FIELD TRIP GUIDEBOOK

53rd Annual Meeting

Sikeston, Missouri
October 6-7, 2006

ASSOCIATION OF MISSOURI GEOLOGISTS

GUIDEBOOK TO FIELD TRIPS

53rd ANNUAL MEETING
OCTOBER 6-7, 2006
SIKESTON, MISSOURI

FIELD TRIP 1, FRIDAY, OCTOBER 6
Chronister Mesozoic Vertebrate Fossil Site Bollinger County, Missouri

Lead by:

Dr. Bruce L. Stinchcomb (emeritus)
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Ferguson, Missouri 63135

FIELD TRIP 2, SATURDAY, OCTOBER 7
Earthquake and Mississippi Embayment Geology of Southeast Missouri

Lead by:

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ASSOCIATION OF MISSOURI GEOLOGISTS

53rd ANNUAL MEETING AND FIELD TRIPS

OCTOBER 6-7, 2006
SIKESTON, MISSOURI

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James Burton for permission to examine the soil cut bank on his property on Crowleys Ridge near Idalia.

Association of Missouri Geologists
2006

Field Trip 1:
Chronister Mesozoic Vertebrate Fossil Site Bollinger County, Missouri

Bruce L. Stinchcomb
St. Louis Community College at Florissant Valley

CHRONISTER VERTEBRATE SITE

Bruce L. Stinchcomb

INTRODUCTION

One of Missouri's geologic anomalies is the Chronister Mesozoic vertebrate fossil Site. Anomalous because most of the state is underlain by Paleozoic or Precambrian rocks rather than Mesozoic and also because the rocks of the site are non-marine or "continental" deposits to quote E. B. Branson who mentioned the site in his Geology of Missouri, 1944.

HISTORY

Mesozoic strata were unknown in Missouri prior to the 1930's. In the mid '30's Willard Farrar and Lyle Mc Manamy working on a WPA financed program with the Missouri Geological Survey, geologically mapped Stoddard County and discovered the presence of Cretaceous clays which was reported in their 1937 Geology of Stoddard County. Interest in the geology of the southeastern part of Missouri continued with a mapping program and thesis (Heller, 1943) extending north of Stoddard County into the Ozark region of Bollinger County. Dan Steward, coming "on board" with the Missouri Geological Survey in 1940 engaged in geologic mapping of an area in the vicinity of Glen Allen which Robert Heller also was investigating at the same time. In 1941 they mapped a structurally complex area along Crooked Creek near Glen Allen west of Marble Hill and Lutesville in Bollinger County. Steward was shown a group of bones which had been recovered from clay while digging a cistern in the back of the house of Lula Chronister. Already aware of blue-grey clays in the banks of nearby Crooked Creek, Steward was open to the possibility that such clay might be of Mesozoic (Cretaceous) age, in light of the fact that marine Cretaceous sediments had been discovered in Stoddard County a few years earlier.

Steward took some of the bones to Rolla, where "Chief Buehler," the State Geologist at the time, is reported to have barked out "Why those are only old cow bones." Convinced that they were fossils and possibly dinosaur, Steward collaborated with Maurice Mehl of the University of Missouri, (the only Univeristy of Missouri at that time in Columbia) in determining what they had. Mehl had worked with Mesozoic vertebrate fossils in Wyoming and affirmed that the bones were indeed dinosaur. Steward and Mehl planned to do a paper on the fossils, however, the fall of 1941 saw the beginning of World War II and things changed. Steward focused on strategic mineral deposits of the Joplin area. Willard Farrar was killed in the war (UMR's Farrar Residence Hall is named after him) and the paper on the Chronister site remained in limbo until after the war when it was published in the Journal of Paleontology. Maurice Mehl had contacted Charles

Gilmore of the U. S. National Museum regarding the bones and in 1945 Gilmore authored the paper on the site with Steward (Gilmore and Steward, 1945).

Little activity took place at the site until 1972 when the author investigated it and found one of the sons of John and Lula Chronister living nearby who expressed considerable interest in my interest in the site. Attracted to it because of an interest and curiosity with Ozark outliers and their fossils, it was decided that a back hoe could probe the area around the now abandoned cistern for additional material. Obtaining a small grant from the St. Louis Academy of Science, we probed the site and at first found nothing in blackish-grey clay. Later digging found bones of dinosaur and turtle in grey and yellow clay. A few years after our initial investigations, Oli Chronister offered to sell the site to me at a reasonable price and seeing how other fossil sites are often made unavailable or lost by ownership changes, I purchased it. Aware that a site such as this has considerable "hands on" educational as well as scientific value, a number of interested persons became involved, including Guy Darrough and Mike Fix. Finding that the site was difficult to work as a consequence of drainage problems and slumping of the clay when wet, the solution for a more or less permanent dig was found in covering the dig site with a plastic tarp-like greenhouse. This is what is currently being utilized to cover the dig and to expose the bone bearing clay.

FOSSIL TAXA FOUND AT THE SITE

The original fossils found in the digging of the cistern in 1940 consisted of 14 caudal (tail) vertebrae of a dinosaur. These were the specimens figured in the Gilmore and Steward paper and were the basis for establishment of what they considered to be a Cretaceous sauropod to which they gave the name *Neosaurus missourensis*. The genus *Neosaurus* was coined in view of their belief that it was the youngest known sauropod, however known only by its tail vertebrae. When excavations of the mid 1970's produced additional material, assistance in dinosaur taxonomy and anatomy was acquired from David Parris of the New Jersey State Museum. It was found that most of the material recovered was of hadrosaur origin (duckbilled dino's), specifically of the genus *Hypsibema* sp. *Neosaurus*, the genus established by Gilmore and Stewart had been placed in synonymy under the genera *Parrosaurus* sp. and *Hypselbema* sp. Other dinosaur material which was found consisted of carnosaur bone and teeth (*Albertasaurus* sp.) and gastroliths.

Considerable amount of fossil turtle remains were also recovered, usually in a fragmentary condition. Most of this turtle material is from the genus *Adocus* sp., a common late Mesozoic turtle related to the still living fresh water turtle *Trionyx* sp., a peculiar beaded turtle of the genus *Naomichelys* sp. was also found, a type of turtle more common in the Jurassic than to the Cretaceous. A portion of the site not covered by the greenhouse was found to yield a large number of specimens of *Adocus* sp. where a novel mechanism explaining their high concentration was suggested by Forir and Stinchcomb, 1996.

The site is considered to have originally been a watering hole as many of the bones exhibit bite marks of two types, one associated with scavenging, the other with predation, Forir, 2001. The sites location appears to be in association with a major fault and was probably preserved by downfaulting in a graben (Fix, 2001).

LOCAL STRUCTURE AND SEDIMENTS OF THE SITE AREA

Cretaceous sediments of the Chronister site have been considered to have been preserved by the following phenomena:

A. A filled sink hole or paleokarst developed in carbonate rocks of the Roubidoux and Jefferson City formations.

B. A sediment filled graben associated with extensive southeastern Missouri faulting and preserved from erosion in a down-dropped fault block. The fault is one of many in the Marble Hill-Glen Allen area.

C. A combination of both A and B, that is a fault block along which there was considerable solution of surrounding carbonate rocks accompanied by filling of the graben by Late Cretaceous (Campanian) sediments.

One of the puzzles of the site is the presence of large boulders of “exotic” rocks embedded in the bone bearing clay. These boulders consist primarily of sandstone layers of the Everton Formation, boulders of the Plattin Limestone and possibly the Bainbridge and Bailey formations. Rock surrounding and outside of the Chronister site valley is the older Lower Ordovician Roubidoux and Jefferson City formations. One suggestion explaining such exotic boulders proposes that a cliff face of younger rock once surrounded the site which during the Campanian was a depression. Boulders of the younger rock on the cliff face would fall into this depression, become buried by the clay along with the fossil bones of animals attracted to what is considered to have been a watering hole (Forir and Stinchcomb, 1996).

Investigation of the site is an ongoing activity. With additional excavation and fossil recovery from other clay lenses at the site, additional (and possibly different) material might be obtained. Other outliers of clay in Bollinger and Butler counties, some of which are shown on the 1979 state geological map, may also yield additional fossil vertebrate and plant material, possibly some of different age than the Campanian age strata of the Chronister site.

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CHRONISTER SITE INVESTIGATIONS: NEW INFORMATION ON THE CRETACEOUS OF MISSOURI

David Parris

INTRODUCTION

More than half a century after its discovery, the Chronister Site continues to challenge investigators. A source of great pride to Missourians, and the primary inspiration for the Bollinger County Museum of Natural History, it is also the provenience for the Missouri State Dinosaur, designated as the original specimen of *Hypsibema missouriense*. All who have contributed to the study of the site have derived much satisfaction from their participation, and the finds of the last few years have rewarded their dedicated service. Now organized as the Missouri Ozark Dinosaur Project, Inc., the excavations there will undoubtedly continue to produce valuable information on the Cretaceous faunas of the eastern subcontinent.

HISTORY OF INVESTIGATIONS

The discovery and narrative of the Chronister Site is well known and has been periodically reviewed in publications, and only the major events need be included here. The dinosaur material was published by Gilmore and Stewart (1945) and the specimen originally reported by them was the only faunal material for nearly four decades, receiving attention primarily by taxonomic reassignments (Baird and Horner, 1979). Renewed investigations by geologist Bruce Stinchcomb, the property owner, resulted in additional faunal material. Joined by collaborators from the New Jersey State Museum, a broader investigation of the geology and paleontology was soon published (Stinchcomb et al., 1994). Excavations since that time have been conducted by the Missouri Ozark Dinosaur Project, Inc., from which the principal investigators have periodically reported the results (Fix and Darrough, 2004). We continue to refine our views of the paleoenvironment of this important site.

METHODS

As reported by Fix and Darrough (2004), the excavations are now protected by an enclosure, preventing water damage and disruption. As a result, plaster jacket removal has become feasible, essentially for the first time. The obscure and much-deformed clay strata made such removal virtually impossible previously. With ample opportunity to expose a meaningful portion of the bone-bearing deposit, the possibility of getting large segments of material to a laboratory for preparation has now become a reality. With the use of mechanical lifting devices, we now have been able to remove jacket specimens weighing more than 400 kg. Recovery of large specimen blocks for laboratory preparation is likely to result in better microfaunal specimens as well as recovery of large bones. A prime example of large specimen recovery is illustrated here. A jacket nicknamed "Gargantua" was recovered during the past year. With semi-articulated specimens, including vertebrae and a probable scapula, this jacket was excavated from the wall of the excavation, which is well below the original ground surface. It was jacketed in place, and lifted by block and tackle, then lowered onto a padded pallet. It was pulled up a ramp that was built for the purpose, using a cable drawn by a truck.

At the opposite end of the spectrum, the washing and screening approach to small specimens has also been refined to the extent that items of considerably less than one millimeter in dimension have now been recovered. We have thus been able to get further information on the smaller aquatic vertebrate taxa.

RESULTS

A revised faunal list for the site is given in Table 1. The microfaunal identifications are based on a sample estimated at 1000 specimens. Most notable among microfaunal identifications are probable hybodont sharks, based on cephalic hooks, tooth fragments, and spines. The minute size of the specimens suggests that they are from small juvenile individuals. The possible environmental implications of hybodonts are noted in the discussion. Batoids have previously been reported from the Chronister Site.

Among large specimens, the most significant new item thus far recognized is a major portion of a lower dentition of a hadrosaurid. We are pleased to attribute the prospective identification to John R. Horner, who noted the breadth and carinae of the teeth and suggested comparison to *Gryposaurus*. (See Horner, 1992)

DISCUSSION/INTERPRETATIONS

Previous interpretations of the Chronister paleoenvironment generally involved a paleokarst, a minor deposit of clay in a sinkhole terrain (Stinchcomb et al., 1994). Contributing to this traditional view is the fact that the Cretaceous deposits of the immediate area are all of small size, and scattered through a carbonate-dominated terrain. The Chronister Site is as yet the only one that has yielded fossil vertebrates. It has seemed likely that it represented a coastal plain edpression that served as an entrapment, particularly when the fauna consisted of one dinosaur. Although marine Cretaceous deposits are found not far away (Gallagher et al., 2005), there are no obvious connections.

However, the overview of the fauna now recorded suggests that other interpretations should be considered. The fauna is highly aquatic and some of the taxa, such as *Trionyx*, are not to be expected in small pond environments. A sizeable coastal plain lacustrine environment seems a much more likely interpretation for Chronister, Consistent with all taxa of the fauna now known. External drainage to the marginal marine environment is likely.

This latter possibility is intriguing, assuming that our identifications of the chondrichthyan taxa are correct. Although batoids and hybodontids are known to have been found in non-marine paleoenvironments, these are generally believed to be proximal to (or remnants of) marine connections. This will be considered as our work continues.

ACKNOWLEDGEMENTS

We thank our many volunteer co-workers, notably Bill Teeters, whose logistical help was critical in the removal of large jacket specimens. Advice and discussions from Jack Horner, Phil Currie, Judy-Gail Armstrong-Hall, Russ Jacobson and Bob Denton have been helpful during recent years. Bruce Stinchcomb has graciously permitted and promoted work on the site, which he owns. State Representative Rod Jetton has provided us with public support and grants critical to our work, including the sponsorship of the original Chronister specimen as Missouri's State Dinosaur!

The ultimate repository of the Chronister Site specimens is designated as the Bollinger County Museum, whose support (coordinated by Eva Dunn) we gratefully acknowledge. Work has previously been supported by grants from the Saint Louis Academy of Sciences.

