Smart Exploration

Deep Targeting using Exploration Tunnels

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new ways to explore the subsurface

LNEG

MIC

SOMINCOR
Sociedade Mineira de Neves-Corvo, S.A.
a subsidiary of lundin mining

Workshop: MERC-Smart Exploration
February 27, 2020-Tornto

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Outline

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- Smart Exploration and who we are and what we do
- A bit of legacy & new data (Ludvika and then Neves-Corvo)
- Prototypes with focus on the GPS-time and E-Vib systems
- Neves-Corvo in-mine survey and results so far

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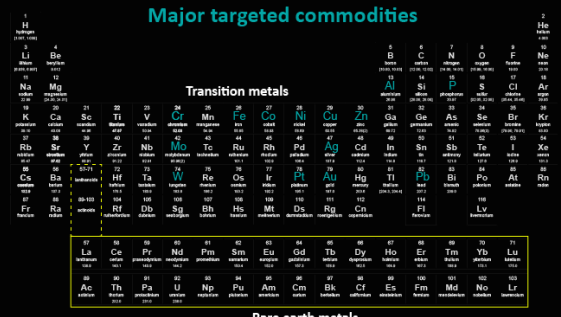
Smart Exploration has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.775971.



Several CRMs

Cr,Mo,W,Fe,Co,Ni,Pt,Cu,Ag,
Au,Zn,Al,Pb,P,REEs

Highlights
Patent: 2
YPs: +20
Publications: +40
Presentations: +60

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Facts:

① 27 partners, 9 European countries (11 R&D, 11 SEMs and 5 stakeholders)

② 36 months project (Dec. 2017-Dec. 2020).

③ Six validation sites

④ Covering a wide range of commodities and exploration fields important for Europe

⑤ Research-Innovation action:

- **Primarily geophysical methods and instruments for deep targeting**
- **Focus on innovation, new markets and solutions addressing exploration issues (of CRMs) in Europe but also globally**

Target TRL: 5-6

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Research-Innovation Action

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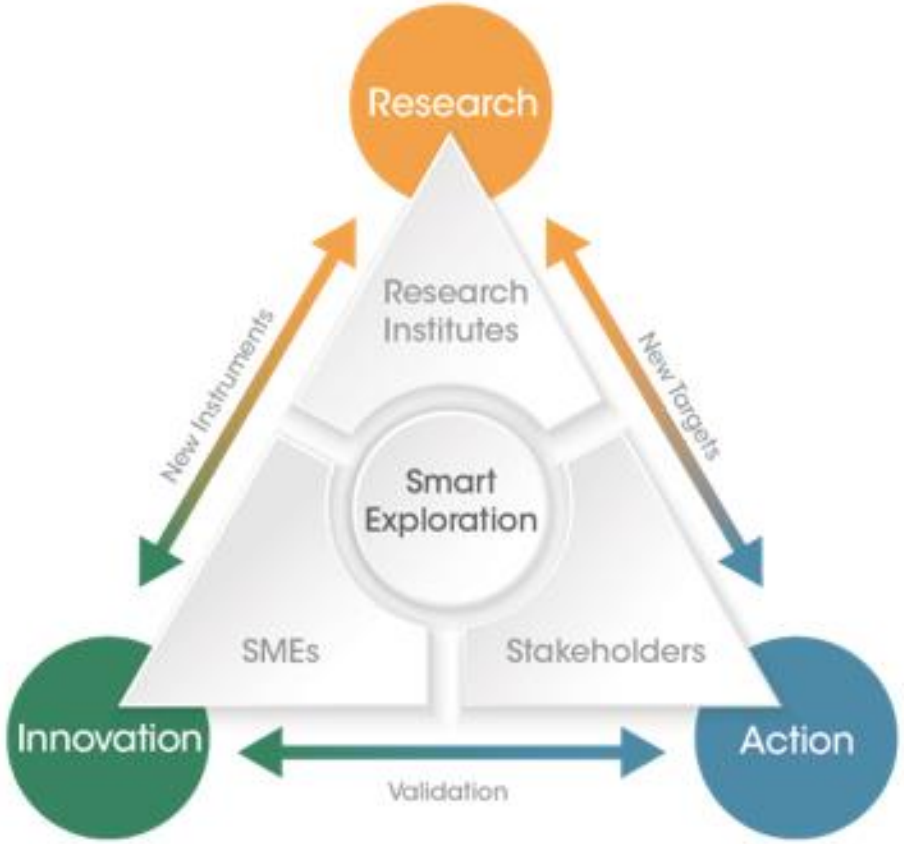
27 Partners
9 EU countries
7 Work packages
6 Test sites
5 Prototypes
6 Methodologies



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New Data & Targets

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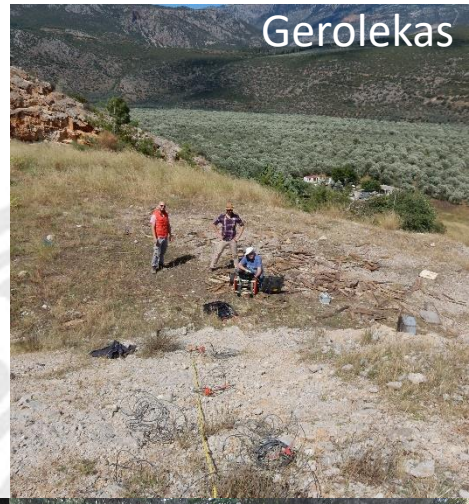
We have generated 2D and 3D data at all our six exploration sites:
Kosovo (Mag-Grav-RES-IP)
Fisoka (Geochem)
Gerolekas (Passive seismic, Grav and in-mine active seismics)
Siilinjärvi (3D passive, active 2D, Mag, GPR)
Neves-Corvo (Semi3D in-mine & surface seismics, tunnel-bench)
Ludvika mines (3D active-source seismics, SkyTEM survey, 2D E-vib)

Field camps, schools and visitors were allowed at most of these. The peaks were at Siilinjärvi (40 persons) and Ludvika (90+60 persons)

