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Map of an Exploratory Trench across the Cottonwood Grove Fault, Lake County, northwestern Tennessee

by

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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INTRODUCTION

The northern Mississippi Embayment, the most seismically active area in the central United States (Hadley and Devine, 1974) was the location of the great New Madrid earthquakes of 1811-1812 (Fuller, 1912). Despite the modern seismicity, evidence for tectonic displacement of Holocene sediments has been found in only one location near Reelfoot Lake, Tenn. (fig. 1). At this location, recent movements have occurred on surface faults that are apparently associated with subsurface faulting in the Paleozoic bedrock (Russ, 1979). Locating and documenting additional areas where Holocene faulting has occurred would provide critical information needed for accurately assessing earthquake hazards and for refining estimates of the recurrence interval major earthquakes in the area.

In September 1980, a 120-long (393.7 ft) trench was excavated near the small town of Cottonwood Grove, Tenn. approximately 5.5 km (3.4 mi) southwest of Ridgely, Tenn., to determine if faulting had disrupted the Holocene sediments in the area (fig. 1). The trench was located 8 m (26.3 ft) south of the pavement edge of Tennessee State Highway 79 which passes through Cottonwood Grove (36° 13′ 40″ N., 89° 31′ 48″ W.), and was oriented N. 82° E., or nearly parallel to the highway.

The trench site is within the modern Mississippi River flood plain which is characterized by numerous abandoned river channels (Fisk, 1944) and very low topographic relief. Most of the topographically high areas in the flood plain are natural levees that developed adjacent to abandoned stream courses. The levees and abandoned channels are easily identified on aerial photographs and detailed topographic maps.

High areas in some parts of the flood plain, especially in the vicinity of Reelfoot Lake, cannot be explained by normal fluvial depositional processes. Geophysical (Zoback, 1979), geologic (Russ and others, 1978; Russ, 1979; Crone and Brockman, 1982), and geomorphic studies (Stearns, 1979; Russ, 1982) have shown that tectonic warping and faulting have deformed the ground surface in northwestern Tennessee into a broad dome named the Lake County uplift. In places, the uplift is bounded by conspicuous scarps, one of which is associated with surface and subsurface faults (Russ, 1979; Zoback, 1979).

The Cottonwood Grove trenching site lies along the southern margin of the Lake County uplift mapped by Russ (1982). No evidence of anomalous topography or lineaments that might be the surface expression of Holocene faulting are present in the immediate vicinity of the trench. The topography in the Cottonwood Grove area is subdued; ancient stream channels, natural levees, and point-bar deposits are responsible for undulations in the ground surface.

The Cottonwood Grove area was considered a likely location to discover Holocene faults despite the absence of any obvious scarps or other visible signs of possible faulting. Seismic-reflection profiles that were run along Highway 79 show a major northeast-trending fault, named the Cottonwood Grove fault, beneath the town (fig. 1) (Zoback and others, 1980). The fault has about 80 m (262 ft) of post-middle Eocene vertical displacement, the largest amount of post-Paleozoic vertical fault offset that has been seen in more than 275 km of reflection profiles run throughout the New Madrid seismic zone. In addition, the Cottonwood Grove fault lies below a northeast-trending segment of the Lake County uplift known as Ridgely Ridge (fig. 1) (Stearns, 1979; Russ, 1982), which may indicate recent movement along the fault. Furthermore, abundant seismicity in the general vicinity of the fault suggests that active

