



2023 SPE EUROPE ENERGY GEOHACKTHON

2. Basics of Geophysics

Magdalena Markovic

4th October 2023

#DatafyingEnergy

Before we start...



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You can find me here:



[linkedin.com/in/magdalenamarkovic](https://www.linkedin.com/in/magdalenamarkovic)



Few words about myself

MAGDALENA
MARKOVIC

Researcher in Geophysics @ Uppsala
University (Sweden)



PhD in Solid Earth Physics (Applied
Geophysics) @ Uppsala University

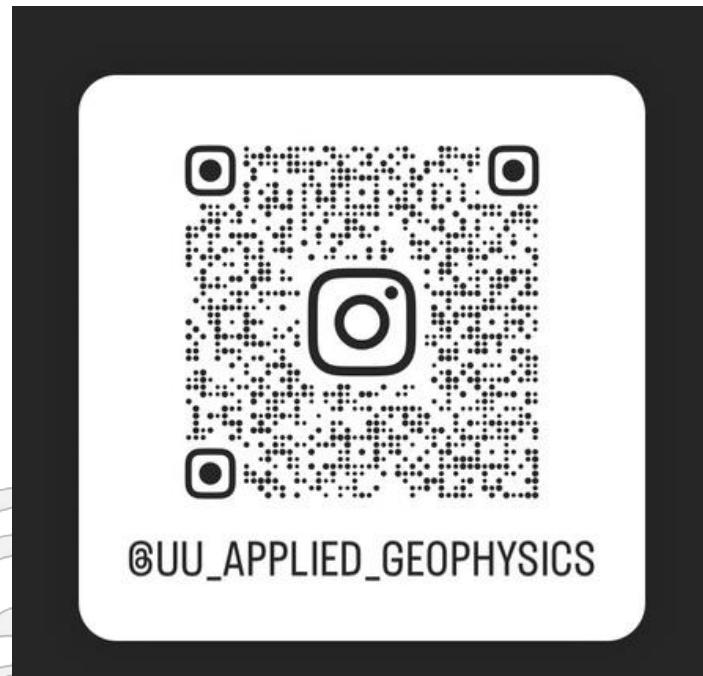
BSc & MSc in Geological Engineering (Applied
Geophysics) @ University of Belgrade

Research interests: Hardrock seismics, AI
applications; Crustal-scale studies





Few words about UU team



RESEARCH AREAS:

Near-surface geophysics (infrastructure projects; landslides; mineral exploration)

CCS projects (land seismic acquisition & data processing)

Crustal-scale projects (e.g. mapping of Moho discontinuity)



Instrumentation development (e.g., landstreamer state-of-the-art system; GPS time tagging system - patented)

Software solutions (e.g., numerous of in-house algorithms for seismic data modeling, processing and interpretation)





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I want to know more about you!

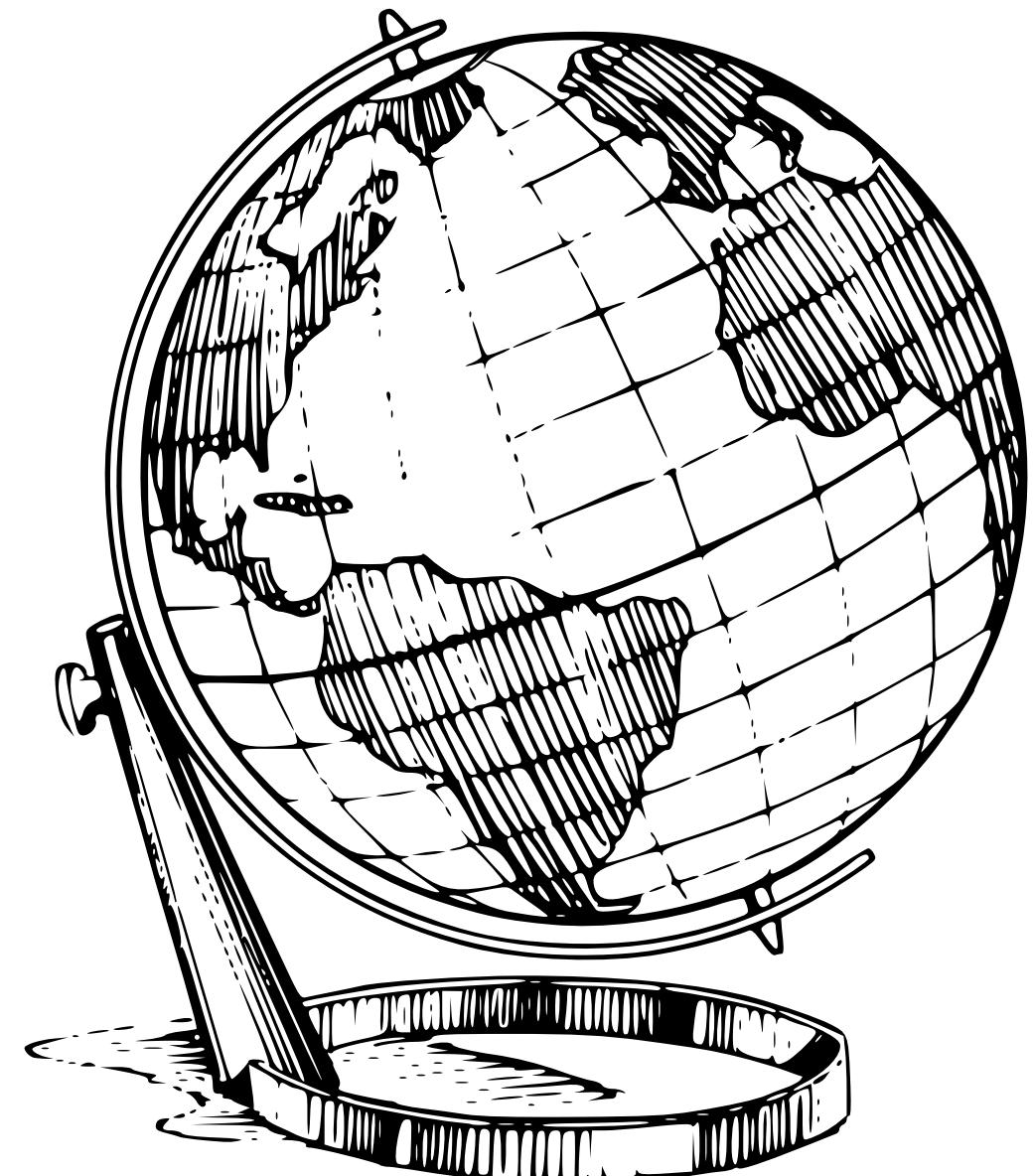
ANONYMOUS SURVEY!

Scan the QR code on the screen, and click on one of the offered options. Once you do that, click submit button!



The question is about your background expertise

The results of the survey will be used for pedagogical project within Academic Teacher Training Course, which I am attending currently, therefore I kindly ask for your help! :)



Let's start!



What is Geophysics?

geophysics /dʒiːdʒə'fɪzɪks/  noun

Britannica Dictionary definition of GEOPHYSICS

[noncount]

: a branch of science that deals with the physical movements and forces of the Earth (such as its climate and oceans)

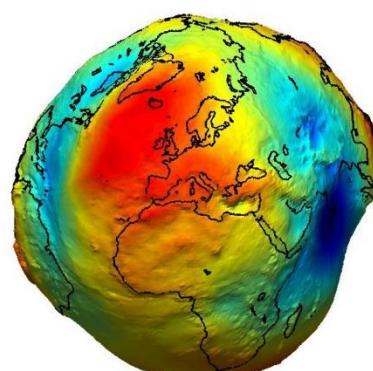
geophysics, major branch of the Earth sciences that applies the principles and methods of physics to the study of the Earth.



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Credit: Rostislav Zatonskiy



What can we observe?

THE EARTH'S STRUCTURE

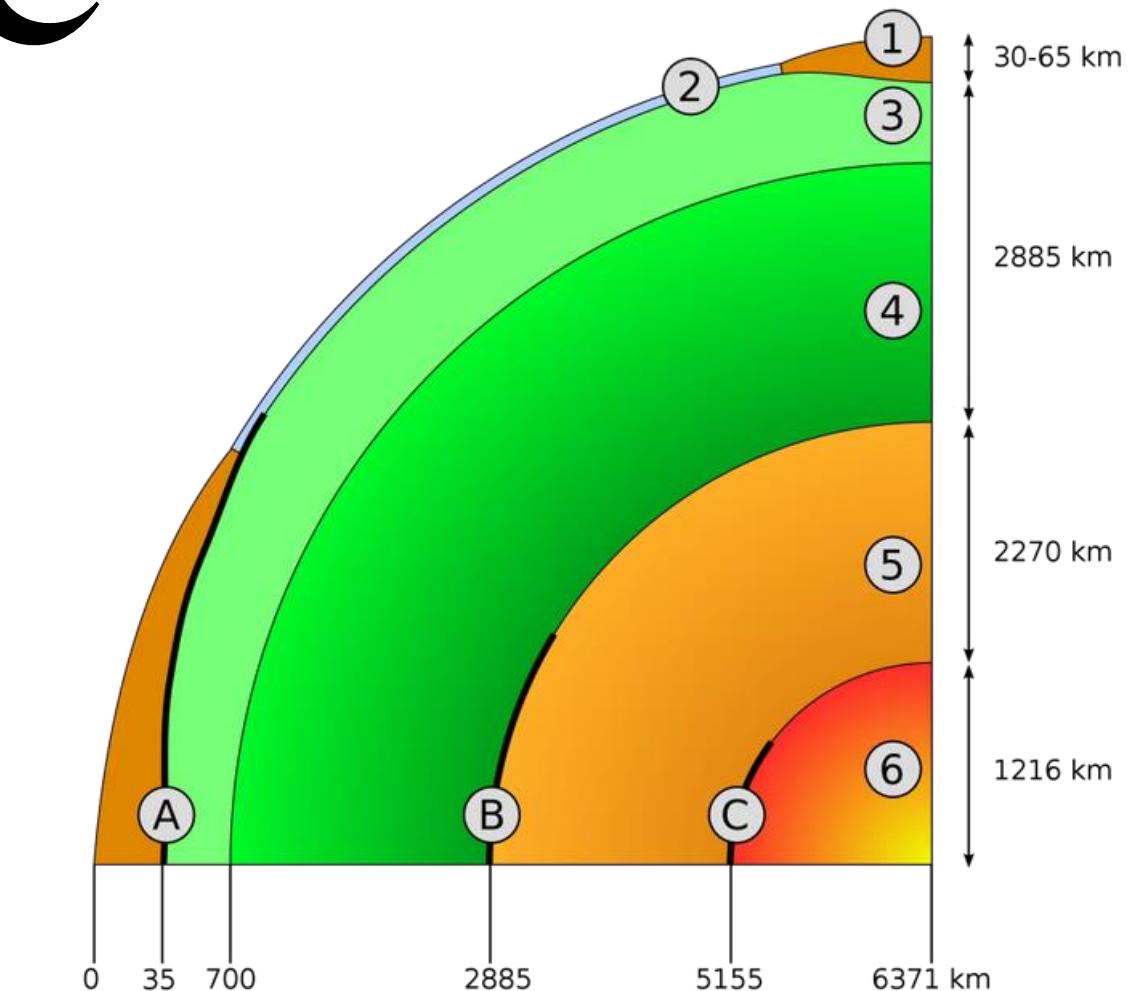
Earth's interior: seismic waves produced by earthquakes

Magnetic field: self-sustained dynamo

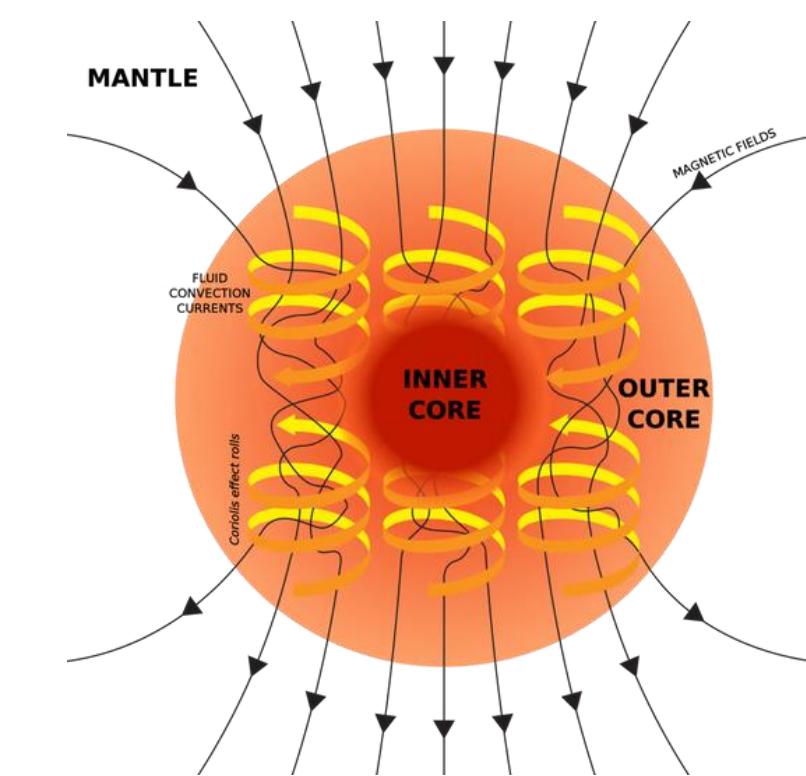
Geoid



Convection currents of fluid metal in the Earth's outer core, driven by heat flow from the inner core, organized into rolls by the Coriolis force, generate circulating electric currents, which supports the magnetic field. (USGS)



Credit: Dake

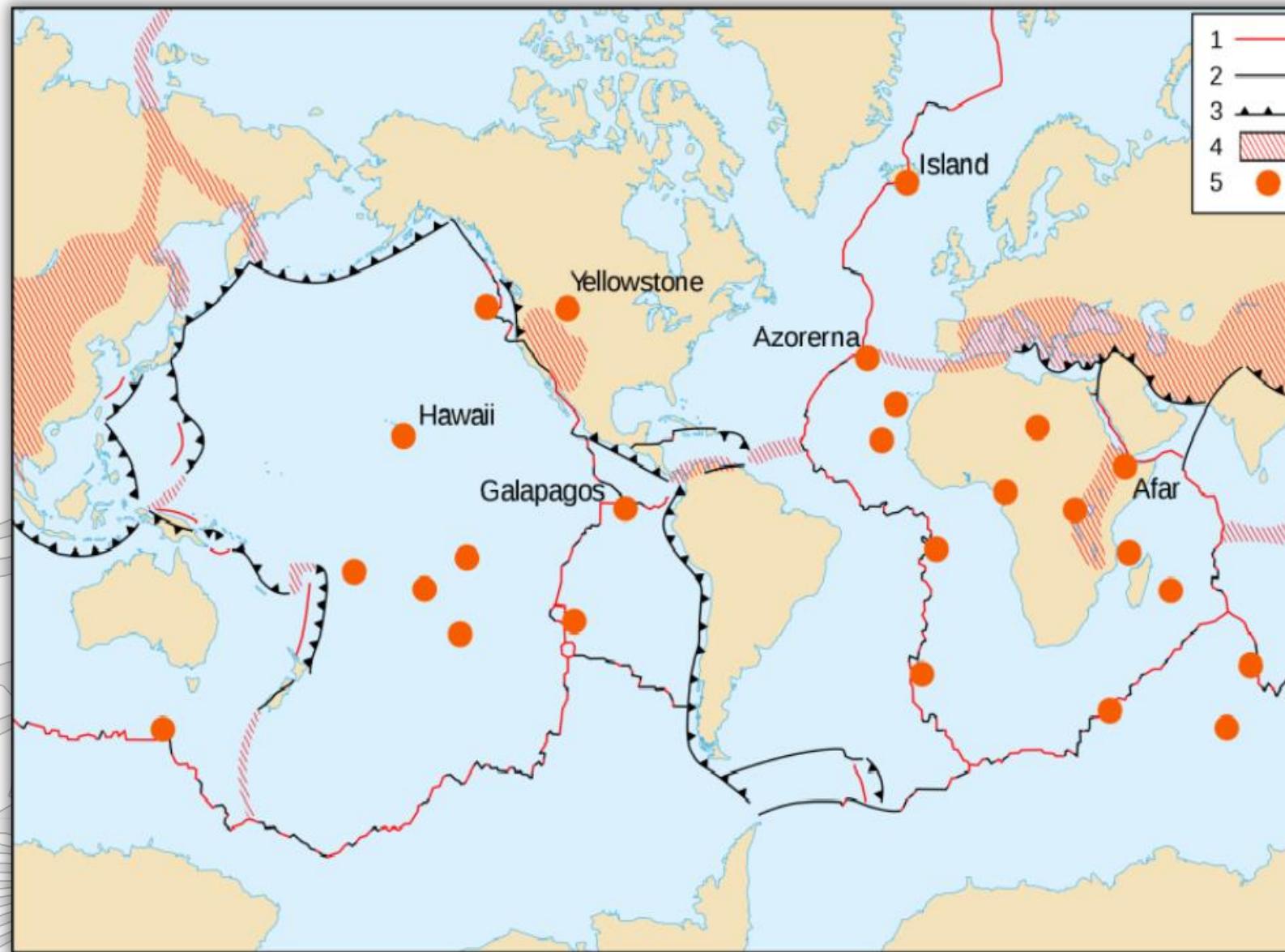


Credit: Getty Images

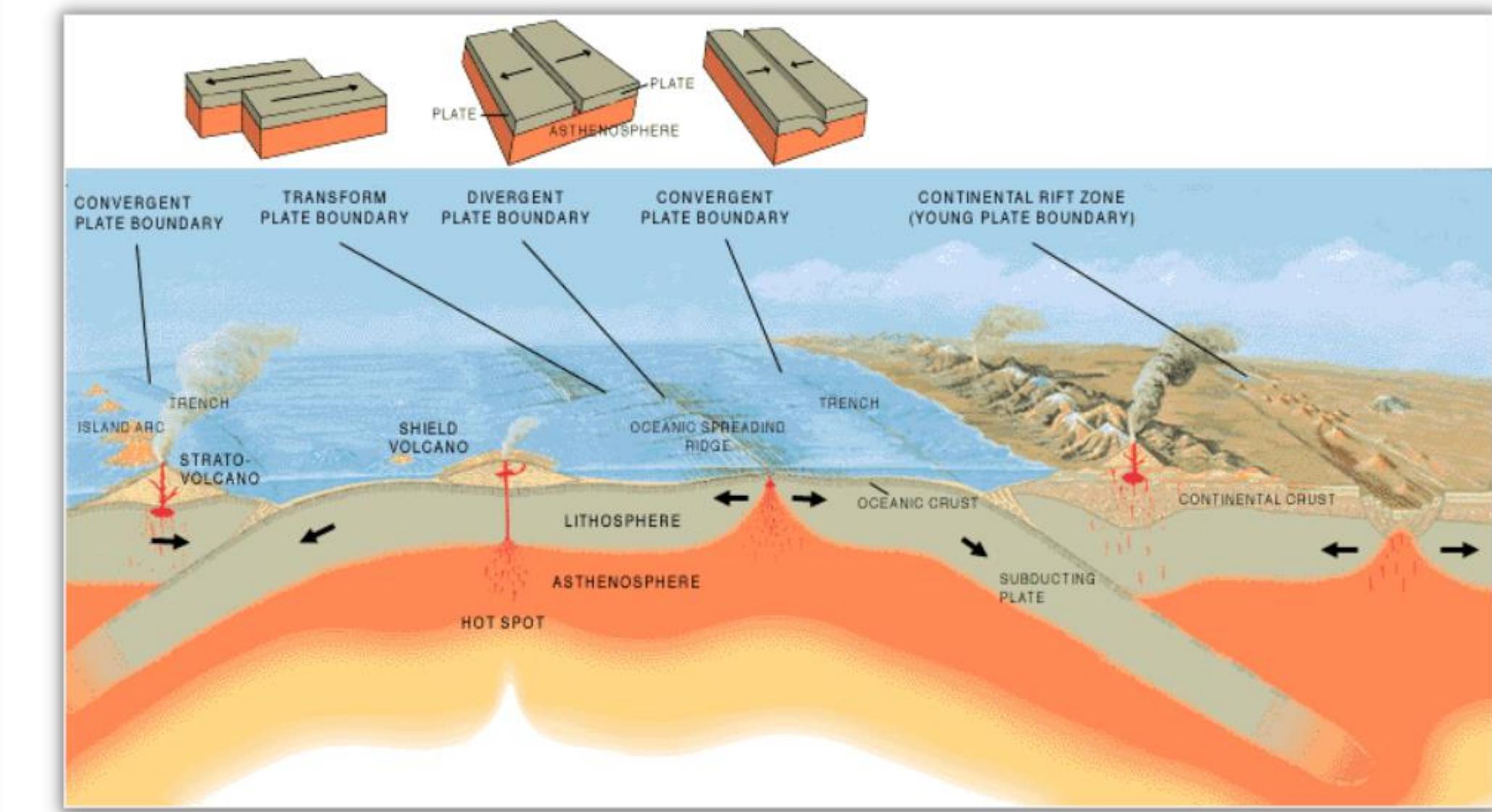


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Our planet is breathing!



Credit: Eric Gaba



Credit: USGS



Geophysical Methods



Different rock types - different physical properties

PHYSICAL PROPERTIES OF ROCKS

Density: Gravity method

Magnetization: Magnetic method

Electrical resistivity: Geoelectrical method

Electrical conductivity: Electromagnetic method

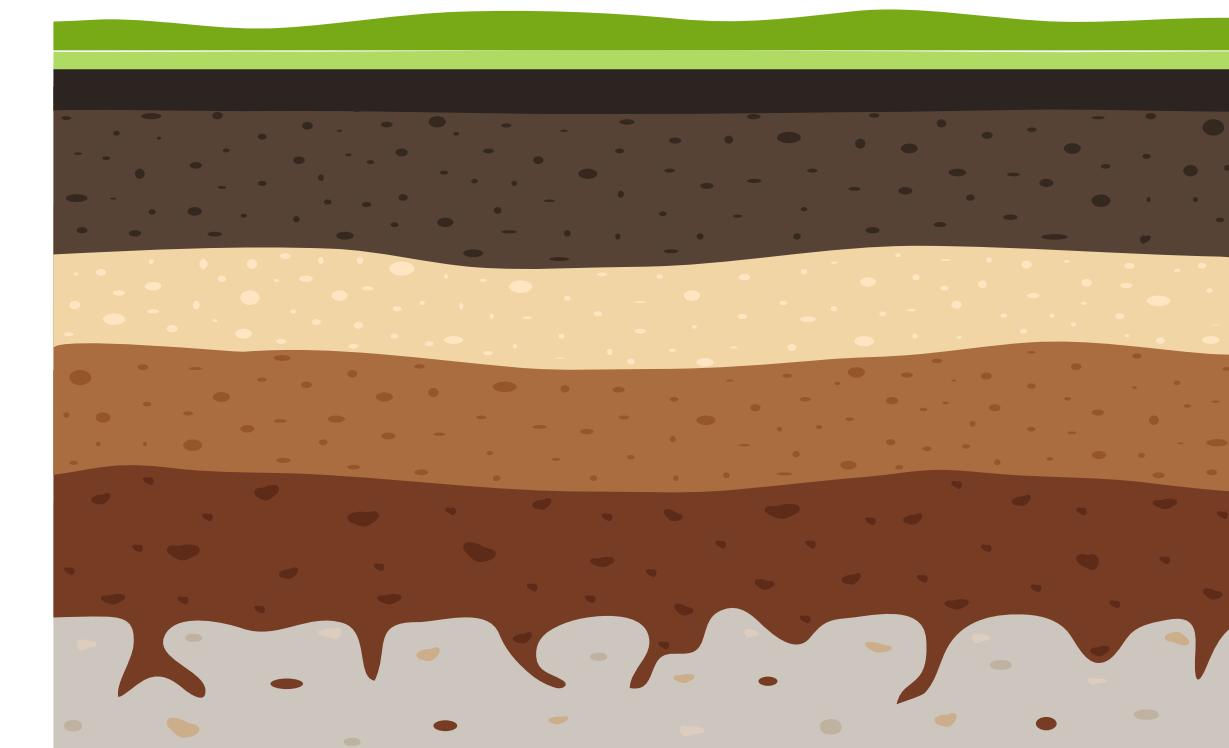
Elastic properties: Seismic method



Acquisition of geophysical data is designed to map these properties, and study their contrasts at different scales (e.g., from rock samples to crustal scales)

Main goal in **processing** of the geophysical data is to increase signal-to-noise ratio (S/N)

Interpretation of geophysical data integrates all other existing knowledge within the area of investigation



Different geological layers/boundaries - contrast in physical properties of rocks

“Everything is recorded
in rocks!”
-Milutin Milankovic



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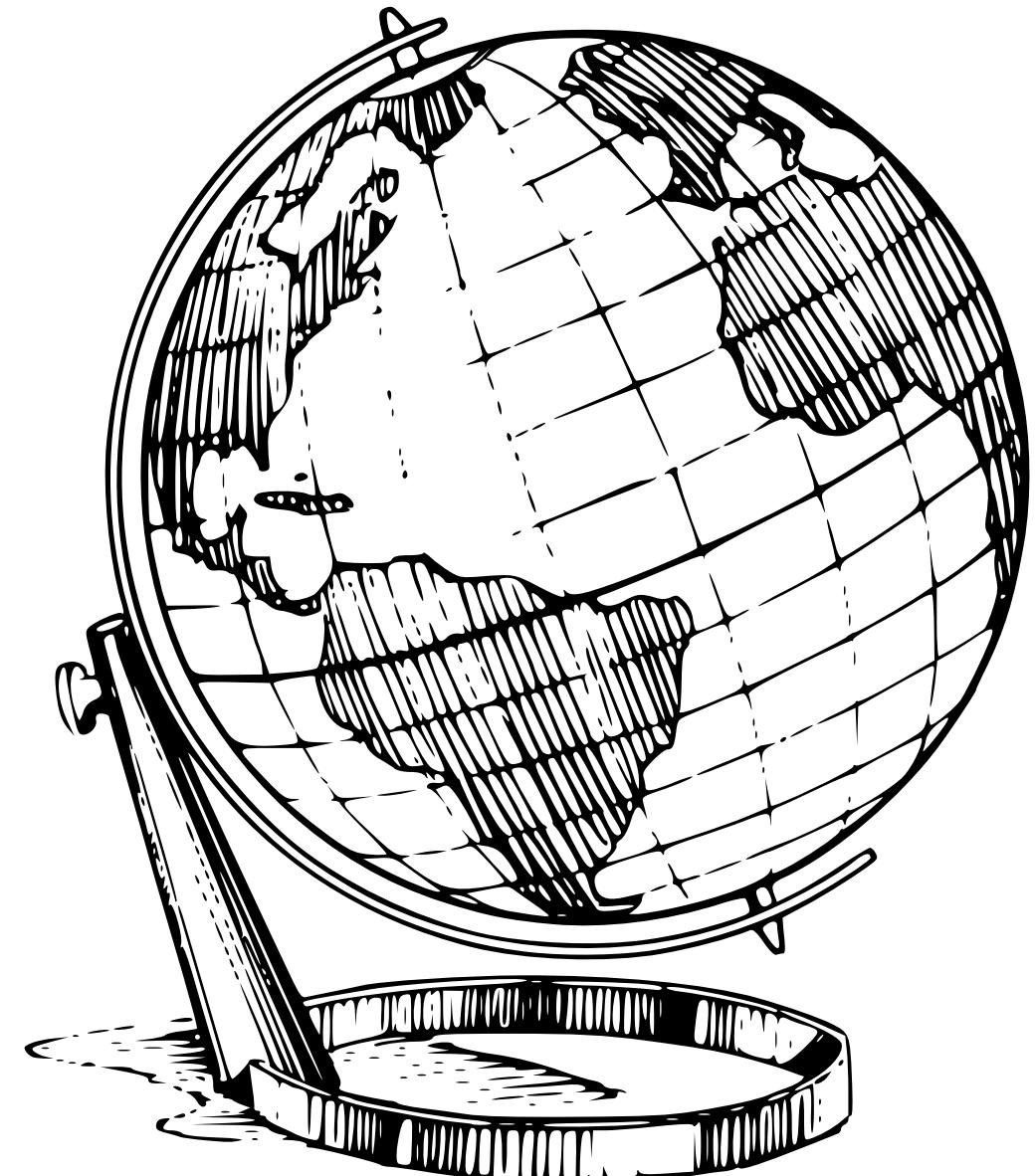
I want to know more about you!

ANONYMOUS SURVEY!

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**The question is about your experience with
geophysical methods**





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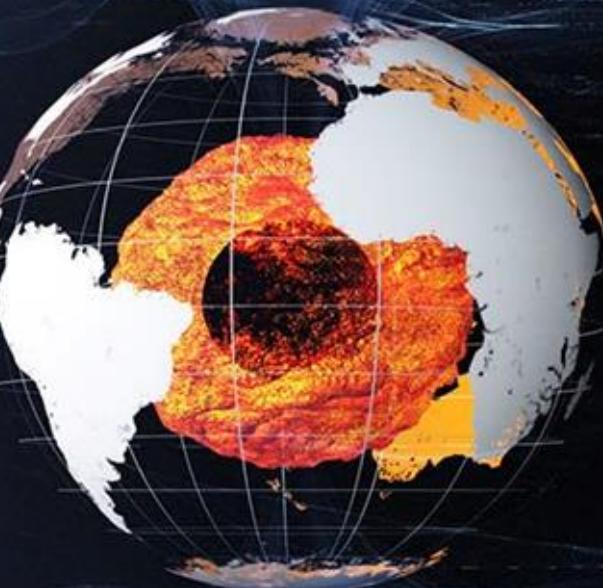
Magnetic method

EARTH'S MAGNETIC FIELD

Magnetic storms (variations of magnetic field)

Van Allen radiation belt
Aurora lights phenomena

Magnetic poles





Magnetic method



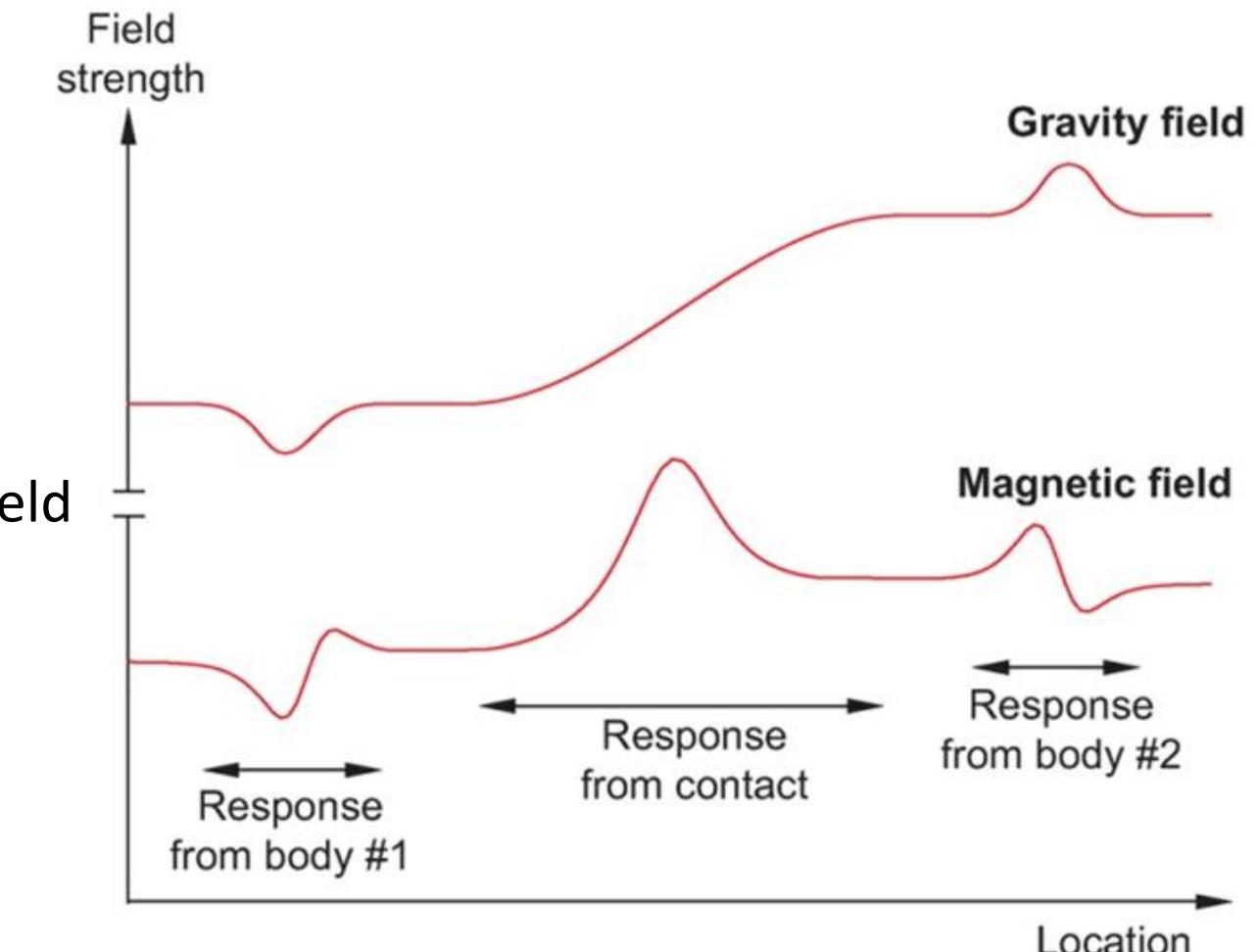
RESPONSE OF MAGNETIC FIELD

$$J_{induced} = \frac{kB}{\mu_0}$$

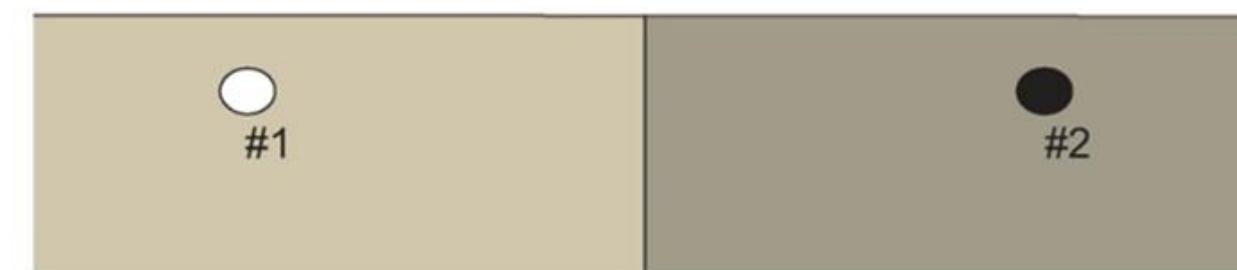
External field

Magnetic (also mass) susceptibility
(degree to which a body can be
magnetized by an external field)

