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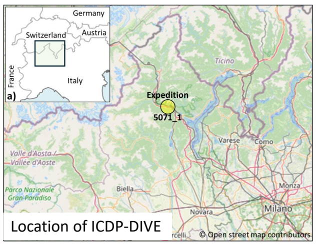
Scientific drilling of the Lower Continental Crust

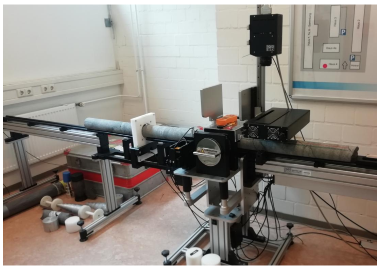
Insights from borehole geophysics and core logging



Location of ICDP-DIVE

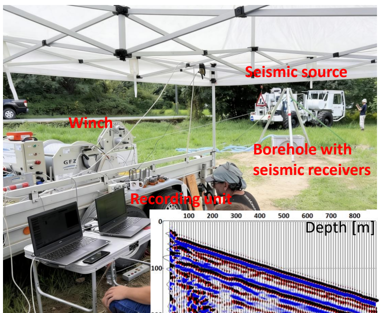
The International Continental Scientific Drilling Program (ICDP) expedition 5071, the Drilling the Ivrea-Verbano zonE (DIVE) project, aims at drilling through the lower continental crust–mantle transition for the fist time in history. A focus of DIVE is the physical and petrological transition towards the crust–mantle boundary at key sites in the Ivrea Zone of the Italian Alps. Geophysics plays an important role in linking physical, structural and lithological parameters of the subsurface.

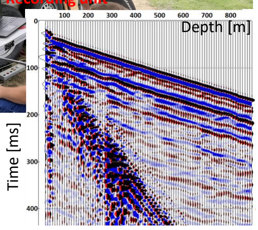
Core logging: Multi-Sensor-Core-logger used at BGR in Berlin



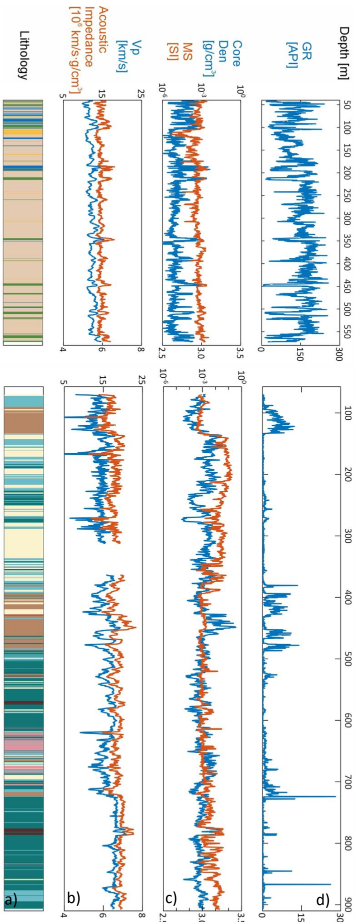
Well logging at borehole 5071_1_B:

Vertical seismic profiling at borehole 5071_1_A:





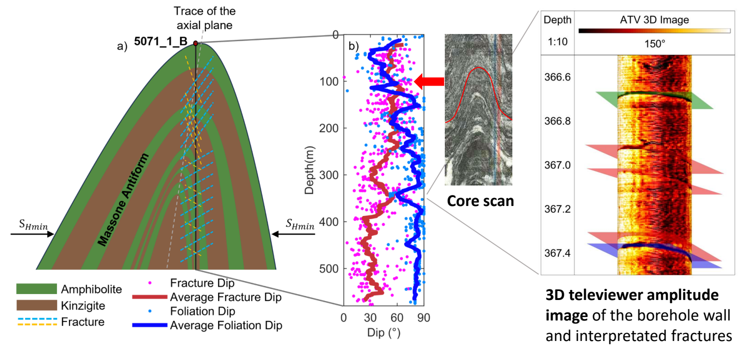
Recorded VSP data



Lithology legend
- Amphibolite
- Kinzigite
- Calcsilicate
- Leucosome
- Anorthosite
- Gabbro
- Garnetite
- Gabbronorite
- Garnet granulite
- Intrusive gabbronorite
- Pyroxenite
- Stronalite

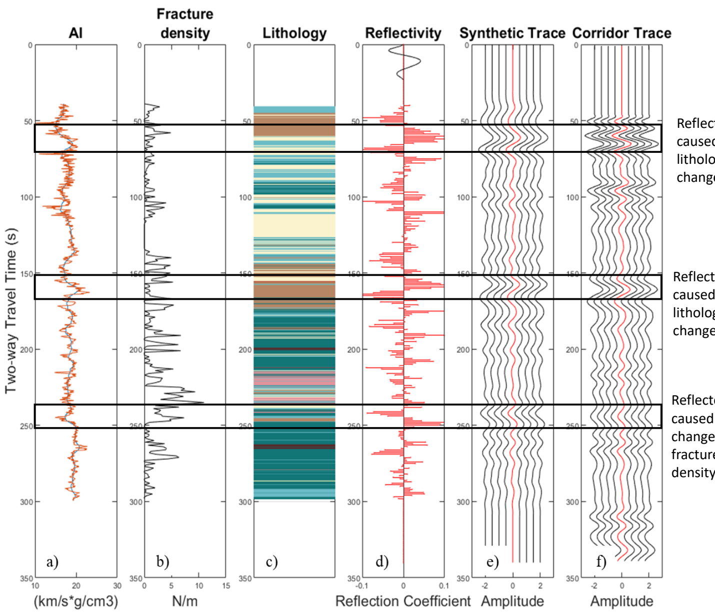
Selected core and well logging data: a) Core lithology, b) Sonic P-wave velocity (Vp), Acoustic Impedance, c) Core Density (Core DEN), Magnetic susceptibility (MS) and d) Gamma ray (GR)

Structural characterisation from acoustic and optical televiewer data of borehole 5071_1_B: a) Interpretation of the Massone-anticline overlain by interpreted fractures b) Fracture and foliation dip derived from televiewer and core data.



