Natural Bridge: Integrated Non-Destructive Analysis

VDOT Virginia Department of Transportation

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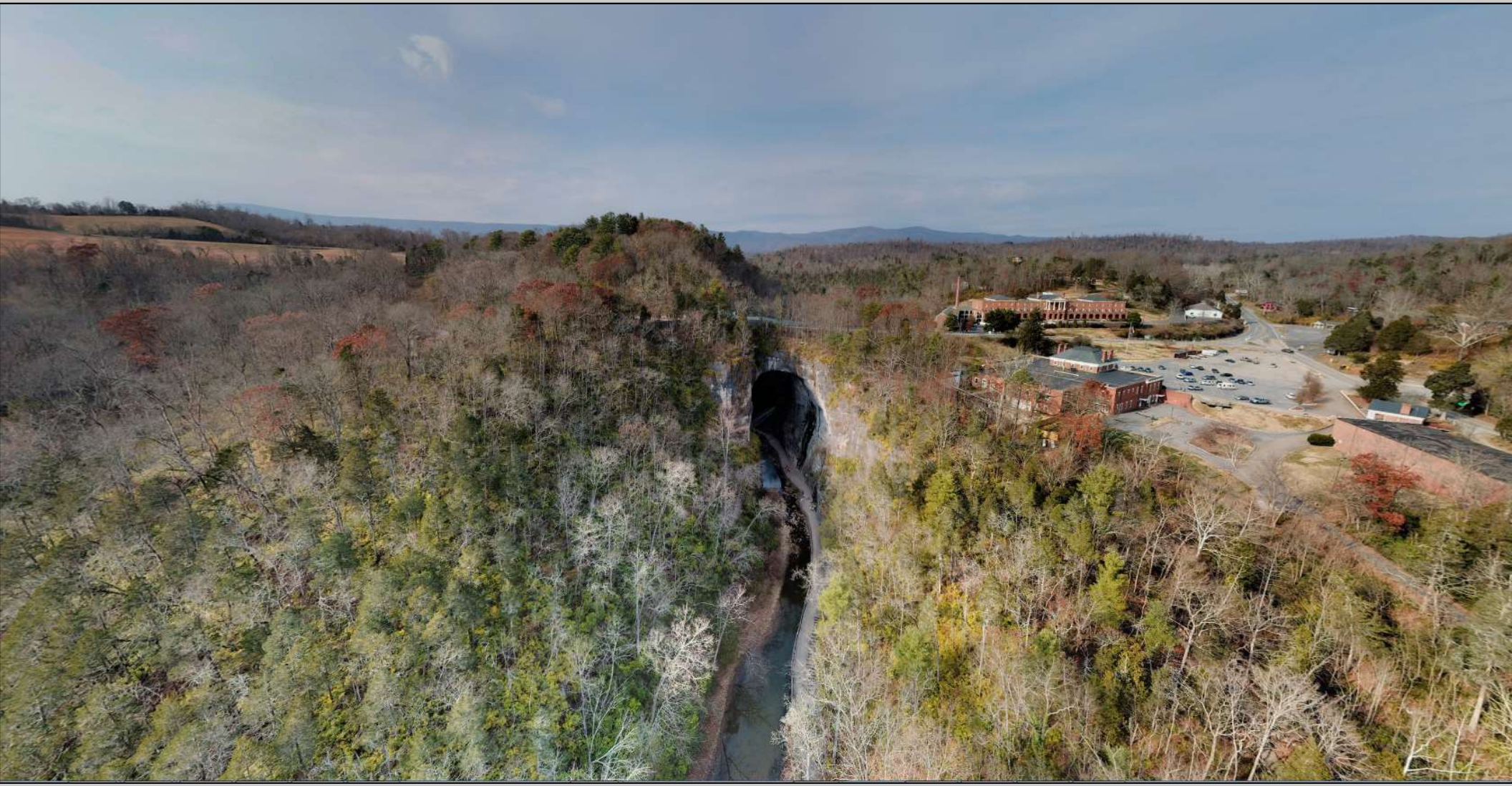
S. Watts, Radford, UAV Imagery



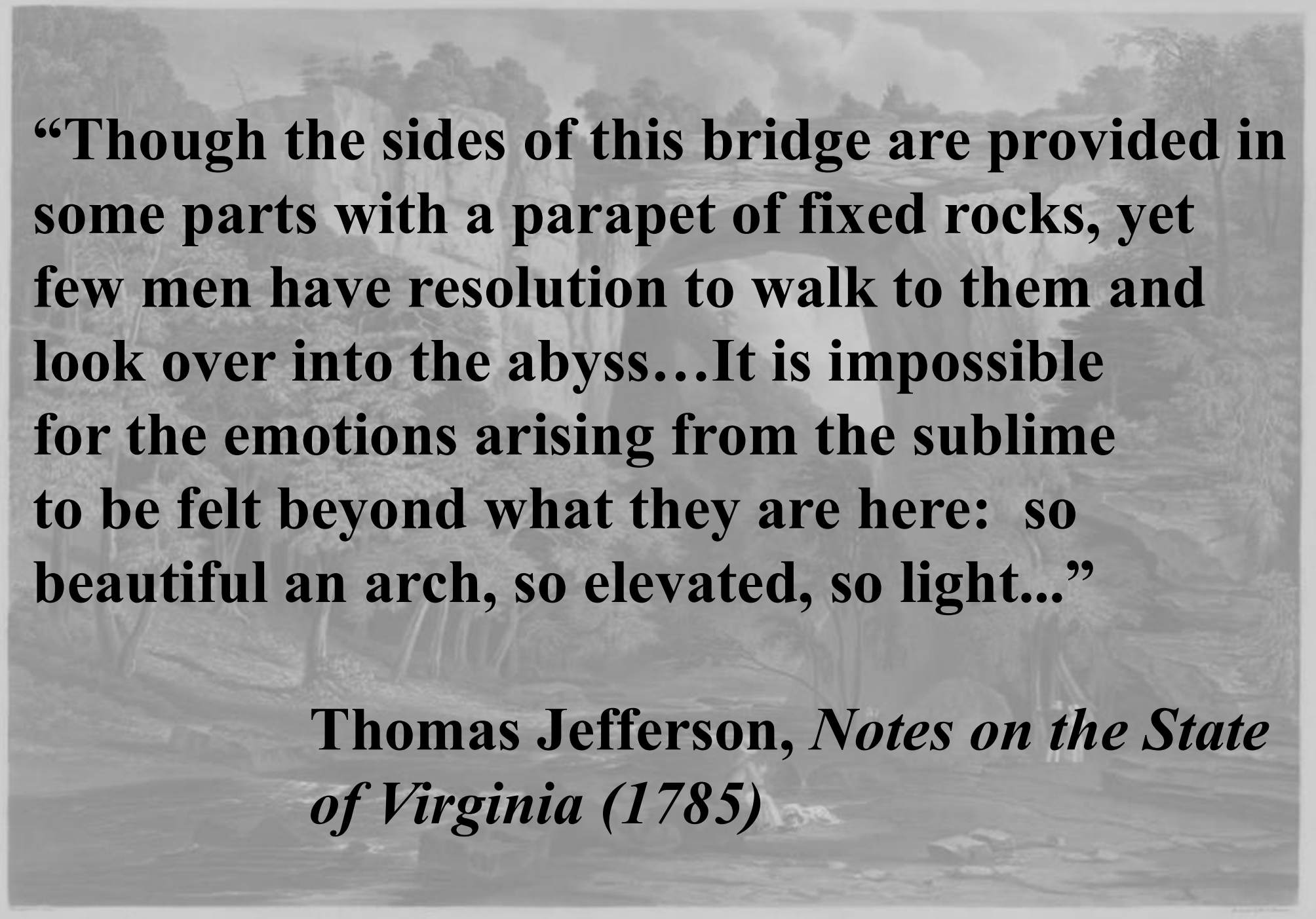
S. Watts, Radford, UAV Imagery

National Gallery of Art

William James Bennett, 1835

“Though the sides of this bridge are provided in some parts with a parapet of fixed rocks, yet few men have resolution to walk to them and look over into the abyss…It is impossible for the emotions arising from the sublime to be felt beyond what they are here: so beautiful an arch, so elevated, so light...”

