Identifying Subsurface Landslide Deposits Using Deep Refraction Microtremor, Washoe Valley, NV, USA

S43G-0424

University of CINCINNATI | University of Nevada, Reno

Daniel Sturmer[1] and John Louie[2,3]

[1]Department of Geosciences, University of Cincinnati - Daniel.Sturmer@uc.edu; [2]Nevada Seismological Laboratory, [3]Terēan - jlouie@terean.com

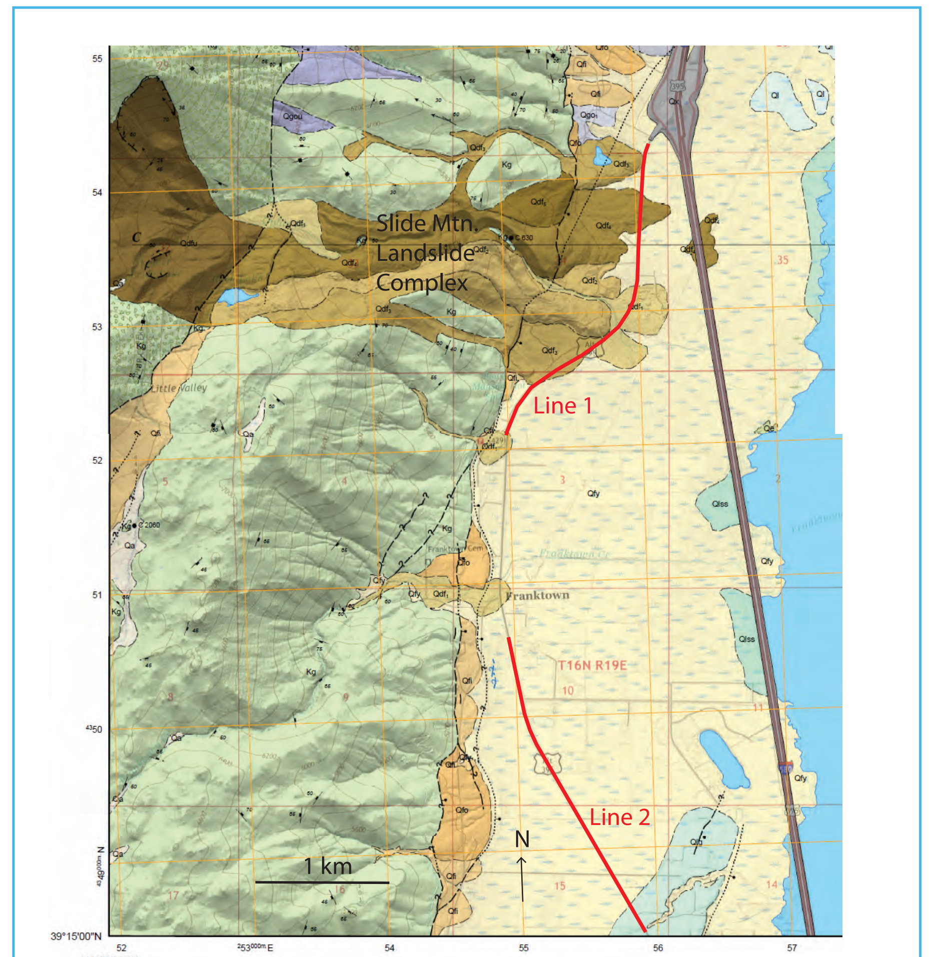
Terēan™

ABSTRACT

The presence and extent of landslide deposits are key bases for understanding long-term landslide occurrence. However, in tectonically active basins landslide deposits frequently become buried, resulting in an incomplete record. Confirming the presence of buried landslide deposits generally requires expensive techniques like drilling boreholes. In this study we used deep refraction microtremor surveys to test whether buried landslide deposits show systematic variability in shear- wave velocity relative to an area without landslide deposits.

The study involved collecting two microtremor arrays in western Washoe Valley, NV. The Carson Range bounds the west side of the valley, bounded by the Sierra Nevada Frontal Fault system. The Slide Mountain landslide complex, which contains a stack of at least 10 Quaternary landslide deposits, sits in the northwestern part of Washoe Valley. The landslides were sourced from Slide Mountain granitic material, flowing down Ophir Creek and exiting onto the valley floor. No other current or past landslide complex is apparent along the western range front.

