Testing Ambient-Noise Tomography as a Geothermal Exploration Method in Switzerland

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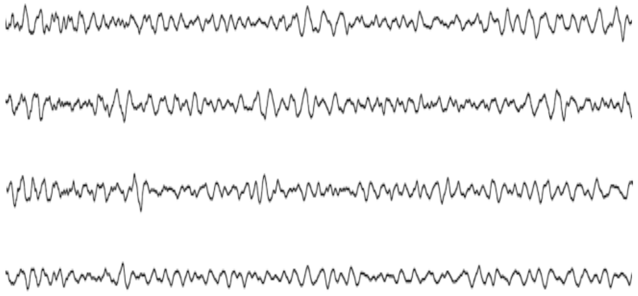
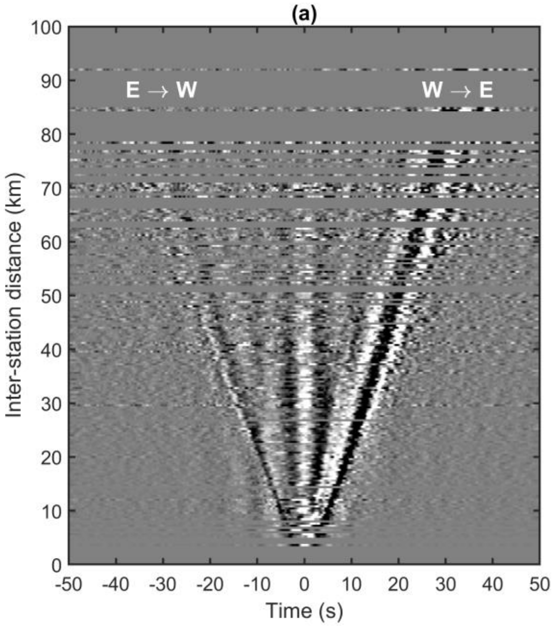




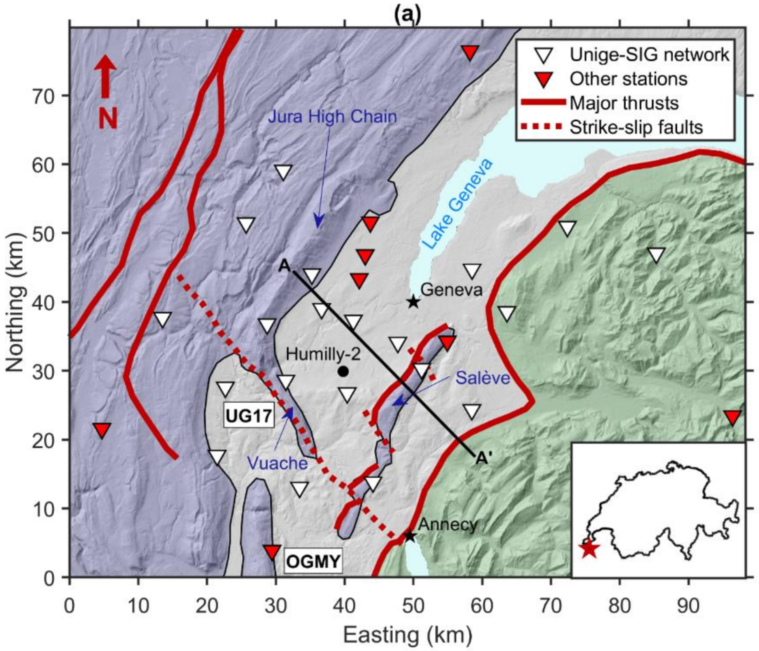
Context

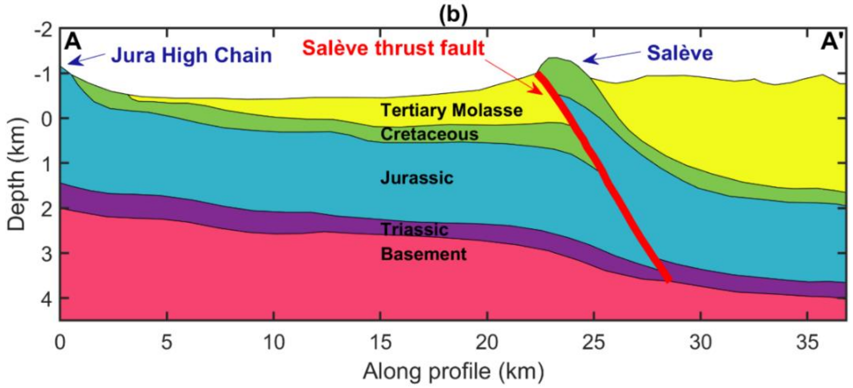
- Conventional exploration techniques, such as active seismic reflection, present **prohibitive costs** and **complex logistics** (urban areas) for the geothermal energy sector.

