A high-resolution seismic survey across the Balmuccia Peridotite, Ivrea Zone, Italy - Project DIVE phase two, site investigation

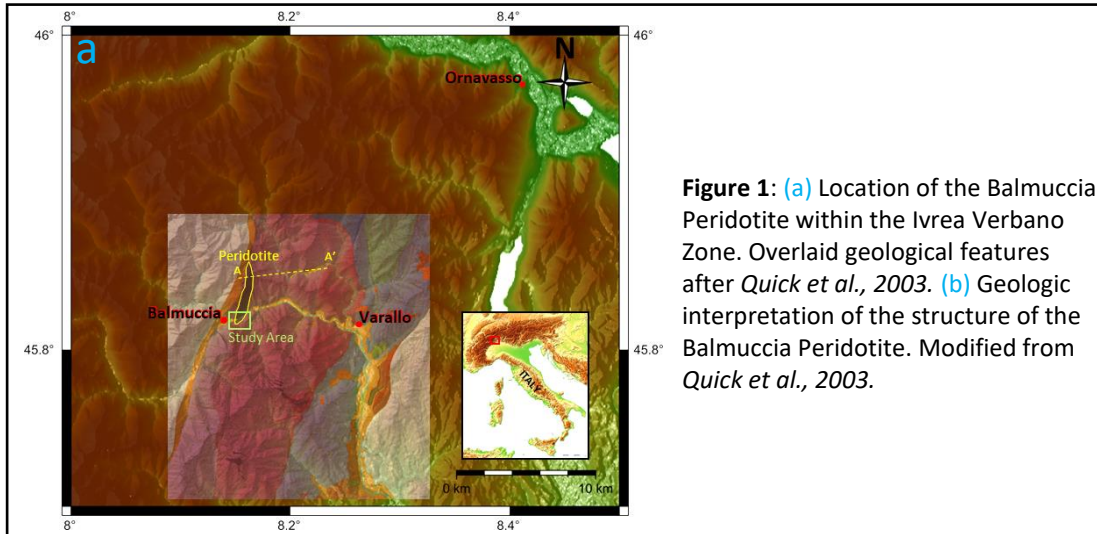D. Pasiecznik[1], A. Greenwood[1,2], L. Baron[2], G. Hetényi[2], F. Bleibinhaus[1]

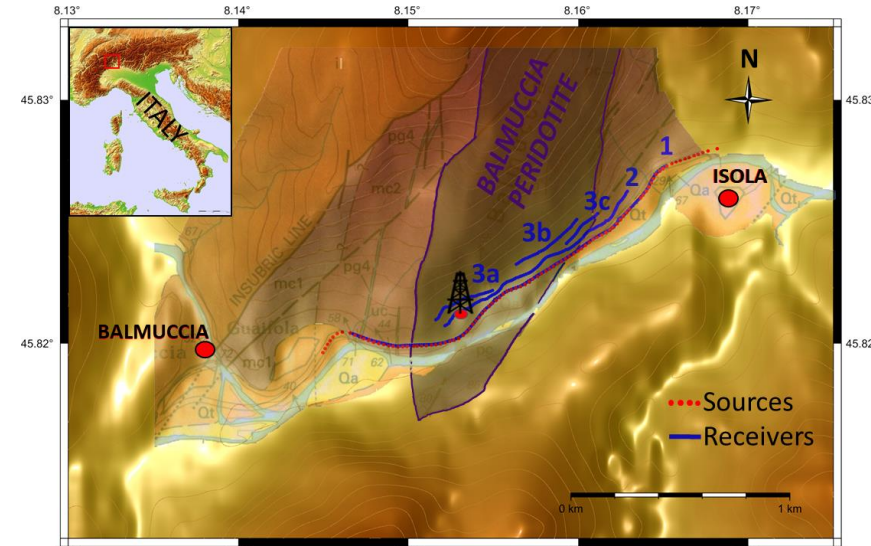[1]*Montanuniversität Leoben* [2]*Université de Lausanne*

Introduction: The Drilling the Ivrea Verbano ZonE project (DIVE) aims to drill the Ivrea Verbano Zone with a 4 km deep borehole in phase two of the project (Pistone et al., 2017). The proposed drill site is in Balmuccia, Val Sesia (study area, Figure 1a), where the Balmuccia Peridotite outcrops. The borehole aims to drill through the lower crust and potentially cross the crust-mantle transition. As a seismic site characterization is required before the drilling phase, a seismic survey has been acquired across the Balmuccia peridotite entitled High-resolution SEismic imaging of the Ivrea Zone (HiSEIZE). The aim of the survey is to define the structure of the Balmuccia Peridotite and its relationship to the lower crust.

