SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
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Results of 2022 and 2023 OSI Field Tests for Non-Seismic Geophysical Techniques

Gaya-Pique[1], L., Motschka[2], K., Boddice[3], D., Toon[1], S., Koivisto[1], E.A.L., Rowlands[1], A. and Labak[1], P.

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CTBTO PREPARATORY COMMISSION | PUTTING AN END TO NUCLEAR EXPLOSIONS

INTRODUCTION AND MAIN RESULTS

In 2022 and 2023, the PTS conducted **2 field tests for the development of seismic and non-seismic geophysical techniques for deep on-site inspection (OSI) applications**. The 2022 Field Test took place in the Austrian Alps over a karst cave system at depths of 40-350 m. The 2023 Field Test was conducted in the UK above the Channel Tunnel consisting of two rail tunnels excavated in chalk marl at 90 m depth. **We present results of electrical conductivity measurements (ECM) and gravitational field mapping (GRV). The ECM results reveal detailed subsurface geology, including direct detection of some shallow caves in the 2022 data. The GRV anomalies are consistent with locations of the 2023 targets.**

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Background

- **Field tests are a key element of on-site inspection (OSI) techniques development process.**
- During a field test, new hardware, software, procedures and/or workflows may be tested for OSI techniques application.
- Based on the results, new approaches may then be adapted for OSI use, leading to development of OSI documentation and training, and ultimately to comprehensive demonstration of the acquired capabilities in the OSI Exercises.

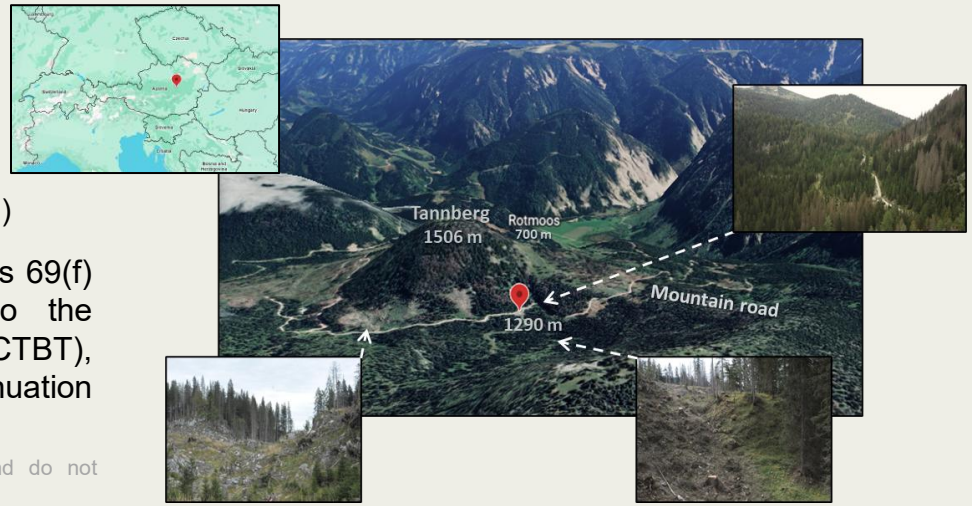
- **In 2022 and 2023, the PTS conducted two field tests for the development of the following seismic and non-seismic geophysical techniques for deep OSI applications:**

- Resonance seismometry (RES)
- Active seismic surveys (ACT)
- Gravitational field mapping (GRV)
- Electrical conductivity measurements (ECM)
  - Electrical resistivity tomography (ERT)
  - Frequency-domain electromagnetics (FDEM)

- These techniques are mandated by paragraphs 69(f) and 69(g) of Part II of the Protocol to the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and can be applied from the start of a continuation period of an OSI.

2022 OSI Field Test in Austria

- A Field Test of OSI Geophysical Techniques for Deep Applications in a Mountainous Environment was conducted September 5-16, 2022, in Styria, Austria over a cave system embedded in limestone with karst voids at depths of 40-350 m.
- The scope of the 2022 OSI Field Test was to assess the OSI geophysical imaging capabilities for deep applications in an integrated manner at a mountainous site with deep geophysical observables of OSI interest.
- This was the first time that an OSI field test was conducted in a mountainous environment. Consequently, a variety of operational, logistical, and technical challenges had to be addressed prior and during the conduct of the event.



