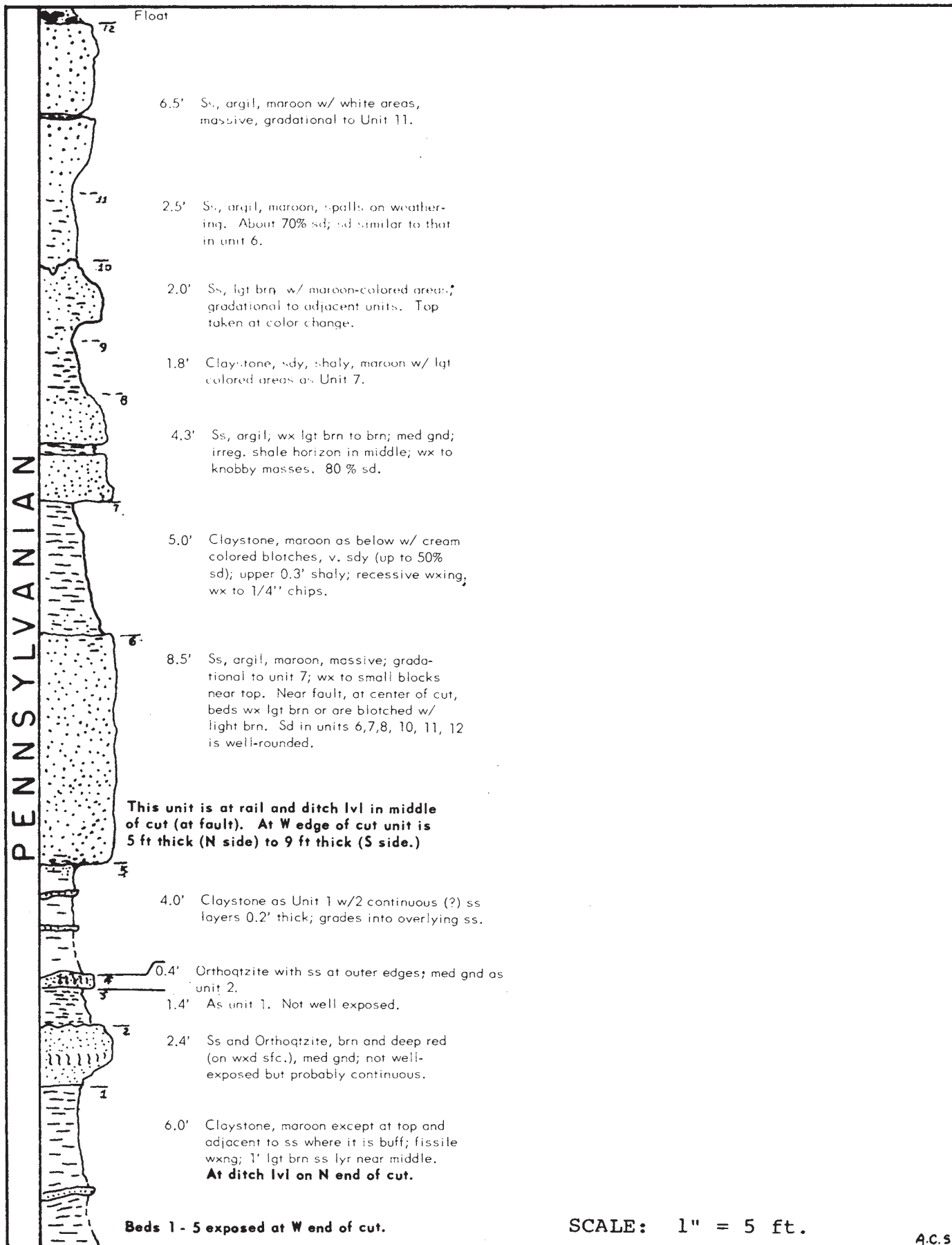
In 1961 the library received a Citation of Special Merit from the Missouri Historical Society for its development of an Ozark Collection of early photographs, documents and books. To this collection the Missouri Geological Survey added a gift of a complete set of official books and reports dating from 1859. Microfilmed census reports of the area for 1830-1880 were added to the collection in 1964.

Governors of Missouri, as well as Mrs. Lyndon B. Johnson, have visited and enjoyed the Lucy Wortham James Memorial Library.

7.70 Cross St. Louis and San Francisco (Frisco) railroad tracks.

- 7.75 Turn left on Springfield Street, parallel to railroad.
- 7.90 St. James City Hall.
- 8.40 "Y" road-junction with Tammy Lane. Continue WSW on Springfield Street, a gravel road. Now in Dillon 7 1/2' Quad.
- 8.80 Beginning of hard surface road.
- 9.60 Inactive quarry 400' northwest of road. Open cut is in Quarry Ledge and other lower beds of Jefferson City Formation. Ripple marked beds of dolomite exposed with small domal reef structures 6-10 feet across and 1-2 feet high. Site of M.G.S. water well location number 16283 is nearby.
- 9.80 Power transmission line crossing, 138,000 volts.
- 9.95 Road-junction; end of hard surface. Continue WSW on gravel road. Outcrops poor to absent.
- 10.95 Junction with gravel road to north. Continue WSW on gravel road. Probable Jefferson City Dolomite residuum in this area.
- 11.60 Wishon Cemetery on north.
- 11.95 Cedar Tree junction with road to south across Frisco tracks. Continue WSW along north side of railroad tracks.
- 12.15 Junction with road to north. Continue WSW on gravel road parallel to Frisco tracks.
- 12.55 Junction with road to south across tracks to "city" of Dillon.
- 12.60 Continue west along Frisco tracks.
- 13.20 End of WSW road at junction with N-S section line road. Cross Frisco tracks to intersection on south side of track.

NOTES

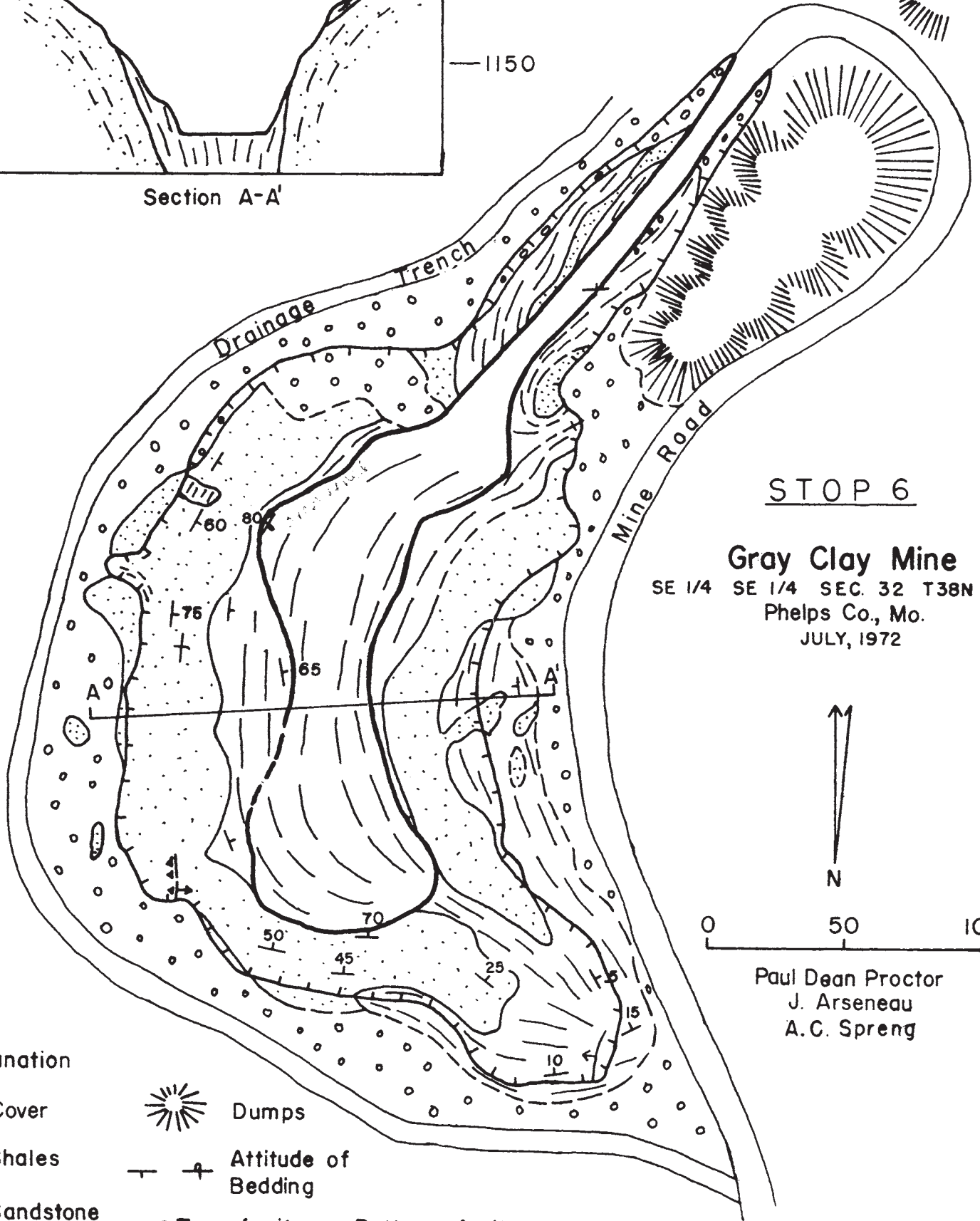
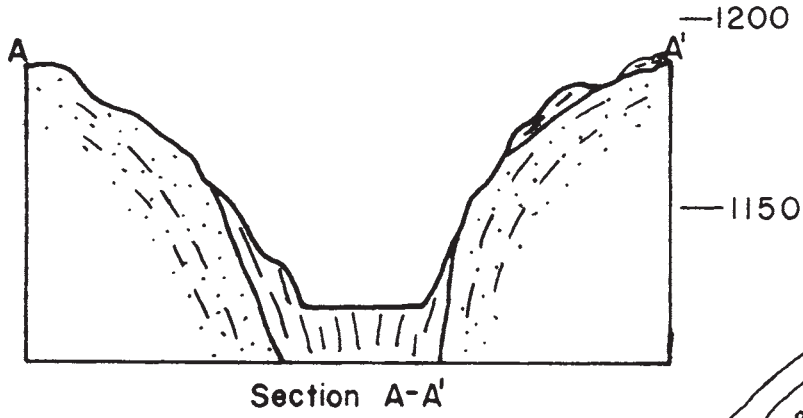


STOP 5 Pennsylvanian section, Frisco railroad cut, 3 miles east of Rolla south of I-44, E. of Co. V interchange. (S 1/2, NE 1/4, NW 1/4, Sec. 32, T. 38 N., R. 7 W. Dillon Quad.)

- 13.25 Turn right onto gravel road WNW and parallel to railroad tracks.
- 13.80 "Y" junction. Keep to left up slight grade. Entering area of Pennsylvanian sediments; poor exposures.
- 14.00 STOP 5 FRISCO RAILROAD CUT (S 1/2, NE 1/4, NW 1/4, Sec. 32, T. 38 N., R. 7 W., Dillon Quad.)
- Top of hill. Railroad cut in Pennsylvanian sandstones and shales to north of road. (Section on page 46.)
- Continue west on road; traverse mainly over Pennsylvanian sediments. About 0.6 mile of new gravel road not shown on 1963 Dillon Quad.
- 15.00 Road junction. Road to northeast to new industrial park of SOME Corporation, manufacturer to-be of plastic pipe, Rolla's newest industry.
- 15.20 Road junction. Turn right on private clay-covered road to Gray's Clay Pit.
- 15.40 STOP 6. GRAY'S CLAY PIT. (SE 1/4, SE 1/4, Sec. 32, T. 38 N., R. 7 W., Dillon Quad.) Take care along steep banks, loose claystone and sandstone on edges of pit. Depth of pit approximately 60' from rim.

GRAY CLAY MINE

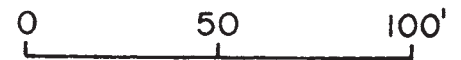
Introduction: The Gray Clay Mine is located about 2 miles east of Rolla and just south of Interstate I-44 and the Frisco railroad tracks in the SE 1/4, SE 1/4, Sec. 32, T. 38 N., R. 7 W. at an elevation of approximately 1190 feet. Operation of the Gray Clay Mine began about 10 years ago under E. H. Wallace, Jr. of Belle, Missouri. Two years later the A. J. Gray Mining Company of St. James took over the property and has mined it since as a one to three truck mining operation. The flint clay product is purchased by the Plibrico of Chicago, Ill.



STOP 6

Gray Clay Mine

SE 1/4 SE 1/4 SEC. 32 T38N R7W
Phelps Co., Mo.
JULY, 1972



Paul Dean Proctor
J. Arseneau
A.C. Spreng

Explanation

- Cover
- Shales
- Sandstone

- Dumps
- Attitude of Bedding
- Top of pit
- Bottom of pit

Geologic Setting of the Deposit: Rock outcrops are absent in the area immediately surrounding the mine. Cover materials consist mainly of residuum from Pennsylvanian sediments. A few hundred feet east along the Frisco Railroad tracks Pennsylvanian sandstones and shales are well exposed (see section on p. 52). These are mainly flat-lying with some local undulations and minor faults present. Both water well logs and rock exposures to the north indicate that the Jefferson City Formation lies directly below the Pennsylvanian sediments.

The Clay Deposit:

Stratigraphy: Chert, quartz sandstone breccias overlain by maroon, pink and white shales with thin interlayered sandstones are exposed in the mine entrance ramp. These beds are moderately to intensely deformed, increasing in deformation toward the main pit. A tan-weathering sandstone forms a rimrock around the main pit. Mainly tan-weathering shales and a tan sandy shale occur above the sandstone. The youngest unit in the mine area appears to be a gray shale or claystone with conchoidal fracture and locally prominent nodular weathering. This is mined from the main pit and shipped as flint clay.

X-ray analysis of both the gray and tan clay members indicate a kaolinite composition. Marcasite-pyrite clusters occur near the contact of the gray shale with the tan shale. Similar occurrences of disseminated and clusters of marcasite-pyrite occur on the tan shale-sandstone contact. Oxidation of these produces the tan to yellowish brown color tones so prominently shown in the mine exposures.

Structure: The overall structure of the deposit is a south to southeast trending, tight to open syncline. In the southeast portion of the body, thin shaly beds are gently inclined and locally dip northerly. Near the west edge of the upper level the beds steepen in dip and strike WNW to form the beginning of the tight syncline of the main body. At this same locality the gray shale thickens abruptly from a few feet to 50 feet or more. Beds on both the east and west limb dip 65 degrees or more toward the central pit. About 150 feet northward the central gray clay zone approximates 50 feet in width, is steeply dipping to overturned to the east on the west wall and vertical to steeply dipping to the west on the east wall.

This tight syncline continues northward toward the entrance ramp where the beds change in strike to northeasterly and are involved in a small, locally overturned syncline and anticline. Up the ramp the beds become more gently inclined. Near the ramp entrance they dip gently toward the pit.

In the central part of the east side of the main pit, just west of the mine road, dips in the gray shales and a tannish gray sandstone unit change from high angle west to moderate west. Directly opposite, on the western rim of the pit, shales and the massive rim rock sandstone are steeply inclined. Bedding in the latter is indistinct. There is a suggestion that these beds are also more gently inclined west of the pit wall. A small local fold and probable bedding plane fault with some breccia occur along the west and southwest walls respectively.

Within the pit the walls indicate the somewhat undulatory, though generally steep attitudes of the tan shale and sandstone.

Origin: The Gray Clay mine exhibits many of the structures described by Bretz (1950) for filled sinks. The undulatory beds and tight folds are indicative of compressive rather than tensional stresses. These suggest an overlying load originally imposed upon the sediments. As the more soluble carbonate rock below was gradually dissolved away, the clay shales and sandstones were forced downward under this load contemporaneously with the downward moving solution interface. Erosion has since cut across the area and exposed the main root structure of the filled sink.

Return to junction with gravel road.

- 15.60 Junction. Turn left (east) on gravel road and retrace route past STOP 5 to "Y" junction.
- 17.00 "Y" junction. Turn left over railroad tracks.
- 17.05 Frisco Railroad. Note STOP 5 to west. Continue on gravel road.

- 17.15 Cross south outer road which runs east along Highway I-44.
- 17.25 Cross Highway I-44 on overpass.
- 17.35 Turn left on outer road west, parallel to Highway I-44. Avoid on ramp to I-44 (left of outer road) (County V continues to north.)
- 17.65 Hy-Point Industrial Park water tower. M.G.S. well log No. 26663. Schwitzer Division Plant (fan blades) to north. Highest point along field trip route (1200').
- 17.75 Junction with old county highway V to north. Good view of topography of dissected Ozark Plateau to south and to northwest. Valleys cut into Pennsylvanian and Ordovician sediments.
- 17.95 STOP 7. P-D FILLED SINK. Cross outer road on foot to ridge parallel to I-44. Observe portion of folded filled sink. You are standing on Pennsylvanian sandstones and shales. The filled sink contains maroon to gray shales and pinkish to white sandstones and minor chert. (See section for STOP 7). A few hundred feet to the north and west, rimrock is exposed some 40' lower than the road level along the edge of the ravine.

