



Istituto Nazionale
di Oceanografia
e di Geofisica
Sperimentale

PITOP FACILITIES FOR GEOPHYSICAL STUDIES APPLIED TO CO₂ AND ENERGY STORAGE SITE CHARACTERIZATION AND MONITORING

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11th July 2024

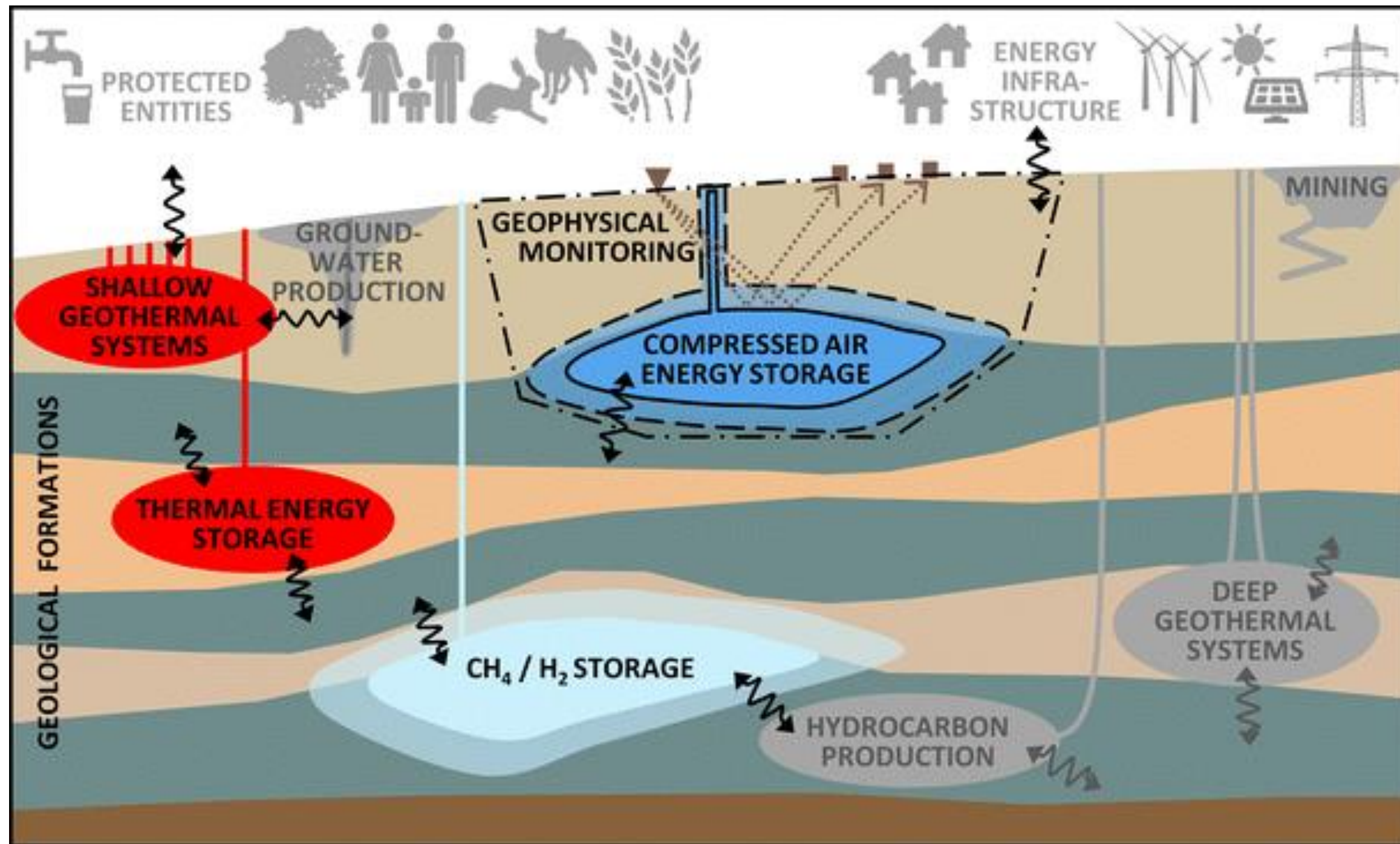
ITALIAN FACILITIES IN ECCSEL

| CAPTURE | TRANSPORT | UTILIZATION | STORAGE (MONITORING) |
|---|-------------------|--|---------------------------------|
| | | | PITOP (OGS) |
| | | | PANAREA NatLAB (OGS) |
| | | | BIOMARINELAB (OGS) |
| | | | CTMO (OGS) |
| | | | AEREO remote sensing (OGS) |
| | | | LATERA NatLab (OGS) |
| | | | DEEPLAB (OGS) |
| CO2_BOX (LEAP) | | CO2_BOX (LEAP) | CO2_BOX (LEAP) |
| | | | ADVANTEST ROCK (Sotacarbo) |
| | | | SOTACARBO Fault Lab (Sotacarbo) |
| COHYGEN (Sotacarbo) | | | |
| ZECOMIX (ENEA) | | ZECOMIX (ENEA) | |
| MEMLAB (UNIBO-DICAM) | | | |
| XTL PILOT PLANT (Sotacarbo) | | XTL PILOT PLANT (Sotacarbo) | |
| MECO2 (Sotacarbo) | MECO2 (Sotacarbo) | | |
| | | PEC LAB (Sotacarbo) | |
| Green Tech Lab for CCU applications (GTL4CCU) (CNR - ITAE) | | Green Tech Lab for CCU applications (GTL4CCU) (CNR - ITAE) | |
| Laboratory of Materials Development for CO2 capture (MADE4CO2-Lab)- CNR STEMS | | | |

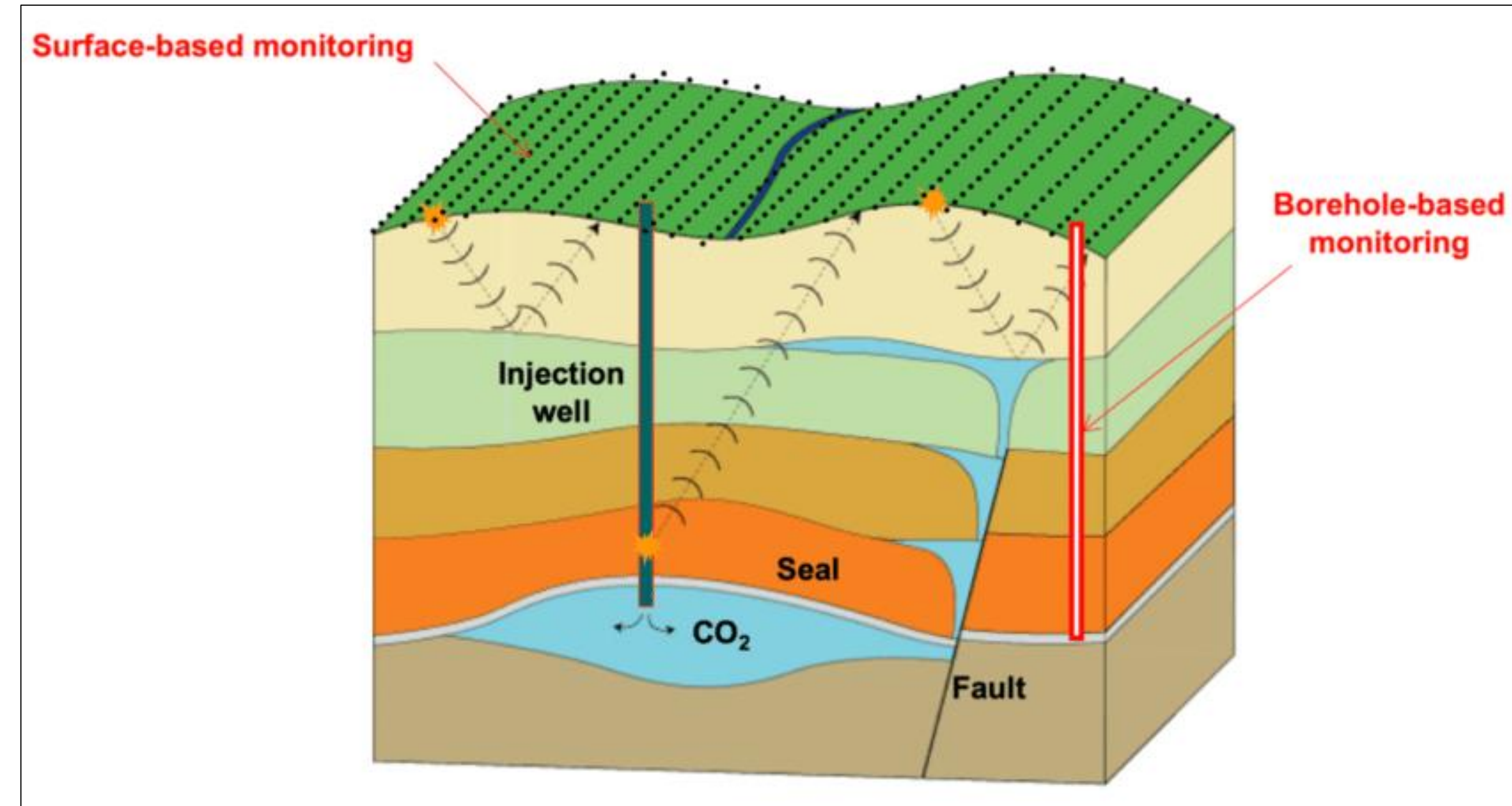
STORAGE SITE CHARACTERIZATION AND MONITORING

NEED: Geophysical characterization and monitoring

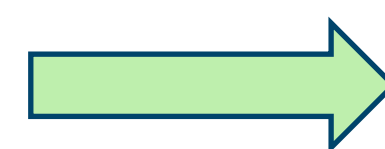
Monitoring of CO₂ storage with both surface and borehole-based seismic



Kabuth et al., Environmental Earth Science (2017)



BW Al-Rumaih · A reduced-order basis approach for CO₂ monitoring from sparse time-lapse seismic data (2019)

