Site-specific Fault Rupture Hazard Assessment—Fluorspar Area Fault Complex, Western Kentucky

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ABSTRACT

We evaluated post-Paleozoic sediments overlying a southerly projection of the Fluorspar area fault complex and coincident with an area of diffuse microseismicity for Quaternary deformation. Nearly 1 km of seismic reflection data were collected and interpreted for evidence of late Quaternary deformation. Five significant high-angle geophysical anomalies were interpreted to extend within approximately 7 m of the ground surface, near the upper limit of the seismic sampling. We subsequently collected 86 closely spaced, 9.1-m-deep, continuous cores above these anomalous features. We performed stratigraphic and chronological analyses on the cores to determine the presence or absence of structure above the geophysical anomalies and define the near-surface extent and age of deformation. Optical stimulated luminescence dates showed the sampled sediment age ranged between nearly 16 ka and greater than 125 ka. Interpretation of the resultant geologic cross-sections indicates identified stratigraphic anomalies were generally constrained to post-date a 53.6 to 75.5 ka loess deposit; however, no perceptible displacement was found at the base of younger loess dated between 16.6 and 23.5 ka.

INTRODUCTION

Identifying and characterizing active faults in areas lacking geomorphic expression is a challenging task, as exemplified in and near the New Madrid seismic zone, including the Fluorspar area fault complex (FAFC) of western Kentucky (Figure 1). In the mid-continent, surface manifestations of active faults are generally obscured by a thick sequence of comparatively weak, water-saturated Mississippi embayment sediment that overlies bedrock. The soft sediment overburden and relatively long recurrence interval between large earthquakes conceal bedrock structure and commonly fail, apart from a few notable exceptions (*e.g.*, Crowley's Ridge, Reelfoot Scarp, and Benton Hills), to produce significant or noticeable surficial tectonic-related geomorphology.

This study evaluated local fault strands of the FAFC that lie beneath a proposed expansion of an existing Department of Energy Class II solid waste facility in western Kentucky (Figure 2). Because of insufficient geomorphic or other surface evidence to indicate whether Holocene-active (within approximately the last 11,000 years) displacement has occurred along the faults, we used integrated near-surface seismic reflection surveys and geologic profiles, constructed from closely spaced cores, to constrain potential Quaternary deformation within the regulatory "footprint" of the site. Typically, the invasive investigative work for this type of study would include an open trench across the entire landfill footprint; however, the sensitive environmental concerns at the site precluded opening paleoseismic trenches.

GEOLOGIC SETTING

The northern Jackson Purchase region of western Kentucky lies at the juncture of two late Precambrian-early Paleozoic rifts, the Reelfoot rift and the Rough Creek graben (Kolata and Nelson 1991) (Figure 1). This area is also coincident with the northern end of the sediment-filled Mississippi embayment. Immediately north of the embayment, in southern Illinois, the exposed FAFC is described by Nelson *et al.* (1997, 1999) as a series of strike-slip pull-apart grabens bounded by N20°E- to N40°E-striking normal and inverted reverse faults. To the south in western Kentucky, the Paleozoic bedrock in the Jackson Purchase is masked by several tens to a few hundred meters of Late Cretaceous and younger sediment. Kolata and Nelson (1991), as well as Wheeler (1997), suggest the continuation of the FAFC into this part of the embayment, but their evidence is primarily inferred from a north-south-oriented, low-resolution, proprietary seismic-reflection profile. Olive (1980) mapped a few faults in Tertiary and Quaternary deposits in the area but stated that these structural interpretations were based on indirect evidence and possibly attributable to

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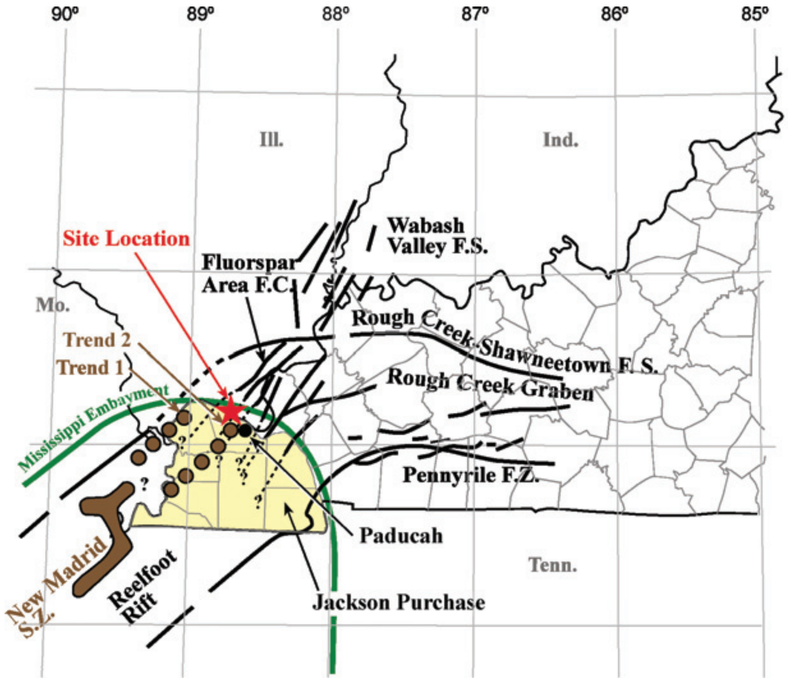
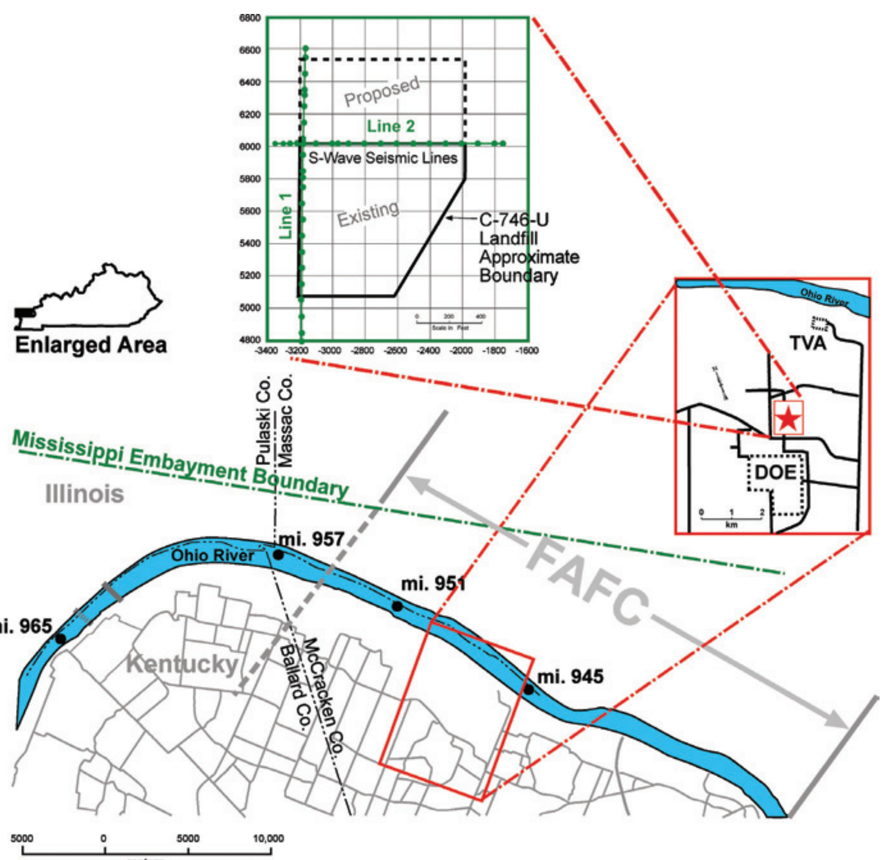


