香港岩土及岩土環境工程專業協會
ASSOCIATION OF GEOTECHNICAL & GEOENVIRONMENTAL SPECIALISTS (HONG KONG)
AGS (HK)

sixense

SIXENSE WEBINAR

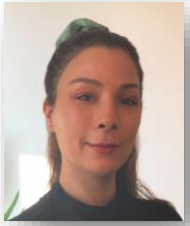
Sissterra: A 3D Passive Imaging Solution For Subsoil Exploration In Urban Context

13/01/2023

Transforming your infrastructure into living assets

SUMMARY

INTRODUCTION



Maria SAADE,

PhD. Seismology,

Seismic data processing expert, 7y. experience

Major references:

- Postdoctoral research #1: passive imaging and monitoring for earthquakes in Japan
- Postdoctoral research #2: scientific team (planetology) of the NASA InSight mission
- Extension to Paris metro lines
- Seismic risk survey for CEA (French Alternative and Atomic Energies Agency) and EDF (Electricity of France)

Clement MOGENIER

MSc applied geosciences

Senior Project Manager, 17y. experience,

Major references:

- West Island (C703) and South Island Lines (C904)
- Shatin to Central Link (C1128)
- Tung Chung New Town Extension
- MRT Putrajaya Line, Kuala Lumpur (MY)
- Nam Theun 2 hydropower dam (Lao PDR)
- 57 km long TELT Lyon-Turin Base Tunnel (FR)
- Metro Tunnel Project in Melbourne (AU)

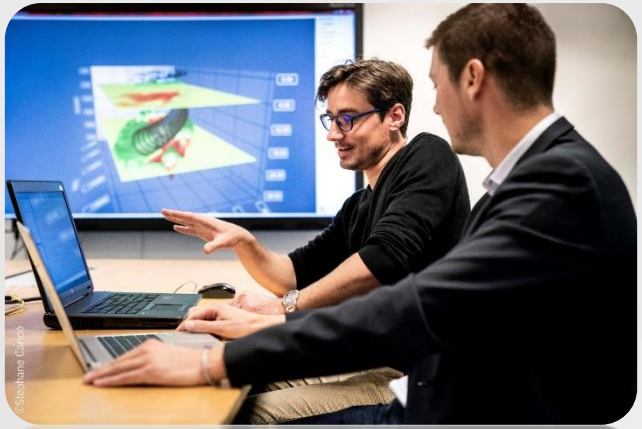
From a global point of view

- Land use density is increasing
- Multiplication of urban construction & maintenance works , especially underground works
- Needs of innovations in risk management & planning optimization

- Reducing carbon emissions and environmental impacts: a need for **greener site investigation techniques**

Geological and geotechnical models for infrastructure projects are mostly based on:

- **Site investigations** (core drillings, SPT, etc)
- **Geotechnical tests** (in-situ and laboratory)
- These tools are **reliable & efficient** but **destructive & fragmented**. In an urban or any restricted area, the fact is that only a few percent are really known,
- Our conviction: need for an **innovative**, **complementary** and **comprehensive** answer, **easy to deploy** in constrained environments, with a **low environmental impact**
- Sissterra was created to consolidate and improve geotechnical models

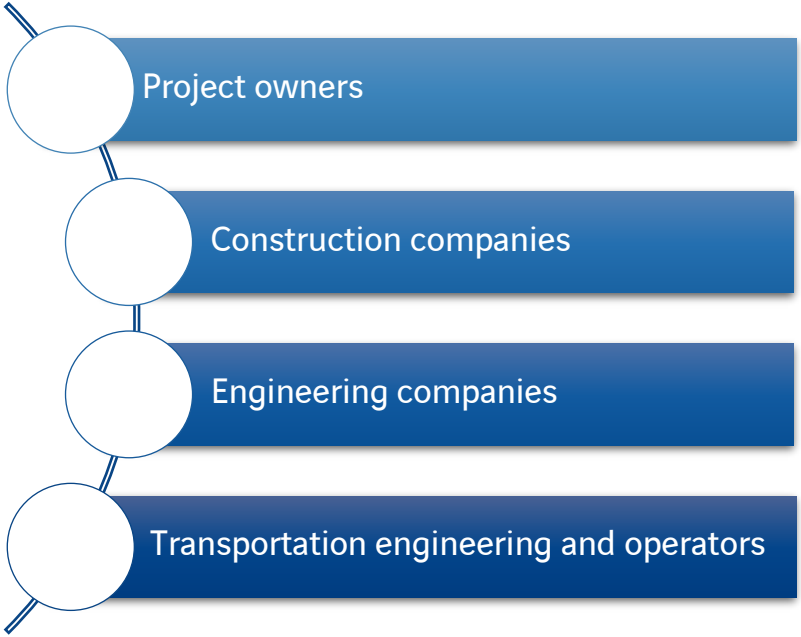


Geophysics always considered as reliable tool in soil investigation but with many limitations:

- Conventional geophysics = source + receiver = sensitive to environmental disturbances (noise)
- Not easy to deploy & medium to low resolution= limited by wired system & fixed numbers of sensors
- Limited credit given to results due to a lack of data & number of stacks

- Development of a scalable, adaptable, and cable free solutions that can make use of the environmental perturbations (telluric) for subsoil exploration

Who are the **users ?**



What are their new expectations for creating a consistent geological model ?

