Electric resistivity tomography inversion guided by passive microtremor data for the detection of karst cavities

Daopu Wang* Dikun Yang[1] Zhentao Yang[1] Qingguo Feng[1] Guihua Long[2] Qingcheng Wang[3]

1. Southern University of Science and Technology, Shenzhen, Guangdong, China
2. Shenzhen Municipal Engineering Corp, Shenzhen, Guangdong, China
3. Shenzhen Tagen Group Co.,LTD, Shenzhen, Guangdong, China

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Gravity, Electrical, Magnetic and Electromagnetic Research at SUSTech

地球与空间科学系 DEPARTMENT OF EARTH AND SPACE SCIENCES

南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Outline

Biography

Education

Southern University of Science and Technology — Shenzhen, China

Master of Science in Earth and Space Science — ***Sep. 2022 - Jun. 2025 (expect)***

GPA : 3.56/4.0

Yangtze University — Wuhan, China

Bachelor of Geophysics — ***Sep. 2018 - Jun. 2022***

GPA : 3.73/5.0

Honors & Awards

2023 **3st Prize**, Geophysical knowledge competition for university student — Hefei, China

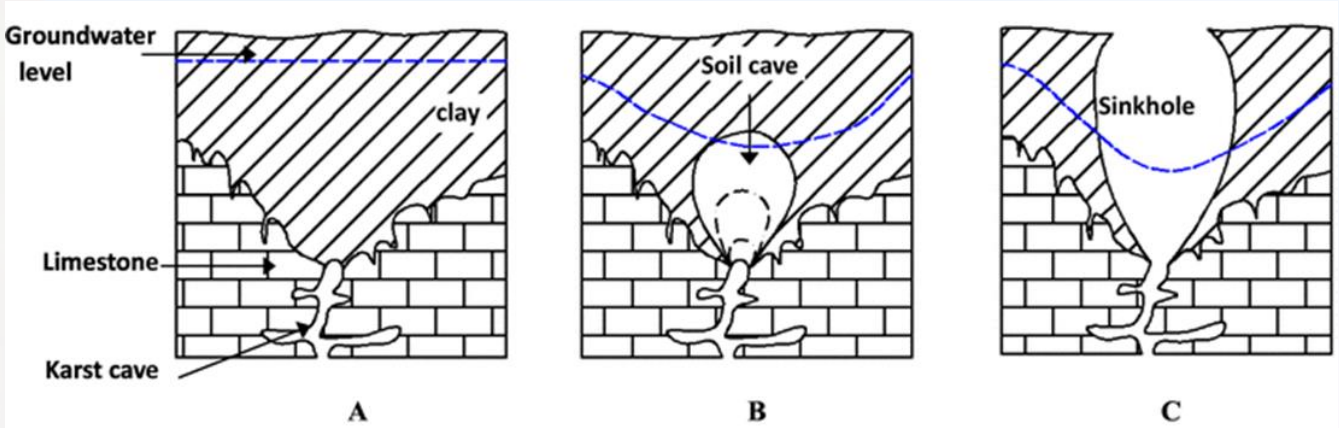
2021 **2st Prize**, Geophysical knowledge competition for university student — Hefei, China

2019 **Winner**, **National Inspiration performances** — Hefei, China

Specialty

Urban **Near-Surface Geophysical** exploration.

01 Introduction



Pipelines , Groundwater extraction…

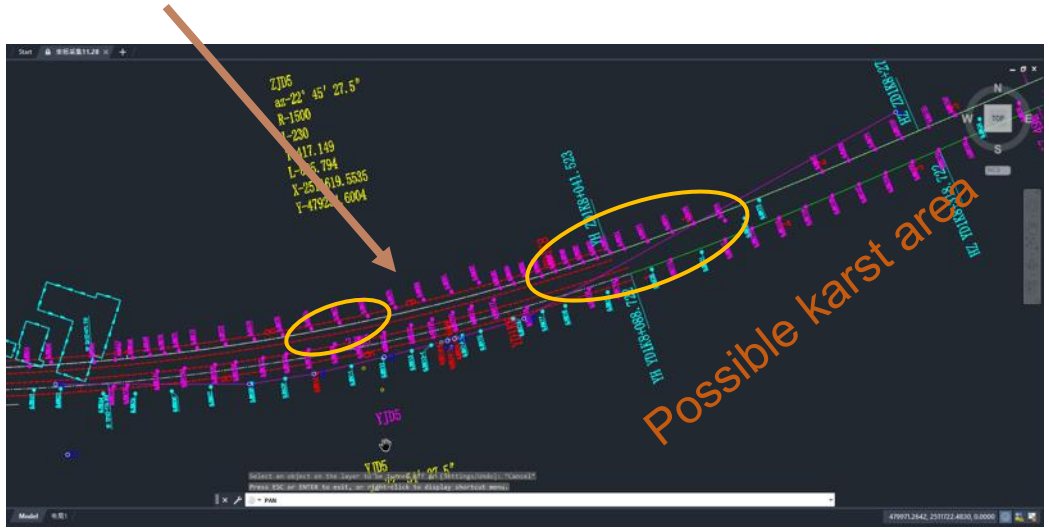
Calcite， Dolomite…

$CaCO_3+H_2O+CO_2 \rightarrow Ca(HCO_3)_2$

01 Introduction

Pingshan-Dapeng Line (Shenzhen, China)

Metro tunnels



(Pingshan Station section)

Karst cavity hazard in Pingshan

Burial depth	10.9 - 73.2 m
Cavity height	0.4 - 21.4 m
Cavity filling	Clay, Gravel soil

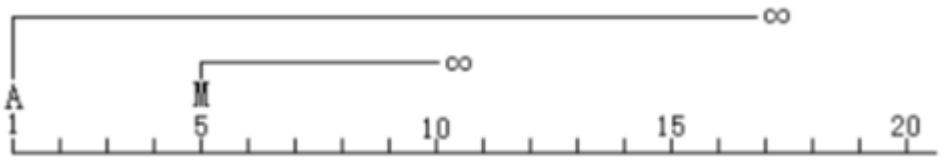
02 Surveys

ERT (electric)