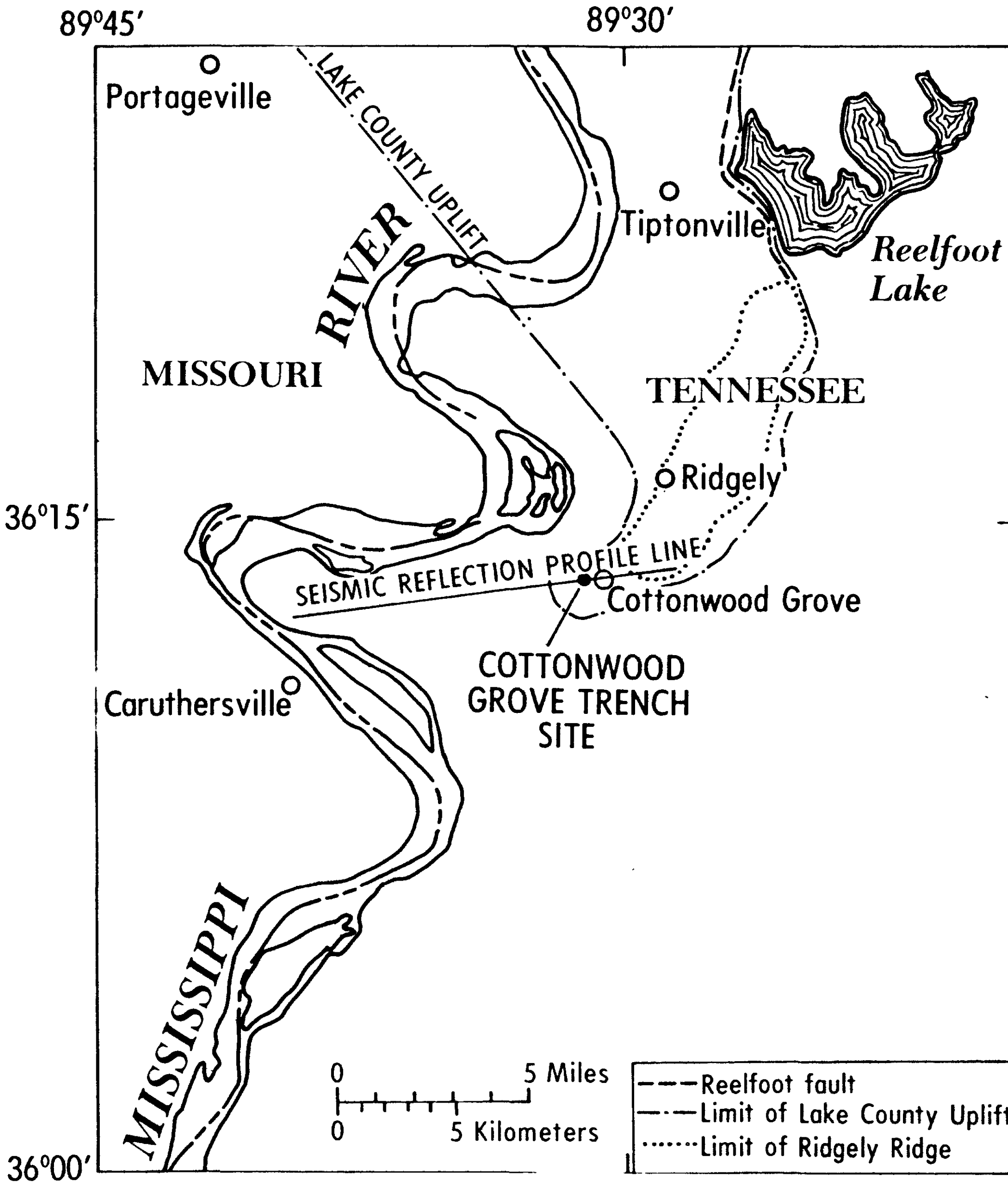

Figure 1.-- Location map of the Cottonwood Grove trench site.

Boundary of the Lake County uplift and Ridgely Ridge from Russ (1982). Location of Reelfoot fault from Zoback (1979).

deformation is presently occurring in the area.

TRENCH LOCATION, EXCAVATION, AND MAPPING TECHNIQUES

The general trench location was determined from the seismic-reflection profiles, but because no obvious indications of possible surface faulting were found, further work was needed to select a specific site. A small-scale seismic-refraction experiment was run across the suspected fault zone for a distance of more than 0.8 km (2625 ft) along the south side of Highway 79 (fig. 2) using a Huntec[1] portable seismic-refraction system. The purpose of the refraction experiment was to identify locally anomalous velocity profiles that might indicate zones of disruption in the near-surface sediments. A metal block, struck with a twelve-pound sledge hammer, provided the energy source for the refraction study. The refraction survey was run as a series of premeasured, 30.5 m (100-ft) long lines (fig. 2). The geophone was firmly anchored at the starting point of each line and the block was struck at 1.5 m (5-ft) increments along the line. First arrivals recorded on the instrument were then used to calculate velocity profiles of the near-surface sediments.