Thomas Jefferson, *Notes on the State of Virginia (1785)*



William James Bennett, 1835
(National Gallery of Art)

Natural Bridge Investigation
Investigation Methods

- Electrical Resistivity Imaging (Radford, Draper Aden, Inc.)
- Unmanned Aerial Vehicle (UAV) Photography and Videography (Radford)
- Seismic Refraction (Radford, Draper Aden, Inc.)
- Multichannel Analysis of Surface Waves (MASW) (Radford, Draper Aden, Inc.)
- Ground Penetrating Radar (VDOT, Radford)
- Unmanned Aerial Vehicle Remote Discontinuity Mapping (Radford)
- GigaPan Imaging (Radford)
- Terrestrial LiDAR (VDOT, Radford)
- Manual Discontinuity Mapping (VDOT, Radford)
- Vibration Monitoring (Radford)

Natural Bridge Investigation

- Voids at both northern and southern end of the arch
- Well-developed joint system
- Blocks/masses susceptible to natural and human-induce weathering
- Water migration throughout the mass
- Traffic vibrations detected in the rock mass
- Areas susceptible to rockfall

Natural Bridge Investigation

- Voids at both northern and southern end of the arch

(Resistivity, GPR)

- Well-developed joint system

(UAV, Manual Mapping, LiDAR, Point-Cloud Modeling)

- Blocks/masses susceptible to natural and human-induce weathering

(UAV, Manual Mapping, LiDAR, GigaPan, Point-Cloud Modeling)

- Water migration throughout the mass

(GigaPan)

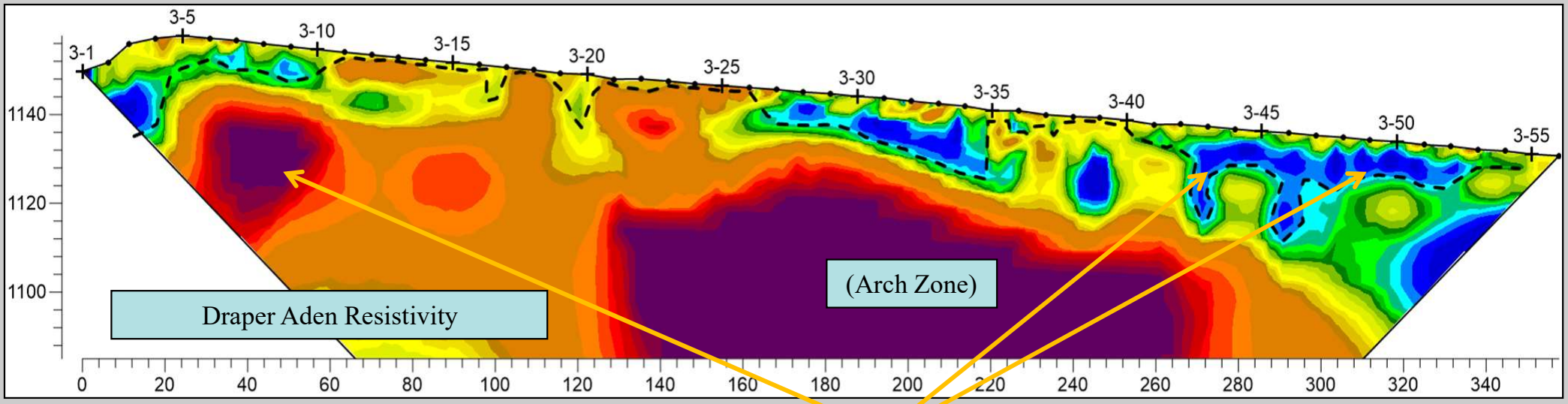
- Traffic vibrations detected in the rock mass

(Vibration Data)

- Areas susceptible to rockfall

(UAV, Physical Mapping, GigaPan, Point-Cloud Modeling)