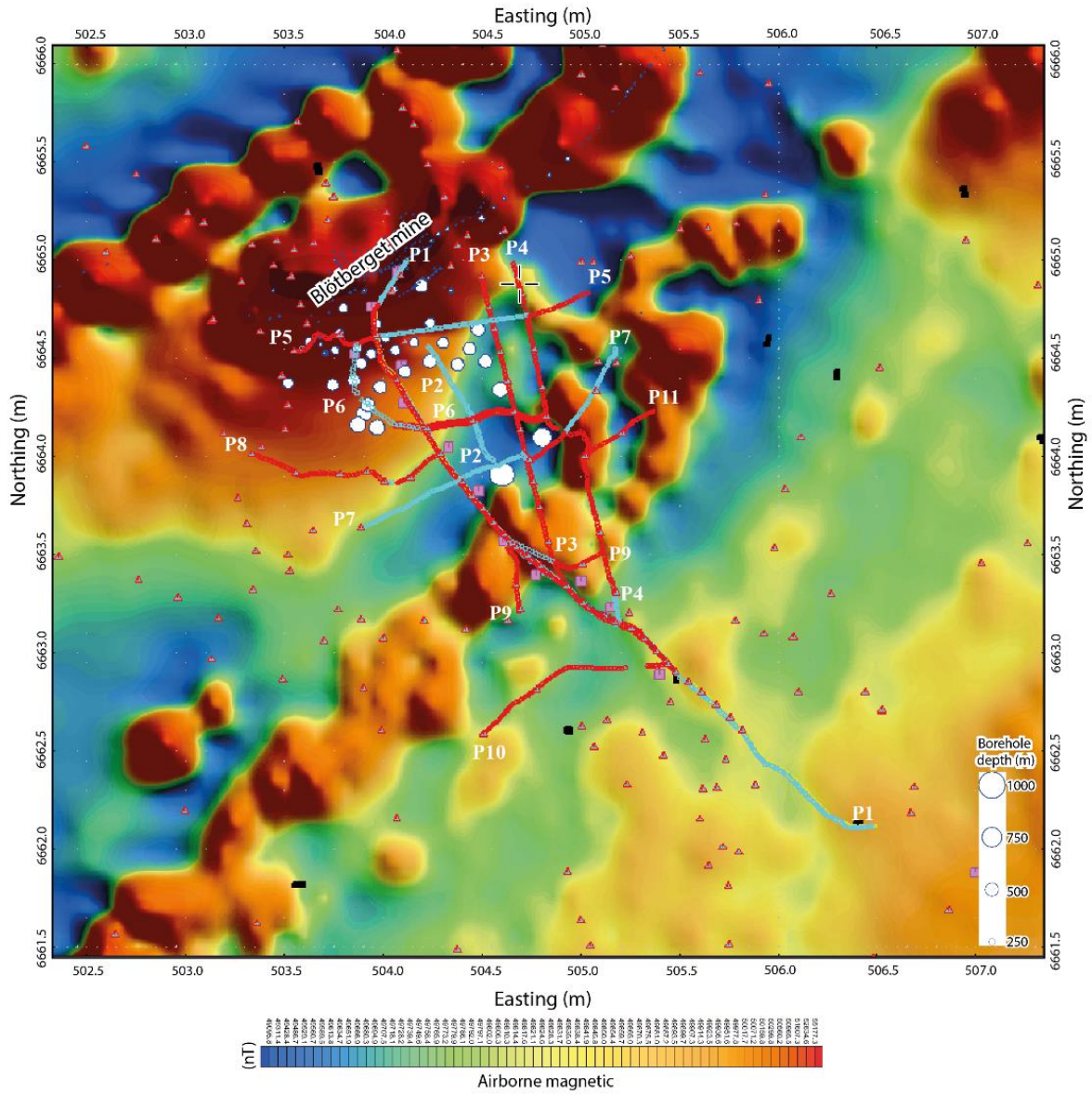


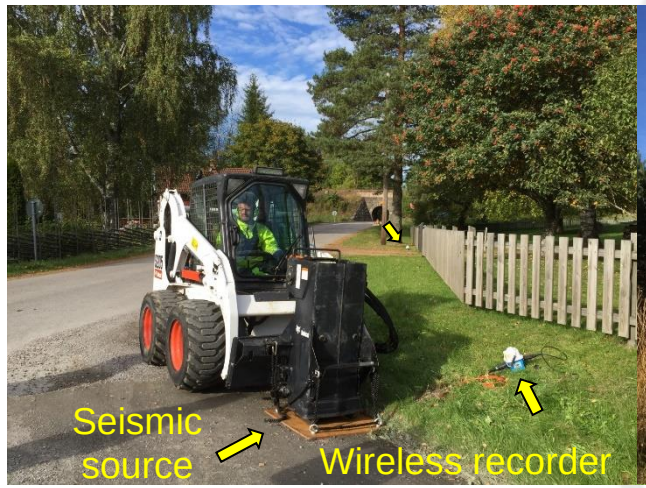
Hands-on experience for many of YPs

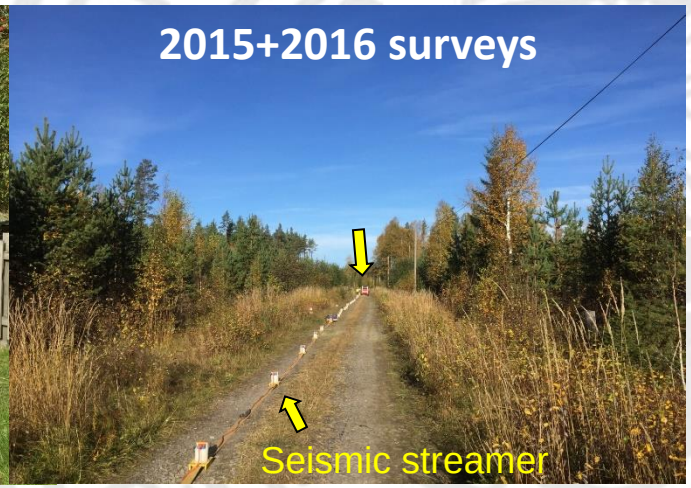
Highlights:
Three sparse 3D seismic surveys (+1200 receivers)
New potential targets at Ludvika Mines, Neves-Corvo, Fisoka and Siilinjärvi

Ludvika surveys

- **2015:** landstreamer seismics (~3.5 km)
- **2016:** Downhole logging conducted in 6 boreholes
- **2016:** Two cross profiles (~2.2 km & 800 m)
- **2016:** Ground-UAV mag, ground gravity and MT
- **2016:** Laboratory mag properties and
- **2019:** 3D seismic survey (c. 2×2 km)
- **2019:** SkyTEM survey
- **2019:** An E-vib 2D test survey along profile 1
- **2020:** Downhole survey planned (1-2 boreholes)
- **2020:** UAV-ground EM planned (small area)







3D seismic survey-Ludvika (May 2019)

