Uncertainty Analysis of Electrical Resistivity Tomography

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Introduction

Environmental and engineering projects require subsurface cavities to be mapped for assessing ground stabilities and construction risks.

However, resistivity imaging is often applied to determine size, position, and depth of cavity, it highly varied based cavity depth.

We examined uncertainty of resistivity methods with survey depths.

Methods

A single cavity (1.5m x 6m) model set at six-different depths of limestone medium, naming cavity targets as $\mathbf{T_1}$, $\mathbf{T_2}$, $\mathbf{T_3}$, $\mathbf{T_4}$, $\mathbf{T_5}$, and $\mathbf{T_6}$ where the cavity set at depths of 2.2 m, 4.2 m, 6.2 m, 8.2 m, 10.2 m, and 12.2 m, respectively (Fig. 1).

Cavity models were simulated to generate synthetic resistivity for dipole-dipole (DD), pole-dipole (PD), Wenner-Schlumberger (WS), and pole-pole (PP) arrays.

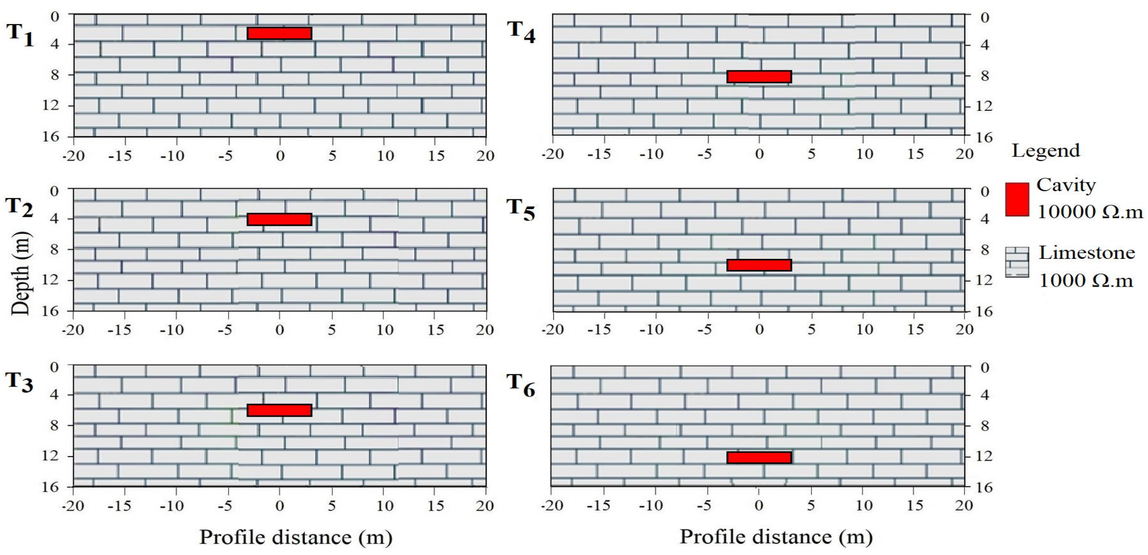

Fig. 1 Resistivity models for cavity set at six-different depths in limestone medium.

Depth of investigation (DOI) index determined.

$$DOI\ (x,z) = \frac{m_1(x,z) - m_2\ (x,z)}{R_b(m_{01} - m_{02})}$$

where m_1 and m_2 are inverted resistivities of the same cell for two inversions.

Results and Discussion

The portion of inverted models above **DOI** index of 0.1 showed better model resolution.

Resolution of cavity anomaly decreases with survey depth (Figs. 2-5).

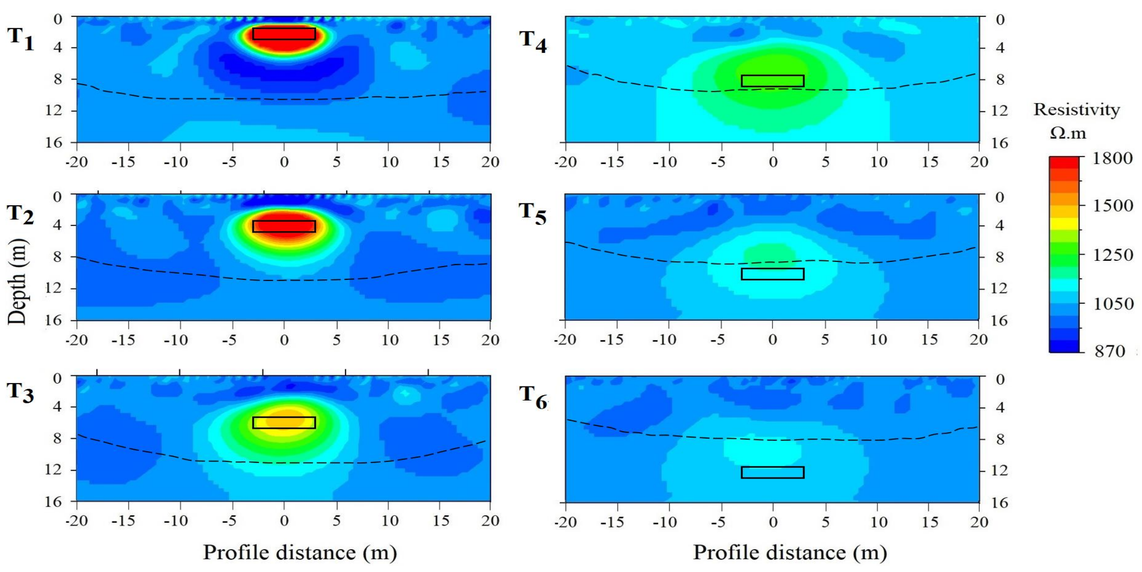

Fig. 2 The inverted models for **DD** array. Broken line represents DOI threshold depth. Rectangular box indicates the actual cavity model.