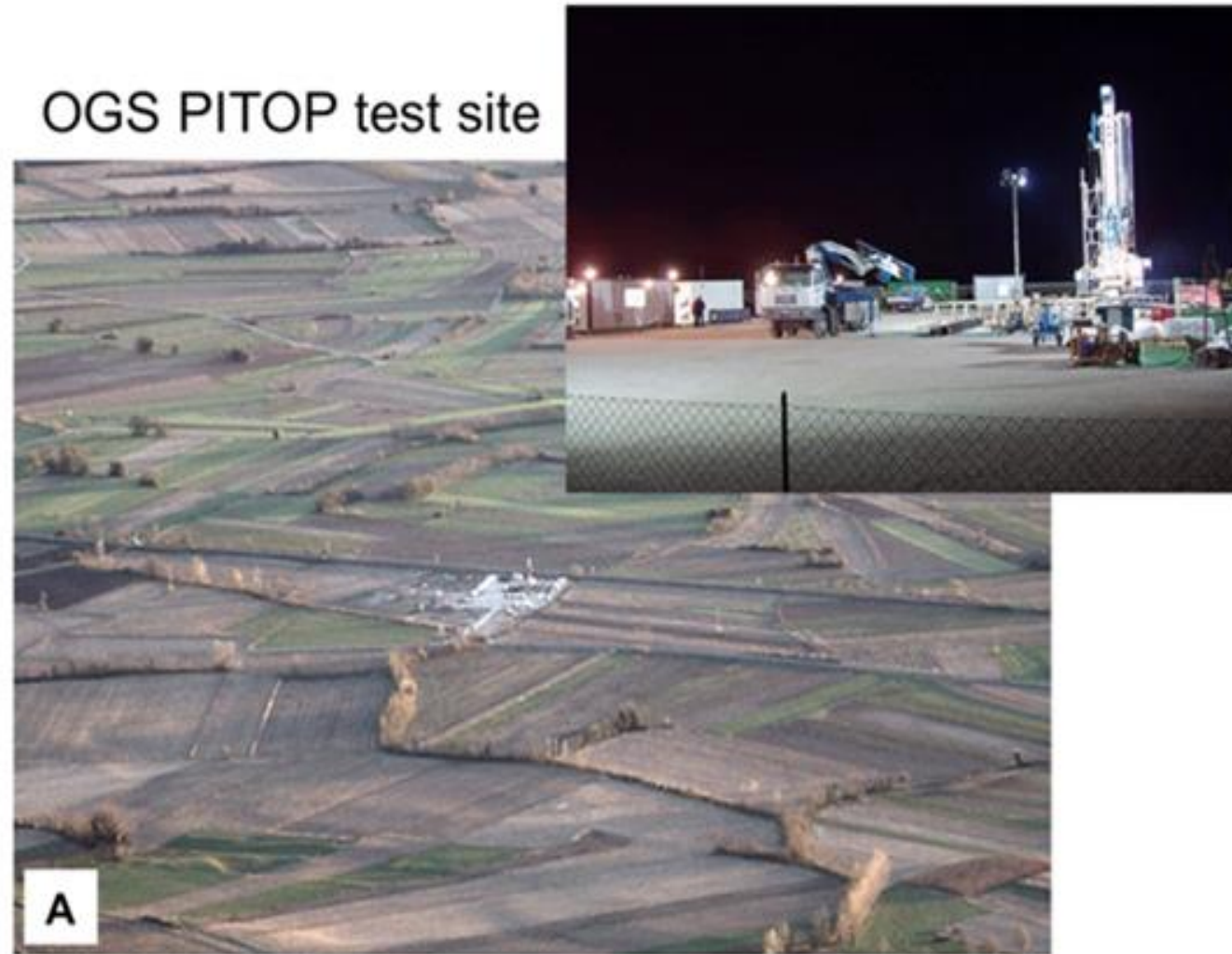


PITOP: geophysical testing site

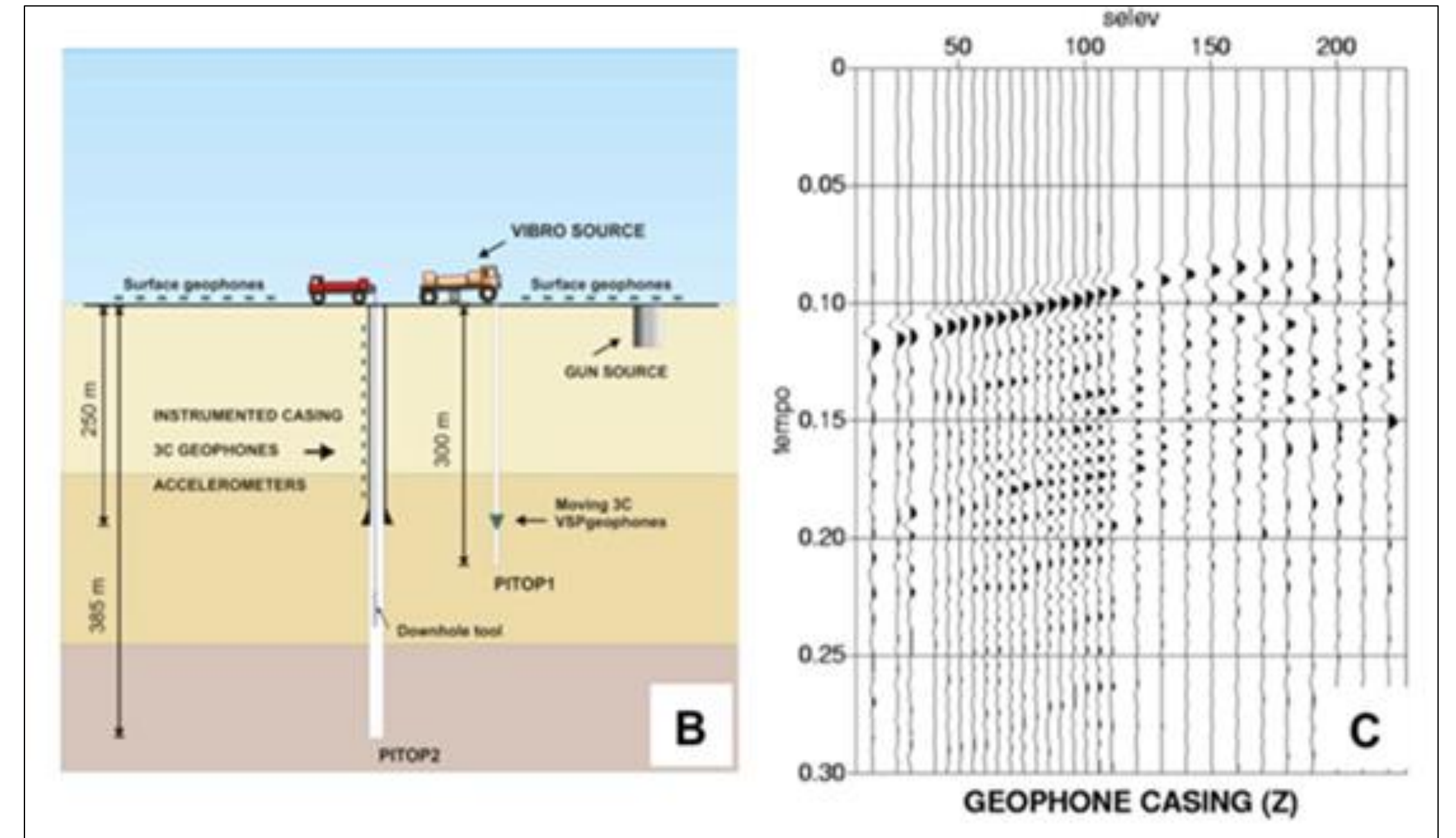
PITOP: GEOPHYSICAL TEST SITE WITH INSTRUMENTED WELLS



OGS PITOP test site



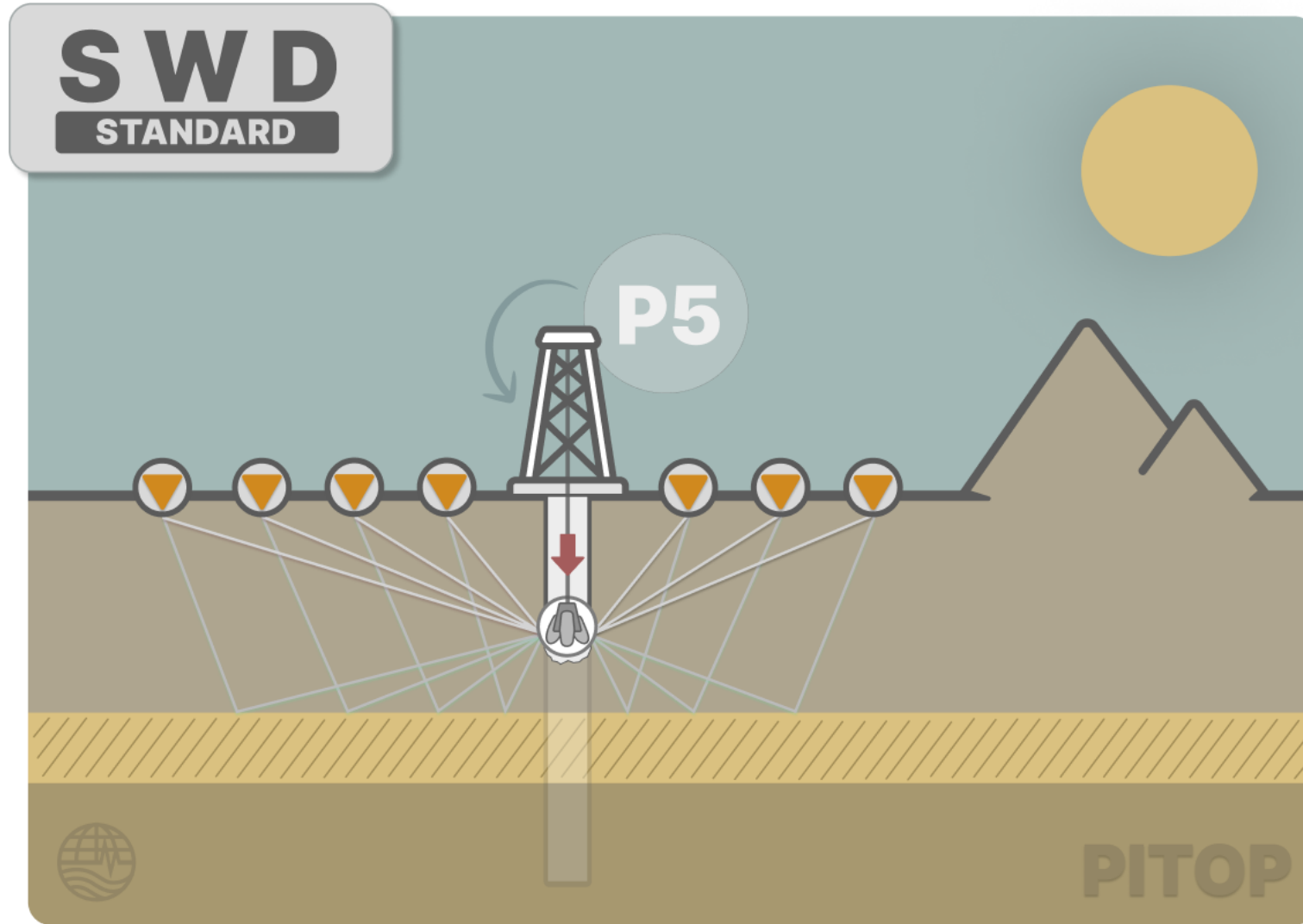
A



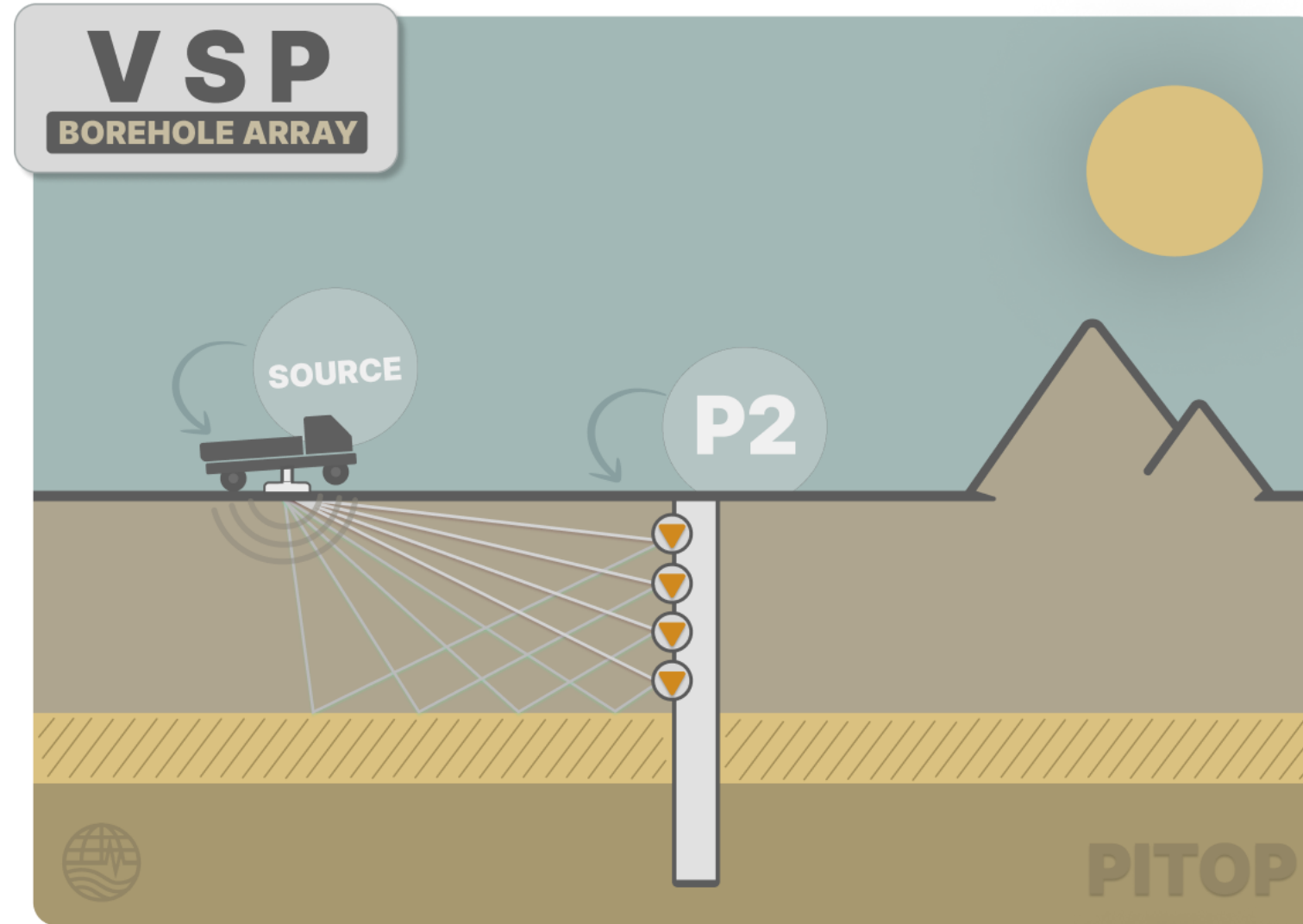
PITOP covers an area of approximately 22,000 m² and was designed and developed with the aim of providing a facility for the study and experimentation of **geophysical methods**, **new technologies** and **borehole/surface tools** under **realistic conditions**

EXAMPLES OF POSSIBLE GEOPHYSICAL TESTS IN PITOP

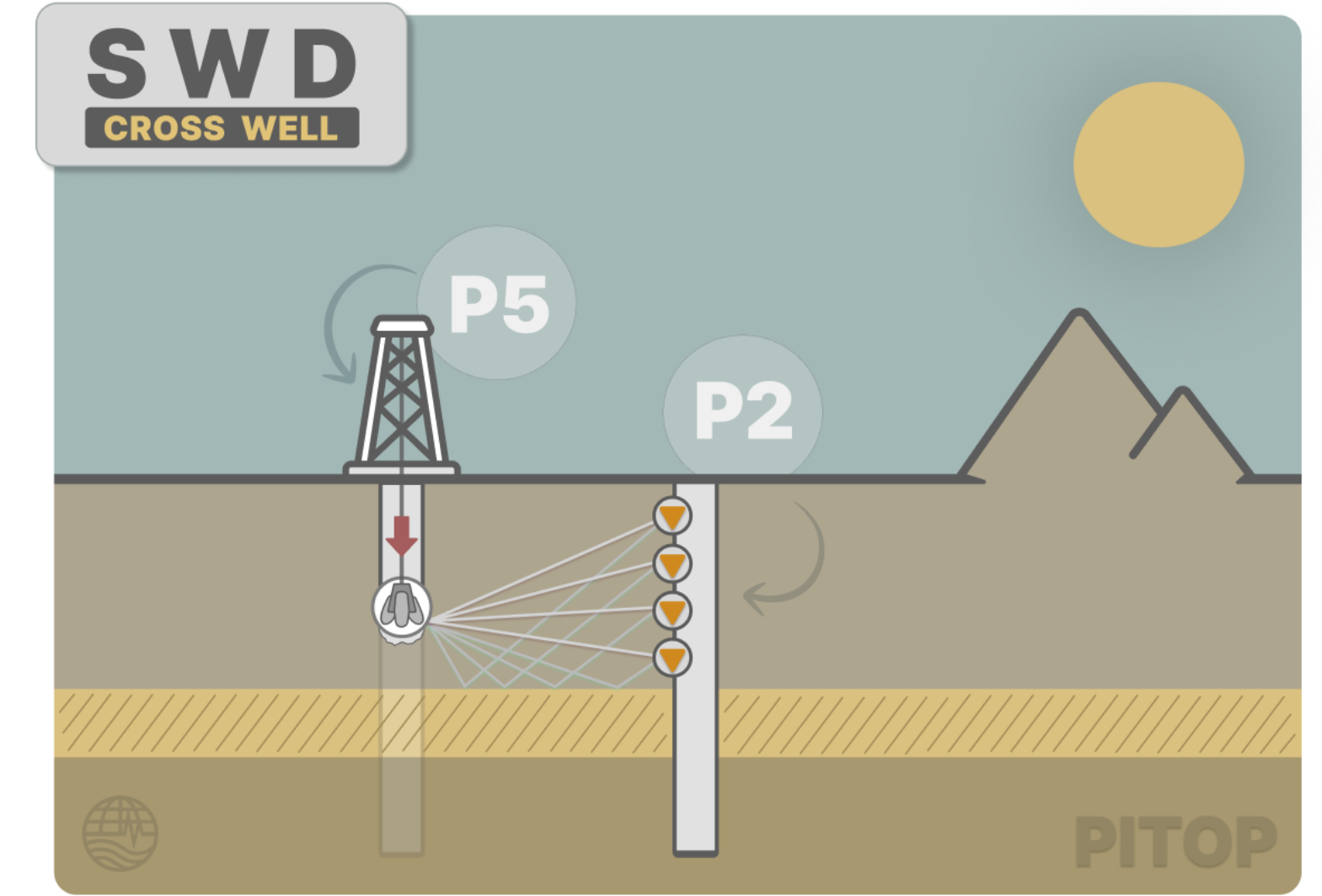
Seismic While Drilling (SWD)