STRUCTURE OF THE P-D FILLED SINK

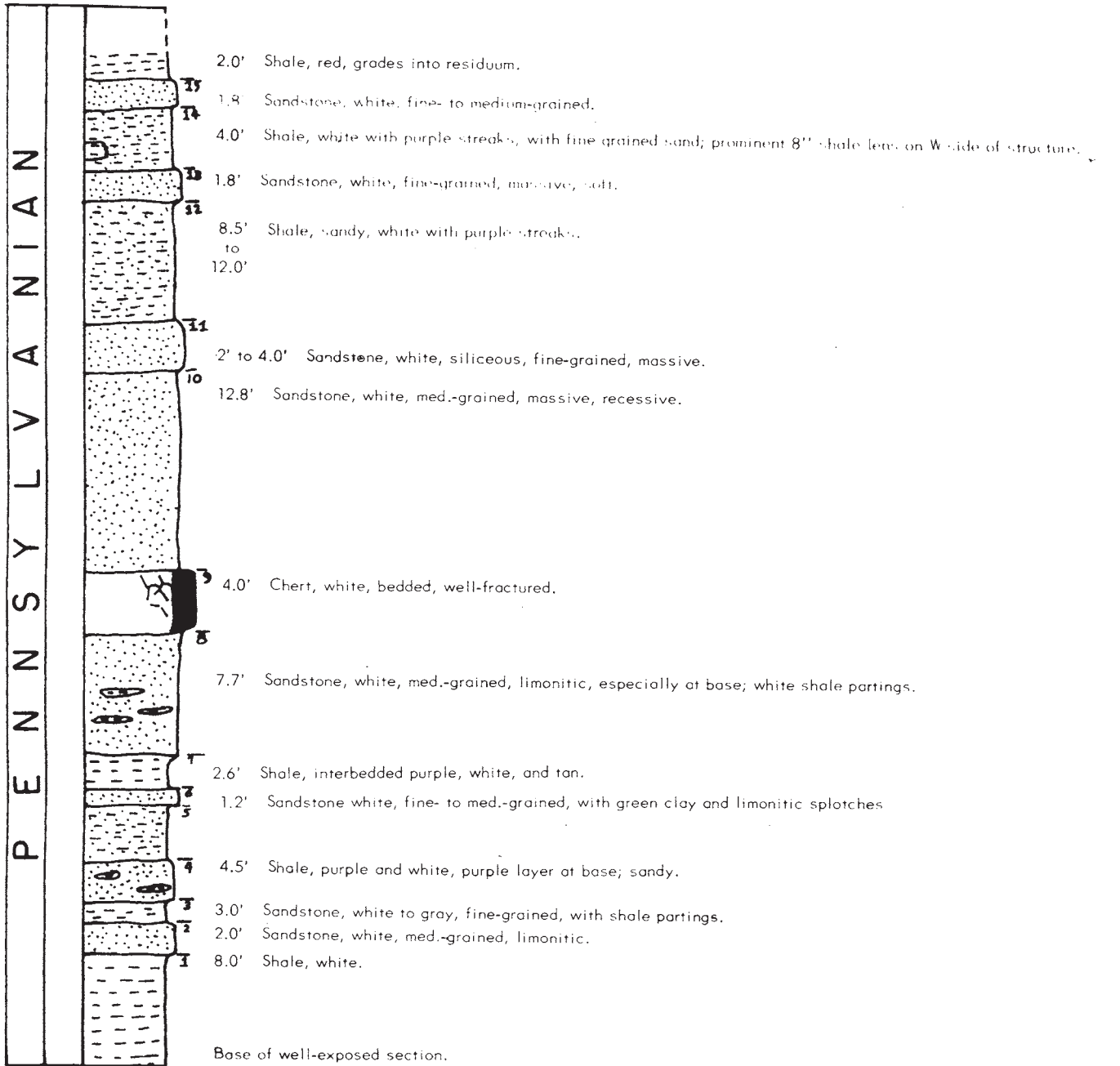
This filled sink has many of the characteristics of similar structures described by Bretz (1950). At least three open asymmetrical synclines and two anticlines are exposed (Cross Section, STOP 7, p. 52). The dip of individual limbs of the folds varies from nearly vertical to essentially flat near the crests and troughs of the folds. Some of the folds show characteristics of disharmonic folding. The structural section exposed in the road-cut is somewhat misleading as it is an apparent view. The folds plunge generally southward away from the face of the cut.

10 Feet
5
0

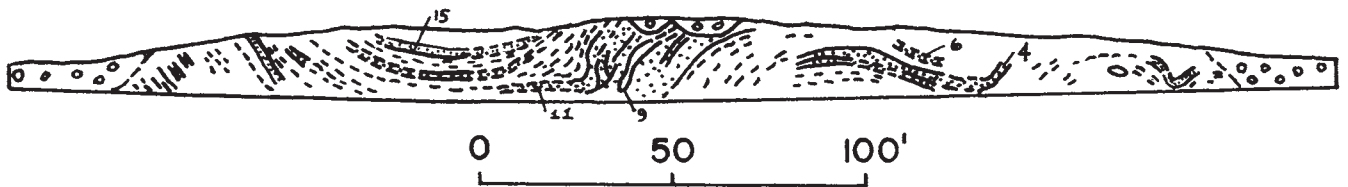
STOP 7. P.D. FILLED SINK

2.3 miles E of Rolla on I-44

(NW $\frac{1}{4}$, SE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 31, T. 38 N., R. 7 W., Dillon 7 $\frac{1}{2}$ ' Quad.)



Some of the unit numbers are shown in the section below.



Geologic Cross-Section of P.D. Filled Sink—Highway I-44

P. D. Proctor T. J. Eyermann



Cover



Pennsylvania Sandstone, Shale and minor Chert

Joints are well developed within the more competent sandstone units. Some of the shales also show prominent fractures. In the easternmost syncline, joints in the upper sandstone have a somewhat fan-shaped arrangement across the fold suggesting a genetic relationship to the fold structure.

Origin of the Structure: The filled sink appears to have formed by the gradual subsidence of the shale-sandstone sequence into a depression below. The fact that Pennsylvanian sandstone and shales just eastward in a railroad cut are not folded, suggests that the structure, like the others in the area, is related to local removal of soluble carbonate rock beneath the much younger shale-sandstone sequence. The relative competency of the sandstones and chert with their associated joint sets suggests that the beds were indurated and under load at the time of the development of the structure. The asymmetry of the folds suggests a generally directed stress from the overlying beds in a westerly direction.

- 19.05 M.G.S. Well location No. 14567 north of road.
- 19.15 Entering Rolla 7 1/2' Quadrangle.
- 19.35 Northwe Market. Field of large sandstone boulders north of store and road. Pennsylvanian.
- 19.40 Pass road junction and College Heights Trailer Park.
- 19.65 Junction with old Highway 66. Continue westward on old Highway 66.
- 19.95 "Northwe" junction. Laborer's International Union local No. 840 building on left. Road to right joins Highway 63 north. Good exposure of Pennsylvanian purple shales and sandstones in road cut. Northwest of roadcut, cherts in fields and on slope of hill contain Middle Mississippian fossils.

- 20.05 Junction with Missouri Highway 63. Turn left.
- 20.35 Large borrow pit on left cut in Pennsylvanian shales and sandstones.
- 20.85 Road junction. Entrance to on ramp west on Highway I-44. Continue on Highway 63 south over I-44.
- 21.00 Tim's Pizza Palace on right constructed of local chert, sandstone, breccia, and Jefferson City dolomite.
- 21.15 "Y" junction. Continue to right (west) on Highway 63 south. Left road is Pine street and leads to Rolla business district and U.M.R.
- 21.20 Thomas Jefferson Residence Hall (private) for UMR students on right.
- 21.25 Turn half right onto hard surface road (by Rolla water tower)
- 21.30 Turn right on Tower Road (behind Rolla water tower.)
- 21.35 Sharp turn right to Thomas Jefferson Parking lot.
- 21.45 STOP 8 FILLED SINK. Vichy Road overpass over I-44 (NE 1/4, SW 1/4, NE 1/4, Sec. 2, T. 37 N., R. 8 W., Rolla Quad.) Walk northward to edge of I-44 road cut. You are standing on Pennsylvanian sandstones and shales in a filled sink. (Sketch in G.S.A. Guidebook, 1958, p. 66). To the north across the highway is a separate filled sink with folded Pennsylvanian shales and sandstones in Jefferson City dolomite. See map and description, p. 83; also see Fig. 3, p. 75 for Jefferson City section adjacent to sink
Leave Thomas Jefferson parking lot.
- 21.50 Junction with Tower Road. Turn left on Tower Road.
- 21.55 Junction with 18th St. (at water tower). Turn right onto 18th St.
- 21.60 Junction with Vichy Road. Turn left on Vichy Road.

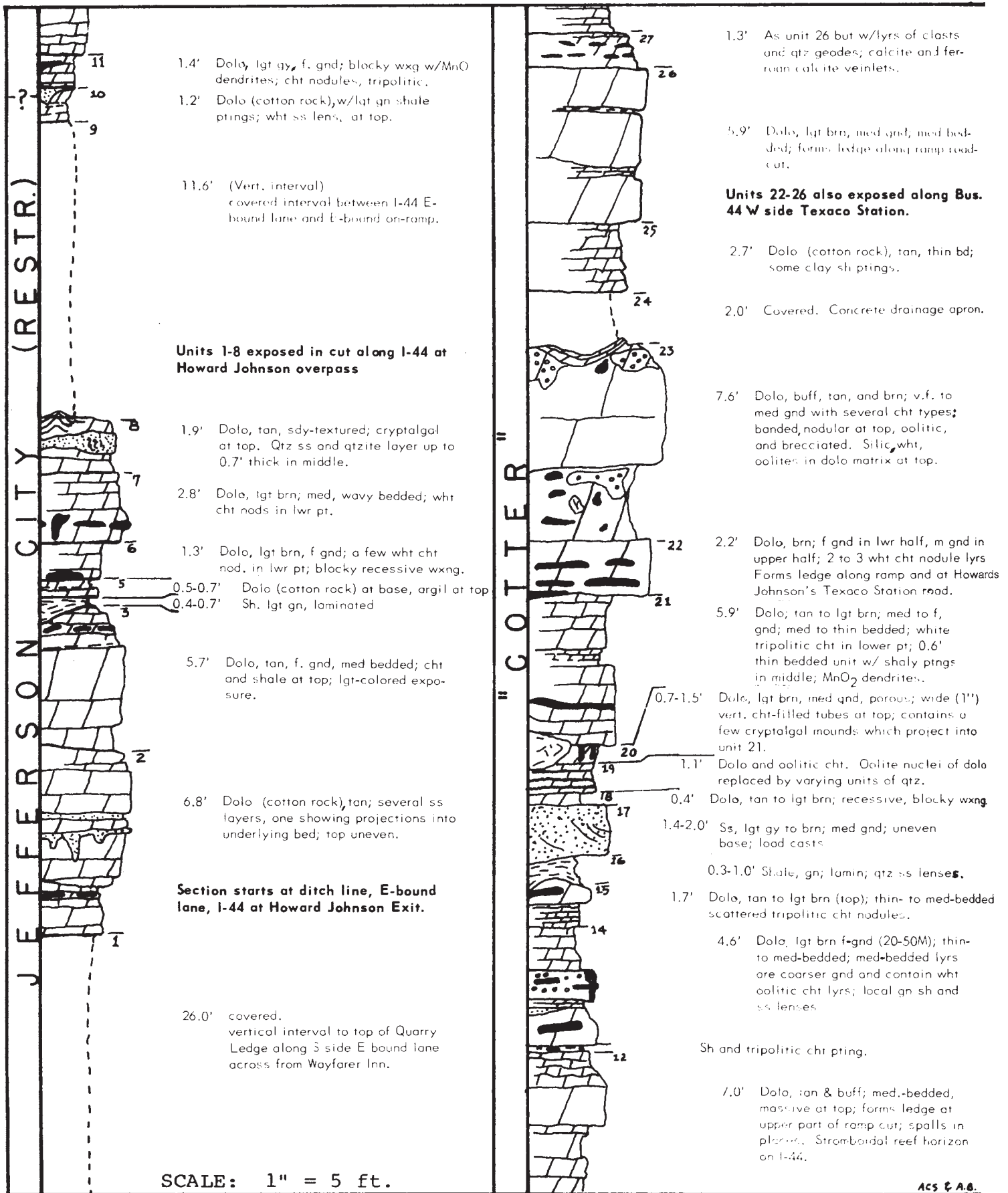
- 21.65 Junction with Highway 63 South. Turn right on highway.
- 21.75 St. Patrick's church on left.
- 21.95 Stop light. Junction with Phelps County E. Continue on 63 South.
- 22.05 U. S. Bureau of Mines Regional Office on left.
- 22.25 Junction with 10th Street. UMR dormitories on left; UMR Field House on right.
- 22.50 Junction with Bus. Loop 44. Turn right on Business 44.
- 22.55 State Land Survey Authority office on right. Survey records for the state are kept here.
- 23.10 Fairground Road to right. Leads to Missouri Geological Survey building (light gray building which can be seen short distance down the road). Clark National Forest Headquarters and the Rolla Regional Diagnostic Clinic are located down this road.

Buehler Park ahead to left of highway. This park was named for H. A. Buehler (1876-1944) who was State Geologist from 1908 to 1944. The park contains a sign giving a brief history of Rolla.

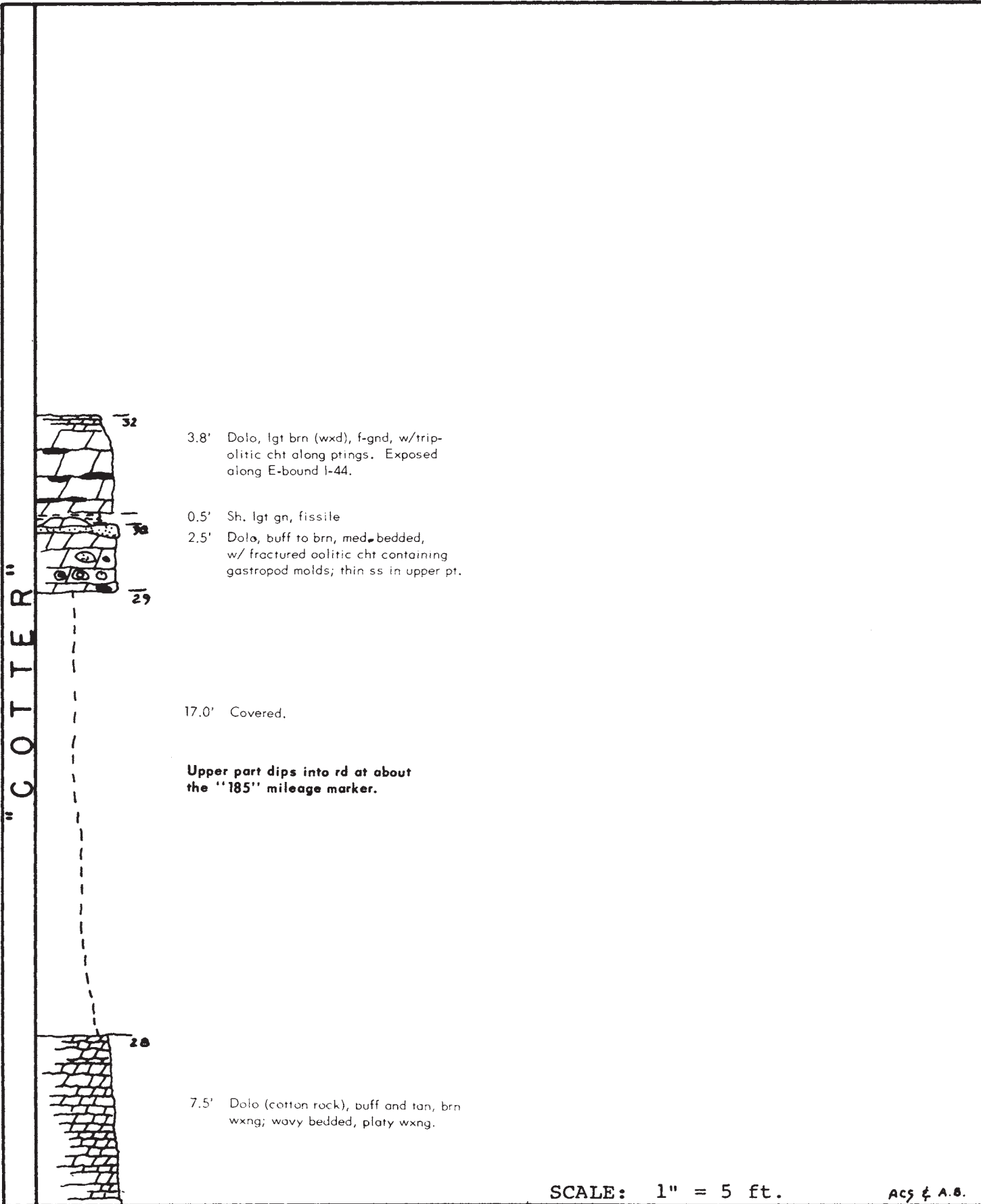
- 23.25 Turn right on road leading to Howard Johnson Parking lot. Jefferson City (unrestricted) exposed at road entrance.
- 23.35 STOP 9. RAMP ROAD, EAST BOUND I-44 (SE 1/4, NW 1/4, SW 1/4, Sec. 2, T. 37 N, R. 8 W., Rolla Quad.)