Magnetic permeability
Vaccume= $4\pi \cdot 10^{-7}$ henry/m



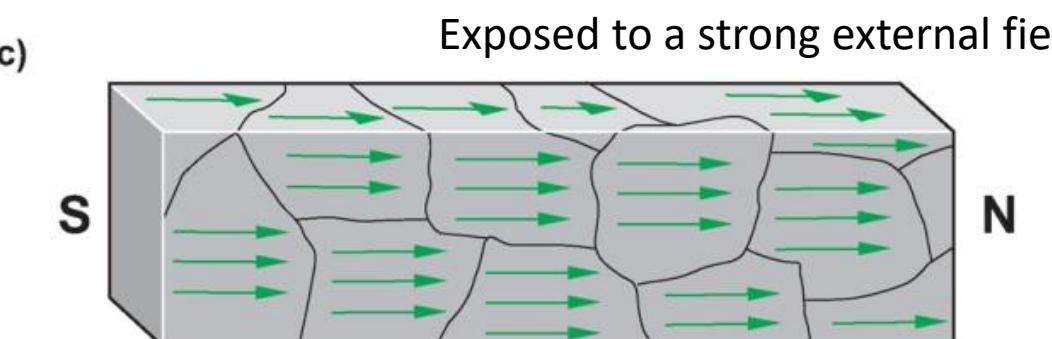
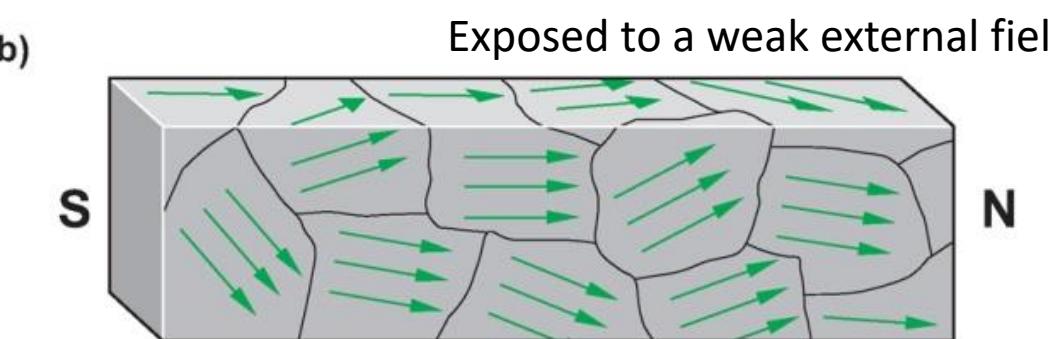
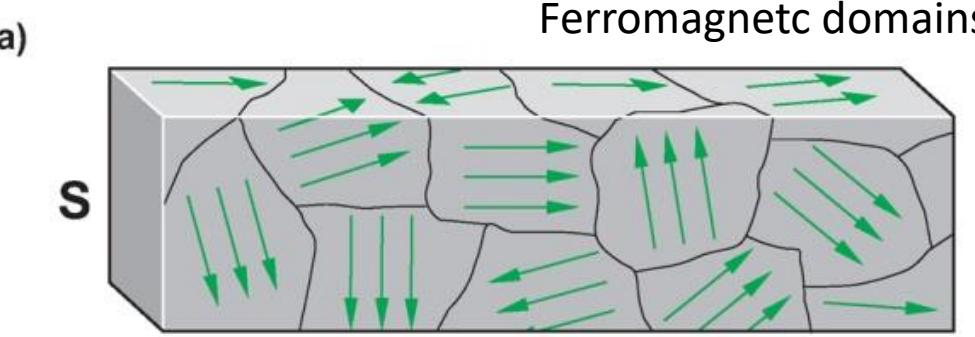
Field susceptibility meter



Density/magnetism
Lowest Highest



Magnetic method



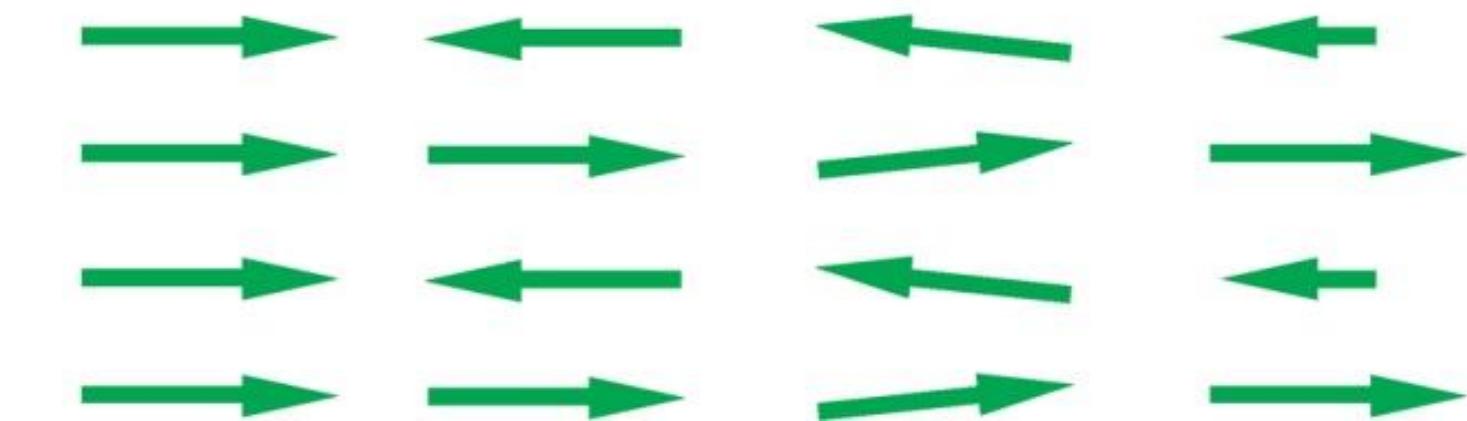
Types of magnetization

Magnetic susceptibility also depends on magnetic permeability:

$$k = \frac{m - m_0}{m_0} = \frac{m}{m_0} - 1$$

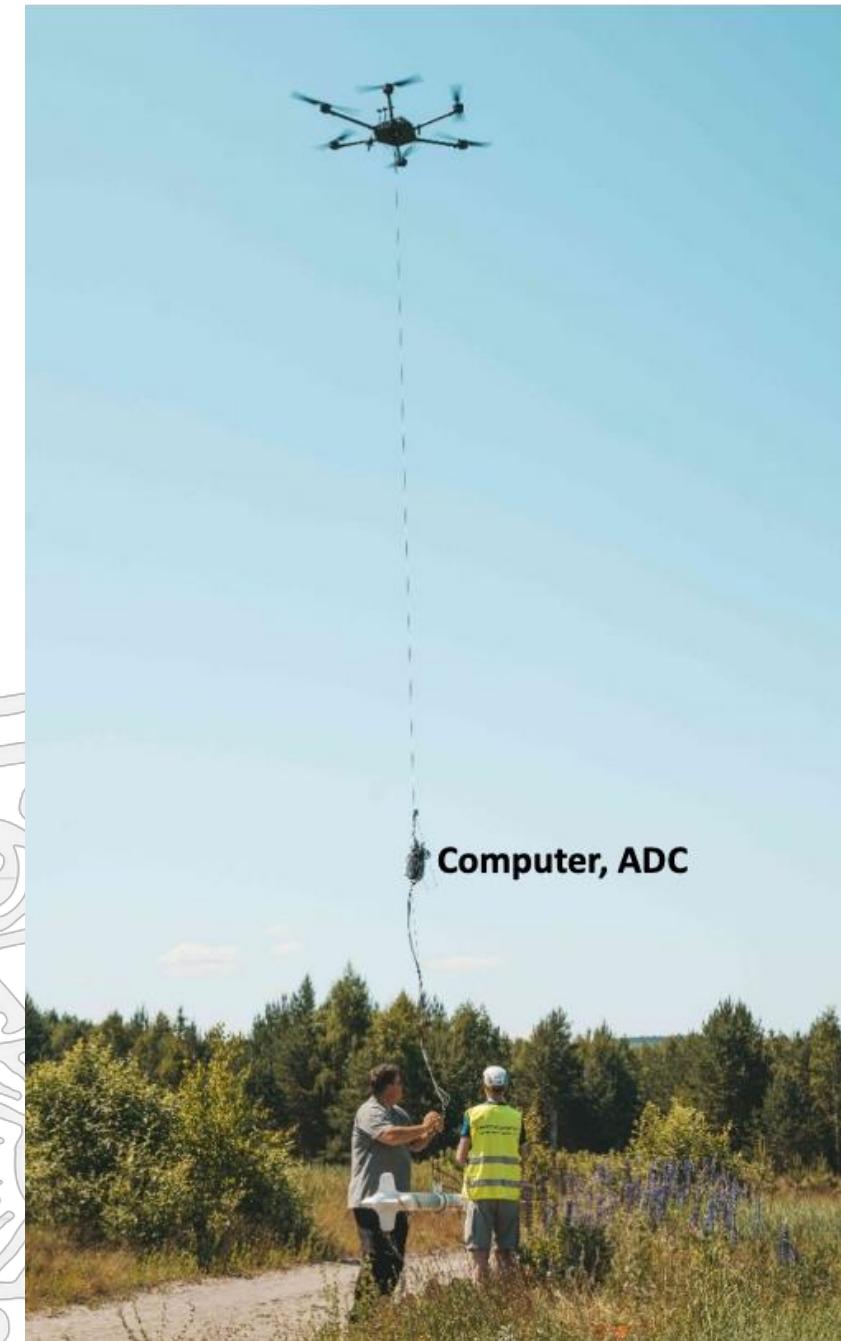
For most non-magnetic minerals the ratio (relative permeability) is 1

Ferromagnetism Antiferromagnetism Canted antiferromagnetism Ferrimagnetism



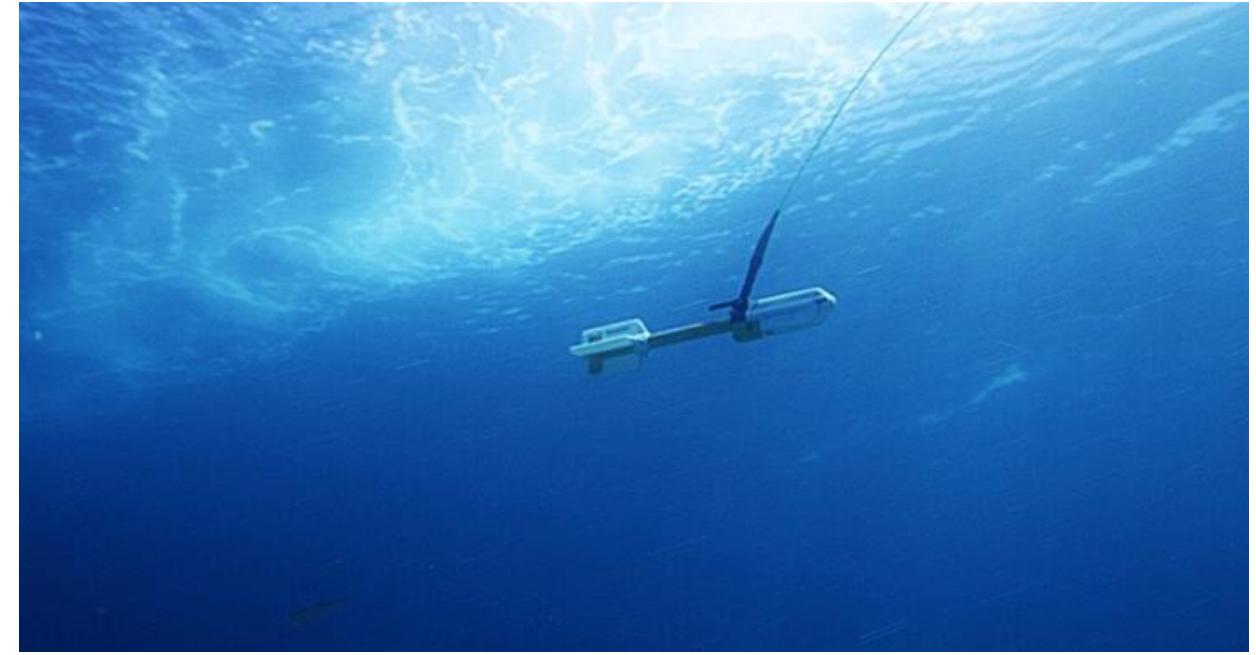


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DATA ACQUISITION

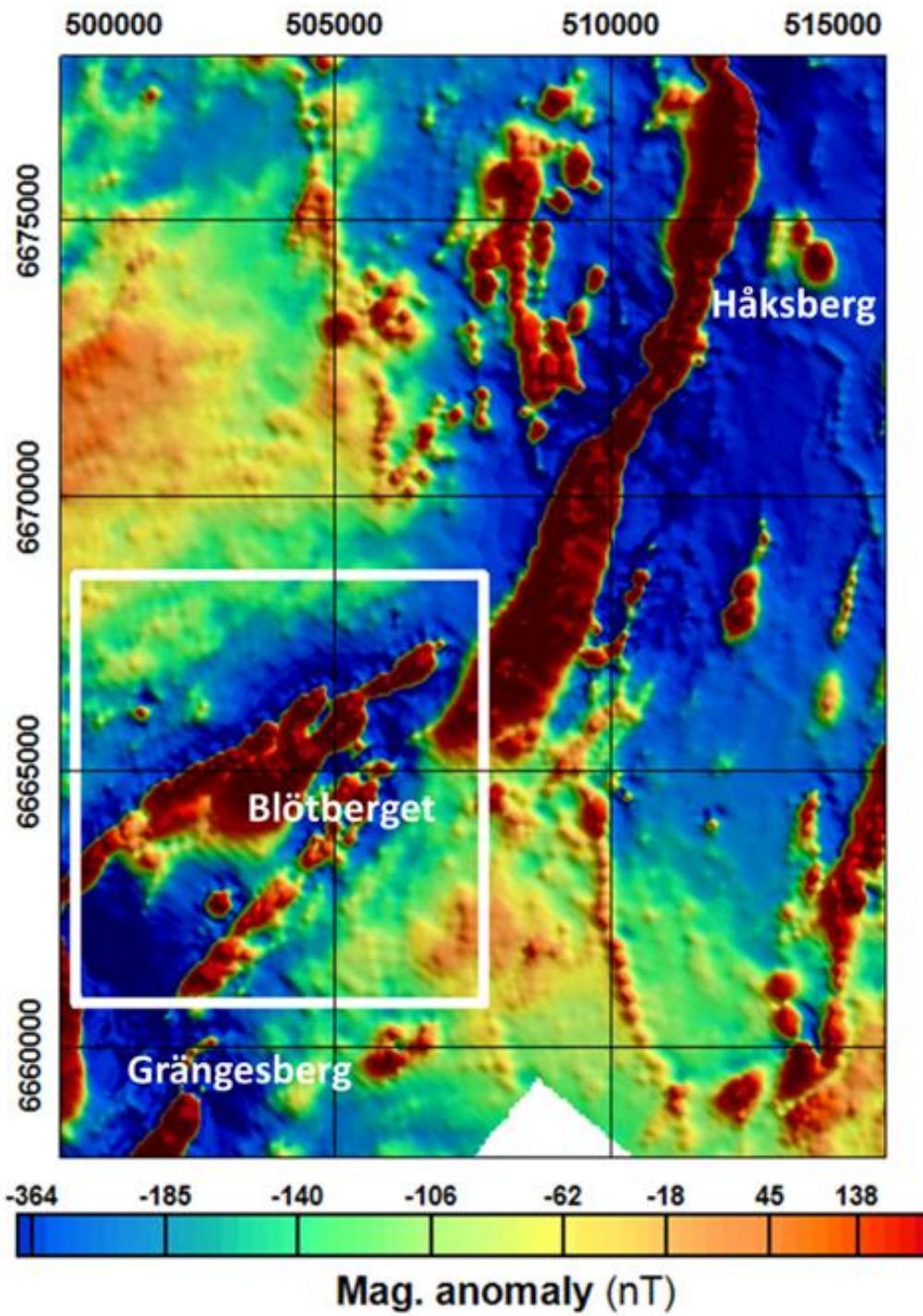
Land
Airborne
Marine



Magnetic method



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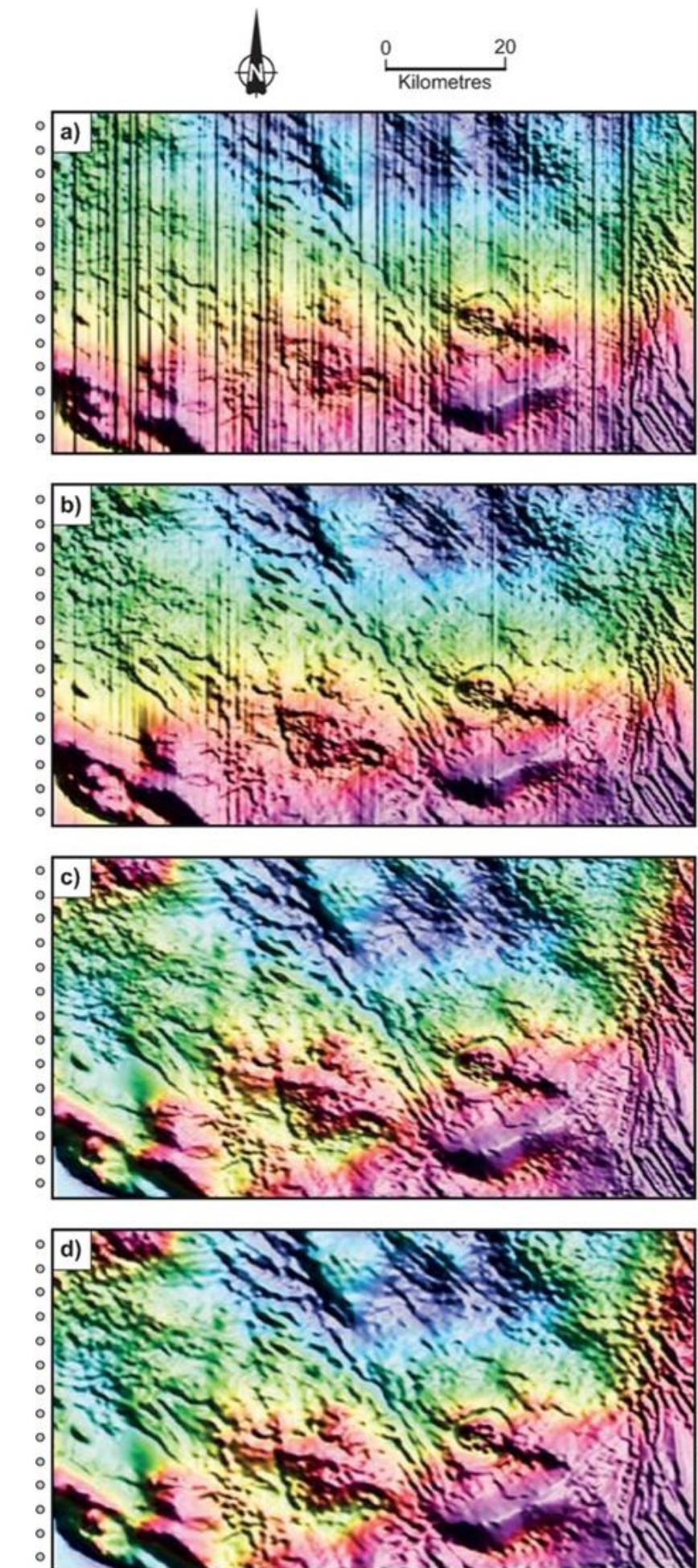


Magnetic method

CASE STUDIES: AIRBORNE MAG

Effects from different stages of data correction:

- a: Aircraft orientation (footprint)
- b: Diurnal variations
- c: Tie-line leveling
- d: Micro-leveling

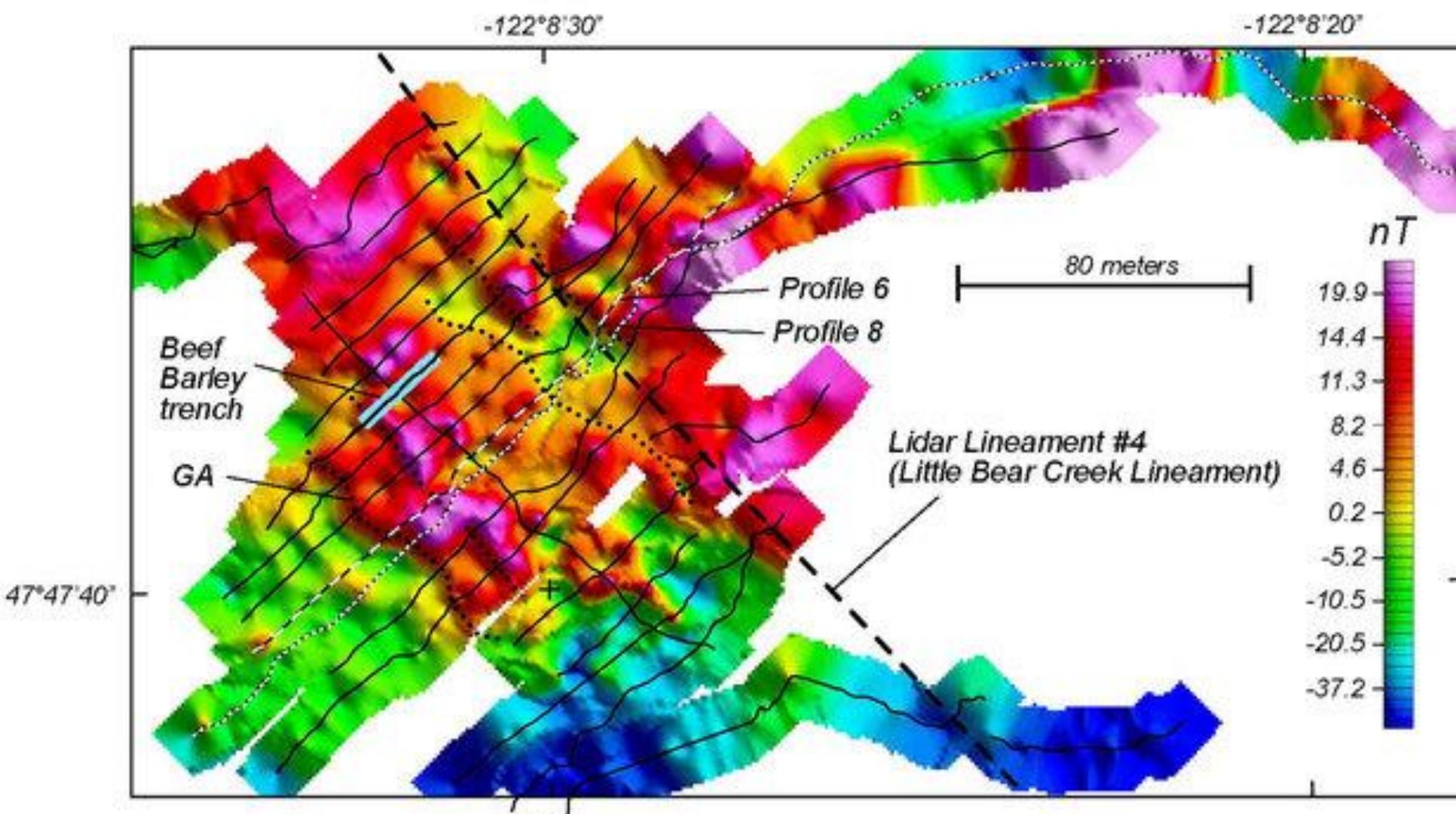




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Magnetic method

CASE STUDIES: GROUND MAG



Sherrod et al., 2005

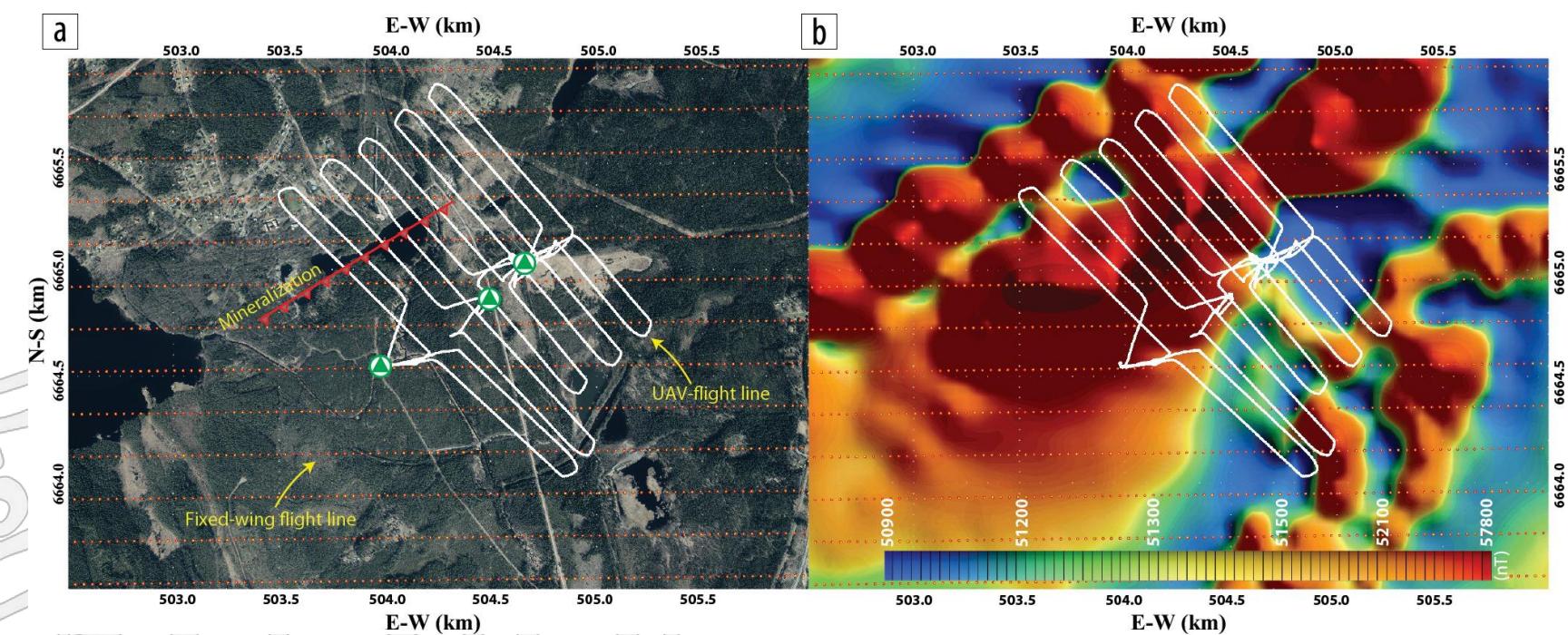




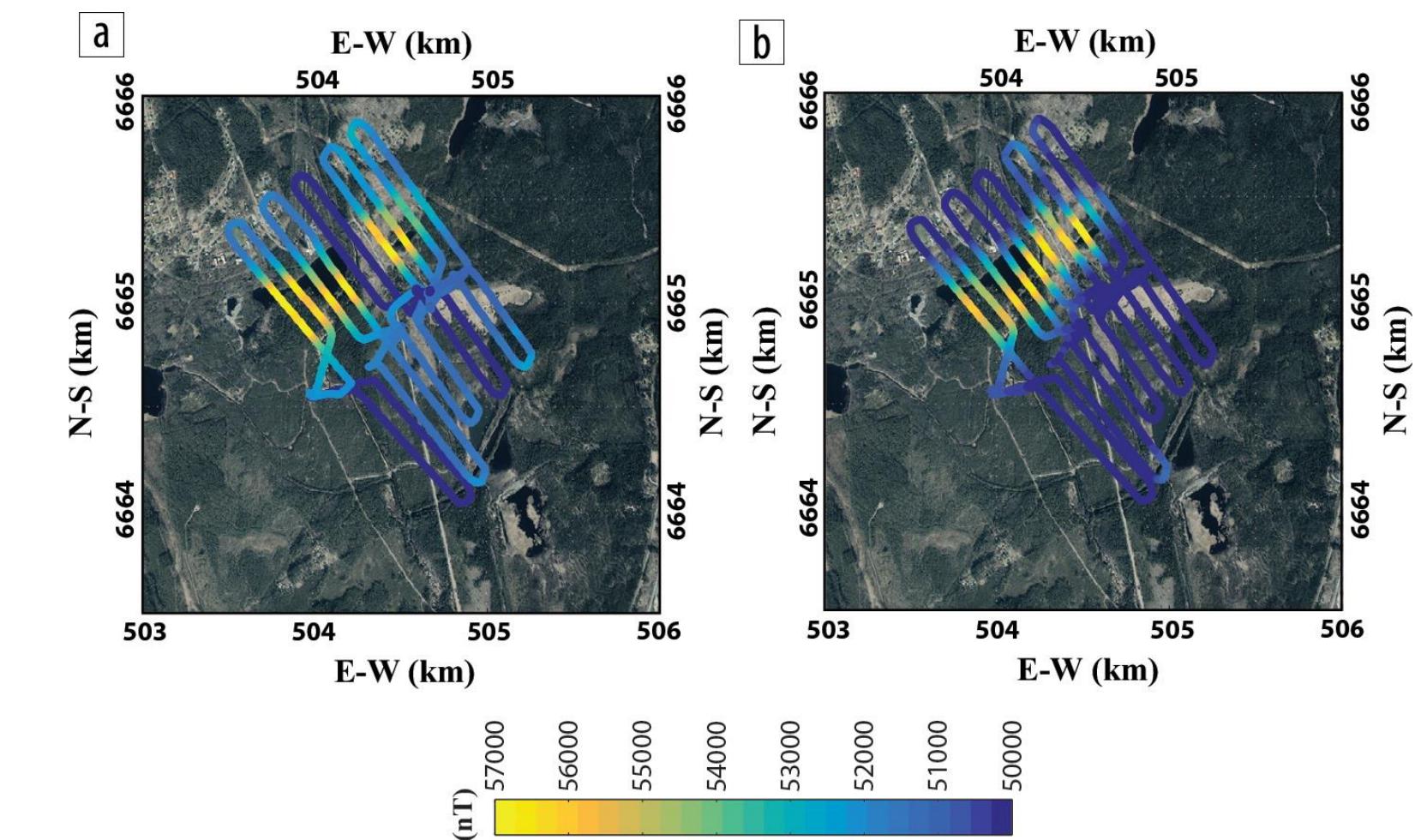
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Magnetic method