▲ **Figure 1.** Major structural features in the central Mississippi Valley (modified from Kolata and Nelson 1991 and Woolery and Street 2002). The lines of brown circles represent the locations of Wheeler's (1997) trends 1 and 2 seismicity in relation to the New Madrid seismic zone (brown shaded area) and the study site (red star). The Jackson Purchase region of western Kentucky is also identified in the light yellow shaded area.



▲ **Figure 2.** Study location in relation to the regional fault map (modified from McBride *et al.* 2002 and Woolery and Street 2002). The inset shows the location of the seismic and geologic profiles relative to the landfill boundary.

non-tectonic mechanisms. More recently, near-surface seismic-reflection investigations by Langston *et al.* (1998) and Woolery and Street (2002) have shown the continuation of the FAFC into the Jackson Purchase with reactivated displacement extending into Quaternary sediments.

There is a lack of scientific consensus regarding the complex structural relationship between the Reelfoot rift, the most seismically active of the central and eastern United States rifts, and the Rough Creek graben, one of the least active major structures (Wheeler 1997). The Rough Creek graben, which lies mainly in western Kentucky, is bounded on the north by the Rough Creek-Shawneetown fault system and on the south by a series of faults that include the Pennyrile fault system (Figure 1). The Rough Creek-Shawneetown fault system extends from Kentucky into southern Illinois for about 25 km, then abruptly turns to the southwest and joins the Lusk Creek and Raum fault zones, which form the northwestern boundary of the FAFC (Nelson and Lumm 1987). The northwestern boundary of the fault complex is suggested to continue southwest across the Jackson Purchase, beneath sedimentary cover of the northern Mississippi embayment, where it would appear to form the northwest margin of the Reelfoot rift, the host geologic structure of the New Madrid seismic zone (Kolata and Nelson 1991). The primary faults that make up the FAFC (*i.e.*, Lusk Creek, Raum, Hobbs Creek, and Barnes Creek) are thought to have originated as a primarily extensional structure in the late Proterozoic to early Cambrian, temporally coincident with the formation of the Reelfoot rift. There is also evidence of multiple episodes of dip-slip reactivation (*e.g.*, late Pennsylvanian and Permian), as well as strike-slip movement that extends into the Quaternary (Nelson *et al.* 1999).

Specifically, our study area (Figure 2) is located near the Ohio River, approximately 10 km west of Paducah, Kentucky, and just south of the northern terminus of the Mississippi embayment where the northeast-oriented FAFC is also coincident with a northeast-oriented band of diffuse microseismicity, interpreted by Wheeler (1997) as a potential projection of New Madrid seismicity (Trend 2 in Figure 1). This northeast-projected weak microseismicity pattern suggests the poorly defined FAFC may have architecture and behavior similar to the faults in the New Madrid seismic zone (*i.e.*, oblique dextral strike-slip faults that have extension and compression deformation components). Consequently, Wheeler (1997) inferred that the Holocene deposits in the FAFC could exhibit tectonic deformation. Nelson *et al.* (1999) and McBride *et al.* (2002) found evidence of Pliocene to early-Pleistocene displacement along the Lusk Creek fault zone in southern Illinois but saw no Holocene sediment displacement. Holocene sediments were also found undisturbed in their observations of the neighboring Raum fault. In the river valleys east of Paducah, sand dikes have been found that cut Pleistocene and recent fluvial and lacustrine sediment (Amos and Wolfe 1966; Amos and Finch 1968; Olive 1966, D87-D88). Although these liquefaction features are not thought to be historical, the sediment into which they terminate has been radiocarbon dated within the past 4,850 years, but the source and magnitude of the responsible event(s) have not been determined (Martitia Tuttle, written communication 2006).