- Seismic **Ambient-Noise Tomography (ANT)** could become an **affordable exploration** method to reduce subsurface uncertainty.

- We present a **surface-wave ANT** of the Greater Geneva Basin showing the large-scale shear-wave velocity structure of the basin.

- The PSIGE project aims to test **refracted body-wave ANT** as a geothermal exploration method.





[1] Ibele (2011), Ph.D. thesis, University of Fribourg.
[2] The Geomol Team (2015), GeoMol project report (http://www.geomol.eu/report).

Figure: (a) simplified tectonic map of the Greater Geneva Basin. The map shows the Helvetic Nappes and Prealps (in green), the Western Alpine Foreland Basin (in grey), and the Jura Mountains (in purple) (adapted from [1]). (b) The northwest-southeast trending schematic cross-section of the GGB, modified after GeoMol [2], shows the interpreted geometry of the sedimentary units composing the basin. The Salève thrust fault (solid red line) brings Lower Cretaceous units to the surface.

Surface-wave ANT of the Greater Geneva Basin

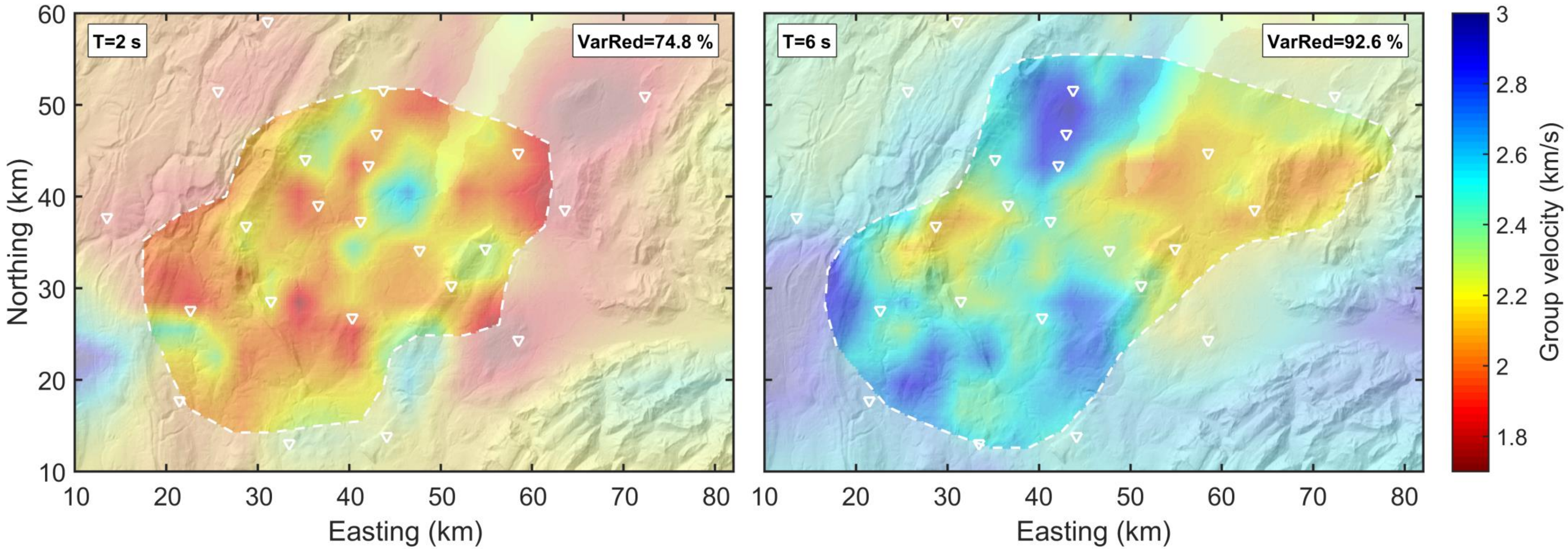


Figure: inverted 2D group velocity maps at periods of T=2 s (left) and T=6 s (right).