GD-20

Pole – Pole

- 40 electrodes
- 5-m spacing



ANT (passive seismic)

SmartSolo 16HR 3C

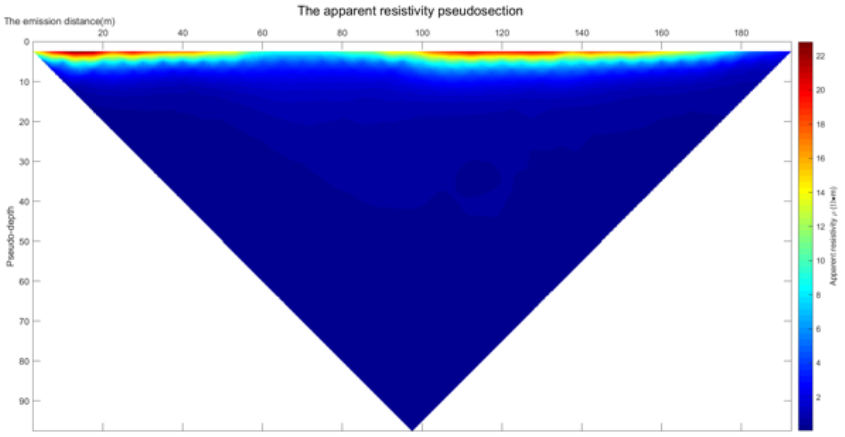
Sample rate : **100Hz**

Number of stations : **84**

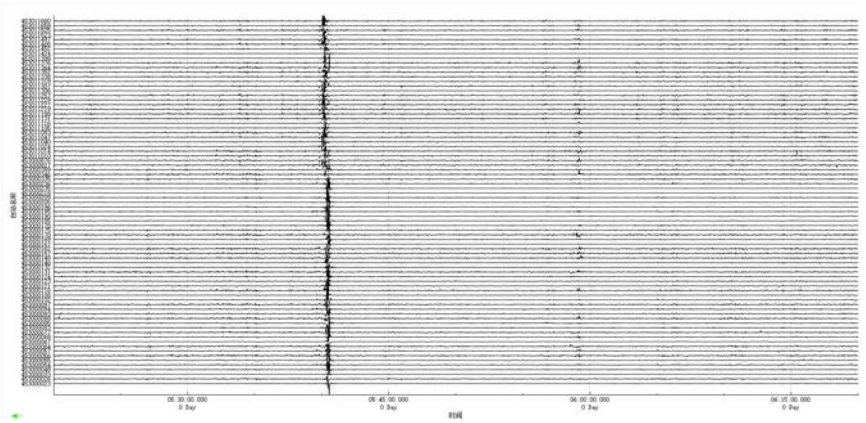
Station distance : **2.5 m**

Acquisition time : **30min**

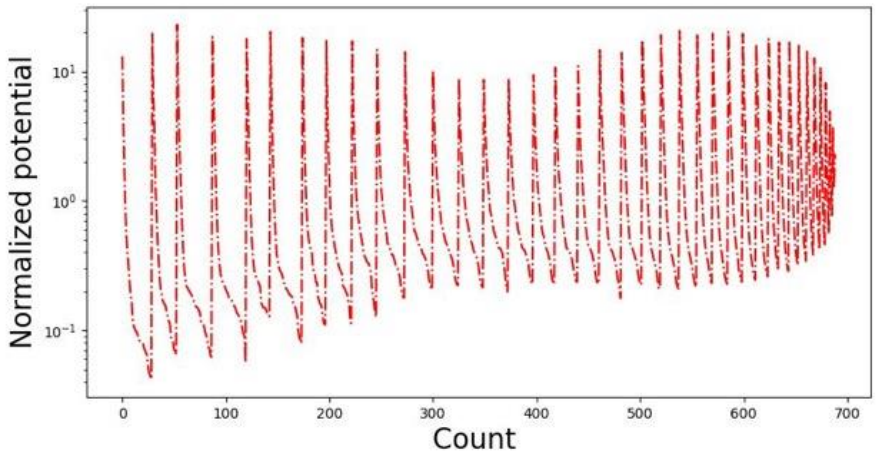
02 Surveys



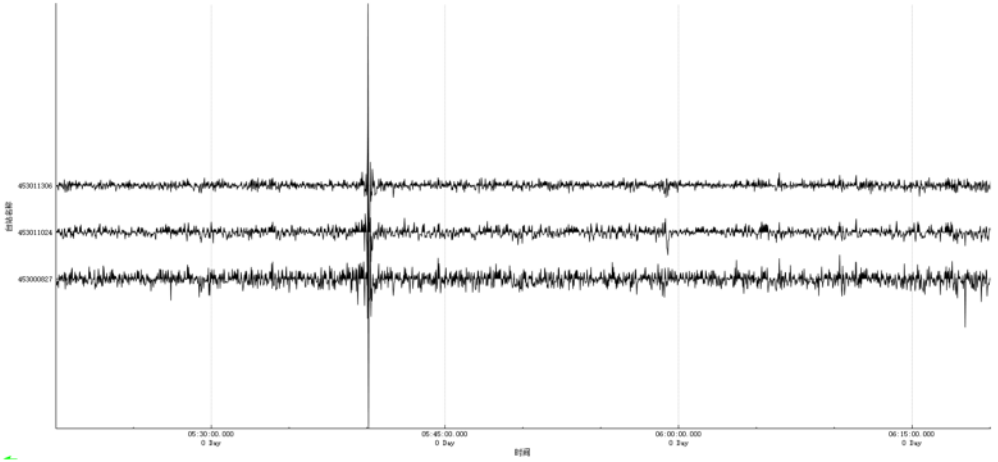
Apparent resistivity pseudo-section



Original seismic signals



Observed potential difference data plot



Passive seismic waveforms

$$\boldsymbol{\varphi(m) = \left\| W_d\left(d_{obs} - f(m)\right)\right\|^2 + \gamma \left\| W_m(m - m_0)\right\|^2}$$

