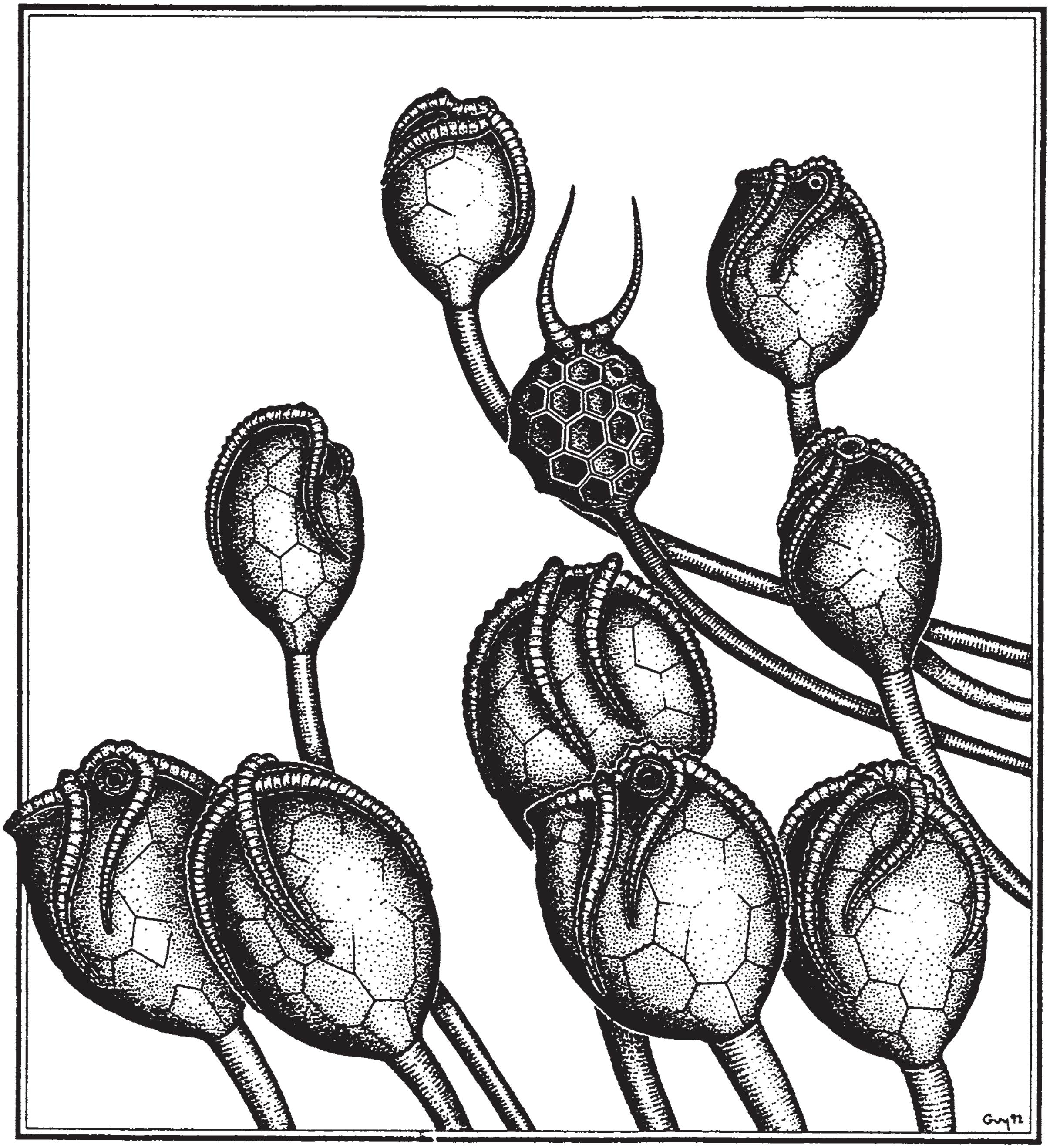
Association of Missouri Geologists

1992 Field Guidebook



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Acknowledgements

AMG wishes to thank the following for hospitality and access to their properties; Bill Janssen, House Springs Quarry, Bill Kreamer, U. S. Silica - Pacific.

For assistance in preparation of the field guide, thanks to Guy Darrough, Arnold, Mo., Mike Fix, Geology Dept., University of Missouri, Saint Louis. For assistance in preparation of this field guide, we acknowledge the assistance of the geology department, St. Louis Community College at Florissant Valley and the various AMG members cited above.

The area covered by this field trip, the northeastern portion of the Ozark dome exposes a sequence of strata from early Ordovician to Pennsylvanian. It represents the area where two major geologic and geographic regions of the midwest, the Ozarks and the margin of the Illinois Basin converge. Elements of both of these areas interact to make this region one of the more geologic complex areas of Missouri. A diversity of geologic phenomena is represented here from the alluvial sediments of the Times Beach clean-up area to the complex Eureka-House Springs structure to paleontology (Hy. 21).

Friday Field Trip -

Stop 1. Times Beach toxic waste cleanup with geological factors relevant the Meramec River flood plain. Times Beach was located on Pleistocene-Holocene alluvial sediments of the Meramec River.

Stop 2. St. Peter Sandstone and overlying Joachim Formation U. S. Silica - Pacific, Mo., Business 44 (Old Hy. 66)

Stop 3. Joachim cuts, I-44,

Saturday Field Trip -

Stop I. House Springs Quarry. Plattin, Kimmswick and Mississippian strata (Fern Glen and Burlington exposed here). House Springs, Mo.

Stop II Bushberg, Fern Glen contact. Hy. 21, Otto, Mo.

Stop III. Submarine? solution features in Kimmswick Limestone and Pelmatazoan gardens. Guy Darrough, 47 Pomme Ave., Arnold, Mo. 63010

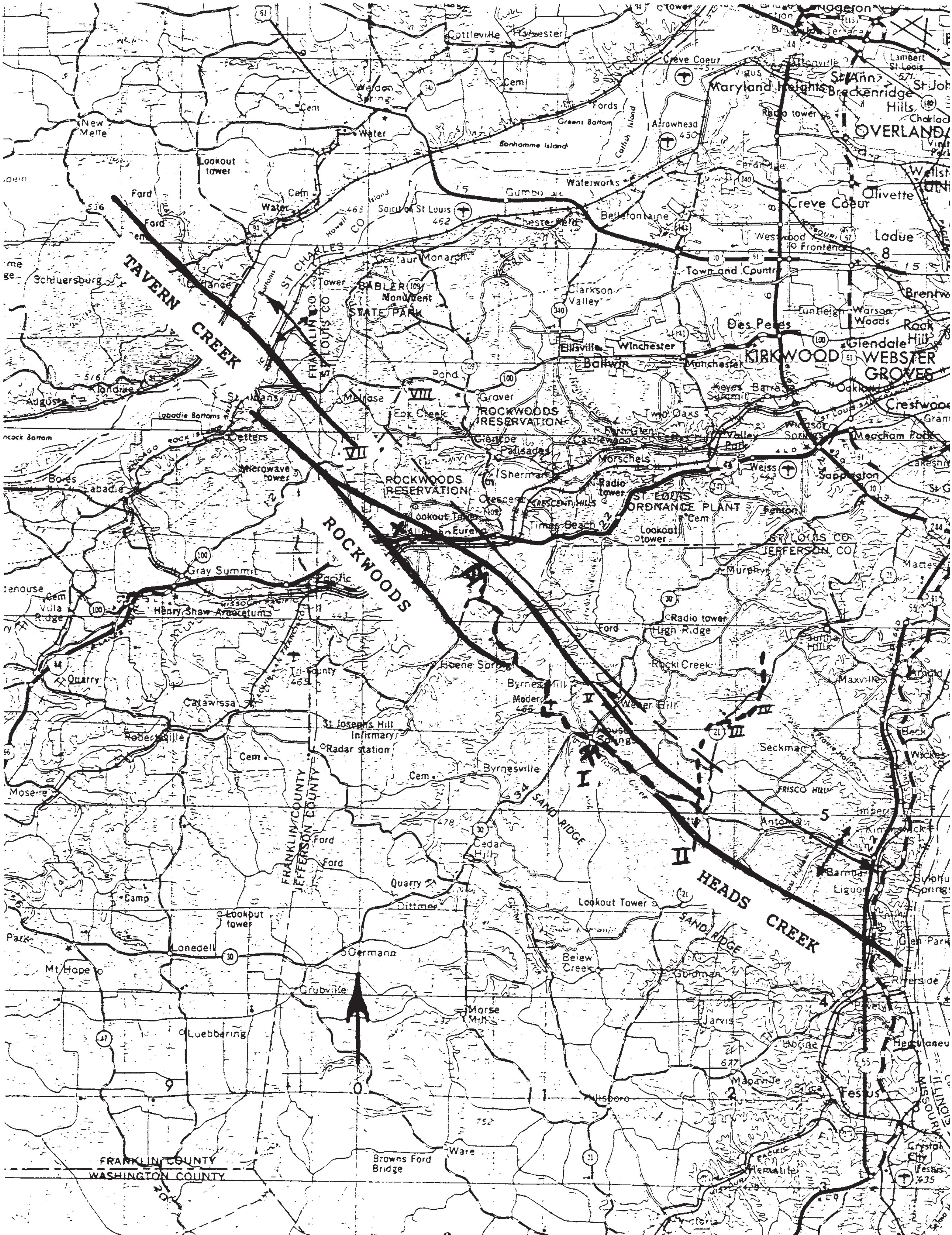
Stromatoporoid and coral reefs, Kimmswick Limestone. B. L. Stinchcomb, Geology Dept., St. Louis Community College at Florissant Valley.

Stop IV. Hy. 30., Eureka-House Springs structure, C. W. Clendenin, 413 Rubinstein, Salem, Mo., 65560

Stop V. Hy. W, Eureka. Eureka Fault System

Stop VI. Hy. 100 Geological puzzle. Solution and fault, House Springs - Eureka Structure?
Carol Sutherland, Maryville College - St. Louis, 13530 Conway Rd., St. Louis, Mo. 63141

Stop VII. Grover Gravels and Paleokarst. Rockwoods Reservation.
B. L. Stinchcomb.


TAVERN CREEK
ROCKWOODS
HEADS CREEK
VII
VIII
VI
V
IV
III
II
I
ST CHARLES CO
ST LOUIS CO
FRANKLIN CO
ST LOUIS CO
JEFFERSON CO
FRANKLIN COUNTY
JEFFERSON COUNTY
FRANKLIN COUNTY
WASHINGTON COUNTY
ILLINOIS
MISSOURI
BABLER Monument STATE PARK
ROCKWOODS RESERVATION
ROCKWOODS RESERVATION
ST LOUIS ORDNANCE PLANT
KIRKWOOD
WEBSTER GROVES
OVERLAND
Creve Coeur
Maryland Heights
Town and Country
Des Peres
Ballwin
Manchester
Ellisville
Winchester
Clarkson Valley
Grover
Eureka
Pacific
Gray Summit
Henry Shaw Arboretum
Labadie
Catawissa
Robertsville
Byrnesville
Cedar Hill
Lonedell
Grubville
Morse Mill
Luebbering
Hillsboro
Festus
Crystal City
Herculaneum
Riverside
Glen Park
Barnhart
Antonia
Seckman
Maxville
High Ridge
Murphy
Fenton
Valley Park
Castlewood
Glencoe
Pond
Melrose
St Albans
Augusta
Schluersburg
New Melle
Weldon Spring
Gumbo
Chesterfield
Bellefontaine
Spirit of St Louis
Ladue
Olivette
Frontenac
Brentwood
Rock Hill
Glendale
Crestwood
Sappington
Meacham Park
Oakland
Twin Oaks
Sherman
Crescent
Times Beach
Lookout Tower
Radio tower
Weber Hill
Byrnes Mill
Quarry
Tri-County
St Josephs Hill Infirmary
Radar station
Dittmer
Oermann
Mt Hope
Browns Ford Bridge
Ware
Fletcher
Hematite
Mapaville
Jarvis
Gorman
Belew Creek
Rock Creek
Frisco Hill
Sand Ridge
Sand Ridge
Bonhomme Island
Greens Bottom
Labadie Bottoms
Moselle
Villa Ridge
Lookout tower
Microwave tower
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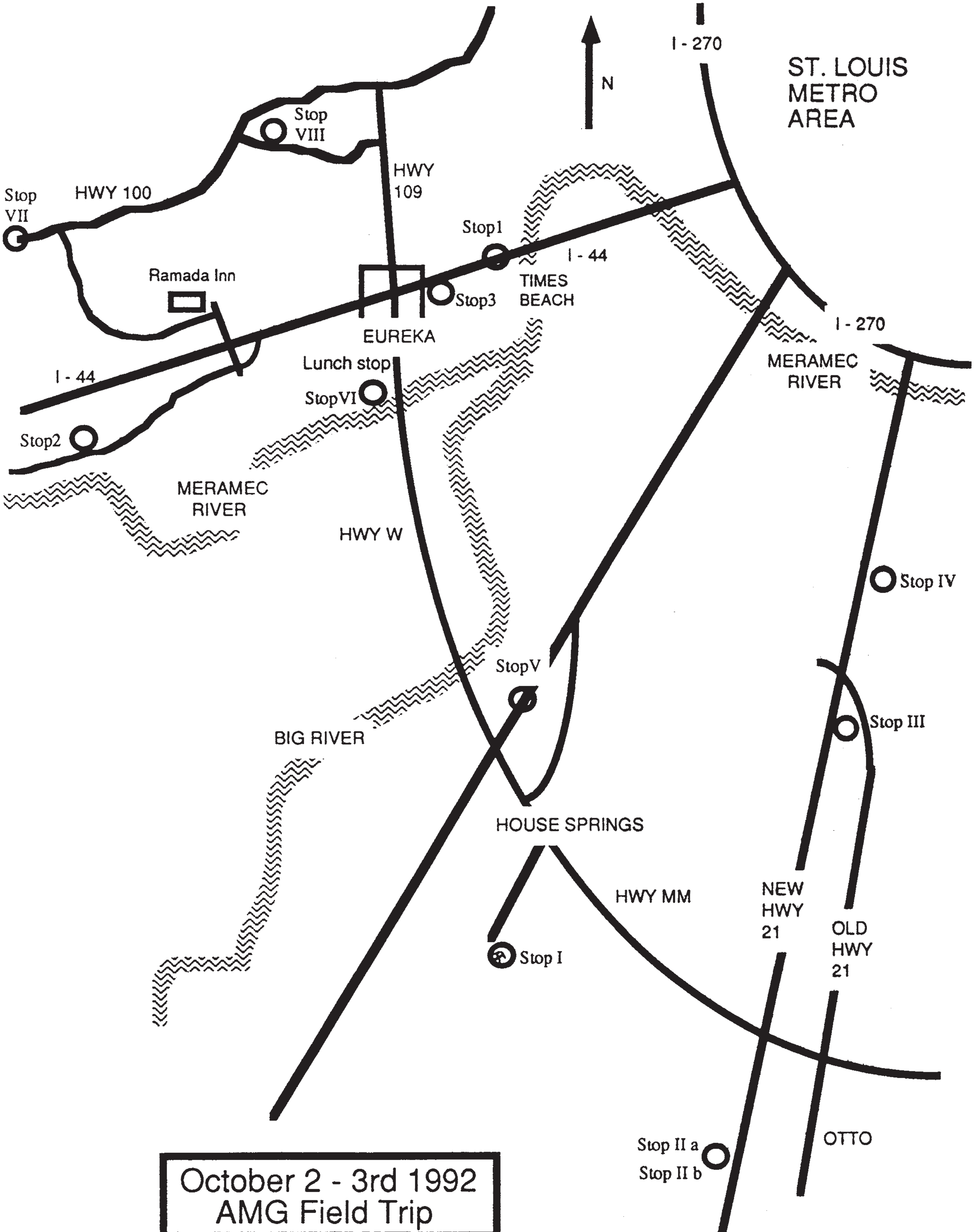