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TABLE 1

CHRONISTER SITE FAUNA

Class Chondrichthyes
- Order Hybodontoidea
  - Family Hybodontidae
    - cf. *Lissodus* sp.
- Order Batoidea
  - Family undetermined

Class Osteichthyes
- Order Semionotoidea
  - Family Lepisosteidae
    - *Lepisosteus* sp.
- Order Amioidea
  - Family Amiidae
    - *Platacodon nanus*

Class Reptilia
- Order Chelonia
  - Family Dermatemydidae
    - *Adocus* sp.
    - *Naomichelys speciosa* Hay
  - Family Trionychidae
    - *Trionyx* sp.
- Order Crocodylia
  - Family Crocodylidae
    - cf. *Leidyosuchus* sp.
- Order Saurischia
  - Family Ornithomimidae
    - cf. ornithomimid
  - Family Tyrannosauridae
    - tyrannosaurid, genus undetermined
  - Family Dromaeosauridae
    - dromaeosaurid, genus undetermined
- Order Ornithischia
  - Family Hadrosauridae
    - *Hypsibema missouriensis* Gilmore
    - cf. *Gryposaurus* sp.

Additionally, eggshell specimens, as yet unattributed to particular vertebrate groups, have been recovered at the Chronister Site.

Association of Missouri Geologists
2006

Field Trip 2:
Earthquake and Mississippi Embayment Geology of Southeast Missouri

David Hoffman
University of Missouri-Rolla

and

James R. Palmer

EARTHQUAKE AND MISSISSIPPI EMBAYMENT GEOLOGY OF SOUTHEAST MISSOURI

David Hoffman and James R. Palmer

SCHEDULE COMMENTS

Included in this guidebook is a schedule for the field trip. The Stops and other key items are listed in the schedule. Many additional drive-by sites and on-bus discussions will be included during the field trip. You will note that the schedule is rather full and makes use of the full day. In order to see as many Stops as practicable and to cover the significant distances involved, this rigorous schedule is necessary. The field trip leaders will be responsible for maintaining the schedule but the participants will be expected to actively cooperate by paying attention to the field trip leader's instructions for reboarding the bus after each stop. Also, the participants must observe the 8:00 AM Saturday departure time from the Best Western Sikeston. Be on the bus with gear loaded before the 8:00 AM time. Some adjustments to the time schedule may be necessary either before the start of the field trip or during the trip as conditions warrant. If the majority of the field trip participants desire an earlier return to Sikeston, the last field trip stop, Stop 6, and the associated drive-by sites will be eliminated. In that case the bus will return to Sikeston directly after Stop 5. Transportation will be on an over-the-road coach-type bus with a rest room onboard.

GENERAL COMMENTS

Some of the stops on this field trip are on private land. The private landowners have been kind enough to allow us access for investigations and field trips such as this one. PLEASE RESPECT THE LANDOWNERS and do not damage, destroy or deface their property or possessions and do not litter or do anything to otherwise annoy the landowner. We would like to return to these sites and be welcomed by the landowner in the future.

EARTHQUAKE AND MISSISSIPPI EMBAYMENT GEOLOGY OF SOUTHEAST MISSOURI

David Hoffman and James R. Palmer

FIELD TRIP SCHEDULE

Saturday, October 7, 2006

Time	Miles	Activity
8:00 AM	0 (0)	Leave Meeting Hotel – Best Western Sikeston, MO
8:45 AM	27 (27)	Stop 1 - Holly Ridge Site – view cutbank and discuss faulting and/or earthquake induced landsliding on Crowleys Ridge outside of the New Madrid seismic zone which is possibly related to the Commerce geophysical lineament - paleoseismology research trenches have also been excavated and seismic reflection survey data collected – discuss Mississippi Embayment sediments
9:30 AM	--	Leave Stop 1
10:20 AM	41 (68)	Stop 2 – Poplar Bluff Vs Site 3 (Mississippi Embayment site) – view and discuss site where shear wave velocity (Vs) testing to determine earthquake shaking properties of the surficial materials was conducted - test borings and sampling were conducted to obtain samples for laboratory Vs testing and field testing of Vs was done using the crosshole, MASW and SCPT techniques.
10:50 AM	--	Leave Stop 2
11:00 AM	6 (74)	Stop 3 – Poplar Bluff Gravel Pit on Route PP and Shear Wave Velocity Test Site13 (Ozark Uplands site) – examine Ozark upland surficial materials and bedrock in a gravel pit

		excavation and view and discuss adjacent site where MASW and SCPT Vs testing was conducted.
11:30 AM	--	Leave Stop 3
12:15 PM	41 (109)	Lunch Stop at Morris State Park - box lunches will be distributed at Stop 4
12: 45 PM	--	Stop 4 – Morris State Park – landslides on Crowleys Ridge – view landslide scarp exposure and discuss earthquake induced landslides and the Mississippi Embayment sediments
1:30 PM	--	Leave Stop 4
2:15 PM	39 (148)	Stop 5 - New Madrid, Missouri - Mississippi River observation deck – discussion of New Madrid seismic zone and events of 1811-1812 – if time permits participants may also visit New Madrid Museum across the street - also drive by seismic retrofit telephone company building on way out of town
3:00 PM	--	Leave Stop 5
3:45 PM	29 (177)	Stop 6 – Towosahgy State Historic Site - archaeology and paloeliquefaction site – a Native American mound site will be viewed and liquefaction features discovered during excavations will be discussed - the technique of dating paleoliquefaction features using cultural artifacts and displaced bones will be discussed
4:15 PM	--	Leave Stop 6
5:00 PM	39 (216)	End of Field Trip - Best Western Sikeston, MO

EARTHQUAKE AND MISSISSIPPI EMBAYMENT GEOLOGY OF SOUTHEAST MISSOURI

David Hoffman and James R. Palmer

INTRODUCTION

The geology and terrane included in this field trip are somewhat different than those of a traditional Association of Missouri Geologists field trip. The area is mostly flat with little or no lithified rock outcrops, the usual object of field trip stops. The exceptions to the flat terrane are Crowleys Ridge and the Ozarks uplands. The flat terrane and absence of rock outcrops makes it difficult to arrange stops where there is something to look at and touch. For these same reasons most data collection and geologic work in the area is done using borings, temporary surface excavations or geophysical investigations. Also some of the important features of the area are too large to effectively see at any one stop. Because of this the Friday evening banquet after dinner presentation will introduce the field trip and give field trip information that is not directly observable in the field or is to expansive to see at a single stop. Some of that information is also given in this guidebook. In addition to the six field trip stops there will be 18 sites viewed from the bus windows as we drive by. These sites offer limited touch opportunities but because they are significant to the geology of the area they will be discussed on the bus using the bus public address and video systems.

All of the field trip route and Stops will be in the Mississippi Embayment except for a small part of the route near Stop 3 in Poplar Bluff, Missouri (Figure 1). The Mississippi Embayment is also the location of the New Madrid Seismic Zone. The field trip will view features of and discuss both the New Madrid Seismic Zone and the geology of the Mississippi Embayment.

MISSISSIPPI EMBAYMENT

The Mississippi Embayment (ME) is a broad reentrant of young Gulf Coastal Plain sediments that extends up the Mississippi River to near Cape Girardeau, Missouri (Figure 2). The ME widens from the north toward the south and is about 125 miles wide at the latitude of Poplar Bluff, Missouri to Kentucky Lake, Kentucky/Tennessee. It is filled with unconsolidated Cretaceous and Tertiary sediments consisting mostly of sands and clays. Figure 3 is a stratigraphic column of the Mississippi Embayment sediments. The ME has very little topographic relief and has a nearly flat surface over much of its extent that genteelly slopes south toward the Gulf of Mexico. The Mississippi River occupies the central axis of the embayment and its alluvial sediments veneer the Cretaceous and Tertiary sediments from the eastern river bluffs near the axis of the ME to the western edge of the ME. In the northern ME very little of the Mississippi alluvial valley extends east of the river. In the east-west direction the ME sediments thicken from feather edges at the margins to a maximum near the central axis and from north to south the ME sediments dramatically thicken toward the Gulf.

The exceptions to the flat terrane of the ME are Crowleys Ridge in Missouri and Arkansas and the bluff line along the east side of the Mississippi River in Kentucky and Tennessee. Crowleys Ridge is a prominent, mostly north-south, long narrow upland ridge of Tertiary and Cretaceous sediments that separates the Western Lowlands from the Eastern Lowlands of the Mississippi alluvial valley. Both Lowlands are west of the Mississippi River. Crowleys Ridge is about 200 miles long from its northeastern end at Thebes Gap just south of Cape Girardeau, Missouri to its southern end at Helena, Arkansas. Crowleys Ridge has a maximum height of about 200 feet above the Mississippi River alluvial lowlands and widths ranging from about 20 miles in part of Missouri to only a mile or two in part of Arkansas and averaging about 5 miles wide.

The Western Lowlands is the location of the ancestral Mississippi River which now occupies the Eastern Lowlands. The river cut through Crowleys Ridge at Thebes Gap about 11,000 years ago thereby abandoning the Western Lowlands. The Western Lowlands is now occupied by the tributaries to the ancestral Mississippi River, including the St. Francois and Black Rivers in Missouri, which flow out of the Ozarks. The evolution of the drainage in the northern ME is very complex and intriguing.

The northern ME is structurally controlled by the failed buried Reelfoot Rift developed in the underlying Paleozoic and older rock (Figure 4). The failed rift formed as the North American continent attempted to pull apart to form an ocean. However, the ocean forming process was not completed but left behind a huge graben or rift and a large zone of crustal weakness. The Reelfoot Rift has been identified on gravity and magnetic anomaly maps (Figure 5) and is also the location of current NMSZ active seismicity. The trough formed by the rift graben has been filled with the younger Cretaceous and Tertiary sediments of the ME.

NEW MADRID SEISMIC ZONE

The New Madrid seismic zone (NMSZ) has been defined by different people in different ways. It is both a regional zone covering a broad area of the Central United States (CUS) and a more focused local zone outlined by the most concentrated and intense microseismicity recorded since 1974 when a local seismographic network was installed to monitor the area (Figure 6). This guidebook will use the latter definition.

The NMSZ has a zig-zag pattern of four fault segments as defined by the microseismicity patterns (Figure 7). There is almost no surface expression of the faults. The southwest arm and the northeast arm of seismicity appear to be near vertical faults that move in a right lateral strike-slip direction due to the east-northeast to west-southwest directed principal stress of the CUS. The central, north-northwest to south-southeast arm of seismicity is in compression and is a southwest dipping thrust fault with the hanging wall to the southwest and the foot wall to the northeast. This central arm appears to be a step-over fault between the southwest and northeast arms. The small, less active, west-northwest arm is more problematic.

Until relatively recently no surface expressions of faulting were known in the NMSZ. This is primarily due to the thick unconsolidated cover of Pleistocene and Holocene alluvium in the ME and the underlying, even much thicker unconsolidated Tertiary and Cretaceous sediments. These young unconsolidated sediments have been frequently rearranged by erosion and new deposition and therefore do not preserve evidence of past faulting at the surface. The major surface feature now identified as a fault scarp, the Reelfoot Fault in Tennessee, formed along a portion of the central thrust arm of seismicity (Figure 8). The earthquake related stops or sites in the NMSZ on this field trip will be associated with secondary earthquake features such as liquefaction, sandblows and landsliding.

Modern seismographs monitor the seismic activity of the NMSZ. Most earthquakes are small or very small and are only recorded by the very sensitive instruments of the monitoring network. About 200 earthquakes a year are recorded or about one every other day. Consequently, there is about a 50% probability that an earthquake in the NMSZ will occur on any day. Several earthquakes large enough to be felt, about magnitude 3.0, occur in the NMSZ each year. More about NMSZ earthquake activity will be discussed at Stop 5.

COMMERCE GEOPHYSICAL LINEAMENT

The first part of the field trip will be outside the NMSZ to the north and west (Figure 8). This area includes another feature recently identified by geophysics and named the Commerce Geophysical Lineament (CGL). The CGL is a gravity and magnetic anomaly in the deep basement and has been modeled as a broad mafic dike swarm. Several sites with documented Holocene faulting or liquefaction features have been found in the Western Lowlands and along Crowleys Ridge in recent years. These sites seem to be associated with the CGL and not the NMSZ. Some of these sites will be visited on the field trip.

FIELD TRIP STOPS AND SITES

Items listed as sites will be drive by views from the bus windows and in almost all cases no actual stop will be made because the bus will be on a highway where stopping would be dangerous or time does not permit. In one or more cases, the bus will stop briefly to allow better viewing of a feature but participants will not be allowed off of the bus. Items listed as stops will be sites where the bus will stop for a period of time and participants will disembark the bus to examine and discuss the feature(s) at the stop.