2023 OSI Field Test in the UK

- A Field Test of OSI Active Seismic Surveys and Selected Geophysical Techniques was conducted May 8-19, 2023, at a farm in Folkestone, Kent, UK, above the Channel Tunnel, consisting of two rail tunnels excavated in chalk marl at 90 m depth.
- The scope of the 2023 OSI Field Test was to complement and expand on the outcomes of the 2022 Field Test in Austria.
- Due to the complementary nature, the objectives of the Field Test varied depending on the specific status and needs of the different geophysical techniques.

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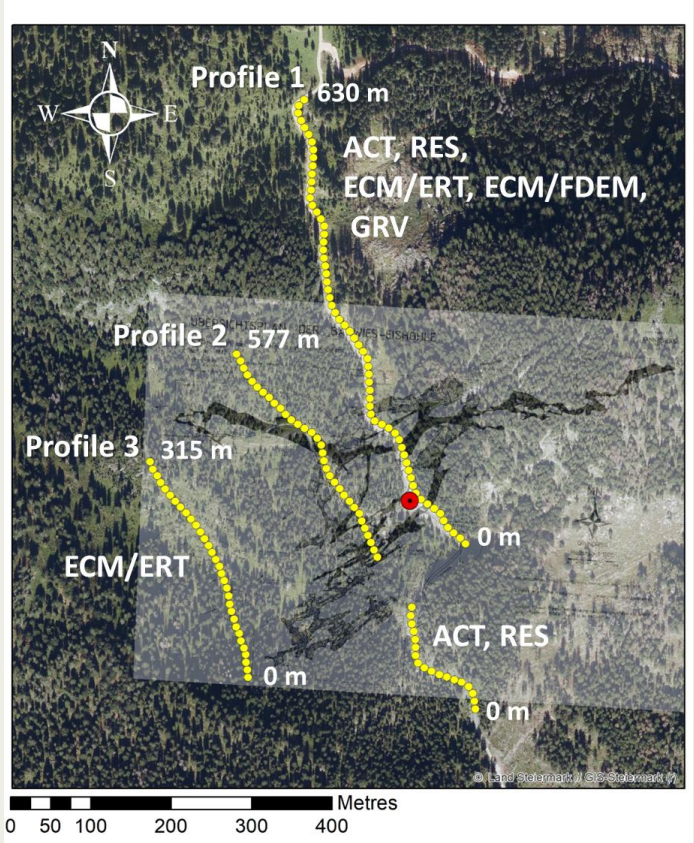
Survey Layout of the 2022 Field Test



3 survey profiles over a cave system embedded in limestone with karst voids 5-15 m in diameter at depths of 40-350 m mimicking tunnels and underground cavities associated with a UNE. Depending on the technique, the lengths of the profiles varied.

Survey Parameters of the 2022 OSI Field Test

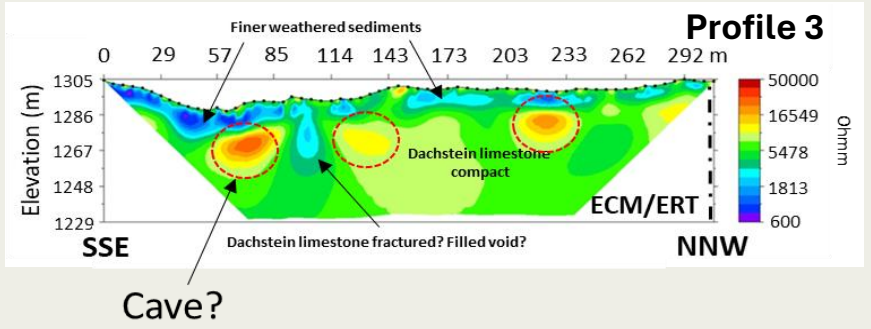
ECM/ERT	Profile 1	Profile 3
Data recording system	Abem Terrameter LS2	Abem Terrameter LS2
Profile length	630 m	315 m
Coverage along the profile	0-630 m	0-315 m
Electrode spacing	10 m	5 m
Number of electrodes	64	64
Configuration	Combination of Schlumberger, dipole-dipole and gradient configurations optimized for 8 channels	Combination of Schlumberger, dipole-dipole and gradient configurations optimized for 8 channels
Data point configured	6778	6777
Data points measured	6770	5764
Measure mode	Apparent resistivity	Apparent resistivity
Stacking	Minimum, 2	Minimum, 2
Error limit	As high as reasonable, 10%	As high as reasonable, 10%
Current	Minimum, 10-20 mA	Minimum, 10-20 mA
Delay time	Small, no underground charging effects expected	Small, no underground charging effects expected
Acquisition time	0.5 s	0.5 s
Power line frequency cut off	50 Hz	50 Hz
Maximum current	500 mA	500 mA
Max power	150 W	150 W
Max output voltage	600 V	600 V
Bad electrode threshold	As high as reasonable, 10%	As high as reasonable, 10%

ECM/FDEM	Profile 1
Data recording system	IRIS Promis
Profile length	480 m
Coverage along the profile	50-530 m (midpoint of transmitter and receiver)
Measurement spacing	10 m
Measurement mode	Horizontal loop, transmitter ahead
Coil (transmitter and receiver) spacing	100 m
Frequencies	110, 220, 440, 880, 1760, 3520, 7040, 14080, 28160 and 56320 Hz.

