Geophysical Investigations of Earthquake-Induced Liquefaction in the New Madrid Seismic Zone

Award # 1434-HQ-97-GR-03192

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Program Element: I (Evaluating National and Regional Hazard and Risk)
Key Words: Geophysics, Paleoliquefaction, Liquefaction, Paleoseismology

Investigations Undertaken

Geophysical surveys were conducted at sites targeted for paleoseismic study in the New Madrid Seismic Zone (NMSZ). The companion geophysical surveys were designed to 1) locate liquefaction features that might provide critical evidence for constraining the dates of prehistoric earthquake-induced liquefaction events, 2) determine the size, distribution and orientation of ground failure features, and 3) determine the site characteristics, such as physical properties of sediments and associated sediment distributions, that might contribute to the liquefaction susceptibility of an area.

Under this grant award, three (3) sites have been investigated in coordination with paleoseismic studies conducted by M. Tuttle (University of Maryland), R. Lafferty (Mid-Continental Research Associates, M. Haynes (Blytheville Arkansas), and E. Schweig (USGS). These sites are located near the municipalities of Steele and Wyatt, Missouri. The principal geophysical methods used were electromagnetic, magnetic and electrical resistivity. With the exception of the Hillhouse site, all sites were surveyed prior to the paleoseismic excavation. The resulting maps of geophysical anomalies were used in combination with soil characteristics and artifact distribution to identify specific locations for trenching. Trenches were sited at places thought to have both buried liquefaction features and Native American occupation horizons. The latter have proven useful for constraining ages of the liquefaction events (see Tuttle and Schweig, 1996; Lafferty, 1996; Collier et al., 1997).

Results

The Dodd Site: In an earlier reconnaissance study, a 5400 m^2 survey grid was placed over an area with a high concentration of sand believed to be a relict sand blow (Collier,

1998). Ground conductivity and electrical resistivity surveys, along with a surface collection of artifacts were performed along this grid to enable cross-correlation of anomalies with high concentrations of artifacts. Ground conductivity data were collected using both vertical and horizontal dipoles at different heights to allow variation in penetration depths. The resistivity data were collected using a Wenner constant spread array with an a-spacing of 5 m. A contour map of the resistivity and conductivity surveys show a northwest-southeast trending geophysical anomaly approximately 10 m wide that appears to extend beyond the limits of the survey site (Figs. 1a and 1b). A trench was placed perpendicular to and directly across the geophysical anomaly. The excavation exposed a large sand blow with two associated feeder dikes filled with clean, medium-grained to fine-grained sand that crosscut finer grained host sediments and a buried A soil horizon (Collier et al., 1997; Tuttle, in press). The orientation of the fissures in the trench matched closely the orientation of the geophysical anomaly. The contrast in the physical properties and moisture content of the sand in the fissures with the finer grained host sediments was thought to be responsible for the geophysical anomaly. Age constraints derived from Native American artifacts and radiocarbon dating indicated that the sand blow was prehistoric in age (Collier et al., 1997; Tuttle, in press).

