# Reflection Seismic Surveys to site the **D**rilling the **I**vrea-**V**erbano zon**E** (**DIVE**) proposed drill-holes, Val Sesia and Val d'Ossola, Italy.

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DIVE

DRILLING THE IVREA-VERBANO ZONE

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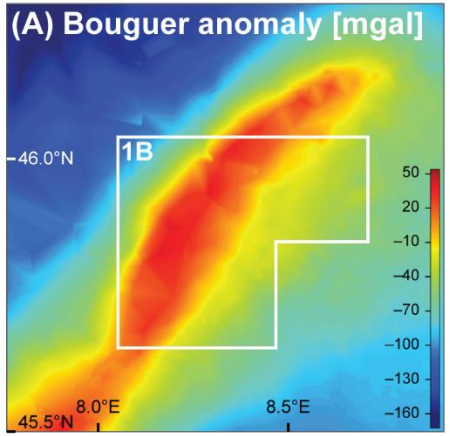
# Drilling the Ivrea-Verbano zone
# Scientific Aims

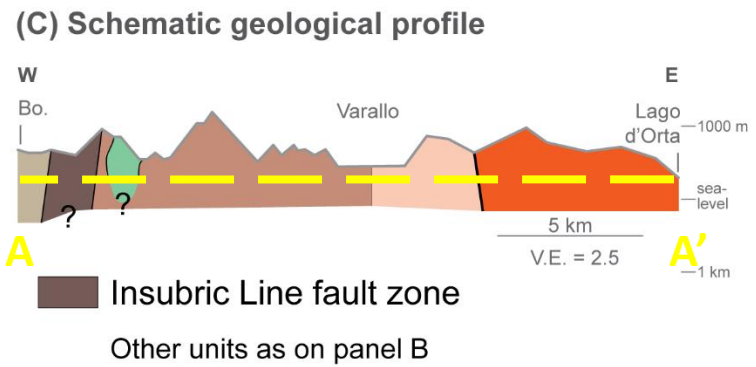
**Improve our understanding of the processes that generate and modify the continental lower crust and Moho transition zone.**

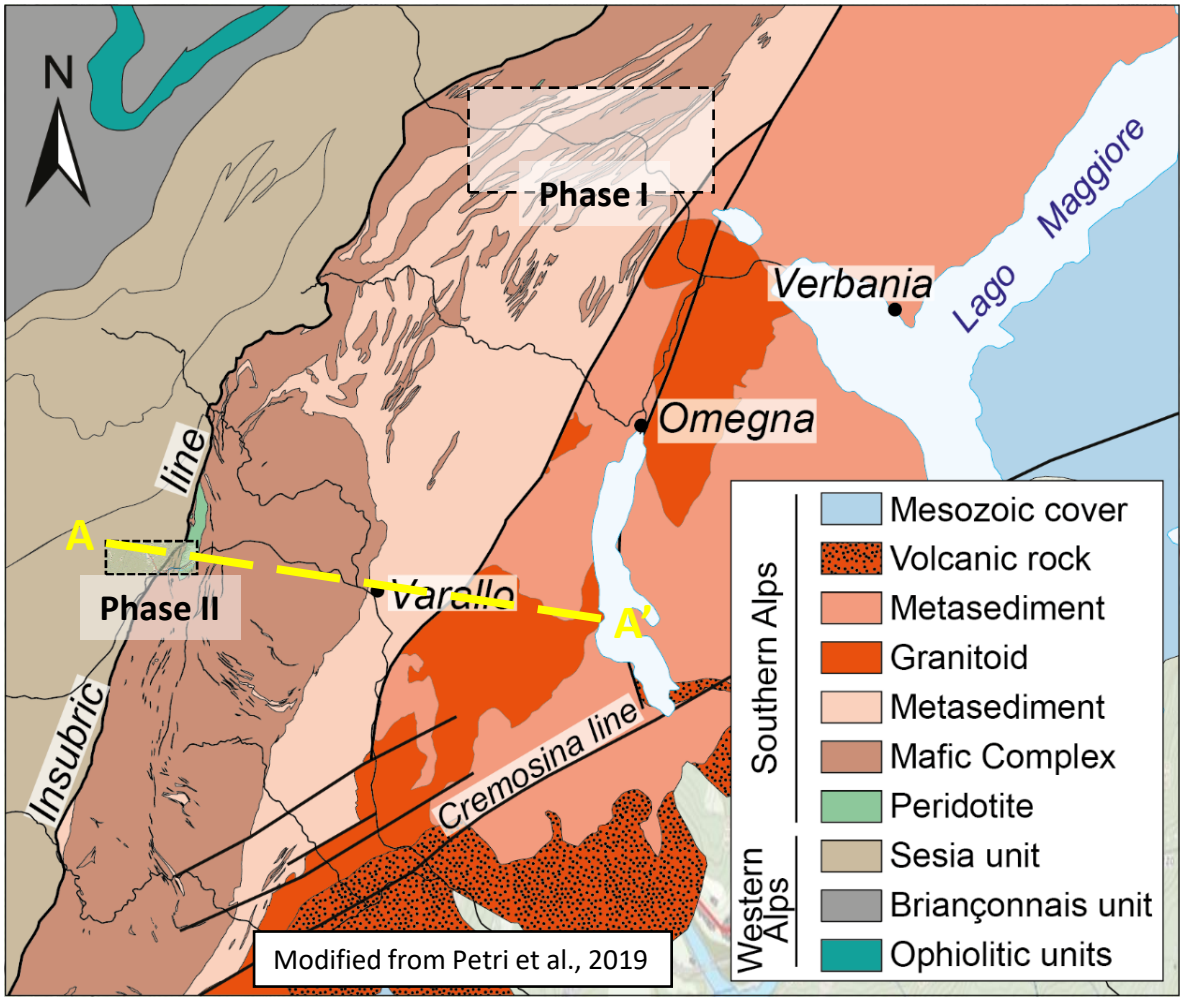
Quantifying the key features of the deep structure and composition of the continental crust–mantle transition zone. (characterisation of **mineral and bulk composition**)
Systematic **refining of relative and absolute chronology of events**
**Characterisation of physical properties** of the drilled sections to improve techniques **for identification of seismic reflectors** and for understanding their nature.

Study of present-day **fluid-rock interaction in crystalline rocks** and **fluid flow/rock permeability along major tectonic structures** study the beginnings of serpentinization processes **Describing extreme niches for hosting microbial life in planetary interiors**

The past and current tectonic and seismic activity around each drill hole will be investigated by a combination of **borehole stress-field measurements,** structural observations, and a dedicated local seismic network.



