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QUATERNARY DISPLACEMENT ALONG THE HOVEY LAKE FAULT OF SOUTHERN INDIANA AND WESTERN KENTUCKY

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Abstract

The Hovey Lake fault extends southwesterly from central Indiana, through western Kentucky, and back into southern Indiana as it passes beneath the Ohio River. Possible Quaternary displacement was evaluated along the Hovey Lake fault in southern Indiana and western Kentucky. A shallow S-wave seismic reflection line acquired across the Hovey Lake fault in southern Indiana reveals Paleozoic bedrock that is folded and normal faulted 10.5 m. The overlying Quaternary alluvium has 2 m of reverse displacement at a depth of 5 m thus revealing structural inversion. Although there is no surface scarp, a line of shallow borings, acquired across the seismically identified fault, indicate that the faulting may come to the surface. Plans to trench at this site were abandoned when permission to excavate was denied.

A shallow S-wave seismic reflection line was acquired across a down-to-the-west scarp within the Hovey Lake fault system in western Kentucky. The reflection line reveals folding and faulting in both Paleozoic bedrock and overlying Quaternary alluvium. A trench excavated perpendicular to the scarp exposed folded 3500 YBP Ohio River alluvium. The fold is a down-to-the-west monocline with an amplitude of 3 m. We believe that the monocline formed as a consequence of underlying down-to-the-west Holocene fault displacement. Fractures within an

undeformed unit that laps onto the scarp, indicate that minor fault reactivation may have occurred within the last 295 years.

Introduction

The Wabash Valley fault system of southern Illinois and Indiana is an important neotectonic province (Fig. 1). Many geologic and geophysical studies have identified numerous northeast-trending faults within this province (Sexton et al., 1986; Kolata and Nelson, 1991; Rene and Stanonis; 1995; Bear et al., 1997; Hildenbrand and Ravat, 1997; McBride et al., 1997; Wheeler, 1997). Historic seismicity demonstrates a "shotgun" distribution of earthquakes coincident with the Wabash Valley fault system that are at best poorly tied to mapped bedrock faults (Pavlis et al., 2002). One of the few exceptions to this history is the 5 (m_b) June 18, 2002 earthquake that appears to have occurred along the Caborn or Hovey Lake faults in southern Indiana (Kim, 2003; Woolery, 2005). A major question is whether these predominantly right lateral strike slip Wabash Valley faults, with local transpressive and transtensive displacement, have been active during the Quaternary.

Paleoseismic studies by Obermeier et al. (1991) and Munson et al. (1997) have documented late Pleistocene and Holocene earthquake liquefaction within the district that strongly argues for Holocene movement on some of these faults. However, no clear field evidence of Holocene displacement has been documented on any of the Wabash Valley faults. One of the strongest candidates for Quaternary fault displacement occurs in the southern portion of the Wabash Valley fault zone along the Hovey Lake fault system of southern Indiana (Woolery, 2005) and western Kentucky (Counts et al., 2007) (Fig. 1).

Using shallow S-wave seismic reflection, Woolery (2005) identified bedrock folding and faulting across the Hovey Lake fault in southern Indiana that appears to normally displace the top of bedrock 10.5 m at a depth of 10 m (Figs. 1 and 2). At a depth of 5 m, the fault is inverted and has 2 m of reverse displacement within unconsolidated sediments. A boring along Woolery's (2005) line identified carbon from 7.7 m depth to be 37,000 YBP. Therefore the folding and apparent faulting revealed in Figure 2 must be younger than 37,000 years.

Subsequent field work was conducted on the Hovey Lake fault (Vance et al., 2005). In this research we collected eight bore holes along Woolery's seismic line HL-A (Figs. 2 and 3). These continuous cores allowed us to construct a detailed shallow geologic cross section. Figure 3 reveals near surface clays and silts overlying sands that are folded and apparently faulted. Between bore holes 2 and 3 we interpreted a fault that displaces near surface sand 1.5 m down-to-the-northwest, in agreement with the earlier work by Woolery (2005). The interpreted fault projects to the ground surface where the surface slope is steepest. Thus, it appears that the fault may have produced a fault scarp. Our bore hole stratigraphy also suggests that the surface silty clay facies on the downthrown side of the interpreted fault may be a colluvial wedge shed off the upthrown side. C^{14} from our borings reveals that at 4 m depth a folded horizon is 31,230$\pm$280 YBP, but that at one meter depth a sample of uncertain stratigraphic position is dated at 1,110$\pm$40 YBP.

