Smart Exploration

Surface-wave methods in mineral exploration

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POLITECNICO DI TORINO

What are Surface Waves?

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- Surface waves travel in a limited layer close to the surface
- Characterized by high energy → **typically considered as** noise in exploration
- Can be used for **high-resolution near-surface characterization**, which can **improve the imaging of deeper targets**.

Static corrections

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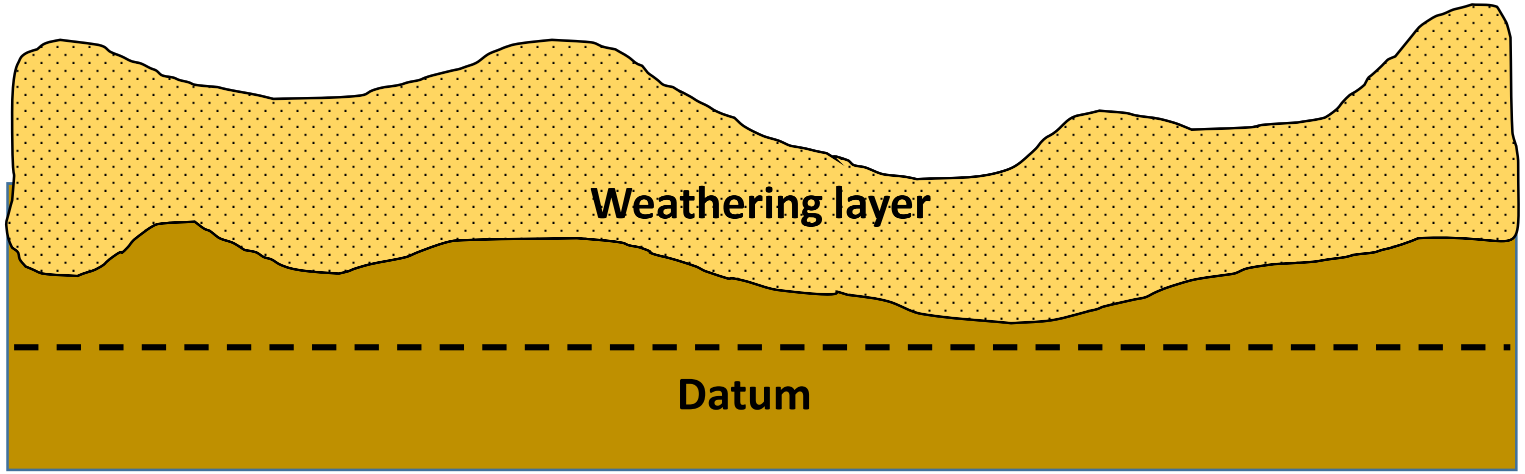
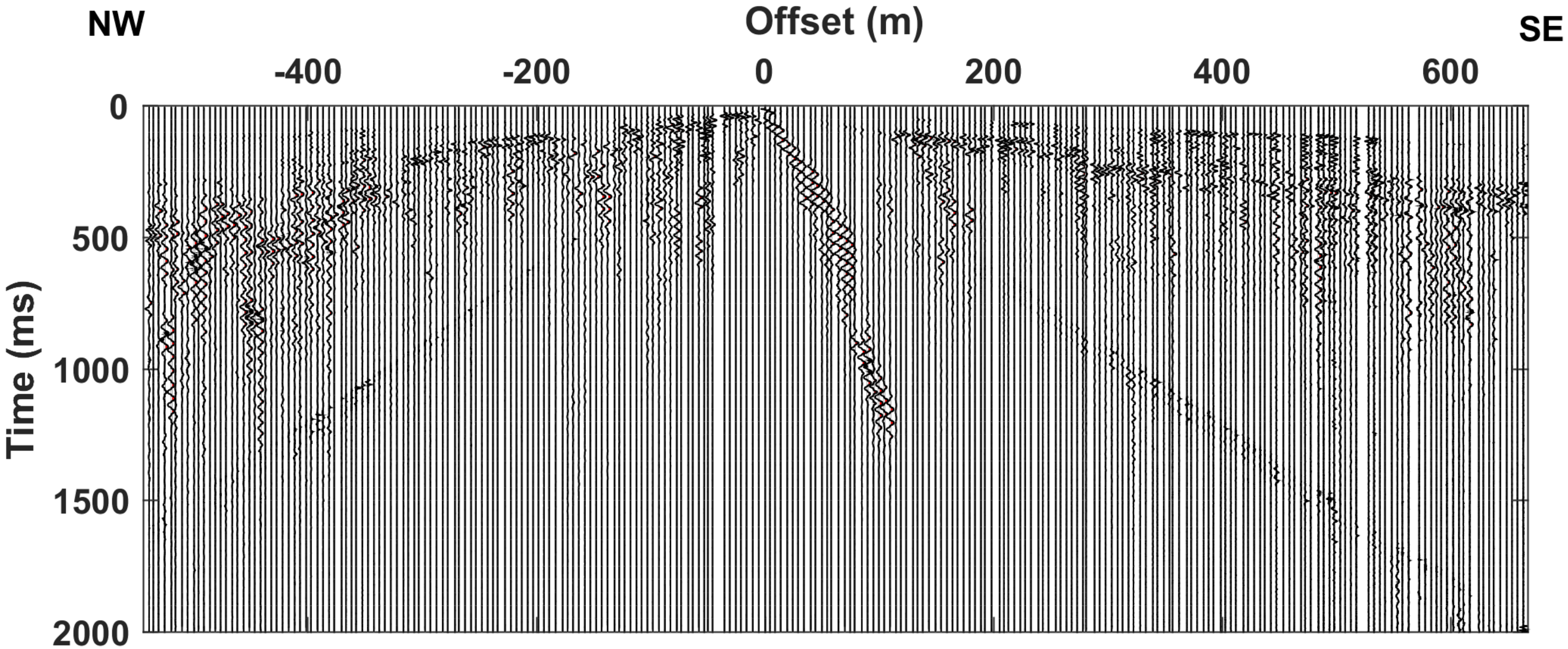
- Static corrections are a **critical step** of the processing workflow of land seismic reflection.
- They are applied on the seismic data to **correct for the effect of the weathering layer.**
- Typically are obtained by **first-break tomography**
  - **Time consumption of fb picking**
  - **Data quality is critical**
- SW:

Sensitive to the near-surface properties.