Stratigraphically, the Mississippian limestone bedrock at the site of Figure 2 is unconformably overlain by approximately 100 m of unlithified sediments that are Late Cretaceous and younger (Olive 1980). Regionally, Late Cretaceous gravel and sand associated with the Tuscaloosa Formation or undifferentiated interbedded Late Cretaceous and Paleocene sands and clays belonging to the McNairy and Clayton Formations rest directly on the Mississippian bedrock. The McNairy-Clayton formations are generally overlain by the Paleocene Porters Creek Clay; however, the Porters Creek Clay has been removed at the subject site by the ancestral Tennessee River (Sexton 2006). Undifferentiated Eocene silty sands and clays unconformably overlie the Porters Creek Clay. The Eocene sands and clays are separated from the Pleistocene loess by Pliocene-Pleistocene sands and gravels, locally referred to as the Continental Deposits (*i.e.*, Mounds Gravel and Metropolis Formation). Three regional Quaternary glacial loess deposits overlie the Continental Deposits: Loveland Silt, Roxana Silt, and Peoria Loess. The oldest loess formation, the Loveland Silt, is primarily an aoelian silt deposited during the Illinoian glaciation between 125 and 185 ka (Follmer 1996; Grimley *et al.* 2003). The Loveland Silt has many physical similarities with the upper part of the Metropolis Formation and thus was undifferentiated at the site; however, a previously unnamed loess deposit with an age range between 53.6 and 75.5 ka was found below the Roxana Silt and presumably above the 125+ ka Loveland Silt. The middle-Wisconsin Roxana Silt lies above these deposits and is defined by a lower colluvial silt unit in the main body of loess that originated between 55 and 28 ka (Curry and Follmer 1992; Leigh and Knox 1993). The Peoria Loess, the youngest of the Pleistocene formations, has an age range between approximately 25 and 10 ka (Follmer 1996; Hansel and Johnson 1996). The Peoria Loess has the most surface exposure in the Jackson Purchase.

Relatively stable interglacial periods allowed soil development in each formation; consequently, these buried paleosols within the formations provide additional marker horizons. Several prominent Quaternary paleosols have been identified in the midwestern United States, and include, in ascending chronological order: 1) Yarmouth Geosol, which developed in the lower part of the Metropolis Formation and upper part of Mounds Gravel (Grimley *et al.* 2003); 2) Sangamon Geosol, which developed into the upper part of the Metropolis Formation and the Loveland Silt; 3) Farmdale Geosol, which formed in the Roxana Silt, and 4) the modern-day soil profile developed in the Peoria Loess.

The upper part of the Continental Deposits (*i.e.*, Metropolis Formation), loess units, and their paleosols form the primary stratigraphic sequence and marker units for the geologic cross-sections constructed from the densely spaced drill-hole samples. Specifically, the detailed descriptions from the 86 drill cores have resulted in the recognition of seven stratigraphic horizons (defined from youngest to oldest as units 1 to 4 and units 5.1 to 5.3) in the upper 9.1 m of sediment (Table 1). In addition,

TABLE 1 Summary of near-surface stratigraphy encountered during the core drilling. Also shown are the correlative boundary assignments, uncertainty estimates, and OSL age determinations.			
Unit Name	**Unit Number**	**Basal Contact Uncertainty (m)**	**Unit Age (1000 × years)**
Upper Peoria	Unit 1	0.18	15.4–25.2
Lower Peoria	Unit 2	0.12	21.8–30.9
Roxana Silt	Unit 3	0.12	32.1–50.7
Unnamed Silt	Unit 4	0.09	53.6–75.5
Metropolis Formation	Unit 5.1	0.15	>125–180
	Unit 5.2	0.12	
	Unit 5.3	*	

the tops of the McNairy Formation and lower Continental Deposits (*i.e.*, Mounds Gravel) are high acoustic impedance boundaries and define the primary seismic-stratigraphy marker horizons.

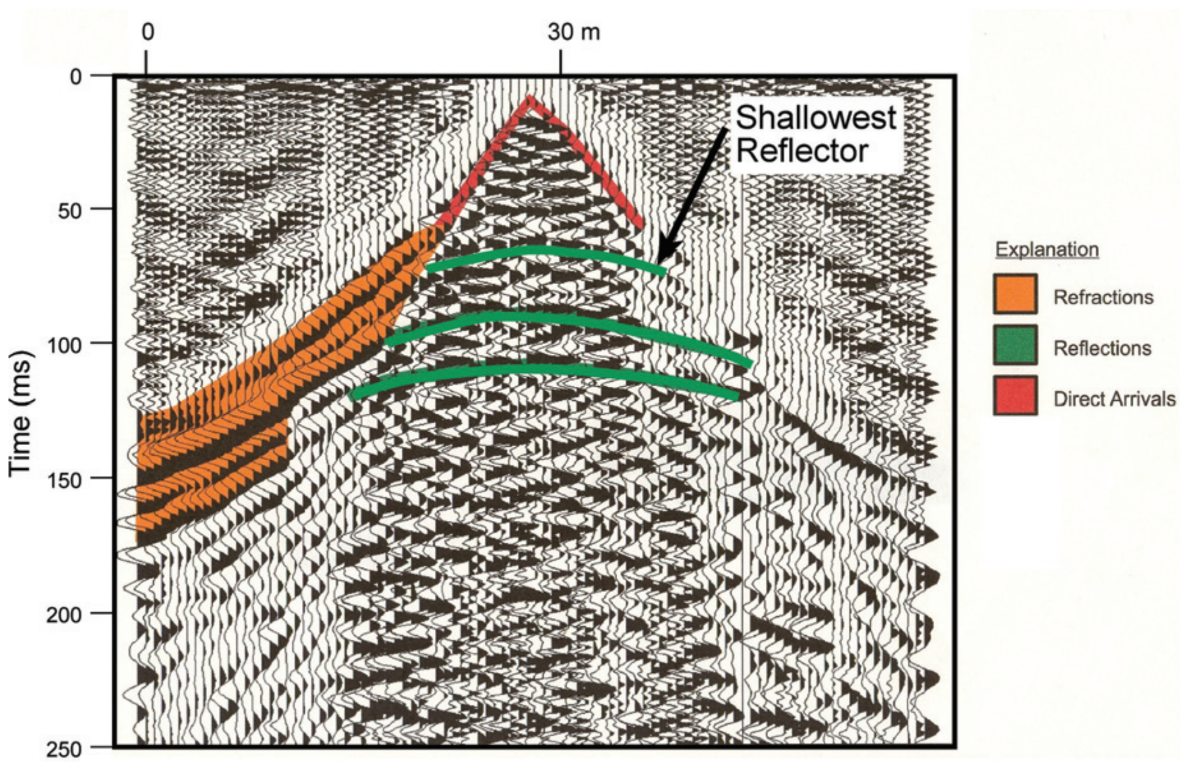
METHODOLOGY

Seismic Imaging

Approximately one kilometer of common-midpoint (CMP) shear-wave (SH mode) seismic-reflection data were acquired across the regulatory "footprint" of the site to identify potential neotectonic structure within the post-Paleozoic sediment (Figure 2). The detailed justification for using the SH-wave in this type of geologic conditions is given in Woolery *et al.* (1993, 1996, 1999), Harris (1996), and Woolery and Street (2002). One of the primary factors these previous studies cite for using the shear-wave source is improved resolution.

