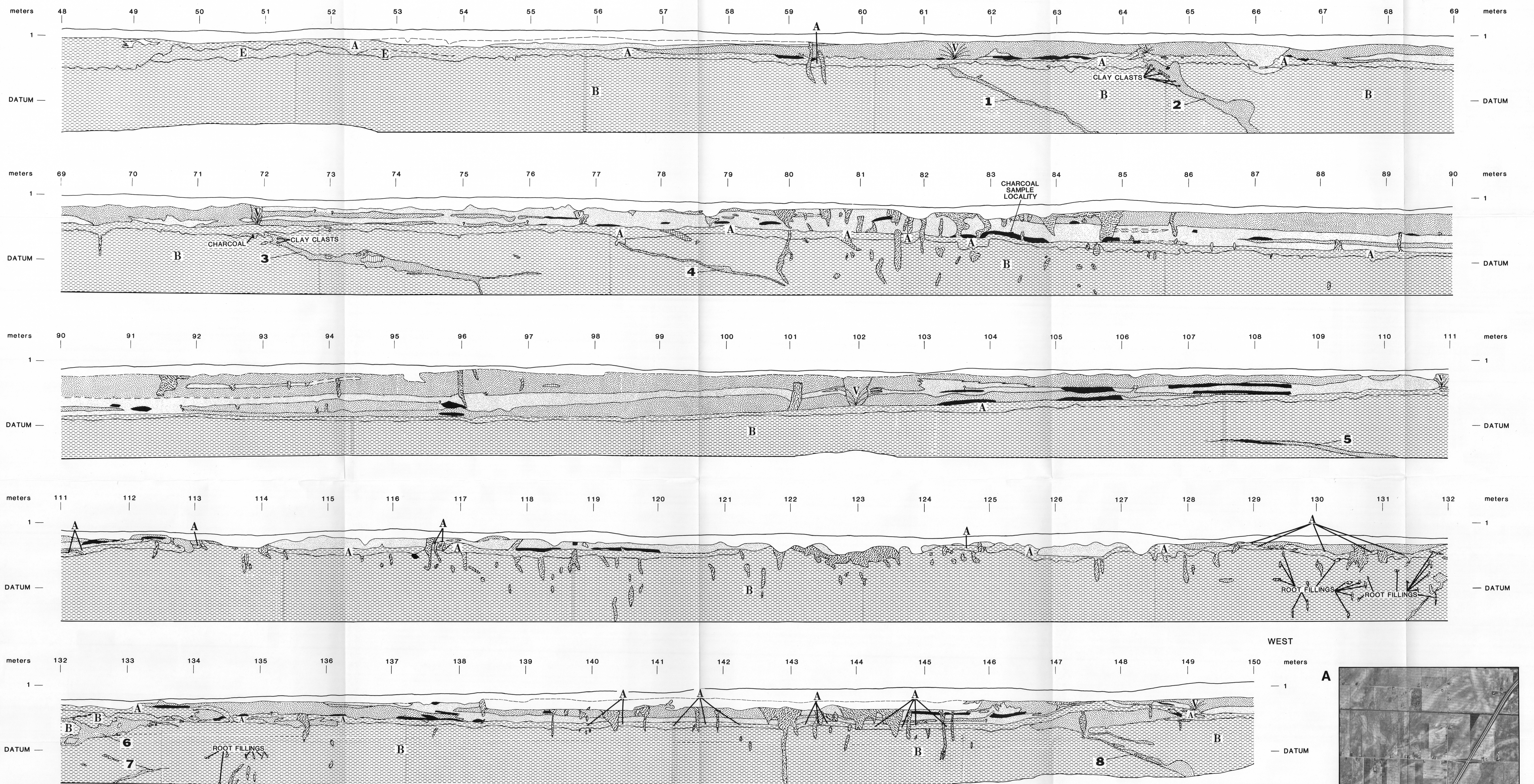
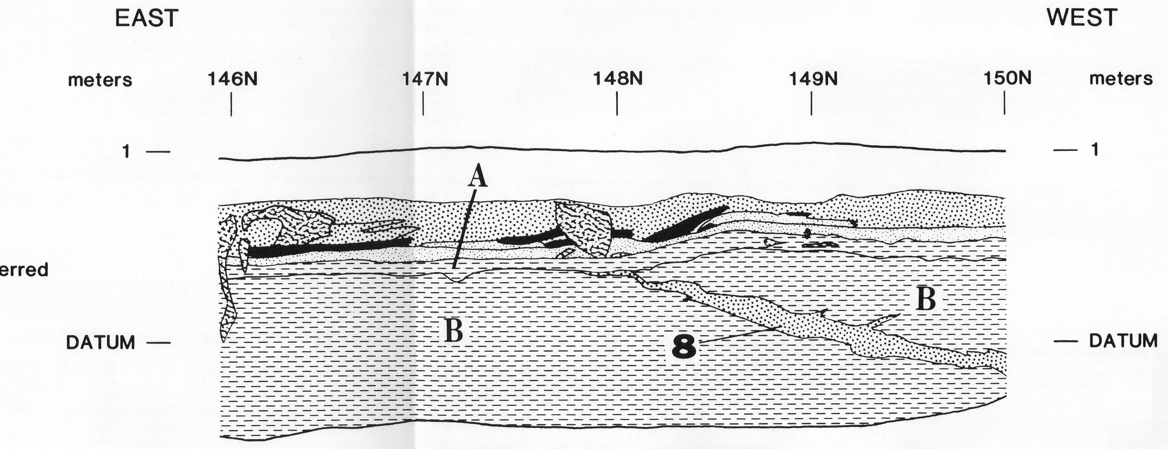
MISCELLANEOUS FIELD STUDIES
MAP MF-1858