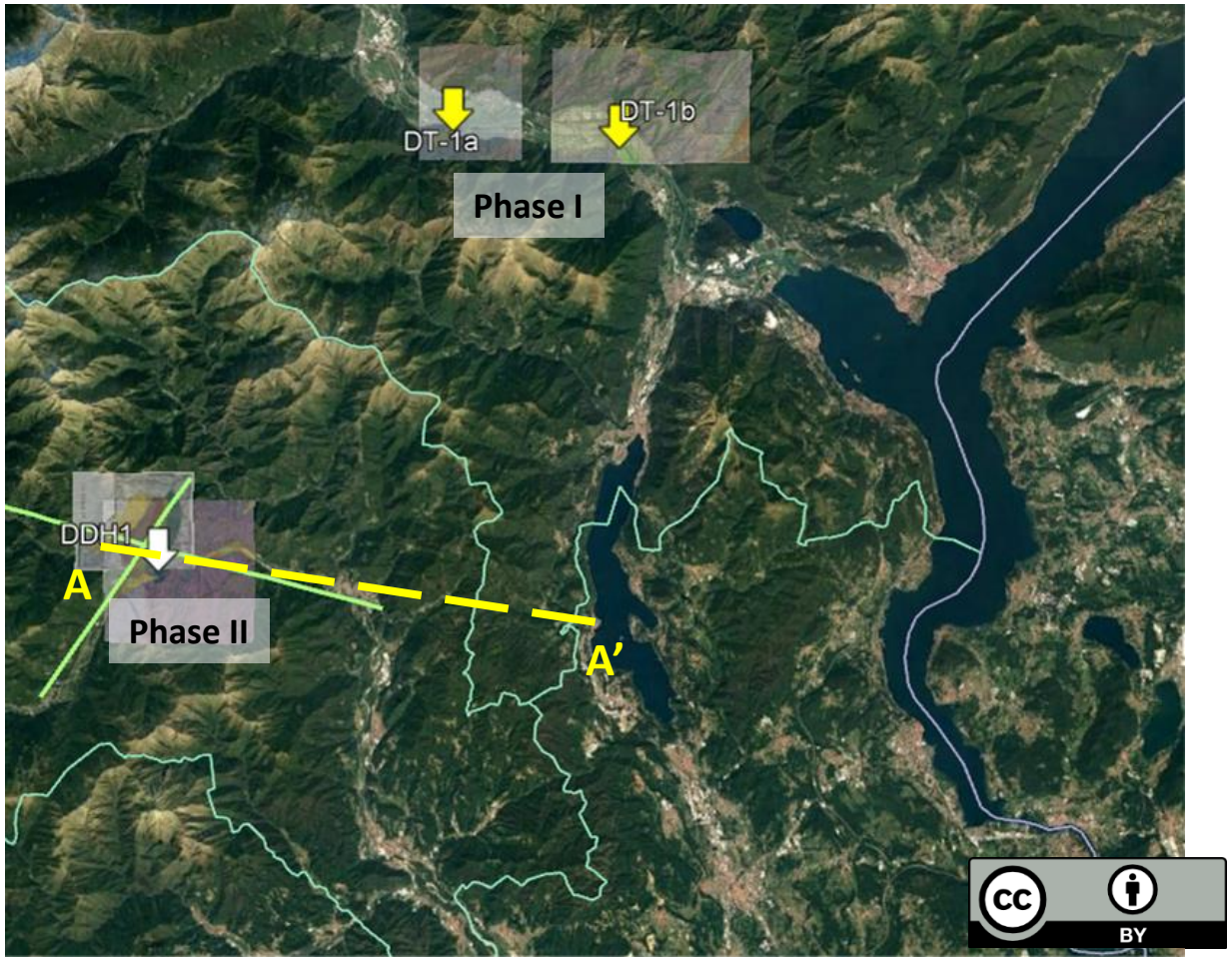

Modified from Petri et al., 2019

**Phase I** – ***pre-Permian mafic and felsic lower crust***

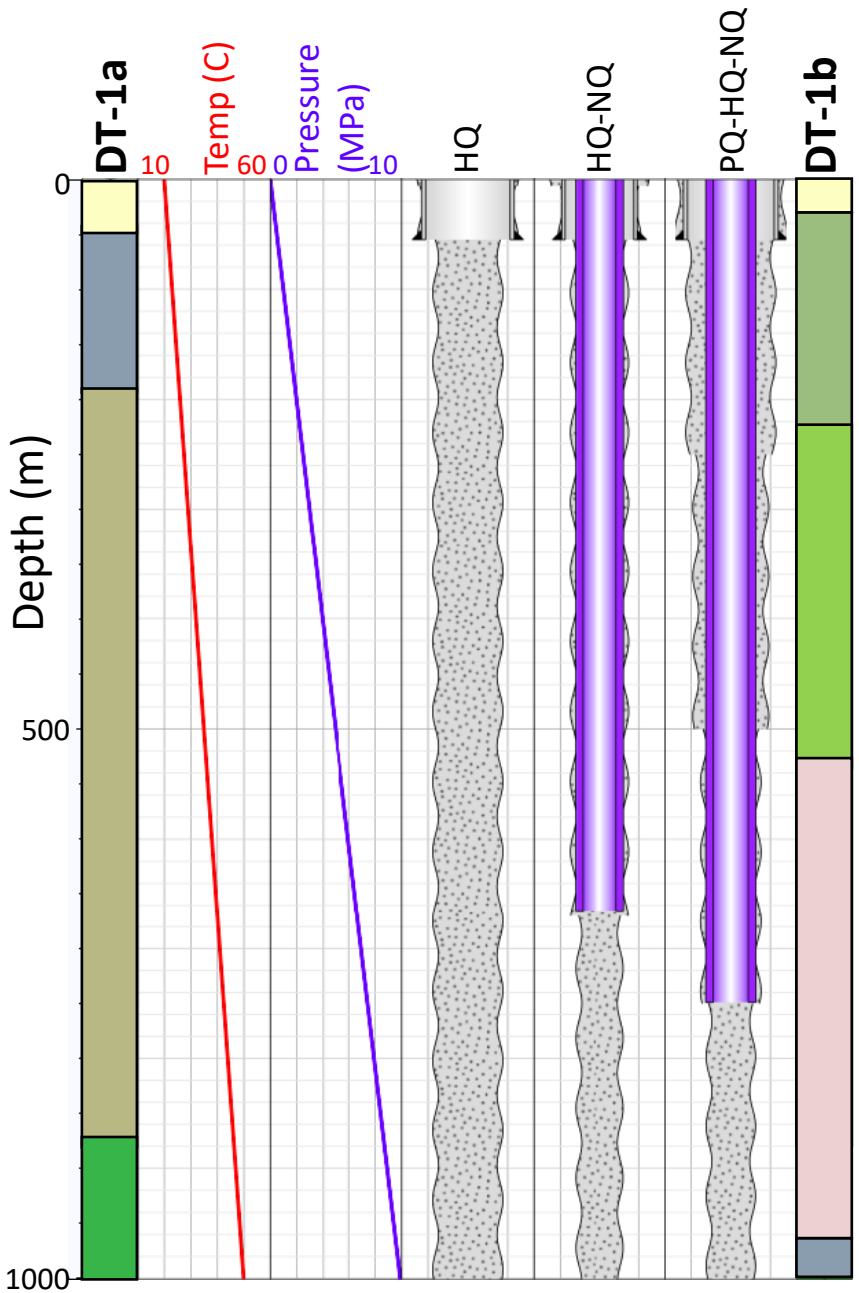
- Megolo (**DT-1a)**: drilling into the dominantly mafic to ultramafic lower crust
- Ornavasso (**DT-1b**): drilling into the pre-Permian dominantly felsic lower crust

**Phase II** – ***Permian lower crust upper mantle***

- 1 x 4000 m drill-hole



# Phase 1 Drilling strategies




**Expected Lithological units**

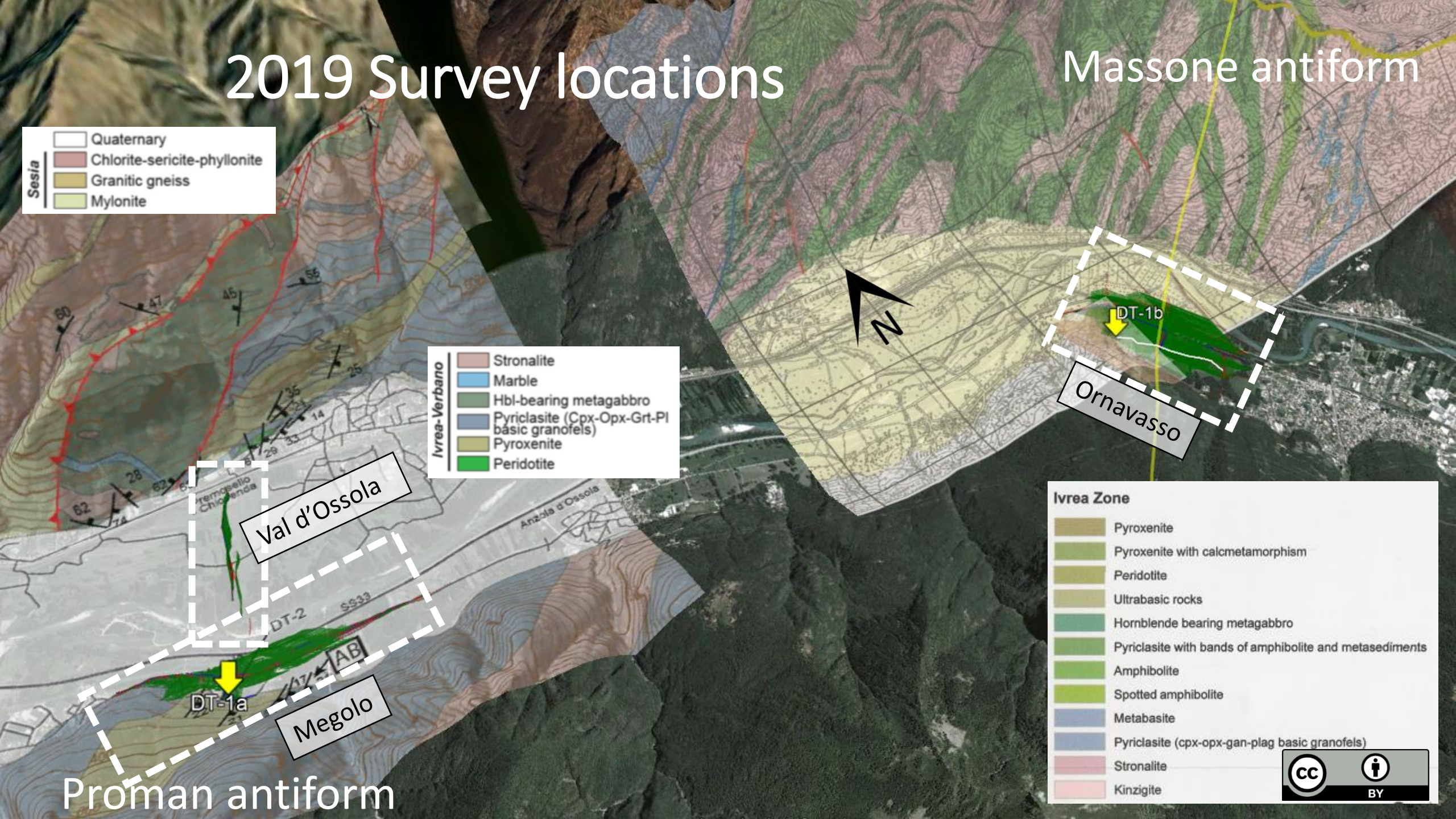
- Quaternary
- Pyriclasite (banded with amphibolite)
- Amphibolite
- Kinzignite
- Metagabro
- Pyroxenite
- Peridotite

**Phase I** – ***pre-Permian mafic and felsic lower crust***

- Megolo (**DT-1a)**: drilling into the dominantly mafic to ultramafic lower crust
- Ornavasso (**DT-1b**): drilling into the pre-Permian dominantly felsic lower crust

# 2019 Survey locations

Massone antiform



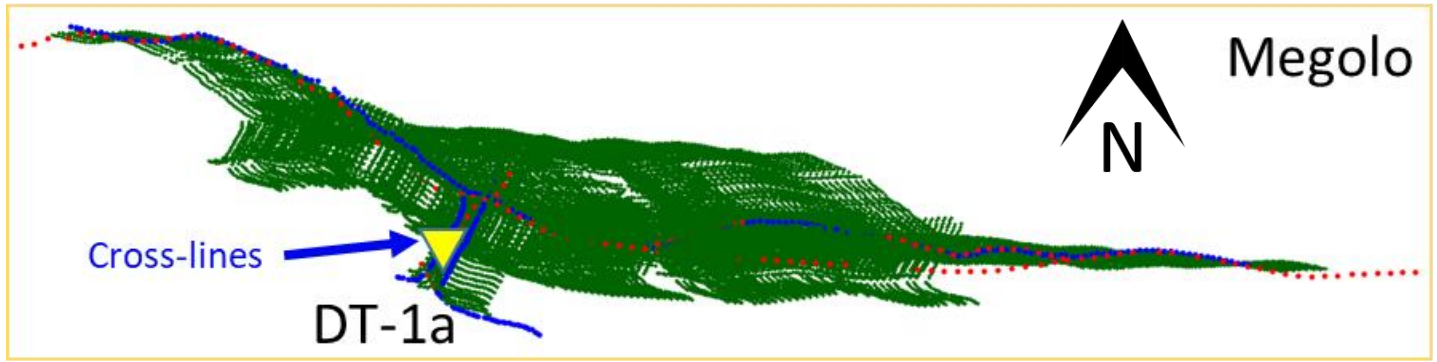

Proman antiform

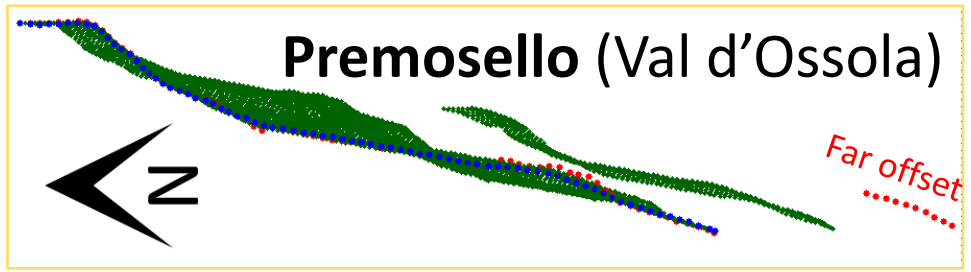
# Acquisition – June 2019

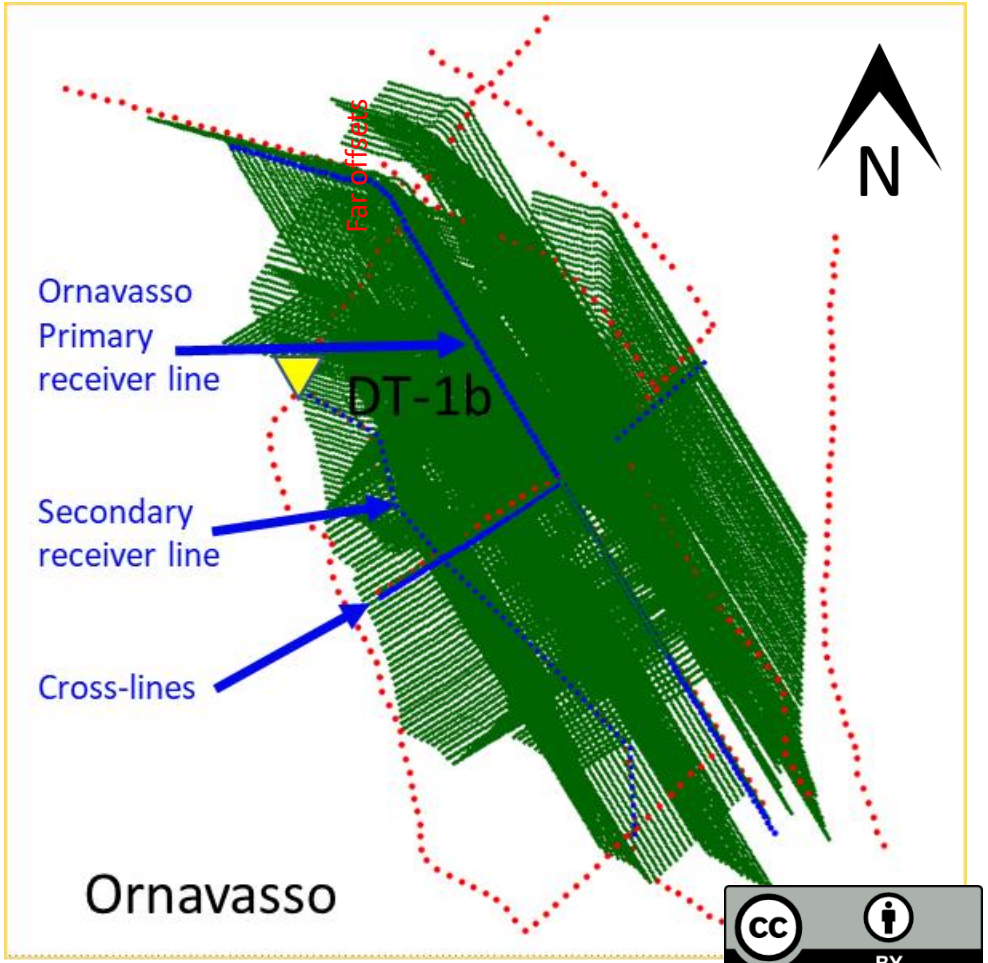
**SOURCE**

EnviroVibe (Courtesy GEO2X)
Sweep – 12-150 Hz linear
12 + 4 seconds

- Receiver's 15 Hz geophones
- Summit X distributed system 240 channels @ 10 m
- GEODE Distributed system 96 Channels @ 5 m