Friday Stops in Arabic Numerals, Saturday Stops in Roman Numerals

ENVIRONMENTAL ANALYSIS AND CLEANUP OF THE TIMES BEACH, MISSOURI, DIOXIN SITE

ASSOCIATION OF MISSOURI GEOLOGISTS
OCTOBER 2, 1992
1:00 PM TO 2:30 PM

By

Larry P. Coen, CPG, CHMM
Mimi Garstang, RPG
Kenneth R. Teeter, CHMM, REP
James O. Silver

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL QUALITY
DIVISION OF GEOLOGY AND LAND SURVEY

INTRODUCTION

Times Beach has captured national attention since its abandonment in 1982. The fear of the contaminant "Dioxin" led to the federal buy out of the residents and businesses of the rural community. Since that time, risk assessments of dioxin and site assessments of Times Beach have brought us to this point in time when remedial actions are being taken to restore the area to beneficial use.

Geological sciences have played an important role in the environmental assessments of Times Beach, but often times not in the sense of traditional bedrock geology. The media of concern to geologists are largely alluvial soils, groundwater, and surface water. Environmental geology encompasses such topics as contaminant fate and migration in both soils and groundwater, hydrologic analyses, monitoring well installation, the assessment of risk to the environment, contaminant exposure to the public, anticipated levels of cleanup, and of course, the effects of underlying bedrock geology. Several of these tasks can only be completed through a multi-disciplined approach involving geologists, soil scientists, agricultural scientists, biologists, engineers, medical professionals, and hazardous materials managers. The expected result of the cleanup of Times Beach will be a public use recreational area free of risk to its visitors.

Times Beach is located in southwestern St. Louis County on Meramec River alluvial deposits. It occupies the northwest corner of the intersection of Interstate 44 and the Meramec River. The topography is relatively flat and was overgrown with weeds and trees until recently. You may recall driving past the area in recent years seeing homes, trailers, and businesses in disrepair and covered with unchecked wild vegetation. Very little activity was allowed until final studies and all legal decisions were reached in mid 1990. Even though no dioxin contaminated soils have been remediated at Times Beach to date, the area looks much cleaner just because of the removal of the structures and vegetation.

SITE HISTORY

The events that led to the end of Times Beach as a community is a long and somewhat confusing trail. Times Beach was originally conceived as a recreational community comprised of subscribers to the St. Louis Times newspaper. Subscriptions were rewarded by small land gifts of property owned by the St. Louis Times (Keffer, 1992), located along the Meramec River floodplain. The recreational property became known as "Times Beach" by the seasonal residents and later became incorporated and residents became largely permanent.

Times Beach was serviced by gravel roads inside the city limits. During the seasonal dry spells, these roads produced tremendous amounts of dust which became a nuisance to many, not the least of which were those who kept house or other dust free areas. It was popular during those days to control dust by applying waste oil to the road surface. This effectively controlled the dust and made the gravel surface more weather resistant and durable. This seemed like a perfect use of waste oil which was difficult to get rid of otherwise. The waste oil used at Times Beach and other areas around St. Louis was more than just waste oil, however.

Late in 1969, a chemical company, Northeastern Pharmaceutical and Chemical Company, Inc. (NEPACCO) leased property and structures in Verona, Missouri, from another company, Hoffman-Taft, Inc. The property had been used to manufacture a defoliant, known as Agent Orange (MDNR files). NEPACCO manufactured hexachlorophene, a cleansing germicide, from 1970 to 1972. A waste from this germicide process was 2,3,7,8 tetrachlorodibenzo-p-dioxin, or dioxin. NEPACCO placed their waste into large tanks already on site which were partially filled with dioxin waste from the Agent Orange process. In order to empty the waste tanks, NEPACCO made arrangements through Independent Petrochemical Corp. (IPC) to obtain the services of Russell Martin Bliss to remove the chemical sludge from the tanks. Russell Bliss was also a waste oil hauler. Bliss and his employees made several different trips to Verona to remove sludge while continuing to service the waste oil needs of other customers. Bliss mixed the dioxin sludge into his waste oil tanks at Frontenac, Missouri. In addition to his waste oil and chemical sludge customers, Bliss also gained customers who sought dust control measures through the spreading of waste oil. Eventually, forty-five sites throughout eastern Missouri were identified as having been sprayed with dioxin contaminated waste oil. These sites included horse stables, gravel roads and parking lots.

Mysterious illnesses, and the deaths of horses and other animals, led to suspicions of chemical contamination problems. Horse training arenas had also been sprayed with waste oil for dust suppression. Investigations conducted by the Missouri Department of Health and the Center for Disease Control eventually made the dioxin connection. Bliss, NEPACCO, and IPC were later defendants in multiple lawsuits concerning dioxin.

Hoffman-Taff, Inc., in the meantime, had been purchased by Syntex Agribusiness, Inc. Through the purchase, Syntex also acquired all assets and liabilities of the company. Liabilities now include a major role in the cleanup of many of the dioxin contaminated areas of eastern Missouri, including Times Beach.

The contamination of Times Beach was confirmed in 1982. By a coincidence of weather, Times Beach was totally flooded shortly thereafter. Because of the fear of the spread of dioxin, the lack of documented knowledge about dioxin, and the flood damages to the community, the federal government agreed to evacuate Times Beach and buy out all the properties. This purchase was made under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) which when later reauthorized became known as Superfund because of the large size of the fund set aside for hazardous waste site cleanups. Access to the area is restricted until the cleanup is complete.

REGIONAL GEOLOGY

Times Beach lies within the Salem Plateau of the Ozarks physiographic province (Miller et al., 1974). Bedrock geology surrounding the area consists of sedimentary formations comprised predominantly of limestone, dolomite, and sandstones of Ordovician age. A generalized stratigraphic column for St. Louis, St. Charles and Jefferson Counties, Missouri, is presented in Figure 1.

Regionally, the bedrock dips gently to the northeast as noted in Figure 2. The regional dip is interrupted by several southeast-northwest trending anticlines, synclines and faults. There are two mapped faults within 10 miles of Times Beach (Figure 3). The Maxville Fault (Miller et al., 1974) is approximately eight miles southeast of Times Beach. The

FIGURE 1

Generalized Stratigraphic Column for St. Louis, St. Charles, and Jefferson Counties, Missouri

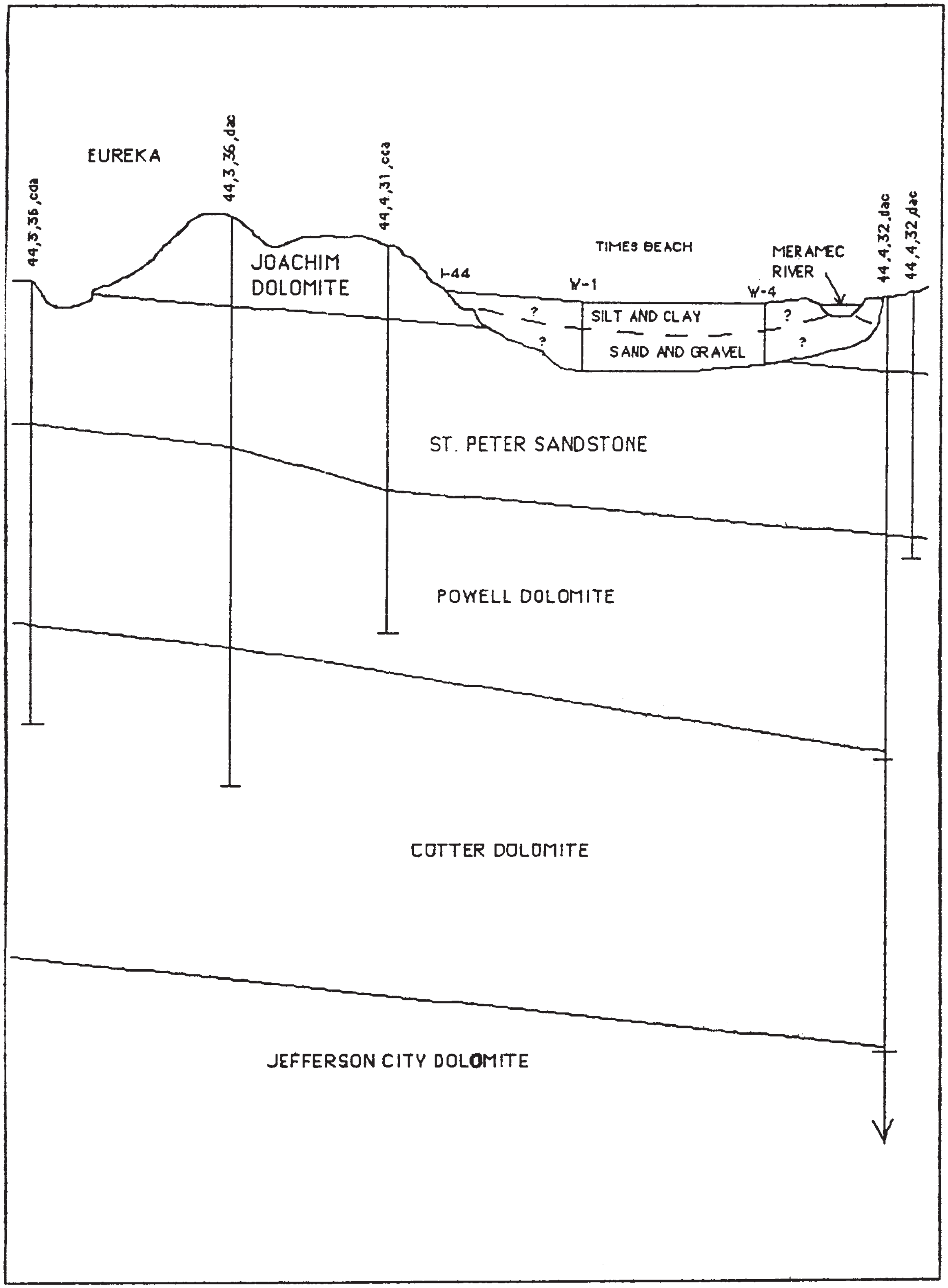
Aquifers most favorable as water sources are shaded

