SH-Wave Imaging of Potential Near-Surface Geologic Controls on Contaminant Plume Migration — Fluorspar Area Fault Complex, Western Kentucky

Almayahi, Ali Z.
azal222@g.uky.edu
Earth and Environmental Science, University of Kentucky,
Lexington, KY

Woolery, Edward W.
ewoolery@uky.edu
Earth and Environmental Science, University of Kentucky,
Lexington, KY

Hampson, Steven
skhampson@windstream.com
Center for Applied Energy Research, University of Kentucky,
Lexington, KY

Abstract

We acquired 18.5 km of near-surface SH-wave seismic reflection profiles to evaluate the post-Paleozoic sediment that overlies the southwestern projection of the Fluorspar area fault complex (FAFC) in western Kentucky for neotectonic deformation in the area of an anomalously migrating contaminant plume. Our previous investigations showed that the late-Precambrian–early Paleozoic FAFC has been reactivated and extends above the Paleozoic carbonate bedrock into the approximately 100 meters of low-velocity unlithified Cretaceous, Tertiary, and Quaternary sediment. Newly integrated reflection images indicate deformation from two northeast striking high-angle bedrock fault strands, extending into the lower part of a Pleistocene-Pliocene sand and gravel aquifer, bound and are coincident with the highest concentrations of the TCE-contaminant plume, suggesting the potential for a preferential groundwater flow path. Ongoing shear-wave birefringence experiments will further evaluate the azimuthally anisotropic properties of the sediment at these sites.

Acknowledgments

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Exhibit 1. The red square indicates the location of site location relative to the Mississippi Embayment in the central United States. The small green stars represent the epicenter of seismic activity in new Madrid seismic zone near to the study site. Also, the exhibit shows two late-Precambrian and early-Paleozoic rifts (Reelfoot Rift and Rough Creek Graben).

Site Stratigraphy

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<th>SYSTEM</th>
<th>SERIES</th>
<th>FORMATION</th>
<th>LITHOLOGY</th>
<th>~THICKNESS (M)</th>
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<td>Quaternary</td>
<td>Pliocene and Holocene</td>
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<td>Tertiary</td>
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<tr>
<td></td>
<td>Paleocene</td>
<td>McNairy</td>
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<td></td>
<td>Tuscaloosa</td>
<td>Mississippian Carbonates</td>
<td>150+</td>
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</tbody>
</table>

Exhibit 2. Stratigraphic section of the study site. Modified from (Woolery et al, 2010).

Exhibit 3. The study site and the seismic reflection profiles and boreholes locations.

Exhibit 4.

a) Final stack seismic profile of line-B, E-W as an example of processed data. The conventional seismic data processing procedure applied using Seismic data Processing Workshop software (SPW 2.1.20), and good improvement in the vertical and horizontal resolution is recognized. Also, the location of the west and east plume are indicated on the profile.
b) Post stack instantaneous amplitude section of the same seismic profile.
c) Post stack instantaneous phase section of the seismic profile. Note, the same seismic data processing procedure was applied to all seismic profiles.
Wavelet Analysis

Exhibit 5. On going work, wavelet analysis, a) BetterWorth band pass filter matching between a seismic trace and the corresponding acoustic impedance log. b) The error associated with transforming the data from the time domain to frequency domain using Fourier and Descrete Wavelet transforms. The figure shows that the associated error using Fourier transform is larger than descrete wavelet transform.

Results and Interpretation

Exhibit 6. An interpreted 3D model from 2D seismic profiles. The orange lines indicate the surface locations of the seismic profiles.

a) Interpolated grids of the seismic reflectors, the reddish grid is the Paleozoic bedrock, the bluish grid is the Cretaceous McNairy formation, and the greenish grid is the Pleistocene Mound Gravel aquifer. Note, the top of Metropolis does not exist in all of seismic profiles, so that it is undisplayed in 3D view model. The manual picking mode used in Kingdom Suite (ver. 8.6).

b) The interpreted high angle faults trending northeast are shown

c) This model demonstrates the location of the fault relative to the formation tops.
Conclusions

1) Shear-wave (SH) reflection methods provide relatively high-resolution images of geologic features in water-saturated low-velocity sediment.
2) 26.4 km of reflection data have identified Late Quaternary faults that extend to within 7 meters of ground surface.
3) Anomalous contaminant plume migration appears controlled by fault structure and geometry.

Exhibit 7. a) A map shows the contamination plume migration paths according to groundwater samples analysis from intense boreholes distribution across the plume. b, c, and d show isochronal maps for the tops of Paleozoic bedrock, the Cretaceous McNairy, and Pleistocene Mounds Gravel formations, respectively. In all isochronal maps, the white areas correspond to the deepest places due to the faults offsets. The faults trends control the migration paths of the contamination plume, north-west and north-east directions in the Mound Gravel Aquifer.