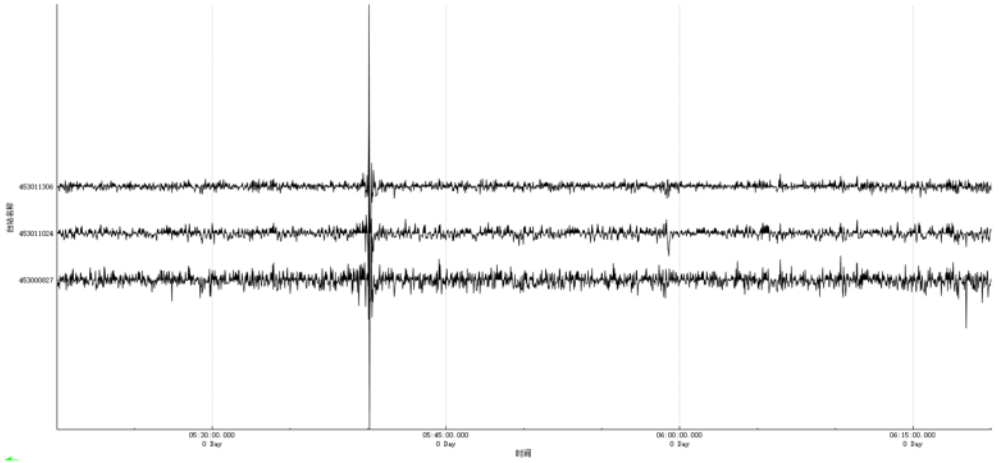
$$\boldsymbol{W_m = \left(\alpha_s I, \alpha_x W_x^T, a_z W_z^T\right)^T}$$

W_m *model weighting matrix*

$\alpha_s, \alpha_x, \alpha_z$ *Weighting coefficients*

m_0 *Reference and initial model*

03 Methods



Passive seismic waveforms

- HVSR

The prominent resonant frequency in the H/V spectrum is used to obtain the thickness of the sediment

$$\text{HVSR} = \frac{\mathrm{H}(\omega)}{V(\omega)} \qquad h = a f_*^b$$

f_* resonance frequency
h soil layer thickness

- Extract the dispersion curves

$$\mathrm{I}(w,k) = \int_0^{+\infty} \boldsymbol{C(r,\omega)}\, J_0(kr)\, r\, \boldsymbol{dr}$$ **F-*J* Method**

(Wang et al., 2019)

$C(r,\omega)$ Cross-correlation function in frequency
$J_0(kr)$ Bessel function

- S-wave velocity

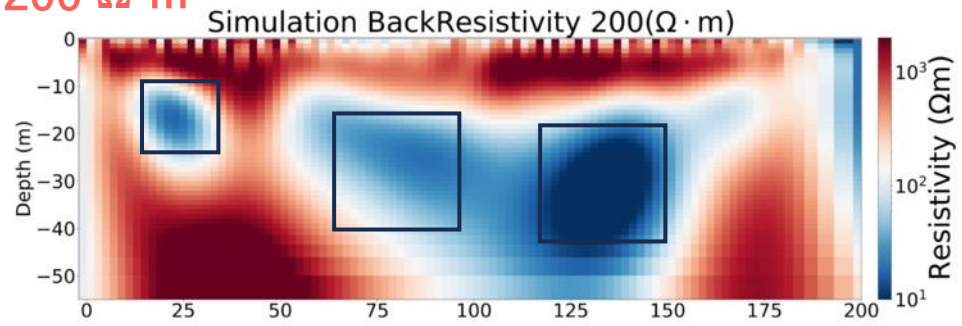
$$f(V_s) = \sum_i \sum_j weight_j (c_{ij}^s - c_{ij}(V_s))^2$$

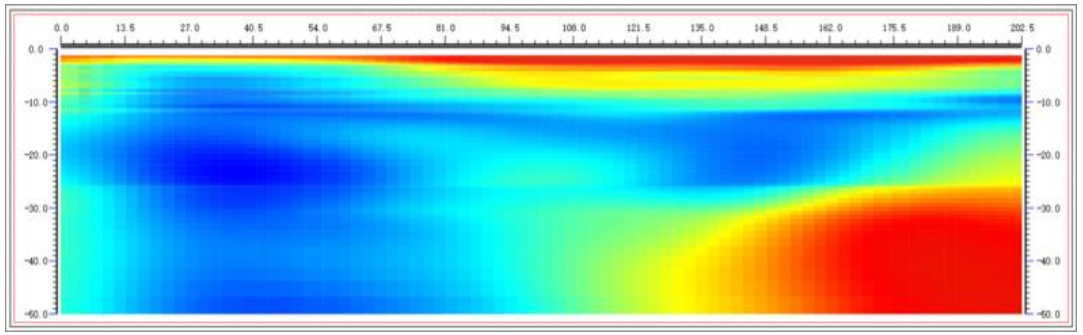
(Chen et al., 2019)

i Frequence
j Order of the dispersion curve
c_{ij}^s Measured phase velocity
c_{ij} Theoretical phase velocity

