FINAL TECHNICAL REPORT

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INVESTIGATION OF SEISMICALLY-INDUCED LIQUEFACTION IN THE SOUTHERN MISSISSIPPI EMBAYMENT

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ABSTRACT

Two new trenches in southeastern Arkansas expose alluvium, paleosols, and vented liquefaction deposits. These trenches are in sand blow fields (Ashley County and Desha County fields) we previously documented with aerial photography, electrical conductivity surveys, and trenching in the lower Mississippi Valley (LMV). Stratigraphic relationships, ^{14}C dates, and soil analysis of these two new sites and our previous field sites suggest multiple episodes of sand venting associated with strong ground motion.

The Morgan trench (Ashley County field) exposed vented fine sand underlain by colluvial clayey sand that is in turn underlain by older vented fine sand. A principal sand vent (25 cm-wide) and many subsidiary dikes ($\leq$2 cm-wide) fed the two sand blows and many minor sills. At the principal vent dike, stratigraphy drops ~50 cm and 10-cm blocks of substrate are displaced upward ~45 cm in a matrix of fine sand. The Golden trench (Desha County field) exposed a vented deposit of brecciated clay clasts suspended in a fine sand matrix that was fed by several dikes (~ 5 cm wide) that extend downward through the source of the clay clasts. This clay horizon (~0.5 m below the blow) is brecciated around the primary feeder dikes, and we interpret it as the hydraulic capping unit that ruptured during ground shaking. Smaller sand dikes ($\leq$3 cm wide) fed the flanks of the principal blow and sub-blow sills ($\leq$10 cm thick). In both trenches, a weak modern soil profile is developed in the blow sand or sand/clay breccia, suggesting relatively recent (with the last 500 years (?)) liquefaction events. Underlying the blow sand deposits, weak paleosols are developed on one or more alluvial depositional events.

We identify at least two sand blow events in the Morgan trench and at least one sand blow event in the Golden trench. Our new ^{14}C age data and observations of degree of soil development suggest that the principal venting episodes at Morgan and Golden sites were late Holocene. Luminescence age analyses for these two sites are in progress. During this second phase of our study, we identified another LMV liquefaction field in Jefferson and Lincoln Counties, Arkansas on late Holocene surfaces, but we did not trench. Together with our previous sand-blow investigations in southeastern Arkansas, a coherent picture is emerging of at least five moderate to strong prehistoric earthquakes affecting the area in middle and late Holocene. We suggest that these earthquakes may be occurring along the southeast-striking Saline River and Arkansas River fault zones at intersections with northeast-striking faults of the Mississippi Valley graben system.

INTRODUCTION

In this second phase of the study, additional trenching built upon our preliminary investigations of two large areas (≥500 km^2) of intense sand venting (the Desha County field and the Ashley County field, Figs. 1 and 2) in the lower Mississippi River Valley (LMV). These liquefaction fields are ≥175 km southwest of the southern margin of the recognized liquefaction field of the New Madrid seismic zone (NMSZ) and ≥250 km southwest of the epicenters of the earthquake responsible for the NMSZ sand blows. Individual sand blows in the LMV are similar in size, shape and spacing to sand blows in the NMSZ. These southern sand blows (~1 m thick, ~10 to 30 m in diameter, and circular to elliptical in plan view) were vented from mid to late Holocene natural levee, channel fill, and crevasse splay sand deposits overlain by clays and silts along abandoned Arkansas River courses (Cox et al., 2000; 2002; 2003; 2004a; 2004b; Cox and Gardner, 2003; Morat et al., 2003).

We identified one field of sand blows in Ashley County, Arkansas and one 40 km to the north in Desha County, Arkansas during the first phase of this project. This was accomplished through inspection of vintage aerial photographs and subsequent push-coring, ground conductivity surveying, and trenching. Aerial photography circa 1951 to 1982 of the southern Mississippi Embayment was examined for circular, light tonal anomalies that are characteristic of seismically-induced sand blow deposits common within the New Madrid seismic zone of the northern Mississippi Embayment (Fig. 1). (Large-scale land leveling post 1970 obscures the signature of sand blows on aerial photography, thus limiting effectiveness of newer photography for mapping sand blows.)

In addition to our continued trenching efforts during this second phase of the project, we identified a third liquefaction field ~500 km^2 in area to the northwest in Lincoln and Jefferson County, AR (Figs. 1 and 2). The Lincoln/ Jefferson County sand blow field was recognized through inspection of aerial photography, field reconnaissance, and a ground conductivity survey. These sand blows are less densely-spaced and more widely distributed than the Ashley and Desha County liquefaction fields. No trenches have been opened in this area.

The southern sand blow fields may be distal liquefaction associated with NMSZ earthquakes or they may be due to local seismogenic faults. If related to NMSZ earthquakes, these sand blows greatly expand the recognized limit of NMSZ liquefaction and hence the area of strong ground shaking. Equally important, if these sand blows are due to local faults, then these possible seismic source zones should be documented, characterized, and incorporated into local hazard assessments. The limits of the Ashley County, Desha County, and Lincoln-Jefferson Counties sand blow fields, as interpreted from aerial photography, can be approximated by ellipses, and the epicenters of three earthquakes responsible for the sand blow fields can be estimated as the centers of the three ellipses. The long-axis radius of each ellipse gives an estimate of the distance from the epicenter of the respective earthquake to the farthest related liquefaction. The long-axis radii of the three fields are 11.5 km for Ashley County, 23.5 km for Desha County, and 16.5 km for Lincoln-Jefferson County. Using the empirical relationship of Ambraseys (1988) of moment magnitude to epicentral distance to farthest liquefaction, estimated magnitudes of single earthquakes inducing the Ashley County field, the Desha County field, and the Lincoln-Jefferson Counties field are M= 5.7, M= 6.0, and M= 5.8, respectively. These magnitudes may be too low due to underestimation of the size of these liquefaction fields, or they may be too high because these fields are actually composites of multiple liquefaction events of smaller radii.

RESEARCH QUESTIONS

1. How many seismic events generated liquefaction features in the southern Mississippi Embayment?

2. What is the age of each venting event?

3. How do these ages relate to large historic and/or prehistoric NMSZ events?

PREVIOUS INVESTIGATIONS

Previous trenching of sand blows at Kelso in Desha County and at Montrose and Portland in Ashley County revealed stratigraphy and cross-cutting relationships that showed evidence of multiple events of seismically induced sand venting (Cox et al., 2004a). Various correlations of liquefaction events between these two fields and between each of these fields and the NMSZ can be accommodated by our