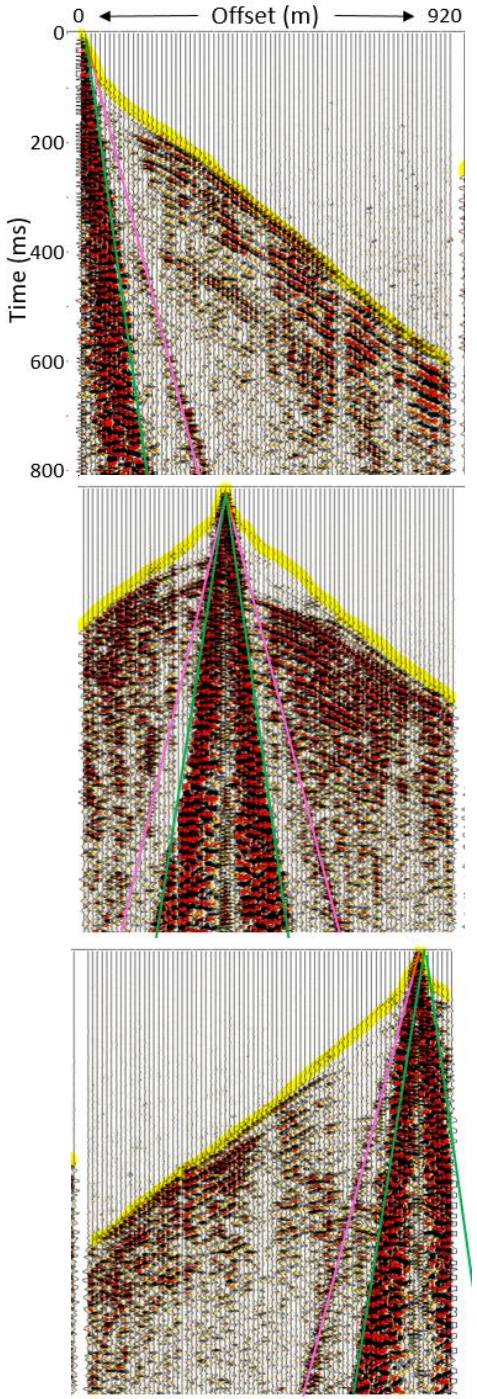

Proposed drilling site

Common-mid-point

Receiver (geophone)

Source (Vibe-point)

# 2019 – First round processing




Example shot records – Ornavasso Secondary line

## Pre-stack Processing

- *Geometry of data*
- *Shot and Trace editing*
- *Predictive deconvolution*
- *Butterworth filtering*
- *Spherical divergence correction*

## Static corrections

- *Elevation statics*
- *First break picking*
- *Refraction modelling*
- *Refraction statics*

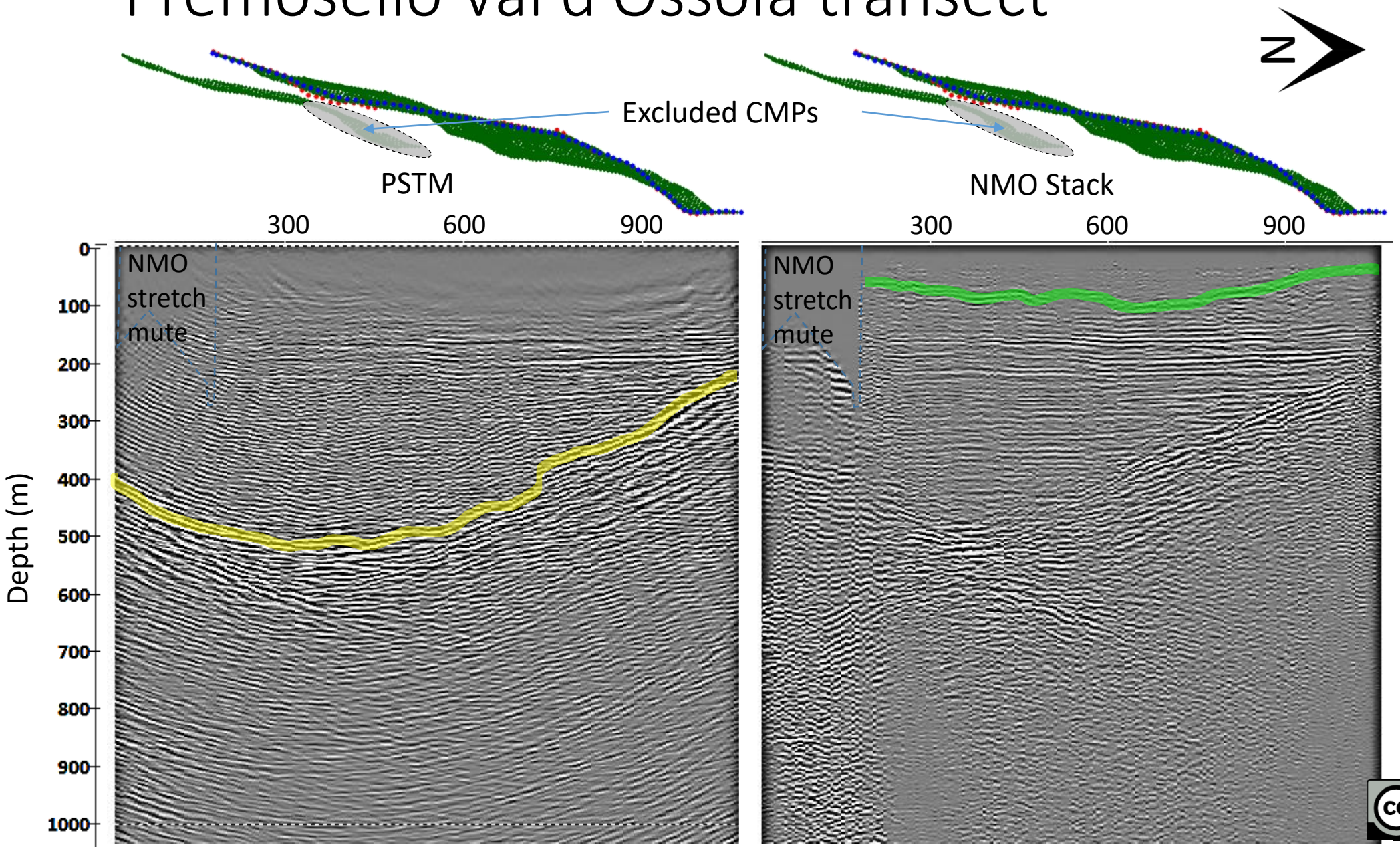
## Wavefield separation

- *f-k filtering (selectively in positive- and negative-offset domains)*
- *Top muting*
- *Ground roll removal – time variant bandpass filtering and/or bottom muting*

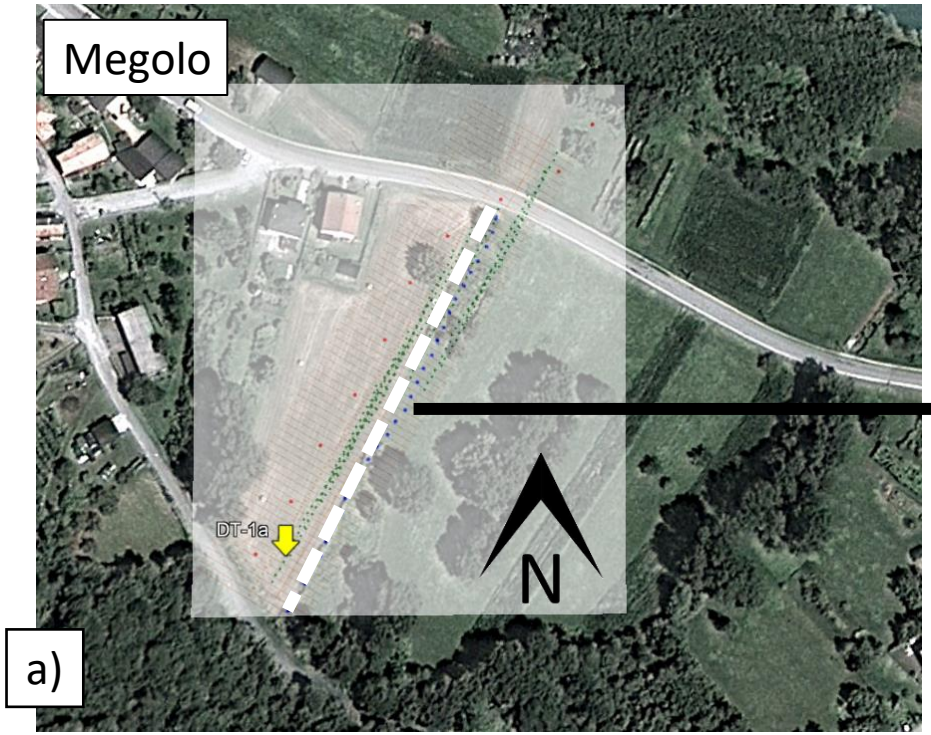
## Stacking

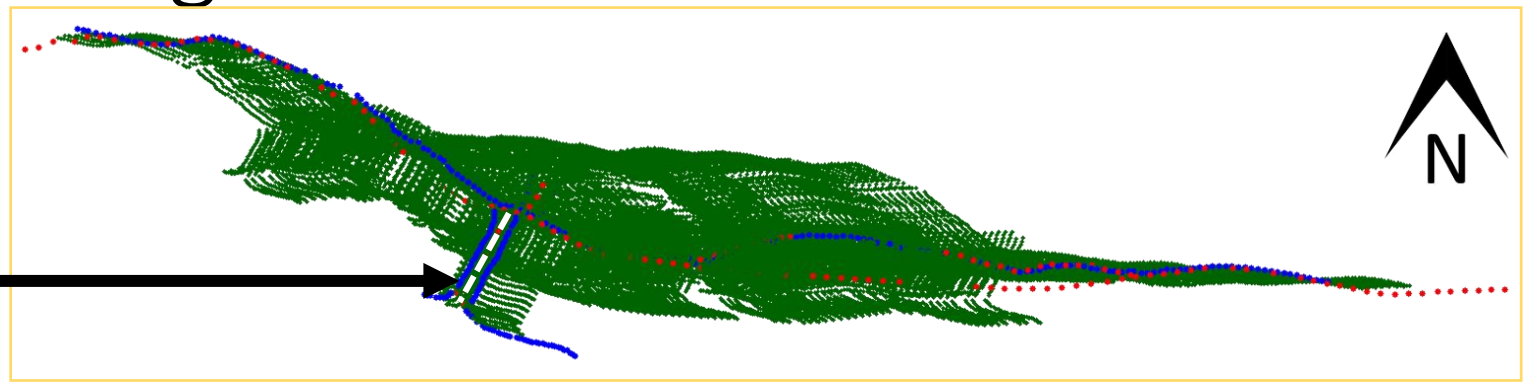
- *Amplitude balancing*
- *Normal moveout correction (NMO) (sediment velocity)*
- *Constant velocity NMO stack*
- *Velocity modelling*
- *NMO Stack (with velocity model)*
- *PSTM (with vel. model)*
- *Post-STM (with vel. model)*
- *Time-to-depth conversion (with vel. model)*