System	Series	Group	Formation	Aquifer Group	Thickness (feet)	Dominant Lithology	Water-bearing Character
Quaternary	Holocene		Alluvium[1]		0-150	Sand, gravel, silt, and clay.	Some wells yield more than 2,000 gpm.
	Pleistocene		Loess		0-110	Silt	Essentially not water yielding.
			Glacial till		0-55	Pebbly clay and silt.	
Pennsylvanian	Missourian	Pleasanton	Undifferentiated	1	0-75	Shales, siltstones, "dirty" sandstones, coal beds and thin limestone beds.	Generally yields very small quantities of water to wells. Yields range from 0-10 gpm.
		Marmaton	Undifferentiated		0-90		
	Desmoinesian	Cherokee	Undifferentiated		0-200		
	Atokan		Undifferentiated				
Mississippian	Meramecian		Ste. Genevieve Formation		0-160	Argillaceous to arenaceous limestone.	Yields small to moderate quantities of water to wells. Yields range from 5 to 50 gpm. Higher yields are reported for this interval locally.
			St. Louis Limestone		0-180		
			Salem Formation		0-180		
			Warsaw Formation		0-110		
	Osagean		Burlington-Keokuk Limestone		0-240	Cherty limestone	
			Fern Glen Formation		0-105	Red limestone and shale.	
	Kinderhookian	Chouteau	Undifferentiated		0-122	Limestone, dolomitic limestone, shale, and siltstone.	
Devonian	Upper	Sulphur Springs	Bushberg Sandstone		0-60	Limestone and sandstone.	
			Glen Park Limestone				
			Grassy Creek Shale		0-50	Fissile, carbonaceous shale.	
Silurian			Undifferentiated		0-200	Cherty limestone.	
Ordovician	Cincinnatian		Maquoketa Shale		0-163	Silty, calcareous or dolomitic shale.	Probably constitutes a confining influence on water movement.
			Cape Limestone		0-5	Argillaceous limestone.	
	Champlainian		Kimmswick Formation	2	0-145	Massive limestone	
			Decorah Formation		0-50	Shale with interbedded limestone.	Yields small to moderate quantities of water to wells. Yields range from 3 to 50 gpm. Decorah Formation probably acts as a confining bed locally.
			Plattin Formation		0-240	Finely crystalline limestone.	
			Rock Levee Formation		0-93	Dolomite and limestone, some shale.	
			Joachim Dolomite		0-135	Primarily argillaceous dolomite.	
			St. Peter Sandstone	3	0-160	Silty sandstone, cherty limestone grading upward into quartzose sandstone.	Yields moderate quantities of water to wells. Yields range from 10-140 gpm.
			Everton Formation		0-130		
	Canadian		Powell Dolomite	4	0-150	Sandy and cherty dolomite and sandstone.	Yields small to large quantities of water to wells. Yields range from 10 to 300 gpm. Upper part of aquifer yields only small amounts of water to wells.
			Cotter Dolomite		0-320		
			Jefferson City Dolomite		0-225		
			Roubidoux Formation		0-177		
			Gasconade Dolomite Gunter Sandstone Member		0-280		
Cambrian	Upper		Eminence Dolomite	5	0-172	Cherty dolomites, siltstone, sandstone, and shale.	Yields moderate to large quantities of water to wells. Yields range from 10 to 400 gpm.
			Potosi Dolomite		0-325		
		Elvins	Derby-Doerun Dolomite		0-165		
			Davis Formation		0-150		
			Bonneterre Formation		245-385		
			Lamotte Sandstone		235+		
Precambrian						Igneous and metamorphic rocks.	Does not yield water to wells in this area.

[1]Basal part may be of Pleistocene age. From (Miller et al, 1974)

NOTE: Stratigraphic nomenclature may not necessarily be that of the U.S. Geological Survey
This figure is from "Water Resources of the St. Louis Area Missouri"

FIGURE 2


EUREKA
44,3,35,cda
44,3,36,dac
44,4,31,cca
JOACHIM DOLOMITE
I-44
TIMES BEACH
W-1
W-4
MERAMEC RIVER
44,4,32,dac
44,4,32,dac
SILT AND CLAY
SAND AND GRAVEL
ST. PETER SANDSTONE
POWELL DOLOMITE
COTTER DOLOMITE
JEFFERSON CITY DOLOMITE

Eureka-House Spring Fault Zone is less than two miles west of the site. Recent mapping (Clendenon, et al., 1992, in preparation) has redefined the Eureka-House Springs Anticline as a strike slip left-lateral fault system extremely complicated in nature. Neither fault is considered to be active.

SITE SPECIFIC GEOLOGY

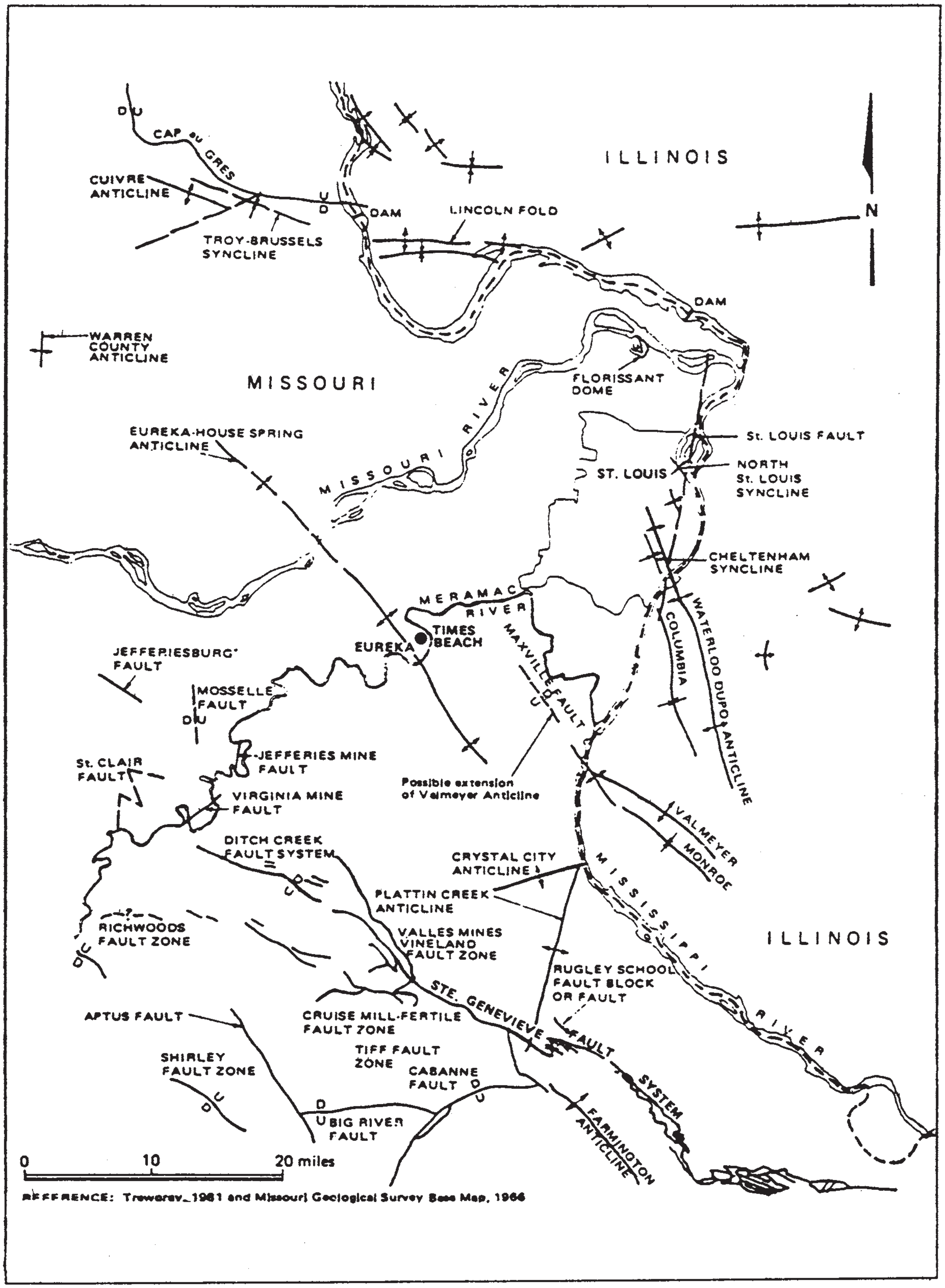
Times Beach is located less than 2 miles east of the northwest-trending Eureka-House Springs Fault System (Figure 3) and is situated in the Meramec River floodplain. Alluvial deposits of the Meramec River and its tributaries fill the deep bedrock valley with stratified clay, silt, sand, and gravel. The ground surface is an area of little topographic relief that typically slopes toward the Meramec River and is subject to periodic flooding. All of the site is located within the 25 year floodplain of the Meramec River and portions of the site are within the 5 year floodplain.

The alluvium at Times Beach ranges in thickness from zero on the bedrock bluffs across the river from Times Beach to almost 70 feet beneath Times Beach itself. The younger fine-grained alluvial sediments range in depth from 18 to 35 feet and are primarily composed of silts and clays. The uniformity of the fine-grained material has been surprising. It was anticipated that numerous buried meander channels could be present across the site. Exploration, however, has revealed a uniform sequence of alluvial material.

Beneath the fine-grained sediments are older alluvial deposits comprised of sands and gravels ranging in thickness from 30 to 40 feet. The sands and gravels are not totally stratified; rather seem to alternate layering to the depth of the bedrock.

Beneath the alluvium is bedrock of Ordovician age. The St. Peter

FIGURE 3



ILLINOIS
MISSOURI
CAP au GRES
CUIVRE ANTICLINE
TROY-BRUSSELS SYNCLINE
DAM
LINCOLN FOLD
N
WARREN COUNTY ANTICLINE
FLORISSANT DOME
MISSOURI RIVER
EUREKA-HOUSE SPRING ANTICLINE
St. LOUIS FAULT
ST. LOUIS
NORTH St. LOUIS SYNCLINE
CHELTENHAM SYNCLINE
MERAMAC RIVER
TIMES BEACH
EUREKA
MAXVILLE FAULT
COLUMBIA
WATERLOO DUPO ANTICLINE
JEFFERIESBURG' FAULT
MOSSELLE FAULT
JEFFERIES MINE FAULT
St. CLAIR FAULT
VIRGINIA MINE FAULT
Possible extension of Valmeyer Anticline
VALMEYER
MONROE
DITCH CREEK FAULT SYSTEM
CRYSTAL CITY ANTICLINE
PLATTIN CREEK ANTICLINE
MISSISSIPPI RIVER
RICHWOODS FAULT ZONE
VALLES MINES VINELAND FAULT ZONE
ILLINOIS
RUGLEY SCHOOL FAULT BLOCK OR FAULT
STE. GENEVIEVE FAULT SYSTEM
APTUS FAULT
CRUISE MILL-FERTILE FAULT ZONE
TIFF FAULT ZONE
SHIRLEY FAULT ZONE
CABANNE FAULT
BIG RIVER FAULT
FARMINGTON ANTICLINE
0 10 20 miles
REFERENCE: Trewerev, 1981 and Missouri Geological Survey Base Map, 1966

Sandstone is the uppermost bedrock beneath the majority of Times Beach that is located on the floodplain. The St. Peter lies beneath the Meramec River and extends south almost to the Interstate. The southern portion of Times Beach is underlain by the Joachim Dolomite. The Joachim lies beneath the alluvium both immediately north and south of I-44 and is the uppermost bedrock beneath the Interstate. The Joachim Dolomite and lower members of the Plattin Group are exposed in the river bluff where the Times Beach Visitor's Center is located. A stratigraphic section measured by T.L. Thompson, 1986, of the Plattin Group and Joachim Dolomite at the Lewis Road exit (entrance to Times Beach Visitor's Center) is included in Figure 4.

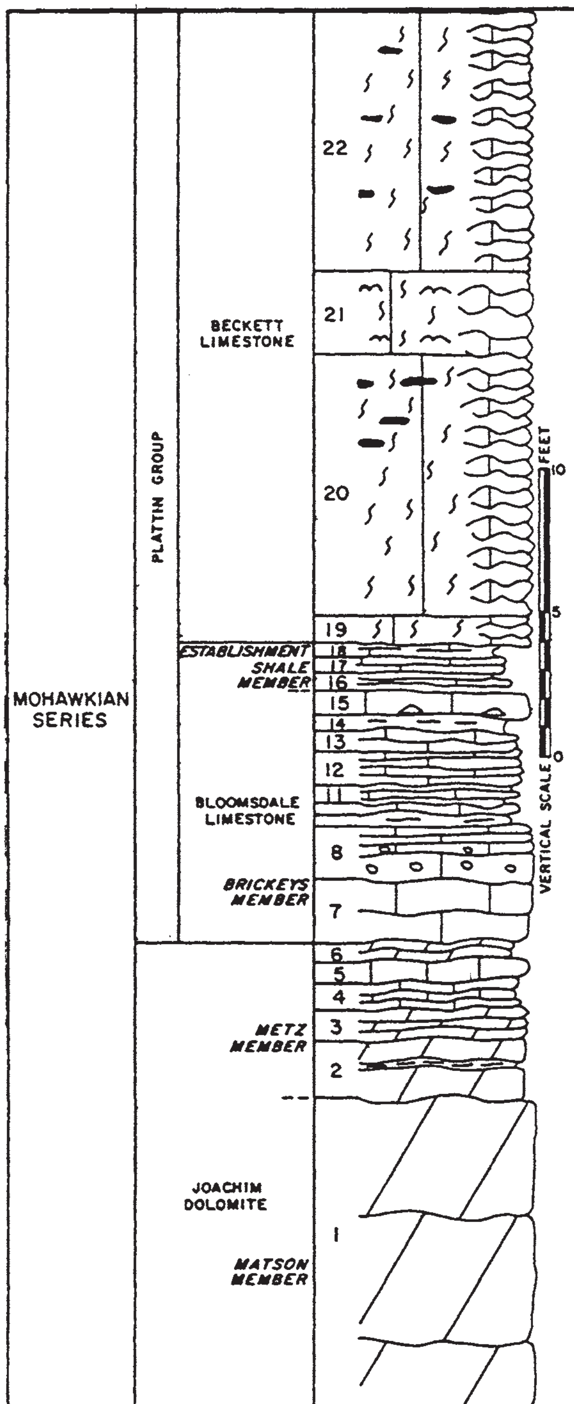
The Matson Member of the Joachim Dolomite is what lies beneath the alluvium at the southern third of the site. It is a tan dolomite that is laminated to vuggy with irregular algal structures that readily weather out. These structures can be as large as 3 feet in diameter and 2 feet high. Sinkholes have been created south of I-44 in Times Beach where the alluvial materials collapsed into voids created by weathering in the dolomite. No contamination is present south of I-44.

