Briefing and Dialogue Session with BCA on Geophysical Survey For Piling in Limestone with Cavities

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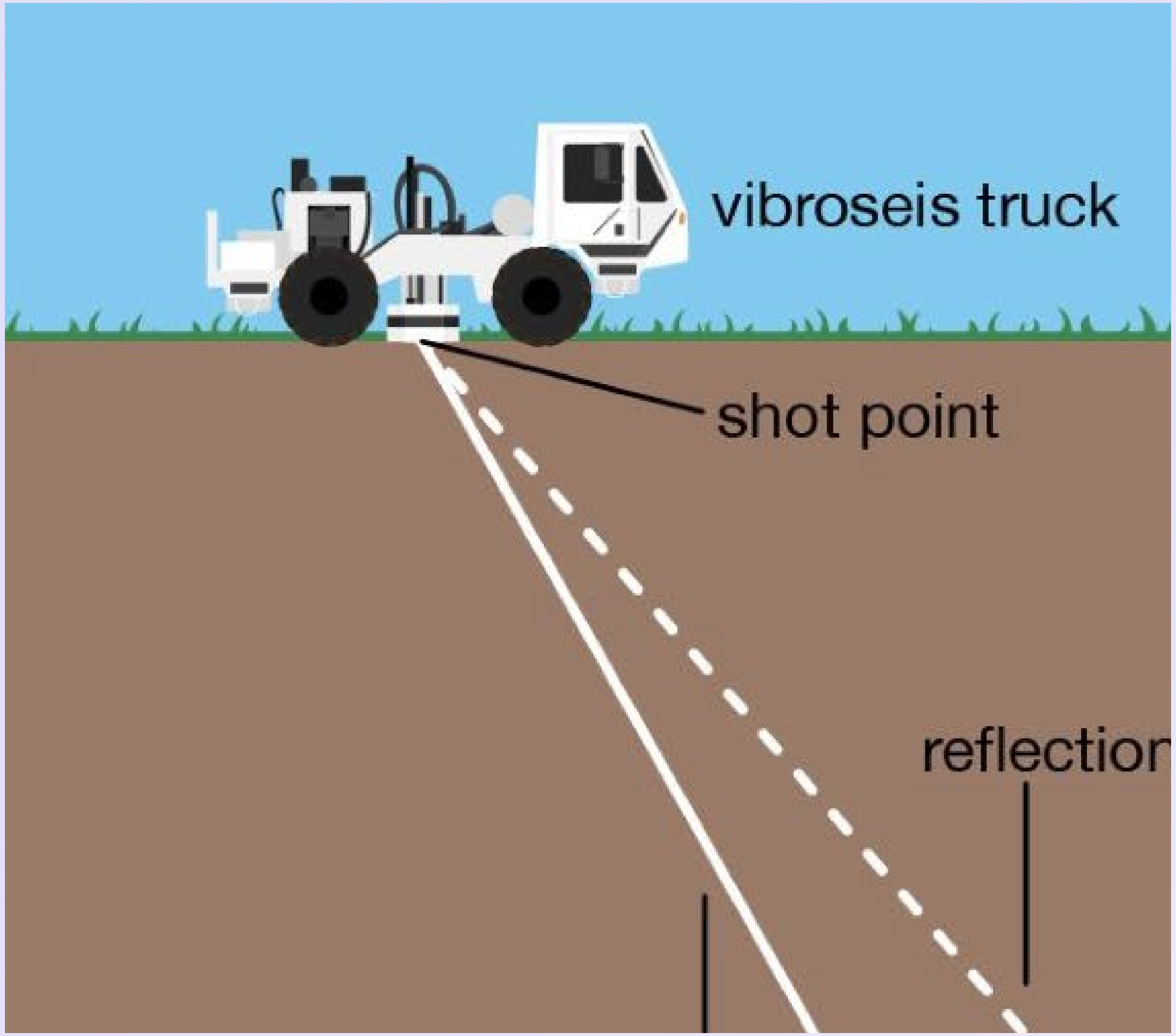
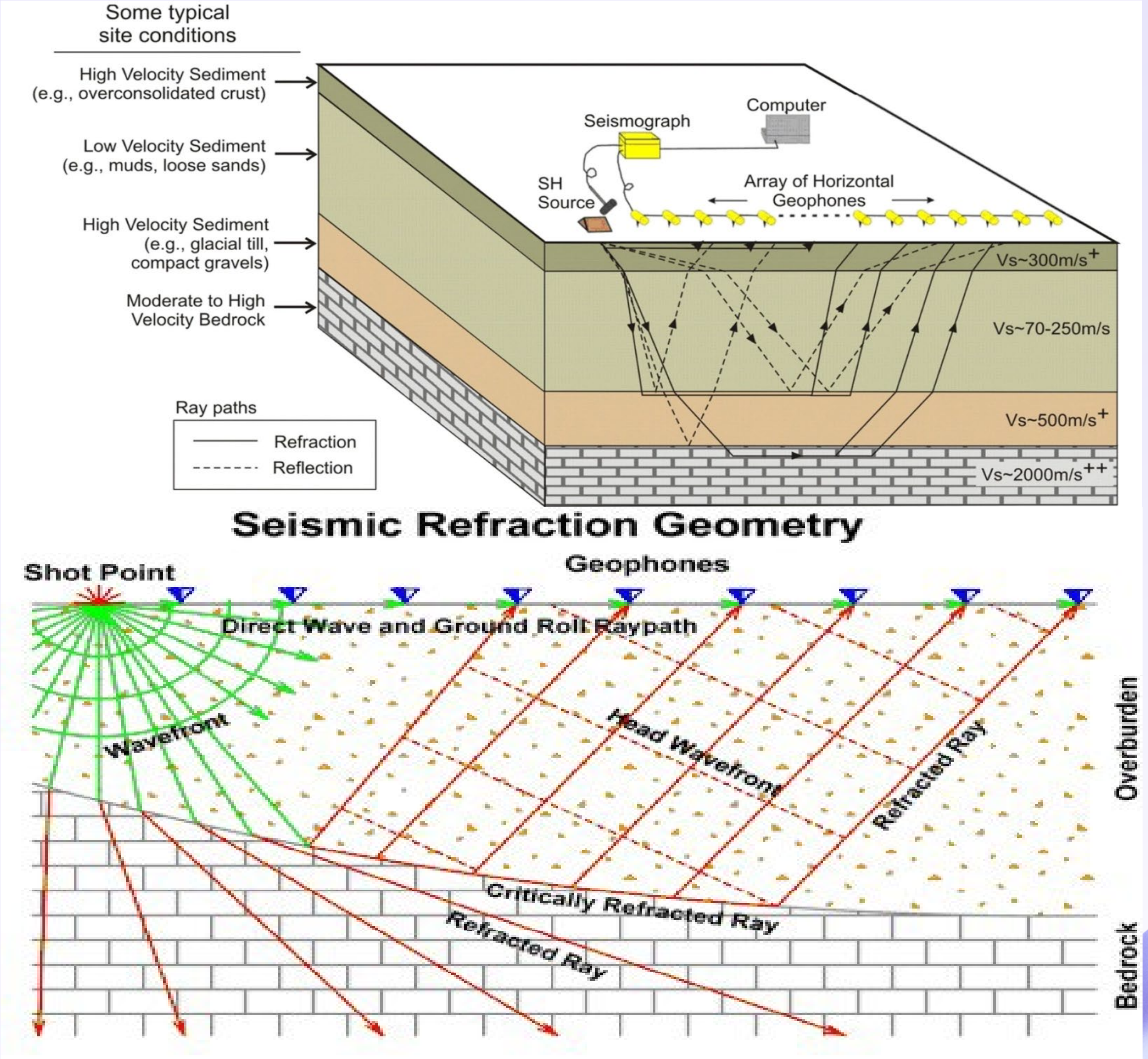
1.1 Introduction to Geophysical Exploration Methods: Refraction





Introduction to Geophysical Exploration Methods: Refraction

Principle

Geophysical refraction methods rely on the propagation of seismic waves through the subsurface. When seismic waves encounter an interface between layers of different seismic velocities, they are refracted according to Snell's Law. By analyzing the travel times of these refracted waves, it is possible to infer the depths and velocities of subsurface layers.

Applications:

1)To investigate depth of overburden;

2)To determine velocity of soil & rock mass

3)To determine bedrock quality (as indicated by seismic velocity);

4)To detect width and location of low velocity zone (weakness zone) in the bedrock

Advantages and Disadvantages

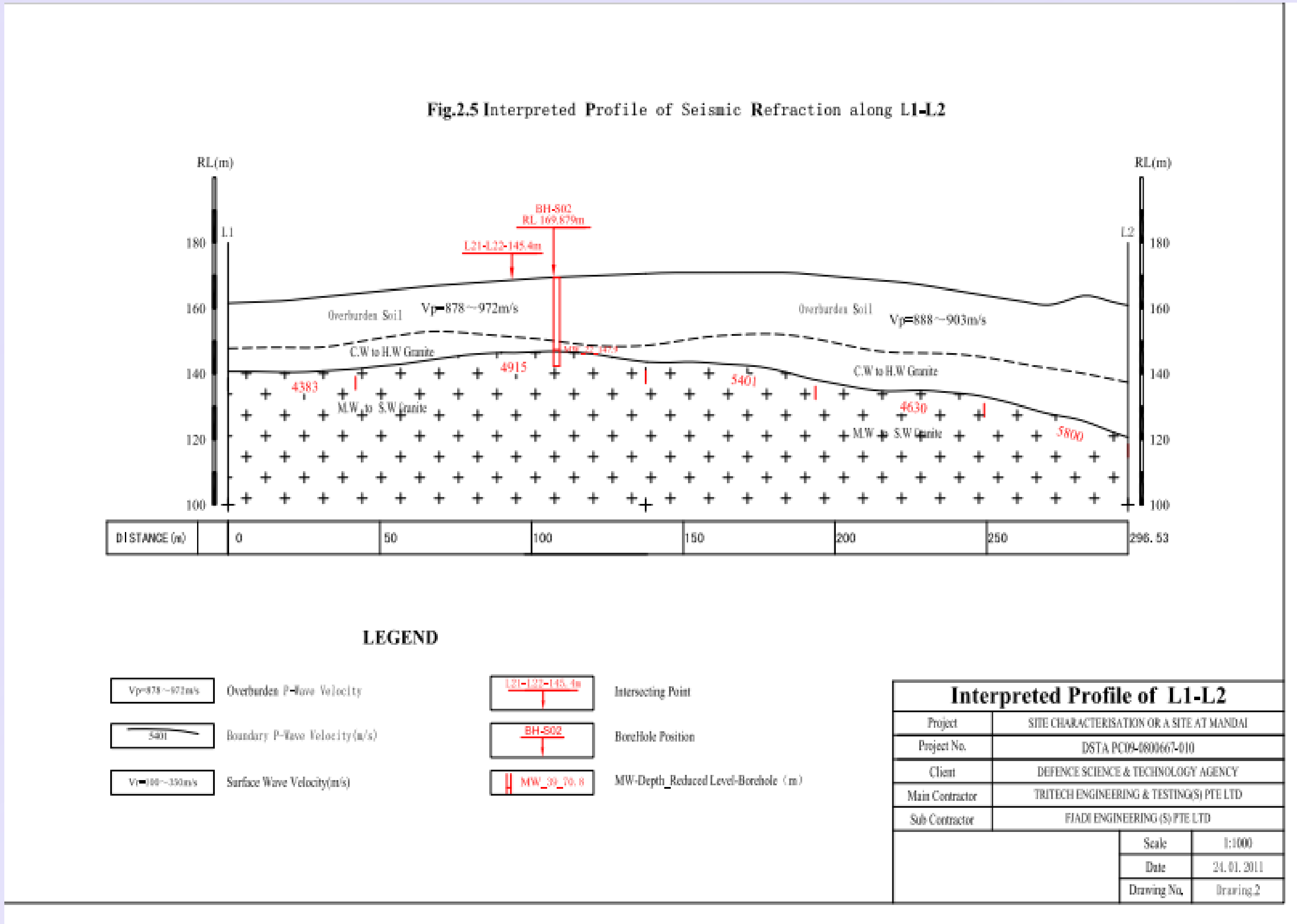
Effective for shallow subsurface investigations.
Can provide high-resolution information about layer depths and velocities.

Limited depth penetration, typically up to several tens of meters. Depth <35 meters
Vl (lower layer)>Vu (Upper layer)
Geophone array length greater than **4-5 times the depth** of objective
Less effective in areas **with complex geology or high levels of noise.**