Statics estimation, without any extra acquisition cost!





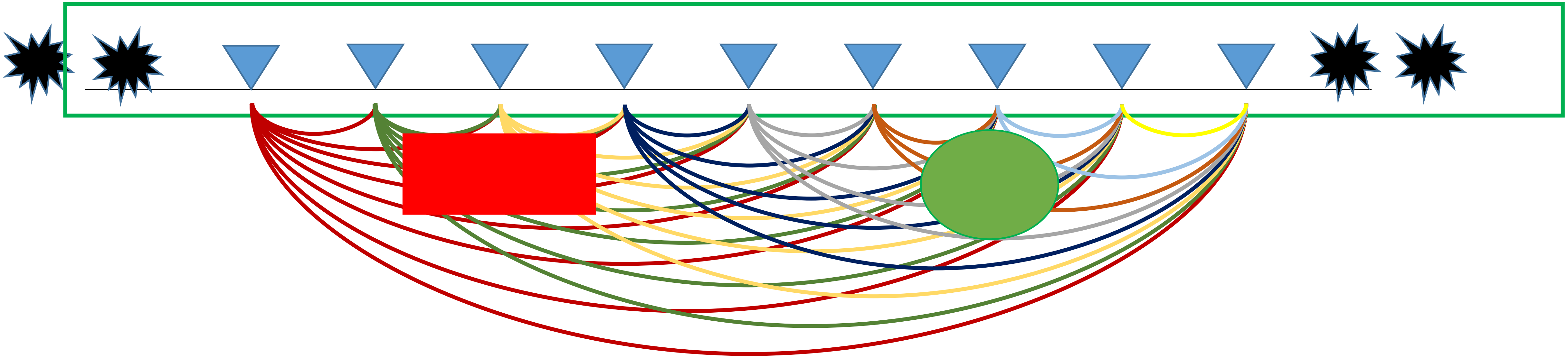
Traditional multichannel methods vs tomography

Two approaches to extract DC: **Multichannel** and **Tomographic**.

- **Multichannel:** lower lateral resolution (but faster!)
- **Tomographic:** increased data processing time (but higher resolution!)
- **Both**: less sensitive to VP

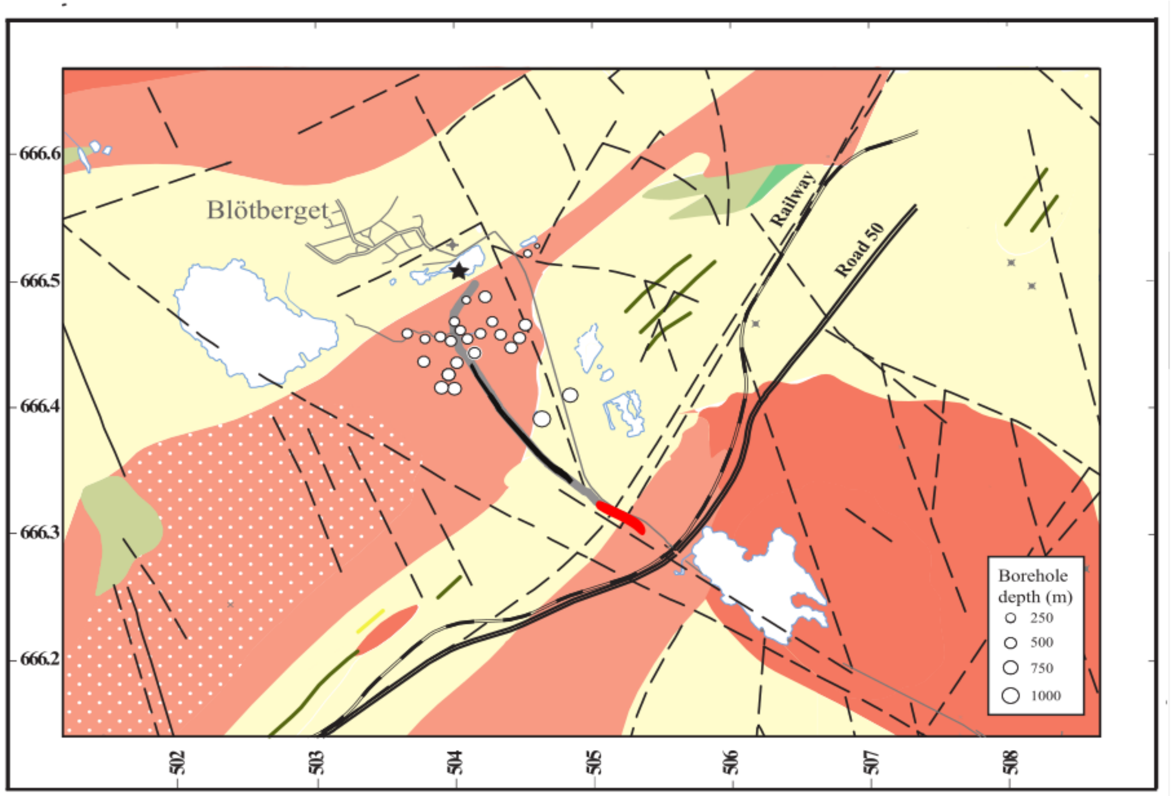
Workflow to obtain the statics from SW Tomography

