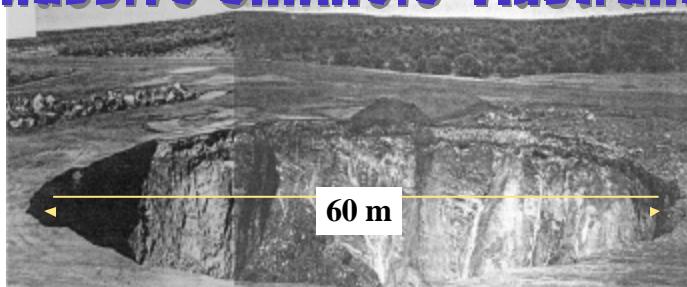


3-D Seismic Tomographic Imaging

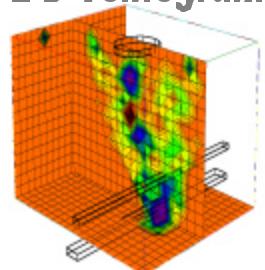
For
**Abandoned Mine Subsidence
Characterization: Case Histories**

By
Khamis Haramy
Federal Highway Administration, Denver, CO

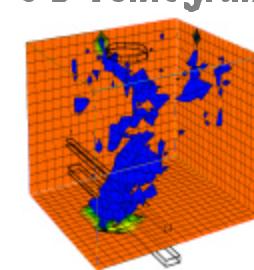
Massive Sinkhole- Australia



2-D Tomogram



3-D Tomogram



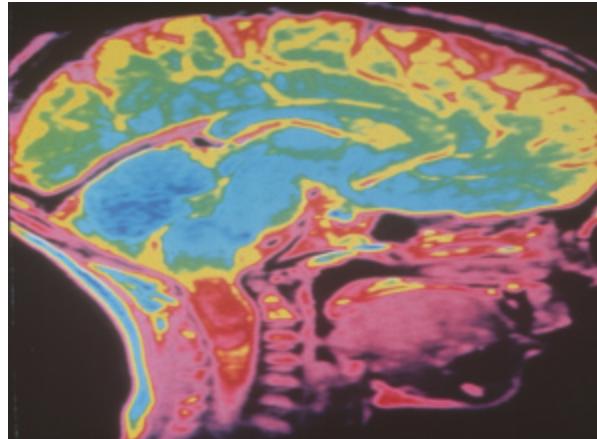


Subsidence Above Mine Openings

- "Trough" – Resulting from full extraction mining or widespread caving over failed pillar panels.
- "Sinkhole" – Failure of isolated areas or individual near-surface openings.



Tomography Background

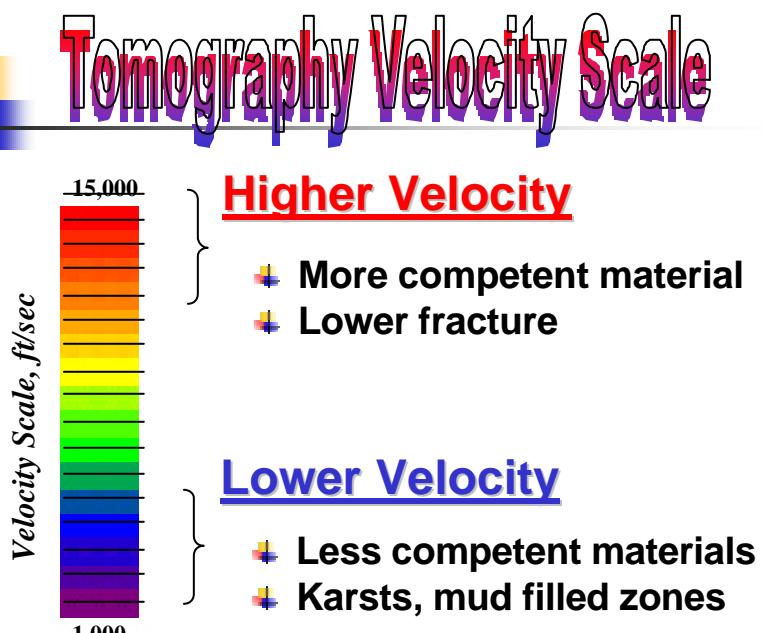


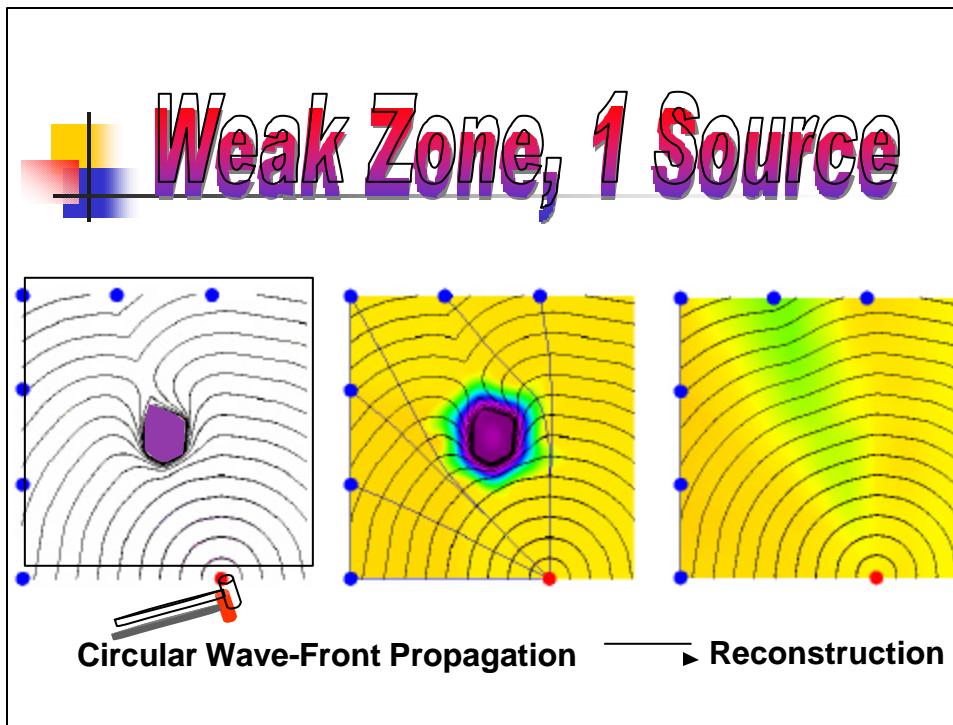
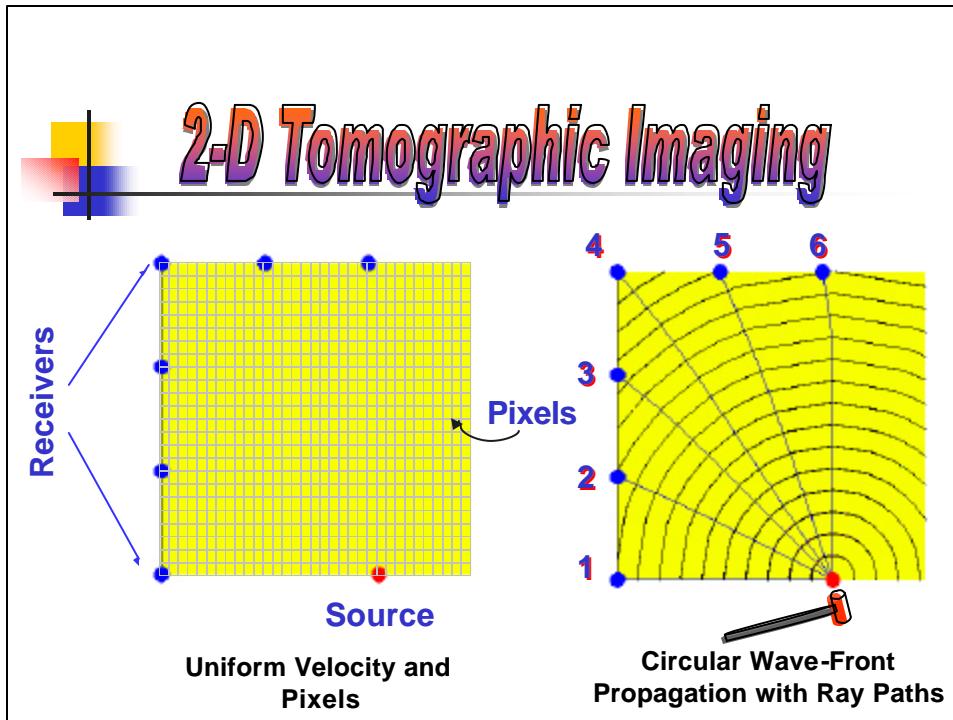
CAT Scan--Computer Aided Tomography

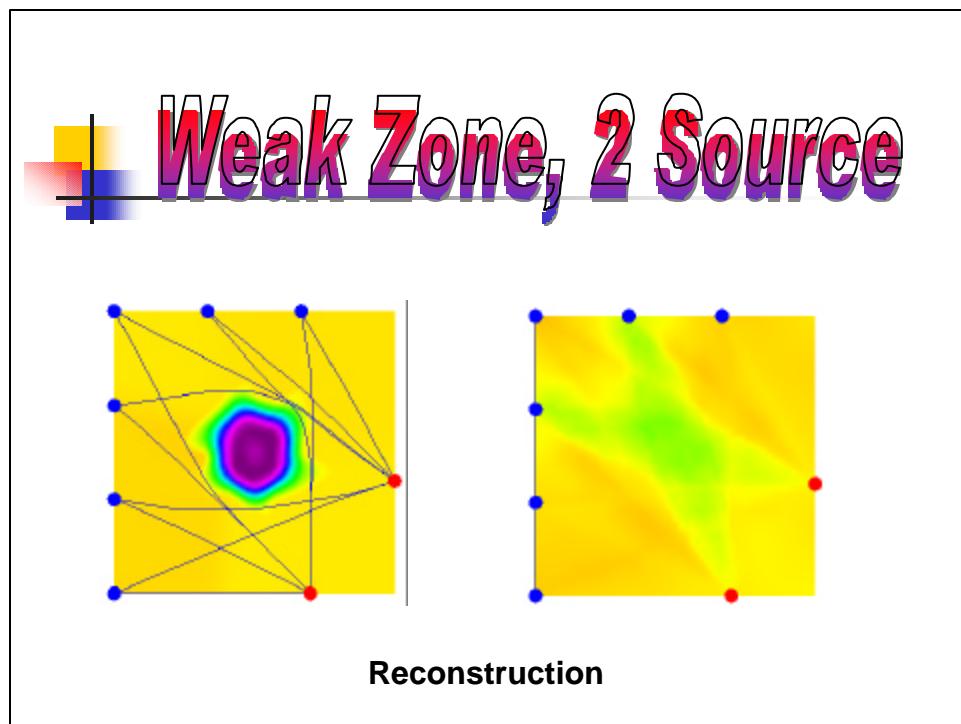
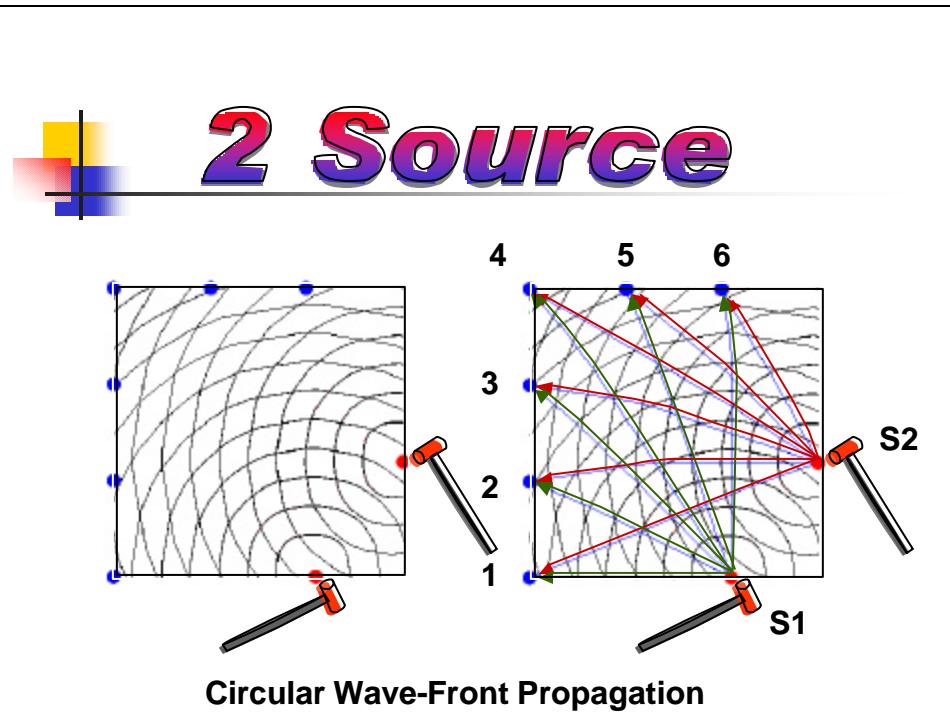