- Anticipate and mitigate underground risks (cavities, voids, settlement areas)
- Offer a 3D overview of the underground, to link and extend drilling results
- Be able to work in constrained areas (traffic, third parties, low headroom, utilities,...)
- Ease of deployment, with a limited number of procedures

02

PRINCIPLES & IMPLEMENTATION

- Academic background
- Principles, deliverables
- Advantages

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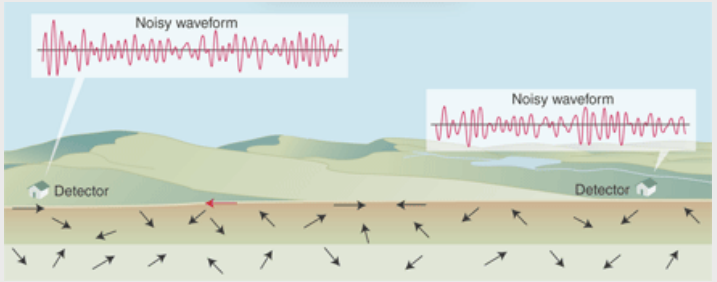
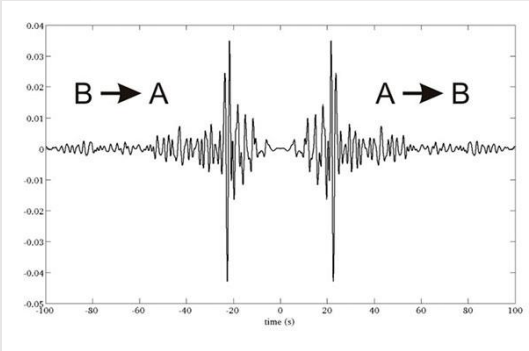
SISSTERRA uses **ambient noise** as the **waves** that are analyzed, which has various **advantages**

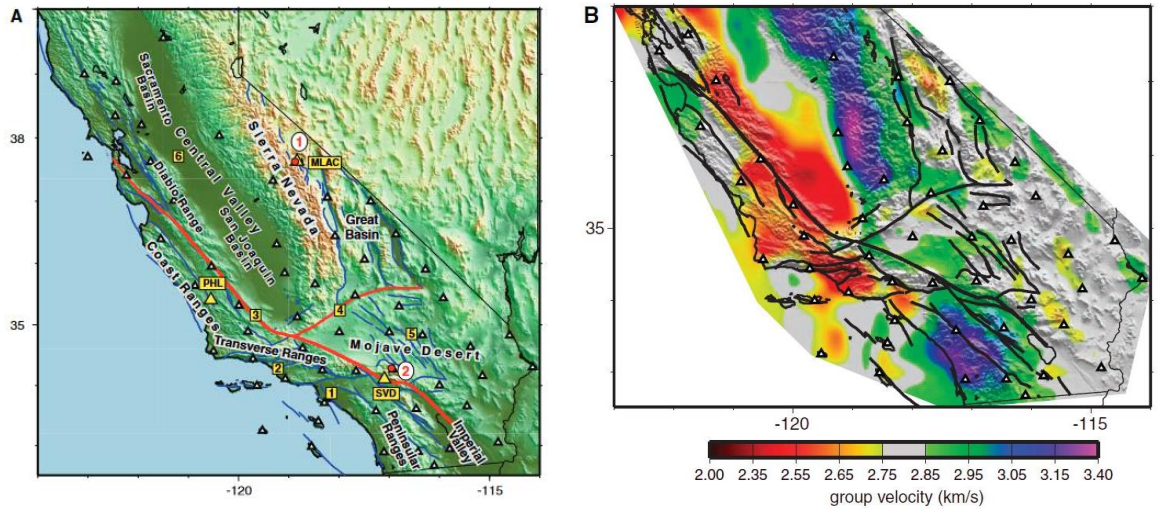


Waves are extracted from the noise using an advanced mathematical procedure
→ **cross-correlation: Shear waves velocity (Vs)**
~ small strain shear modulus



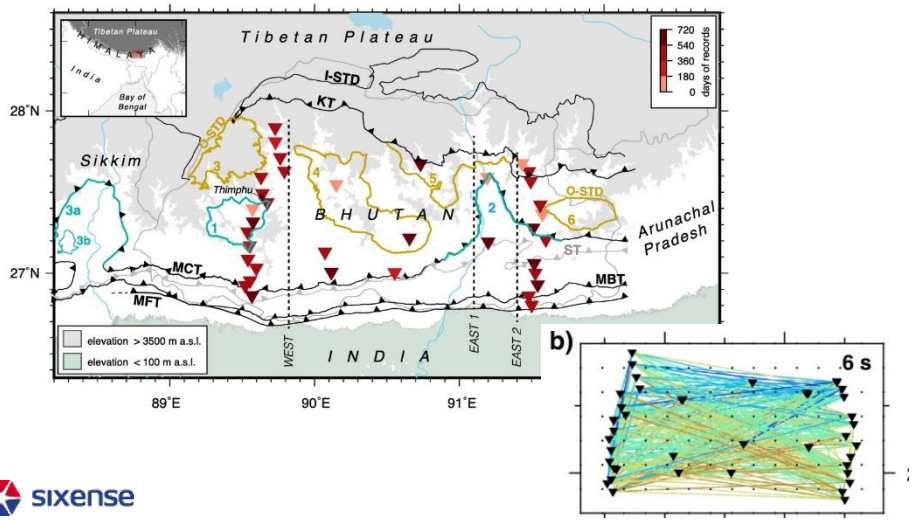
Shapiro et al. 2005, Science

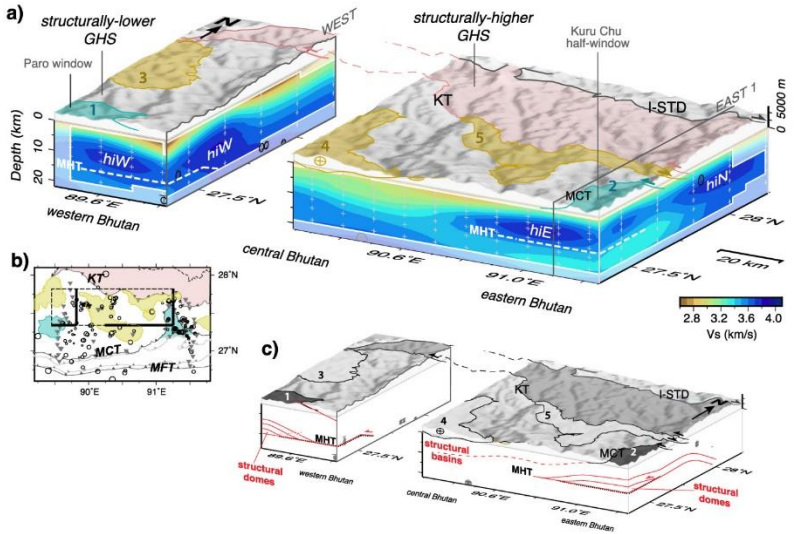
- High-Resolution Surface-Wave Tomography from Ambient Seismic Noise in California, for crust imaging
- Cross-correlation of 1 month of ambient seismic noise recorded at USArray stations
- tomographic images of the principal geological units of California:
  - Low-speed anomalies corresponding to the main sedimentary basins
  - high-speed anomalies corresponding to the igneous cores of the major mountain ranges.