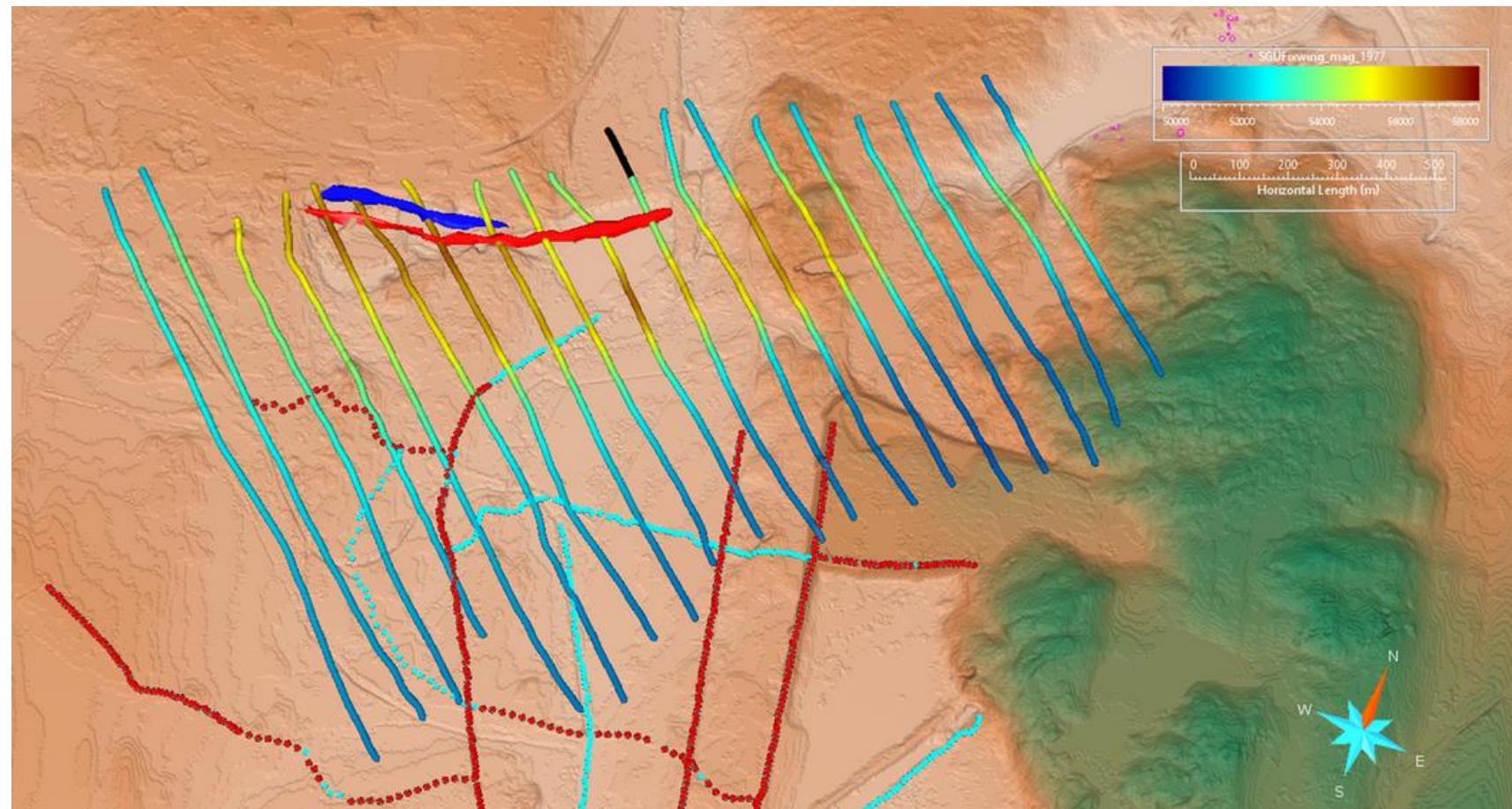
CASE STUDIES: UAV



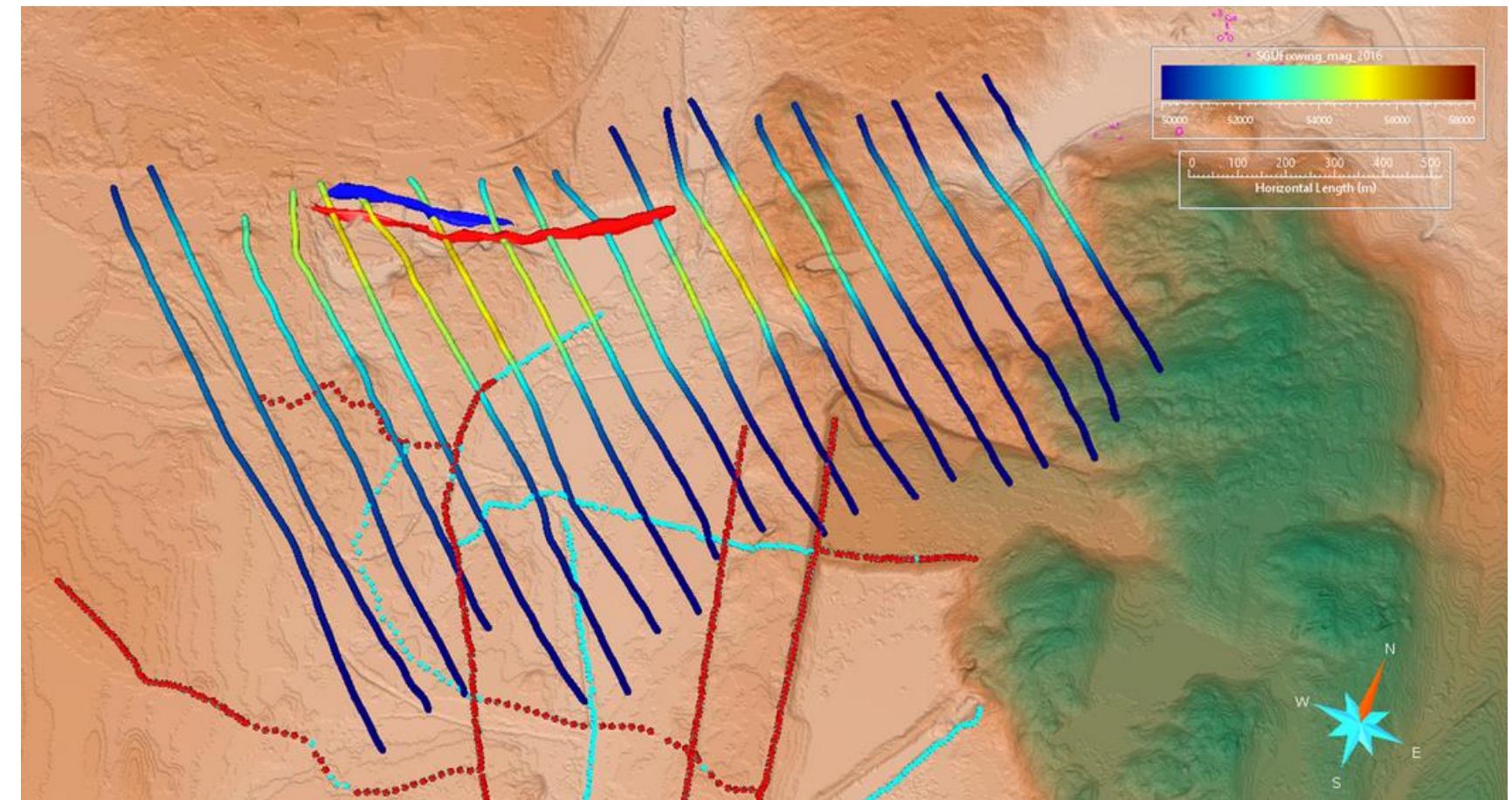
Malehmir et al., 2017



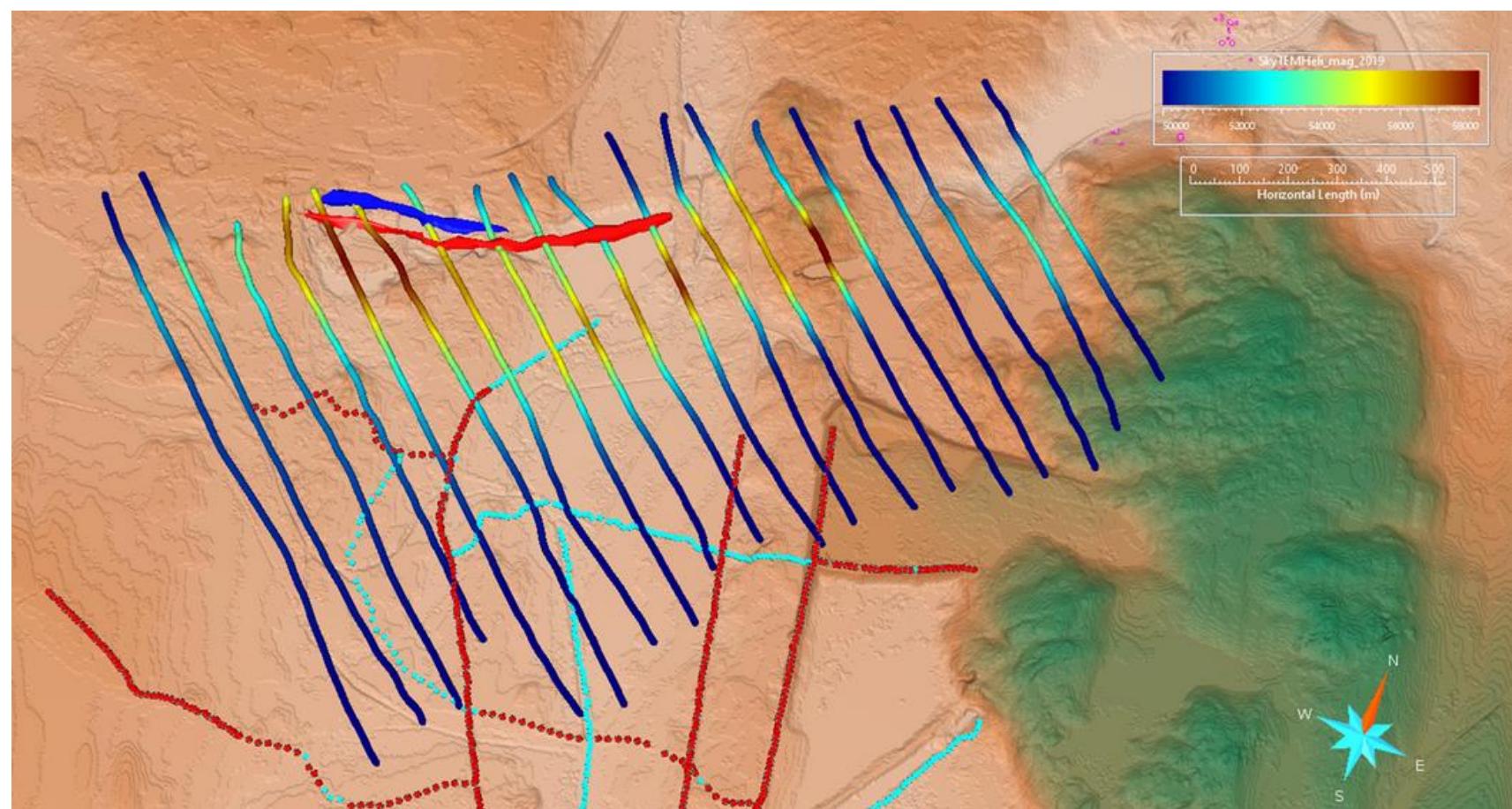
(a) Total-field magnetic data as acquired by the rotary-wing UAV system and (b) those from 1972 acquired by a fixed-wing airplane approximately 30 m above the surface.



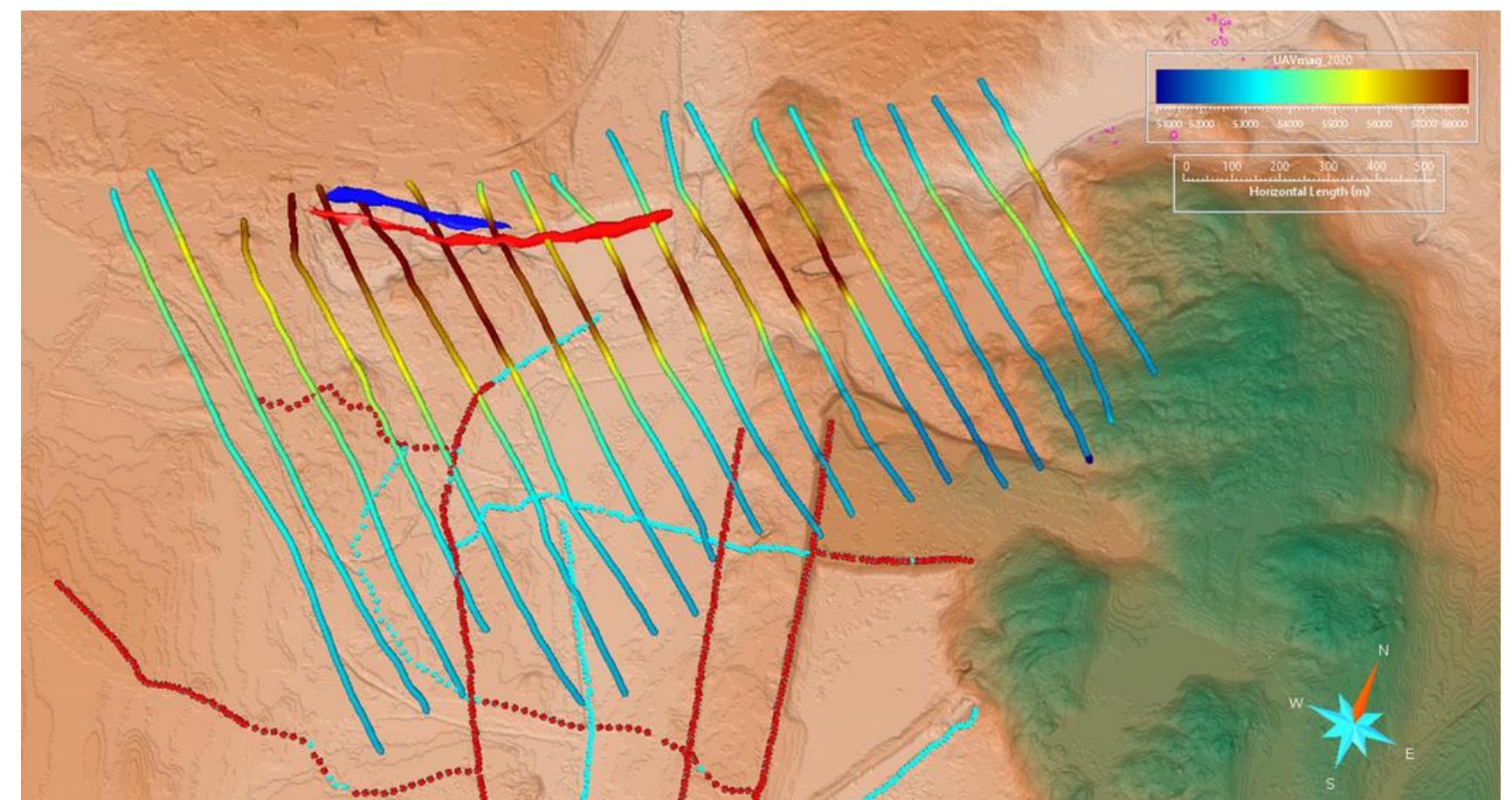
Fixed wing (1972): 30 m



Fixed wing (2016): 70 m



Helicopter (2019): 70 m



UAV (2020): 70 m



Geoelectric method

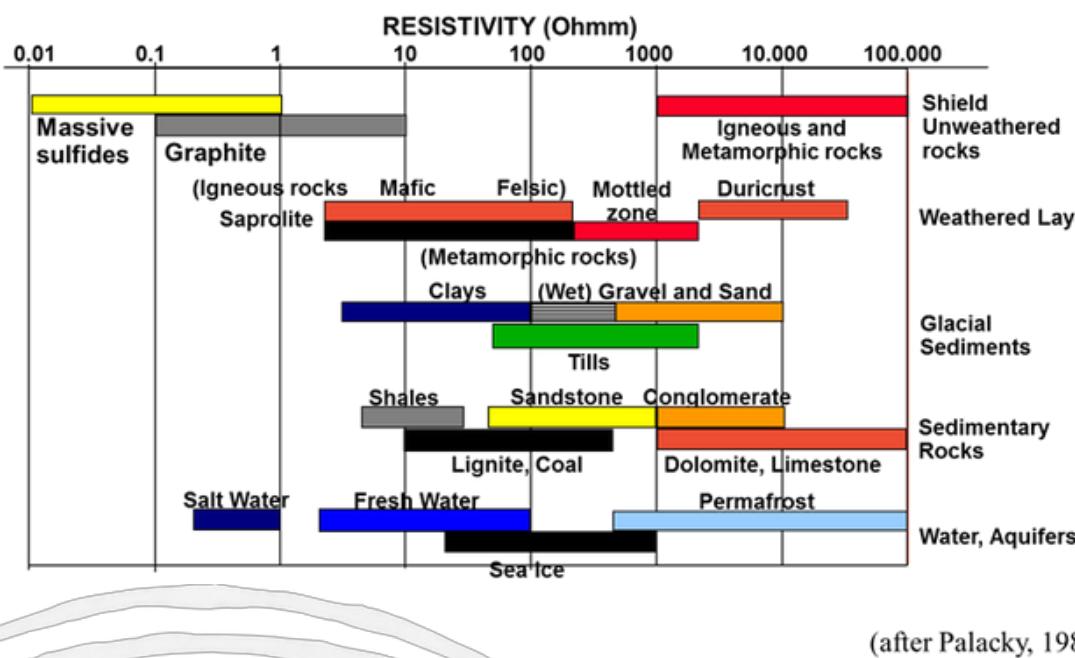
PRINCIPLES

Different electrode arrays
Electric resistivity

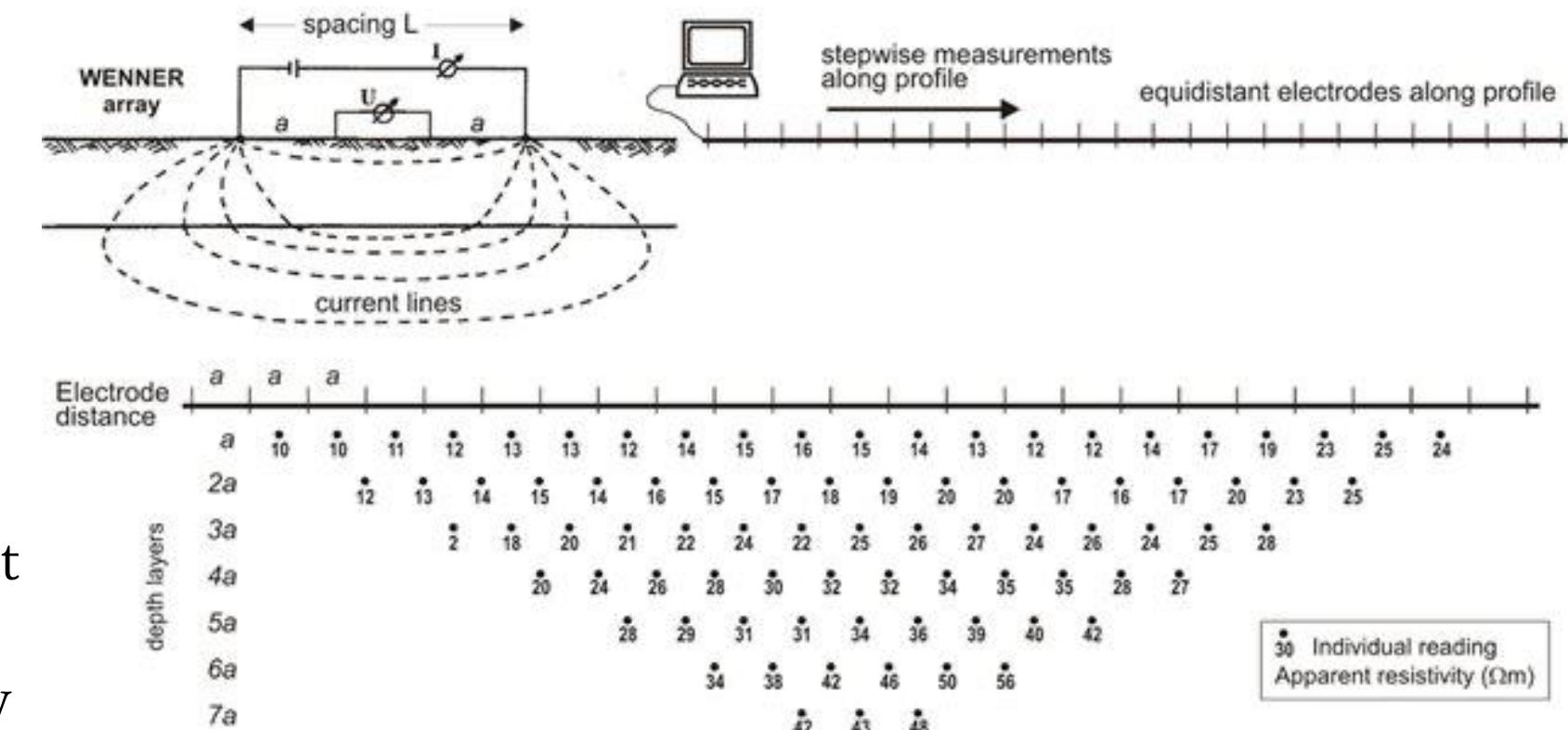
Direct current of strength I is injected into the subsurface at two points and the electric potential U generated thereby is measured between two other points.

From the two measured values I and U and a factor K calculated from the distances of the four electrodes the so-called apparent electrical resistivity rho.

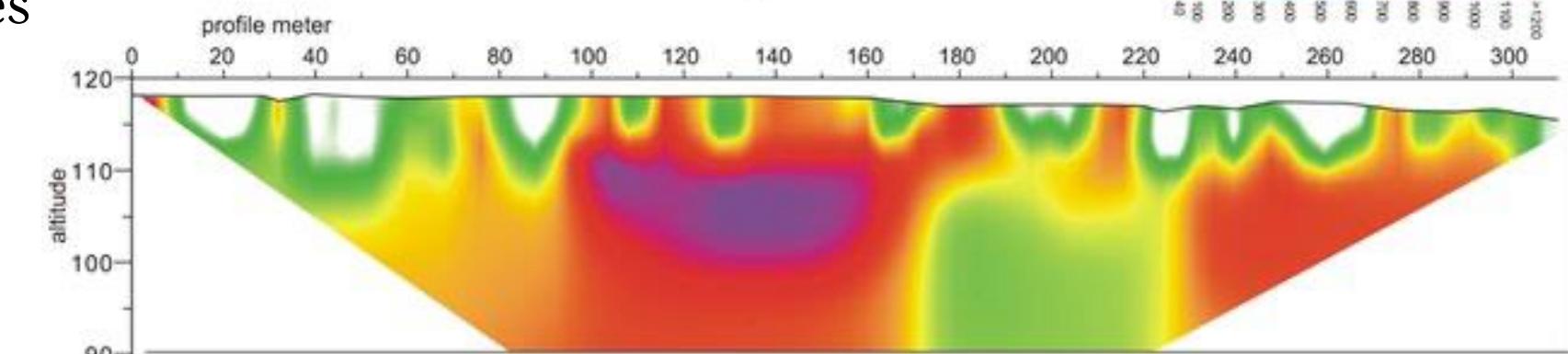
$$\rho = 2\pi^*a * (U / I)$$



A) Principle of geoelectric profiling / tomography



B) Resistivity tomogram

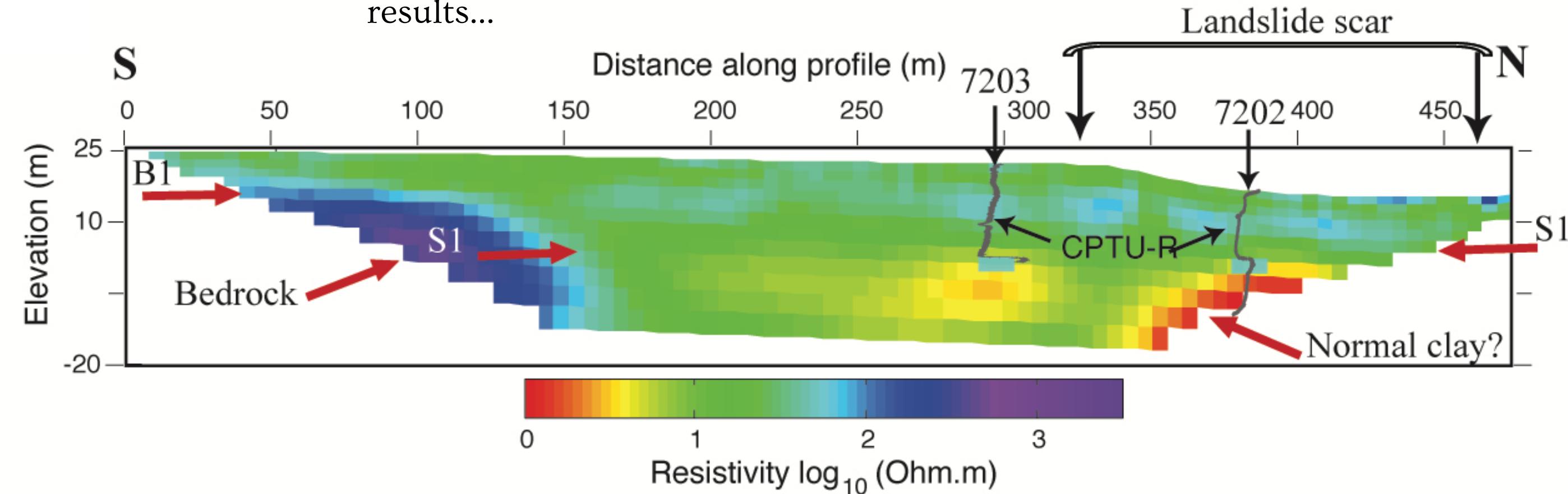


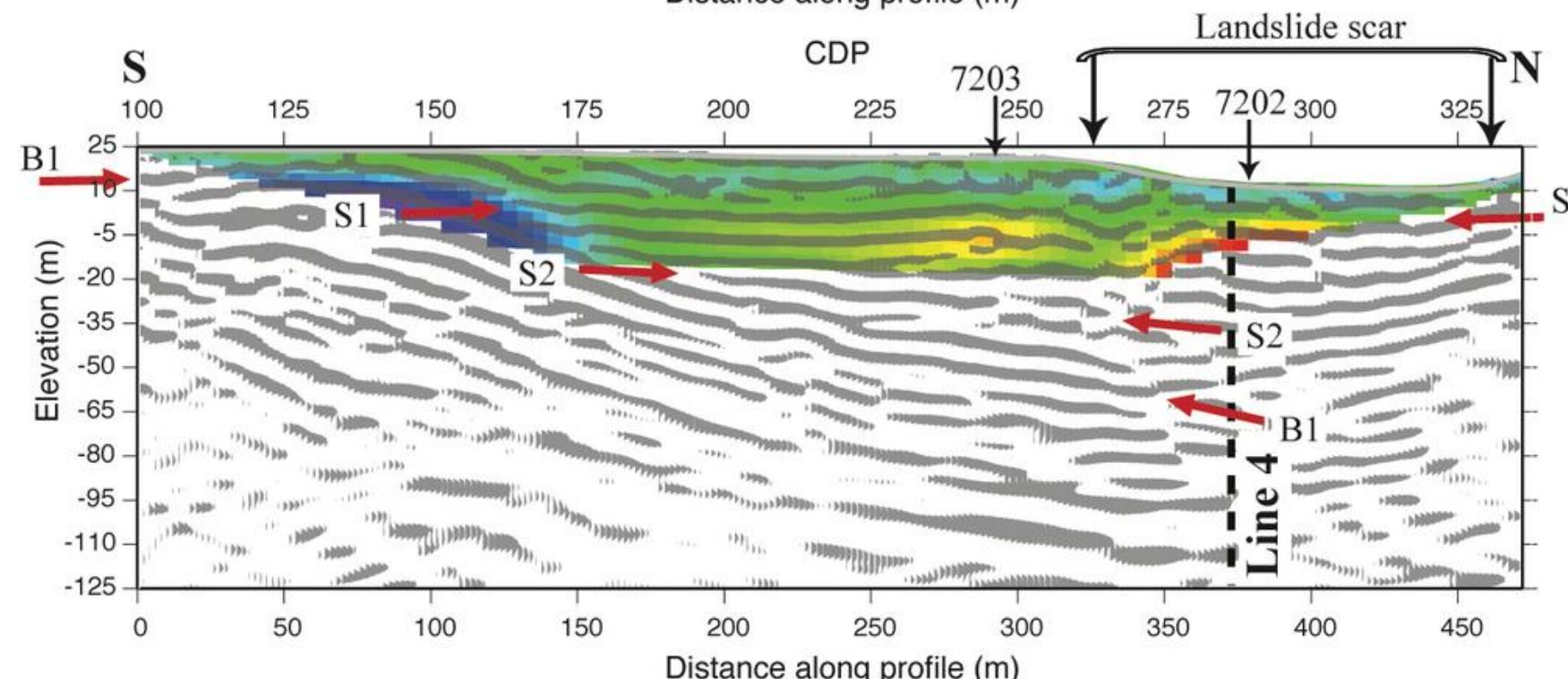
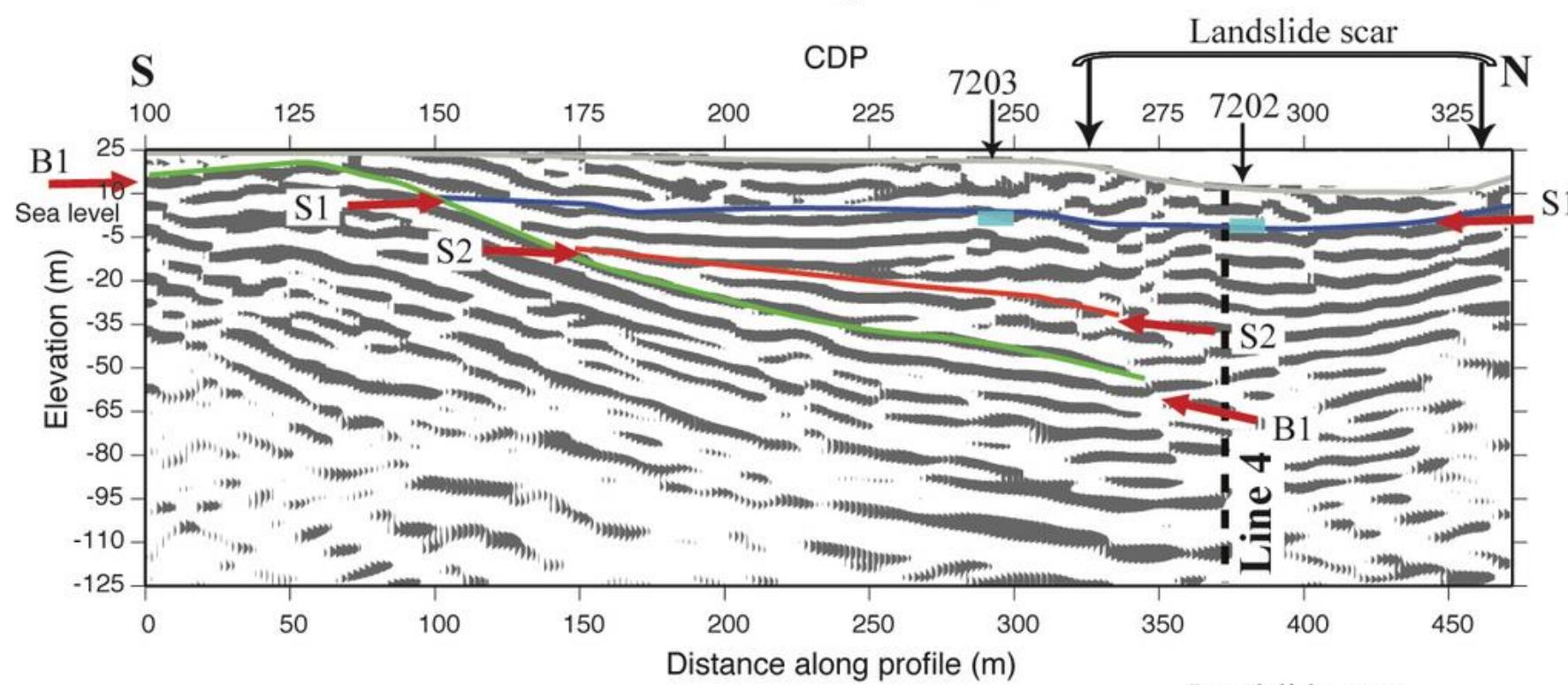
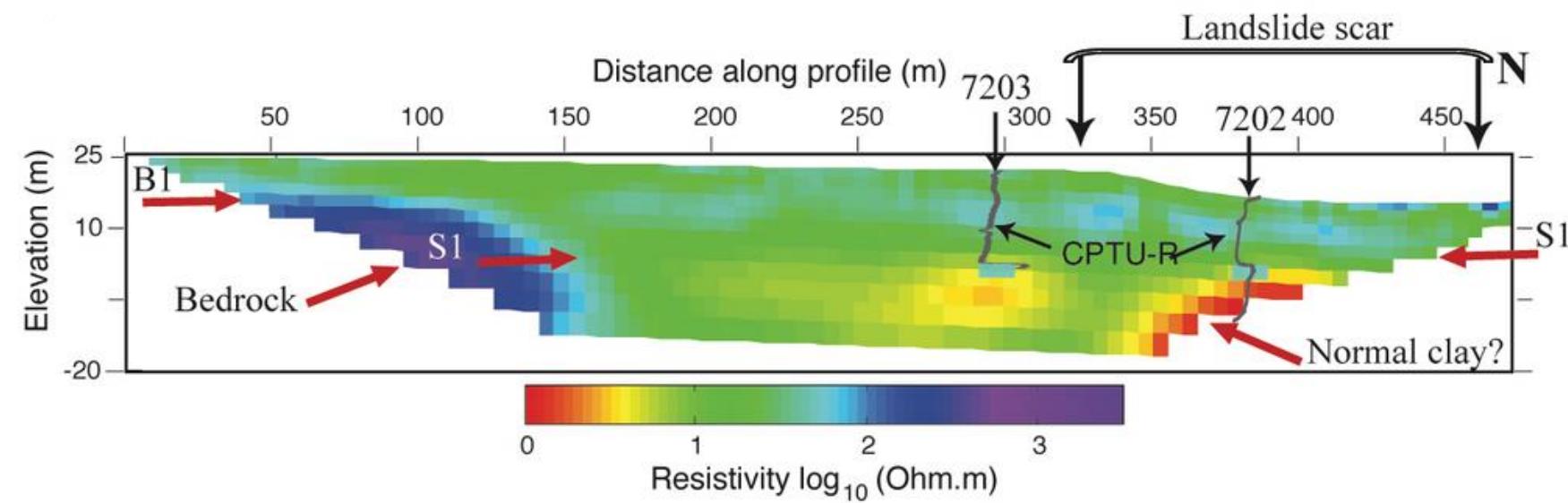


Geoelectric method

CASE STUDIES: QUICK CLAY LANDSLIDE IN SWEDEN

Method is usually conducted for groundwater exploration
Cost-effective method but ambiguous results...







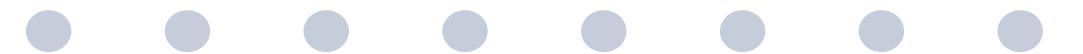
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Let's take a break

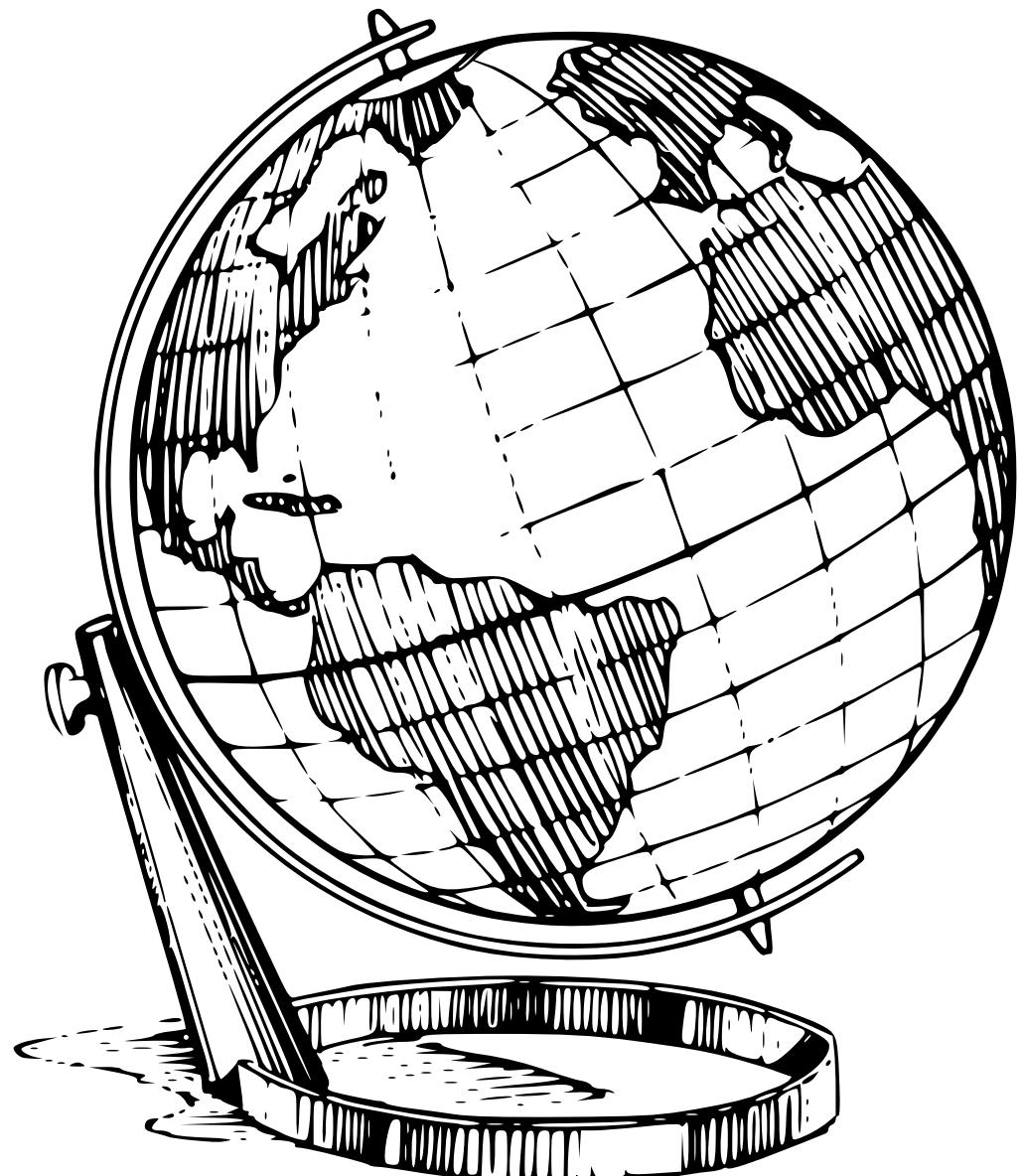
ANONYMOUS SURVEY!