Tomogram Interpretation

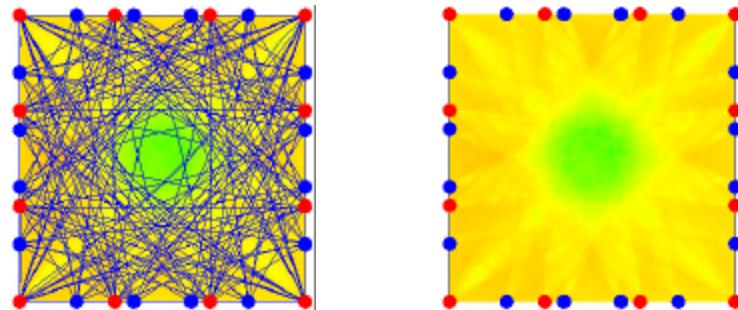
- Measures seismic energy transmitted through the medium.
- Color coding used to represent velocity or attenuation levels.
- Area imaged is within ray path coverage only.





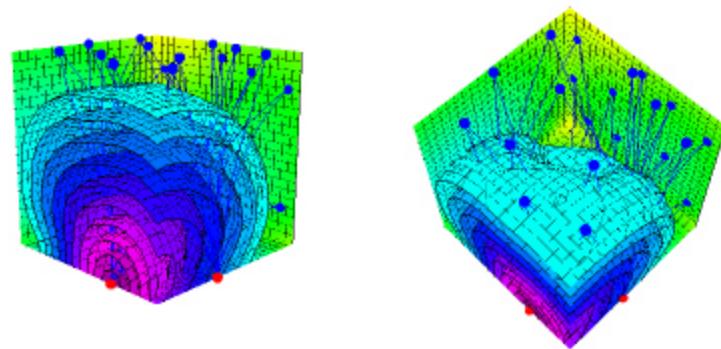


Weak Zone, 12S & 16R



Reconstruction

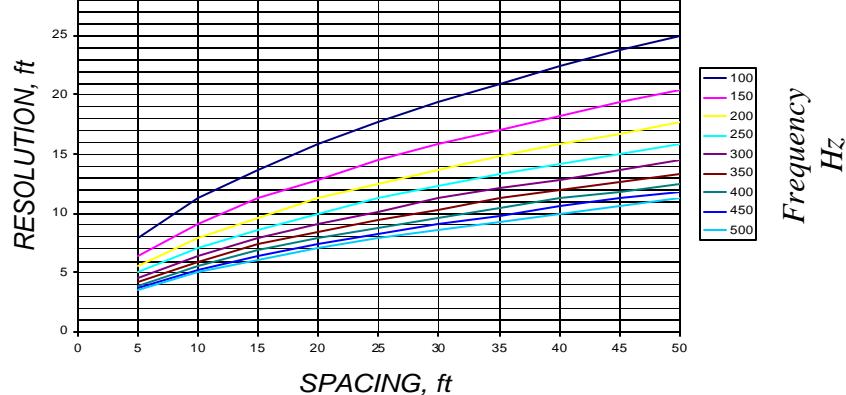
3-D Wave-Front Propagation



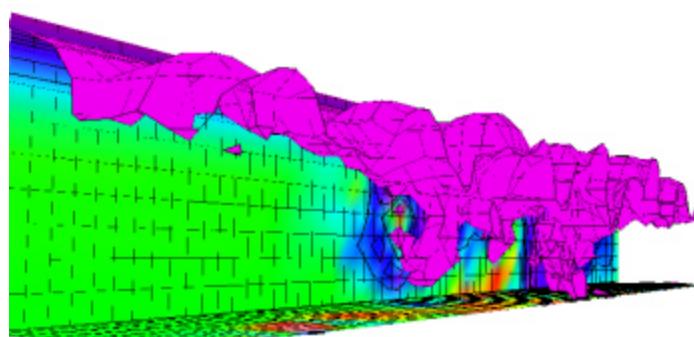
Seismic Tomogram Resolution

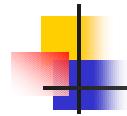
Velocity = 10,000 ft/s

$$\text{Resolution} = \text{SQRT}(\text{Spacing} * \text{Velocity} / (8 * \text{Frequency}))$$



Case Histories

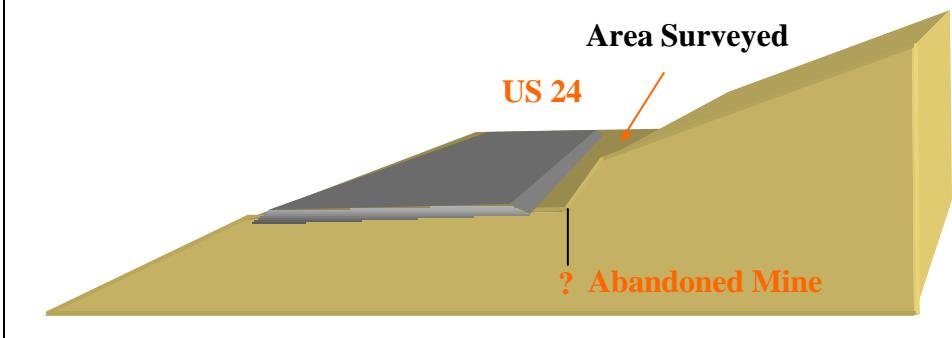




Case History 1

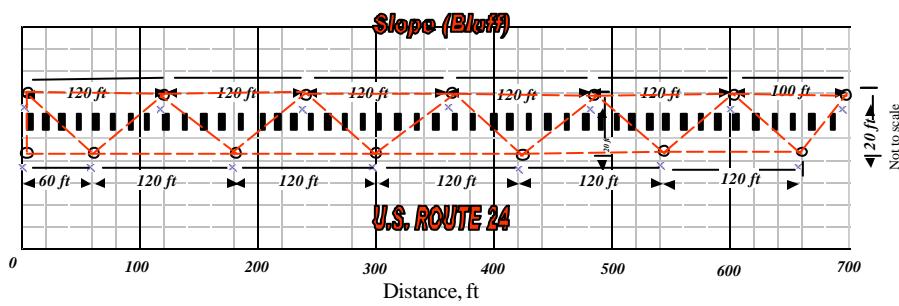
PROJECT: Retaining Wall Foundation US Route 24- IDOT