Acquisition: Three seismic lines were deployed crossing the Balmuccia Peridotite (Figure 2). Line 1 comprises of 80 3-component accelerometers + 80 3-component geophones interleaved at ca. 11 m spacing, and Lines 2 and 3 which utilized 200 vertical geophones spaced ca. 10m. The three sub parallel lines are spaced 50-80 m apart. A single 17.000 kg Vibroseis source was utilized at 22 m spacing along a 2.4 km line emitting a 10 s linear sweep, from 12 to 140 Hz, with 3 s listening time.

Figure 1: (a) Location of the Balmuccia Peridotite within the Ivrea Verbano Zone. Overlaid geological features after *Quick et al., 2003.* (b) Geologic interpretation of the structure of the Balmuccia Peridotite. Modified from *Quick et al., 2003.*

p: Peridotite
mc2: Gabbro and norite
uc: Ultramafic rocks
pg4: Banded quartzofeldespetic paragneiss
pc: Pegmatitic clonopyroxenite

Figure 2: Digital Elevation Model of the Study area depicted in figure 1a, with seismic lines, source line and overlaid with geological features (modified from *Quick et al.,2003*) .

200 Vertical geophones

80 3C-geophones

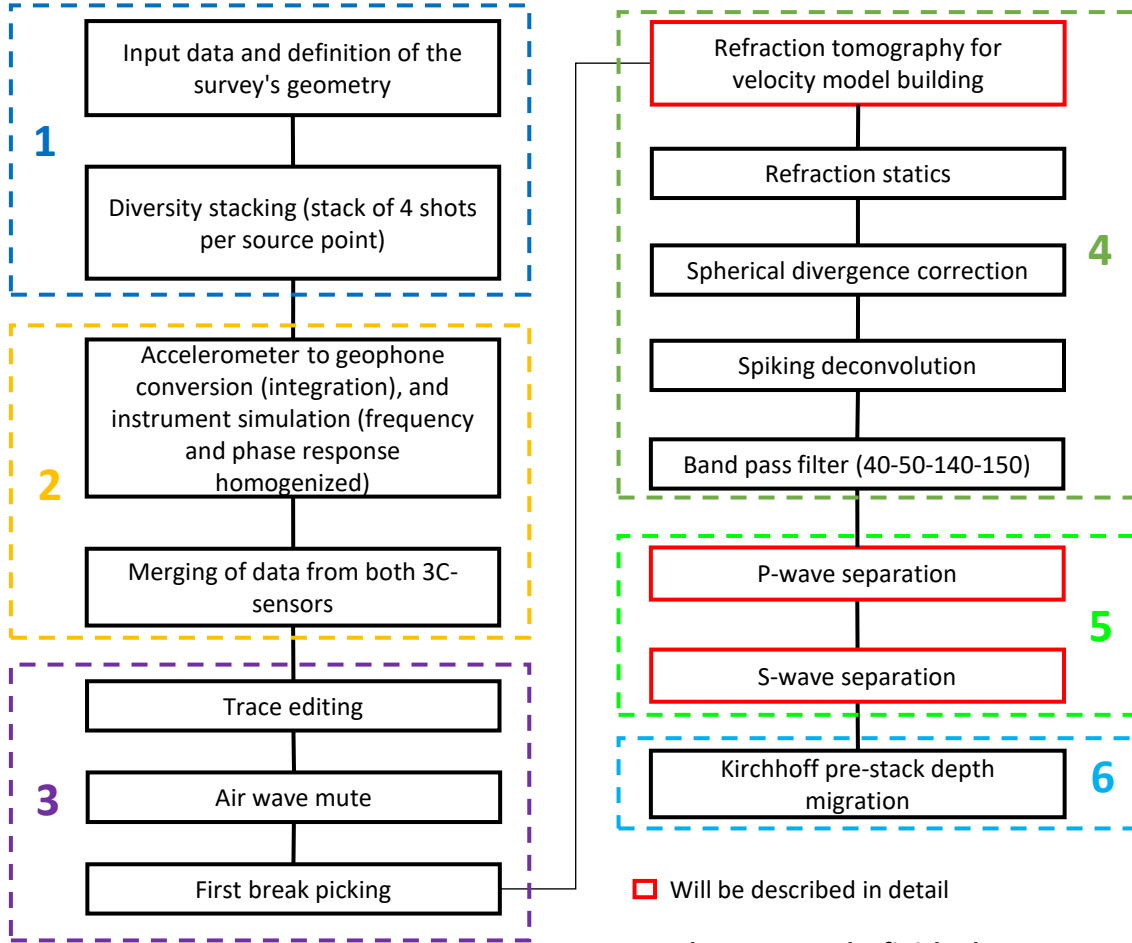80 3C-accelerometers

Vibroseis