Nordic Iron Ore

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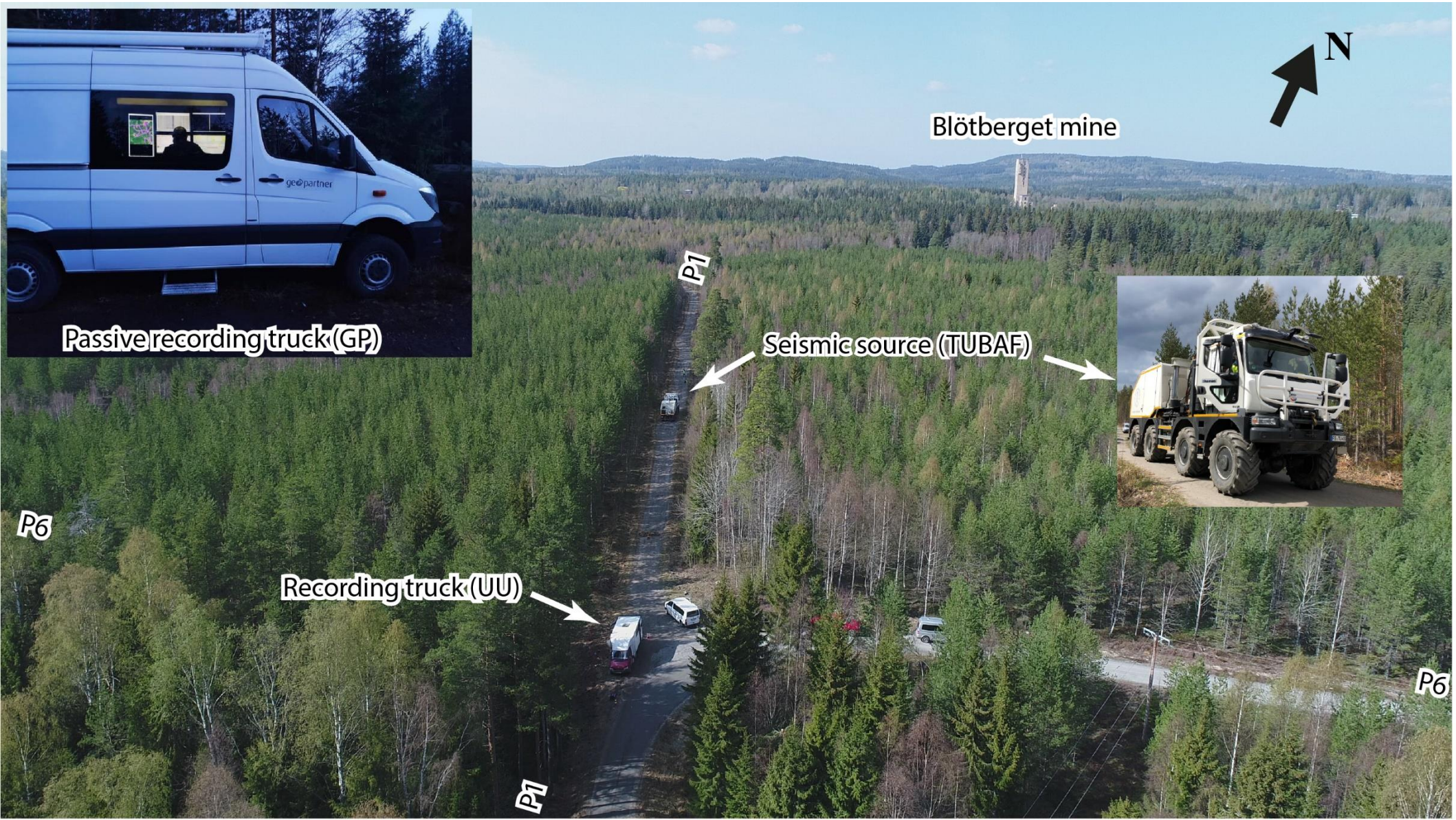
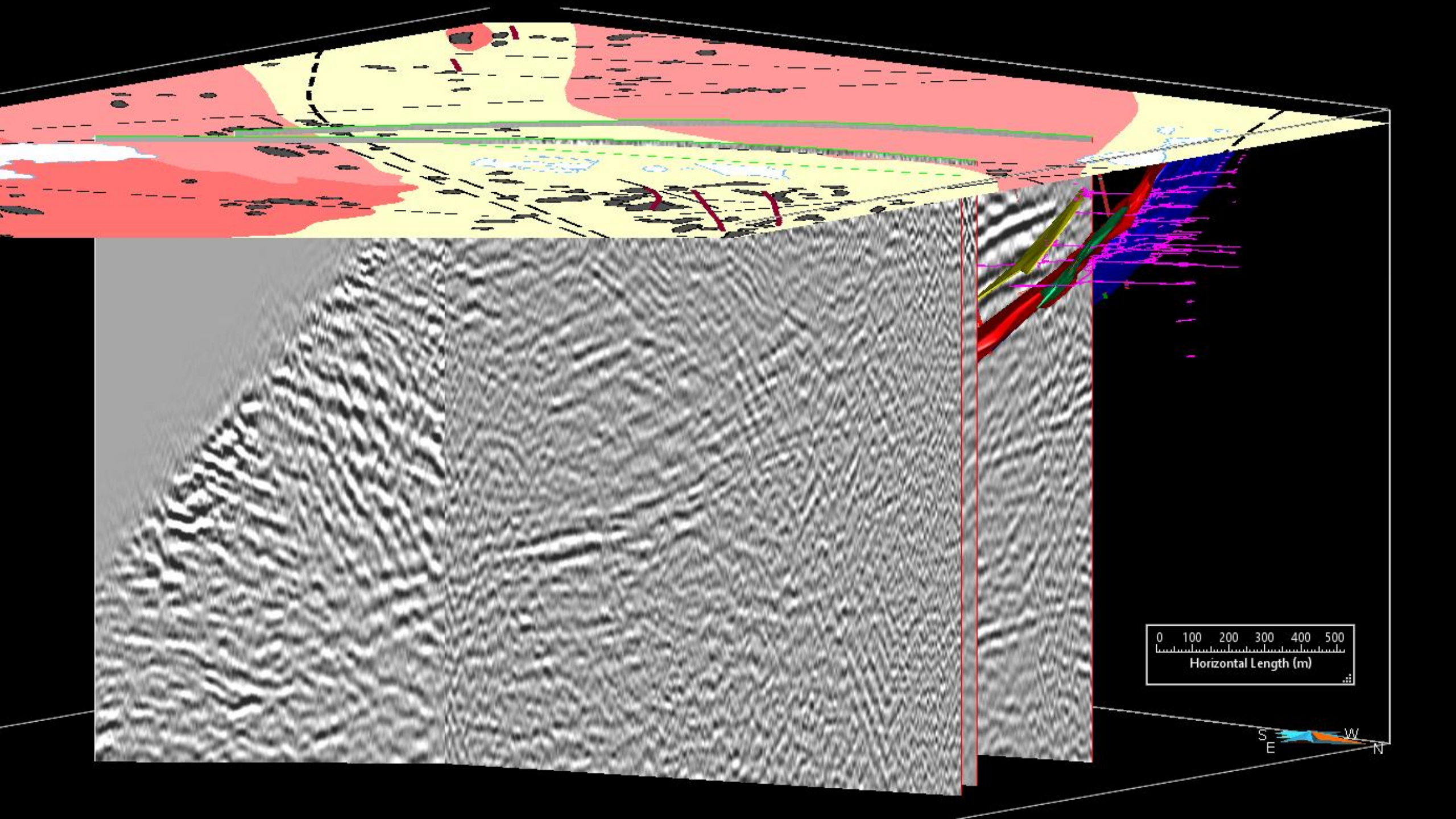
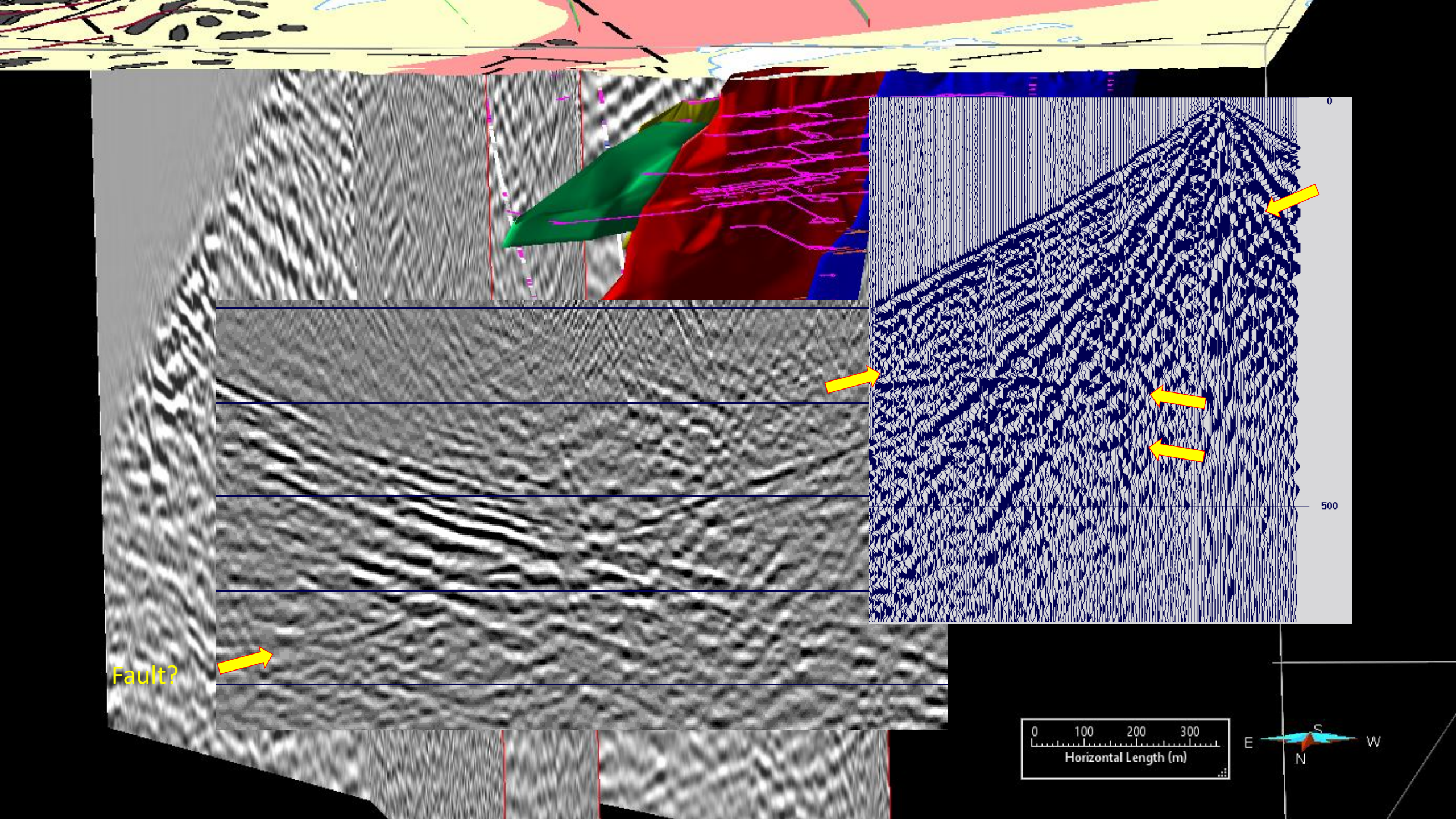


11 lines
10-20 m source and receiver spacing
Two cabled lines for QC
Over 1250 stations
Over 900 shot positions
Vib 32 t
Sweeps: 10-160 Hz
Sweep length: 20 s
Sampling rate: 1-2 ms
60% Drive force

TU BERGAKADEMIE FREIBERG

geopartner


0 100 200 300 400 500
Horizontal Length (m)
S
E
W
N


0
500
Fault?
0 100 200 300
Horizontal Length (m)
S
E
W
N

Nordic Iron Ore™

Legacy 2D seismic data (2015+2016 datasets)