PURPOSE: Locate Old Workings

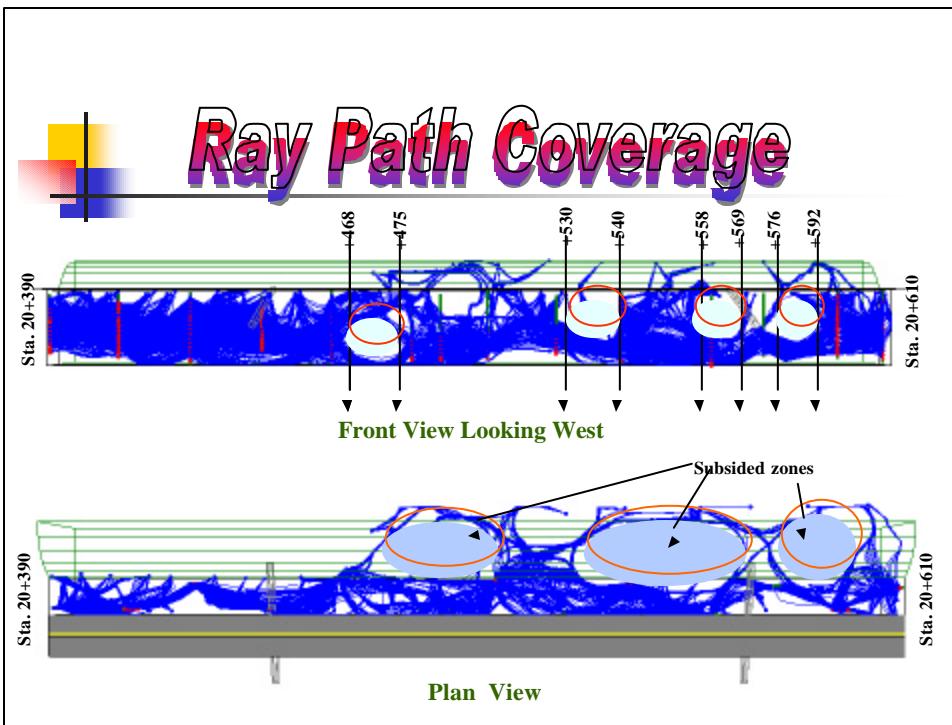


Retaining Wall Foundation US Route 24, IL

Crosshole and Surface Seismic Tomography

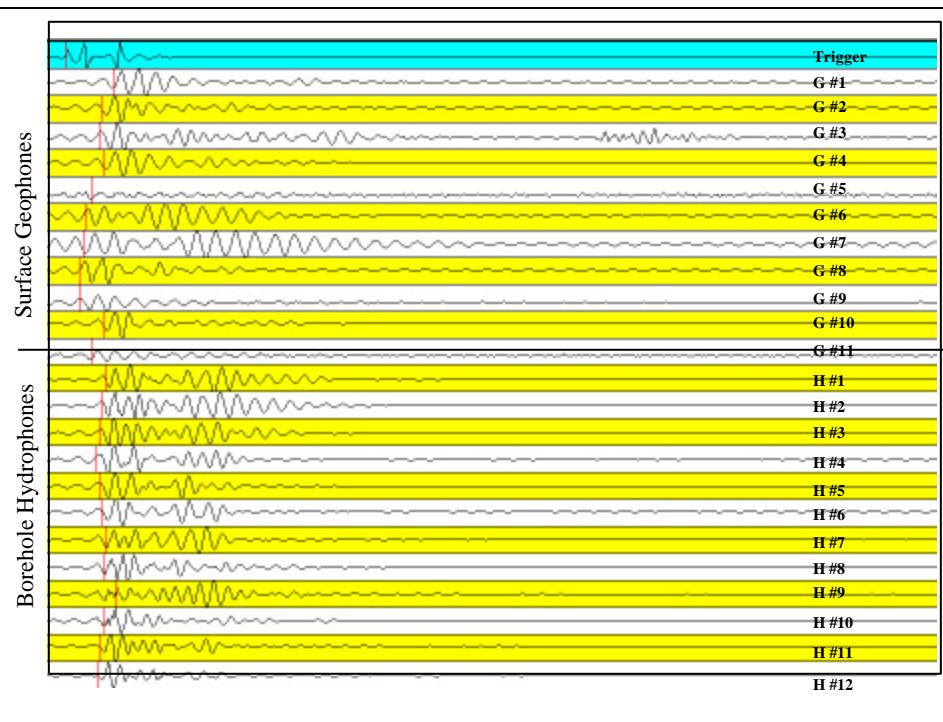
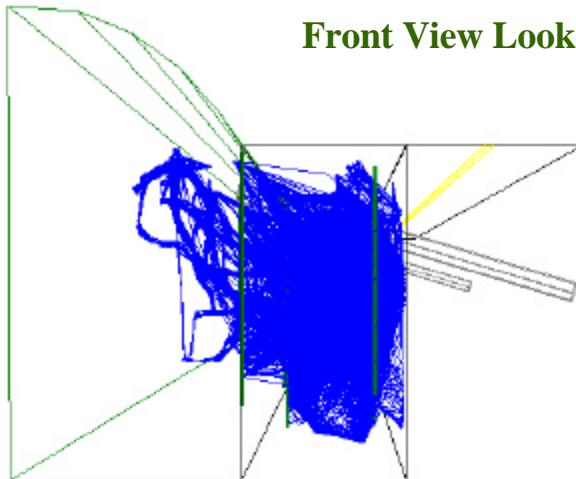