Vertical Seismic Profiling (VSP) Borehole Array

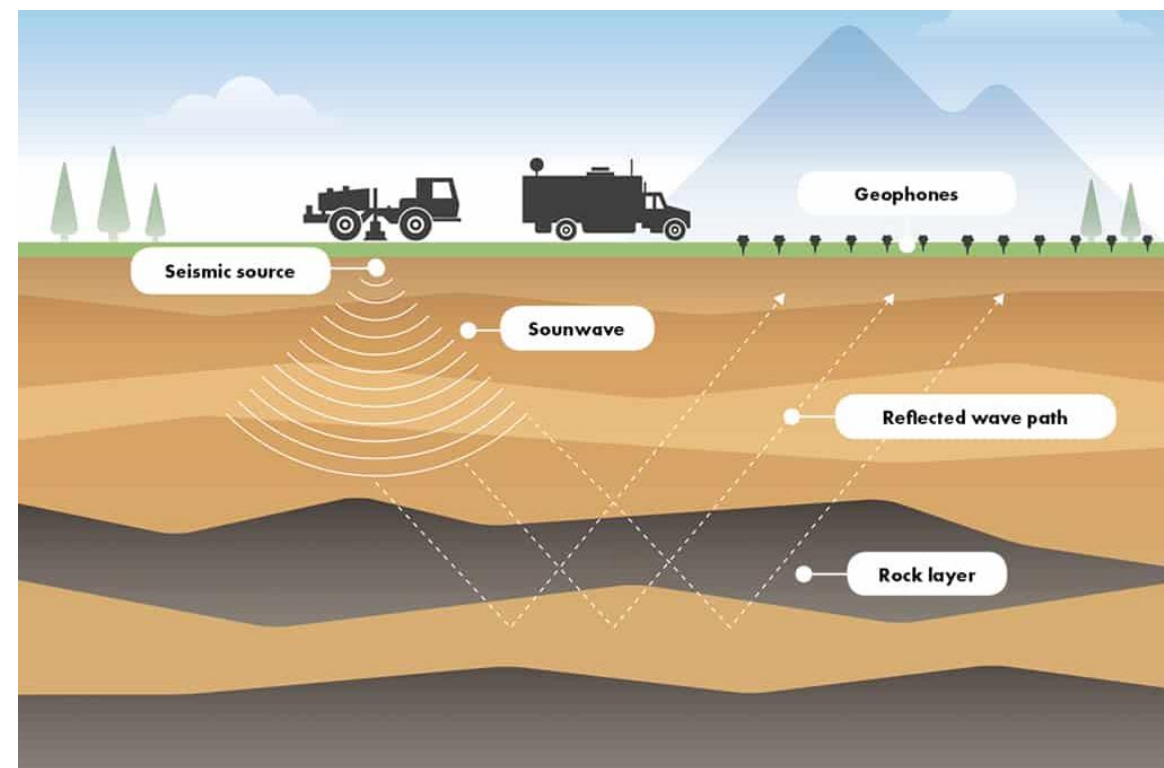


Cross-well seismic



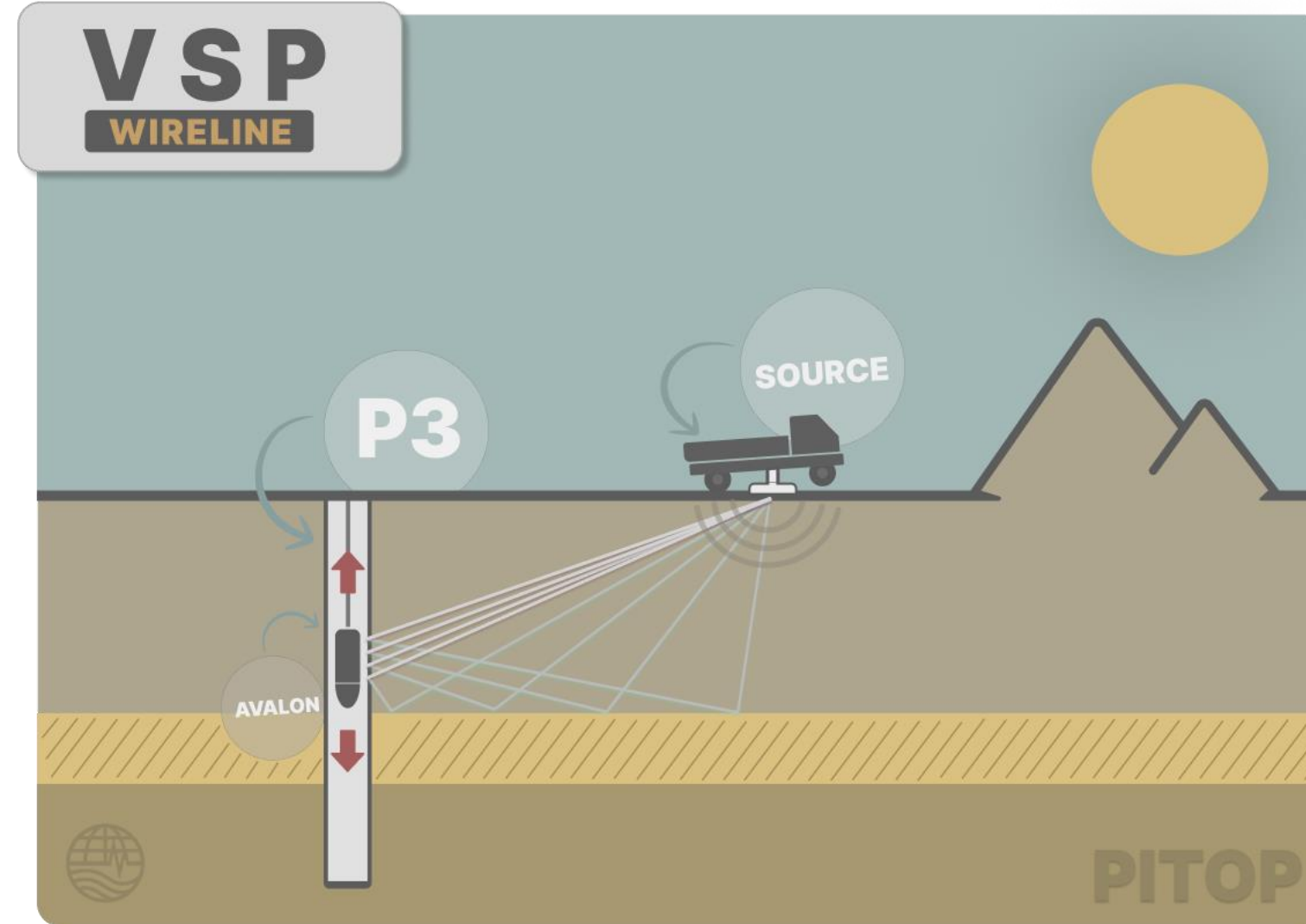
Pictures by Paolo Bernardi (OGS)

Surface Seismic

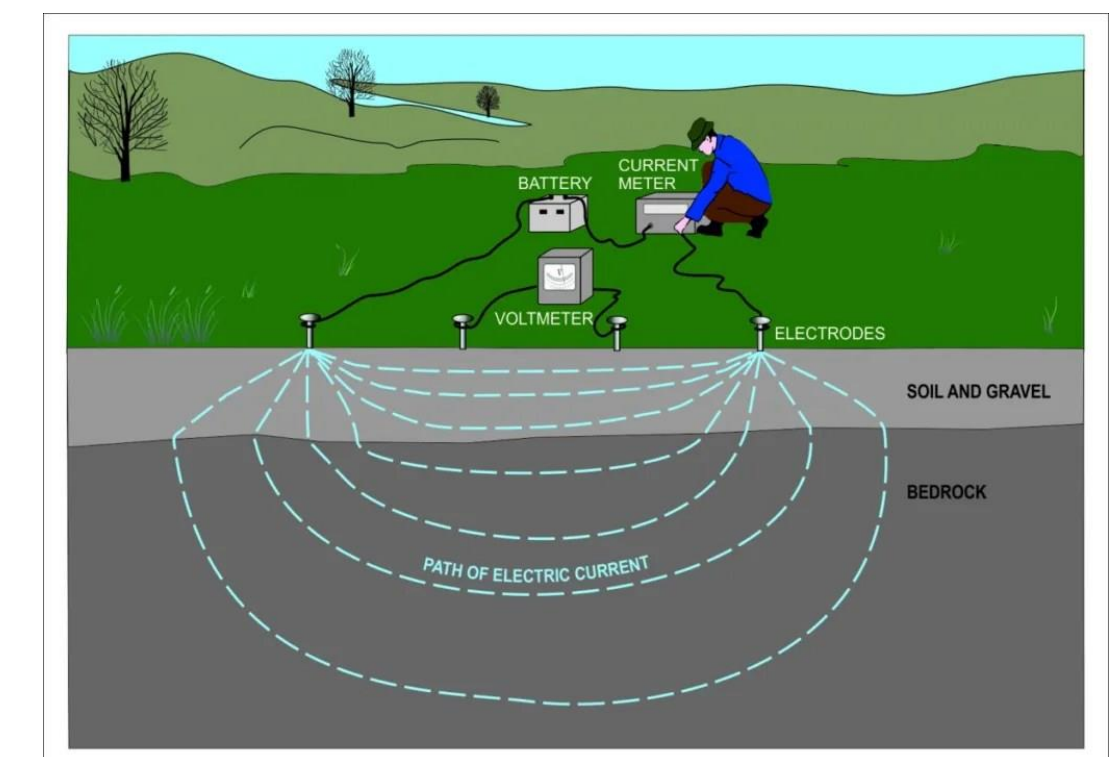


<https://energyinformationaustralia.com.au/seismic-surveys/>

VSP Wireline



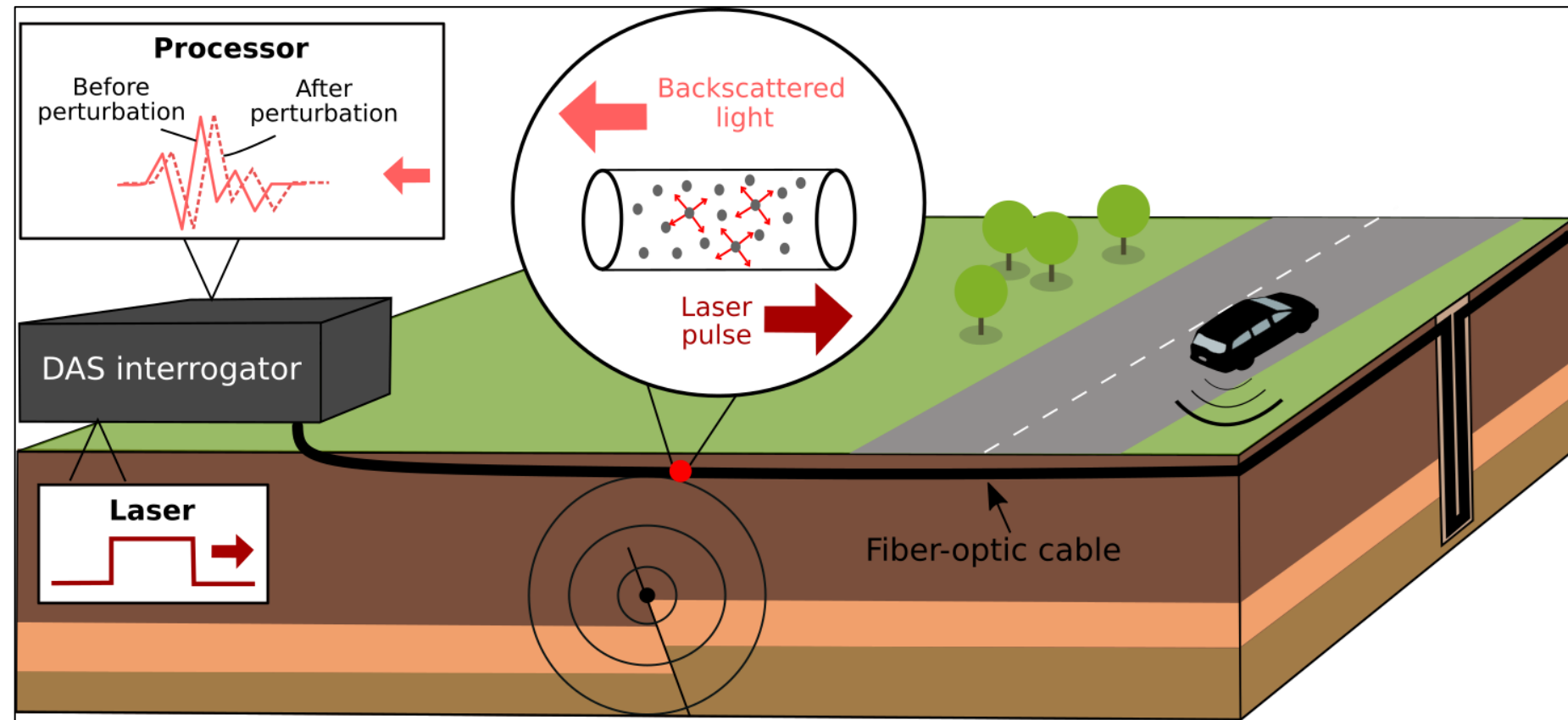
Electrical Resistivity Tomography (ERT)



<https://geologyscience.com/geology-branches/geophysics/electrical-resistivity-surveys/>

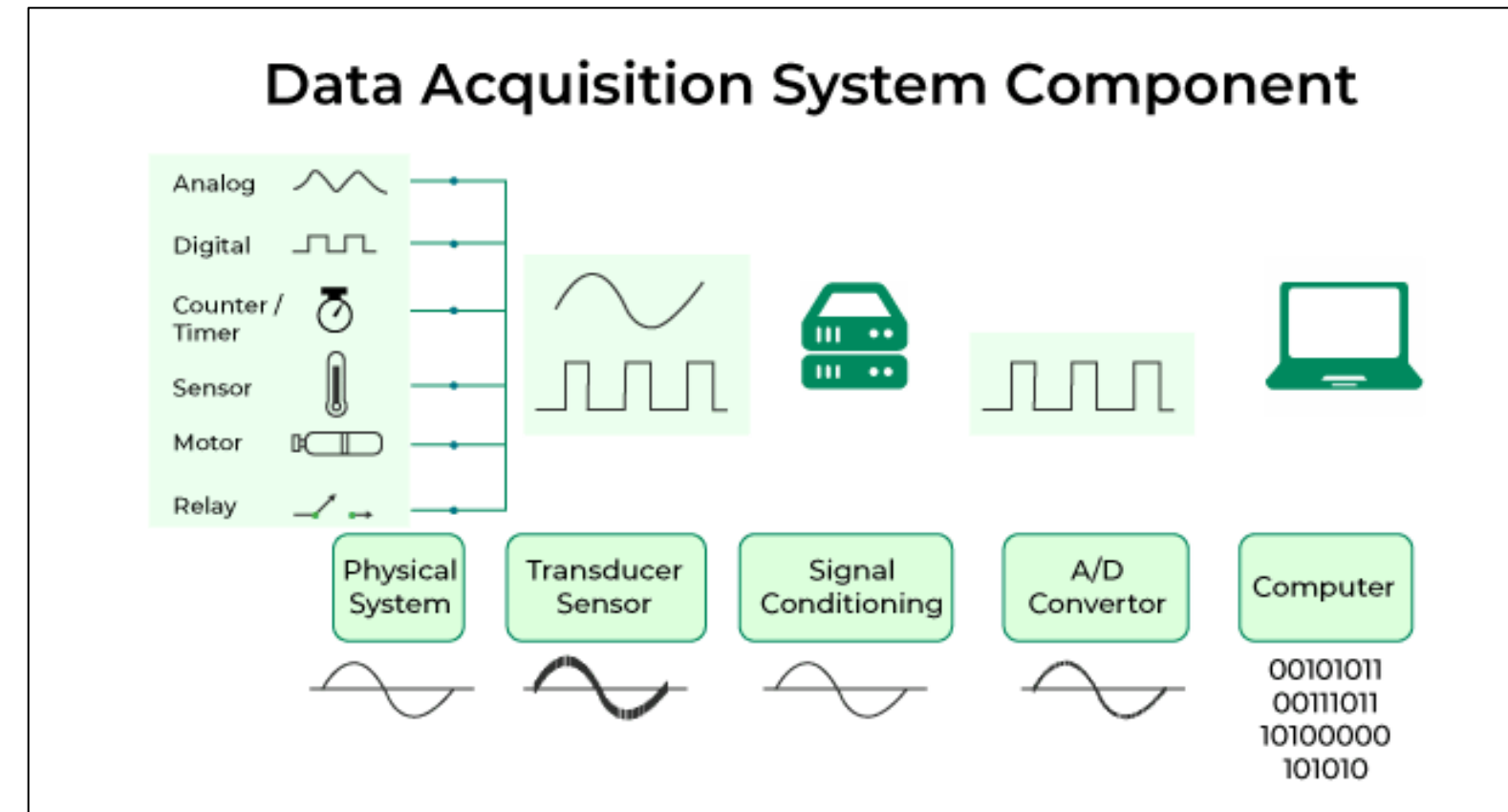
FURTHER FACILITIES/SERVICES AVAILABLE IN PITOP

