TAI

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

# Harnessing the power of geophysics for tunnel/ underground projects in pre-construction, construction, and maintenance stages

**by**

**Dr. Sanjay Rana**

PARSAN Overseas Pvt. Ltd.

*Sanjay@parsan.biz*

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

- An ISO 9001:2015 certified geophysical company
- Promoters recognized as leaders in region for launching new technology. Responsible for launch of:
  - Ground Penetrating Radar Technology- 1996
  - Shear Wave Seismic Refraction- 1997
  - High Resolution Seismic Tomography- 1998
  - Passive Seismic Tomography for Oil Exploration- 2008
  - Innovative use of geophysical methods for high resolution non-destructive testing of dams- 1998
  - **BEAM (TBM Ahead Monitoring)- 2022**
- Highly experienced and trained staff.
- Offices in Delhi, Kolkata, Jammu, Bhopal, Singapore, Bahrain & Saudi Arabia
- Work experience in India, Nepal, Bhutan, Saudi Arabia, Bahrain, Kuwait, Oman, Afghanistan, Singapore, Greece, Iran, Algeria, Georgia…….

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

- Professional Geophysicist, with **33 years** of work experience. Chairman AF Academy & Managing Director, PARSAN, An engineering geophysics company
- **Gold Medalist- 1990**, University of Roorkee (Now IIT-Roorkee)
- Pioneered use of Near Surface Geophysics (Private Sector) in India in **1995.**
- Completed geophysical investigations of **>2000** projects.
- Member of various working committees for development of Code of Practices and Standards, **including BIS, IRC, TAI, IndSTT**.
- Principal author of
  - Guidelines on Geophysical Investigation of Dams
  - Guidelines for Geophysical Investigation of Tunnels (TAI)
  - Guideline for Geophysical Investigations for Bridges (IRC)
  - Indian Code for Subsurface Utility Mapping.


November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

'Safe & Sustainable Development of Underground Space' refers to the strategies and practices involved in responsibly constructing and managing subterranean areas in a way that ensures the safety of those who use it, minimizes environmental impact, and promotes the efficient use of resources.

November 22-23, 2023, Mumbai, India

Even comprehensive exploration programs recover a relatively minuscule drill core volume that is less than 0.0005 percent of the future excavated volume of the tunnel


Note: The 0.0005% sampling level is equivalent to one vertical 100 mm diameter borehole for every 100 m length along a 5 m diameter tunnel and, if we did not have other information to guide us, such a sampling proportion would certainly not be enough. *Parker (1996)*

# Tunnelling Asia' 2023

## International Conference on Climate Change Resilience and Sustainability in Tunneling and Underground Space

November 22-23, 2023, Mumbai, India

1. Expertise & engineering solutions available for dealing with any (almost) ground condition
2. The problem is 'meeting the unexpected' and 'uncertainty' of ground conditions **(Geological Surprises).**

## Necessary Investigation Steps

- Study available geological maps
- Study satellite images
- Geological Mapping
- **Geophysical Investigations**
- Drilling (with geophysical logging)
- Hydrogeological studies
- Seismicity Study
- ……..

## Why Geophysics?

- Engineering geophysics provides valuable and **continuous** information for the planning and execution of tunnel construction projects.
- The main goal is to achieve an accurate and **continuous model of the subsurface** in a relative **short period** of operation time
- Engineering geophysics plays an important role during the various phases: geological investigation, tunnel planning, execution of tunnel construction and QC of completed tunnels.
- If hazards are well known in advance of a tunnel project the safety of workers will essentially be increased and **geological risks will be minimized** by means of successful and interdisciplinary cooperation.