3-D Tomographic Imaging

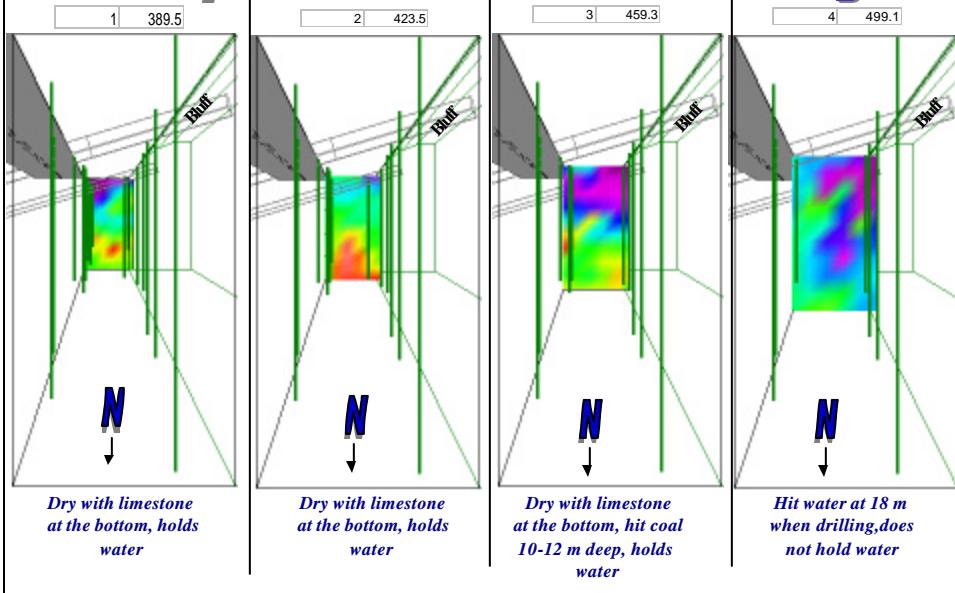


Ray Path Coverage

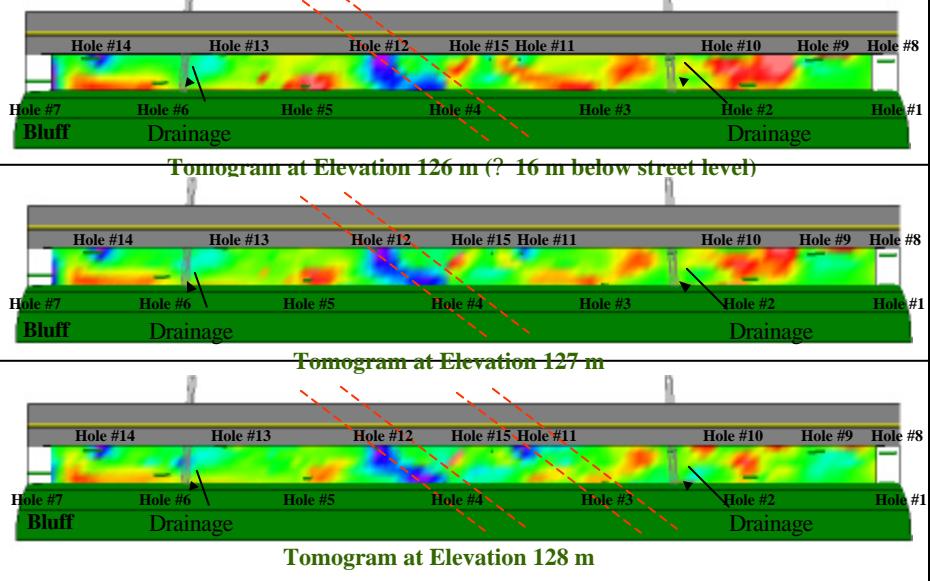
Front View Looking North



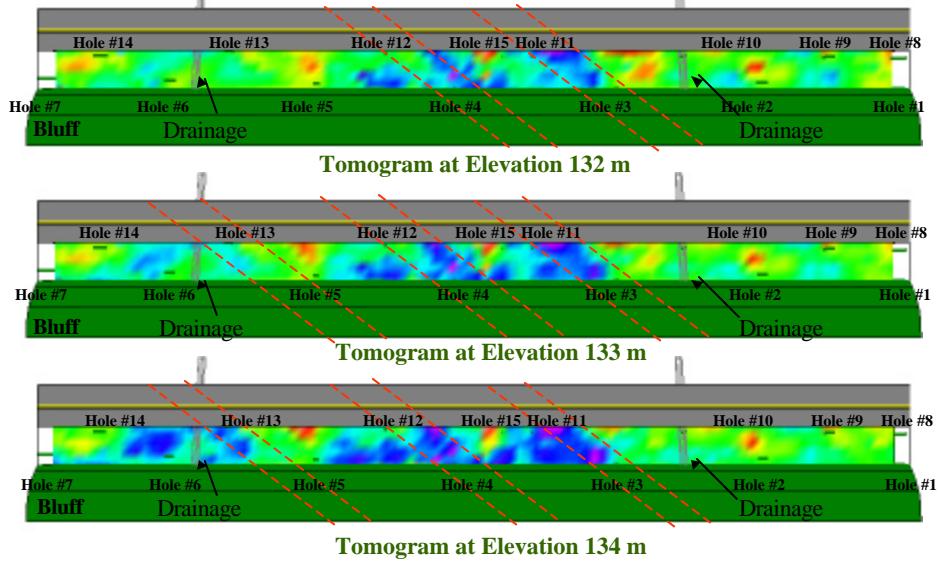
Comparison with Borings



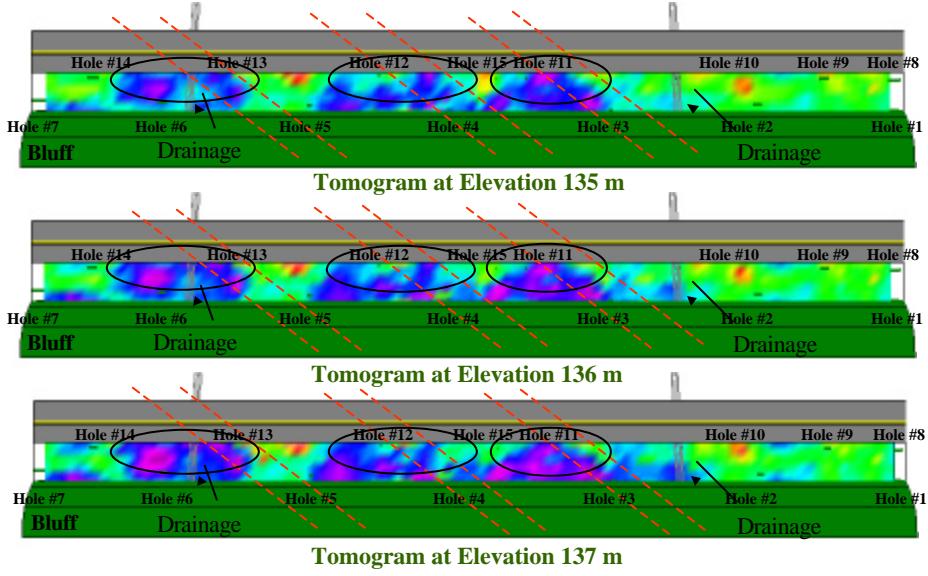
2-D Horizontal Cross-Sections



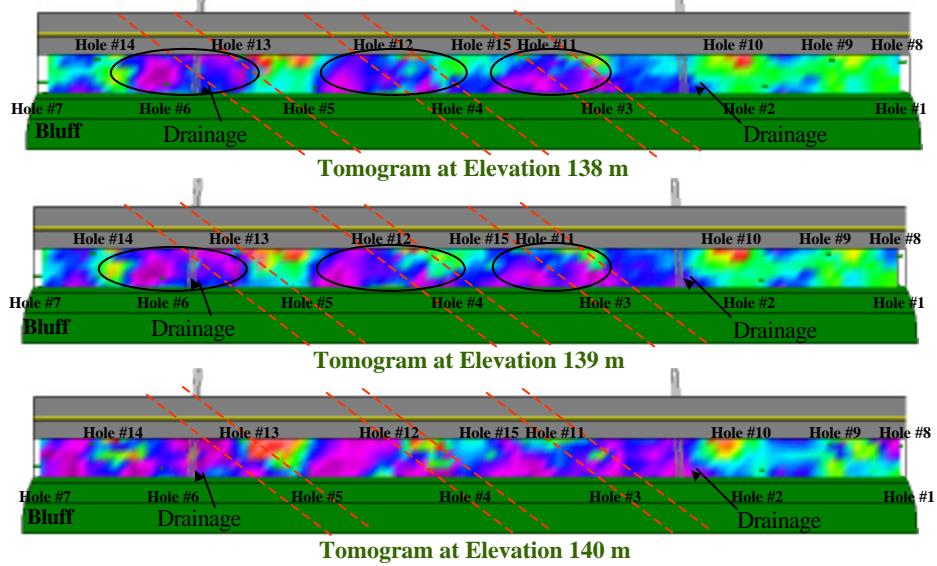
3-D Tomographic Imaging



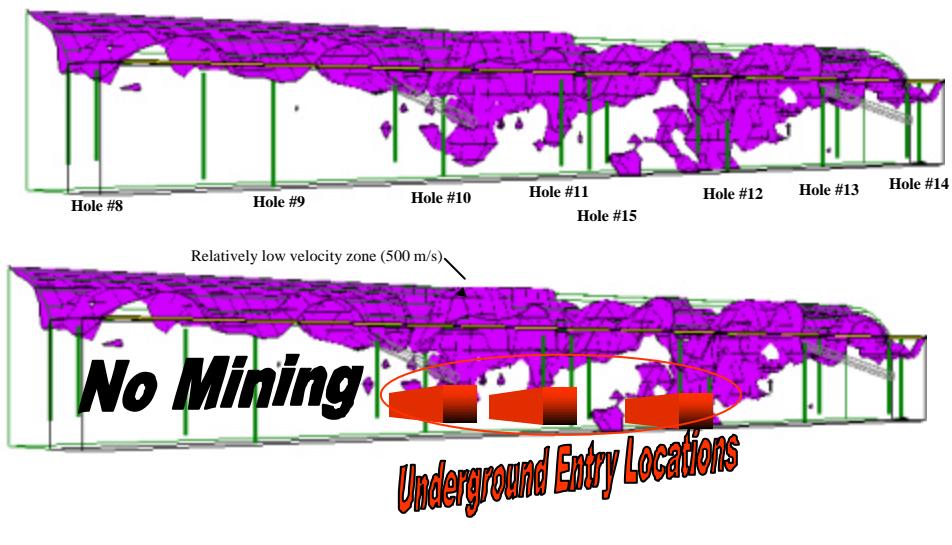
3-D Tomographic Imaging



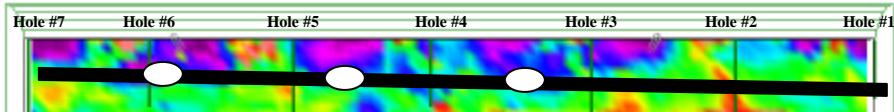
3-D Tomographic Imaging



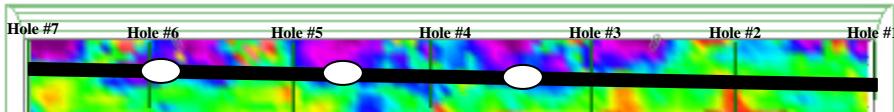
3-D Tomographic Imaging



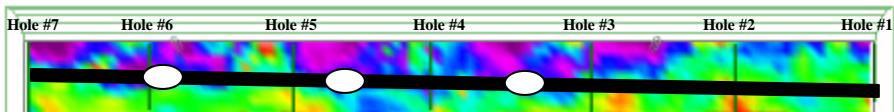
3-D Tomographic Imaging



Tomogram at 12 m from the edge of the street

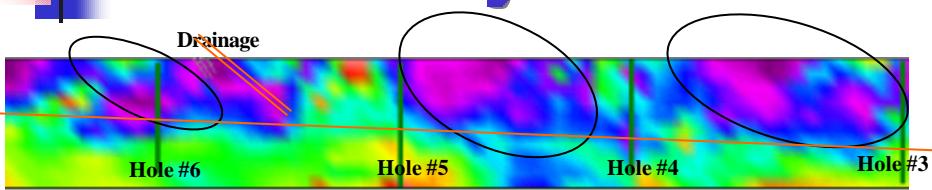


Tomogram at 13 m from the edge of the street

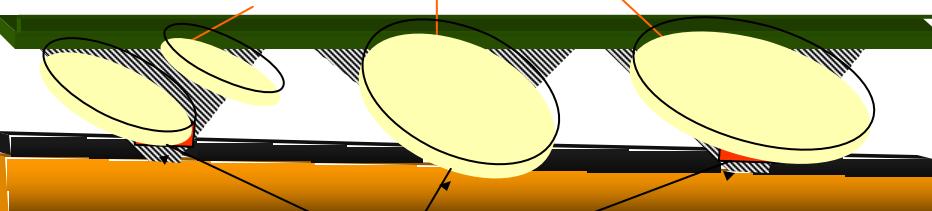


Tomogram at 14 m from the edge of the street

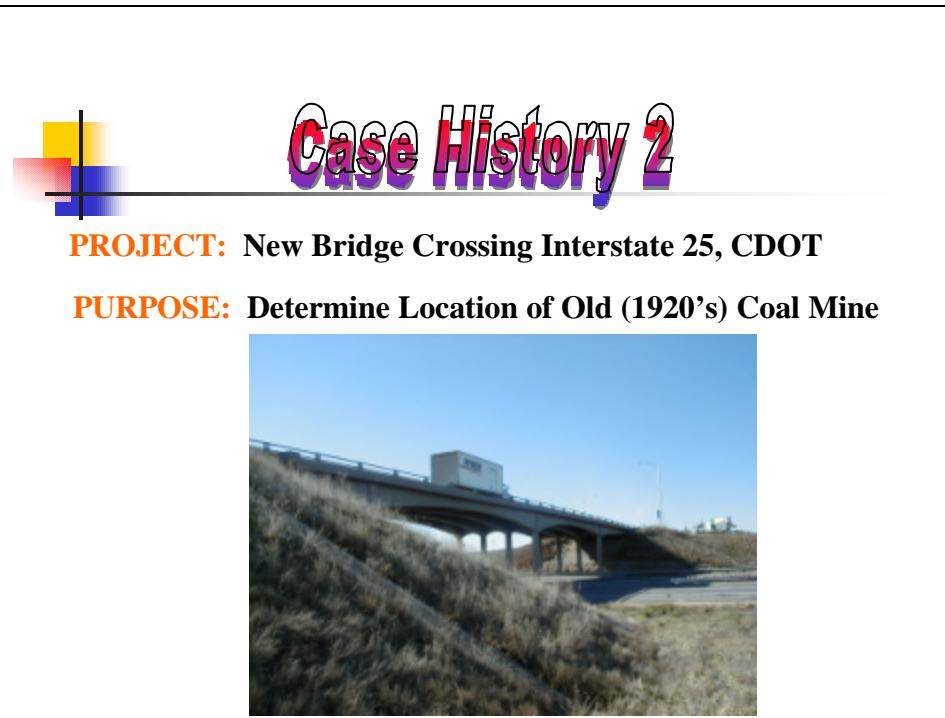
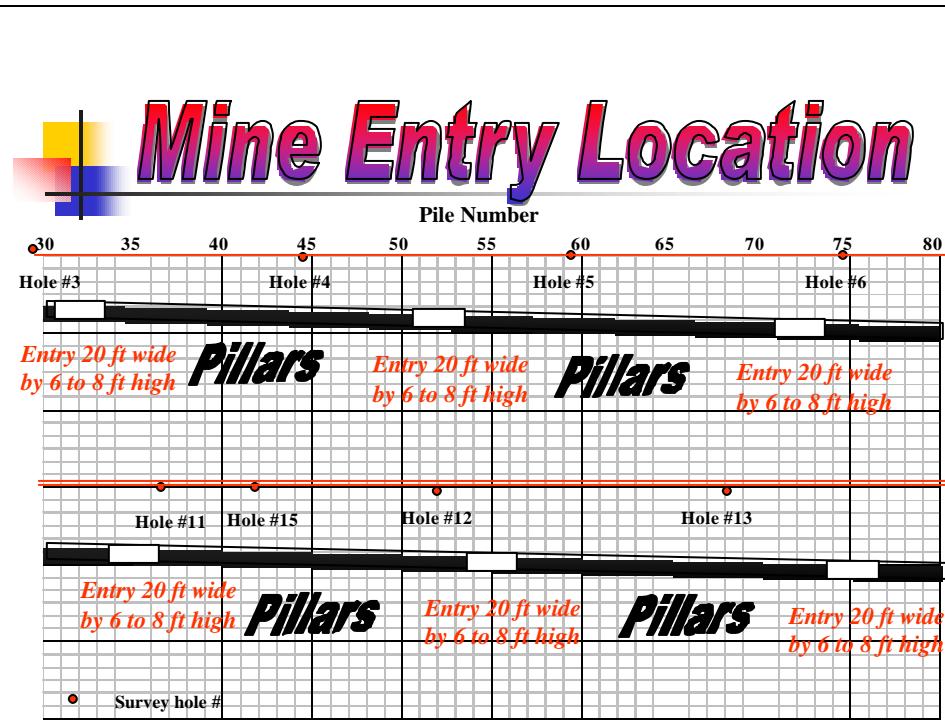
Mine Entry Location