In this investigation, the reflections from the Metropolis and Mounds Gravel Formations are observed in the seismograms at approximately 50 and 120 ms, respectively, and have average velocities of 210 and 340 m/s and dominant frequencies of 89 Hz and 56 Hz, respectively. These geophysical parameters yield a resolvable limit (*i.e.*, one-quarter wavelength criteria) of 0.6 m and 1.5 m, respectively (Sheriff and Geldart 1989). The spatial resolution of the reflections is constrained between approximately two and four shotpoints based on the radius of the first Fresnel zone.

The SH-mode reflection data were collected with a 96-channel engineering seismograph and shot as a symmetrical spread with 96 40-Hz horizontal geophones oriented perpendicular to the array alignment. The group and shot intervals were 0.6 m. The seismic energy was generated by a horizontal controlled-vibration source that produced four eight-second sweeps per station. The linear upsweeps ranged between 40 and 300 Hz, with a 1.3 kN peak ground force. The recording acquisition parameters included a low-cut filter of 18 Hz (high-cut filter was out), 0.5 ms sample interval, and one-second record length. An example field file is shown in Figure 3. The seismic data were processed using commercial UNIX-based signal-processing software, and the general processing sequence is shown in Table 2.



▲ **Figure 3.** Example field file showing direct arrival (red), refracted arrival (orange), and reflections (green). The earliest arriving reflection is 55 ms in this example.

TABLE 2
General seismic data processing flow.

Processing Step	Relevant Parameters
Reformat	
Geometry	
Amplitude Gain Recovery	
Spiking Deconvolution	80 ms operator; 0.01% noise
Filter	30/300 Hz
Elevation Statics	
CMP Gather	
Velocity Analysis	
NMO Correction	
Residual Statics	50–300 ms gate; 1 ms maximum shift
AGC Scaling	100 ms gate
CMP Stack	
Migration	95% smoothed RMS/interval velocities

Core Drilling and Age Dating

Eighty-six direct-push technology (DPT) continuous cores were collected spatially coincident with the seismic reflection profiles. The borehole spacing along each transect varied, but the initial spatial borehole interval was 12.2 m. This spacing was followed by smaller intervals of 6.1 and 3.0 m in areas containing possible fault-related features interpreted from seismic data or inferred from preliminary cross-sections developed from the initial boreholes. The drill advanced small-diameter thin-wall tubes to recover continuous soil samples down to the top of the Continental Deposits (*i.e.*, approximately 9.1 m) at each borehole location. Four of the 86 DPT cores were collected in light-sensitive sample liners, and prepared for optical stimulated luminescence (OSL) analysis.

The cores were described using the Unified Soil Classification System and standard geologic and pedologic observations to identify stratigraphic marker horizons, buried soils, and any evidence of vertical Quaternary tectonic deformation. Geologic cross-sections were developed from the seven horizons identified in the core descriptions (Table 1). Other than the base of the Metropolis (unit 5.2) and the uppermost part of unit 5.3, the geologic cross-sections are stratigraphically above the horizons imaged by the seismic-reflection surveys.

We also considered the uncertainty in the stratigraphic boundary assignments. Six related sources of uncertainty were possible: 1) natural stratigraphic variability, 2) mechanical measurement error, 3) survey elevation error, 4) core compression and/or recovery, 5) contact correlation and interpretation, and 6) inclined basal contacts potential. The dominant types of uncertainty (4 to 6) were critically evaluated during sampling and logging. Core compression and recovery (4) was documented for each core during the core acquisition and analysis phases. Because the DPT method obtains cores by pushing the sampling tube, core compression often accounts for most, if not all, of the "missing" core where recovery was less than 100% for each extraction. The contact correlation and evaluation uncertainty (5) was the confidence estimate in the basal contact selection and is a measure of contact identification difficulty. The uncertainty was evaluated by independently estimating the average of basal contact picks from each co-author who logged the core. Significant non-horizontal or inclined basal contacts (6) were evaluated only for the lower part of the Metropolis Formation, the site's only steeply inclined contact. The final uncertainty applied to the geologic cross-sections was the largest uncertainty estimated from (4), (5), and (6) (Table 1).

The age of sediment samples was determined by optical stimulated luminescence (OSL) analyses of 12 sediment samples, as well as stratigraphic position and cross-cutting relations. Eight potential samples for radiocarbon analysis, using the accelerator mass spectrometry technique, were submitted; however, none were useable due to insufficient amount of available carbon. Pedogenic development also provided a means to assess relative ages of deposits among the core samples and to obtain correlative ages by comparison with well-dated soil chronosequences in the region (*i.e.*, Farmdale vs. Sangamon Geosols).