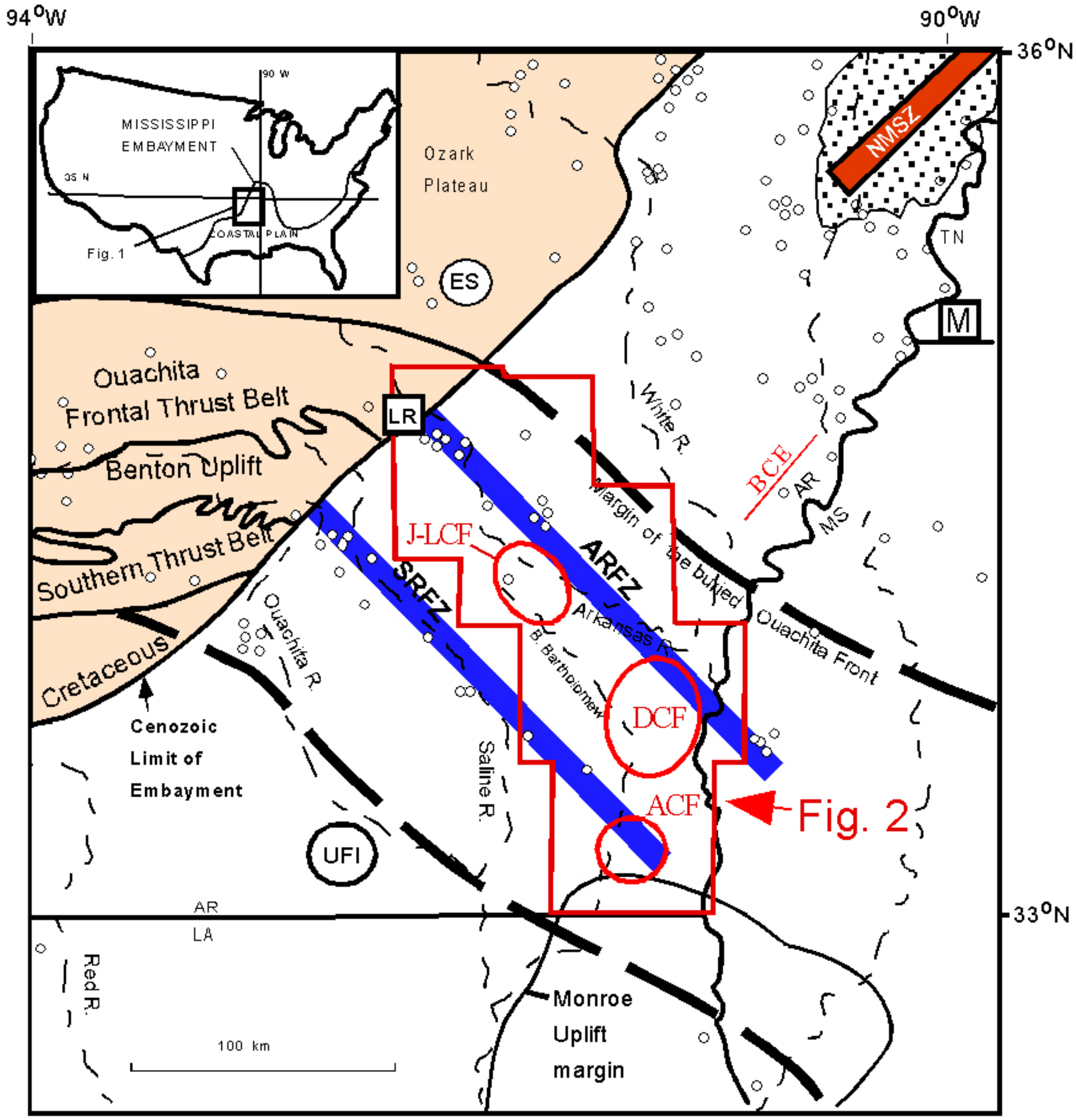

FIGURE 1. Structural elements of the study region. Open circles = epicenters (1900 to 2000, NEIC & CERI catalogs). Epicenter clusters: NMSZ = New Madrid seismic zone; ES = Enola swarm; and UFI = induced by underground fluid injection (Cox, 1991). Stippling = NMSZ liquefaction of >1% of surface (Obermeier, 1989; Tuttle et al.,1998); ACF= Ashley County field; DCF= Desha County field; J-LCF= Jefferson-Lincoln County field. SRFZ = Saline River fault zone; ARFZ = Arkansas River fault zone; BCE = Big Creek escarpment (Fisk, 1944; Cox 1994; Cox and others, 2000). M = Memphis; LR = Little Rock.

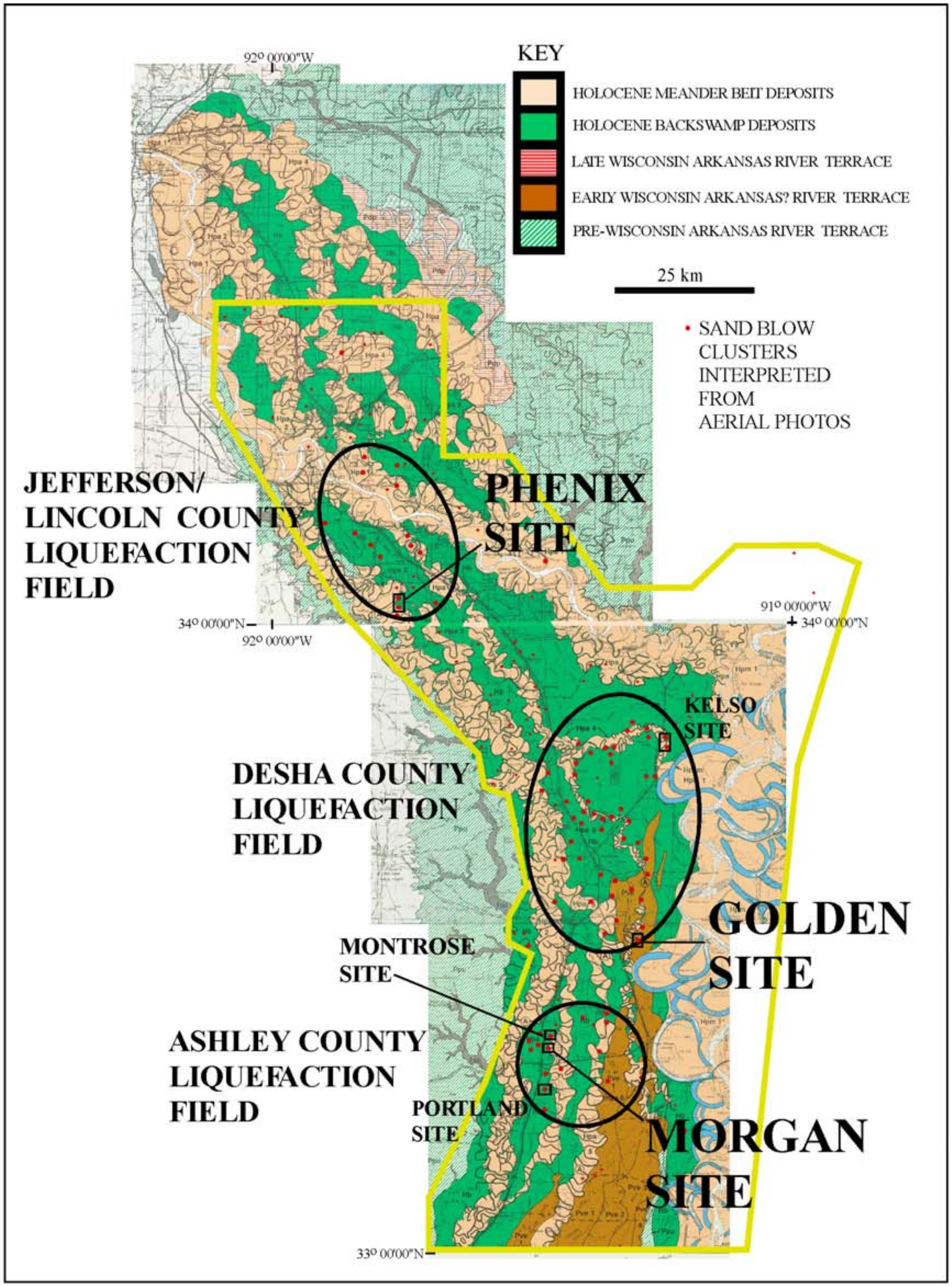

FIGURE 2. Quaternary geology of the alluvial valley of the Arkansas River in southeast Arkansas (from Saucier, 1994). Each red dots denotes a section (640 acres) that contains circular to elliptical, light tonal anomalies on aerial photography that are characteristic of sand blows (large dots denote many distinct anomalies; small dots denote few or vague anomalies). These anomalies have been shown to be liquefaction bodies of vented sand at the trench sites on the map (Cox and others, 2000; 2002; 2003; Morat and others, 2003). We excavated the Montrose, Portland, and Kelso sites during the initial phase of this project. The Golden and Morgan sites are new excavations during this phase of the project. The Phenix site has not been excavated.

radiocarbon and optically stimulated luminescence (OSL) ages of sediments pre-dating and post-dating vented sand deposits in our trenches. These ages indicate a major liquefaction event at both the Ashley and Desha County fields between 4600 and 5500 years ago and another significant event at the Ashley County field ca 700 years ago. The early venting episode is older than the documented NMSZ chronology, and so we do not know if it can be ascribed to a NMSZ seismic source. The age of the later venting episode is within the time span of the NMSZ chronology but is not consistent with a NMSZ event. Our trench logs show at least three other moderate to minor sand venting episodes at the Ashley County field and two at the Desha County field. One of these venting episodes may be the same event at both fields ca 2200 years ago. Building on these previous investigations, our current work fills in spatial gaps in the previous investigations and will aid in the definition of liquefaction fields and in constraining the dates of venting and perhaps in constraining the seismic source (Fig. 2).