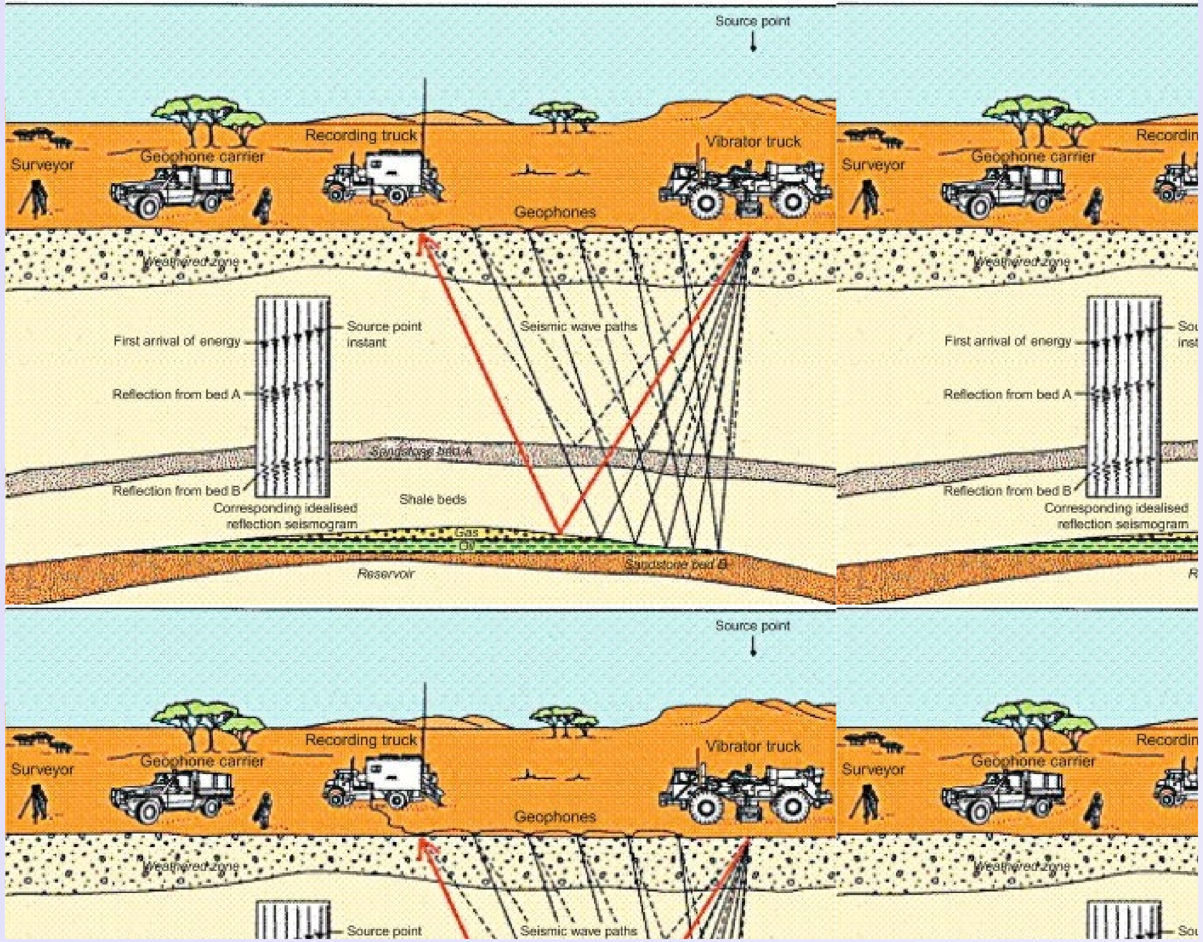
Results Presentation

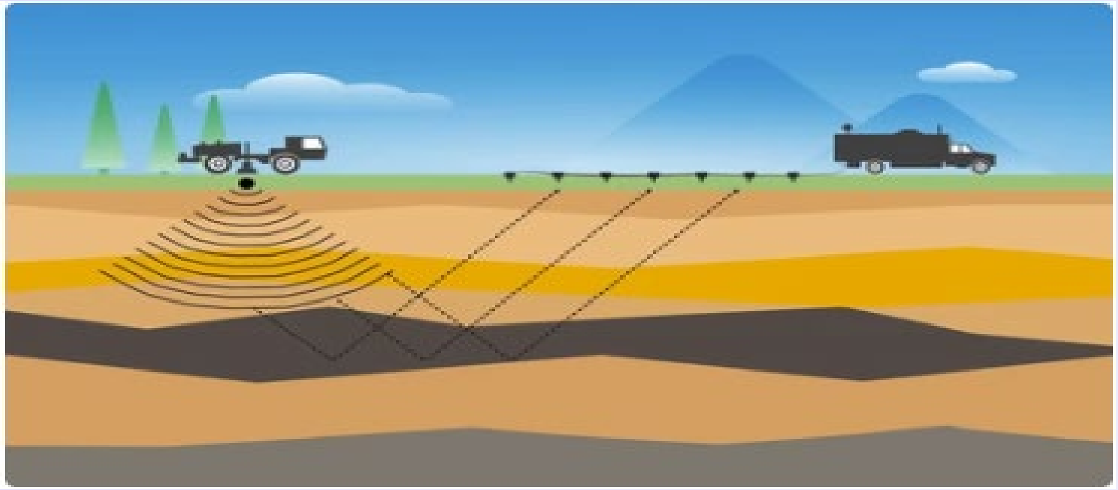
Travel-time curves: Graphs showing the travel times of seismic waves versus the distance from the source. These curves help identify the velocities of different subsurface layers.
Velocity models: Cross-sectional views that display the seismic velocities of different layers. These models can show the depth and thickness of geological strata.
Layer depth profiles: Diagrams illustrating the depths of various geological layers based on the refraction data.

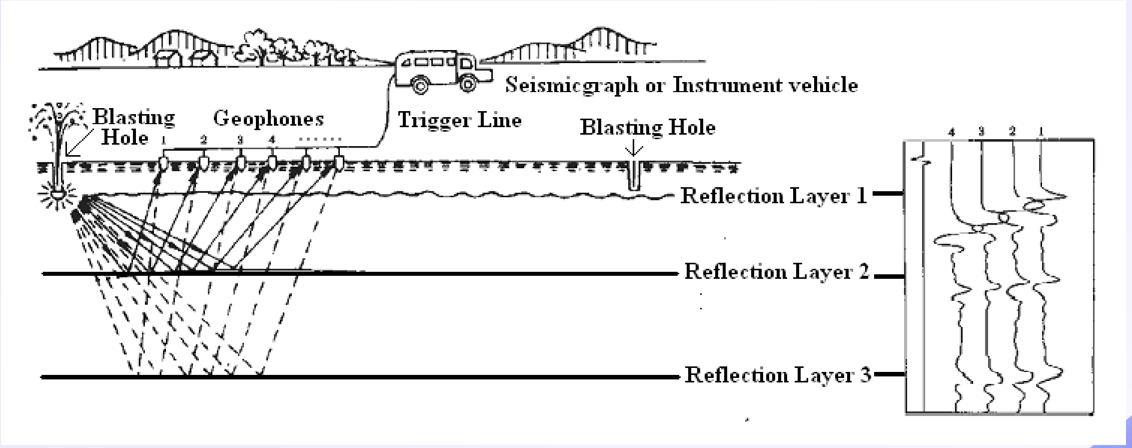
Results from refraction surveys and site photos



1.2. Introduction to Geophysical Exploration Methods: Reflection







Introduction to Geophysical Exploration Methods: Reflection

Principle

Geophysical reflection methods utilize seismic waves to image subsurface structures. When seismic waves encounter boundaries between materials with different acoustic impedance, a portion of the wave energy is reflected back to the surface. By recording and analyzing the travel times and amplitudes of these reflected waves, geophysicists can create detailed images of subsurface layers and features.

Applications:

1)To classify geological formations;
2)To investigate depth of overburden, weathered rock & bedrock;
3)To detect width and location of fracture zone (weakness zone) in the bedrock;
4)To detect width and location of anomaly (such as cavity) underground

Advantages and Disadvantages

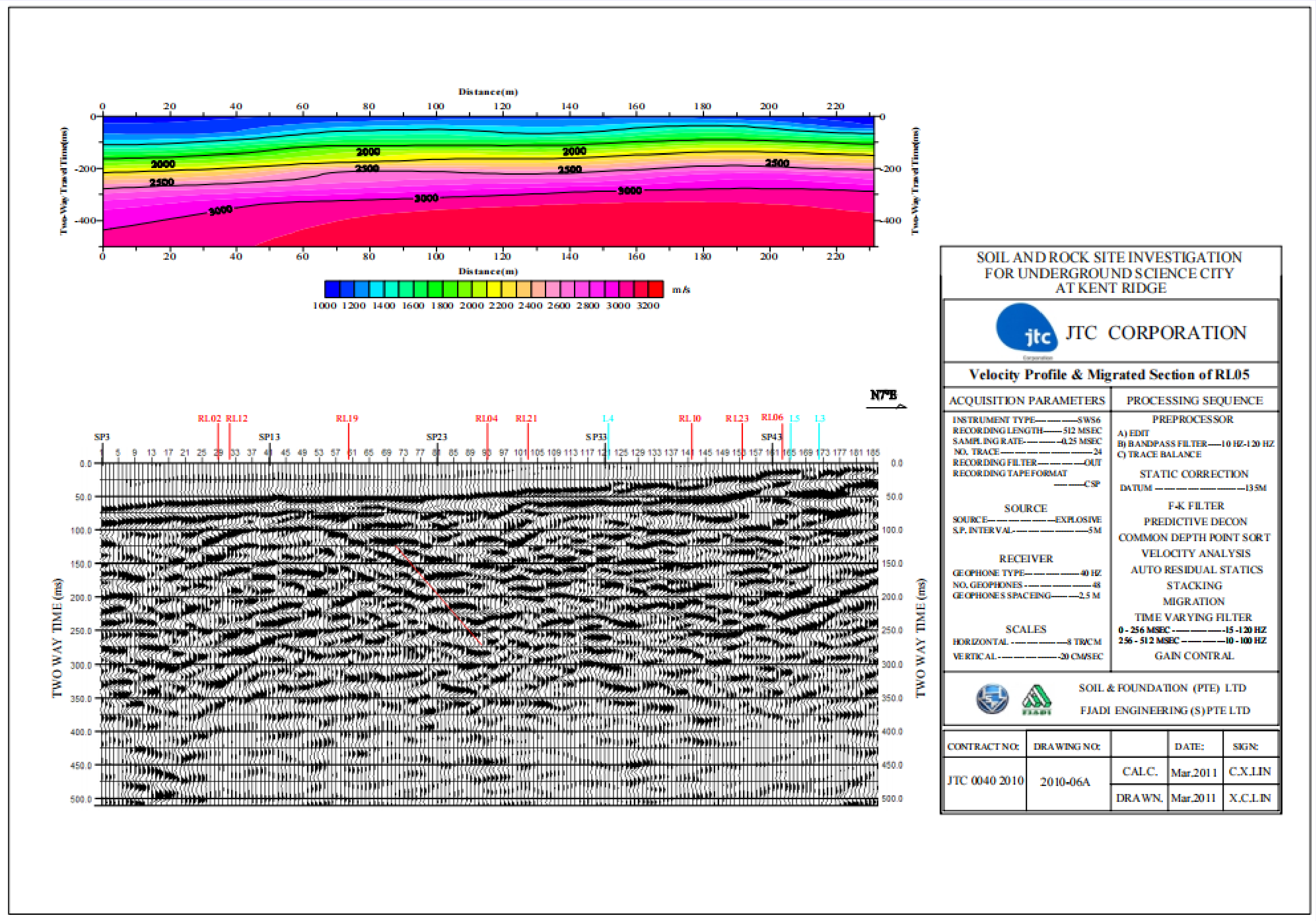
Capable of imaging deep subsurface structures with high resolution.
Provides detailed and continuous profiles of subsurface geology.
Effective for identifying and mapping complex geological features.

More **expensive and time-consuming** than other geophysical methods.
Requires sophisticated data processing and interpretation.
Sensitive to noise and requires good coupling of seismic sources and receivers. **Depth >15~20m.**

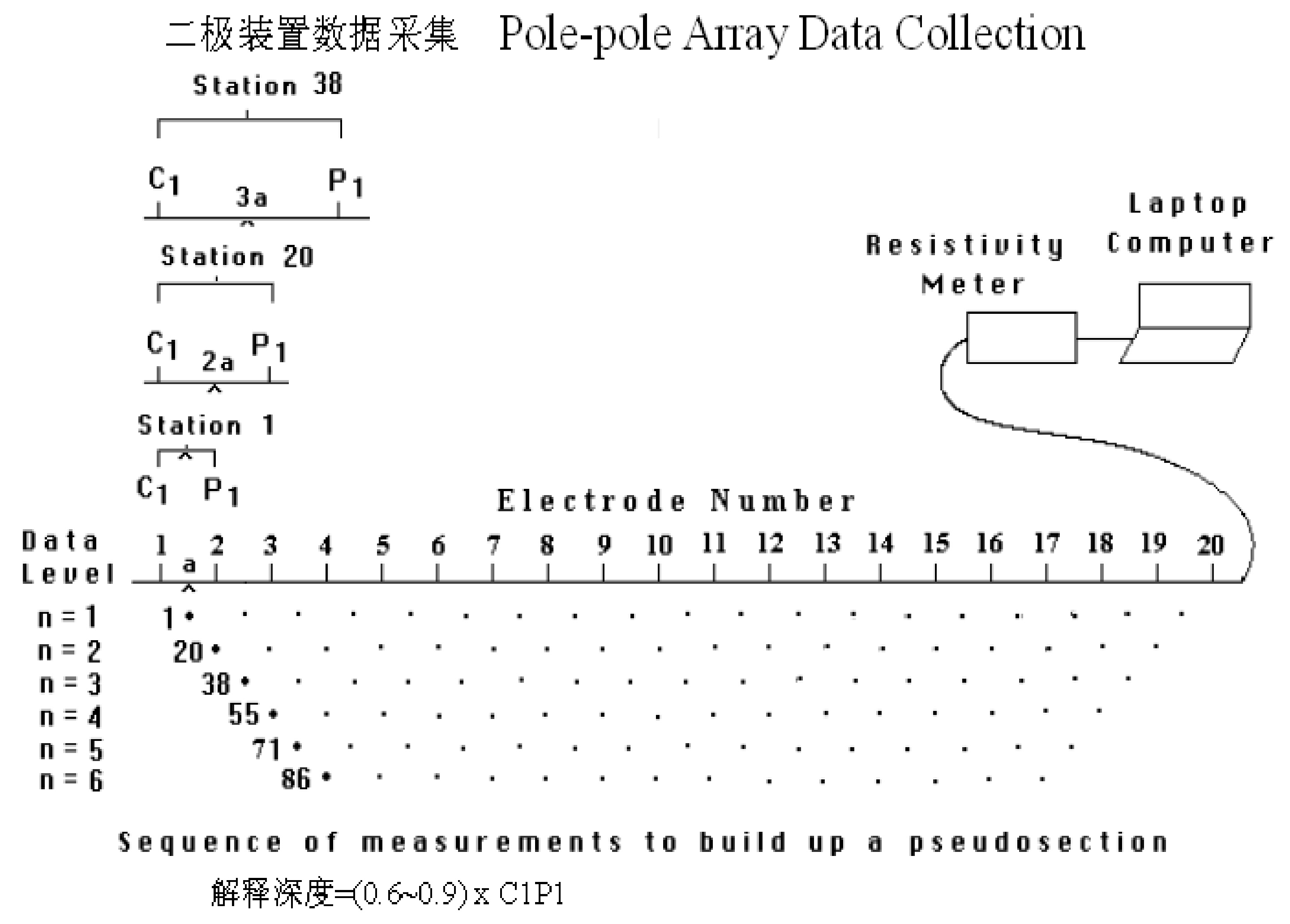
Results Presentation

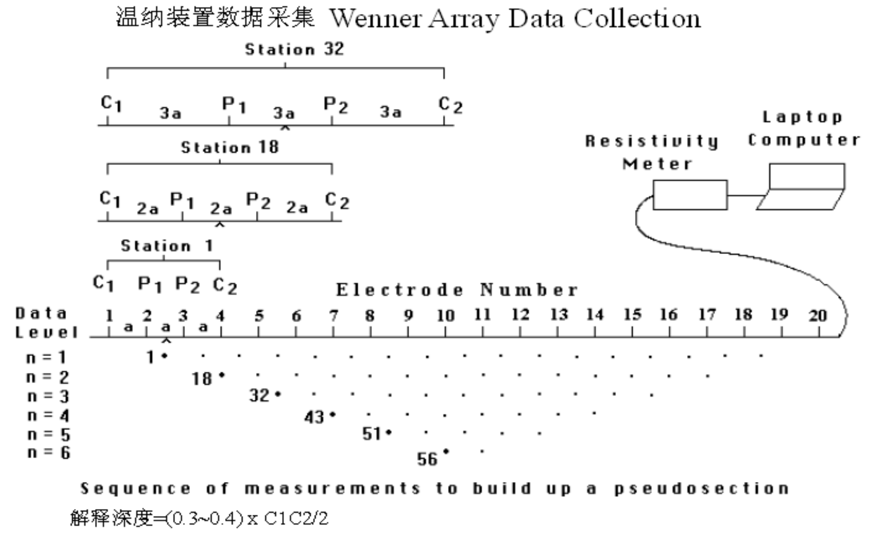
Seismic reflection profiles: Cross-sectional images displaying subsurface reflections, revealing the geometry and continuity of geological layers.
Time-depth sections: Diagrams converting travel times of reflected waves into depths, helping to visualize the subsurface in a more intuitive manner.
Amplitude maps: Visual representations of the strength of reflected waves, which can indicate variations in rock properties and fluid content