The prospective Quaternary fault in Figure 3 was scheduled for excavation in 2007. However, permission to trench was denied and so we sought another site within the Hovey Lake fault system for further study. An excellent possible fault target was brought to our attention by Ronald Counts of the Kentucky Geological Survey. A 5 km long, linear, north-south trending, west-facing scarp, lies along the Kentucky portion of the Hovey Lake fault system (Figs. 1 and

Figure 1. Hovey Lake fault in Indiana and Kentucky. Red line is location of Figures 2 and 3. Box is area of Figure 4.

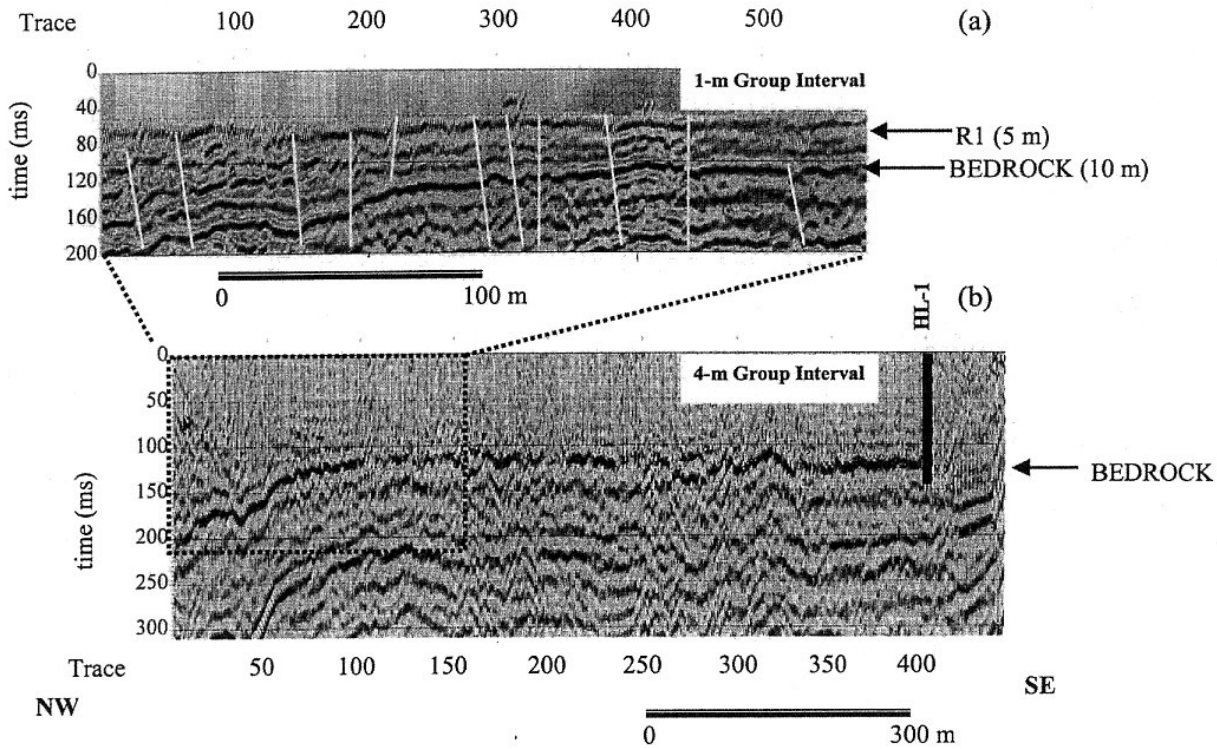

Figure 2. S-wave seismic reflection profiles HL-b and shallower HL-a acquired across the Hovey Lake fault zone in southern Indiana at red line in Figure 1 (from Woolery, 2005).