03 Methods

200 Ω·m



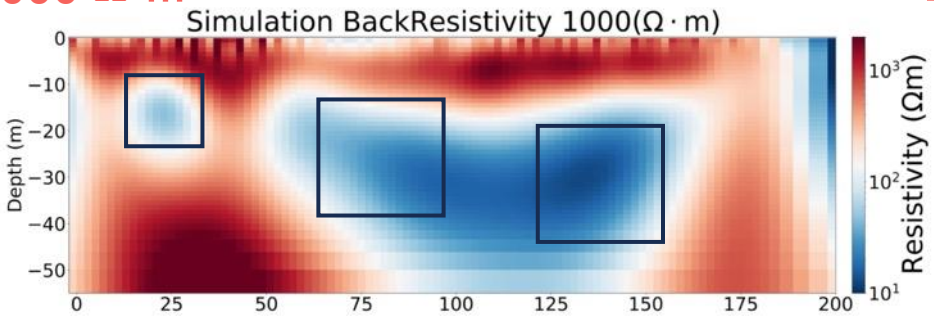


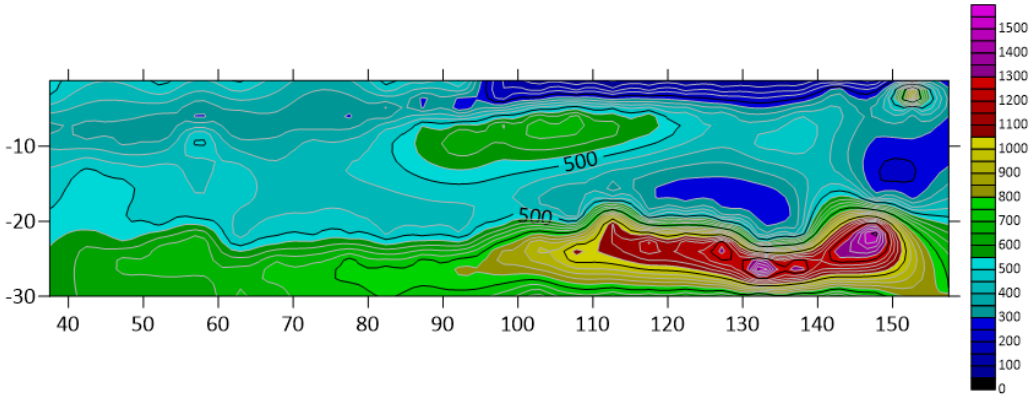
Electrical/seismic structure

Normalized HVSR image

1000 Ω·m

Not consistent

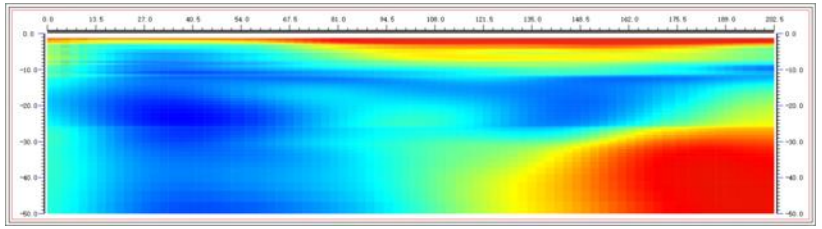




Resistivity Results

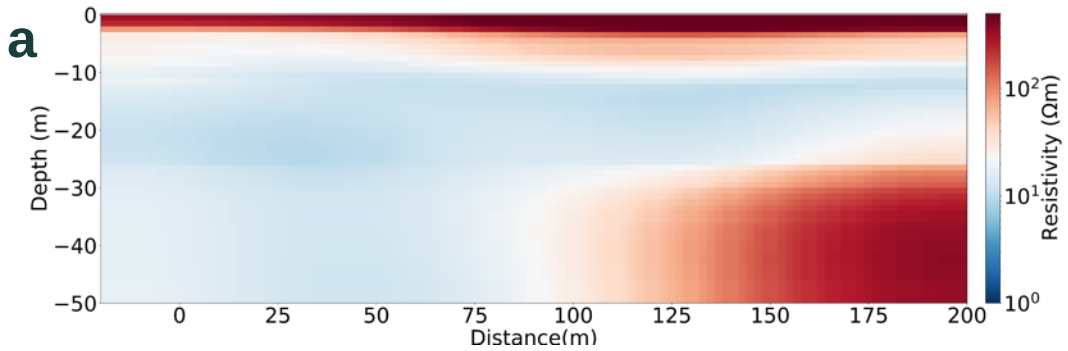
Shear wave velocity image

04 Results

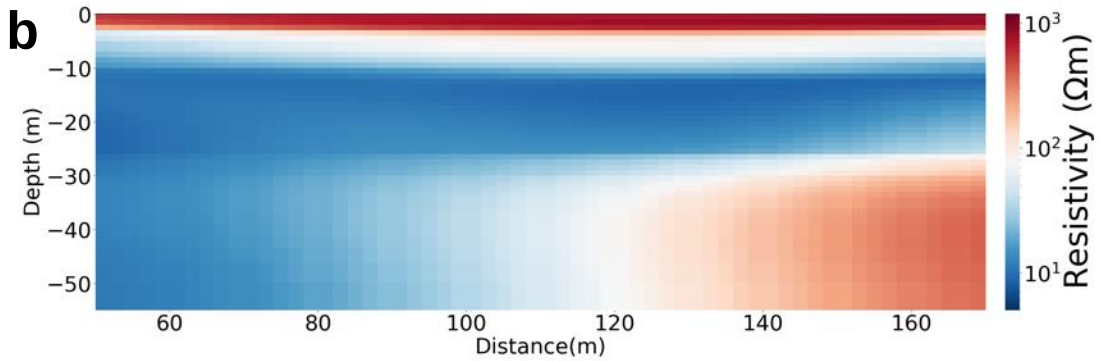


HVSR

Mapping resistivity

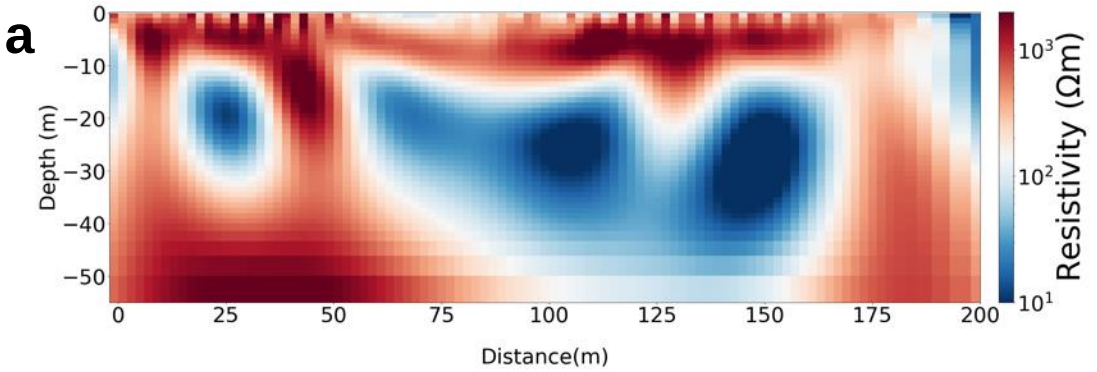


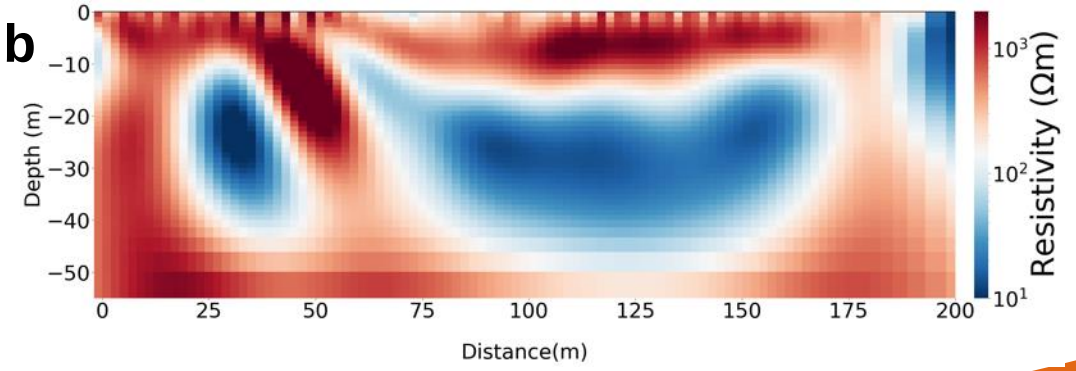
$$\rho = 10^{3*HVSR}$$