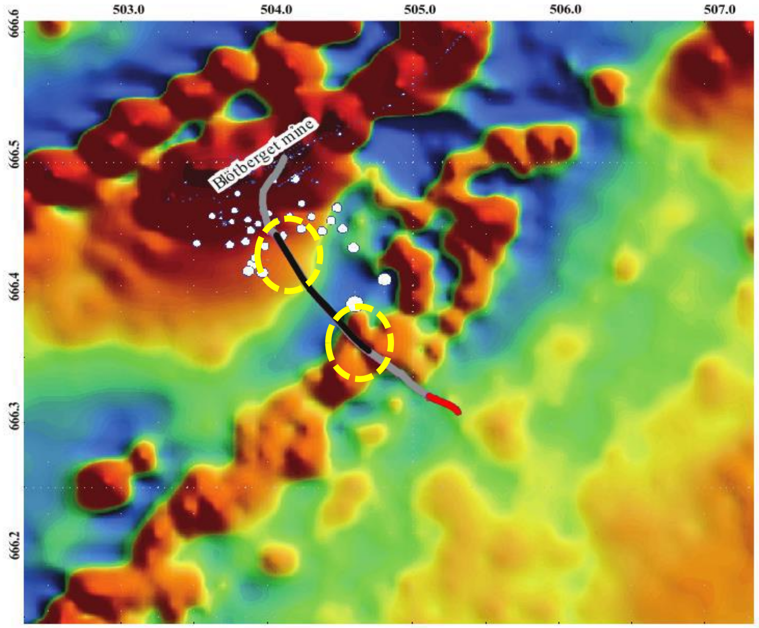
Multi-station → DC



2 station → Path-average DC

Ludvika, Sweden
2016 2D dataset





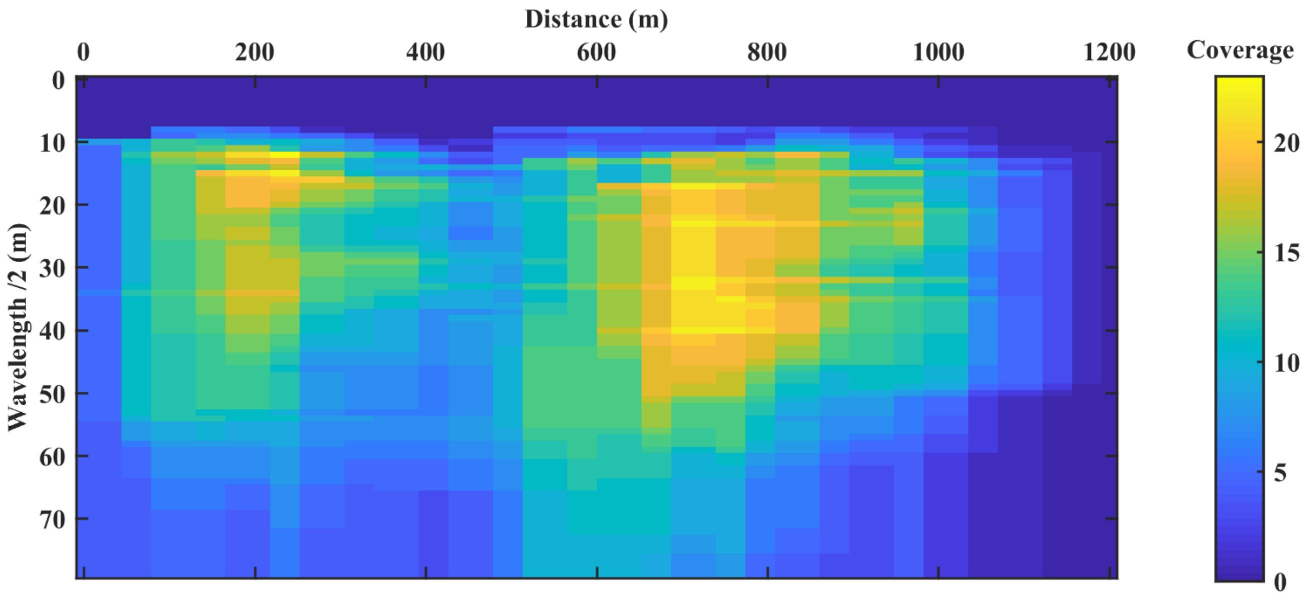
Seismic data acquired in **2016** in the Blötberget iron-oxide mining area of Ludvika Mines in central **Sweden**.

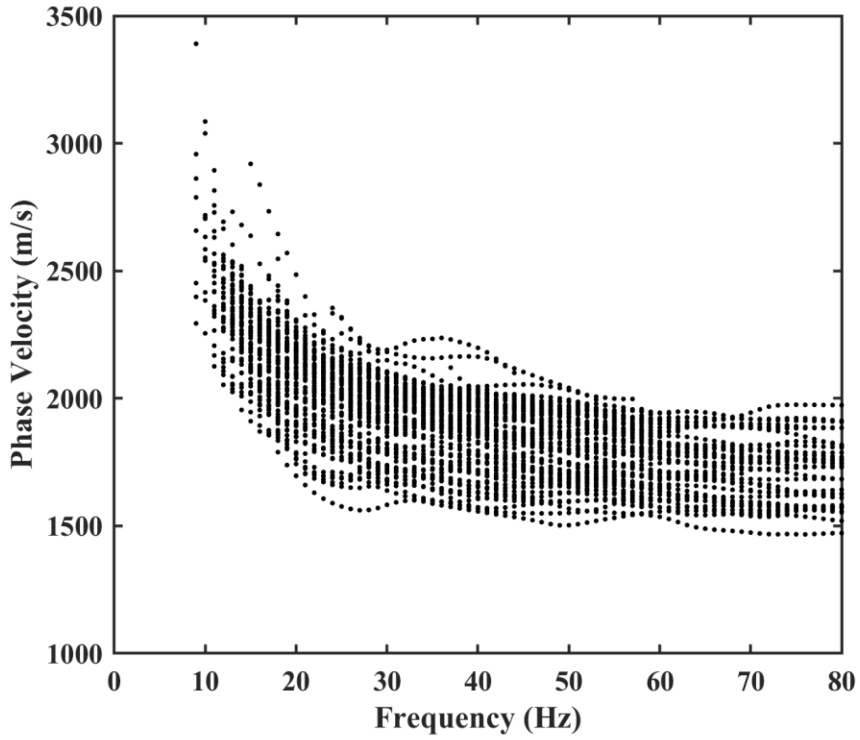
Production of the field was abandoned but there has been renewed interest!