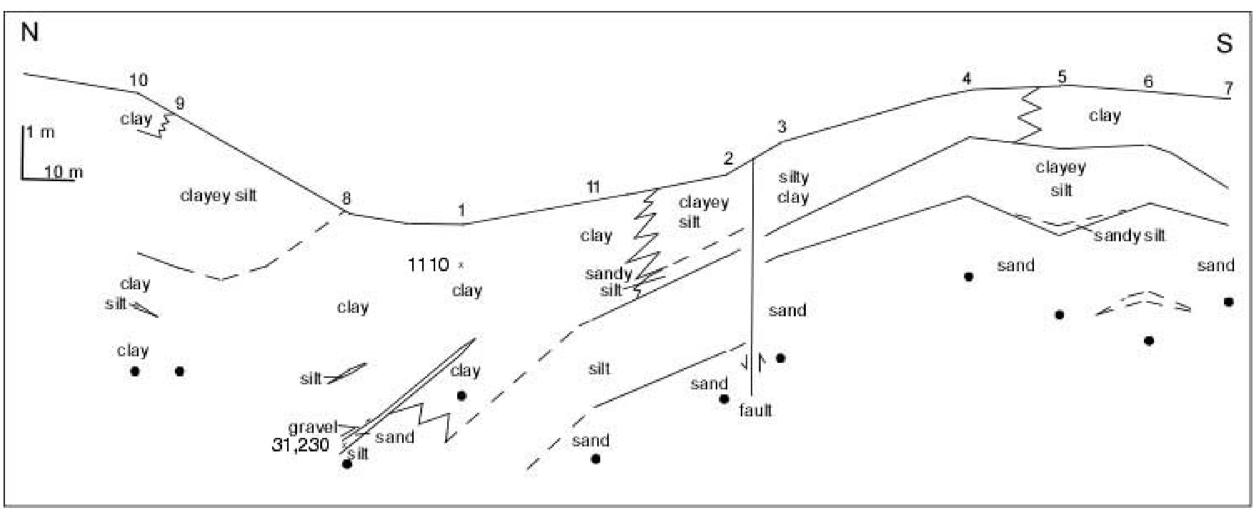

Figure 3. Shallow geologic cross section across a portion of the Hove Lake fault zone in southern Indiana. Core sites are labeled 1-11 on the landscape. This cross section corresponds with the area between trace 150 to 350 of seismic line HL-a of Figure 2. Folding and faulting of unconsolidated surficial sediments are suggested in this cross section. 1,110 and 31,230 are YBP C^{14} dates acquired at the X locations. VE = 10X.

4) (Counts et al., 2008). This scarp is up to 2.5 m high and marks the boundary between the Ohio River flood plain and a low-lying terrace that is sometimes flooded along its western margin.

Seismic Reflection Profile across a Scarp within the Kentucky Portion of the Hovey Lake Fault System

To test whether the western Kentucky scarp in Figure 4 is an Ohio River terrace margin or a fault scarp, we acquired a shallow S-wave seismic reflection line that crossed the southern projection of the scarp (Fig. 5). Figure 5 illustrates Quaternary Ohio River flood plain sediments overlying Paleozoic rock (bedrock surface) (Johnson and Norris, 1976). Coal exploration borings confirm that the top of the Paleozoic is at a depth of approximately 40 m in the area. Folding and faulting of the Paleozoic bedrock continue into the Quaternary alluvium near the western end of the seismic line. At this location we interpret the scarp to be a fault line scarp.

Trench across the Western Kentucky Scarp

A 33 m long trench was excavated 3 m deep across the western Kentucky scarp (Figs. 4 and 6). The trench exposed silt overlying sand in the eastern portion of the trench, but a more complicated stratigraphy overlies the scarp in the western end of the trench. [The scarp is not evident in Figure 7, but projects through the trench at 23 m in the trench log.] Starting from trench location 18 m the soil diverges westward. The surface soil continues to the western end of the trench and a paleosol continues at depth to the western end of the trench and is evident in the western-most boring. This paleosol is a black buried A horizon. We interpret the western end of the trench as having a basal sand overlain by a silt that are the same units as in the eastern portion of the trench. However, at the western end of the trench the lower silt is capped by a paleosol that is in turn overlain by a younger silt. The sand and immediately overlying silt appear to have been flexed into a 3 m monocline at 23 m. In the flexure, fractures are evident within the younger silt.