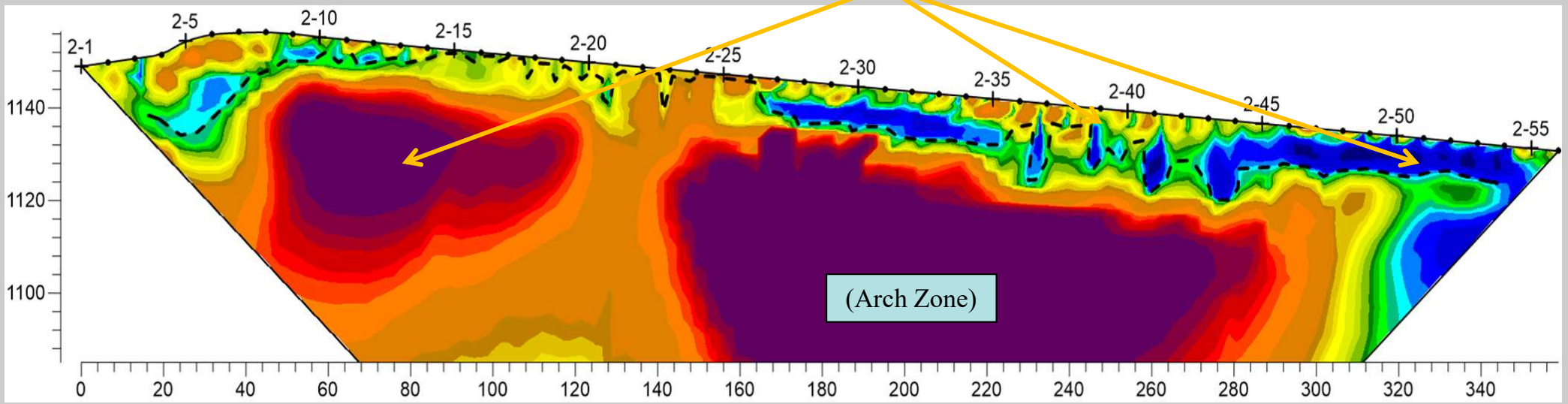
Natural Bridge Investigation
Voids



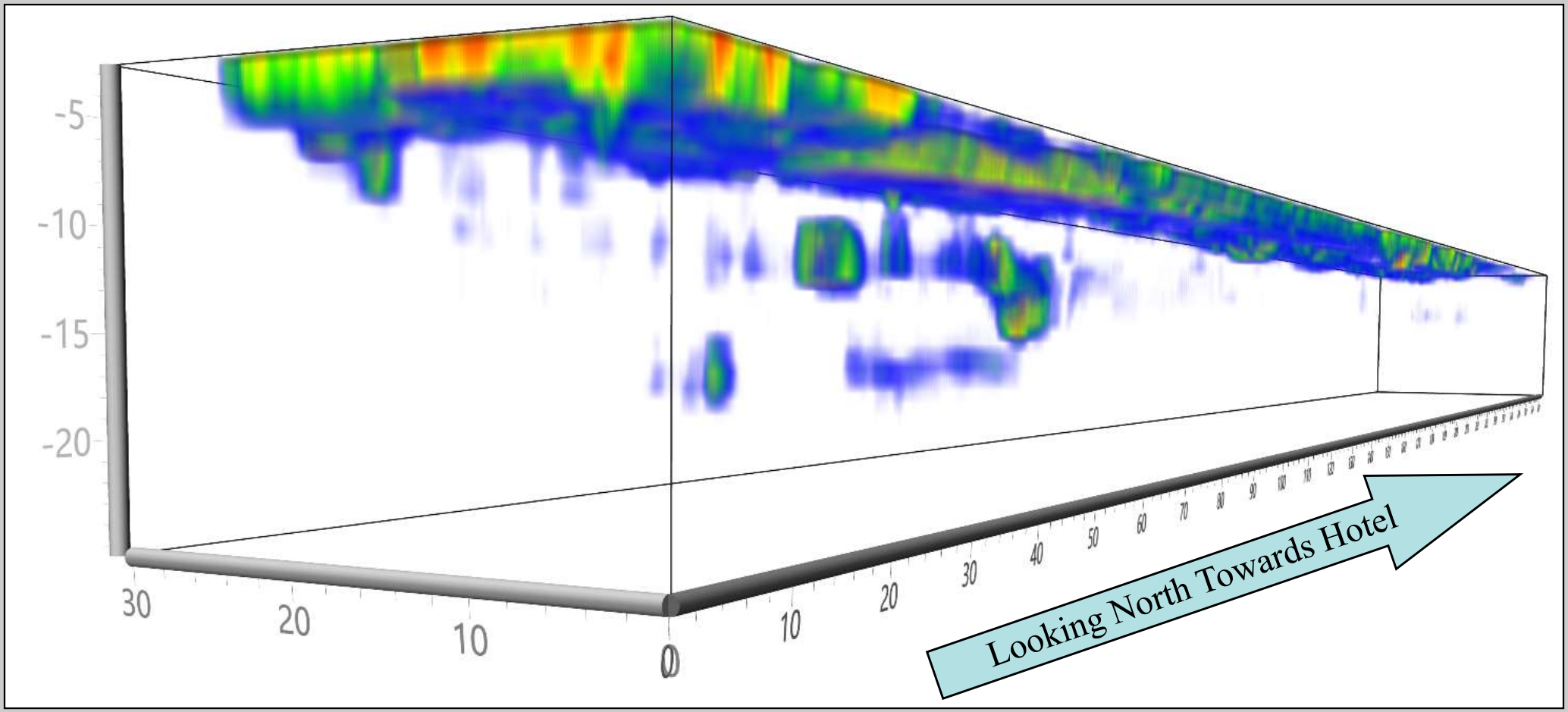
South

Possible Voids

North

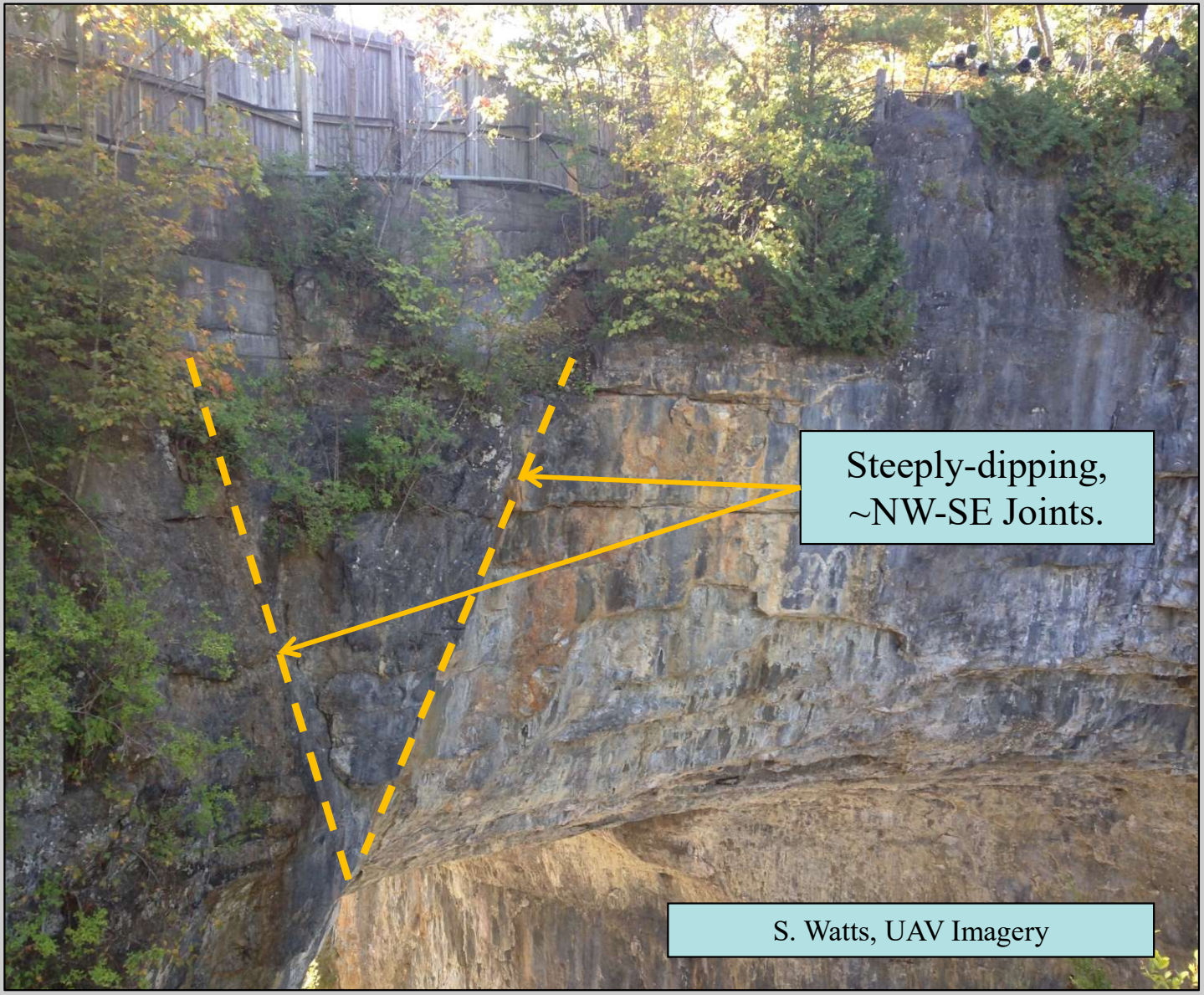


Natural Bridge Investigation
Voids

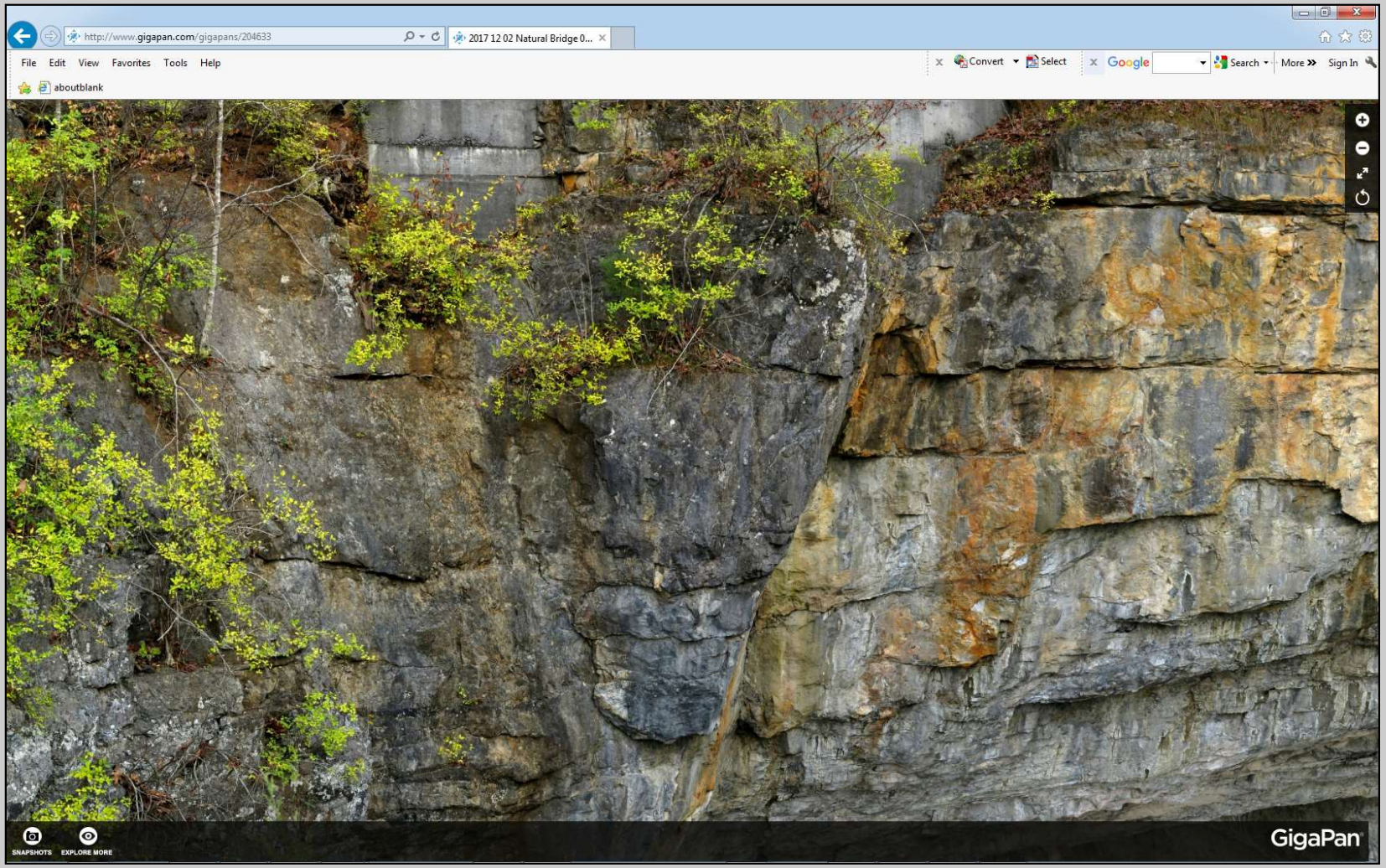