Scan the QR code on the screen, and write one word in each box. Once you do that, click submit button!

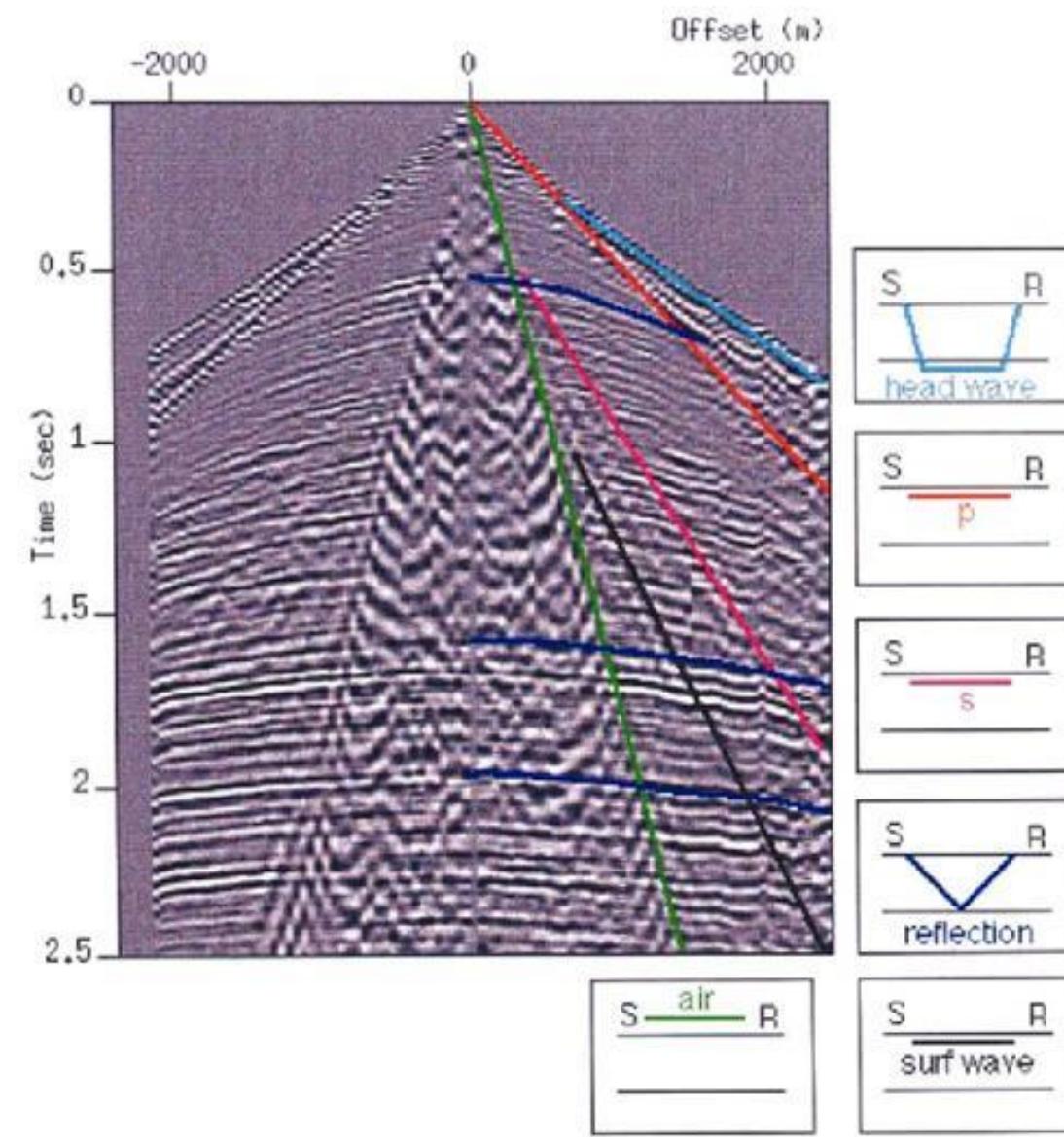


The question is about the most interesting part of presentation so far





Seismic method

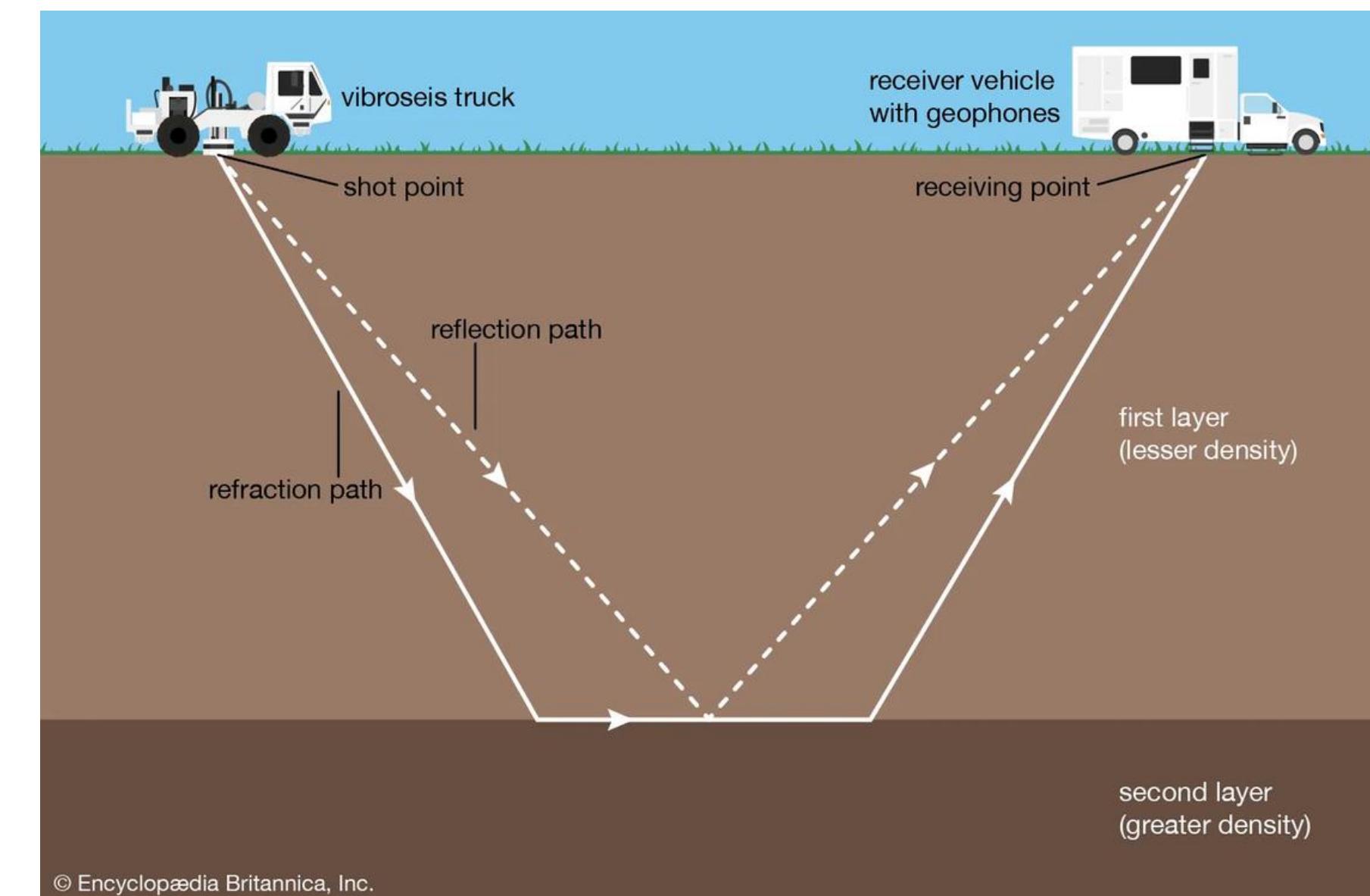


SEISMIC REFLECTION

Vibrations generated on surface- seismic waves propagate

We measure the time required for wave to travel into subsurface and reflect back (two-way travel time)

Method was primarily developed for exploration in oil & gas industry





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Seismic method

CASE STUDIES: CCS

Energy transition: carbon
neutrality in Denmark by
2050!

22 000 million tons CO₂ can be
stored

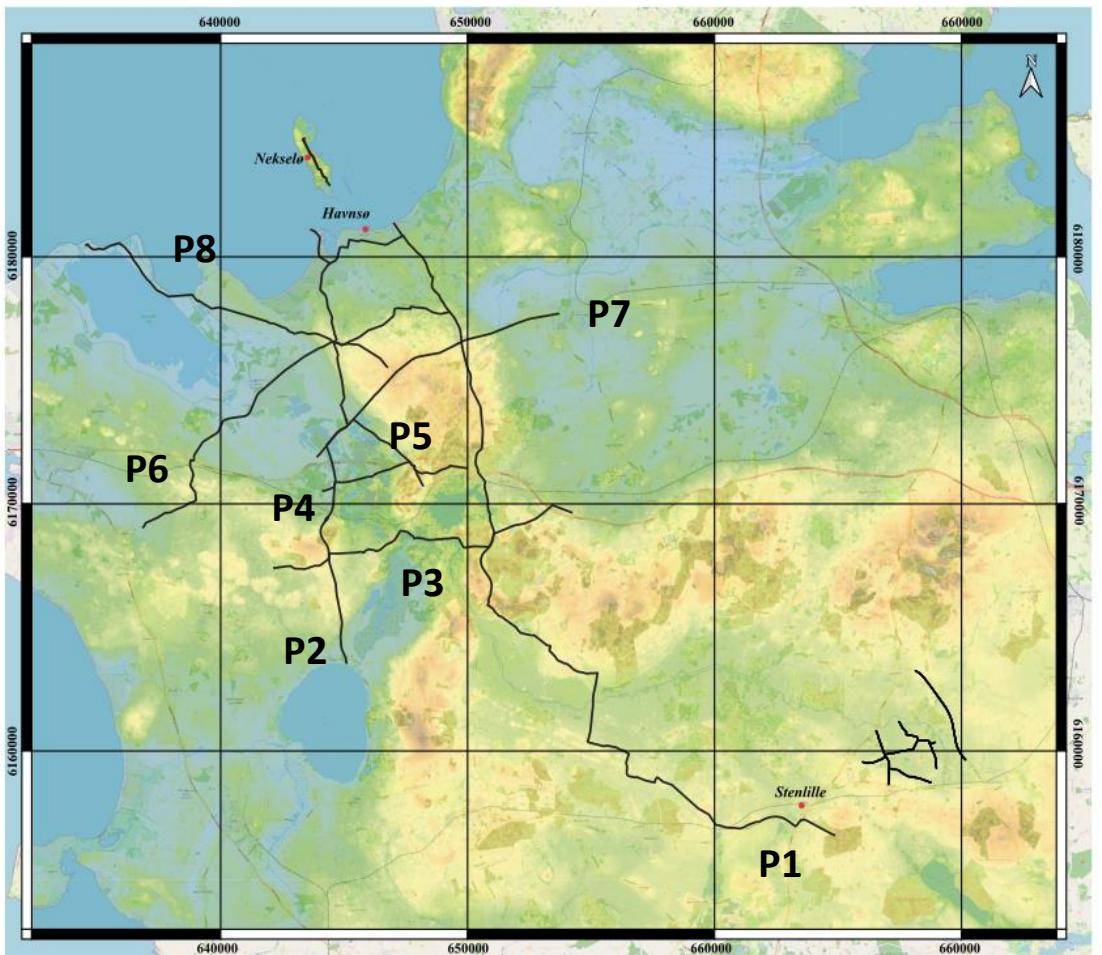


Papdopoulou et al., 2023





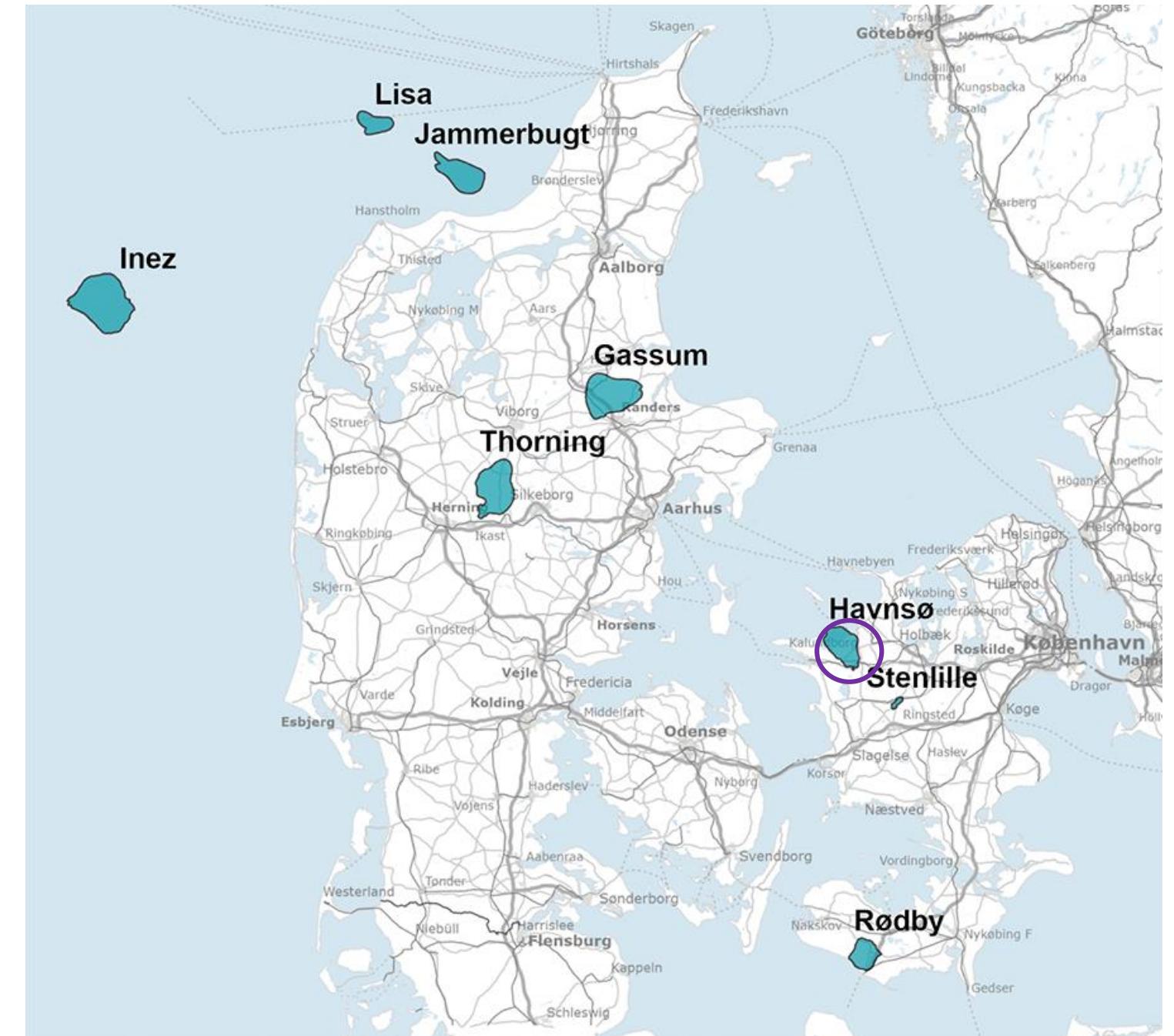
Seismic method



CASE STUDIES: CCS

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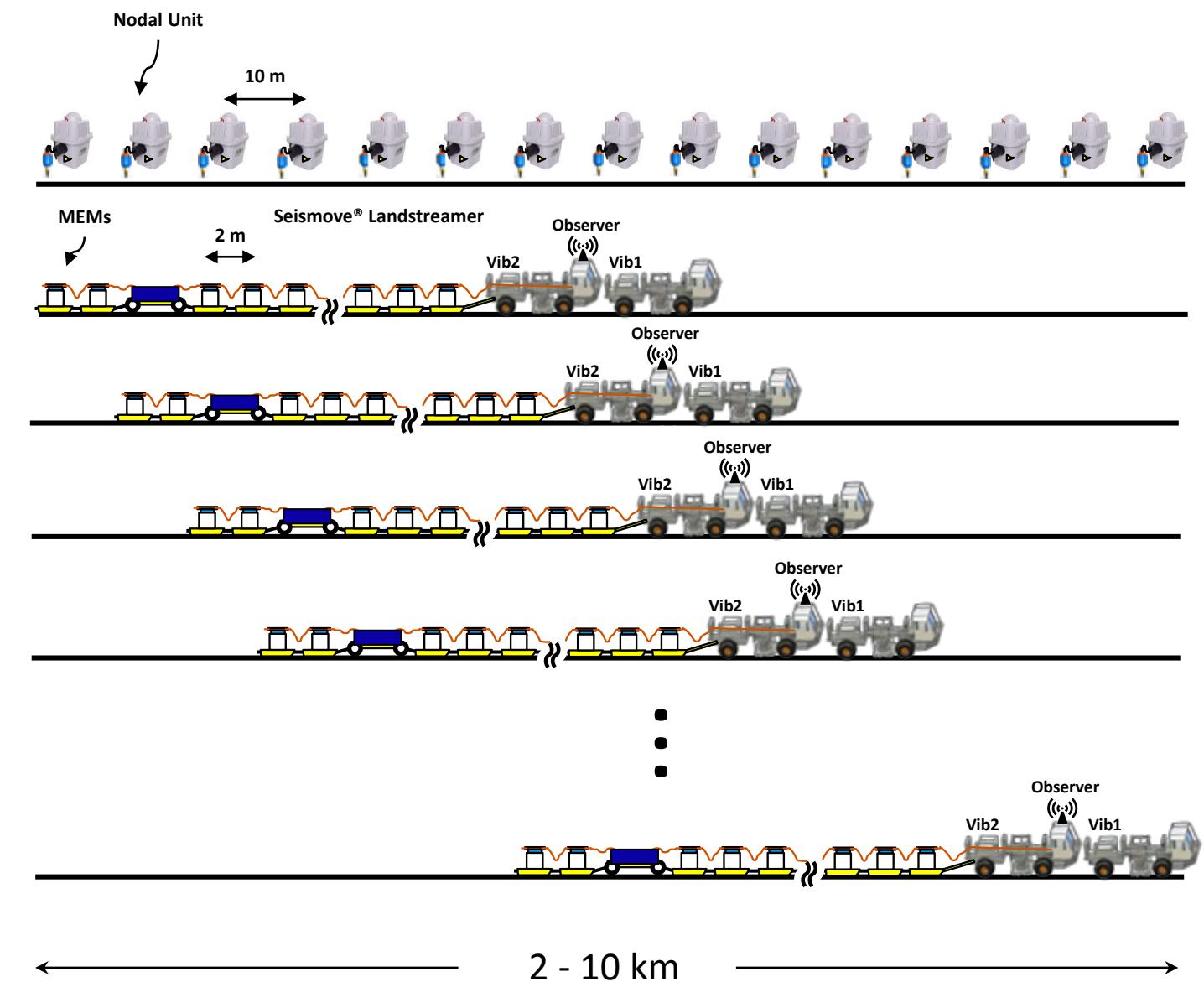




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Seismic method

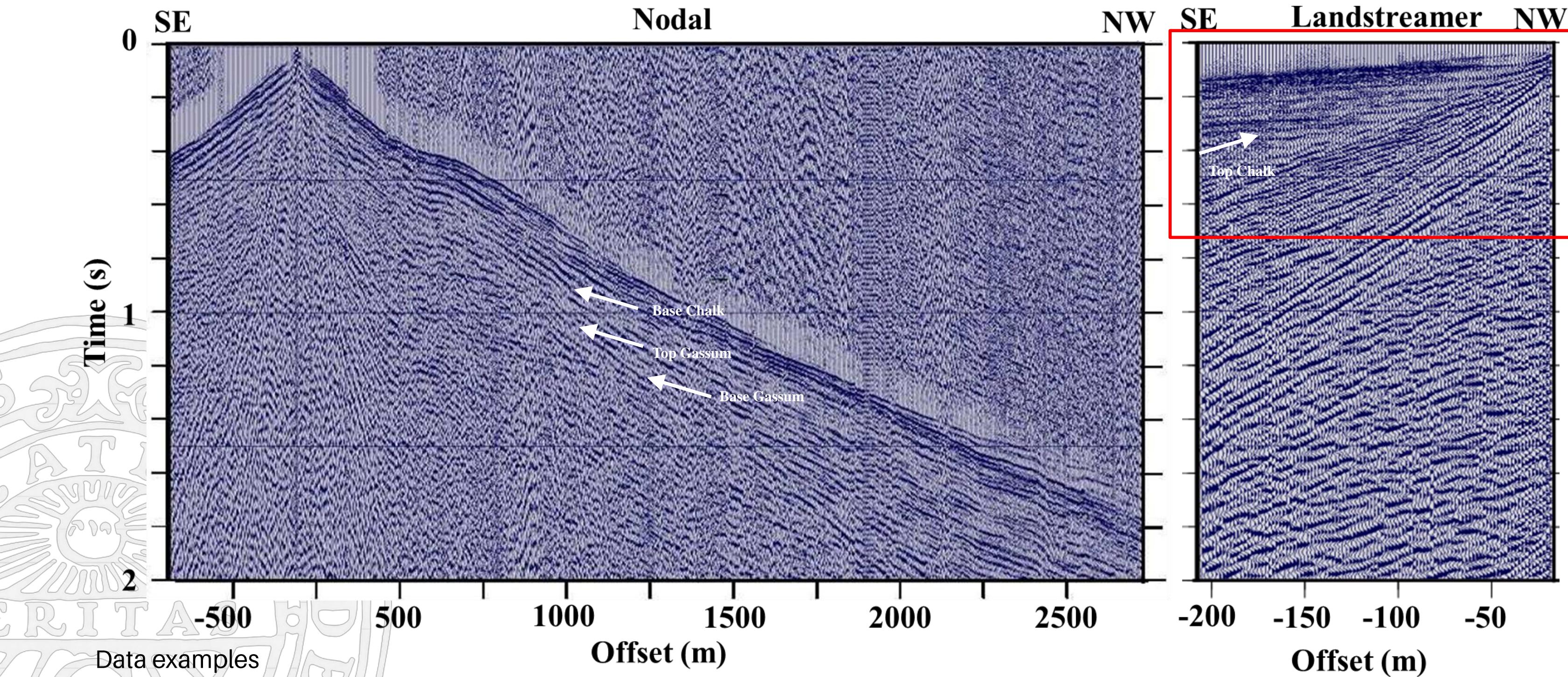
CASE STUDIES: CCS





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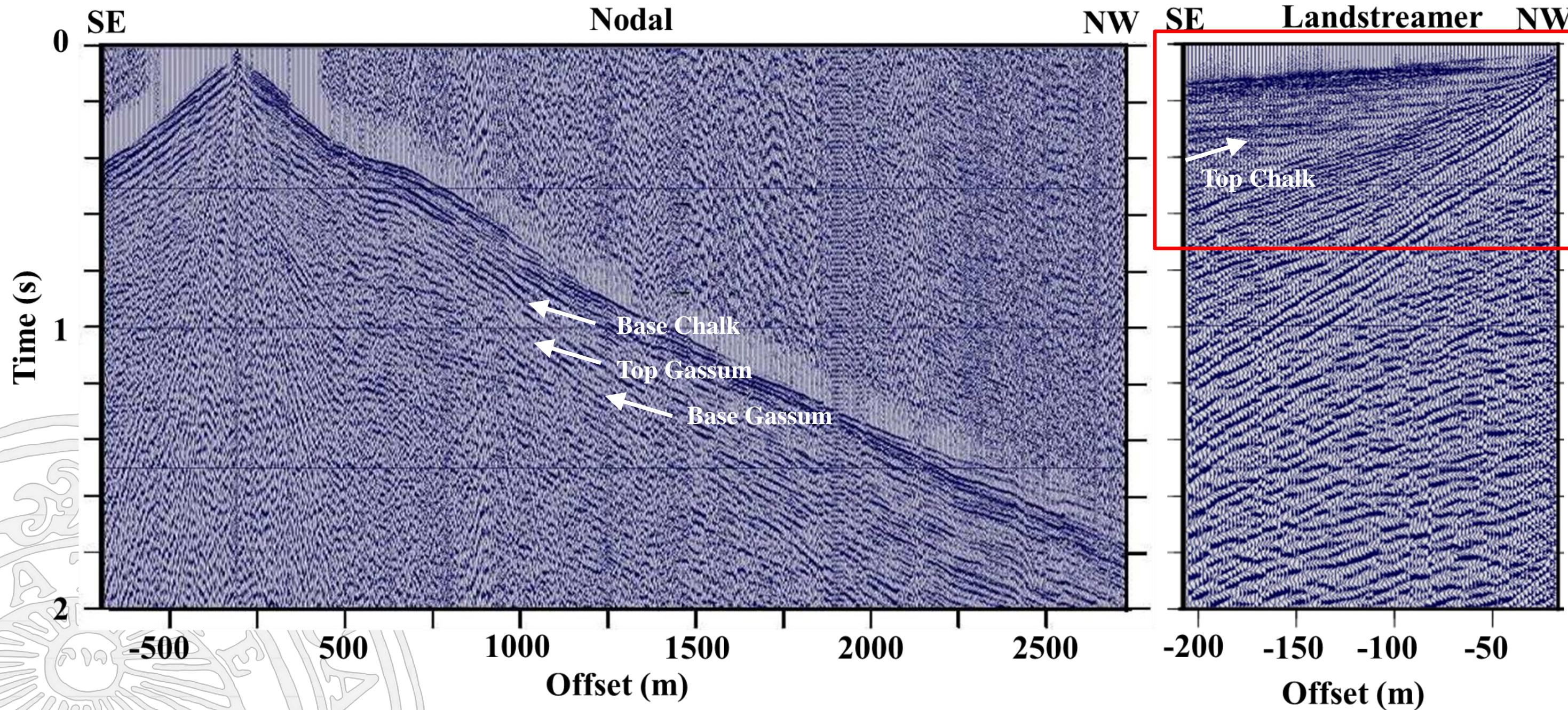
Seismic method





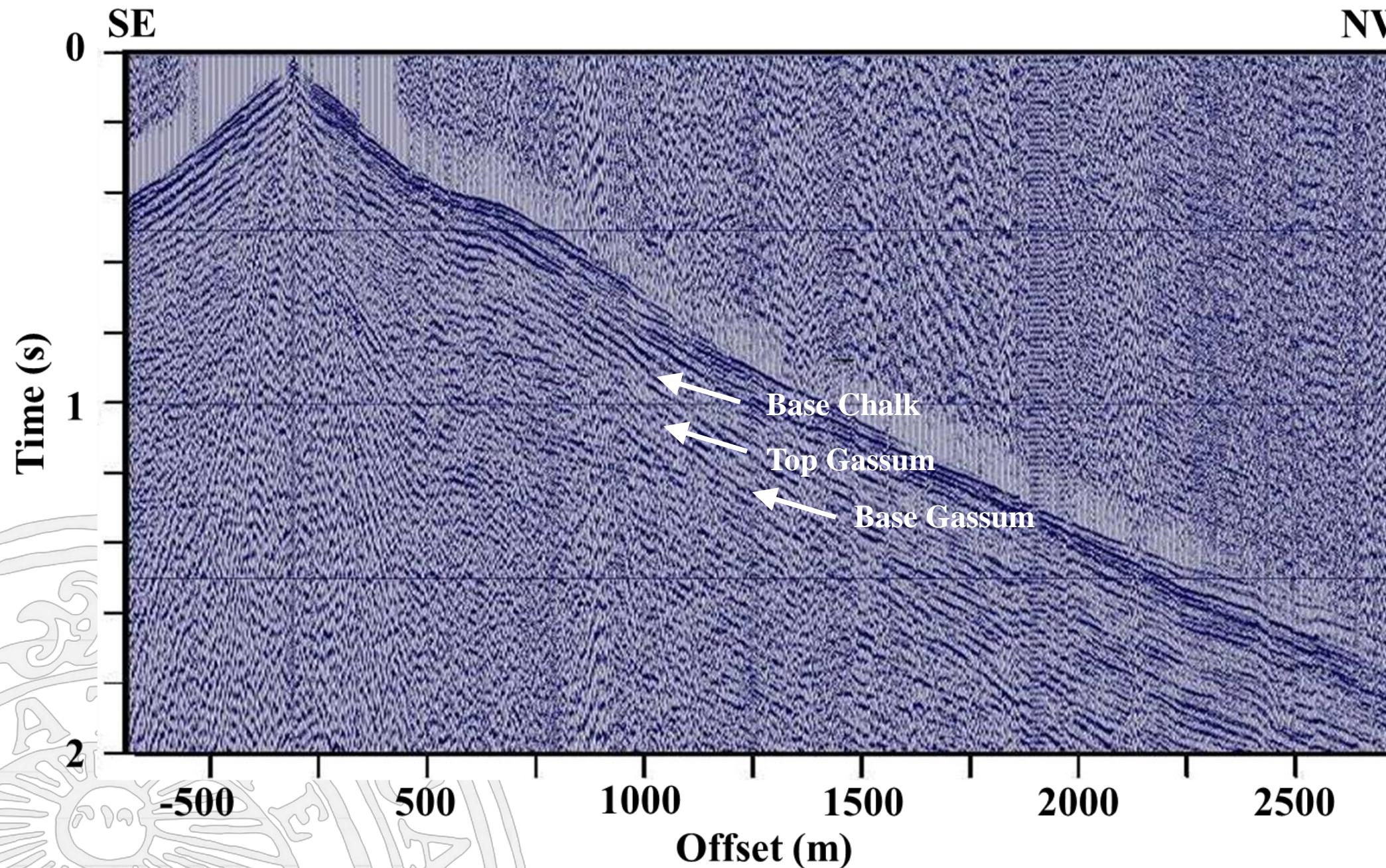
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PROCESSING STEPS





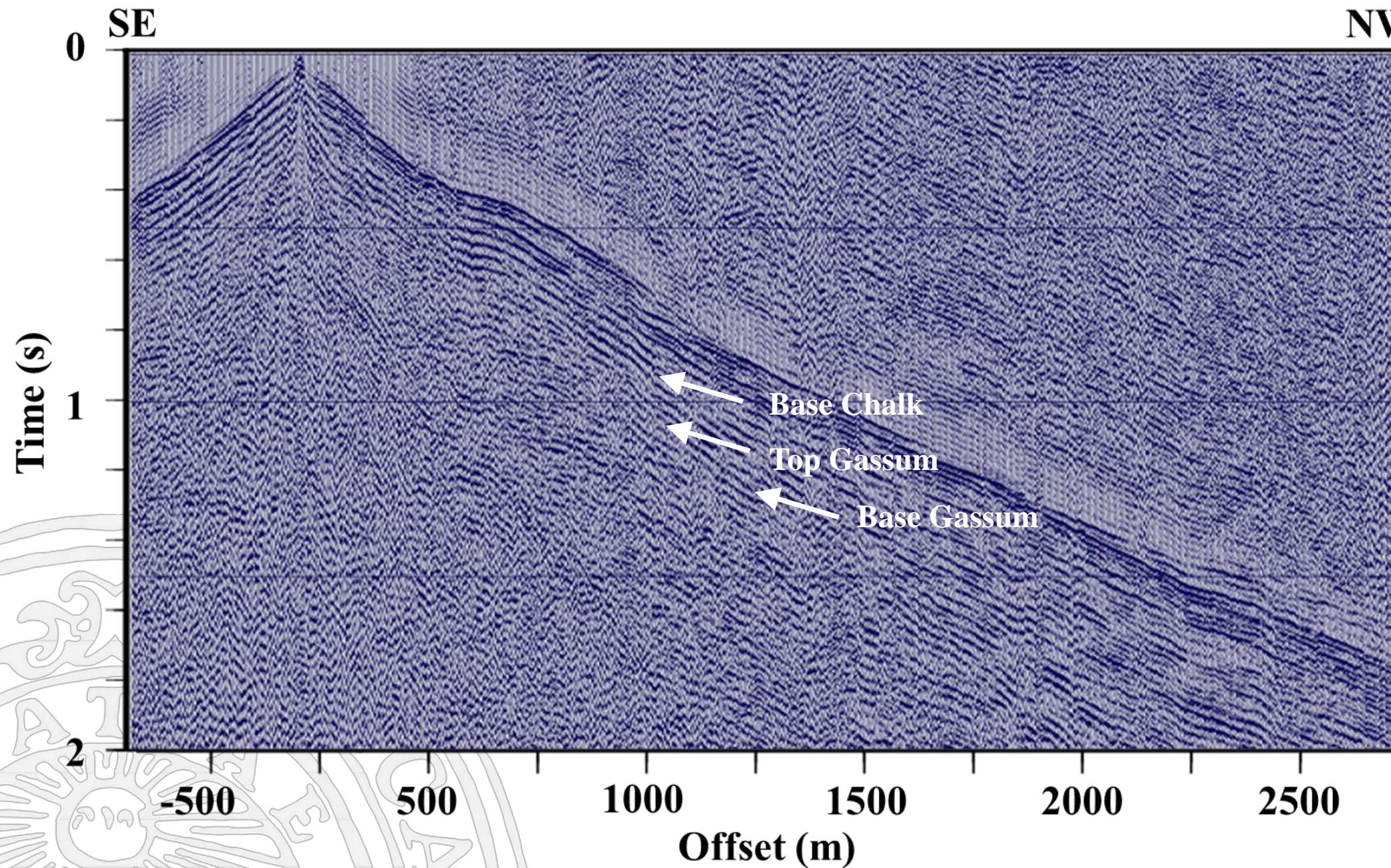
PROCESSING STEPS



- Band Pass filter (20-30-70-90 Hz)
- Band Stop filter (48-49-51-52 Hz)
- Airwave attenuation (velocity 330 m/s)
- Median horizontal filter (2200 m/s)
- Median horizontal filter (1000 m/s)
- First-break mute
- Refraction statics
- Elevation statics (40 m, 2500 m/s)
- Surface-consistent refraction corrections (one-layer model)
- Surface-consistent residual static corrections lopped with NMO (2 rounds)