# Premosello Val d'Ossola transect

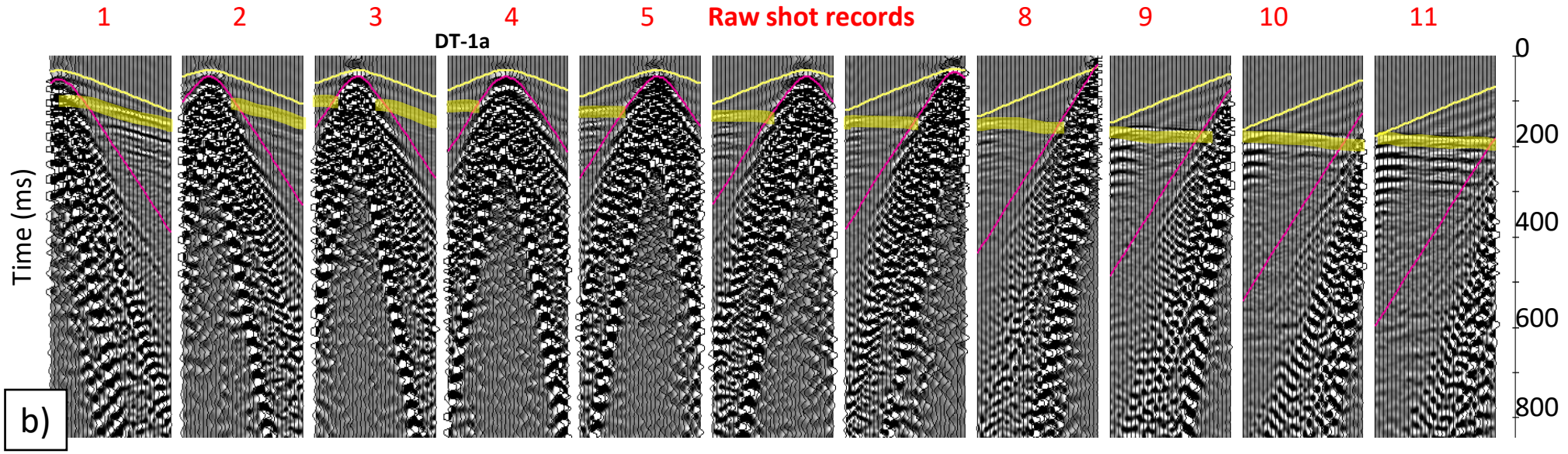


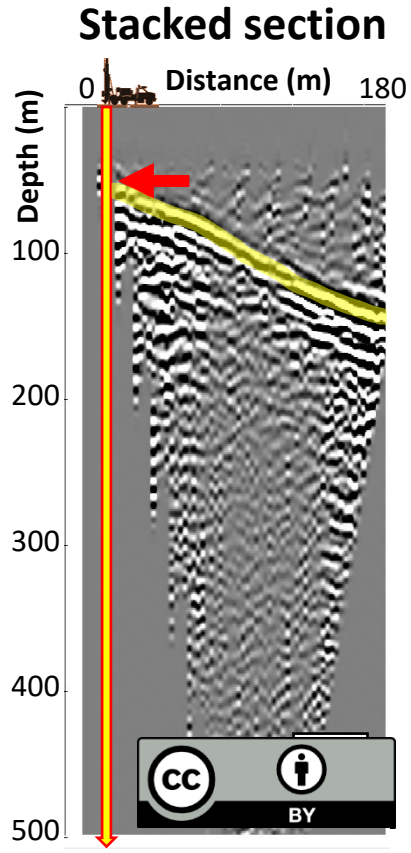
# Megolo -crossline



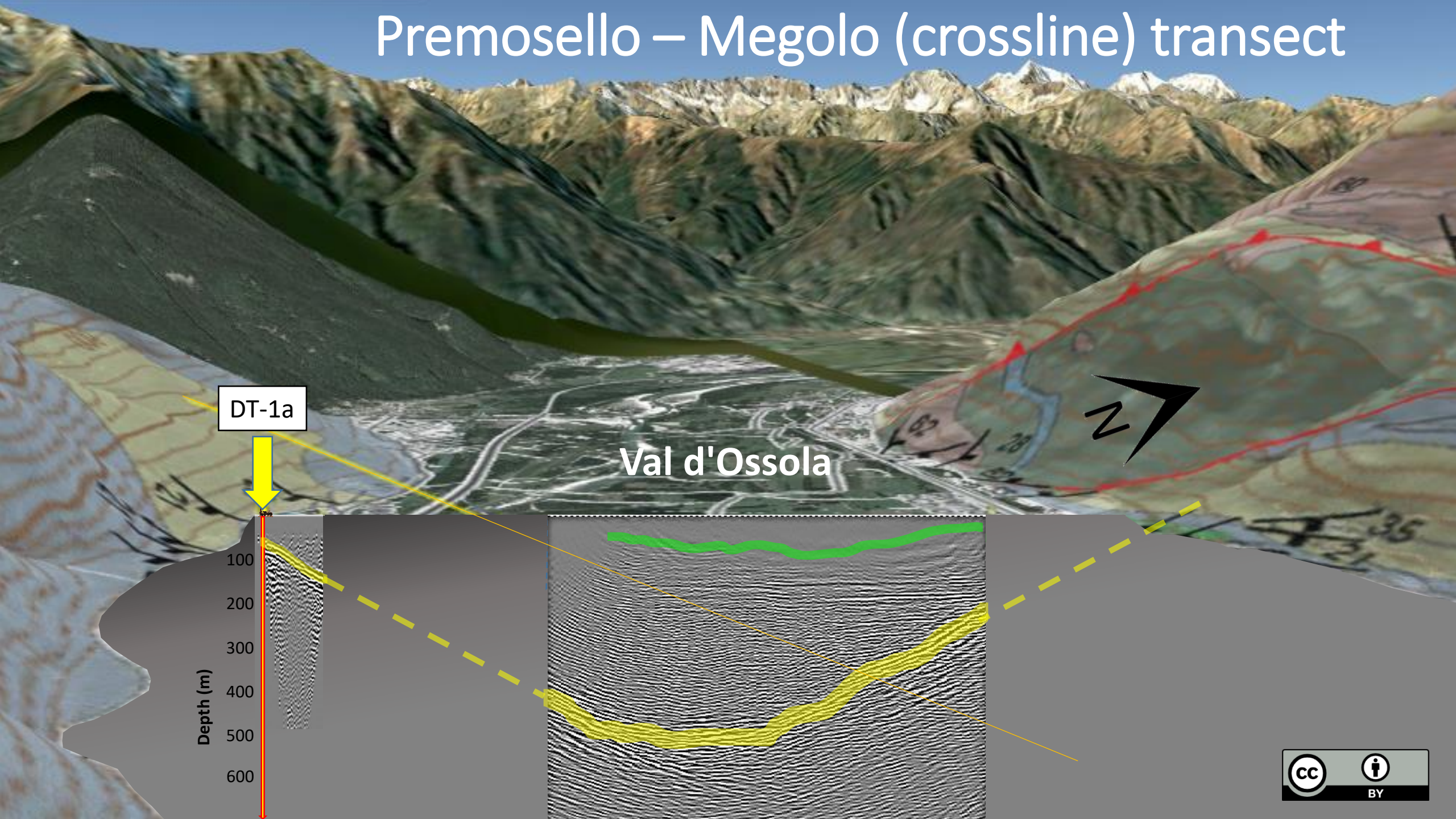




- Source location
- CMP
- Receiver location
- Dipping reflector
- Refracted wave arrival (1350 m/s)
- Air wave arrival (340 m/s)