Singer et al. 2017

- Along-strike variations in the Himalayan orogenic wedge structure in Bhutan from ambient noise tomography
- Upper crustal structure beneath Bhutan is mapped down to 18 km depth:
  - high shear-wave velocity anomalies as quarzite-dominated rocks or felsic migmatites with large intrusions of leucogranites
  - high-velocity anomalies in the orogenic wedge in eastern and western Bhutan correlate with the local geometry of the Main Himalayan Thrust (MHT) and provide evidence for the formation and depth extent of localized duplexes of quartzite lithology

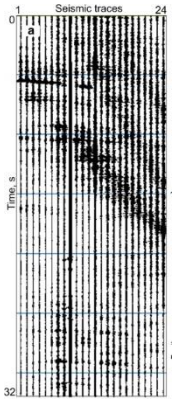


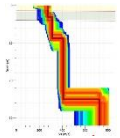


A typical setup in urban context:

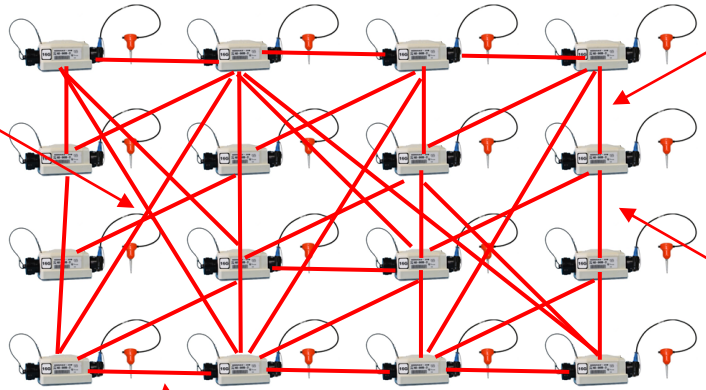
- Recording time: few days
- Area dimensions: hundreds of meters
- Tens/hundreds of autonomous nodes (1C/3C)
- Submersible geophones for river crossings

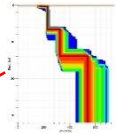
Raw signals

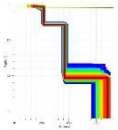


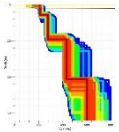


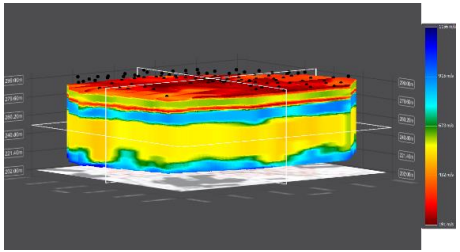
Cross correlations











3D Velocity model (Vs)

80 nodes = 3240 pairs = 3240 measurements

Sissterra, a proven solution

- Multiple References in geotechnical application (TBM, construction, etc), seismic assessment, ..., for major projects
- Solution 100% operational from the design to the results analysis
- High processing capacity

Advantages of ambient noise imaging over conventional solutions

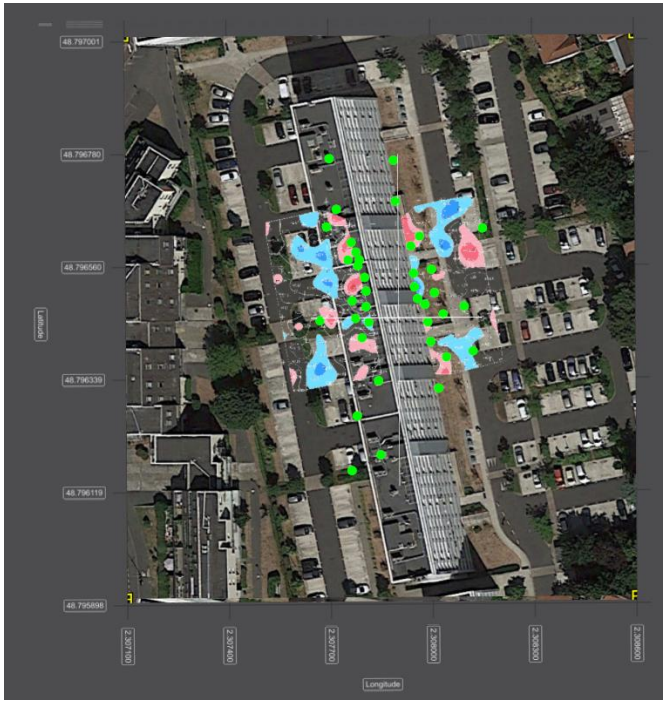
- Sissterra® is suitable for dense and hard-to-reach areas
- Sissterra® is complementary to geotechnical solutions
- Highly reliable & robust compared to active seismic methods

03

CASE STUDIES

- Line 14 South extension (Paris, FR)
- Bagneux (FR)
- Power plant (Oman)
- Industrial site (Morocco)