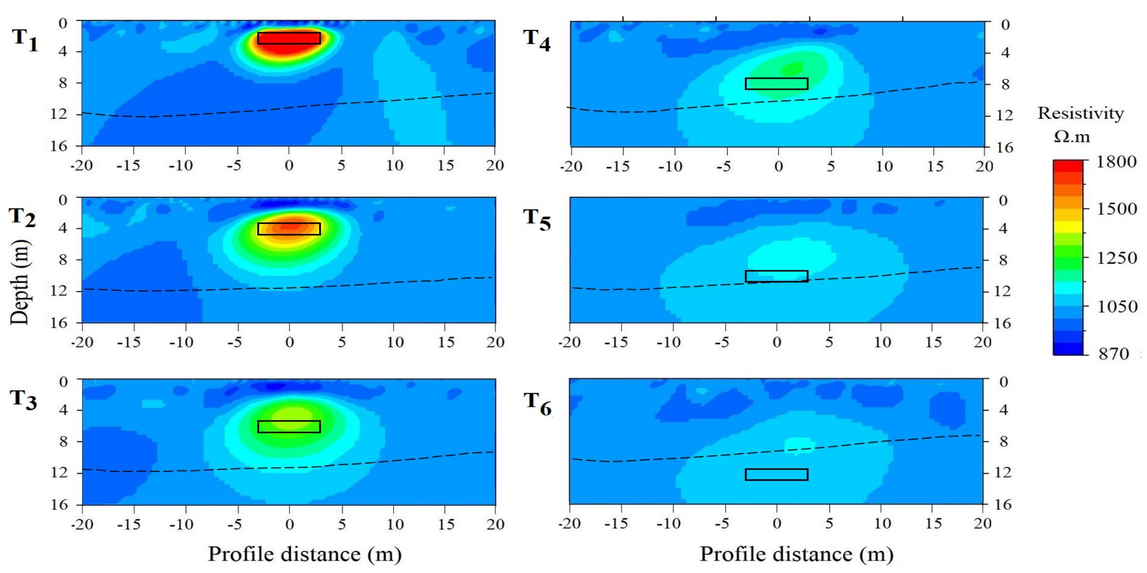

Fig. 3 The inverted models for **PD** array.

DD array resolved the highest model resolutions that indicate relatively distinct anomaly boundaries, yet the detection level limited with increasing target depth.

WS and **PD** arrays recovered good resolution but determining the anomaly boundaries were relatively challenging.

PP array provided the lowest resolution, and its anomalies were also far from the actual cavity models.

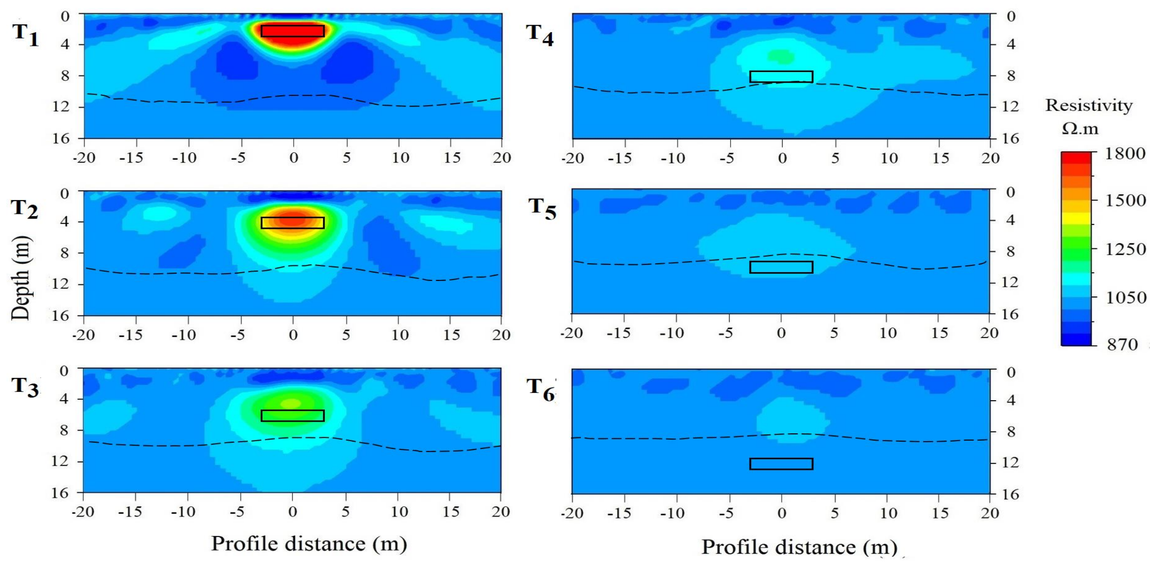

Fig. 4 The inverted models for **WS** array.