Distributed Acoustic Sensing (DAS) as sensors



<https://blogs.egu.eu/divisions/sm/2020/09/01/from-light-to-waveform-how-fiber-optic-cables-can-be-repurposed-as-seismic-arrays/>

Hardware/software for acquisition systems and data management



<https://www.geeksforgoeks.org/data-acquisition-system/>

Remote connection to data/instruments through virtual access



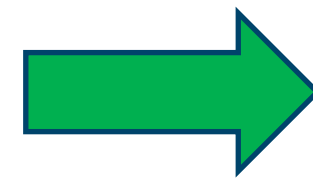
<https://www.vecteezy.com/vector-art/4579015-man-is-analyzing-cloud-server-data-security>

PITOP FOR ENVIRONMENTAL SUSTAINABILITY

PITOP OFFERS STATE-OF-THE ART TECHNOLOGY FOR:

- ✓ Studies for **CO₂ storage** site characterization and monitoring
- ✓ **Geothermal field** characterization
- ✓ **Hydrogen storage** site characterization and monitoring
- ✓ **Water resources** applications

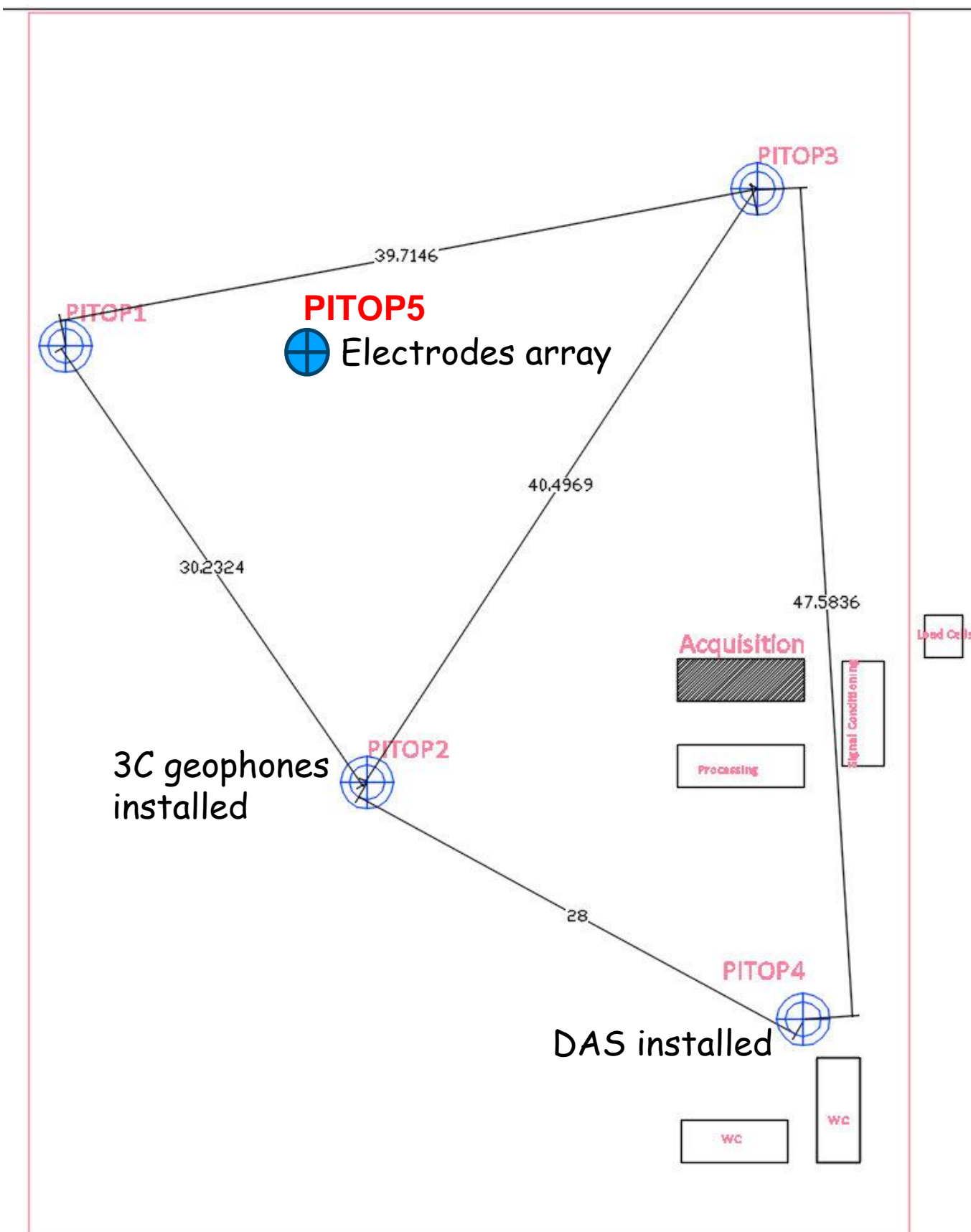
Sustainable environment and geenergy



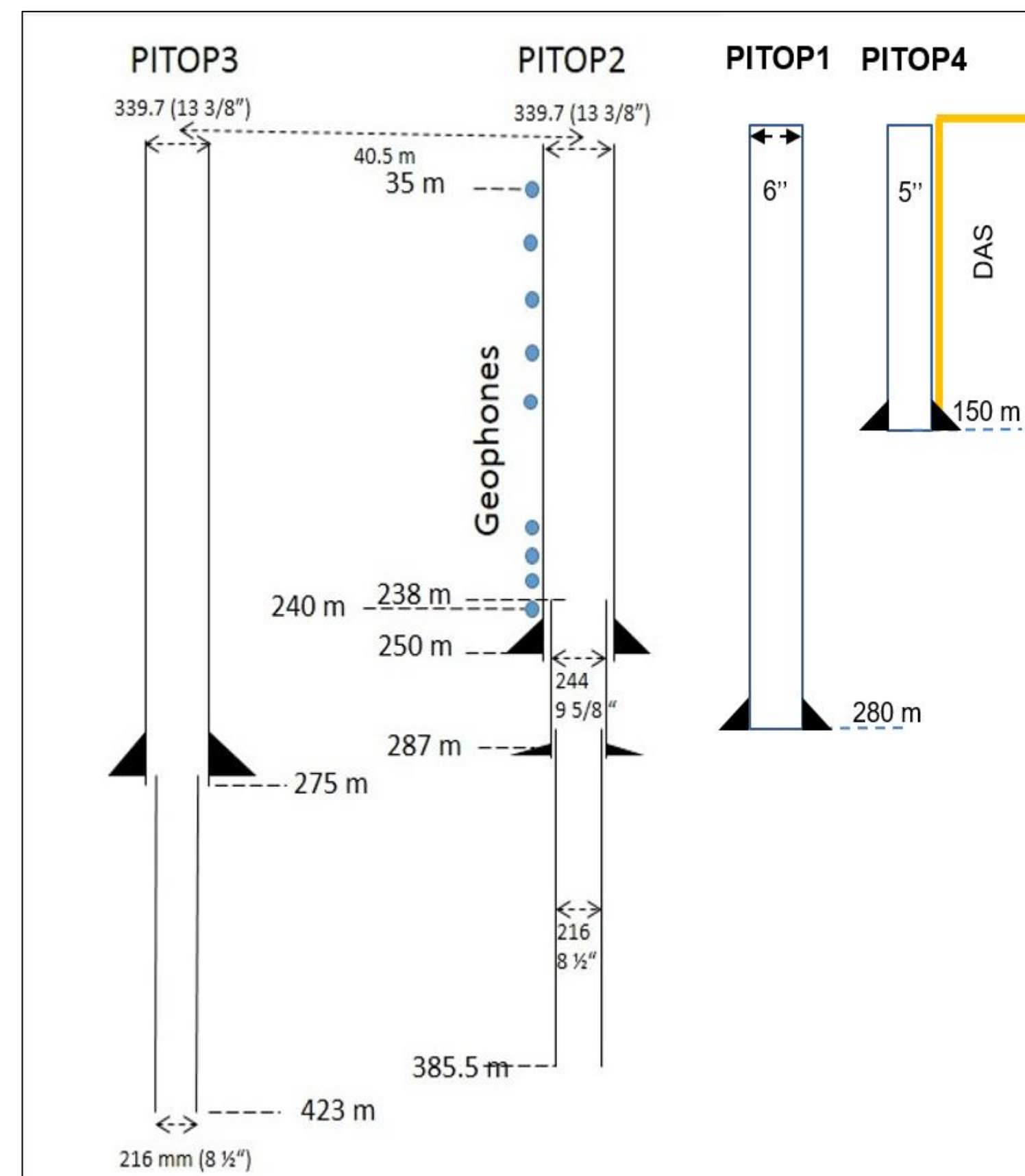
<https://fiinnovationblogs.wordpress.com/2014/04/18/>

PITOP: TESTING SITE UPGRADE (NEW WELL PITOP5)

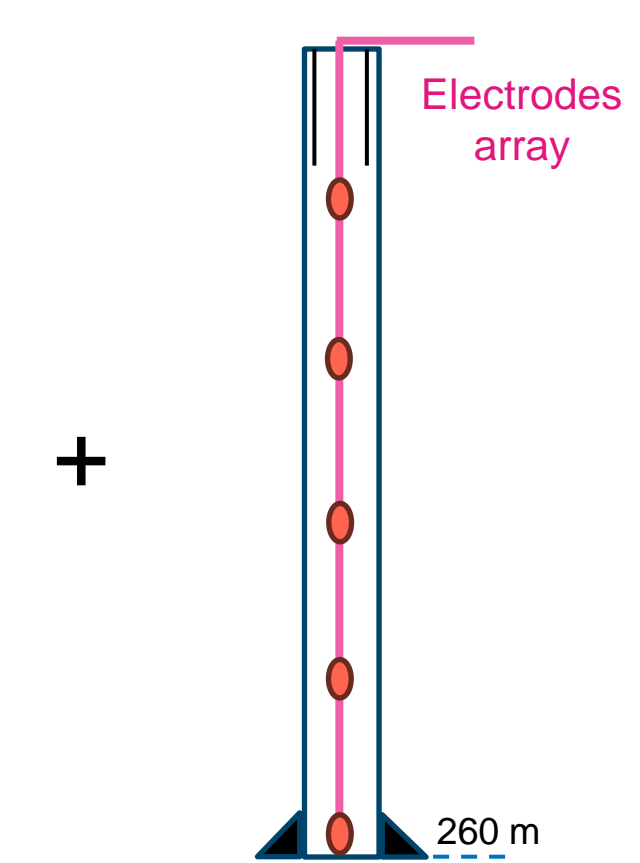
PITOP TOP VIEW MAP



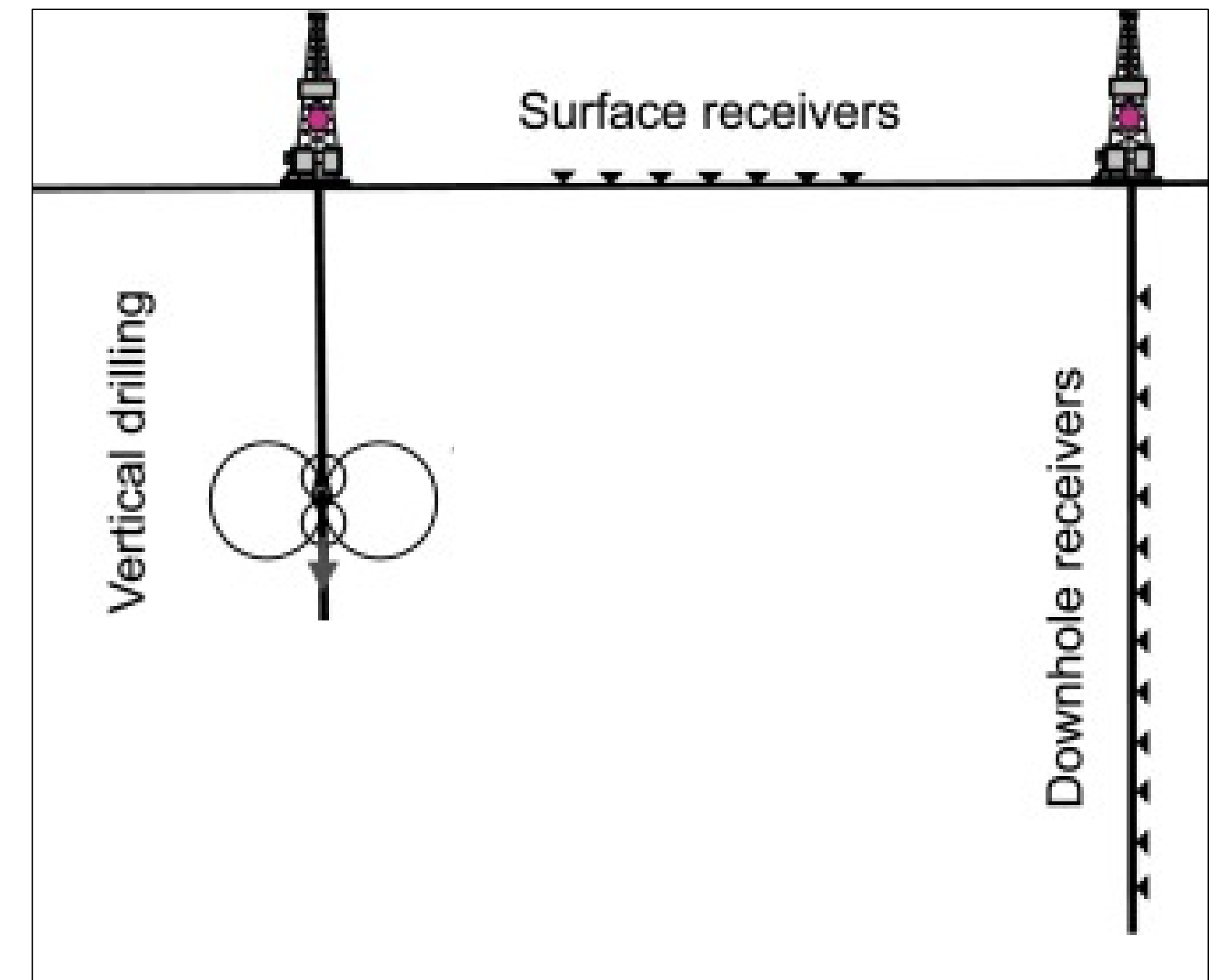
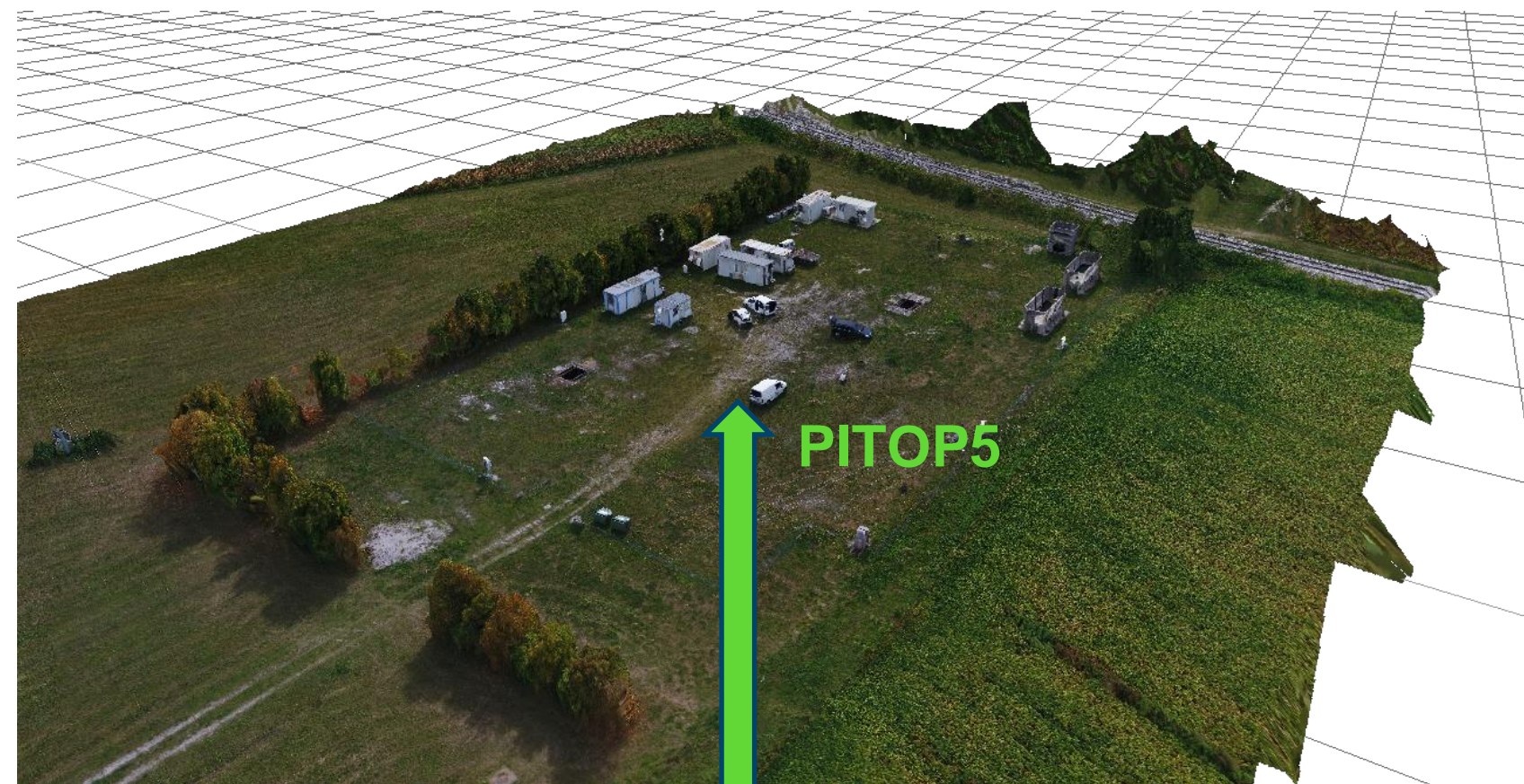
PITOP WELLS SKETCH