STUDY AREA

Fieldwork associated with this research project was conducted in southeastern Arkansas in Ashley, Chicot, Desha, Jefferson, and Lincoln Counties. Specific field sites were identified based on remote sensing and geophysical data in the form of aerial photography and ground conductivity surveys, and confirmed with field reconnaissance. Yellow polygon in Figure 2 denotes study area.

Study areas are located near the urban areas of Memphis, TN and Little Rock, AR. Infrastructure in the region, including pipelines and highway bridges, could be impacted by local ground motion strong enough to generate the liquefaction features explored in this research. Our documentation of strong Holocene ground shaking in the southern Mississippi Embayment is important in understanding the seismic hazard in the central United States. Moreover, this study advances understanding of seismic hazards of intraplate settings in general.

INVESTIGATIONS UNDERTAKEN

Excavation of sand blows and age analysis of related deposits have been highly successful for the establishment of a chronology of strong paleoseismicity in the eastern U.S. (Talwani, 1989, 1996; Tuttle and Schweig, 1996; Tuttle et al., 1998; Tuttle, 2001). Field excavation sites were identified through inspection of aerial photographs that pre-date extensive agricultural modification of the land surface. Following evaluation of spatial extent of the interpreted sand blow field and prior to excavation, ground conductivity surveys and push core samples were collected to assess the site stratigraphy. Lowest conductivity anomalies (highest sand content) were selected for trenching (see Golden and Morgan site maps, Figs. 3 and 6).

Two trenches have been excavated during this second phase of the project, the Golden Trench (Desha County sand blow field) in August of 2003 and the Morgan Trench (Ashley County sand blow field) in October of 2003, each named for the land owner or current farmer of the property. Sand blows were excavated by backhoe, and trench walls were logged in detail to describe the stratigraphic relationships of vented liquefaction deposits to alluvial deposits and soil horizons. Organic-rich crater fill and soil units, along with wood and charcoal from substrate units, were collected for radiocarbon age analysis. In addition, buried silt and/or sand units were sampled for luminescence age analysis (optically stimulated luminescence). This phase of our study is a continuation of our investigation of liquefaction features across the southern Embayment, and methods and techniques used are consistent with our previous effort to systematically document and delineate areas of past strong ground motion in this region.

RESULTS

Golden Trench

Golden trench is located in the southern part of the Desha County sand blow field near Halley, Arkansas on Lester Golden Road at 33^{o}29.199'N, 91^{o}18.325'W. A ground conductivity survey (Fig. 3) revealed two elliptical anomalies consistent with previously excavated sand blows. This blow, located in a

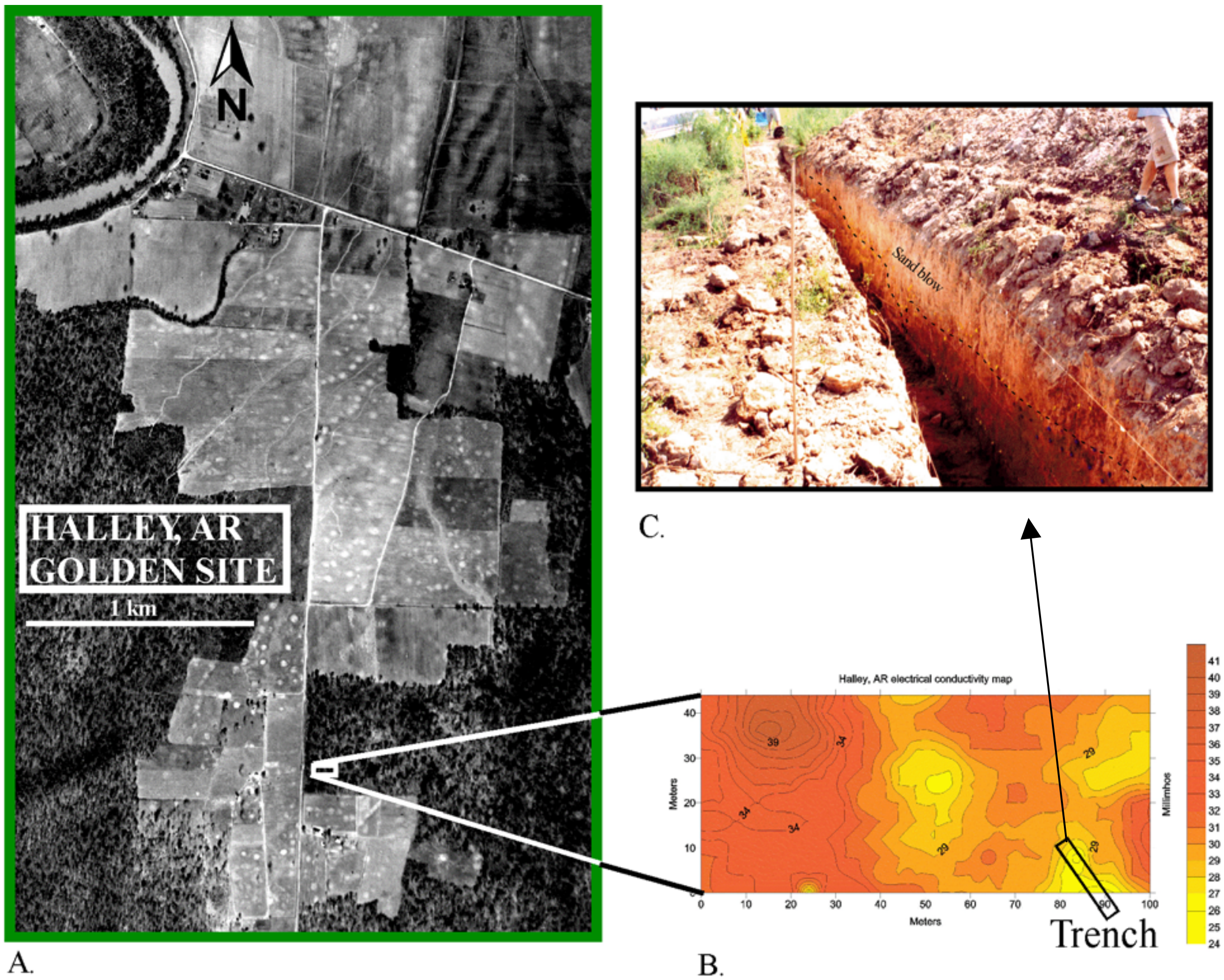

Figure 3. Golden site near Halley, AR in the southern part of the Desha County sand blow field. A) Aerial photo of the site and vicinity showing sand blows aligned along shallowly-buried crevasse splay channels. B) Electrical conductivity map of site showing low value anomalies of sand blows (this spot has been cleared of trees since aerial photo). C) photo of Golden trench showing champaign-glass shaped sand blow.

Table 1: Golden Trench Description of Stratigraphic Units (see following trench log, Fig. 4).