Acquisition Parameters	
Length	1200 m
Time	10 s (2 s for processing)
SR	1 ms
Receiver spacing	5 m
Source type	500-Kg Bobcat-mounted drophammer
Source spacing	5 m

Extraction of path-average DCs

The path-average DCs are obtained from couples of traces, based on the **two-station method**. A **reference multichannel DC** is used to ensure that the correct maxima are picked. In total, 109 path-average DC were picked. They provided a **multiple coverage** along the 2D line.

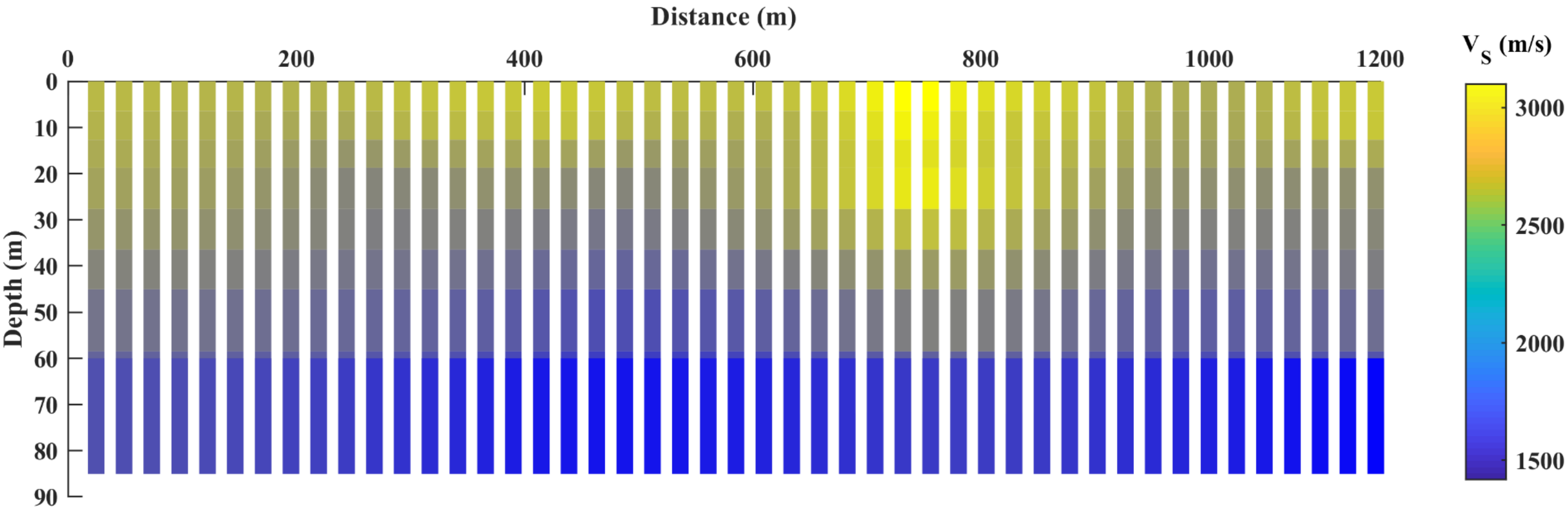




109 path-average DC

Papadopoulou, M., F. Da Col, L. V. Socco, S. Hu, E. Bäckström, M. Schön, P. Marsden, and A. Malehmir, 2019, Surface-wave tomography at mining sites: a case study from central Sweden: 25th European Meeting of Environmental and Engineering Geophysics.

Tomographic inversion



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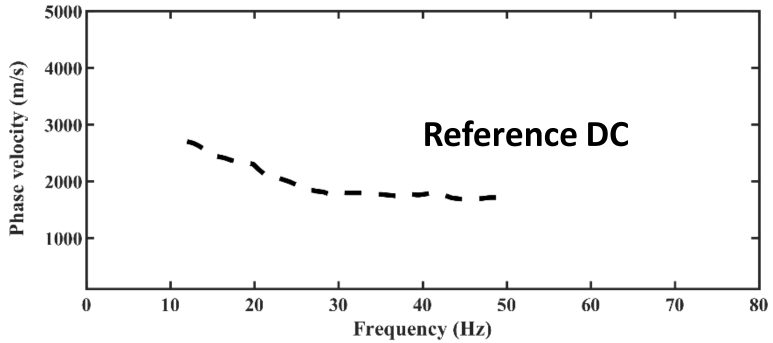
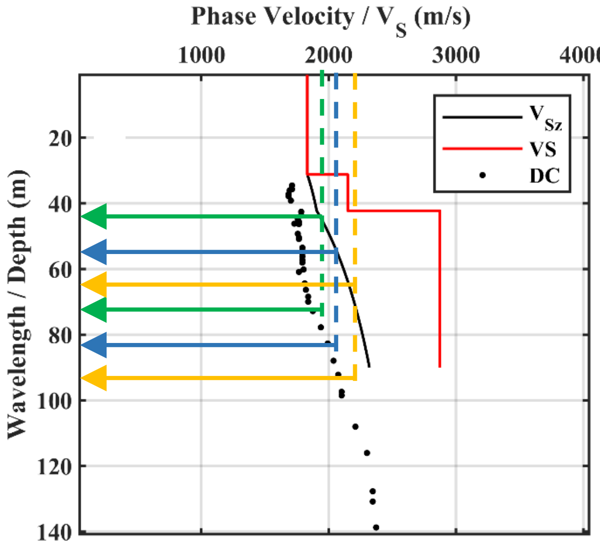
Wavelength – depth method