EXPLANATION

- CONTACT—Dashed where indistinct; queried where uncertain
- MODERN PLOW ZONE
- SANDBLOW DEPOSITS
  - Medium quartzose sand
  - Fine to very fine silty sand
- BURIED A HORIZON
- BURIED E HORIZON
- BURIED B HORIZON
- ROOT FILLINGS
- CHARCOAL
- ANIMAL BURROW
- RIP-UP CLAY CLAST
- "ERUPTIVE VENT"
- SANDBLOW FEEDER DIKE—Referred to in text by number



NORTH WALL OF TRENCH

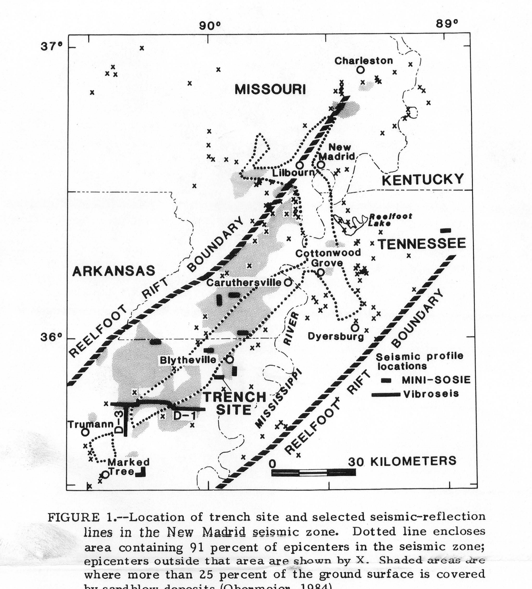


FIGURE 1.--Location of trench site and selected seismic-reflection lines in the New Madrid seismic zone. Dotted line encloses area containing 91 percent of epicenters in the seismic zone; epicenters outside that area are shown by X. Shaded areas are where more than 25 percent of the ground surface is covered by sandblow deposits (Obermeier, 1984).