## Planning Stage (Alignment).....

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

# Heliborne TDEM.....

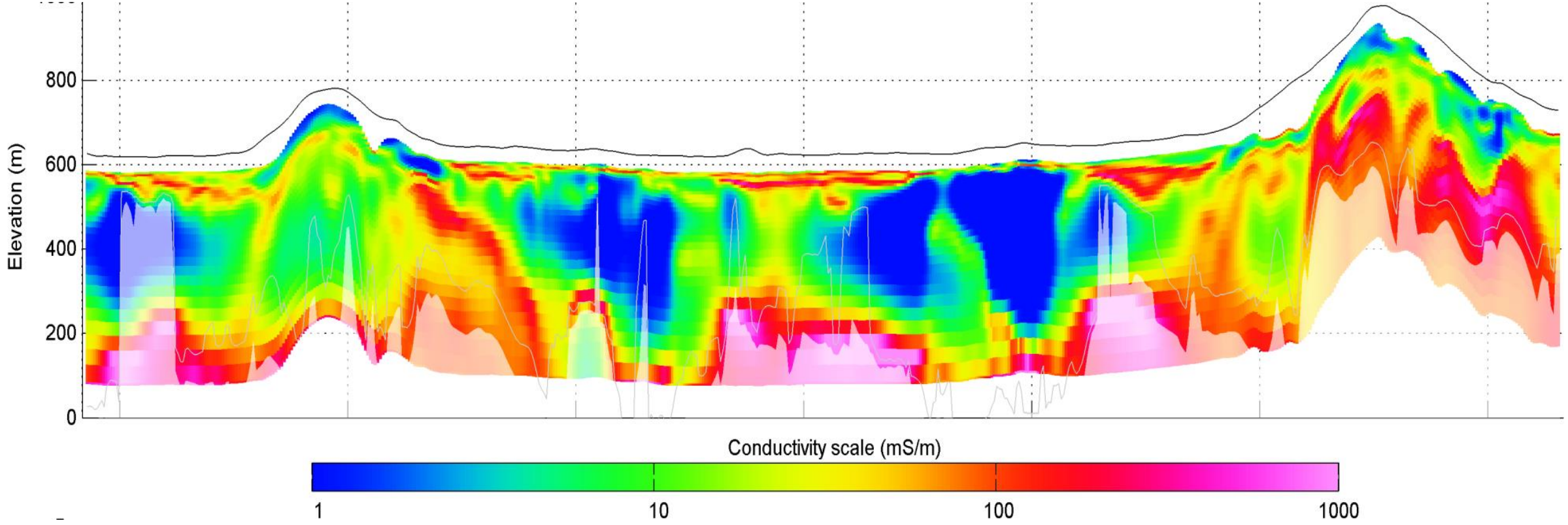
November 22-23, 2023, Mumbai, India


SKYTEM

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION




November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

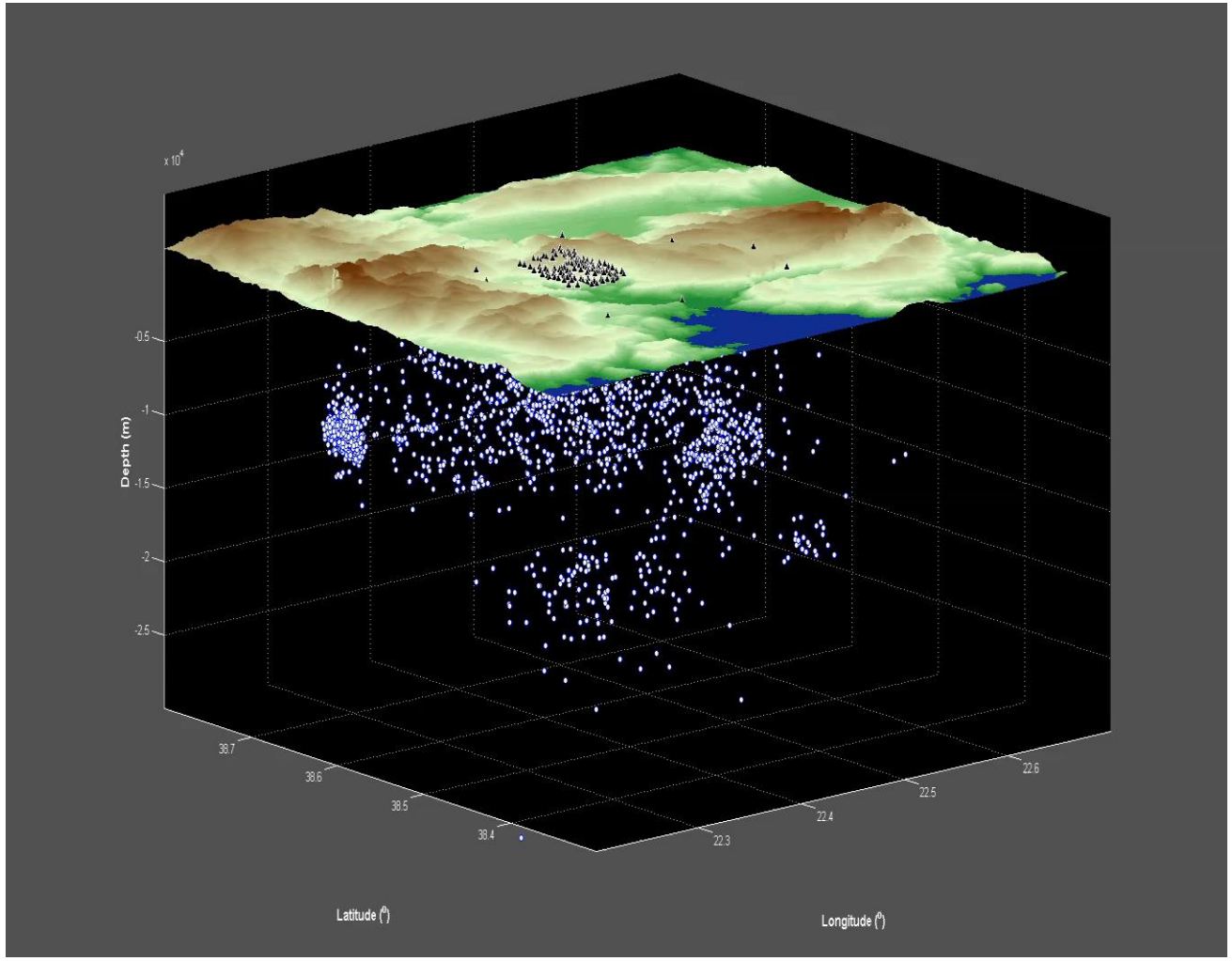
ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