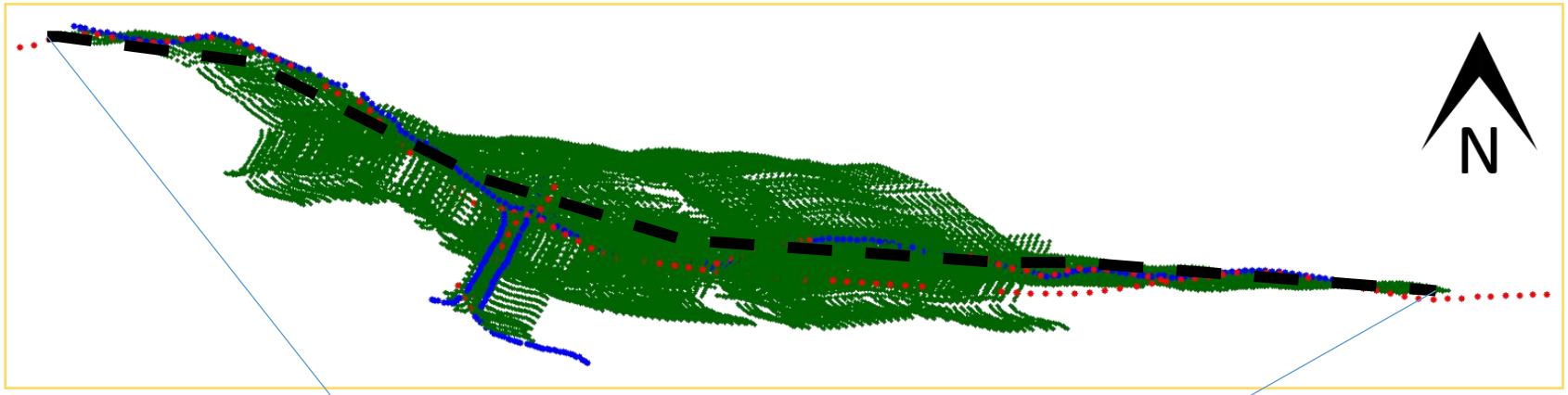


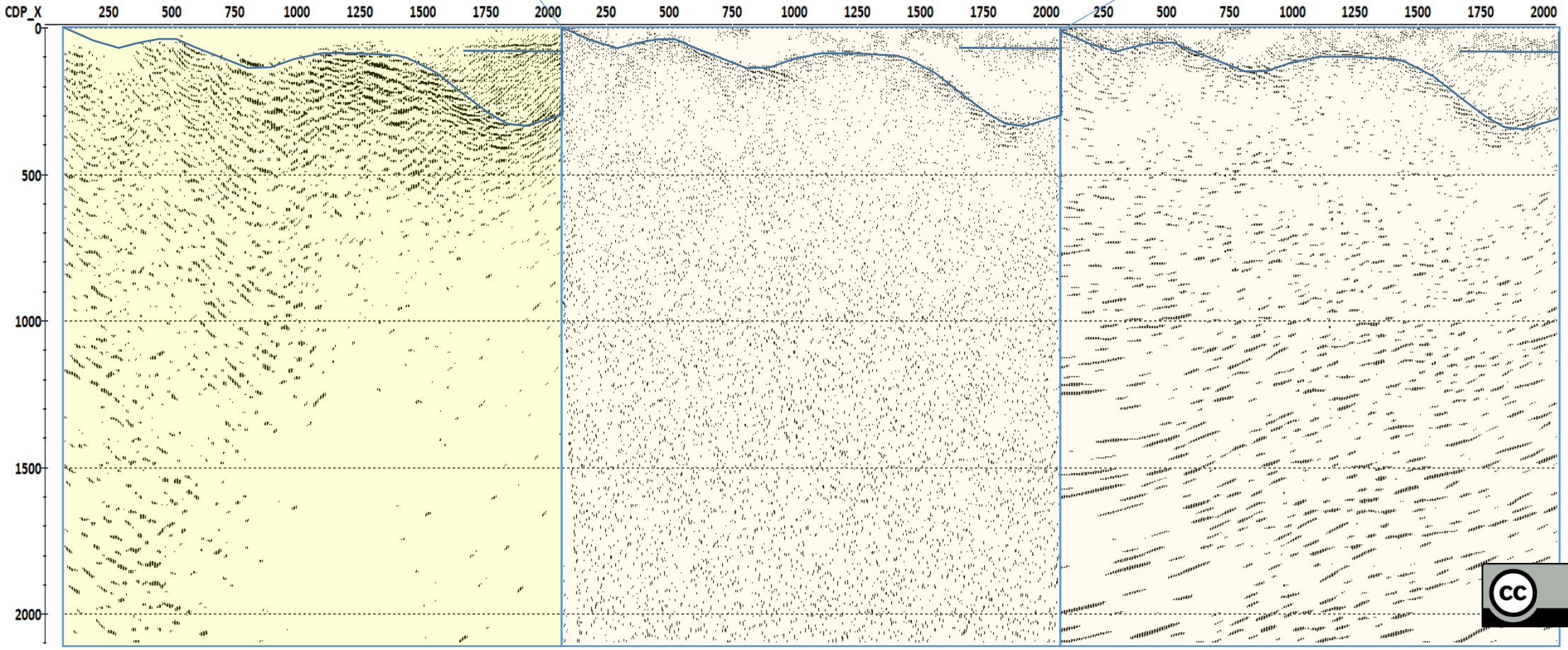
# Premosello – Megolo (crossline) transect



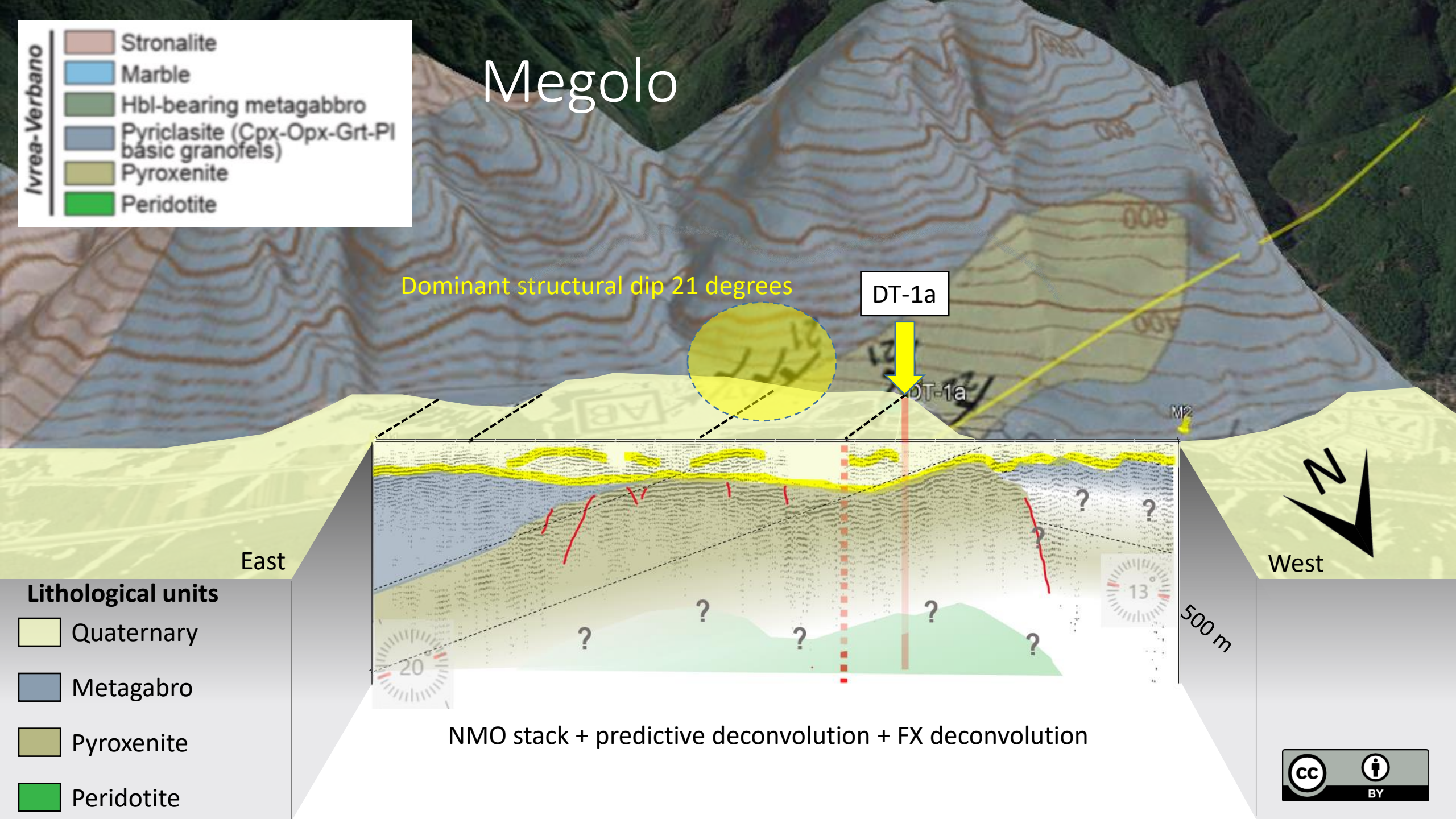
# Megolo




PSTM NMO stack PostSTM

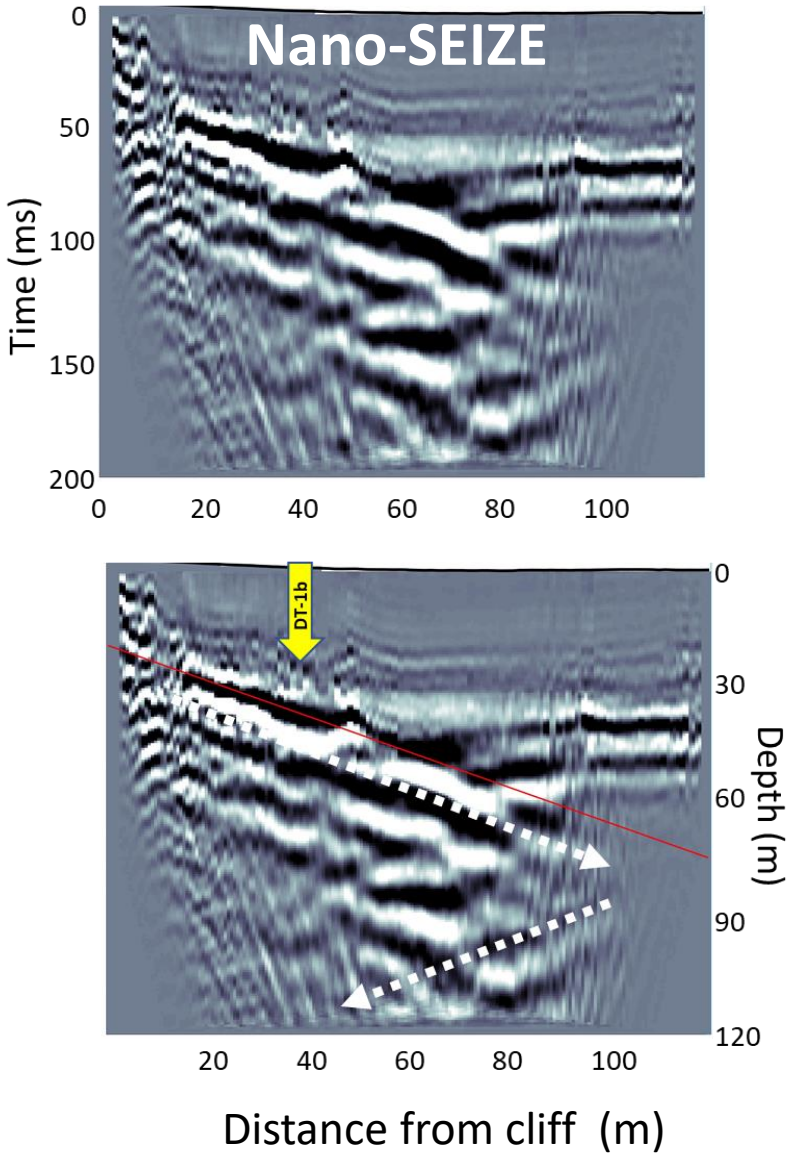


# Megolo




NMO stack + predictive deconvolution + FX deconvolution

# Ornavasso




**Primary Line**

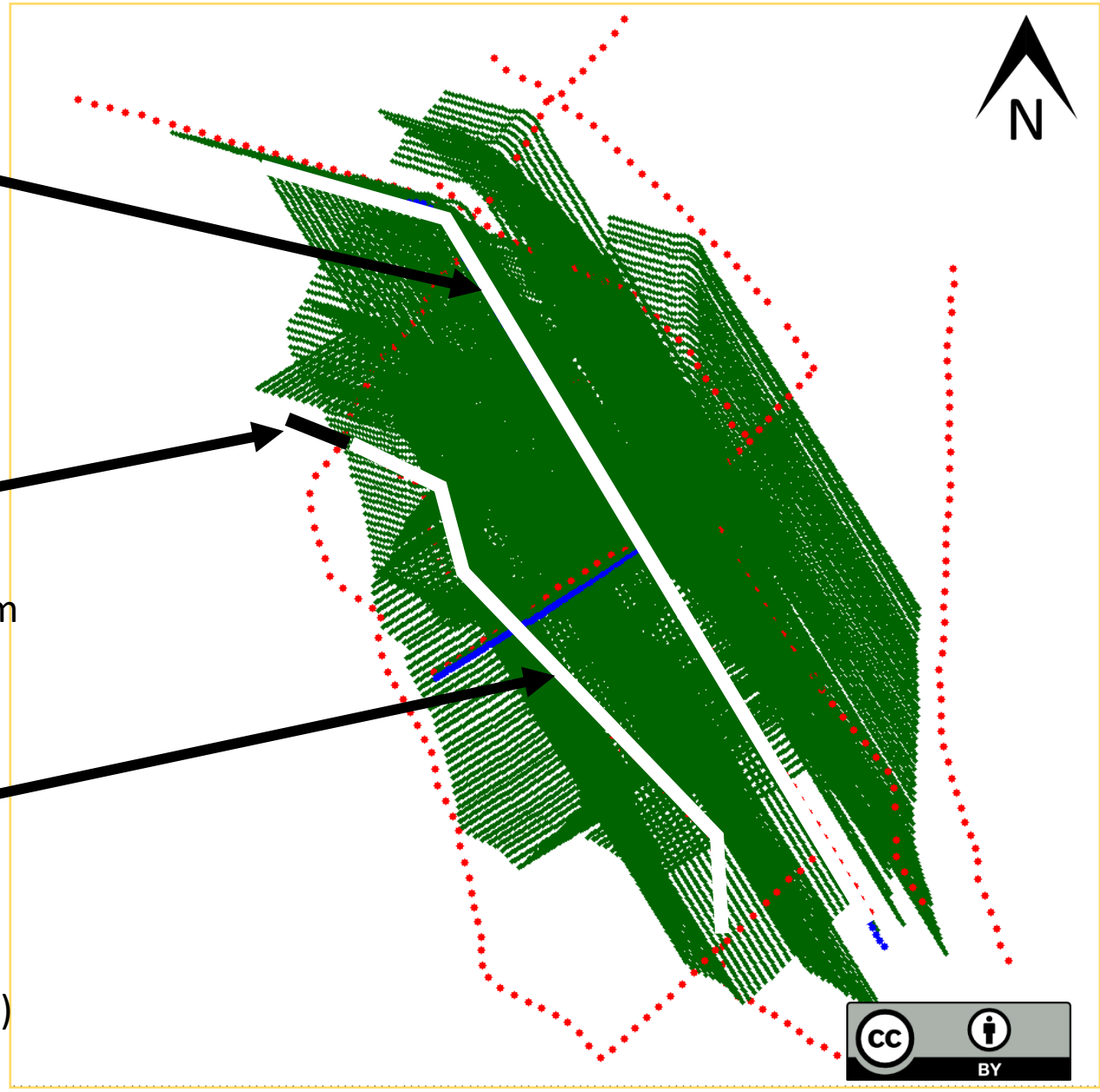
- 192 x 15Hz geophones @ 10m
- EnviroVibe (20m)