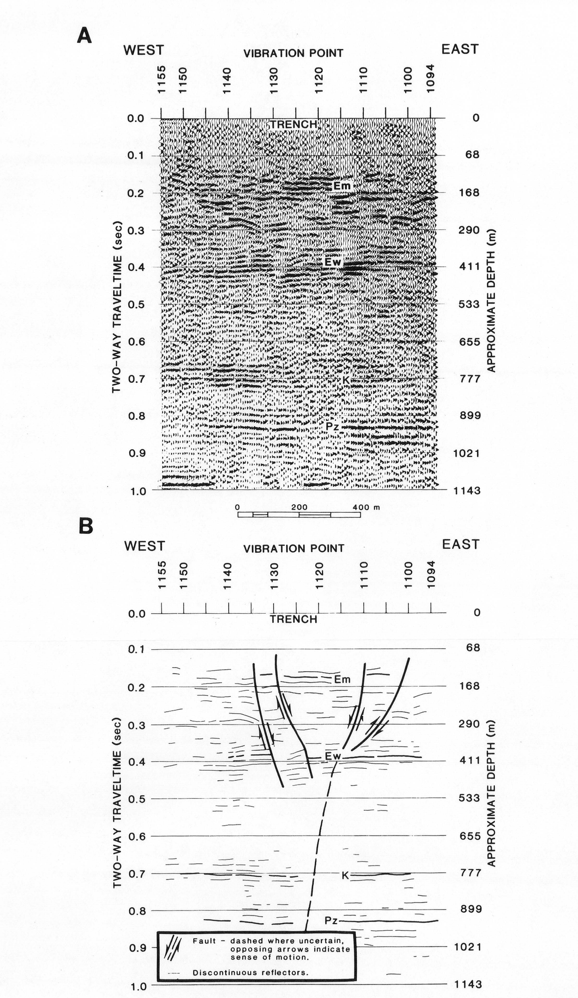


FIGURE 2.--A, Profile and B, Interpretive line drawing of M-S seismic-reflection profile located near the trench. Reflectors labeled in A and medium lines labeled in B are tops of the Paleozoic rocks (Pz), Cretaceous rocks (K), Eocene Wilcox Group (Ew), and Eocene Memphis Sand (Em).

FIGURE 3.--A, Aerial photograph of the trench site. B, Sketch map of the trench site and M-S reflection profile line. Numbered dots on B correspond to M-S vibration points labeled in fig. 2; spacing between 10 vibration points is 160 m. Dashed line in B is aligned light-colored sandblow deposits shown in A.

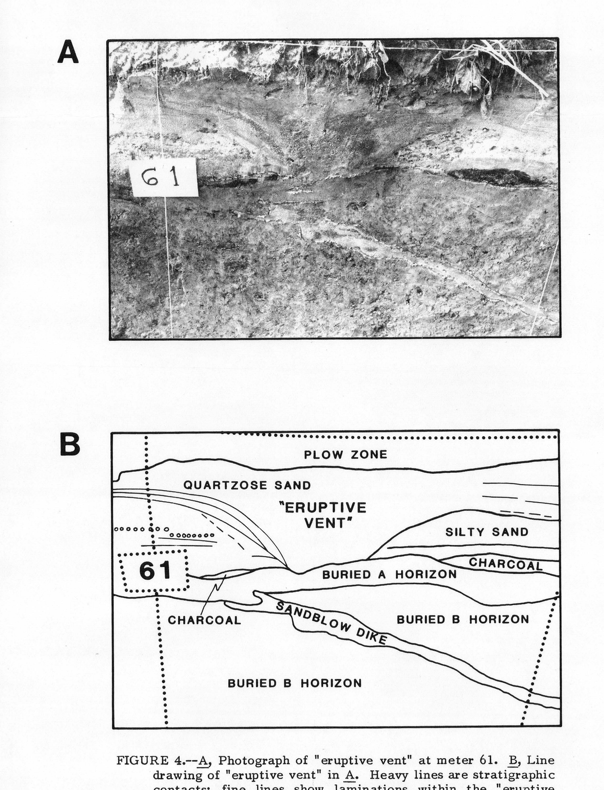


FIGURE 4.--A, Photograph of "eruptive vent" at meter 61. B, Line drawing of "eruptive vent" in A. Heavy lines are stratigraphic contacts; fine lines show laminations within the "eruptive vent," dashed where discontinuous. Open circles are aligned clay fragments. Dots show 1-meter-square mapping grid.