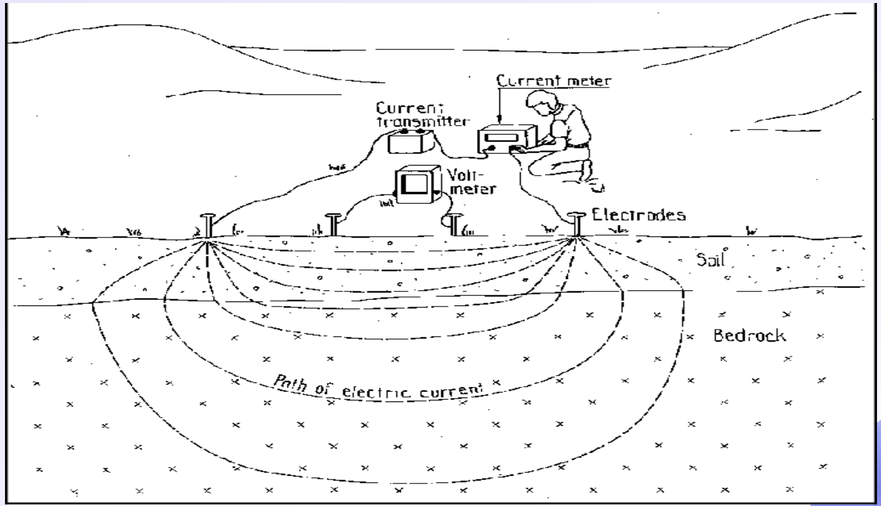
Results from reflection surveys and site photos



1.3. Introduction to Geophysical Exploration Methods: High Density Electrical Method







Introduction to Geophysical Exploration Methods: High Density Electrical Method

Principle

The High Density Electrical Method is a geophysical technique that measures the electrical resistivity of subsurface materials. It involves **injecting electrical current** into the ground through electrodes and measuring the resulting voltage differences. By doing this across many closely spaced points, a detailed resistivity profile of the subsurface can be created. The variations in resistivity correspond to different types of materials or conditions, such as soil, rock, or the presence of water.

Applications:

1)To classify geological formations;
2)To investigate depth of overburden, weathered rock & bedrock;
3)To detect width and location of fracture zone (weakness zone) and fault in the bedrock;
4)To detect width and location of anomaly (such as cavity, boulder) underground

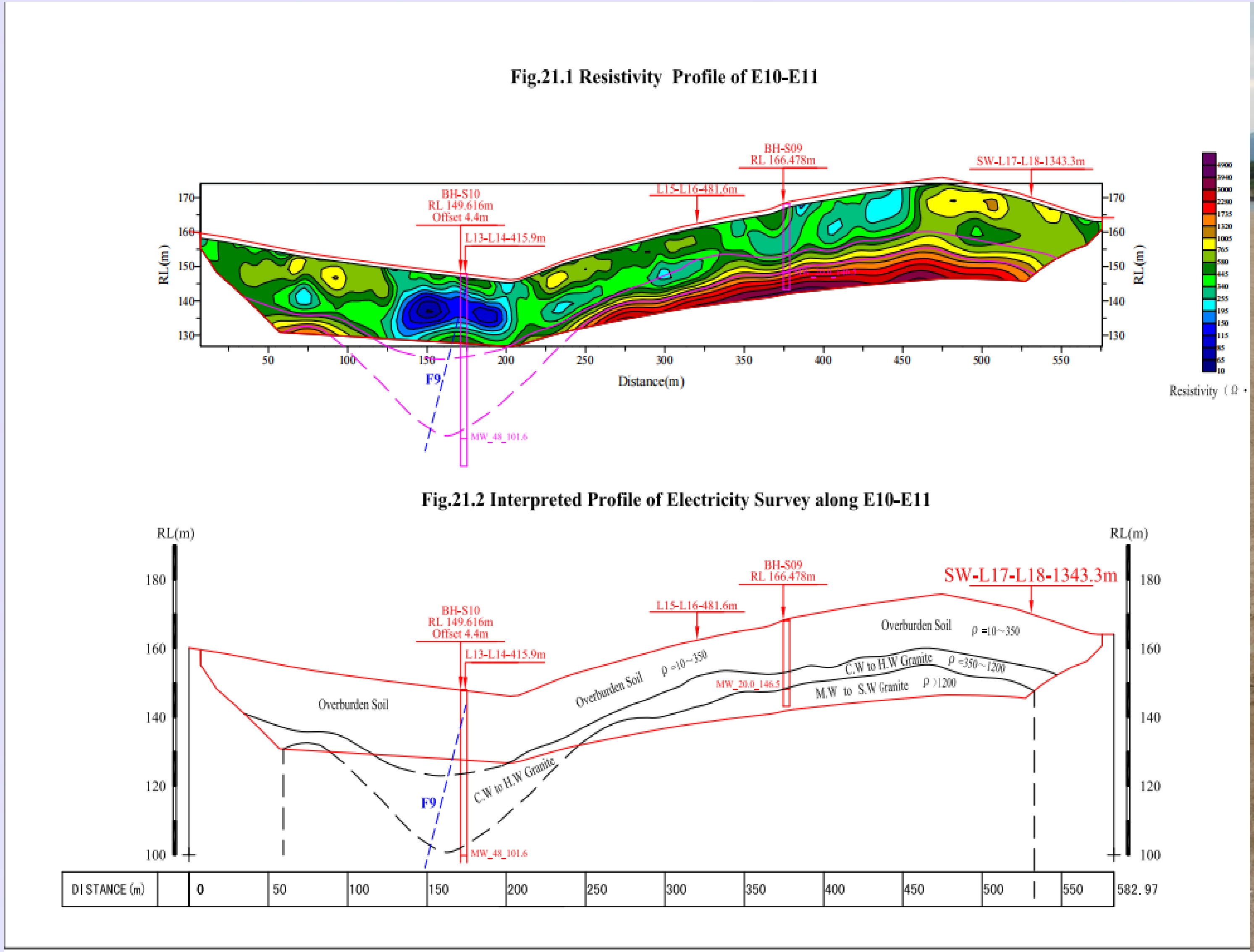
Advantages and Disadvantages

Non-invasive and relatively fast to deploy.
Provides high-resolution images of subsurface resistivity variations.
Capable of detecting a wide range of subsurface features, including small-scale anomalies.
Useful in diverse environments, including urban and rugged terrains.
Sensitive to **surface conditions**, requiring good electrode contact with the ground.
Resistivity measurements can be affected by **temperature, moisture content, and other environmental factors.**
Interpretation of results can be complex, requiring skilled analysis.
Limited depth penetration compared to some other geophysical methods, typically up to tens of meters.

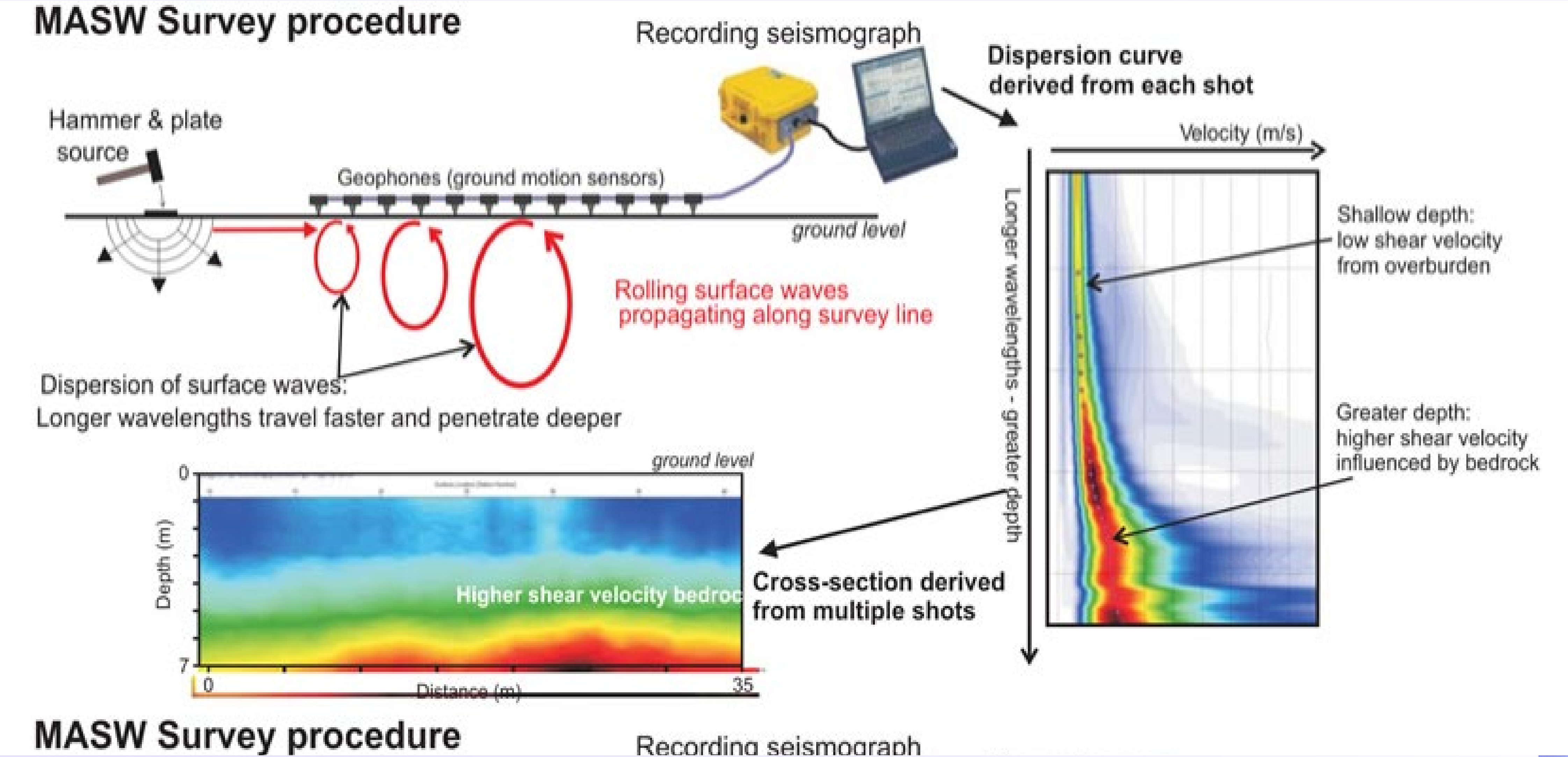
Results Presentation

Resistivity tomograms: 2D or 3D images showing variations in resistivity across the surveyed area. These images help identify different subsurface materials, voids, and other features.
Anomaly maps: Visual representations highlighting areas of interest, such as low-resistivity zones that may indicate water-filled cavities or high-resistivity zones suggesting dry rock or voids.
Cross-sectional profiles: Detailed views of subsurface resistivity variations along specific transects, used to infer geological structures and other features.

Results from reflection surveys and site photos



1.4 Introduction to Geophysical Exploration Methods: Surface Wave



Introduction to Geophysical Exploration Methods: Surface Wave

Principle

Surface wave methods rely on the generation and recording of seismic waves that travel along the Earth's surface. The principle is based on the fact that the velocity of surface waves, particularly Rayleigh waves, is influenced by the mechanical properties of the subsurface layers, such as density, shear modulus, and layer thickness.soil characterization, and geotechnical investigations.

Applications:

1)To classify geological formations;
2)To determine velocity of soil & rock strata;
3)To investigate depth of overburden, weathered rock & bedrock;
4)To detect width and location of low velocity zone (weakness zone) in the bedrock;
5)To detect width and location of anomaly (such as cavity) underground
6)To verify the quality of the soil improvement

Advantages and Disadvantages

Effective for Shallow Investigations: Ideal for studying the upper tens of meters of the subsurface.
Cost-effective: Generally less expensive compared to more invasive techniques.
Rapid Data Acquisition: Data can be collected relatively quickly over large areas.
Limited Depth Penetration:
Complex Data Interpretation:
Influence of Surface Conditions: Results can be affected by **surface irregularities and environmental noise**.

Results Presentation

Dispersion Curves: Graphs showing the relationship between phase velocity and frequency. These curves are crucial for the inversion process to obtain subsurface velocity profiles.
Shear-Wave Velocity Profiles: Vertical profiles displaying the variation of shear-wave velocity with depth, which indicate the stiffness and layering of the subsurface materials.
Seismic Site Classification: Categorization of sites based on shear-wave velocity, which is used in seismic hazard assessment and building code applications.