The St. Peter Sandstone consists chiefly of fine-grained, well sorted, friable sandstone. The St. Peter exhibits high porosity but low permeability. It serves as a regional aquifer in this portion of the State. The St. Peter Sandstone recharges the alluvium at the site with water high in total dissolved solids, sodium chloride, iron and magnesium. Just west of Times Beach the water quality within this formation greatly improves.

HYDROGEOLOGY

Groundwater in this region includes water from both bedrock aquifers and the alluvial aquifer adjacent to the Meramec River. Both aquifer

FIGURE 4



ORDOVICIAN SYSTEM - MOHAWKIAN SERIES

PLATTIN GROUP

Beckett Limestone (22-25 ft)

22. Limestone, like no. 20; to top of outcrop. (8-10 ft)
21. Limestone, gray to brown, slightly dolomitic, argillaceous, coarsely burrowed; weathers coarsely pitted. (3 ft)
20. Limestone, light-gray, sublithographic, heavily burrowed (0.25-0.5 in.); very hackly 0.5-1 in. beds; scattered brown chert in upper third. (10 ft)
19. Limestone, light-gray, lithographic; prominent vertical burrows; not as hackly as above. (1 ft)

Bloomsdale Limestone

Establishment Shale Member (1 ft 1 in. - 1 ft 10 in.)

18. Shale and argillaceous limestone, gray-green; hackly bedding; very fossiliferous. (4 in.)
17. Limestone, gray, argillaceous; "birdseye" structures; very irregular. (4-10 in.)
16. Shale, gray-green, blocky; two irregular 1-2-in. brown argillaceous limestone beds in middle; very irregular base; top contact with no. 17 hackly. (5-7 in.)

Brickeys Member (8 ft)

15. Limestone, light-gray, argillaceous; pebble conglomerate in upper half; base wavy, irregular; single bed. (8-10 in.)
14. Shale, greenish-gray; upper 1-2 in. fissile, lower 3-4 in. blocky; base wavy. (4-6 in.)
13. Limestone, brown, finely crystalline; upper 2 in. irregular, wavy bedded. (8 in.)
12. Limestone, gray, argillaceous; prominent "birdseye" structures; single bed that weathers to even 3-4 in. beds. (1 ft 3 in.)
11. Shale and limestone; two shale beds with limestone (like no. 10) between them; upper shale blocky (1-4 in.); middle limestone very nodular and irregular (0-3 in.); lower shale fissile (1-3 in.). (4-6 in.)
10. Limestone, dark-gray, argillaceous; very irregular beds. (2-4 in.)
9. Shale, gray-green, platy to fissile. (2 in.)
8. Limestone, brown, sublithographic, partly oolitic; very fossiliferous; basal bed 1 ft thick; upper beds 4-6 in. thick; top at base of 2-in.-thick shale. (2 ft 2 in.)
7. Limestone, light-gray, very finely crystalline to sublithographic; no oolites; bedding irregular; very irregular base; two 1-ft limestone beds with 1-2 in. shale between. (2 ft 2 in.)

Joachim Dolomite (19 ft 6 in. - 20 ft)

Metz Member (7 ft 6 in.)

6. Dolomite, buff, laminated; "birdseye" structures; bedding irregular; top irregular. (1 ft)
5. Limestone, light-gray, sublithographic; single irregular nodular bed; "Plattin-like." (6-8 in.)
4. Limestone, light-gray, laminated; base very irregular; weathers to hackly, incipient 0.5 in. beds. (1 ft)
3. Dolomite, light-gray, dense; "birdseye" structures prominent as dark gray spots; large 1-2 in. calcite-filled vugs; very irregular bedding, top very irregular; weathers tan. (1 ft 6 in.- 2 ft)
2. Dolomite, light-yellow-brown, argillaceous; red brown "birdseye" structures; 2 beds with 2-in. shale 8-10 in. below top. (2 ft 6 in.)

Matson Member (12 ft)

1. Dolomite, tan to brown, laminated to "vuggy"; laminated part tan and finely crystalline; vuggy part darker brown and coarser grained; irregular discontinuous bedding; irregular algal structures weather out (lower roadcut on exit ramp). (12 ft)

Base of exposure at I-44 level.

Matson *and* **Metz Members of the Joachim Dolomite** *and the lower part of the* **Plattin Group,** *exposed in roadcuts at the Lewis Road exit to I-44, St. Louis County, east-central Missouri, center W½ SW¼ sec. 33, T. 44 N., R. 4 E., Manchester 7½' Quadrangle. Adapted from a field description by T.L. Thompson, 1986.*

systems are used extensively for water supply in the Times Beach area. The Ordovician aquifer and the Meramec River both exert a large influence on the alluvial aquifer underlying Times Beach. The St. Peter Sandstone provides an upward gradient into the alluvial material and the river recharges the alluvium during flooding or rising river stages.

Prior to the floods of 1982 and 1983, the city of Times Beach operated two water supply wells and a distribution system for public water supply. During the floods, the system was rendered inoperable by flood waters and the city was evacuated a short time later. Prior to the installation of the city water supply wells in the 1960's, the residents of Times Beach relied on private water wells. Over 350 individual wells were on record and each had to be located and properly abandoned as part of the remediation of the site. All the private wells were shallow (30-40 feet in depth) and produced from the upper portion of the water table.

Groundwater occurs in the alluvial aquifer under unconfined conditions. The depth to water as measured to date ranges from 18 to 27 feet. Where coarse alluvial sediments are hydraulically connected to the river, water levels change significantly in response to river stage fluctuations. The definite connection to the river, the coarse materials, and direction of groundwater flow are all evidence of the potential for any contamination in the groundwater to move toward the Meramec River. The hydraulic gradient probably changes as seasonal variations in precipitation affect the stage of the Meramec River. Variations will be greatest close to the river. No dioxin has been detected in the monitoring wells at the site.

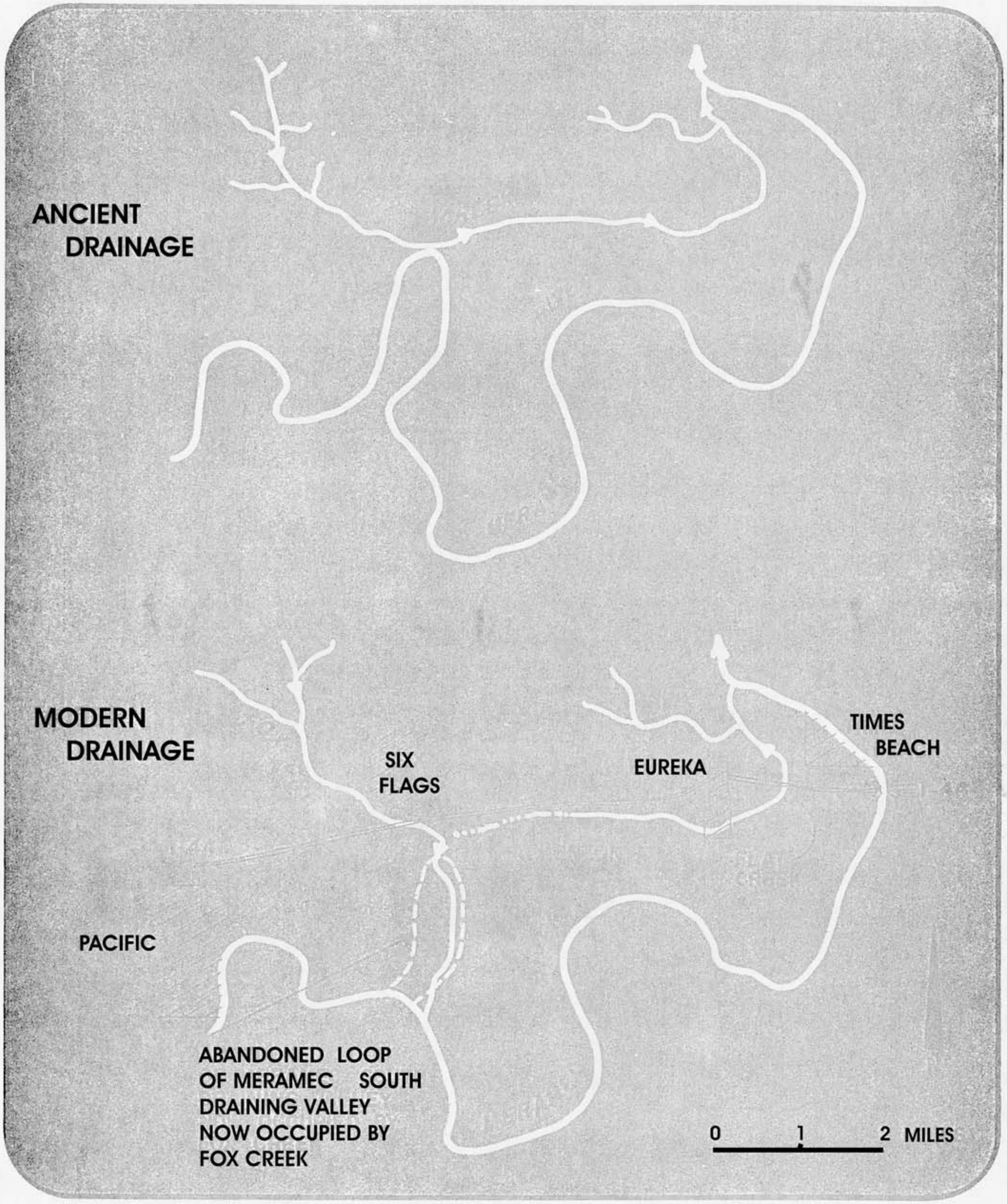
In the fall of 1991, five new monitoring wells were installed at the Times Beach site to compliment the eight existing monitoring wells installed in 1984 during the initial field investigations. The new wells were designed to detect any leakage from the demolition landfill cell or any problems associated with the disposal area for the incinerator ash. Another goal to be accomplished with the drilling program was to continuously sample all the unconsolidated materials to the depth of bedrock to help determine whether or not buried meander channels exist in the alluvium at the site. The State was concerned that they may provide preferential pathways for groundwater and contaminant movement.

The State was suspicious of such channels because the modern surface drainage of Flat Creek did not always exist as we observe it today. A stream piracy captured Fox Creek (which flows just west of Six Flags) rerouting it to the south into the Meramec River. It abandoned its ancient stream channel originally flowing directly east along the I-44 corridor to where it entered the Meramec River near Times Beach. Some effects of the original Fox Creek drainage were anticipated to be evident in the Times Beach alluvium. The exploration to date has not identified ancient channels in the alluvium. Figure 5 illustrates the stream patterns both before and after the piracy.

CONTAMINANT INVENTORY

In order to prepare for the eventual cleanup, a complete contaminant inventory of Times Beach had to be implemented. Certainly the main contaminant was the dioxin located on the roads, road shoulders, and ditches. Many other items had to be planned for as well, however. Every structure could very easily contain materials which require special handling. Every home in this country probably contains "household hazardous waste." Many of these items are very common and also very hazardous. Nationally, the average household contains 6 or 7 pounds of hazardous materials (Keffer, 1991). The small community of Times Beach included about 600 households; therefore, as much as two tons of hazardous

Figure 5



Ancient drainage (Top) and modern drainage (bottom) of the Meramec River and Fox Creek waste could be found. Additionally, the Times Beach households had been flooded, containers were exposed to the elements and leaking. Some of the structures were even unsafe to enter. The following materials have been found in Times Beach.

Class 1 Explosives

This class includes boxes of center-fire and rim-fire small arms ammunition as well as a few larger pieces of military explosive ordinance. These materials had to be wiped clean for disposal in cooperation with standard law enforcement procedures.

Class 2 Compressed and Liquefied Gases

Flammable gases included propane and acetylene cylinders as large as 1,000 gallons and cannisters of ether for starting cars. Non-flammable gases included freon from air conditioners, refrigerators, and freezers. Poisonous gases included many types of pesticides. As much as possible, large containers and gases were tested for dioxin, cleaned, and recycled. Others were collected for disposal.

Class 3 Flammable Liquids

This class included solvents, paints, aerosol sprays, naptha, wood preservatives, gasoline additives, oils, greases, and household cleaners. In addition to household concerns, some commercial structures contained drums of materials and gasoline distributors still contained petroleum products in their tanks.

Class 5 Oxidizers and Organic Peroxides

These included fertilizers, auto body plastic repair kits, and other minor materials.

Class 6 Poisons/Toxics

This category included pesticides such as chlordane, lead and arsenic pesticides, and lead paints and asbestos.