INTRODUCTION

During the winter of 1811-12, at least three major earthquakes having estimated magnitudes of M_S 8.3-8.8 (Nuttli and Herrmann, 1984) struck the area near New Madrid, Mo. Since the 1811-12 series of earthquakes, 20 damaging earthquakes have occurred in the area (Nuttli, 1982), making the New Madrid seismic zone (fig. 1) the most seismically active area in the Eastern United States (Hadley and Devine, 1974). The zone, extending from about lat 35° to 37° N., approximately parallels the Mississippi River and encompasses an area roughly 50 km wide (Nuttli, 1979).

The northeast-striking Reelfoot rift (fig. 1) is the major structural element in the New Madrid seismic zone (Ervin and McGinnis, 1975). The rift is more than 300 km long and 70 km wide (Kane and others, 1981) and has 2-3 km of structural relief (Hildenbrand and others, 1982). The earthquakes in the New Madrid seismic zone are concentrated in three trends: (1) axial trend--a narrow, well-defined, northeast-striking, 120-km-long trend from Caruthersville, Mo., to Marked Tree, Ark.; (2) cross-rift trend--a trend of intense seismicity striking north-northwest from Dyersburg, Tenn., to New Madrid, Mo.; and (3) rift-margin trend--a poorly defined, northeast-striking trend extending from Lilbourn to Charleston, Mo.

Several lines of evidence indicate that the axial trend contains a northeast-trending system of parallel or subparallel faults. Fault-plane solutions from earthquakes in the area show dominantly right-lateral strike-slip on nodal planes having the same orientation as the seismic trend (Herrmann, 1979). Multichannel seismic-reflection profiles (locations of D-1 and D-3, fig. 1; Zoback and others, 1980; Hamilton and Zoback, 1982) indicate that the faults and deformation are coincident with the seismicity and may have as much as 1 km of total structural relief.

Because of the abundant seismicity and the history of large damaging earthquakes in the New Madrid seismic zone, the trench described in this report was excavated to provide additional geologic data on near-surface faults in the axial trend and, if possible, to document recurrent movement on these faults. In spite of extensive efforts to find an optimal site, evidence of near-surface faulting was not observed in the trench; however, numerous earthquake-induced liquefaction features were exposed and documented.

PREVIOUS STUDIES

Two previous trenching studies in the New Madrid seismic zone have focused on identifying near-surface faulting in the cross-rift trend. Near Reelfoot Lake, Tenn. (fig. 1), a trench across one of the few prominent scarps in the region exposed numerous faults (Russ and others, 1978); stratigraphic relationships in the trench documented ground ruptures associated with at least two pre-1811-12 earthquakes. Data from this trench suggest a recurrence interval of approximately 600 years for large earthquakes (Russ, 1979). A second trench, near Cottonwood Grove, Tenn., was located across the projection of the subsurface trace of the Cottonwood Grove fault. This fault, first identified on seismic-reflection profiles, has the largest amount of Tertiary-age vertical displacement of any known fault in the New Madrid seismic zone (Zoback and others, 1980). The trench failed to expose any near-surface faulting but did reveal abundant earthquake-induced liquefaction features (Crone and others, 1982).

This study is the first investigation of near-surface faulting associated with the axial trend, even though faults along this trend may have been the source for at least one of the 1811-12 earthquakes. Isoseismal maps (Nuttli, 1973) and the distribution of sandblow deposits (Obermeier, 1984) indicate that at least one episode of intense ground shaking originated in northeastern Arkansas. Reconnaissance studies of liquefaction features in a ditch near Trumann, Ark., suggest multiple liquefaction events but the evidence is inconclusive (S. F. Obermeier, written commun., 1983).