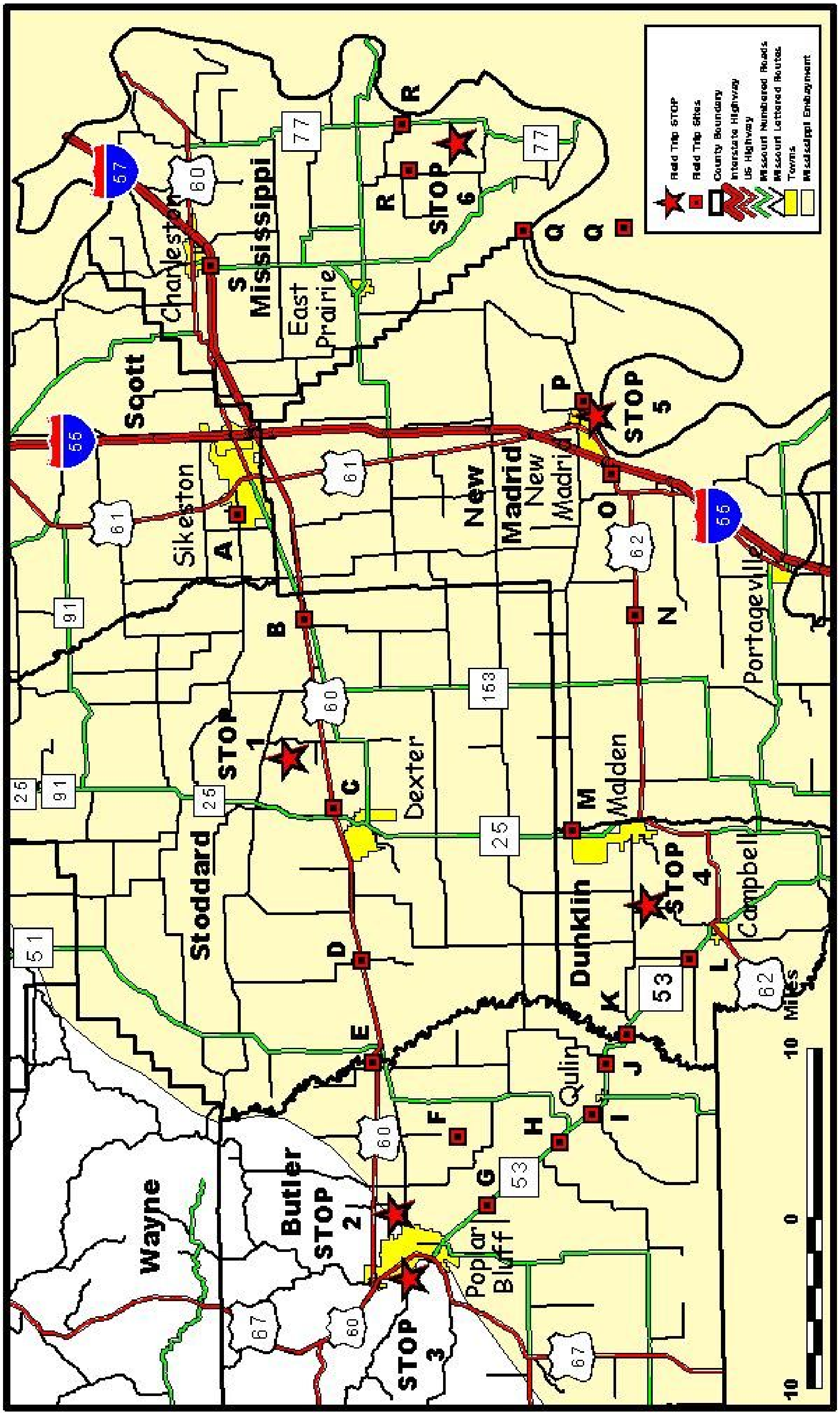


Figure 1. Map of Field Trip Route

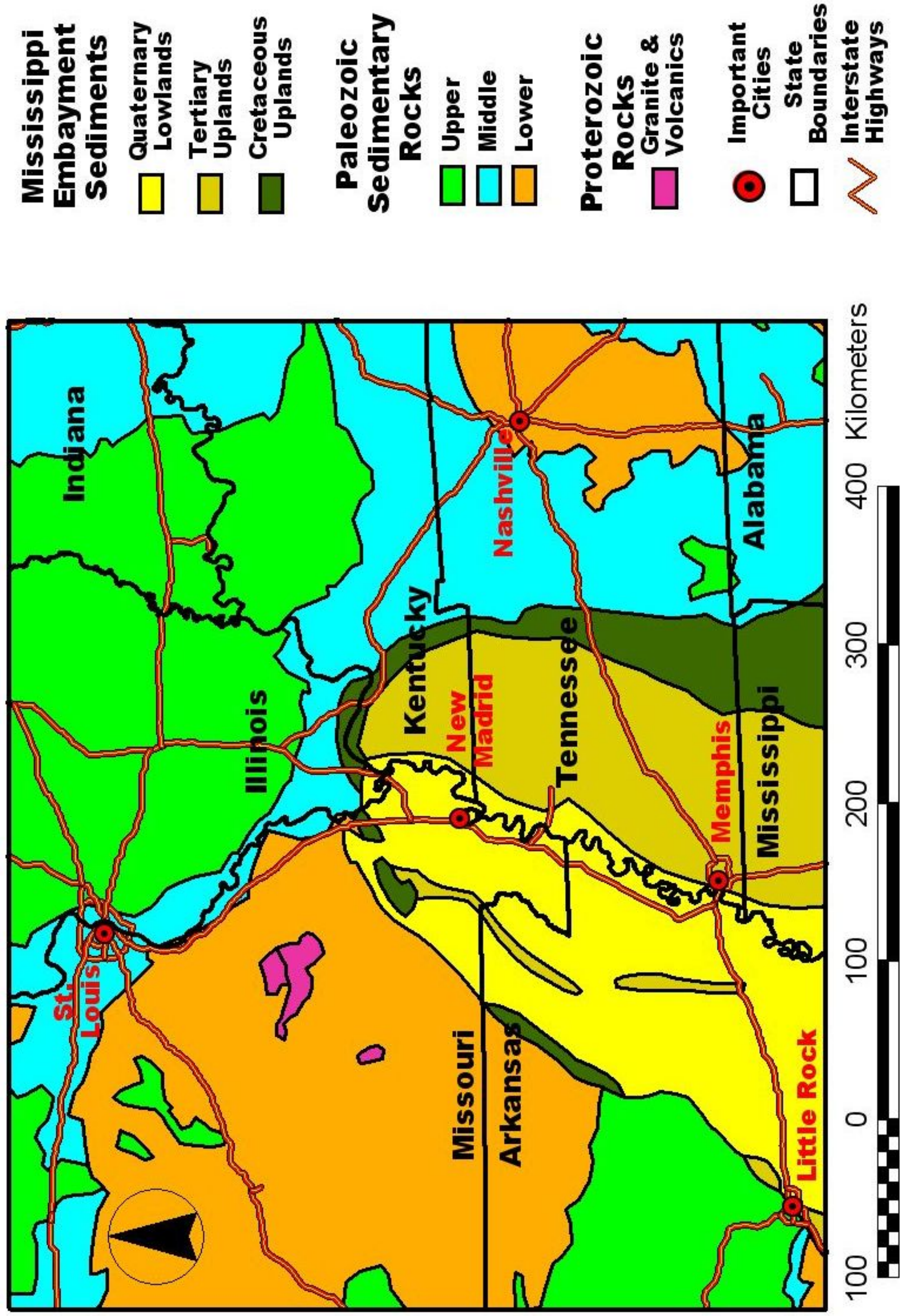
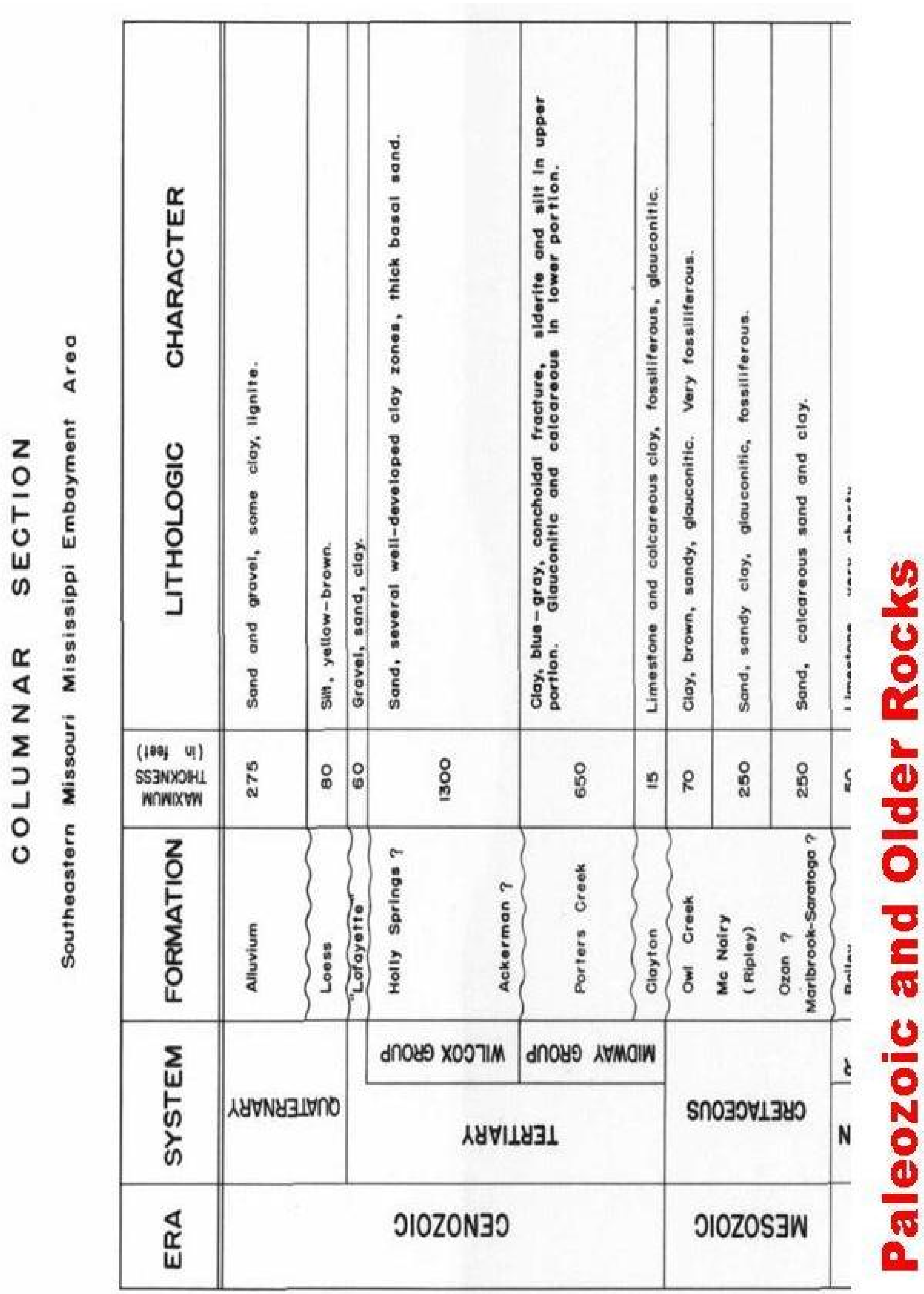


Figure 2. Geology Map of Northern Mississippi Embayment Area



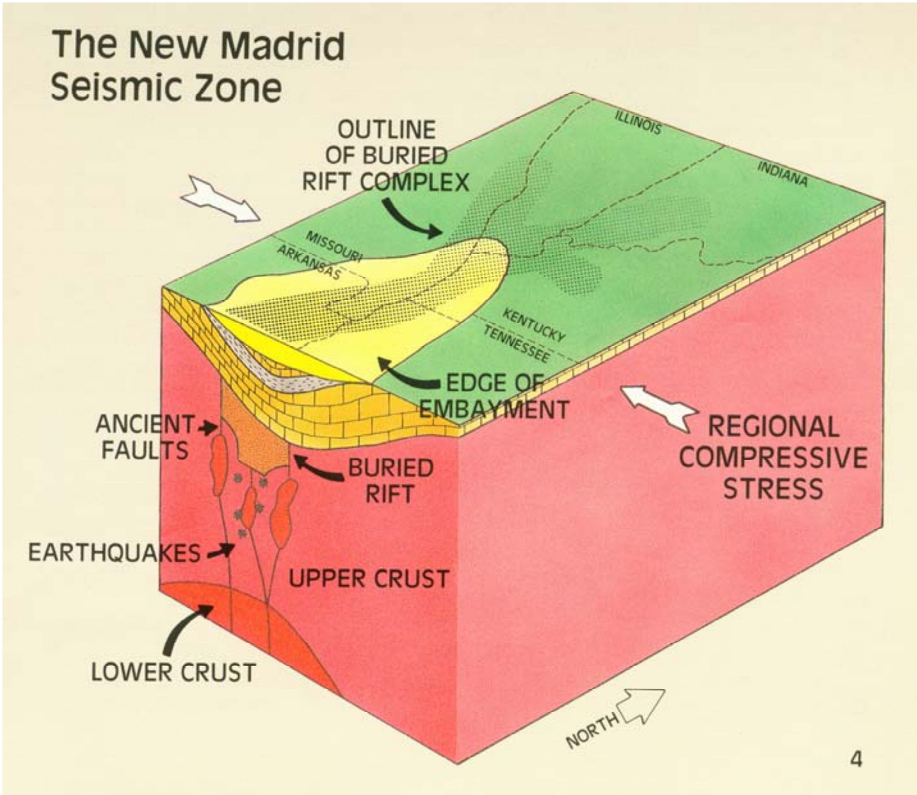
COLUMNAR SECTION

Southeastern Missouri Mississippi Embayment Area

ERA	SYSTEM	FORMATION	MAXIMUM THICKNESS (in feet)	LITHOLOGIC CHARACTER
CENOZOIC	QUATERNARY	Alluvium	275	Sand and gravel, some clay, lignite.
		Loess	80	Silt, yellow-brown.
	TERTIARY	Lafayette	60	Gravel, sand, clay.
	WILCOX GROUP	Holly Springs ? Ackerman ?	1300	Sand, several well-developed clay zones, thick basal sand.
	MIDWAY GROUP	Porters Creek	650	Clay, blue-gray, conchoidal fracture, siderite and silt in upper portion. Glauconitic and calcareous in lower portion.
		Clayton	15	Limestone and calcareous clay, fossiliferous, glauconitic.
MESOZOIC	CRETACEOUS	Owl Creek	70	Clay, brown, sandy, glauconitic. Very fossiliferous.
		Mc Nairy (Ripley)	250	Sand, sandy clay, glauconitic, fossiliferous.
		Ozan ? Marlbrook-Saratoga ?	250	Sand, calcareous sand and clay.
	N ?	Bailey	50	Limestone, very cherty