Draper Aden GPR, 3-D Interpretation

Natural Bridge Investigation
Joints

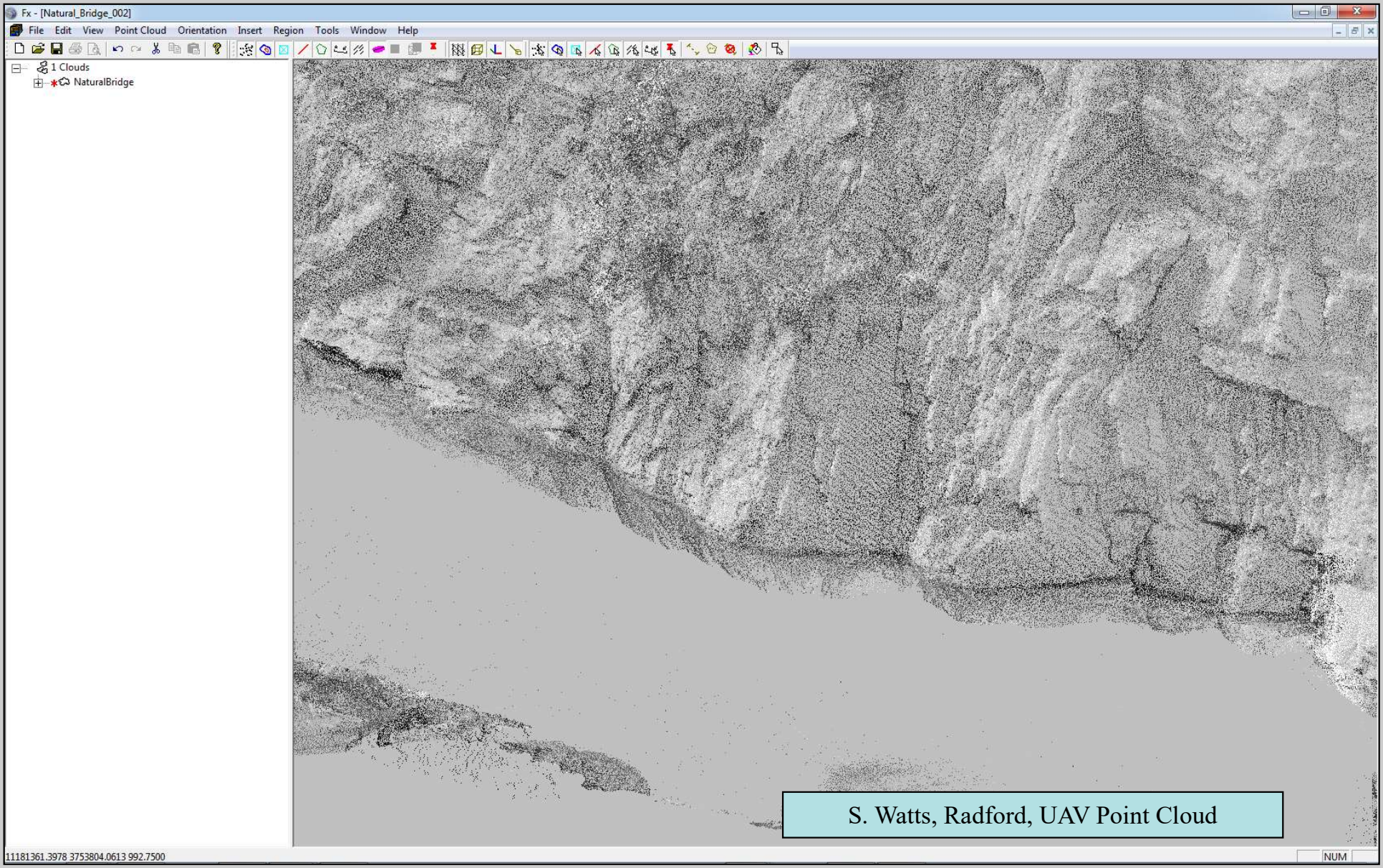


Natural Bridge Investigation
Weak Planes/Masses

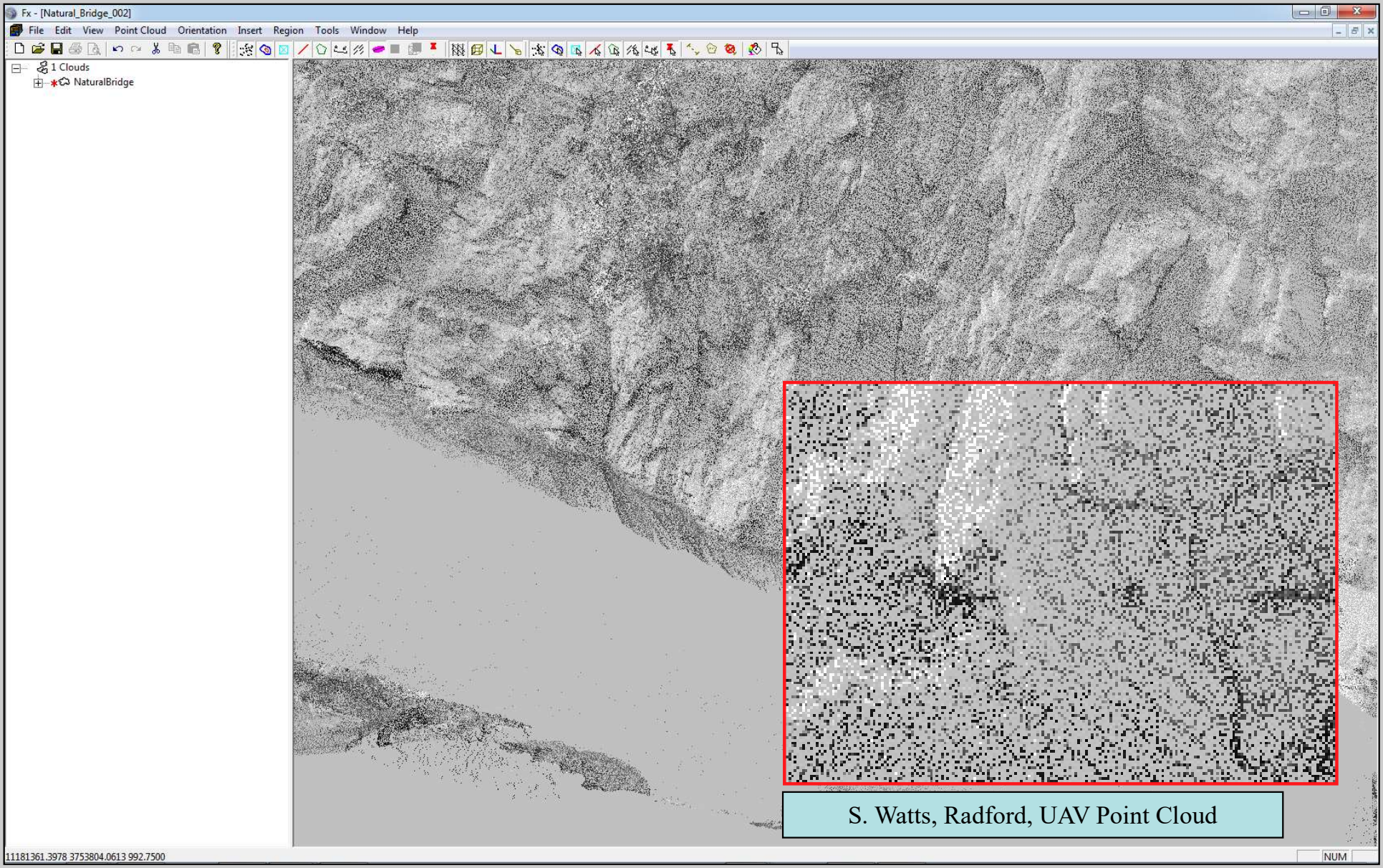


Radford, GigaPan

Natural Bridge Investigation
Weak Planes/Masses