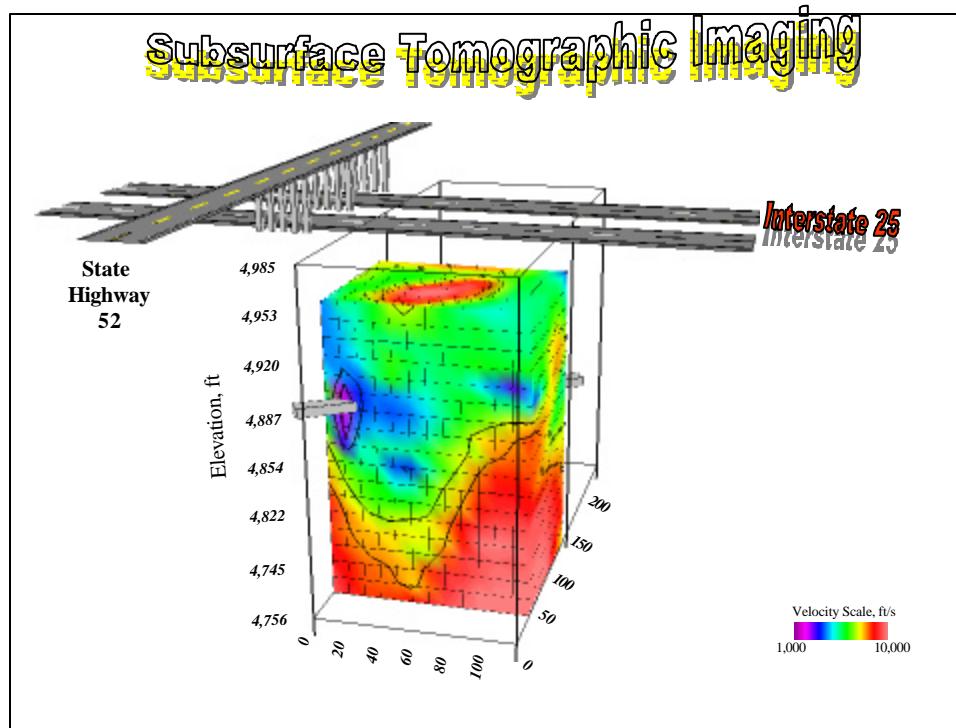
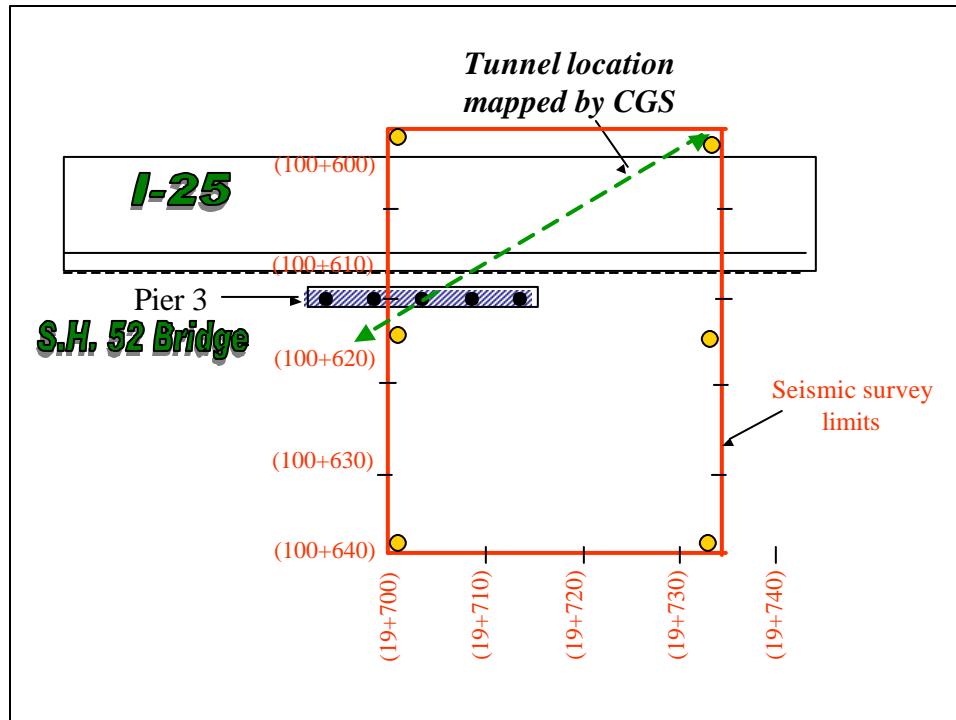
Caved zones above mine entries



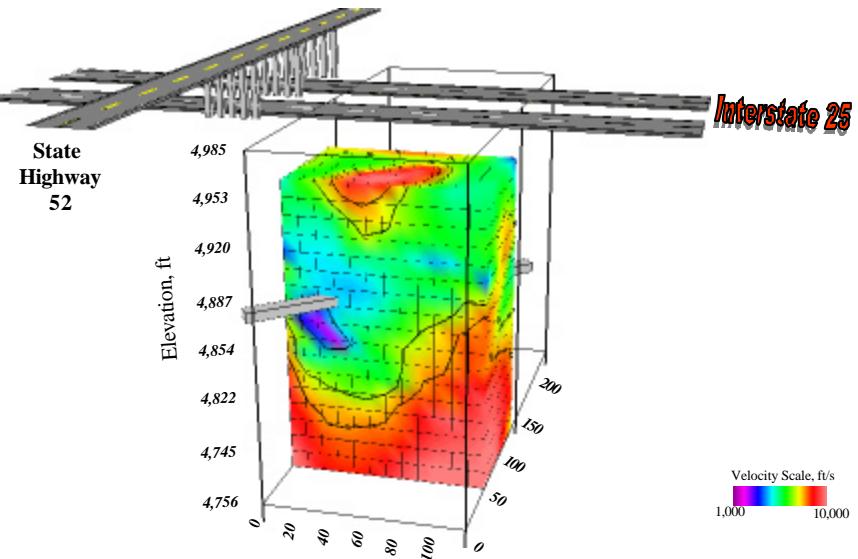
Mine entries and caved zones at centerline of imaged area