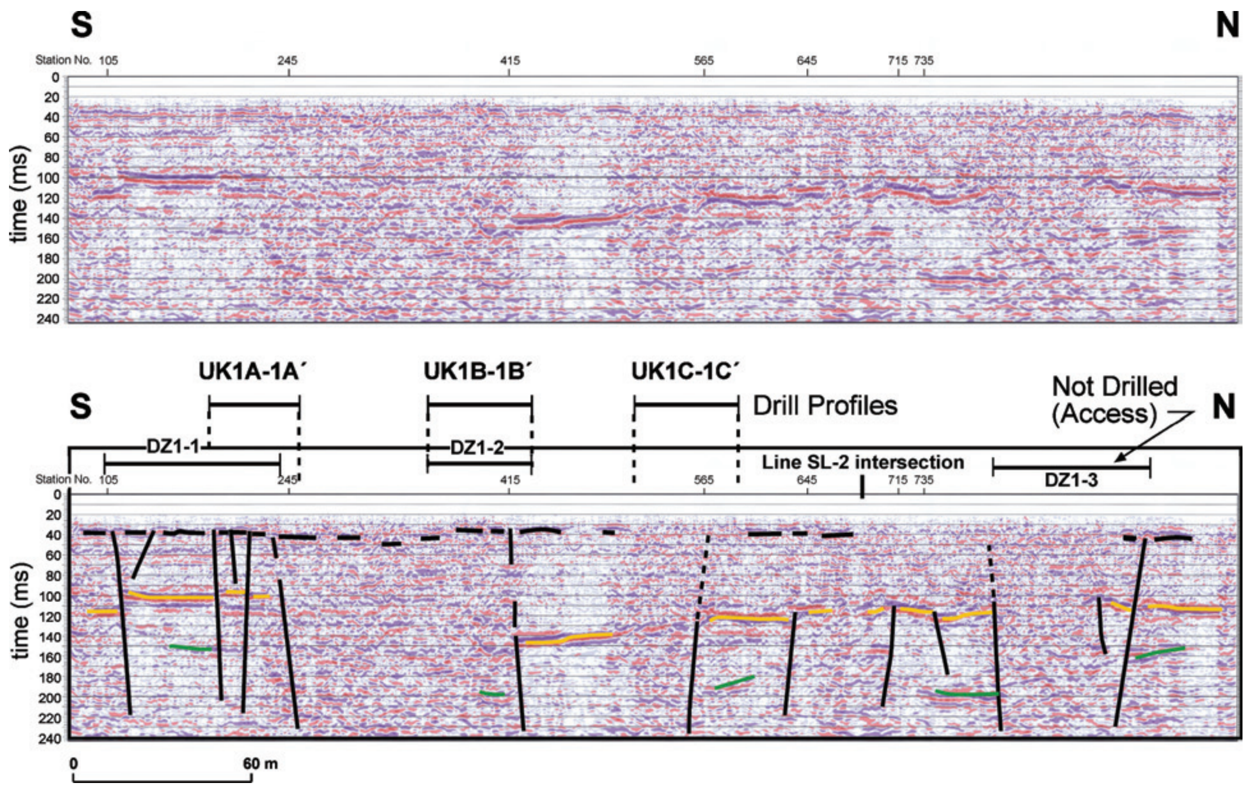
RESULTS

Seismic Surveys

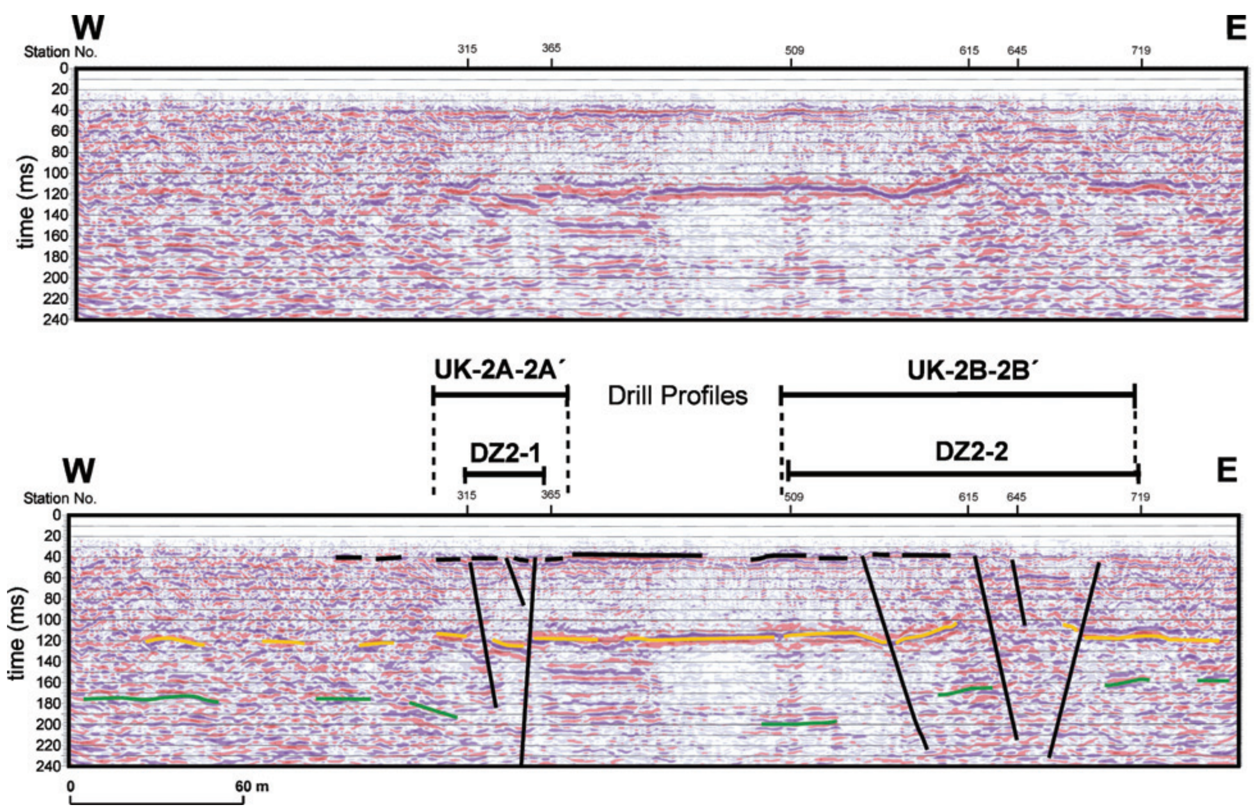
The shear-wave (SH) seismic-reflection dataset includes two orthogonal 48-fold stacked profiles collected along unimproved roads parallel to the reservation boundaries (Figure 2). Specifically, the reflection data consist of a 548-m-long north-south-oriented line (Line 1) along the landfill's western perimeter and a 426-m-long east-west-oriented line (Line 2) along the northern boundary of the existing landfill. Despite the relatively large fold for a near-surface seismic reflection survey, the data quality of the resultant stacks is considered "fair" compared with similar shear-wave data collected in the area (*e.g.*, Langston *et al.* 1998; Woolery and Street 2002).