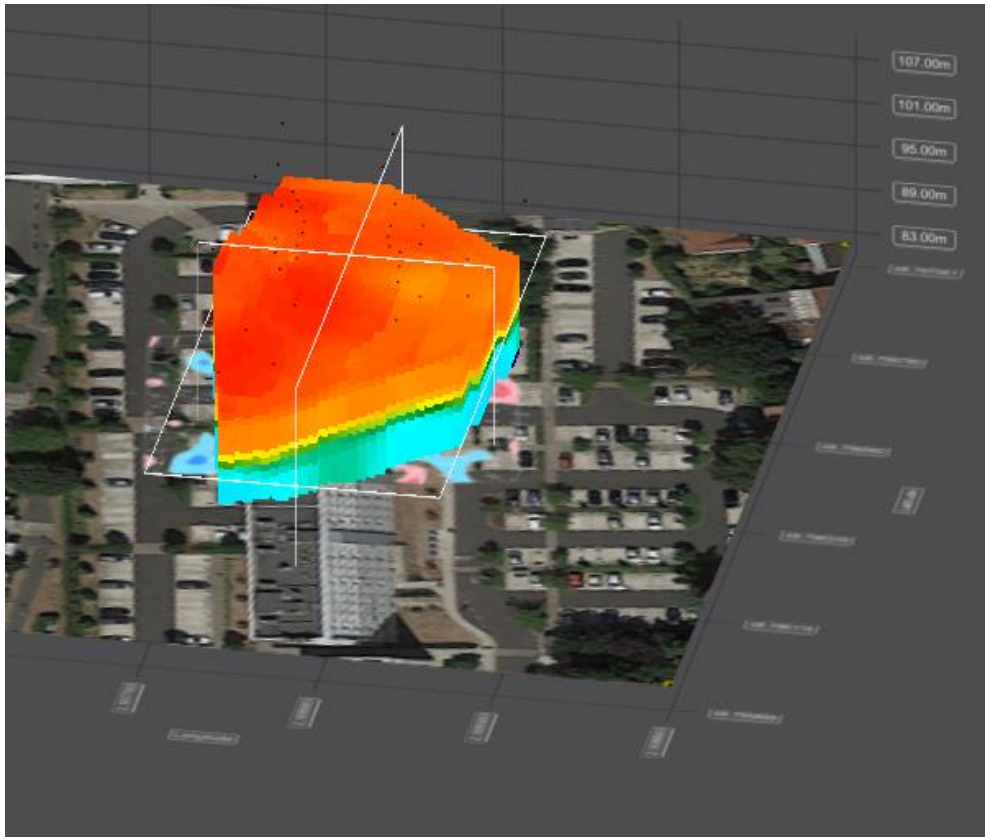
CASE STUDY #1 | **RESIDENTIAL COMPLEX (BAGNEUX, FR)**

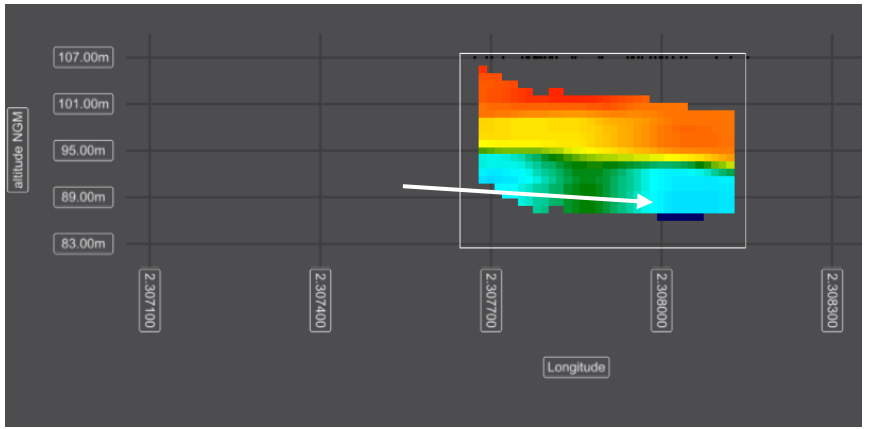


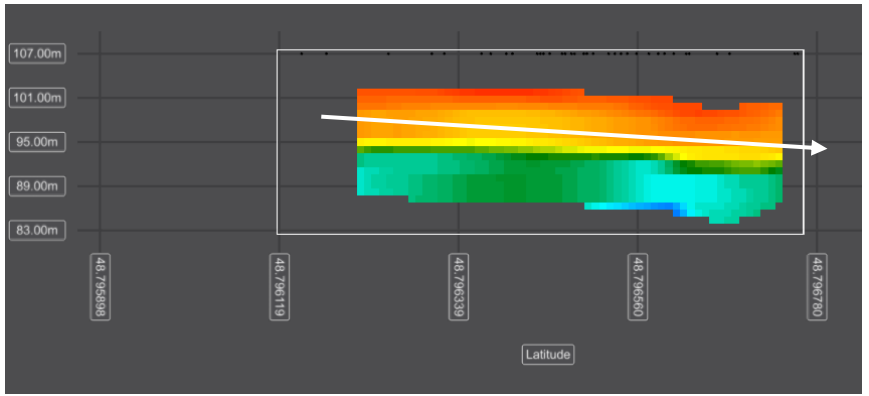
Benefits

- Dedicated to urban areas
- Third parties & occupants
- Determination of the origin of the cracks

CASE STUDY #1 | **RESIDENTIAL COMPLEX (BAGNEUX, FR)**







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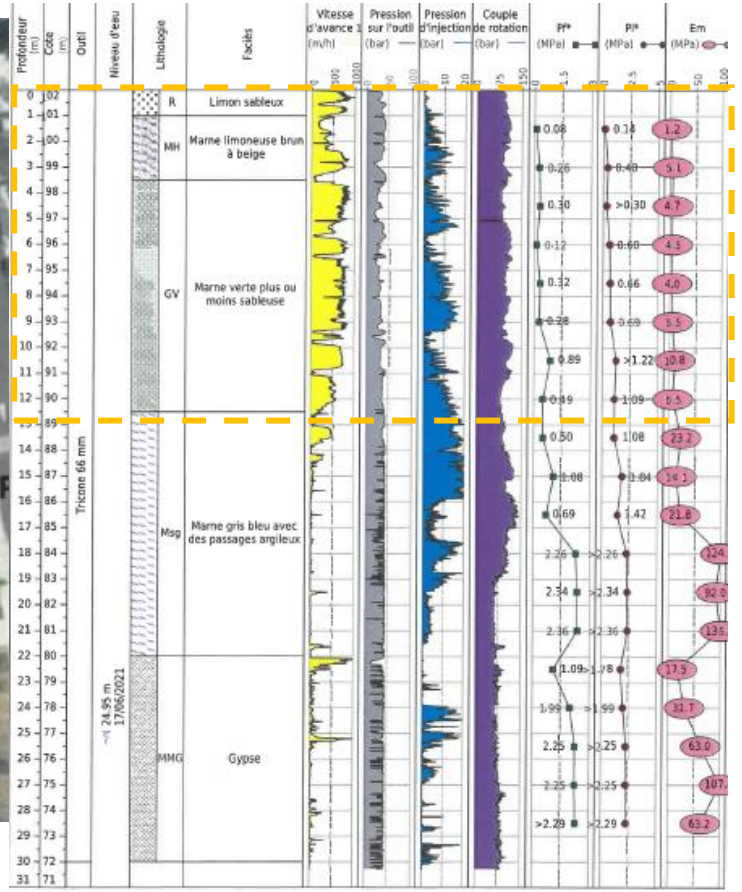