Unit	Field Description	Dating Sample
A	Plow Zone- fine sand and silt, loose, 10YR6/2 (light brownish gray)	
B	Organic fill and burrow fills-10YR4/3 (brown)	S1, S2 (^{14}C)
C	Principal vented deposit- Sand dikes, blows, and sills. Clay breccia clasts- hard, 10YR6/4 (light yellowish brown) Fine sand matrix- soft, 10YR7/4 (very pale brown)	
D	Clay-rich sand- slightly hard, 7.5YR4/6 (strong brown). Lenticular body absent in vent area.	
E	Very fine sand- soft, 10YR6/6 (brownish yellow). Lenticular bodies	
F	Medium/ fine oxidized sand (minor clay)- soft, 7.5YR4/6 (strong brown) pervaded by fine white sand fissures and blows. Principal blow substrate	S6, S10 (OSL)
G	Hydraulic capping unit. Clay- hard, 5YR4/3 (reddish brown) in upper 10 cm and 10YR6/4 (light yellowish brown) below to bottom of trench. Brecciated/ fractured in area at base of sand blow.	

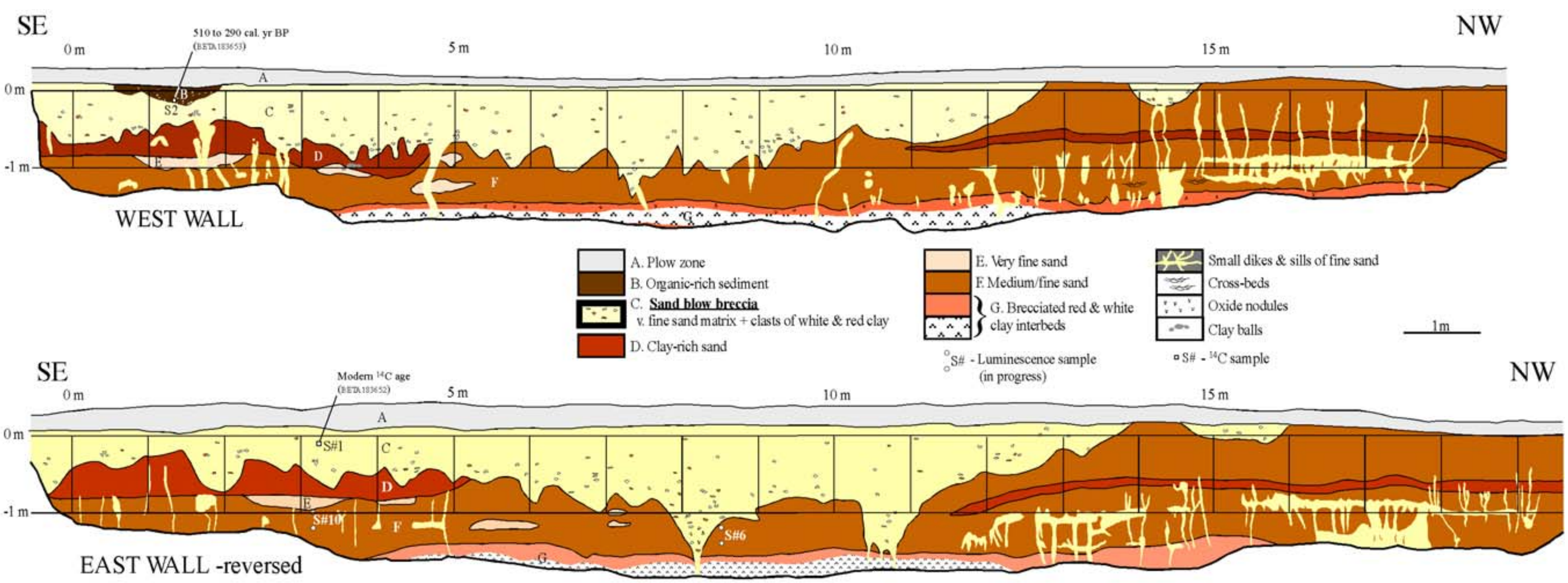

FIGURE 4. Log of trench walls at Golden site, Halley, AR. See Table 1 for descriptions of stratigraphic units.

fallow field, was excavated in August of 2003. A field team of University of Memphis faculty, graduate and undergraduate students logged the trench walls, collected bulk sediment samples for lab analysis, carbon samples for radiocarbon dating, luminescence samples for dating, and photography of the trench walls. Dating samples were submitted for analysis to BETA Analytic, Inc, Miami, Fl for ^{14}C dating and to Luminescence Dating Research Laboratory, University of Illinois at Chicago for optically stimulated luminescence (OSL) dating. Thus far, a ^{14}C age of 510 to 290 cal. yr BP has been obtained for a lens of organic sediment post-dating venting at this site. Other dating results are expected in mid 2004.

The Golden trench exposed a principal vented deposit of brecciated clay clasts suspended in a fine sand matrix (Unit C, Table 1). This blow, a champagne glass shape in cross-section (Figs. 3 and 4), was fed by several dikes (~ 5 cm wide) that extend downward through the source of the clay clasts (Unit G, Table 1) that is ~0.5 m below the blow. Unit G is brecciated around the primary feeder dikes, and we interpret Unit G as the hydraulic capping unit that ruptured during ground shaking. A network of smaller sand dikes (<0.5 to 3 cm width) and sills (<10 cm thick) is present below the flanks of the principal blow, and some of these dikes are linked to the principal blow. Spatial relationships in the Golden trench suggest the sand dikes, sills, and blows formed during a single earthquake. Alternatively, some of the "sills" and other sand lens (Unit E) may be older buried blows. Our OSL dates should indicate if there was an older event.

Soil analysis in Golden Trench

The soil trench and sub-trench pit exposed approximately 280 cm of section (Fig. 5). The upper 96 cm comprises blow sand with a weakly developed modern soil profile, the lower part of which is brecciated. Eighty cm of pedogenically-modified, brecciated alluvium (C horizons) underlies the blow sand. A very weakly developed buried soil profile, again partially brecciated, extends into underlying red

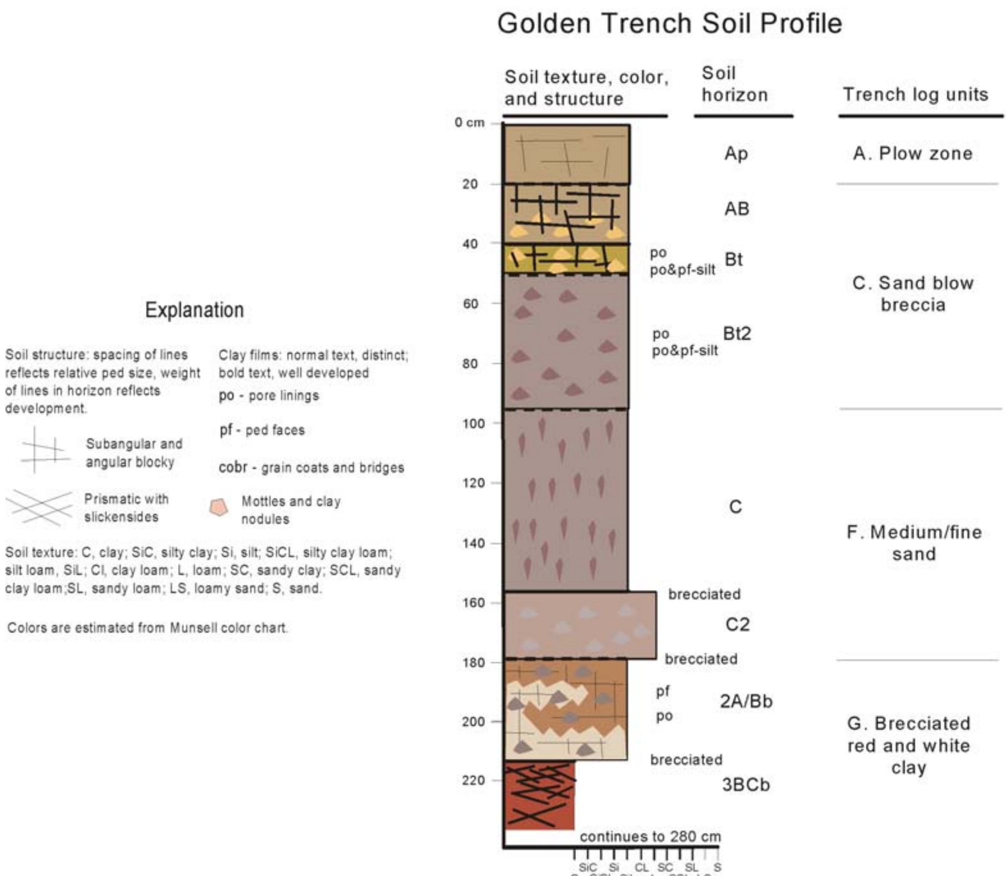

FIGURE 5. Soil profile for Golden site.

and gray clay that underlies the upper horizons. This basal clay shows little pedogenic modification. No carbonate accumulation is observed in any horizons and weak clay accumulation is observed only in the surface soil and the buried soil profile overlying the red and gray clay.