Paleozoic and Older Rocks

Figure 3. Stratigraphic Column of the Mississippi Embayment Sediments



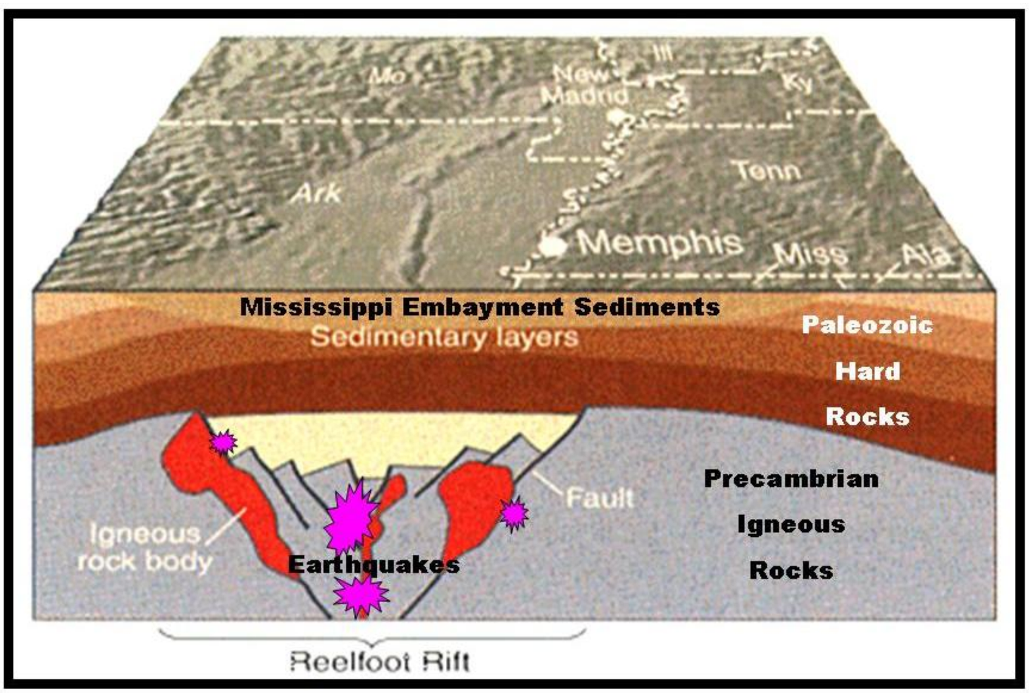


Figure 4 upper & lower. Block Diagrams of Reelfoot Rift and Seismicity

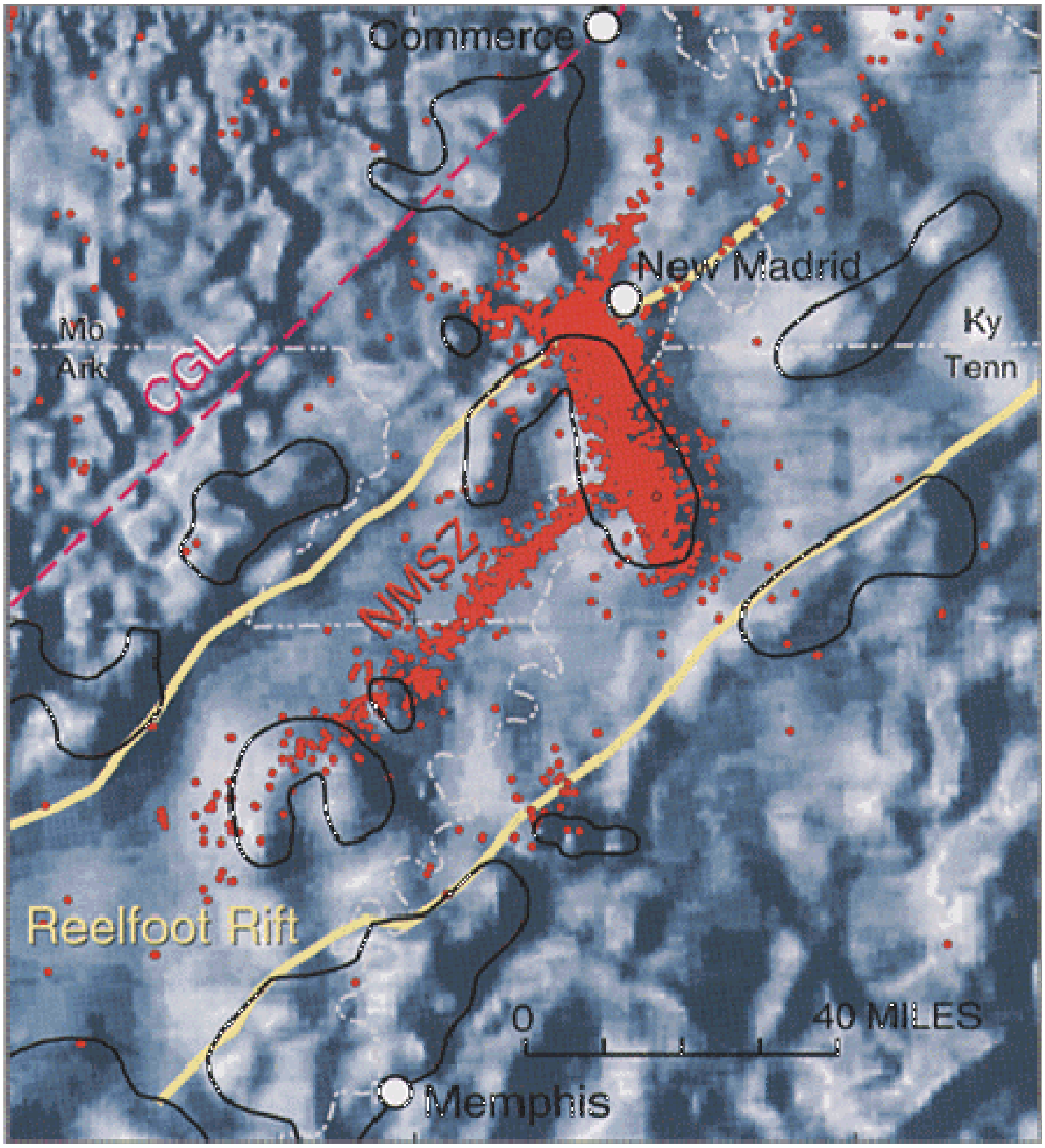


Figure 5. Magnetic Intensity Map of Reelfoot Rift and CGL

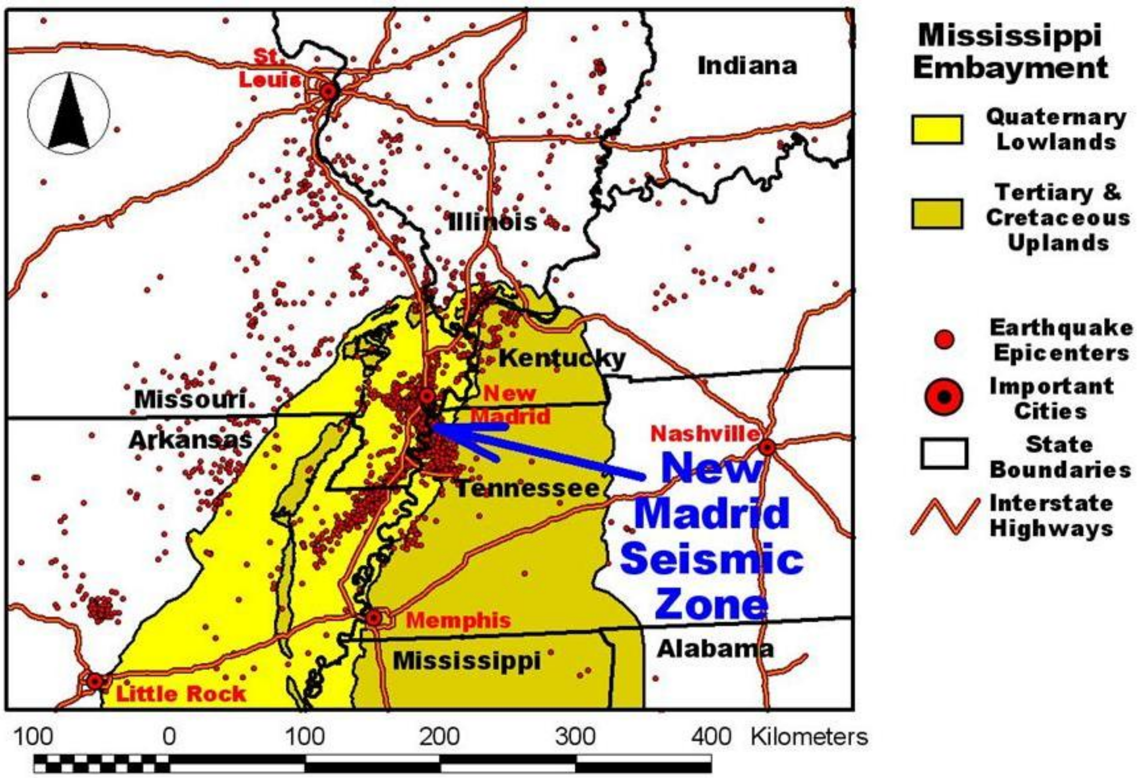


Figure 6. Map of New Madrid Seismic Zone Region Seismicity

Figure 7. New Madrid Seismic Zone Fault Pattern

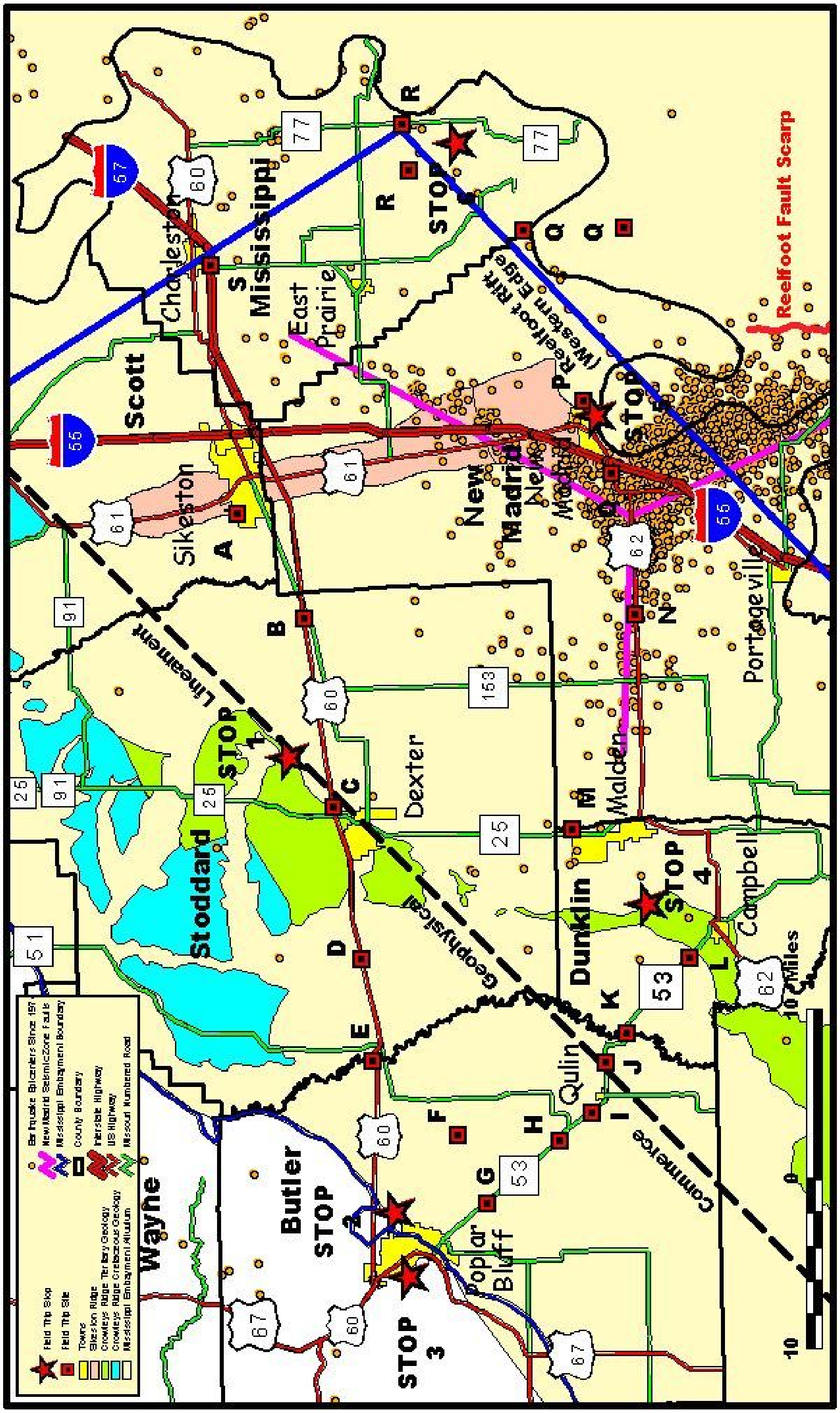


Figure 8. Field Trip Route with Geology

Site A

Sikeston Ridge and Sikeston Power Plant

Sikeston Ridge is a subtle landform located in the Eastern Lowlands (Figure 8). It is oriented north-south and is about 30 miles long, 2-3 miles wide and 15-20 feet high. The northern end starts near the southwestern corner of the Benton Hills portion of Crowleys Ridge and the southern end becomes hard to recognize south of New Madrid.