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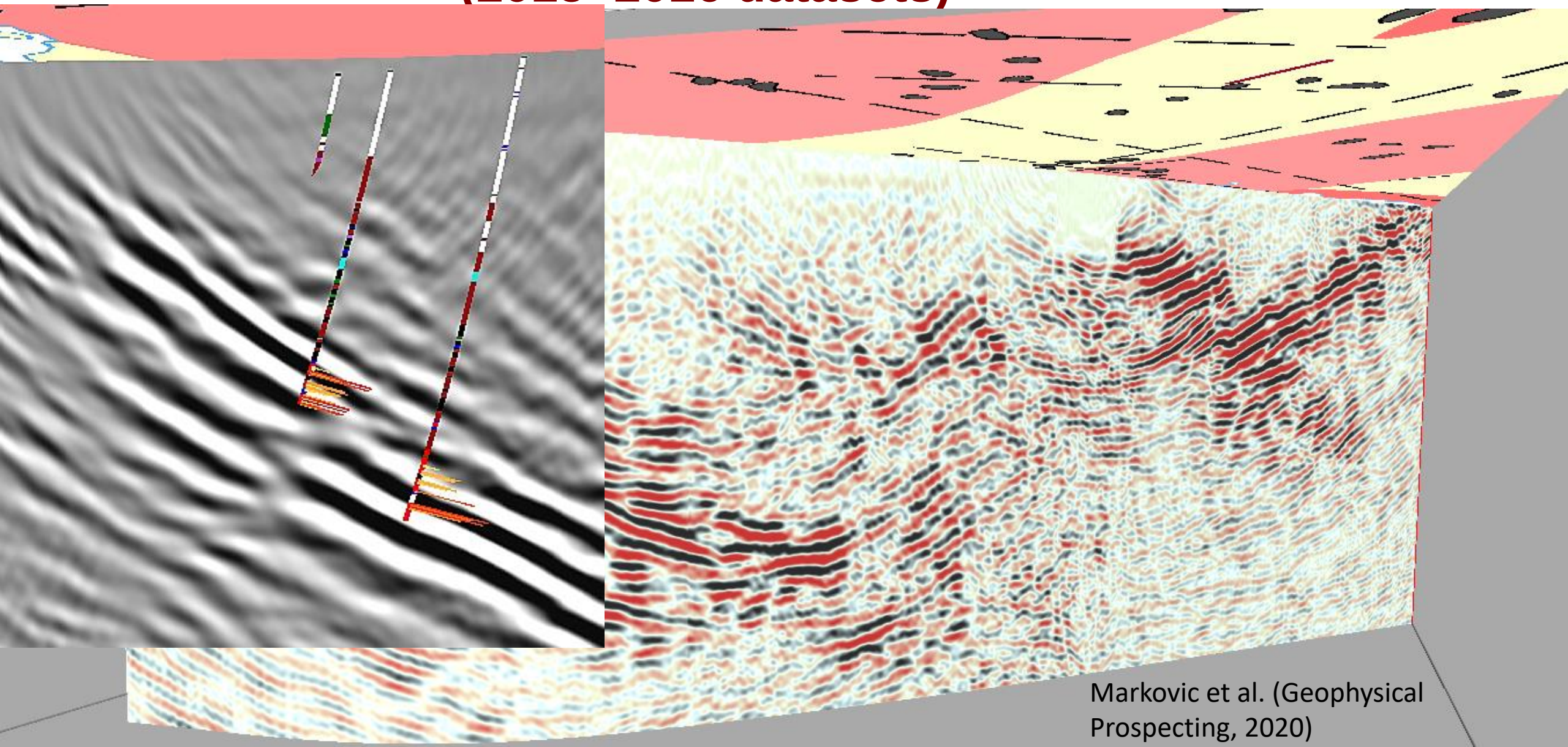
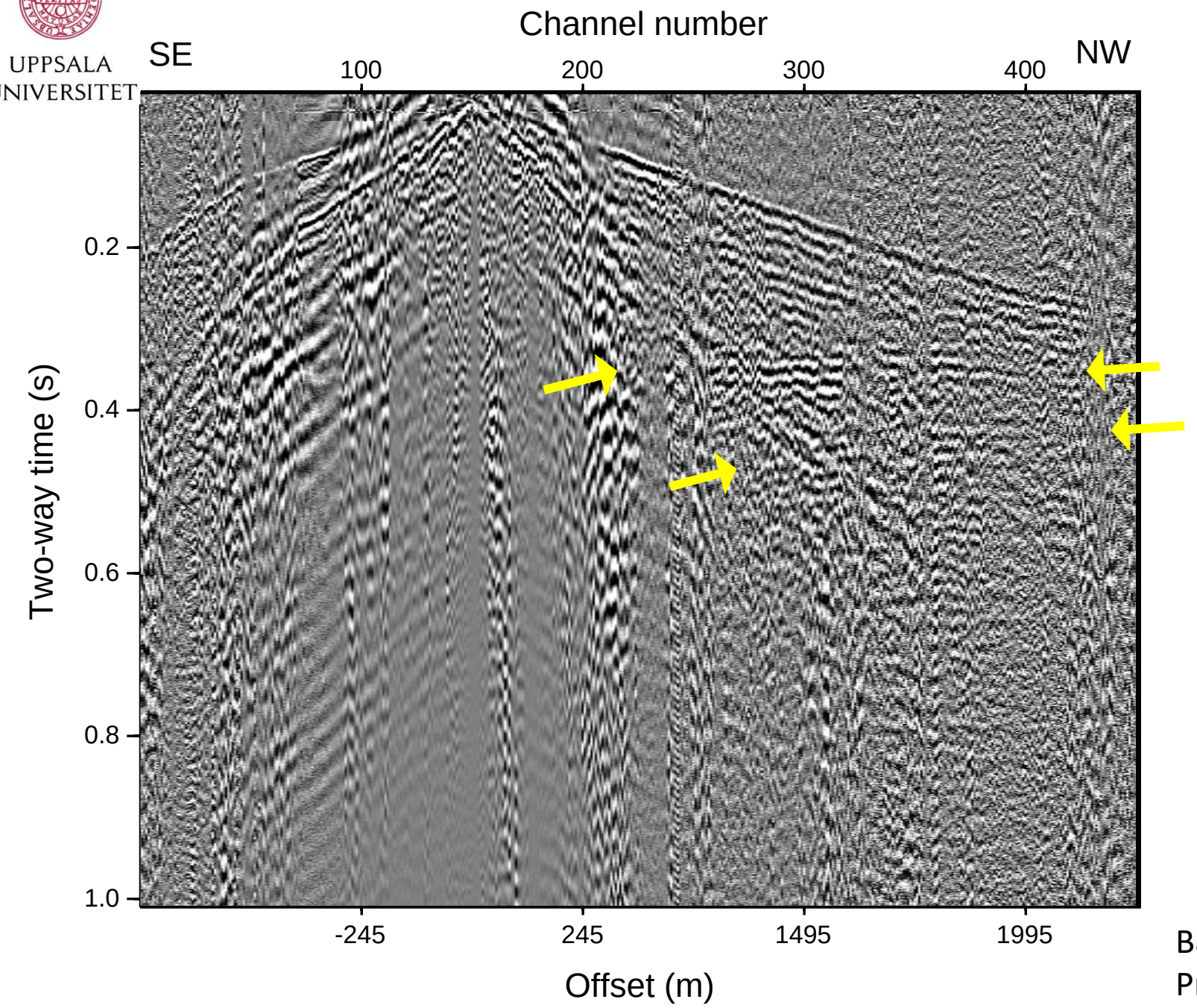


Markovic et al. (Geophysical Prospecting, 2020)



Adoptive surface-wave attenuation through a data driven approach (interferometry)

FK- or Median filter while can be effective, it may destroy certain steep reflections and frequencies

If surface-waves can be accurately modelled it can be removed more effectively from the data and also used for near-surface static solutions.

Balestrini et al. (Geophysical Prospecting, 2019)