<u>Morgan Trench</u>

Morgan trench is located near Montrose, Arkansas just off of US highway 165 at 33°19.801'N, 91°29.077'W ~1.3 km south of our previous Montrose trenches. As at the Golden trench site, a ground conductivity survey of the Morgan trench site (Fig. 6) revealed elliptical anomalies consistent with previously excavated sand blows. One of these blows located in the non-cultivated corner of a center-pivot irrigation quarter section of cotton crops was excavated in October of 2003. A field team of

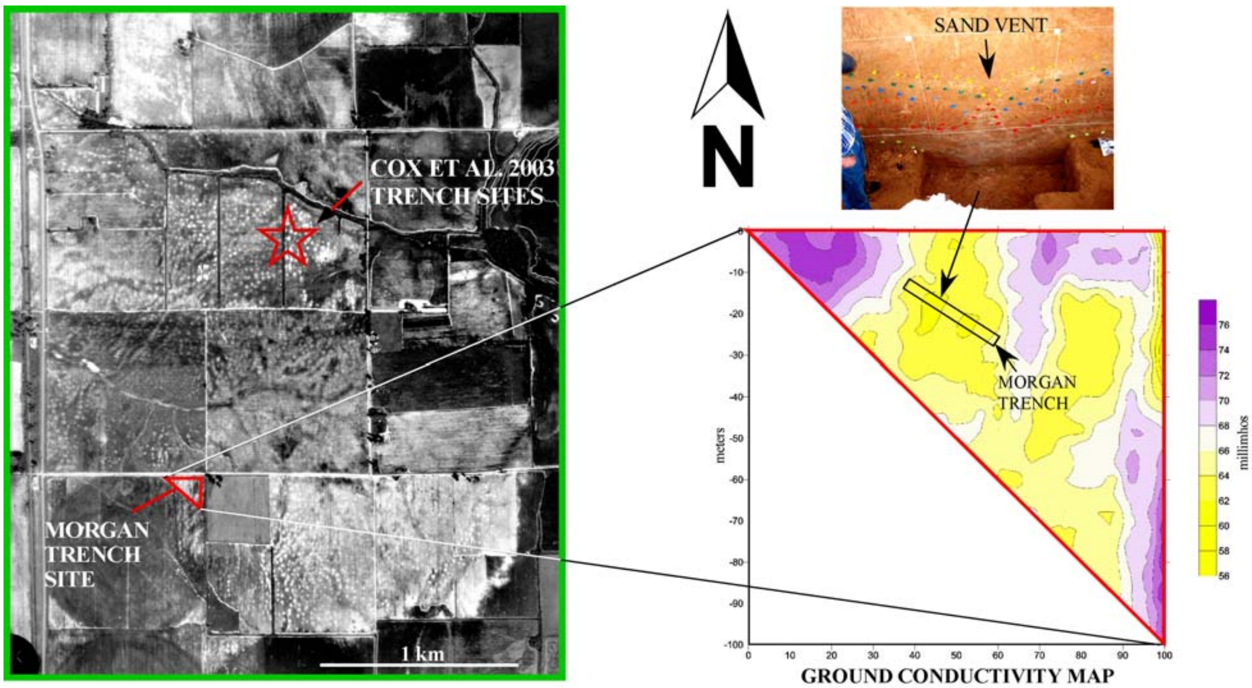

FIGURE 6. Morgan site near Montrose, AR in the northern part of the Ashley County sand blow field.

University of Memphis faculty, graduate and undergraduate students logged the trench wall, collected bulk sediment samples for lab analysis, carbon samples for radiocarbon dating, luminescence samples for dating, and photography of the trench walls. Dating samples have been submitted for analysis and results are expected. The team was joined by faculty from the University of Louisiana at Monroe and members of the Arkansas Archaeological survey.

The Morgan trench (Fig. 7) exposed a principal vented deposit of loose fine sand (Unit B, Table 2) underlain by a colluvial clayey sand (Unit C, Table 2) that in turn is underlain by an older vented fine sand (Unit E, Table 2). A principal sand vent (35 cm-wide, Fig. 7 right photograph) and many subsidiary sand dikes ($\leq$5 cm-wide) were linked to the two sand blows and to many minor sand sills (e.g., left photograph). Stratigraphy had subsided ~50 cm at the principal vent. However, 10 cm coherent blocks of Unit J (Table 2) had been transported upward ~45 cm in a matrix of fine sand in the principal vent dike (Fig. 7 right photograph).

Table 2: Morgan Trench Description of Stratigraphic Units.

Unit	Field Description	Dating sample
A	Plow Zone- fine sand, 10YR6/3 (pale brown)	
B	Very fine quartz sand – rounded, loose, 10YR6/4 (dark yellowish brown), mottles 7.5YR 6/6 (reddish yellow). Principal vented deposit- Sand dikes, blows, and sills.	S9 (^{14}C)
C	Clayey very fine sand – slightly blocky, slightly hard, 10YR5/4 (yellow brown), mottles 7.5YR5/8 (strong brown), colluvial deposit restricted to venting area (reworked units D & E?).	S11 (OSL)
D	Very fine quartz sand – rounded, loose, 10YR6/4 (dark yellowish brown). Older sand blow deposit	
E	Fine sandy clay – blocky, hard, 7.5YR5/6 (strong brown), absent from venting area (pre-blow surface removed during venting?)	
F	Fine to very fine quartz sand, sub-rounded, soft, 10YR4/6 (dark yellowish brown). Fine oxide nodules. Only present below unit D.	S12 (OSL)
G	Fine to medium quartz sand, sub-rounded with minor clusters of oxide nodules (<1cm), soft, 7.5YR4/6 (strong brown). Only present near main vent (older blow?)	
H	Fine quartz sand, sub-rounded, cross-bedded with patches of oxide nodules (<1cm), soft, 7.5YR4/6 (strong brown)	S6, S13 (OSL)
I	Fine to very fine clayey sand, cross-bedded, slightly hard, 7.5YR4/6 (strong brown), minor muscovite & opaques, clusters of oxide nodules (<1cm). Units H & I are a crevasse splay deposit.	
J	Very fine quartz sand, sub-angular, cross-bedded, soft, 7.5YR5/4 (brown)	S5 (^{14}C)
K	Fine quartz sand, sub-angular, cross-bedded, soft, 7.5YR4/4 (brown). Units J & K are a crevasse splay deposit.	