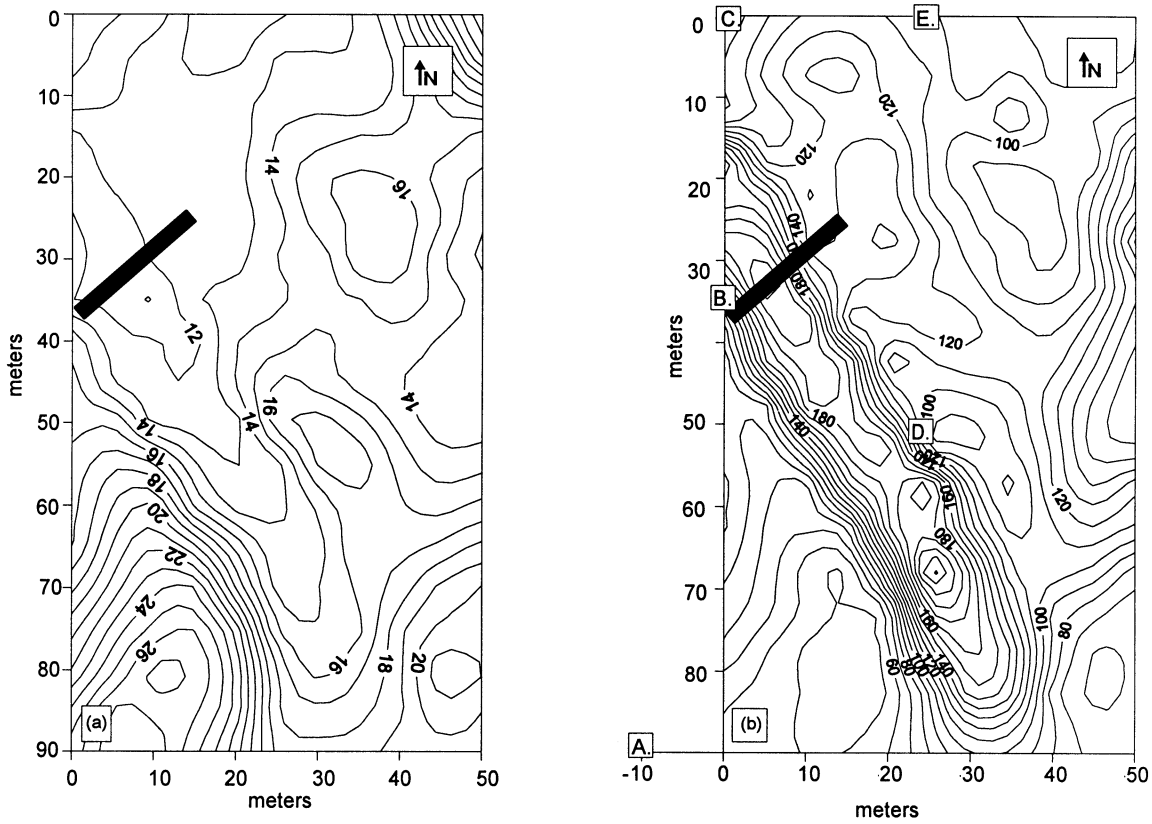

Fig. 1. (a) Ground conductivity in m/mS; (b) Resistivity in ohm-m. Trench position is noted by rectangle and is oriented perpendicular to the NW-trending geophysical anomaly.

To promote confidence in the relative age assessment of the sand blow, the site was revisited and examined for further evidence of crosscutting relationships between the liquefaction and cultural features. A magnetic survey was used to identify locations along the sand fissures that might contain buried occupation horizons. Two areas were

identified and excavated. Both contained cultural features that were useful for constraining the age of the liquefaction event. In addition to the surface surveys, several resistivity depth-soundings were performed to ascertain the thickness and characteristics of subsurface layers (Fig. 2). Results show that a low resistivity layer, associated with a fine-grained topstratum, is present in the southwest portion of the site (sounding position A), but is absent in the northern portion of the site (sounding positions C and D). This facies change at the site may have played a role in determining where the ground failure fissures formed.