TRENCH-SITE SELECTION

The initial stage of evaluating potential trench sites involved identifying lineaments in the axial trend, followed by collecting high-resolution seismic-reflection data at several likely sites. Many of the lineaments were sandblow deposits and sand fissures (Heyl and McKeown, 1978) that, from the air, appear as circular to subcircular, aligned, light-colored bodies. Sandblow deposits and sand fissures, general indicators of proximity to seismic source zones, are abundant in the vicinity of the axial trend and were thought to be likely locations where faults may approach the surface, such as those observed in the Reelfoot scarp trench (Russ and others, 1978). The lineaments were first identified on mosaics of 1:24,000-scale aerial photographs; any lineament that was obviously related to fluvial depositional or erosional processes was eliminated from further consideration. About 100 of the most distinct remaining lineaments were then field checked. High-resolution M-S (MINI-SOSIE[1]) reflection data were collected across the 10 most prominent field-checked lineaments (fig. 1).

The M-S profiling technique uses earth tampers as energy sources. The tampers have a peak energy input at about 45 Hz, but a significant amount of high-frequency energy (above 100 Hz) is also supplied, thus improving the resolution of shallow reflections. A source sensor, attached to the foot of each tamper, marks a time break for each impact of the foot. The time break for each impact is then transmitted to the recording truck by radio. Crosscorrelation of the input signal and signals received by the geophones is performed in the field and electronically stored while data from succeeding impulses are crosscorrelated. Each vibration point consists of a total of 1,500 impulses from three simultaneously operating tampers, achieving a good signal-to-noise ratio. The shot-point spacing was 16 m. Approximately 15 km of profiles were obtained in these surveys.

The field data were processed using a standard sequence of processing steps at the U.S. Geological Survey facilities in Denver, Colo. Processing steps included tape reformat and gain recovery, CDP (common-depth-point) sort, velocity analyses, normal moveout correction, spectral whitening, band-pass filtering, and final CDP stack. The resulting unmigrated record section consisted of 1 s (two-way traveltime) of 12-fold CDP data.

Under favorable conditions, reflectors as shallow as 37 m and reflectors as deep as 1,062 m could be detected. The tops of the Paleozoic and Cretaceous rocks produced nearly continuous reflectors on many of the profiles, including the profile (fig. 2A) near the trench site. Other shallower reflectors, including the top of the Eocene Wilcox Group and the top of the Eocene Memphis Sand, were discontinuous but recognizable on many of the profiles. Near-surface structural discontinuities on the profiles were of special interest because they might indicate shallow, youthful faulting.

The final location of the trench site (fig. 1) was determined by the presence of prominent near-surface discontinuities on the reflection profile (fig. 2) and a well-defined lineament that could be identified in the field. An additional factor that favored the Blytheville site was the parallelism between the lineament and the northeast-trending seismicity (fig. 3).

The site was located 7.2 km southwest of Blytheville, Ark., in the S½SE¼SE¼ sec. 31, T. 15 N., R. 11 E. The trench, excavated in August 1982, was parallel to and 14.5 m north of the center of Mississippi County Road 312 and 1.3 km west of the Interstate 55 overpass (fig. 3B). The 1-m-wide, 150-m-long trench was 1.2-1.8 m deep; the depth of the trench was restricted by a high water table. The south wall of the trench was scraped with mason's trowels to enhance structural details and stratigraphic contacts. The entire south wall of the trench was mapped in the field, but meters 0-48 are not shown on the trench log because the stratigraphy was similar to the stratigraphy mapped between meters 48 and 52. Locally, parts of the north wall were also cleaned to aid in visualizing the lateral continuity of the structures seen on the south wall; the westernmost 4 m of the north wall (meters 146N-150N) were mapped in detail because of major differences in the structure and stratigraphy between the north and south walls. A 1-square-meter grid, established using spikes and string, was used to provide reference datums for the mapping.