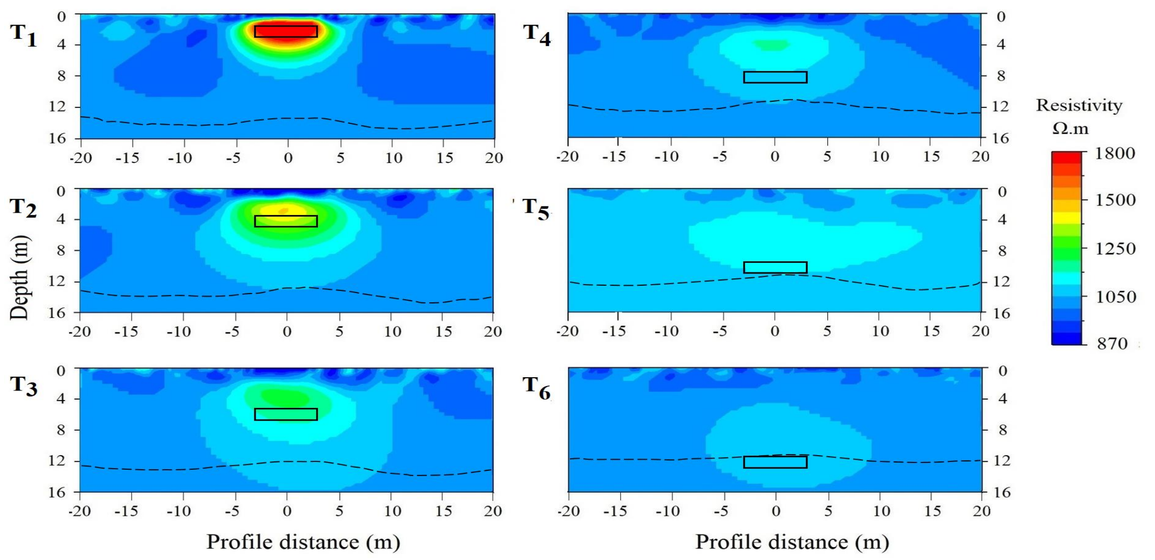

Fig. 5 The inverted models for **PP** array.

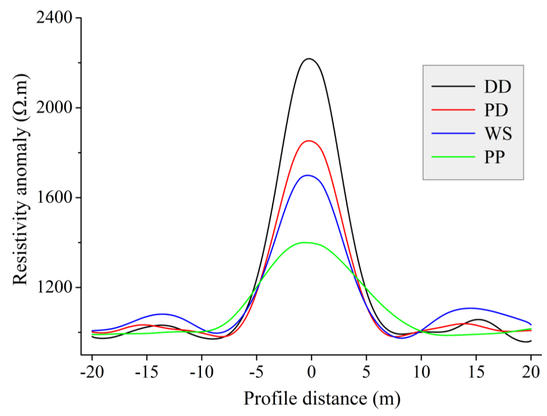

Fig. 6 **1D** resistivity profile (anomaly gradient) over cavity $\mathbf{T_2}$ that extracted at 4.2m depth.

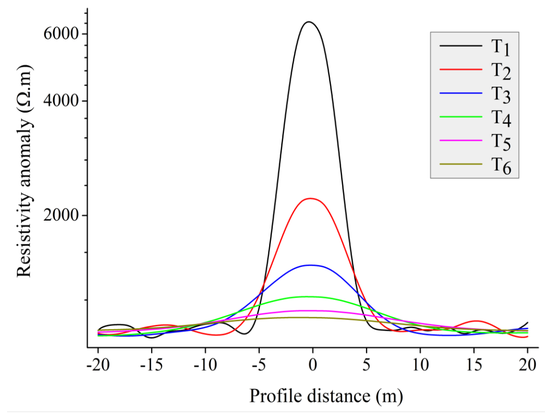

Fig. 7 **1D** resistivity profile using DD array for cavities; $\mathbf{T_1}$, $\mathbf{T_2}$, $\mathbf{T_3}$, $\mathbf{T_4}$, $\mathbf{T_5}$, and $\mathbf{T_6}$ at depths of 2.2 m, 4.2 m, 6.2 m, 8.2 m, 10.2 m, and 12.2 m.

Steeper anomaly gradient can indicate more distinct cavity boundaries, while the gentler anomaly gradient limits the inference of cavity boundaries (Figs. 6 & 7).

Conclusions

At deeper depths, inverted models showed a reduction in model resolutions, overestimation in anomaly sizes, and deviation in anomaly positions, which can create ambiguity in resistivity model interpretations.

DD array is the most appropriate, **PD** and **WS** arrays are adequate while **PP** array is the least suitable for cavity studies.

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