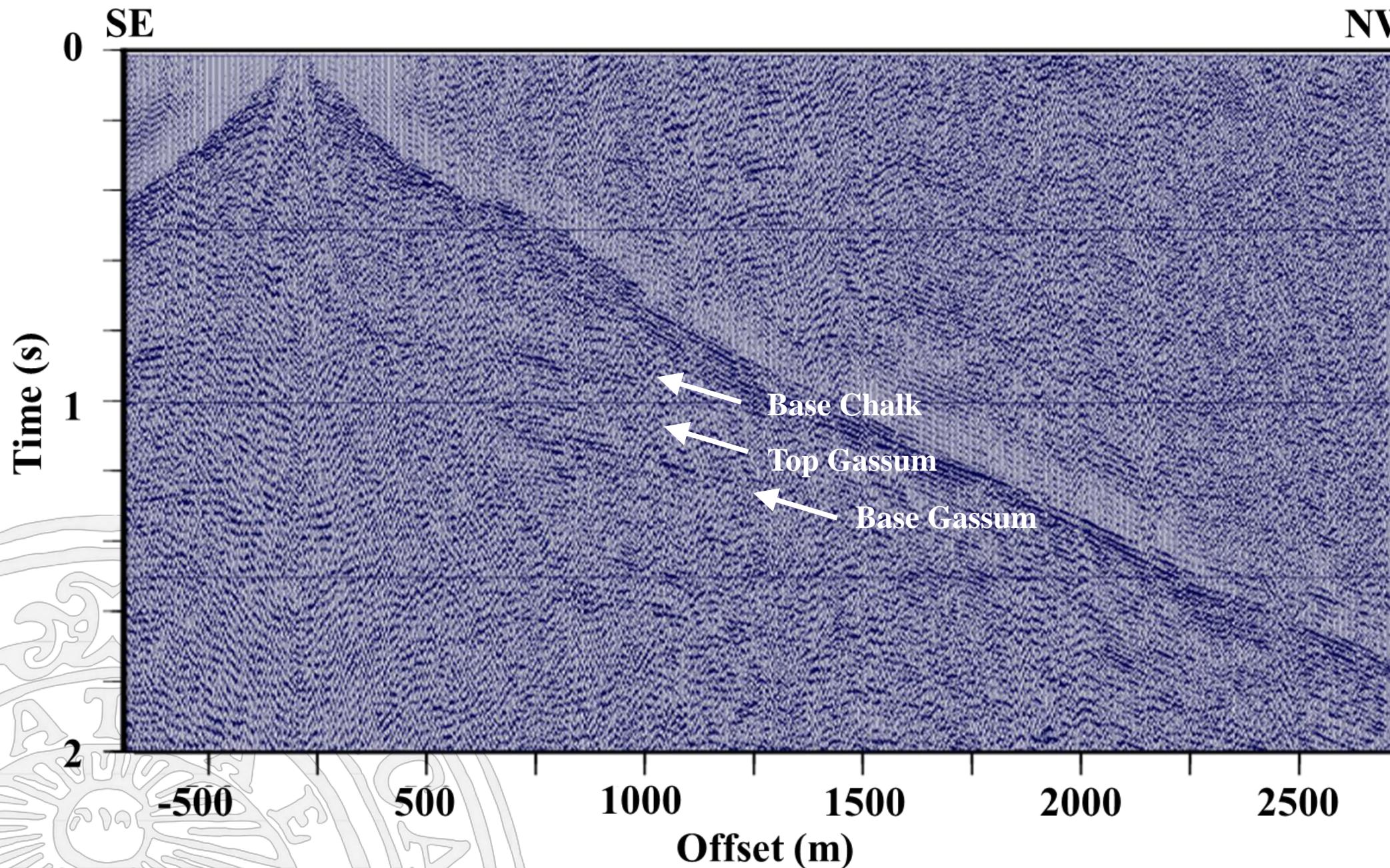
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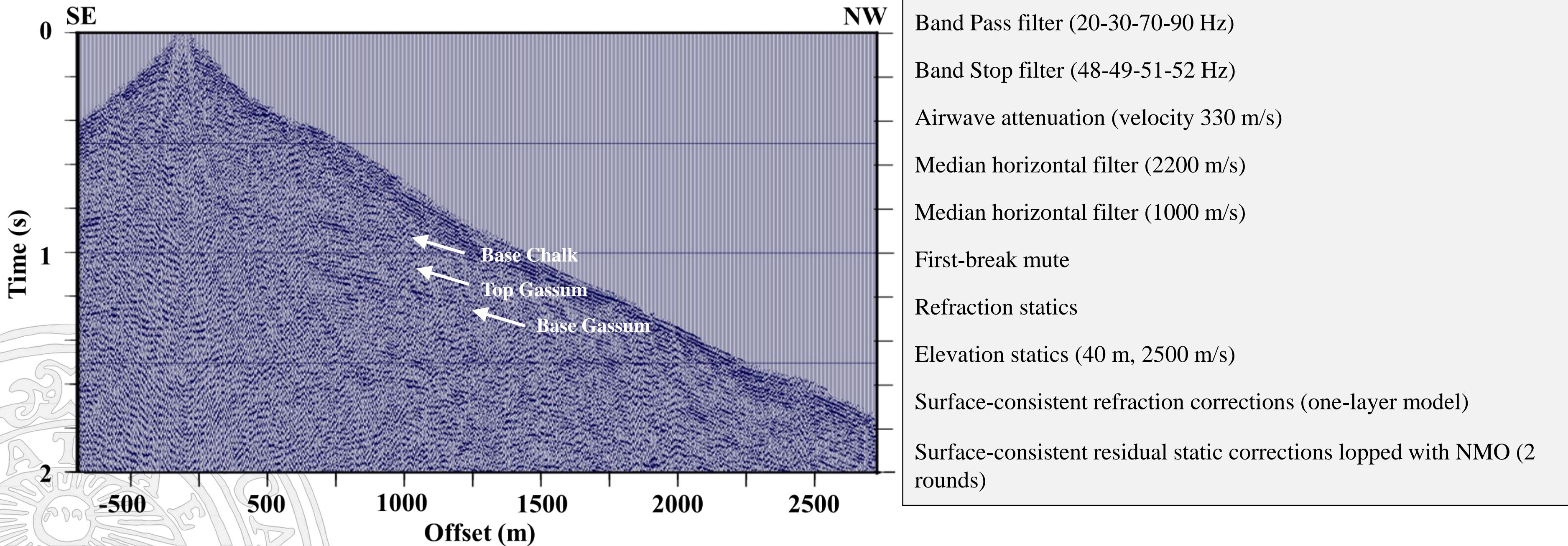
PROCESSING STEPS



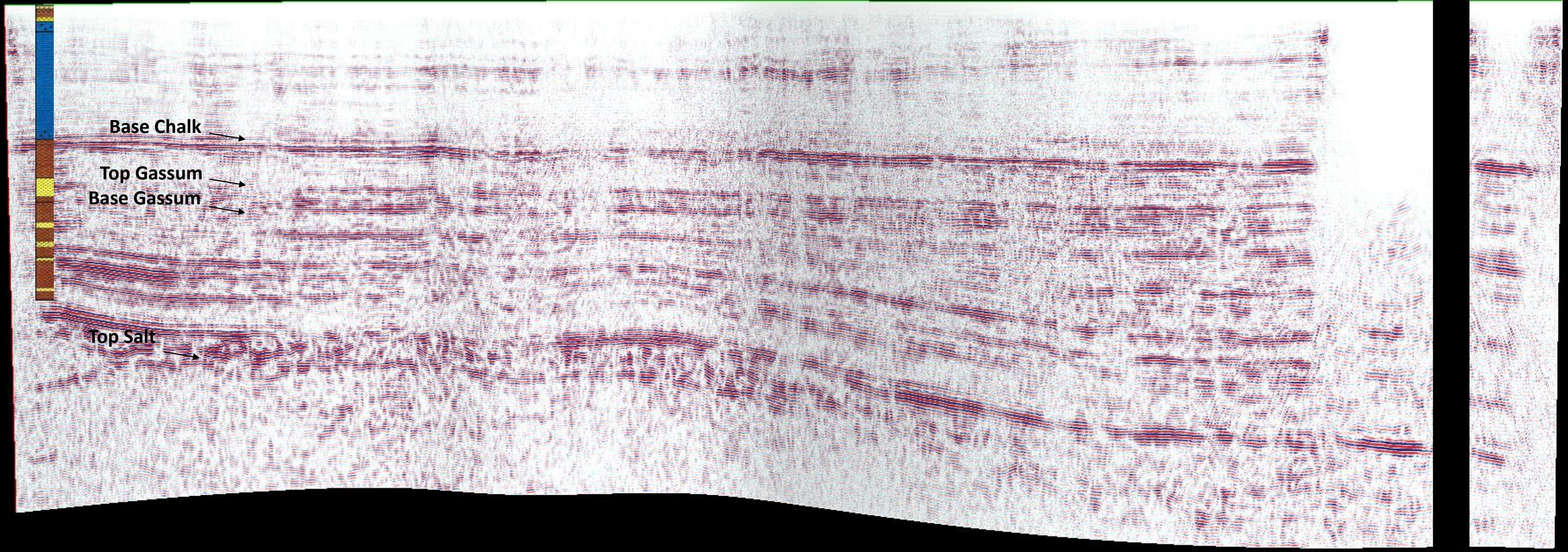
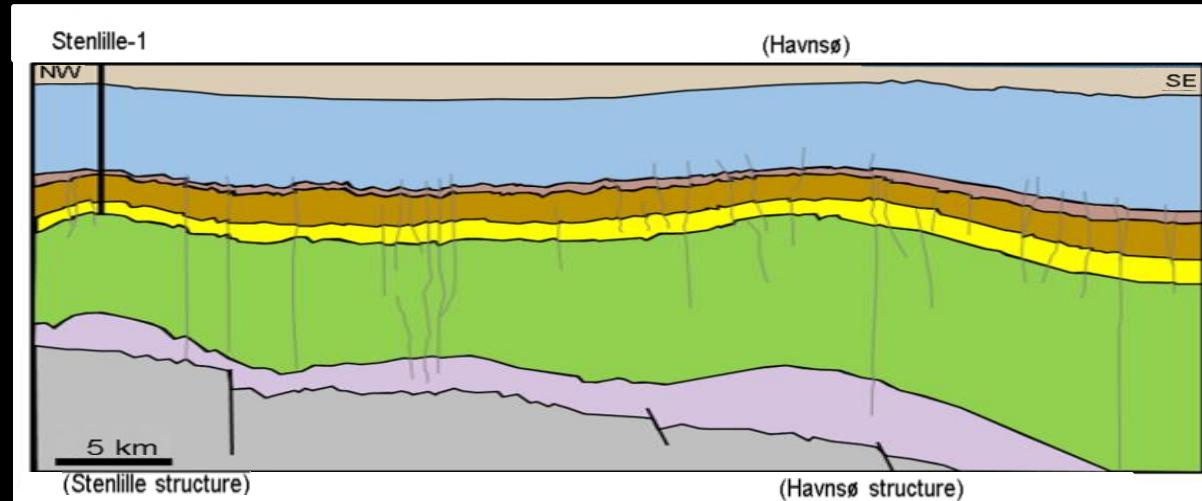
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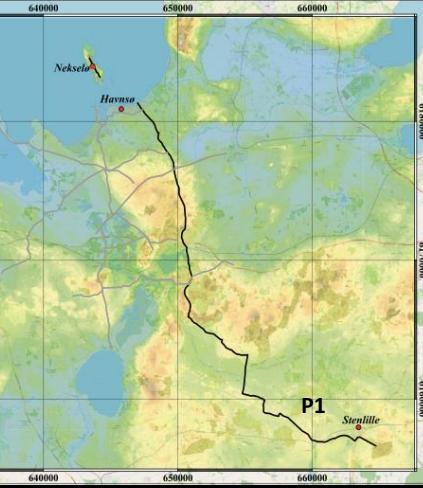
PROCESSING STEPS



Nodal

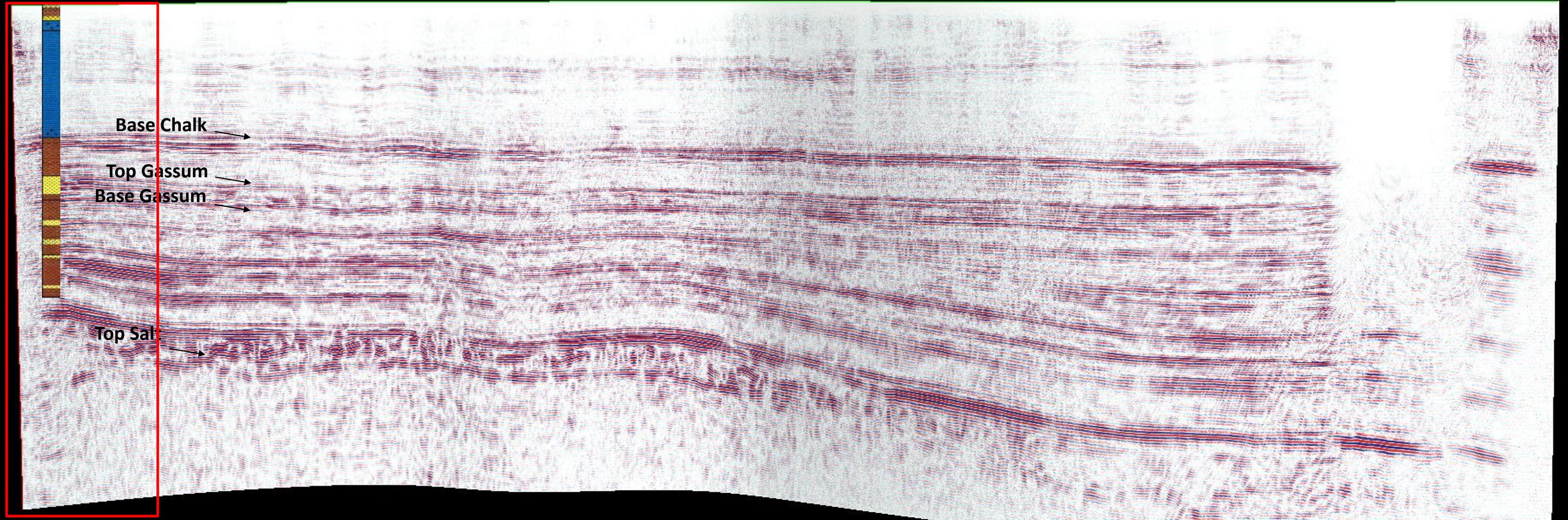


Horizontal Distance (km)



Nodal + Landstreamer + Marine

Stenlille-19

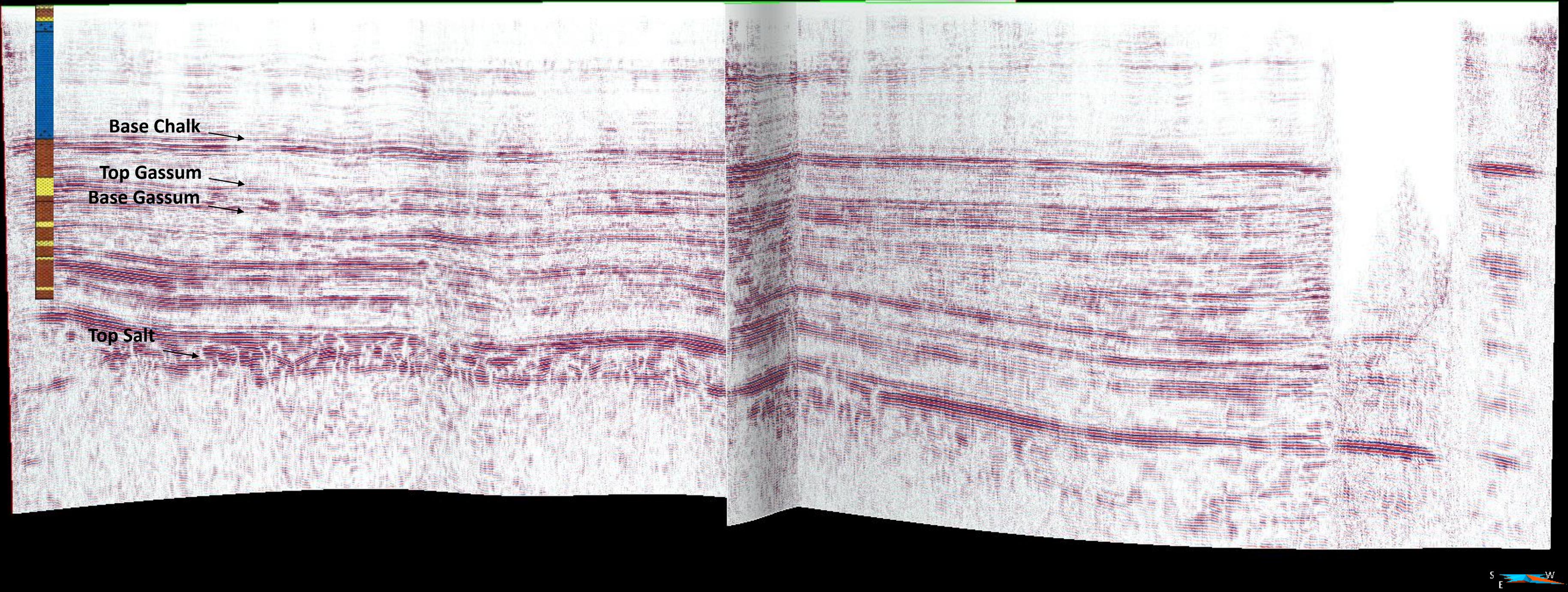


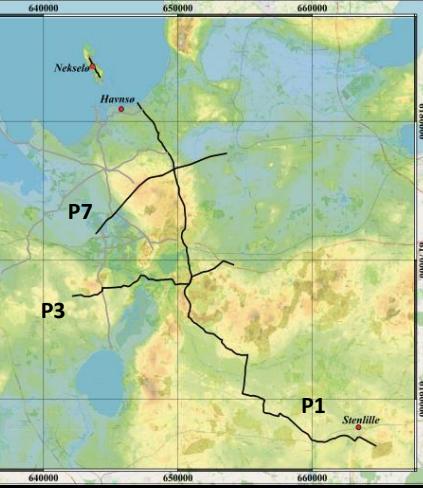
S
E
W
N

0 1 2 3
Horizontal Distance (km)

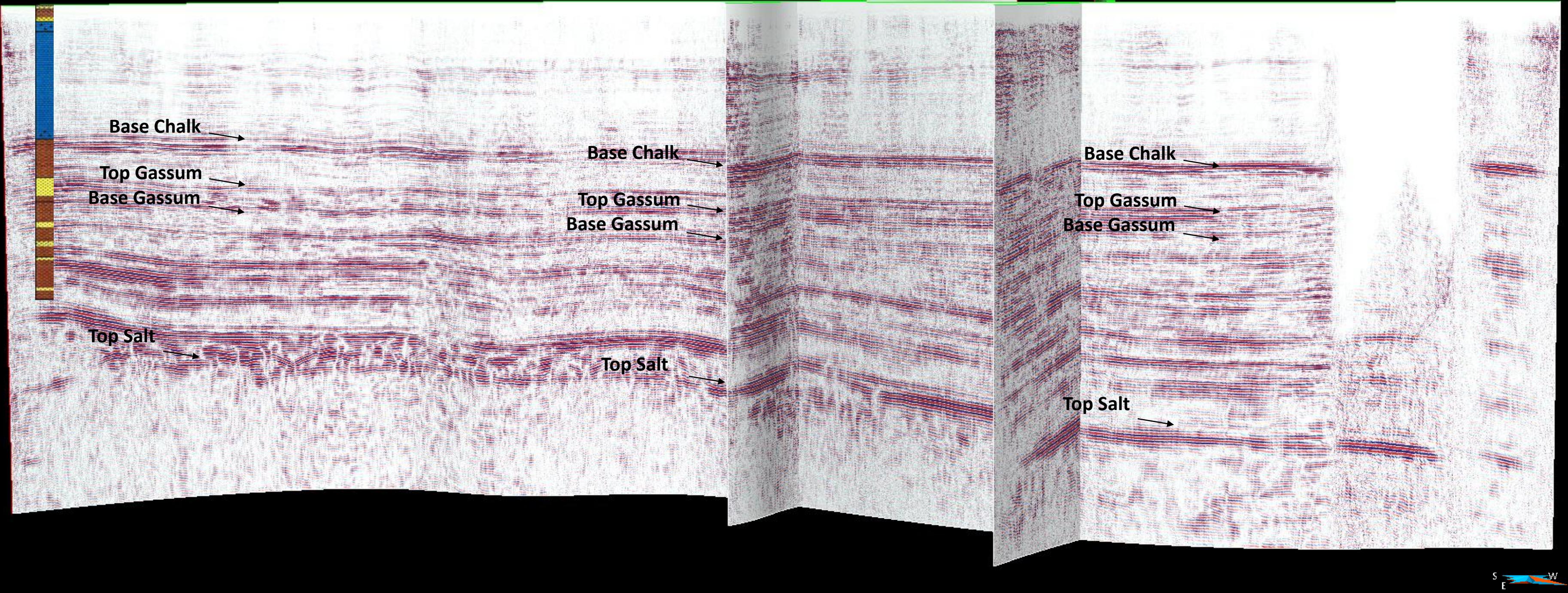


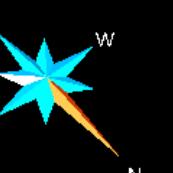
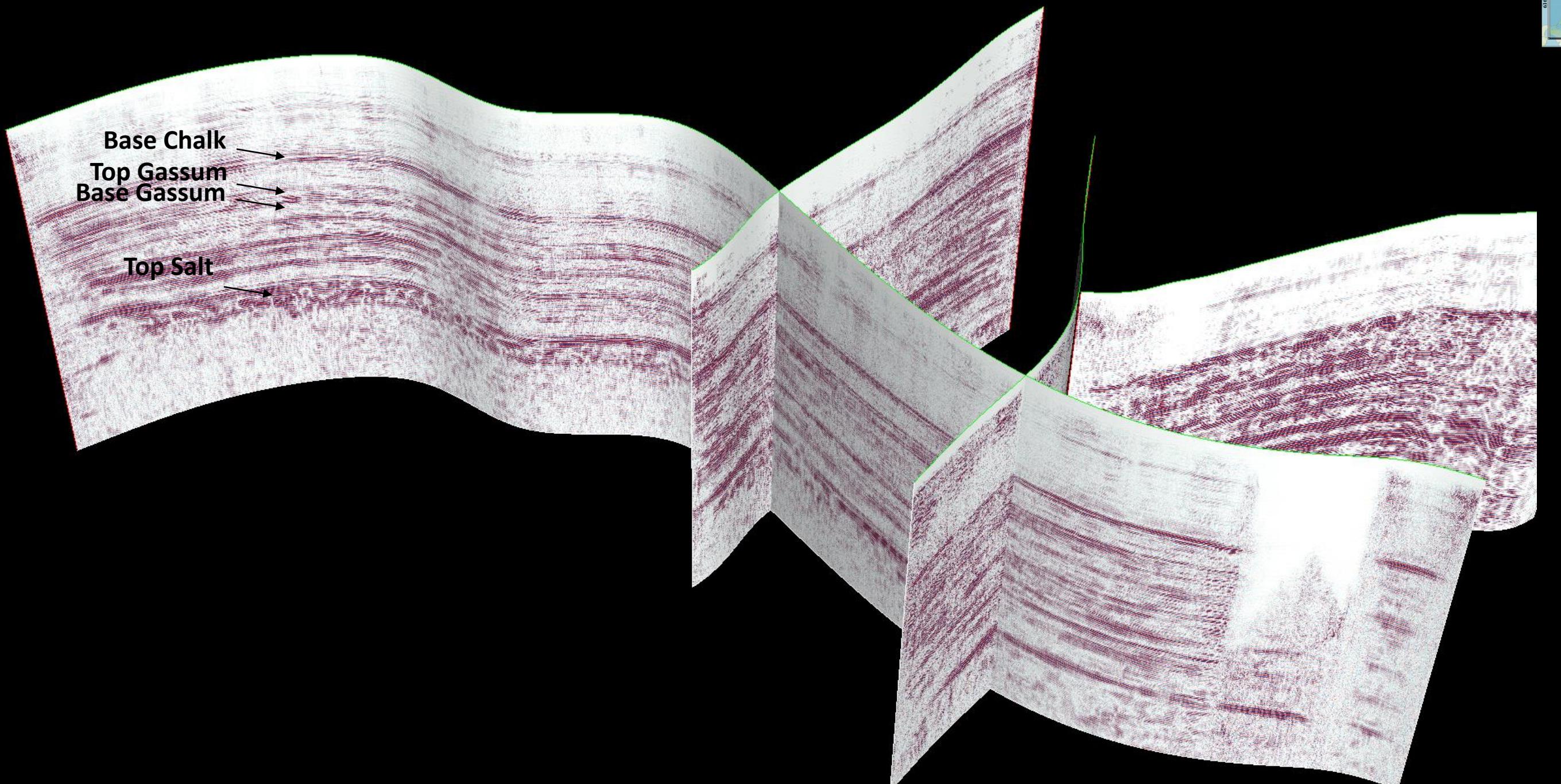
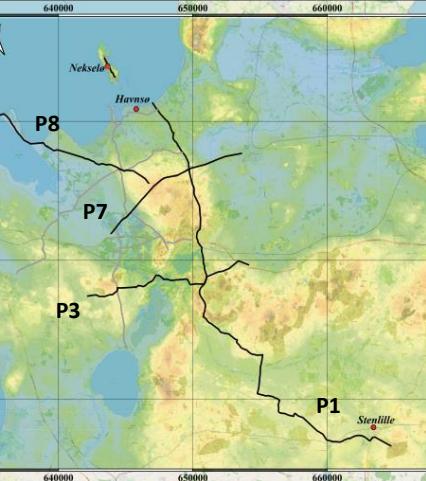
Stenlille-19



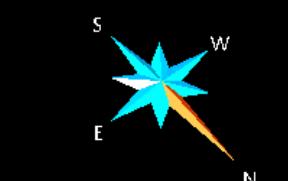
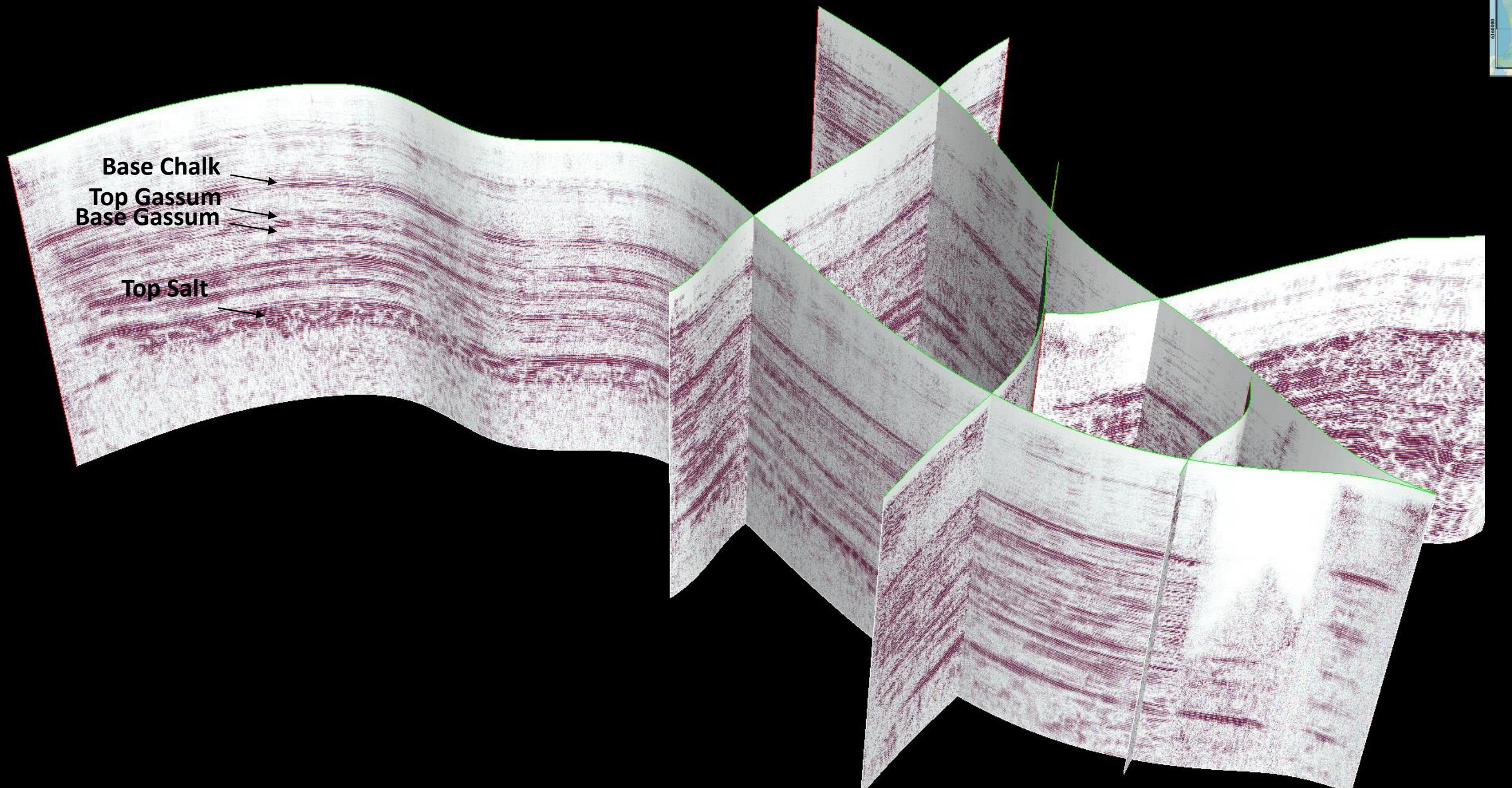
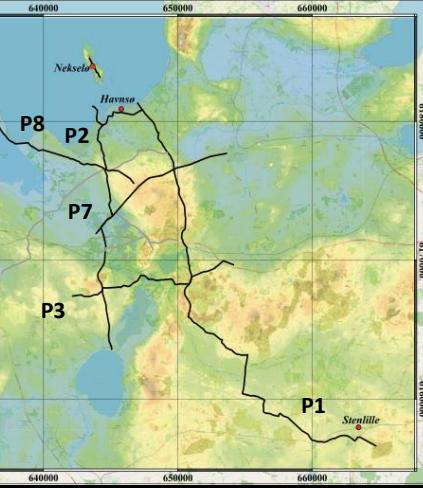


Stenlille-19

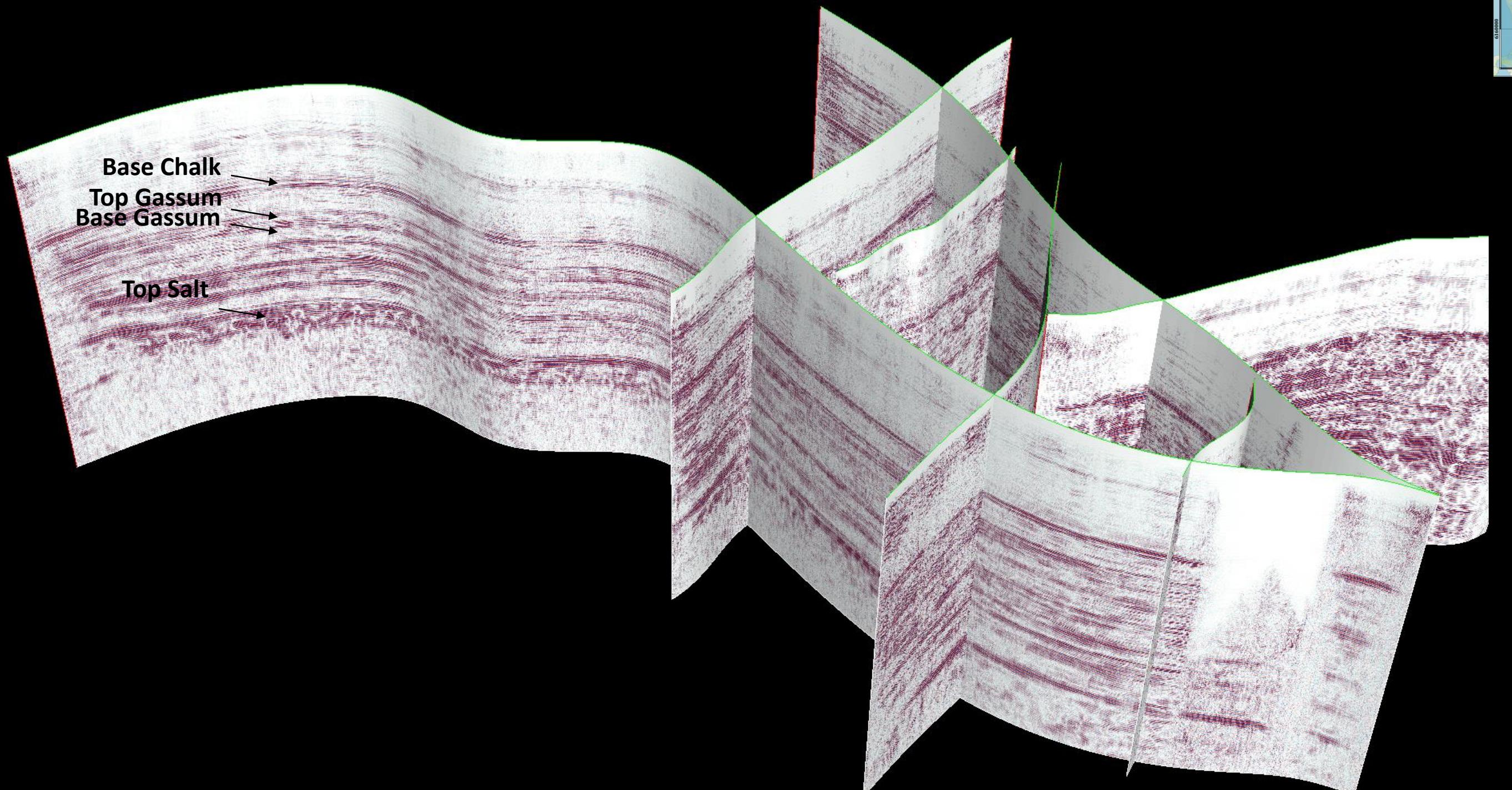
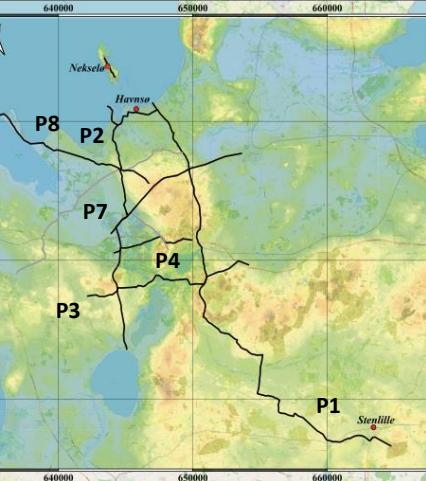