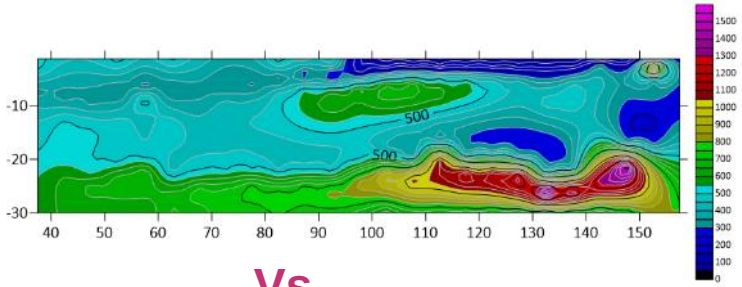
$$\rho = 0.0449(1 + HVSR)^{7.049}$$

Inverted results



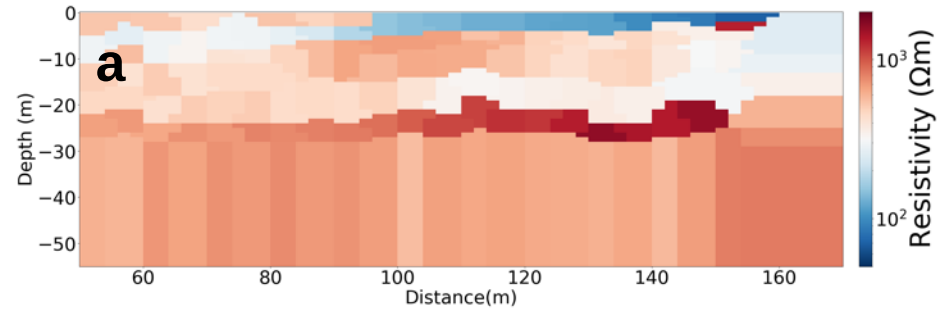


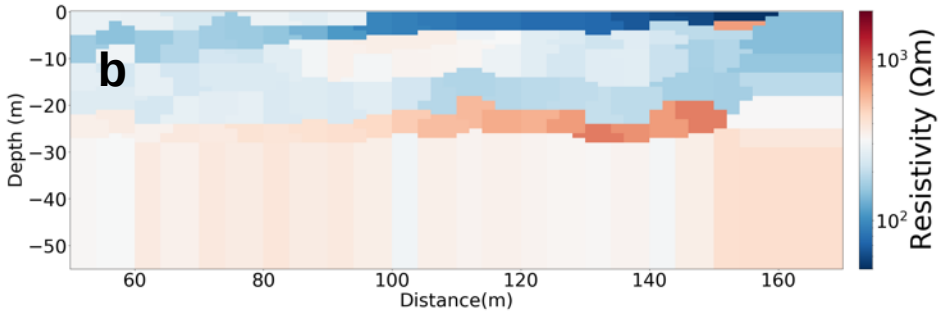
04 Results

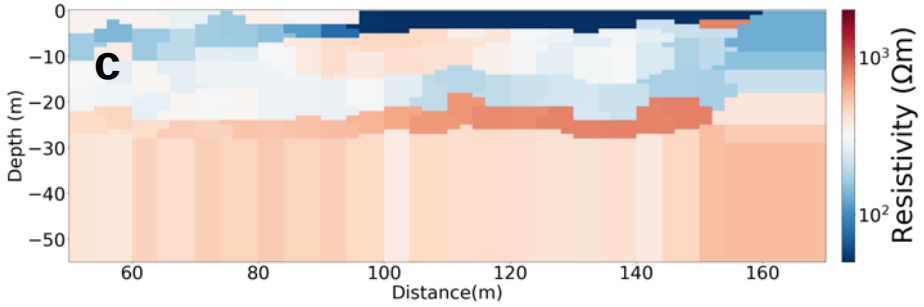


Vs

Mapping resistivity





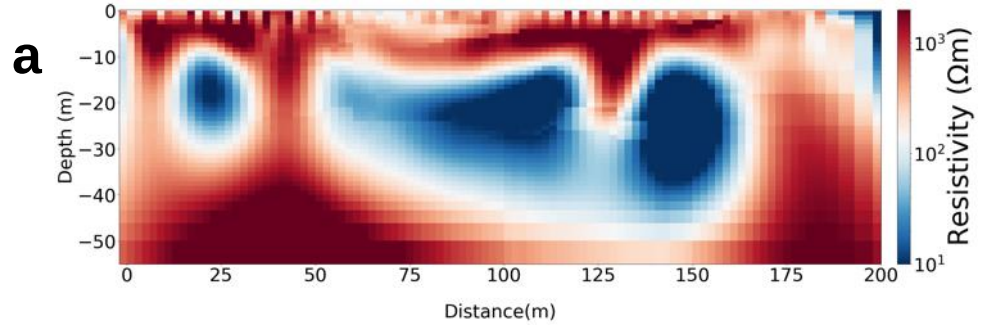


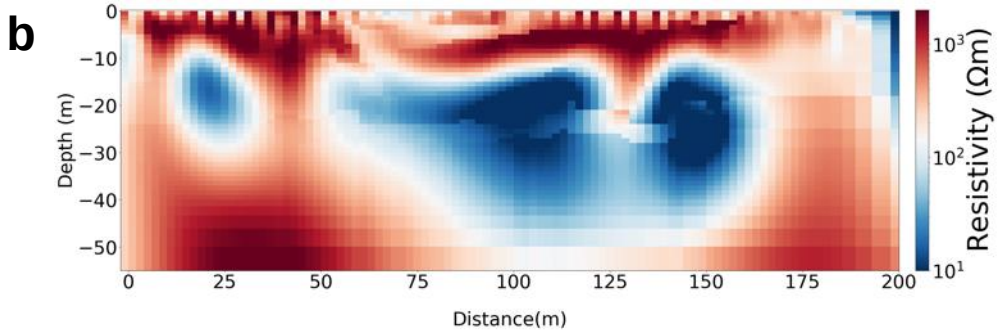
$$\rho = V_s$$

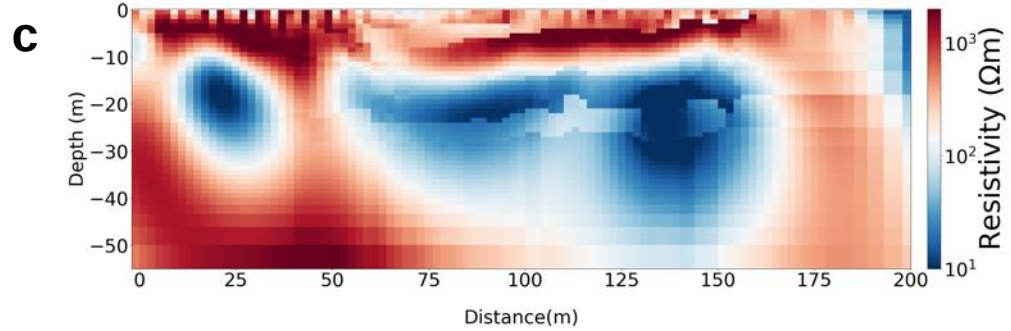
$$\rho = \frac{V_s + 33.289}{1.995}$$

$$\rho = -1.9e\text{-}07 * V_s^{3} + 1.7e\text{-}04 * V_s^{2} + 7.39e\text{-}01 * V_s - 65.6$$