C^{14} dates were obtained from the basal sand at 18.2 m (sample 16, 3270$\pm$25YBP), overlying silt at 11.7 m (sample 1, 3745$\pm$25 YBP), and from the silt that overlies the scarp at 20.6 m (sample 8, 295$\pm$25 YBP).

Discussion and Conclusions

A seismic reflection profile and sediment coring across the Hovey Lake fault in southern Indiana suggest Quaternary faulting (Figs. 1-3). A second seismic reflection line reveals apparent faulting beneath a west-facing scarp in western Kentucky that is interpreted to coincide with a fault within the Hovey Lake fault system (Figs. 1, 4, and 5). We have named this the Uniontown fault (Counts et al., 2009). A trench excavated across the Uniontown fault scarp revealed Holocene Ohio River alluvium folded into a down-to-the-west monocline with approximately 3 m of structural amplitude (Fig. 6). We believe that the Ohio River flood plain sediments were folded due to approximately 3 m of down-to-the-west displacement on the underlying Uniontown fault. The geologic history of the site (Fig. 7) is interpreted as follows: 1) deposition of fluvial point bar sand and overlying overbank silt during flood plain construction at approximately 3500 YBP, 2) soil formation on the overbank silt across the flood plain, 3) the

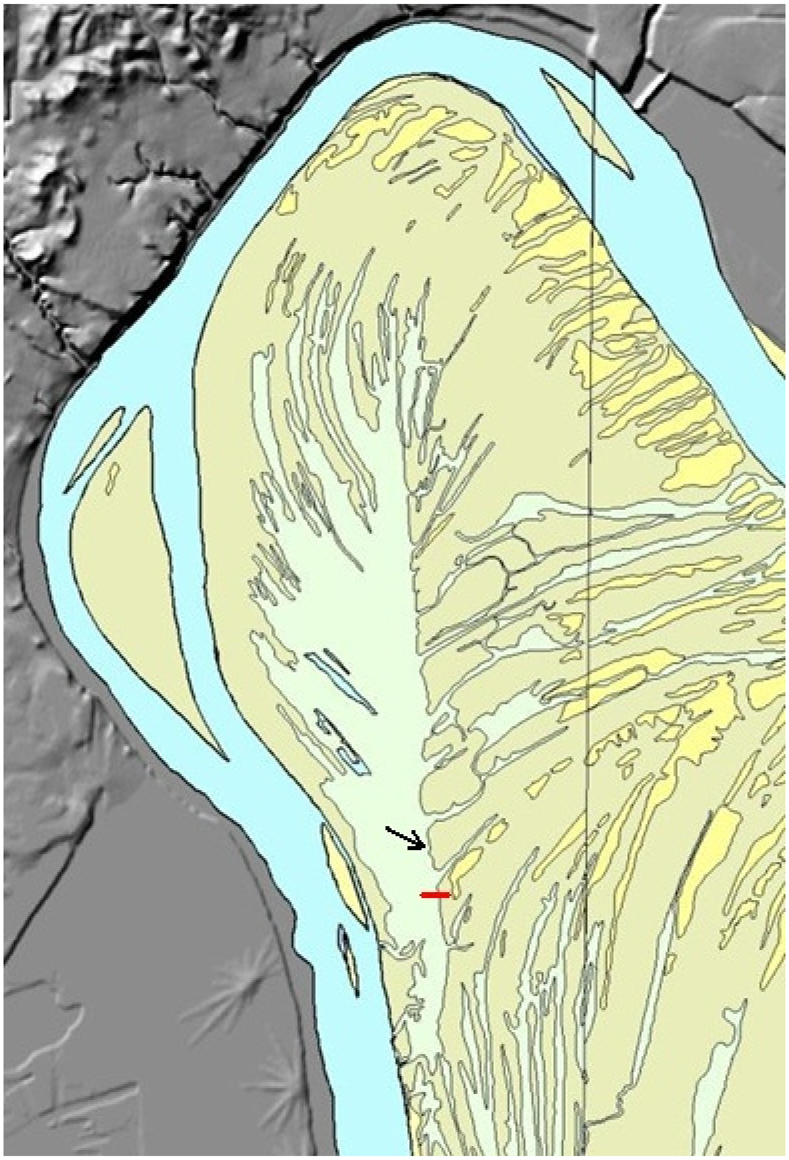

Figure 4. North-trending Uniontown fault scarp with seismic reflection line in red and trench location at head of arrow.