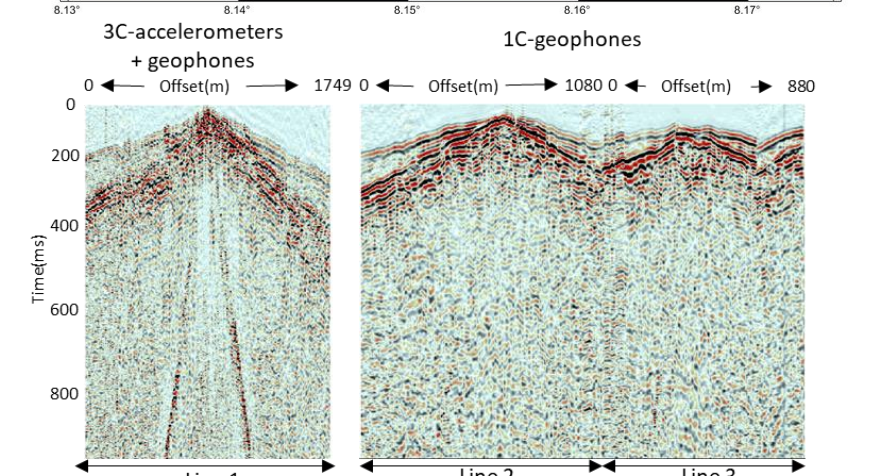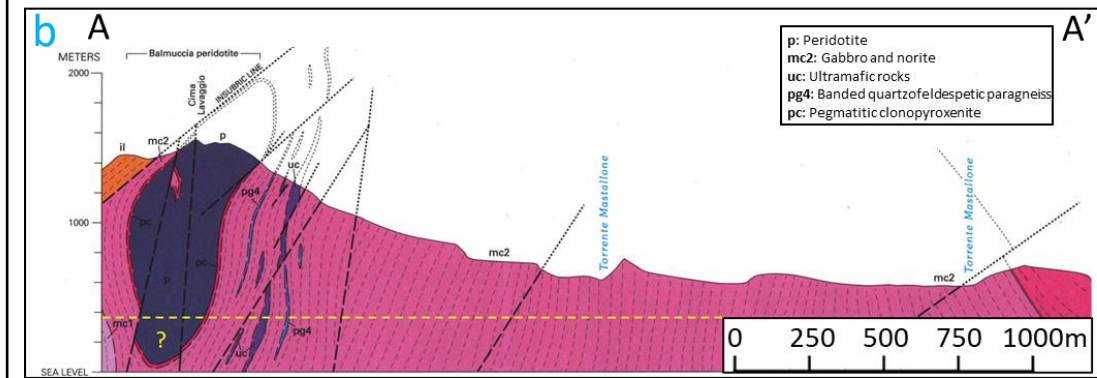
Figure 3: Raw shot records (AGC applied for visualization).

Processing, Line 1: The following processing workflow was proposed and is applied to Line 1. The objective of which, is to obtain a successful processing workflow that can be applied later to Lines 2 and 3.

PROCESSING WORKFLOW*

1
- Input data and definition of the survey's geometry
- Diversity stacking (stack of 4 shots per source point)

2
- Accelerometer to geophone conversion (integration), and instrument simulation (frequency and phase response homogenized)
- Merging of data from both 3C-sensors

3
- Trace editing
- Air wave mute
- First break picking

4
- Refraction tomography for velocity model building
- Refraction statics
- Spherical divergence correction
- Spiking deconvolution
- Band pass filter (40-50-140-150)

5
- P-wave separation
- S-wave separation

6
- Kirchhoff pre-stack depth migration

□ Will be described in detail

- **Phases 1,2 and 3 finished**

- **Phases 4, 5 and 6 in process**

* The workflow is still in development due to possible changes of parameters and techniques that would allow for a better result.