0 2 4 6
Horizontal Length (km)

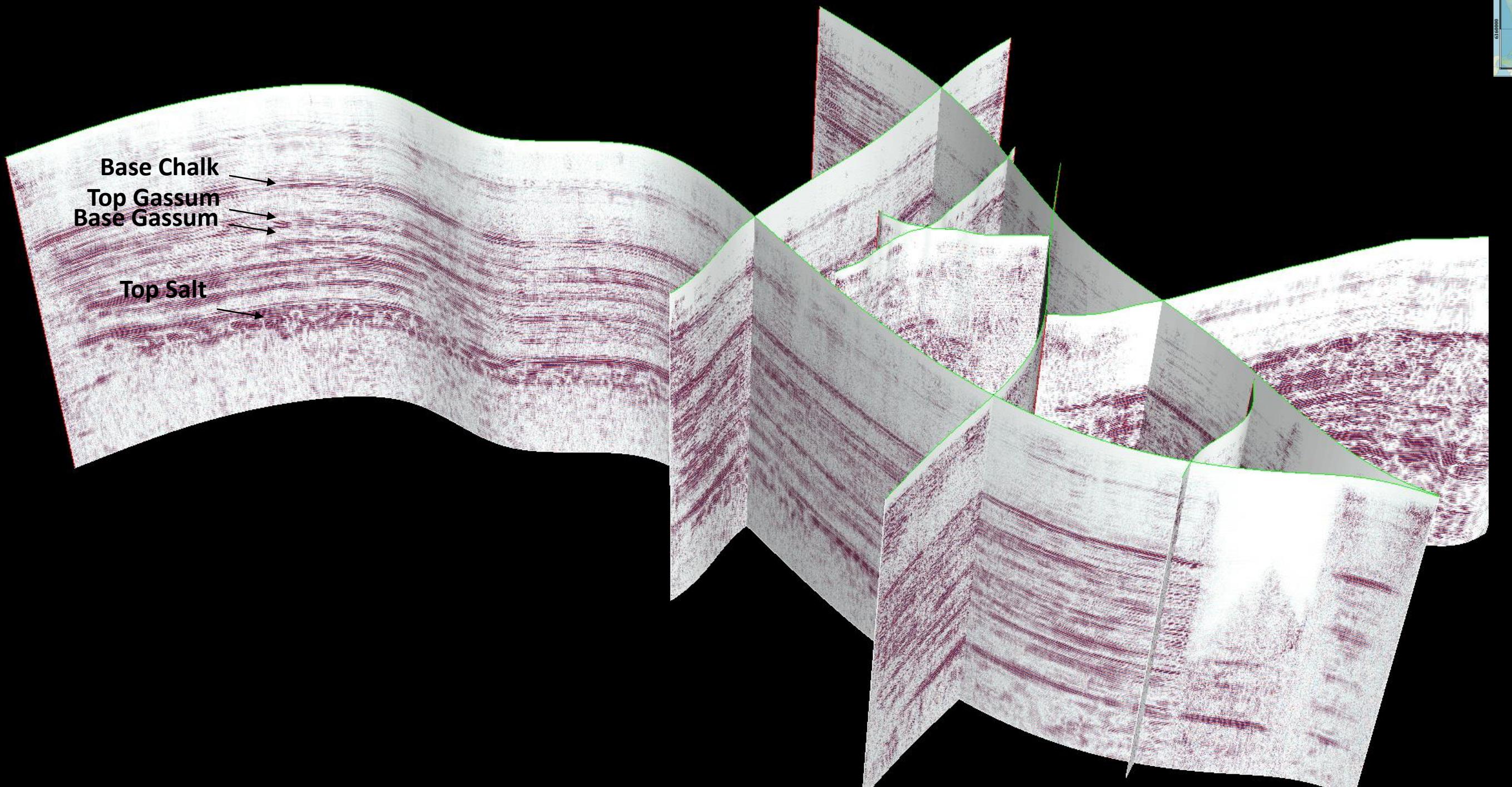
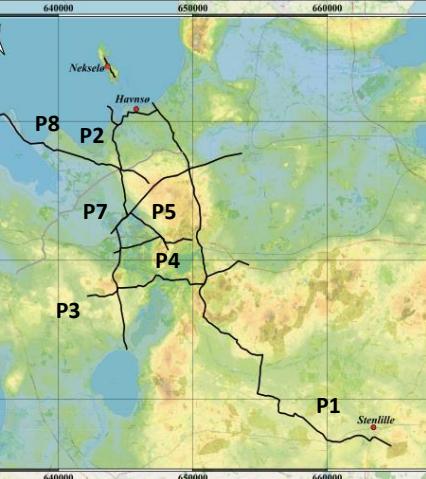


0 2 4 6
Horizontal Length (km)

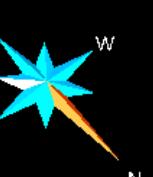
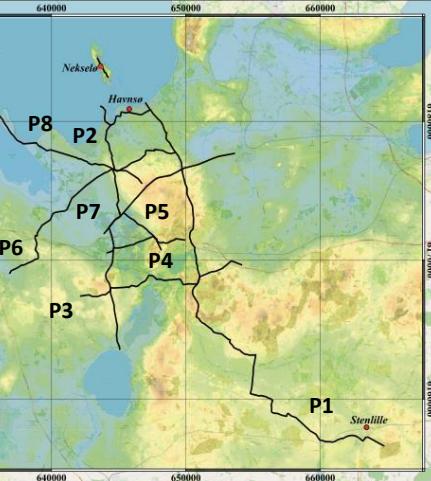
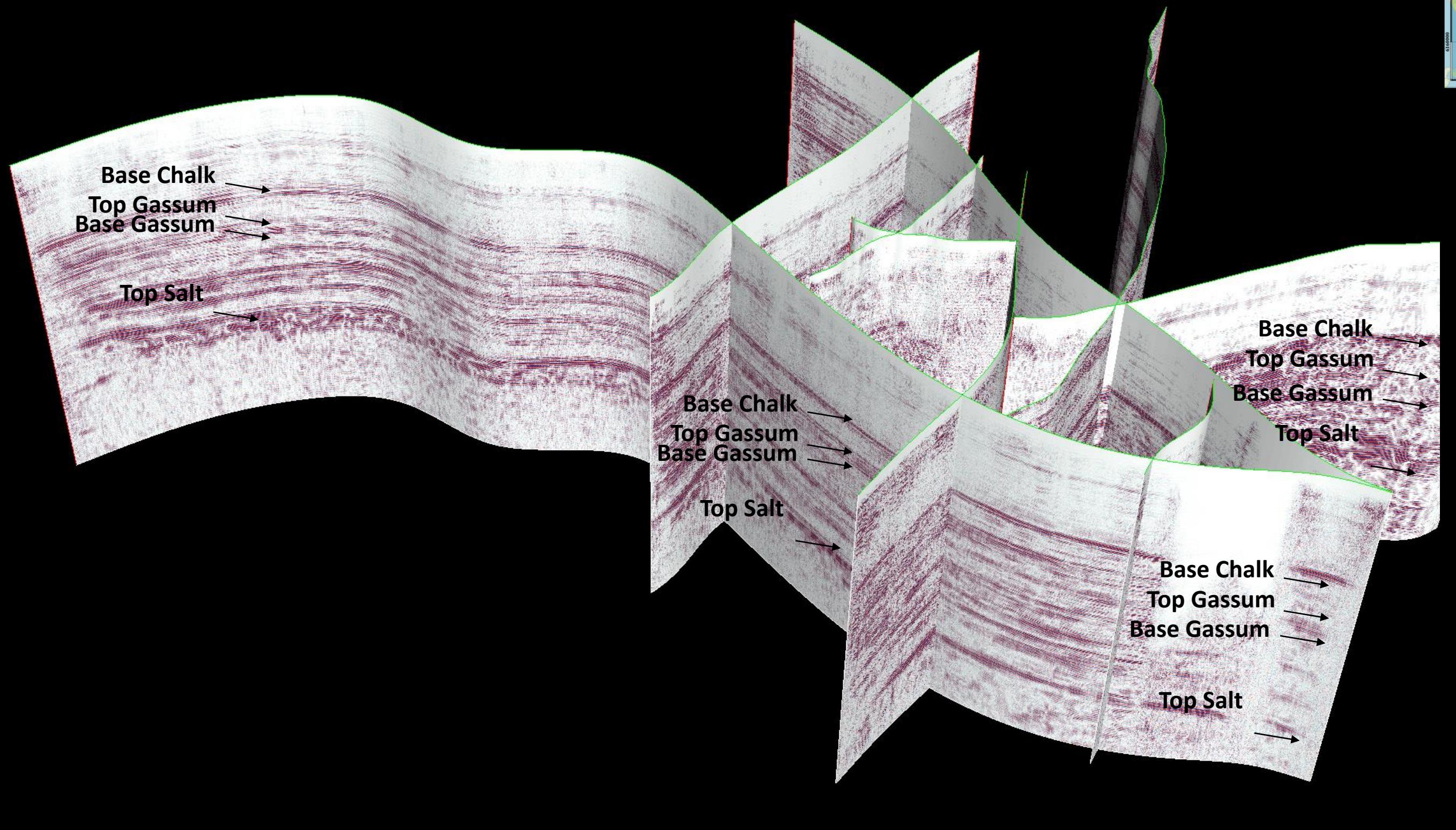


0 2 4 6
Horizontal Length (km)

A scale bar at the bottom right indicating horizontal distance in kilometers, ranging from 0 to 6 km.

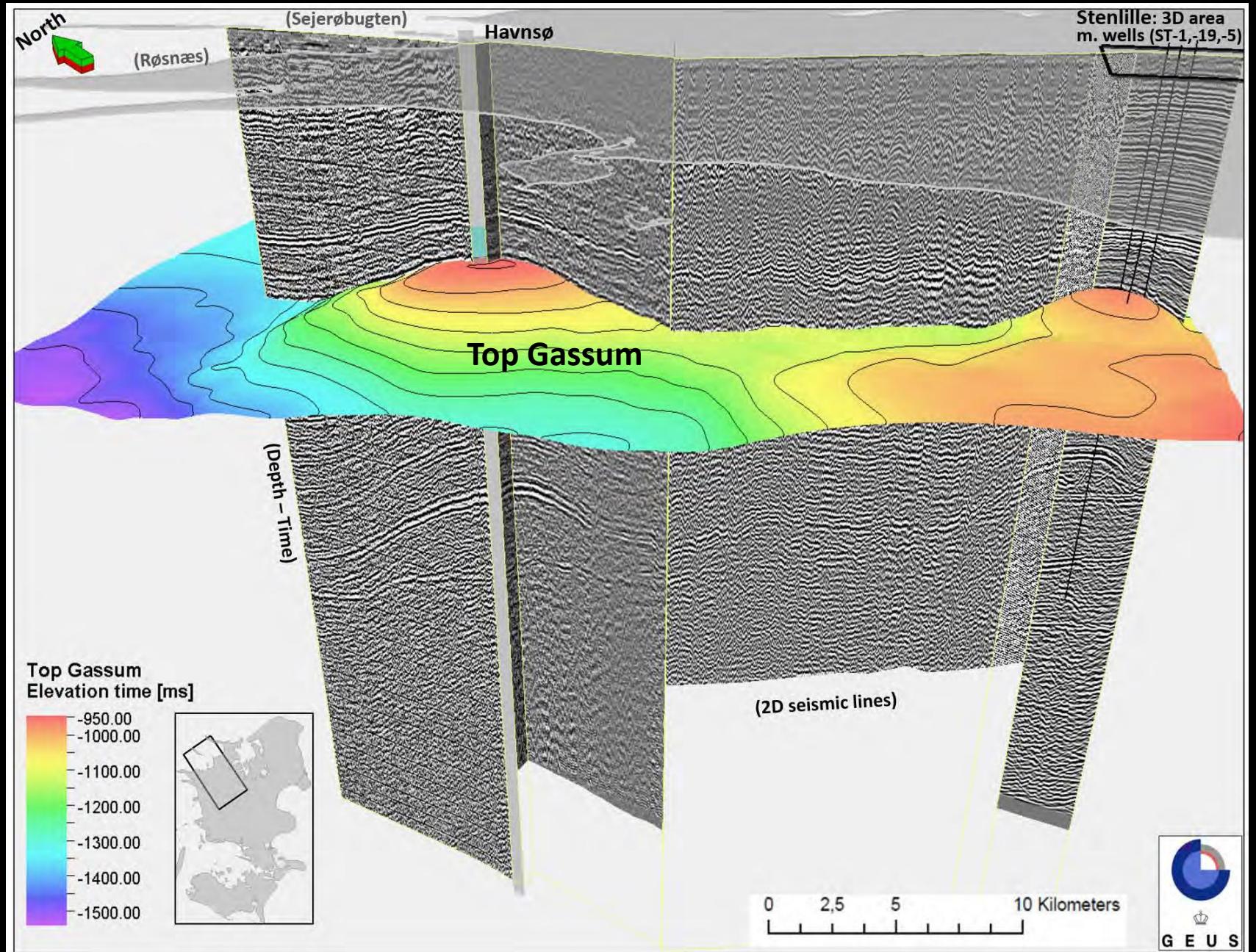


- Extension of the reservoir structure

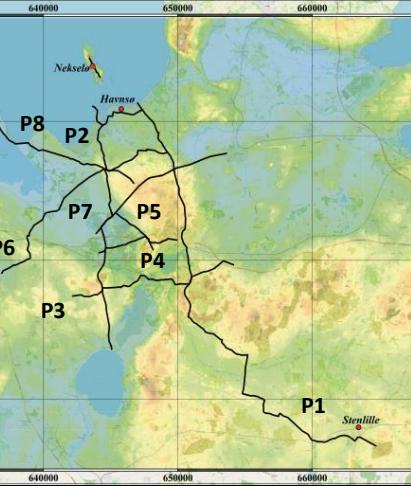
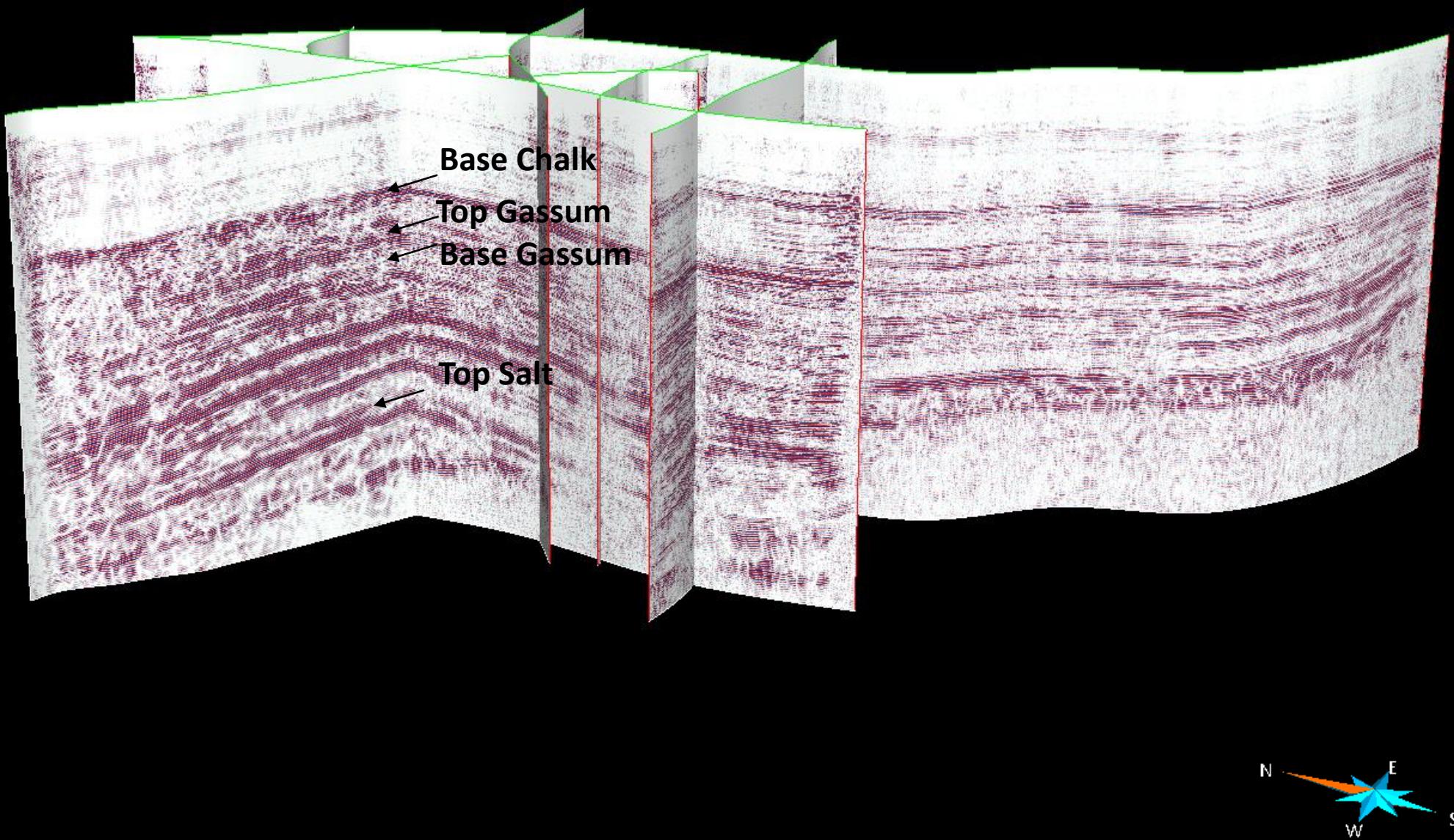


0 1 2 3
Horizontal Length (km)

- Extension of the reservoir structure
- Indication of structural closures
- High quality at shallow depths



Gregersen, 2020



0 2 4 6
Horizontal Length (km)



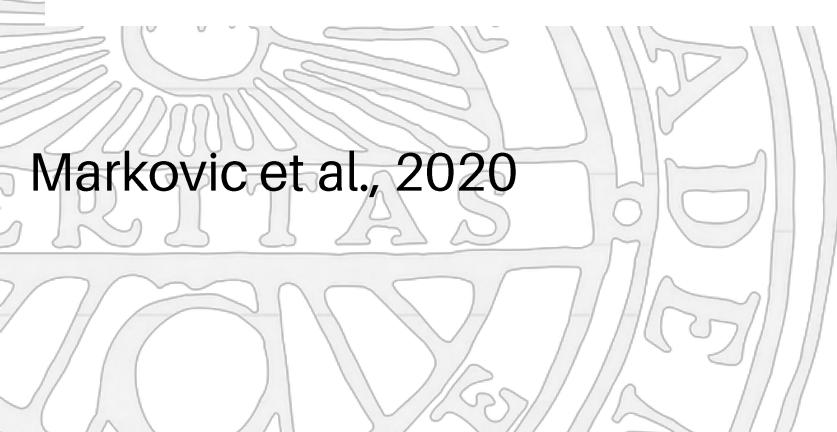
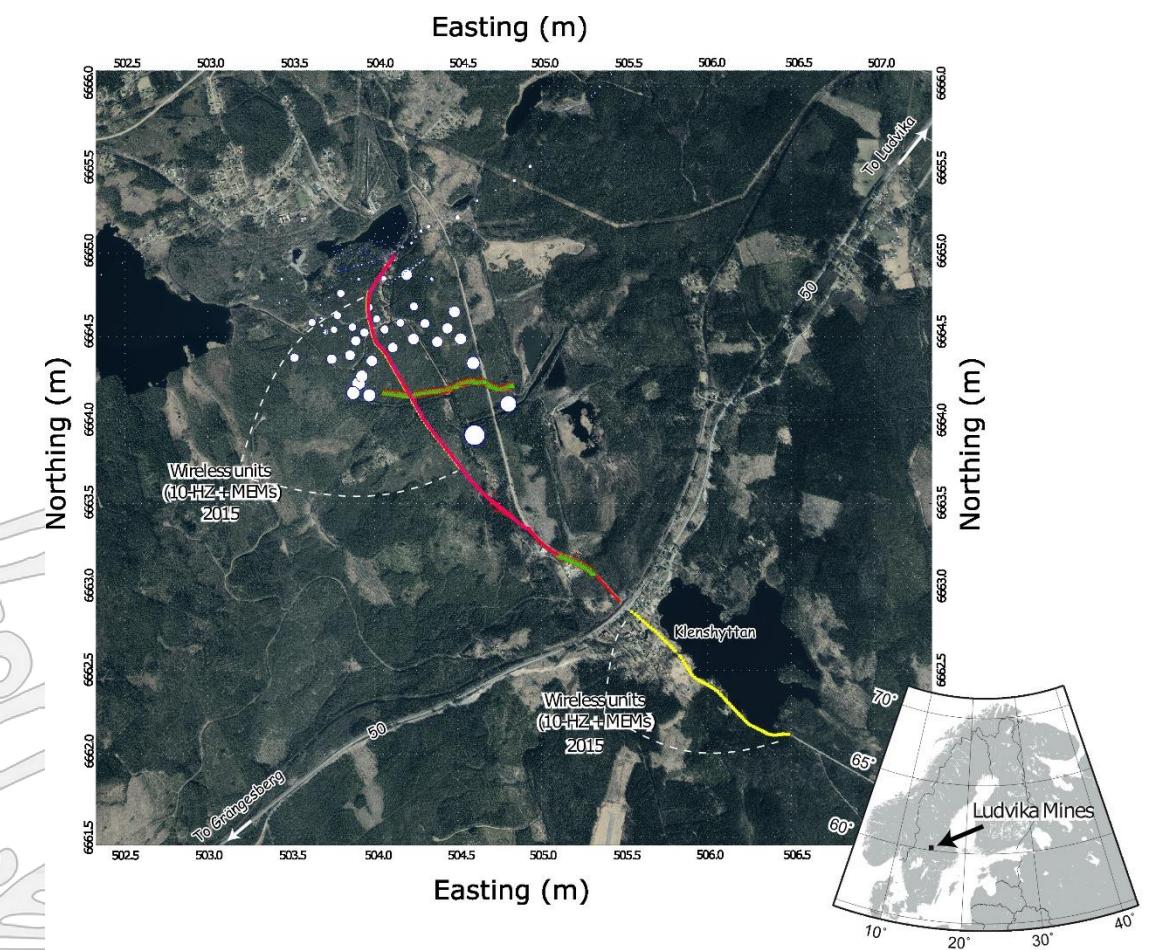
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Seismic method

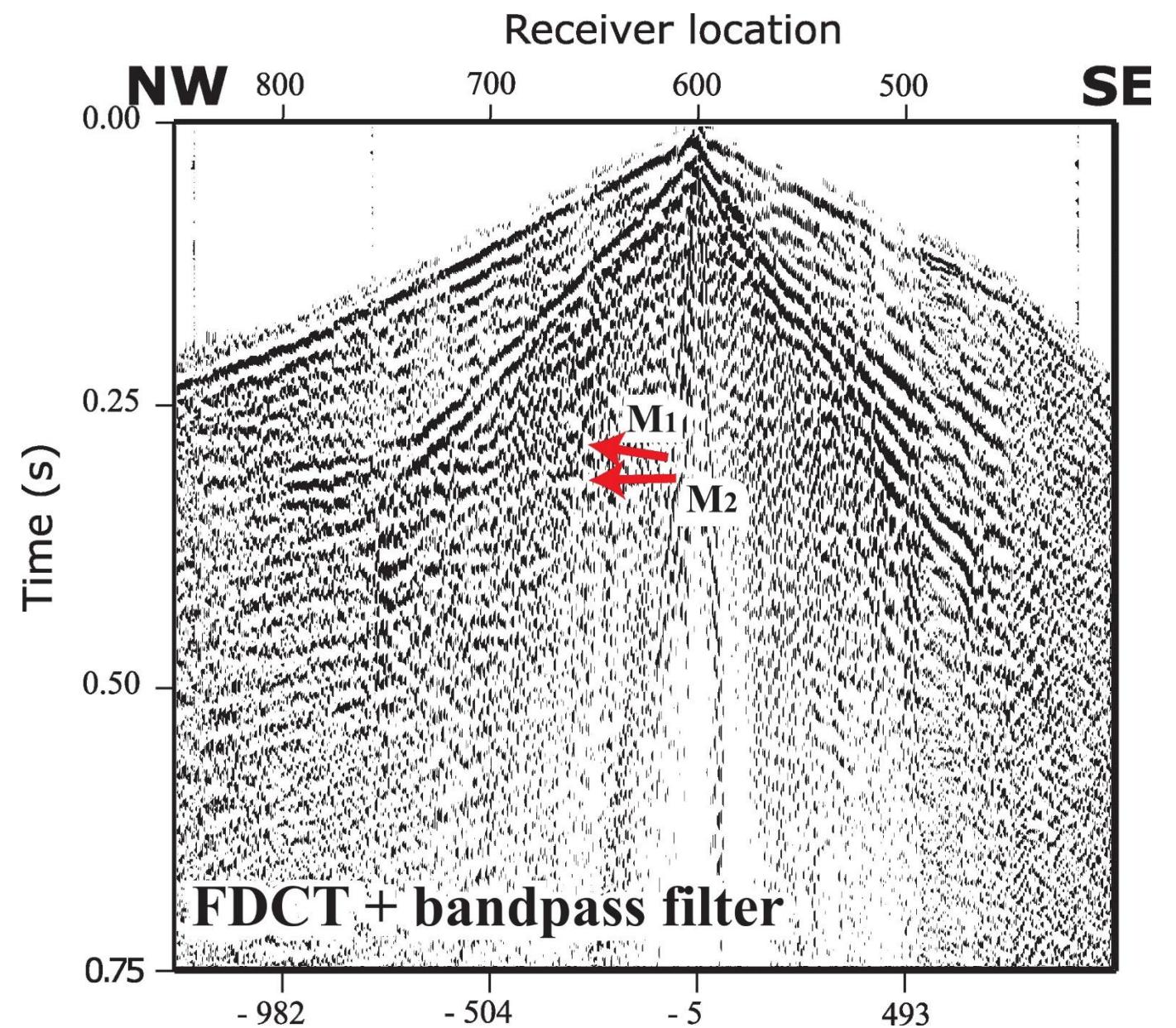
CASE STUDIES: MINERAL EXPLORATION

Iron-oxide mineralization in
Ludvika, Sweden

2D reflection seismic survey



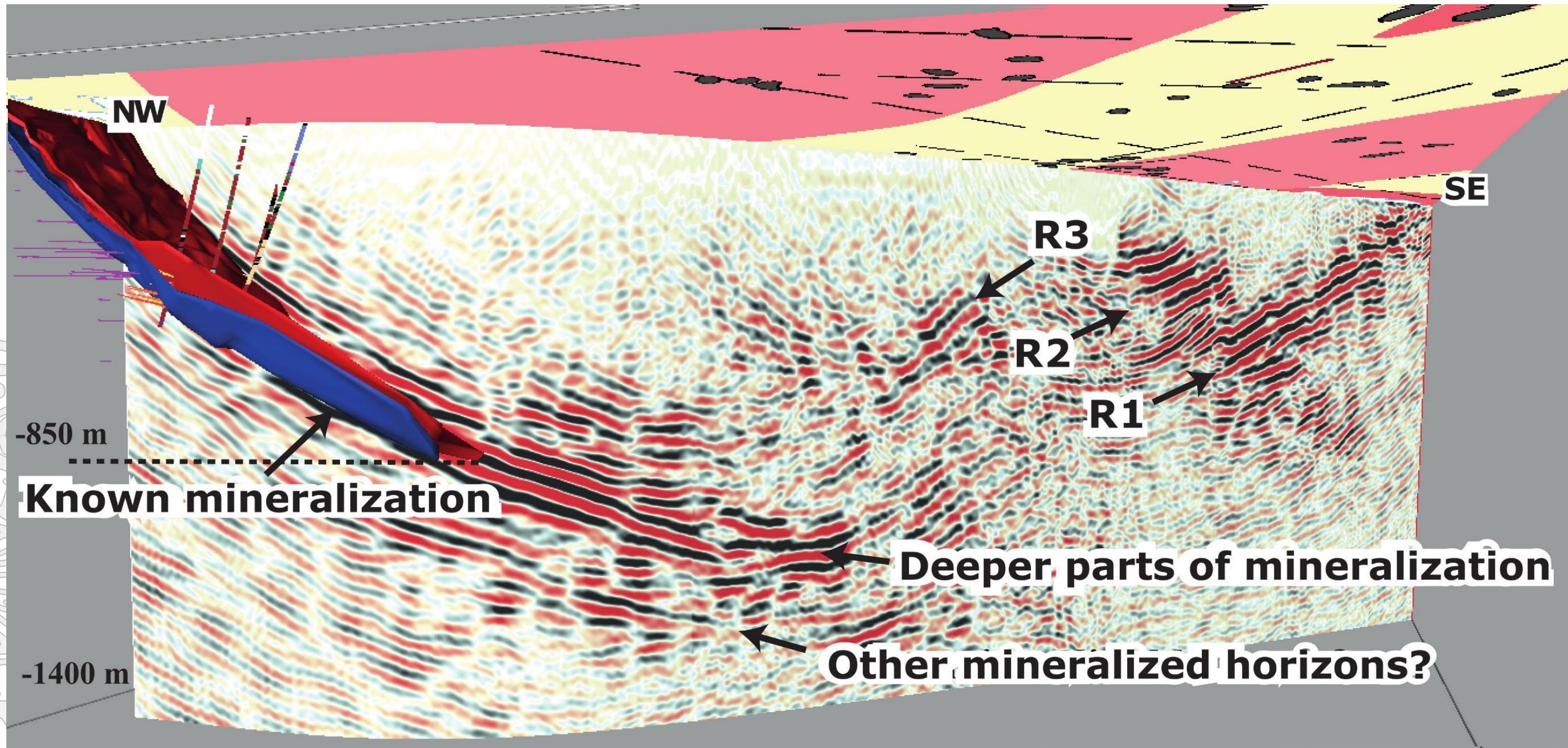
Markovic et al., 2020





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Seismic method

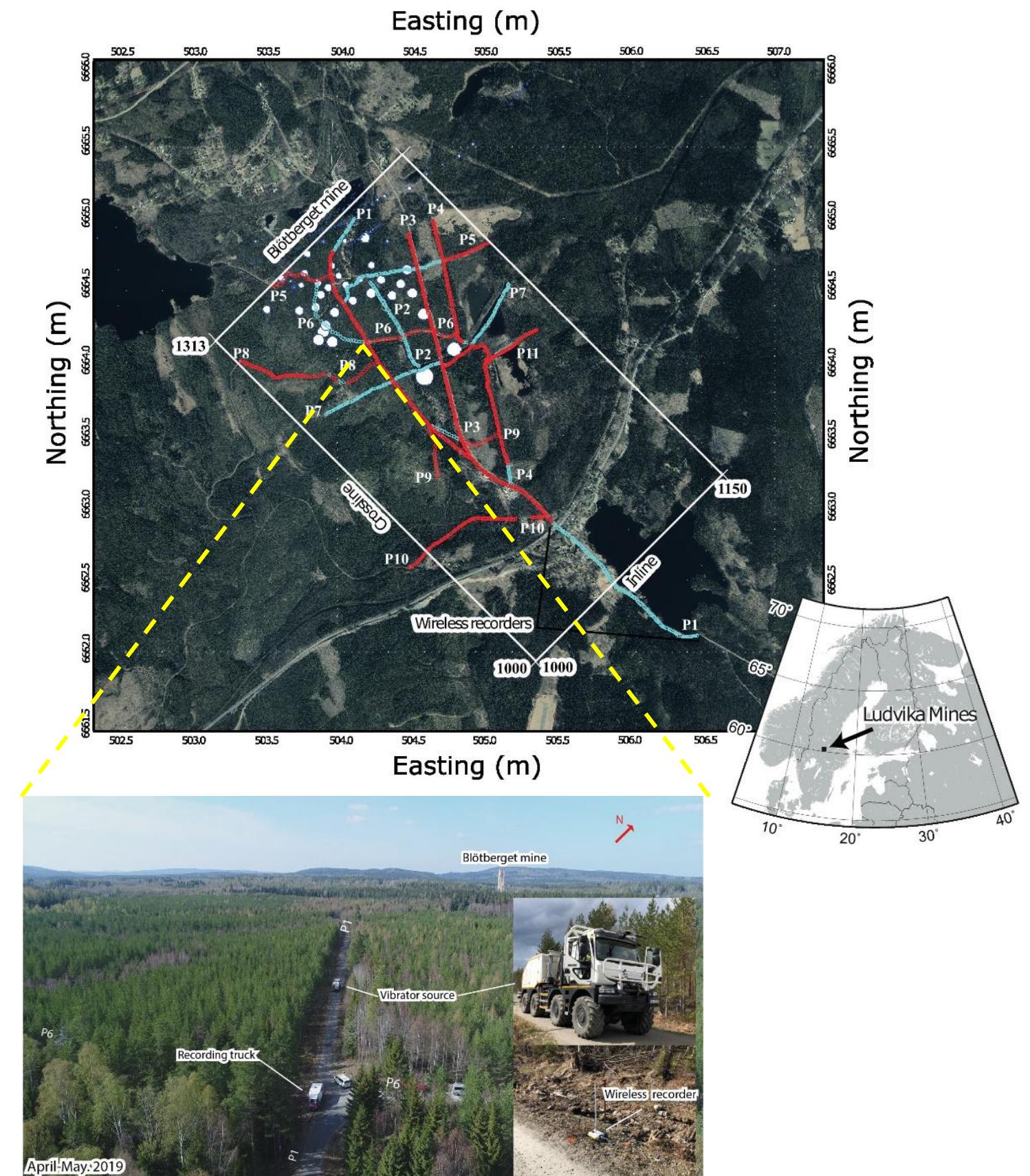
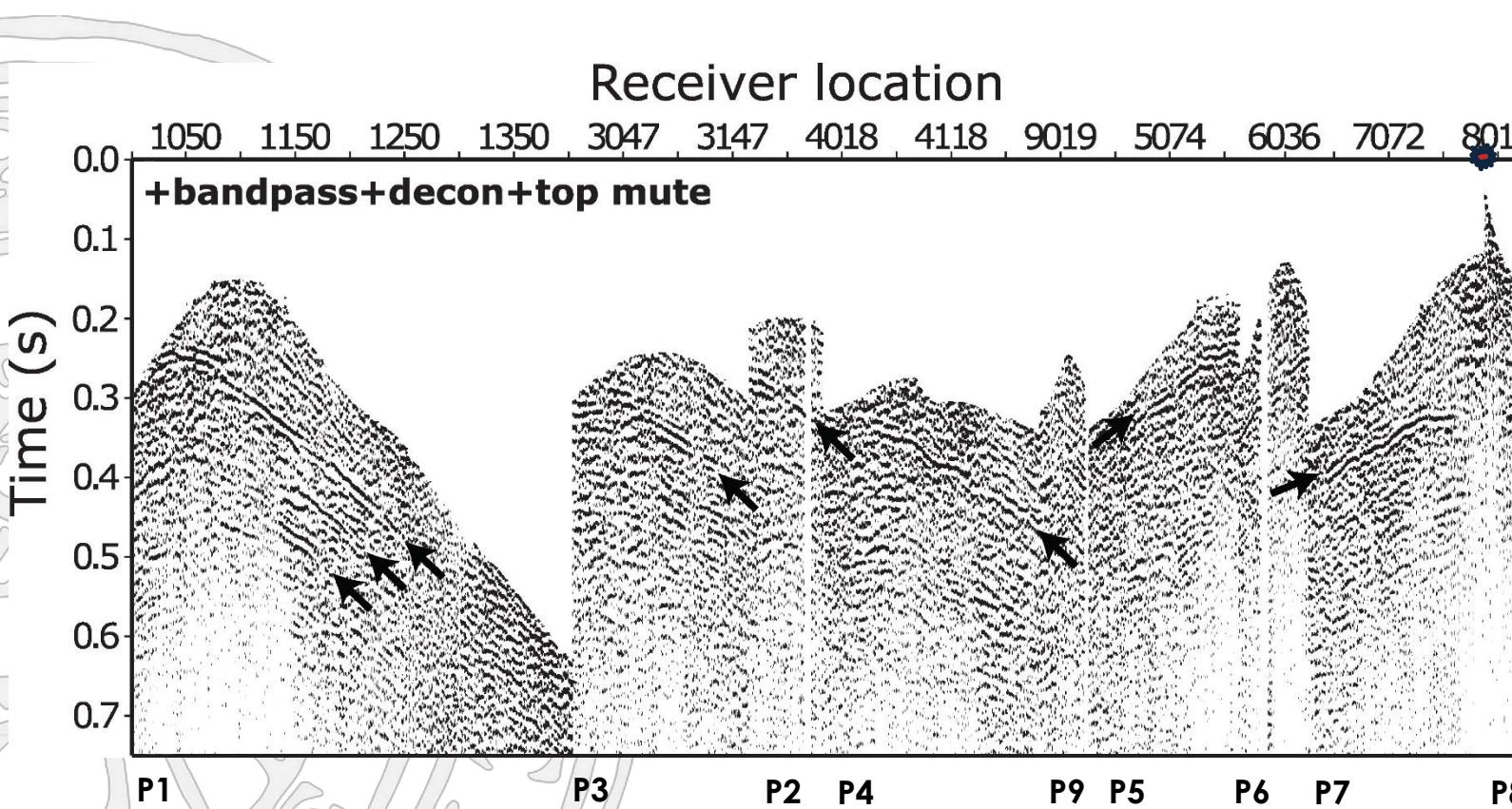