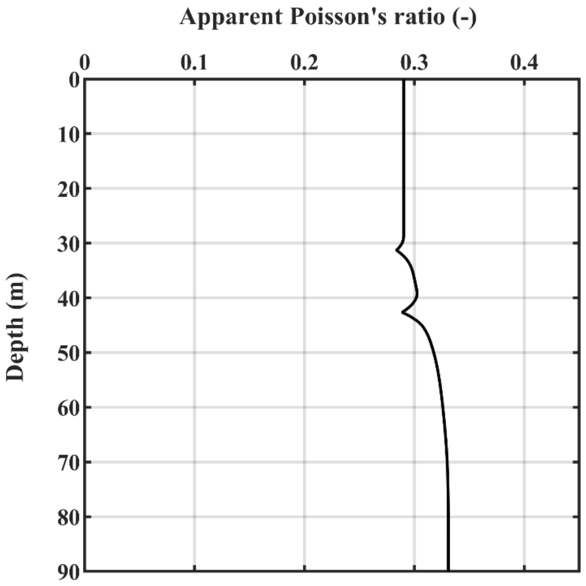


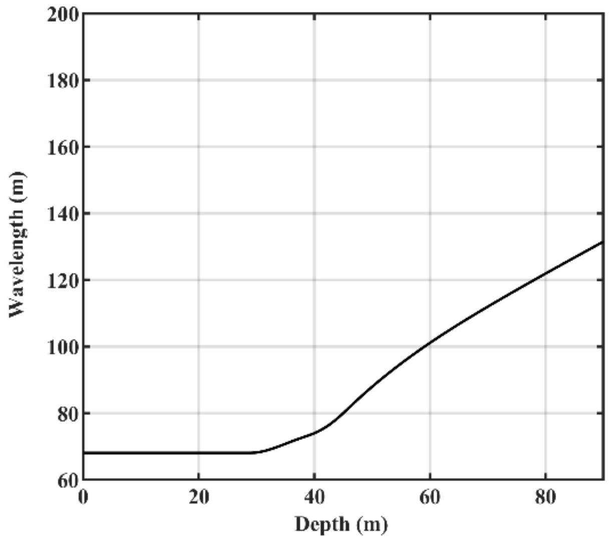
$$\lambda = \frac{V_R}{f}$$

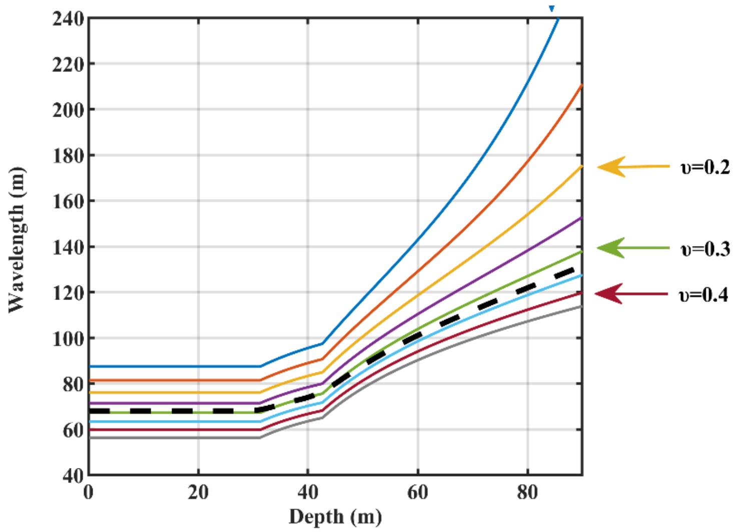
$$V_{S_z} = \frac{\sum_n h_i}{\sum_n \frac{h_i}{V_{S_i}}}$$

h_i: Layer thickness
V_{S_i}: Layer V_S









Papadopoulou, M., F. Da Col, B. Mi, E. Bäckström, P. Marsden, B. Brodic, A. Malehmir, and L. V. Socco, 2020, Surface-wave analysis for static corrections in mineral exploration: A case study from central Sweden: Geophysical Prospecting, 68, 214–231.

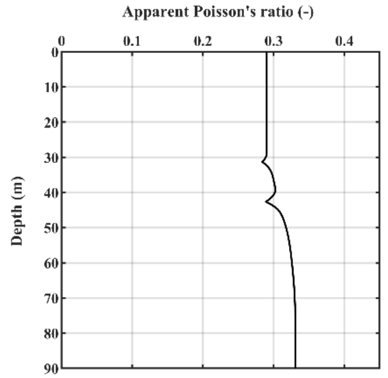
The V_S is transformed into time-average V_S :

$$V_{S_z} = \frac{\sum_n h_i}{\sum_n \frac{h_i}{V_{S_i}}}$$

h_i: Layer thickness
V_{S_i}: Layer V_S

Time-average V_S is transformed into time-average V_P :

$$V_{P_z} = V_{S_z}\sqrt{\frac{2\upsilon_z - 2}{2\upsilon_z - 1}}$$



The statics are estimated as:

$$t_d = \frac{datum}{V_{P_{z_{datum}}}}$$

Not only statics. . .