3D televiewer amplitude image of the borehole wall and interpretated fractures

Origin of reflectivity of lower crustal rocks: Comparison of vertical seismic profiling (VSP) data of 5071_1_A (f: Corridor trace) with a synthetic trace (e) modelled from well log and core data to identify the origin of reflections. a) Acoustic impedance (AI) log, b) Fracture density from acoustic televiewer data c) lithology column and d) reflectivity series (red) and seismic wavelet (black) extracted from the VSP data



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DIVE – Drilling the Ivrea-Verbano zonE

icdp

FWF

The research is supported by the DIVE science team and partners: https://dive2ivrea.org/

Using Drill Bit Vibrations as a Passive Seismic Source

Assessing the detectability of extremely weak continuous signals

In an FWF-funded project we work towards using the very weak vibrations of a diamond core drill bit that we recorded with a surface array of 45 sensors (Fig. 1) during a scientific drilling project in the Western Alps for seismic imaging. Diamond core drill bits generate much weaker seismic energy than conventional drill bits (e.g., tricone bits), because they gently grind into the rock rather than breaking it through strong impacts. The study examines whether seismic signals from such a weak source can be detected. With further processing, these signals can reveal information about the subsurface.

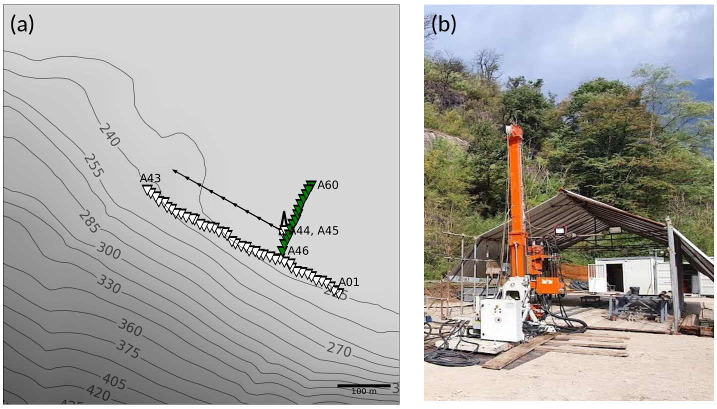

Figure 1: (a) Seismic sensor array and (b) an example of a typical drill rig.

By applying cross-coherence between sensor pairs, coherent continuous vibrations can be enhanced and made visible (Fig. 2).

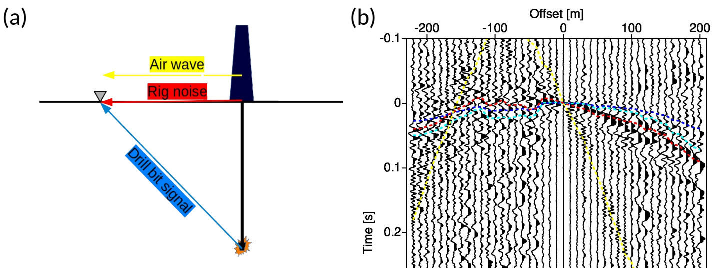

Figure 2: (a) Sketch of the expected seismic phases and (b) cross-coherence function between station 23 and all other stations with the expected arrival times of the different seismic phases highlighted in corresponding colours.

We then apply time shifts to the cross-coherence traces based on trial source positions and evaluate the aligned signals using semblance analysis. The required time shifts are calculated from a velocity model derived by up-scaling a 1D sonic log (Fig. 3).

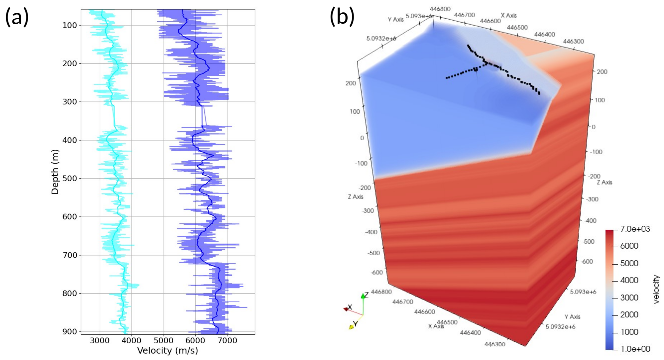

Figure 3: (a) 1D sonic log (b) up-scaled 3D velocity model

Peaks in semblance reveal where weak vibrations align, making continuous drill bit signals visible in the subsurface. Synthetic tests show that sources can be detected up to a signal-to-noise ratio of 1/40 (Fig. 4a). However, under real field conditions, the drill bit signal cannot be reliably detected (Fig. 4b).

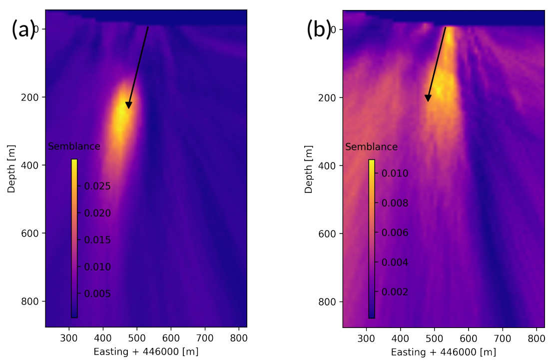

Figure 4: Semblance images for (a) a synthetic drill bit signal with observed background noise and (b) an observed drilling operation.

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