PITOP5 (March 2024)



DRILLING OF PITOP5 AND RELATED EXPERIMENTS



Objectives:

- Enrich the **subsurface knowledge** of the site enhancing previous available datasets
- **Test** new seismic instrumentation (e.g. NuSeis nodes)
- Make a **multidisciplinary survey** that enables to perform an **integrated data analysis** with different methodologies

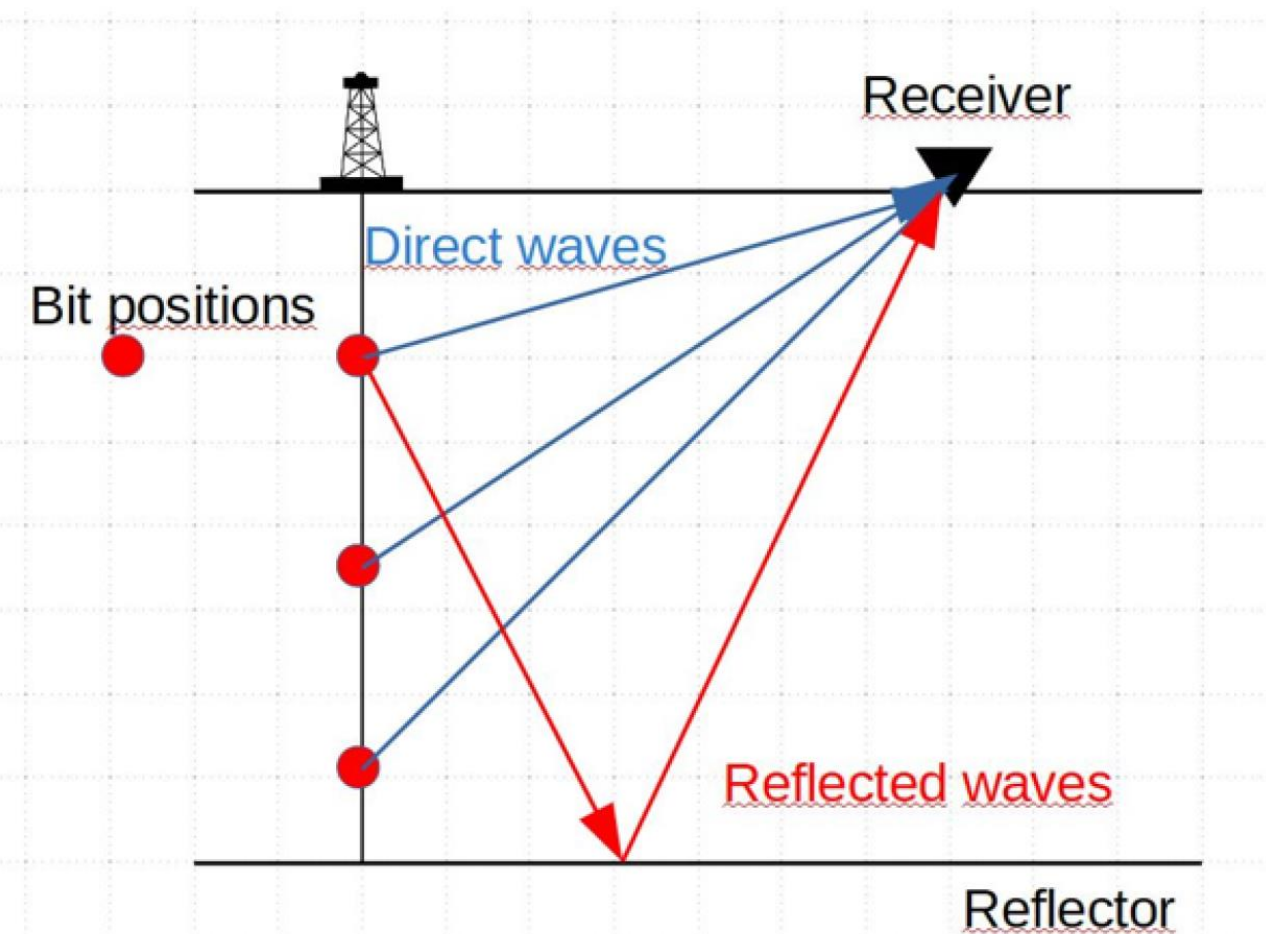
SEISMIC WHILE DRILLING (SWD) EXPERIMENT

SWD enables **prediction ahead of the bit**

Bit noise used as a **seismic source**, recorded by:

- **Geophones** array installed in **well PITOP2** for **cross-well** test
- **Surface receivers**: NuSeis (new geophones) and Summit Xone (reference geophones)

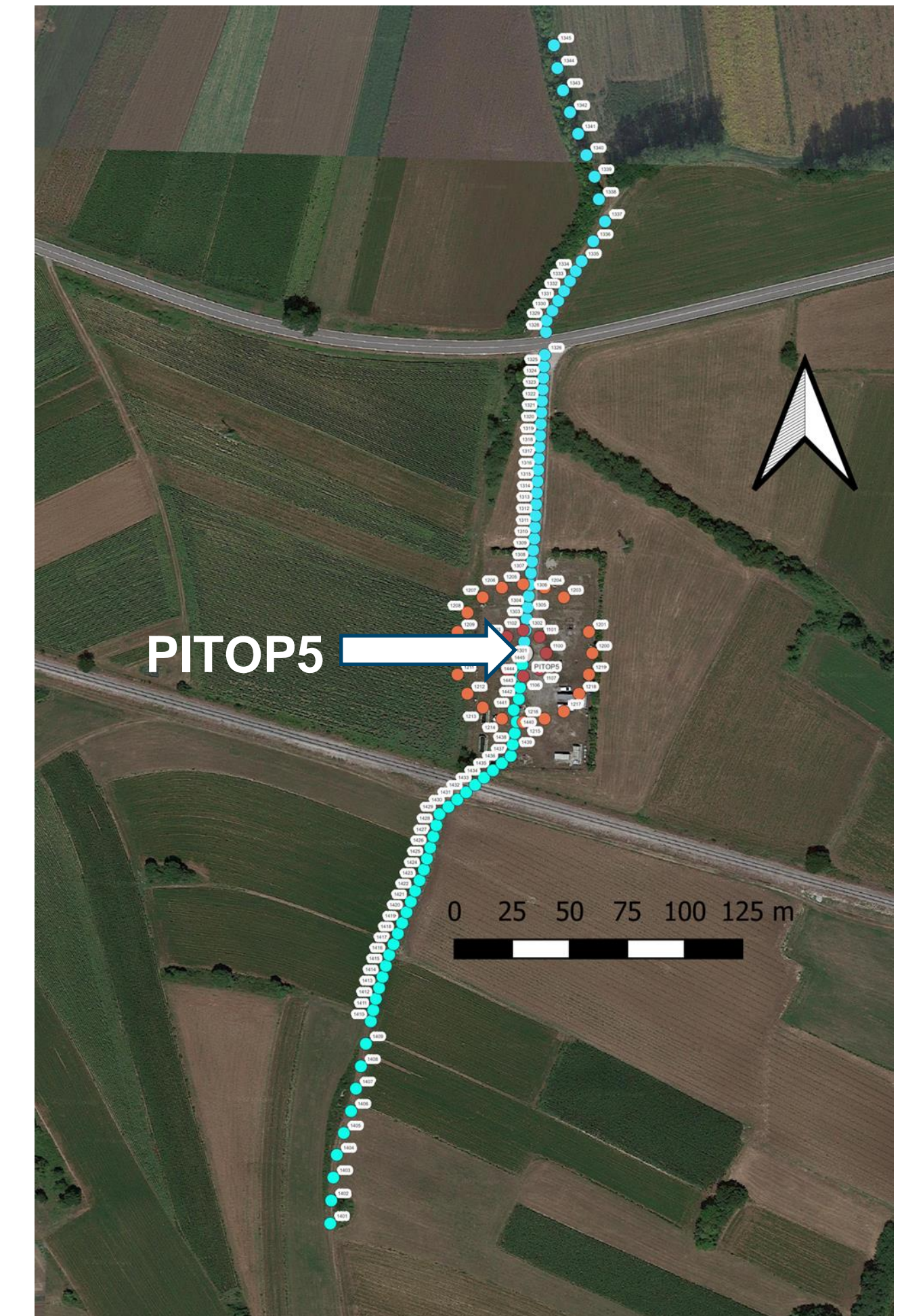
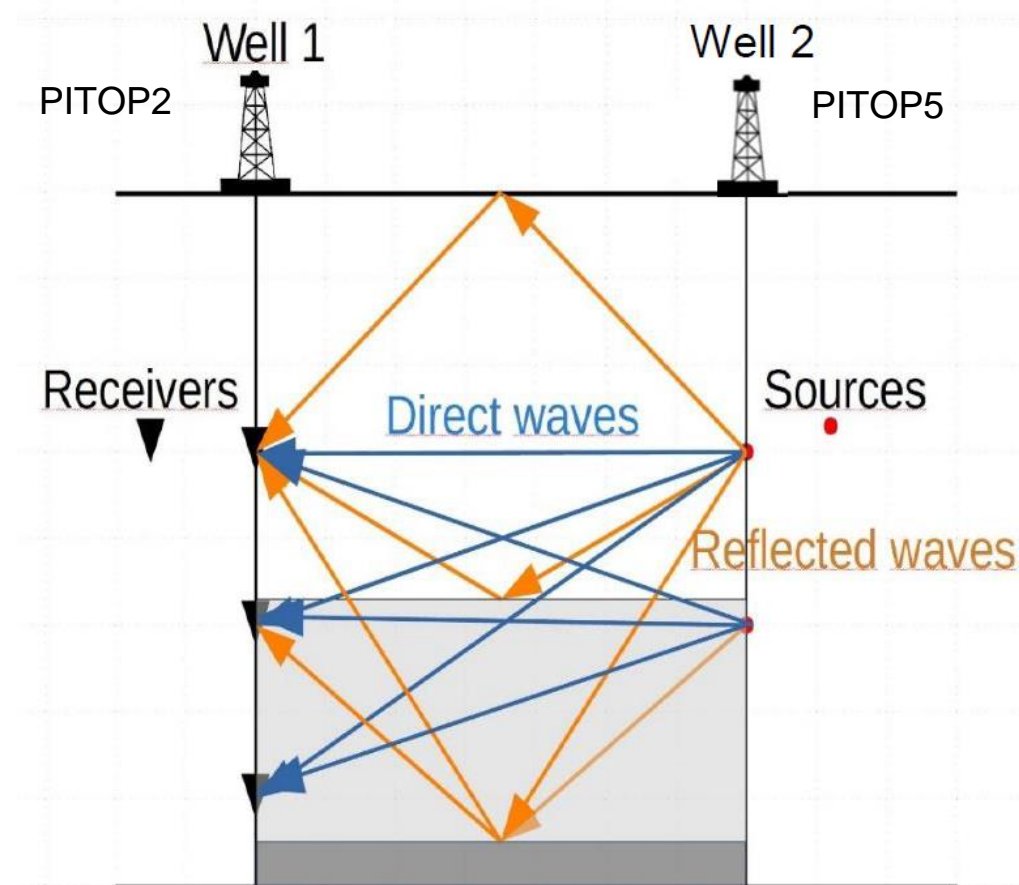
SWD