Times Beach. A perimeter air monitoring system was installed by Syntex Agribusiness, with the USEPA installing collocated units to act as a check. These monitors operate 24 hours a day and are set up to detect inhaleable particulates and dioxin. Dust is collected on a special filter which can be analyzed for contaminant particles.

The Meramec River water and sediments are sampled up river, along Times Beach, and down river at several points to document any contaminant movement by the river. Groundwater monitoring wells are likewise installed and sampled for contaminant movement. These are placed upgradient in Times Beach and downgradient to track groundwater quality. Because Times Beach is along the Meramec River floodplain, the groundwater is tied very closely to the Meramec River levels and is affected by rainfall events or droughts just like surface water levels. River sediments and groundwater are sampled quarterly to ascertain whether or not any dioxin is migrating off-site through water movement, including rainfall events.

Finally, soil borings and surface soil sampling has been completed to characterize the contaminant levels present in Times Beach. The dioxin is confined to the roadways and ditches only to a very shallow depth of generally less than one foot. Petroleum contaminants and other solvents have been found down to groundwater levels and has occurred both from dumping or leaking tanks in the past.

CLEANUP PLAN

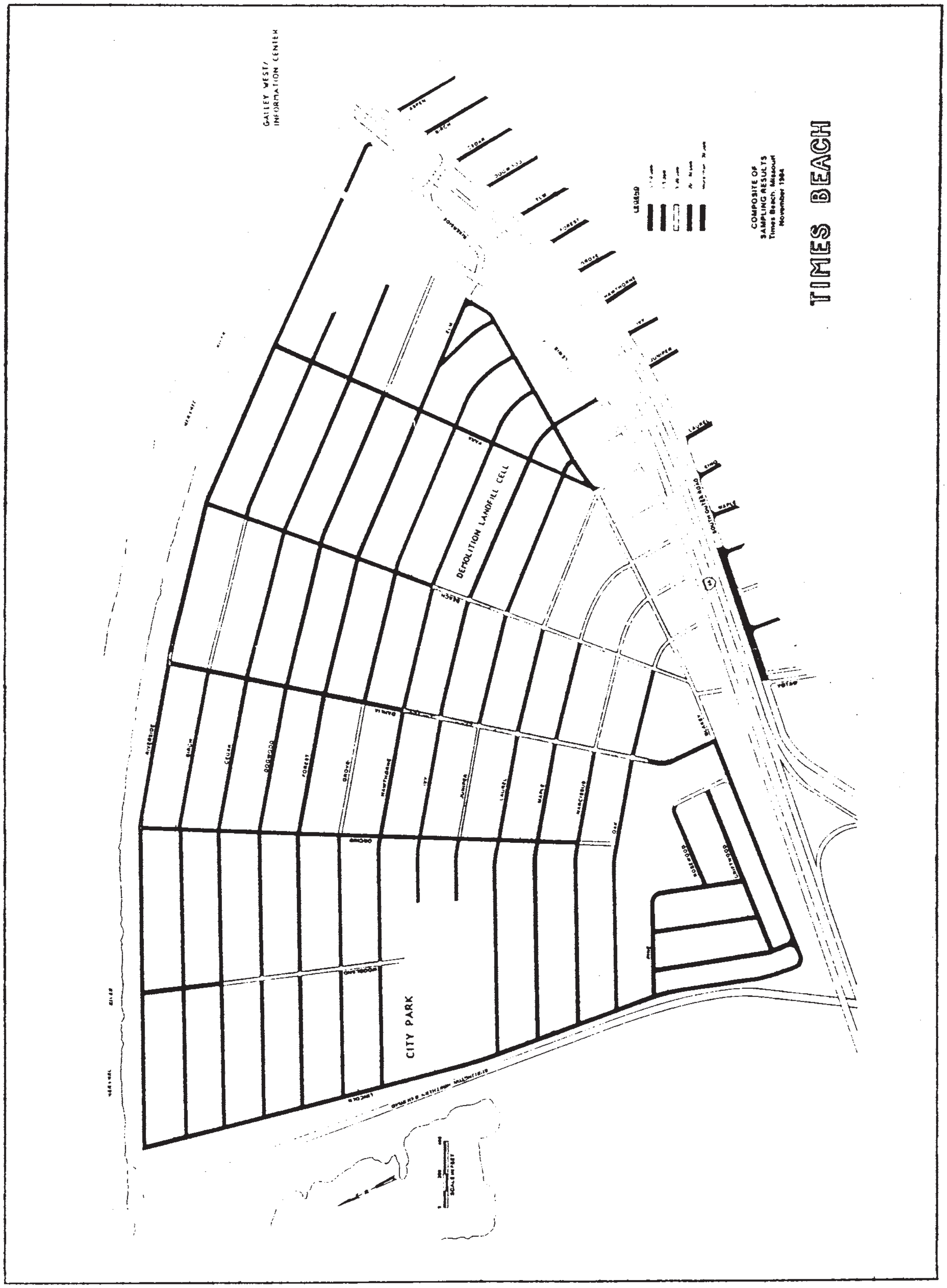
At Times Beach, most of the remedial work is to be performed by Syntex Agribusiness and their contractors, with the Department of Natural Resources and the United States Environmental Protection Agency providing oversight. A landfill cell was constructed on-site to accept uncontaminated debris from the demolition of the structures left after the evacuation of Times Beach (Figure 6). All of the structures, except for six buildings to be used during the project, have been placed in the landfill cell. Any ground disturbed by demolition activities was graded to natural contours and a vegetative cover was established. Prior to demolition, each structure was inventoried, and any household hazardous materials were removed. These materials, along with fluids extracted from vehicles left on-site, were segregated according to hazard classifications and either disposed of off site by the USEPA at an approved disposal facility or solidified and placed into the landfill cell. An asbestos survey was also taken and those structures containing friable asbestos were abated, with that material disposed of off site at an approved facility. Freon from appliances was extracted and disposed of off site.

A number of underground storage tanks were left in place when the buy out of Times Beach was completed, and it became the responsibility of the Department of Natural Resources to remove those petroleum tanks that were leaking. All contaminated soils were excavated, combined at one location within Times Beach at a non-dioxin location, and remediated on-site by a combination of landfarming and biological degradation. About 3,000 cubic yards of contaminated soils were treated by this method. Sampling has shown that the soils are now acceptably clean and support vegetation.

In the former city park area, contamination by several different chemicals was possibly caused by illegal dumping. The USEPA is in the process of devising a method for remediating that area.

The next phase of work at Times Beach will be to construct a ring levee in which the incinerator will be placed, after approval of the RCRA permit for dioxin incineration. This levee will be three feet higher than the projected one hundred year flood. The remediation of materials contaminated by 2,3,7,8 TCDD (dioxin), due to the actions of Russell

FIGURE 6

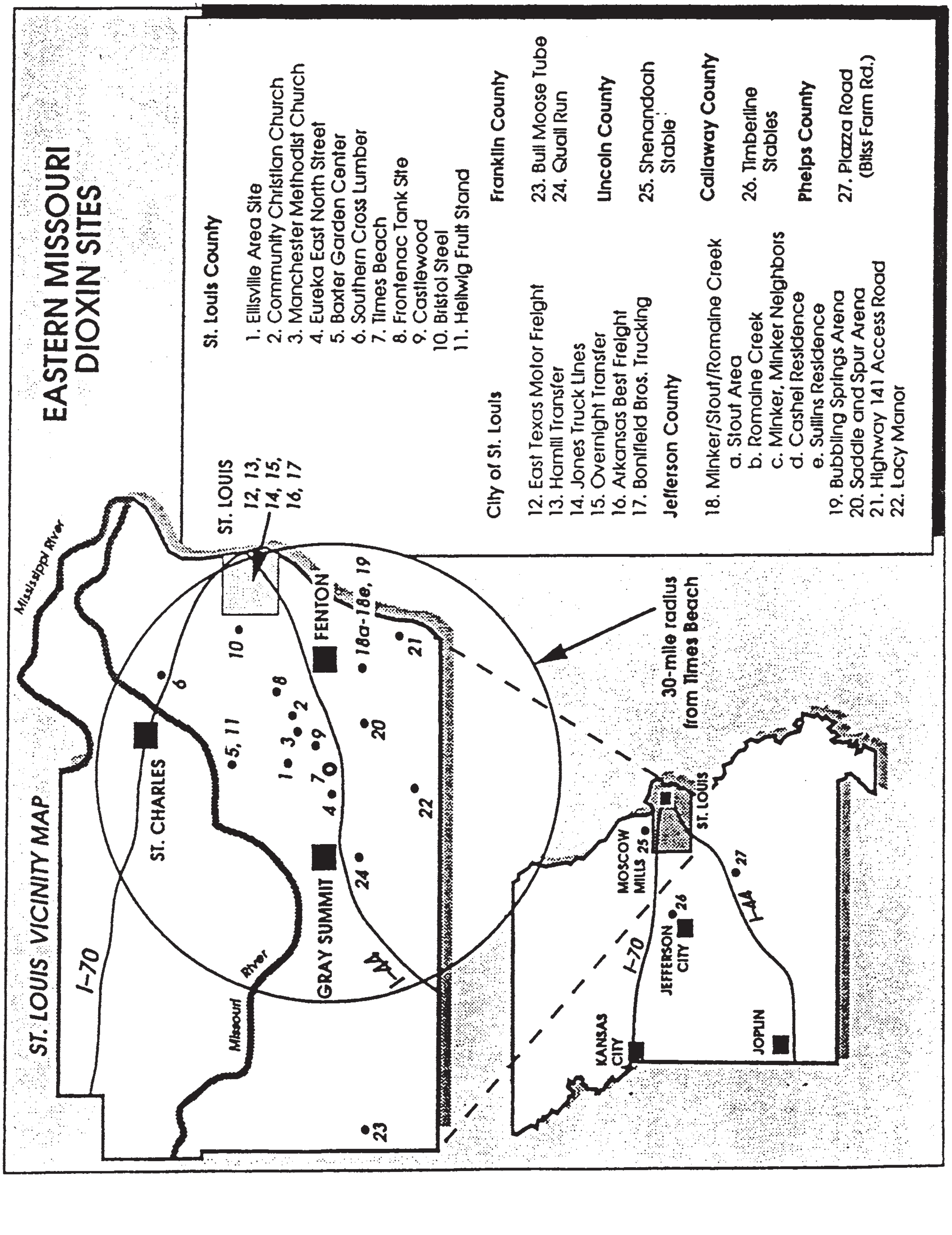


TIMES BEACH
COMPOSITE OF
SAMPLING RESULTS
Times Beach, Missouri
November 1984
LEGEND
DEMOLITION LANDFILL CELL
CITY PARK
GATLEY WEST/
INFORMATION CENTER

Bliss, is governed by a Consent Decree signed by Syntex, the USEPA, and the State of Missouri. That decree and the accompanying work plans define specifically the work that each party is responsible for during the remediation of 27 of the 45 identified dioxin contaminated sites (Figure 7). The remaining sites do not pose any significant threat to the public. Thus far the USEPA, which is responsible for remediating all of the sites other than Times Beach, has completed the remediation of fourteen of the larger sites. That contaminated material, approximately 60,000 cubic yards to date, is in temporary storage in buildings constructed on those sites. This material will be transported to Times Beach when the incinerator is operating. The dioxin cleanup levels for those other areas, as recommended by the Center for Disease Control, is less that one part per billion (<1ppb) at the surface and <10ppb under one foot of clean soil.

EBASCO, contractor for Syntex Agribusiness, will remediate the dioxin contaminated streets of Times Beach. This will be completed by one of two methods. In those areas where the contamination is <10ppb, the soil can be inverted so that a one foot layer of clean soil is covering the contaminated soil. In areas where contamination is >10ppb, the soil will be excavated and burned in the incinerator. In either case, the contamination must be <1ppb at the surface after remediation. This will be verified by sampling and laboratory analysis. After the soil has been incinerated, it will be deposited in trenches and covered with two feet of clean soil. The treatment technology involved in the incineration process may be simplified as follows. Dioxin is created as a wasted product from the incomplete combustion of organic materials such as petroleum products. Incineration will complete the oxidation process in the organic materials which effectively destroys the dioxin.

FIGURE 7


EASTERN MISSOURI
DIOXIN SITES
St. Louis County
1. Ellisville Area Site
2. Community Christian Church
3. Manchester Methodist Church
4. Eureka East North Street
5. Baxter Garden Center
6. Southern Cross Lumber
7. Times Beach
8. Frontenac Tank Site
9. Castlewood
10. Bristol Steel
11. Hellwig Fruit Stand
City of St. Louis
12. East Texas Motor Freight
13. Hamill Transfer
14. Jones Truck Lines
15. Overnight Transfer
16. Arkansas Best Freight
17. Bonifield Bros. Trucking
Jefferson County
18. Minker/Stout/Romaine Creek
a. Stout Area
b. Romaine Creek
c. Minker, Minker Neighbors
d. Cashel Residence
e. Sullins Residence
19. Bubbling Springs Arena
20. Saddle and Spur Arena
21. Highway 141 Access Road
22. Lacy Manor
Franklin County
23. Bull Moose Tube
24. Quail Run
Lincoln County
25. Shenandoah Stable
Callaway County
26. Timberline Stables
Phelps County
27. Piazza Road (Bliss Farm Rd.)
ST. LOUIS VICINITY MAP
I-70
Missouri River
Mississippi River
ST. CHARLES
GRAY SUMMIT
FENTON
ST. LOUIS
12, 13, 14, 15, 16, 17
18a-18e, 19
30-mile radius from Times Beach
I-44
KANSAS CITY
JEFFERSON CITY
MOSCOW MILLS
JOPLIN

After all of the contaminated soil from eastern Missouri has been incinerated, the incinerator will be removed from Times Beach. The ring levee will be removed, and the area will be graded to natural contours. After establishment of a vegetative cover, most signs of human influence will have been eliminated. Times Beach will become a recreational landmark for the State of Missouri which will signify the importance of the proper management of all hazardous materials.