Jefferson City-Cotter section on ramp road west of Howard Johnson Inn. (See Howard Johnson and Holiday Inn sections, pp. 56 - 48)

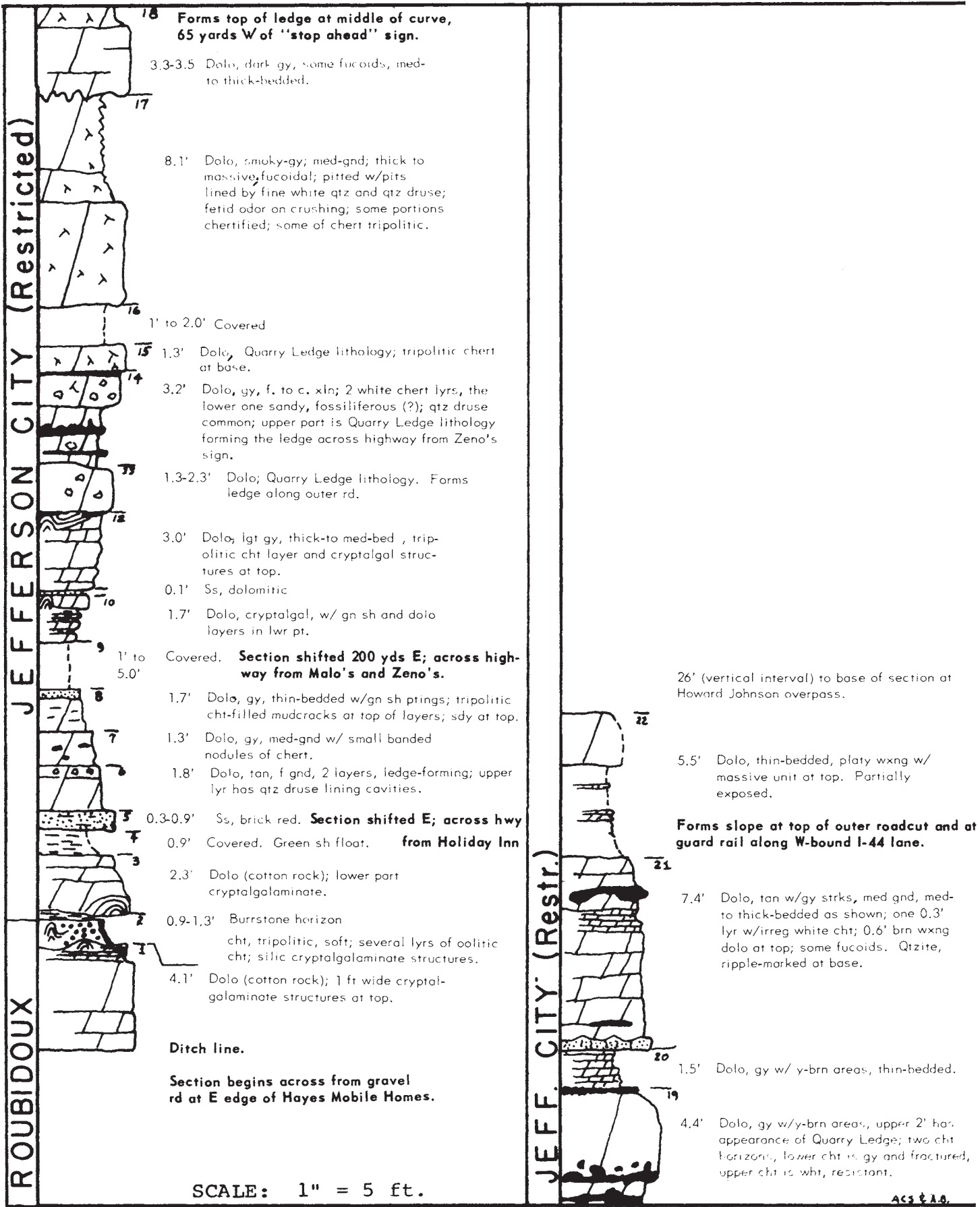
END OF EAST ROAD LOG



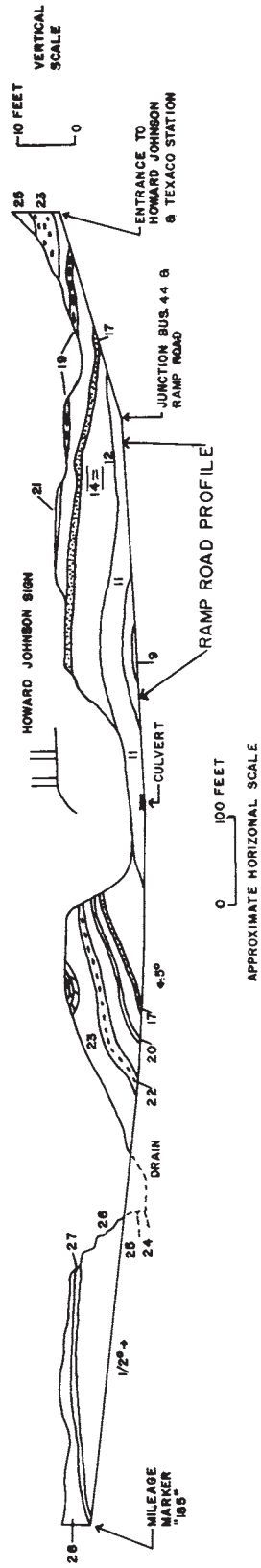
STOP 9 Stratigraphic section along ramp west of Howard Johnson Inn. The "Cotter" is shown as correlated with the Frisco Railroad cut of Grawe and Cullison (1931).



STOP 9 Howard Johnson Inn section, concluded.



STOP 9 Holiday Inn section along outer north road. Section based on exposures occurring for about 2000 feet along the road. (N 1/2, SW 1/4, T. 37 N., R. 8 W. Rolla Quad.)



STOP 9

GROSS-SECTION SKETCH ALONG N-S HOWARD JOHNSON RAMP ROAD SHOWING LOCATION OF UNITS IN MEASURED SECTION

OPTIONAL ROAD LOG TO ABANDONED CLAY PITS

(From St. James north and west to Rolla.
Route in Rosati, Safe, and Dillon
Quads.)

START
Miles

- 0.0 Highway 68 overpass on I-44. State Federal Soldier's Home southeast of overpass area. Proceed NNW on Highway 68, hard surface road.

STATE FEDERAL SOLDIERS' HOME

The State Federal Soldiers' Home was originally established as the Federal Soldiers' Home by the Women's Relief Corps and the Grand Army of the Republic organization of the Department of Missouri, on October 25, 1896. The three story former dwelling of the James family was remodeled to contain 23 dormitory rooms housing 61 persons.

The purpose of the Home remains the same today as when it was first established: to provide a home for indigent veterans, their wives, widows and army nurses, where they can be supplied with the necessities of life, receive medical care and spend their last days free from want and care. Mothers of veterans and female veterans of the Armed Services who meet the requirements of age, service and need are also admitted.

On June 25, 1897, the Home was sold to the state of Missouri for the nominal sum of one dollar. It now consists of 12 buildings on 52 acres of land. Facilities include a 95 bed hospital, a chapel, canteen, garage, powerhouse, laundry, sunshine cottage, dining room, dormitories for men, women and married couples, a guest cottage and administration building.

- 0.15 Junction Highway 68 and Highway V. Continue on Highway 68.
- 0.30 Jefferson City Quarry Ledge exposure in road cut. Beginning of large filled sink.
- 0.60 Bridge across upper Bourbeuse River.

- 0.80 Junction with gravel road to west (Craig Road). Proceed westward on this section line road.
- 1.40 Matlock Cemetery south of road.
- 2.70 Junction with gravel road to south. Proceed westward.
- 2.95 N-S crossroad. Proceed west.
- 3.50 STOP 10. CLAY PIT, ABANDONED. (Along E edge NE 1/4, NE 1/4, NW 1/4, Sec. 9, T. 38 N., R. 7 W., Safe 7 1/2 Quad.).
- Pit has been worked out and is water-filled, but the rimrock structure and section in haulage way can still be observed.
- 4.00 N-S crossroad. Proceed west.
- 4.30 Clay pit 200' north of road.
- 4.50 STOP 11. CLAY PIT, ABANDONED. (SW 1/4, SW 1/4, SE 1/4, Sec. 5, T. 38 N., R. 7 W., Safe 7 1/2 Quad.).
- Turn off road to right to dump and clay pit. Well-exposed rimrock on pit walls. Good section of Pennsylvanian shales and sandstones along eastern entrance ramp. Section described by Parikh (1970, p. 74).
- 5.00 Road junction. Turn left (south).
- 6.00 Junction with Highway V. Proceed south on hard surface "V".
- 7.00 Junction with E-W crossroad. Clay pits on NW and SE corners of junction. Continue on Highway V.
- 7.65 Enter Dillon 7 1/2' Quadrangle.
- 8.30 Major power transmission line (138,000 volts) crosses Highway V. Power line extends from Bagnold Dam to Rivermines, Mo. Substation for Rolla 1 1/4 mi. to the ESE.
- 9.10 Junction of new Highway V and old Highway V.
- 9.20 Schwitzer Division of Wallace Murray Corporation Plant (fan blades).
- 9.40 Junction with Outer Road north of Highway I-44. Gulf Station on east. Hy-Point Industrial Park to west.
- 9.50 Center of overpass over Highway I-44 and V.

OPTIONAL ROAD LOG TO MOSELLE NO. 10 MINE

Miles
Start

- 0.00 Start at junction of Mo. Highway 63 and Bus. Loop I-44 in the SW part of Rolla. (Mile 22.50 on east road log.) Go south on Highway 63. Continue on Hwy. 63 until mile 7.65.
- 0.10 Frisco RR underpass.
- 0.30 T.-Junction with Mo. Highway 72. Continue south on Highway 63.
- 3.0 Bray Construction Company quarry. Jefferson City (unrestricted) beds above the Quarry Ledge are exposed in quarry.
- 5.25 Beaver Creek
- 5.50 Leaving Rolla Quad.; entering Yancy Mills Quad.
- 6.75 Vida, Missouri
- 7.65 Junction with gravel road just over crest of hill. Turn right onto gravel road.
- 8.5 Junction with another gravel road. Continue northwest on gravel road.
- 9.25 Junction with road into Moselle Mine. Gate at road. Note sign regarding permission to enter. Turn left onto mine road. Follow road into valley to abandoned Moselle mine.
- 9.55 STOP 12 MOSELLE NO. 10 MINE. Description of mine on following page.

MOSELLE NO. 10 MINE

INTRODUCTION: This iron ore and pyrites mine is about 9 miles S 20° W of Rolla in the NE 1/4 of sec. 20, T36N, R8W in a tributary to Gourd Creek at an elevation of about 920 feet. Although only an optional part of the guidebook trip, it is described because of its large size and unique character among the solution features in the area.

MINE DEVELOPMENTS: Iron ore shipments of hematite began in 1872 and continued through 1880. Crane (1912) describes the mine as an open pit 200 feet long, 90 feet wide and 32 feet deep. Sandstone formed the east wall and the others were debris covered.

The mine was inactive until 1933. In this year a 12 foot shaft was cut in the bottom of the old pit exposing pyrites. In 1934, lessees Thomas and Williams shipped iron ore to Granite City, Illinois. Additional exploration work by Bailey and Libhart revealed about 20 feet thickness of sulphides. By October of 1934 pyrites were shipped. Open pit mining was later initiated. The bottom of the sulphides was reached at a depth of 190-200 feet beneath the highest point of the rim, and the pyrites found to be 140-150 feet thick. Upper walls of the deposit consist of Roubidoux sandstone and are almost vertical. The pit apparently bottomed in the lower part of the Gasconade Formation.

ORE DEPOSIT: An excellent photograph by Grawe (1945, Plate II) shows the characteristics of the deposit. At that time the mine consisted of an oval open pit, 300 feet long, 240 feet wide, with the eastern side to a depth of 185 feet. The base of the open cut was about 150 feet in diameter. His geological cross section is shown below.

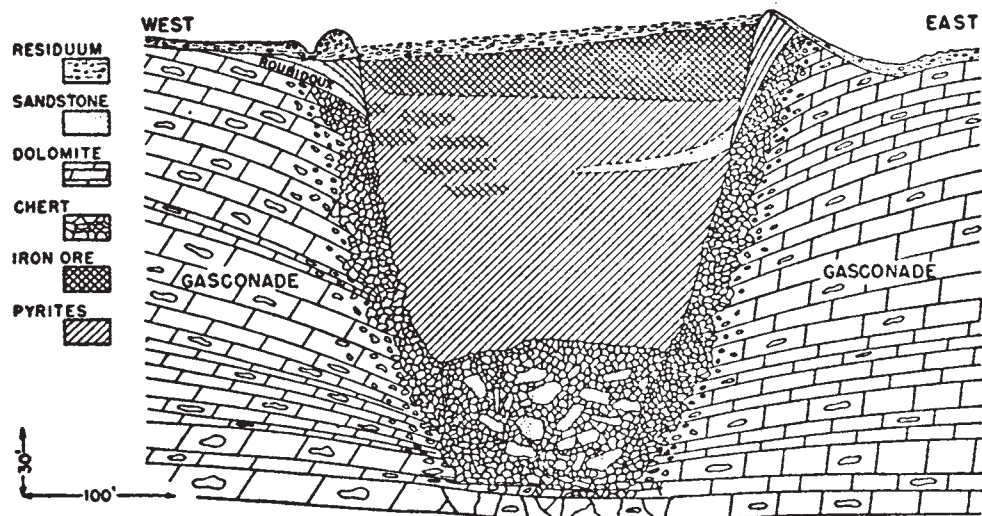


Diagram of Moselle No. 10 Filled Sink Structure
(Bretz, 1950, Fig. 19)

Mining of the deposit revealed that the pyrites had been oxidized to hematite ore near the surface. This changed downward to a zone of partially oxidized ore with a basin-like structure which divided the sulphide mass into two zones. The partially oxidized zone was 35 feet thick with good pyrites below it. Compact granular forms of pyrite were most abundant in the upper part of the pyrites zone and Grawe (1945, p. 75) suggests it might be analagous to the zone of secondary enrichment of other sulphide deposits directly below the oxide zone. He also notes a progressive decrease in crystallinity downward through the deposit "by the inclusion of black, earthy sulphide within masses of more crystalline ore".

MINERALOGY: The mineralogy of the deposit, as compiled from various references, includes the following minerals and their variants:

Pyrite crystals to 1" on a side	Hematite, red, hard, compact	Iron salts Yellow Jasper
Pyrite clusters	Hematite, soft and earthy	Chalcedony
Radial pyrite	Hematite, scaly crystalline	Chert
Granular marcasite, irregular concretions, banana shaped, to 37 cm long	Specularite Blue hematite Goethite	Quartz-(Mainly in geodic cavities) Amethyst Citrine Smoky Clear
Marcasite concretions	Yellow ochre Massive limonite	Chalcanthite
Reniform marcasite		Metallic Copper Halloysite (Metahalloysite)
Radially fibrous marcasite		
Ropy stalactic marcasite coated with fine druses of pyrite		

ORIGIN: Grawe (1945, p. 187) suggests that the original sink structure at the Moselle No. 10 mine was a cavern formed through the solvent action of groundwater, at or near the contact of the Roubidoux-Gasconade Formations, probably in an area of slight initial sag in the sediments. The enlargement of the cavern ultimately caused parts of the roof to sag over the walls of the cavern, or break into fragments and accumulate as rubble on the cavern floor. Cavern formation was followed by cavern filling, probably accompanying the peneplanation of the Ozark region. Source of the iron is thought to have been from the weathering and leaching of Pennsylvanian sediments as they were being eroded away. Other sediments carrying iron could also have supplied some of the iron to the sink. The sulfur source is suggested as somewhat saline groundwater charged with hydrogen sulfide. The sink structure acted as a large leaching basin or funnel, and ferrous bicarbonate in solution reacted with hydrogen sulfide bearing waters to precipitate pyrites.

Bretz (1950, p. 815) is opposed to the cavern-collapse fill origin postulated by Grawe. The abrupt bending of the Roubidoux sandstone from a gentle dip to vertical with little visible fracture does not resemble any cave structure known to him. He suggests replacement of the central part of the sink by sulfides during and after the making of the structure, and cites cogent evidence for replacement: shearing of the sandstone slab in the filled sink, a water table at or above the oxidized zone and too high to form the postulated cavern proposed by Grawe, difficulties in the sequence of cavern events, and the distinct geometric plan of the body. (He also describes nearby Gourd Creek cave in the same rock unit which has little in common to the Moselle body except that both are consequences of phreatic solution in the same formation.)

ORE AND PRODUCTION: Ore grade of the early mined earthy red hematite as given by Chauvenet (1886) was 55.21% iron and 0.074% phosphorous. Specularite ore was also present, possibly of much higher grade. The pyrites beneath the iron oxide were nearly pure and contained 48-51% sulphur with about 45% iron, and minor silica.

Production of iron ore approximated 10,000 tons prior to 1892 (Nason, 1892, p. 321), and Grawe (1945, p. 396) indicates less than 1500 tons since then. Beginning in 1934 and continuing into 1940, total pyrites production was 134,513 tons with a value of \$332,434.

NOTES ON THE ORDOVICIAN STRATIGRAPHIC SECTION IN THE ROLLA AREA

A. C. Spreng

INTRODUCTION

Lower Ordovician (Canadian) rocks comprise a large outcrop area of the Ozark Plateau. The three units which make up the Lower Ordovician in the Ozarks underlie the field trip area: The Gasconade Dolomite (base), the Roubidoux Formation and the Jefferson City Dolomite.

The Gasconade dolomites form the bluffs and ledges in at least the lower parts of the deeper valleys, i.e., Roubidoux Creek, the Gasconade River, the Meramec River. The Roubidoux Formation generally forms the gentler upper slopes of the valleys and in places forms sandstone bluffs. The Jefferson City dolomites cap the hills and usually make gentle slopes with the exception of the Quarry Ledge "Member" which forms a 5 to 8 foot ledge near the base of the formation.

These three units form a pattern of dolomite, dolomite and sandstone, and dolomite which persists into the subsurface on the flanks of the Ozarks; a similar pattern of lithologies crops out again in the Wisconsin-Minnesota area in the same stratigraphic position.

These units were named in this part of Missouri but other, older names had previously been applied to these lithologies as shown in the tabulation below.

Jefferson City (Winslow, 1894)	Second Magnesian limestone
Roubidoux (Nason, 1892)	Second Sandstone
Gasconade (Nason, 1892)	Third Magnesian limestone

As an additional historical note all of these units were once included by Ulrich in his Ozarkian System, with the Jefferson City at the top of the System in unconformable contact with the overlying St. Peter Sandstone. Later he moved the top of the System down to the top of the Gasconade.