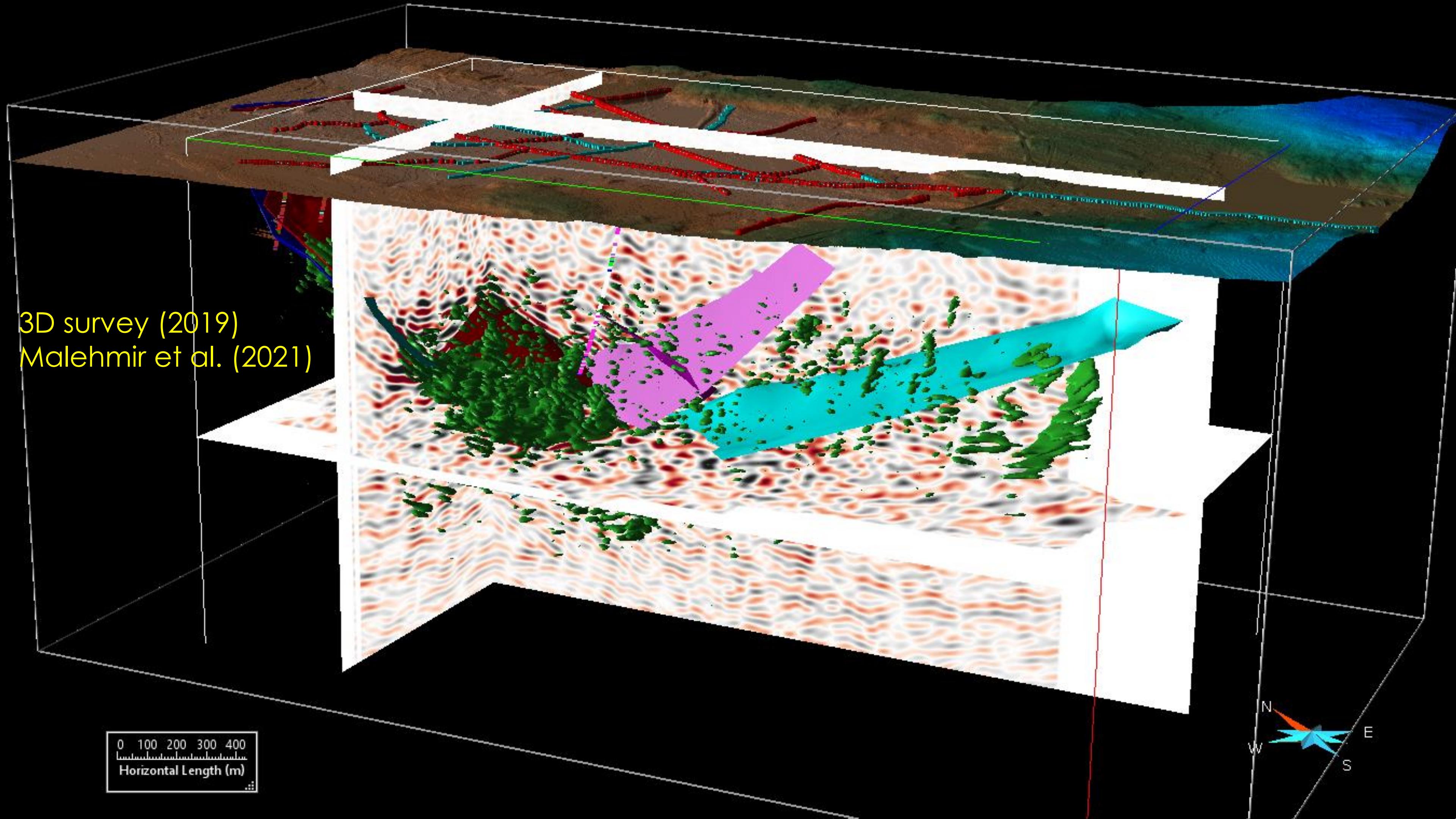


Seismic method

CASE STUDIES

Iron-oxide mineralization in
Ludvika
Sparse 3D reflection seismic
survey







Seismic method

CASE STUDIES

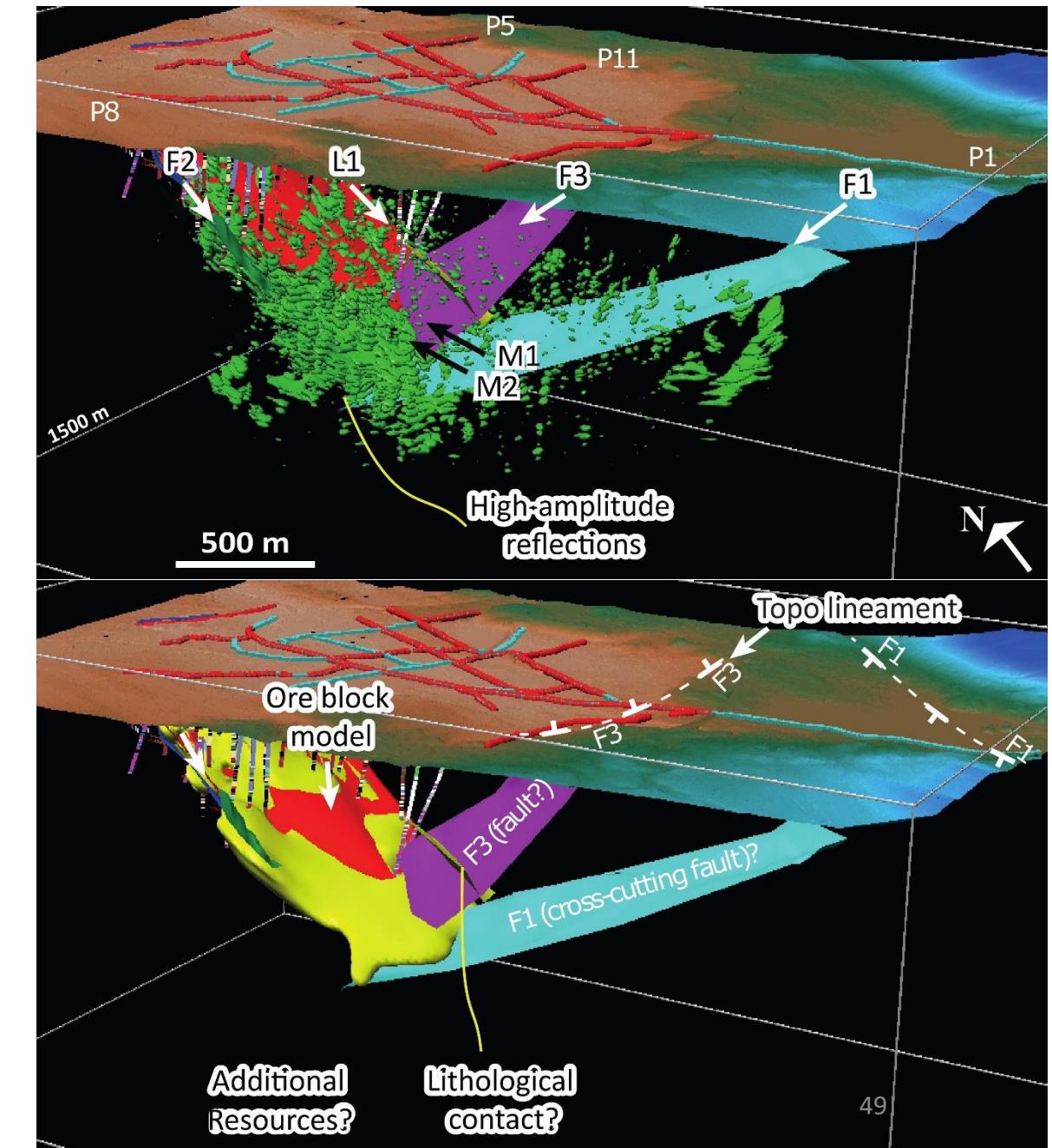
Additional resources?

Estimated resources
approximately 10 Mt!

Nordic
Iron Ore™

Nordic Iron Ore AB has applied for an additional exploration permit at Blötberget

Nordic Iron Ore AB has submitted an application to The Mining Inspectorate of Sweden (Bergsstaten) for an additional exploration permit in connection with the Blötberget mine. The background is the interesting indications obtained from the Smart Exploration research project. Which makes this area very interesting for exploration and, in the case of successful exploration, a possible expansion of Nordic Iron Ore's mineral resources.





AI implementation in geophysics



CASE STUDIES

Spot robot dog: for mine safety
(measures radioactivity levels;
methane leak)

Drone platforms

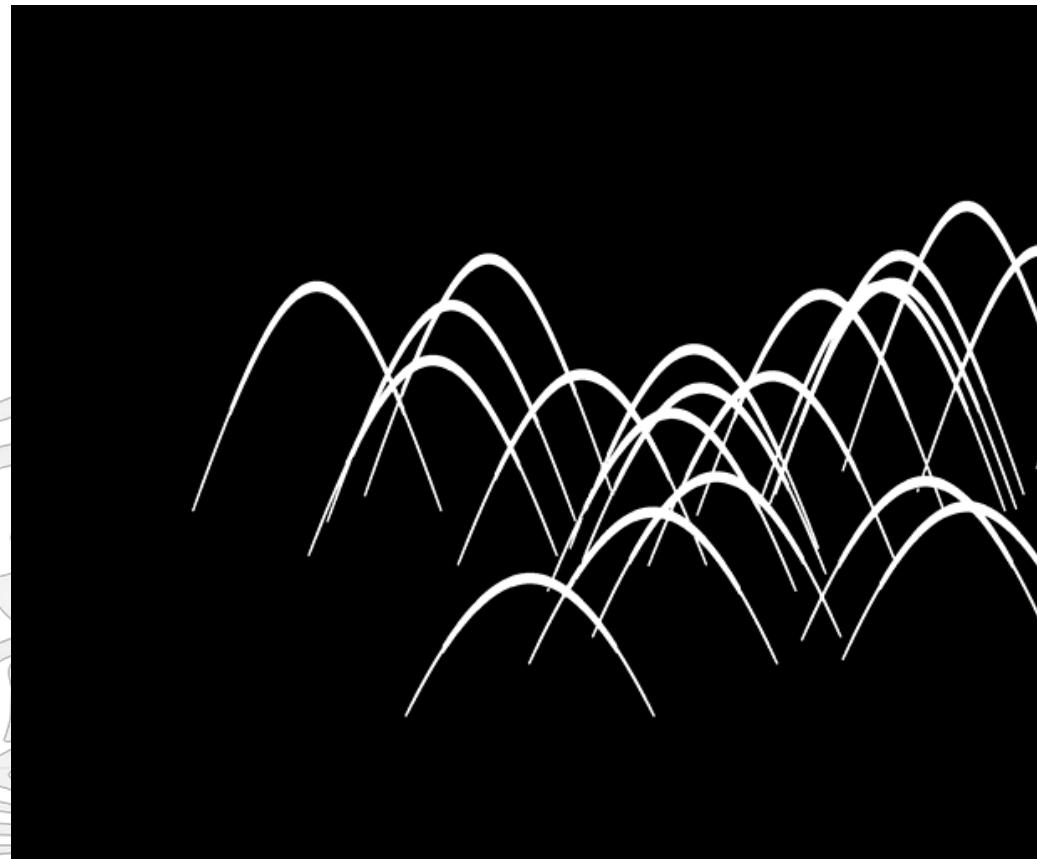




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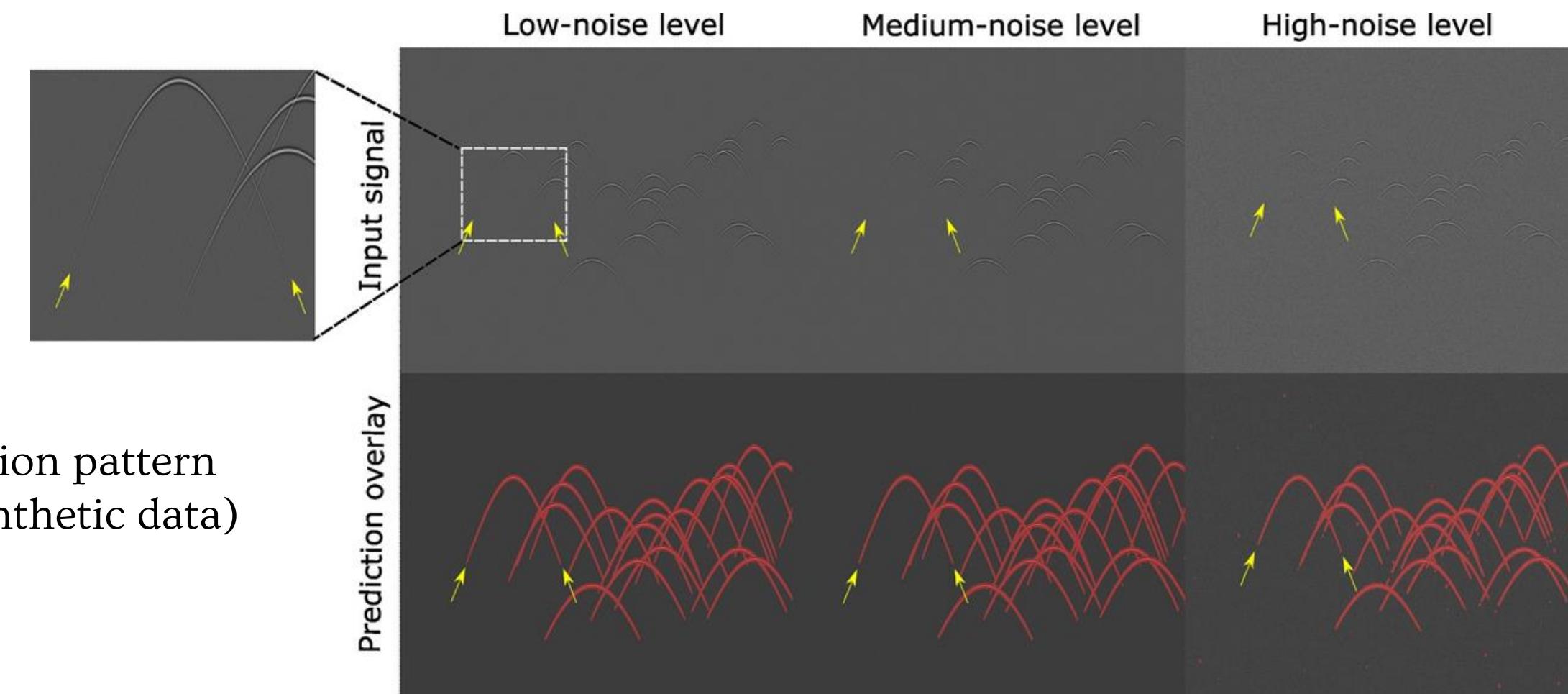
AI implementation in geophysics

CASE STUDIES

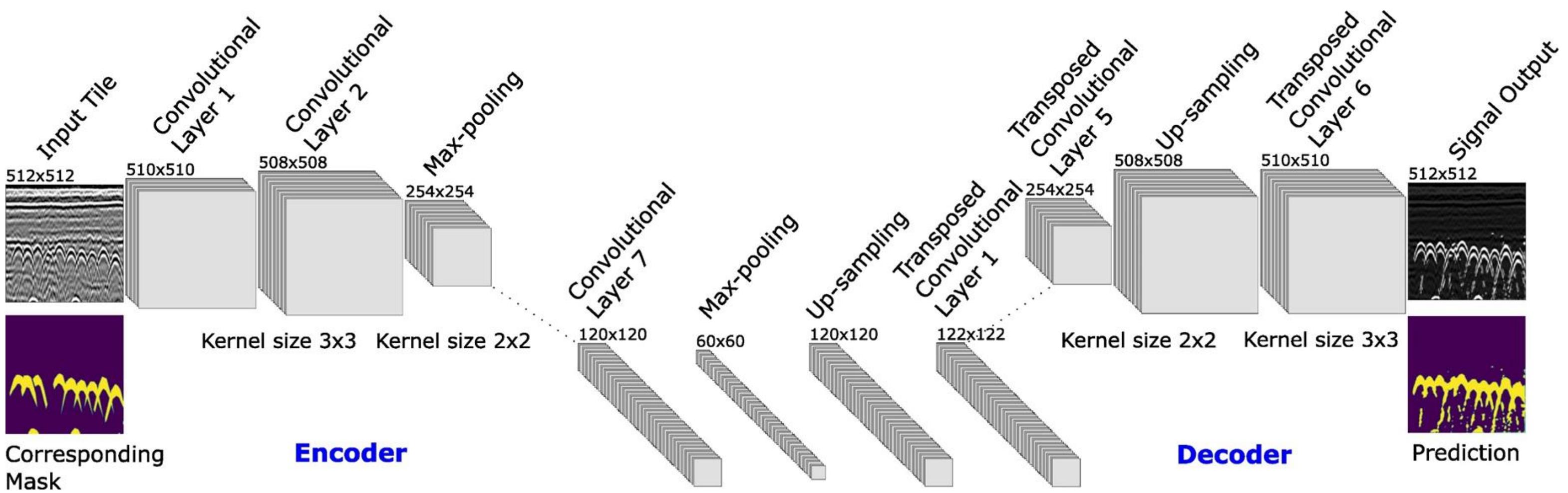
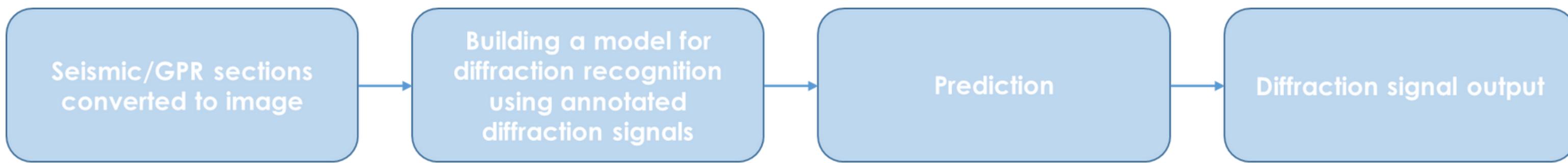


Annotation

Seismic diffraction pattern
recognition (synthetic data)



Over 100 zero-offset sections were created using a 50-Hz Ricker wavelet and 10 m trace spacing
Background velocity of 5900 m/s was used for the medium



U-net algorithm for diffraction delineation
Markovic et al., 2022

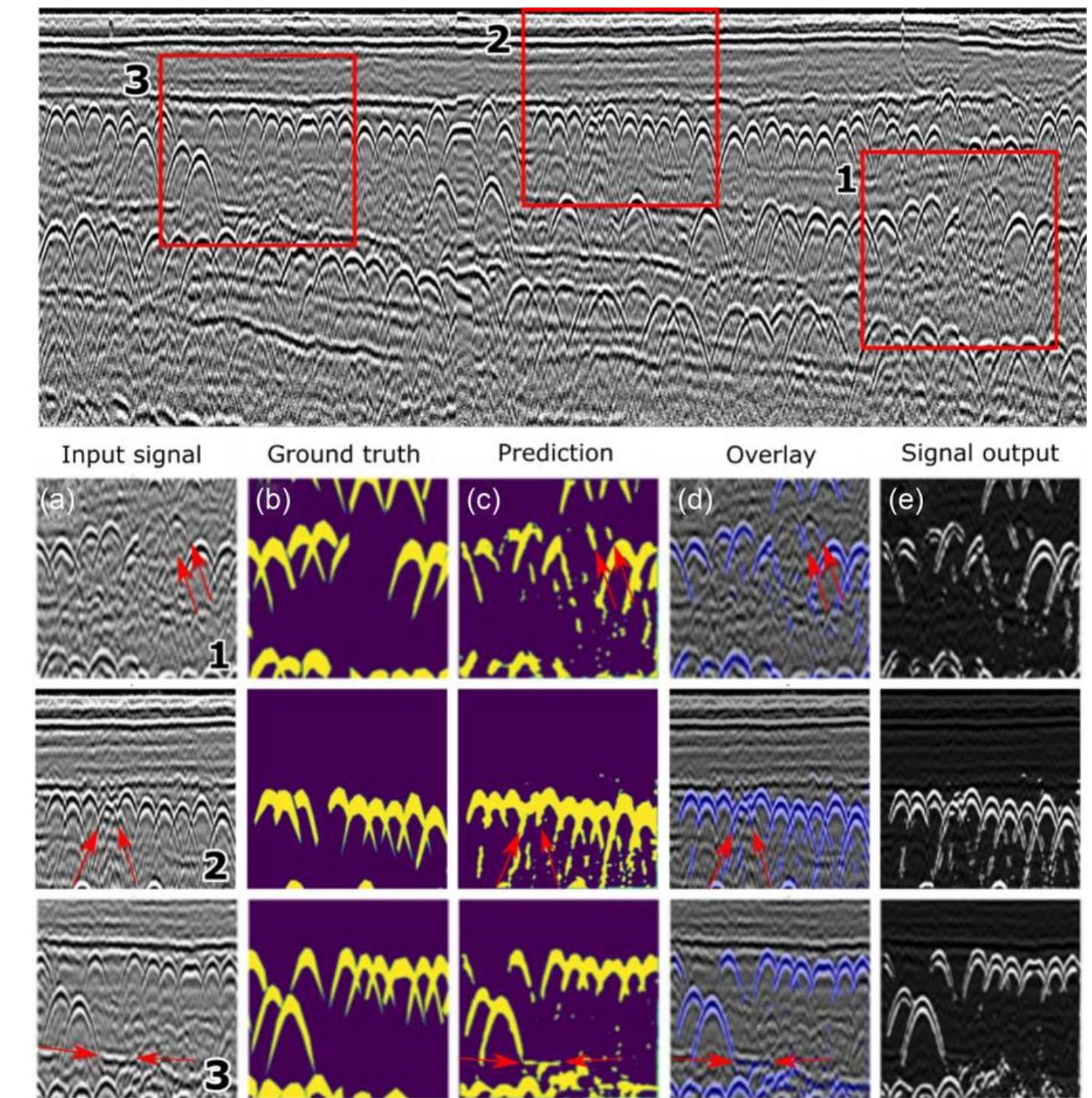
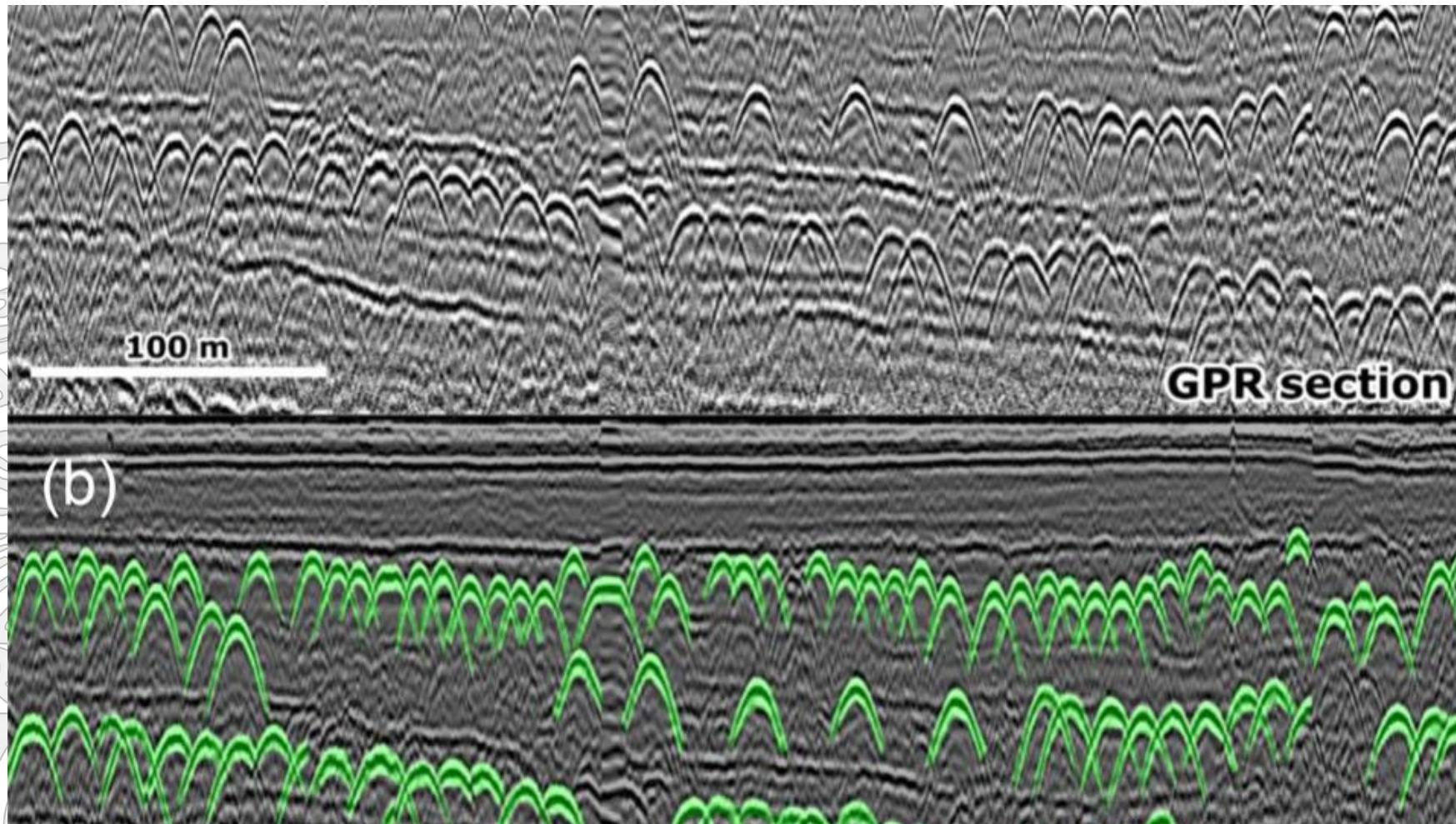


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AI implementation in geophysics

CASE STUDIES

U-net applied to GPR data for
diffraction signal recognition





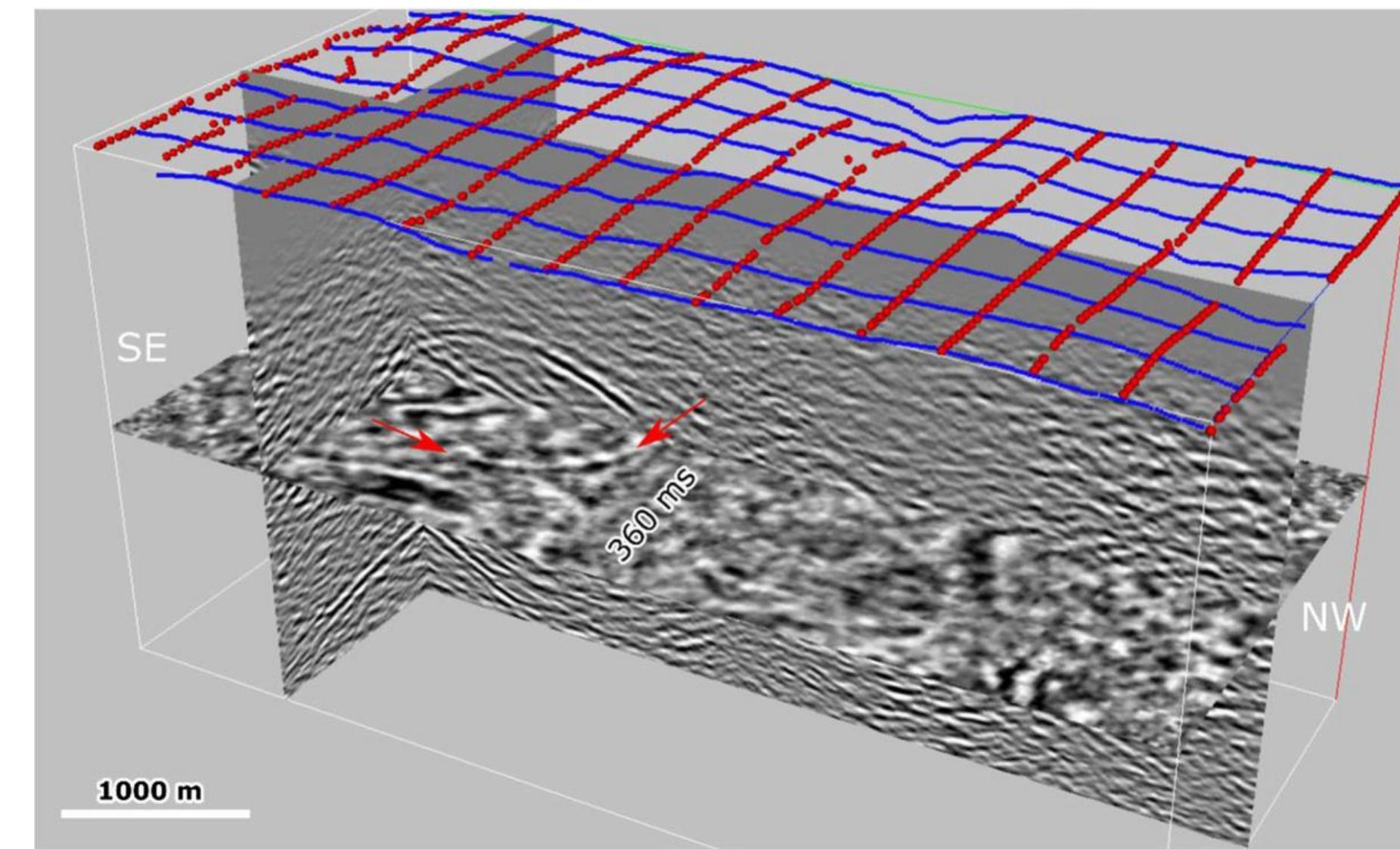
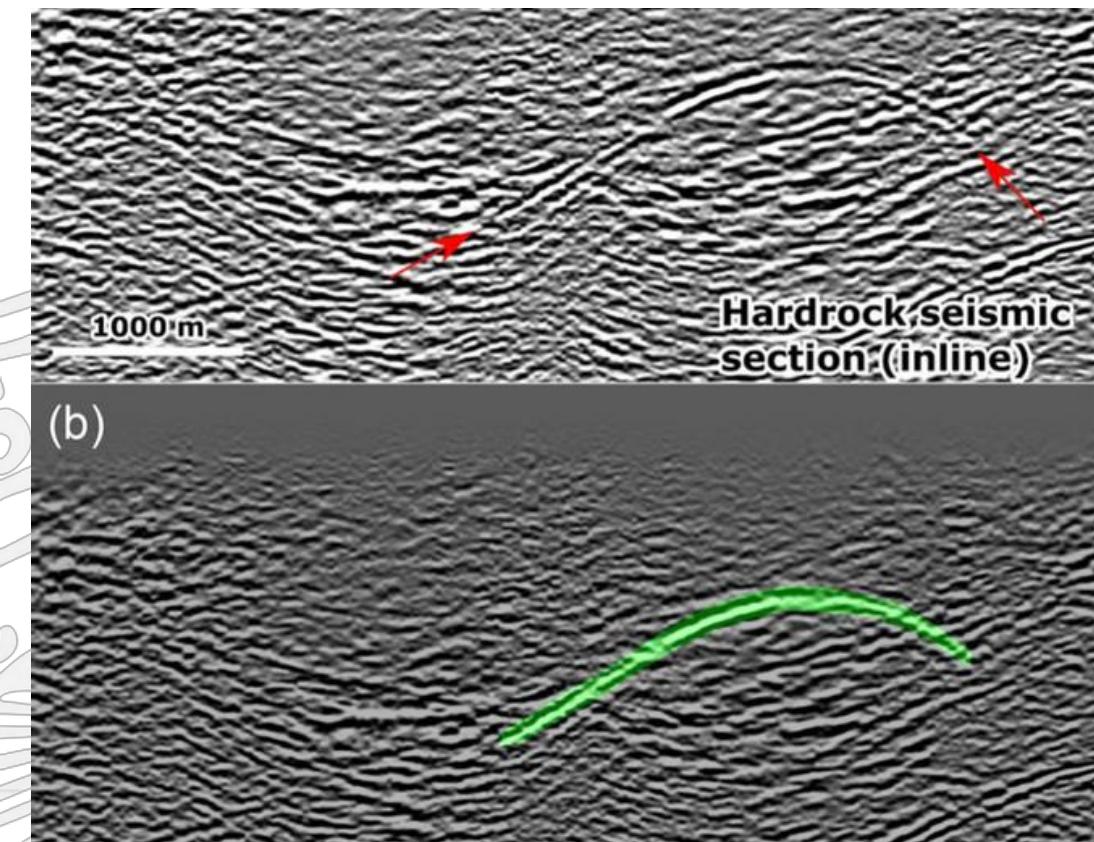
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CASE STUDIES