[1]Any use of trade names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

TRENCH STRATIGRAPHY AND STRUCTURE

Four stratigraphic units were recognized in the trench. The lower three units were interpreted as horizons of a paleosol. Although these units have similar bulk compositions, subtle differences in color and occasionally in texture permitted differentiation of the units. The upper unit was interpreted as sandblow deposits that buried the paleosol; the sand in these deposits was derived from substratum sands that underlie much of this part of the Mississippi Valley (Saucier, 1974). In addition to these four units, root fillings were present throughout the trench, and a disrupted zone caused by modern farming was mapped at the top of the trench.

The lowest unit in the trench, interpreted as the B horizon of the paleosol, consisted primarily of a massive, clayey silt. It was typically yellowish brown to brown and grayish brown, and commonly was extensively mottled. Upward, the color gradually became lighter and mottling decreased.

Above the B horizon between meters 0 and 54, an E horizon was mapped (shown on the log between meters 48 and 54). It consisted of a massive, pale-brown, slightly sandy, clayey silt. The E horizon, less mottled than the B horizon, was hard and porous. The lighter color and slight increase in sand content also distinguished the E horizon from the B horizon.

The uppermost unit of the paleosol, the A horizon, was yellowish-brown and dark-grayish-brown, slightly sandy, massive, clayey silt and silty clay. Typically, it was slightly mottled and noticeably darker than the underlying horizons. The darker color indicated a higher organic matter content, thus the A horizon designation. The top of the A horizon was probably the ground surface prior to the 1811-12 earthquakes. Between meters 0 and 54, the A horizon rested on and graded into the E horizon; in the remainder of the trench the A horizon was underlain by the B horizon. A typical section of the complete paleosol occurs at meter 51 of the trench log.

The sandblow deposits overlying the paleosol extend to the present ground surface and were subdivided into two facies: (1) a well-sorted, medium quartzose sand and (2) a fine to very fine silty sand. The quartzose sand was interpreted as substratum sand that was transported by large volumes of water to the surface through feeder dikes and erupted onto the landscape. Locally clay clasts, charcoal clasts, and disseminated charcoal were concentrated along bedding planes and laminations in the quartzose sand.

The silty sand was interpreted as a facies of finer grained sediment, winnowed from the quartzose sand, and locally concentrated by the water that drained from the ground surface immediately following the liquefaction event. The silty facies was typically brown to dark brown, massive to laminated, mottled, and locally contained disseminated charcoal. The quartzose sand and silty sand interfingered and had gradational to sharp contacts; both facies had sharp contacts with the underlying paleosol.

Eight sandblow feeder dikes (1-8 on trench log), conduits through which the substratum sand rose to the surface, were identified in the trench. The dikes, composed of medium quartzose sand, were obvious because they cut the finer grained soil horizons with sharp contacts. These dikes had strikes between N. 56° W. and N. 27° E. All had westerly apparent dips with the exception of the dikes located between meters 132 and 134 (dikes 6 and 7). The sand in the dikes contained clay clasts, charcoal clasts, and disseminated charcoal. The clay clasts were fragments of sediment ripped from the walls of the dike by the intruding sand; the charcoal probably consisted of remnants of wood fragments that were originally deposited in the substratum sand and were transported to the surface in the liquefied sand.

"Eruptive vents" in the sandblow deposits formed near where the feeder dikes broke through the top of the paleosol (fig. 4). The strong ground motion associated with the 1811-12 earthquakes liquefied the unconsolidated, water-saturated substratum sands; the mixture of sand and water then migrated upward, breaking through the overlying sediments. When it reached the surface, the sand flowed out of the dike and covered the nearby ground surface. As the eruption continued the sand in the vent was scoured, leaving a small depression that dipped inward, toward the mouth of the vent. During the waning stages of the eruption, the force of the erupting sand and water diminished and the depression was gradually filled. Elongate clay clasts in the erupted sand produced an inward-dipping laminated appearance in the sandblow deposit at the mouth of the vent. Farther away from the mouth, the dip of the laminations flattened and eventually dipped away from the vent. The laminations show that, in cross section, the erupted sand was thickest near its source and gradually thinned away from the vent.