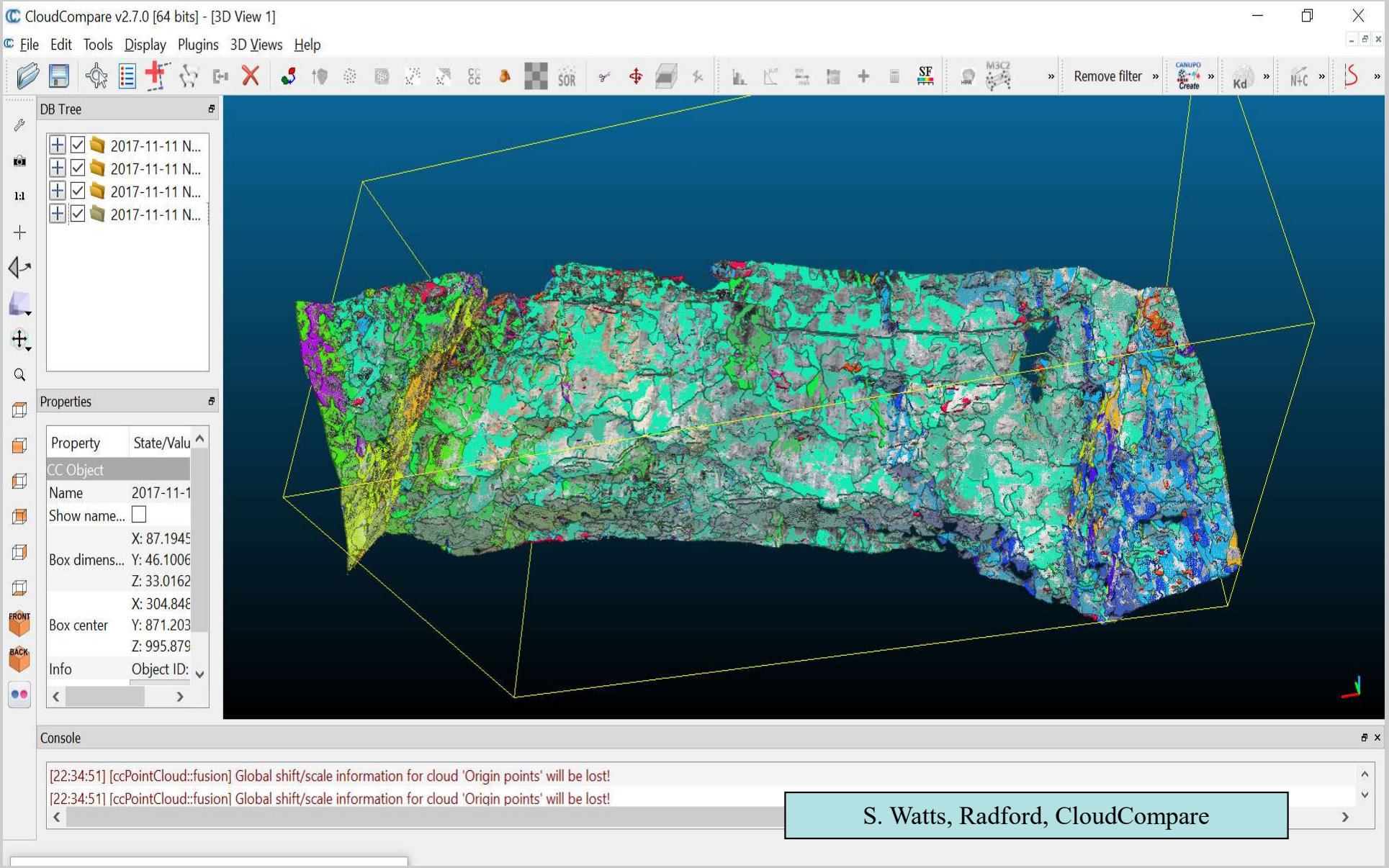


Natural Bridge Investigation
Weak Planes/Masses



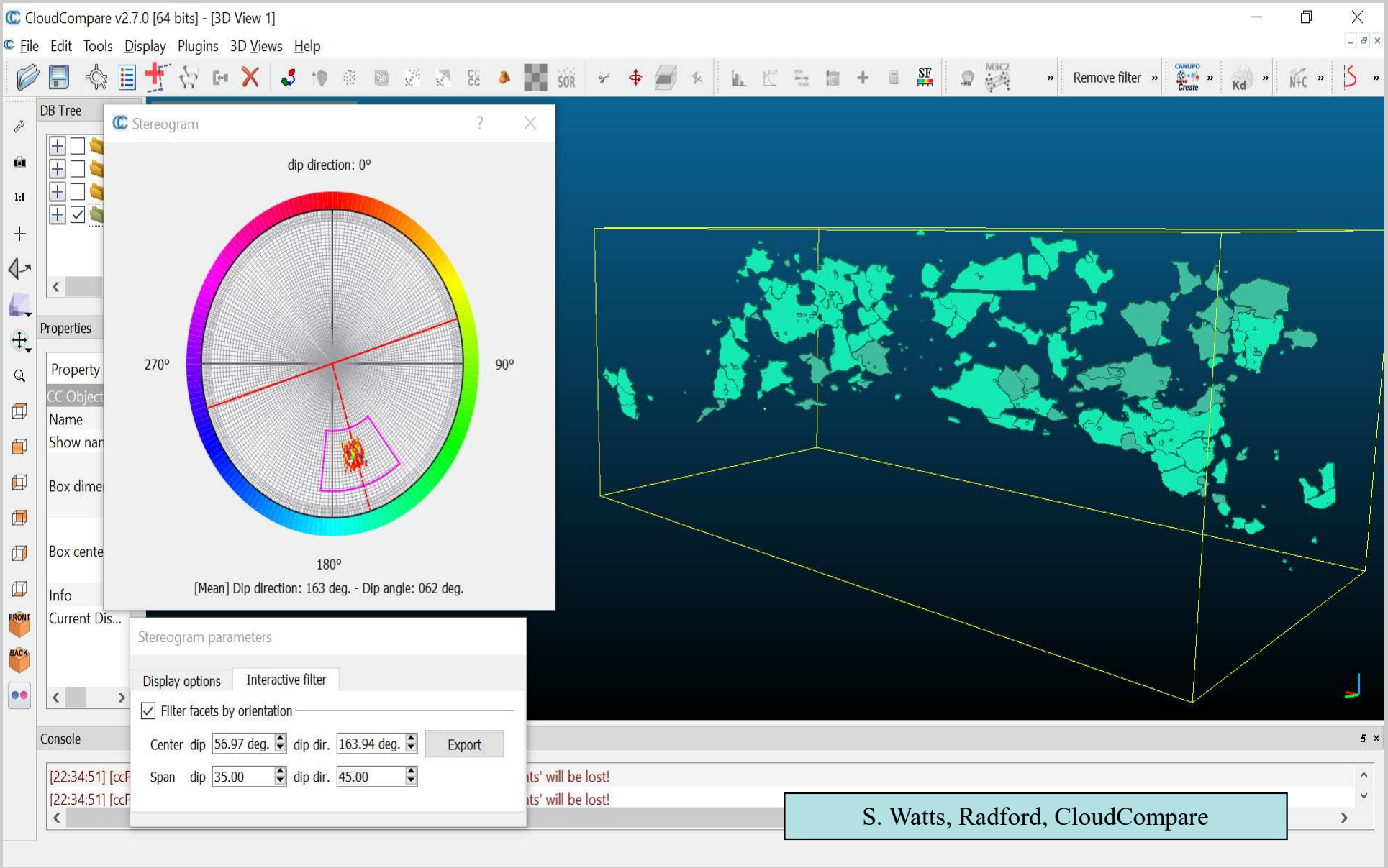
S. Watts, Radford, UAV Point Cloud

Natural Bridge Investigation
Weak Planes/Masses



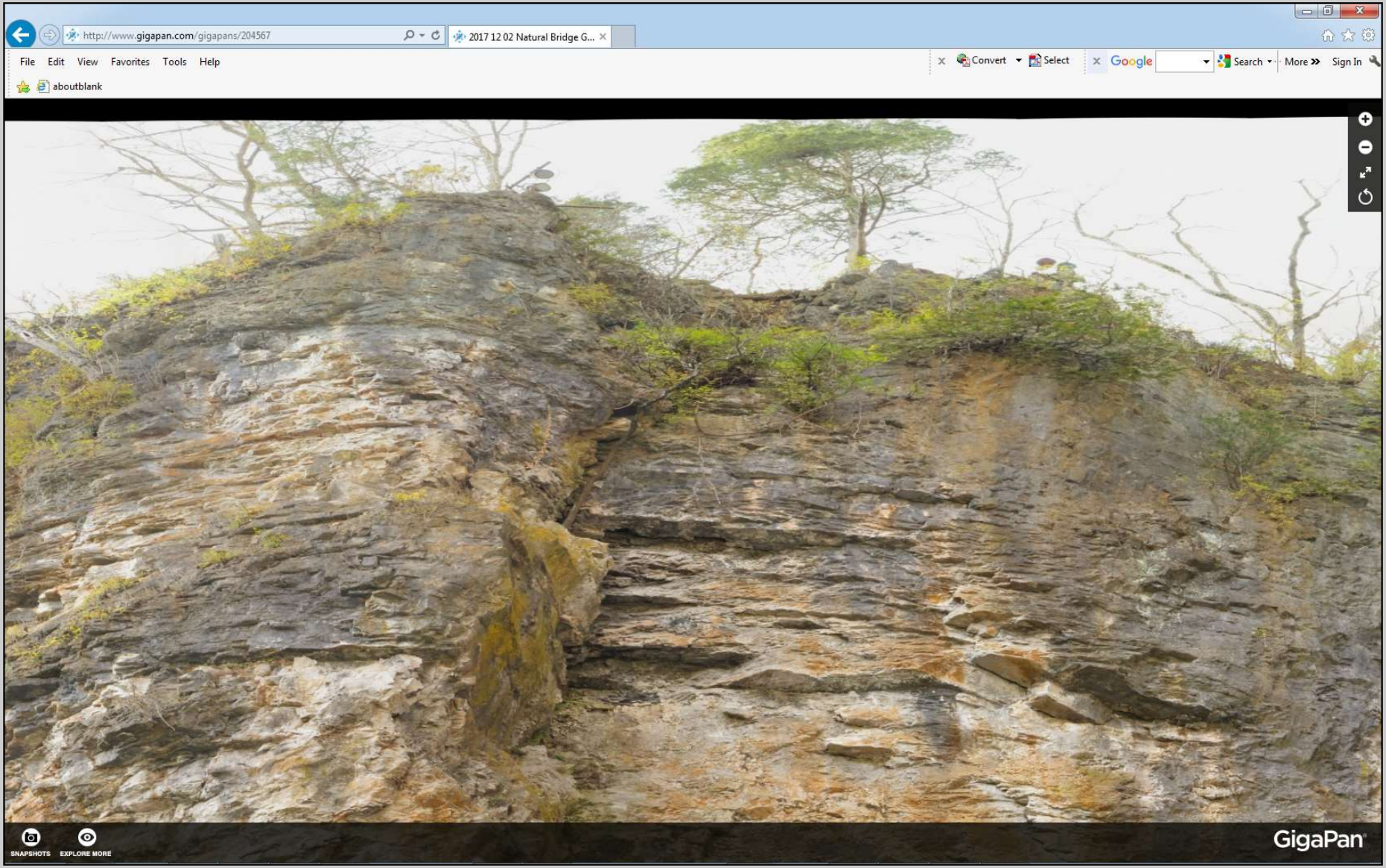