GRV	Profile 1
Data recording system	Scintrex CG-5 gravimeter
Profile length	205 m (135 m after discarding unusable data)
Coverage along the profile	30-235 m (100-235 m)
Station spacing	5 m
Read time	30 s
Number of repeated measurements at each station	20
Base station frequency	~1 h

Results of the 2022 OSI Field Test

- Development of **ECM workflows, documentation and training**
- **Testing of the CG-5 gravimeter of the PTS**, leading to a recommendation to test new hardware for GRV.
- **Position finding** workflows for the techniques.
- Development of **GIMO** for the techniques.
- Operational, logistical and technical challenges of a **mountainous environment** addressed.



ECM/ERT results for Profile 3 showing possible shallow caves as high-resistivity anomalies.

See poster **P3.3-556** on the seismic geophysical techniques

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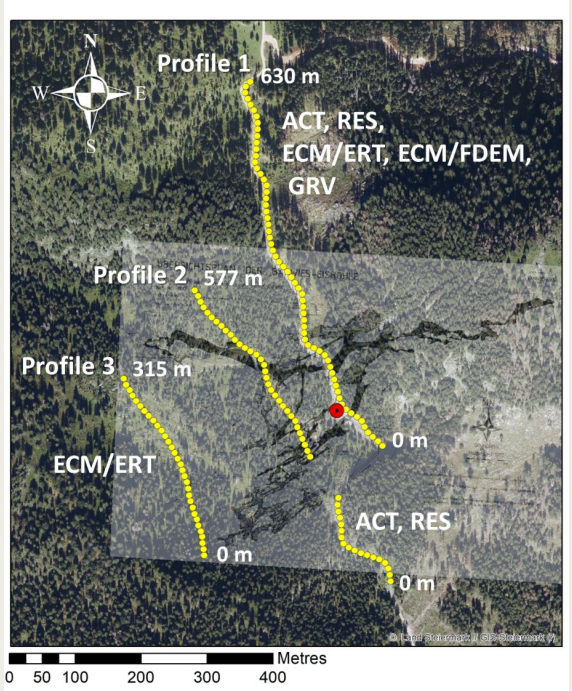
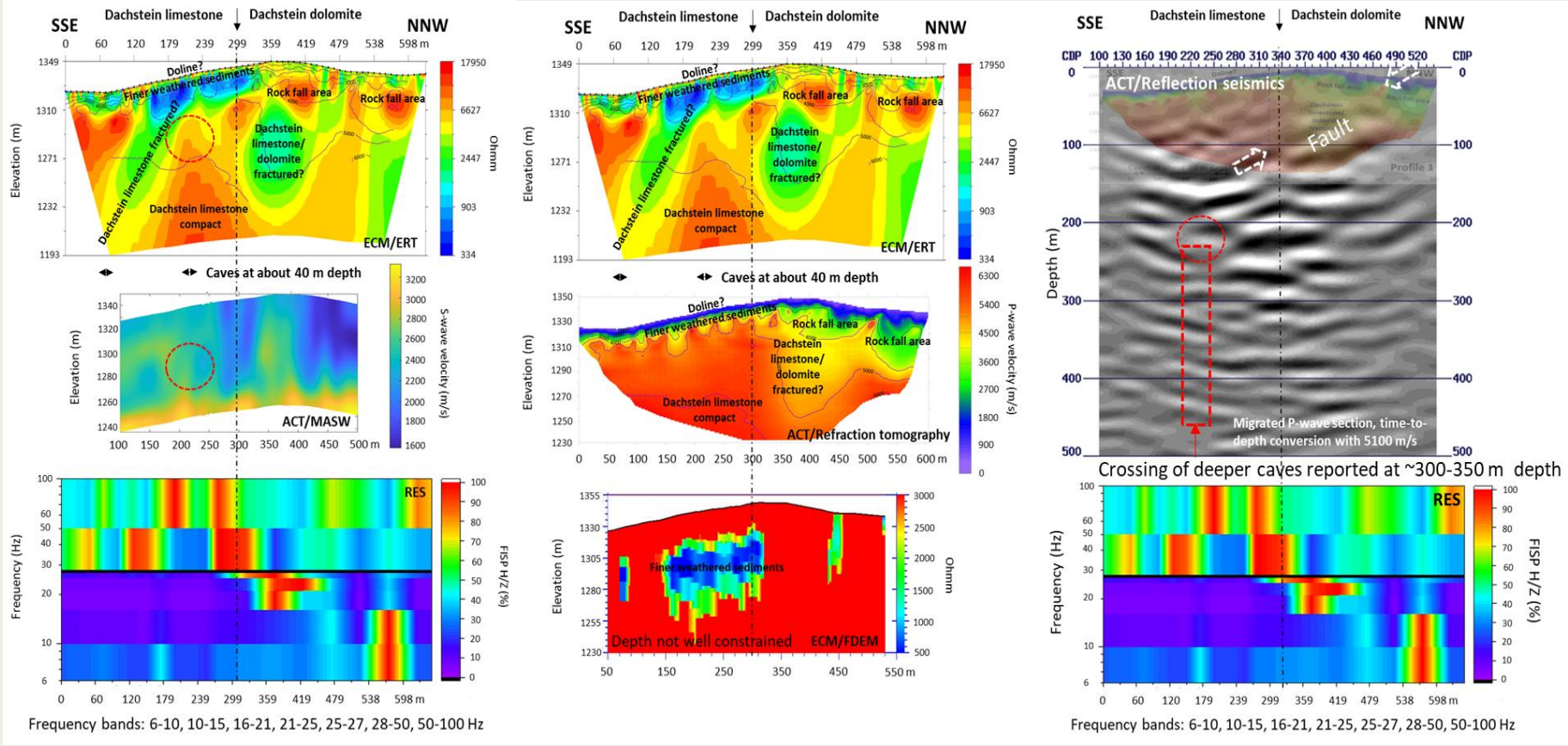