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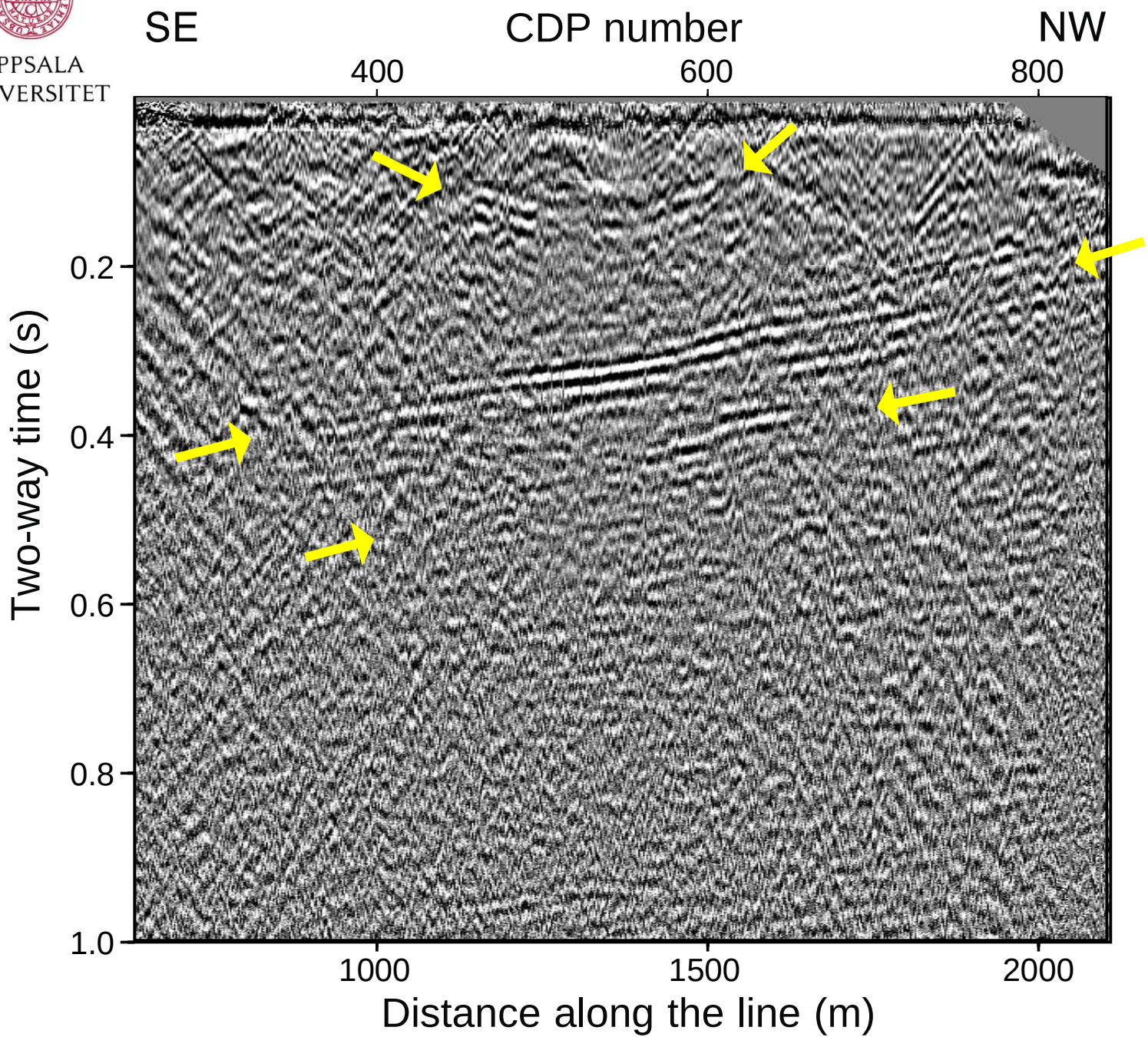
TU Delft



Comparisons unmigrated stacks

Surface-wave is dominant in the dataset as the brutestack shows

The adoptive surface-wave attenuation method works effectively on this dataset allowing even features unseen before to be unravelled.

Balestrini et al. (Geophysical Prospecting, 2019)

Seismic legacy data at Neves-Corvo

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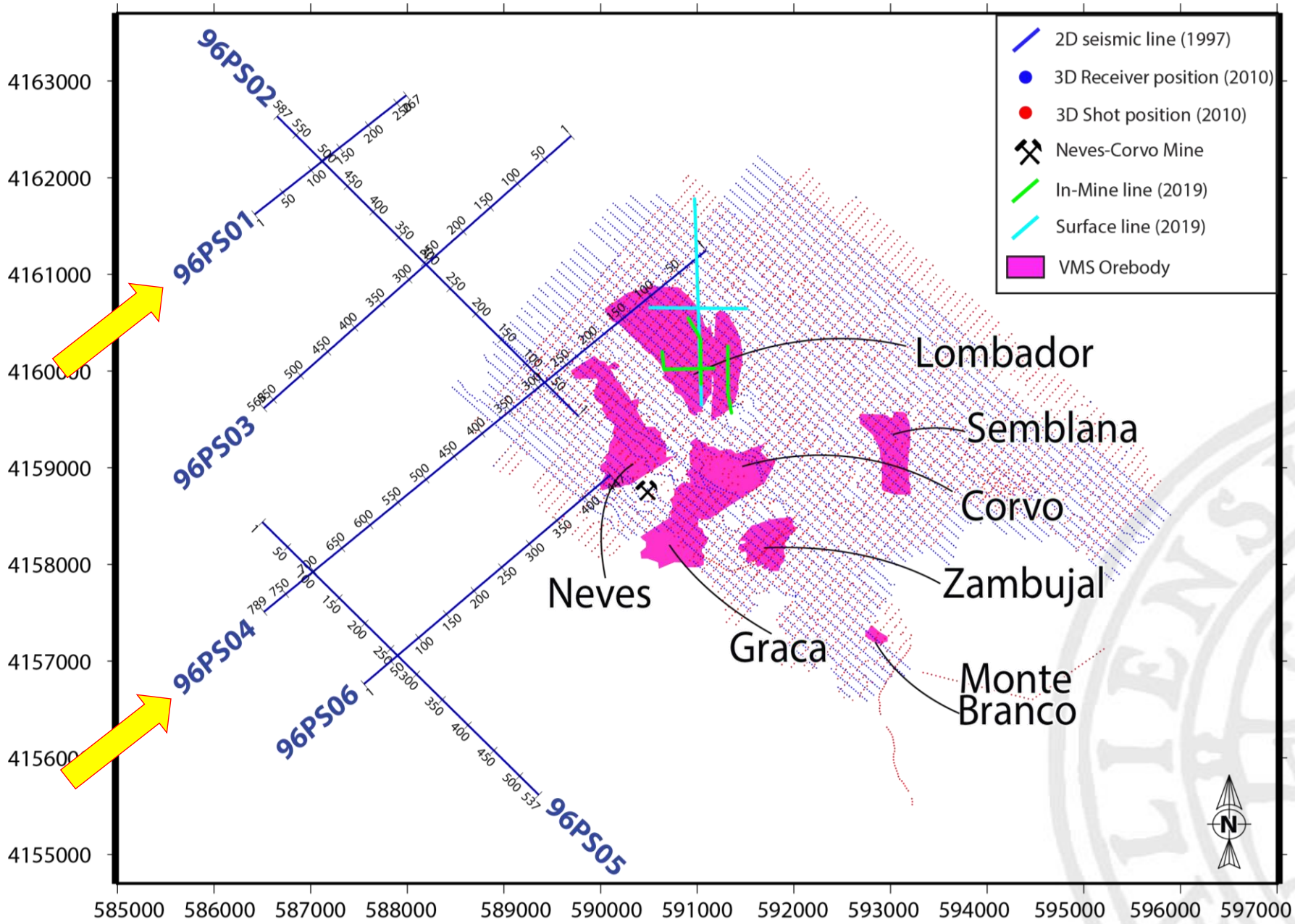
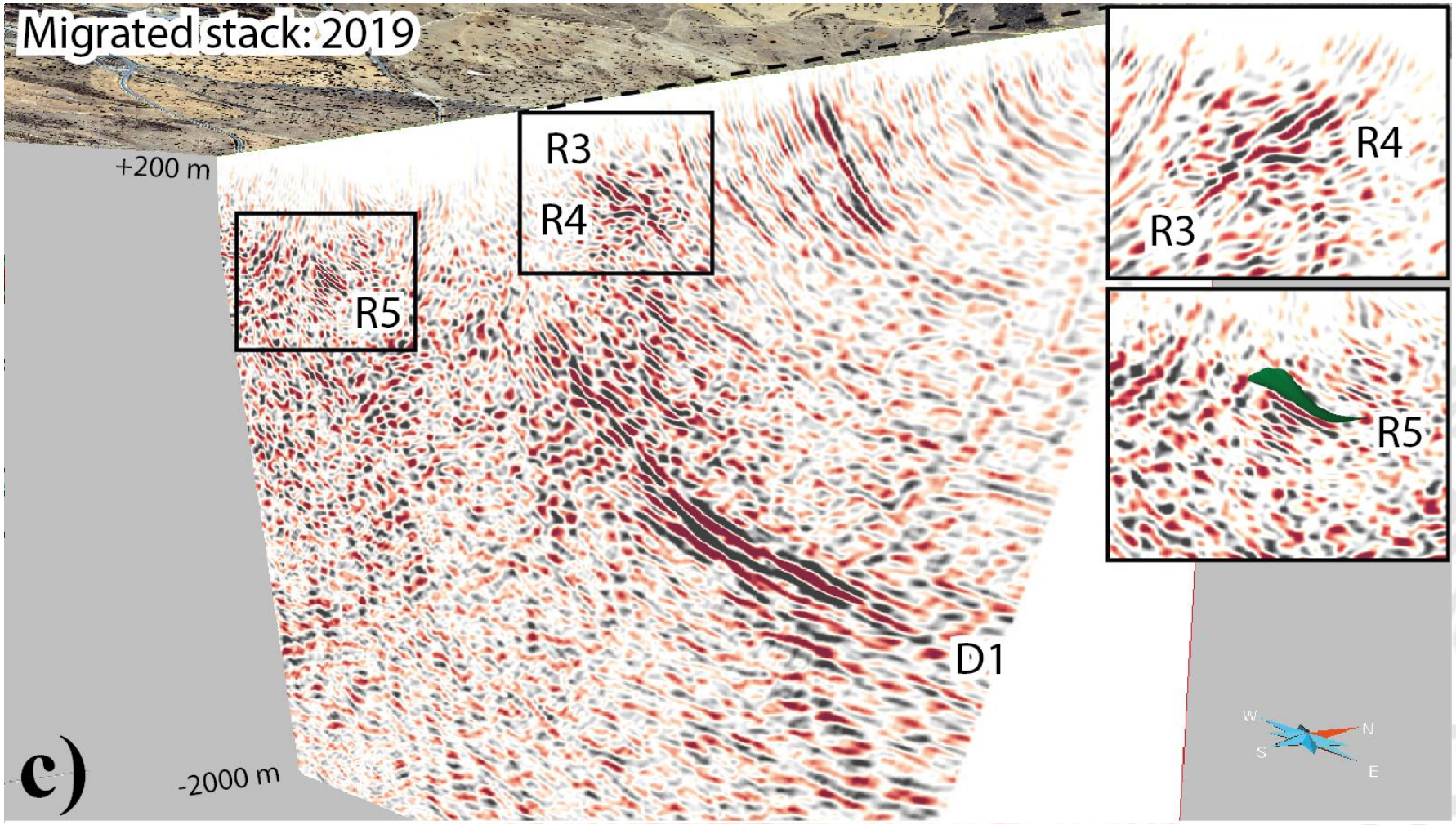


