Chasing a hidden fracture using seismic refraction tomography: case study Preonzo, Switzerland

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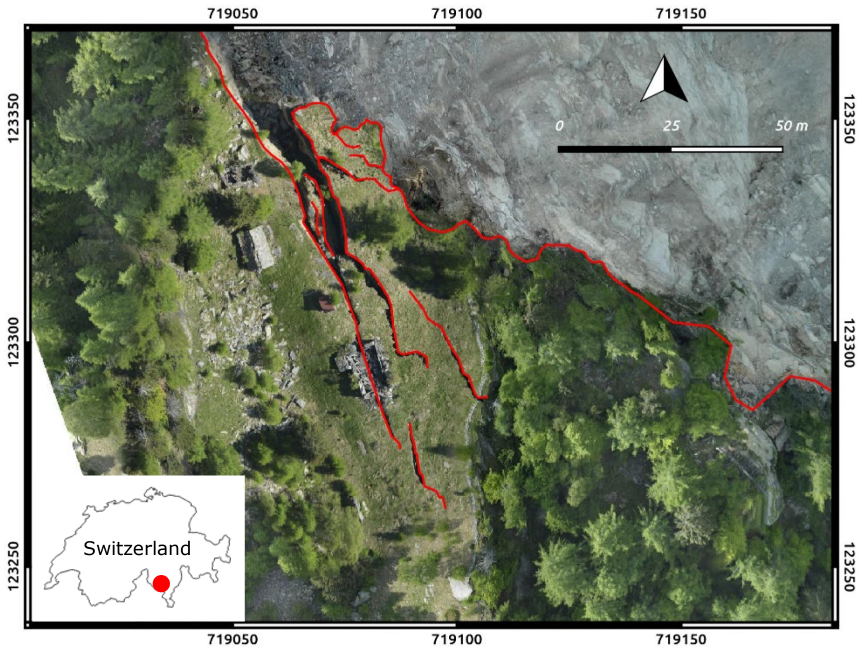
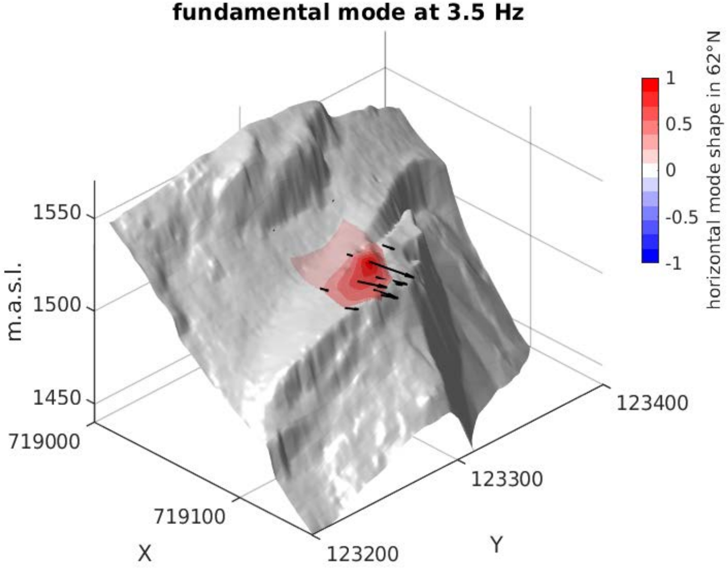
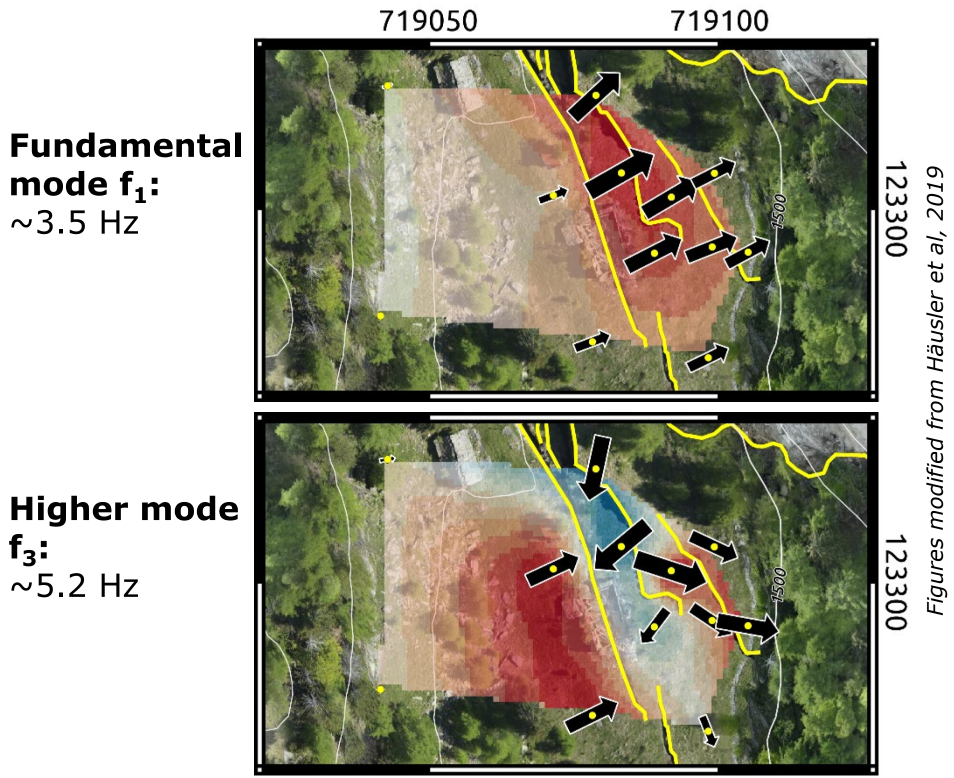
Preonzo rock slope instability



