

Characterizing the Identifiability of Air-Filled vs. Water-Filled Karst Conduits Using Time-Domain Electromagnetic and Electrical Resistivity Tomography Methods

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I. Hypothesis & Scientific Gap

Time-domain electromagnetic (TDEM) and electrical resistivity tomography (ERT) methods exhibit fundamentally different identifiability characteristics for karst conduits. Neither method can reliably distinguish conduit fill type based on geophysical response alone without prior geological information. While both geophysical methods are routinely applied to karst exploration, existing literature primarily uses ERT and TDEM complementarily rather than systematically comparing their identifiability for specific karst features. Chalikakis et al. (2011) provide qualitative adequacy assessments, but quantitative comparison of resolution limits, depth of investigation, and feature detection thresholds for different conduit types is absent. Recent studies (Rey et al. 2020; Mendoza et al. 2021) demonstrate combined application but do not establish which method optimally characterizes specific karst targets.

II. Scientific & Societal Value

This research addresses a fundamental question in applied geophysics: how do different methods resolve the same subsurface target? Systematic comparison of TDEM and ERT identifiability will: establish quantitative detection thresholds (minimum size, maximum depth) for conduits of varying fill states, define the trade-offs between resolution and depth penetration inherent to each method, and provide a framework for interpreting ambiguous geophysical signatures in karst terrains. The methodology developed could then be extended to other geophysical applications beyond karst systems.

Karst aquifers supply 20-25% of the global population with drinking water. This percentage is even higher in the Balkan region, where I am from. Their complex systems create significant challenges for groundwater management and contamination risk assessment. Improved characterization could directly impact water resource management, contamination vulnerability, and geohazard mitigation.

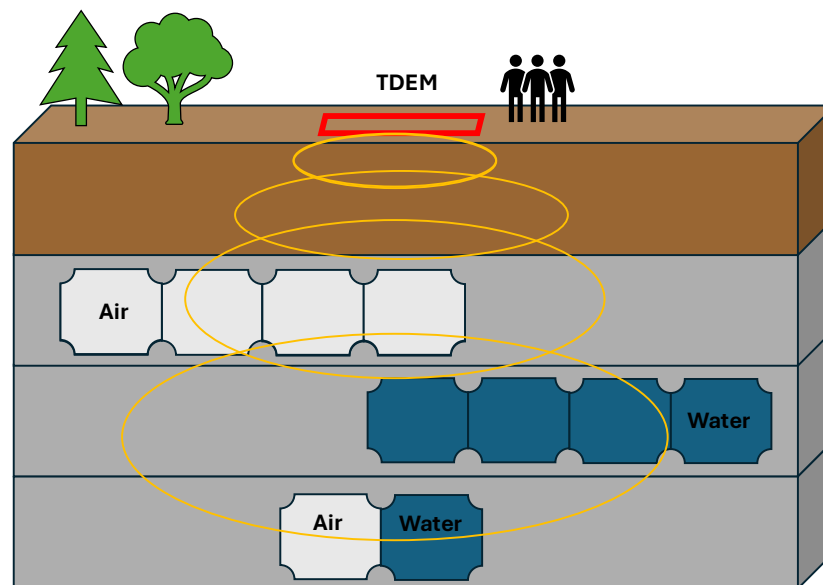
III. Analysis Plan

This research will utilize TDEM sounding and existing ERT data collected from the Kartchner Caverns in AZ. The analytical approach consists of three phases. First, forward modeling will generate synthetic TDEM and ERT responses for karst conduits of varying dimension and fill. Detectability metrics will quantify theoretical detection limits for each method. Second, field data will be inverted through SIMPEG, with inverted models validated through forward modeling. Third, comparative analysis will directly compare resistivity profiles, determine depth of investigation limits, quantify

minimum detectable conduit size versus depth, and identify non-unique cases where different conduit fills produce similar geophysical responses.

The hypothesis will be supported the two methods reliably distinguish fill type. The hypothesis will be refuted if methods show equivalent performance across all conditions. Alternative explanations for poor method correlation could include heterogeneity, different investigation volumes, near-surface conductivity effects on TDEM, or 3D geometry effects.

IV. Key Figure



V. Timeline & Milestones

Milestone 1 (March): Complete forward/inverse modeling framework and simulated testing.

Milestone 2 (April): Field data processing and modeling.

Milestone 3 (May): Comparative analysis and identifiability assessment.

Milestone 4 (June): Complete thesis and defend.

VI. References

Chalikakis, K., et al. (2011). Contribution of geophysical methods to karst-system exploration: an overview. *Hydrogeology Journal*, 19, 1169-1180.

Rey, J., et al. (2020). Geophysical characterization of aquifers in southeast Spain using ERT, TDEM, and vertical seismic reflection. *Applied Sciences*, 10(20), 7365.