Results of Surface Wave surveys and site photos

Fig.14.1 Colour-shaded Contours Section of Surface Wave Velocity along SW-2A

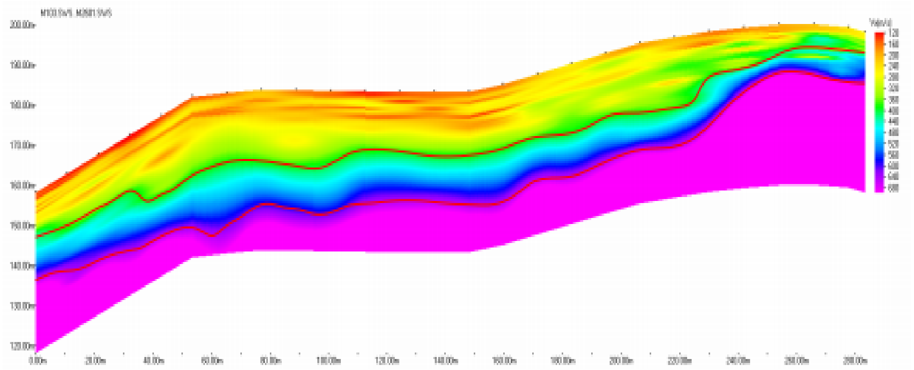


Fig. 14.3 Colour-shaded Contours Section of Surface Wave Velocity along SW-2B

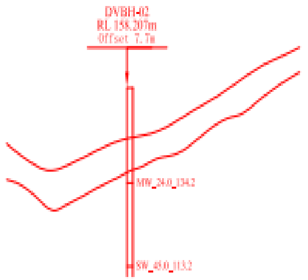


Fig.14.2 Interpreted Profile of Surface Wave Survey along SW-2A

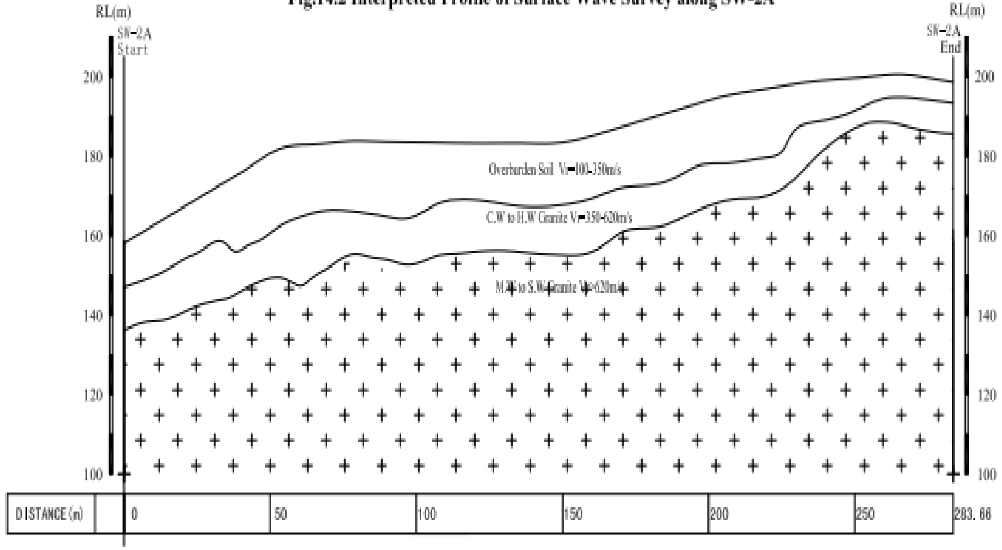
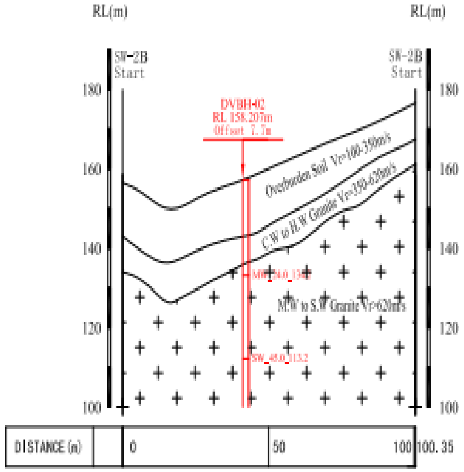
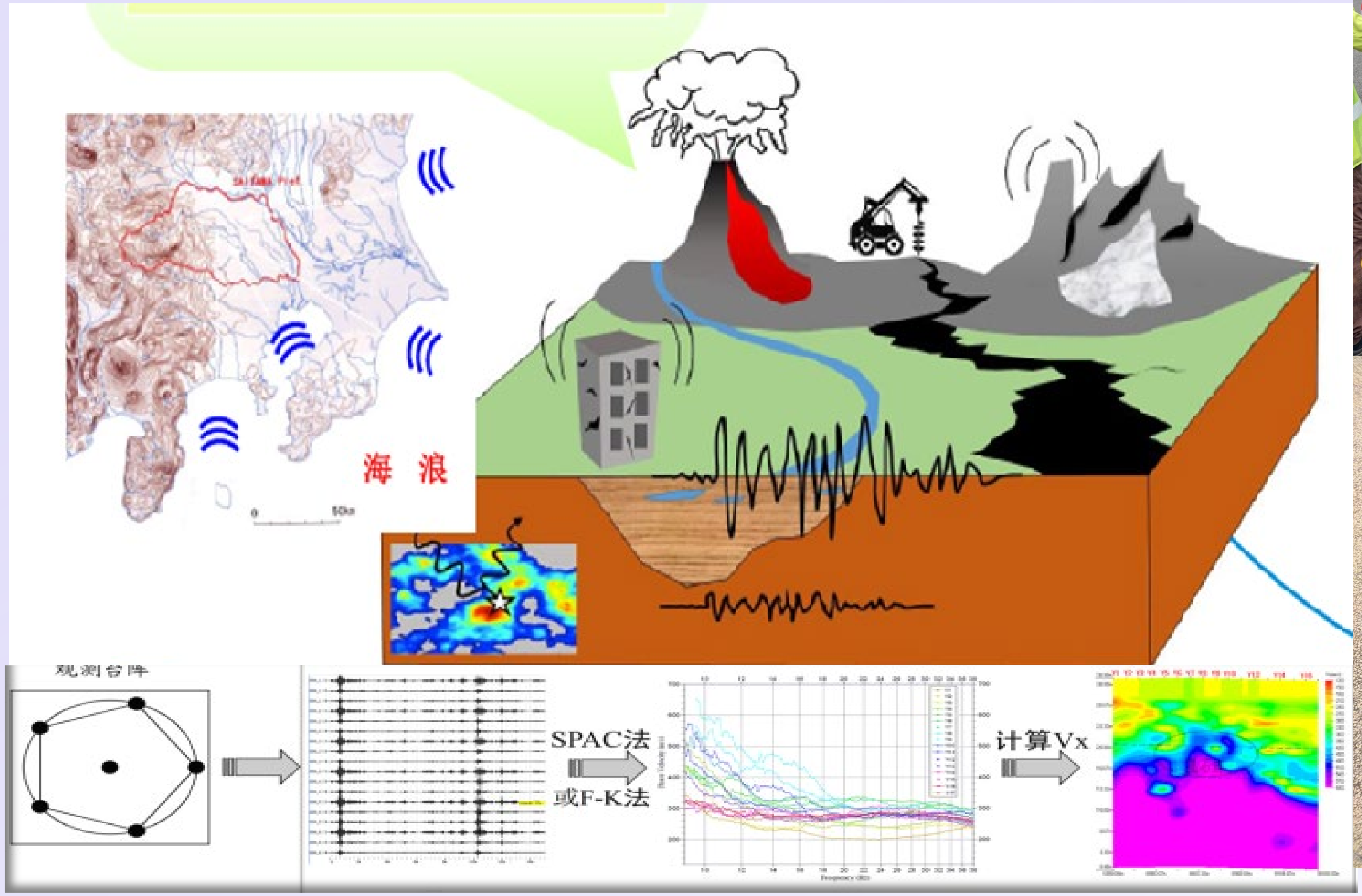


Fig.14.4 Interpreted Profile of Surface Wave Survey along SW-L2B



1.5 Introduction to Geophysical Exploration Methods: Microtremor

The Microtremor geophysical survey is a non-invasive, highly adaptable technique with minimal environmental disruption, suitable for a wide range of applications from shallow engineering studies to deep subsurface investigations.



Introduction to Microtremor Geophysical Exploration Methods

Principle

There is a **natural weak vibration** on the surface of the earth at any time and anywhere, which is referred to as Microtremor or constant Microtremor;
1. Low frequency part (<1Hz): mainly caused by changes in weather, air pressure, waves, tides and other natural phenomena,
2. High frequency part (>1Hz): human life and production activities including vehicle and mechanical vibration,
To extract the dispersion information of surface waves from the collected micro motion data and infer the velocity structure of the underground medium.

Applications:

Boulder, earth cave, karst, and gob detection
Detection of faults, fracture zones, and fissure-dense zones
Detection of underground obstacles such as box culverts, underground passages, etc.
Evaluation of the effectiveness of ground grouting reinforcement
Investigation of foundation toe level
Investigation of underground cable tunnels, sewers, gas, and water pipes

Advantages and Disadvantages

High Accuracy
Non-destructive detection method,
Friendly Surface condition
No effect of electromagnetic interference
No artificial vibration
Large detection depth, from few meters to thousands meters

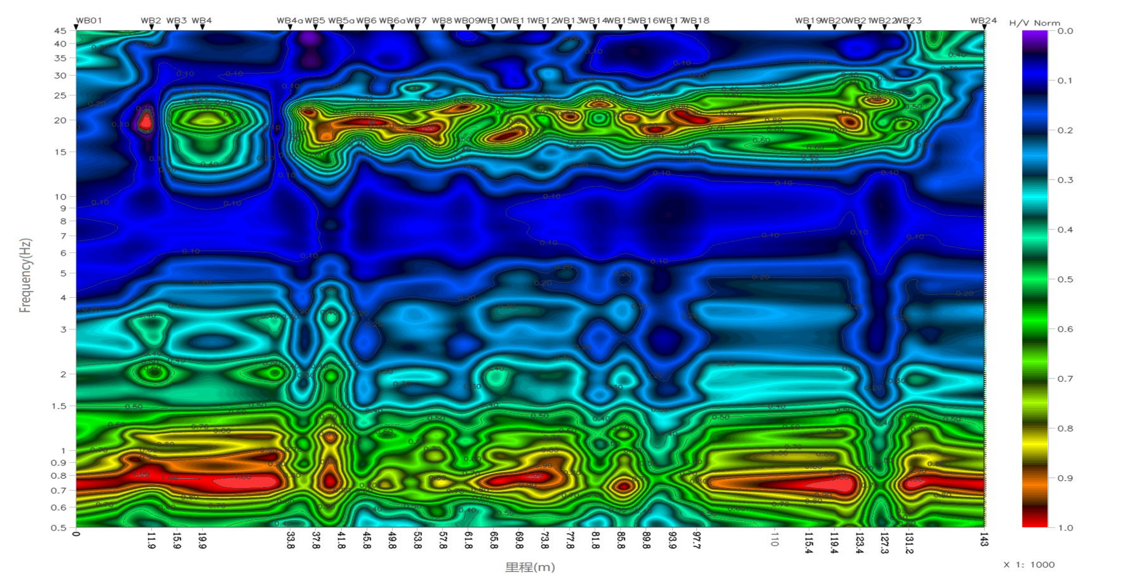
Data processing and interpretation can be complex, requiring specialized knowledge and experience.

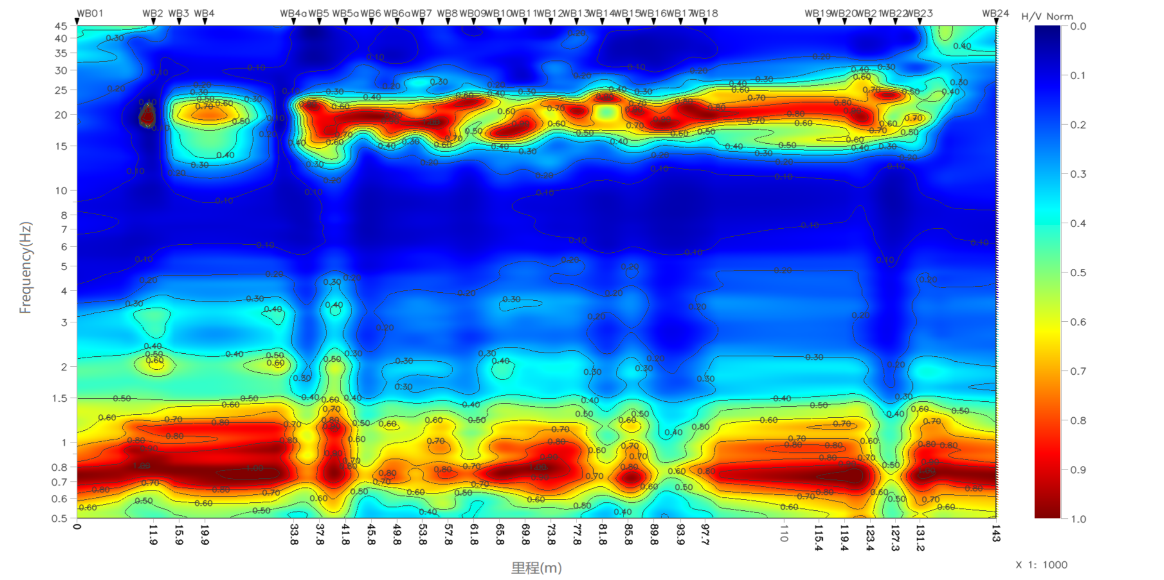
Results Presentation

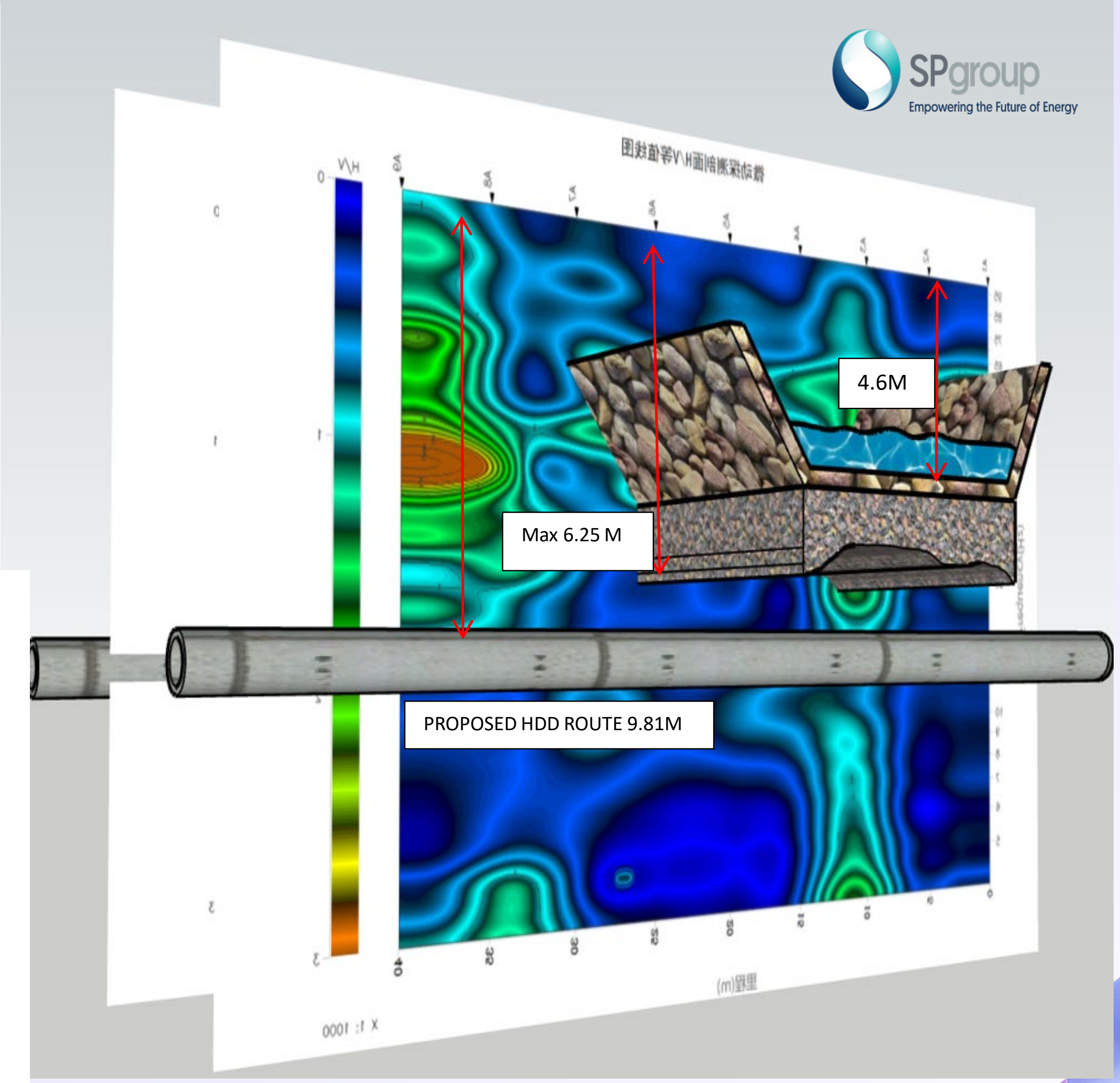
Dispersion Curves: Graphs showing the relationship between phase velocity and frequency. These curves are crucial for the inversion process to obtain subsurface velocity profiles.
H/V Spectral Ratio Curves: One of the primary outputs is the horizontal-to-vertical (H/V) spectral ratio curve, This curve is used to identify resonance frequencies, which are indicative of subsurface layers.