flood plain sequence and overlying soil were folded due to subsurface faulting resulting in a west-facing monocline scarp, 4) erosion denuded the scarp thereby removing the soil and most of the silt in the scarp, 5) a new soil developed on the denuded scarp, 6) sedimentation of the younger silt 295 YBP buried the scarp and down thrown side of the scarp, thereby preserving the buried soil as a paleosol, and 7) subsequent minor flexing of the scarp, possibly caused by minor fault reactivation, formed fractures in the 295 YBP silt above the monocline.

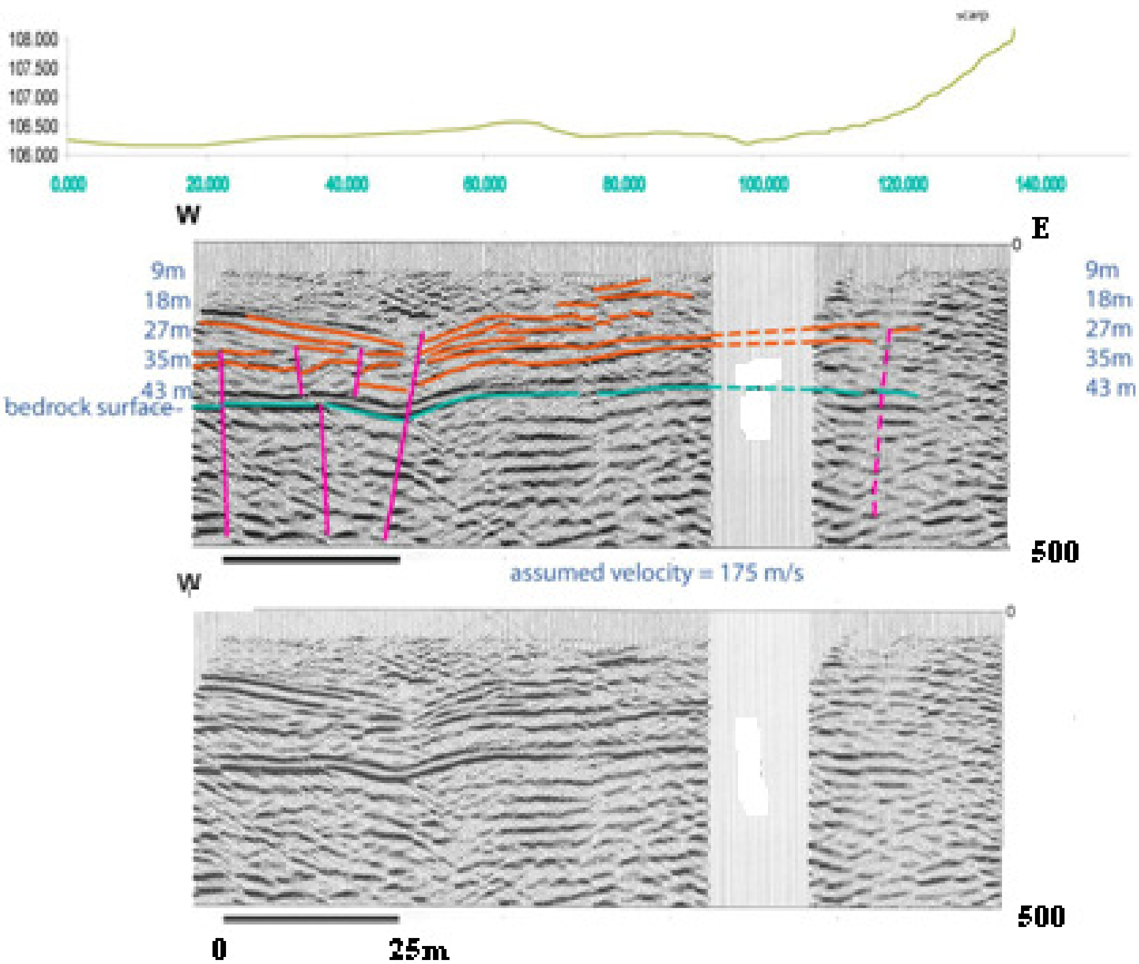

Figure 5. Topographic profile and S-wave seismic reflection line along red line in Figure 4. Break in profile is due to a bridge.