The velocity analyses from the refraction data yielded a simple two-layer model for the near-surface sediments. The upper layer had a velocity of about 304-365 m/s (1000-1200 ft/s) and extended to a depth of approximately 3.7 m (12 ft); a deeper layer had a velocity of about 1097-1280 m/s (3600-4200 ft/s). The velocity increase at 3.7 m (12 ft) was probably caused by the water table which hand augering and later, excavation of the trench, showed to be at that depth.

[1]Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S.G.S.

Except for the first five lines, each refraction line had a 12.2 m (40 ft) overlap with the previous line (fig. 2). The overlap was sufficient to continuously refract energy through the higher velocity layer below 3.7 m, (12 ft) and thereby determine if there were any areas where abrupt changes in the depth of the boundary between the two layers that might indicate faulting in the sediments.

The final site selection for the trench was based primarily on the refraction data. Most of the lines had refraction patterns that were consistent with a simple two-layer velocity profile, but several lines had anomalies or deviations that could have been caused by disrupted sediments. A few of the anomalous profiles were scattered among normal profiles and may have been caused by poor coupling between the geophone and the ground, or by difficulty in getting sufficient energy propagation. Several consecutive anomalous lines occurred in only one part of the entire refraction survey. Furthermore, the location of these anomalous lines coincided perfectly with the projection of the Cottonwood Grove fault to the ground surface. On the basis of this information, the exploratory trench excavated along the area covered by runs 10 to 16 (fig. 2); this location seemed to hold the most promise for detecting a surface fault in the area if such a fault existed.

The trench, excavated with a backhoe, was 120 m (393.7 ft) long, approximately 1 m (3.2 ft) wide, and varied from 1.5 to 2.8 m (4.9-9.2 ft) in depth. Wooden shoring was used in deeper parts of the trench to reduce the danger of caving. The south wall of the trench was scraped clean to enhance details in the sediments and carefully mapped; in areas where the sediments appeared to be disturbed, portions of the floor and north wall were also scraped and examined. A 1-m-square grid system using spikes, string, and an

Abney hand level was laid-out on the south wall to provide accurate vertical and horizontal reference points for mapping. Key sedimentologic contacts and structural features were traced along the wall; their positions were transferred onto graph paper using the 1-m trench grid for reference.

GENERAL STRATIGRAPHY AND STRUCTURE

The alluvium exposed in the trench was dominantly fine grained fluvial sediments deposited within the modern meander belt of the Mississippi River (pl. 1). Light-gray to light-brown sandy silt and silty, fine- to very fine grained sand were the most common sediment types. Most of the sediments were massive, but some of the well-sorted sands were distinctly laminated. Virtually all of the sediments were mottled by rust-orange blebs of iron oxide. In many parts of the trench the sediments were penetrated by what is interpreted to have been an extensive network of tree roots which had decomposed and were later infilled by carbonaceous, grayish-brown silty clay. In the areas between 82 m and 84 m and between 87 m and 88 m, the network of filled root tubes was so dense and complex that individual tubes were not mapped.

The uppermost 0.2-0.7 m of sediment exposed in the trench was highly disturbed by plowing and in places contained artificial fill with fragments of manmade objects. Below the plowed zone, individual stratigraphic units could be identified and the contacts between adjacent units could be easily traced for many meters along the trench wall. Some units gradually became indistinguishable from overlying or underlying sediments because of facies changes.

From east to west along the length of the trench, a gradual but distinct change occurred in the character of the sediments. At the eastern end, dark-gray silty clays and clayey silts were dominant, but toward the west, the sediments were generally more sandy, and discrete, laminated sand beds were more common.

Several sand-blow dikes that abruptly cut across the stratification were exposed in parts of the trench. A thin sand-blow dike, located about 14 m from the east end of the trench, could be traced across the trench floor and up the north wall with a strike of N 19^{o} E. It cut through a small, filled root tube on the floor of the trench. A sample was collected to determine if enough organic carbon was present to yield a radiometric date and establish a maximum age for the intrusion of the dike. Several clasts of the intruded sediments, torn up during injection of the sand, were incorporated into the dike.