The shallowest horizon imaged in the two profiles is a moderately coherent, discontinuous reflector between 35 and 45 milliseconds two-way travel time (TWTT) (Figures 4 and 5). The depth (*i.e.*, 4 to 5 m) likely correlates with the Metropolis Formation (unit 5.2?) based on local well logs. Only one relatively coherent and consistent impedance boundary is exhibited by both profiles; this horizon, ranging between 90 and 140 milliseconds TWTT (*i.e.*, 9 and 17 m in depth), correlates stratigraphically with the top of the Mounds Gravel. The deepest signal observed is a very incoherent, discontinuous horizon, ranging between approximately 150 and 200 milliseconds TWTT (*i.e.*, 18 and 24 m in depth) that correlates with the top of the McNairy Formation. These seismic-stratigraphic correlations are based on nearby well logs and are also consistent with other findings reported in nearby investigations (*e.g.*, Woolery and Street 2002; Sexton 2006).

Structural interpretations were defined by: 1) offset reflectors, 2) abrupt termination of strong reflections, 3) residual diffraction patterns, 4) abrupt change in reflection dips, and 5) associated folds. Noticeable sediment thickening on the



▲ **Figure 4.** Uninterpreted and interpreted seismic-reflection profile SL-1. The reflection horizons highlighted by black, orange, and green correlate with the Metropolis Formation (unit 5.2?), Mounds Gravel, and McNairy Formation, respectively.



▲ **Figure 5.** Uninterpreted and interpreted seismic-reflection profile SL-2. The reflection horizons highlighted by black, orange, and green correlate with the Metropolis Formation (unit 5.2?), Mounds Gravel, and McNairy Formation, respectively.

displaced downthrown side was considered a possible structural indicator. Temporal continuity of an anomaly across the seismogram was also used to better discriminate between structure and erosion (deposition) and/or soft-sediment deformation features. Other potential errors that can occur when interpreting the 2-D images include: 1) an oblique intersection angle of the seismic line and a fault plane may obscure the actual displacement image and exaggerate the width of the overall structure, and 2) spatial sampling inside the horizontal resolution can obscure distinct separation of the vertical displacement, making it appear as a monoclinal fold. Overall, the data show several discontinuities, as well as evidence of warped and folded stratigraphy that extends above the Paleozoic bedrock into overlying Quaternary sediment close to the base of the loess deposits (Figures 4 and 5). Specific deformation zones interpreted on the seismic profiles are discussed below.

Line 1 Profile

Three primary deformation zones, DZ1-1, DZ1-2, and DZ1-3, are interpreted along Line 1 (Figure 4). The approximately 79-m-wide DZ1-1 lies along the southern part of the line and is characterized by a series of steep, north- and south-dipping faults that exhibit both normal and reverse displacement. The northern margin of the zone exhibits an abrupt and nearly total loss of signal coherency. Interpreted displacement on faults within DZ1-1 ranges between 7.6 m at the top of the Mounds Gravel and 0.9 m across reflectors within the Metropolis Formation (unit 5). DZ1-2 is a narrower, 49-m-wide deformation zone defined by a steep north-dipping fault that extends upsection into unit 5. Immediately south of the fault is the northern extent of the previously identified incoherent signal. This segment does not exhibit any identifiable, laterally continuous reflectors and may be indicative of a broad "rubble" zone bounded by the two faults. The existing data are not extensive enough to corroborate this interpretation, however. DZ1-3 is a 36-m-wide anomaly located at the northern end of Line 1 and is characterized by a sudden loss of signal coherency. The incoherent zone is bounded by faults with apparent down-to-the-south vertical displacement (*e.g.*, the top of the Mounds Gravel exhibits ~3 meters of displacement). The data quality above this reflection is insufficient to extend the southern boundary fault any higher into the section; however, the northern fault appears to extend into the youngest resolvable reflectors (*i.e.*, unit 5). South of DZ1-3, the Mounds Gravel reflector has a distinct south dip (apparent) before being truncated by a fault at station 735. The latter fault, as well as interpreted normal faults at stations 715, 645, and 565, does not appear to extend above the Mounds Gravel. However, DZ1-3 was not included in the follow-up geologic investigation because we could not access the area with a drilling rig.

Line 2 Profile

Two primary zones of deformation, DZ2-1 and DZ2-2, were interpreted along Line 2. The 27-m-wide DZ2-1, located in the central part of the profile between stations 315 and 365, exhibits three relatively high-angle faults that offset the coherent and continuous Mounds Gravel and unit 5 reflectors (Figure 5). The primary fault, located near station 360, has an apparent westerly dip and branches upsection into a half-flower structure accompanied by two apparent east-dipping faults that offset unit 5 horizons.

The 128-m-wide DZ2-2, located in the eastern part of the profile between stations 509 and 719, is a prominent anomaly with at least four high-angle east- and west-dipping interpreted faults that exhibit both normal and reverse displacement. The top of the Mounds Gravel is displaced approximately 3.0 m, and unit 5 reflections exhibit 0.6 m vertical displacements. The western and eastern boundary faults show high-angle east and west apparent dips, respectively. The horizons between these two faults exhibit an upward relative displacement, although the section between the interior fault strands (*i.e.*, between stations 615 and 645) cannot be interpreted because of poor data quality. Overall, the pattern and style of deformation across DZ2-2 is indicative of a positive "flower" structure.