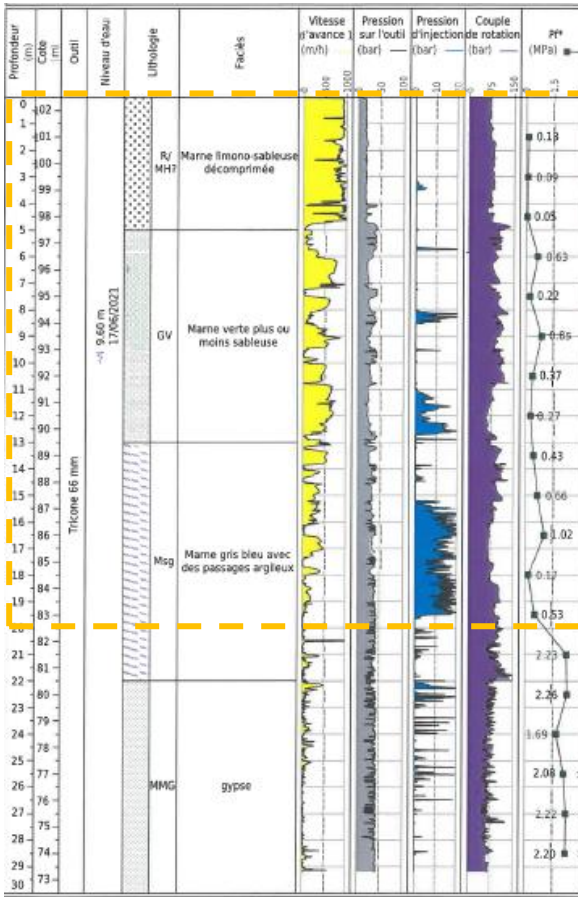

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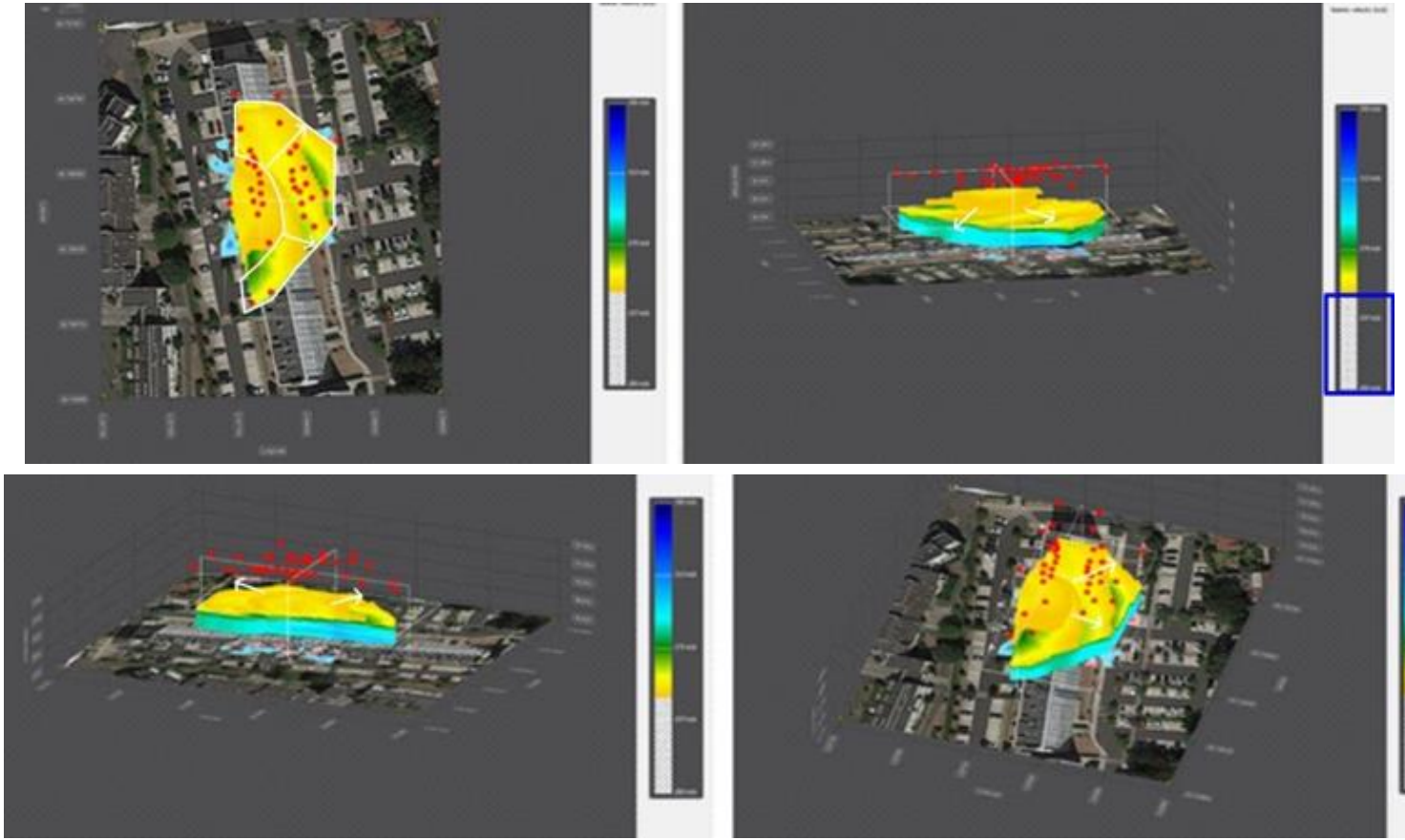
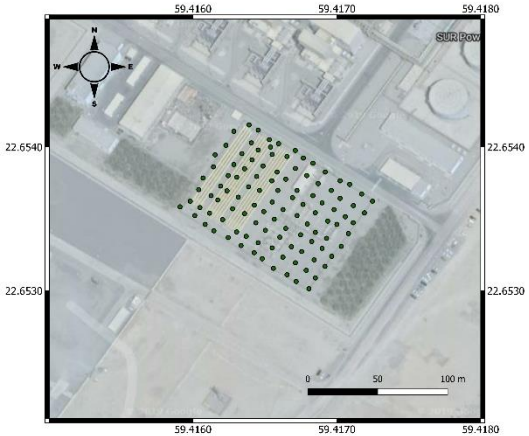