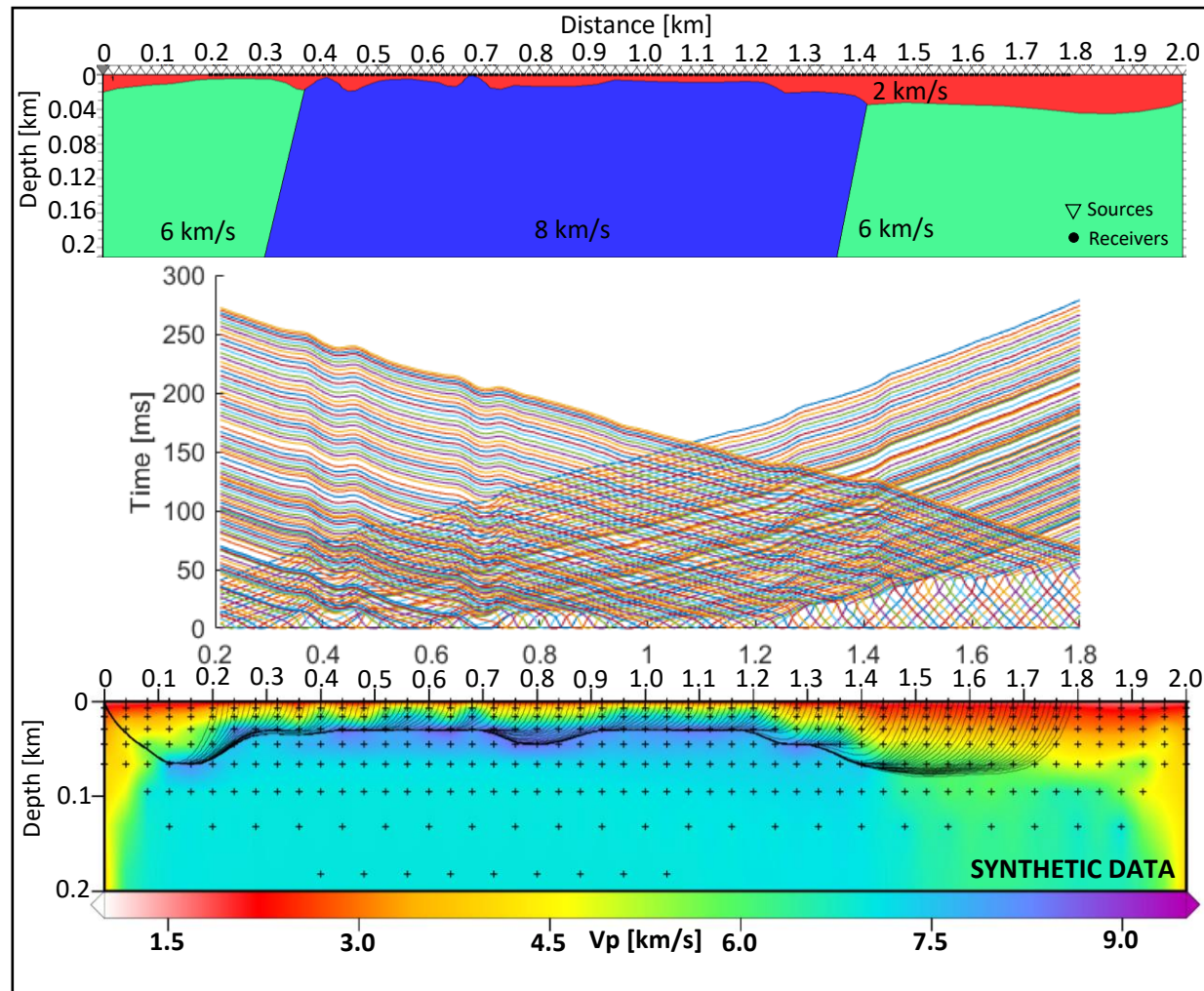**Refraction travel time tomography:** In the absence of horizontal refractors and reflectors, travel time tomography is used to obtain a near-surface velocity model. The package SIMULR16 (*Bleibinhaus and Gebrande, 2006)* is used for this task. The resulting velocity model is used in the application of refraction statics and Kirchhoff pre-stack depth migration.