- Retrogressive rock instability (active since 18th century)
- Last large collapse in May 2012: 210’000 m^3
- Remaining unstable volume: ~140’000 m3
- More information, e.g. Gschwind et al., (2019)

Normal mode analysis





- Normal mode analysis of ambient vibrations (see Häusler et al., 2019, using data by Burjánek et al., 2018) shows the fundamental mode at ~3.5 Hz and several higher modes
- Seismic amplifications are high in the unstable area (up to factor of 40).
- Zero-crossings of higher modes preferentially coincide with fracture network

Hypothesis

- **But…**
- We observe high amplification on two stations (PRE003, PRE004) in the stable area (up to a factor of 8)
- The fundamental mode should represent the entire unstable volume
- Therefore:
  - Stations PRE003 and PRE004 are part of the unstable volume as well
  - The instability is larger than determined by open fractures visible at the surface
  - We suggested (in Häusler et al., 2019), that the effectiv border of the instability is an additional, hidden (infilled) rear fracture further uphill

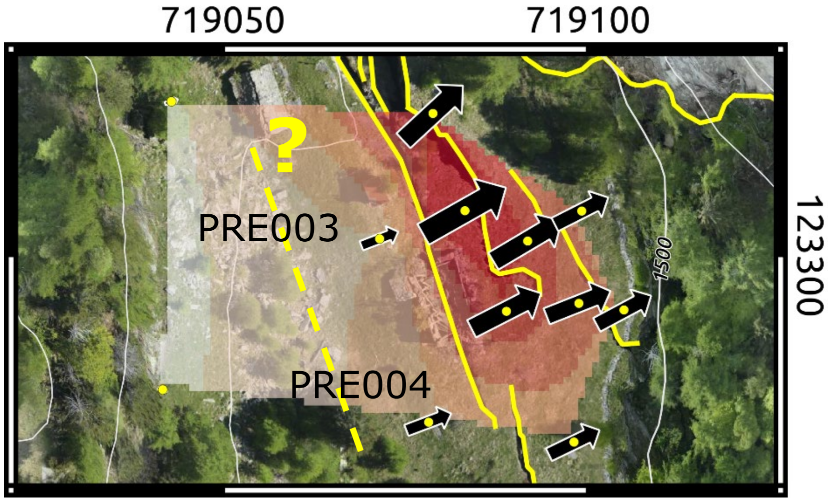
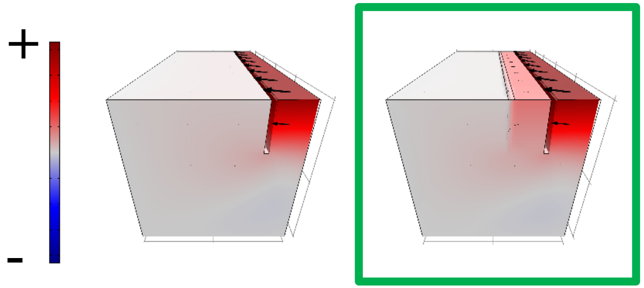