An example: Neves-Corvo

2007 reprocessed vs. 2019 Smart Exploration reprocessed



Donoso et al. (2020, Geophys. Pros.)

Note the Lombador Tier 1 (+150 Mt VMS) seismic signature both in the earlier and reprocessed works!

Line 1

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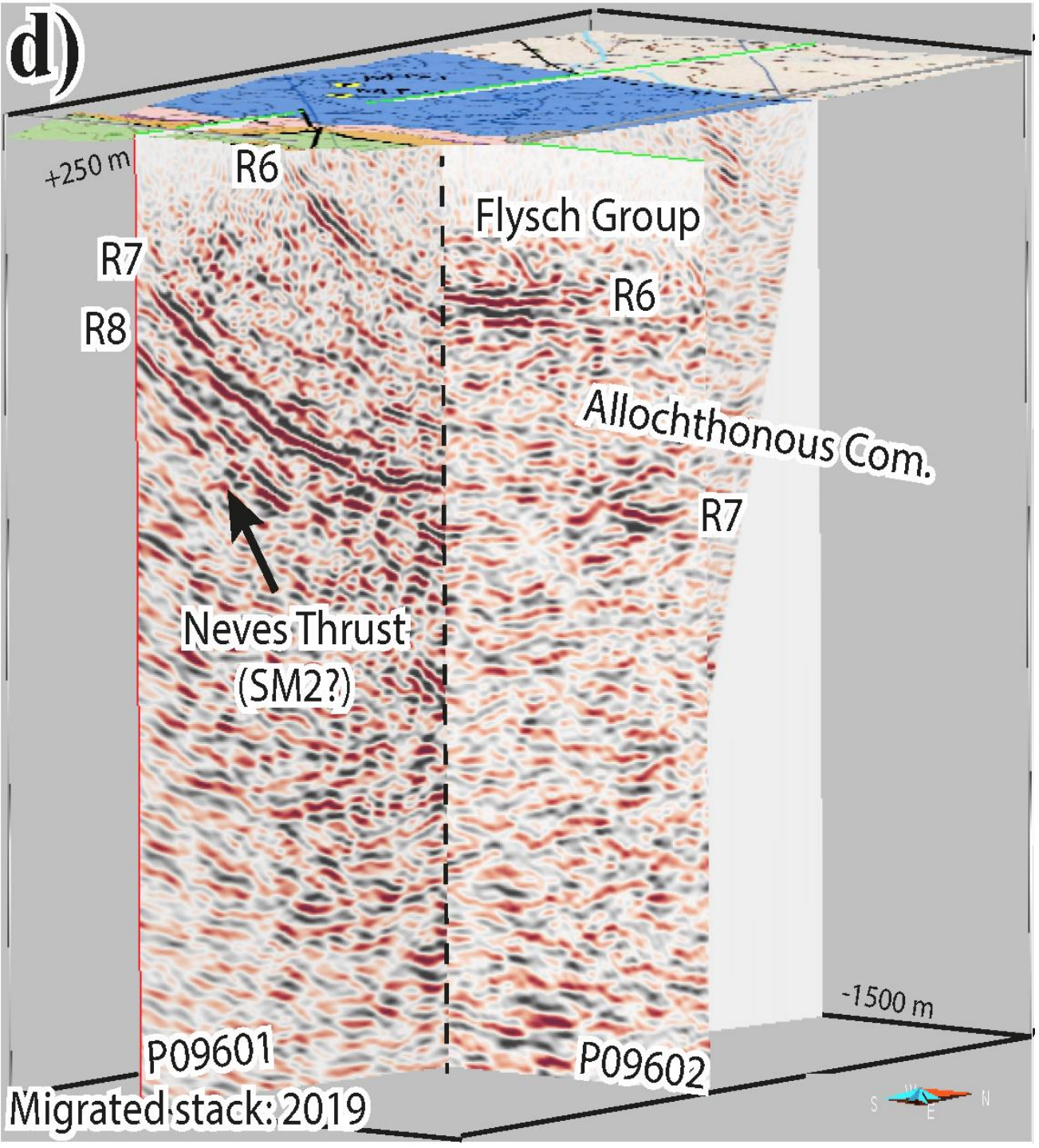

A huge improvement was possible while being relatively consistent with what was offered in the earlier re-processing works.

Base of the Neves Thrust and the overlying VMS-bearing volcano-sedimentary rocks imaged with a great success.

In most cases, the base of the Flysch Group is clearly imaged allowing to constrain existing models or verify them.

Donoso et al. (2020, Geophys. Pros.)

Prototypes

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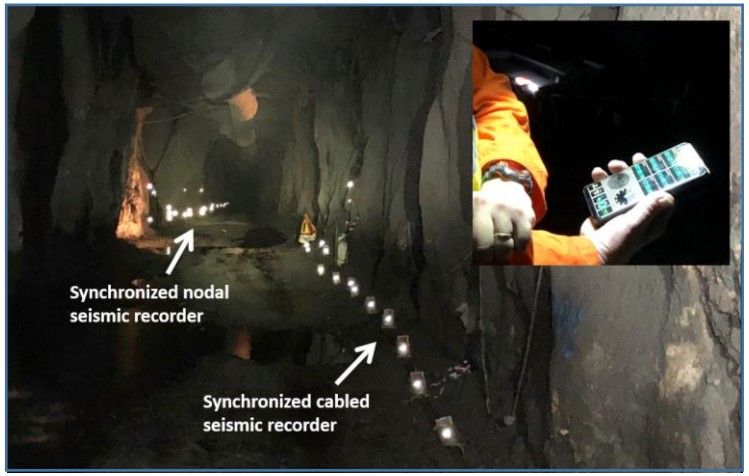
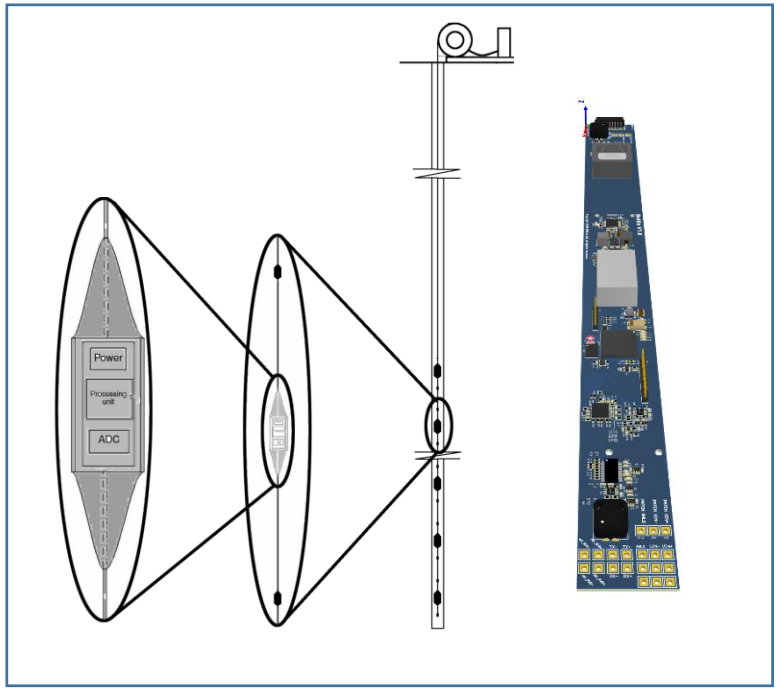
GPS-time transmitter



E-Vib seismic source

Deep penetrating HTEM

Slimhole-modular system



UAV-Ground Mag/EM system

Five **Smart Prototypes** have been developed for various exploration challenges!