GASCONADE DOLOMITE

Lithology: The Gasconade is a dolomite with a considerable amount of chert. The dolomite is usually coarse-grained and light gray or very light gray in color, and is thick and sometimes massive-bedded. Thinner beds are fine-grained and are buff or gray in color. Cherts occur as layers and less often as nodules. Where fresh, the chert is white or banded gray and white. The layered chert shows evidence of being secondary in origin in that layers grade laterally into dolomite. Chert also occurs as replacement of algal structures. These are mound-shaped structures with bands of different colored chert; in places chert alternates with dolomite. Layers of silicified oolites also occur in the Gasconade. In the upper Gasconade, oolites have been formed with nuclei of dolomite. Light colored chert nodules and fragments mark the outcrop of the formation as residuum where the dolomite has been dissolved. Several workers, among them Ulrich (Bain and Ulrich, 1905) and Wallace Lee (1913) have pointed out that the surficial rocks contain more chert than fresh rock and they suggest that the silica originally was dispersed in dolomite and segregated by solution to form nodules and layers.

Fossils: Fossils are few and the variety is likewise limited. Preservation is best in chert, which preserves detail quite well. High-spined and some low-spined gastropods, some cephalopods, and numerous algal structures are found in the formation. In the sections studied for the guidebook, gastropods have been found in unit 7 of the Waynesville I-44 section and in float at the top of the abandoned quarry section at Highway 8-68 at Maramec Spring.

The most abundant fossil remains are the algal structures which are particularly common in the upper half of the formation. They are difficult to recognize when they are not silicified. It is believed they represent non-calcareous, blue-green or green algae. Since thin sections reveal little or none of the internal structures of these algae the term "cryptalgal" was proposed by Aitken (1967) to indicate the uncertain structure of these forms. The generic name of Cryptozoa has been applied to this form but the name is not now considered to represent a definable genus. Algal stromatolites, fixed cryptalgal structures with non-planar laminations, and cryptalgalaminates, a form with planar laminations, (stromatolites of some workers), both occur in the Gasconade Dolomite. A distinctive and persistent, usually silicified, cryptalgal zone occurs 60 to 90 feet below the top of the Gasconade. It is generally three feet thick but varies up to six feet and serves as a useful mapping horizon sometimes called the Richland Chert Zone.

Thickness: The full thickness of the Gasconade is not exposed in the Guidebook area. Well data, available from the Missouri Geological Survey, give a thickness ranging from 260 to 290 feet in the area (well log numbers 9690 and 3074). The base is marked by a sandy dolomite (Gunter Sandstone), sometimes treated as the basal member of the Gasconade Dolomite.

GASCONADE-ROUBIDOUX CONTACT

The Roubidoux represents the only extensive sandstone deposition in the Lower Ordovician of this area. The break between the Roubidoux and the Gasconade, however, is not sharp, although minor disconformity is seen at STOP 1 West. The lower Roubidoux contains dolomites similar to those of the Gasconade and there are thin sandstone layers and sandy dolomites at the top of the Gasconade. The contact is placed at the first pronounced sandstone ledge which occurs above the top of the uppermost dolomite ledge or cliff in the Gasconade. The contact is usually recognized in the field on the basis of this general difference in lithology.

ROUBIDOUX FORMATION

Lithology: The Roubidoux consists of both dolomites and sandstones with a variety of cherts. In the Rolla area there are two massive sandstones near the base. These are generally seen in natural exposures while the associated dolomites are usually leached away. Because of this leaching complete sections are not found and collapse structures are common in outcrops.

Lee (1913) has divided the Roubidoux of the Rolla area into seven members with the two lower, massive sandstone units designated as members 3 and 5. The Waynesville I-44 cut (STOP 7) is interesting because sandstone comprises an inconspicuous part of the section. This section has not yet been correlated with the Rolla section.

The dolomites, at least in the lower part, are similar to Gasconade dolomites. Like the Gasconade dolomites, they also contain abundant chert, especially replacement chert.

Ripple marks, cross-bedding, mud crack filling (sometimes preserved by chert) are fairly common features in the sandstones. Ripple marks and some mud cracks occur in the dolomites.

Fossils: Fossils are rare in the Roubidoux except for cryptalgal structures in the dolomites. These are similar to those in the Gasconade. The molluscan fauna is next in abundance. The large, low-spined gastropod Lecanospira, the commonly found gastropod in the area, occurs above the lower massive sandstone in the Rolla area (Lee's unit 5) but was not seen in the Waynesville section. Heller (1954, p. 22-25) gives a discussion of the fossils in the area.

Thickness: According to Lee, the thickness of the Roubidoux in the Rolla area ranges from 115 to 150 feet. The predominantly dolomitic, Waynesville Roubidoux section is 130 feet thick. This is also approximately the thickness in the logs of the water wells in the Rolla - St. James area.

ROUBIDOUX - JEFFERSON CITY CONTACT

It is difficult to define the Roubidoux - Jefferson City contact because the interval is usually covered and beds in the interval vary from place to place. According to Lee (1913, p. 22) these beds were formed under shallow water conditions where lateral variations would be expected. Lee places the contact at the top of a thin sandstone which is persistent in the area. It lies about 25-30 feet below the Quarry Ledge unit which forms a recognizable and continuous outcrop in the area. He suggested this as the contact because some of the underlying beds have Roubidoux fossils. This sandstone may be seen in the stratigraphic section on the I-44 outer road across from the Holiday Inn on the west side of Rolla (STOP 9 - East). It cannot be pinpointed in the section at Waynesville where several thin sandstones (less than one foot) occur at about this position.

The Missouri Geological Survey has used an oolitic chert with quartz lined pits ("the Burrstone" or Maries County oolitic horizon) as the top of the Roubidoux (Kenneth Anderson, personal communication). They find this chert persistent and useful for subsurface correlation in the central Ozarks. This unit occurs in the St. Roberts - Waynesville section (Unit 34) and also in the Rolla Holiday Inn section (Unit 2) where it occurs about three feet below Lee's sandstone marker.

JEFFERSON CITY AND COTTER FORMATIONS

The Jefferson City and Cotter formations cap the hillside ridges in the eastern part of the field trip area.

Terminology: When the Rolla Quadrangle was mapped by Lee (1913) all of these higher dolomites above the Roubidoux were included in the Jefferson City Formation. Bridge and Charles (1922) found specimens of Hormotoma in the upper part of the Jefferson City of the Rolla Quadrangle which had affinities to forms in the Cotter Dolomite which is widespread in the southern Ozarks. Ulrich's study of some cherts in the Macedonia area, along Missouri Highway 63 north of Rolla, suggested those beds had affinities to the Cotter (Grawe and Cullison, 1931, p. 308). Ulrich found a sandstone associated with these cherts which he took to be the base of the Cotter. Later Cullison (Grawe and Cullison, 1931, p. 307-8) traced the sandstone from Macedonia into the Rolla area. A location where they recognized the Cotter has been restudied and the section is shown graphically in Fig. 1. In 1944, Cullison stated that later work indicated to him that the Cotter is not present here and that the term Cotter should be confined to the southern Ozarks. However, subsurface geologists of the Missouri Geological Survey do recognize the Cotter in this area on the basis of insoluble residues. No solution to this problem is attempted here other than to present the problem and show some of the stratigraphic sections involved.

When Cullison redefined the units in the Rolla area (1944), he also elevated the Jefferson City to Group status and divided it into two formations, the Rich Fountain (at the base), and the Theodosia above. This nomenclature was used in the G.S.A. Ordovician Correlation Chart (1954) but has not been popular in local usage because of difficulty in recognizing the formations in the field. A temporary solution is to use the term "Jefferson City (unrestricted)" as a matter of expediency for the beds which cannot be subdivided into Cullison's or Grawe and Cullison's units.

Lithology: The Jefferson City lithology as well as that of the so-called Cotter is predominantly dolomite. According to Cullison (1941, p. 11) some of the dolomites are very siliceous. Cherts are less common than in the underlying Roubidoux and Gasconade. Lenses of sandstone and shale are common and some of the sandstones, although only a foot or more thick, are persistent.

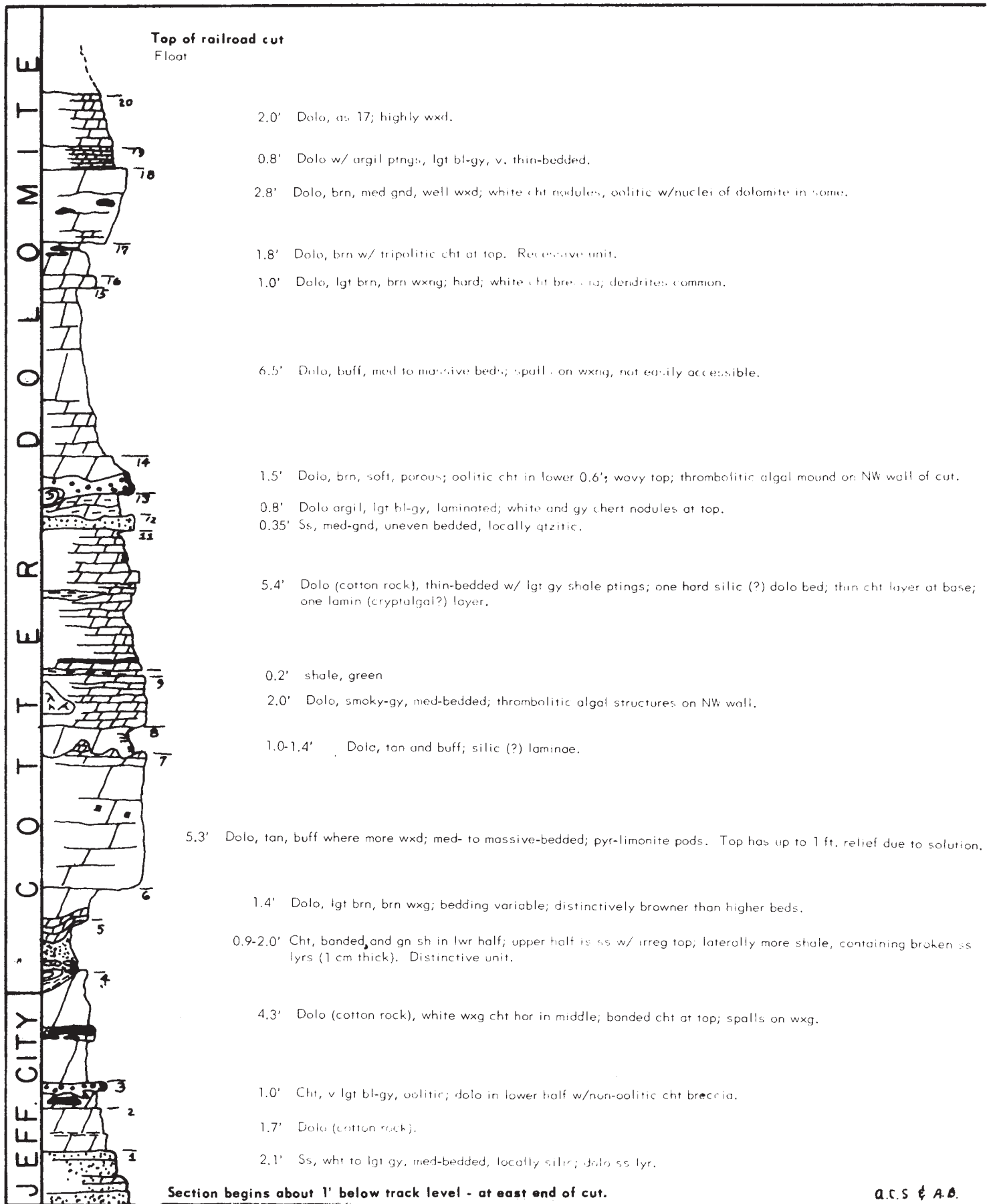


Fig. 1 Frisco railroad cut at west edge of Rolla (NW 1/4, NW 1/4, SW 1/4, Sec. 11, T. 37 N., R. 8 W.). The section was measured on the southeast wall of the cut. Grawe and Cullison's (1931) names are used for the units.

A conspicuous dolomite unit in the Jefferson City is the Quarry Ledge member (School Mine Ledge of Cullison, 1944). It may be seen at Stops 2, 7, and 10 West, at the east edge of the Holiday Inn and along the outer road across from the Holiday Inn (see STOP 9 East section). This unit occurs about 25 feet above the poorly defined and usually covered base of the Jefferson City and hence is a useful mapping horizon in the area.

Most of the overlying dolomites are fine-grained, buff to gray in color, may be slightly argillaceous or silty, and may have green shale partings. These dolomites are often referred to as "cotton rock."

Sandstones occur at numerous horizons within the section. Grawe and Cullison (1931), in endeavoring to establish the base of the Cotter in this area, made mechanical analyses of these sands with the intention of identifying differences in those of the Jefferson City (restricted) and the basal Cotter sandstone. They found there were some major differences in the characteristics of the two as listed below:

<u>Jefferson City (restricted)</u>	<u>Basal Cotter</u>
1. Modal Class is 1/2-1/4 mm class There may be a secondary 1/4-1/8 mm class also.	1. Modal class is 1/4-1/8 mm class
2. It has a pronounced fine admixture.	2. Better sorted than Jefferson City sandstones. (Has a more pronounced peak on the histogram.)
	3. Has more sand in the coars admixture than fine admixture.

The sandstones in the new cuts in the Rolla area were analyzed and histograms plotted in order to help correlate these sections. Tentative correlation could be made between the section studied by Grawe and Cullinson (Frisco railroad cut, Fig. 1) and the section on the ramp road behind Howard Johnson's Inn (STOP 9). The Jefferson City (restricted) - Cotter boundary is drawn in the Howard Johnson section on the basis of the character of the sand. The correlation between the two sections is otherwise not particularly convincing. The sands in the section east of the U.M.R. General Services Building on I-44 (Fig. 2) and in the section at the Vichy overpass (Fig. 3) more closely fit "Cotter" properties described by Grawe and Cullison than they do those of the Jefferson City (as restricted by them).

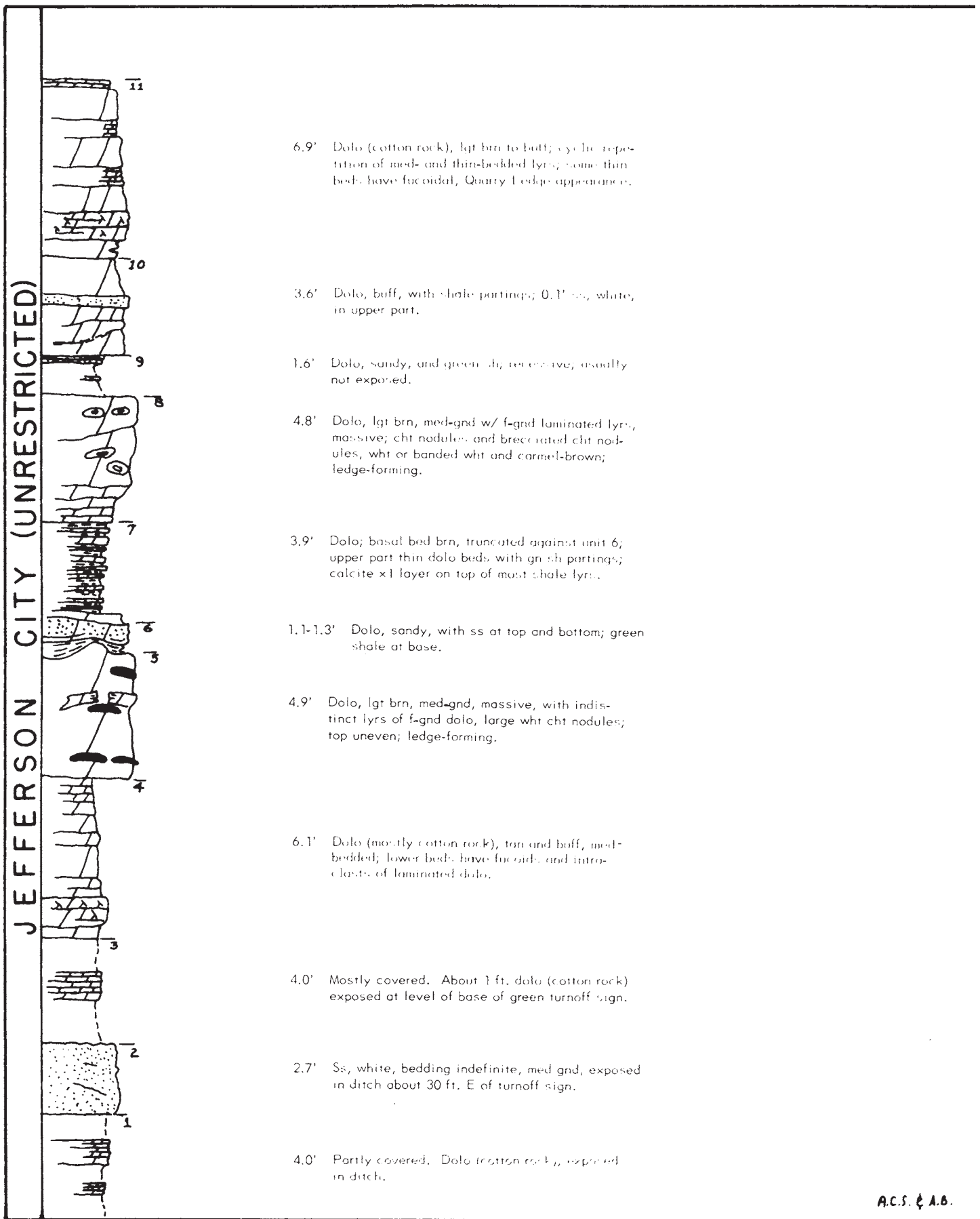


Fig. 2 I-44 roadcut, north side of the interstate, east of UMR General Services Bldg. and south of cable TV tower (NE 1/4, NE 1/4, SW 1/4, Sec. 2, T. 37 N., R. 8 W.). Histogram of the sands in units 2 and 6 suggest similarity to Grawe and Cullison's basal "Cotter".

