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# Resonance Seismometry: Search for Tiny Tot Underground Nuclear Explosion at Nevada Test Site

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seismic software & services


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## INTRODUCTION

Cavities resulting from Underground Nuclear Explosions (UNE) alter the local wavefield of regional earthquakes.

Analyzing earthquake recordings, we locate and identify subsurface anomalies.

## METHODS/DATA

We analyzed seismic data for a M3.8 earthquake in southern Nevada recorded on a temporary array on the Climax Stock at the Nevada Test Site.

We applied a combination of spectral analysis, hierarchical clustering and the onset delay method.

START

## RESULTS

We identified multiple anomalies in the survey area, which coincide with geological fault lines, topography and UNE Tiny Tots suspected cavity and tunnel system.

## CONCLUSION

Earthquake data can be used for the horizontal mapping of subsurface anomalies.

A combination of automated and interactive methods enables robust identification of anomalous sites without a-priori information.

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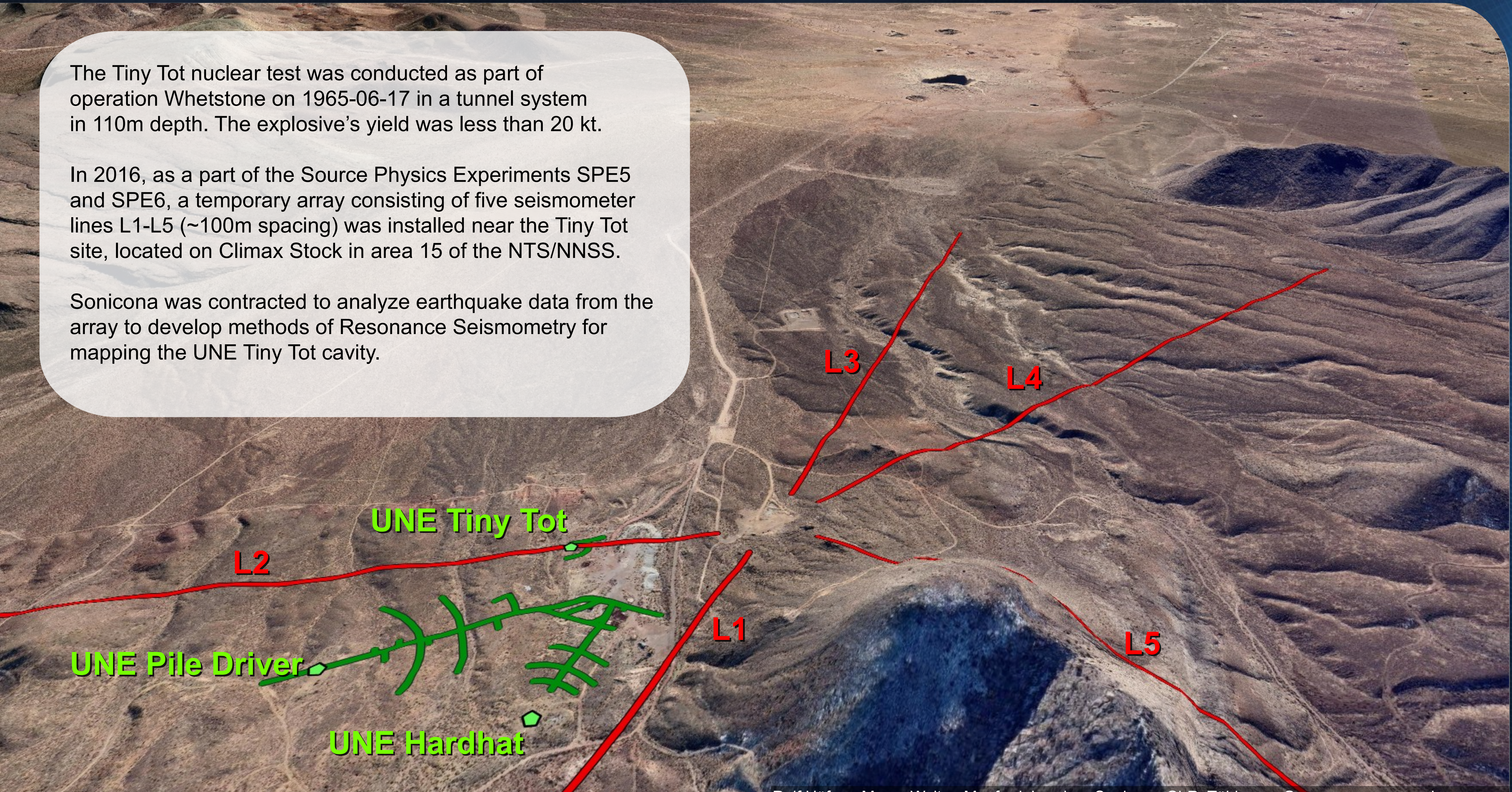
# Introduction: UNE Tiny Tot at the Nevada Test Site (NTS)