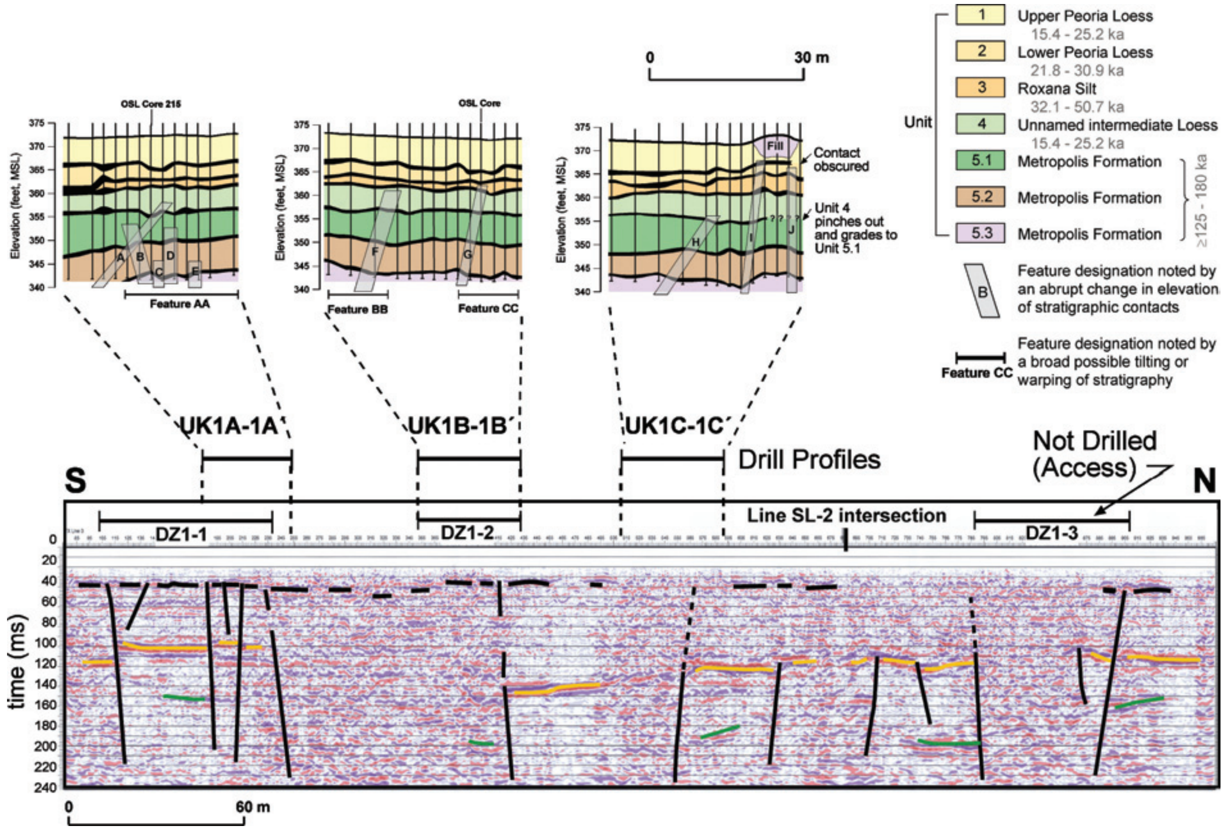
Geologic Cross-sections

The geologic cross-sections are constructed coincident with, and overlap, the uppermost part of the deformation zones interpreted in the seismic profiles. The cross-sections show lateral continuity along several distinct lithologic loess strata and soil horizons, as well as older fluvial strata (Figures 6 and 7). These strata and paleosols were used as strain gauges for assessing zones of deformation (*e.g.*, warping, folding, and faulting) interpreted from seismic reflection lines 1 and 2.

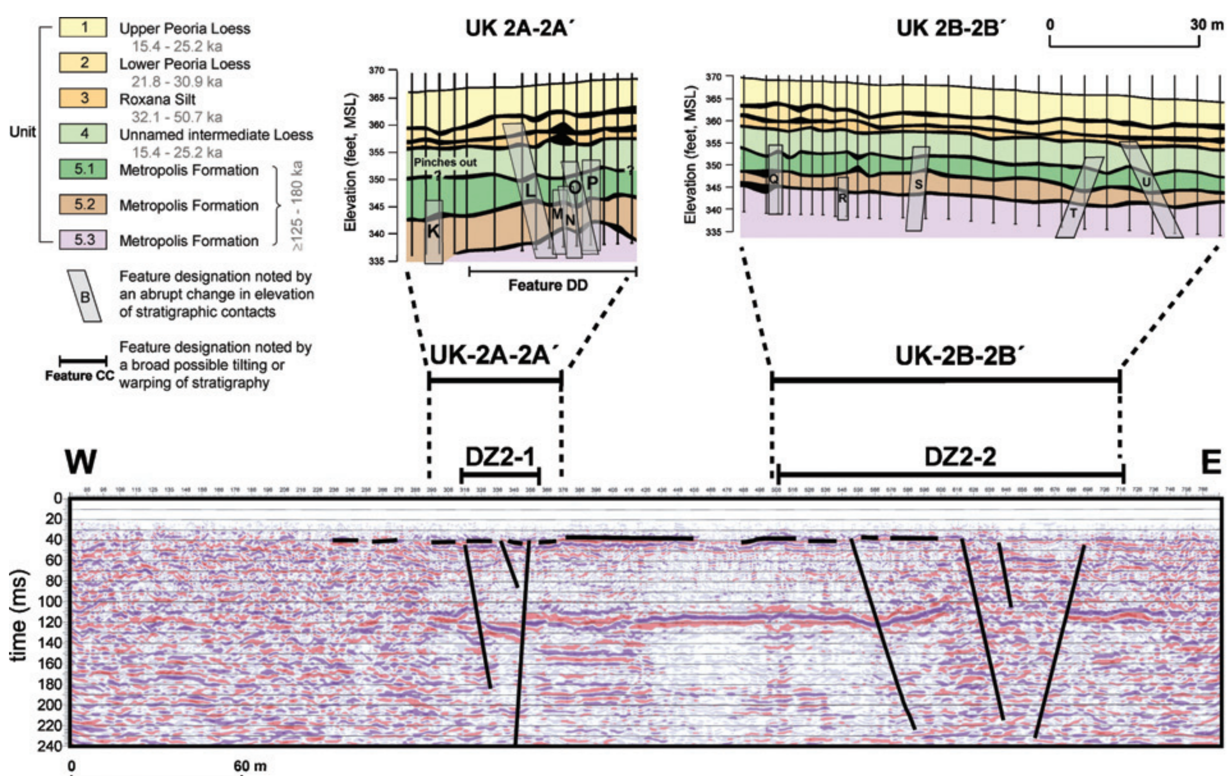
Three geologic cross-sections were constructed along the Line 1 reflection profile. These three sections, designated from south to north as UK-1A-1A′, UK-1B-1B′, and UK-1C-1C′, are shown in Figure 6. Similarly two cross-sections, designated from west to east as UK-2A-2A′ and UK-2B-2B′, are constructed along the Line 2 reflection profile (Figure 7). All cross-sections have a four times (4×) vertical exaggeration in order to display thin stratigraphic and pedogenic horizons, as well as to identify subtle changes in stratigraphy across the site that may be representative of faulting or folding or could be original perturbations in the paleotopography. The cross-sections allow the interpretation of as many as four relatively large folds or warps and 21 features with elevation changes across stratigraphic and/or pedologic boundaries. More specific descriptions follow.