Siilinjärvi site

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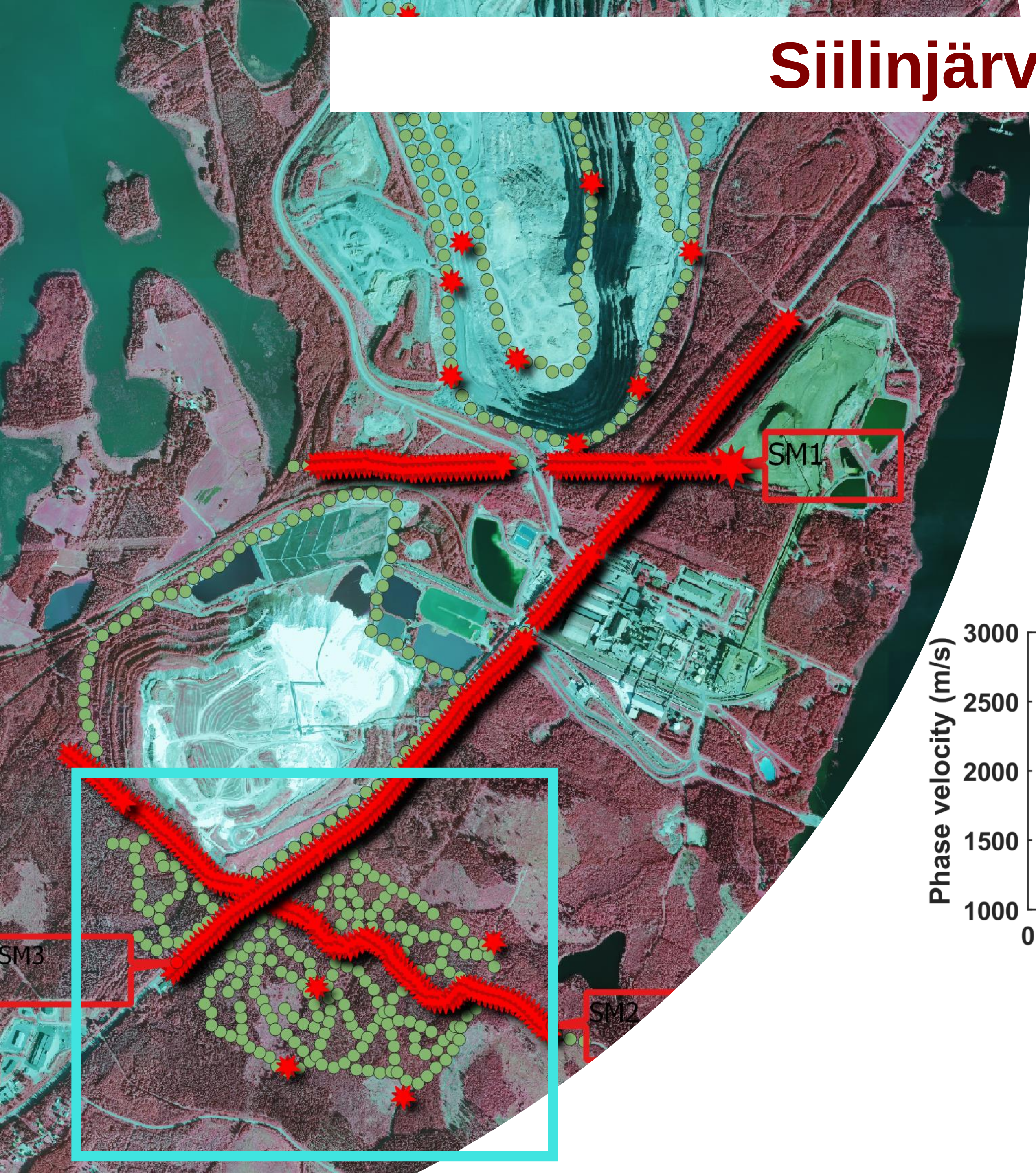
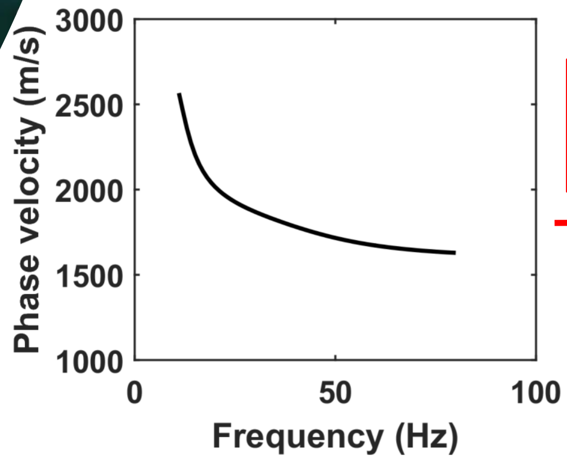
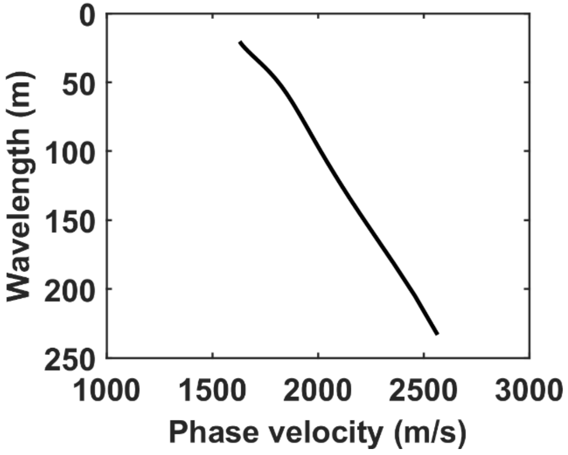