- Challenging environment with severe access limitations
- Overall, consistent results for all techniques
- ERT signatures of shallow caves
- Some indications of a deeper cave in the reflection seismic data
- Possible Multichannel Analysis of Surface Waves (MASW) S-wave signature of shallow caves

Integrated Results for the 2022 Field Test – Profile 1



See also
P3.3-817 Advancing the Onset-Delay-Method for Resonance Seismometry
O3.3-604 Analysis of Seismic Ambient Noise for Resonance Seismometry OSI Technique – the FISP Method

Contact us if you are interested in working on the data!

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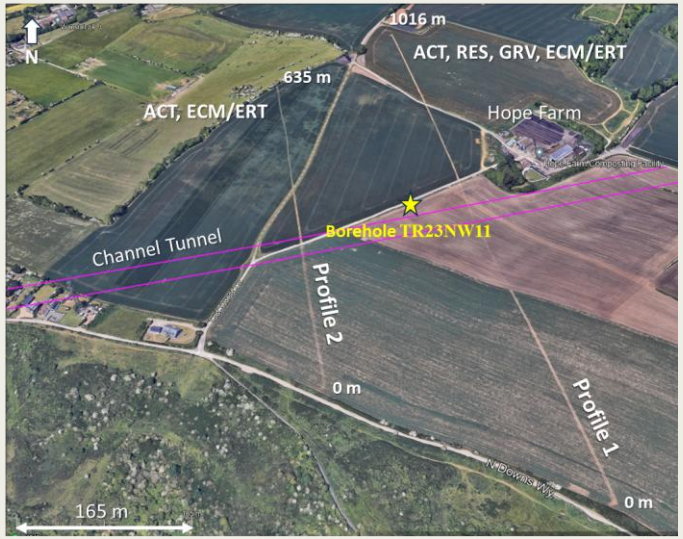
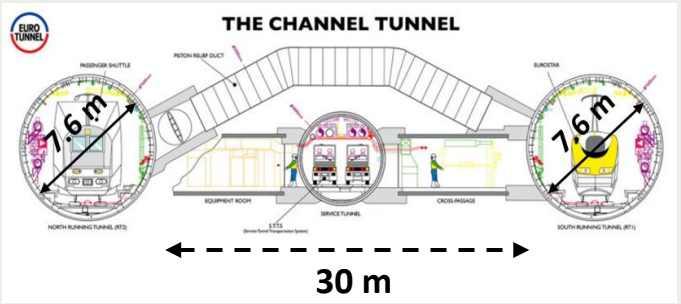
Survey Layout of the 2023 Field Test