Two passive-source linear arrays were collected on the western side of Washoe Valley. One array (Slide) was placed across the toe of the Slide Mountain landslide complex near Ophir Creek. The second array (Franktown) was ~2 km south in an area with no apparent past landslide deposition. Each line consisted of 100 Fairfield 3-component seismic nodes with ~22 m spacing for total line lengths of 2.2 km. The nodes collected data for ~4 hours for each array and data were analyzed using VsSurf ReMi 2dS™ from Terēan. The Slide array shows abundant heterogeneity in the upper ~200 m (including velocity inversions) that are not present in the Franktown array. We interpret the heterogeneity in the Slide array to represent landslide deposits, with velocity heterogeneity resulting from the generally larger but variable clast size in the landslide deposits. The more homogeneous Franktown array is interpreted to not record any landslide deposits. These results suggest that landslide deposits can be identified in the subsurface using the refraction microtremor technique.



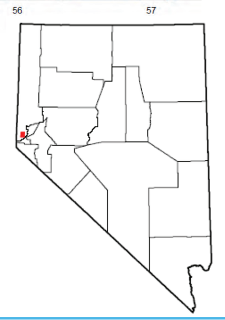


Figure 1. Geologic map showing location of two seismic arrays (Lines 1 and 2) and the Slide Mountain landslide complex. Map from Carlson et al. (2019). Map in lower right shows approximate location of map within Nevada.

Data for this survey are available at Sturmer, D. and Louie, J., 2021, Determination of the deep shear wave velocity structure of Hidden Valley and western Washoe Valley, NV [Data set]: International Federation of Digital Seismograph Networks, https://doi.org/10.7914/SN/Z8_2021

INTRODUCTION

- The goal of this project is to test whether buried landslide deposits can be identified using the passive-source deep refraction microtremor technique
- Refraction microtremor generates subsurface shear wave velocity profiles
- We hypothesize that areas with buried landslide deposits will generally have higher shear wave velocities and more lateral variability than areas without buried landslide deposits
- To test this hypothesis, we collected data along two ~2.2 km-long arrays in Washoe Valley, NV during 2 days in June 2021
- Line1 was across the toe of the Slide Mountain landslide complex, whereas Line 2 was farther south, in an area with no known landslide events (Figs. 1 and 2)

METHODS

- Seismic data were collected using 100 Fairfield 3-component seismic nodes borrowed from the EarthScope PASSCAL Instrument Center (EPIC).
- Nodes were deployed over two days (one line per day), with data collected for a minimum of 4 hours (Fig. 2).
- Analyses were done using the VsSurf ReMi 2dS™ software from Terēan.
- Data were gathered into 30 minute records, which were combined for refraction microtremor processing and modeling.
- Velocity profiles were modeled for each whole line, and for 9, 20-node subarrays-for each line (Figs. 3 and 4).
- The subarrays were then stitched together to form 2D velocity profiles.
- The 2D velocity profiles for each line used picks from the subarrays as well as deep picks from the full array (Fig. 5).

Figure 2. Field photos from deployment. A. Fairfield seismic nodes. B. Node deployment. C. Field crew measuring Line 1. D. Field crew measuring line 2. E. Field crew for Line 1, including faculty and students from University of Cincinnati and University of Nevada, Reno. F. Photo of Slide Mountain (background) and landslide deposits (foreground). All photos from D. Sturmer except A (from PASSCAL website).