# Passive Seismic Tomography.....

November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

## International Conference on Climate Change Resilience and Sustainability in Tunneling and Underground Space

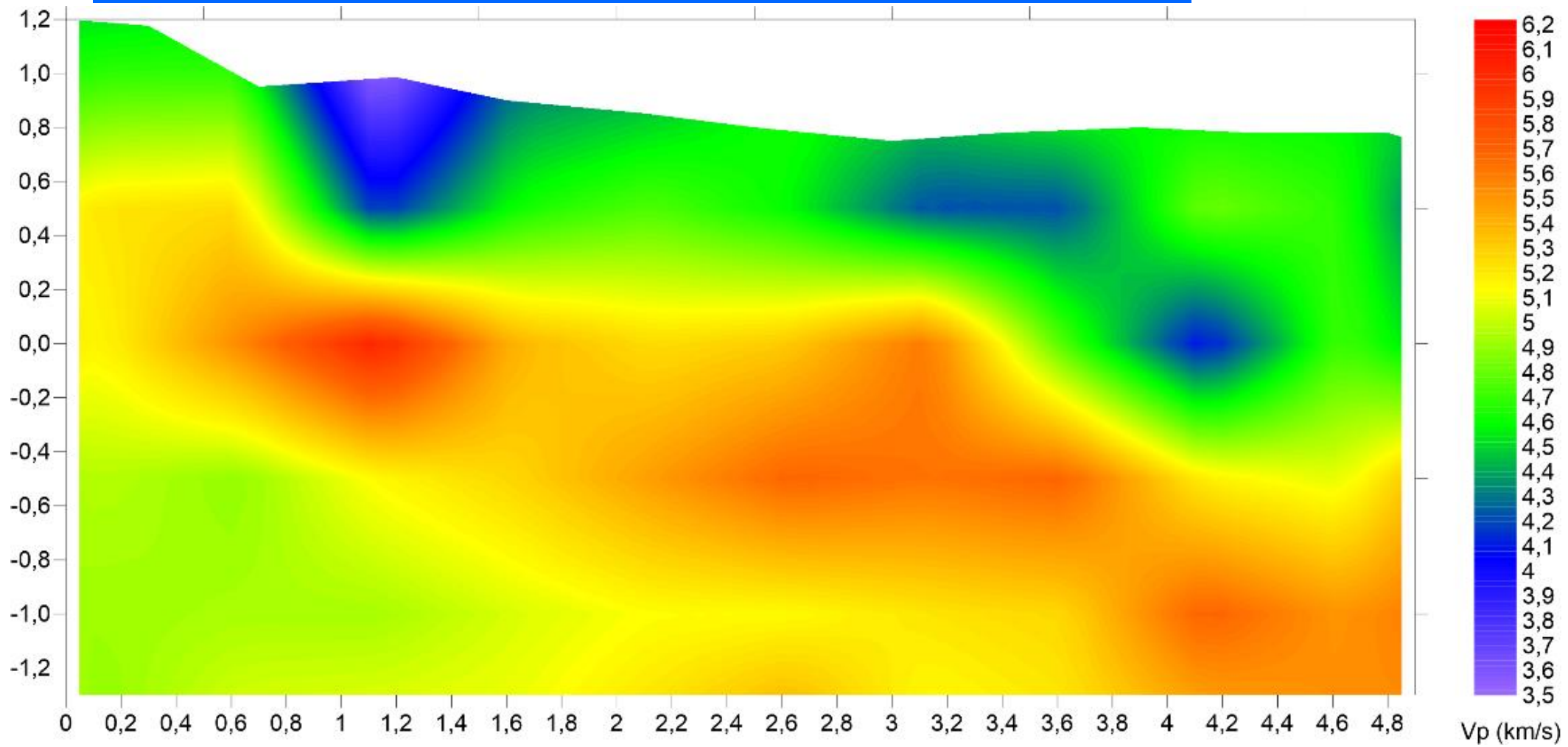



November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION




November 22-23, 2023, Mumbai, India

**Depth Investigated > 2km**

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

# Planning/ Construction Stage (Detailed Investigations)

November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

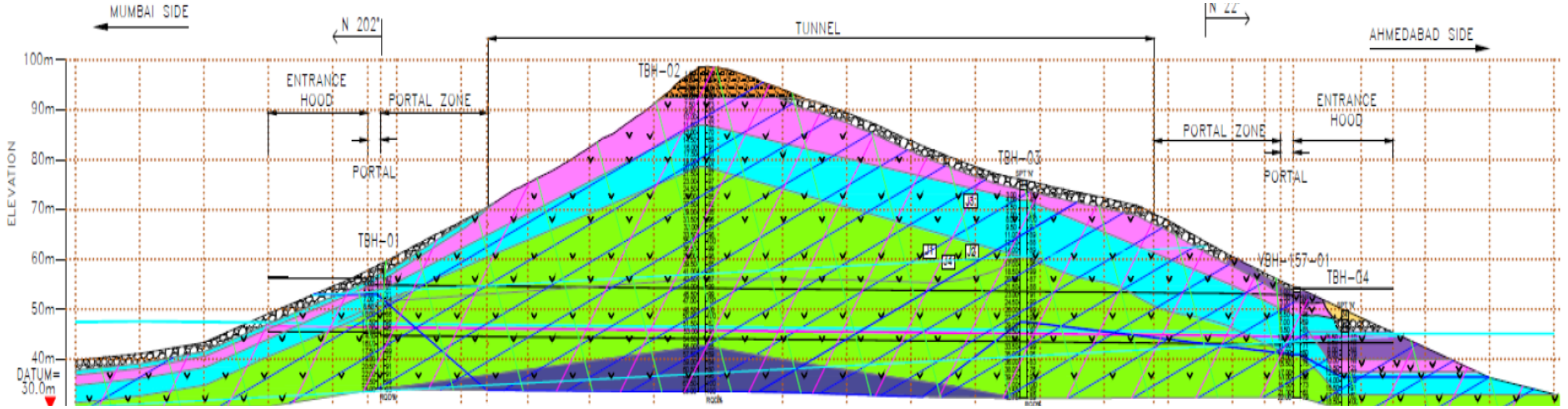
# Seismic Refraction Tomography.....

November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

## International Conference on Climate Change Resilience and Sustainability in Tunneling and Underground Space

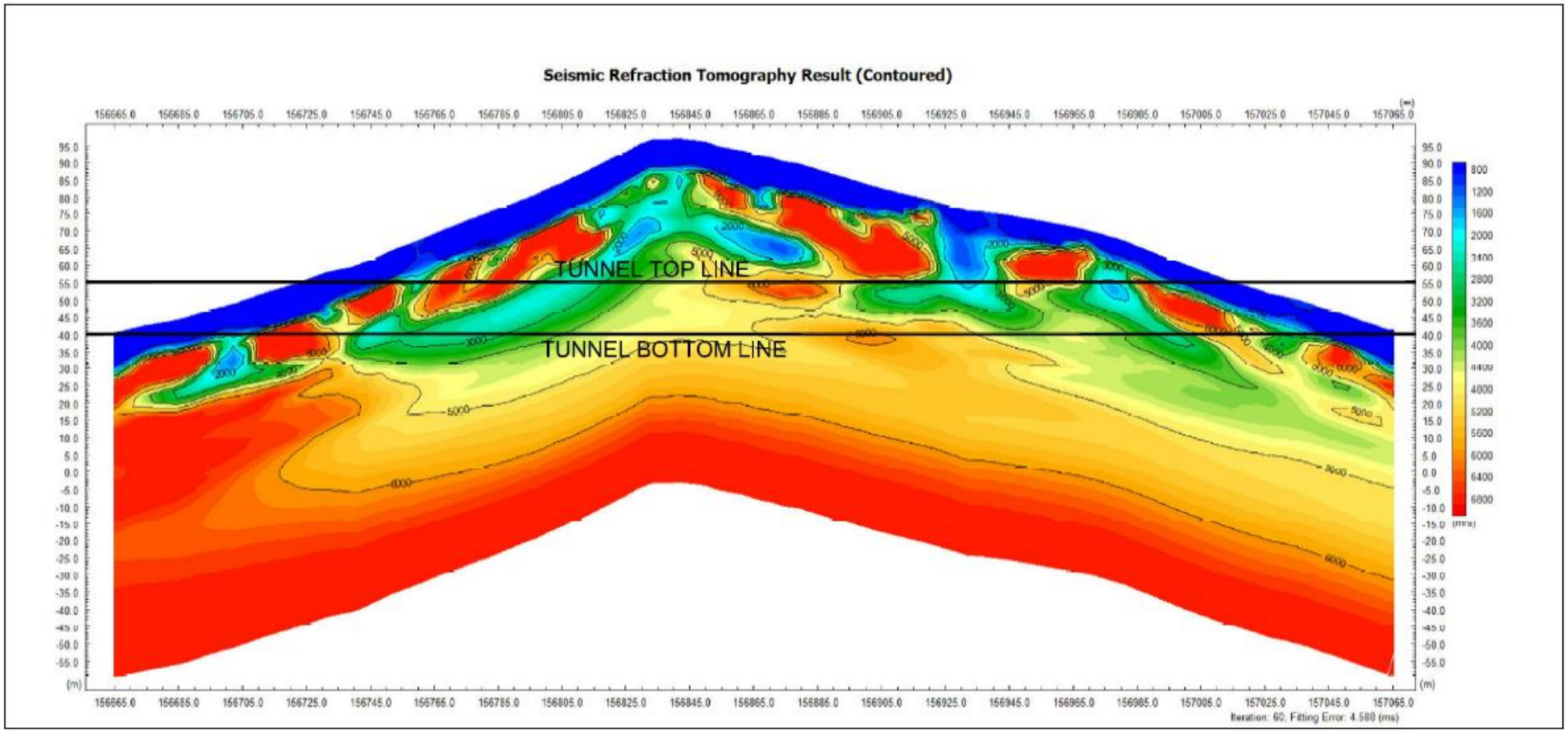
ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION




November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

## International Conference on
## Climate Change Resilience and Sustainability in Tunneling and Underground Space




November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

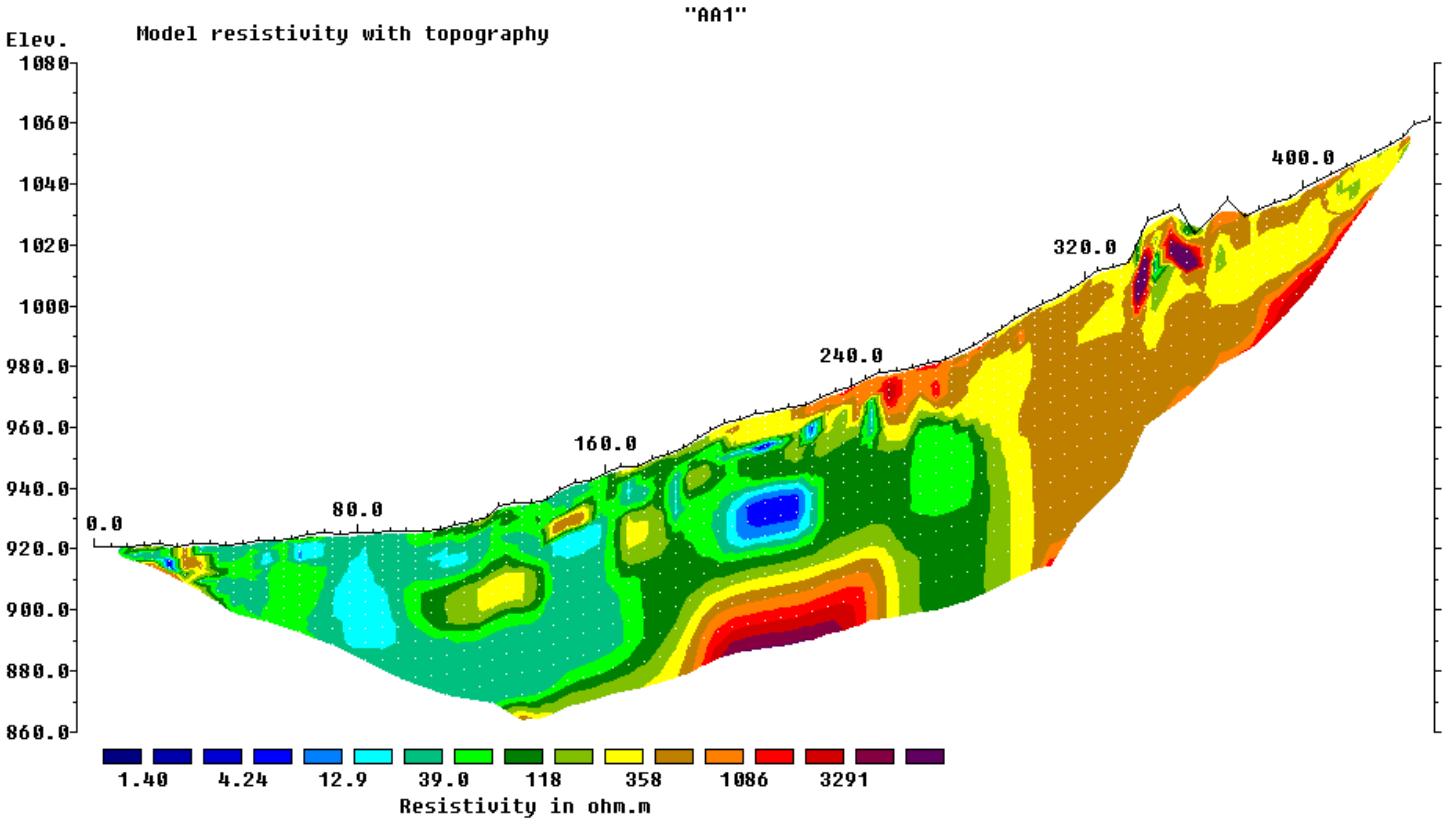
ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

# Electrical Resistivity Imaging/ Tomography.....

November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

## International Conference on Climate Change Resilience and Sustainability in Tunneling and Underground Space




November 22-23, 2023, Mumbai, India

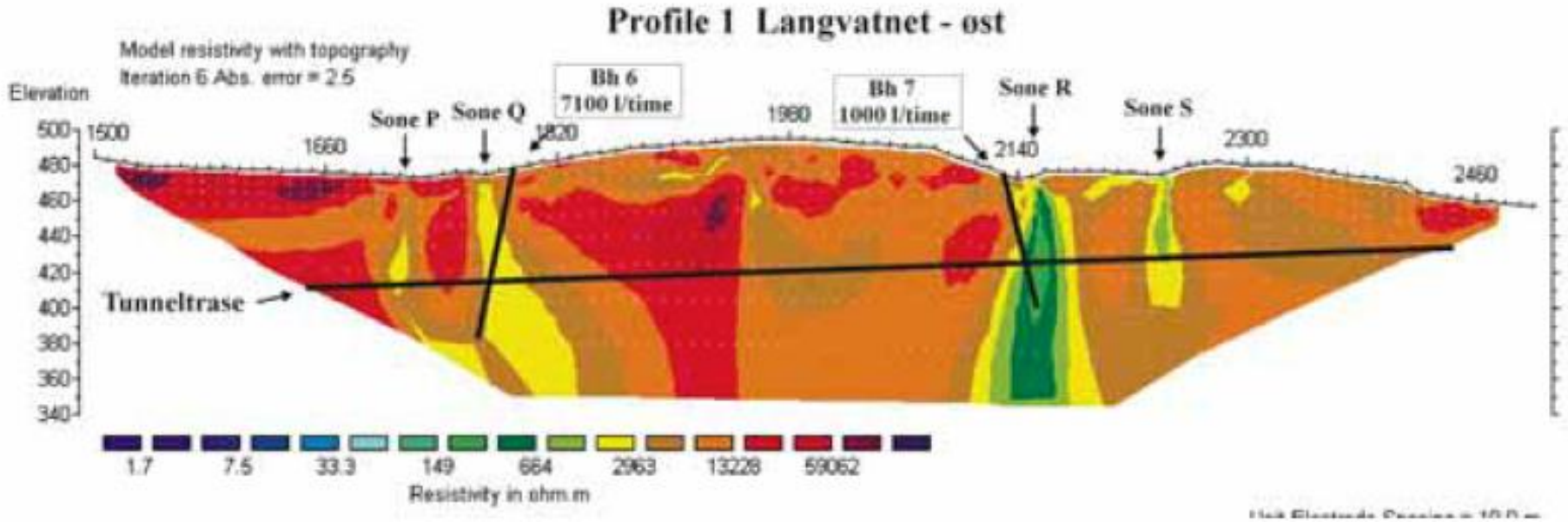
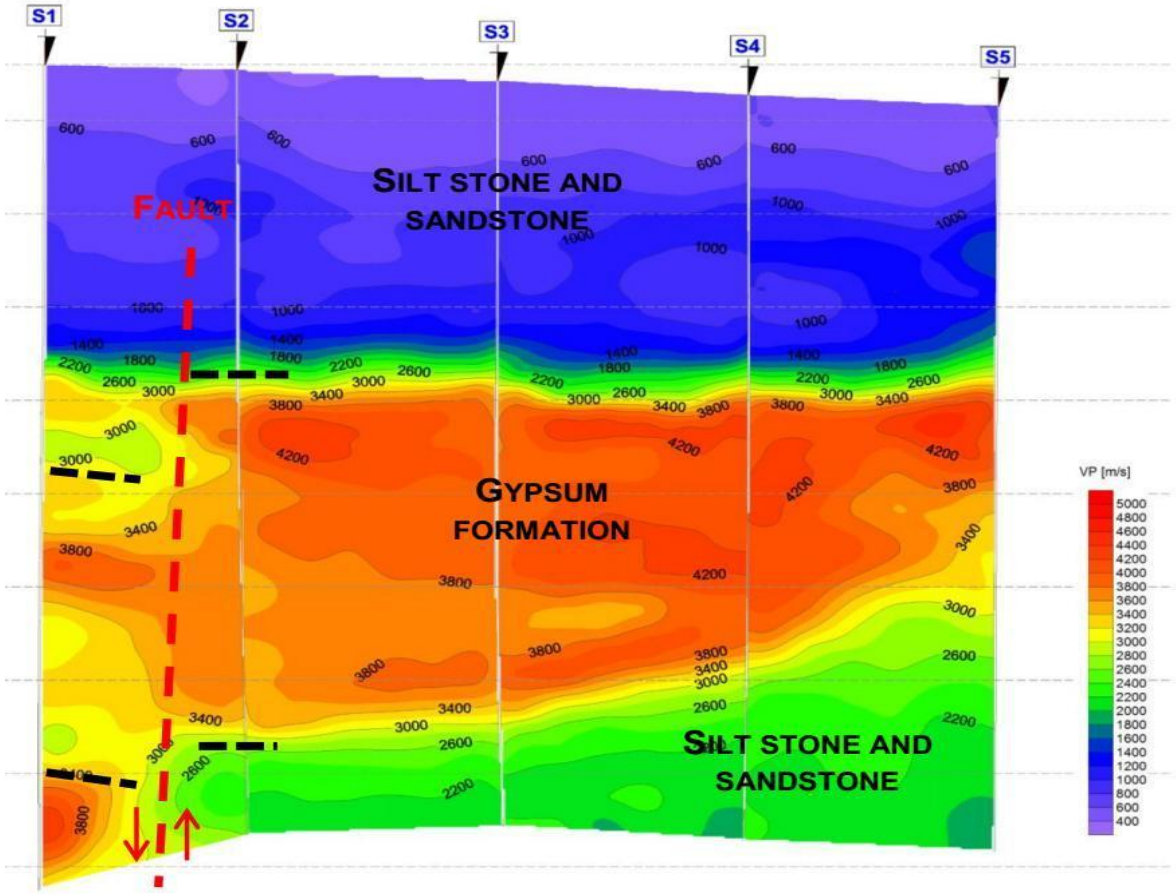