S. Watts, Radford, CloudCompare

Natural Bridge Investigation
Kinematics



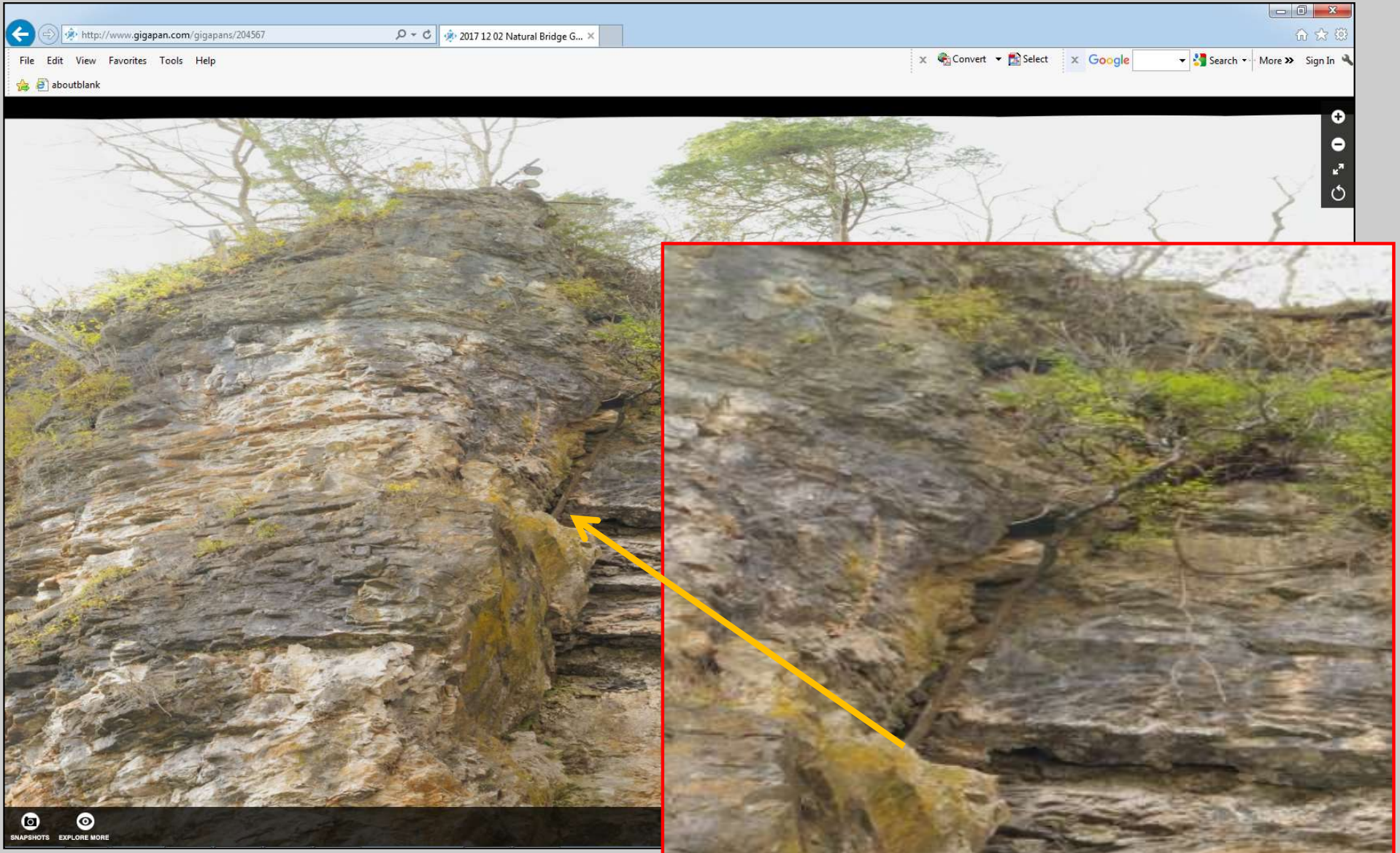
S. Watts, Radford, CloudCompare

Natural Bridge Investigation
Water Migration



Radford, GigaPan

Natural Bridge Investigation
Water Migration