Drilling bit



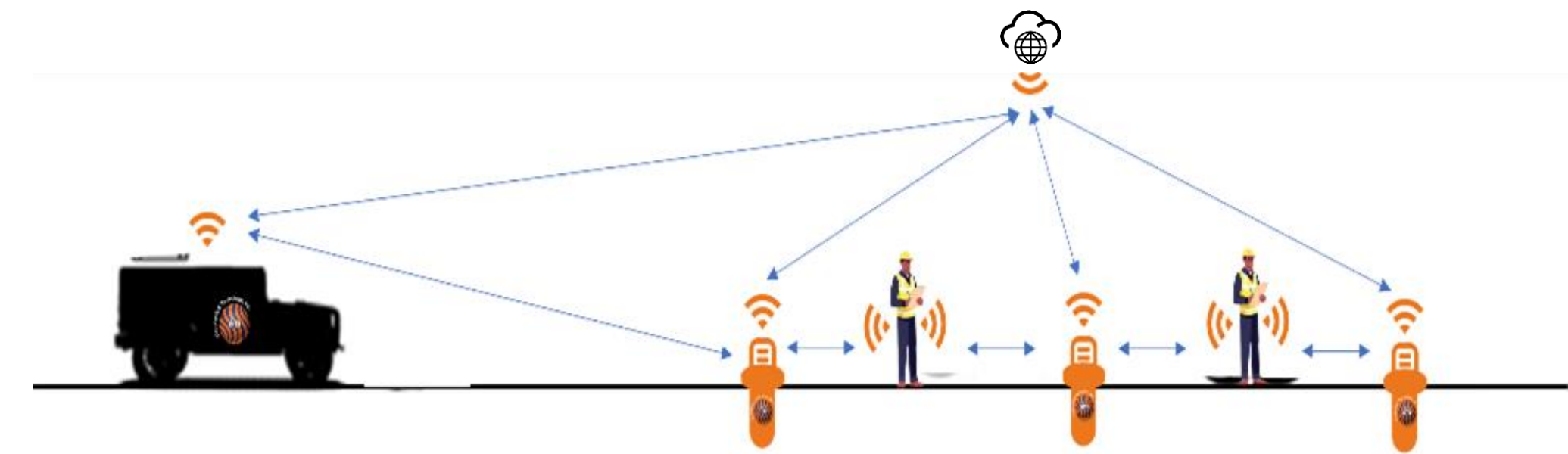
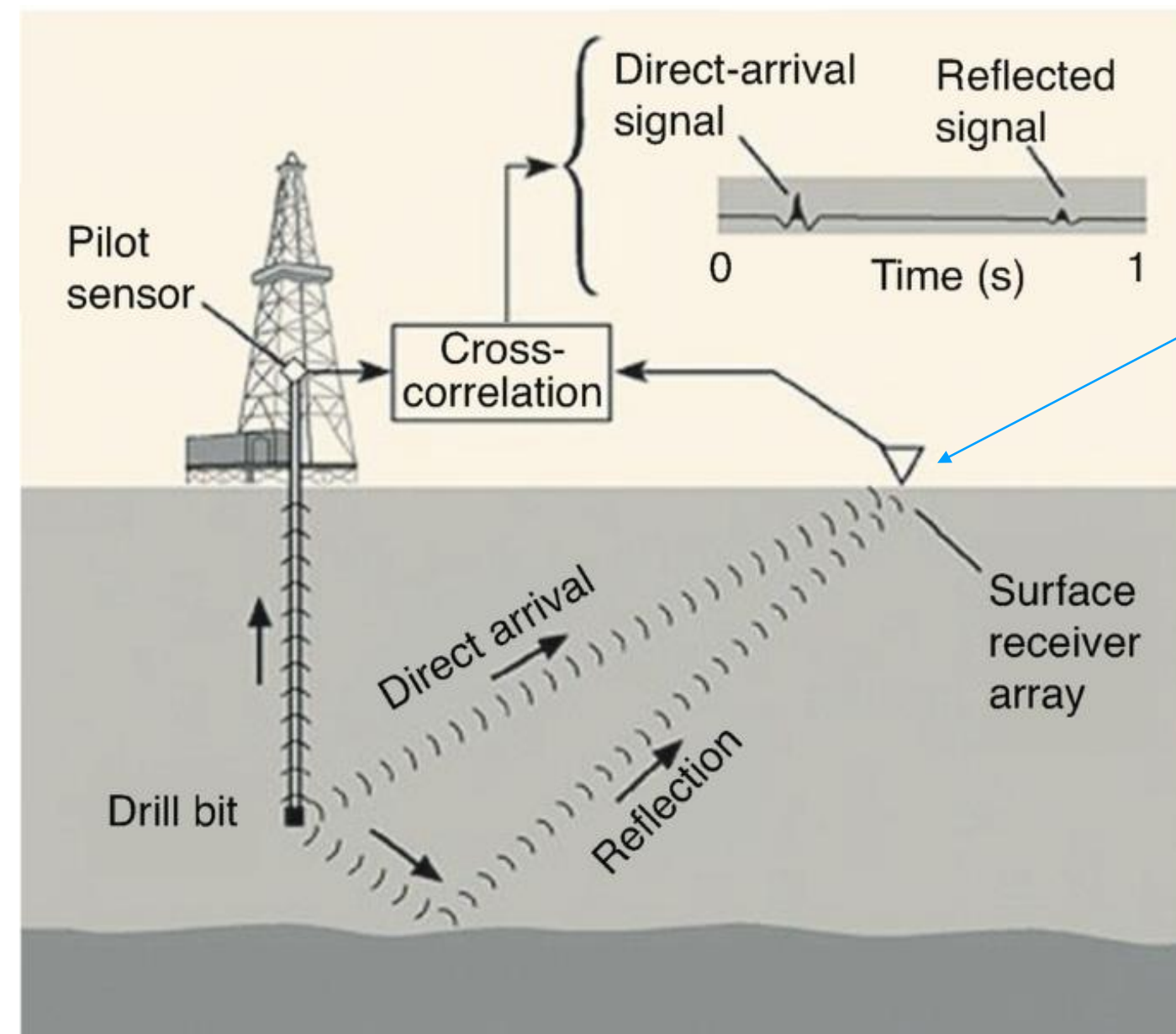
Cross-well



Deployment of surface geophones during the drilling of PITOP5

IMPLEMENTATION OF PITOP SEISMIC EQUIPMENT

New wireless nodes (**NuSeis**) mono and three components geophones



NuSeis Description:

- Long battery life: providing up to 45 days of continuous operation.
- Wireless recording units
- GNSS and BLE comms: easy deployment and retrieval.
- SEG standard data formats: compatible with all major seismic processing software.
- Expandable storage
- Rugged and durable

TESTING SEISMIC INSTRUMENTATION

Seismic surface receivers used during PITOP upgrade experiments: NuSeis and Summit X One

Seismic surface source: Vibroseis MiniVib



<https://geodevice.co/product/summit-x-one/>

Summit X One surface receivers (representative images)



IMPLEMENTATION OF PITOP GEOELECTRIC EQUIPMENT

Electrodes array installed in PITOP5



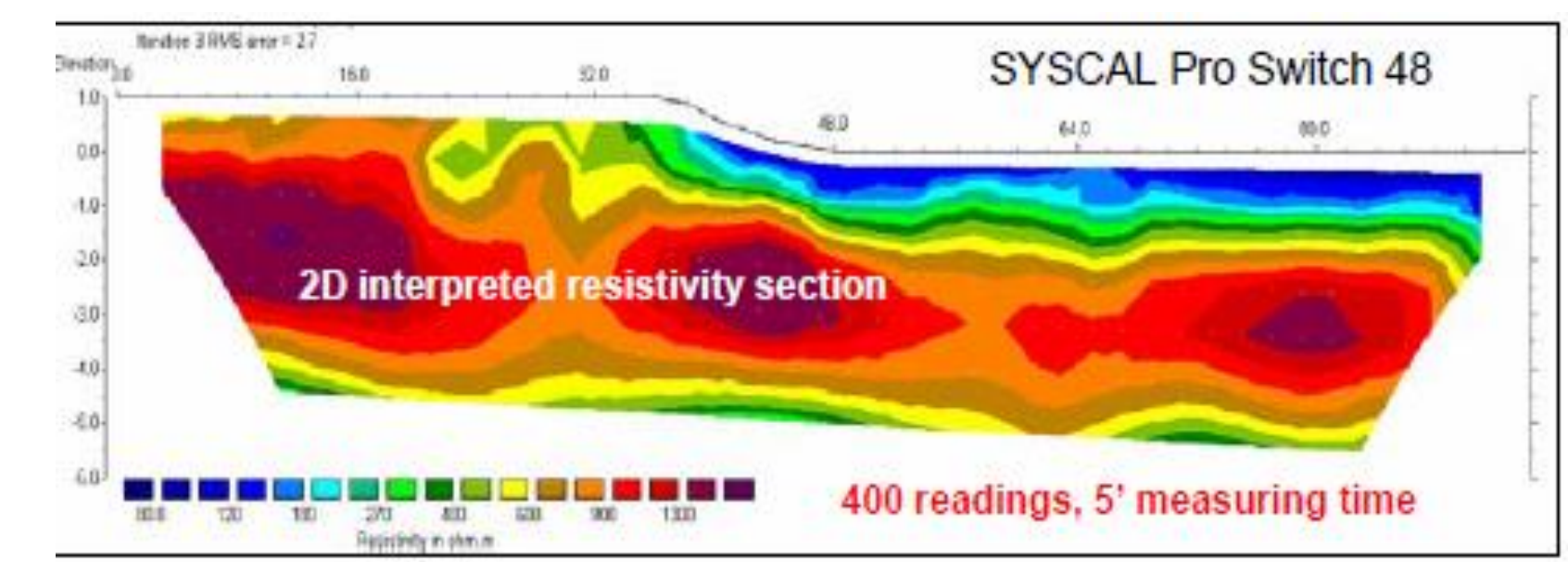
Electrodes arrays (mobile)



IRIS V-FullWaver for geoelectric surveys



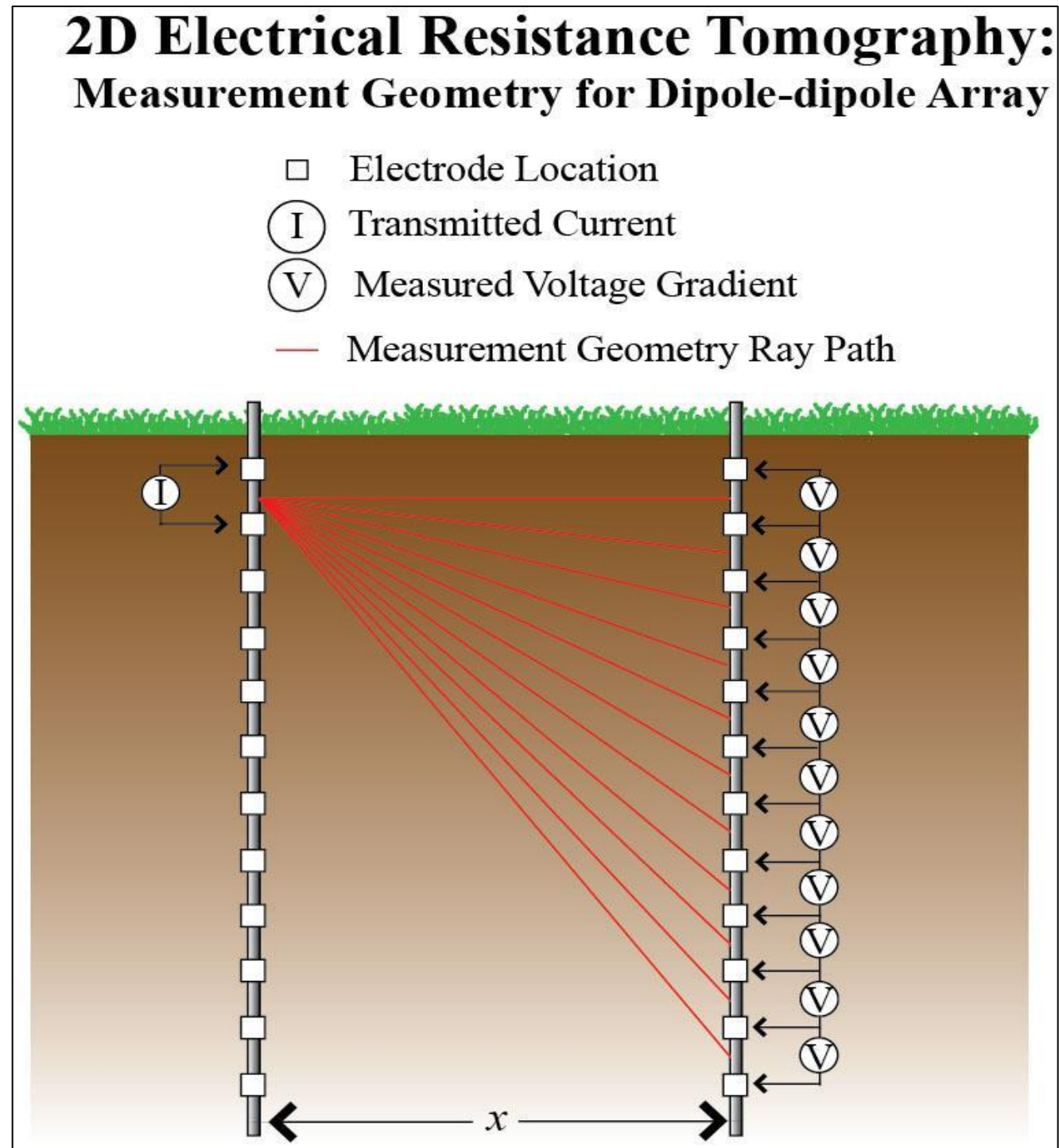
ERT (electrical resistivity tomography)



Representative resistivity map (Syscal Pro)