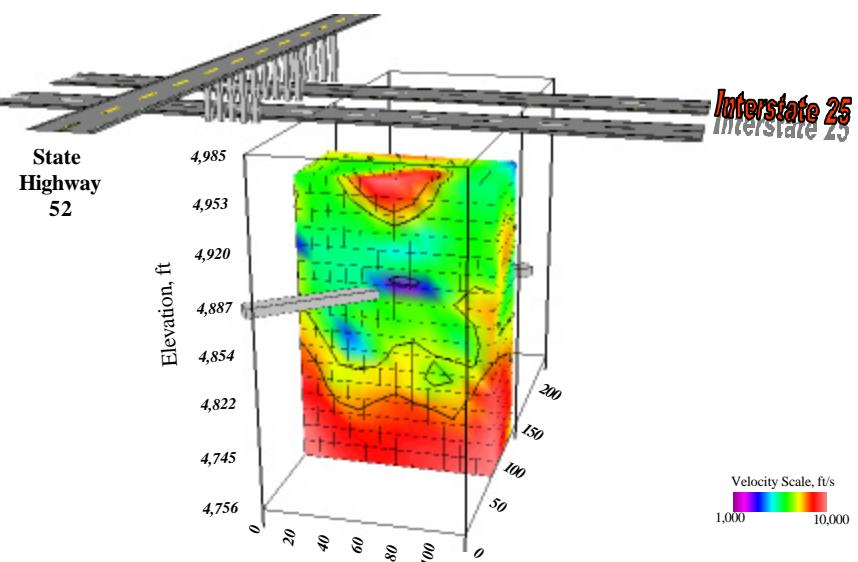




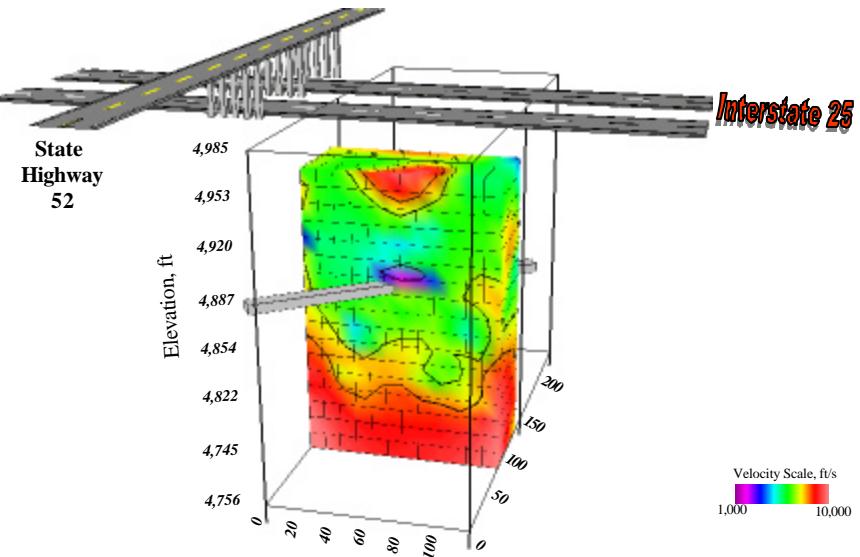
Subsurface Tomographic Imaging



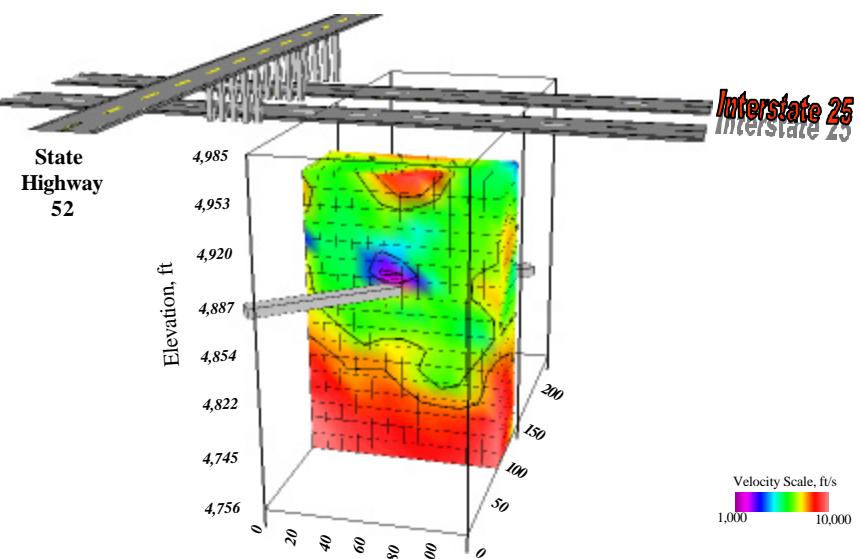
Subsurface Tomographic Imaging



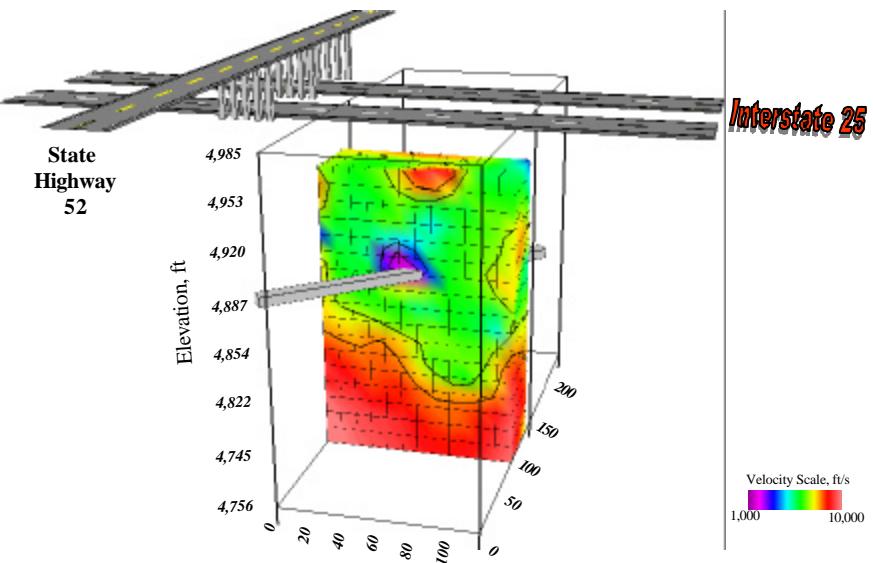
Subsurface Tomographic Imaging



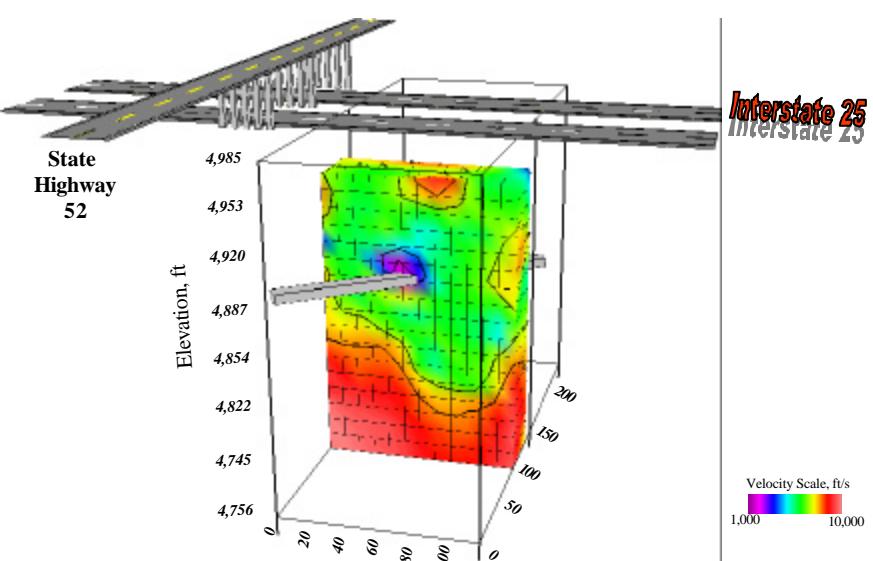
Subsurface Tomographic Imaging



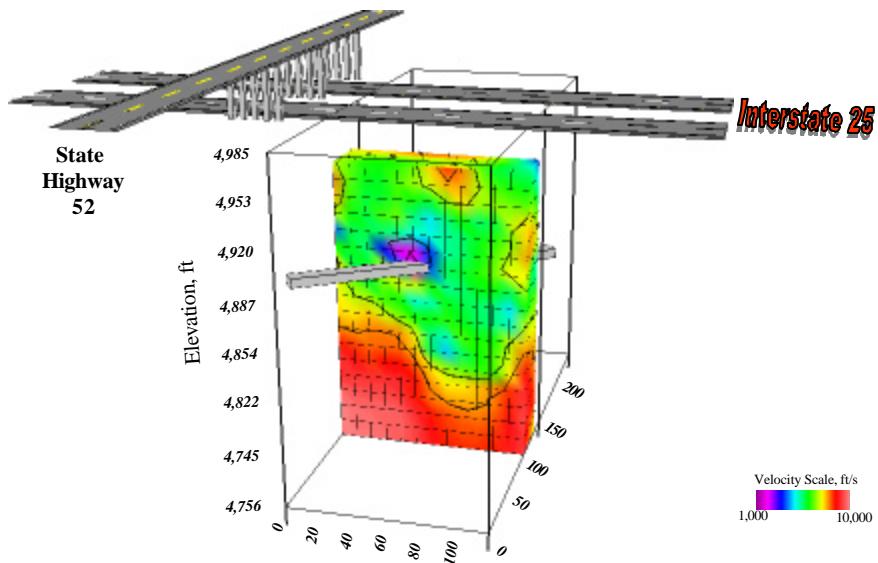
Subsurface Tomographic Imaging



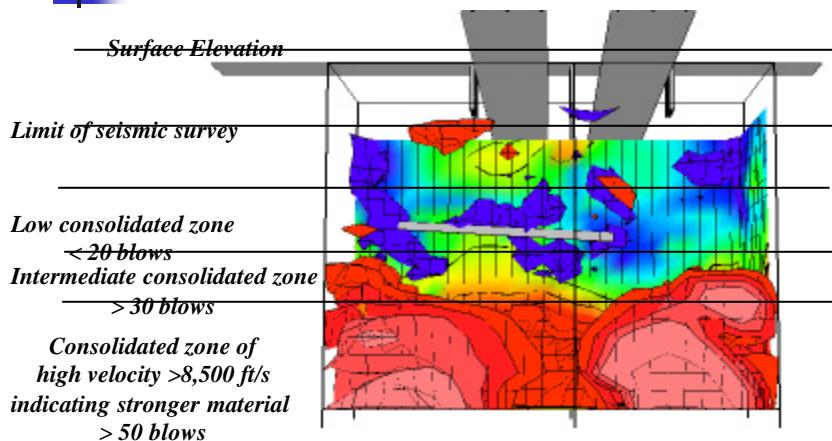
Subsurface Tomographic Imaging

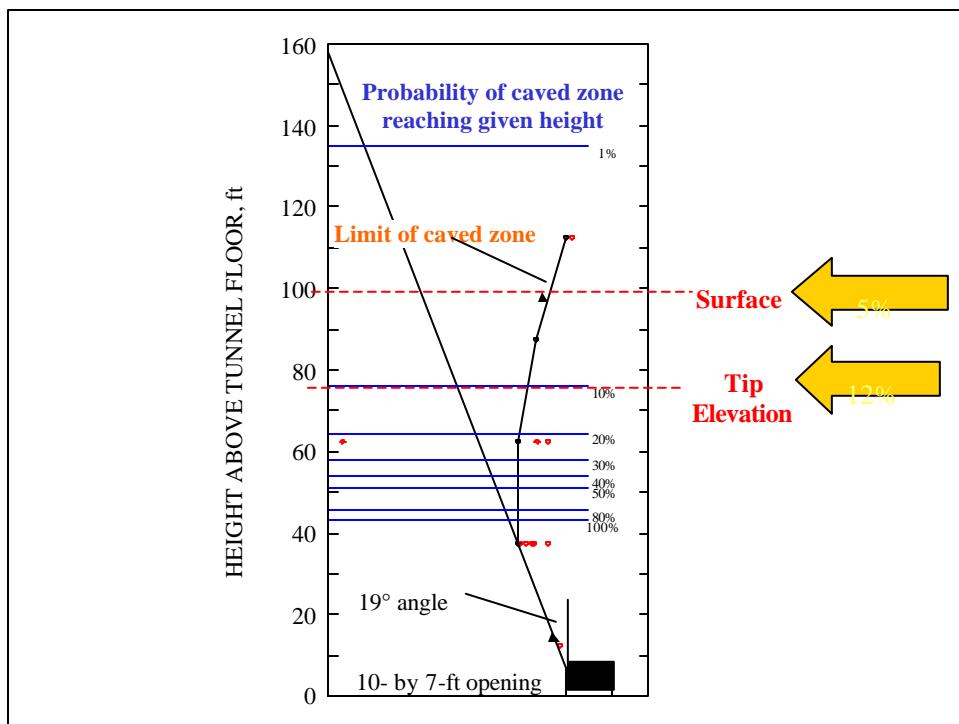
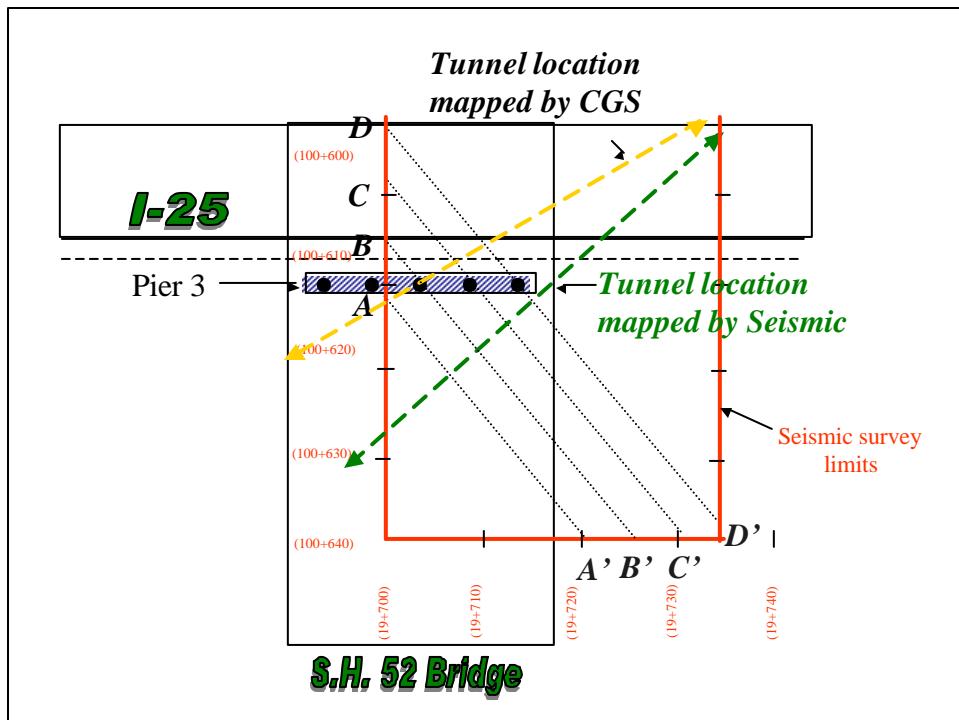