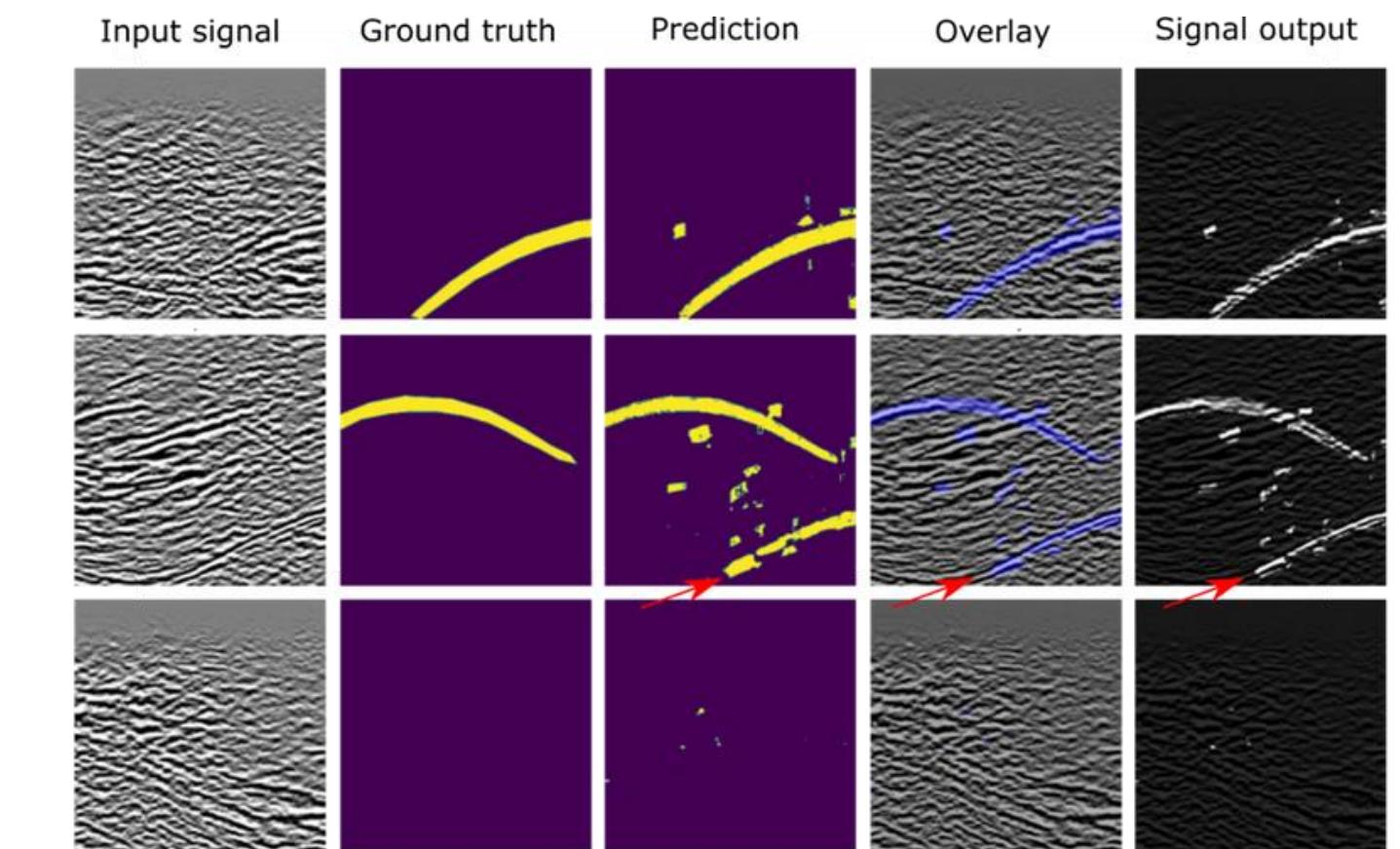
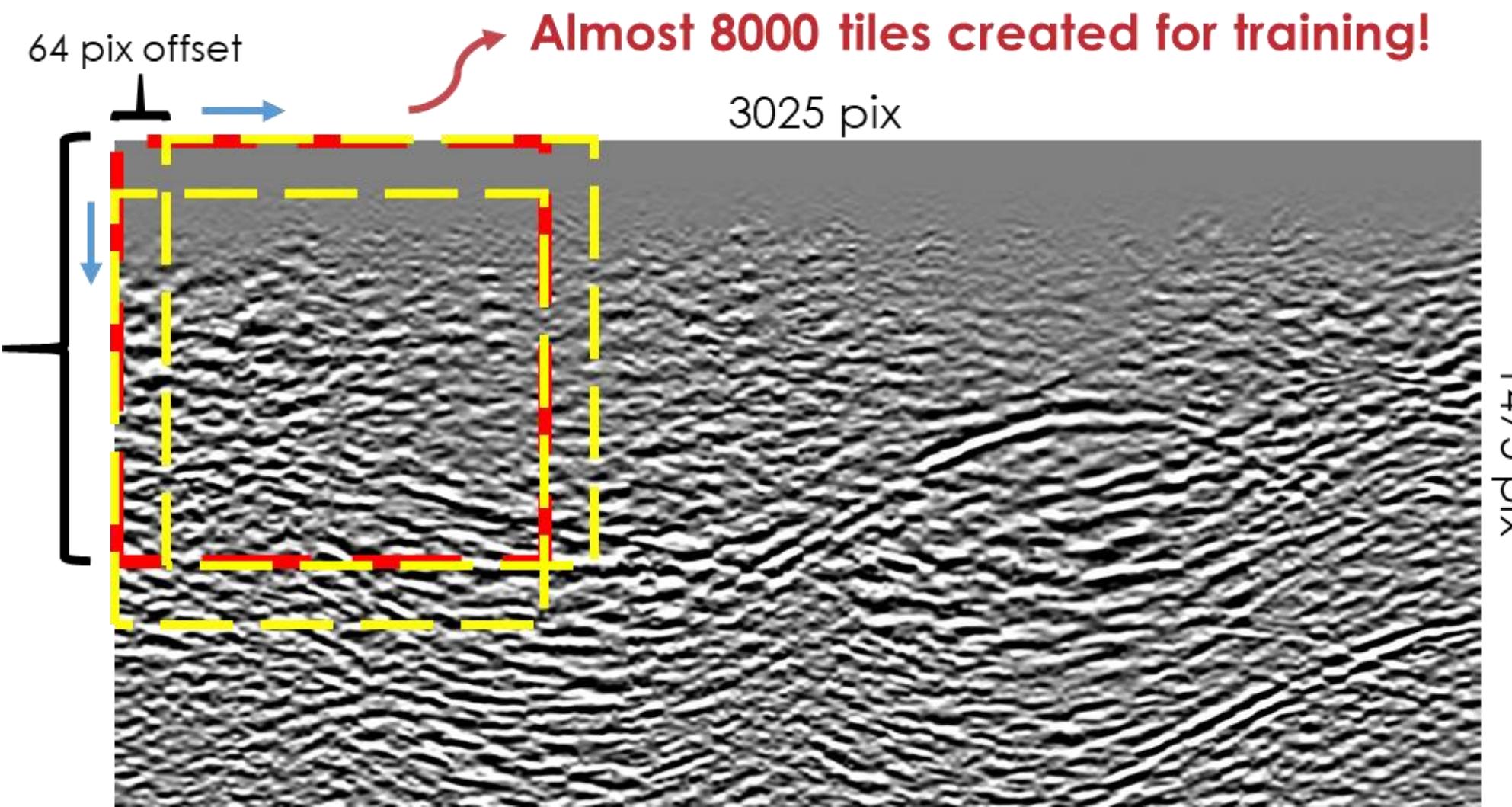
U-net applied to hardrock
seismic data

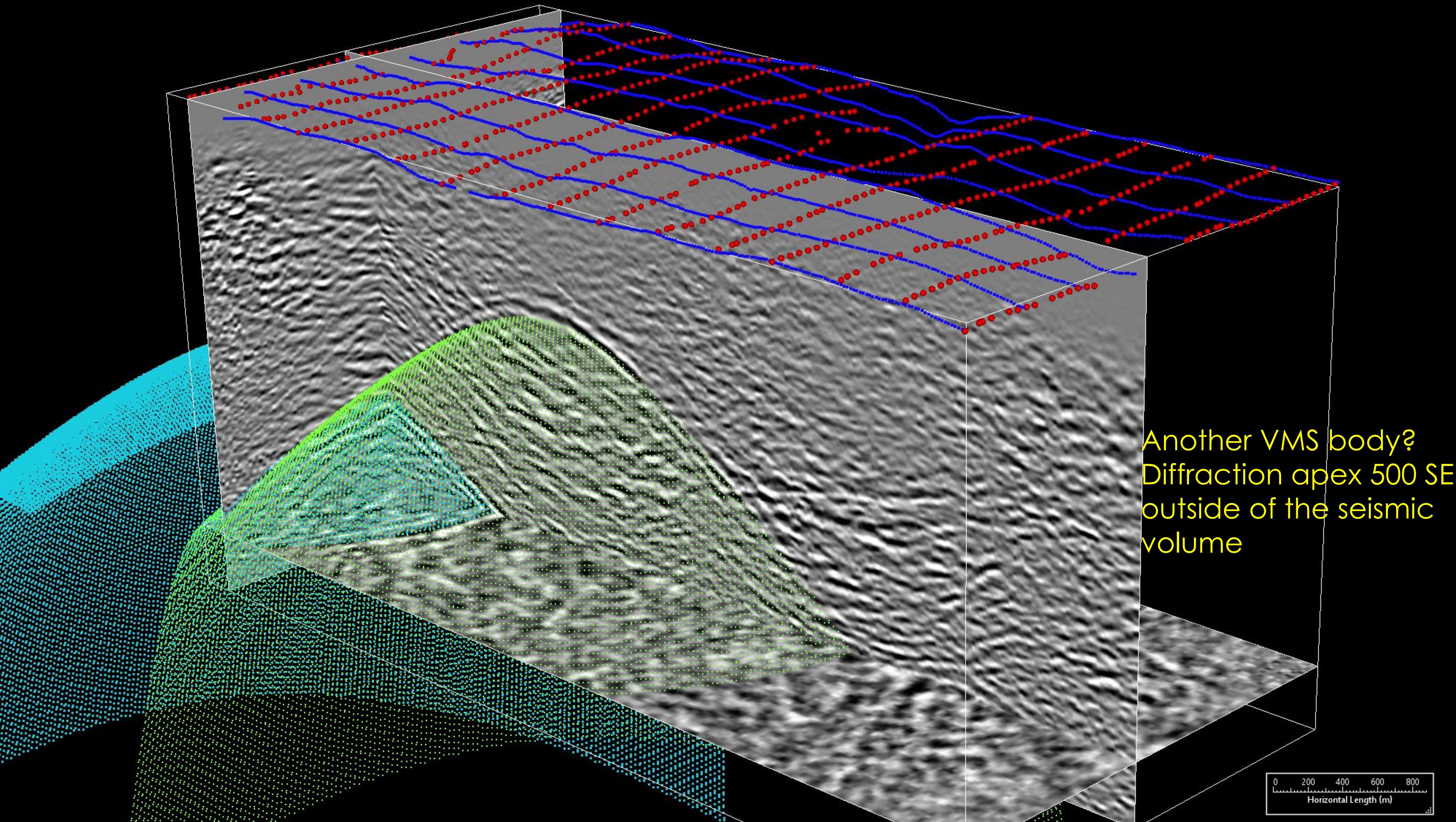
Diffraction generated from
VMS body



AI implementation in geophysics

CASE STUDIES





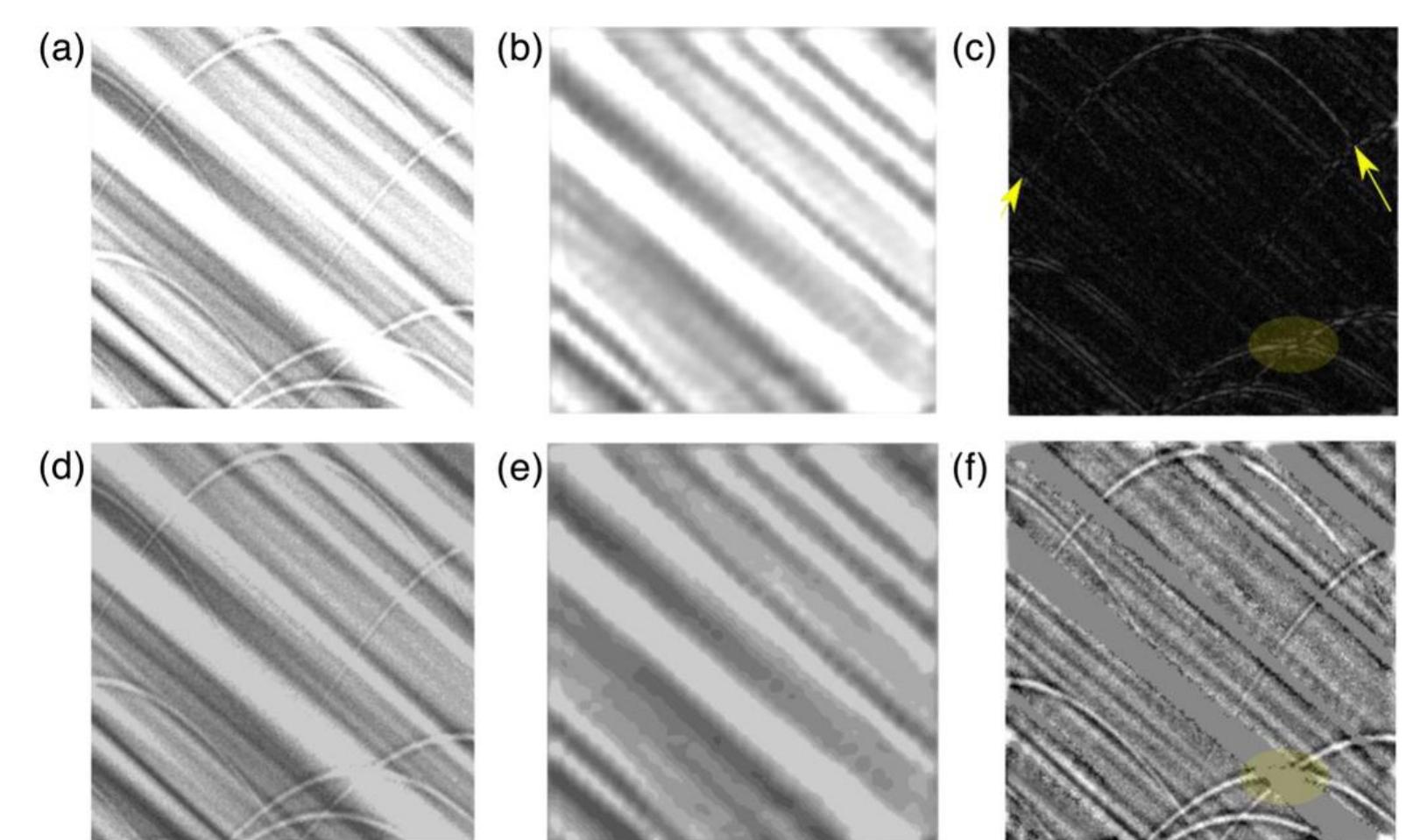
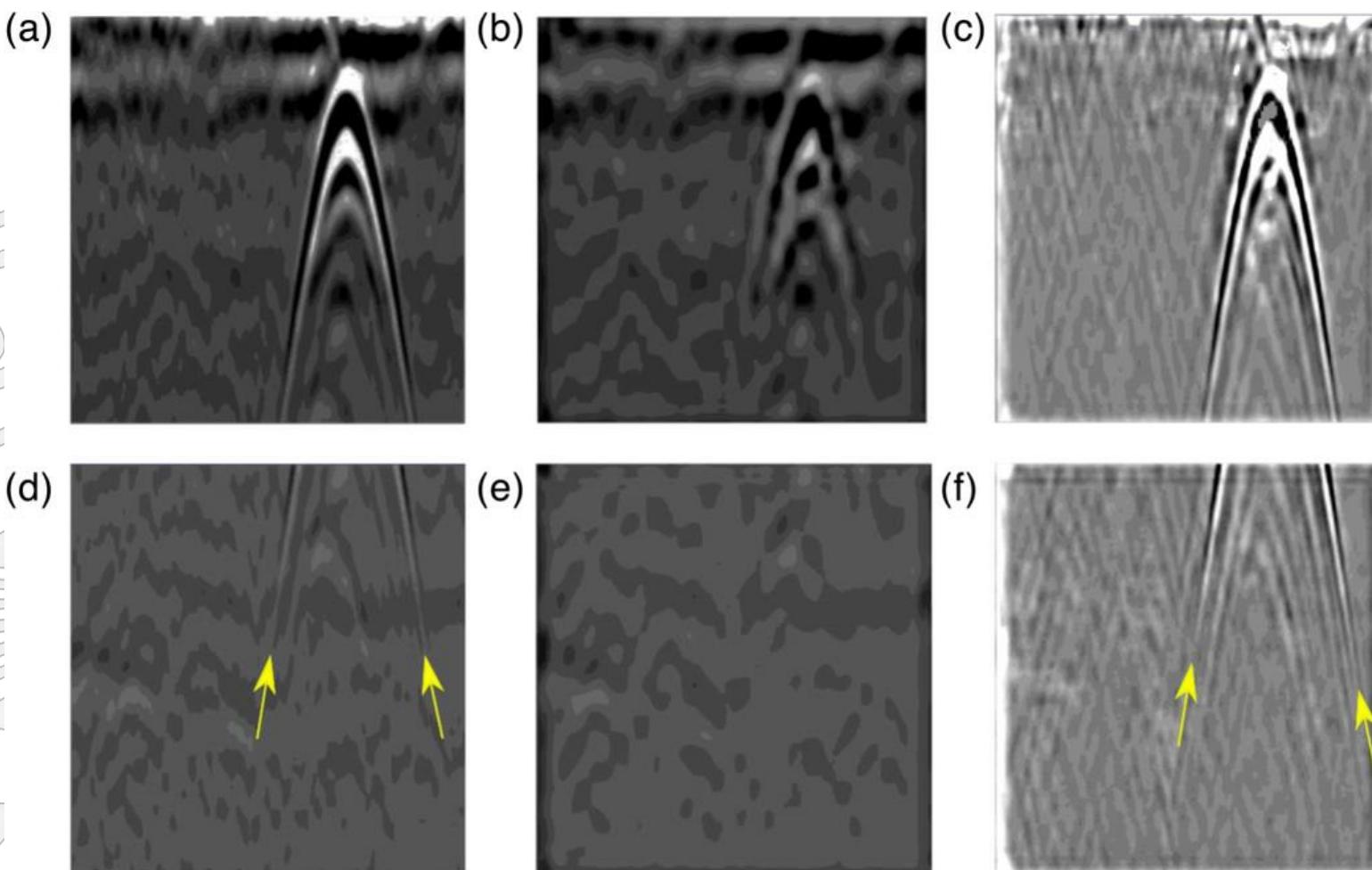


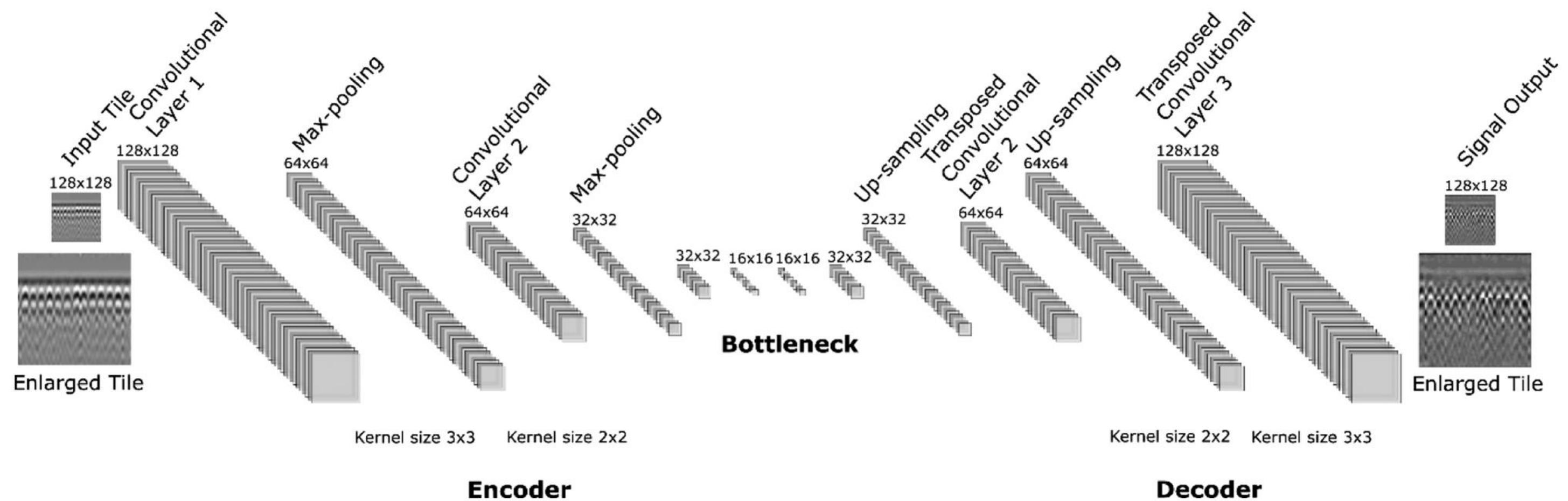
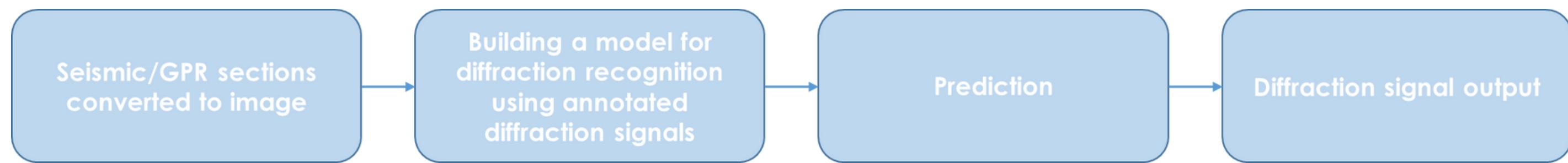
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AI implementation in geophysics

CASE STUDIES

Seismic and GPR diffraction
denoising using autoencoder





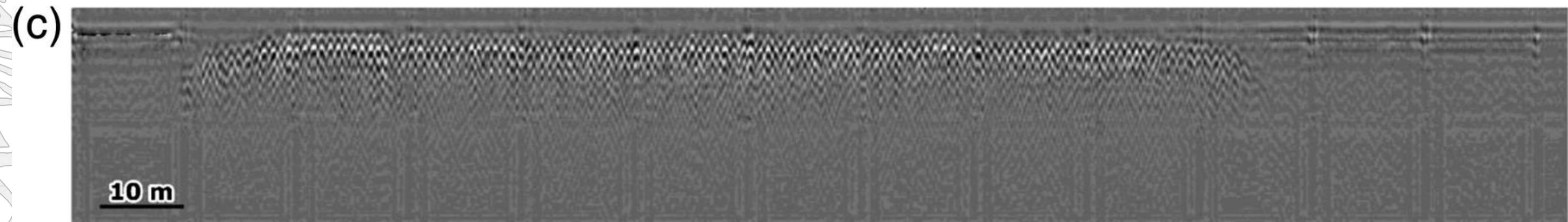
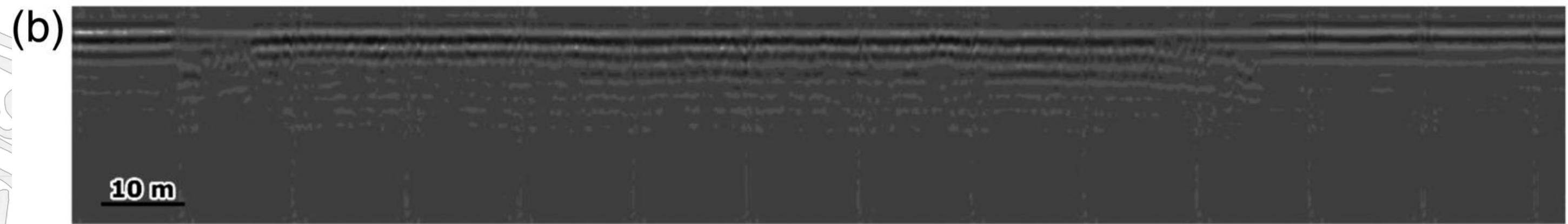
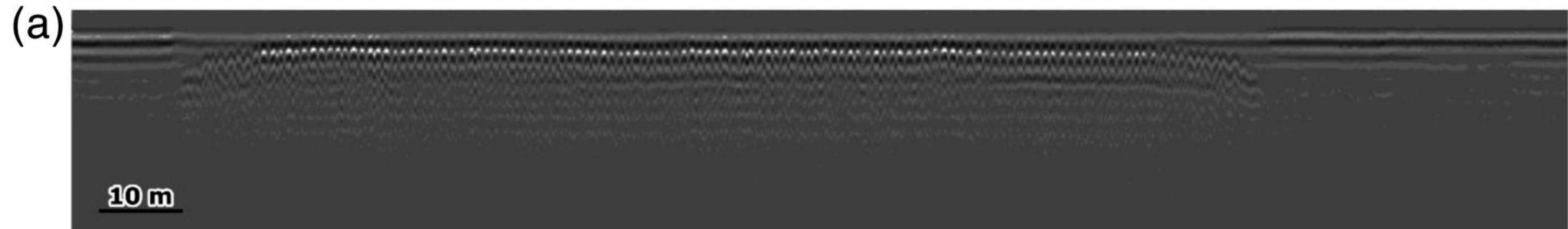
Autoencoder algorithm for diffraction denoising
Markovic et al., 2023



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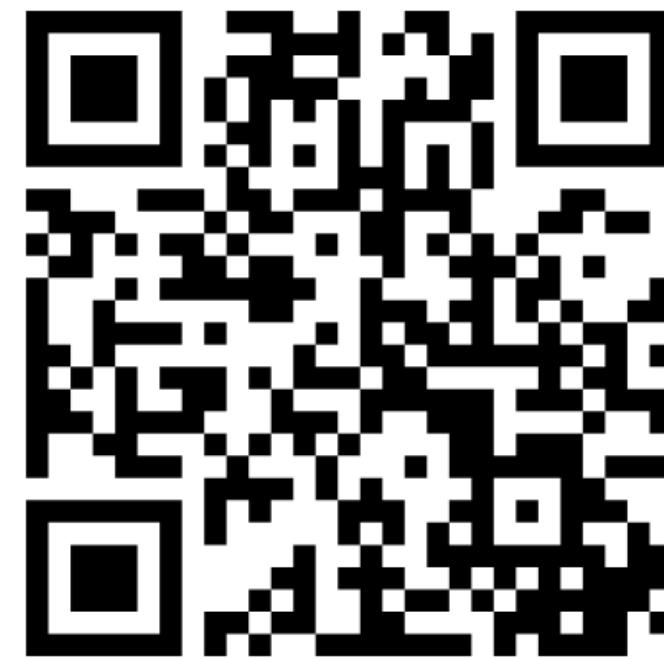
CASE STUDIES



Lot of information
to take in!



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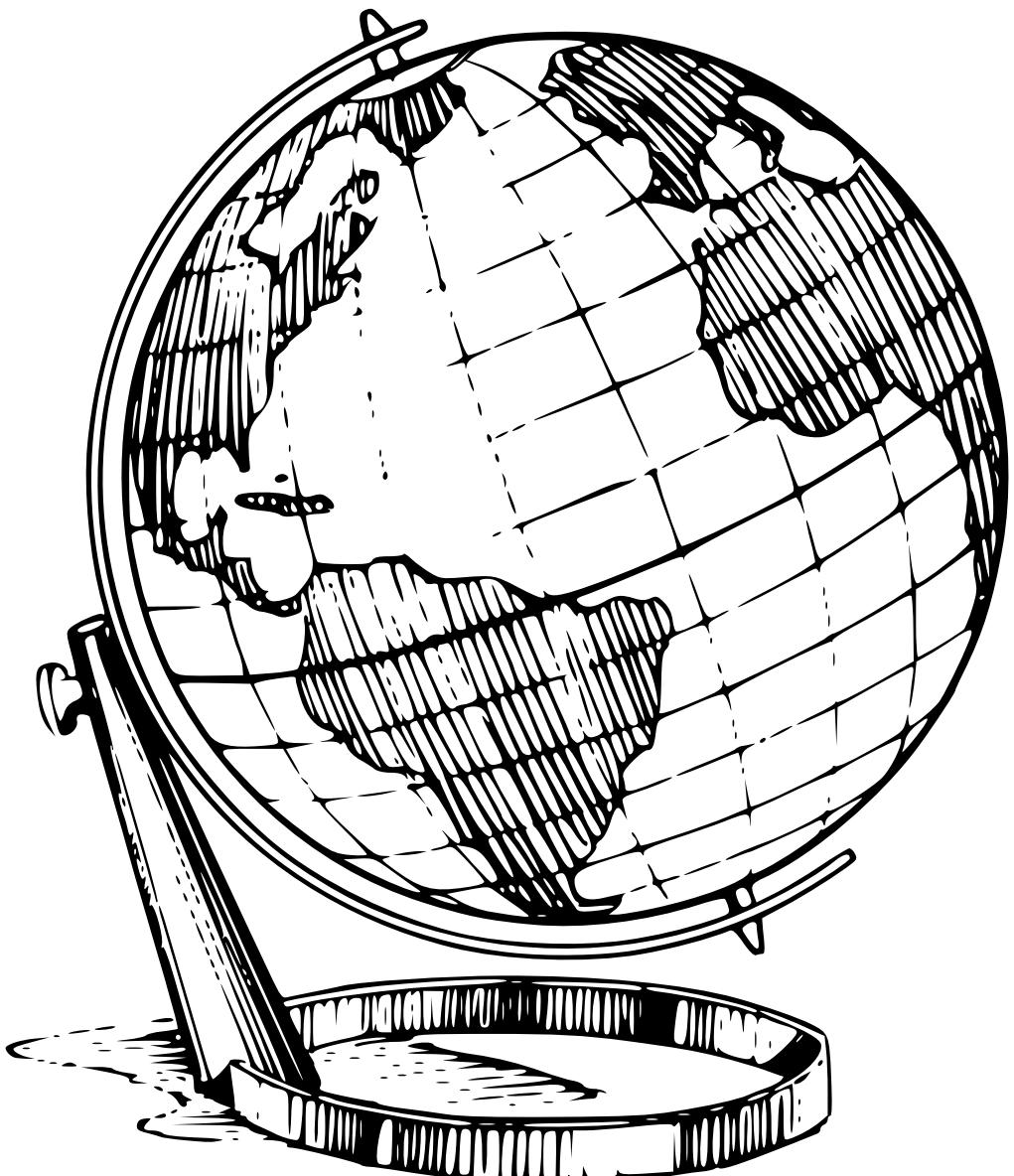
Last one I promisse

ANONYMOUS SURVEY!

Scan the QR code on the screen, and write one word in each box. Once you do that, click submit button!



The question is about the most interesting part of presentation overall



Thank you all,
I hope you enjoyed

Q&A



Italian Section



Netherlands Section



London Section



Romanian Section



Croatian Section



Central Ukraine Section



Geothermal Technical Section



Data Science and
Engineering Analytics
Technical Section

ENERGY

Geo Hackathon

Society of Petroleum Engineers

www.spehackathon-eu.com

#DatafyingEnergy



SPE Europe Region