Cross-sections UK-1

Cross-section UK-1A-1A′ is oriented along the southern end of Line 1 and overlaps a narrow zone of steeply dipping normal faults interpreted as DZ1-1 (Figure 6). One broad warp (designated feature AA) and five possible distinct changes in the elevations of some stratigraphic contacts (designated A to E) are inferred in the cross-section. UK-1B-1B′ lies along the central part of Line 1, coincident with a broad zone of moderately disturbed reflectors DZ1-2 (Figure 6). In section UK-1B-1B′, two subtle warps (designated features BB and CC) and two anomalous features associated with possible vertical elevation changes across stratigraphic boundaries (designated F and G) are interpreted. Cross-section UK-1C -1C′ does not cross any



▲ **Figure 6.** Geologic cross-sections UK-1 and interpreted anomalies in relation to the Line 1 seismic-reflection profile. The geologic cross-sections are coincident with the seismic reflection profile and extend down to the upper part of the Metropolis Formation.



▲ **Figure 7.** Geologic cross-sections UK-2 and interpreted anomalies in relation to the Line 2 seismic-reflection profile. The geologic cross-sections are coincident with the seismic reflection profile and extend down to the upper part of the Metropolis Formation.

primary deformation zone interpreted from the seismic survey but overlies a single, steep, south-dipping fault (Figure 6). UK-1C-1C′ exhibited three discrete anomalous features (designated H to J) associated with elevation changes across stratigraphic boundaries. Feature I is the only anomaly in which vertical separation across all overlying loess units can be interpreted; however, these displacements are considered suspect, because several of the inferred separations are based on anomalous contacts in the core. The cores experienced adverse drilling and sampling conditions due to a moderately thick artificial fill that may have influenced the location of the stratigraphic boundaries. Consequently, the apparent vertical separation potentials across the loess boundaries are considered unlikely.

Cross-sections UK-2

Geologic cross-section UK-2A-2A′ overlaps a narrow zone of interpreted steeply dipping reverse faults and numerous discontinuities defined as DZ2-1 (Figure 7). UK-2A-2A′ exhibits an interpreted antiform (feature DD) and numerous distinct elevation changes (features K to P) across intra-Metropolis Formation boundaries. Cross-section UK-2B-2B′ lies along the eastern end of seismic-reflection Line 2 coincident with the east- and west-dipping faults defined in DZ2-2 (Figure 7). Overall, UK-2B-2B′ exhibits: 1) relatively flat-lying stratigraphy and 2) five distinct elevation changes (features Q to U) that are limited primarily to unit 4 and older units, except for feature Q, which extends into Roxana Silt.

SUMMARY

Nearly 1 km of seismic-reflection profiles and 86 9.1-m-long, continuous cores provided images and detailed stratigraphy for characterizing the extent and age of possible reactivated faults in the Fluorspar area fault complex of western Kentucky, an area also coincident with moderate levels of microseismicity. The seismic surveys imaged five significant deformation zones containing high-angle faults that were interpreted to extend to within approximately 7 m of the ground surface (*i.e.*, late-Quaternary sediment), at or near the upper limit of the seismic sampling. Subsequent analyses of the coincident core sampling, including detailed logging, stratigraphic correlations, and numerical age determinations, provided high-resolution definition of locations and ages of the possible faults. The anomalous zones are constrained by stratigraphic continuity of late Pleistocene loess and fluvial deposits, as well as pedogenic horizons developed within these deposits. Analyses show there are at least seven late Pleistocene stratigraphic and pedogenic deposits present in the site's upper 9.1 m of sediment. Numerical dating (OSL) of several late Quaternary strata provides well-constrained ages on the aeolian and fluvial deposits, including an unnamed loess (53.6 to 75.5 ka), the Roxana Silt (32 to 50 ka), the Lower Peoria Loess (22 to 30 ka), and the Upper Peoria Loess (10 to 25 ka). The upper three units (*i.e.*, the Upper Peoria Loess, the Lower Peoria Loess, and the Roxana Silt) generally are flat-lying and mantle pre-existing topography. In contrast, the four lower horizons have rare subtle to abrupt undulations in stratigraphic contacts, which may reflect fluvial depositional processes and/or tectonic deformation. Specifically, geologic cross-sections allow the interpretation of as many as four relatively "broad" folds or warps and 21 features with elevation variation anomalies across stratigraphic and/or pedologic boundaries. These possible elevation changes represent differences in the elevation of a given stratigraphic boundary that exceed the uncertainty in the boundary depths based on laboratory measurements and thus probably are related to natural (tectonic or non-tectonic) processes. The 25 potential fault-related features represent the most distinct and vertically continuous features that can be interpreted as faulting or folding. Furthermore, the geologic cross-sections indicate that most abrupt elevation changes are constrained to post-date the 53.6 to 75.5 ka loess deposit; however, no perceptible displacement was found at the base of younger loess dated between 16.6 and 23.5 ka. Collectively, these data indicate an absence of Holocene (<11,000 years) deformation at the site.

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