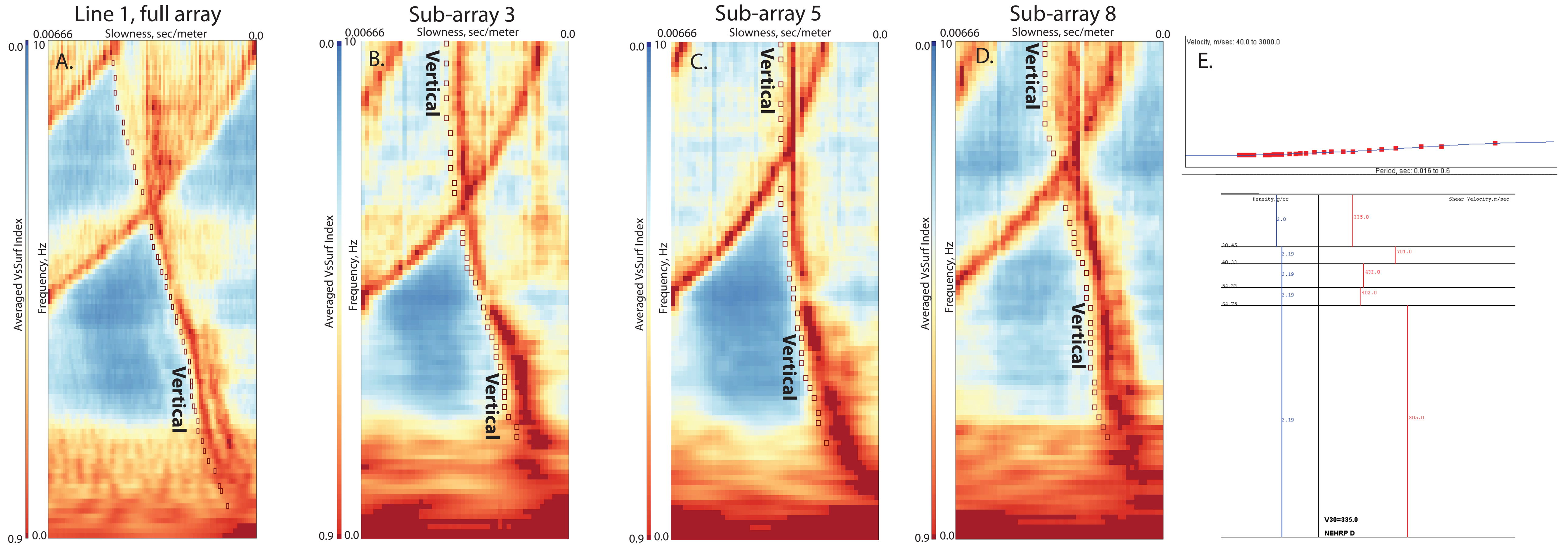


Figure 3. Picks (boxes) for Line 1 on VsSurf ReMi™ software dispersion images in the frequency-slowness domain for frequencies of 0-10 Hz. A. Full data set. B. Sub-array 3, nodes 20-39 (midpoint at 675 m). C. Sub-array 5, nodes 40-59 (midpoint at 1125 m). D. Sub-array 8 (midpoint at 1800 m). E. Example model fit of dispersion curve (top) and resulting velocity model for the upper 200 m of the subsurface (bottom). Model is for Sub-array 5. Note that velocity inversions were present in line 1 but not in line 2.
The Line 1 dispersion results show many veritcal runs of dispersion, where phase velocity is constant over a range of frequencies. Vertical runs can suggest velocity inversions.