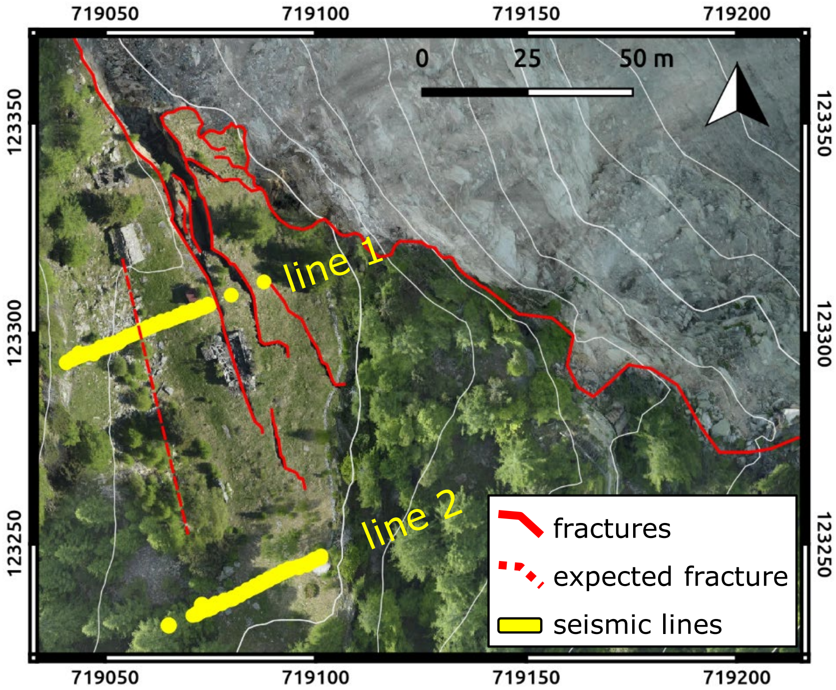
Figure modified from Häusler et al., 2019

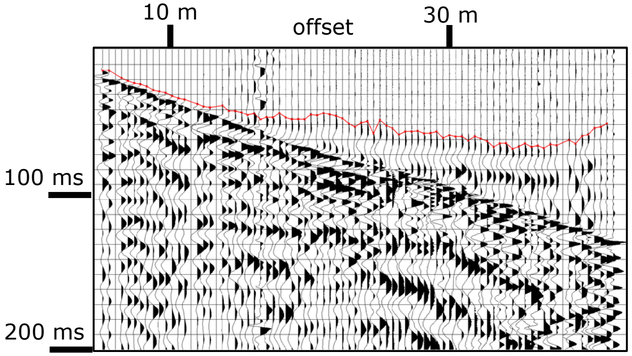


the case we expect

→ We performed seismic refraction tomography to obtain evidences of the existence of such a fracture