Phase Velocity (Vr) Profiles:

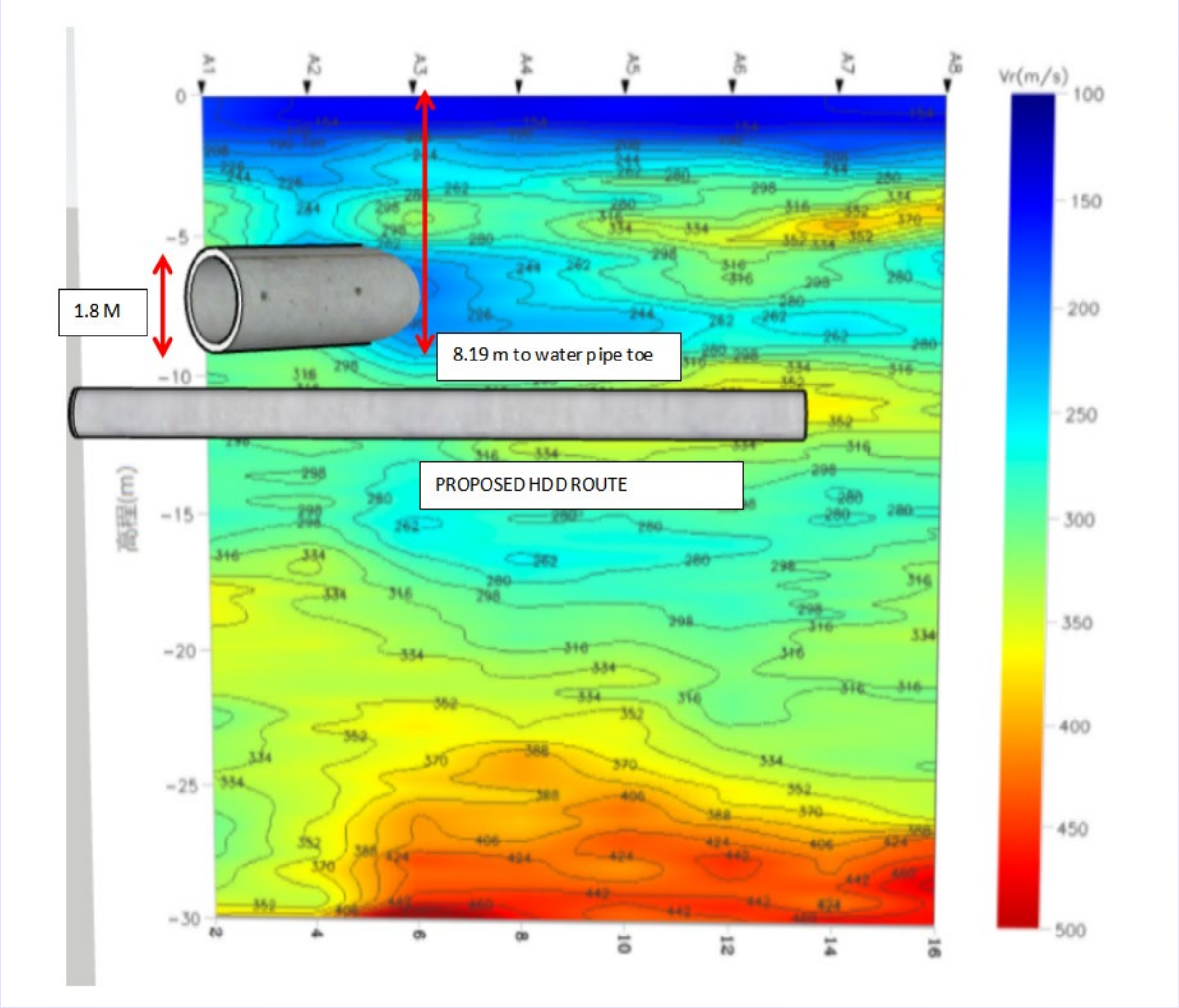
Results of Microtremor and site photos

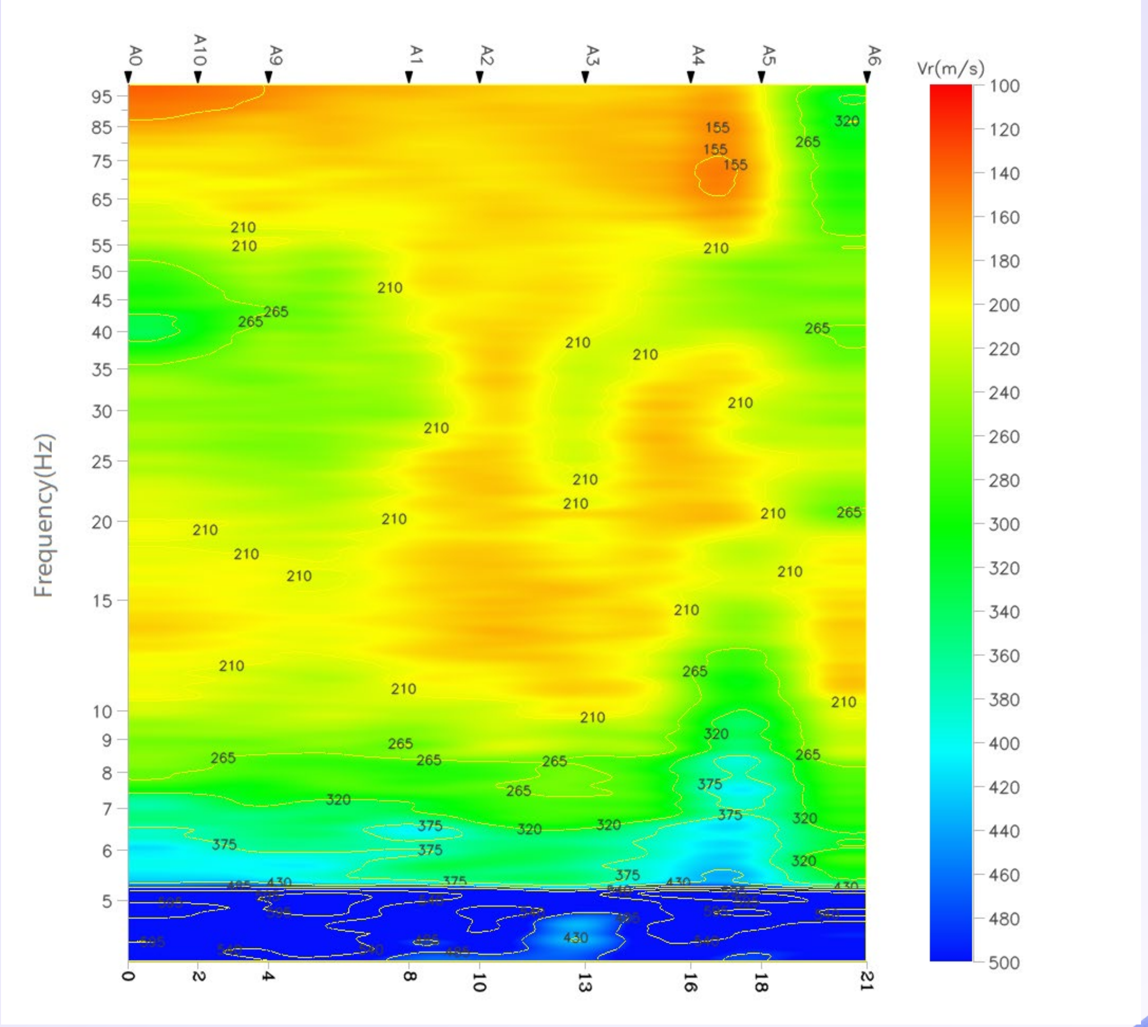






Results of Microtremor and site photos





2. Geophysical characteristics of limestone

2.1 Composition Porosity Permeability

2.2 Seismic Properties and Karst Topography

Geophysical characteristics of limestone

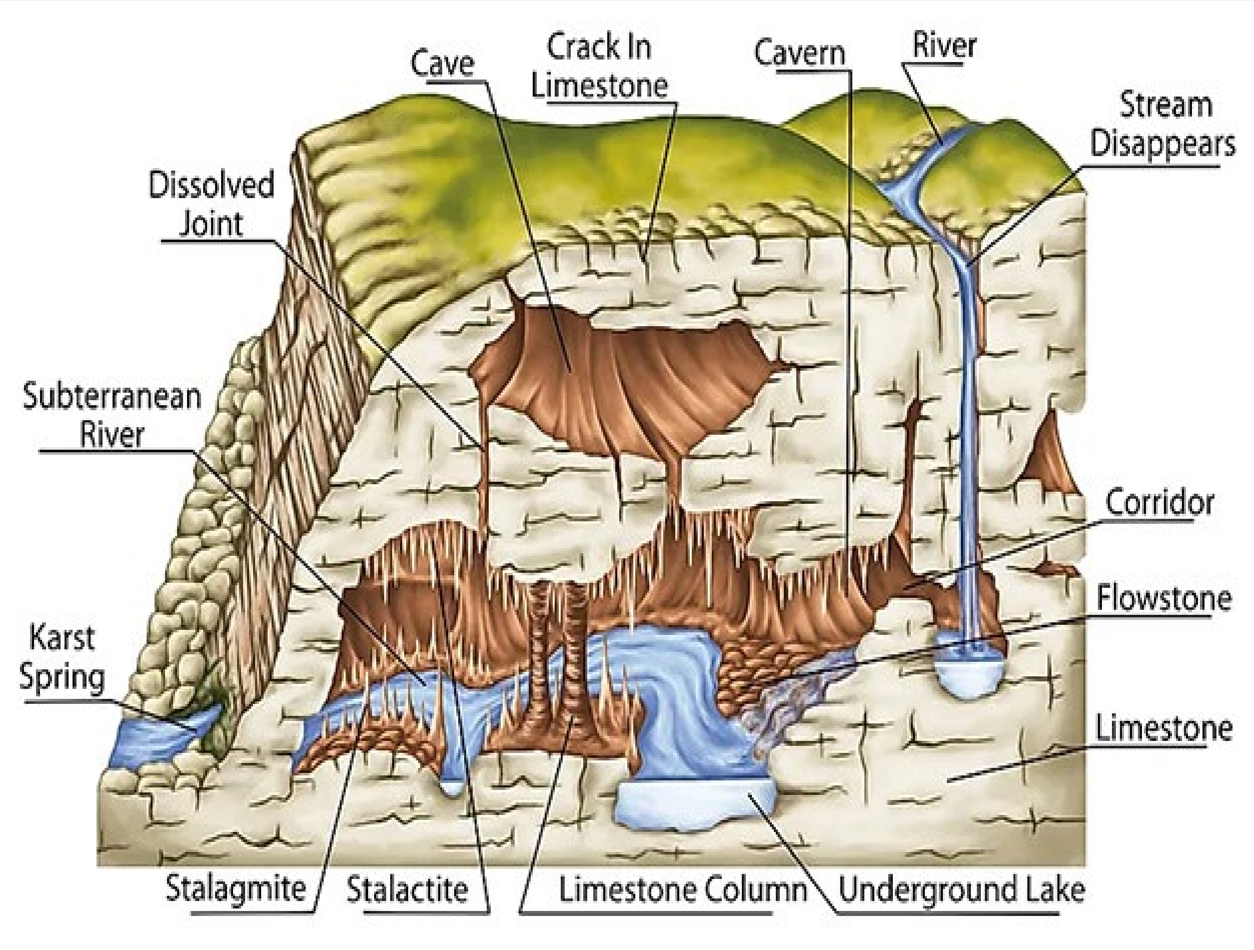
2.1 Composition Porosity Permeability

Calcium Carbonate ($CaCO_3$): Limestone is primarily composed of calcium carbonate, which is formed from the skeletal remains of marine organisms like coral and mollusks.

Minerals: The primary mineral in limestone is calcite, but it may also contain small amounts of quartz, fPorosity and Permeability:

Porosity: Limestone can be highly porous, especially if it has undergone chemical weathering, which creates **voids and channels within the rock.**

Permeability: The permeability of limestone varies depending on its porosity and the degree of fracturing. Karst formations, which are common in limestone regions, have high permeability due to extensive networks of **caves and channels.eldspar, pyrite, and clay minerals.**



Geophysical characteristics of limestone

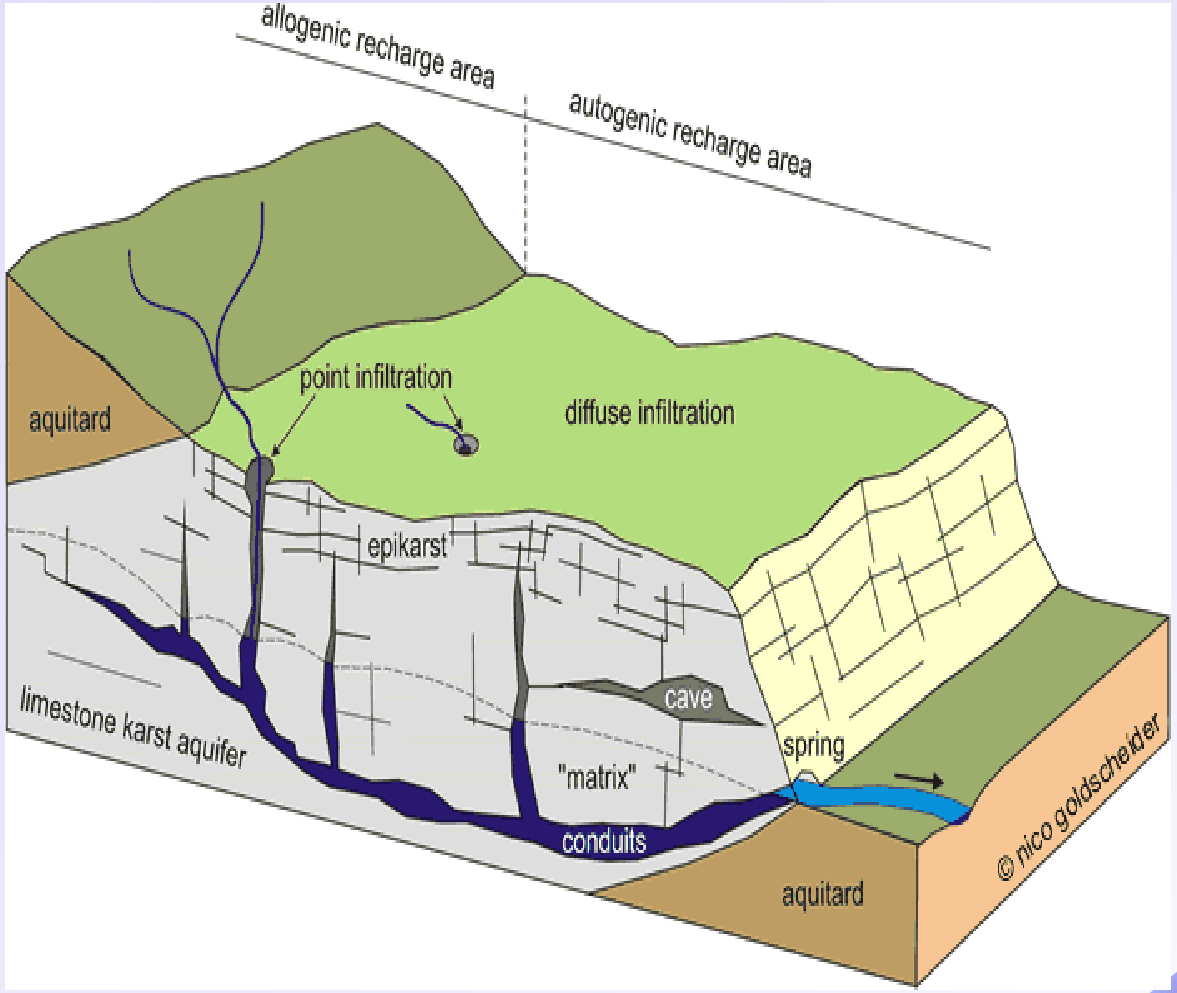
2.2 Seismic Properties and Karst Topography

Seismic Properties:

Seismic Velocities: Limestone typically has high seismic velocities, with P-wave velocities ranging from 4 to 6 km/s. These values depend on factors like porosity, degree of fracturing, and saturation.