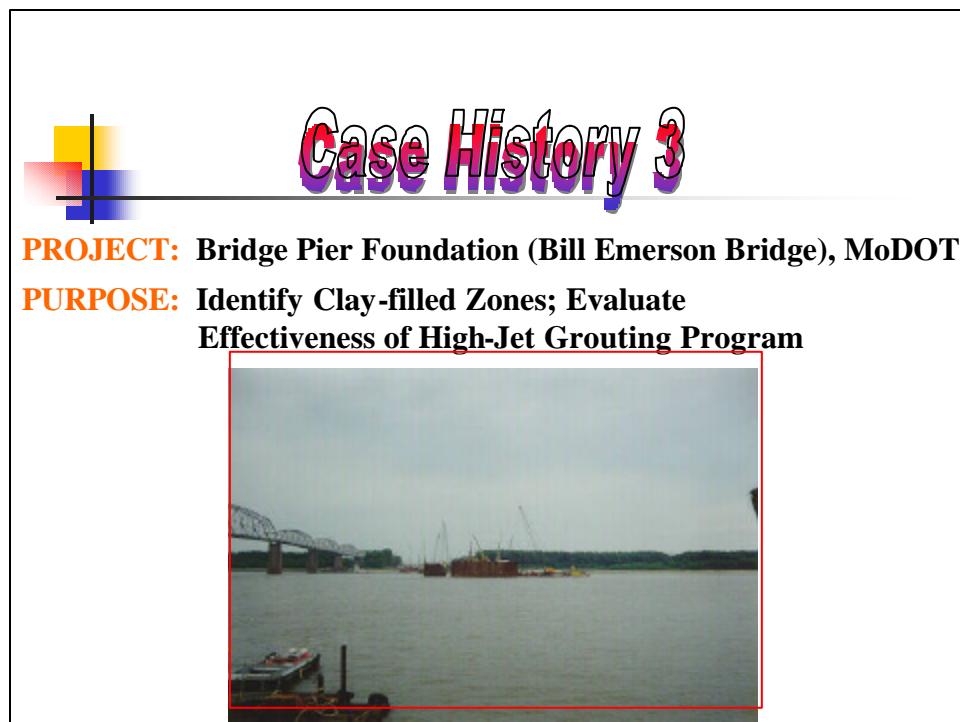
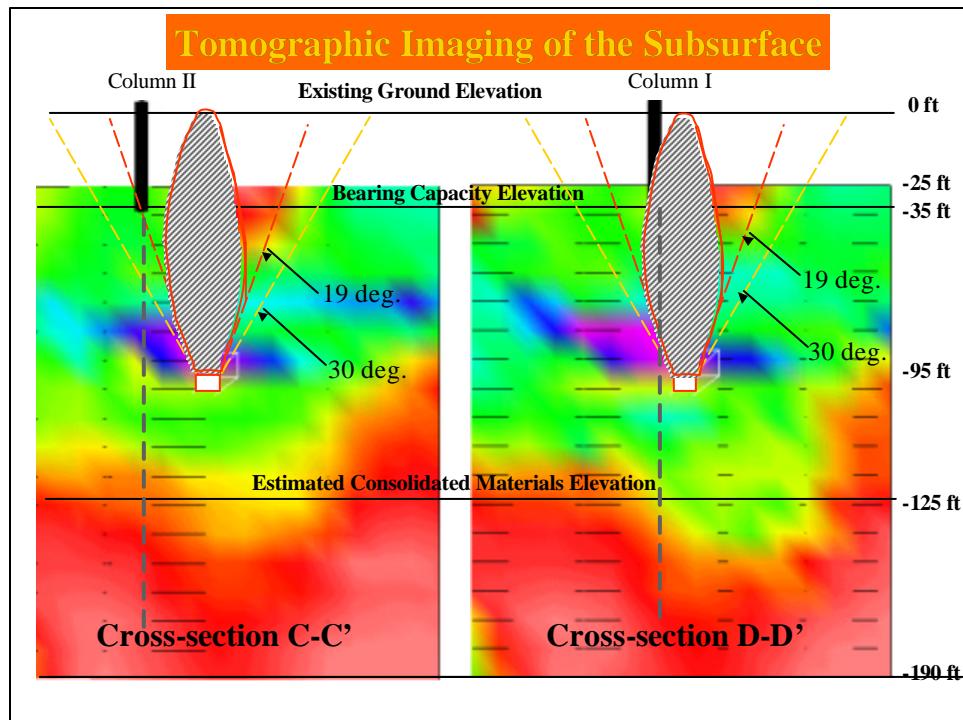
Subsurface Tomographic Imaging



Tomographic Imaging of the Subsurface at SH 52 and I-25



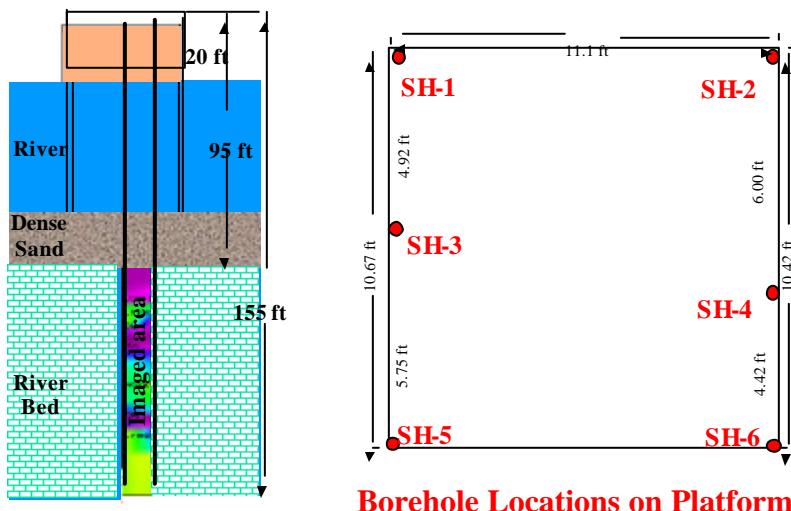




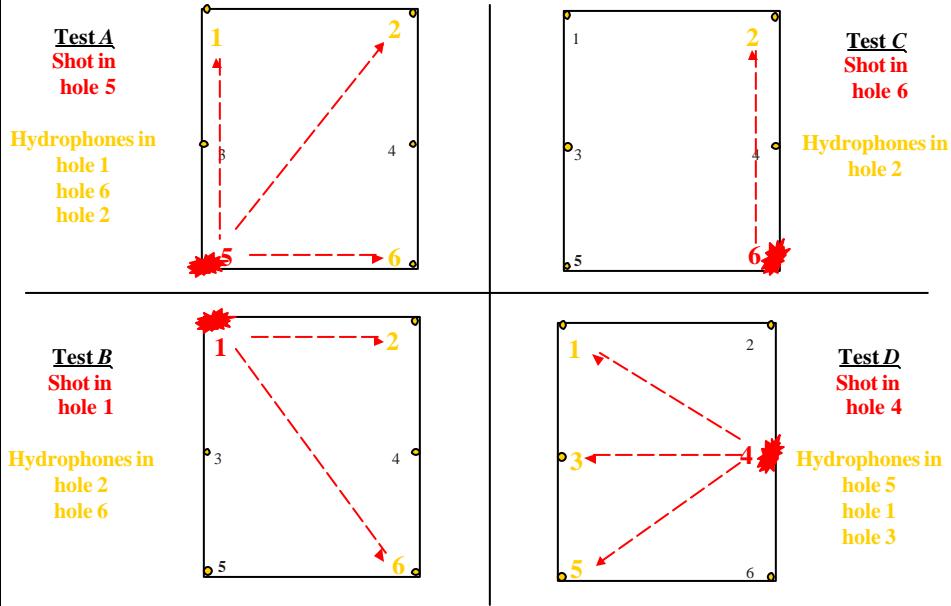
Seismic System



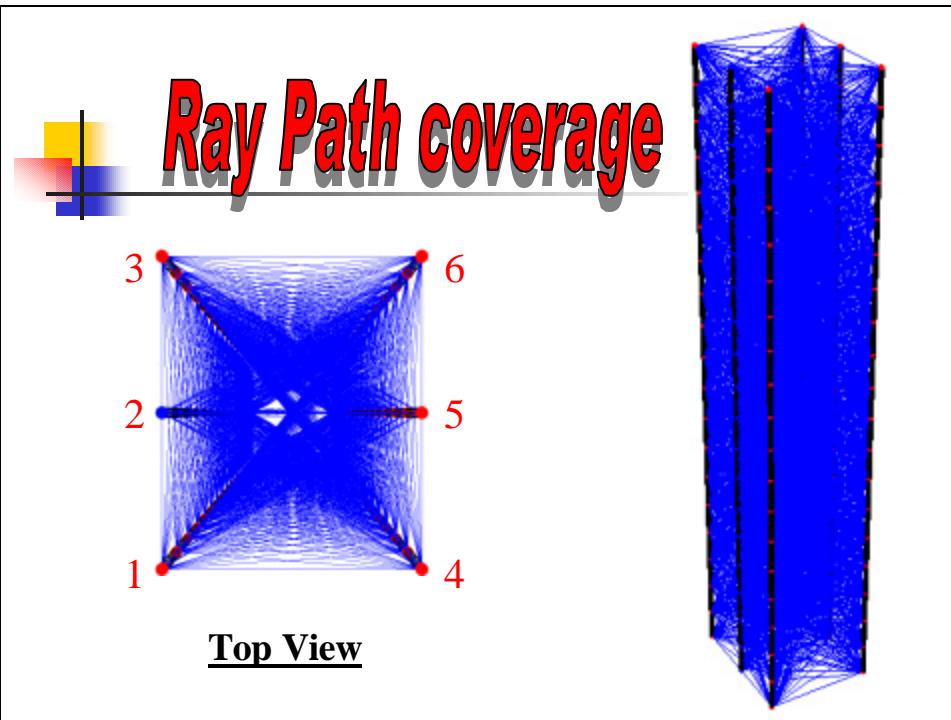
Seismic Test Procedure

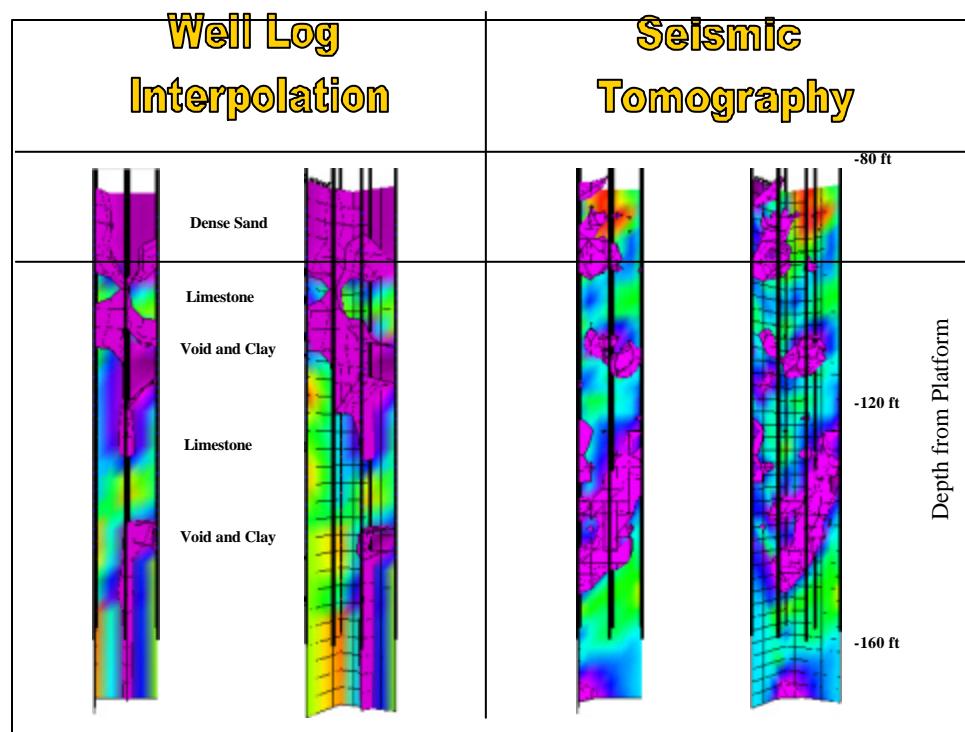
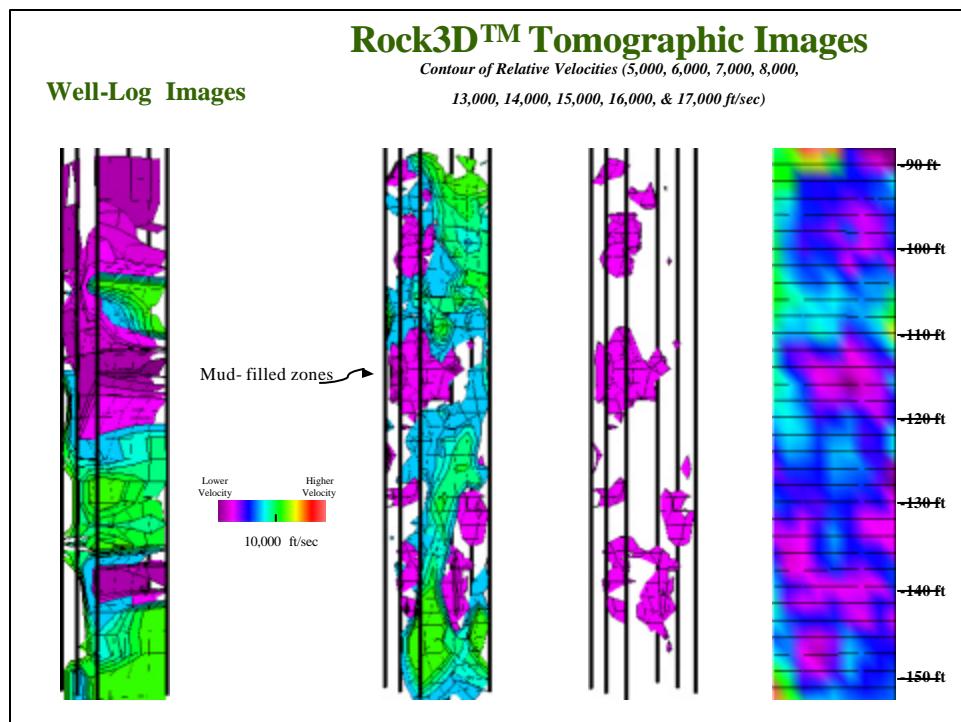