Seismic Refraction Tomography: Setup





example common source gather on line 1

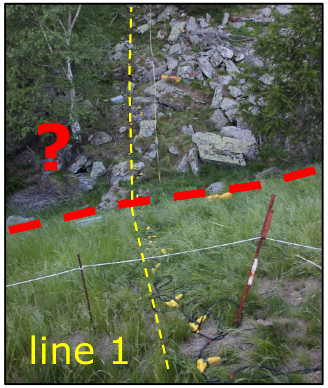
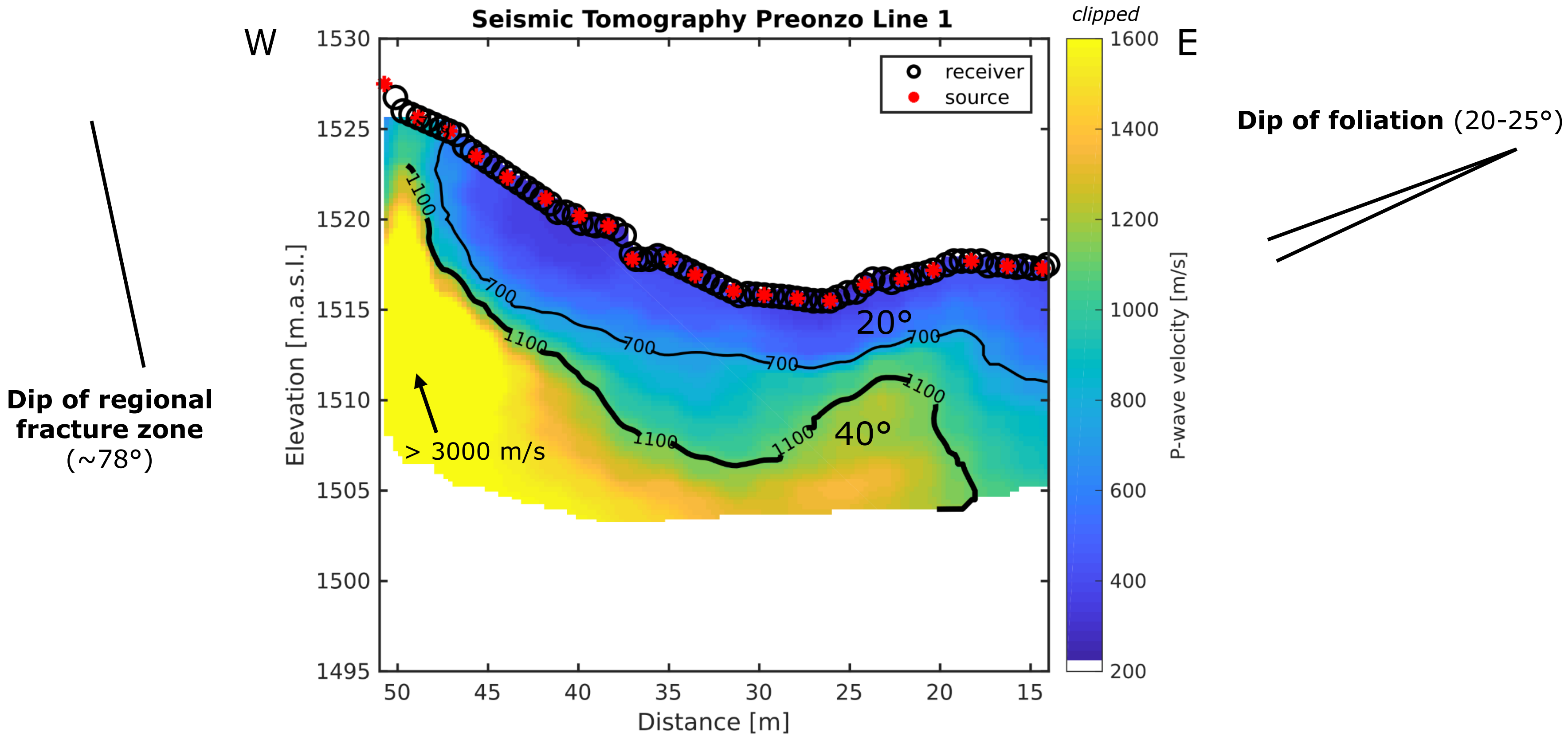


photo courtesy of J. Igel

- Seismic refraction tomography on two lines, using 30 Hz 1-C geophones (Geode system), 0.5 and 1.0 m receiver spacing, spread limited by cliffs and fractures
- Sledgehammer source, 1.0 and 2.0 m source spacing, respectively
- Inversion using software inv2dm (Lanz et al., 1998)