Three prominent "eruptive vents" were present at meters 61½, 72, and 102; smaller ones occurred elsewhere in the trench. Feeder dikes for the vents at meters 61½ (dike 1) and 72 (dike 3) are shown on the log, but the dike that fed the vent at meter 102 was located in the floor of the trench and was destroyed during excavation. It did not extend to the south wall and thus is not shown on the log.

In several places near the western end of the trench stratigraphic relationships suggest that liquefied sand was injected beneath and delaminated the A horizon from the underlying parts of the paleosol. At meters 147-149, a 30-cm-thick, 2-m-long lens of clean quartzose sand occurred between the A horizon and the B horizon. The continuous A horizon was warped up over the sand lens. The feeder dike (dike 8) that supplied the sand could be traced from the base of the south wall through the B horizon to the lens. To the east and west of the sand lens, the paleosol horizons occurred in a normal sequence and were overlain by sandblow deposits. On the north wall at meters 147N-149N, the feeder dike could be traced through nearly all of the paleosol; no lens of injected sand was present between the A and B horizons. Here also, the normal sequence of horizons in the paleosol was overlain by sandblow deposits. Thus, this upwarp of the A horizon is a local feature.

The variation in the stratigraphic sequence near the upwarped A horizon suggests that, locally, the mesh of interwoven roots provided enough strength and coherence in the A horizon to allow it to delaminate from the underlying parts of the paleosol. During the earthquake, liquefied sand and water rose toward the surface and broke through the lower parts of the soil, but the dense network of roots initially prevented the sand from breaking through the A horizon. The injected sand spread laterally between the A and B horizons until the pressure in the sand lens ruptured the root mesh. An "eruptive vent" formed at the rupture point, and the sand and water flowed onto the ground surface. Laminated sediment dipping steeply toward the mouth of the feeder dike was present (meter 149), but the exact point where the A horizon ruptured was out of the plane of the trench. Therefore, the A horizon appears coherent on the trench log. Similar smaller lenses of sand, probably also caused by the delamination of the A and B horizons, are present at meters 134 and 135-136.

DISCUSSION

The trench described in this report contained evidence of a single episode of liquefaction that, based on the stratigraphic position and the lack of extensive soil development of the sandblow deposits, was presumably associated with the 1811-12 earthquakes. Disseminated charcoal in the sandblow deposits above the paleosol could have two possible origins: (1) it could be carbonized fragments of living plants that were buried by the liquefied sand, thus providing a minimum age for the liquefaction event, or (2) it could be carbonized fragments of very old wood that were originally deposited in the substratum sands. Charcoal in the sandblow deposit collected at meter 83¾ had a ^{14}C age date of greater than 40,000 yrs B.P., suggesting that it was transported from depth in the liquefied substratum sand. Thus, the charcoal was of no use in dating the age of the liquefaction event.

The lateral continuity of the stratigraphic horizons precluded any surface faulting in the trench, yet abundant seismicity, numerous sandblow deposits (Obermeier, 1984), major structural discontinuities (Zoback and others, 1980), and the possibility that one of the 1811-12 epicenters was located nearby (Nuttli, 1982) all suggest that, at depth, there are seismogenic faults in the area. The lack of near-surface faulting in the trench could be attributed to poor site selection. Alternatively, displacements at depth during a major earthquake may not have propagated to the surface. The poorly consolidated Cretaceous and Tertiary rocks that overlie competent Paleozoic rocks are about 790 m thick in the study area (Cushing and others, 1964). It is possible that displacements in competent rock at depth could be absorbed by non-brittle deformation within the Cretaceous and Tertiary sedimentary rocks. Thus there may not be any near-surface deformation associated with fault displacements at depth. Furthermore, since strike-slip movement is the predominant mode of faulting in this area, the vertical component of slip is likely to be small and may not be obvious near the surface.

ACKNOWLEDGMENTS

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LOG OF AN EXPLORATORY TRENCH IN THE NEW MADRID SEISMIC ZONE NEAR BLYTHEVILLE, ARKANSAS

By
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1986

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