**Nano-seize**

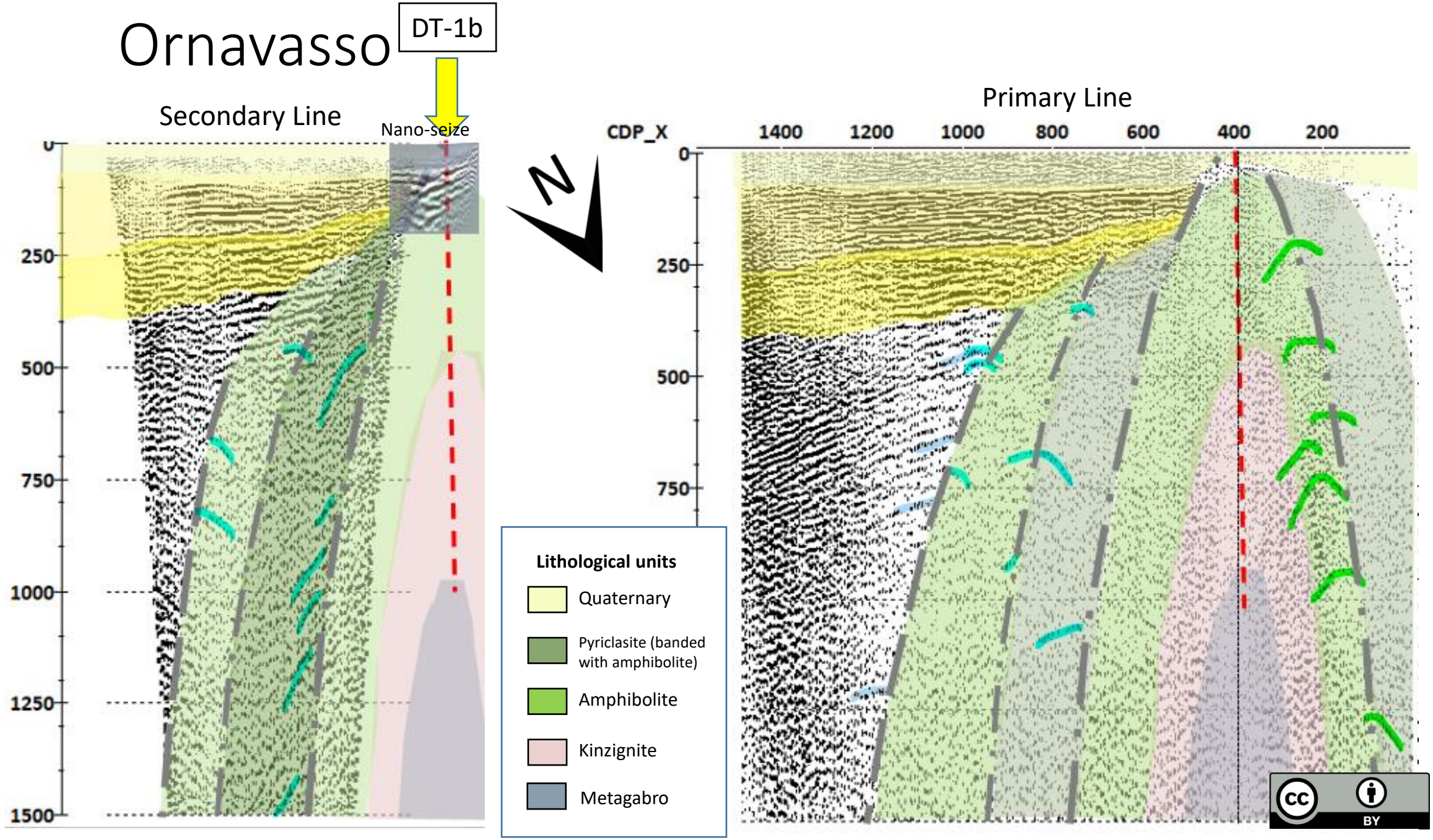
- 60 x 15Hz geophones @ 2m
- ELVIS vibrator (2m)

**Secondary line**

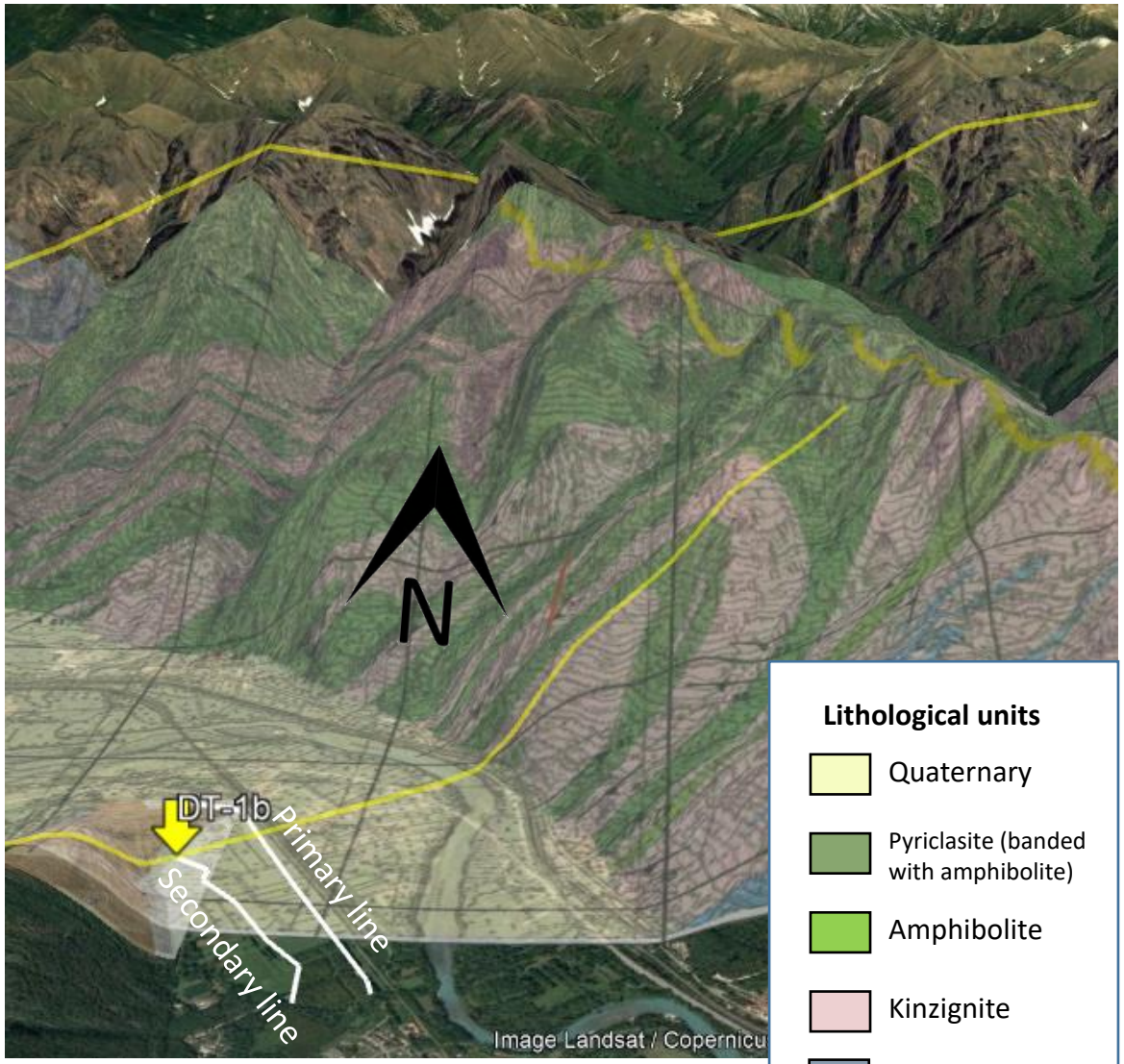
- 80 x 15Hz geophones @ 12m
- EnviroVibe (12m)



# Ornavasso

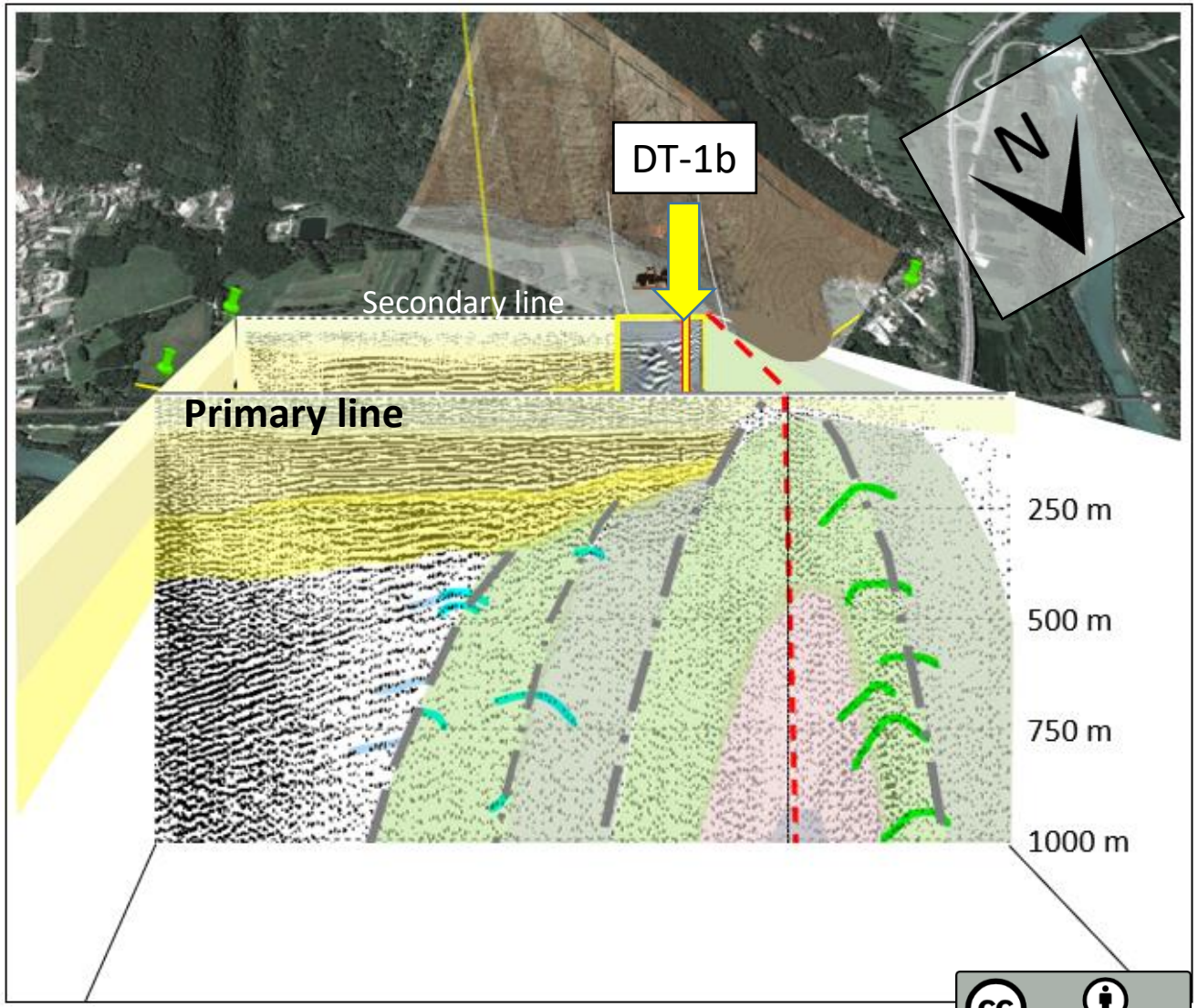

DT-1b
Secondary Line
Nano-seize
Primary Line
CDP_X
1400
1200
1000
800
600
400
200
0
250
500
750
1000
1250
1500
N
Lithological units
Quaternary
Pyriclasite (banded with amphibolite)
Amphibolite
Kinzignite
Metagabro