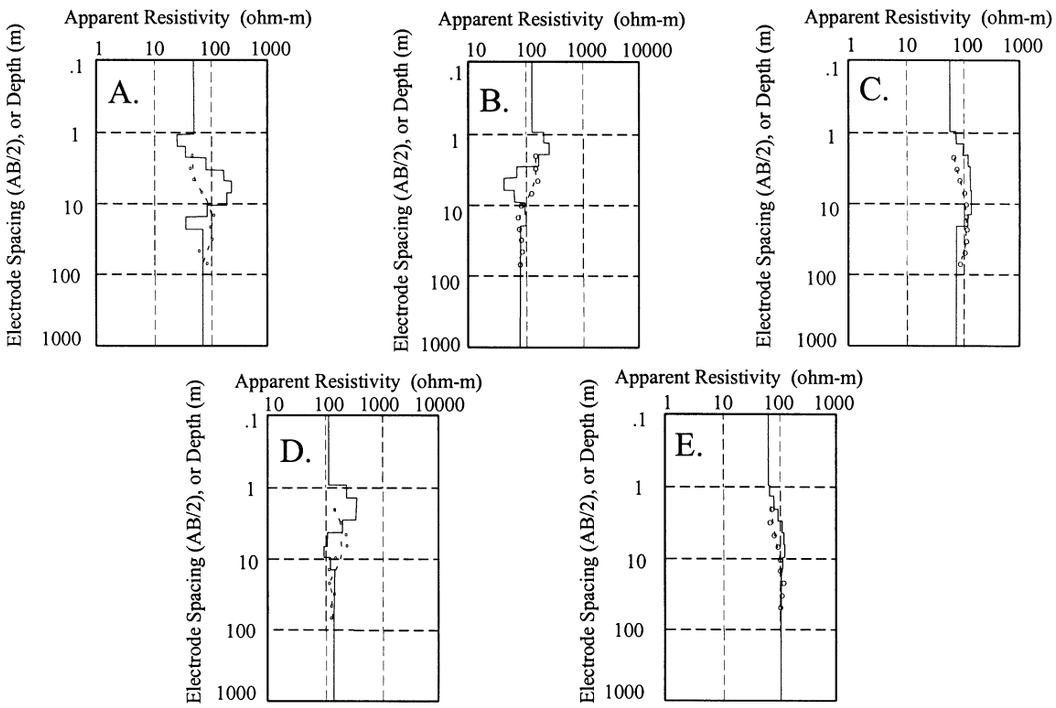

Fig. 2. Resistivity depth-soundings at Dodd Site (see Fig. 1 for sounding locations). Values are in ohm-m. Solid lines indicate model interpretation. Open circles are observed data.

The Brooke Site: The Brooke site was chosen for its archeological significance (R. Lafferty, unpublished report, 1997). A surveying strategy similar to that used at the Dodd site was adopted; the survey grid was positioned in an area containing both the sand blow and a relatively high density of artifacts. Ground conductivity, electrical resistivity and magnetic surveys were conducted. Conductivity measurements were made using three different surveying heights to obtain subsurface information at three different depths. Results show two trends in the geophysical anomalies: one is a broad, east-west trending anomaly and the other consists of smaller north-south trending anomalies. In each case, the anomalous areas were interpreted to reflect higher percentages of sand. Two trenches were excavated in areas containing the highest artifacts, near, but not directly in, areas having extreme values in the geophysical data. Thus the trenches did not intersect what was inferred to be the thickest area of the sand blow. The excavations revealed that although the cultural horizons were buried by the sand blow, a pre-agricultural A horizon

was lacking. Thus it was concluded that the sand blow was not prehistoric and may have been formed during the 1811-1812 events (M. Tuttle, personal comm.). Feeder dikes exposed in the trenches trended N-S and were related to the N-S anomalies observed in the geophysical data. Because the feeder dikes were quite small (~7 to 10 cm wide), it was inferred that the geophysical trends were associated with suites of small dikes or larger dikes not excavated. Human bones were encountered during the trenching and therefore additional excavation of the site was stopped.

The Hillhouse Site: This archeological site was excavated in 1996 by R. Lafferty of Mid-Continental Research Associates. Upon the discovery of sand-filled cracks during the excavation, a paleoseismic study ensued. Four sand dikes, all < 1 m and trending approximately N 80 W, were exposed in trenches made during the paleoseismic study (M. Tuttle, personal comm., 1997). Unlike the two sites described above, no large sand blow was observed at the Hillhouse site. Tuttle describes a graben-like structure filled with a chaotic deposit believed to have formed shortly after or during a prehistoric liquefaction event. The presence of the graben-like feature and lack of vented sand suggests that the ground failure features may have formed as the result of lateral spreading.