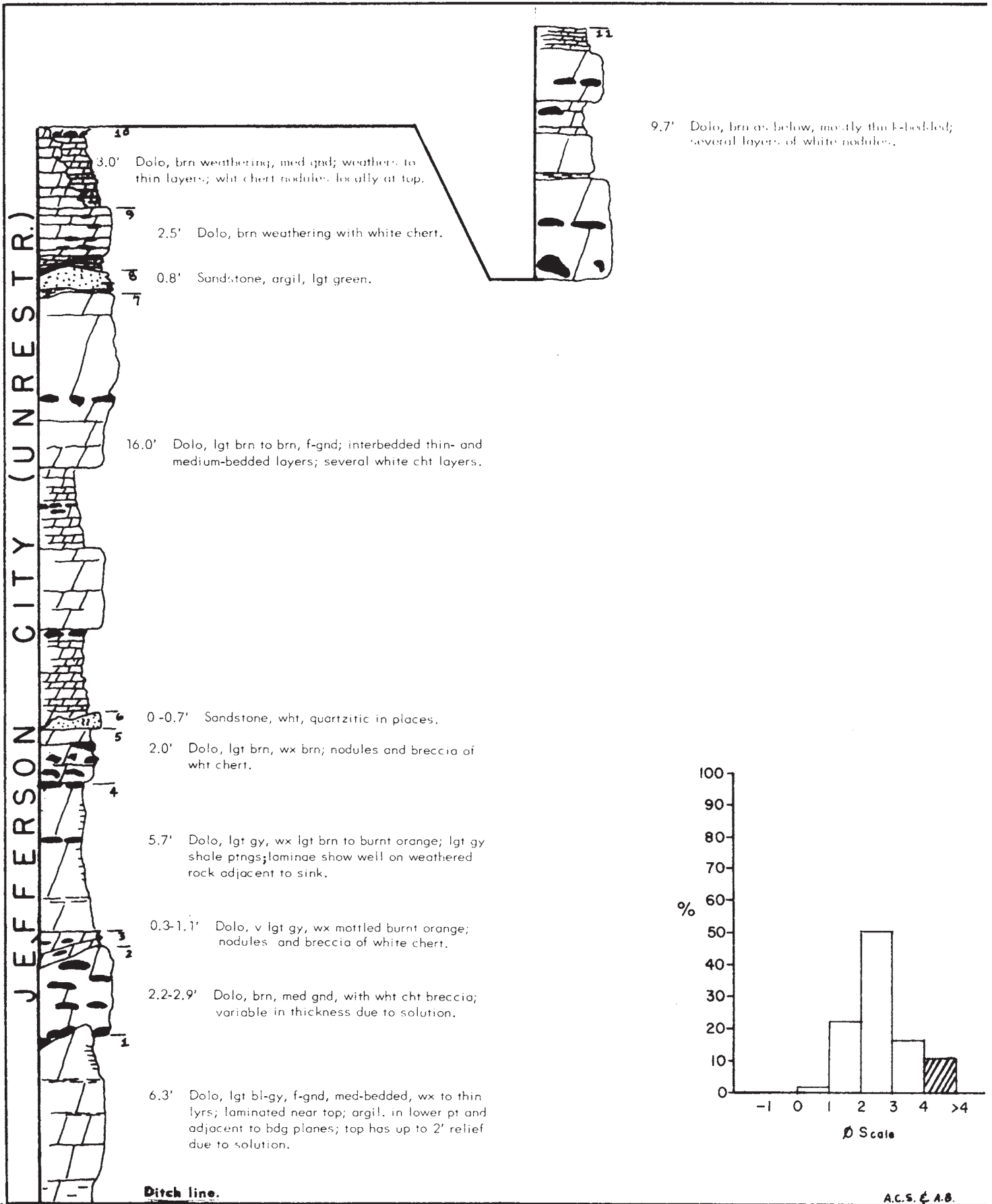


Fig. 3 I-44 roadcut at Vichy overpass (STOP 8 East). Section measured on the south side of the interstate adjacent to the sink fill. The histogram shows the sand of unit 6 to have a "Cotter" pattern.

Fossils: Fossils are scarce in the Jefferson City. Diligent examination of weathered cherts is necessary to find specimens. Cullison considers trilobites to be the most characteristic fauna of the lower Jefferson City (Rich Fountain). They, as well as high-spined gastropods (Hormotoma) may be found just above the Quarry Ledge member. The Quarry Ledge contains well developed sponge cylinders (such as Ozarkocoelia and Archeoscyphia). Specimens do not appear common, however, in the section around Rolla.

SUBTERRANEAN DRAINAGE OF THE GASCONADE RIVER BETWEEN
HAZELGREEN AND WAYNESVILLE, MISSOURI

Harry C. Bolon (Deceased) District Engineer, Surface Water
Branch, U.S. Geological Survey*

In the fall of 1953 the time was appropriated to determine several facts concerning the flow of the Gasconade River and tributaries, one of which was to have on record the flow at various points during a serious drought. The flow was very steady over the entire basin and near a record low, as may be seen by the following table:

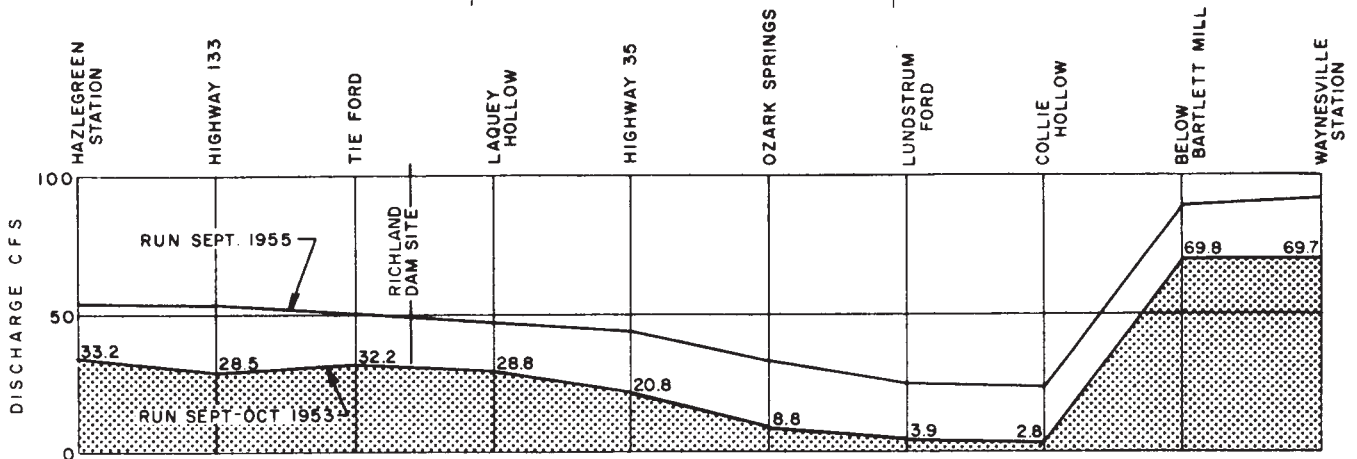
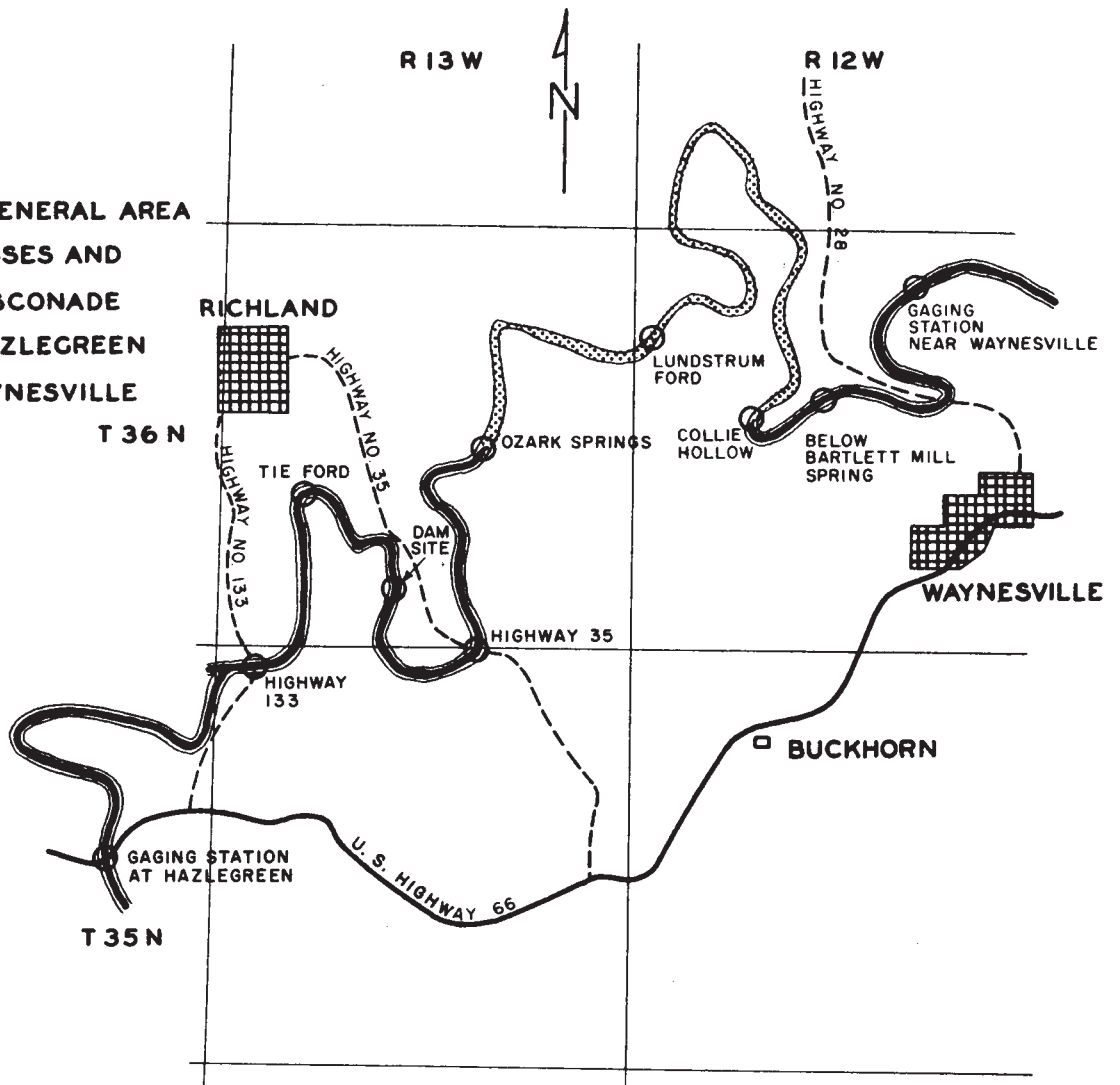
<u>Stream</u>	<u>Period of Record</u>	<u>Minimum on Record Date Flow (cfs)</u>	<u>Sept. 16, 1953 Flow (cfs)</u>
Gasconade - Hazelgreen	1929 to date	Aug. 1936 18	35
do - Waynesville	1921 to date	Aug. 1936 50	70
do - Jerome	1923 to date	Sept. 1936 294	370
do - Rich Fountain	1921 to date	Aug. 1934 276	390
Big Piney - Big Piney	1921 to date	Aug. 1934 75	110
Little Piney - Newburg	1928 to date	Aug. 1936 24	45
James River - Galena	1921 to date	Aug. 1936 22	50

Two parties were organized and on September 17 and 18 about 50 measurements were made. The results caused us to make 13 additional measurements below Hazelgreen on the main stem and tributaries.

It was startling to find that the Gasconade River is, to use an Ozark colloquialism, a "sinking river". Between Tie Ford (see map) near Richland and Lundstrum Bridge southeast of Swedeborg the flow diminished from 32.2 to 3.9 cfs with most of the loss occurring between Mokane Bridge and Ozark Spring. Other measurements showed that within the 3/4-mile reach just below the mouth of Collie Hollow to just below Bartlett Spring at Pippin's Lodge the flow increased from 4.3 to 69.8 cfs. Most of this increase could be seen boiling up through the gravel in and adjacent to the channel. Other flow issued from Creasy, Falling, Bartlett Mill, and other deep-rooted springs, so called deep-rooted because of their temperature of 56 to 57 degrees.

* Reprinted from "Guidebook to the geology of the Rolla area emphasizing solution phenomena" (1960). By permission of Anthony Homyk, District Chief, Water Resources Division, Missouri District, U.S. Geological Survey and Wallace B. Howe, State Geologist and Director, Missouri Geological Survey and Water Resources.

SKETCH SHOWING GENERAL AREA
SURFACE WATER LOSSES AND
RETURN ALONG GASCONADE
RIVER BETWEEN HAZLEGREEN
AND GAGE NEAR WAYNESVILLE



GRAPHICAL PRESENTATION OF LOW WATER FLOW OF THE
GASCONADE RIVER — HAZLEGREEN TO WAYNESVILLE, MO.

The temperatures of the gravel boils were about 5 degrees warmer, which implies that the water had not traveled far enough underground to assume deep-ground temperatures. Water cress, which usually identifies what is normally thought of as a true spring, is absent at these boils.

At Ozark Spring an appreciable flow from the Gasconade can be seen entering a sinkhole at the west side of the river immediately north of the approach to the bridge.

Additional series of measurements were made through this reach which implies that the underground channel, or channels, carry a relatively constant flow (from 18 to 30 cfs) regardless of stage of the main river.

It so happens that our gaging stations at Hazelgreen and below Waynesville straddle this reach and, therefore, are not affected by these underground channels. However, what happens in this reach of the Gasconade River causes us to believe similar conditions might well exist anywhere in the carbonate area of the Ozarks, and in fact does occur on Osage Fork of the Gasconade River above Big Spring near Morgan. There, too, the Osage Fork flows, then goes dry, for a stretch just above Big Spring, some distance above Missouri Highway 5.

(The area which Mr. Bolon describes is some 15 miles from Waynesville upstream as the crow flies, but much greater than that distance in terms of river miles because of the meandering course of the Gasconade. The Gasconade River has been cited often as an exemplary stream for entrenched meanders in the Ozarks. Five miles northwest of Waynesville, a loop of the Gasconade is five miles long and the cutoff distance would be only two tenths of a mile (Richland 15' quadrangle). This stream is also a favorite for "float" trips -- a method of fishing especially popular in the Ozarks. Floats are generally made in flat-bottomed boats capable of navigating the swift, shallow, and sometimes treacherous shoals. Outboard motors for speeding the trips through eddies are optional. The "average" (a some-

what meaningless term in this case) length of a day's float is ten to fifteen miles. A float may last several days with night camps on gravel bars. The experienced floater is prepared for both casting and fly fishing and often carries a gun for shooting frogs in season.)

NOTES ON

VICHY ROAD - HIGHWAY I-44 FILLED SINKS (STOP 8)

Two well exposed cross sections of filled sinks are located directly east of the Vichy Road overpass on Highway I-44 on the northwest side of Rolla, Missouri, in sec. 34, T. 38 N., R. 8 W. Each of the structures demonstrates rather unique sedimentation and structural features. Because of the highway location, a complete geologic map of the structures is not possible. The description which follows relates mainly to the northern exposure for which a geologic map has been prepared. Brief comments and a geologic cross section are also presented for the southern filled sink deposit.

VICHY ROAD (NORTH) - HIGHWAY I-44 FILLED SINK

Paul Dean Proctor and R. J. Lance

The northern body occurs on the north side of Highway I-44 just east of the Vichy Road overpass in the NE 1/4, SW 1/4, NE 1/4, Sec. 2, T. 37 N., R. 8 W., Phelps County, Missouri. Here an excellent stratigraphic section of both the Jefferson City Dolomite host rock and the filled sink shales and sandstones is exposed. (See section, Fig. 3, p. 75).