The solution

- 100 autonomous and geo-localized geophones
- Imaging weak zones and bedrock

Key figures

- 103 geophones
- 9600 correlations
- Investigation depth 30m
- 200 h recorded
- 415 Go of data



CASE STUDY # 2 | **POWER PLANT AFFECTED BY SINKHOLES (OMAN)**

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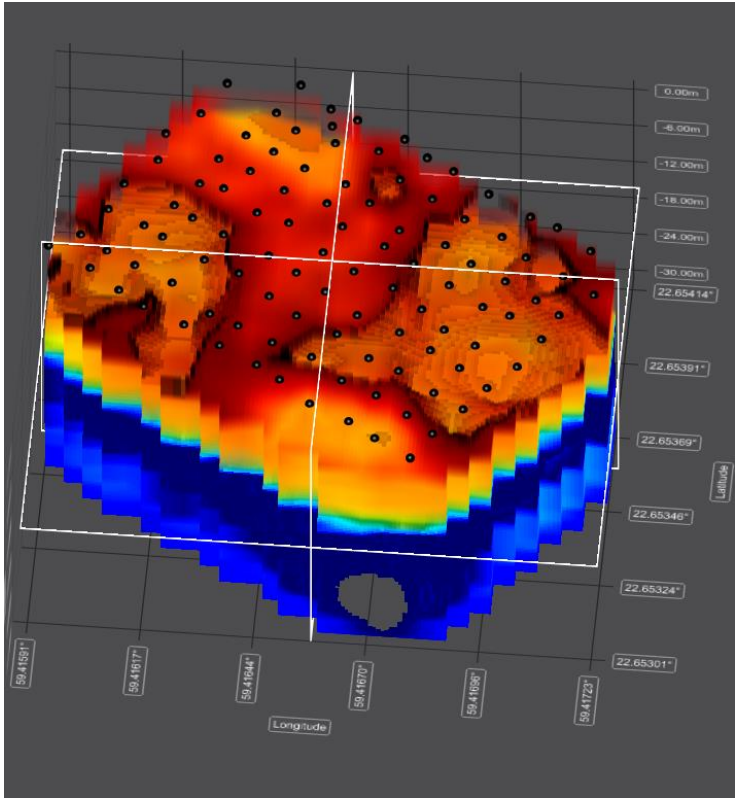
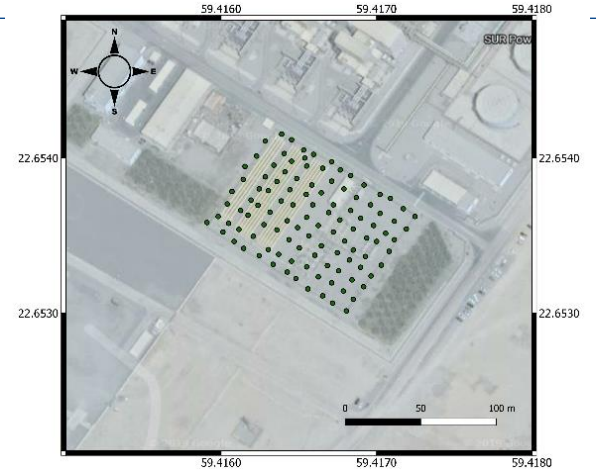
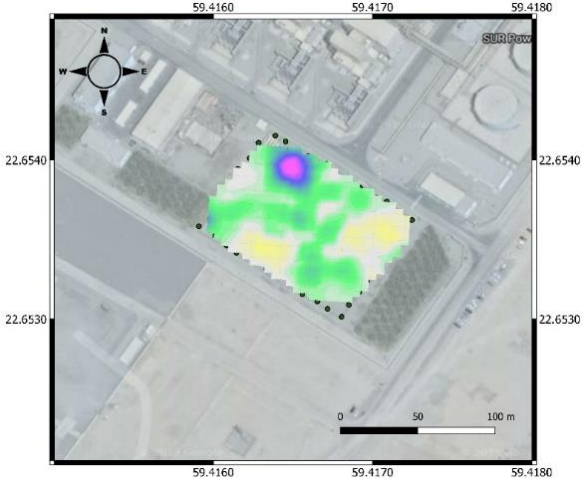


Benefits

- Non destructive solution within a very sensitive site (gas processing plant)
- Delineation of low velocity zones: origin to differential settlements





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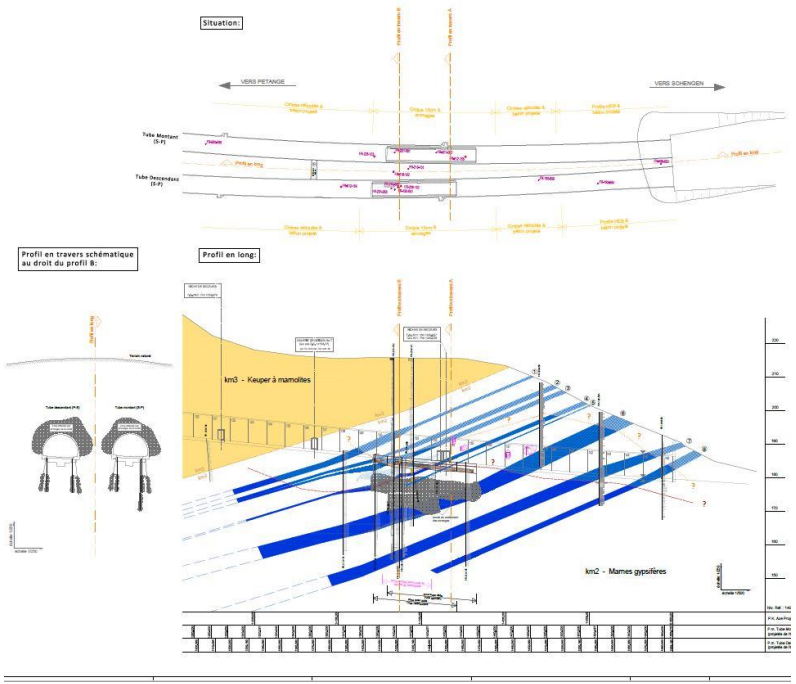
The solution