Inverted results

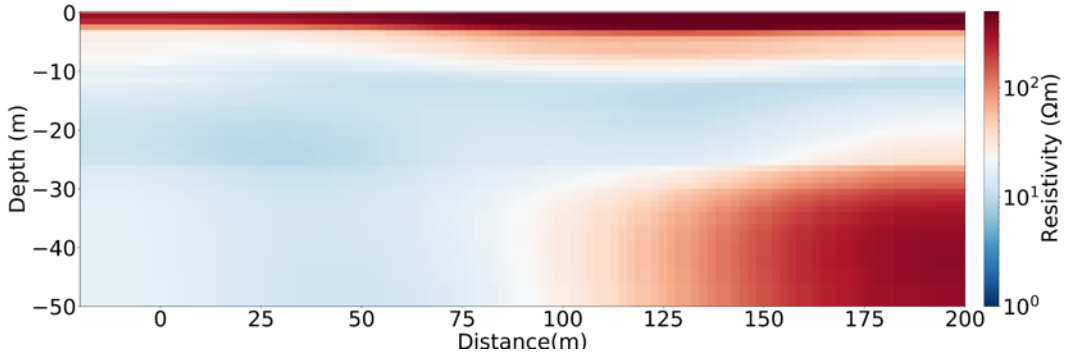




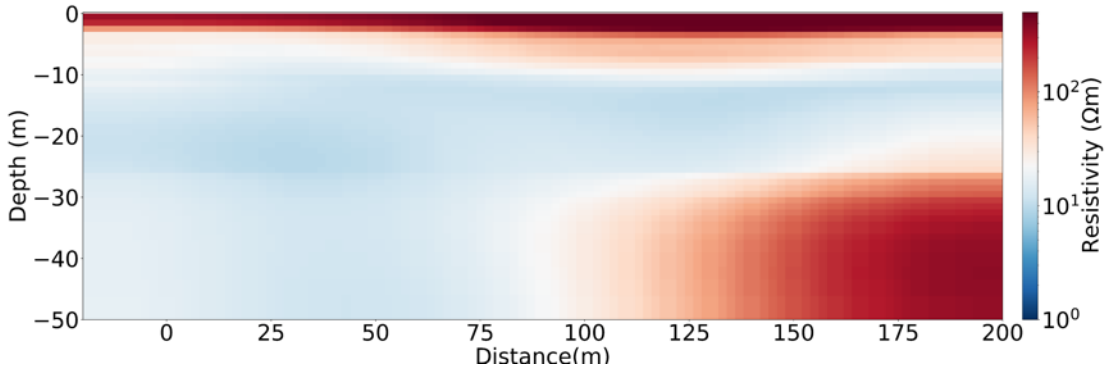


04 Results

$$W_m = \left(\alpha_s I, \alpha_x W_x^T, a_z W_z^T\right)^T$$



(Initial model)



(Reference model)