Thin greenish shales and a chert breccia approximating 5 feet thick lie near the contact and overlap on to the older, gently in-dipping, Jefferson City, tannish-brown dolomites. About five feet of interlayered maroon shales, gray sandy shales, and sandstones occur above these basal sediments. These are overlain by three feet of much sheared pinkish and gray sandstone and minor maroon shale. At least four feet of maroon shales and an interlayered, pinkish, fine-grained sandstone lie above these beds. A repetitive section of sheared tannish and purplish shales and thin white sandstones up to 13 feet thick lies above. The gray shales are plastically deformed and locally thickened. A distinctive, brown, quartz-sandstone, as much as 12 feet thick with distinctive cross-layering

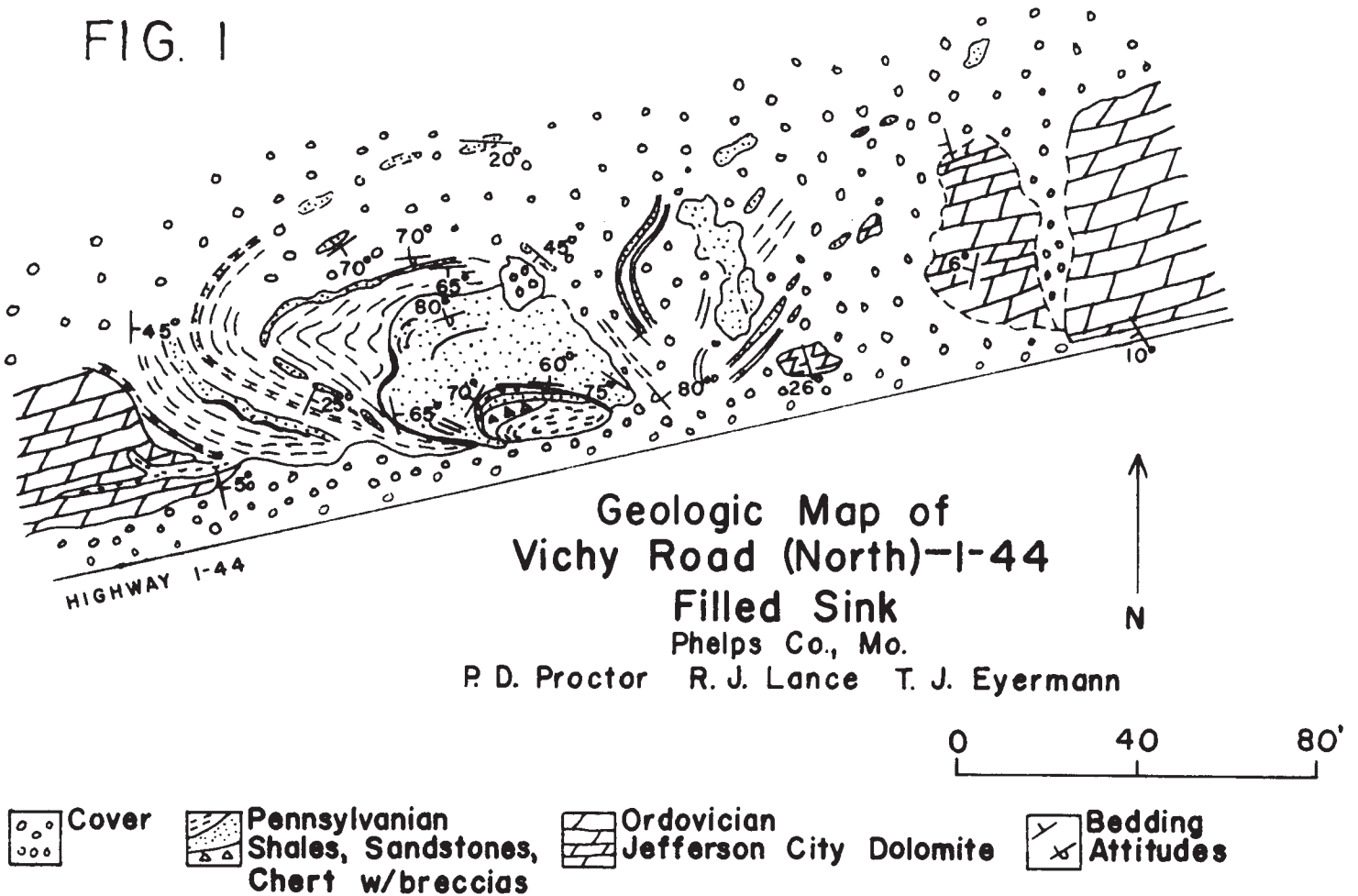
near the top lies above the shale-sandstone sequence. Youngest beds within the structure appear to be a two foot thick brown sandstone, about two feet of brownish to purplish shale and tannish-gray sandstone to two feet thick, overlain by a distinctive white sandstone breccia of variable thickness, but generally less than 5 feet, and a dark purplish shale about 8 feet thick. The highway covers part of this bed and any younger ones to the south.

Internal Structure of the Deposit: The geologic map (Figure 1, p. 83) shows an elliptical-shaped filled sink approximately two hundred feet long and at least 80 feet wide. The southern portion of the structure is covered by the highway. Beds on the west side dip from 25-45 degrees eastward toward the center of the structure. At the top of the highway cut the north strike and east dips change abruptly to easterly strikes and steeply south to overturned north dips. About 35 degrees north of the cut in the central part of the section, the dip of the beds changes to about 20 degrees south.

The eastern part of the structure is quite complex with the Jefferson City Dolomite dipping westward into the structure from about 6 degrees to 26 degrees. The younger filled sink shales and thin, interlayered sandstones dip from moderately west to steeply overturned to the east. Two large masses of sandstone, probably exotic blocks, without visible internal structure, lie along the east flank of the sink.

The center of the structure is a tight to overturned syncline. Cross-layering of the ledge sandstones directly above and north show excellent top-bottom relationships. The center or trough area of the structure has a distinctive white sandstone breccia with blocks up to one foot in diameter overlain by a squeezed and sheared purple shale.

FIG. 1



Both the shales and sandstones show thinning along the flanks of the fold. The central ledge sandstone apparently thins very rapidly toward the south limb, yet retains, without visible distortion, the noted cross-bedding. Minor faults are visible, others may be present and account for the thinning of some of the units. Along the west side of the structure, gray shales appear to have been deposited in a solution channel in the older dolomites.

Origin: The structure has features similar to the PD-Highway I-44 filled sink, several miles to the east, but the fold structures are much more complex and intense. Apparently the beds were competent enough to fracture and shear and able to retain primary structures such as cross-bedding during the deformation. This suggests the sedimentary sequence was already lithified when the material began to sink downward into a

solution depression in the Jefferson City dolomite. The overturning, shearing, and abrupt bends in the bedding suggest the material had considerable load above it and probably subsided contemporaneously with the solution removal of the underlying carbonate rock.

VICHY ROAD (SOUTH) - HIGHWAY I-44 FILLED SINK

Paul Dean Proctor, A.C. Spreng, T. Eyermann

The Vichy Road (south) filled sink on Highway I-44 lies directly across the highway from the intensely folded Vichy Road (north) filled sink deposit in the NE 1/4, SW 1/4, NE 1/4, Sec. 2, T. 37 N., R. 8 W. The close spatial relationship suggests continuity between them, but both the stratigraphy and structure are distinctly different and suggest different geologic development. Host rock for both structures is Jefferson City dolomite. (See stratigraphic section, Fig. 3, p. 75.)

Stratigraphy: At least thirty feet of alternating gray sandstones and shales are exposed in the road cut. Individual beds are as much as six inches thick, but the majority are less. There is a tendency for the uppermost beds to be slightly thicker and more sandy than in the middle and lower sections. Some minor maroon to purple shales up to one foot thick occur along the west side of the structure. While not measured, more massive sandstones crop out above the alternating thin sandstones and shales. These form a platform above the main highway cut.

Primary structures in the sediments include cross-bedding, local unconformities, "squeeze-ups" of sand across the thin shales and some small fluting structures on the bottom of some of the sandstone beds.

Two exotic blocks, one now dislodged, occur near the east side of the structure within the shale-sandstone sequence. The one in place is about five feet in length, three feet thick and an unknown third dimension and the shape is roughly hemispherical upward. The shales and sandstones appear to wrap around this rock body. The block consists mainly of tan-weathering dolomite and minor quartz grains very much resembling dolomite of the Jefferson City.

The dolomite body displays a unique and distinct, concentric, internal layering around the sides and over the top, as much as 6 inches thick. This is not visible on the lower boundary nor in the center of the body. These concentric layers weather free as layers in an onion.

A distinctive and conspicuous parting plane cuts across the center of the main block and parallels its base.

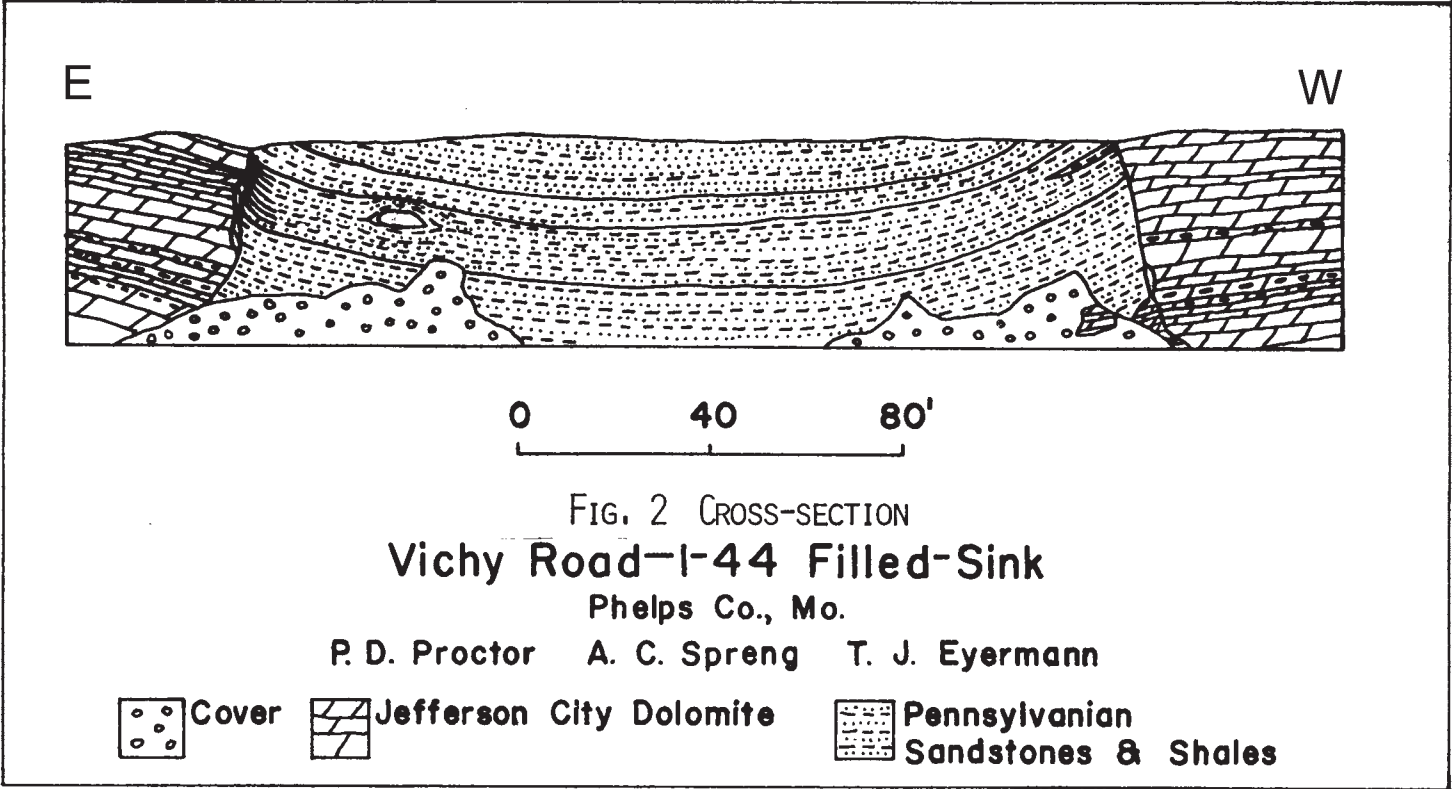


Dolomite block in sediments
in Vichy Road (south) - Highway
I-44 sink structure, Rolla, Missouri

The internal structure and that of the beds surrounding it suggest a forceful emplacement of a concretion. The composition and appearance of the block suggest Jefferson City dolomite. Emplacement of a loose or dropped block of the latter without disturbance of the thin beds below and to the side argues against this origin. While the body could be a projection of dolomite from the wall rock, the internal concentric structure is not a feature known to the Jefferson City dolomite.

Internal Structure of Sink Fill: The filled sink structure is a broad open syncline with beds dipping gently toward the center as shown in Fig. 2, p87. Near the eastern boundary the beds are dragged upward to an almost vertical attitude, and are cut by a steeply dipping fault. The

inner block moved downward. The western margin shows some steepening of the beds and local adjustments which have partly obliterated the bedding. The geologic section below illustrates the overall structure.



NOTES

MODEL SIMULATIONS OF FILLED SINK AND CIRCLE DEPOSIT STRUCTURES

Paul Dean Proctor and Terry Harris

INTRODUCTION

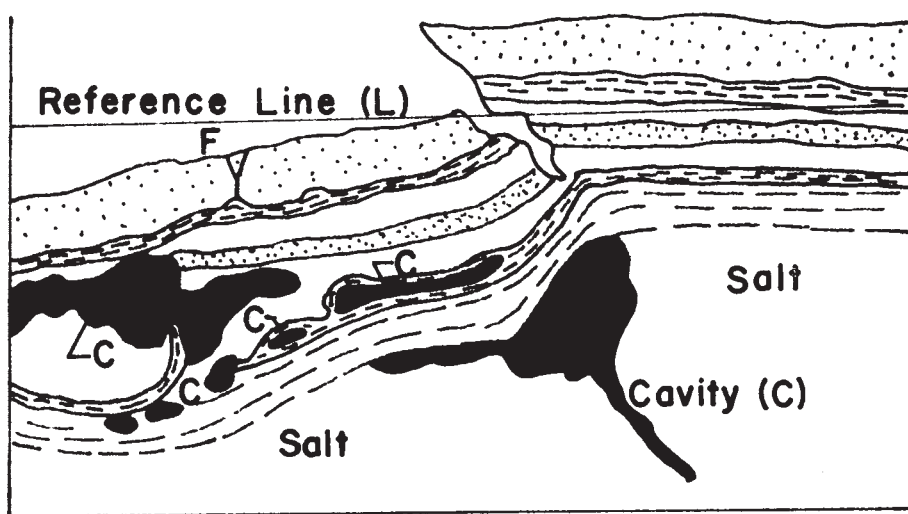
Laboratory model simulations of sink hole development were carried on about the same time as the field investigations of the filled sink structures and circle deposits in the Rolla, Missouri area. The purpose of the laboratory experiments was to study the surface and subsurface structures which might develop under conditions of extensive solution activity of a soluble bed below:

- (1) a relatively thin cover of insoluble sediments having both competent and incompetent characteristics;
- (2) relatively thin layers of competent and incompetent units with contemporaneous sedimentation in the sinking trough area.

A model box was constructed to effect these conditions. The results of both experiments are combined in this report.

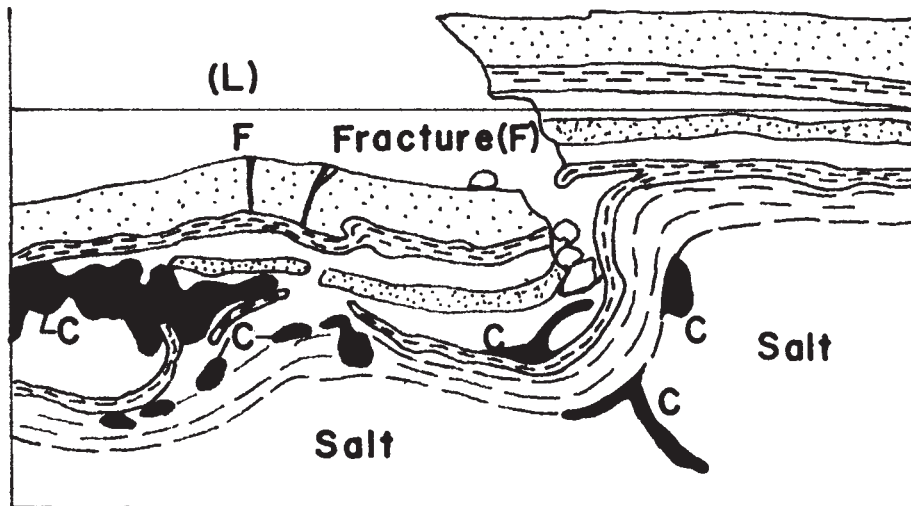
Model Box and Materials: A model box was constructed having two double strength glass sides 18 inches high for subsurface viewing and two marine plywood sides of the same size all set in a base 22 inches square of similar wood. The box was open at the top. Five holes were drilled into the base for inlet and outlet of water to permit solution activity. These openings were arranged so they could be opened or closed, or used interchangeably, thus permitting localized control of the water flow.

Only rough scaling of model materials was attempted with respect to strength, bedding characteristics, permeability, porosity and solubility characteristics. Some insoluble stones were placed on the base in the back of the model behind the wooden sides to assist in

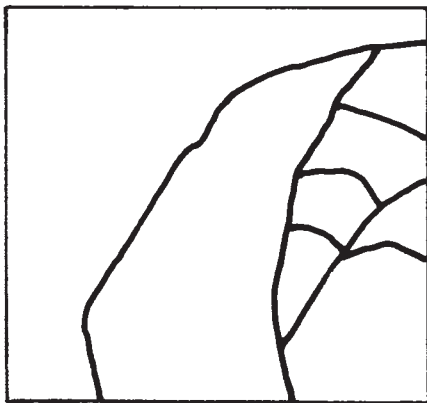


A. Early stage collapse structures from solution of salt below.

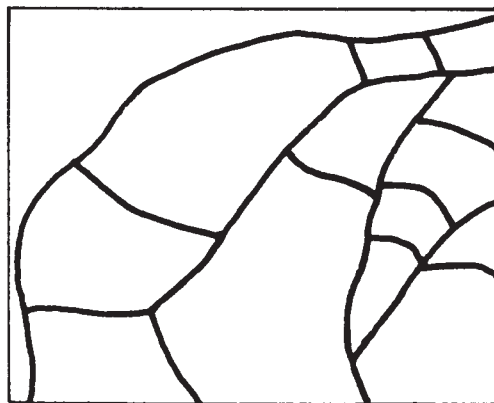
0 SCALE 3.75"



B. Late stage collapse structures from solution of salt below.



C. Early stage surface fractures.



D. Late stage surface fractures.

Figure 1. Model Simulation of Solution Collapse Structures. A and B - Cross Sections; C and D - Plan View.

localizing solution activity in the area of the glass sides.