The objective of the geophysical surveys, which took place after the paleoseismic investigation, was to detect the presence of other buried sand-filled fissures, assess their general trend, and identify buried occupation horizons or cultural features. The geophysical surveys followed the same survey grid that was used for the archeological surface collection so that future excavation targets could be identified. The surveys included ground conductivity (EM-34 and EM-31, horizontal and vertical dipole orientations), electrical resistivity and magnetics. Contour plots of conductivity (EM-31) and resistivity data are shown in Figs. 3a and b. A northwest-southeast trending "valley" of relatively lower conductivity values (higher resistivity values) seen in the central portion of the site is believed to be associated with higher percentages of sand, whereas the northern and southern portions of the site contain a relatively larger amount of finer-grained sediment. The trend of the anomaly runs subparallel to a topographic break located less than 20 m from the exposed dikes and parallel to the trend of the dikes exposed in the trenches. This break may have controlled the orientation of ground failure at the site. The combination of results from different imaging depths indicates that the trend of the anomaly continues to at least 15 m depth. The two trenches excavated did not coincide with areas having the most anomalous values of those observed in the geophysical data; however, they do occur on the general anomaly trend. A possible site for future excavation was identified.

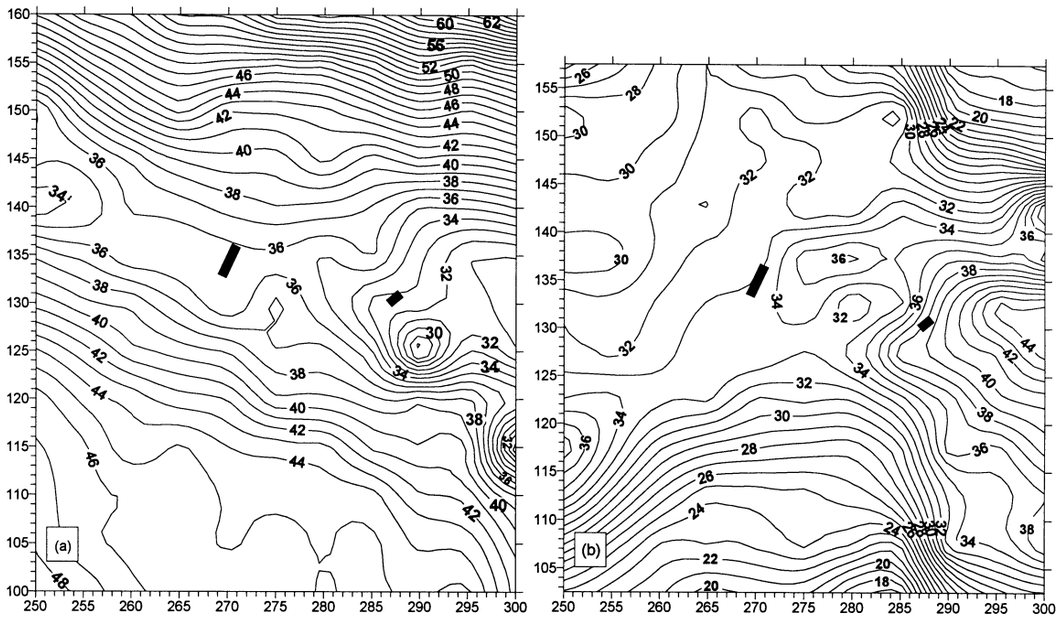

Fig. 3. (a) Ground conductivity in m/mS; (b) Resistivity in ohm-m. The northwest-trending geophysical anomaly runs subparallel to a nearby topographic break located nearby. Unlike other locations, this site lacked a surface sand blow but contained small subsurface sand fissures observed in trenches along the anomaly.

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Non-technical Summary

Geophysical surveys were conducted at three sites near the municipalities of Steele and Wyatt, Missouri, in conjunction with paleoseismic studies in the New Madrid Seismic Zone. The companion geophysical surveys were designed to 1) locate ground failure features that might provide critical evidence for constraining the dates of prehistoric earthquakes, 2) determine the size, distribution and orientation of ground failure features, and 3) determine the site characteristics, such as physical properties of sediments and associated sediment distributions, that might contribute to the ground failure susceptibility of an area. Results will contribute to understanding earthquake-induced ground failure in alluvial environments.