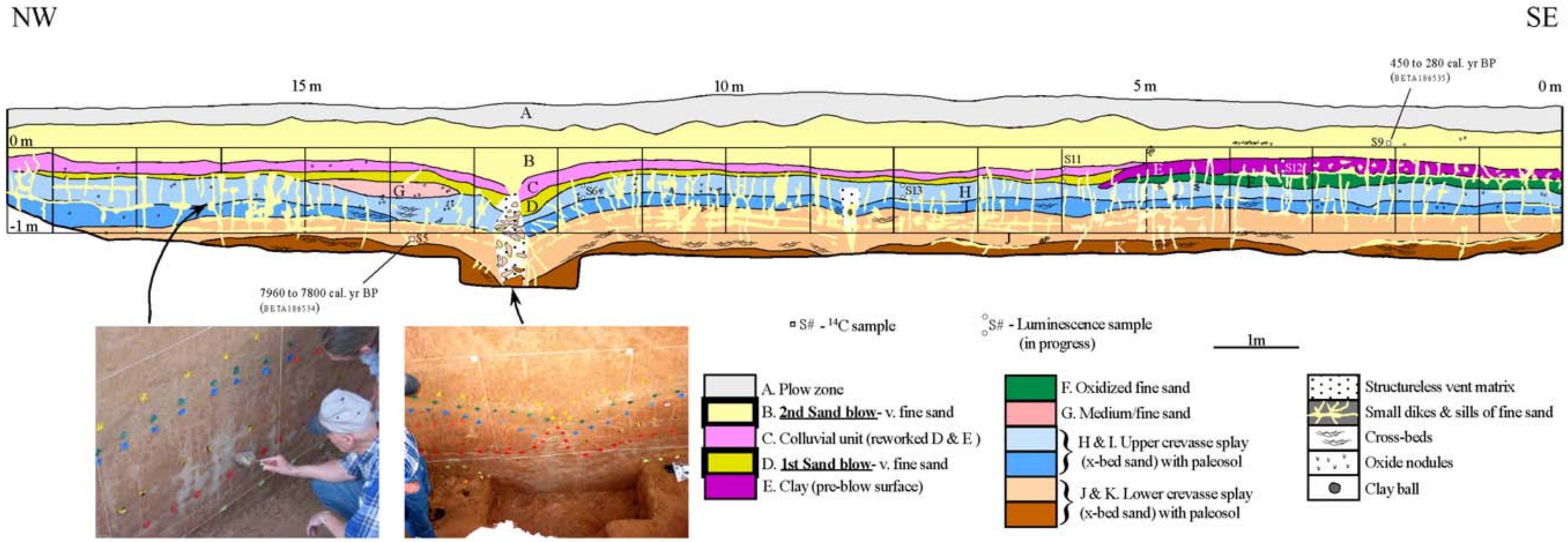

FIGURE 7. Log of northeast trench wall at Morgan site, Montrose, AR. See table 2 for descriptions of stratigraphic units.

Soil analysis in Morgan Trench

The soil trench exposed approximately 180 cm of section (Fig. 8). The upper 67 cm is a weakly developed modern soil developed in blow sand. The underlying units comprise alternating sandy and sandy clay deposits associated with crevasse splay alluvial deposition. The clay-rich intervals are typically broken or brecciated, presumably from liquefaction processes. Three weakly to well developed buried soil profiles are present in the crevasse splay deposits. Pedogenic modification is best developed in the finer grain parts of the crevasse-splay alternations, whereas the sandy portions are either massive or retain depositional structures (ripple cross-lamination). In general, the trench stratigraphy reflects a dominance of alluvial processes over soil development. No carbonate accumulation is observed in any horizons and weak to strong clay accumulation is observed only in the buried soil horizons. The red and gray clay at the base of the Golden and Portland trenches is not present in this trench.

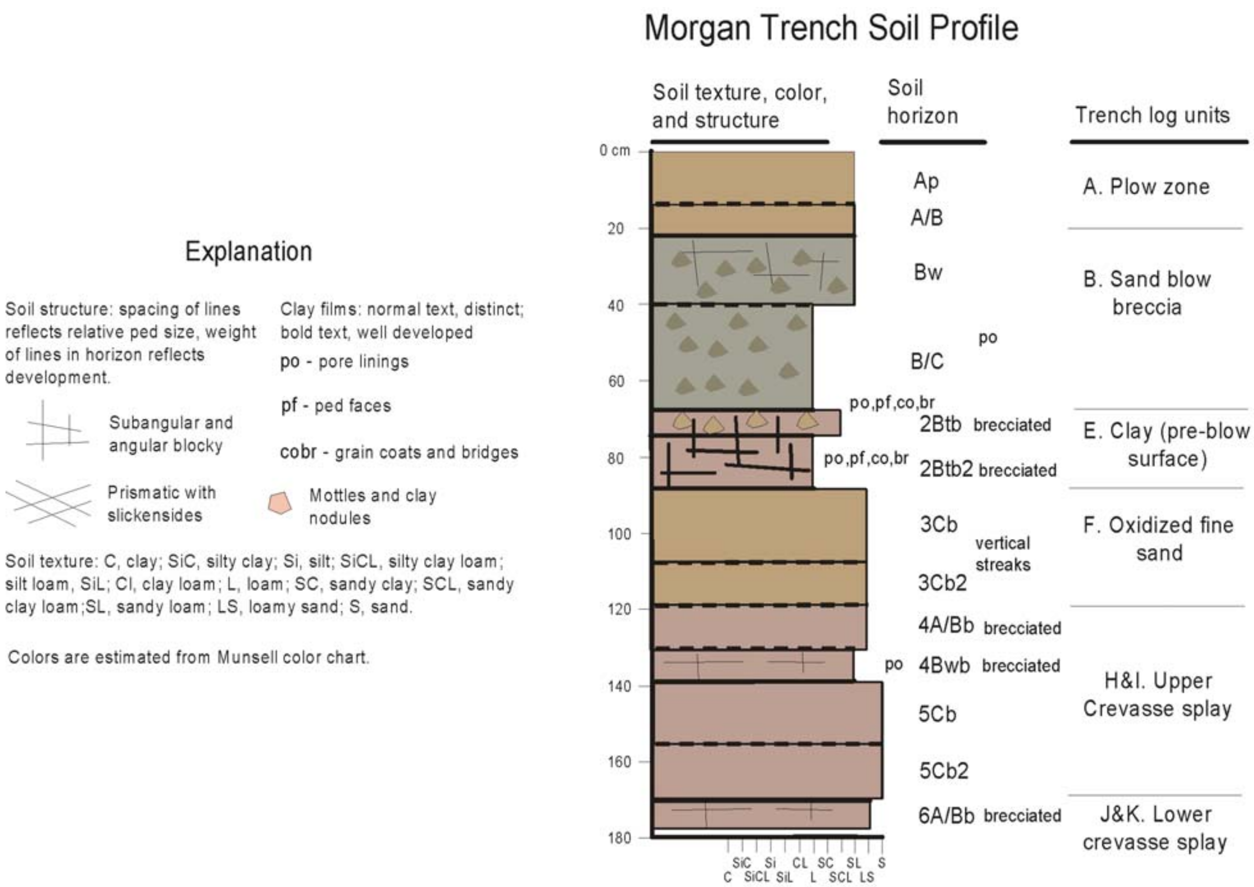

FIGURE 8. Soil profile for Morgan site.

Phenix site

In our reconnaissance of the Phenix, AR locality in the Lincoln-Jefferson Counties field (Fig. 2), we observed patches of sandy soil, but agricultural activity has obscured the original geomorphic expression of the tonal anomalies. However, the anomalies have low ground conductivities (Fig. 10) characteristic of seismically-induced sand blows at our previous excavation localities in Ashley and Desha Counties.

The Phenix “sand blows” show patterns suggesting they are crevasse splay sands adjacent to the Stage 3 paleocourse of the Arkansas River (Coles Brake, circa 6000 y.b.p. to 4500 y.b.p.) (Saucier, 1994). These sands appear to have been liquefied and vented after burial by Arkansas River Stage 2 paleocourse overbank deposits (Sneeds Brake, circa 4500 y.b.p. to 3000 y.b.p.). The final Stage 2 paleocourse, Bayou Bartholomew (circa 2200 y.b.p.), appears to postdate the liquefaction event (i.e, earthquake).