# Ornavasso – Massone antiform




**Lithological units**

- Quaternary
- Pyriclasite (banded with amphibolite)
- Amphibolite
- Kinzignite
- Metagabro



# Phase I Summary

- Val d'Ossola is symmetric at depth with an approximate sediment thickness of 500 m
- DT 1a and 1b have approximately 30-50 m of Quaternary overburden covering (pre)Permian crystalline rocks of interest.
- The strong acoustic impedance contrast between the Quaternary cover and crystalline rocks has enabled good mapping of the Quaternary/(pre)Permian contact at all locations but inhibits reflections from within the (pre)Permian crystalline rocks.
- Preliminary analysis of the DIVE – Phase I active surveys confirm the continuation of surface geological observations to depths greater than 1000 m through interpretation of changes in seismic characteristics at depth. Advanced processing is ongoing to improve and strengthen current interpretations.

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# Phase II – GFZ Potsdam SEIZE survey (Oct. 2020)


**GFZ- Potsdam**

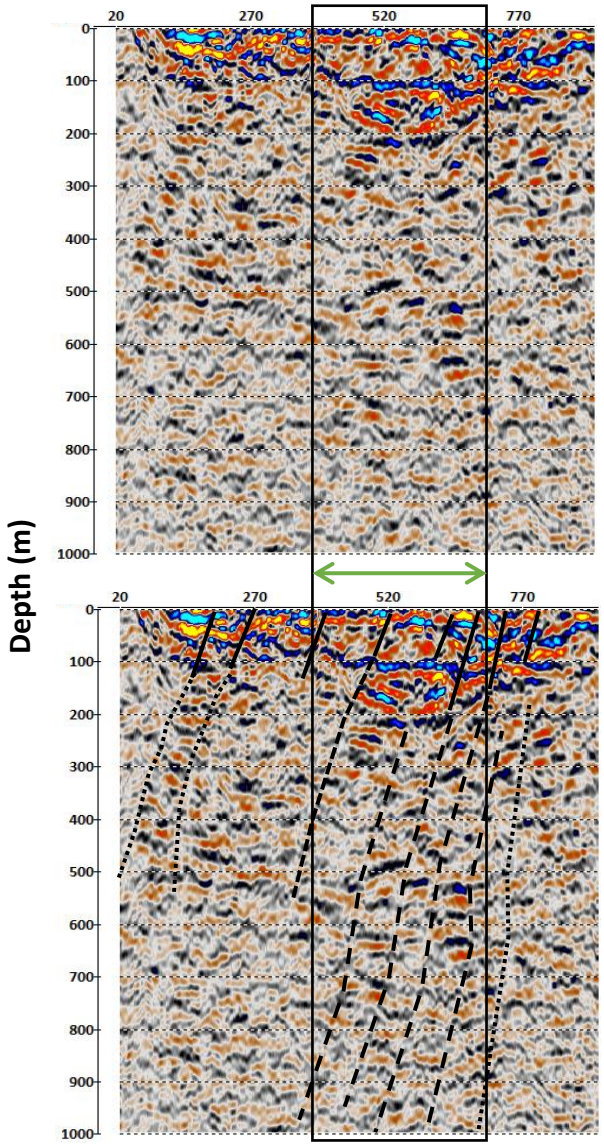
- 2 x 2D surface seismic
  - 17 km West-East
  - 11 km South-North
- 2+1 60klb Vibrators
- 400+ Seismic Cubes

**Montanuniversitaet Leoben**

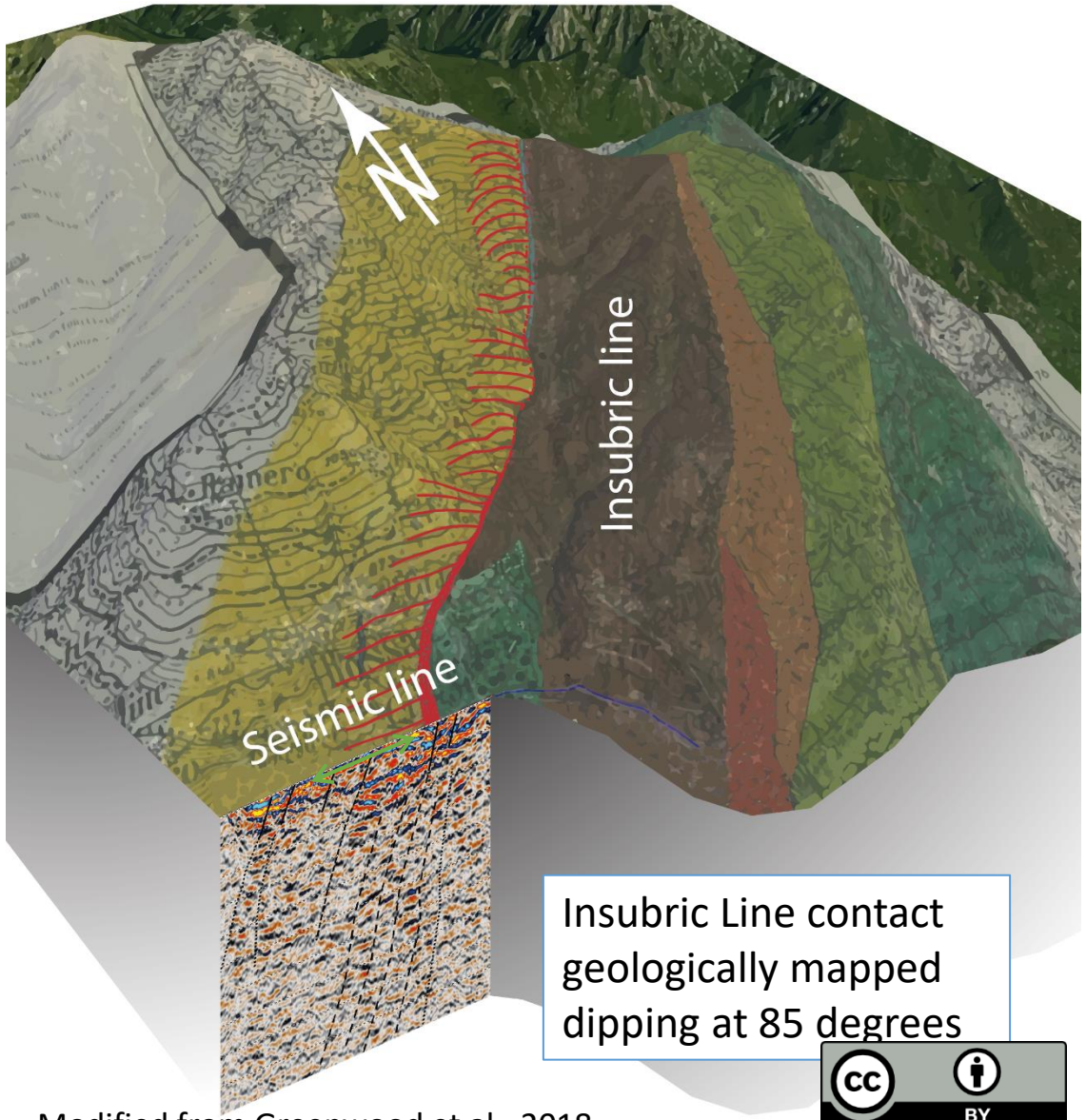
- DT-2 Focused array
- 75 Sercel UNITE’s

# Seismic reconnoitre Balmuccia 2017


192 geophone stations
144 live channels
5 m receiver stations
5 m source stations
2 stacks