*Figure 4 Resistivity profile from a section of the Lunner tunnel. Zones of low resistivity are further examined by borehole logging.*

## Seismic (Sonic) Tomography

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

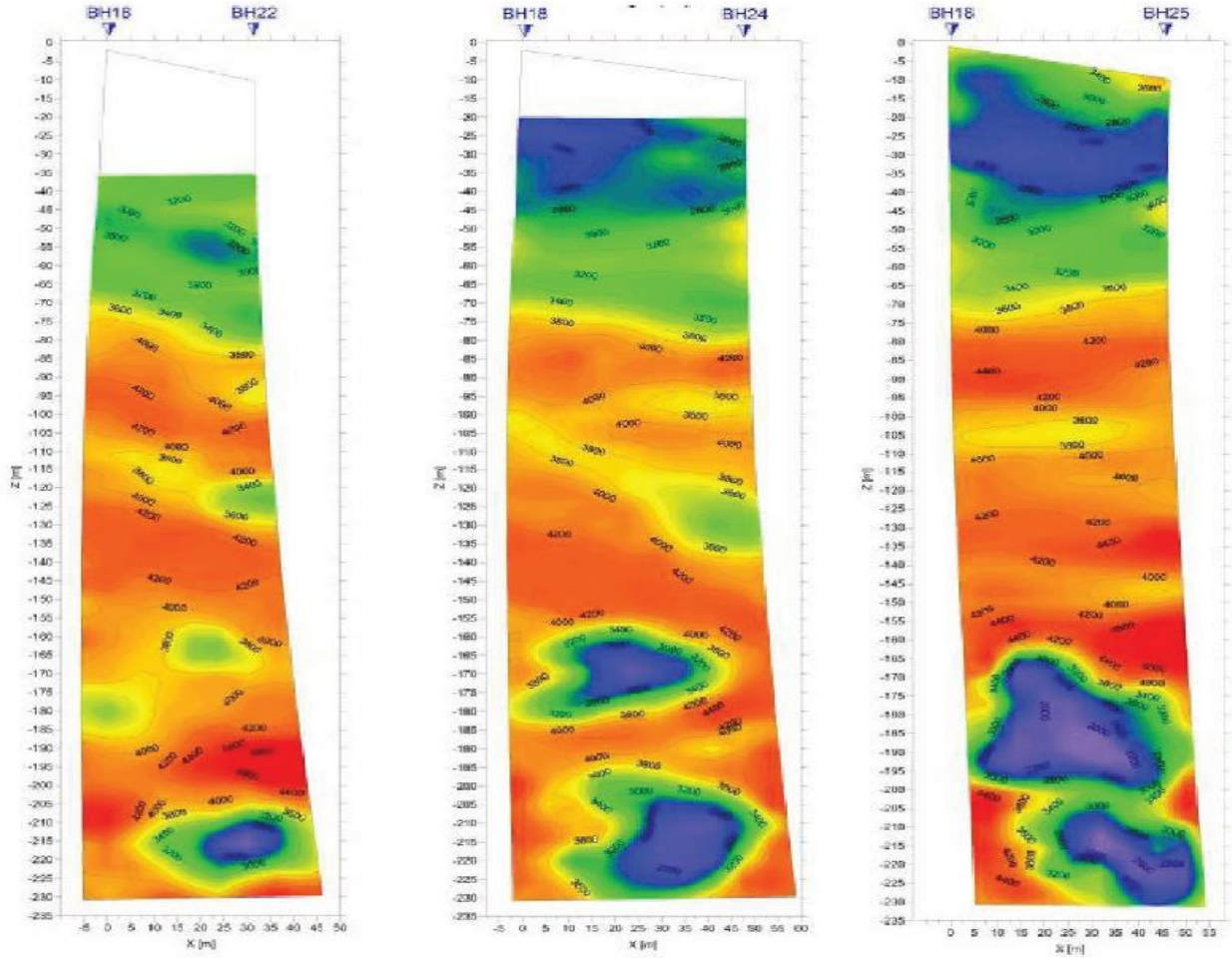



November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

## International Conference on Climate Change Resilience and Sustainability in Tunneling and Underground Space

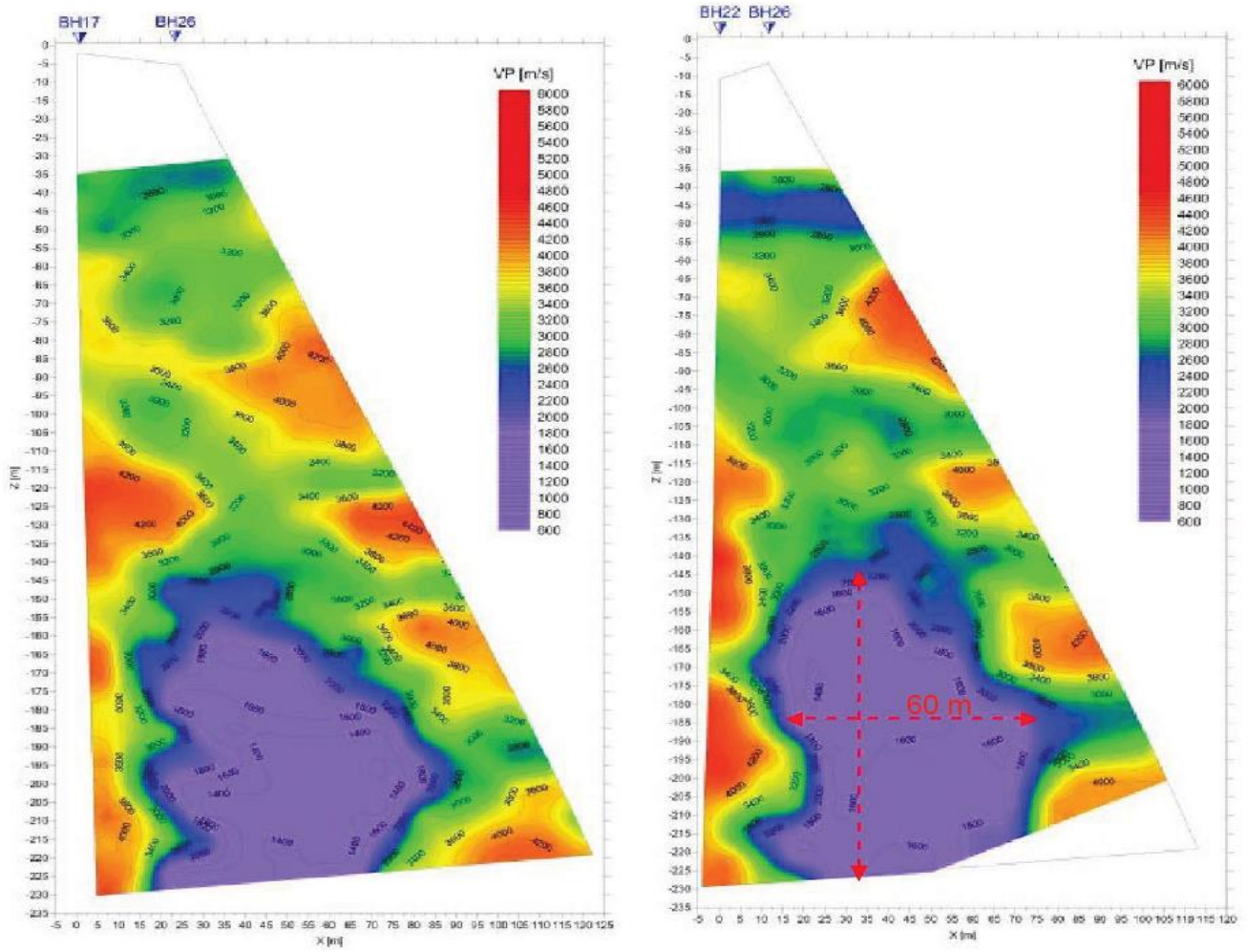
ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION




November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

## International Conference on Climate Change Resilience and Sustainability in Tunneling and Underground Space




November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

## MASW/ ReMi

## Seismic Reflection

## Magneto Telluric

## Ground Penetrating Radar

## Other…

November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

# Execution Stage

November 22-23, 2023, Mumbai, India

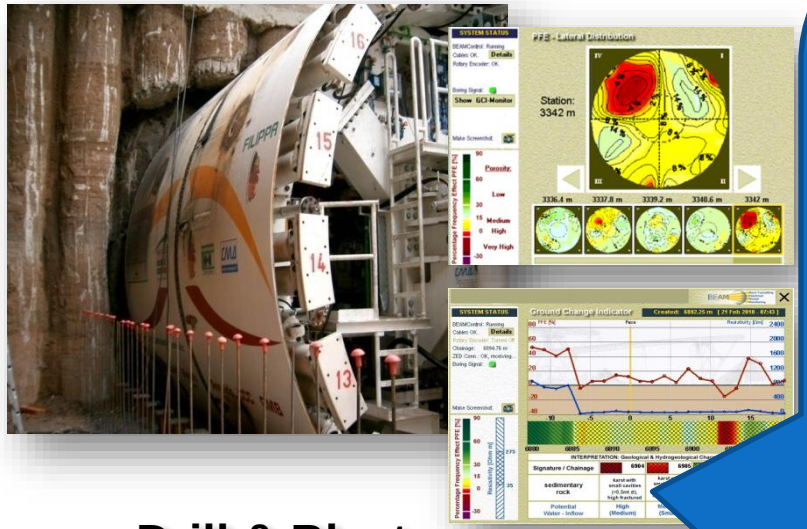