Refraction statics were calculated by: (1) defining a datum at 800m depth and (2) computing the time shifts to be applied, considering the distance from receivers/shots positions on the surface to the defined datum (Figure 4).
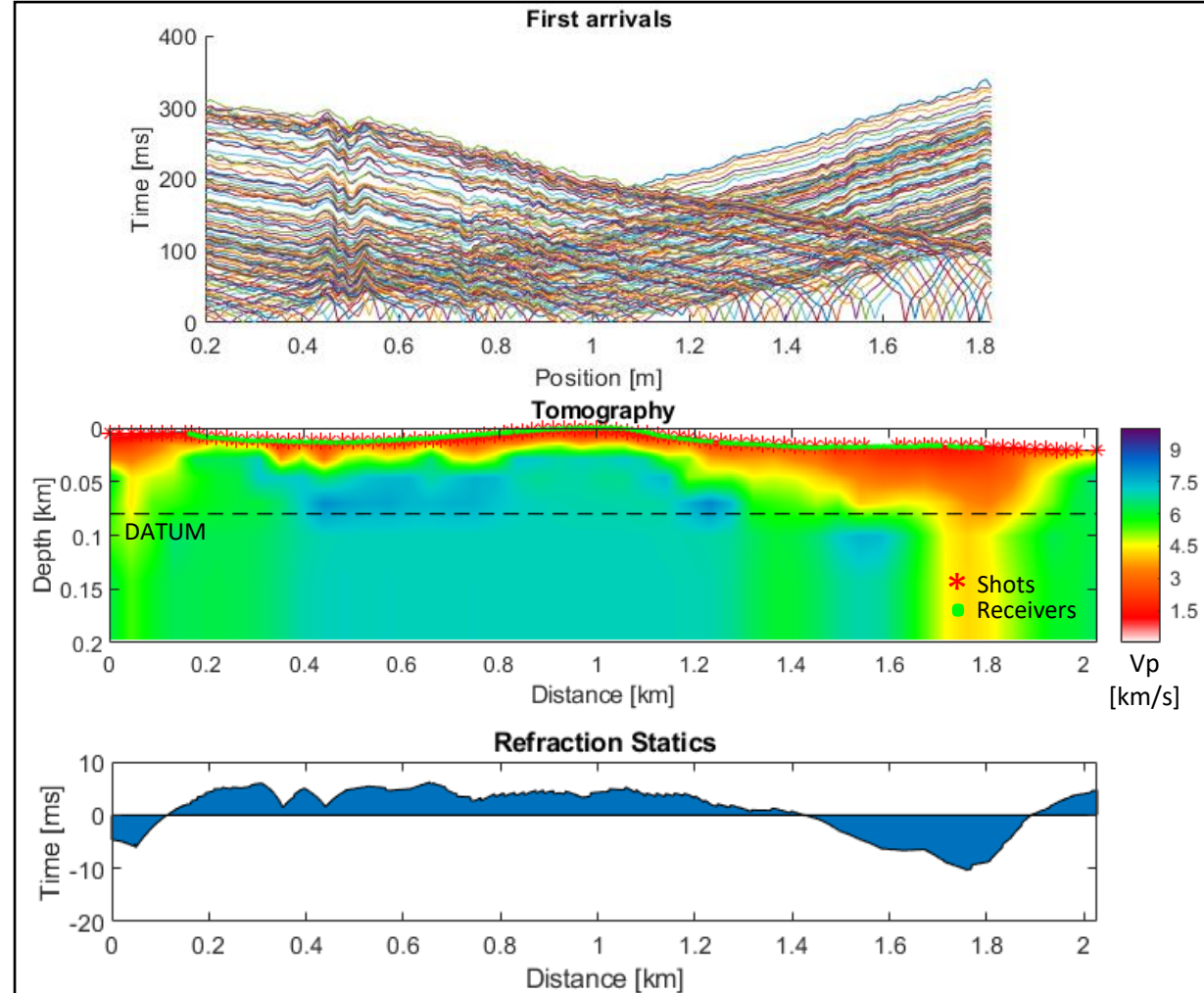

Figure 4: First arrivals for shot points (top). Travel time tomography and defined datum with shot and receivers' positions (middle). Computed refraction statics (bottom).