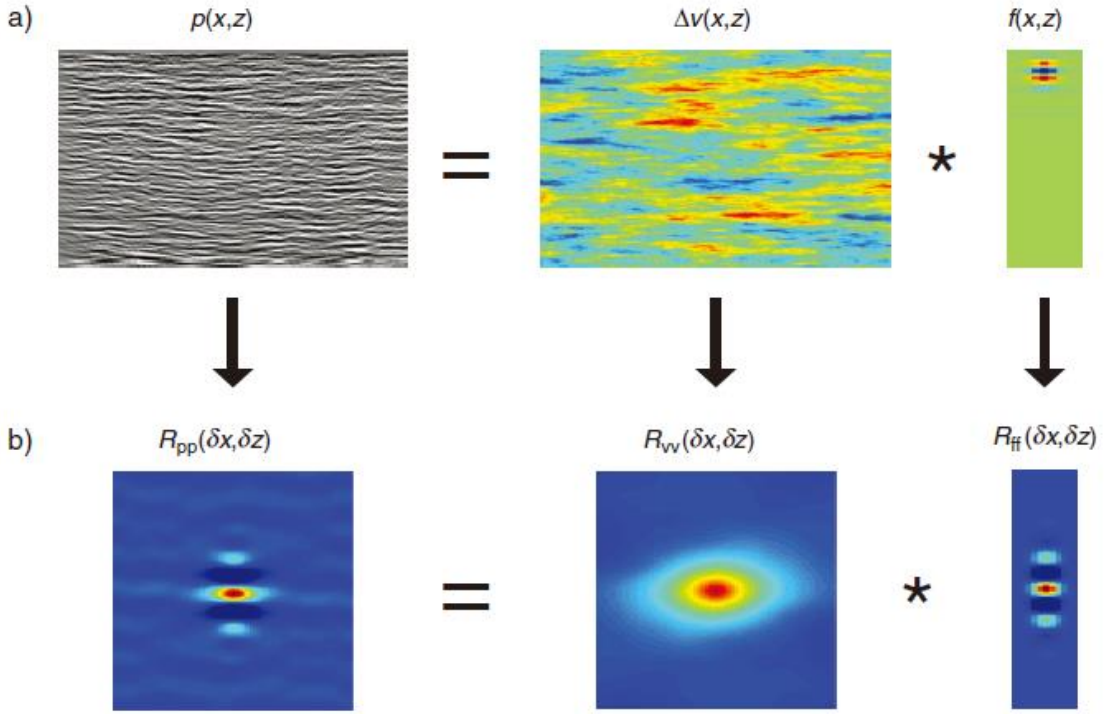

Approximately 1:1



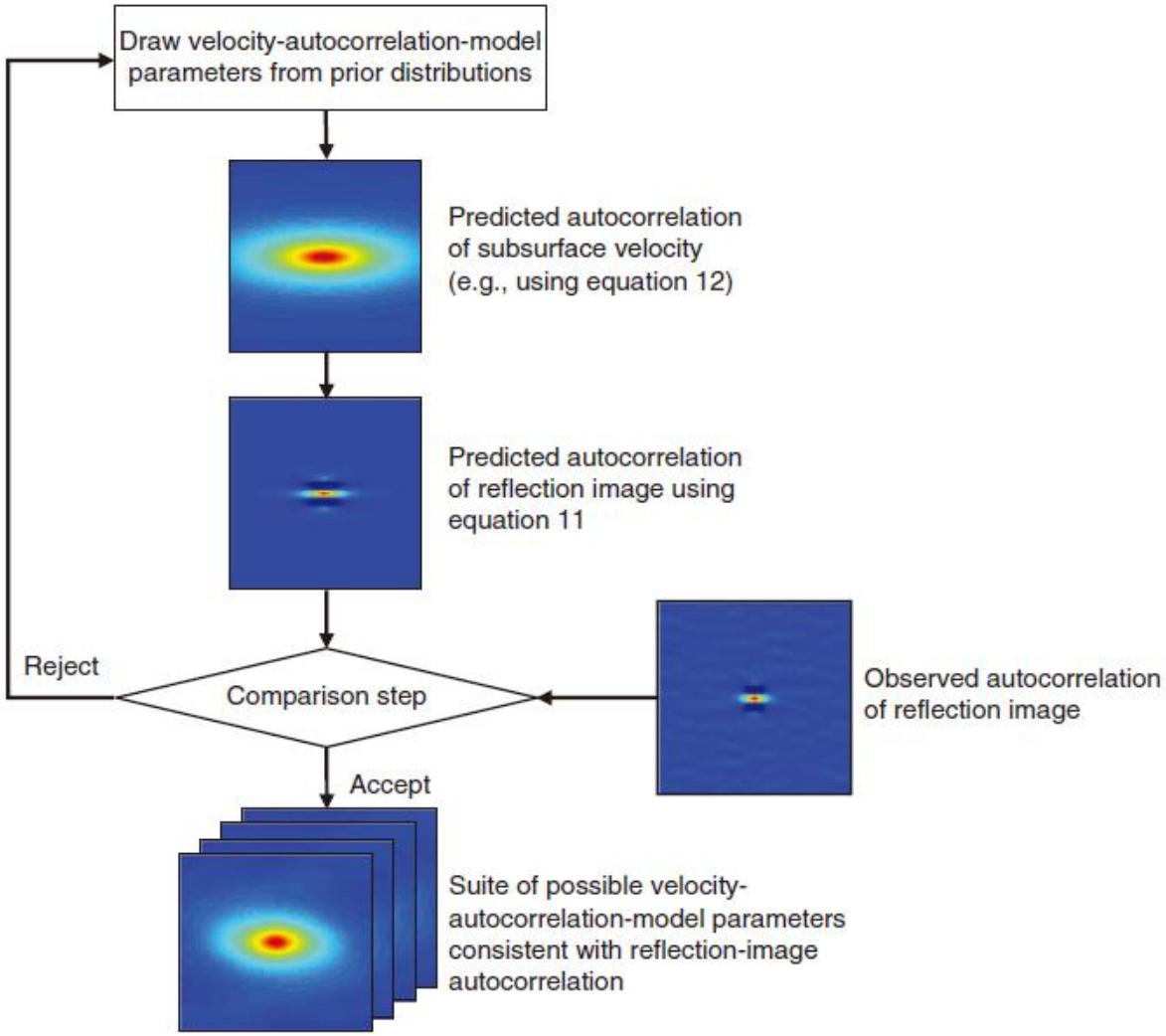

Insubric Line contact geologically mapped dipping at 85 degrees

Modified from Greenwood et al., 2018

# Geostatistical structural aspect ratio analysis of seismic images



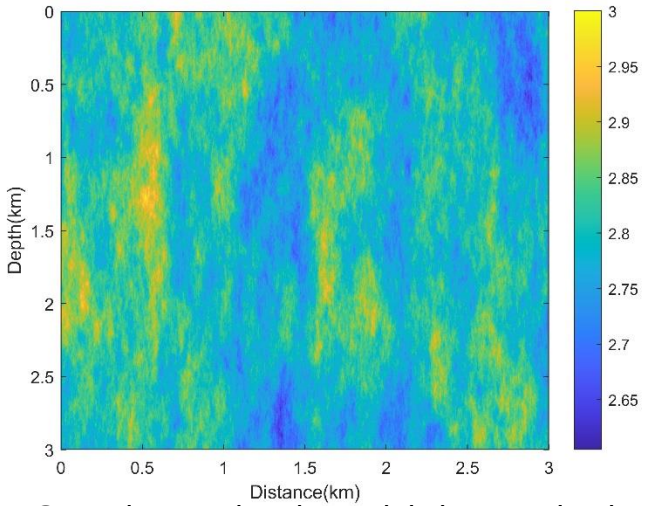

- Schematic illustration of (a) a modified PRS model, which links a seismic-reflection image to the underlying impedance perturbation field, and (b) the corresponding relationship between the 2D autocorrelations.



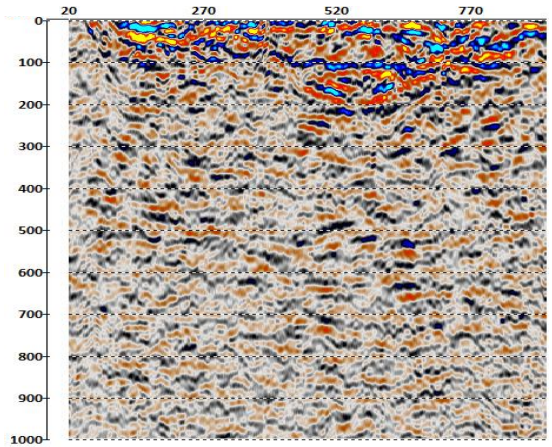

- Flowchart illustrating a Monte Carlo approach for estimating the model parameters that describe the autocorrelation structure of the impedance-perturbation field given the autocorrelation of a seismic-reflection image.

*(Irving et al., 2010)*

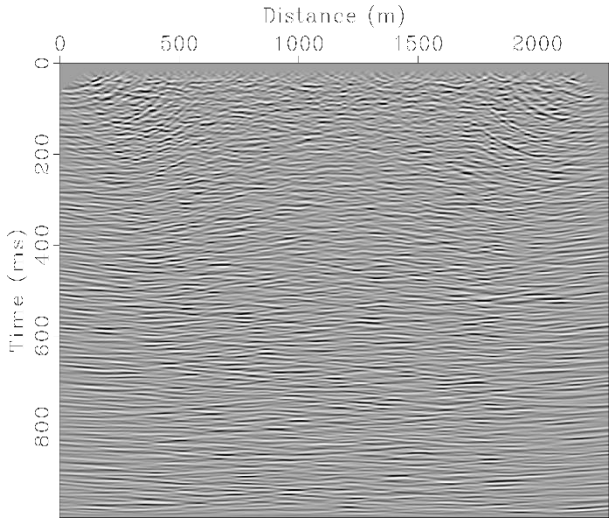
# Geostatistical analysis of synthetic and Balmuccia data



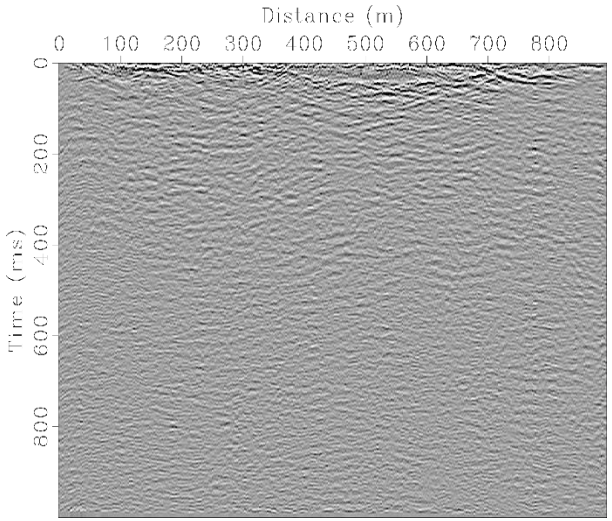

Gaussian stochastic model characterized by sub-vertical structures



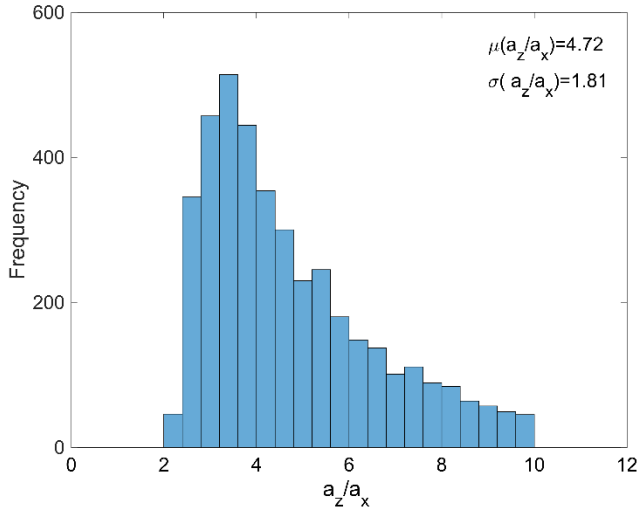
Migrated stack of Balmuccia line 1



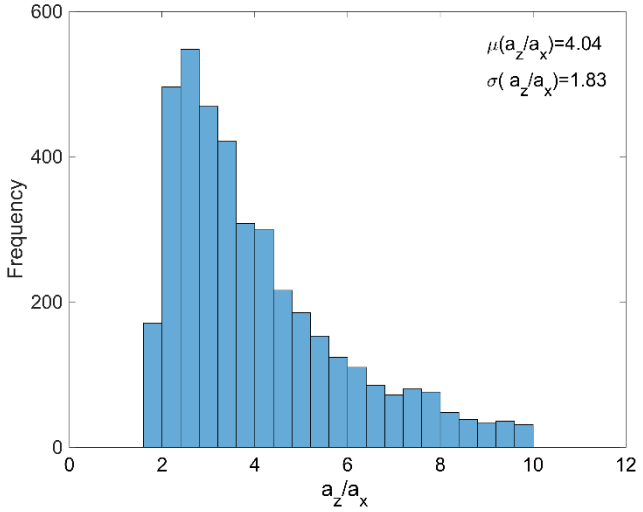

Migrated stack of elastic finite difference data from the Gaussian stochastic model




Migrated stack of Balmuccia line 1




Estimated aspect ratio of correlation structure from the synthetic data




Estimated aspect ratio of correlation structure from the field data

# Phase II Summary

- DIVE – Phase II active seismic surveys (SEIZE) are approved and planned for Oct 2020
- Geostatistical structural aspect ratio analysis of Gaussian stochastic models with vertical structures substantiate the interpretation of the migrated primary-reflectivity-section (PRS) of Balmuccia, where the structure is known to be dipping near vertically at surface.

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# References

Greenwood A, Baron L, Merz K, Langone A, Petri B, Kard AO, Zanetti A, Pistone M, Hetényi G, Weber M, Müntener O, Holliger K (2018) High-resolution seismic reflection survey across the Insubric Line, Italian Alps. *8th International Conference on Environmental and Engineering Geophysics, 10-14 June 2018, Hangzhou, China.*

Irving, J. and Holliger, K., 2010. Geostatistical inversion of seismic and ground-penetrating radar reflection images: What can we actually resolve?. *Geophysical research letters*, *37*(21).

Petri, B., Duretz, T., Mohn, G., Schmalholz, S. M., Karner, G. D., & Müntener, O. (2019). Thinning mechanisms of heterogeneous continental lithosphere. *Earth and Planetary Science Letters*, *512*, 147-162.