• At T=2 s (left): sensitive to the upper 2 km of the sedimentary cover; some velocity anomalies correspond to Bouguer anomalies and/or to outcrops of mesozoic sequences.

• At T=4 s (right): sensitive to the whole sedimentary cover and to the upper part of the basement; the low-velocity region might correspond to the deeper part of the basin.

➡ Surface-wave ANT with sparse sensor networks can retrieve large-scale Vs models but cannot provide detailed intra-basin information relevant for geothermal exploration.

➡ Dense nodal network and body-wave ANT?

*[Planès et al, 2020, GJI **220**:370-383]*

The PSIGE project

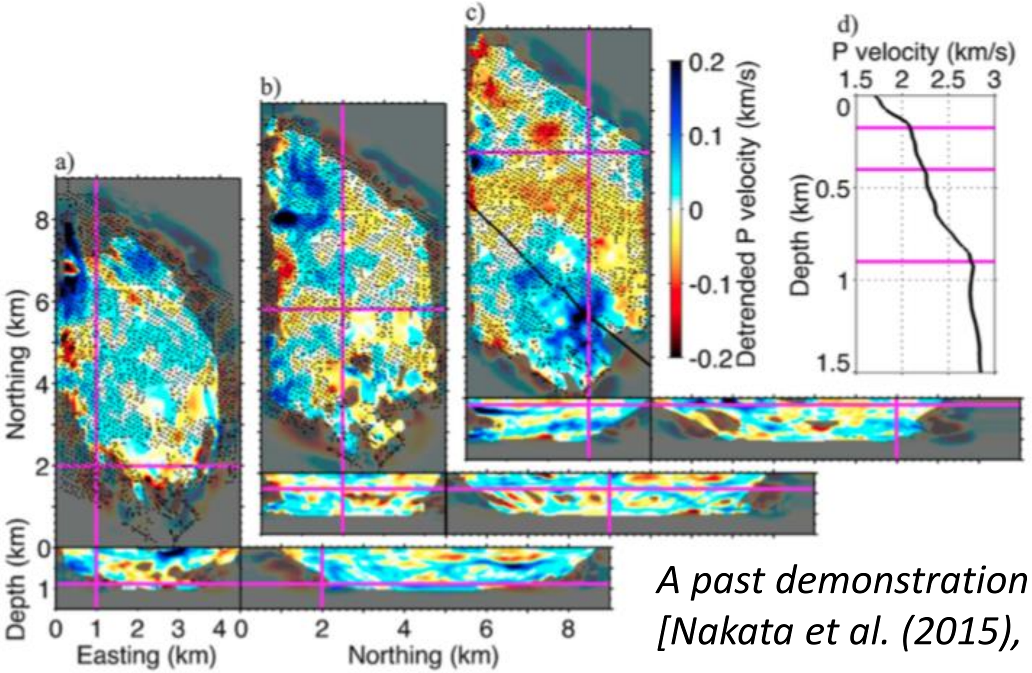
Passive Seismic Imaging for Geothermal Exploration (BFE-Unige)

Thomas Planès, Matteo Lupi, Anne Obermann (ETHZ), + others (September 2019 – August 2022)

Objectives:

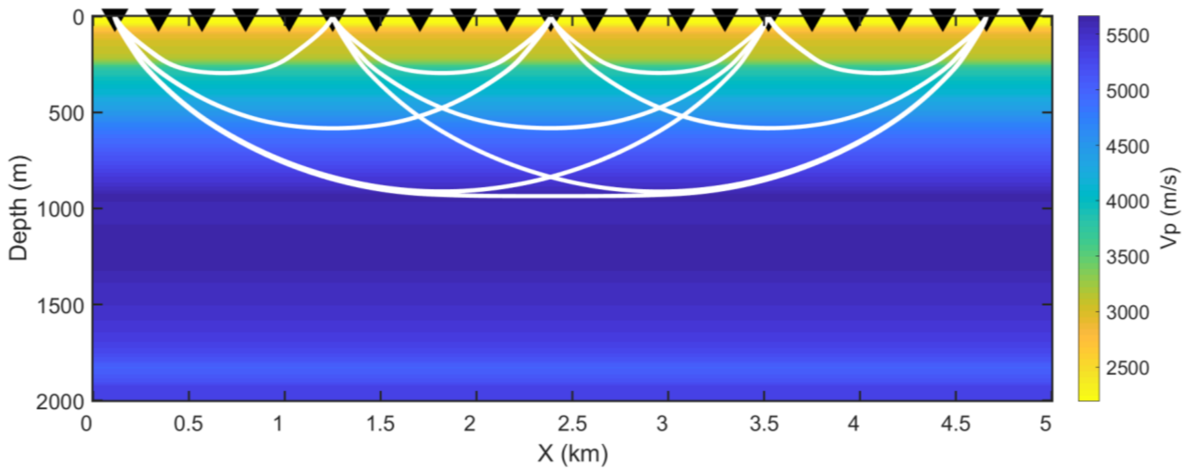
- Performing ambient-noise acquisitions with dense nodal networks (500 nodes?) at Swiss geothermal exploration sites.
- Producing high-resolution surface-wave ANTs and attempting refracted P-wave ANTs.
- Exploring the possibilities to extract refracted S-waves and reflected body waves from ambient-noise.
- Benchmarking and interpreting the obtained models with results from 3D active seismic acquisitions.
- Assessing if ANT can be combined with classical active seismic methods to lower the cost of subsurface exploration for geothermal projects.

DTCC SmartSolo 3-component seismic nodes

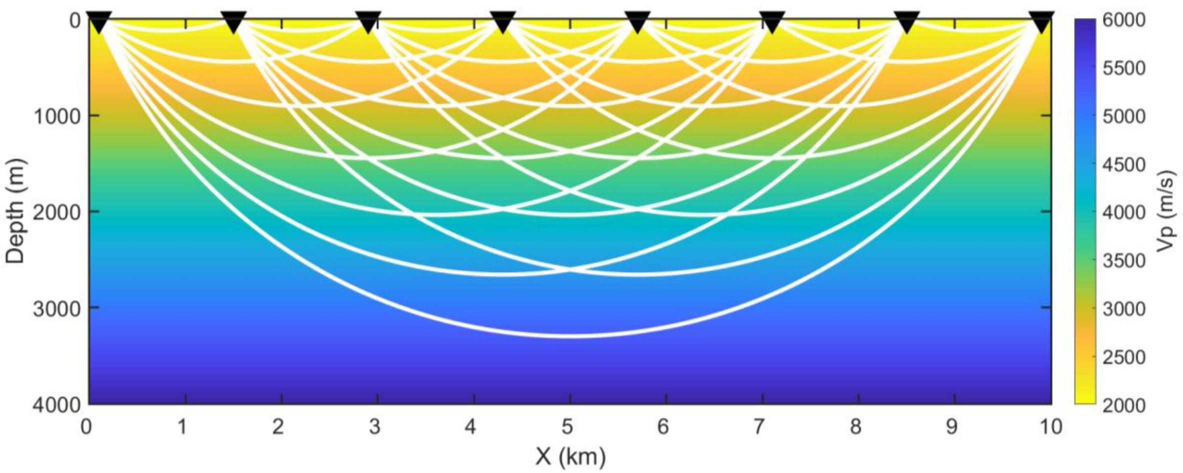


*A past demonstration of refracted P-wave ANT [Nakata et al. (2015), JGR **120**:1159-1173]*

Refracted P-wave tomography: synthetic tests



Ray-tracing example 1 (Geneva-Humilly velocity model)
“Shallow” configuration: 5 km aperture – 1 km depth