The Tiny Tot nuclear test was conducted as part of operation Whetstone on 1965-06-17 in a tunnel system in 110m depth. The explosive's yield was less than 20 kt.

In 2016, as a part of the Source Physics Experiments SPE5 and SPE6, a temporary array consisting of five seismometer lines L1-L5 (~100m spacing) was installed near the Tiny Tot site, located on Climax Stock in area 15 of the NTS/NNSS.

Sonicona was contracted to analyze earthquake data from the array to develop methods of Resonance Seismometry for mapping the UNE Tiny Tot cavity.



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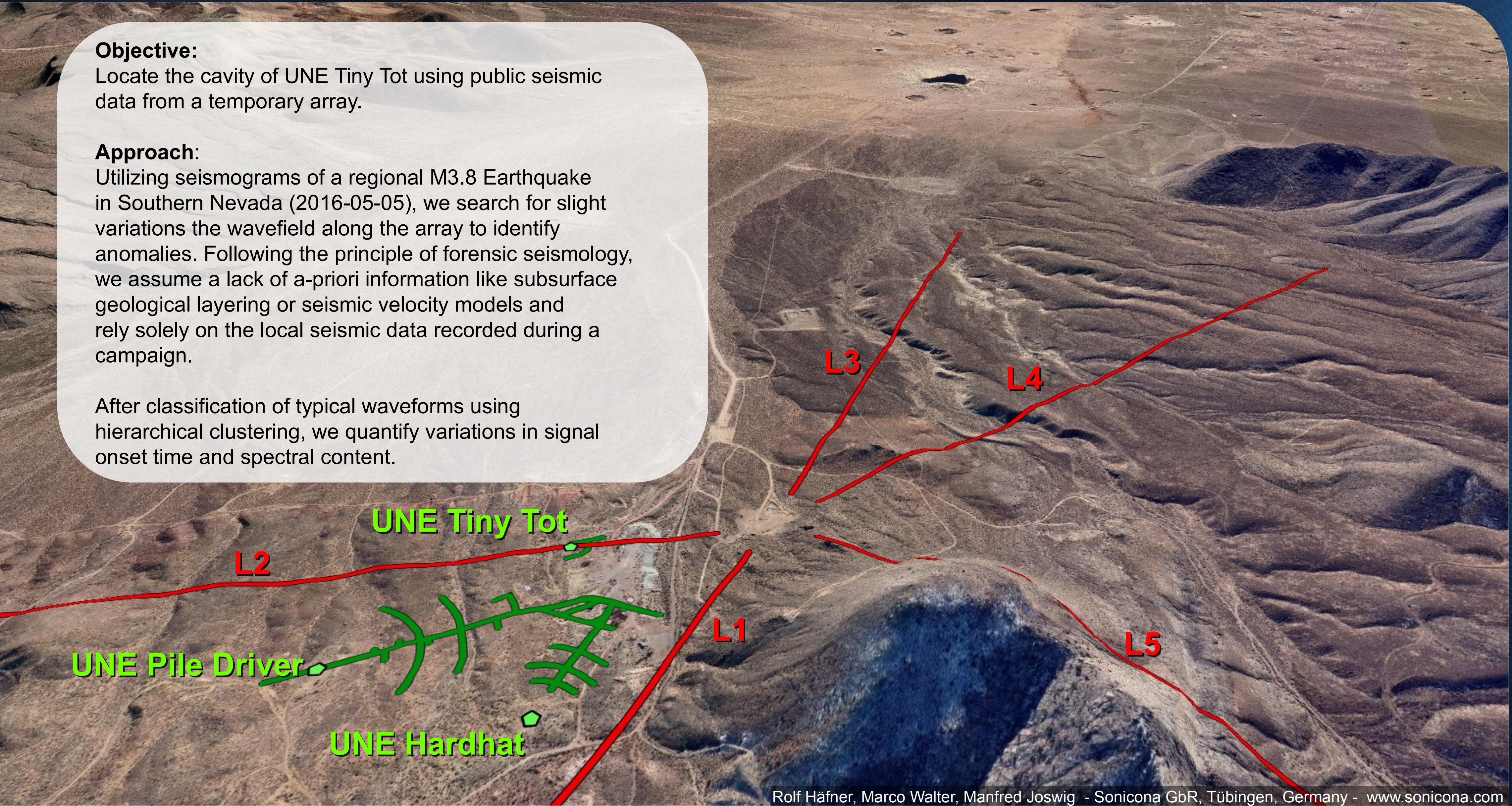
# Objective: Locate the UNE cavity