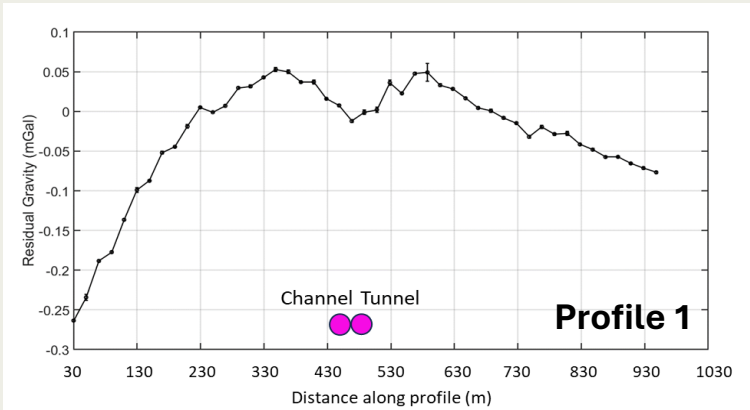
2 survey profiles across the Channel Tunnel, consisting of two rail tunnels 7.6 m in diameter and 30 m apart, excavated in chalk marl at 90 m depth. Depending on the technique, the lengths of the profiles varied.

Survey Parameters of the 2023 OSI Field Test

GRV	Profile 1
Data recording system	Scintrex CG-6 gravimeter
Profile length	940 m
Coverage along the profile	0-940 m
Station spacing	20 m
Number of measurement points	47
Read time	30 s
Number of repeated measurements at each station	3
Base station frequency	~1 h

ECM/ERT	Profile 1	Profile 2
Data recording system	Abem Terrameter LS2, 4 x cable sets with 32 electrode take-outs @20 m spacing	Abem Terrameter LS2, 4 x cable sets with 32 electrode take-outs @5 m spacing
Profile length	1016 m	635 m
Coverage along the profile	0-1016 m	0-635 m
Electrode spacing	8 m	5 m
Number of electrodes	128	128
Configuration	A combination of Wenner and Schlumberger	A combination of Wenner and Schlumberger
Data point configured	5621	5621
Data points measured	5621	5621
Measure mode	Apparent resistivity	Apparent resistivity
Stacking (minimum, maximum)	1, 2	1, 2
Error limit	3%	3%
Delay time	0.3 s	0.3 s
Acquisition time	0.5 s	0.5 s
Power line frequency cut off	50 Hz	50 Hz
Minimum current	1 mA	1 mA
Maximum current	500 mA	500 mA
Max power	200 W	200 W
Max output voltage	600 V	600 V
Bad electrode threshold	5kΩ	5kΩ

Results of the 2023 OSI Field Test



GRV results for Profile 1 showing an anomaly consistent with the Channel Tunnel target.

- Further development of **ECM workflows, documentation and training.**
- **Testing of CG-6 gravimeter**, leading to procurement of a new gravimeter.
- Development of **GRV software** (See also **P4.5-538**), **workflows, documentation and training.**
- Development of **forward modelling capacity for non-seismic geophysical techniques** (See also **04.5-276**).

See poster **P3.3-556** on the seismic geophysical techniques

See also
P4.5-538 Development of an OSI Software Package for Gravitational Field Mapping Data Processing
O4.5-276 Development of OSI Forward Modelling Capacity for Non-Seismic Geophysical Techniques