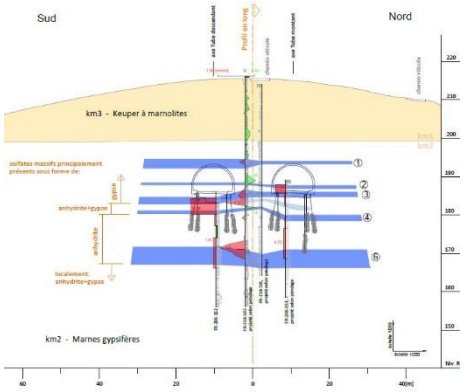
- 200 nodes on surface & 40 nodes in tunnels
- 3D imaging above and beneath the tunnels

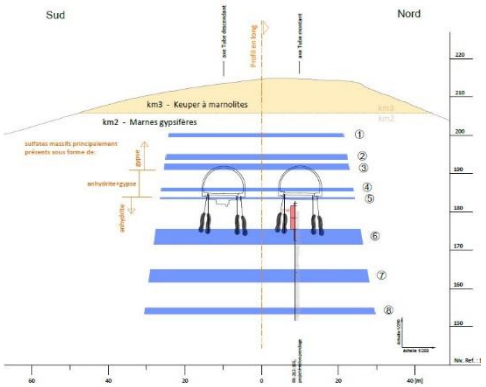
Key figures

- 200 + 40 geophones
- 21k correlations
- Investigation depth 60m
- 336 h recorded

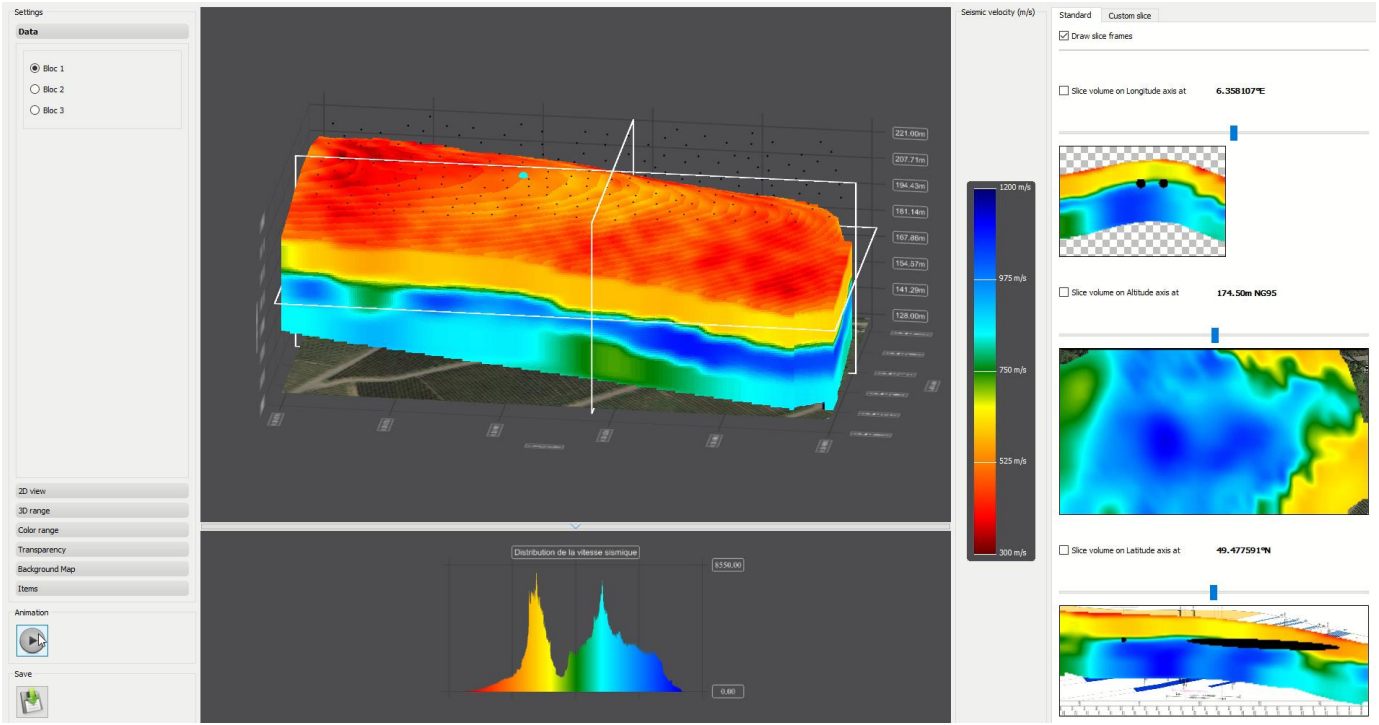
CASE STUDY #3 | RISK ANALYSIS TUNNEL AREA (LUXEMBOURG)







CASE STUDY #3 | RISK ANALYSIS TUNNEL AREA (LUXEMBOURG)



Benefits

- 3D dealed imaging
- Detection of heterogeneities and risk areas around the tunnels
- Better decision-making for rebuilding the tunnels