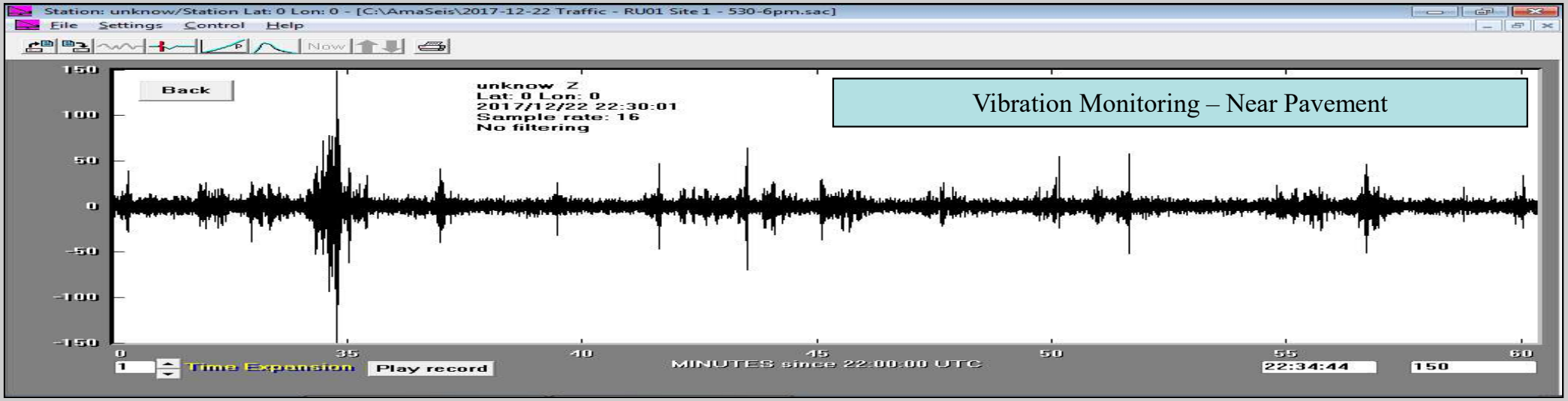


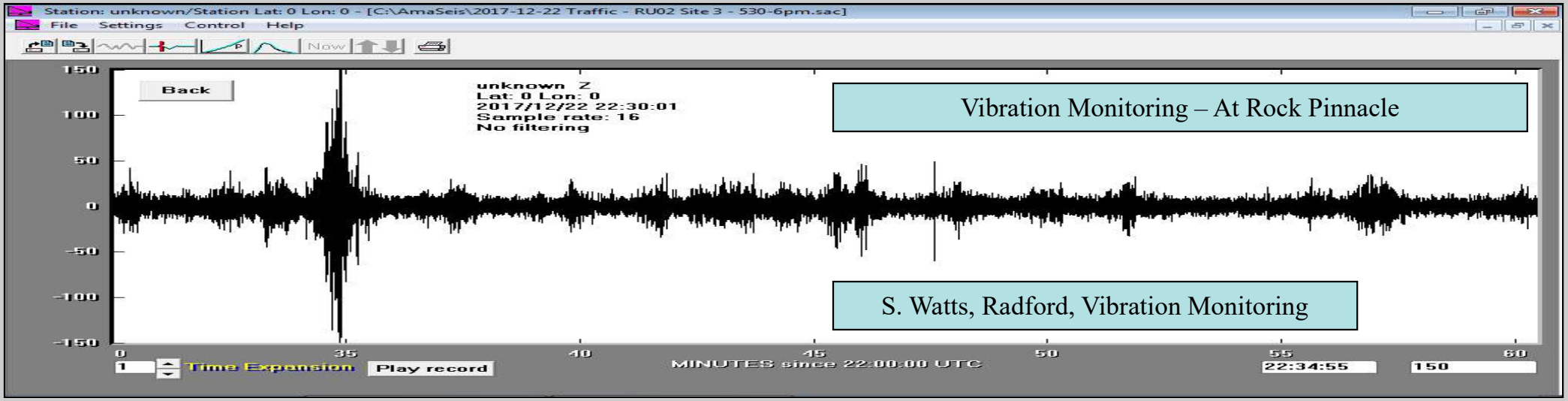
Radford, GigaPan

Natural Bridge Investigation
Rockfall

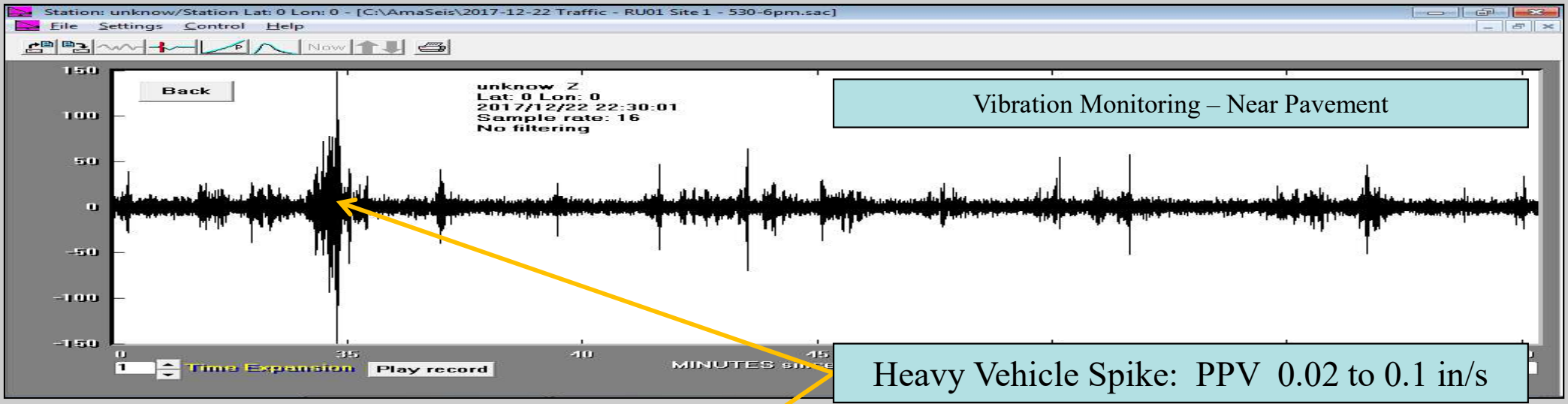
Radford GigaPan

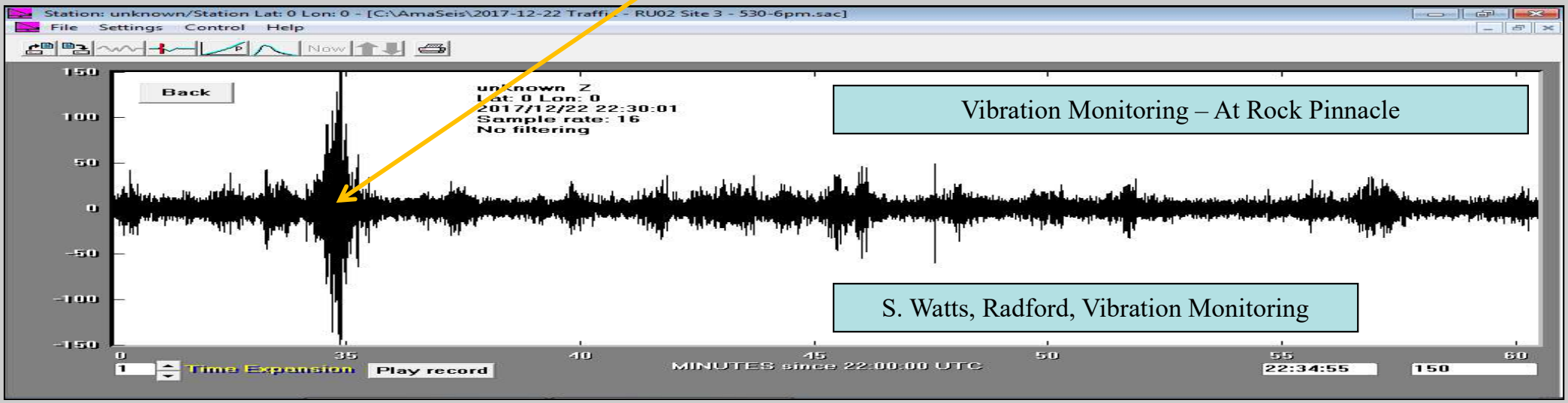
Natural Bridge Investigation
Vibration Data