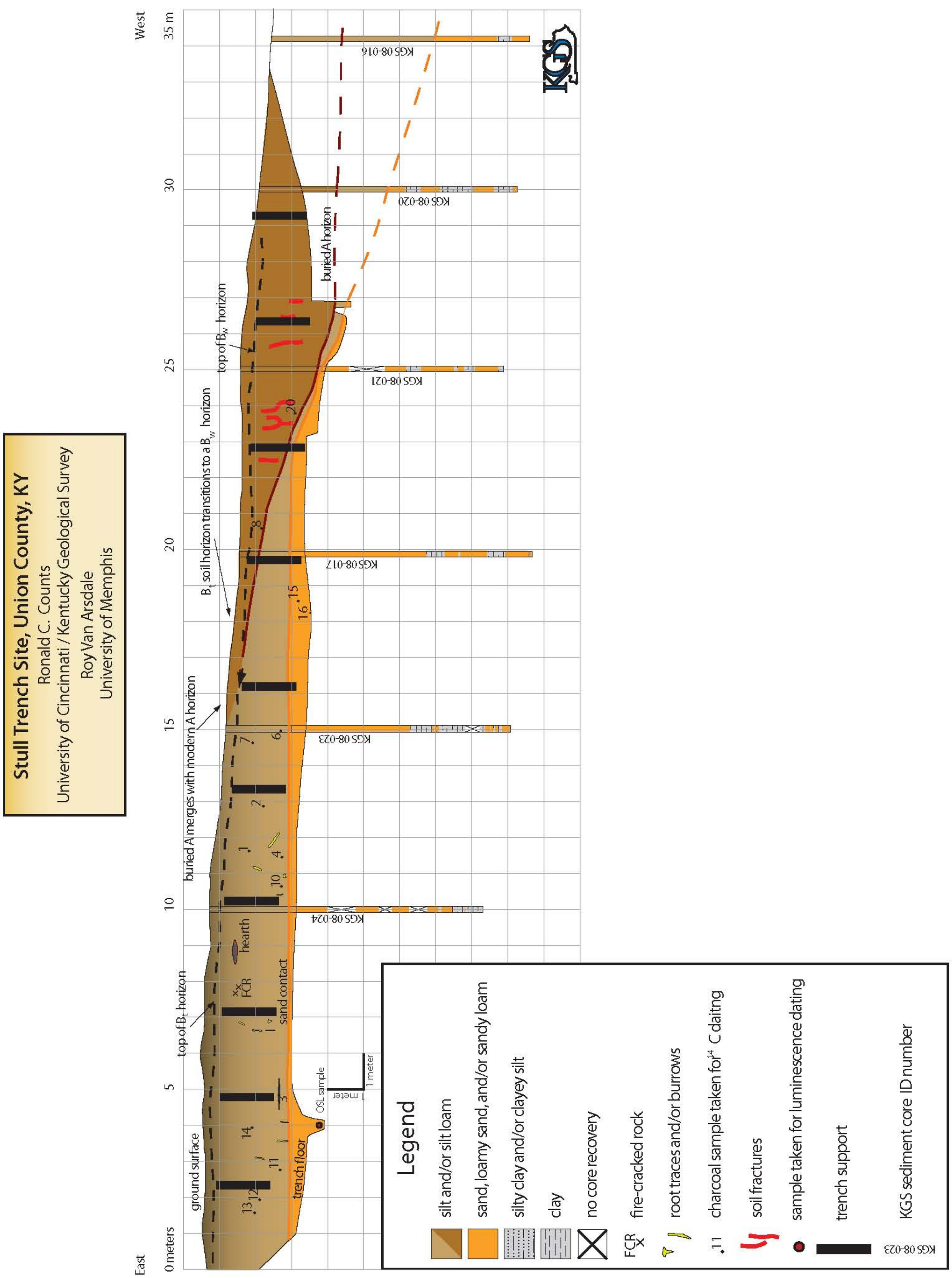

Figure 6. E-W trench and boring logs looking south. Trench located in Figure 4.