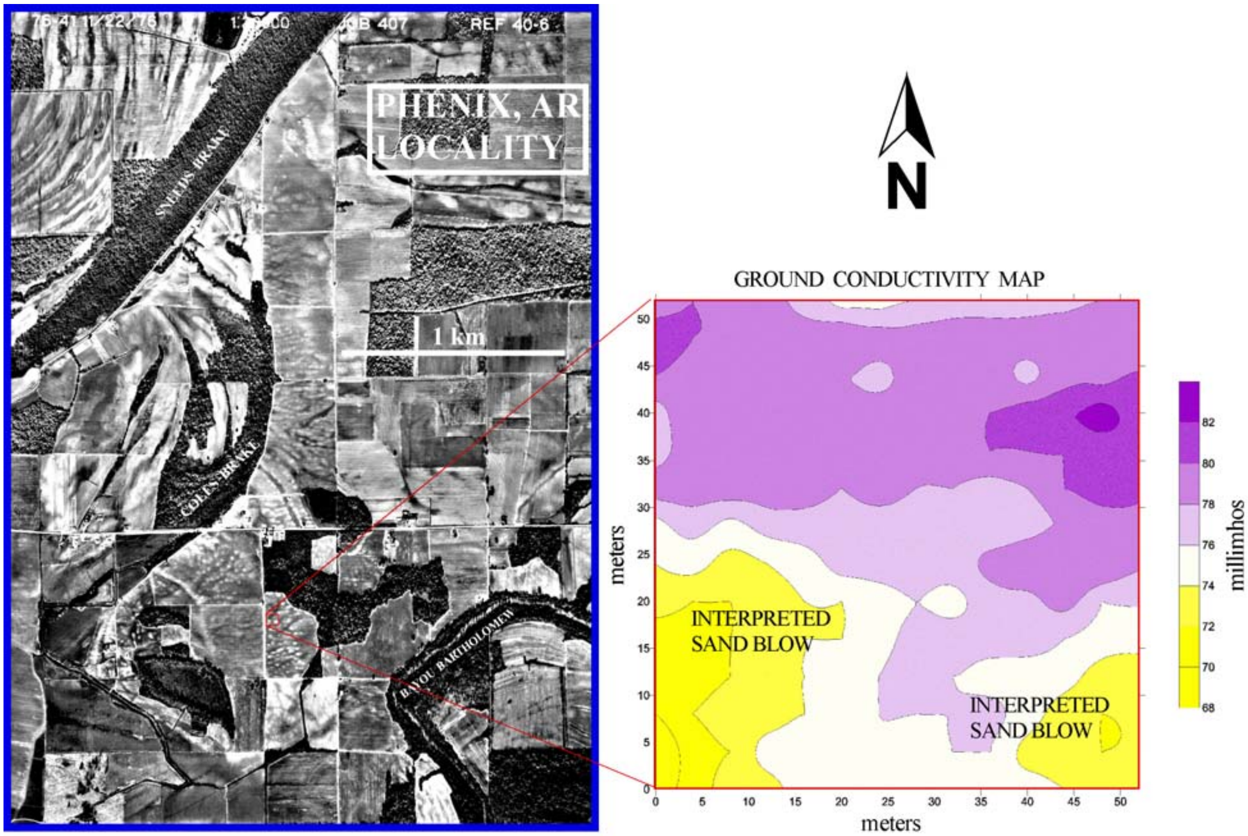

FIGURE 10. Aerial photograph showing sand blows near Phenix, AR in the southern part of the Jefferson-Lincoln County sand blow field.

SUMMARY

We recognize one significant sand-blow event (unit C), a breccia of clay clasts in a very fine sand matrix at the Golden site. Small lenticular sand bodies (unit E) may be an earlier venting episode. Stratigraphic horizons are warped downward immediately north of the vent area, suggesting subsidence accompanying venting. Truncation of unit D and other stratigraphy in the vent area may be due to winnowing of material by vented water or possibly by explosive cratering similar to that reported by Rydelek and Tuttle (2004) during the Bhuj Indian 2001 earthquake and by Youd and Keefer (1994) during the San Juan Province Argentinean 1977 earthquake.

At the Morgan site, Units B and D record two sand-blow events. Unit C is a colluvial mix of unit D sand blow and the pre-venting surface (unit E). Unit E (a Bt horizon buried by unit B) and unit F are missing in the vent area, suggesting winnowing of material by vented water. Minor dikes “roll” into the vent area where stratigraphy is warped downward, suggesting these dikes pre-date subsidence associated with the principal venting episode (unit B event).

Both the Golden and Morgan sites exhibit shallow “sills” of sand associated with minor dikes. Alternatively, these “sills” may be liquefied source material for the minor dikes. Many of these dikes could not be traced to the bottom of the trench wall, consistent with such a shallow source.

The surface and buried soils at the Morgan and Golden trenches are, in general, weakly developed. In both trenches, the surface soil is developed in sand blow material and shows weak to moderate inceptisol development. Based on observations in other trenches and regional soil development, these soils reflect development over a few hundred years.

In the Golden trench, the underlying paleosol is too brecciated to discern unequivocal soil development. The base of the soil profile at the Golden trench is in red clay, similar to that at the Portland trench site (Fig. 2) (Morat et al., 2003) but with little soil development and no carbonate accumulation. In the Morgan trench, a sequence of alternating sand and clay layers (crevasse splay deposits) is present beneath the blow sand, with weak to moderate soil development in the clay loam to loamy sand intervals. The greatest degree of soil development is present beneath the pre-blow surface and reflects inceptisol or weak alfisol development. The red clay was not identified in the Morgan trench, which may be a reflection of the trench location in close proximity to Holocene meander belts of the Arkansas River.

Ages of sand venting episodes at Golden and Morgan sites are poorly constrained by ^{14}C dates, but they pre-date historic 1811 NMSZ events. Weak soil development suggests these sand blows are late Holocene. These blows may be distal effects of prehistoric NMSZ earthquakes, but the sequence at Morgan site is most similar to previously documented venting episodes at our most southern site (Portland) and this sequence differs from those observed at more northerly sites (Montrose and Kelso) which differ from the NMSZ chronology (Fig. 11). We are awaiting results of optically stimulated luminescence (OSL) dating of surfaces buried by the vented sand at Golden and Morgan sites.