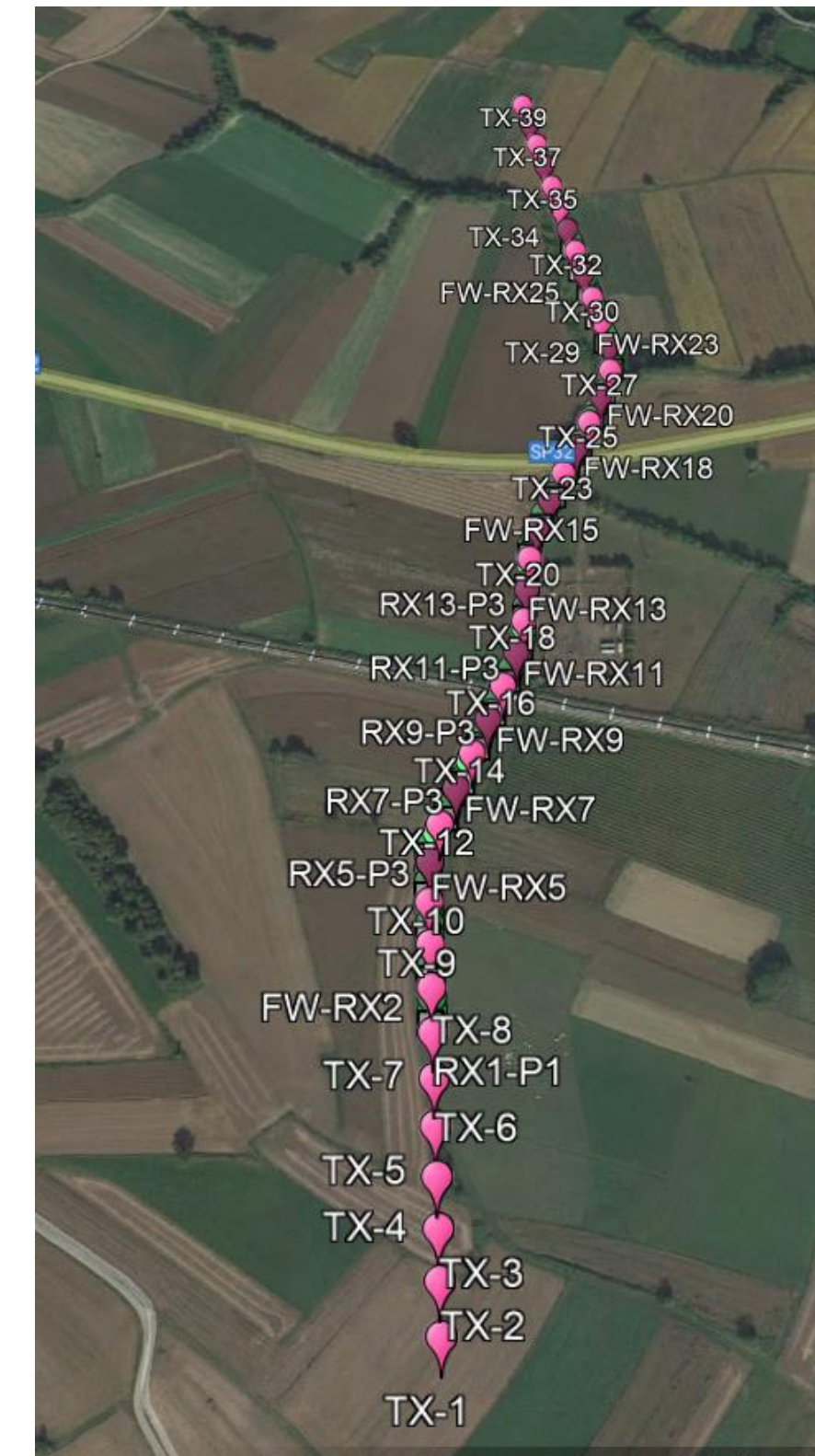
GEOELECTRIC EXPERIMENTS DURING PITOP UPGRADE

Borehole geoelectric survey using
SYSCAL system



https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity_methods.html

Electrodes for surface (V-FullWaver) geoelectric acquisitions
deployed alongside the surface geophones line

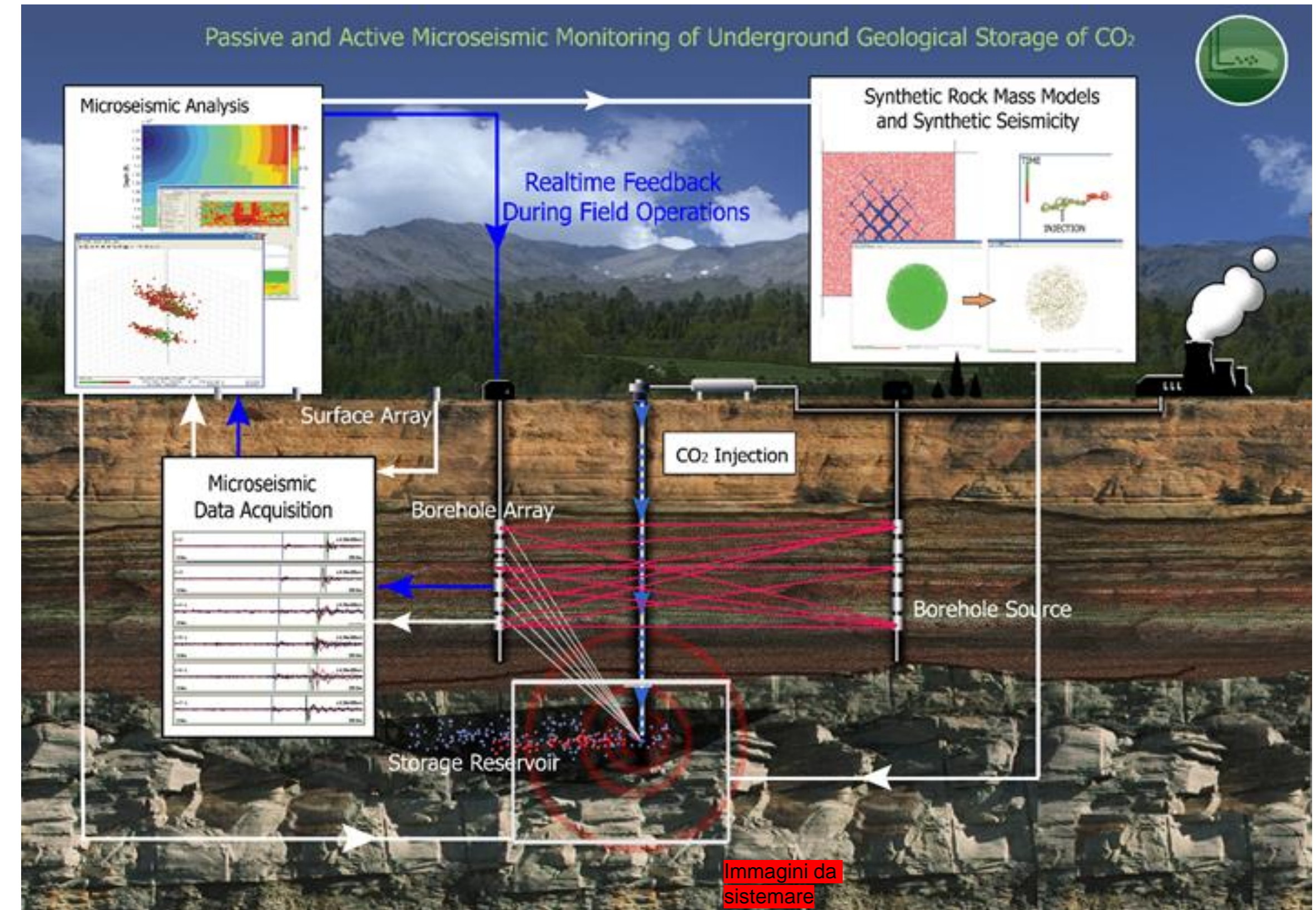


OVERVIEW OF PITOP EXPERIMENTS

OVERVIEW OF MULTIDISCIPLINARY AND INTEGRATED EXPERIMENTS PERFORMED DURING PITOP UPGRADE

- ✓ **SEISMIC EXPERIMENTS** (SWD AND CROSS-HOLE) WITH DIFFERENT TYPES OF SOURCES AND ACQUISITION SYSTEMS
- ✓ **GEOELECTRICAL EXPERIMENTS** (SURFACE AND WELL)

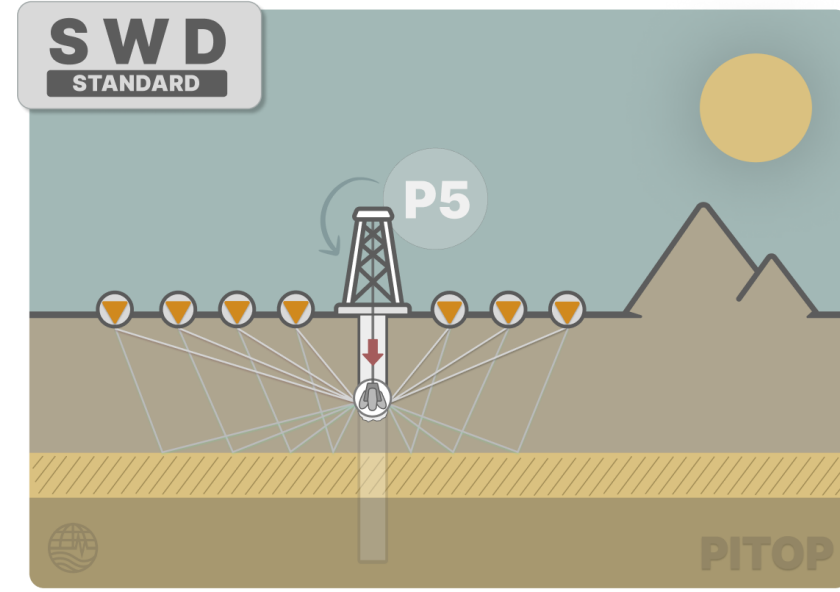
All acquired geoelectrical data will be used for an integrated analysis with seismic data



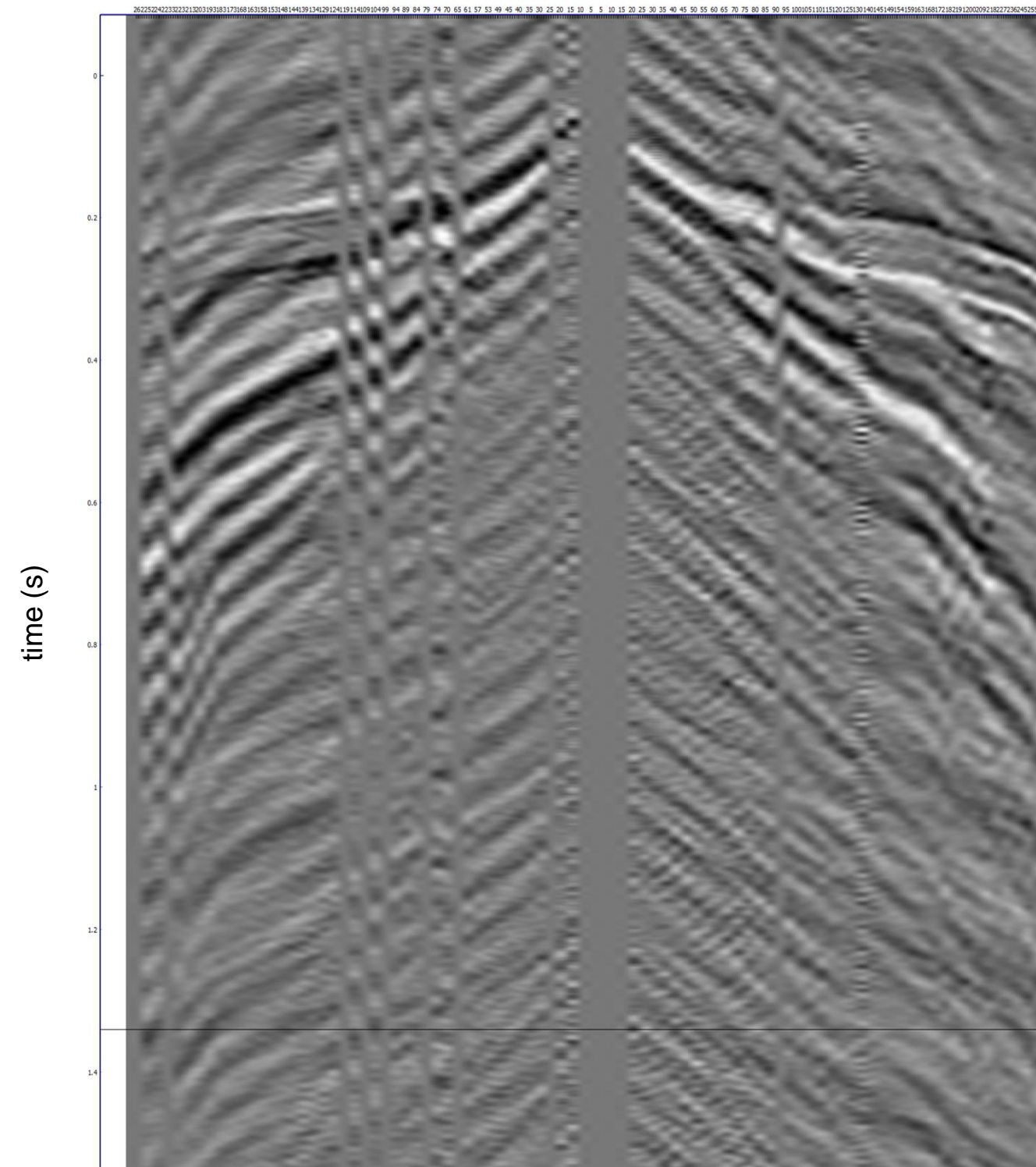
Representative image on seismic monitoring of underground storage of CO₂
(<https://www.appliedseismology.co.uk/applications/co2-storage/>)