Seismic Refraction Tomography: Results Line 1

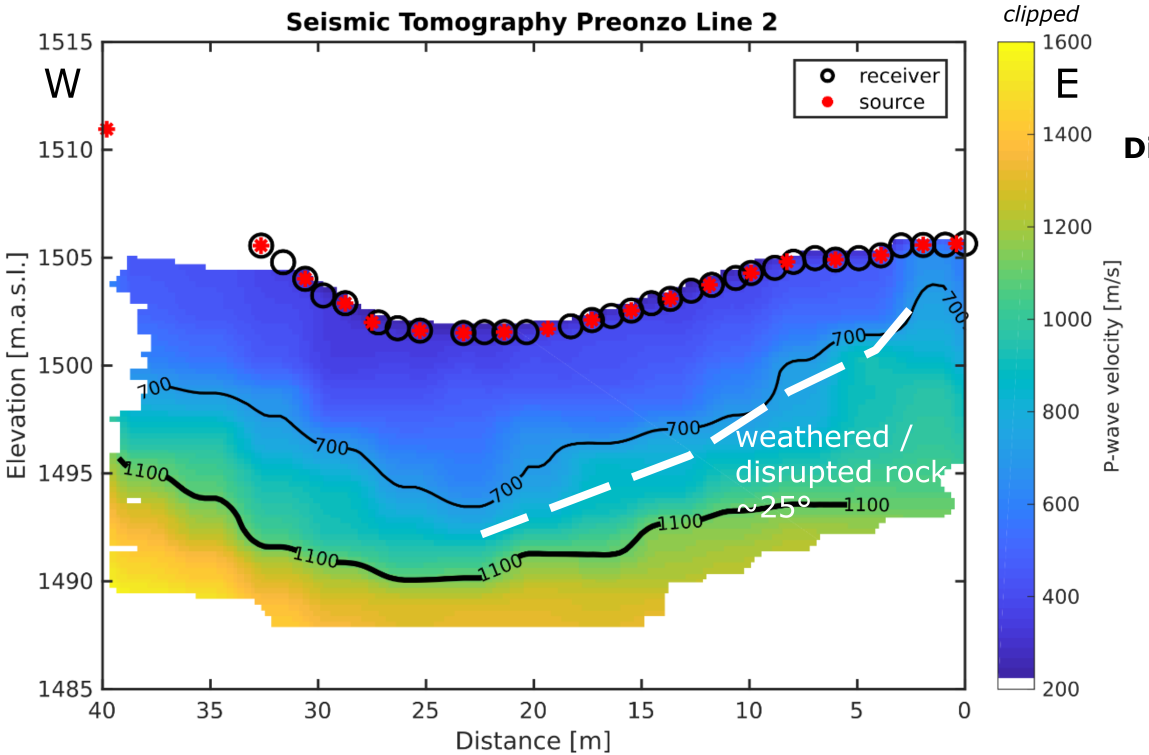


- Very low P-wave velocities. Soil is shallow (few cm to dm) in the eastern part, western part is covered by talus material

- We found a deeper-reaching velocity anomaly at the center of the profile, with slopes steeper than the foliation