Karst Topography:

Karstification: Limestone regions are often associated with karst topography, which is characterized by features like **sinkholes, caves, and underground rivers** due to the dissolution of limestone by acidic water.

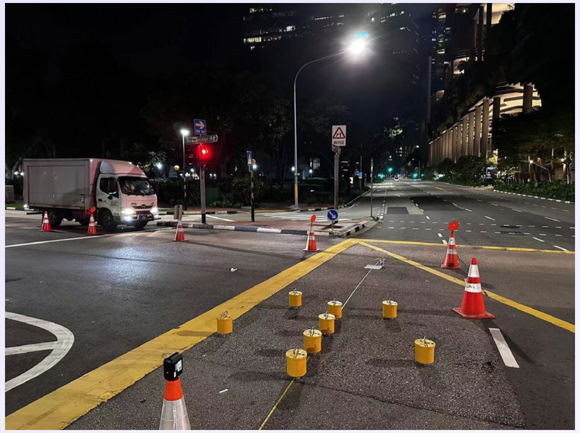


3. Microtremor Geophysical Exploration Research of Limestone

3.1 Working Principle

3.2 Data Analysis



Working Principle

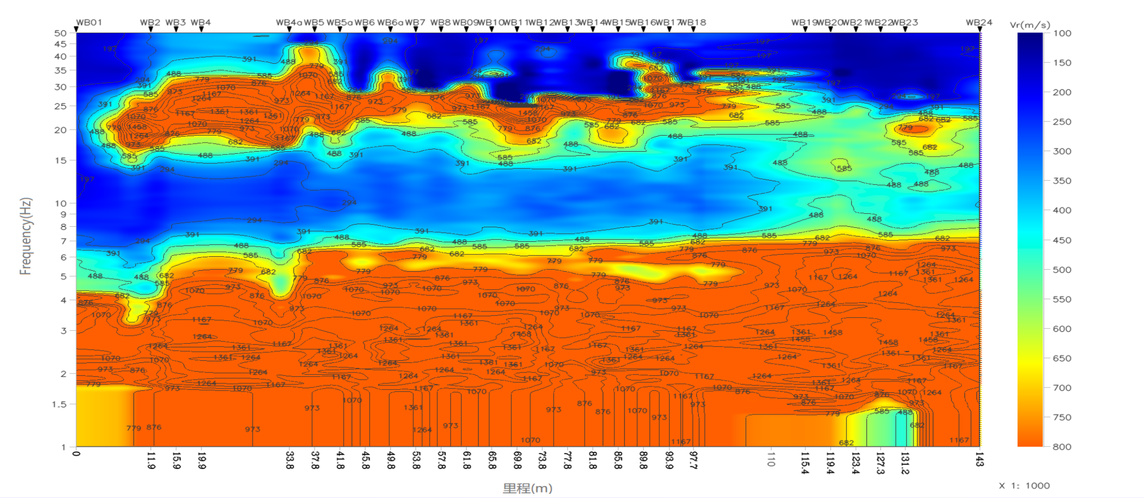
Micro-seismic technology detects longitudinal and transverse unfavorable geological bodies (karst, boulders, pile foundations, etc.) using two result parameters:

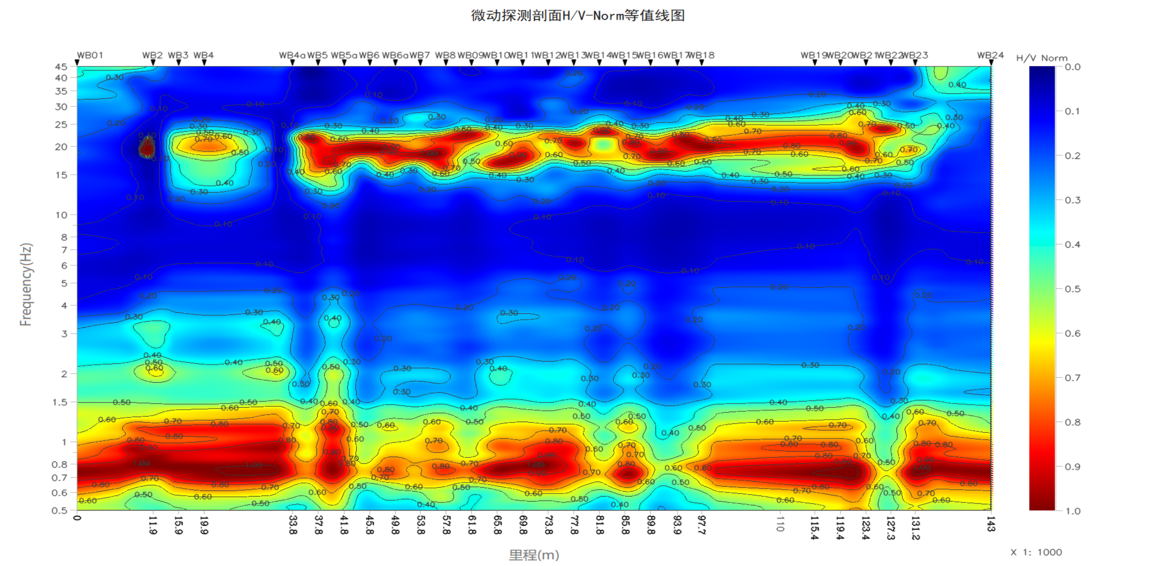
1) Velocity parameter (velocity difference - v)

2) H/V parameter (impedance difference - ρv)

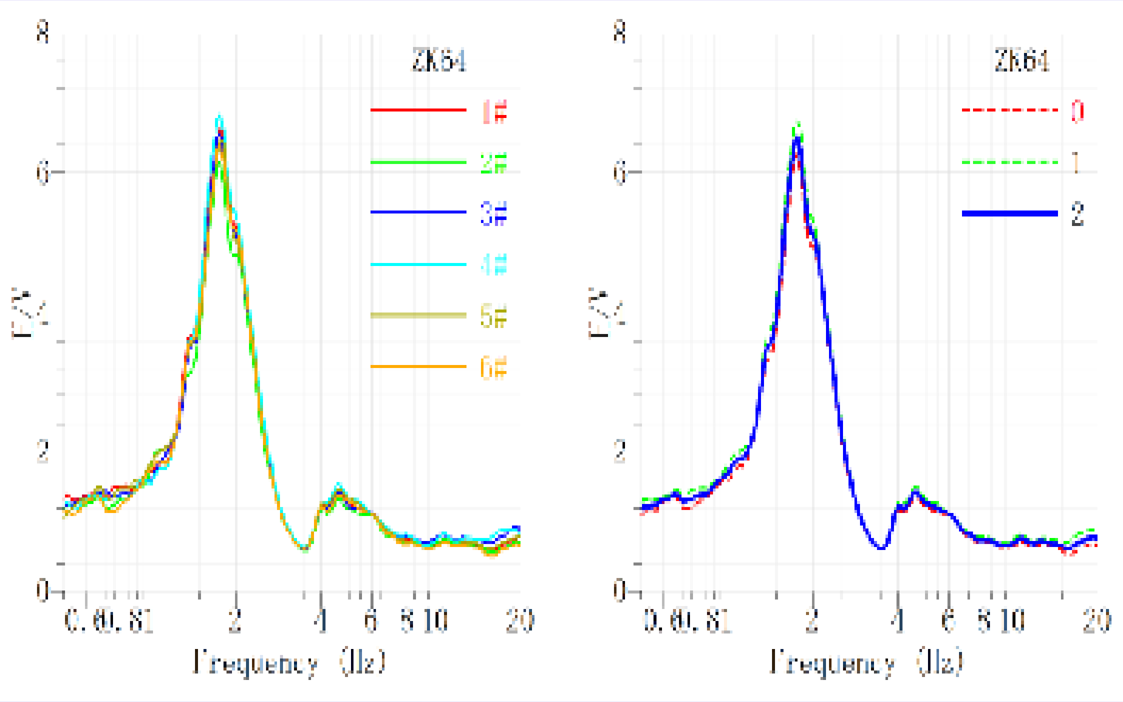
Karst, pile foundations and surrounding rock and soil bodies have velocity and density differences, and abnormal responses will appear in terms of velocity and impedance.

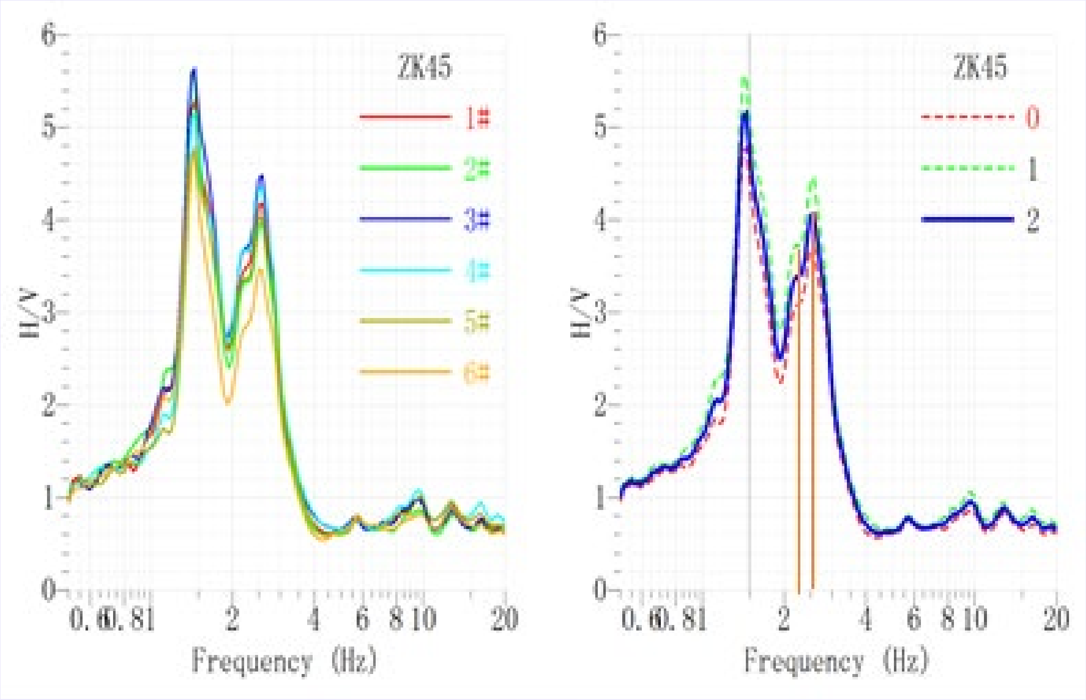
Therefore, combining the two parameters for comprehensive judgment helps to improve the accuracy of identifying unfavorable geological bodies (karst, boulders, pile foundations, etc.)