Sikeston Ridge traditionally has been thought of as an terrace erosion remnant between two former glacial meltwater flood channels of the Mississippi River. The channel to the west formed first when the Mississippi River cut through Crowleys Ridge in the Bell City-Oran Gap. After eroding the western edge of the Sikeston Ridge terrace this western channel was abandoned by the Mississippi River when the river cut a new route to the east through Crowleys Ridge at Thebes Gap. This new eastern route is thought to have eroded the eastern side of Sikeston Ridge terrace thus leaving the long narrow ridge between the two channels. The abandoned Mississippi River channel on the west side of Sikeston Ridge then became the channel of a minor drainage named the Little River.

There is some evidence and speculation that Sikeston Ridge may be bounded by faults and thus would be a tectonic feature. A few geophysical surveys and some trenching studies have shown mixed results for faulting at the margins of Sikeston Ridge.

The Sikeston Power Plant is located in the low land just west the western edge of Sikeston Ridge. As we approach the power plant, recognizable by the big smoke stack, we will descend from Sikeston Ridge. Watch closely as the hill is easy to overlook.

In the fields on both sides of the road and directly north of the power plant are linear liquefaction sandblow fissures. When the fields are empty and not obscured by crops you can see the north-south, light colored sandblow fissure sands surrounded by the darker colored silty-clay soils. When crops are in the field the location of the sandblow fissures can sometimes be detected by noting the areas with stunted crops which have a hard time growing in the sandy sandblow soils.

These linear liquefaction sandblow fissures go directly under the power plant. This has obvious implications for the survivability of the power plant during a large earthquake if design considerations did not include liquefaction possibilities.

Site B

Little River Drainage Ditch/Wahite Ditch Bridge

US 60 crosses the Little River drainage ditch on Wahite Ditch Bridge just west of a railroad crossing. Here the Little River is no longer recognizable due to alterations during a major swamp drainage project conducted in the early 1900's. The Little River was channelized in to a ditch to promote drainage of the surrounding swamp so that it could be used for farm land. The Little River Drainage District maintains the drainage ditches.

This bridge site has been studied to evaluate its seismic response characteristics and to determine its survivability during a large earthquake. Highway 60, including this bridge, is the MoDOT designated primary emergency access route in to southeast Missouri after an earthquake. MoDOT is committed to keeping US 60 open or to be able to reopen the route very rapidly after an earthquake to at least emergency rescue vehicles.

STOP 1

Holly Ridge Site

As we approach the Holly Ridge site on US 60 and then MO Route FF look to the west and note the long northeast-southwest ridge line in the distance. This is the southeastern escarpment of Crowleys Ridge. Here the drainage pattern on Crowleys Ridge is very asymmetric with long wide gentle drainages to the west and narrow steep short drainages to the east. This suggests that here Crowleys Ridge has been tectonically tilted to the west with faulting at the eastern escarpment.

The Holly Ridge site is a surface faulting site located on the southeast escarpment of Crowleys Ridge. At this location the Commerce Geophysical Lineaments also underlies the southeast edge of Crowleys Ridge (Figure 8). The site was identified in 1997 when a new artificial cut in a small automobile salvage yard was examined (Figure 9). Initial cleaning and logging of the existing and expanded cut identified three main faults forming a graben-horst-graben-horst pattern. A shear zone and many secondary faults also exist. Faulting at the site is very complex and some of it in the loess is difficult to identify until the faulted basal contact is exposed. The basal loess contact was excavated and exposed when mapping the site but the excavation has now been refilled. Vertical separations on the main faults are more than 11 m, 7 to 9 m and 4.5 to 7 m respectively (Figure 10). All three main faults displace thick Peoria loess (12.5-25 k bp), the youngest sediment at the site. Therefore, these faults are inferred to be of Holocene age. The underlying Roxana silt, Sangamon geosol, Pliocene-Pleistocene Mounds gravel and Tertiary Wilcox formation sand are also exposed at this site.

Because of the position of these faults on the steep southeast escarpment of Crowleys Ridge the possibility that they were caused by a landslide had to be considered. During the summer of 2001, two seismic reflection lines were run adjacent to the site. The results of these surveys show the faulting extends to great depth thereby confirm a tectonic origin.

Trenching at this site has also been conducted downhill across the road from the cut bank exposure. The trench exposed additional faults and liquefaction features. The majority of the faults are associated with the ridge about 100 yards across the field at the trees.

A shallow high-resolution seismic reflection profile was run about 1.5 miles to the northeast at Idalia. This profile war run across the southeastern escarpment of Crowleys Ridge along MO Route E which is at the north edge of Idalia (where we left the paved road). The profile showed faulting up in to the shallow subsurface.

The faulting at the Holly Ridge Site suggests possible recent movement along the Commerce Geophysical Lineament (CGL). The damaging magnitude 5.5,1968 southern Illinois earthquake was located near the northeast continuation of the CGL which also suggest recent seismic activity associated with the CGL. The CGL extends from central Arkansas west of Little Rock to central Indiana and crosses under the Wabash Valley Seismic Zone. The CGL could be another source of earthquake concern in the Central United States.

. Complex shear zone at Holly Ridge site

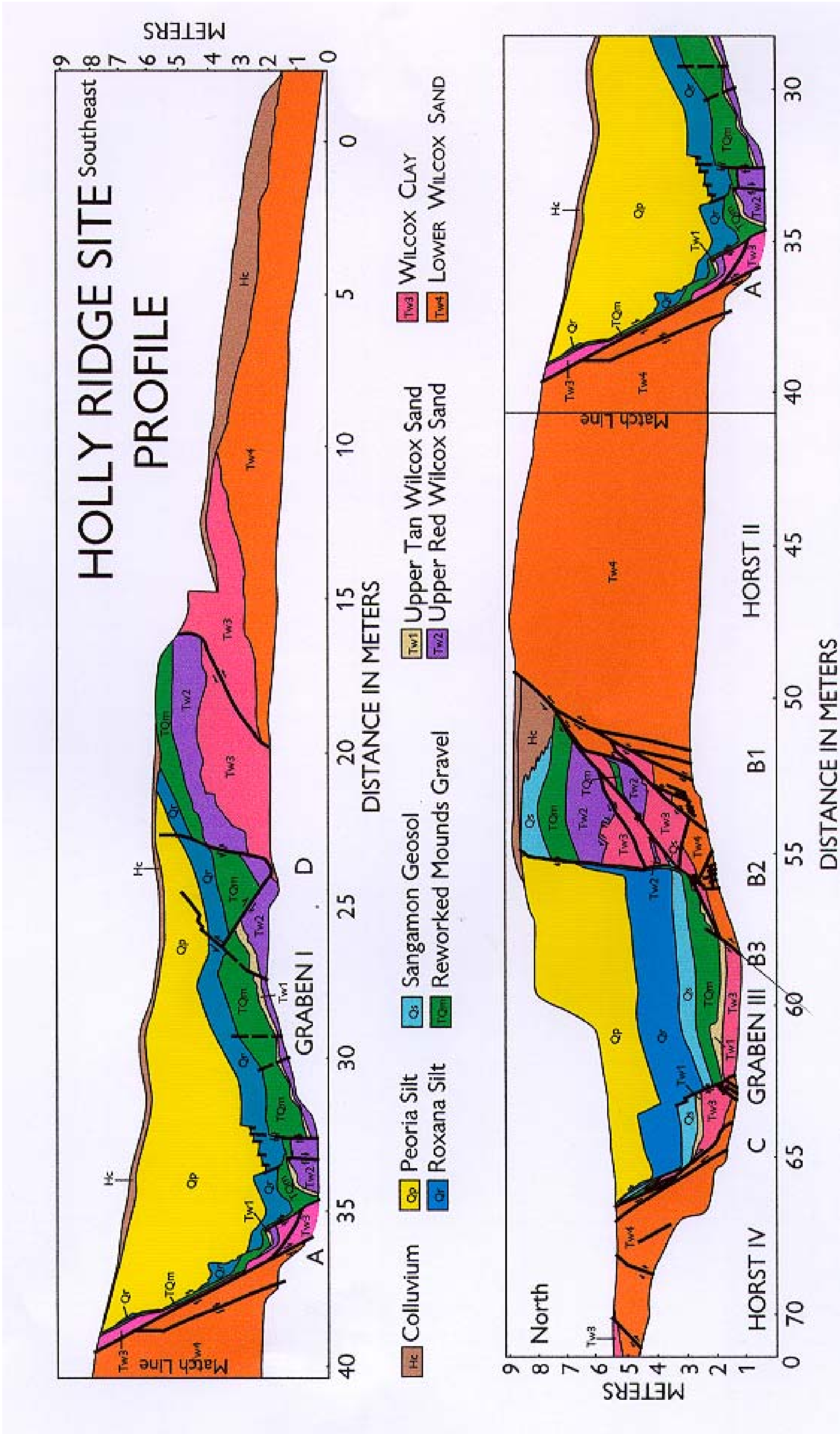


Figure 10. Log of Holly Ridge site

Site C

Crowleys Ridge at US 60

US 60 crosses Crowelys Ridge here near Dexter. We are leaving the Eastern Lowlands, crossing over the ridge and then descending in to the Western Lowlands. Dexter is located in a gap in Crowleys Ridge that is used by the railroad and old highway US 60. The new US 60 bypasses much of Dexter to the north and does not go thru the gap in the ridge. Crowleys Ridge is about 2.5 miles wide where US 60 crosses but is wider to the north and south. On the west side of the ridge US 60 follows one of the long broad flat gradient valleys that drain the west side of the tilted ridge and forms a embayment in the ridge here.

Site D

Dudley Ridge at US 60

Dudley Ridge, at the town of Dudley, is another subtle landform. It is even more subtle than Sikeston Ridge. US 60 goes through a shallow cut here at the Dudley exit overpass. The ridge is just high enough here, about 15 feet, that the cut thru the ridge permits the highway to maintain its flat gradient and still allow sufficient clearance at the overpass for the at grade road on the crest of the ridge. The ridge is approximately an elongate ellipsoid oriented north-south. The north-south axis is about 5-6 miles long and the east-west axis is a maximum of about 1.5 miles wide.

Dudley Ridge is possibly a tectonic upwarp. Two east-west shallow high-resolution seismic reflection lines were run across the western edge of the ridge. One line was about 0.5 miles north of US 60 and the other about 1.5 miles south of the highway. Both lines were inconclusive as to the existence of faulting at the western edge of the ridge.

Site E

St. Francis River and St. Francis River Bridge

US 60 crosses the St. Francis River just northeast of Fisk. The St. Francis River is a major river that flows from the Ozarks and occupies the Western Lowlands, the former channel of the Mississippi River. Here the St. Francis River has been altered during another major swamp drainage project and levees to contain the river have been constructed. The flow of the river is controlled by the release of water from Lake Wappapello, a Corps of Engineers flood control reservoir located at the edge of the Ozarks about 11 miles north-northwest.

This bridge site has been studied to evaluate its seismic response characteristics and to determine its survivability during a large earthquake. Highway 60, including this bridge, is the MoDOT designated primary emergency access route in to southeast Missouri after an earthquake. MoDOT is committed to keeping US 60 open or to be able to reopen the route very rapidly after an earthquake to at least emergency rescue vehicles.

Site F

Sand Dunes

It is a little known fact that Missouri has sand dunes. These sand dunes in the Western Lowlands are not currently active. They have stabilized under current climatic conditions which have allowed vegetation to grow on the dunes and to stabilize them. The dunes formed during the Pleistocene when glacial melt waters seasonally flowed down braided stream channels. During the low flow winter periods sand and silt would blow out of the dry channels and off of the braid bars with the sand being deposited nearby as dunes and the silt being carried further east to be deposited on the bluffs, such as Crowleys Ridge, as loess. There are more extensive dune fields east of this location a few miles.

Because of the unusual nature of sand dunes in Missouri, this area was chosen as a geophysical testing location to measure the earthquake shaking properties of the soils as characterized by their shear wave velocity. This was part of a bigger project to measure and map earthquake soil amplification characteristics in the Poplar Bluff area. That project will be discussed at Stop 2 and Stop 3. The geophysical tests conducted at this site included MASW, SCPT and shear wave seismic reflection. These tests will also be discussed at Stop 2 and Stop 3.

STOP 2

Poplar Bluff Shear Wave Velocity Test Site 3

This site located in the alluvial sediments of the ME was used as a primary testing and control site for evaluating the shear wave velocity techniques evaluated for the Poplar Bluff earthquake soil amplification mapping project. This two part project started as an Association of Central United States Earthquake Consortium State Geologists (CUSEC-SG) project funded by the US Geological Survey (USGS). After the CUSEC-SG project was finished the project continued as a MoDOT funded research grant.

The objective was to make a map of the Poplar Bluff area, in both the ME and Ozark Uplands areas, that would show the relative earthquake shaking amplification that is caused by the surficial materials in the area. The study area included 4 USGS 7.5' quadrangles (Figure 11) The USGS produced National Earthquake Hazards Maps adopted by building codes provide ground motion accelerations for bedrock only as that does not vary much over relatively moderate distances. However, the surficial materials overlying the bedrock can alter the shaking by time it reaches the ground surface. The surficial materials usually amplify the bedrock ground motion but they can also attenuate the shaking. The surficial materials can also vary rapidly over short distances making for a great variety of shaking conditions in a local area. Understanding these local variations is important to emergency management planners and responders, building officials, engineers, business owners and home owners in understanding the earthquake threat they need to consider.