Forward modeling analysis: The objective of this analysis is to interpret the results from the Line 1 travel-time tomography and compare this with tomographic results obtained from a synthetic geological model. A 2D-numerical model was developed using the geological map of *Quick et al., 2003,* as well as features and velocities observed in the Line 1 first arrival data. A viscoelastic finite-difference code was used with this model to generate synthetic seismograms and provide synthetic first arrival times. The extracted first arrival times are employed to obtain a tomographic image of the model (Figure5).

Forward modeling analysis: The comparison between tomographic images of the real and synthetic data shows that the travel time tomography has successfully outlined the top of the peridotite body. Furthermore, structural features proposed in the numerical model, have been imaged with the tomography, and match results observed in the real data (Figure 6).

Figure 5: 2D-geologic model (top), trave times for every shot point (middle) and output after tomography.
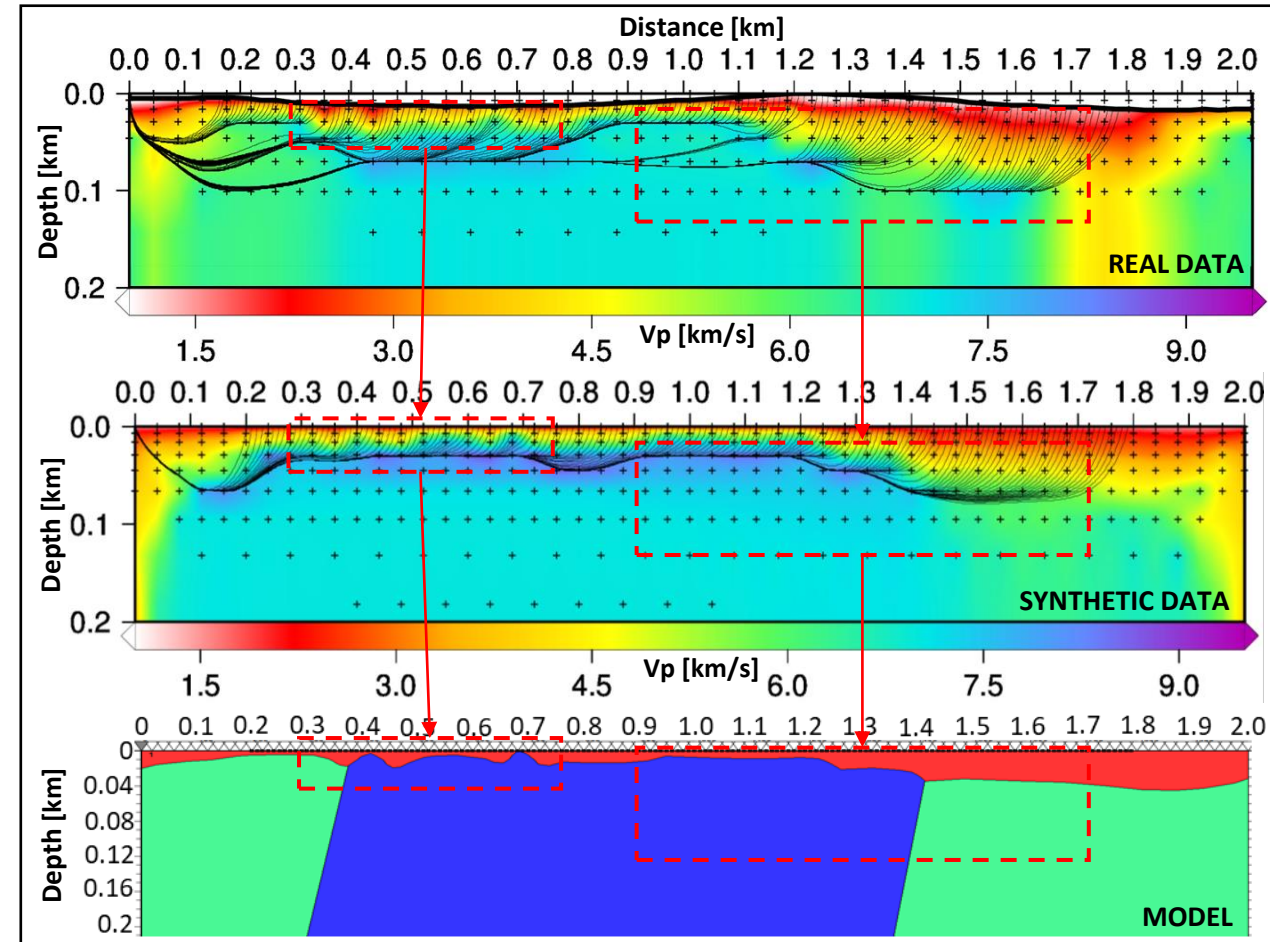
Figure 6: Comparison between tomography results obtained from the real data (top) and synthetic data (middle). Features observed in both results can be related to boundaries defined within the numerical model (bottom).
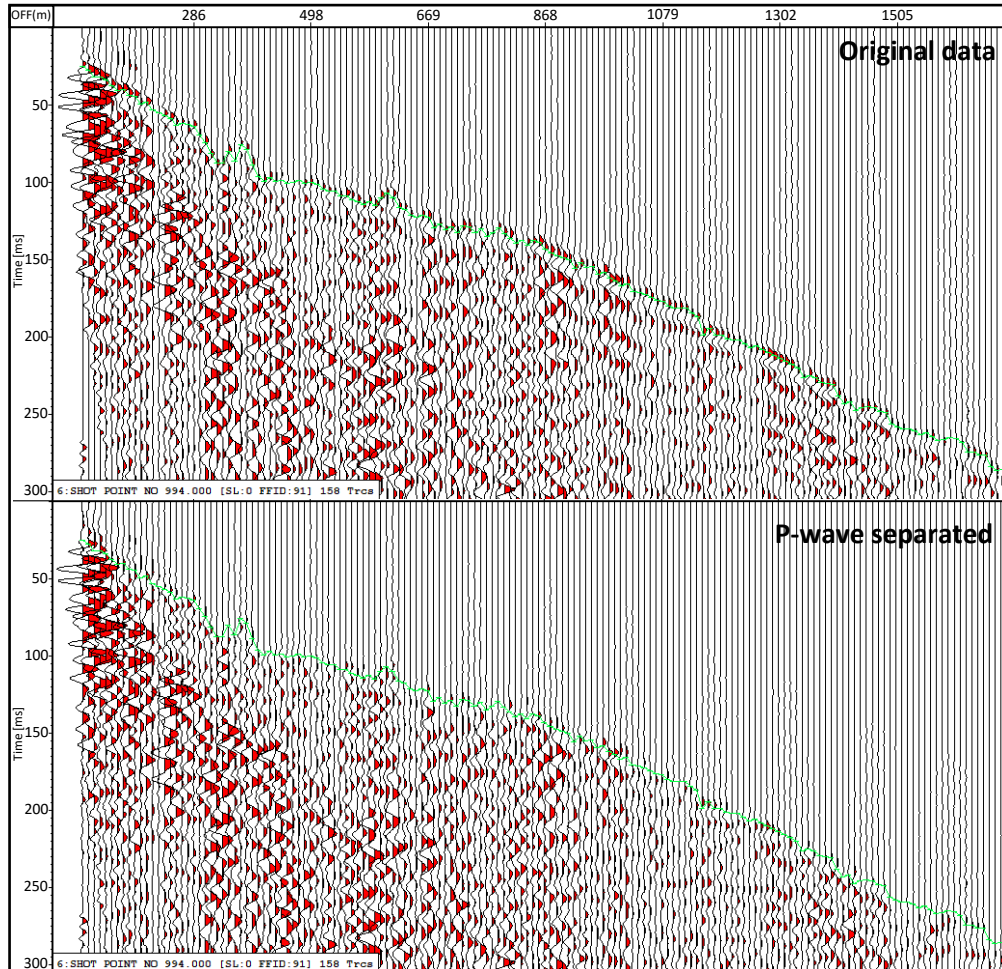
P- and S-wave separation: Direct P-wave and high amplitude S-wavefileds present throughout the data require the application of filters to separate and remove them from the desired reflected wavefields .

The process used for the separation of the P-wavefield consists of:

1. Align the first breaks to a defined time datum (datum = 100 ms)
2. Calculate an alpha trim mean filter (traces per window = 9, trim percentage = 33%)
3. Subtract the calculated filter from the data and then restore the traces to their original positions in time.