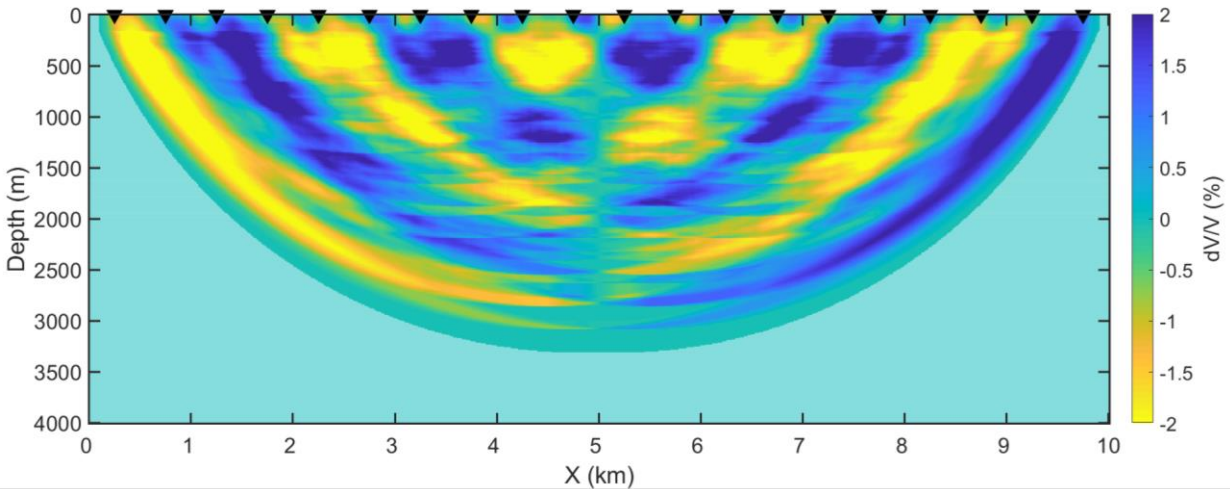


Ray-tracing example 2 (synthetic velocity model)
“Deep” configuration: 10 km aperture – 3 km depth

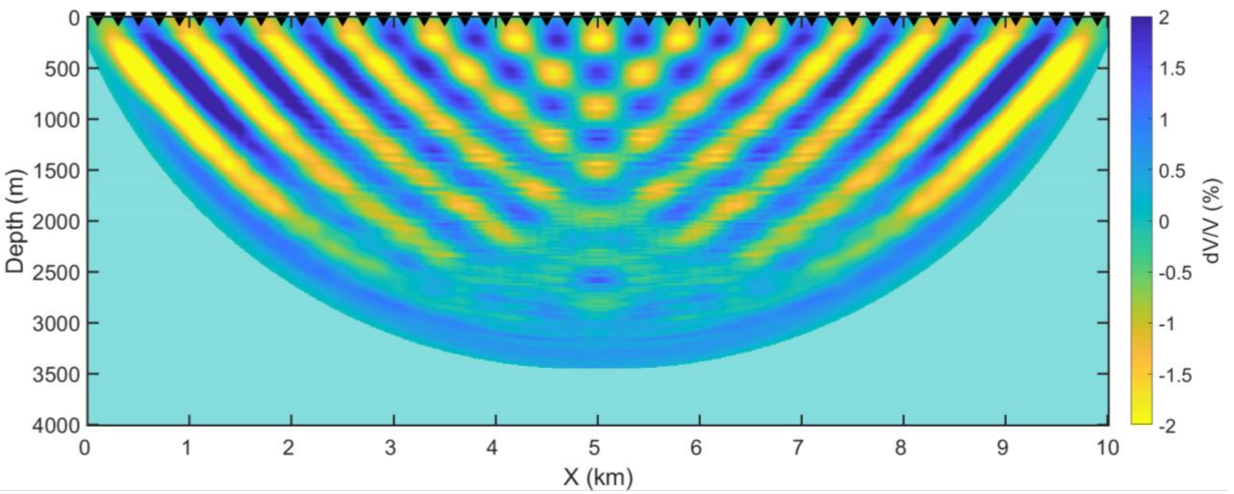
Depth of investigation (refracted P-wave tomography):

- From 1/5 to 1/3 of the network aperture.
- Depends of the local velocity model.
- Maximum depth is strongly limited by Low Velocity Zones.

Refracted P-wave tomography: synthetic tests



Checkerboard test 1 (synthetic velocity model)
"Sparse" configuration: 10 km aperture – 20 sensors



Checkerboard test 2 (synthetic velocity model)
"Dense" configuration: 10 km aperture – 50 sensors

Resolution:

- Controlled by wavelength and sensor spacing.
- Reaching a high resolution in 3D requires a **large number** of sensors.
- With ~500 sensors: 3D resolution expected to be in the 500 m – 1 km range.
- Much higher resolution potential for 2D lines.