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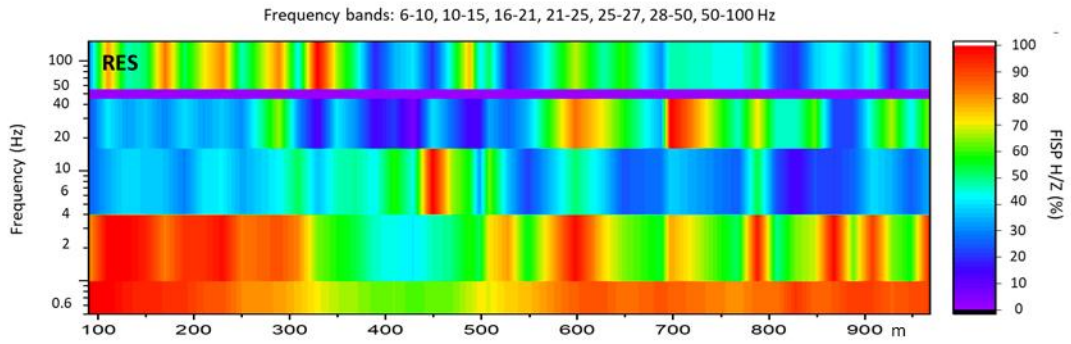
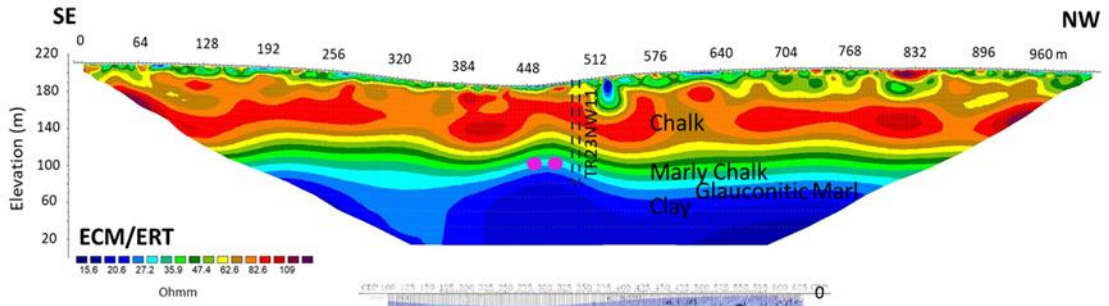
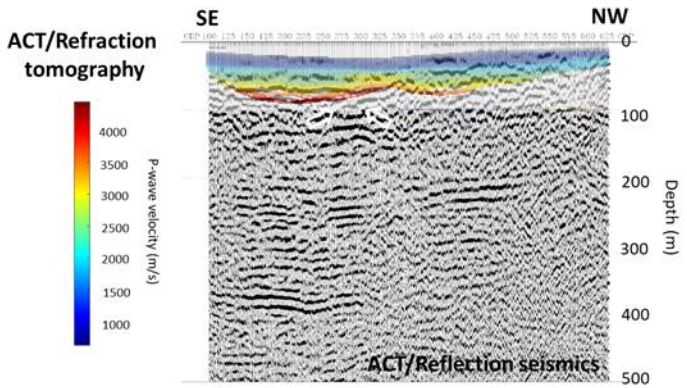
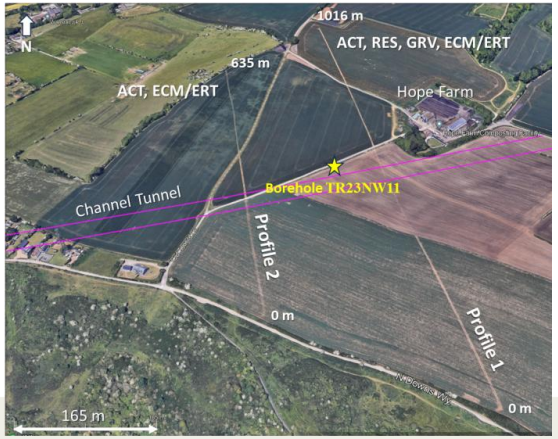
Integrated Results for the 2023 Field Test – Profile 1

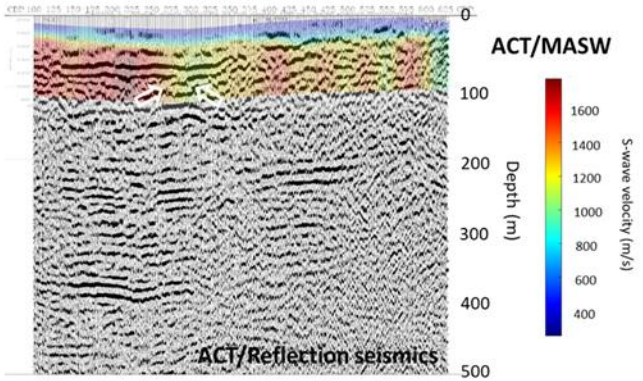






Unmigrated P-wave section, time-to-depth conversion with 2000 m/s





Unmigrated P-wave section, time-to-depth conversion with 2000 m/s

- Direct P- and S-wave diffraction signals from the tunnels
- Overall, consistent results for all techniques

See also **P3.3-527** Automated workflows for rapid understanding of ACT and RES imaging potential in an OSI context
O3.3-604 Analysis of Seismic Ambient Noise for Resonance Seismometry OSI Technique – the FISP Method

Contact us if you are interested in working on the data!