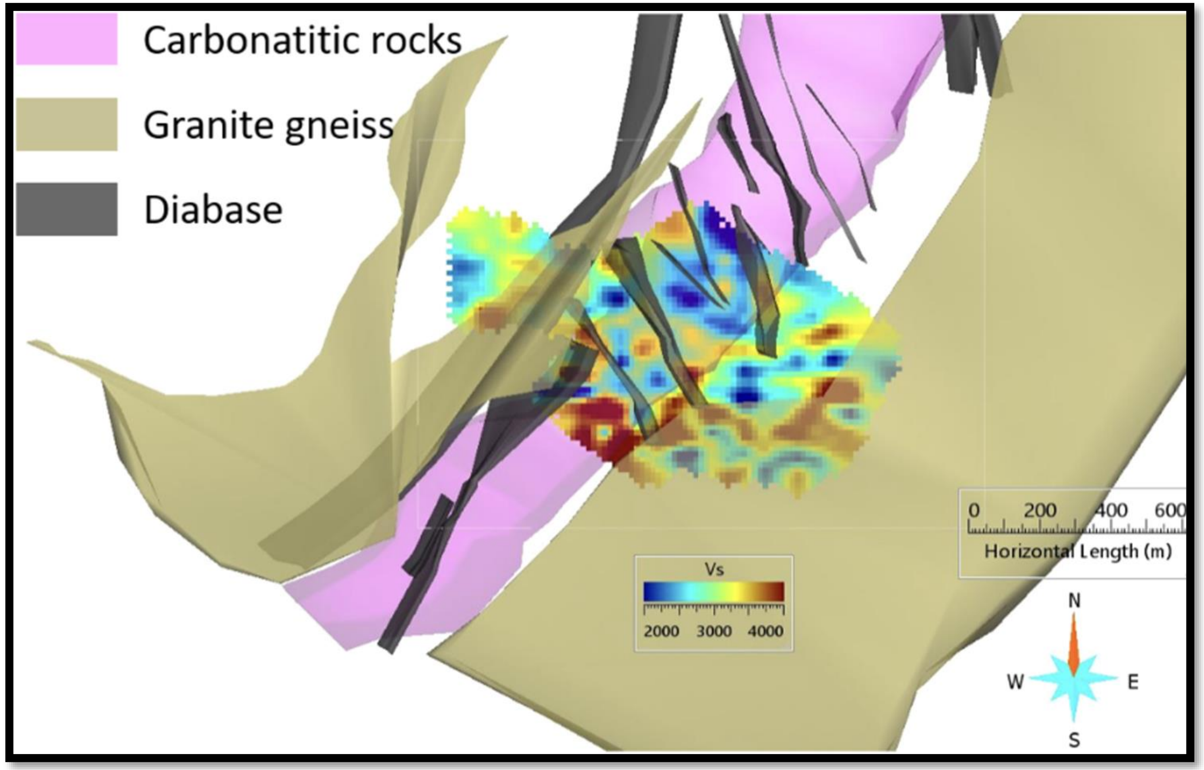
High seismic velocities of mineral exploration sites allow deeper SW investigation → Possible imaging of mineralization



$$\lambda = \frac{V_R}{f}$$



Active 3D tomography



The estimated V_S model is in agreement with prior information on the site.

Da Col, F., M. Papadopoulou, E. Koivisto, Ł. Sito, M. Savolainen, and L. V. Socco, 2020, Application of surface-wave tomography to mineral exploration: a case study from Siilinjärvi, Finland: Geophysical Prospecting, 68, 254–269.

Passive SW tomography

Possible when no active data can be acquired (e.g. due to safety restrictions)

Cheaper → No active sources required

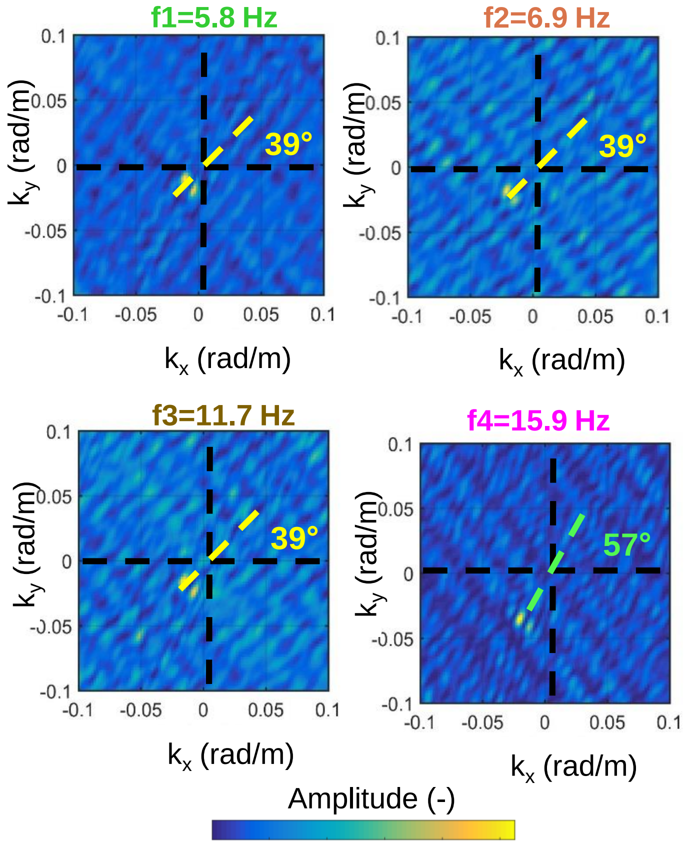
Possibly longer wavelengths?