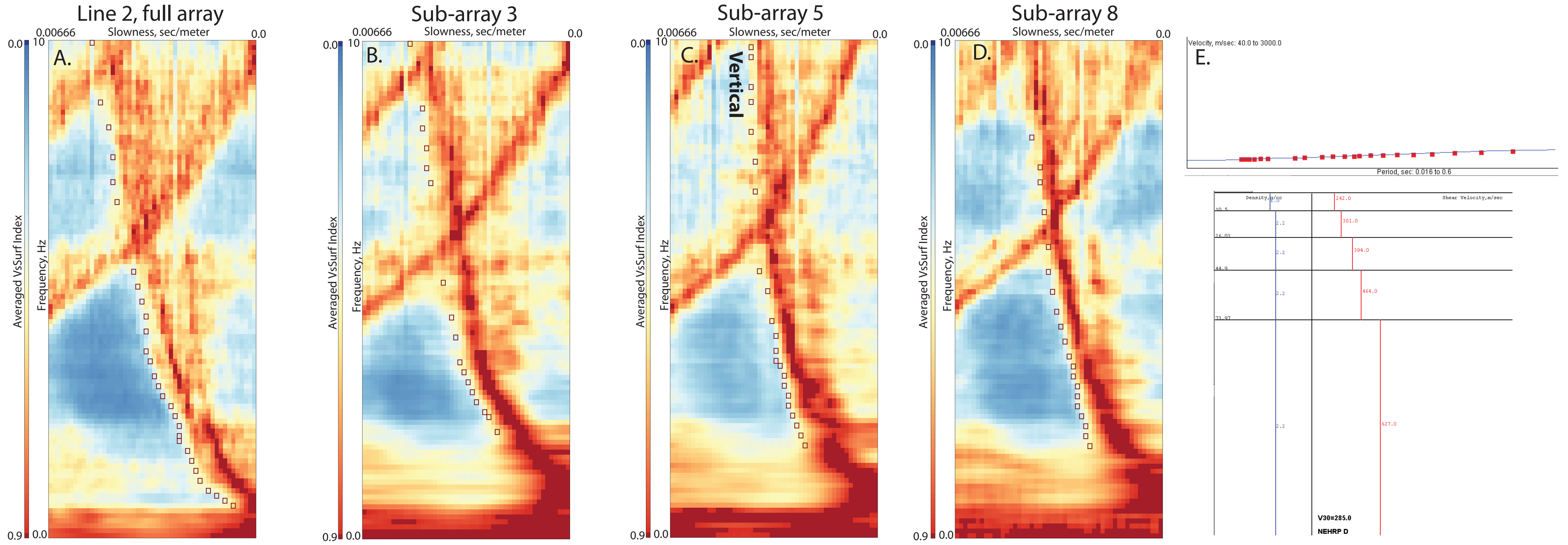


Figure 4. Picks (boxes) for Line 2 on VsSurf ReMi™ software dispersion images in the frequency-slowness domain for frequencies of 0-10 Hz. A. Full data set. B. Sub-array 3, nodes 20-39 (midpoint at 675 m). C. Sub-array 5, nodes 40-59 (midpoint at 1125 m). D. Sub-array 8 (midpoint at 1800 m). E. Example model fit of dispersion curve (top) and resulting velocity model for the upper 200 m of the subsurface (bottom). Model is for Sub-array 5. Vertical runs of dispersion are much more rare on Line 2.

Results: Landslide Deposits Show Velocity Inversions

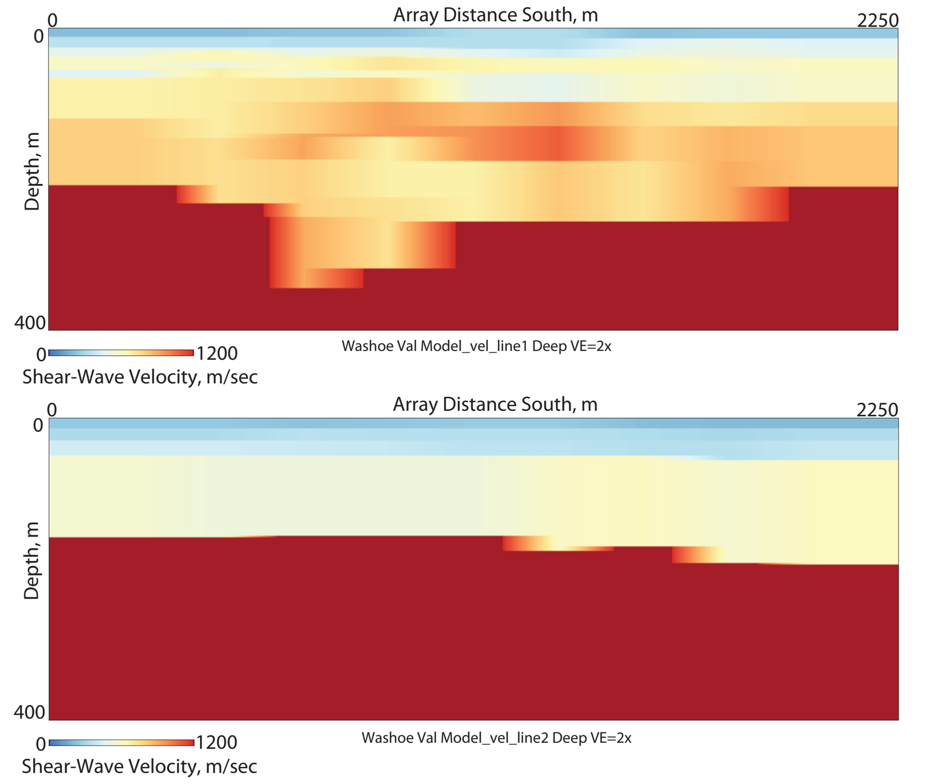


Figure 5. 2D shear-wave velocity-depth profiles for lines 1 (upper) and 2 (lower) from Terēan's VsSurf ReMi 2dS™ software. Heterogeneity and velocity inversions with depth in the low-velocity basin fill may result from blocky landslide deposits.