**Objective:**
Locate the cavity of UNE Tiny Tot using public seismic data from a temporary array.

**Approach**:
Utilizing seismograms of a regional M3.8 Earthquake in Southern Nevada (2016-05-05), we search for slight variations the wavefield along the array to identify anomalies. Following the principle of forensic seismology, we assume a lack of a-priori information like subsurface geological layering or seismic velocity models and rely solely on the local seismic data recorded during a campaign.

After classification of typical waveforms using hierarchical clustering, we quantify variations in signal onset time and spectral content.



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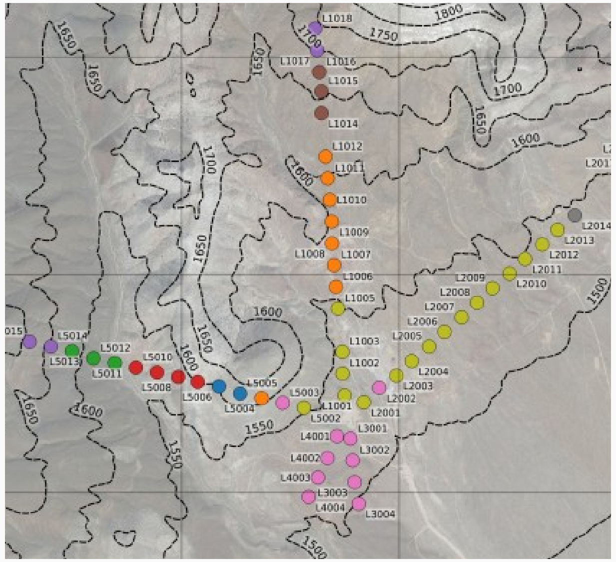
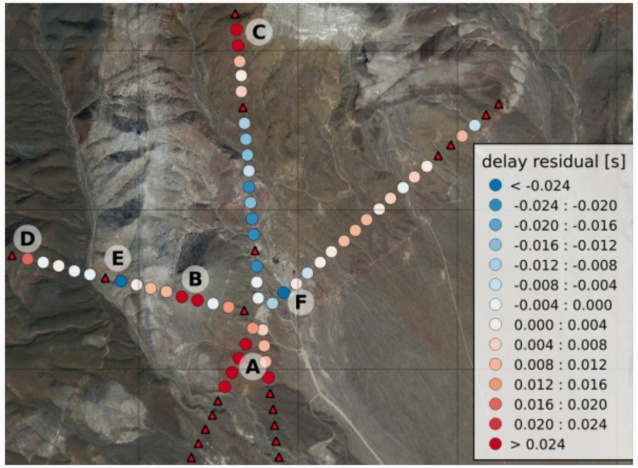
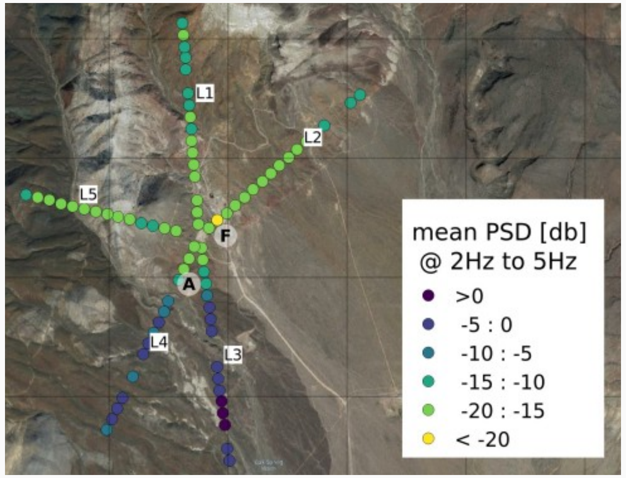
# Methods: Resonance Seismometry for Earthquake data