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GPS-time & E-Vib systems

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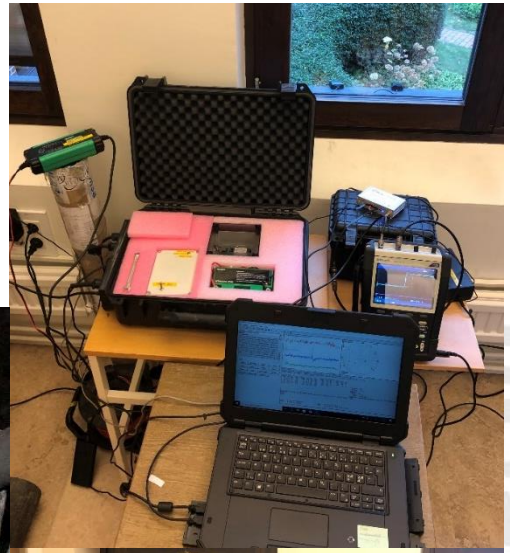
Pressing needs:

1) Could **underground space** (tunnels/drifts and boreholes) be **better** utilized for a cost-effective **exploration** and planning purpose?
2) Could remote-sensing methods/instruments (geophysical) be better utilized in this **highly noisy and logistically challenging mining** environment without a need for new sensor-type invention?



Issues:

- Not every source is welcome to enter (logistical issues)!
- Broadband signal needed in this highly noisy environment
- Time stamping and sampling issues with a full-scale survey

Neves-Corvo 3D surface/in-mine survey:

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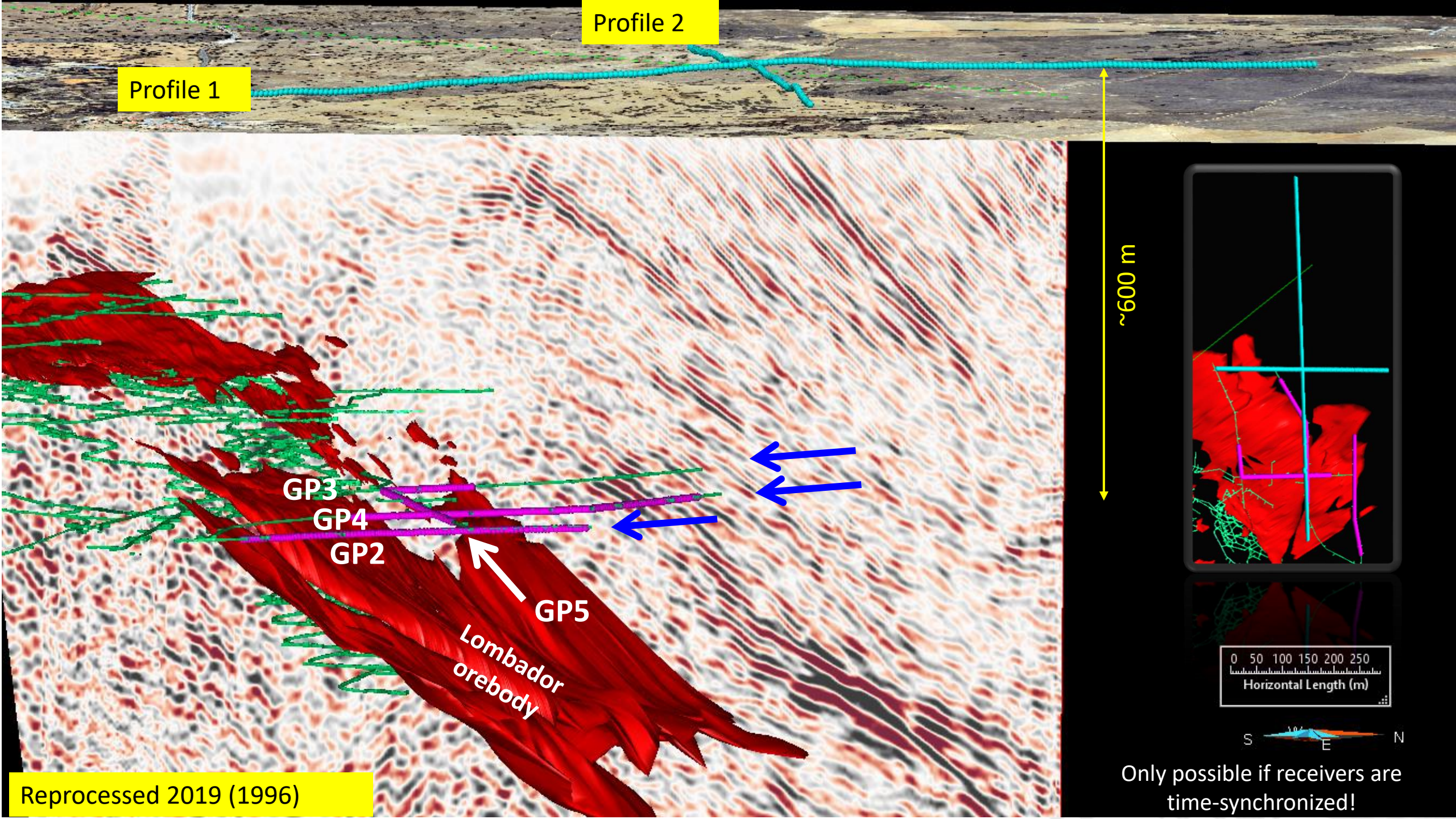
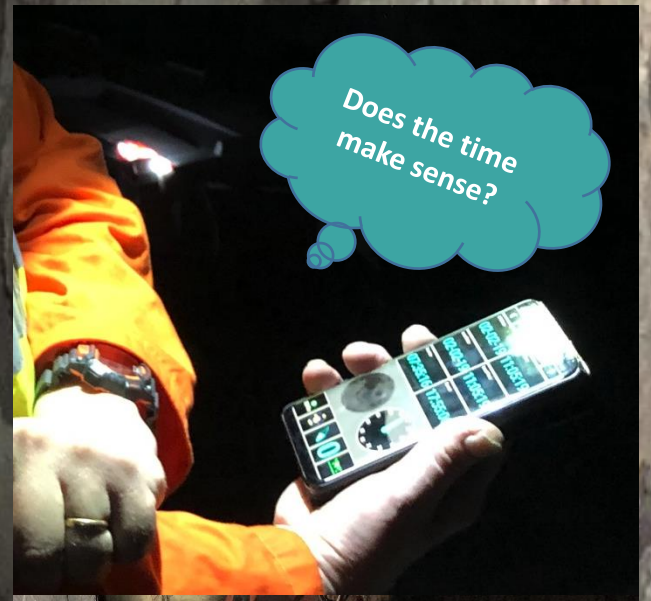
- **Real-mine condition** (exploration tunnels utilized)
- Synchronized **30 wireless recorders** in the mine, +600 cabled sensor (seismic recording system) and 350 wireless recorders on the surface
- Combination of **fiber optic and antenna**
- 8-days of operations
- Time-drift on the order of **10-15 microsecond**/day (two shifts)

We made it possible **for the first time to conduct a full-scale simultaneous shooting-recording 3D surface-3D in-mine seismic survey**


Profile 2
Profile 1
~600 m
GP3
GP4
GP2
GP5
Lombador orebody
0 50 100 150 200 250
Horizontal Length (m)
S
E
N
Only possible if receivers are time-synchronized!
Reprocessed 2019 (1996)