The Poplar Bluff project used existing surficial materials mapping by the Missouri Geological Survey Program and characterized the map units for their shaking potential using the shear wave velocity (Vs) property of the surficial materials to depth of 100 feet. Several techniques were used and compared for measuring the Vs. These techniques were compared for the quality of their results and for the cost effectiveness of the method.

The Vs testing techniques were primarily geophysical in nature although one method used borehole sampling and laboratory testing. The geophysical Vs testing techniques were Multi-channel Analysis of Surface Waves (MASW), Seismic Cone Penetrometer Test (SCPT), and crosshole (CH) and the laboratory Vs technique was ultrasonic pulse velocity (UPV).

All Vs testing techniques were use at test Site 3. Two borings about 15 feet apart were made here. Both boring penetrated all of the alluvium at about 114 feet and bottomed in bedrock after 10-foot of rock was cored at about 124 feet. Extensive soil sampling and standard penetration tests (SPT) were done in the surficial materials. After completion of the holes plastic casings were installed and grouted so that they could be used for crosshole Vs testing. The soil samples were sent to the laboratory for UPV testing.

At the site a profile of 5 SCPT spaced 125 feet apart were done parallel to the highway over a distance of 500 feet. A profile of 17 MASW tests spaced 30 feet apart were also done along the same 500 foot location as the SCPT. In addition 3 cross traverse MASW tests were run perpendicular to the profile line. The profiles and cross traverses allowed for determining the lateral variation in the surficial material Vs characteristics.

In total 40 sites in the Poplar Bluff area were tested for Vs (Figure 12). Sites varied as to the number and types of Vs tests conducted. The MASW technique was the quickest and most cost effective so it is the only test run at all sites. SCPT were the second quickest test to run but the cone could not penetrate the thick gravel surficial materials in the Ozark Uplands so no SCPT could be run in that part of the study area. The crosshole tests were the most time consuming and expensive field test used due to the necessity for twin cased borings. The laboratory UPV test was also expensive and time consuming due to the need for a boring and to take samples which could be shipped back to the laboratory.

The final soil amplification mapping showed marked differences between the alluvial ME surficial materials and those of the Ozark Uplands (Figure 13).

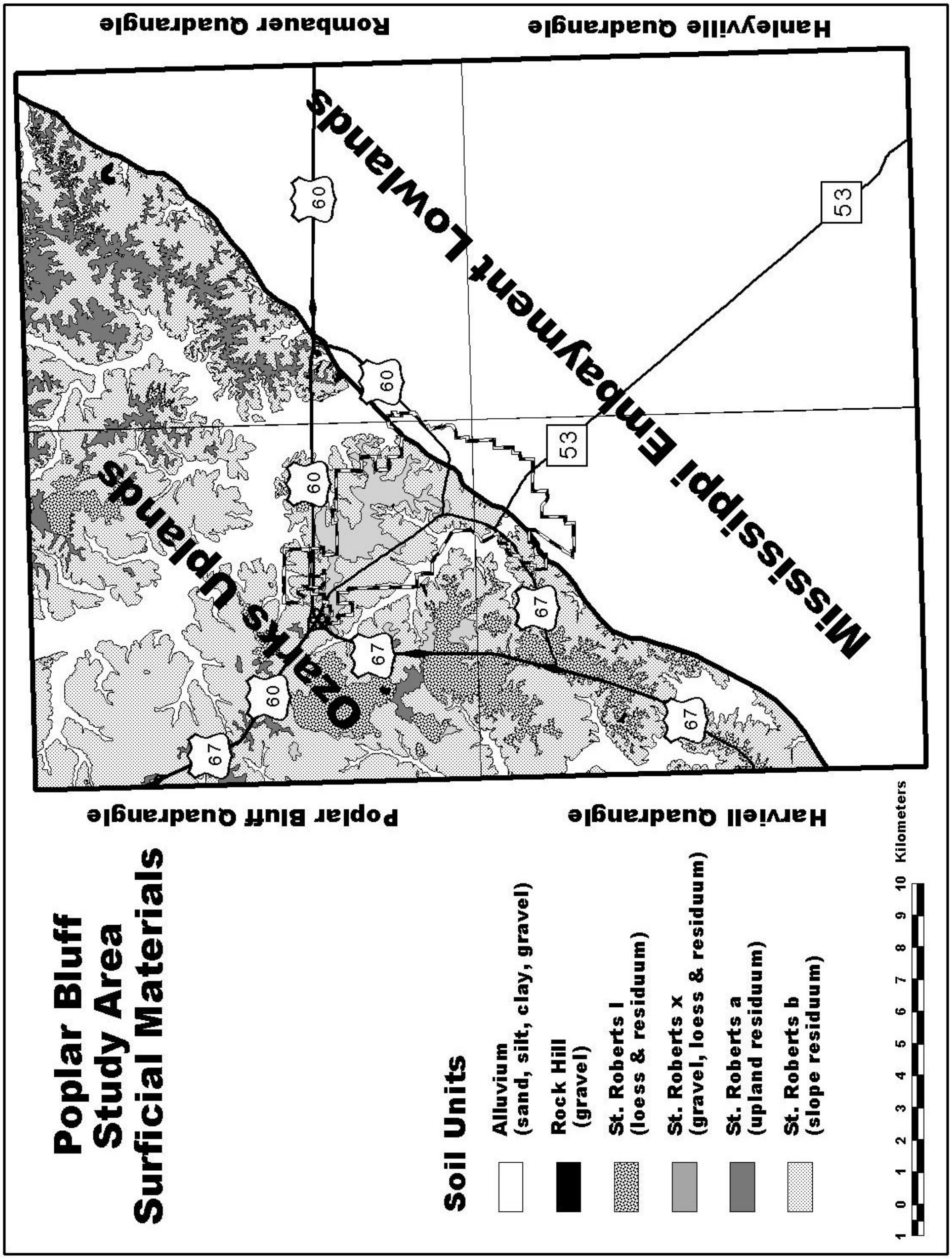


Figure 11. Poplar Bluff Study Area and Surficial Materials

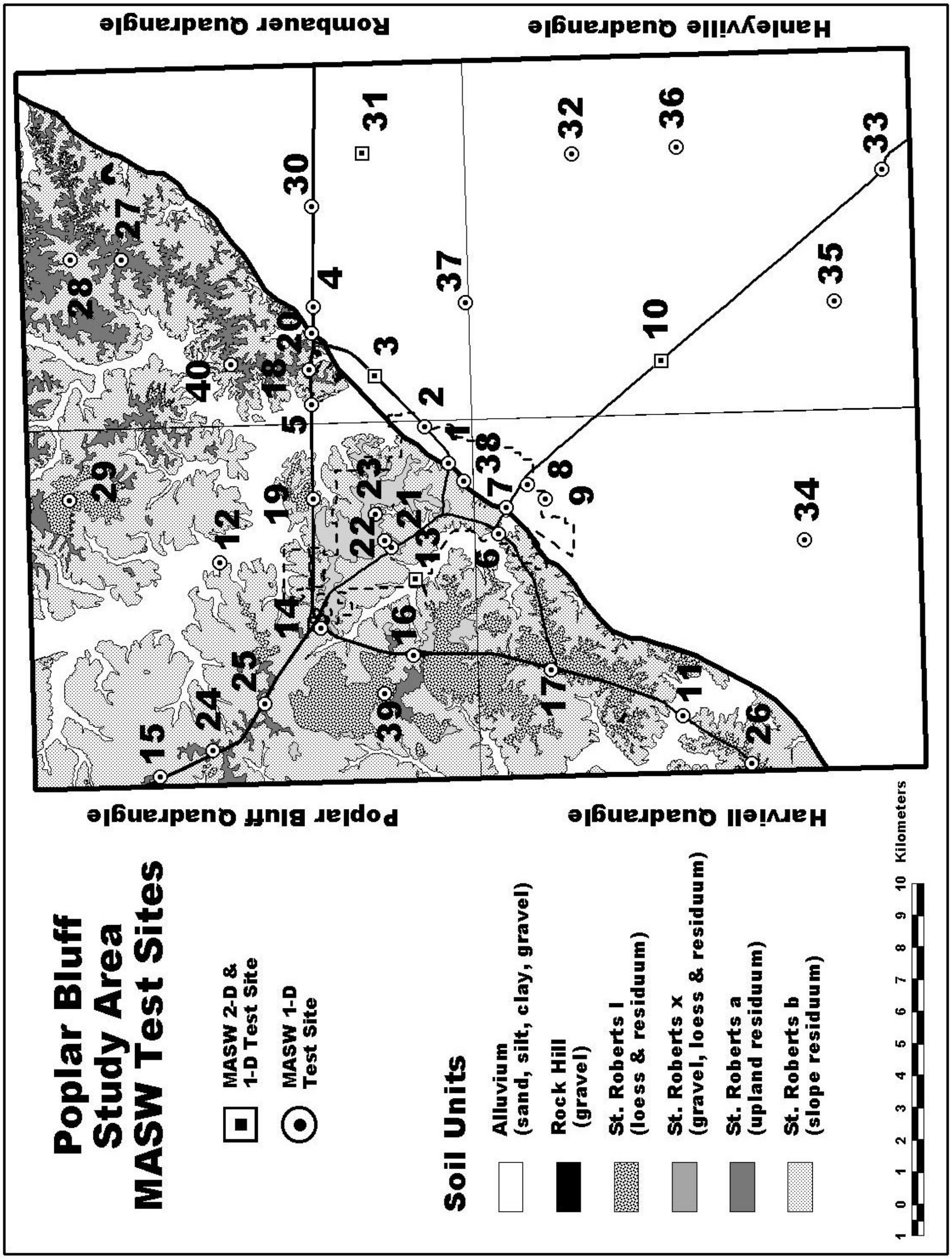


Figure 12. Location of Shear Wave Velocity Test Sites

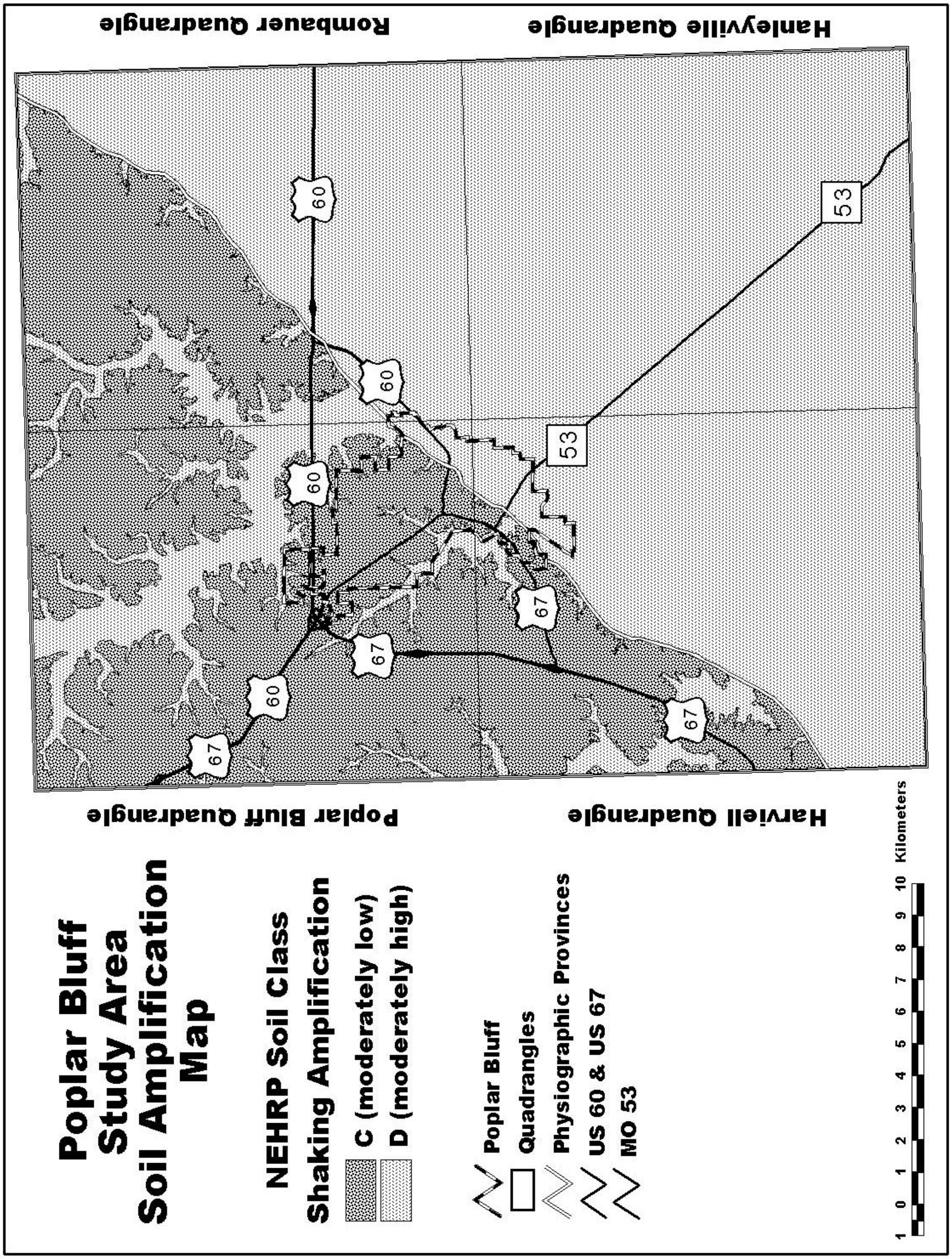


Figure 13. Soil Amplification Map for the Poplar Bluff Study Area

STOP 3

Poplar Bluff Gravel Pit on Route PP & Shear Wave Velocity Test Site13

This gravel pit has been mapped as having a fault in Tertiary sediments. It is a good place to examine the thick gravelly surficial materials of the Ozark Uplands. Some materials are weathered residuum from the underlying bedrock, usually Roubidoux formation in the Poplar Bluff area, and some materials appear to be Tertiary gravelly sediments. We will look at the exposures in the excavation and discuss the materials are.