The same approach was applied for the S-wavefield separation. For this case, the S-wave "picks" were obtained by multiplying the first break times by a ratio of 1.7 (Vp≈√3Vs) and then manual adjustments were made where necessary.

Figure 7: Comparison before (top) and after (bottom) P-wavefield separation (AGC applied for better visualization).

Preliminary results: The outcome after the application of the wavefield separation processing shows an enhancement of reflected, and scattered signal, allowing the interpretation of possible reflectors . The P-wavefield was successfully separated from the data, whereas for the S-wavefield, separation was a success in most shot gathers.
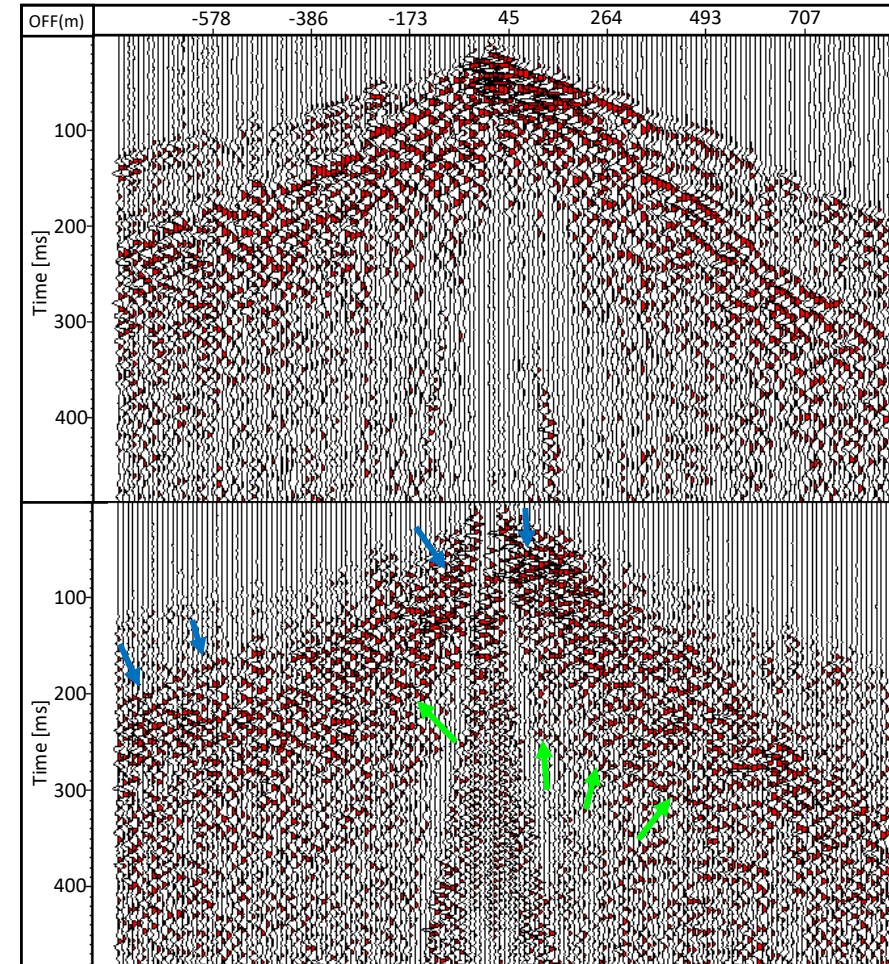
Figure 8: Raw (top) and processed (bottom) data after the application of the proposed workflow (AGC applied for better visualization). Two possible reflections marked as green and blue arrows.

icdp

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Future steps and challenges:

- Improve S-wavefield separation: There are remnants of the S-wavefield that must be removed before migration

- Improve velocity model: Travel time tomography has shown that the top of the peridotite body can be outlined. However, there is still work to do to generate a velocity model at greater depths

- The 3-component data will be used to separate the P- and S-wavefields

- After finalizing a processing workflow for Line 1, a similar processing workflow will be applied to Lines 2 and 3

- Data from Lines 1,2 and 3 will be combined to derive a 3D model of the Balmuccia Peridotite

- Data from the horizontal components will be used to analyze the Vp/Vs ratio and anisotropy in the area

- The structural complexity of the area encourages the use of advance imaging techniques, such as P-S-wave and diffraction imaging

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