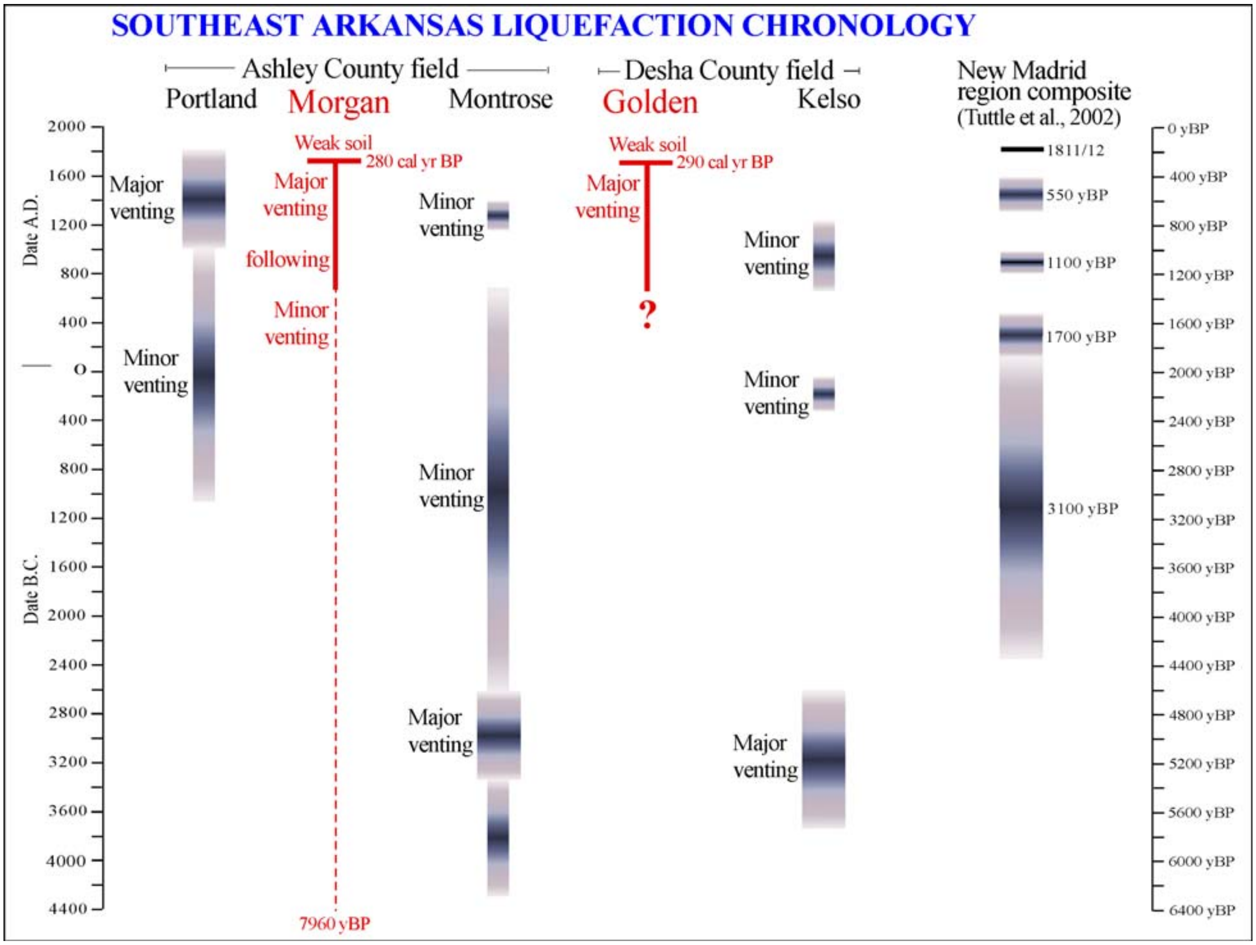

FIGURE 11. Timing of sand venting episodes in the southern LMV. Vertical bars denote ranges of age uncertainities for sand venting episodes. Ages ranges for Portland, Montrose, and Kelso sites (our previous excavation sites) are constrained by 14C and OSL dates (Cox et al., 2004a). We are awaiting OSL dates for Morgan and Golden sites (dates shown are 14C, see trench logs). Investigation sites are arranged south (left) to north (right).

OSL analyses are being conducted at the Luminescence Dating Research Laboratory, University of Illinois-Chicago, Department of Earth and Environmental Sciences, and we anticipate these results July of 2004. With these OSL dates we can better interpret and correlate venting sequences.

CONCLUSIONS

Radiocarbon and luminescence dates from our work show the Ashley County and Desha County liquefaction fields each experienced at least three earthquakes in the last 6000 years large enough to vent sand. Our new paleoseismic data from the Golden and Morgan trench sites are consistent with late Holocene strong ground motions in southeast Arkansas. In the Lincoln-Jefferson County field, interpreted sand blows are present on natural levees and crevasse splays of early Stage 2 and older courses of the Arkansas River, but not on late Stage 2 or Stage 1 courses, suggesting these sand blows were triggered by a mid-Holocene earthquake ca. 2200 to 3000 yr BP.

The seismic source for these liquefaction events may be NMSZ earthquakes more than 175 km to the northeast. However, there are several discrepancies in the timing of southern LMV sand venting episodes and NMSZ events. Moreover, sand blow distributions in the southern LMV are clustered into three fields, and mapped Holocene surficial geology (meander belts, backswamp, and crevasse splays) are continuous between these fields (Fig. 2). Within these liquefaction fields, sand blows are found on surfaces of contrasting geology (compare Golden and Morgan trench logs). These field relations suggest that the principal control on sand blow distributions in this region is not surficial geology, but rather proximity to a local seismic source (such as the Saline River fault zone (SRFZ) or Arkansas River fault zone (ARFZ); see Fig. 1). Following the empirical relation of magnitude to liquefaction area presented in Ambraseys (1988), the areal extents of these sand blow fields suggest earthquakes of magnitudes between 5.5 and 6.0 occurring within the limits of these fields.

The principal sand venting episode at the Morgan site shows similar late Holocene timing to the principal episode at the Portland site in the southern part of the Ashley County field. These blows are both preceded by relatively minor venting. This sequence differs from major mid-Holocene venting followed by at least two minor episodes observed at the Montrose site in the north of the field. We have recently acquired shallow seismic reflection profiles that show near-surface ruptures of the SRFZ 0.3 km to the north of the Montrose site (Cox and Harris, in preparation). We interpret the principal vented sand deposit at the Montrose site as a record of the first strong earthquake on the SRFZ following deposition of local mid-Holocene alluvium. The two subsequent episodes of venting and cratering at this site are interpreted herein as the two events recorded at the Morgan and Portland sites to the south. We suggest that these two later events, particularly the last one, were larger in magnitude than the initial Montrose event, and thus they triggered liquefaction at a greater distance from the SRFZ than the mid-Holocene event (see Figs. 1, 2 and 11). Sand venting was minor at the Montrose site during these later events because the source sand had been largely vented and compacted during the mid-Holocene event.

The Golden site is at the southern periphery of the Desha County field, and it does not record the major mid-Holocene venting episode seen at the Kelso site, but rather records a major late Holocene event probably correlative to the latest event at Kelso. We interpret this setting to be similar to the Ashley County field history in as much as the Desha County field near the ARFZ projected trace (Kelso site) shows a history of paleoseismicity that is longer and includes more events than the distal part of the field (Golden site) (see Figs. 1, 2 and 11).

Our results suggest that earthquakes in the southern LMV are occurring repeatedly at the same locations. We suggest that this clustering is occurring at weak areas at intersections of the SRFZ and ARFZ with northeast-striking faults associated with the Mississippi Valley graben system (Johnson et al., 1994). For example, the Desha County liquefaction field may be at the intersection of the ARFZ and the fault associated with the northeast-striking Big Creek escarpment (Fig. 1) shown by drilling (Krinitzsky, 1950) and seismic reflection profiling (Harris et al., 2000) to be underlain by faulting. The Jefferson-Lincoln County field may be at the intersection of the ARFZ and a southwestward continuation of the fault associated with the southern arm of the NMSZ. Co-seismic uplift or subsidence at this intersection may have diverted the Arkansas River from its southern course to the Red River in central Louisiana to its present direct course to the Mississippi ca. 2000 yr BP (Saucier, 1994). Finally, we further speculate that LMV earthquakes may be remotely triggered by earthquakes at other sites within the southern LMV (suggested by similarity in mid-Holocene paleoseismicity of the Desha and Ashley County fields) and/or by large earthquakes within the NMSZ.

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NON-TECHNICAL SUMMARY

Aerial photography of a portion of the southern Mississippi River and Arkansas River valleys was inspected for light spots characteristic of earthquake-generated sand blows, and numerous occurrences were identified in southeastern Arkansas. We documented the dates of prehistoric earthquakes that produced the sand blows by collecting sediments that predate and postdate the blows and then established the ages of the sediments by laboratory analyses. In this phase of the project, we identified at least one sand blow event by excavating a trench in northern Chicot County (Golden site) and at least two sand blow events in our trench in eastern Ashley County (Morgan site). We also identified another area of sand blows in Jefferson and Lincoln Counties, Arkansas, but did not open a trench. This work adds to our initial phase of study that documented at least five earthquakes in this region and advances us toward our goal of finding out the recurrence interval of strong earthquakes in this region. Our ultimate goals also include mapping the geographic extent of each liquefaction event, and from these maps we will make an estimate of epicenter and magnitude of the earthquake associated with each event.

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