Between the 26 and 30.5 m marks, a large body of medium- to very fine grained sand was intruded into the sediments. This dike also contained large clasts of the sediments. From the west end of the main body of sand, a 1-cm-thick sand stringer, which may have been the source conduit for the sand, extended eastward for a distance of almost 5 m (16.4 ft).

Two other possible sand blow dikes were observed in the trench; one at the 58 m marker and the other between the 64 and 65 m marks. Both dikes were only a few centimeters wide and appeared as discontinuous pods of sand in the trench wall.

Detailed mapping of the trench wall did not reveal any evidence of tectonic faults or folds in the exposed sequence of fluvial sediments. The generally distinct stratification of heterogeneous sediments provided excellent reference planes for the detection of even minor offsets and flexures, however no such deformation was observed.

DISCUSSION

The lateral continuity, nearly horizontal stratification, and undisturbed character of the sediments in the Cottonwood Grove trench suggests either that no recent movement on the Cottonwood Grove fault has occurred, or that any recent movement was insufficient to cause a ground-surface rupture. This conclusion assumes that the trench is located where ground rupture caused by movement on the fault would occur. Based on the seismic-reflection profiles and the refraction study conducted prior to trenching, we believe that the site selected for the trench held the most promise for exposing young faults. Individual stratigraphic units do terminate laterally in the trench, but all of these terminations are the result of sedimentologic processes and not tectonic activity. There was sufficient stratigraphic control to clearly show that there were no faults exposed in the trench.

The sediments in the trench are primarily point bar and overbank deposits associated with abandoned meanders of the Mississippi River. Geologic and geomorphic studies by Saucier (1974) indicate that in this area the Mississippi River adopted a meandering regime about 6000 years ago. Thus, near-surface sediments that are approximately 6000 years old have not been faulted. Therefore, based on the available data, the last apparent movement on the Cottonwood Grove fault is post-middle Eocene (Zoback and others, 1980) but is older than 6000(?) years.

However, the absence of faults in the trench does not eliminate the possibility that movement has occurred on the Cottonwood Grove fault within the past 6000 years. It is possible that considerable vertical movement could occur in competent bedrock along the fault but that soft-sediment deformation, flowage and compaction within the overlying unconsolidated sediments and alluvium could compensate for, and conceal, the movement. Subsurface information shows that the unconsolidated sediments are approximately 700 m thick in the vicinity of Cottonwood Grove. A high-resolution seismic reflection survey conducted subsequent to the trenching shows that displacement on the Cottonwood Grove fault decreases toward the surface and does not displace reflectors at about 200 milliseconds two-way travel time, leading to the conclusion that faulting has affected rocks as young as middle to late Eocene in age (Sexton and Jones, 1981). However, given the incompetent character of the late Cretaceous, Tertiary and especially the Quaternary sediments, soft-sediment deformation compensating for vertical movements on faults is a distinct, but as yet, unproven possibility.

On the other hand, if movement on Reelfoot fault (fig. 1) and the associated scarp is taken as an analogous example, it seems unlikely that a substantial amount of late Holocene movement occurred on the Cottonwood Grove fault without disturbing the near-surface sediments. Zoback (1979) and Russ (1979) demonstrated recurrent movement on Reelfoot fault and Reelfoot scarp and suggested that recent movements at depth have offset Holocene sediments and produced a topographic scarp. Thus, in this case, it seems that, even with a thick veneer of unconsolidated sediments, major vertical movements may result in near-surface faulting and deformation. No such faulting or deformation was found in the Cottonwood Grove area. Certainly, the possible effects of soft-sediment processes merits more study to help resolve conflicting interpretations of the age of movement on faults in the area.

Finally, there is also the possibility that the trench was incorrectly located to intersect the fault, but in light of the extensive preliminary work, we believe that the most promising location was selected.

The sand-blow dikes exposed in the trench show that there has been sufficiently strong ground motion in the area to liquify sediments; however, sand-blow phenomena are widespread throughout the northern Mississippi embayment and are not necessarily a good indication of proximity to an active fault.

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