The Eureka-House Springs structure -- *Which structure are we discussing?*

C.W. Clendenin[1], M.A. Middendorf[2], T.L. Thompson[2], J.W. Whitfield[2]

During the past year, several discussions have been held in the field about the question of what one thinks of when the Eureka-House Springs anticline or structure is mentioned. The Eureka-House Springs structure is described by McCracken (1971, p. 29) as "part of an anticlinal structure that extends from near Riverside in Jefferson County on the Mississippi River through the House Springs-Eureka area ... northwest across the Missouri River ... to north of New Melle." An anticline commonly cored in outcrop by St. Peter Sandstone can be traced from Sulfur Springs northwestward along Glaize Creek through the House Springs-Eureka area to north of St. Albans island where the fold crosses the Missouri River. Mapping indicates that this anticline is fairly continuous along strike and that it plunges southeast toward Sulfur Springs and northwest across the Missouri River toward Defiance. Exposures along both Glaize Creek and the Missouri River show that the fold is asymmetric with a steeper northeast flank.

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The dilemma is that *this anticline* is not the structure prominently exposed in several roadcuts in the Eureka-House Springs area. The structure exposed south of Eureka on Route W and northeast of House Springs on Highway 30, which is referred to as the Eureka-House Springs structure, is part of what is herein termed the Eureka fault system. The Eureka fault system strikes northwest and lies to the southwest of the previously described anticline. The two structures are subparallel and are separated by less than 1000 m through the House Springs-Eureka area. The juxtaposition of the two structures and the structural style of fault deformation in the House Springs-Eureka area are believed to be reasons for previous lack of differentiation.

The Eureka fault system is one of a number of northwest-striking faults in eastern Missouri. The fault system consists of three en echelon fault segments which are right-stepping to the northwest (See Map). The fault segments are referred to here, from southeast to northwest, as the Heads Creek segment, Rockwoods segment, and Tavern Creek segment, respectively. The Heads Creek segment extends northwest from north of Riverside, crosses Interstate 55 north of Pevely, continues south of Otto, and is finally lost in the northwest-trending Heads Creek valley. The Rockwoods segment overlaps the Heads Creek segment north of Otto; overlap represents the first right step in the fault system in a northwest direction. The Rockwoods segment can be traced northwest through the House Springs-Eureka area across Interstate 44 to Highway 100 and is finally lost at St. Albans on the Missouri River. The Tavern Creek segment overlaps the Rockwoods segment near Hollow on Highway 100, creating the second major right step in faulting. The Tavern

Creek segment extends northwest from Hollow to where it crosses the Missouri River at St. Albans island and is lost northwest of Boone's Home on Femme Osage Creek in St. Charles County.

Faulting on each segment is confined to a relatively narrow linear zone dominated by sub-vertical fault planes. Intensity of deformation and number of sub-vertical fault planes varies along strike of each segment. Such fault planes are marked by sub-vertical to sub-horizontal slickensided striae, and vertical offset of beds indicates a dip-slip component. Low-profile marginal thrusts or splays marked by reverse separation diverge upward and outward from sub-vertical faults, and splays can be traced 10's of meters from the throughgoing fault. Splay vergence reverses from southwest on the Heads Creek segment to northeast on the Rockwoods segment and back again to southwest on the Tavern Creek segment.

Changes in splay vergence and in intensity of deformation characterize structural style along the Eureka fault. Harding (1990) points out that such fault characteristics are reliable indicators of convergent strike-slip faulting. En echelon fault segments and relatively linear zones of deformation support the interpretation of strike slip faulting based on structural style. Offset stratigraphic contacts along the Rockwoods segment provide ground proof of strike slip faulting and indicate a minimum of 10 km left-lateral offset exists on the Eureka fault. However, deformation asymmetries and slickensided striae, where visible, indicate oblique rather than pure strike-slip displacement occurred along the fault. Bartlett et al. (1981) explained that a small amount of dip-slip offset between forcing blocks results in asymmetric splaying over the down-thrown side.

Structural style varies more on the Rockwoods segment than on the other two segments. From St. Albans to Highway 100, faulting on the Rockwoods segment is characterized by a zone of vertical slabs that rose upward periodically through the Paleozoic. Stratigraphic markers indicate movement on this segment occurred during Middle-Late Ordovician, Middle Devonian, and post-Mississippian. The segment bifurcates southeast of Highway 100 into two branches which bound a downdropped block of Kimmswick Limestone along Fox Creek road just west of Six-Flags Amusement Park (See Map). The southern branch can be traced southeast to Hoene Spring. The northern branch of the segment is the structure commonly referred to as the Eureka-House Springs anticline and can be traced to north of Otto.

In the Route W roadcut south of Eureka, three periods of deformation are recognized. The first period of deformation produced an asymmetric anticline that verges to the northeast. This fold is interpreted to be the result of drape folding above an underlying fault block with a down-to-the-northeast dip-slip component. Folding occurred prior to propagation of a sub-vertical fault plane upward through the crestal area of the fold; this faulting marks the second period of deformation. The third period of deformation is defined by a set of north-northeast-verging low-profile imbricate thrusts. Intensity of deformation varies across the road cut; and on the east side, a low-profile thrust deforms the steeper northeast flank of the drape fold fault into a thrusted force fold. Although the imbricate thrusts tend to mask earlier periods of deformation, the trap door nature of thrusting near eroded ramps can be traced southeast toward Highway 30.

In roadcuts along Highway 30 northeast of House Springs, structural style is quite different from that observed on Route W. The principal displacement fault is on the northeast end of the roadcut and is marked by a sub-vertical plane with sub-horizontal slickensided striae which dip 20° west. Northeast-verging splays diverge from this fault, and reverse separation eliminates Ordovician section. Southwest-verging shears and a pronounced southwest-verging recumbent fold in the uplifted block indicate post-Mississippian movement on the fault. The overall structural style exposed in this roadcut is a large flower structure along a convergent strike-slip fault.

With a down-dropped block lying to the northwest along strike of the Rockwoods segment, uplift to the southeast in the House Springs-Eureka area is believed to have resulted from deformation of a southeast turn (i.e., compressive bend) in the northern branch of the fault segment. Such a compressive bend would have resulted in antiformal folding and imbricate thrusting as the underlying blocks converged at the southeast turn during episodes of left-lateral strike-slip faulting. Although a true anticline lies immediately to the northeast, this strike-slip structural style has confused mapping in and discussions of the House Springs-Eureka area for many years. The two structures do need to be clearly differentiated, and the Eureka fault system needs to be added to the list of known northwest-striking faults in eastern Missouri.

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Harding, T.P., 1990, Identification of wrench faults using subsurface structural data: Criteria and pitfalls: Amer. Assoc. Petro. Geol. Bull., v. 74, p. 1590-1609.

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THE HIGHWAY 100 ROADCUT

Carol S. Sutherland*
Arthur W. Hebrank**

In western St. Louis County, Highway 100 dramatically exposes part of the Eureka-House Springs structure, a complex fault/anticline, approximately 30 miles long with a general NW-SE strike. The center of this roadcut lies 0.5 mile east of the St. Louis County/Franklin County line and rock exposures extend for 0.3 mile on both sides of Highway 100.

This section of the structure is heavily faulted, exhibiting vertical or nearly vertical normal fault segments as well as some apparent compressional faults. Several of the fault zones are characterized by fault gouge and slickensides.

The oldest formation observed at this location is the middle Ordovician Plattin Limestone, which is overlain by the Decorah Group (parts of which contain abundant brachiopod and bryozoan fossils), which in turn is overlain by the Kimmswick Limestone. Mississippian formations include the Bachelor, Fern Glen and Burlington (the latter containing abundant crinoid fragments).

An apparent filled sink containing Pennsylvanian sandstone and shale is located near the western end of the roadcut.

The graphic sections published here were reduced from originals measuring 13.3 feet (south side) and 31.6 feet long (north side). The roadcuts were first photographed in segments; the photos were enlarged and mosaics prepared. Rock exposures were field "mapped" directly onto the photos. Finally, graphic sections were drafted, based on the photo mosaics.

The purpose of this project was simply to prepare detailed geologic sections of the Highway 100 roadcuts. No attempt was made by the authors to analytically examine this or other exposed segments of the Eureka-House Springs structure (Highway W, Eureka; Highway 30, House Springs; I-55; etc.) or to develop an in-depth structural history interpretation.

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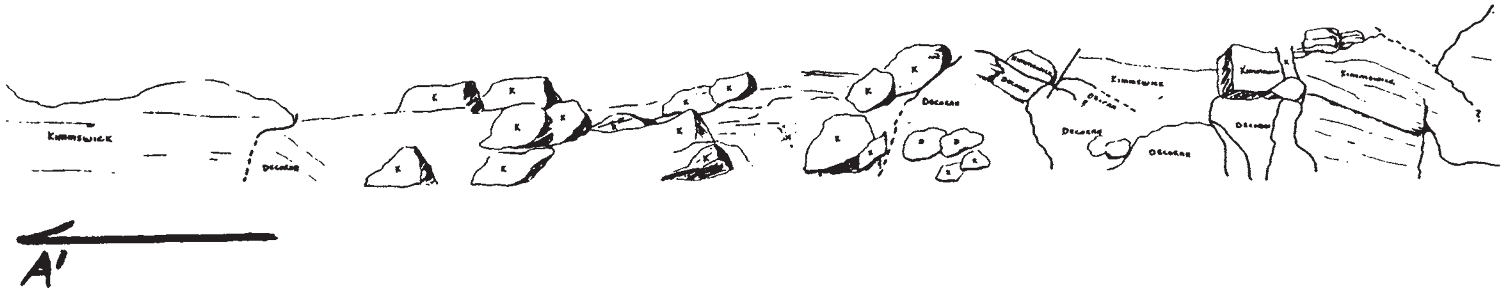
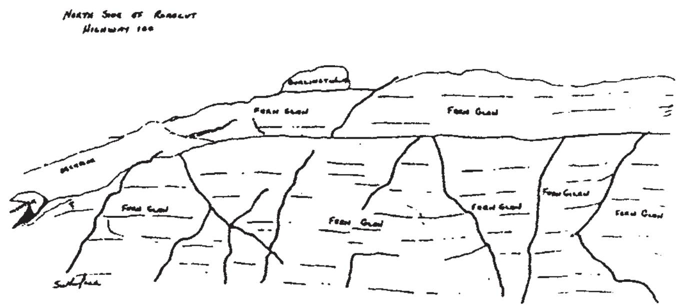
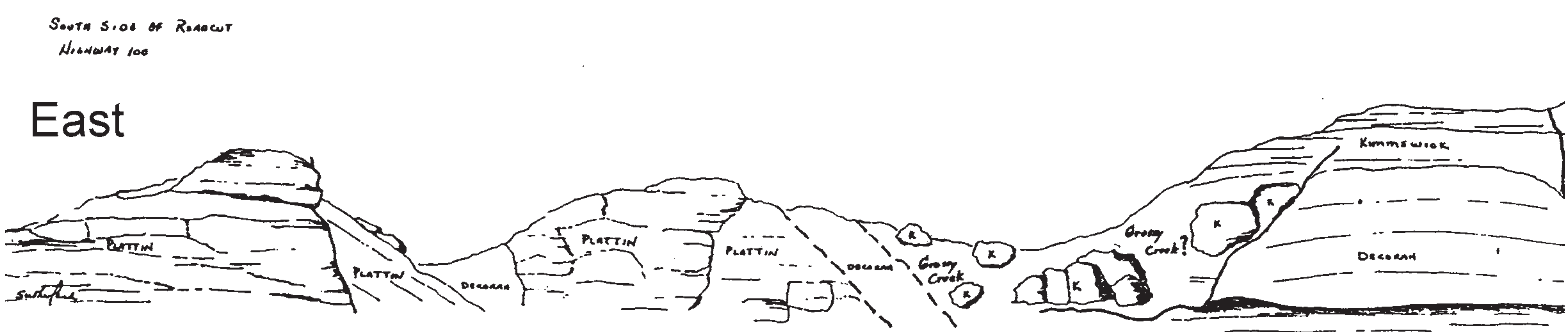