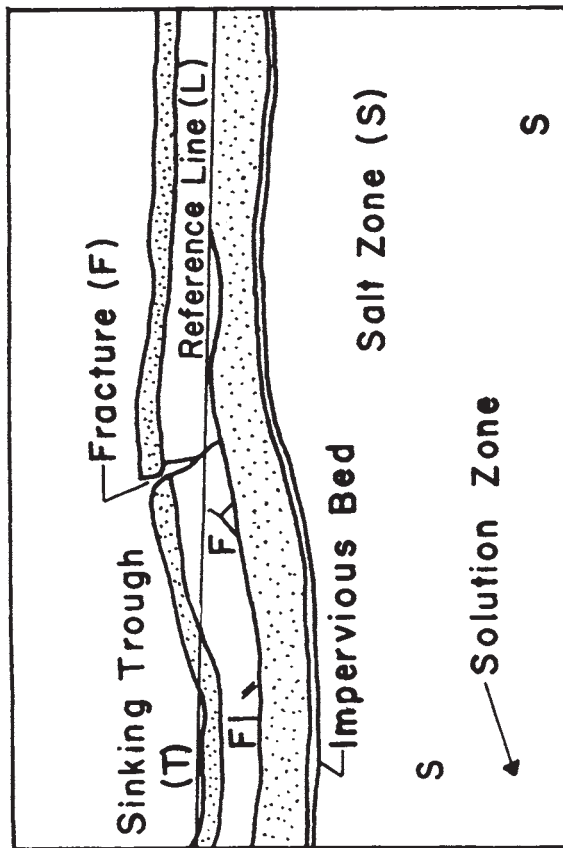
Rock salt was used to represent underlying soluble limestone and/or dolomite and was 5 3/4 inches in thickness. A thin layer of modeling clay was placed directly on the rock salt to prevent sediments from sifting into the underlying salt. White flour and Roubidoux sandstone grains comprised the other sediments. The sand, when wet, was cohesive and had sufficient strength to fold and fracture broadly. The flour was more plastic and reacted somewhat like an incompetent shale or clay bed. Individual layers in the model ranged from 1/4" to 1 1/4" thick.

Black and white and color still photographs and color motion pictures were taken in order to record carefully details of the experiment on a time base. Measurements of the amount of individual layer movement were directly recorded against base lines placed on the glass sides of the model box.

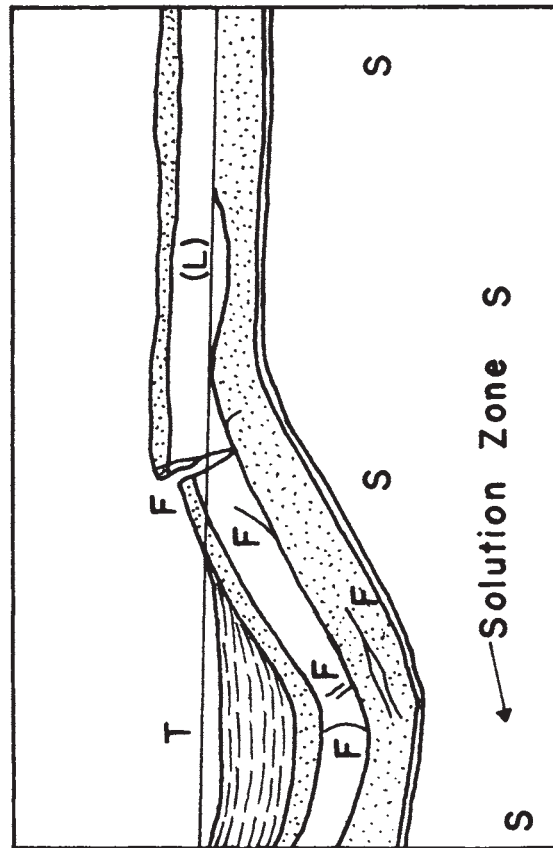
Water was introduced into the base of the salt through two of the openings on one side. Three other openings on the opposite side were used as outlets for the water.

Results: 1. In the first experiment, after three minutes of water circulation, a sinuous cave appeared in the salt. This was followed by gradual collapse of the cave and subsequent downward bending of the overlying sediments into a synclinal form with minor fracturing.

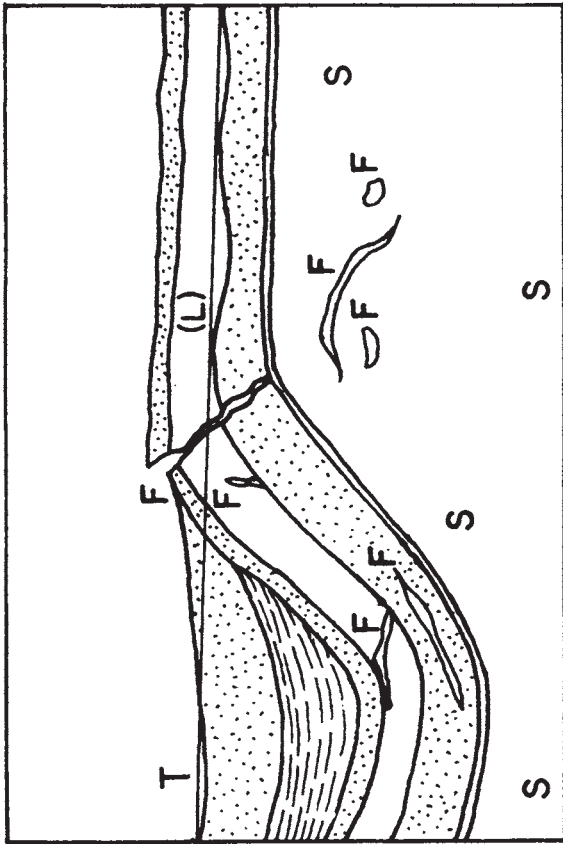
Solution activity continued in the underlying salt. Relatively large cavities appeared in the salt and also within the sediments as partial settlement took place (Figure 1-A). Continued downwarping, enlargement of the open cavities and extension of the fractures occurred as additional salt was removed from below. The main fracture dipped away from the subsiding block. With subsidence of the block into the open cavities in the salt, some minor folding and faulting occurred in the block. On the margin of the dndropped block the beds assumed a near vertical attitude (Fig. 1-B). Breccia blocks from behind the section were caught in the open fracture and on the surface.



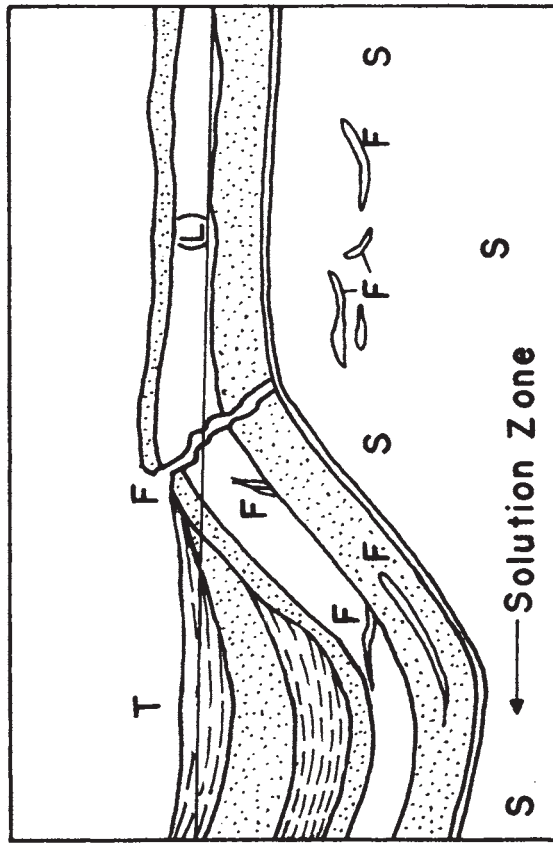
A. Early stage - sinking trough and fracture development from solution of salt below.



B. Trough deepening, sedimentation and fracture development with solution of salt below.



C. Continued sedimentation, trough deepening, fracture extensions, and solution of salt below.



D. Experiment end. Note widening of major fracture by downward movement of trough and infolding of younger sediments.

Figure 2. Model Simulation of Filled Sink Structure

The plan views (Fig. 1, C and D) show a well developed peripheral fault pattern and interconnecting radial pattern. These apparently reflect the adjustments of the individual block over the solution cavities below. The entire experiment ran approximately four hours and a half. Water flow was restricted to two hours and 48 minutes.

2. In the second experiment, salt solution occurred below thin competent and incompetent layers with contemporaneous deposition effected in the downwarped trough area of the model. The time of the experiment was approximately three hours. Figure 2 (A-D), sketched from black and white photographs of the experiment, summarizes the main structural events as the solution activity and contemporaneous sedimentation was effected. Fewer and smaller visible cavities developed in the salt. The fractures in the sediments, in general, duplicated those of the first experiment. However, fractures with an inclination of about 45 degrees to the beds developed in the sinking trough block in the second layer down (Fig. 2-A). Others also developed parallel to the attitude of the lowermost bed (Fig. 2-B). The major fracture had the characteristics of a tension opening; the others had the appearance of shear fractures.

With additional solution activity the original sediments were much downwarped and folding of the younger filled sediments occurred in the trough. The main tension fracture was extended into the underlying bed and separation of the beds occurred across this main fracture. The folded section apparently moved slowly into the trough closing up the center trough fracture and extending and opening others (Fig. 2-C).

By the time the experiment ended (Fig. 2-D), the original beds had acquired dips as much as 45 degrees. Sediments which had been deposited in the lower part of the subsiding trough contemporaneously with the downwarping acquired attitudes of as high as 25 degrees. The inclination of these beds gradually decreased upward in the younger sediments. Finally the downfolded and faulted block was separated from the less disturbed one.

Conclusions: While the models are but rough simulations of possible conditions in a developing karst area certain conclusions seem warranted.

(1) The main fracture in both models occurred at the hinge position of the downwarped structure. This fracture dips away from the trough and not toward the zone of subsidence.

(2) The fractures formed are of tensional origin and agree with strain ellipsoid analysis of the model.

(3) The less competent beds within the model fold downward almost contemporaneously with solution activity in the soluble sediment below.

(4) In the absence of contemporaneous sedimentation, more competent units act as struts and may support the blocks above open cavities. These may later fracture and form local breccia which drops into open spaces. Some beds may broadly downfold in the area of the solution cavity development.

(5) Rate of solution activity is important in determining the behavior of sediments above developing solution cavities. Rapid solution rate may cause abundant fractures and related blocks to form. The latter may tilt and slide into open spaces formed. Circle-type deposits may result from such a process as this. Slow solution rate may result in broad folds developing with related tensional fractures forming in the hinge areas.

(6) In the plan view, peripheral fault patterns develop around a localized solution zone. These are penecontemporaneously interconnected by a series of roughly radial fractures as the individual blocks adjust themselves over the solution cavity below.

(7) With contemporaneous sedimentation in the trough and downwarping from solution activity, fewer fractures develop and the fold assumes a more symmetrical form.

(8) Fractures in the filled sink simulation occur along the hinge line and in the trough at almost right angles to the downwarped beds. Less

conspicuous fractures form in the limbs at about 45 degrees to the bedding. A third set parallels the bedding planes. These increase in length as the experiment continues, while the vertical trough fractures disappear. The large tension fracture in the hinge zone extends into underlying beds and is further opened.

(9) The sediment load in the downsinking trough inhibits the development of large-scale solution cavities in the salt. Visible openings in the salt are small and linear in contrast to large goblet-like openings in the salt where load was present.

(10) The final result in the filled sink simulation is a downwarped trough, symmetrical in form, having shear zones, with the trough bounded by an open tension fracture. Sediments deposited in the downward sinking trough are broadly folded and show a distinct overlap onto the older, more folded, sediments. The angle of dip of the limbs of the older units is 20 to 45 degrees more than the inclination of the younger sediments.

THE SANDSTONE RIMROCK OF THE FILLED SINK STRUCTURES
OF THE ROLLA-ST. JAMES AREA

Upendra Parikh

Ozark-Mahoning Co., Rosiclare, Illinois

The occurrence of filled sinks in this northern Ozark Plateau area has been known for a long time. A sandstone bed, commonly called the rimrock sandstone, usually occurs at the outer margin of these filled sinks forming a rim around them (such as at Stop 6, East). This rimrock varies from 2 to 10 feet and is usually underlain by chert breccia containing various types of chert fragments, probably derived from the underlying Ordovician rocks. The sandstone is white, light yellow, light brown, or red and violet in color. The shades of colors are due to the presence of ferrous and/or ferric compounds in the matrix of the sandstone. It is fine-grained, massive, friable, and slickensided at the base. The sand grains are rounded to well-rounded, frosted and composed of quartz. Secondary enlargement of these grains makes them angular. At limited exposures in the area of Roubidoux outcrops it is not always easy to distinguish rimrock sandstone from Roubidoux sandstone.

The rimrock and associated "fill" rocks of the filled sink structures in this area are generally considered to be basal Pennsylvanian in age, although in one sinkhole, in the southern part of section 34, T. 40 N., R. 7 W., beside a county road connecting state highway 28 and Maries Co. H, north of St. James, Mississippian marine fossils occur in the rimrock chert breccia. These may represent Mississippian rocks reworked in Pennsylvanian time. Devonian marine fossils have also been reported from sands in other sand fills north of this area. Some filled sinks outside this area contain coal beds.

About 170 rimrock sandstones were sampled at localities between Highway 66 and Missouri Highway 28 about 20 miles to the north. Mechanical analyses were made of 115 samples; heavy mineral analyses were made of 10 of these and thin sections of 6 samples. The data which follow are based on these samples.

Mineralogically, the rimrock sandstone is very simple and is petrologically mature, containing the stable mineral quartz with an exceedingly small amount of heavy minerals which are, in order of abundance: tourmaline, zircon and a few grains of anatase and rutile (?). Opaque minerals such as hematite and limonite are found as cementing materials in some of the samples studied. Authigenic pyrite is also present which has been, at some places, replaced by hematite forming pseudomorphs.

Thin sections of the sandstone are colorless and transparent and are composed of more than 98% quartz. The grains are fine-grained, rounded to well rounded, but angular if secondarily enlarged. Interpenetration of grains is not commonly observed in these thin sections. In those sandstones which have very little clay matrix, cementation seems to have been brought about through silicification by silica-rich solutions. No cementation or enlargement of grains is observed on grains in argillaceous sandstone due undoubtedly to the lack of pore space and low permeability in such a sediment, a situation noted by Sevier (1959, p. 55) in his study of cementation of sandstones in Missouri and adjacent states.

The average grain size (arithmetic mean) for the samples of the rimrock in this area varies from 1.5ϕ (0.36 mm) to 3.1ϕ (0.12 mm) which is a medium to fine sand. The median value of the average grain sizes from all the localities (determined by plotting a cumulative curve of the average sizes and taking the 50 percentile value) is 2.15ϕ (0.225mm) which is in the fine sand range very close to the boundary between medium and fine sand (2ϕ or 1/4 mm).

According to Folk's (1965, p. 46) classification scale for sorting, the rimrock sandstone should be classified as moderately well-sorted.

The possible source rock or rocks and the direction of transportation are two of the most interesting questions concerning the rimrock sandstone.

The sandstones which would reasonably have been available as source rocks for the rimrock would be the Roubidoux and St. Peter sandstones based on knowledge of the geologic history of the area and mineralogic maturity of the sandstones.

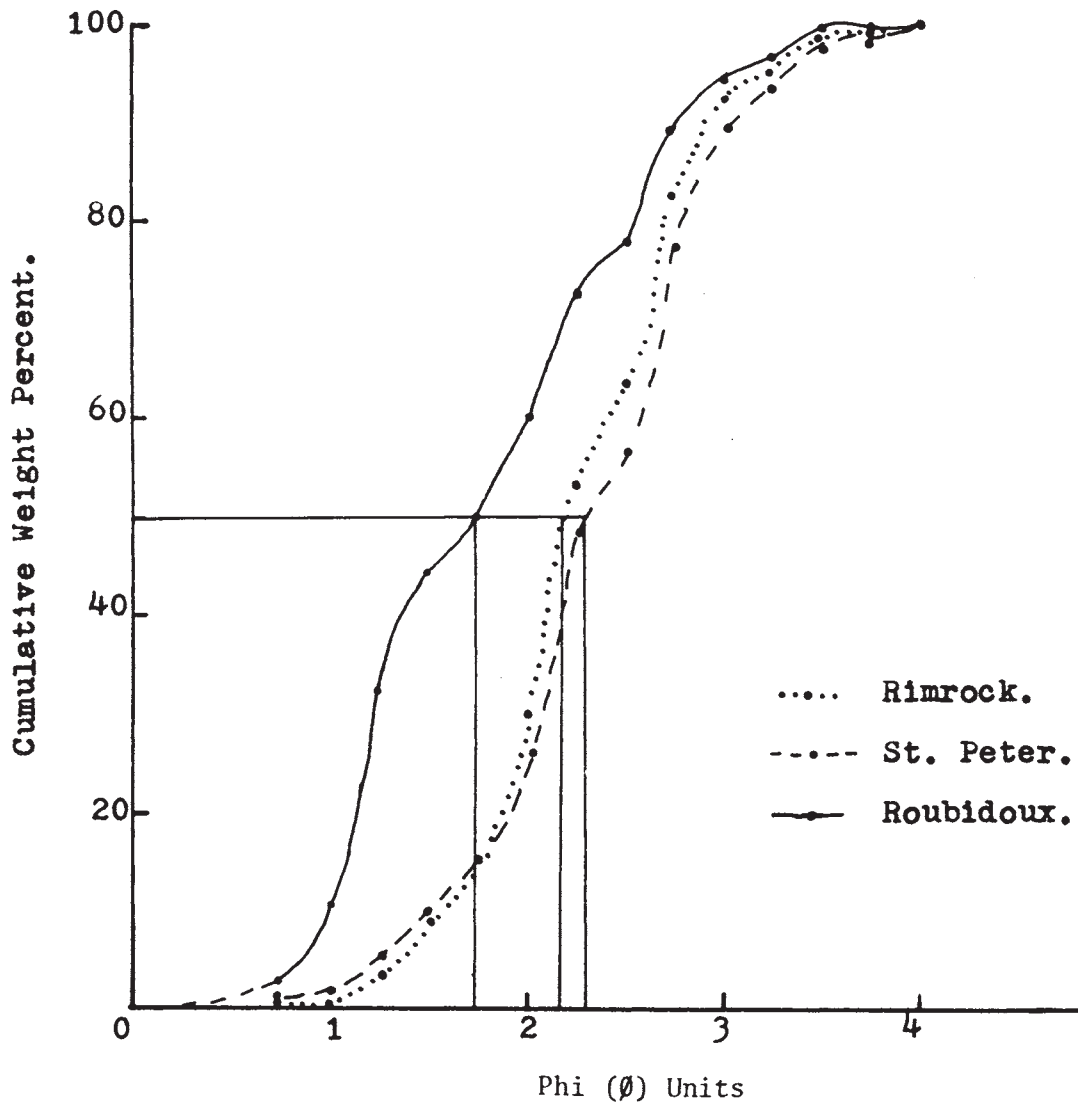


Fig. 1 Cumulative curves of the representative examples of Roubidoux, St. Peter, and Pennsylvanian rimrock sandstones. The Roubidoux sample is from northwest of Cuba, Mo. The St. Peter is averaged from samples from Hermann, Holstein, and Pacific, Mo. The rimrock sample is from a filled sink in the Rolla area.