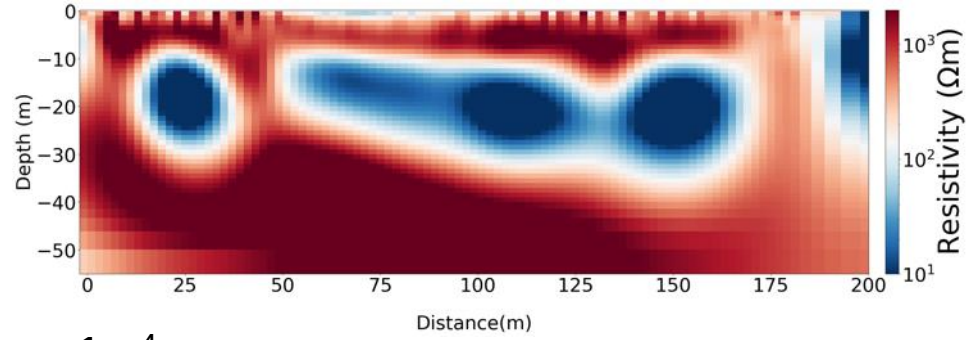
$$\rho = 10^{3*HVSR}$$

Increase

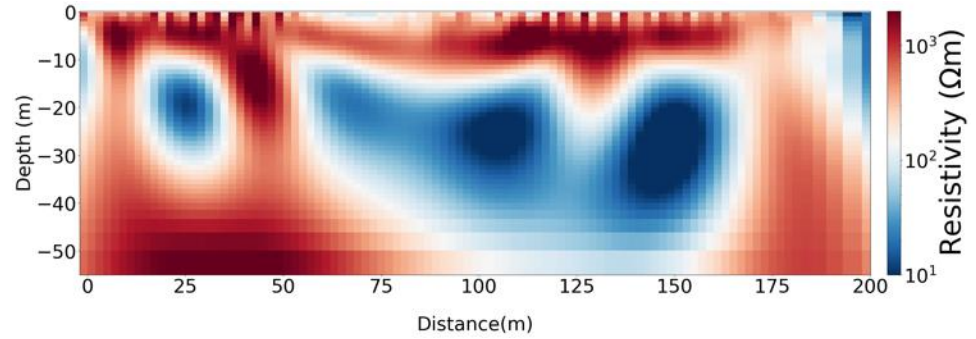
α_s

Decrease

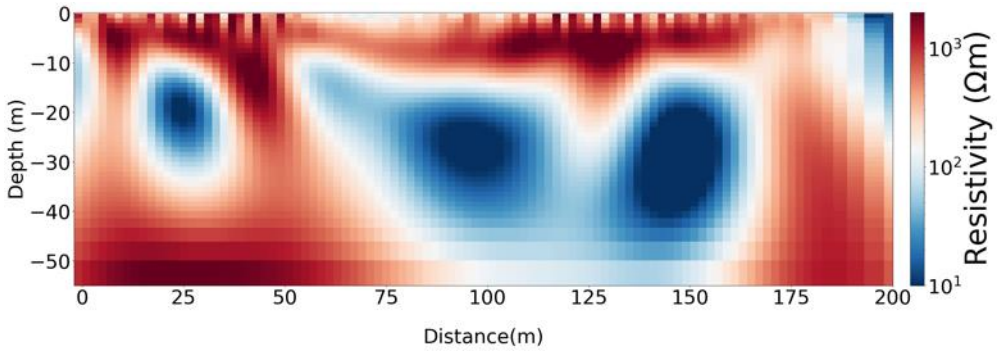
α_s : 1e-2



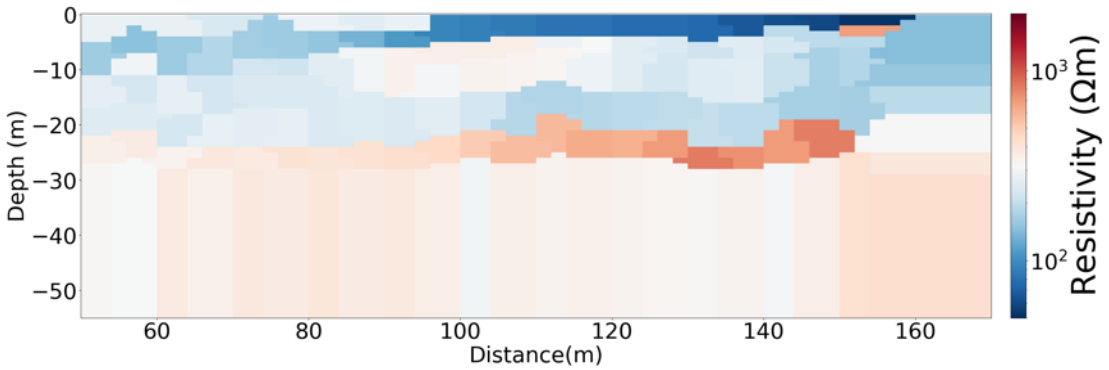
α_s : 1e-4



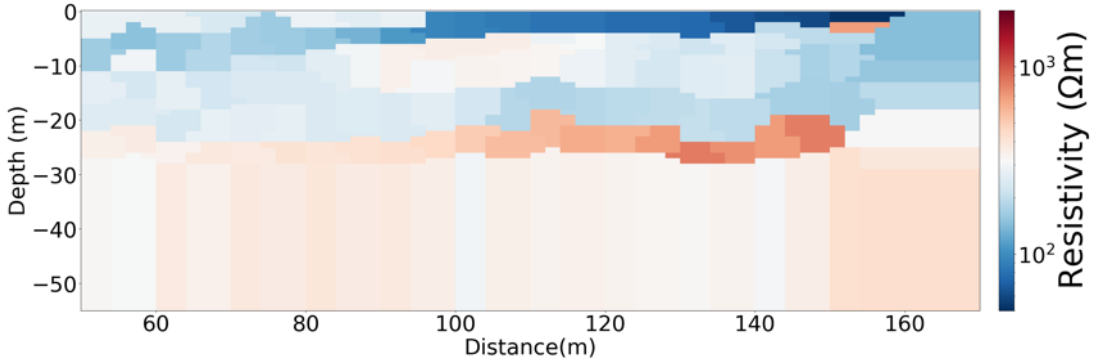
α_s : 1e-6



04 Results



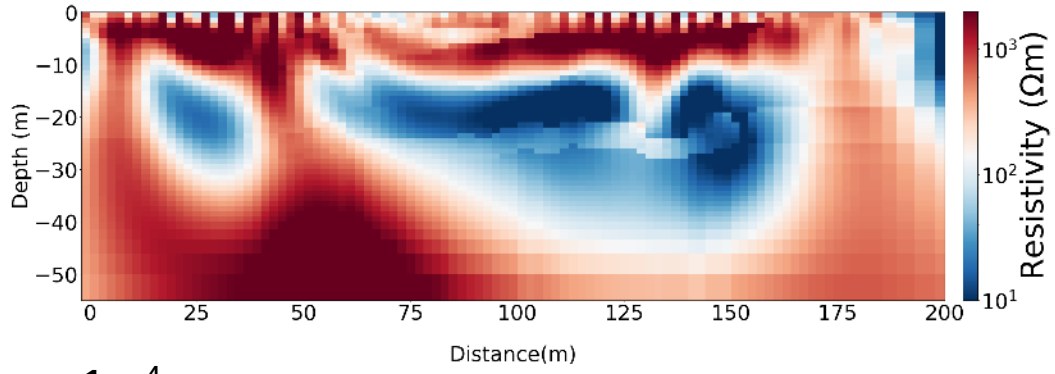
(Initial model)



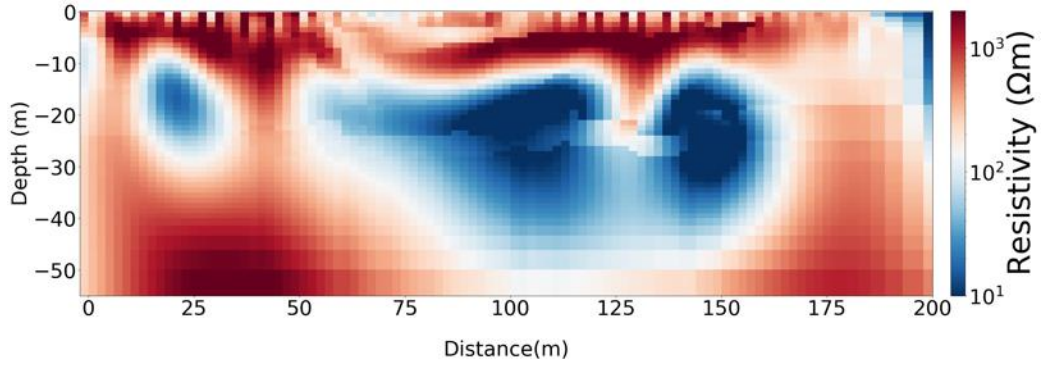
(Reference model)

$$\rho = \frac{V_s + 33.289}{1.995}$$

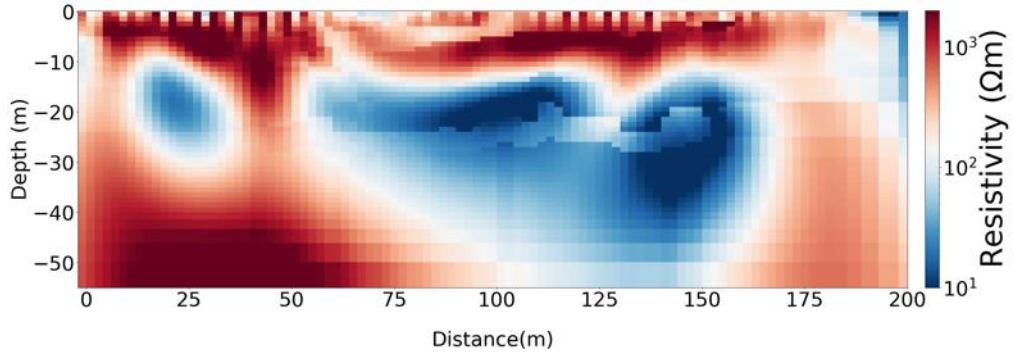
α_s : 1e-2



α_s : 1e-4



α_s : 1e-6



Conclusions:

- ERT combined with ANT successfully delineated the low resistivity anomalies at 25m and 100m, 150m along the survey line
- Alternative initial and reference models from seismic can help us more thoroughly explore the model space in the electrical resistivity inversion
- Information from the velocity image can help improve the resolution at depth in ERT inversion (bottom depth of cavities)
- Uncertainties and non-uniqueness in seismic models should be considered in the future

THANKS!

Q & A?