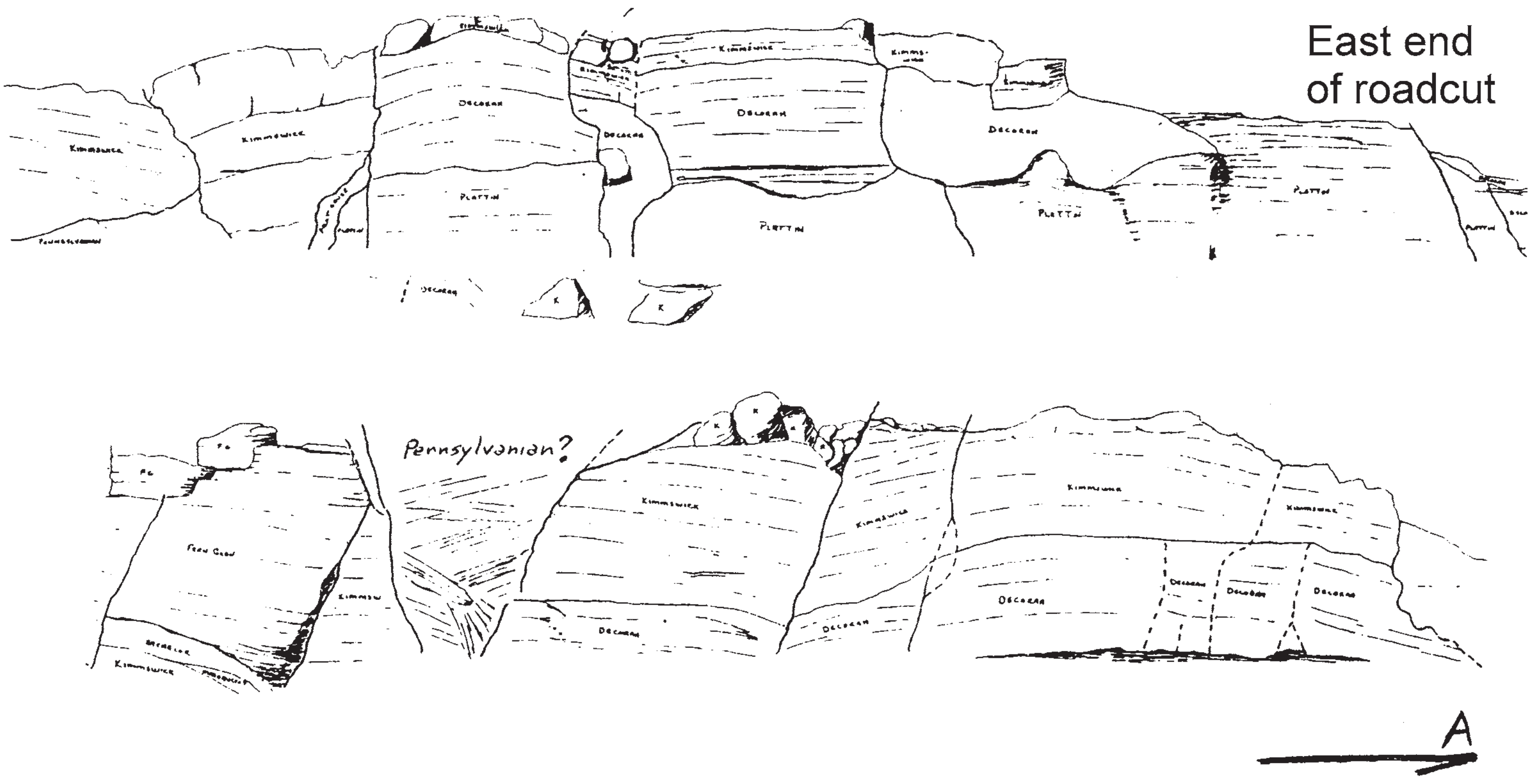
West end of
North side of roadcut

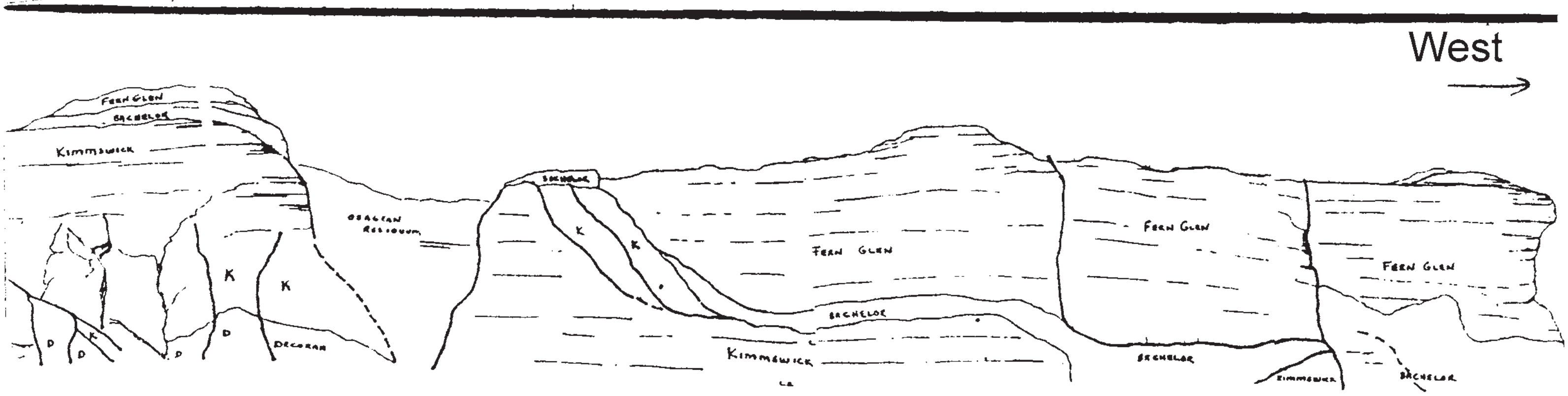


East



<u>South side of Hy. 100</u>





South side of Hy. 100

Hy. 100 roadcut

IMPACT OF FIELD CONDITIONS

ON

ROUTE 21 DESIGN

Rich Johnson & Ray Linebach

In the mid-60's the Missouri Highway Department proposed to upgrade Route 21 from Route 141 to south of Route M in Jefferson County, a distance of about 10 miles. The then current location of Route 21 was basically a ridge road consisting of a series of sharp horizontal curves without adequate passing sight distance throughout much of its length. These deficiencies made renovation of the existing alignment impractical and not cost effective. This stretch of old 21 was hazardous if not traveled prudently. Driver error and impatience contributed to a high accident rate which included a fairly large percentage of fatalities. Once a relocation of this section had been determined, the Jefferson County Commission pushed for a "scenic highway" which would enhance this portion of their county and showcase the beauty of the landscape. The State Highway Commission agreed to this concept and proceeded with the design. Because of the steepness of the terrain and frequency of side hill conditions, a split grade design was selected. This allowed the designer to take advantage of the side-hill slope and reduce the amount of excavation. In order to accomplish the split grade, a wide median was incorporated and many "no clear" areas resulted within the median. A "split grade" means one set of lanes are built at a different elevation and gradient than the other set. This helps keep the southbound vehicles from being distracted by the passing northbound vehicles, and vice-versa. It is tantamount to building two highways, and increases the cost considerably. Even though many grades were near the highest permissible level, some cuts and fills still generally averaged 80 feet. The large cut just south of Heads Creek road, near the end of this job, is reputed to be the second largest single highway cut in Missouri's history, with over one million cubic yards of material excavated.

Field work for the geologic survey began in the spring of 1969. This stretch of road approaches and crosses the more steeply inclined beds at the rim of the Ozark dome. From northeast to southwest we encounter the Warsaw, Burlington-Keokuk, Fern Glen, Batchelor, Bushberg, Maquoketa, and Kimmswick formations. Topographic relief in the area is on the order of 340'. In order to design grades and slopes, the soil and rock materials involved have to be identified and classified according to various factors which determine internal stability. In addition, the quantities of cut and fill should have a rough balance, that is the volume of excavation should equal the volume of embankments proposed. Usually, soil will reduce in quantity as it is compacted in a fill, and rock will "swell" when it is shot. To be able to calculate earthwork quantities, the designer needs a soil/rock line on the cut cross-sections (every 100'), and shrink and swell factors. Obviously, the magnitude of excavation proposed here would call for close control of these parameters in order to project quantities with any accuracy. All of this information is gathered in the field with a routine drilling program including NX rock cores, undisturbed soil samples, and a pattern of auger borings across each cut cross-section. The design evolved through a series of modifications, and geology field work continued, off and on, until about the time the first contract was let in the summer of 1985.

The sequence of lithologies in this geologic setting presented some interesting problems. The fill material would be composed of cohesive soils with considerable granular material in the form of chert, limestone boulders, and sand. In general, it compacted into a dense embankment with adequate internal strength to stand on a 2:1 slope. Cavernous ground was not a significant problem in fill areas and there were no major stream crossings, so fill and fill foundation stability were not a source of concern.

Classification of materials in place and cut slope design was a much more difficult undertaking. The bedding sequence of Burlington/Fern Glen over Bushberg over Kimmswick in the hills traversed by Rte. 21 was the cause of the difficulty.

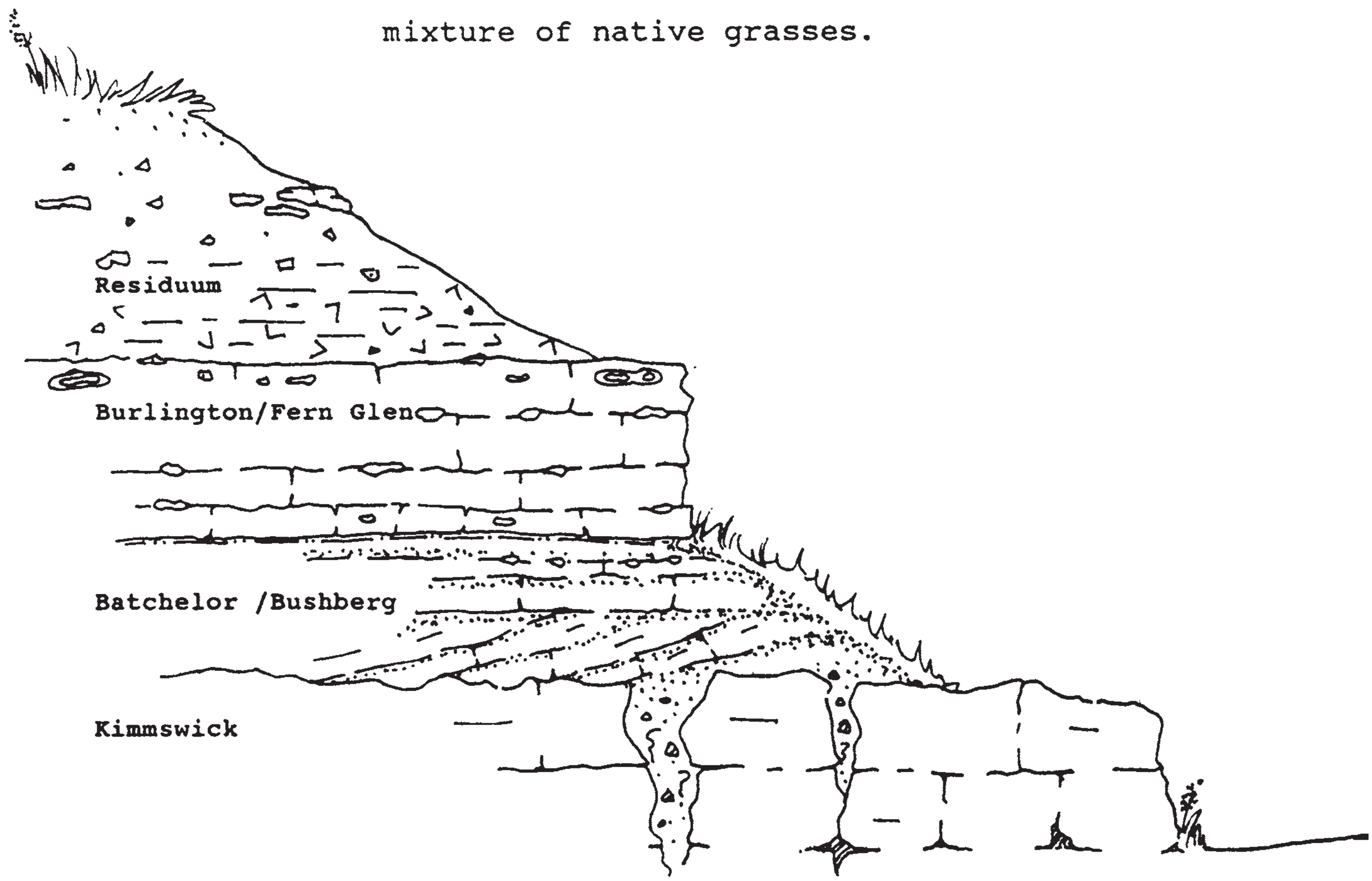
Visual examination of the natural slopes was misleading. They were very steep, with coarse scree, and ledges of rock appeared to outcrop about 2/3 of the way up the hillsides. It was easy to visualize hills of solid rock with a thin soil cover. This notion was reinforced as auger bits usually found a limestone or chert boulder in the coarse residuum well above competent rock, conjuring up an erroneous rock line. Those holes that reached depths of 40′ were thought to have penetrated an enlarged joint. The false rock lines that were generated were extremely irregular, suggesting a rock surface with relief of as much as 35′. This was eventually disproved by the core logs. The residual mantle of Burlington residuum was found to be 35′ to 40′ thick at ridge summits, thinning to a few feet near the toe of slopes. The apparent outcrops in the upper part of the slopes proved to be floaters. Even after the true depth of the residuum was established it was difficult to draw a rock line with a sharp pencil. There was a gradual transition from soil to competent limestone. Residual clay graded with depth into a breccia of fractured chert which graded into typical Burlington facies. This transition material contained up to 80% dense, glassy-textured chert. It was angular and interlocked so it would not let drill bits "push" through it. The core drills made slow progress for the same reason as the auger drills: the residual soil/chert armor was extremely abrasive, and roller-cone bits wore rapidly. Also, the drillers expected to set casing within 15′ feet of the surface (as indicated by the auger borings) and often had to pull and reset their casing after coring through a boulder. That and the steep terrain and thick vegetation prolonged the drilling program considerably.