Heavy mineral analysis suggests that the sands of the rimrock sandstone have undergone more than one sedimentary cycle. However, the heavy mineral analyses do not provide any real information concerning the source of the sands. There is too much similarity in the heavy mineral suites of all three sandstones.

Textural analysis however, does give some clues by which a distinction and a comparison can be made between these sandstones.

TABLE I

Comparison of the Average Grain Size Parameters of the Roubidoux, St. Peter, and the Rimrock Sandstones. The various parameters compared are: σ_1 , the inclusive standard deviation; ϕ , diameter in phi units; \bar{X} , arithmetic mean diameter; 1 percentile size, the diameter at which 1% by weight of the sample is larger, taken from the cumulative curve.

Name of Sandstone	No. of Samples	σ_1		\bar{X}		1% tile size	
		ϕ	mm	ϕ	mm	ϕ	mm
1. Roubidoux	30 ^a	0.72	0.61	1.87	0.28	0.38	0.78
2. St. Peter	11 ^b	0.52	0.70	2.43	0.18	1.06	0.49
3. Penn. rimrock	115 ^c	0.52	0.70	2.14	0.22	1.02	0.50

a. based on 7 samples collected by Heller (1954, p. 20) in various localities and 23 samples collected by the writer and other graduate students in the Rolla area (Parikh, 1970, p. 39, 40).

b. based on 8 samples collected in Missouri by Thiel (1935, 559) and 3 by the writer in Missouri (Parikh, 1970, p. 40).

c. based on samples collected by the writer in the Rolla-St. James-Cuba-Owensville area.

On comparing the various grain size parameters (Table I and Fig. 1) it becomes clear that the rimrock sandstone is texturally more similar to the St. Peter sandstone than to the Roubidoux sandstones, which leads

to the conclusion that the St. Peter is probably the source rock for the sandstone at the rim of the filled sinks in the area. This should be considered as a tentative conclusion since the data, for the Roubidoux at least, are limited stratigraphically and geographically.

Features such as ripple marks, cross-bedding, current lineations, etc., usually provide useful clues to determine the direction of transportation of a sediment. However, no sedimentary structures except bedding and rare cross-bedding have been observed, nor are there any distribution patterns present. Hence, it is not possible to determine the location of the source area and the direction of the currents that deposited this sandstone.

INDIANS OF THE OZARK HIGHLANDS

Jack Scrivner

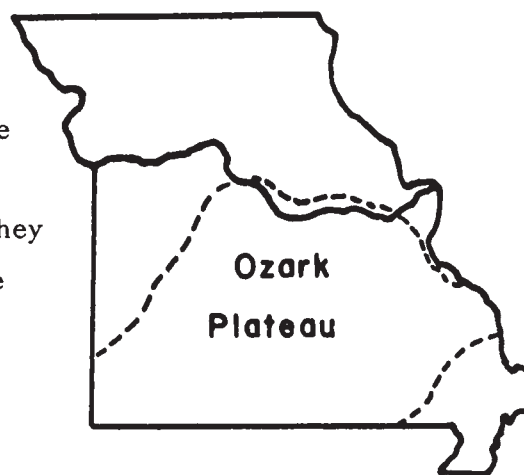
Most archaeologists agree that the American aborigine or Indian reached the American continent by crossing the Bering Strait from Asia, sometime during the Pleistocene. During this period, large portions of Canada and the Northern United States were covered by ice. With the resultant lowering of the sea level, it is likely that there was a land bridge between Northern Asia and Alaska.

It is not known precisely when during the Pleistocene the very first migration took place, probably during the span 20,000 B.C. to 40,000 B.C. (Willey). By 10,000 B.C., however, early man was well established, although thinly scattered, throughout the entire continent.

These early people were "hunters and gatherers". Their economy consisted of hunting animals and gathering edible plants and fruits. Some of these people even hunted those Pleistocene animals which are now extinct, like the mastodon, mammoth, native camel, and others (Wormington).

The various Indian cultures in Missouri may be divided into three rather generalized periods. These are: (1) Archaic Period, 8000 B.C. to 500 A.D., (2) Woodland Period, 500 A.D. to 1000 A.D., and (3) Mississippi Period, 1000 A.D. to 1800 A.D. One should bear in mind that one period did not change suddenly into another. The transition often took several hundred years. Consequently, cultural styles or patterns were much the same in the latter part of the Archaic Period, for instance, as they were in the early part of the Woodland Period.

The Archaic Indians in Missouri, and in particular, those in the Ozark Highlands (see Figure 1) hunted deer, bear, elk and smaller animals like beaver, raccoon, and possum. They fished and hunted some birds, especially the turkey. Their entire material economy was centered around the hunt. To these ends



they made projectile points for hunting, knives for butchering, and scrapers for hide working and other uses (Fig. 2). The local cherts were used for these items. The projectile points were rather large and were fastened to a shaft and used as a hand spear or with an atlatle, or throwing stick. Deer antlers were probably used in flint knapping. (Flint knapping is the art of chipping stone tools). Bone tools were used in fashioning hides for clothing. Axes were ground from hematite, greenstone, and diorite. Hematite was abundant locally. Greenstone and diorite were obtained from the glacial till. The nearest supply was the Missouri River.

These people made their camps and villages on the terrace of the river bottoms. These camp sites are easily located, especially in newly plowed fields, by the presence of broken stone tools and the profusion of scattered flint chips, the waste product of flint knapping. The density of sites is quite high in this area, it being almost impossible to walk a half of a mile without finding at least one.

In inclement weather they occupied caves or shelters, areas where the bluffs form extensive overhangs. Most of the caves in Phelps and adjoining Counties are in the Gasconade Formation. Virtually every cave in this area large enough to walk into shows evidence of past occupancy, especially caves that do not face North. Some of these caves have culture-bearing deposits as much as six feet deep. The Rogers Shelter on the Pomme De Terre River, in Benton County, has a very deep talus slope directly in front of it. This talus slope had cultural material at a remarkable depth of thirty feet (McMillan, 1966).

The profusion of open sites and great depth of deposits at sheltered sites does not imply a large concentration of people. In fact, quite the opposite is apparently true. The accumulation of cultural material took place over a long time span, possibly 10,000 years, by a small group or groups of people. The number of individuals in a group may not have been more than eight or ten, probably all related, i.e., an extended family. A specific group presumably would occupy a site for a period of time until the game was depleted. Then they would move on to a new area, occasionally encountering another such group or family.

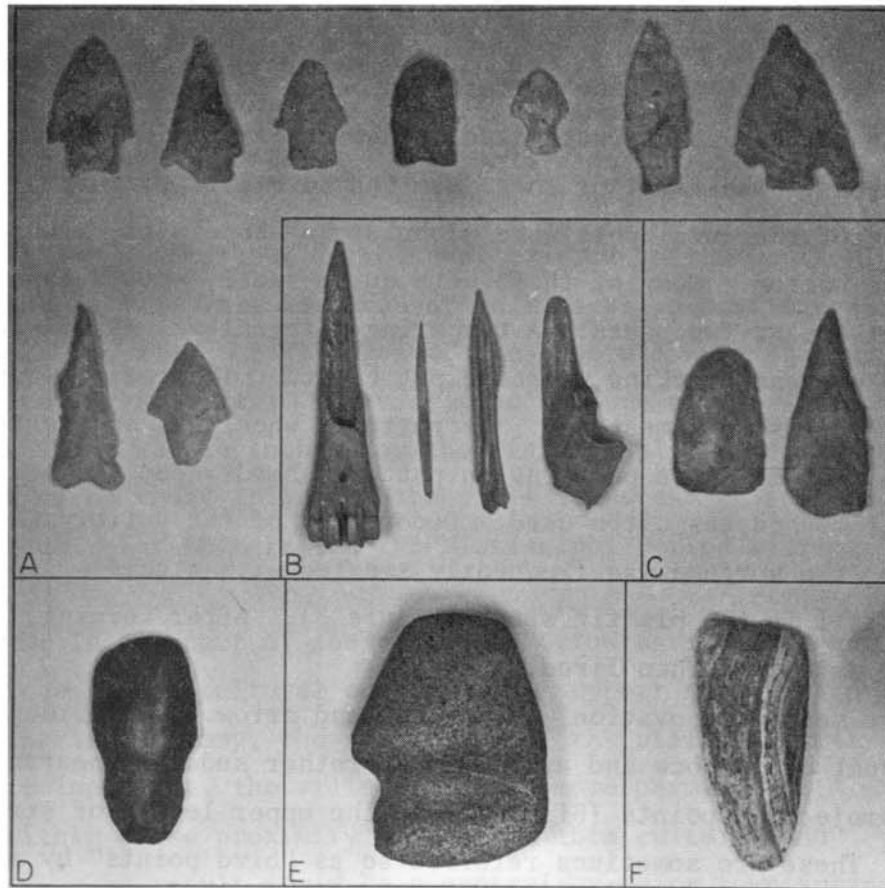


Figure 2. Archaic Period Artifacts. (A) Projectile points, (B) Bone tools, (C) Stone knives, (D) Hematite axe, (E) Diorite axe-3/4 groove, (F) Adze.

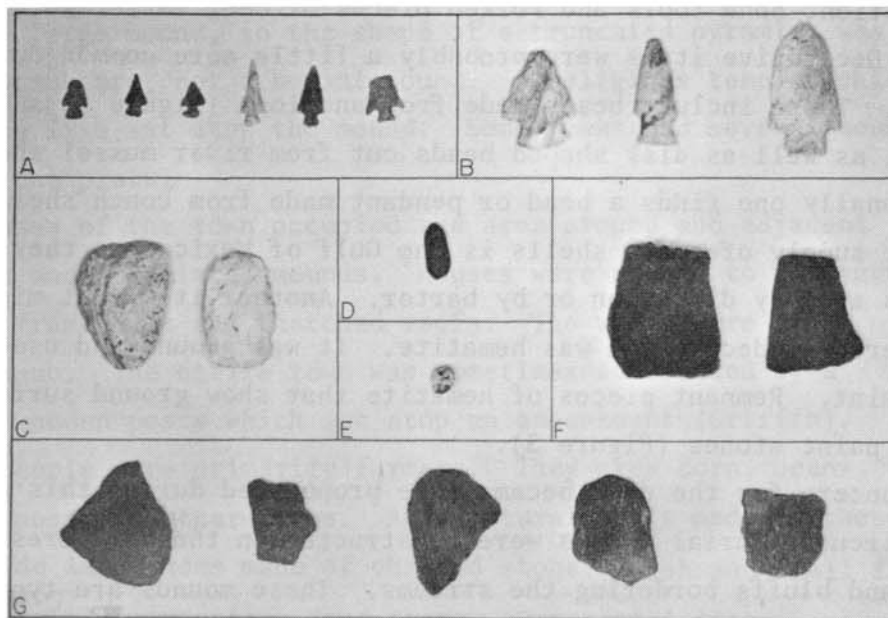


Figure 3. Woodland Period Artifacts. (A) Arrow points, (B) Projectile Points, (C) Scrapers, (D) Hematite paint stone, (E) Anculosa beads, (F) Pottery sherds-rims, (G) Pottery sherds-body.

By about 500 A.D. the culture had begun to change slightly. The Woodland Period was characterized by the appearance of two important innovations. The first of these was the advent of pottery. The majority of the local pots were globular in shape with a round or conoidal bottom. Many of these were quite small, with a capacity of about one or two pints. A tempering material was mixed with the clay to prevent cracking when the pot cooled. The temper was typically crushed limestone. The potter's wheel was apparently unknown, but fracture patterns on pottery sherds seem to indicate that the coil method was often used. Decoration of the pottery was rare. However, the surface was frequently treated with a cord-wrapped paddle while still in the plastic stage (Figure 3). After forming, the pot was air dried and then fired.

The second innovation was the bow and arrow. The evidence for the advent of the bow and arrow is the rather sudden appearance of small projectile points (Figure 3) in the upper levels of stratified sites. These are sometimes referred to as "bird points" by amateur collectors, the implication being that they were used only to kill birds. However these were true arrow points and were capable of killing even the largest game.

The larger points also continued to be made during this period. In addition, bone tools and worked pieces of deer antler were still used. Decorative items were probably a little more common during this period. These include beads made from *anculosa* (Figure 3) and periwinkle shells, as well as disk shaped beads cut from river mussel shells. Occasionally one finds a bead or pendant made from conch shell. The nearest supply of conch shells is the Gulf of Mexico, so they arrived in this area by diffusion or by barter. Another item that might be considered as decoration was hematite. It was ground and used as body paint. Remnant pieces of hematite that show ground surfaces are called paint stones (Figure 3).

Concern for the dead became more pronounced during this period. Low, circular burial mounds were constructed on the very crest of the hills and bluffs bordering the streams. These mounds are typically

fifteen to thirty feet in diameter and one to two feet high. They are constructed of dirt, rock, or both. Mortuary items are rare, but when present, consist of pottery, stone tools, and occasionally a pipe made of clay or stone.

No full-blown Mississippi Period ever existed in the Ozark Highlands (Chapman, 1948). This is because the Mississippi culture was riverine in nature, i.e., the villages of these people were in areas adjacent to the larger rivers. However, the culture of the Indians in the Ozark Highlands was influenced by the Mississippi people, much as the large cities of today influence the small towns and rural areas adjacent to them. For this reason the Mississippi Period will be discussed.

During the latter part of the Woodland Period agriculture came into practice. Since an agricultural economy will support more people than a hunting-gathering economy, the population of the villages surely increased. More important, the villages became more permanent. A group of villages within close proximity might then form cultural and political ties. The result would be a central or major town surrounded by dependent villages within a radius of, say, thirty miles (Chapman, 1964). Near Cahokia, Illinois, just east of the present day St. Louis, is an example of such a metropolitan culture center.

The major town often contained a large mound adjacent to a plaza. This large mound, in the shape of a truncated pyramid, was a ceremonial structure, not a burial mound. A religious temple, chief's house, or the like sat atop the mound. Some towns had several mounds surrounding the plaza.

The houses of the town occupied the area around and adjacent to the plaza and associated mounds. Houses were square to rectangular with wooden frameworks and thatched roofs. The walls were often wattle and daub. The entire town was sometimes surrounded by a palisade of wooden posts which sat atop an embankment (Griffin).

These people were primarily farmers. They grew corn, beans, squash, and possibly other crops. Agricultural tools made by these people include large hoes made of chipped stone. Fish and shell fish (mussels) were also important food items. Ornamental items, e.g.,

beads and gorgets, were made from shell, as well as utilitarian items like shell spoons and hoes.

Hunting was still practiced but it was secondary to gardening. Small arrow points, either triangular shaped or willow leaf shaped, were chipped from stone. Ground stone items included celts (ungrooved axes) made of diorite or greenstone.

One of the most prominent industries of the Mississippi people was the production of pottery. This was, no doubt, women's work. Pottery was both abundant in quantity and varied in form. Forms included long necked water bottles, shallow bowls, and cooking jars with loop handles. Mississippi pottery was characteristically tempered with crushed shell.

The dead were buried in special cemeteries or often in the village itself. The burials were typically less than four feet deep. The most common grave goods were pots containing items of food.

Archaeological evidence points to the fact that at the time the Mississippi culture was flourishing along the Mississippi River the Indians in the Ozark Highlands were practicing the more primitive Woodland culture (Chapman, 1964). This was, in part, caused by geographic isolation. Another reason might have been cultural choice (Wood 1967). One clean piece of evidence for this co-existence is the appearance of shell tempered-pottery in stratified sites of the Ozark Highlands. These shell tempered-sherds are found in the very top levels, overlying levels containing limestone-tempered sherds. Usually the top levels have a mixture of these two kinds of sherds (McMillan, 1965).

Certainly trade went on between these two groups. Items which were traded to the Mississippi people included nuts, salt, and hematite. Hematite was highly prized by the riverine people. It was ground and used as a body paint as well as paint for pottery vessels.

During the latter part of this period, early explorers, trappers, and traders made contact with the Mississippi people. Goods of European manufacture are found at some Mississippi village sites. Items found include glass beads, knives and gun parts of iron, and kettles, rings and small bells made of brass or copper.

In historic times there were two known Indian tribes living in Missouri. These were the Missouri tribe on the Missouri River in Saline County and the Osage tribe on the Osage River in Vernon County. The influence they

may have had on the Ozark Highlands is rare to non-existent. By 1810 both tribes had moved out of the State of Missouri.

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