# BEAM®
# Bore-tunnelling Electrical Ahead Monitoring

*Real-time Ground Prediction While TBM Boring*

International Conference on
Climate Change Resilience and Sustainability in Tunneling and
Underground Space

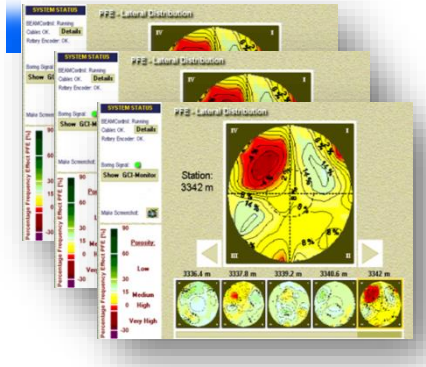
BEAM
Bore-tunnelling Electrical Ahead Monitoring

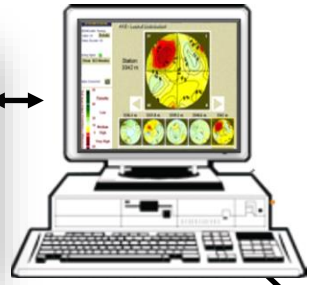
**TBM**




**Drill & Blast**


Most efficient and cost effective is the use for TBM ahead prediction because of the **automatic, continuous and non-invasive data acquisition, processing, evaluation, interpretation and documentation in real time without hindrance or stopping of TBM operation**.



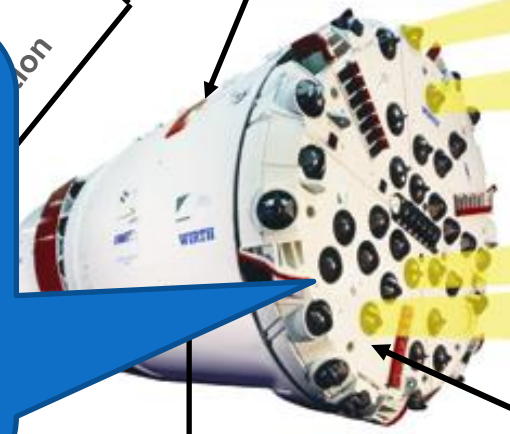


remote access

**A1 (+)**
**guard electrode**
(e.g. shield, cutter head, armed lining)

current beam

**The focused-electrical system comprises the measuring electrode A0 which uses for the Integral mode the rotating and forward moving cutter head which therefore is well coupled to the face (1D forefield exploration).**



inside or outside the tunnel)