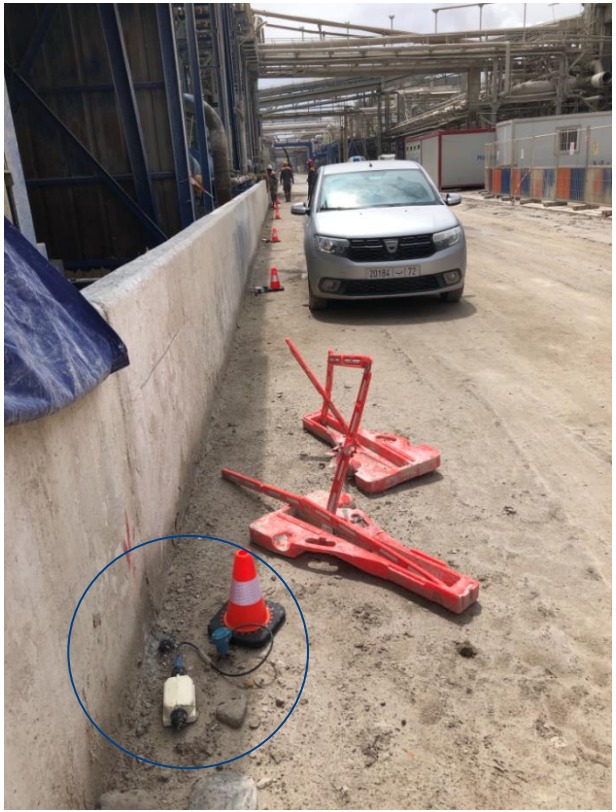
Assessment of soil quality and risk analysis at industrial site

Seismic network on surface (11 zones)

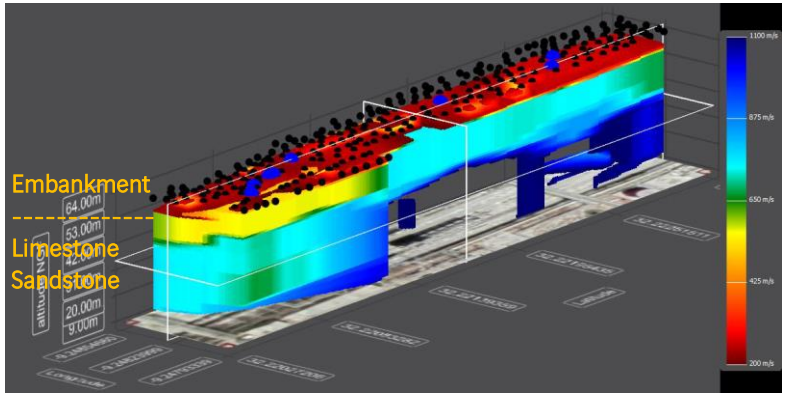
The solution

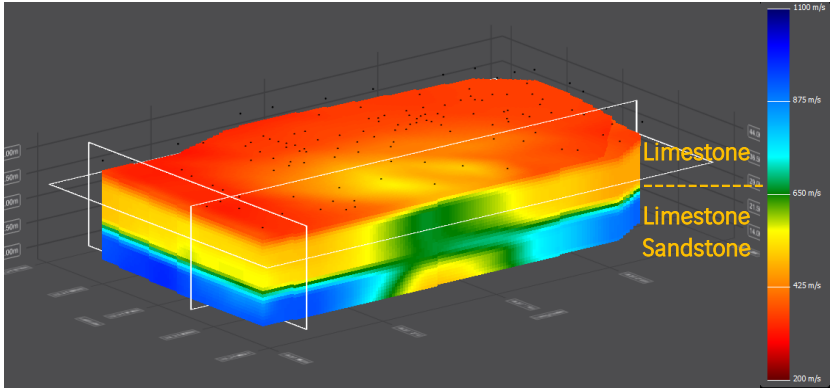
- Identify the presence of karstic cavities under industrial facilities that could lead to settlements / collapses on the surface.
- Recommend a targeted geotechnical campaign.

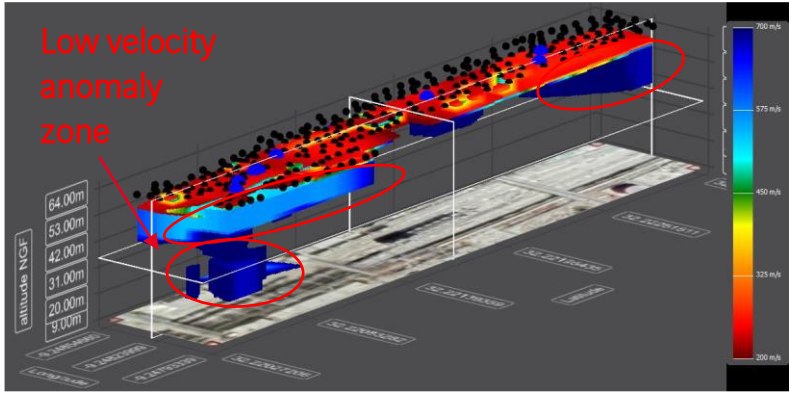
CASE STUDY #4 | INDUSTRIAL COMPLEX (MOROCCO)

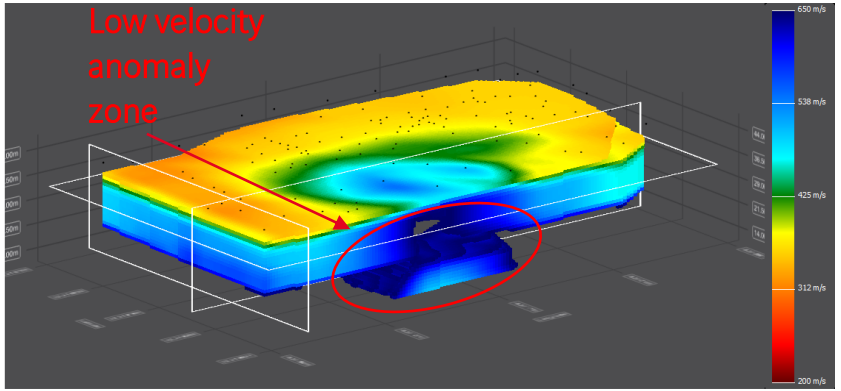


Assessment of soil quality and risk analysis at industrial site









04

Q&A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Thanks