Across the highway is Vs Site 13 where a profile of 5 SCPT spaced 125 feet apart were done parallel to the highway over a distance of 500 feet. A profile of 17 MASW tests spaced 30 feet apart were also done along the same 500 foot location as the SCPT. These tests were conducted in the alluvium of Pike Creek to determine if the larger alluvial valleys in the edge of the Ozarks have the same shaking properties as the alluvium in the ME.

Site G

Ackerman Ditch Shear Wave Velocity Test Site 10

Shear wave velocity test site 10 is located just northeast of highway MO 53 at the Ackerman Ditch bridge. This is another site where a profile of 5 SCPT spaced 125 feet apart was done over a distance of 500 feet and 17 MASW tests spaced 30 feet apart were done along the same 500 foot location as the SCPT.

Site H

Black River Bridge Vs Site 31

Another Vs test site where single SCPT and MASW tests were conducted.

Site I

Qulin Ridge

Qulin Ridge is another subtle ridge or terrace located in the Western Lowlands. Look out the front window of the bus about one mile past the MO 51 junction as we approach Qulin and you can see a very minor rise in the highway surface.

Site J

Osborn Church Mini-Sosie Line

The USGS with assistance from the Missouri Geological Survey ran a shallow high-resolution Mini-Sosie seismic reflection line at this location from about 1.5 miles north of MO 53 to about 2 miles south of the highway. This geophysical test was targeted to look for young faulting associated with the CGL which passes under this location. The processed records did in fact show faulting up into Quaternary sediments.

Site K

Duke Power Gas Turbine Power Plant and St. Francis River

Just after crossing the St. Francis River bridge look out the left (north) side of the bus and you can briefly see the Duke Power gas turbine power plant. This is a new power plant built to use natural gas from the transmission pipeline that goes through this area. This pipeline from the Gulf coast serves areas to the north and east as far as Ohio. Interestingly this transmission pipeline coincidentally follows the CGL from northern Arkansas to near the northern edge of the ME. Two other gas turbine power plants had been proposed along this pipeline including one near Stop 1 at the Holly Ridge Site. If earthquakes were to occur on the CGL they could cause liquefaction of the ME sediments which could cause damage to the pipeline.

The St. Francis River flows generally south thru the Western Lowlands from where it exits the Ozarks to just south of this location. It then turns east and cuts thru Crowleys Ridge. It is difficult to explain how this modest river could flow all the way across the Western Lowlands, formed by the much larger ancient Mississippi River, and then cut across Crowleys Ridge that the Mississippi did not breach.

Site L

Crowleys Ridge at MO 53

Here we will cross Crowleys Ridge again. Here Crowleys Ridge is about 2 miles wide with a relief of about 100 feet. In this area the drainage on Crowleys Ridge is mostly to the east indicating tilting in that direction.

STOP 4

MORRIS STATE PARK LANDSLIDE

The landslide at Morris State Park is one of many that may be found along nearby steeper slopes of Crowleys Ridge (Figure 14) and at other locations around the Mississippi Embayment. This slide appears to be young, post 1811-12, based on the preservation of a steep scarp at the head of the slide and the downslope hummocky or blocky topography. In developed areas large landslides pose a threat to the built environment and may damage or destroy critical infrastructure elements. The threat of earthquake-induced ground failure, including large landslides is significant in the New Madrid region.

SETTING AND SITE GEOLOGY

Crowleys Ridge is generally considered an erosional landform and is formed of Paleozoic, Cretaceous, Paleocene, Eocene and younger rocks and sediments. In the vicinity of Morris State Park, the sands and clays from the weakly consolidated Paleocene-Eocene Wilcox Group is the oldest exposed stratigraphic sequence. The scarp at the head of the landslide has a sequence of Wilcox Group sands and a Quaternary sequence composed of gravelly alluvium and loess (Figure 15). The drainage basin west of the scarp is beheaded, and the paleo-alluvial sequence points to a period during the Quaternary when uplands east of Crowleys Ridge must have been present to supply gravel to the stream. If the stratigraphic relations shown are accurate an upland east of Morris State Park persisted through the Middle Wisconsinan.

This segment of Crowleys Ridge lies west of the Reelfoot Rift margin, and east of the Commerce Geophysical lineament. The segment of the ridge north of Campbell has scarps that strike between N35-40E and N40W trends that are similar to fault strikes elsewhere in the Mississippi Embayment. In particular, late Quaternary faults that have strike about N35E are found south of Cape Girardeau in Thebes Gap (Harrison and others, 1999) and at the Holly Ridge Site (this volume) and from seismic reflection data along the Commerce Geophysical Lineament. While some areas of Crowleys Ridge may be fault controlled, the few deep well logs that are present in the upland portion of the ridge suggest that Paleocene-Eocene sequence is nearly horizontal in the vicinity of Campbell (Figure 16). There are no well data available to determine if faults are present along the base of the uplands.

LANDSLIDES AND EARTHQUAKE-INDUCED GROUND FAILURES

Historical accounts of ground failures associated with the 1811-1812 earthquake series describe bank caving along major streams probably including liquefaction-induced lateral spreads. These low-relief landslides occur in saturated sandy deposits that develop high pore pressure during long duration earthquakes. Ground failures described by Fuller (1912) likely include both simple landslides and lateral spread failures. Fuller also described large landslides he attributed to

1811-1812 that still had broken and tilted trees on rotated or slumped blocks. A later survey of steep slopes in western Tennessee and Kentucky (Jibson and Keefer, 1984) found numerous landslides, but apparently few that could be directly and unequivocally linked to the 1811-1812 earthquakes. Many of the slides found in western Kentucky and Tennessee are described as shallow rooted earth flows and rotational slumps that had formed within loess deposits along slopes of 40 feet or more. Deep-rooted, translational landslides, with horst and graben topography were less common that either earthflows or rotational landslides as described by Jibson and Keefer (1984). In an analysis of the stability of slopes in western Kentucky and Tennessee, Jibson and Keefer (1984) determined loess slopes less than 40 feet high should be stable during moderate magnitude earthquakes.

Slopes in many areas of Crowleys Ridge are not only formed in loess, but also are have sandy and plastic clays from Tertiary and Cretaceous sequences. These clays can focus groundwater movement and, under sufficient load, act as a glide plane for the base of landslides. The well logs used to construct the cross section (Figure 3) shows a thick Wilcox Group clay bed between 400 and 300 feet mean sealevel. The top of the clay is within 20 feet of the toe of the landslide and may contain the glide plane for the slide.

Topography along the southeastern margin of Crowleys Ridge near Morris State Park has other areas that exhibit similar surface expression as the area of the landslide. Arcuate or boxy steep ravine heads are indicated at arrows A and B (Figure 17). These ravines lack significant drainage area and have sides with over 40 feet relief in less than 150 feet. Moreover, topography between A and B is hummocky at elevations between 375 and 350 feet mean sealevel, within the approximate elevation of the top of the thick Wilcox clay bed. These areas may not be isolated landslides, but instead are reactivated portions of a large composite landslide along the eastern slope of Crowleys Ridge. There are no data to indicate if these slides are earthquake-induced or spontaneous ground failures.

The landslide described here does not pose a hazard to infrastructure. However, many areas in Mississippi Embayment have had large earthquake- and non earthquake-induced ground failures. Where geologic conditions are favorable for ground failure, or where ground failure has occurred in the past, the risk to co-located infrastructure is significant. Future hazard mapping should focus on these co-located geologic and earthquake hazards, and serve to highlight risk to homeowners as well as private and government critical infrastructure.

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Jibson, R. W. and David Keefer, 1984, Earthquake-induced landslides in the central Mississippi Valley, Tennessee and Kentucky, in Proceeding s of the The Symposium on “The New Madrid Seismic Zone”, Paula L. Gori and Walter W Hays eds., USGS Open-file Report 84-770, 468 p, 1 plate.

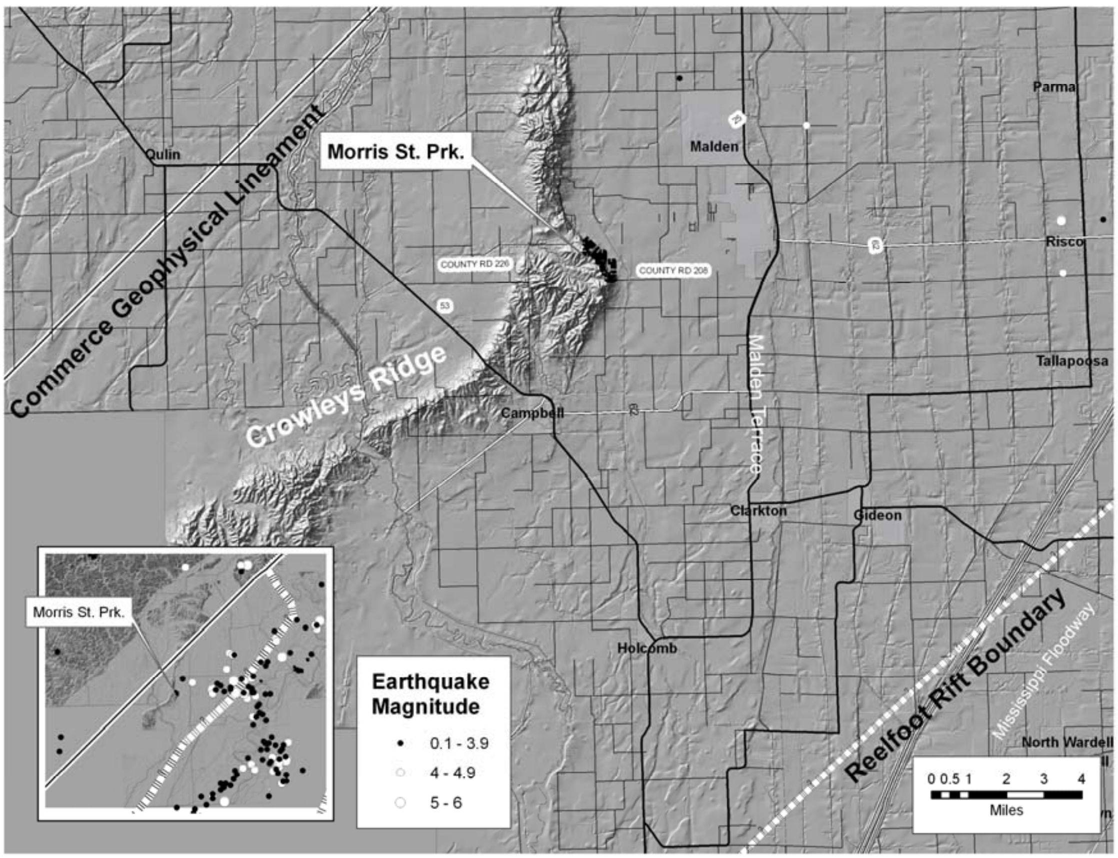

Figure 14. Location of Morris State Park.

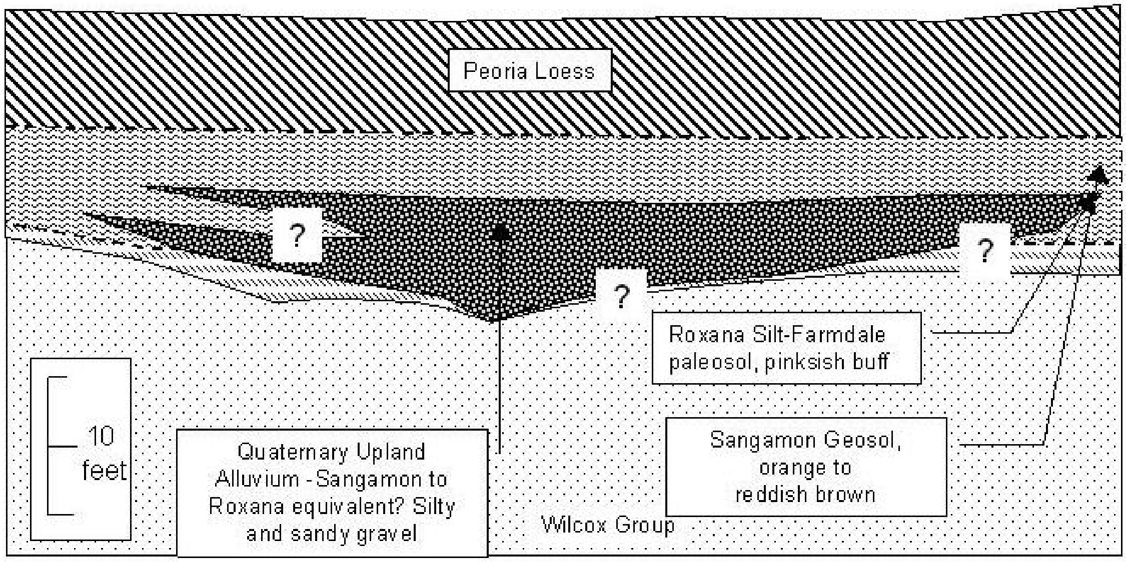

Figure 15. Stratigraphy at Morris State Park – Head of Landslide.