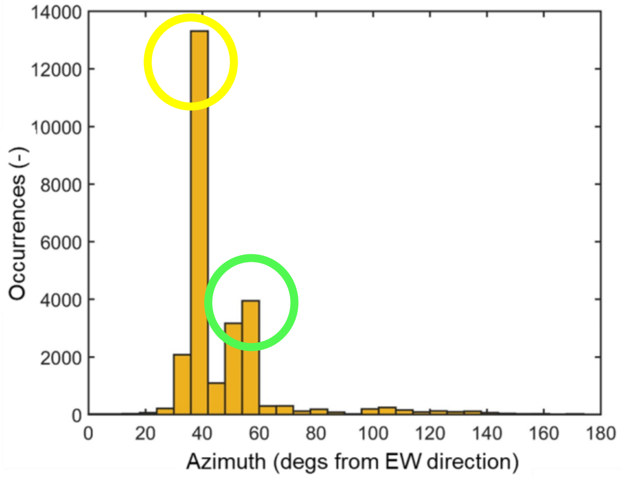
Passive 3D tomography

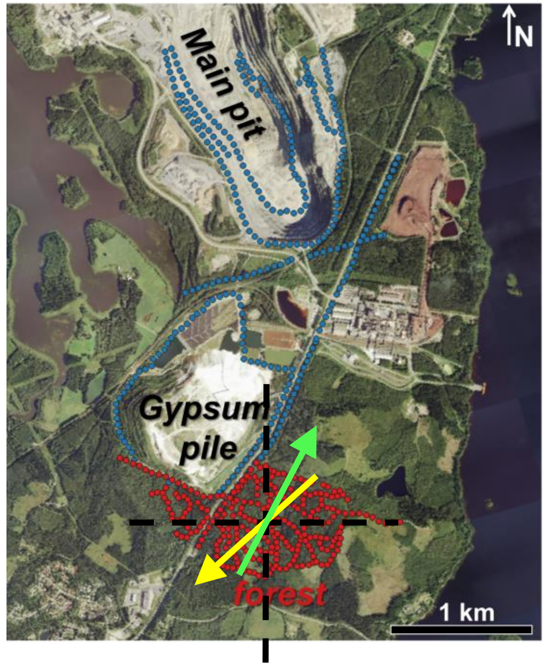
1. Window the data in 2s windows

2. Find the windows with dominant SW energy

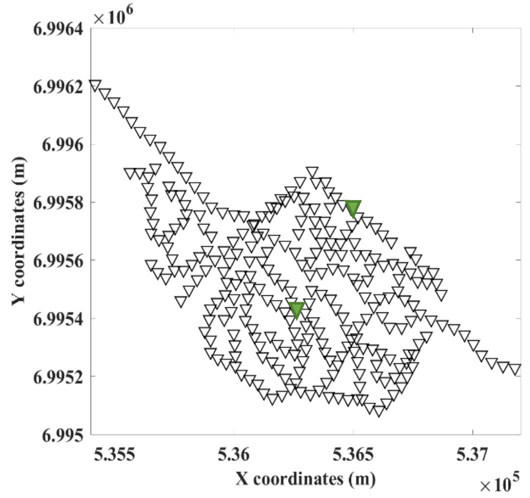
3. Dominant energy azimuth of each window



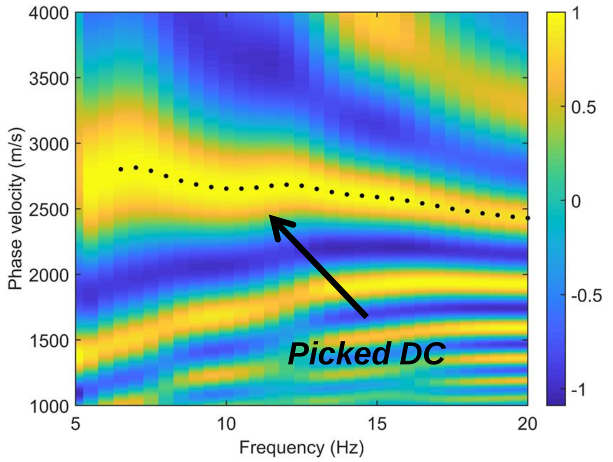




4. Receiver pair selection

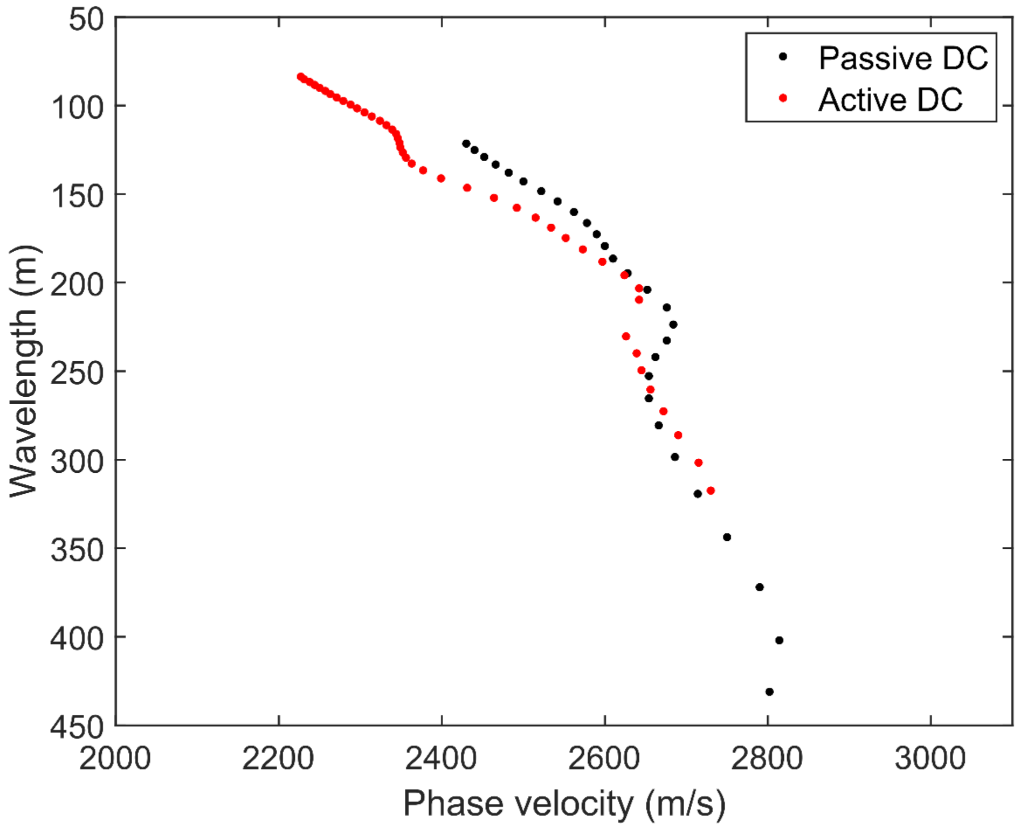


5. Stacked cross-multiplication matrix and DC picking



Colombero, C., M. Papadopoulou M., F. Da Col F., E. Koivisto, M. Savolainen, Ł. Sito and L. V. Socco, 2020, Extraction of surface-wave dispersion curves from ambient noise data in a mineral exploration site in Finland: EAGE Extended abstracts.

Passive 3D tomography



Longer Wavelengths of passive DCs → Deeper investigation

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Conclusions

- SW methods are **a valid alternative** to the standard method of statics estimation.
- **Completely independent from BW data** → Useful when obtaining BW is less effective (e.g. BW traveltimes cannot be picked due to noise).
- SW tomography → originally developed for global seismology, but **effective in exploration!**
- In mining sites, SW can provide high **resolution & investigation depth**.
- The use of passive data is possible
- Use not only in exploration, but also mine planning

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THANK YOU

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