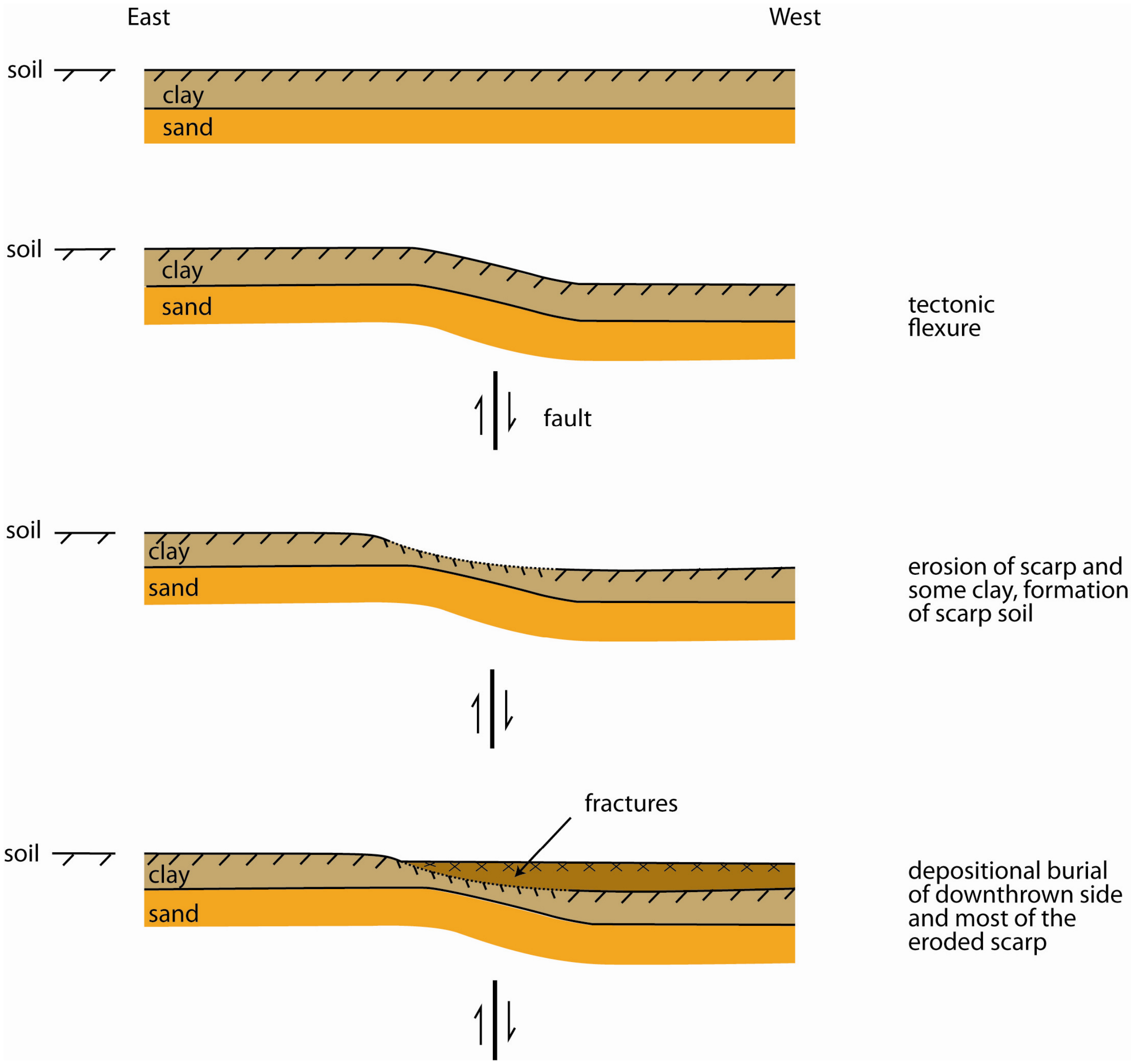

Figure 7. Formation and evolution of the Uniontown fault scarp.

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