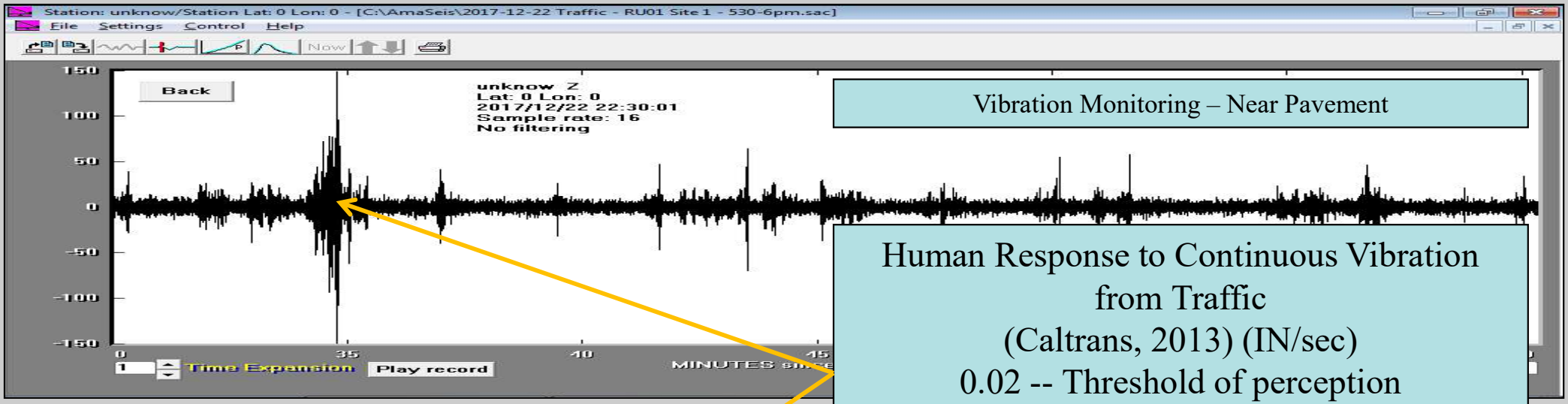


Natural Bridge Investigation
Vibration Data



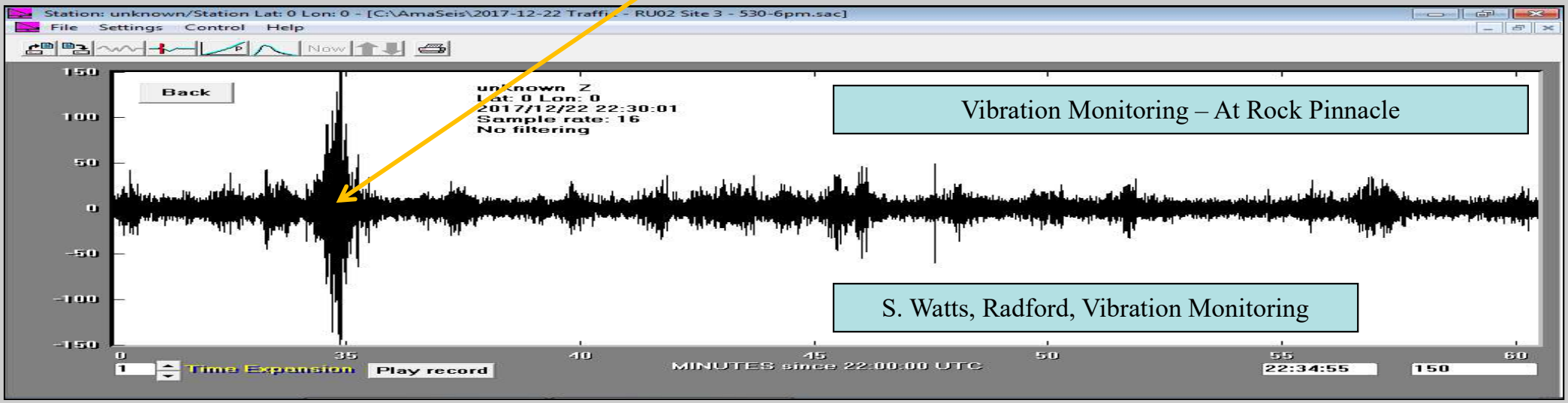


Natural Bridge Investigation
Vibration Data



Vibration Monitoring – Near Pavement

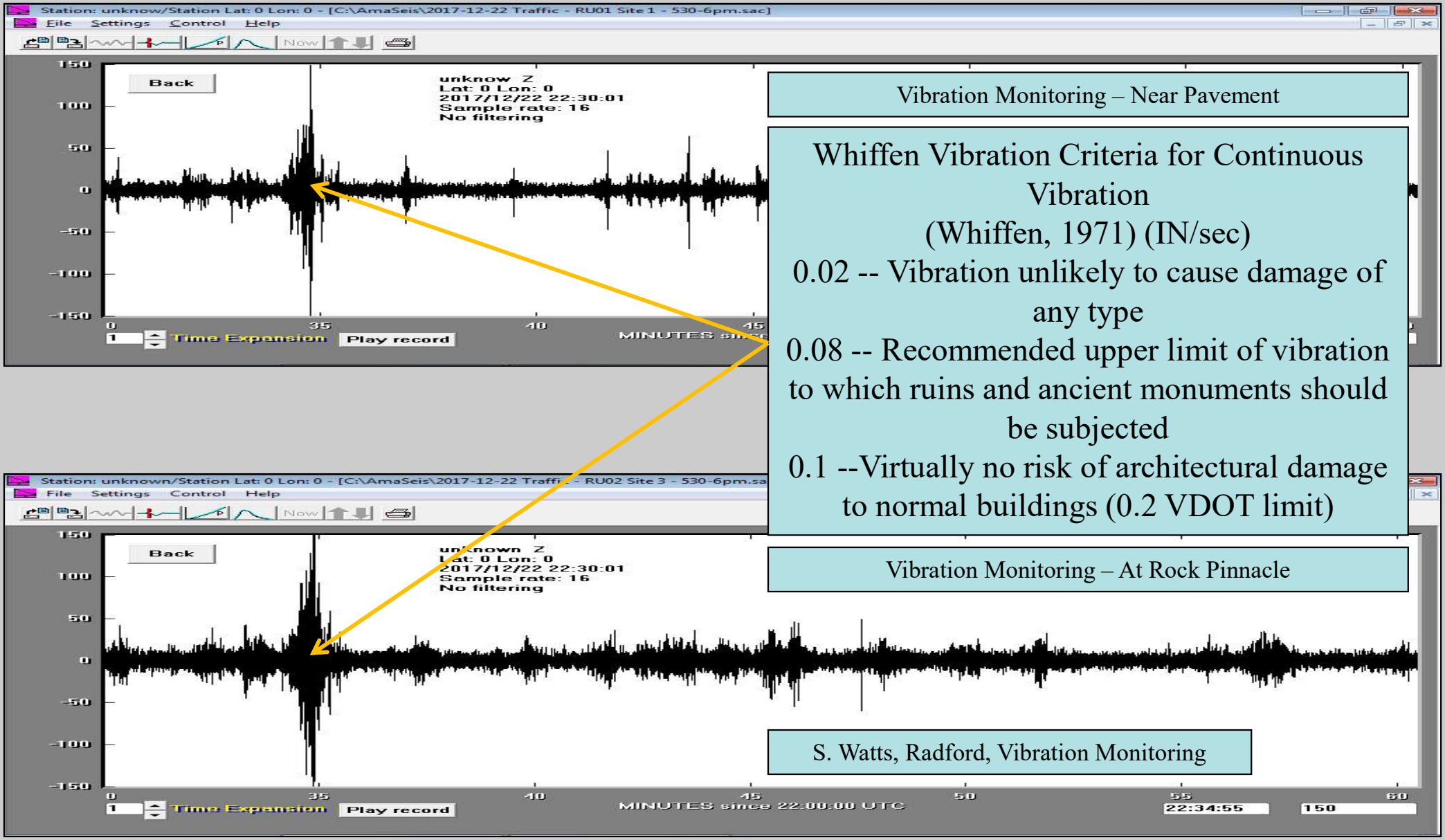
Human Response to Continuous Vibration from Traffic
(Caltrans, 2013) (IN/sec)
0.02 -- Threshold of perception
0.08 -- Readily perceptible
0.1 -- Begins to annoy



Vibration Monitoring – At Rock Pinnacle

S. Watts, Radford, Vibration Monitoring

Natural Bridge Investigation
Vibration Data



Vibration Monitoring – Near Pavement

Whiffen Vibration Criteria for Continuous Vibration
(Whiffen, 1971) (IN/sec)

0.02 -- Vibration unlikely to cause damage of any type

0.08 -- Recommended upper limit of vibration to which ruins and ancient monuments should be subjected

0.1 --Virtually no risk of architectural damage to normal buildings (0.2 VDOT limit)

Vibration Monitoring – At Rock Pinnacle

S. Watts, Radford, Vibration Monitoring

Natural Bridge Investigation Findings

- The data indicate that the arch is currently suitable for vehicle traffic.
- Natural weathering and human activities will eventually reduce the suitability for vehicle traffic – 7,500- 10,000 years
- Of greatest concern are the sensitive areas – but risk can be lowered.
- Measures to reduce water infiltration and increase drainage may improve safety.
- Building a new bridge over Natural Bridge is *not* recommended.
- Vehicular traffic should be eventually removed from Natural Bridge.

Natural Bridge Investigation
New Alignment Options