PRELIMINARY DATA FROM SWD EXPERIMENT

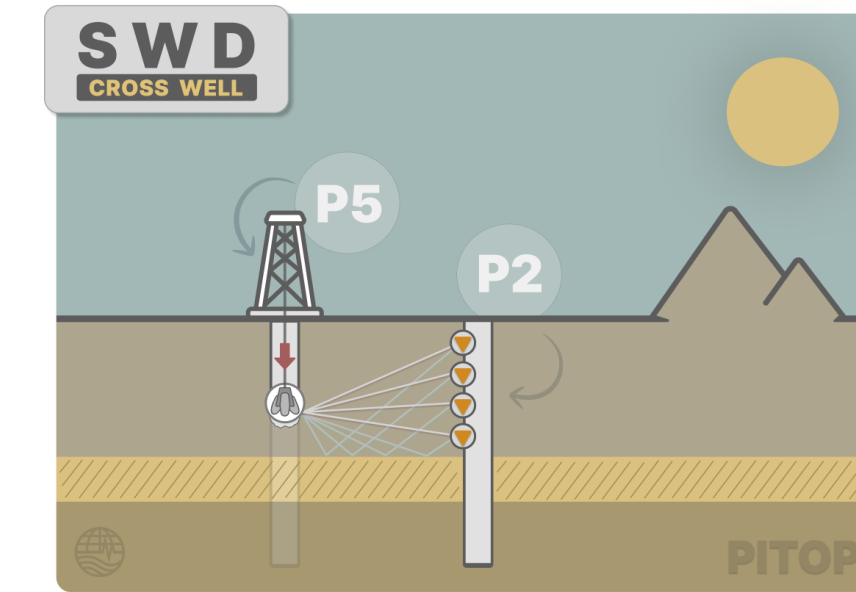
SWD



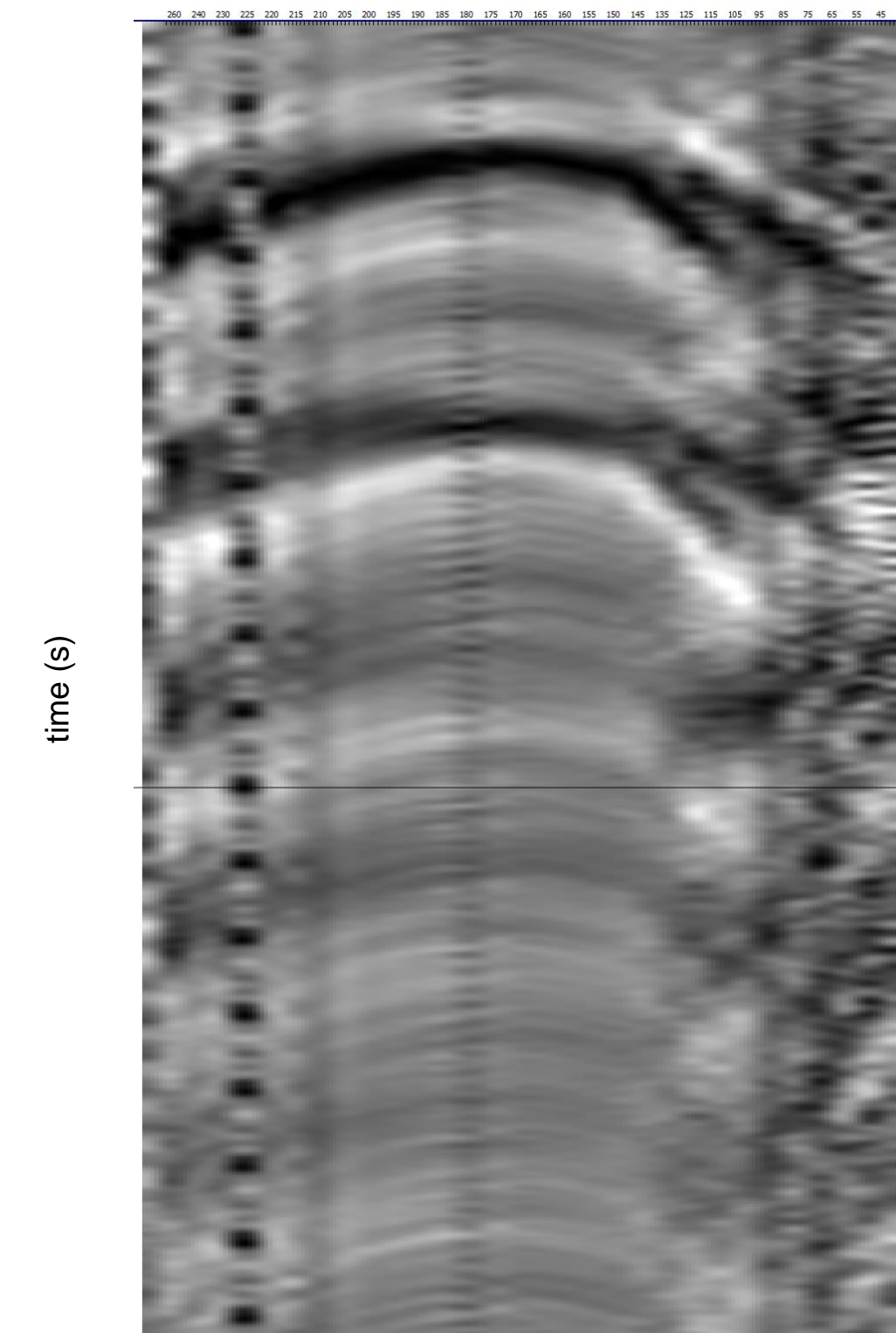
Offset (m)



Cross-well



Receiver depth (m)



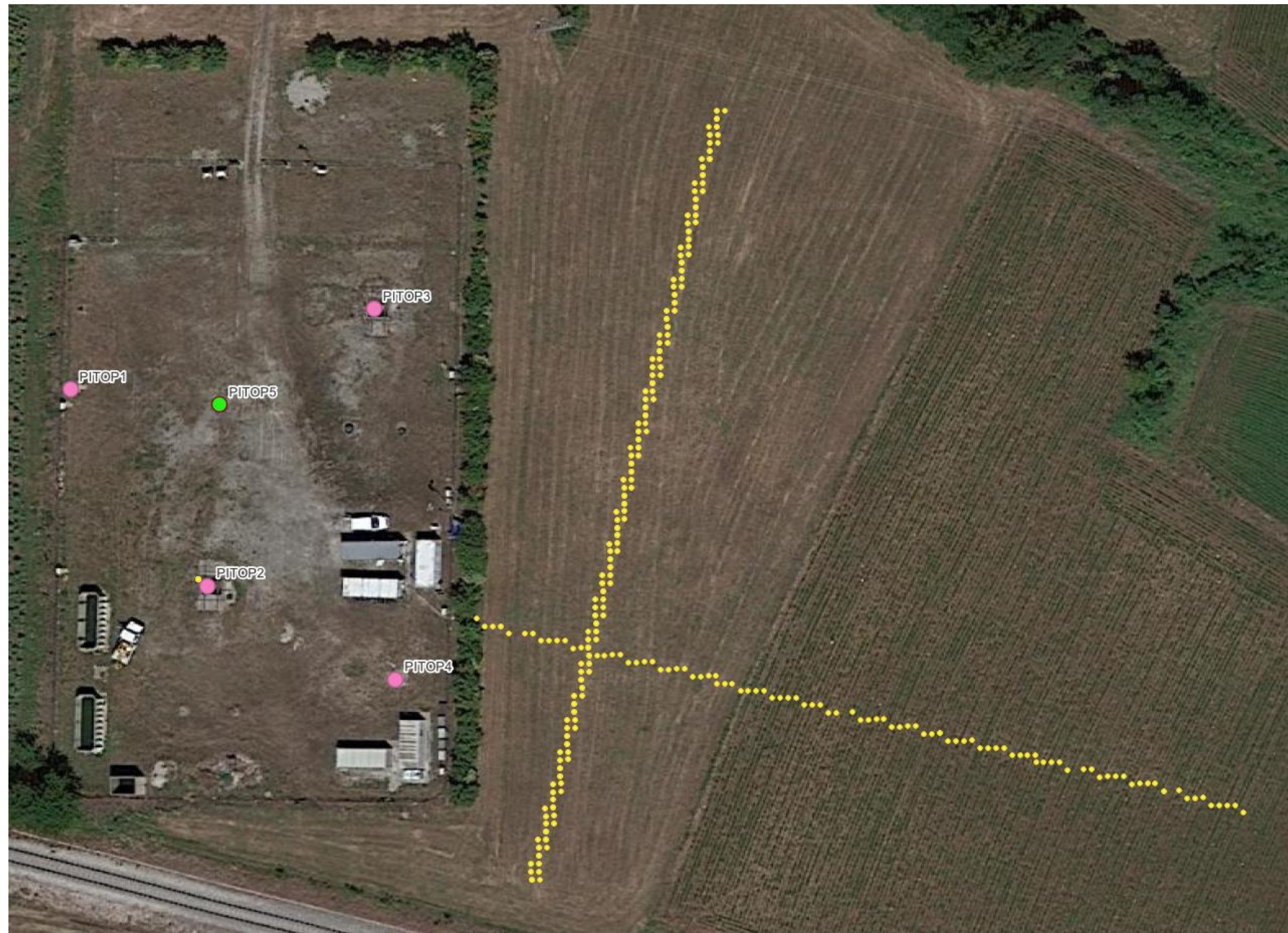
FURTHER PITOP IMPLEMENTATION

- ✓ **New housing unit** as laboratory and office built with sustainable materials
- ✓ **Weather station**
- ✓ **New video camera system** for real-time monitoring of the site
- ✓ **Improved virtual and remote access** to the site instrumentation

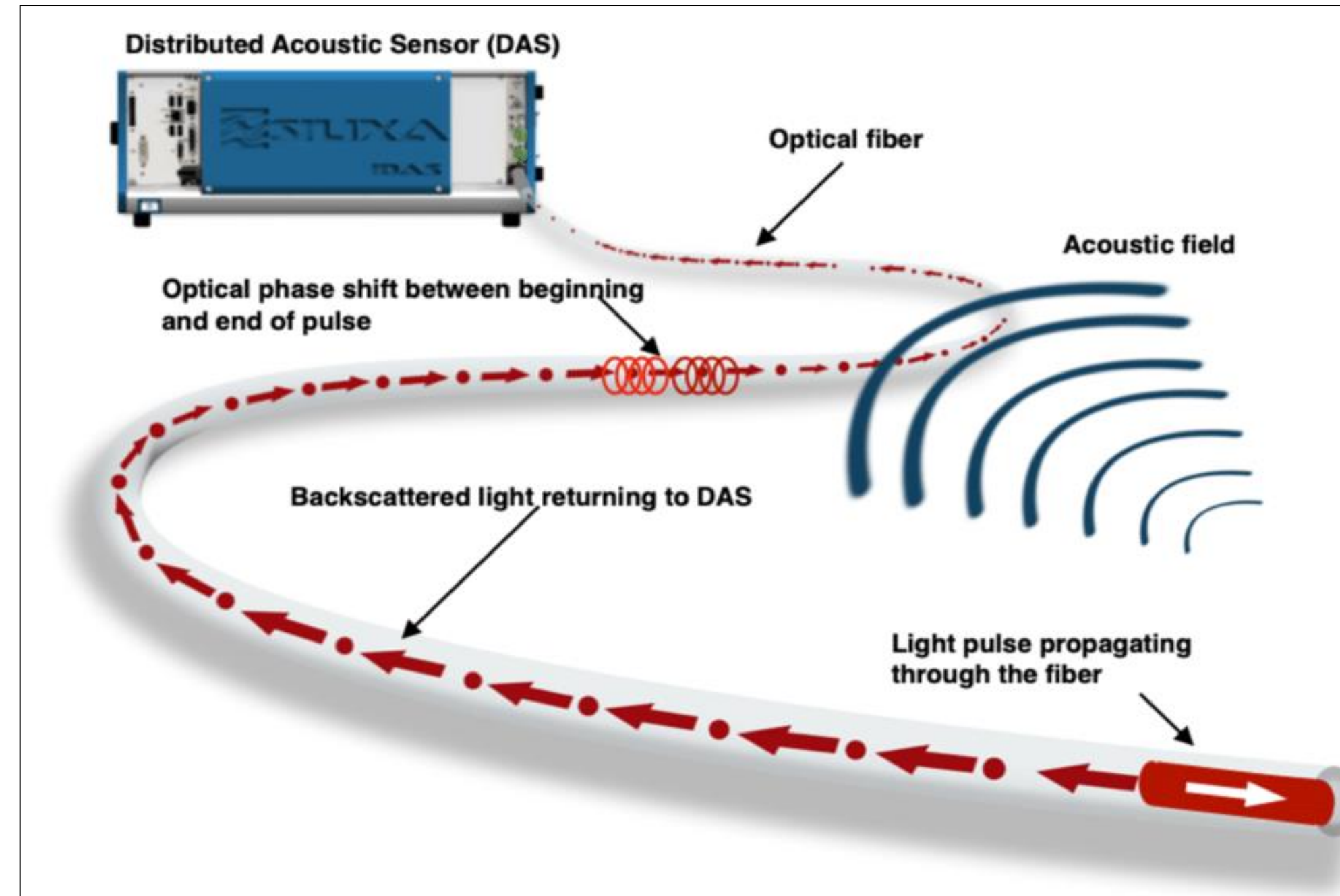


DAS IMPLEMENTATION IN PITOP

Distributed Acoustic Sensors (DAS): 3 fiber optic cables as mobile units and 2 interrogators



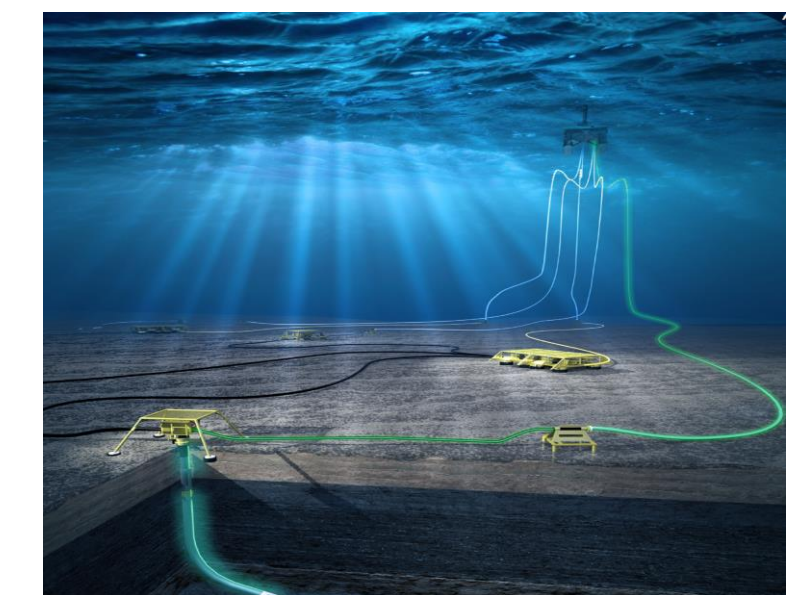
DAS lines in shallow trenches in PITOP



High Definition Seismic and Microseismic Data Acquisition Using Distributed and Engineered Fiber Optic Acoustic Sensors - Sergey Shatalin, Tom Parker and Mahmoud Farhadiroushan (2020, Silixa Limited)



Carina® Sensing System (Silixa)



Available facilities and methods in PITOP

| Main Available facilities | Methods/Approaches |
|------------------------------------|-------------------------------------|
| NuSeis Nodes Standard Geophones | ✓ SWD ✓ VSP ✓ Surface seismic |
| DAS and interrogators | ✓ All seismic surveys |
| V-Full waver and electrodes array | ✓ Geoelectrical surveys |
| Instrumented wells | ✓ Seismic and geoelectric surveys |
| Seismic sources | |
| Remote/virtual access | |

PITOP (OGS): REFERENCES AND CONTACTS

- ✓ *PITOP is available for transnational access and scientific collaborations*
- ✓ *In situ technical support can be provided*

Poletto F., Malusa M., Miranda F. and Tinivella U.; 2004a: Seismic while drilling by using dual sensors in drill strings, *Geophysics*, 69,1261–1271.

Poletto F., Petronio L., Malusa M., Schleifer A., Corubolo P., Bellezza C., Miranda F., Miandro R., Gressetvold B.; 2004b: Prediction and 3D Imaging While Drilling By Drill-Bit 3D RVSP, *WORLD OIL*, 225.

Poletto F. and Bellezza C.; 2006: Drill-bit displacement-source model: Source performance and drilling parameters, *Geophysics*, 71(5).

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Poletto F., Bohm G., Schleifer A., Craglietto A., Meneghini F., Zgauc F., Pinna G., Corubolo P., Peronio M., Farina B., Bellezza C., Lovo M., Pasciullo V., Cristofano G., Cappelli G. and Ghidini P.; 2015: CO2 MONITOR: Sviluppo di tecniche innovative per il monitoraggio di siti di stoccaggio dell'anidride carbonica. <https://hdl.handle.net/20.500.14083/6658>

Poletto F., Finfer D., Corubolo P. and Farina B.; 2016: Dual wavefields from distributed acoustic sensing measurements, *Geophysics*, Vol. 81, NO. 6 P. D585–D597, 10.1190/GEO2016-0073.1

Poletto F., Schleifer A., Zgauc F., Meneghini F. and Petronio L.; 2016b: Acquisition and deconvolution of seismic signals by different methods to perform direct ground-force measurements, *Journal of Applied Geophysics*, Vol. 135, Pages 191-203.

Poletto F., Goertz A., Bellezza C., Bergfjord E.V., Corubolo P., Lindgård J.E., Moskvil L.M.; 2022: Seismic-while drilling by drill-bit source and large-aperture ocean-bottom array. *Geophysics*, 87(2)

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- ✓ *In situ technical support can be provided*

Link to PITOP in ECCSEL website: <https://www.eccsel.org/catalogue/126>

Article under revision to Bulletin of Geophysics and Oceanography:

“Geophysical exploration case histories at the geophysical test site PITOP - a key facility in the ECCSEL-ERIC consortium: an overview” (Bellezza et al. 2024)

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Erika Barison

Thank you!