Once casing had been set and the core barrel had encountered solid limestone, drilling was fairly routine except that circulation of drilling water was usually lost to a joint or other void in the rock. This meant additional water had to be hauled from the nearest stream, slowing work even more. Another source of aggravation was soon apparent: the danger of "sticking" the diamond bit in the sand bed under the Fern Glen fm. The Fern Glen/Batchelor contact is an abrupt line of solid limestone over poorly cemented sand. The down-pressure required to core the cherty limestone is considerably more than necessary to cut the soft sand below it. The bit would suddenly "drop", displacing more sand than could be flushed with the drilling water, plug up the bit waterways, and the sandstone cuttings would immediately seize the core barrel. In this event the drill string would have to be driven back with a slide hammer until free.

Over much of the project area the streams are incised to the depth of the Kimmswick fm. It is massive, coarsely crystalline, and virtually pure calcium carbonate and dissolves relatively quickly by groundwater. Joints are enlarged and mud-filled wherever the Kimmswick outcrops. The overlying Bushberg fm., up to 20' thick, functions as a blanket sand drain, facilitating groundwater movement through the Burlington/Fern Glen into the Kimmswick. Small caves and wet weather springs are commonly associated with the Kimmswick in the area.

Cut slopes in the Kimmswick were designed on the vertical, but where possible, with enough bench on top to accommodate a 2:1 slope because of the wide mud-filled joints. Slopes of

Batchelor/Bushberg were all cut at 2:1 and capped with soil and seeded for erosion control (crown vetch). Slopes of competent Fern Glen and Burlington were cut on the vertical. Chert breccia and residuum was graded on 2:1 slope and seeded with a mixture of native grasses.



The scenario envisioned is that of a low-lying erosion surface underlain by a massive, thick, limestone, high in calcium content. Acid phreatic conditions over time would have carried away the carbonate cement leaving the insoluble clay minerals and nodular chert typical of the Burlington. With uplift, the bedded chert settled and broke up into a collapse breccia of angular chert fragments in a clay matrix. At ridge summits, where the oldest surfaces are preserved, small filled-sink structures containing Pennsylvanian and younger sediments are common.

There are local indications that uplift is on-going. Cross-sections of valleys which have developed floodplains clearly show channels are currently being deepened. In many cases where rock is exposed in stream channels it is being degraded as well as the alluvium. In the reconnaissance stage for the Route 21 relocation and the proposed Route M relocation, vertical control in the area was researched. Survey traverses were run along M from the Mississippi river to Route 21 (8 miles +/-), and from the Meramec river along 21 to Rte. M (10 miles +/-). USGS benchmarks show an increasing positive elevation error from east to west and from north to south along these traverses. These data indicate that the surface of the northeast flank of the Ozark dome has experienced a slight tilt to the northeast in the last half century.

MISSOURI'S CRINOID GARDENS (stop #4)

Last winter, fellow fossil collector Bob Schmidt showed me a piece of Ordovician limestone (Kimmswick formation) which was composed almost entirely of crinoid root systems. This occurrence was very unusual for the Kimmswick formation. Shortly thereafter, Bob showed me the roadcut where he found it. About halfway up the roadcut, I made an exciting discovery, a massive echinoderm reef, composed of thousands of crinoid holdfasts, perfectly exposed and cleaned by natural forces.

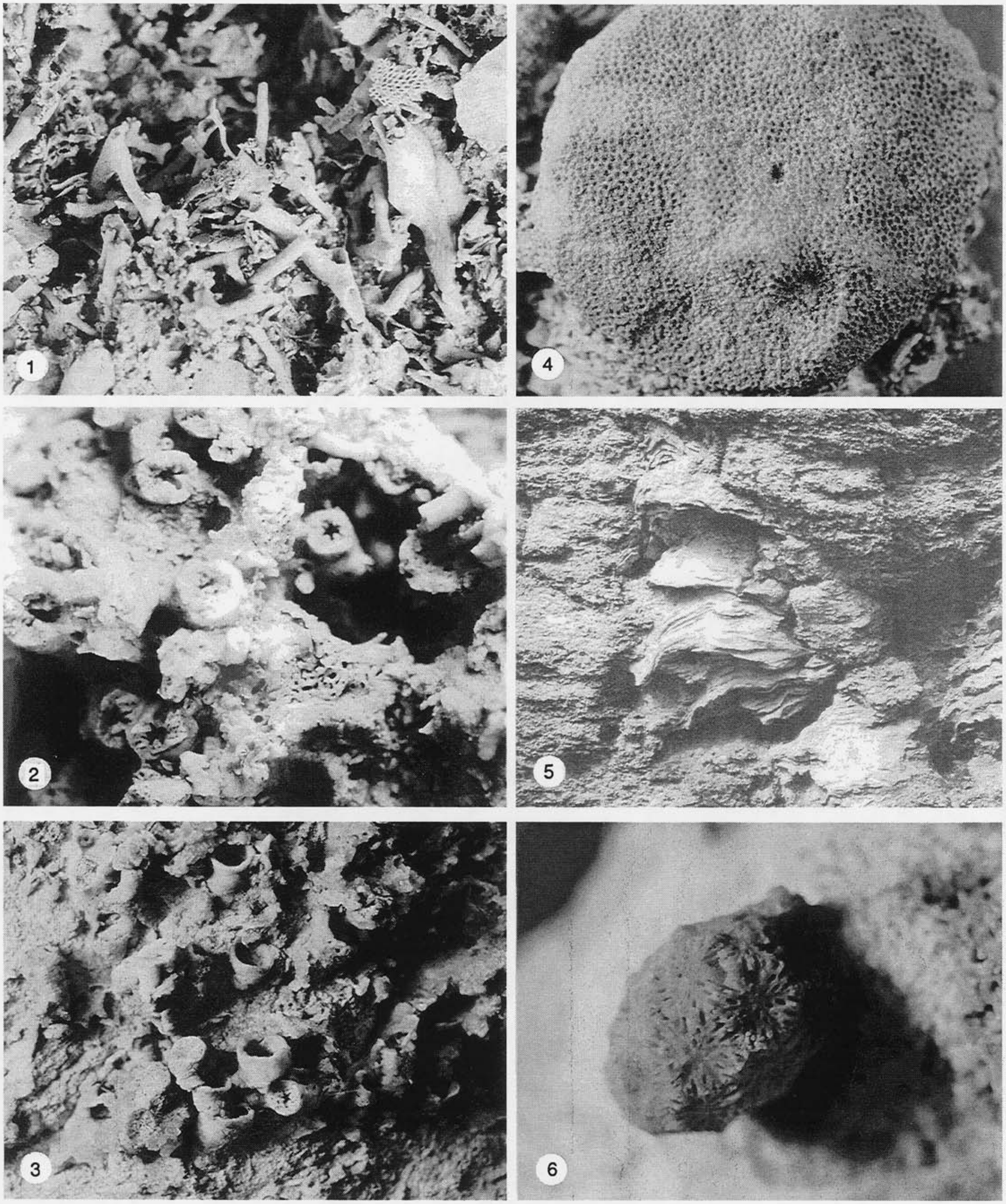
Preliminary studies of the site seem to indicate an unusual sub-tidal environment where opportunistic animals built up colonies on irregular masses of cemented sediment. These irregular masses were probably created when crinoid root systems, bryozoans and stromatoporoids formed an organic layer on the ocean bottom. Storms may have washed away the sediment surrounding these encrusted areas, leaving them on a raised surface. As more and more organisms attached themselves, the surface area increased. In time these hard, free-form shapes became the dominant features on the sea floor, providing nooks and crannies for a variety of exotic animals. Periodicly, these reef-like structures were buried by sediment which helped to preserve the delicate animal life. A few of the other reef inhabitants are shown on page 14. One can only imagine the beauty and color of thousands of swaying crinoids and cystoids that once thrived in this very spot more than 450 million years ago.

STROMATOPOROID REEFS (stop #4)

To geologists, roadcuts are like books that you read while traveling down the highway. And every once in a while, one of these books provides a natural window to the past - stop #4 is such a window. The most striking features exposed are the stromatoporoids (sponges) which look like stalagmites growing from the sea bottom. These sponges provided a living substrate for many animals to attach, much as coral reefs do. If you look directly under the base of the stromatoporoids, you can see a mass of crinoid root systems. These intertwined roots formed a solid footing which allowed the stromatoporoid to withstand storms or currents.

As it grew larger and taller by producing new layers, animals such as corals, bryozoans and cystoids would attach themselves. These stromatoporoid pillars are relatively unabraded, which seems to indicate that they were quickly and completely buried. If you look closely at the coarse, sandy sediment surrounding the sponges, you will notice that it is composed of mostly fossil debris. Also notice the cross-bedding due to wave action and currents. To identify other animals that lived on the reef, match the following numbers with the indicator numbers on the roadcut.

#1. Crinoid calyx (head).
#2. Nautiloid cephalopod, a squid-like mollusk.
#3. Crinoid calyx.
#4. Stromatoporoid (sponge)
#5. A colonial coral.
#6. Crinoid root systems.
#7. Cystoid calyx.
#8. Brachiopod.
#9. Toppled stromatoporoid, reflecting possible storm action.



REEF ANIMALS

1. Close-up of the small fossil animals which make up the Kimmswick formation. 2. Crinoid root systems. 3. edrioasteroids, exotic relatives of the of the crinoids. 4. Colonial coral. 5. Stromatoporoid (sponge). 6. Cystoid calyx.

Some Notes on Outcrops seen on the October 3rd Field Trip

NE Ozark Escarpment

B. L. Stinchcomb

BUSHBERG SANDSTONE. New highway 21 cut near Shady Valley. Thick, cross-bedded sandstone overlying phosphate pebble bearing sandstone is exposed on the southbound lane of Highway 21 just above thin grey Maquoketa shale, .6 mile south of Rock Creek.

Is the cross bedded sandstone a fluvial deposit? Abnormally thick in this area, this highly cross bedded sandstone has no marine fossils. Some Bushberg outcrops are fossiliferous and the sandstone can grade both vertically and laterally into the fossiliferous Glen Park limestone.

HOUSE SPRINGS QUARRY -

The thick Plattin limestone exposed here is quarried in the NE Ozark escarpment area, usually for crushed rock for the St. Louis market and adjacent areas. Urbanization has made the extensively utilized St. Louis limestone of Mississippian (Meramecian) age less accessible for quarry operations and many operations have been relocated to northern Jefferson County in the Plattin limestone.

The Kimmswick is quite thin here but is quarried along with the Decorah and Plattin formations. The Kimmswick thickens to the east to over 100 ft. along the MIssissippi River. Maquoketa is also quite thin and forms the top of the main quarry face.

The Mississippian Fern Glen (Mappin) and Burlington limestones are also quarried, however, the silty and cherty nature of parts of these two units can result in a less marketable crushed stone.

NORTH BOUND EXIT OF HIGHWAY 21 ONTO OLD HY. 21.

Large cuts in the Kimmswick limestone exhibit a profile intensely affected by solution. Joints in the Kimmswick appear superficially to have been enlarged by solution. Close examination of the joint surfaces show pelmatazoan holdfasts (cystoids?) in place, seemingly emplaced so that the animals grew in a depression or possibly in a sea cave.

Might this exposure reflect a mid-Ordovician submarine Karst system? See front cover of field trip guidebook by Guy Darrough.

Stromatoporoids are quite frequent in this sequence. In light of the environment of a submarine Karst system it is interesting that stromatoporoids are now considered to be a type of sponge (sclerosponge) and not a coral! Living sclerosponges were found recently (1985) to be living in submarine caves in Jamaica. Might some of these Kimmswick occurrences have had a similar occurrence along with the pelmatazoans?

ST. PETER SANDSTONE AT PACIFIC -

The St. Peter forms the basis for an extensive glass manufacturing industry. Without this easily mineable, high purity, raw material, would high quality glass such as used in "one way" bottles etc. be possible?

The St. Peter - Joachim contact is quite sharp. The St. Peter in part of the operations is being mined by room and pillar with the Joachim as the cap rock.

BUSHBERG SANDSTONE - HY. 100 CUT -

On the south side of this geologic complex, part of the Eureka-House Springs Anticline, phosphate pebble and placoderm tooth-bearing sandstone occur. However, cross-bedded sandstone such as found in Jefferson County is absent. The grey shale on the south cut is presumably Grassy Creek. Ptychodus Teeth also have been found in it.

FINAL STOP - GROVER GRAVEL, ROCKWOODS RESERVATION -

The provinance and age of these gravels remains problematic. Most of the cobbles and pebbles are chert and chert types characteristic of the Ozarks. However, cobbles of red or purple quartzite occur suggestive of the Sioux or Baraboo quartzite of mid-Proterozoic age. This would suggest a northern provinance, perhaps ancestral Missouri or Mississippi river deposits. These gravels are underlain by Pennsylvanian paleokarst deposits. The site was mined in the 1940's for both gravel, fire and tile clay.