Seismic Test Procedure

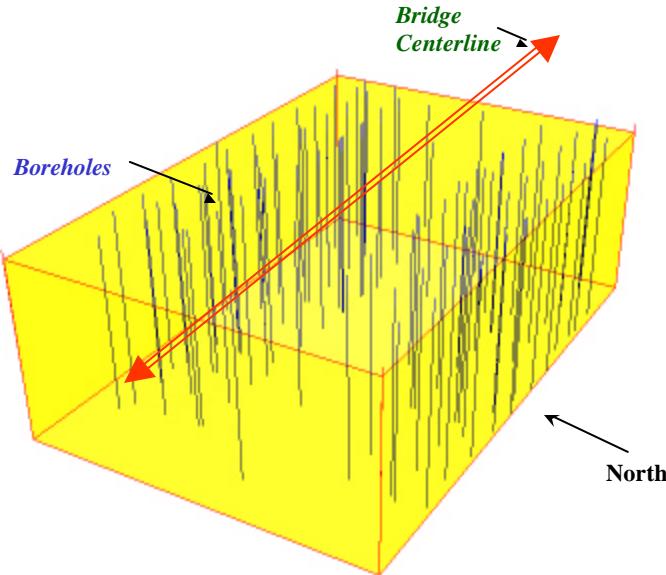


Ray Path coverage





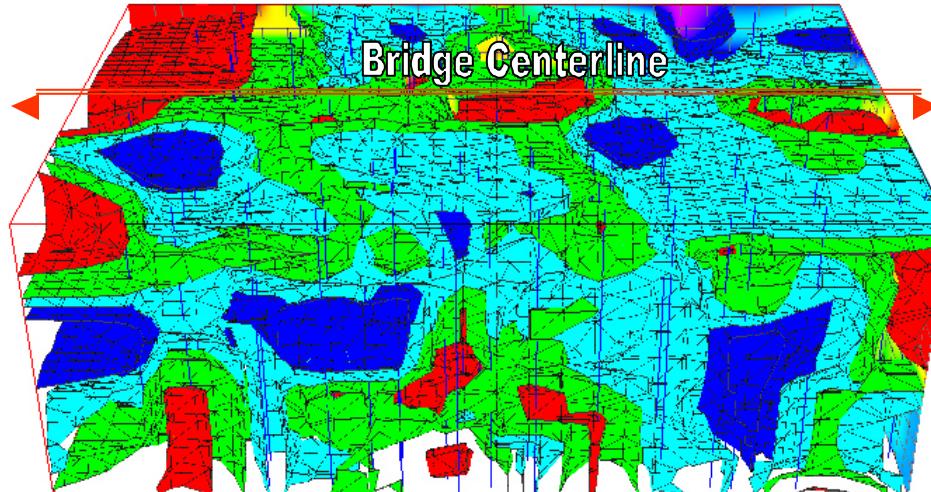
Well-Log Geological Image



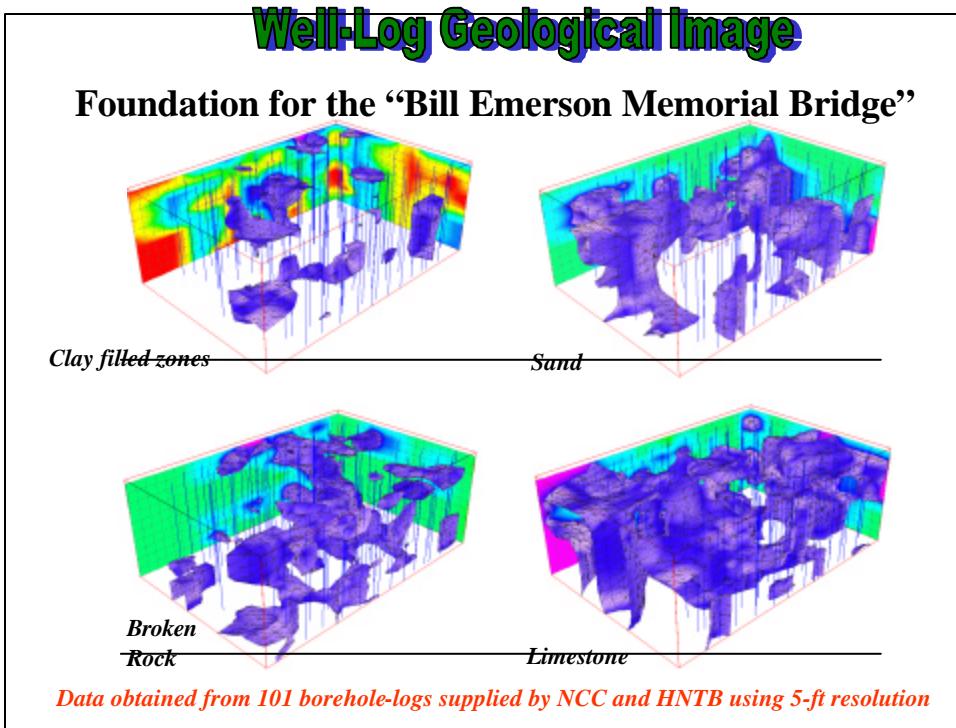
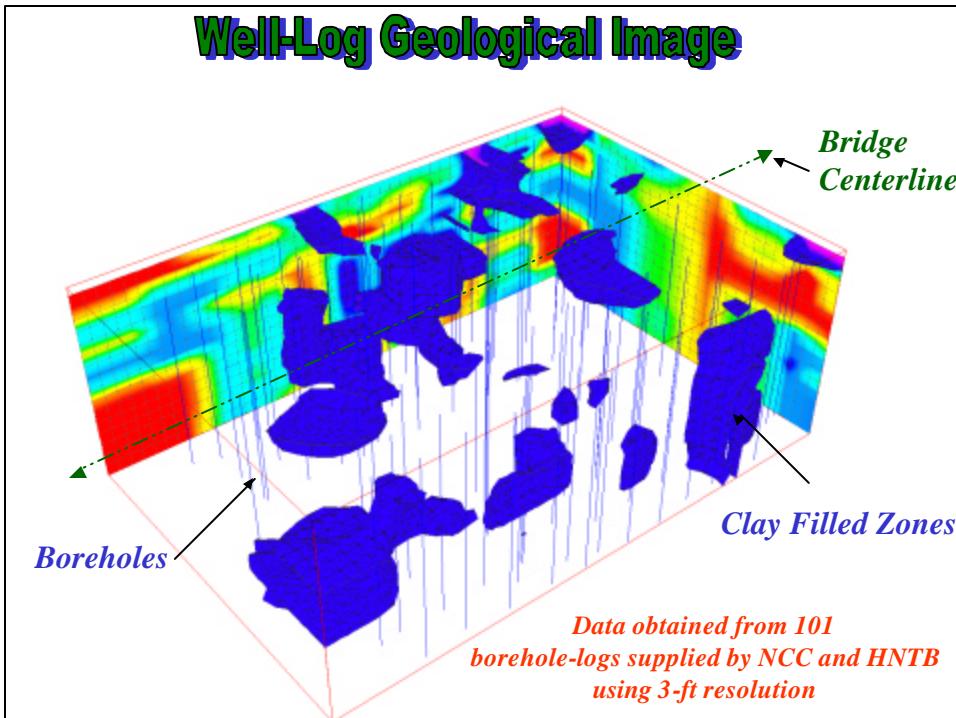
Data obtained from 101 borehole-logs supplied by NCC and HNTB

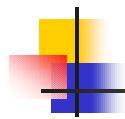
Boreholes Used	
P3-1	SE5-7
P3-1A	SE5-9
P3-2	NE5-3
P3-3	NE5-3R
P3-4	NE5-5
P3-5	NE5-7
P3-6	NE5-9
P3-7	SW1-1
P3-8	SW1-3
P3-9	SW1-5
P3-10	SW1-9
P3-11	NW1-1
P3-12	NW1-3
P3-13	NW1-5
P3-14	NW1-7
P3-15	NW1-9
P3-16	SW3-1
P3-17	SW3-3
P3-18	SW3-3R
P3-19	SW3-5
P3-20	SW3-5R
P3-21	SW3-7
P3-22	SW3-9
B-5	NW3-1
B-6	NW3-3
SE1-3	NW3-3R
SE1-5	NW3-3
SE1-7	NW3-5R
SE1-9	NW3-7
NE1-1	NW3-9
NE1-3	SW5-1
NE1-5	SW5-3
NE1-7	SW5-3R
NE1-9	SW5-5
SE3-3	SW5-5R
SE3-5	SW5-7
SE3-7	SW5-9
SE3-9	NW5-1
NE3-3	NW5-3
NE3-3R	NW5-5
NE3-5	NW5-7
NE3-7	NW5-9
NE3-9	NW5-9R
NE4-1	SE1-1
SE5-1	NE2-2
SE5-1R	NE5-1
SE5-3	NW5-4
SE5-5	SW2-11
	SW4-11

Well-Log Geological Image



Data obtained from 101 borehole-logs supplied by NCC and HNTB using 5-ft resolution





CONCLUSIONS

3-D TOMOGRAPHIC IMAGING IS FIELD PROVEN WITH THE FOLLOWING ADVANTAGES:

- Tomography Has Multiple Applications
- The Methods Are Quick, Simple, & Cost Effective
- 3-D Images Effective in Public Presentations
- Project Risk Is Reduced for Owner & Contractors