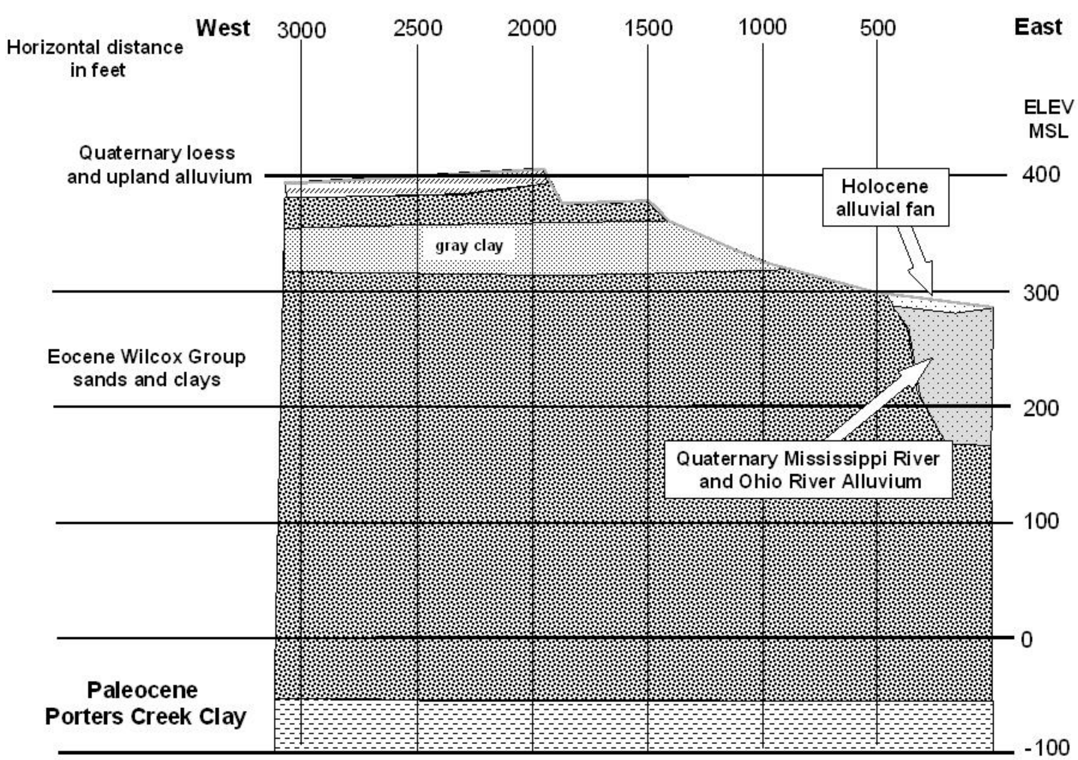

Figure 16. Generalized Cross Section Campbell Area.

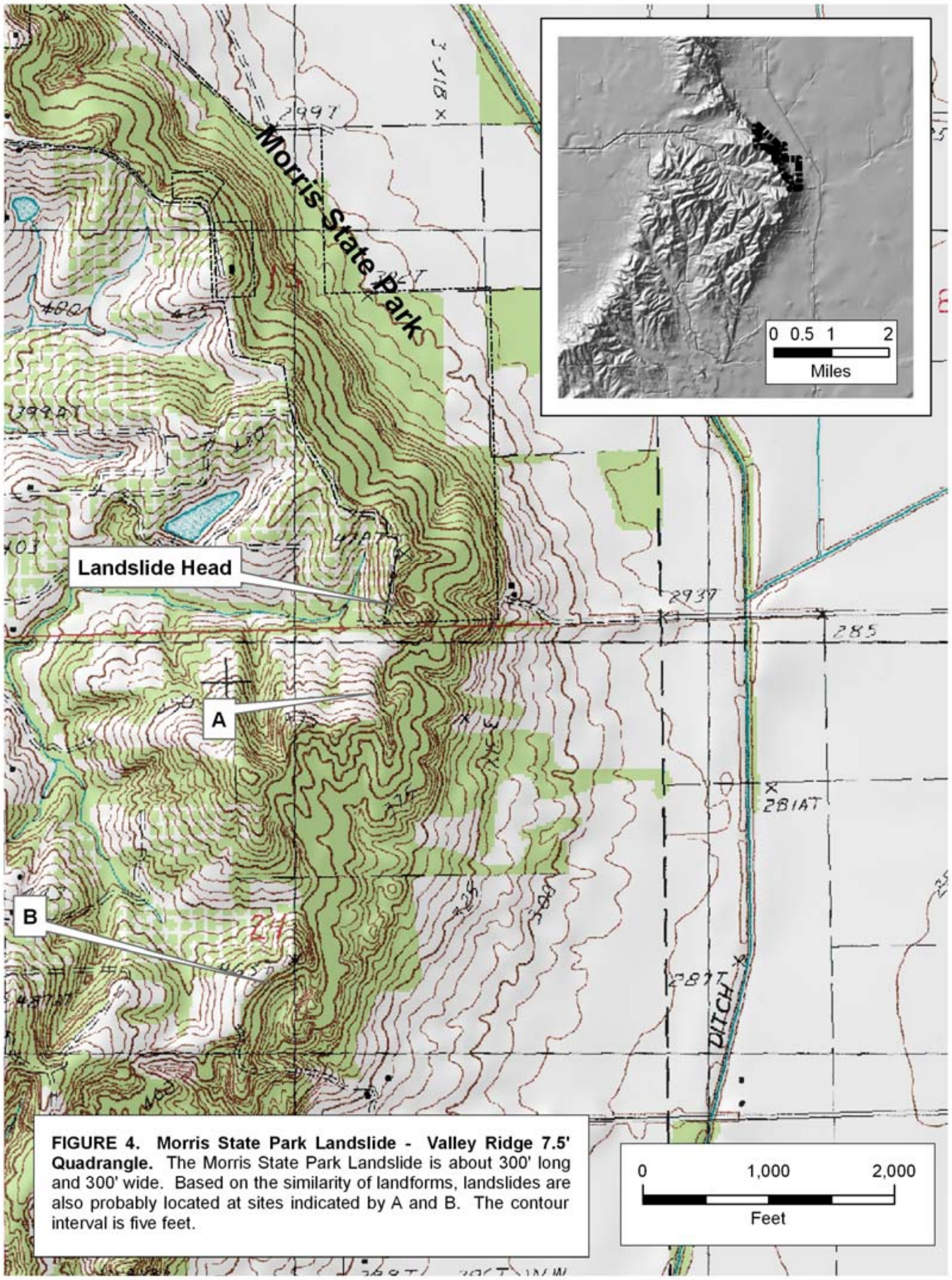

Figure 17. Morris State Park Landslide – Valley Ridge 7.5' Quadrangle.

Site M

Malden Terrace

Malden Terrace is another subtle landform located in the Eastern Lowlands. The eastern edge of the terrace is marked by a small scarped about 15 feet high at this location. The scarp extends from Dexter at the north to south of Malden. There are suspicions by some that this very linear scarp could be tectonic in origin. One attempt a running a shallow high-resolution seismic reflection line across the scarp at this location yielded no results due to the data being recorded incorrectly.

Site N

Little River Drainage Ditch at US 62 and Sandblows

We cross the Little River drainage again here on US 62. Notice how much bigger the drainage ditch is here than further north where we saw it near Sikeston on US 60. We are in the NMSZ and approaching the town of New Madrid. This area is in the heart of sandblow country. Look for sandblows in the fields along the way. When the fields are not obscured by crops you can spot the sandblows by their light sandy soils surrounded by the darker colored silty-clay soils. When crops are in the field the sandblows can sometimes be detected by noting the areas with stunted crops which have a hard time growing in the sandy sandblow soils.

Site O

Indian Mounds at New Madrid Cemetery

Just before reaching I-55 we past the New Madrid Cemetery to the north. The cemetery is located on prehistoric Indian mounds. There are a number of such mound complexes scattered around the ME. Dating of archaeological artifacts associated with sandblow liquefaction features is used to help date prehistoric earthquakes in the NMSZ. This will be discussed more at Stop 6.

STOP 5

New Madrid, Missouri

This stop discusses the NMSZ and the historic town it is named after. In 1811, the frontier town of New Madrid was the largest town between St. Louis to the north and New Orleans to the south. It had a bright future and was the capitol of the territory. On December 16, 1811 at about 2 AM, the first of three extremely powerful earthquakes struck somewhere near New Madrid. The second earthquake struck on January 23, 1812 and the third, generally considered the largest, struck on February 7, 1812. From December 16, 1811 to March 1812 the earth shook almost constantly and then quakes gradually diminished after that. A man named Jared Brooks, who lived in Louisville, Kentucky about 250 miles to the northeast up the Ohio River, built crude instruments using pendulums and springs to detect the earthquakes and made a log of them. He logged 1874 shocks between December 16, 1811 and March 15, 1812 when he got tired of keeping his log. The more powerful earthquakes were felt all the way to the East Coast of the United States. Church bells rung in Boston, scaffolding around the Capitol Building in Washington, D.C. was knocked down, and land subsided in Charleston, South Carolina. This series of earthquakes has traditionally been considered to be the most powerful earthquake to strike the conterminous United States in historic times. The moment magnitude of the largest earthquakes in the series had been estimated to range from the middle 7's- to as high as 8.

Because New Madrid was on the frontier and there were few European white settlers living in the area, there was not a lot of first person information written and preserved about the earthquakes. However, from the relatively few documents available a very dramatic and horrifying account of the earthquakes and their destruction has been pieced together. Much of the information is about conditions on or adjacent to the rivers because it comes from boatmen going down the Ohio and Mississippi Rivers to New Orleans. They constituted the largest segment of the population in this area of the frontier.

Huge waves formed on the river, water geysers erupted from the river bottom, banks caved in, islands disappeared, and the river even ran backward for a short period of time. At least one short lived waterfall formed across the Mississippi River near New Madrid, which caused many boats to capsize and an unknown number of people to drown.

On land, many bizarre and confusing phenomena occurred. These included formation of huge cracks and fissures in the ground, geysers of water spouting, craters forming, sand erupting, flooding, and subsidence and uplift of the land surface. Several large lakes formed due to subsidence. All in all, most of the small number of settlers in the area fled in terror. The once fertile land appeared ruined and could not easily be farmed due to thick sand deposits and fractured ground. To bail the settlers out of their predicament, the fledgling United States government instituted its first public assistance program to trade homesteads in the devastated area for valuable land elsewhere. Of course, this also led to a major scandal as some scoundrels swooped in and bought the ruined land at a cheap price before the bewildered owners found out about the government offer. They then claimed valuable land elsewhere.

On the way out of New Madrid the bus will briefly stop for to see the seismic retrofit, exterior structural steel framework around the telephone company building (Figure 18).

Figure 18. Seismic retrofit structural steel frame around telephone company building in New Madrid

Site P

St. Johns Bayou – Mississippi River Floodway

St. Johns Bayou enters the Mississippi River just south of our route. To the north the bayou drains a large area of land along the eastern side of Sikeston Ridge almost all of the way to the Mississippi River and south of the Benton Hills portion of Crowelys Ridge. This drainage has one segment that heads at the Mississippi River nearly opposite Cario, Illinois. Corps of Engineers levees along the Mississippi River protect the land west of the river. Supplemental levees bracket the drainage that heads near Cario and form what is called the Mississippi River Floodway. If a large flood threatens the levees on the Mississippi River a levee plug at the head of the Floodway can be blasted allowing water pass through the Floodway and thereby relieve pressure on the main river levees.

Site Q

County line – Sassafras Ridge, TN Seismic Monitoring Station

The New Madrid-Mississippi County line is at the end of MO Route WW. We will continue on a paved Mississippi County road. About 6 miles south of here where we cross the county line is the village of Sassafrass Ridge in Tennessee. A seismic monitoring well has been installed there by the Kentucky Geological Survey and University of Kentucky. The well is 800 feet deep and has monitoring instrumentation a 3 levels in the well, at the bottom, about a third of the way down and at the top. Data from this monitoring well is showing how ground shaking increases as the seismic waves approach the ground surface. Very small shaking at depth becomes very large shaking at the ground surface.

STOP 6

Towosahgy State Historic Site

Towosahgy State Historic Site is another prehistoric Indian mound archaeological site. Archaeological excavations at this site have found buried bones that have been disrupted by liquefaction dikes. Radiocarbon dating of the bones and dating of other archaeological materials have been used to bracket the date of the sandblow event and hence the earthquake that caused the sandblow. Dating of many, many sandblows over a large area of the NMSZ has shown the dates to cluster and several different times. This has led to a chronology for prehistoric NMSZ earthquakes and estimates for their magnitudes and characteristic mode of occurrence. Based on this type of research prehistoric large earthquake series in the NMSZ similar to those in 1811-1812 have happened in about 1450 AD, 900 AD and 300 AD.

Site R

Wolf Island – Oil/Gas Well

About 2.75 miles west of the village of Wolf Island there is an oil and gas well prospect. The site has had exploration drilling conducted a considerable number of years ago. That well was drilled thru the ME sediments in to the underlying Paleozoic rocks at about 1500 feet deep. After drilling in to the Paleozoic a few hundred feet the well was lost due to a high pressure gas blowout. Just a few years ago a wildcatter attempted to line up funding to drill additional holes.

Site S

Charleston, MO Earthquake 1895

In 1895 a estimate magnitude 6.5 earthquake occurred at or near Charleston, Missouri. The earthquake destroyed much of the town of Charleston and caused liquefaction and sandblows in an area about 15 miles in diameter. Little historic information is known to exist for this earthquake other than widespread old newspaper accounts of people having felt the earthquake. A huge area of the Central and Eastern United States felt the earthquake.

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