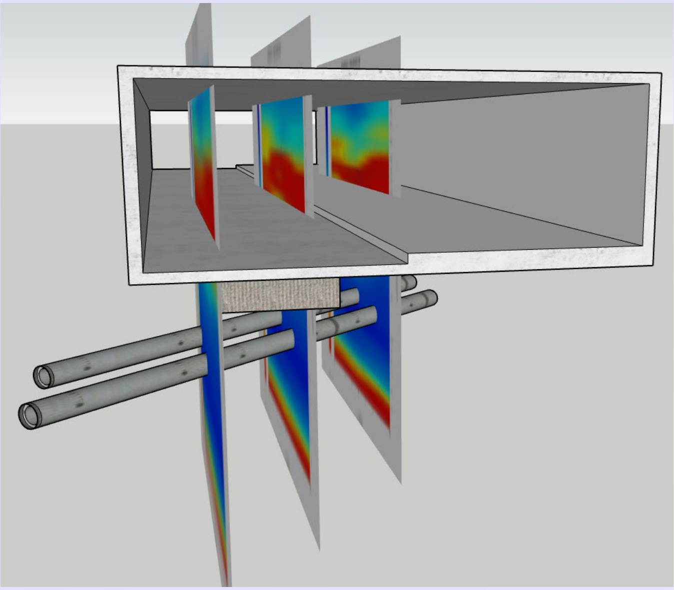
Data Analysis

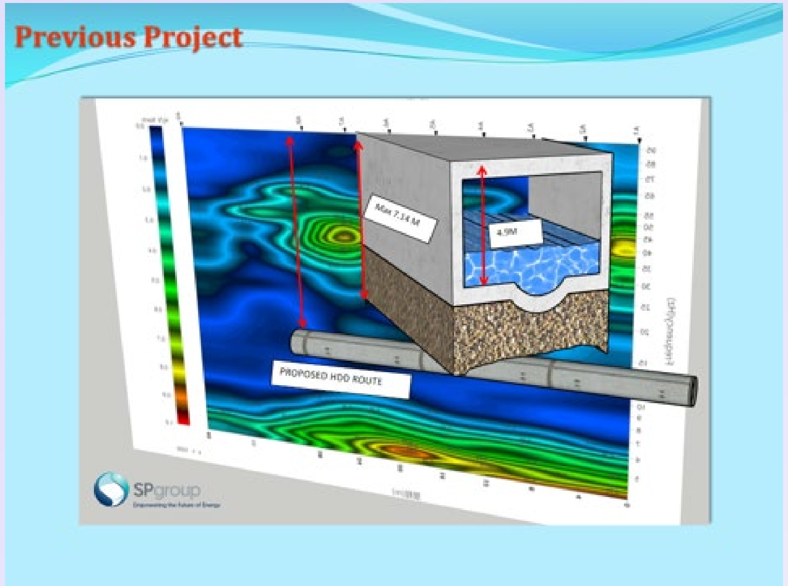


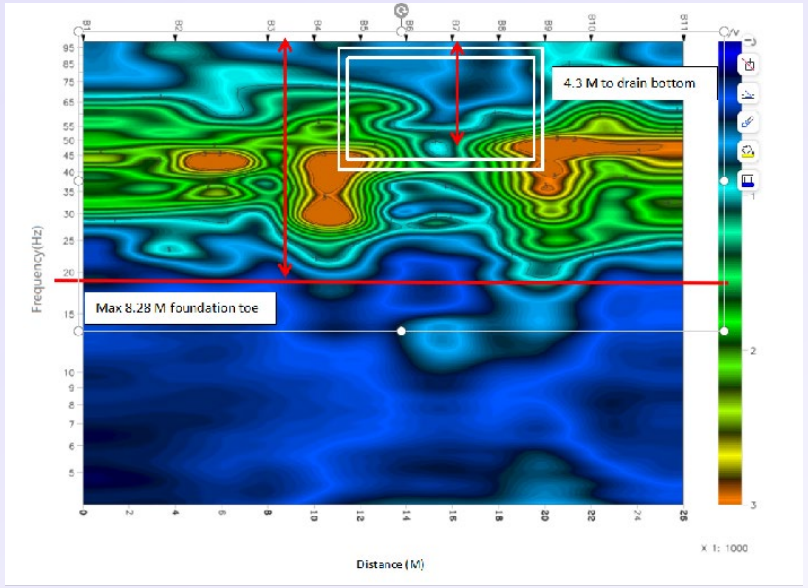


- The H/V curve of the borehole without karst is a sharp single peak type.
- The H/V curve corresponding to the borehole with karst is multi-peak type.

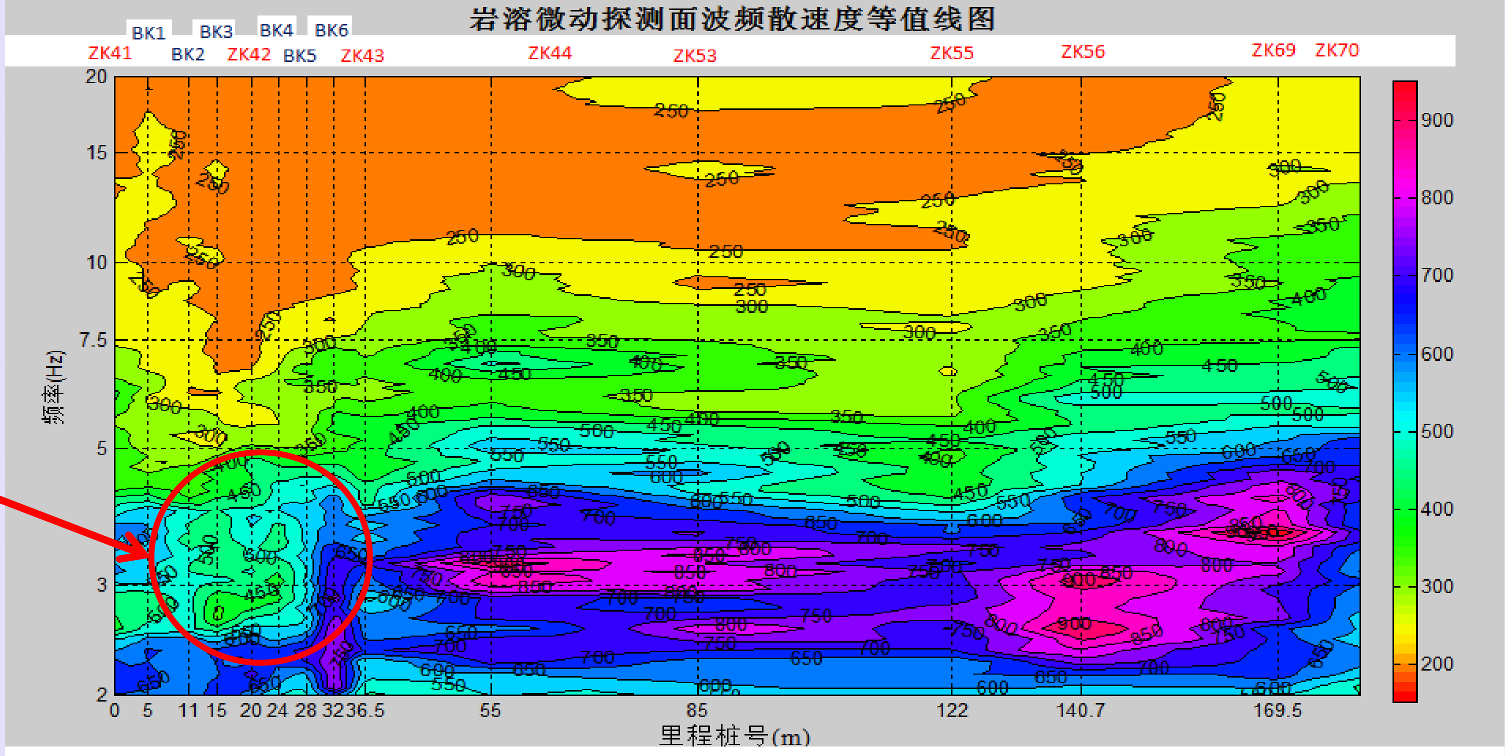
4. Microtremor Geophysical Detect Limestone Case Study

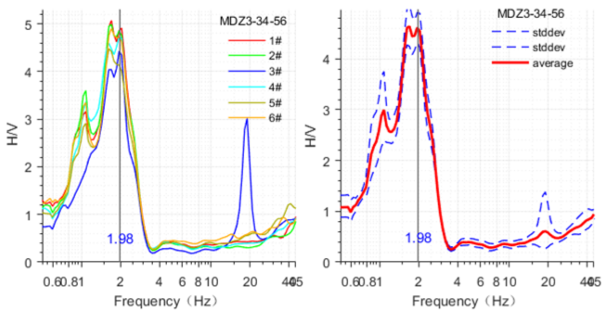


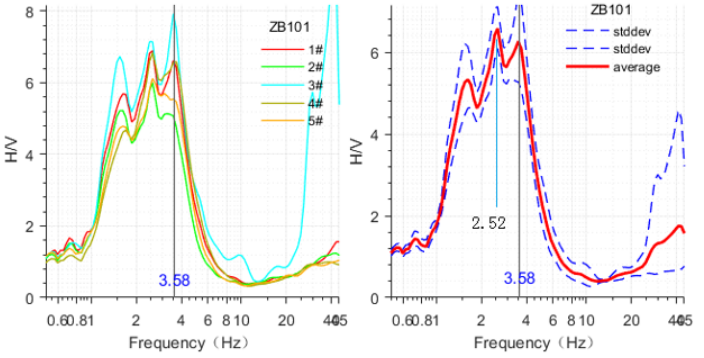




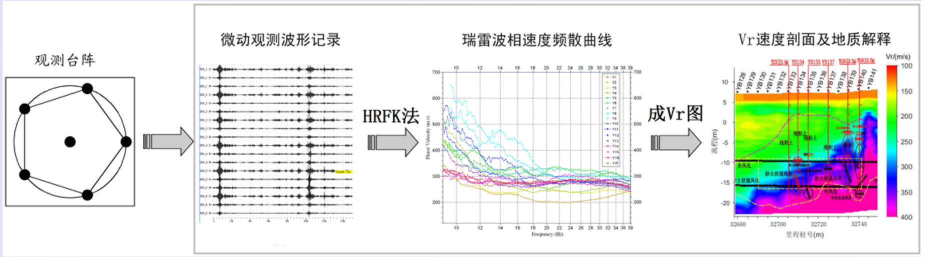
In karst development areas, there is a significant difference in velocity between the karst and surrounding rock and soil layers.

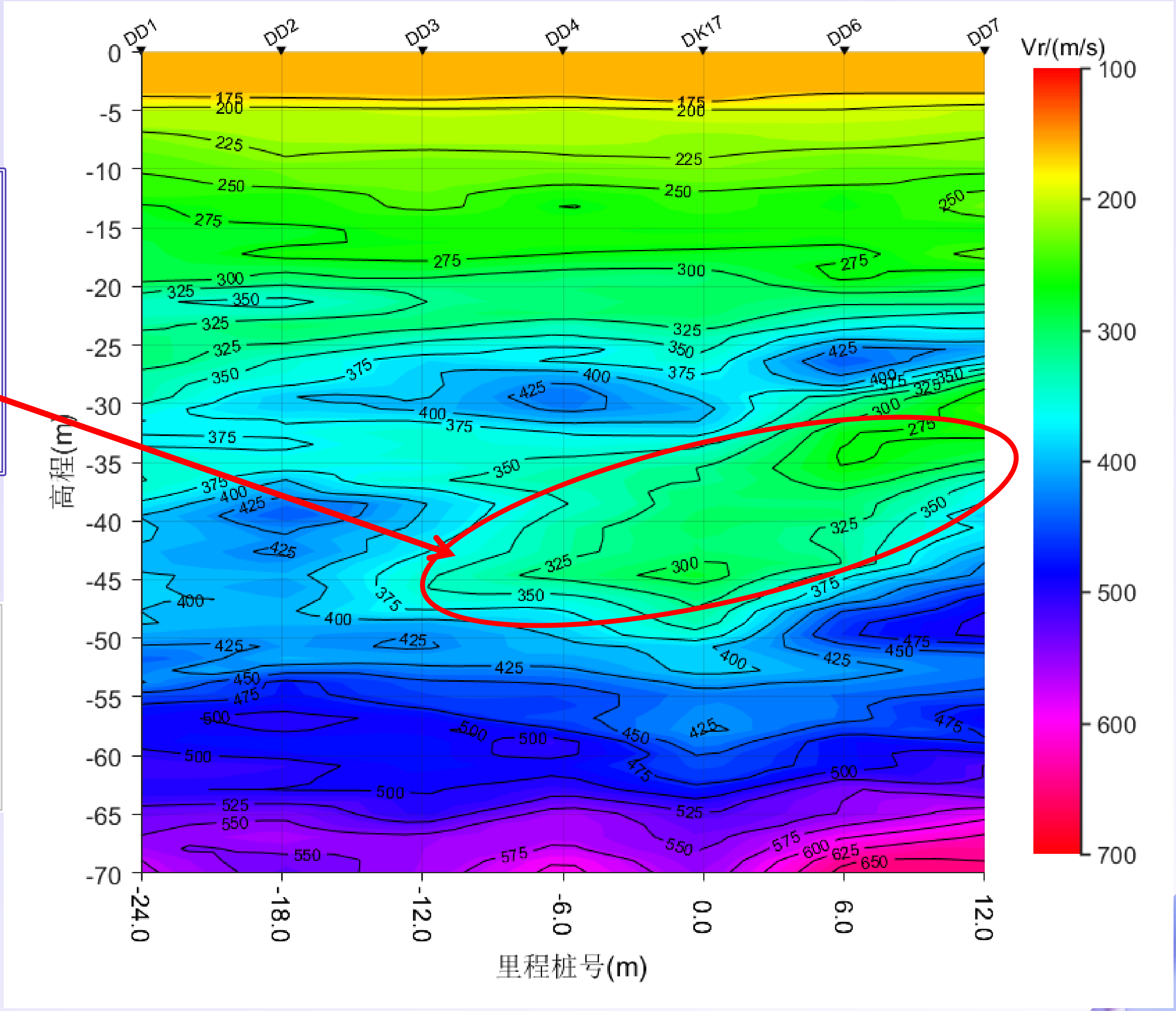


Depth (m)	Geotechnical Properties	H/V Curve
0.0 – 2.6	Miscellaneous fill	
2.6 – 17.0	Silt	
17.0 – 17.9	(With mud) coarse sand	
17.9 – 19.7	Silty soil	
19.7 – 20.1	Fragmented strongly weathered granite	
20.1 – 27.03	Moderately weathered granite	

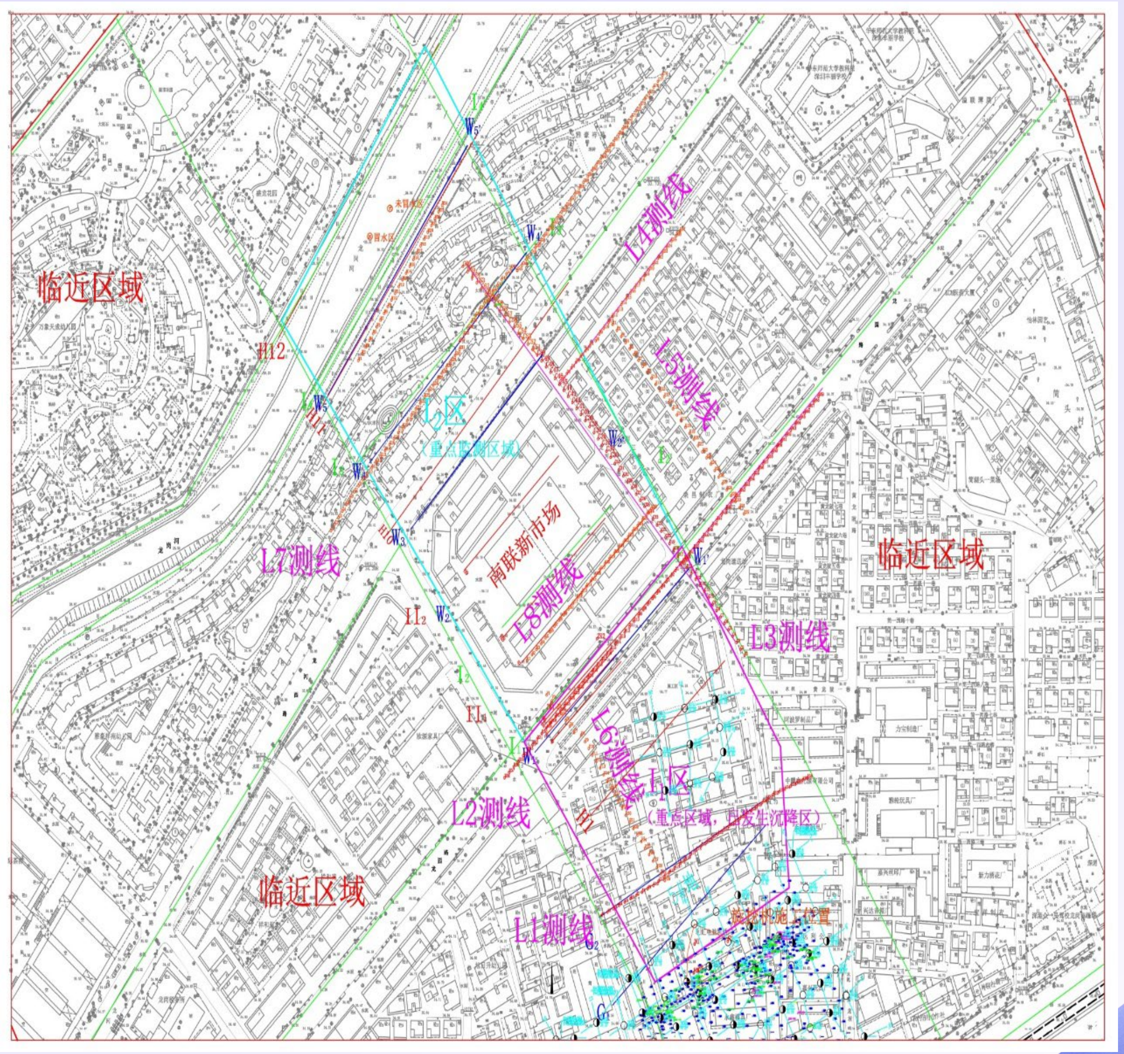
Depth (m)	Geotechnical Properties	H/V Curve
0.0 – 3.6	Miscellaneous fill	
3.6 – 5.8	silt	
5.8 – 13.5	solidary stone	
13.5 – 22.6	Sandy strong weathered syenite porphyry	
22.6 – 24.77	Moderately weathered syenite porphyry	

The DK17 borehole revealed that the depth from 41.1 to 48.4 m was karst, filled with clayey soil and gravel. It was inferred that karst also existed beneath the nearby DD4, DD6 and DD7 measuring points.