Continuing Work: Assessing Potential for Basin Amplification of Seismic Shaking in Reno's Industrial Areas

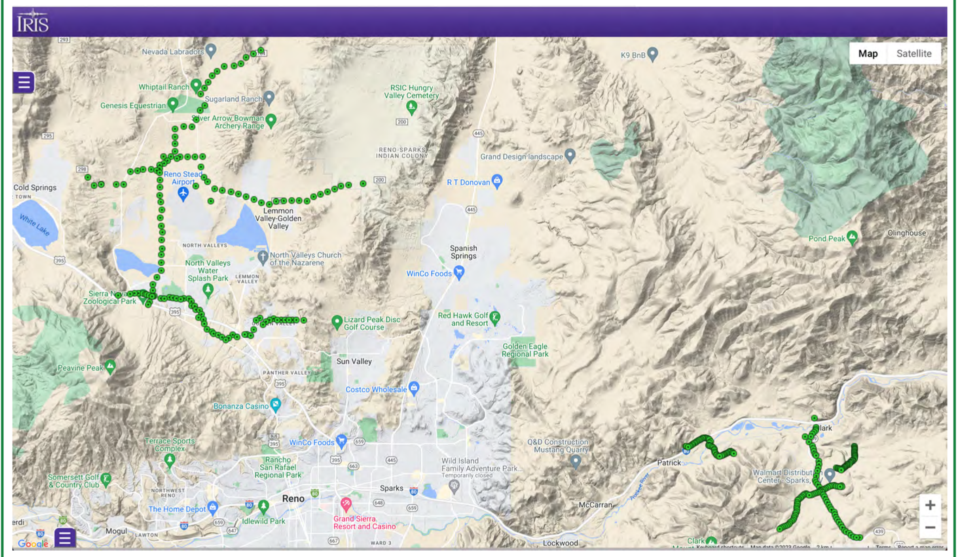


Figure 6. Current USGS-NEHRP project making deep refraction microtremor and gravity surveys in Reno-Stead and the Tahoe-Reno Industrial Center at the stations shown here at http://ds.iris.edu/gmap/#network=5K&planet=earth Assessing thickness of basin sediments will allow improved seismic-shaking predictions in these areas, which host more than 20,000 jobs (e.g., Tesla, Panasonic, Amazon). Christopher Kratt and CTEMPs (http://ctemps.org) are key facilitators for this year's field and analytical work.

DISCUSSION AND FUTURE WORK

- Line 1 has abundant lateral heterogeneity in the shallow subsurface that is not observed in Line 2.
- Velocity inversions also occur in Line 1 but not in Line 2.
- Heterogeneity in Line 1 is interpreted to represent landslide deposits, with faster velocities resulting from dominantly larger clast size within the landslide deposits.
- Line 2 is more homogeneous, suggesting abscence of landslide deposits in the subsurface and a more uniform depositional history and environment along that array.
- These initial analyses suggest that landslide deposits can be identified in the subsurface using the refraction microtremor technique.
- H/V spectral analysis as well as interferometric analyses will be performed on this data set.
- We will search for any well-log and gravity data from the area to tie to the velocity profiles.
- Further testing will include other basins with known buried landslide deposits and areas suspected of having buried landslide deposits.

REFERENCE

Carlson, C.W., Koehler, R.D., and Henry, C.D., 2019, Geologic map of the Washoe City quadrangle, Washoe County, Nevada: Nevada Bureau of Mines and Geology Open-File Report 19-4, scale 1:24,000, 7 pp.

ACKNOWLEDGMENTS

- Donors of the American Chemical Society Petroleum Research Fund (ACS PRF #58626-DN18).
- Seismic instruments provided by EarthScope-SAGE through the PASSCAL Instrument Center at New Mexico Tech. Data collected are available through the IRIS Data Management Center, Arrays **Z8** and **5K**. The facilities of the IRIS Consortium are supported by the National Science Foundation's Seismological Facilities for the Advancement of Geoscience (SAGE) Award under Cooperative Support Agreement EAR-1851048.
- This material is based upon work supported by the U.S. Geological Survey under Grant Nos. G23AP00242 and G23AP00244. *The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Geological Survey. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Geological Survey.*
- Thanks to the students and faculty from the University of Nevada, Reno, CTEMPs, and the students from the University of Cincinnati who participated in the seismic deployments in 2021 and 2023.
- Field work for these studies took place on the unceded lands of the Washoe, Shoshone, and Pyramid Lake Paiute Tribes. We gratefully acknowledge these stewards of the lands on which we conducted these studies. To learn more about the tribes please visit https://washoetribe.us, https://www.rsic.org, and https://plpt.nsn.us