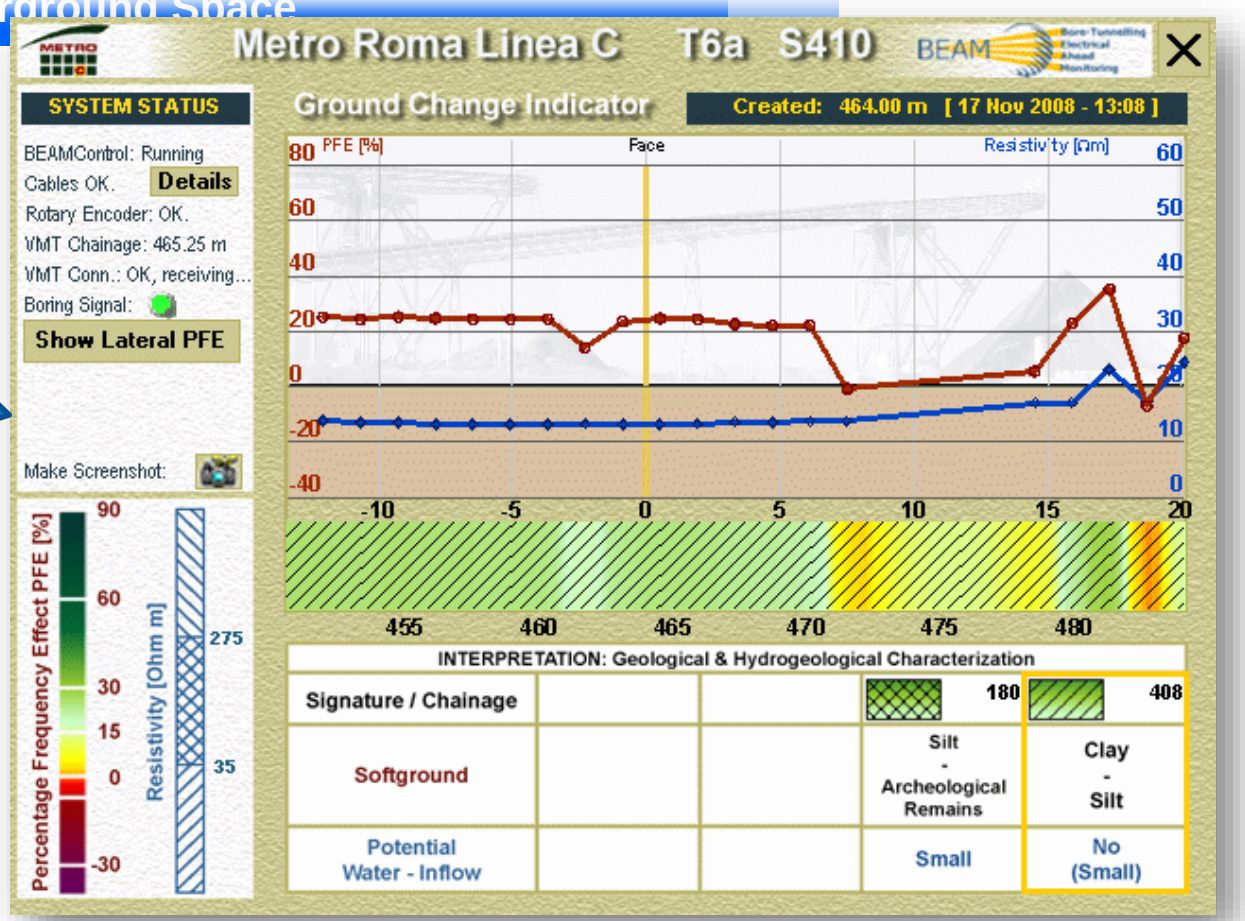
**A0 (+) measuring electrode**
(e.g. cutter head, excavation tools)


**Automation:**
guidance system

**BEAM unit** (placed in operator cabin)

# Visualisation BEAM INTEGRAL (Animation)

This is a fast motion animation of a BEAM prediction during TBM drive of Rome Metro Line C. Different ground changes have been detected and characterized by various geoelectrical classes.




**System:** BEAM-SCAN inclusive INTEGRAL
**TBM type/supplier:** 4 EPB-TBMs Herrenknecht, each about 6.7 m boring diameter
**Geology:** gravel/sand, clay/silt and pyroclastics
**Exploration targets:** water-and air-filled cavities, archaeological remains


Publishing of BEAM results with kindly permission by METRO C

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

# QC/ Maintenance Stage

November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

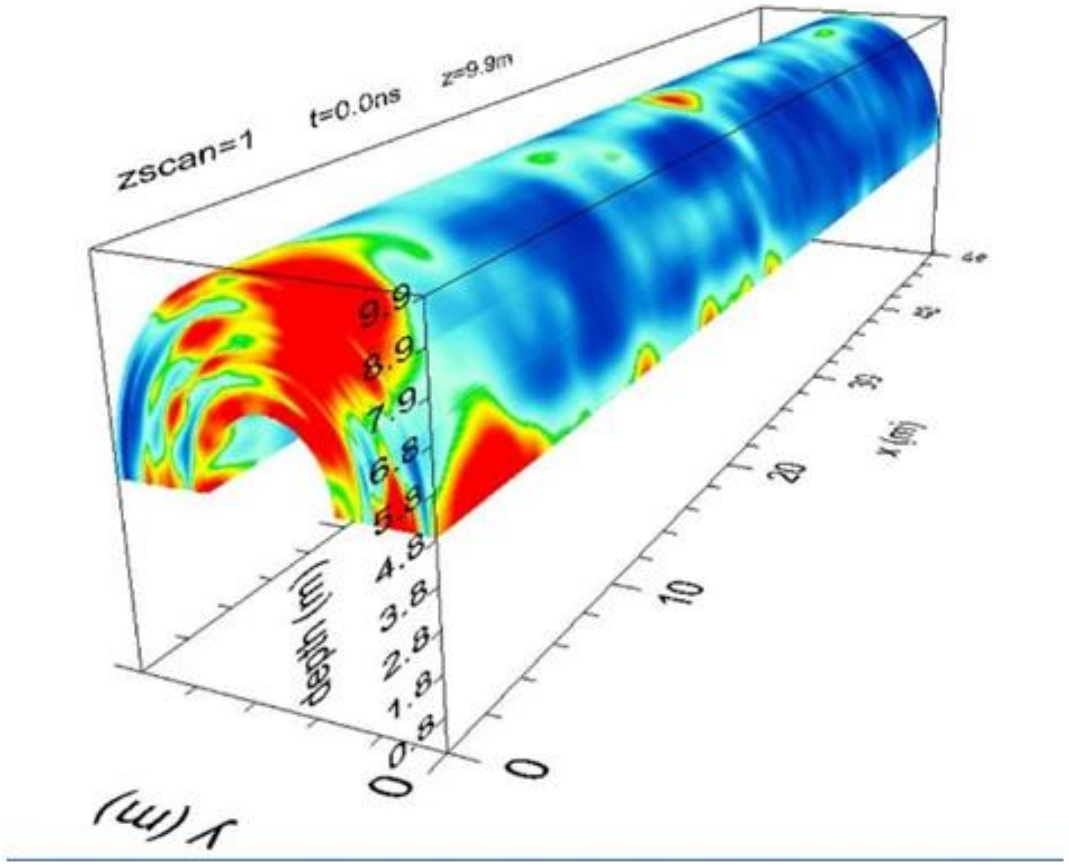
**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION



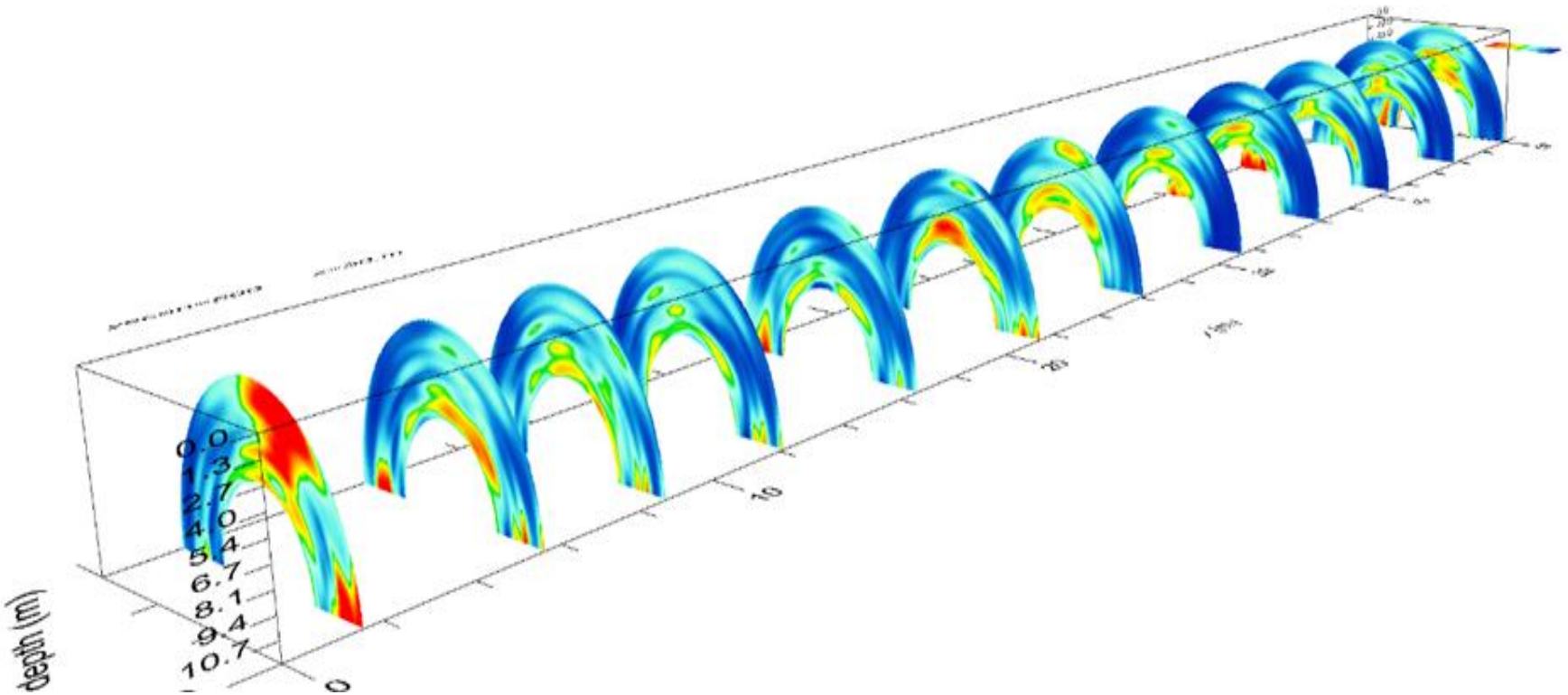

November 22-23, 2023, Mumbai, India

PARSAN

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION




November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

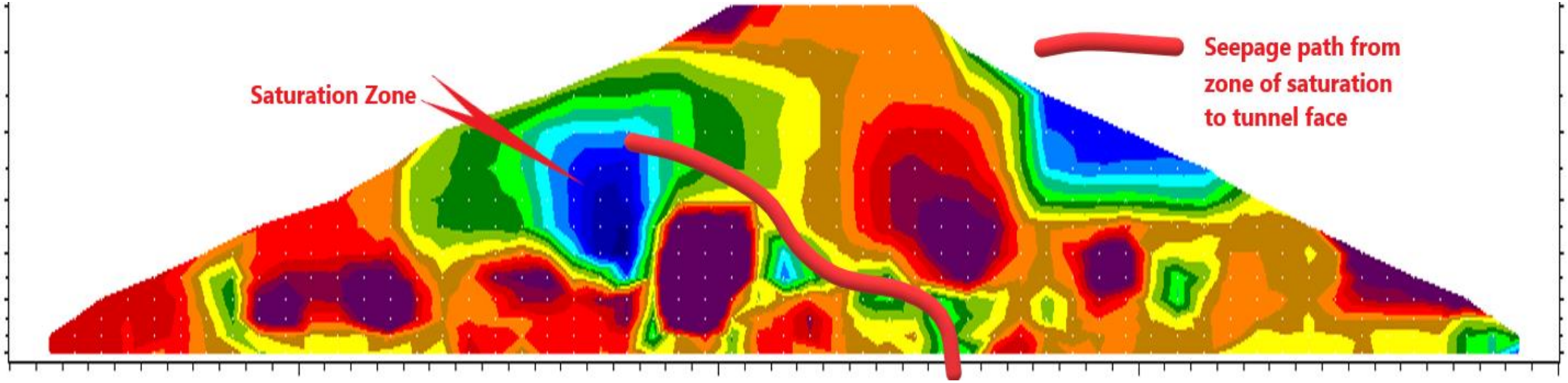
**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**


November 22-23, 2023, Mumbai, India

# Tunnelling Asia' 2023

**International Conference on**
**Climate Change Resilience and Sustainability in Tunneling and Underground Space**

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION




November 22-23, 2023, Mumbai, India

## Limitations & Reasons for Failures?

- Inadequate Planning and Survey Design
- **Wrong tool selection**
- Method lacking desired resolution
- Geology ignored
- **Only single tool used**
- Technological Failures
- Data Processing & Interpretation Errors

## Conclusions:

- Engineering geophysics provides valuable and continuous information for the planning and execution of tunnel & underground projects.
- The application of geophysical methods in addition to usually applied geological and geotechnical exploration is necessary to achieve accurate and continuous models of the subsurface in a short time schedule
- To achieve optimum benefit from geophysical investigations it is necessary to apply these methods:
  - After intensive discussions between geologists, engineers and geophysicists
  - At an early stage of the project.
- The combination of different methods—geophysics, geology, and geotechnics as well as the so-called joint interpretation techniques— will be of essential importance.
- **Increased safety….decreased risk**

# Thanks for your attention

**Dr. Sanjay Rana**

**sanjay@parsan.biz**

**+91-9811168288**