Exploration of Deep Targets: Tunnel-surface seismic, Neves-Corvo

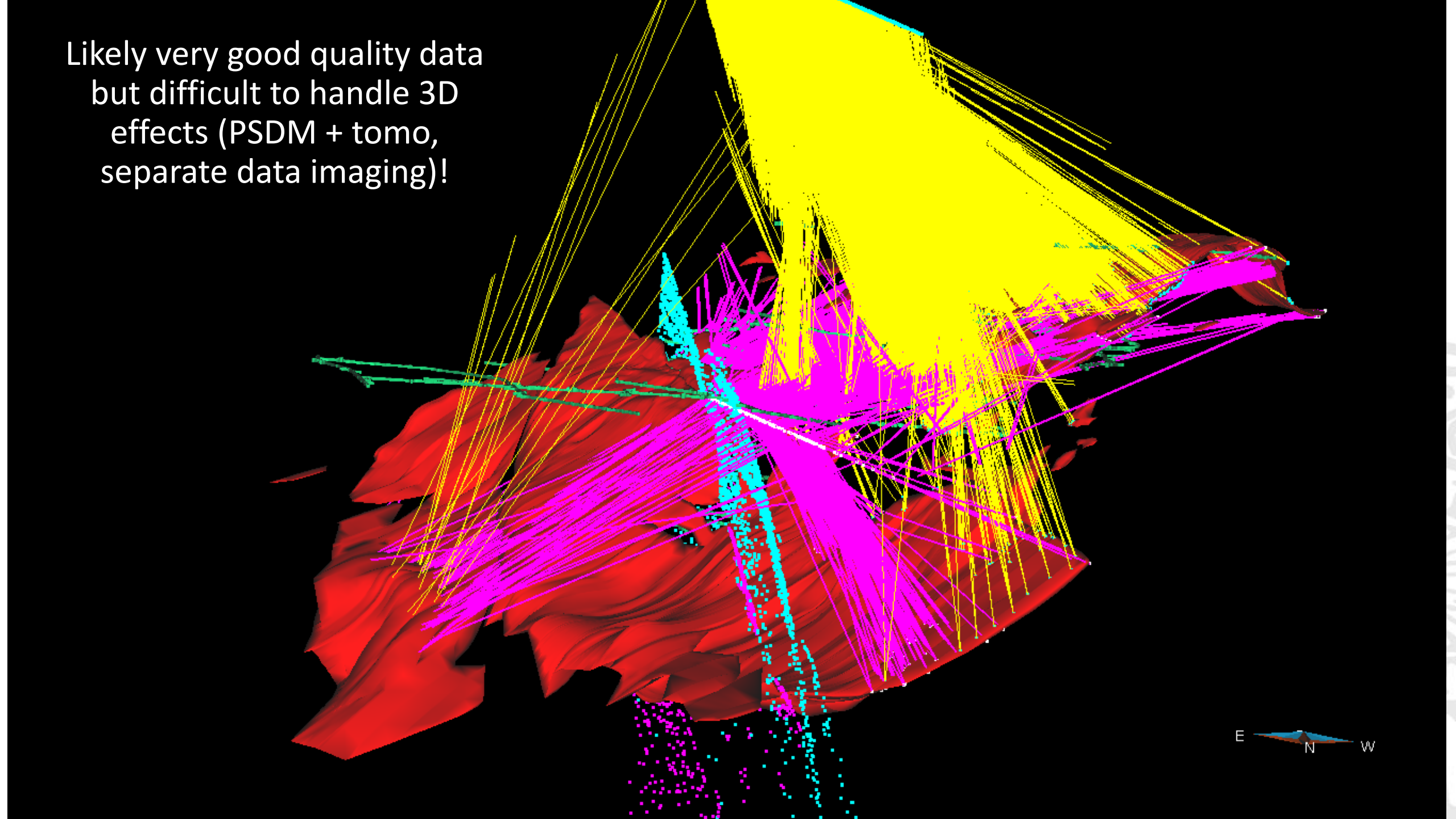


Synchronized nodal seismic recorder

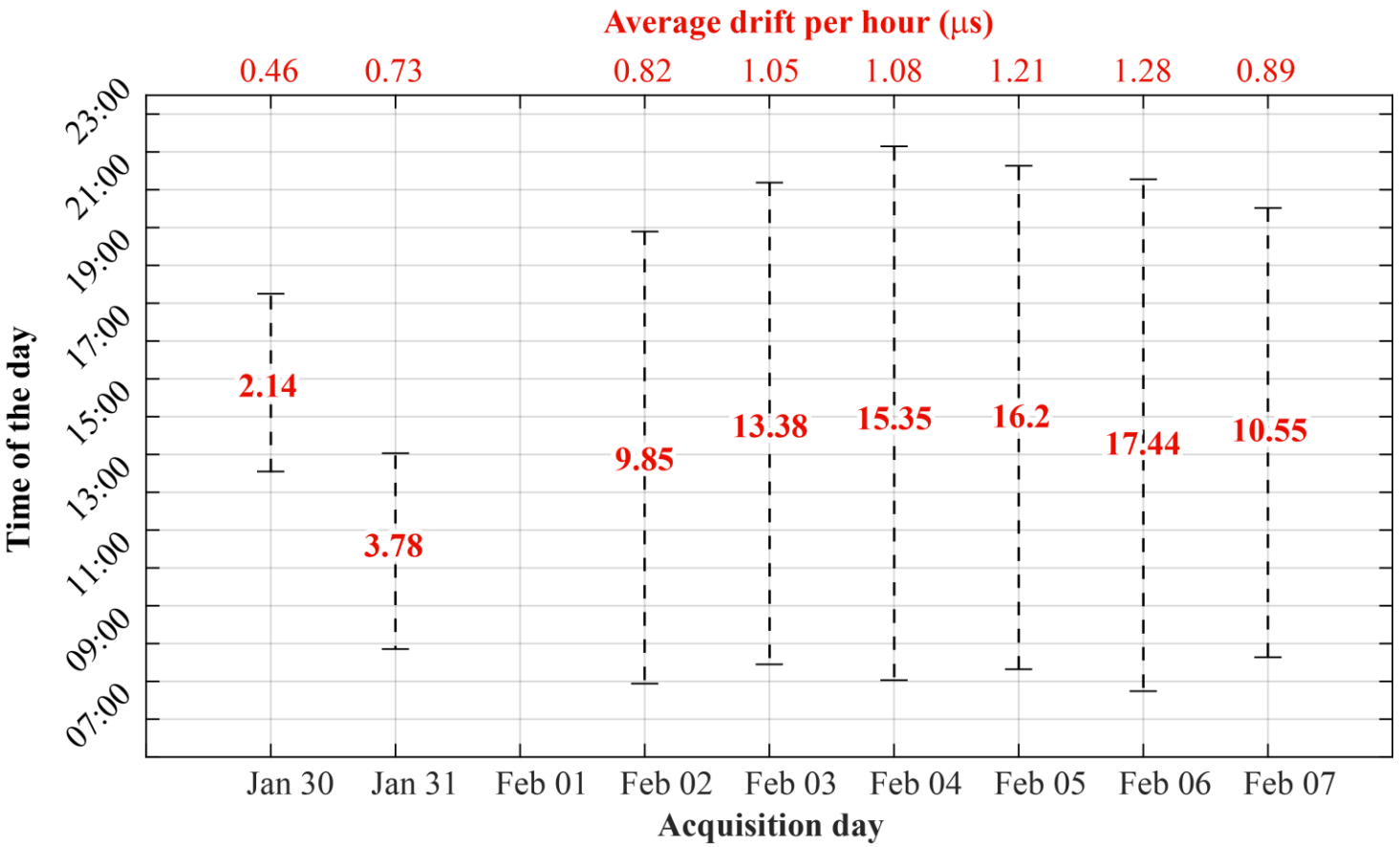
Synchronized cabled seismic recorder

GP4: Exploration tunnel (Lombador orebody)

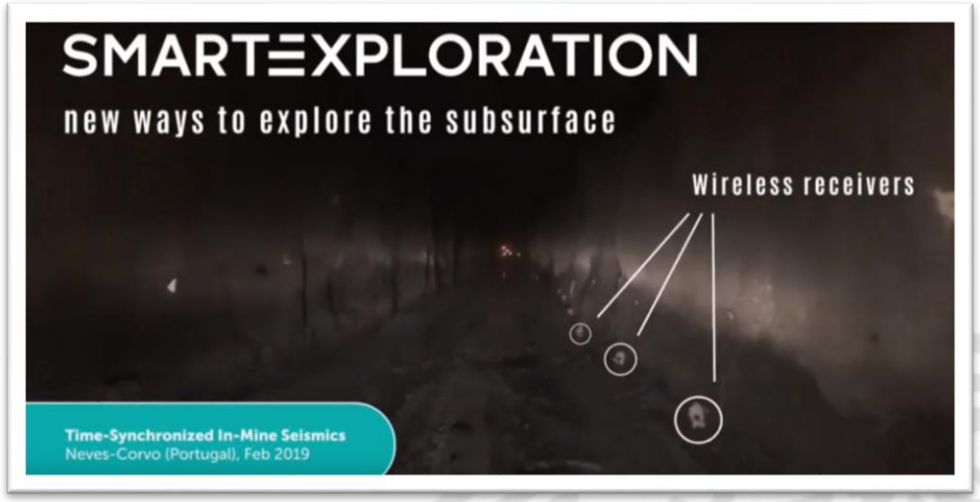
Likely very good quality data but difficult to handle 3D effects (PSDM + tomo, separate data imaging)!



Drift analysis and final words



av. drift= 13 micro-second/10 hrs



YouTube video:
https://www.youtube.com/watch?v=bBYwLLZimIs
Or:
https://smartexploration.eu/

YES:
We work hard and long days to get here!

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THANK YOU

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