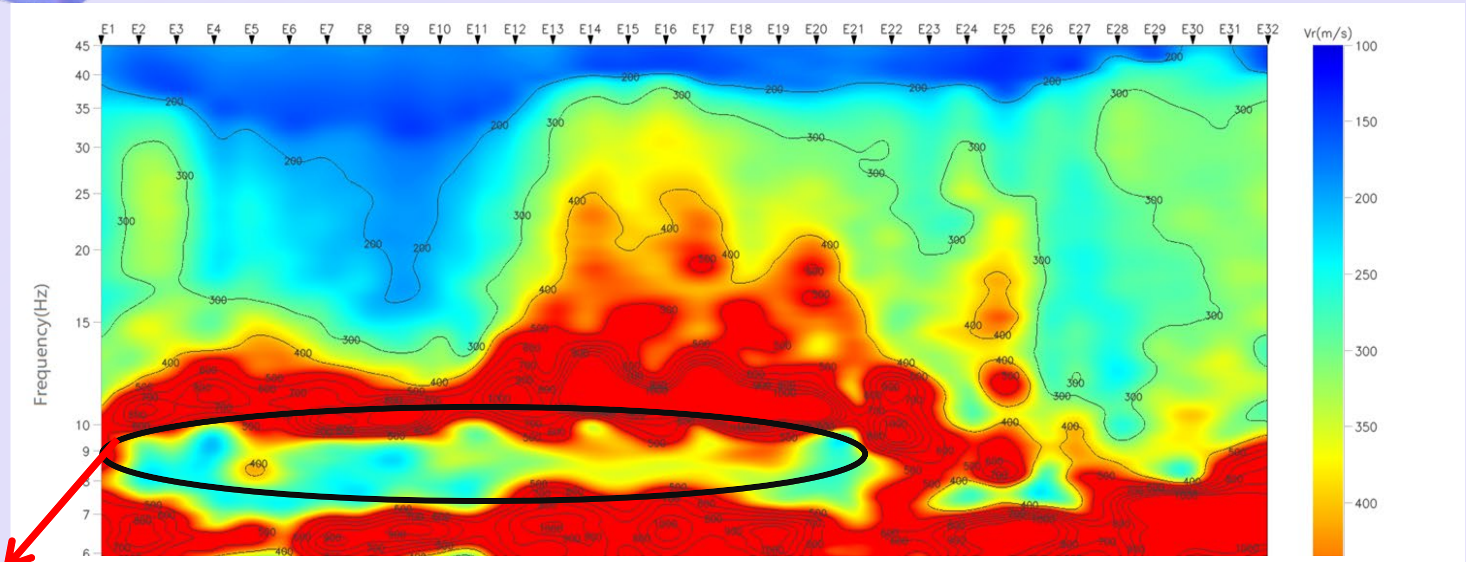




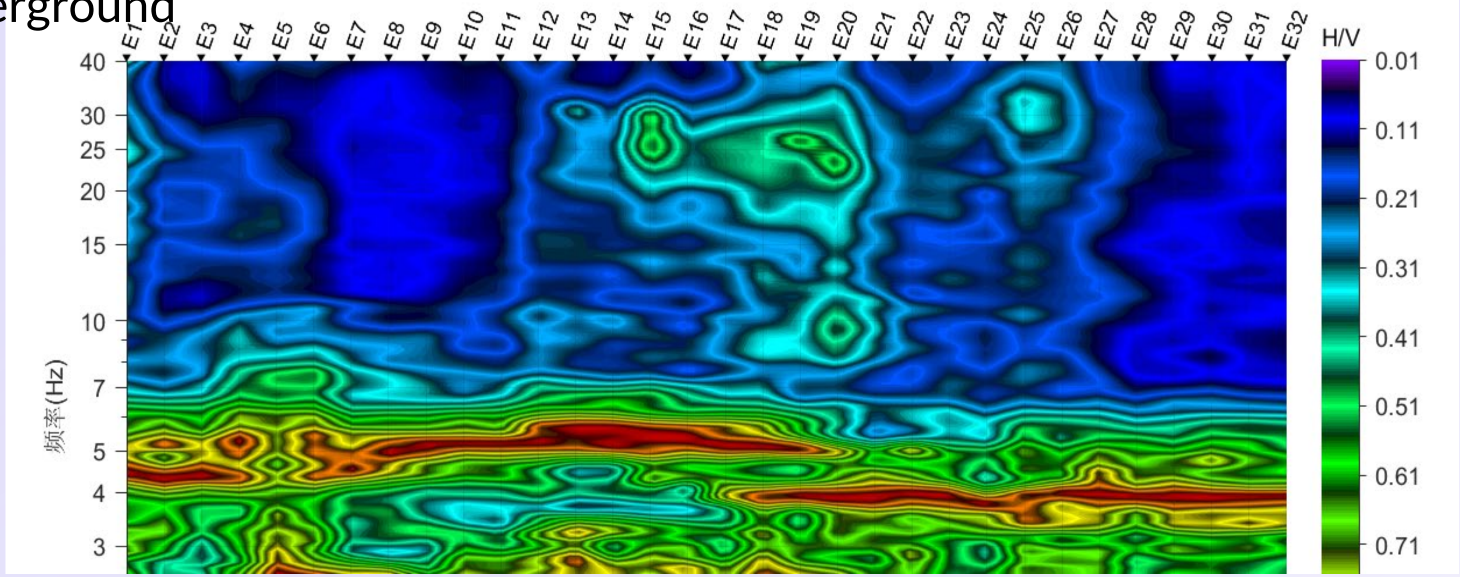
Microtremor Case Study

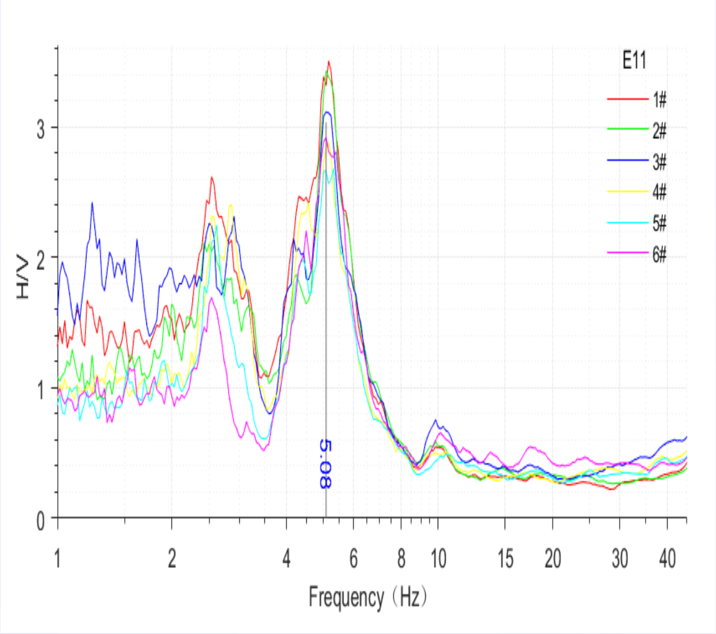


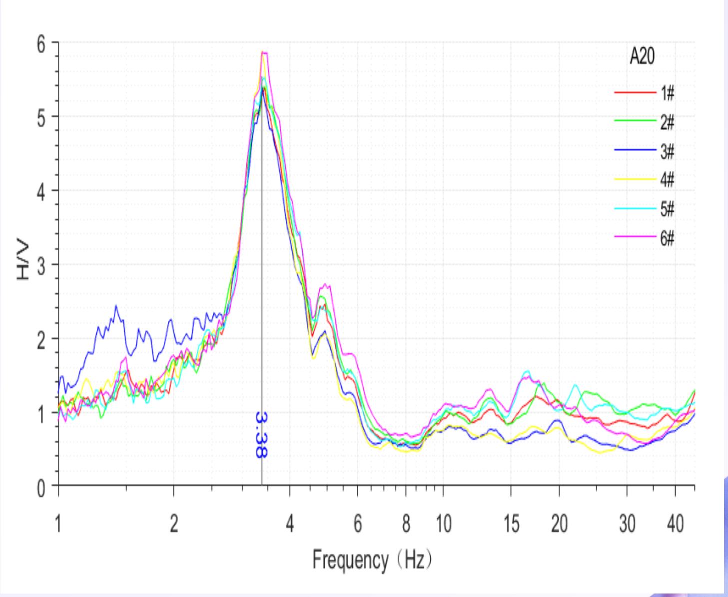
Microtremor Case Study



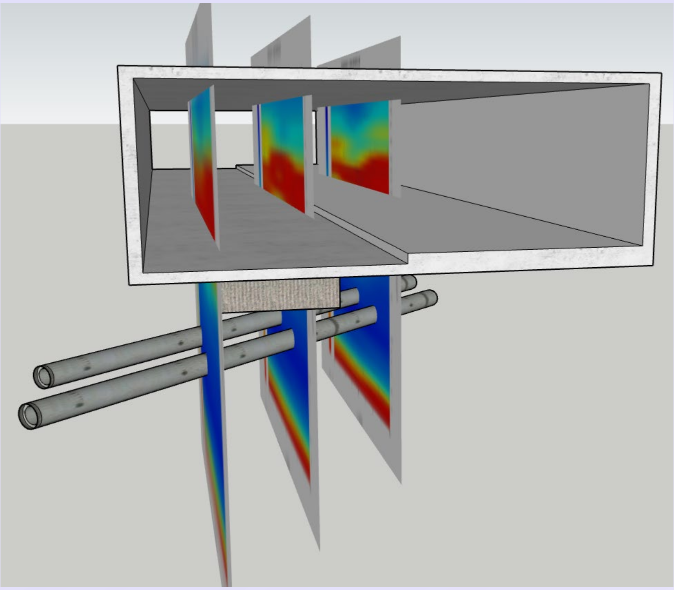
Underground river

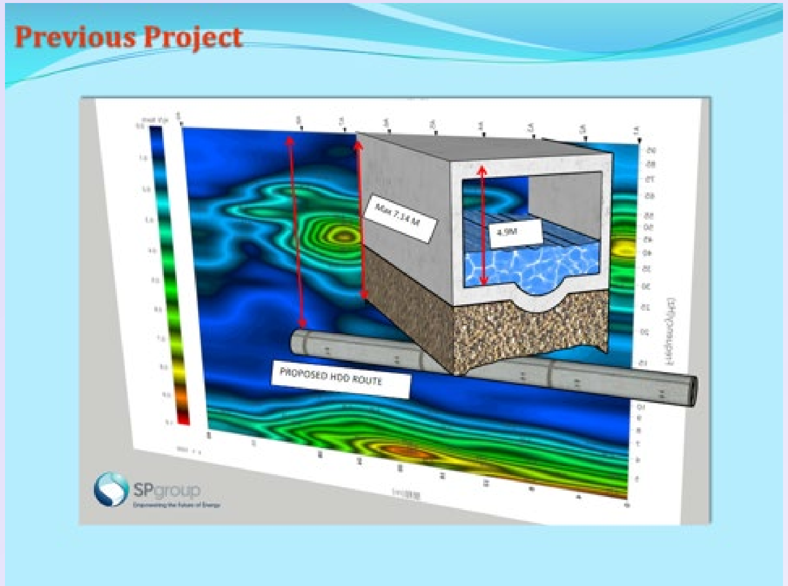


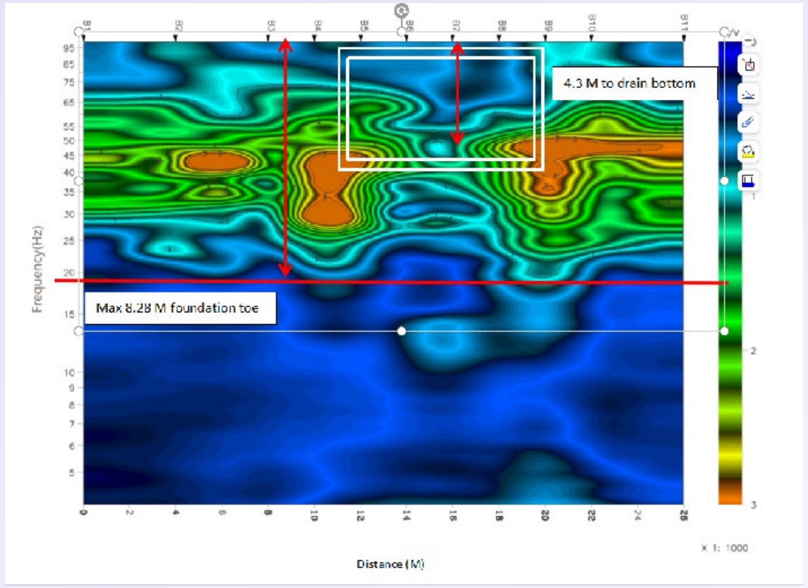




5. Q & A




Previous Project
Max 7.14 M
4.9M
PROPOSED HDD ROUTE
SPgroup


4.3 M to drain bottom
Max 8.28 M foundation toe
Frequency(Hz)
Distance (M)

SMART UNDERGROUND DETECTOR PTE LTD.

Thanks