Seismic Refraction Tomography: Results Line 2

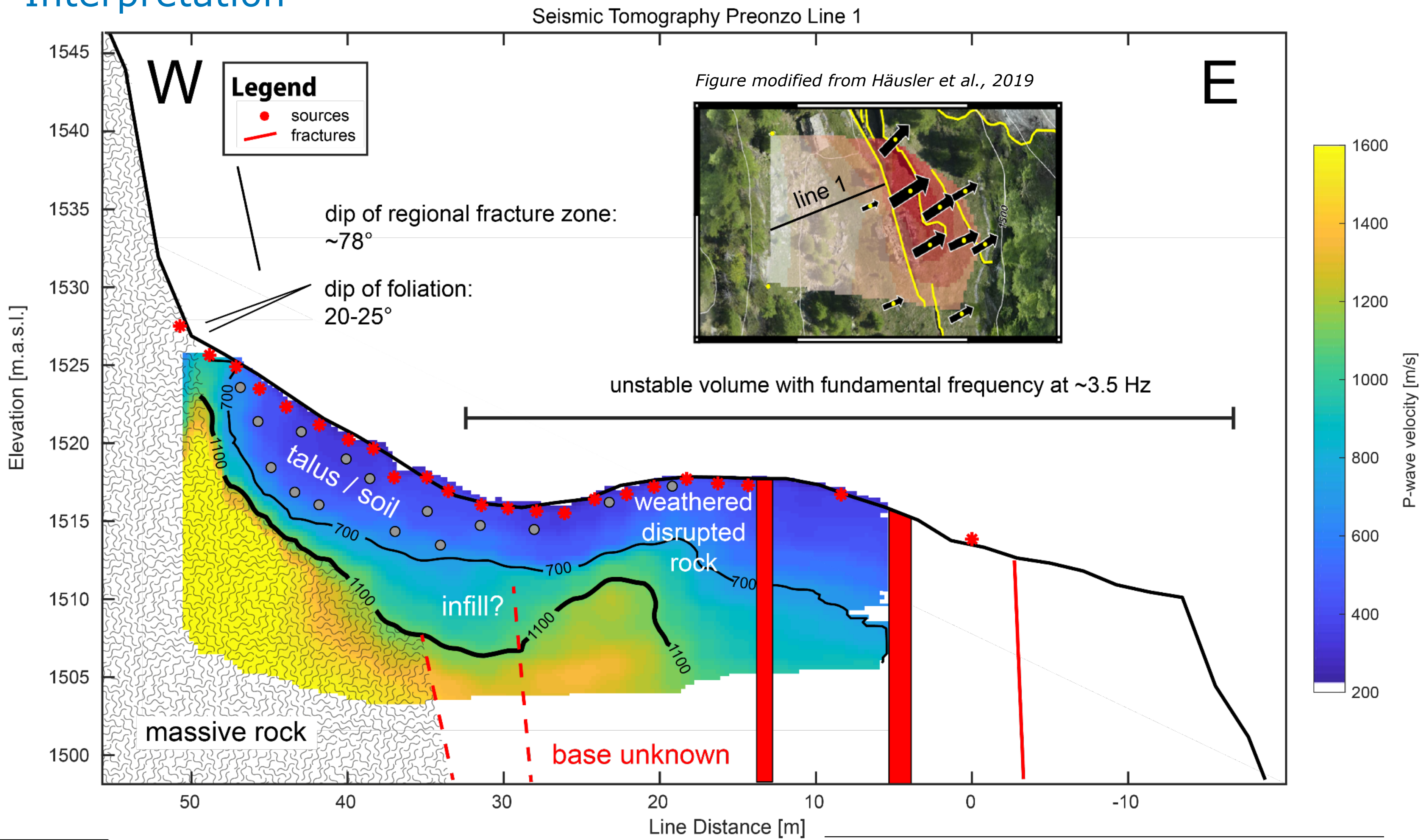
Dip of regional fracture zone (~78°)



Dip of foliation (20-25°)

- Bedrock is outcropping at the eastern end of the line
- Velocities are as low as on line 1. A small valley-shaped low velocity zone is visible. However, it does not cut the dip of the foliation
- Penetration depth not sufficient to reach a clear contrast to high P-wave velocities as observed on line 1 (spread geometry limited by cliffs)

Interpretation



Conclusions

- Normal mode analysis of ambient vibration data can help to map fracture networks on unstable rock slopes.
- At the Preonzo site, the results of normal mode analysis suggested an additional rear fracture that is dominating the seismic response. However, no clear surface expressions of that fracture are visible.
- We performed seismic refraction tomography across the predicted fracture and found a low velocity anomaly ($Vp < 1000$ m/s) on one seismic line. We associate this anomaly with the hidden fracture.
- A second seismic line further away from open fractures showed no clear velocity anomaly, but also did not reach the clear contrast to higher seismic velocities that was observed on line 1 (limited penetration depth).
- Considering the extend of this additional crack, the volume of the unstable rock mass increases by about 40%. However, our results do not provide information on the kinematic activity level of this additional volume.
- These findings are encouraging to perform ambient vibration analysis in the initial phase of characterizing and assessing landslide areas (as one contribution in a multidisciplinary approach).

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References

Burjánek, J., Gischig, V., Moore, J.R., and Fäh, D. (2018). Ambient vibration characterization and monitoring of a rock slope close to collapse. Geophys. J. Int., 212, 297-310. https://doi.org/10.1093/gji/ggx424

Gschwind, S., Loew, S., and Wolter, A. (2019). Multi-stage structural and kinematic analysis of a retrogressive rock slope instability complex (Preonzo, Switzerland). Engineering Geology, 252, 27-42. https://doi.org/10.1016/j.enggeo.2019.02.018

Häusler, M., Michel, C., Burjánek, J., and Fäh, D. (2019). Fracture Network Imaging on Rock Slope Instabilities Using Resonance Mode Analysis. Geophysical Research Letters, 46, 6497-6506. https://doi.org/10.1029/2019GL083201

Lanz, E., Maurer, H., and Green, A.G. (1998). Refraction tomography over a buried waste disposal site. GEOPHYSICS, 63, 1414-1433. https://doi.org/10.1190/1.1444443