**Hierarchical Clustering** of waveform onsets is an automated method revealing large scale subsurface variations: boundaries of geological zones and topography.
A correlation matrix is calculated from the seismic data and provides a distance matrix for the clustering algorithm. This collates stations into clusters of minimal waveform variation (shown as color in the map).




The **Onset Delay Method** visualizes deviations in onset arrival times in the array. Delays are first estimated by cross-correlation and enhanced in an interactive process. Then, the effect of the wave's finite propagation velocity within the array is subtracted to produce residual delays which signify anomalous behaviour.
This resolves variations in arrival times of the order of milliseconds. Significant contrast in onset delays translate to subsurface anomalies (A-F in the map).




In **Spectral Mapping**, power spectra for each stations' seismogram are calculated and visualized in a spectral histogram. This plot is used to identify spectral bands where PSD varies across the array, indicating local subsurface absorption of the seismic wave. PSD in such bands can be mapped, to identify the anomalous stations within the array.
This complements the map produced by the Onset Delay Method.

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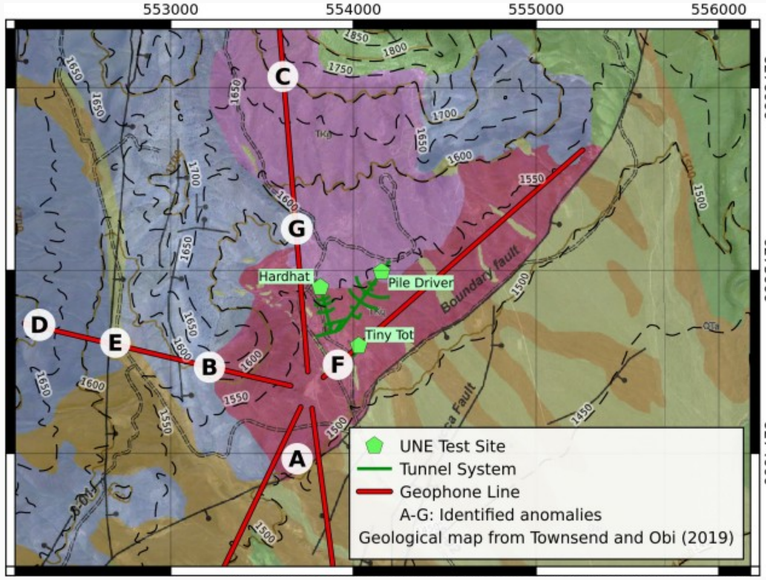
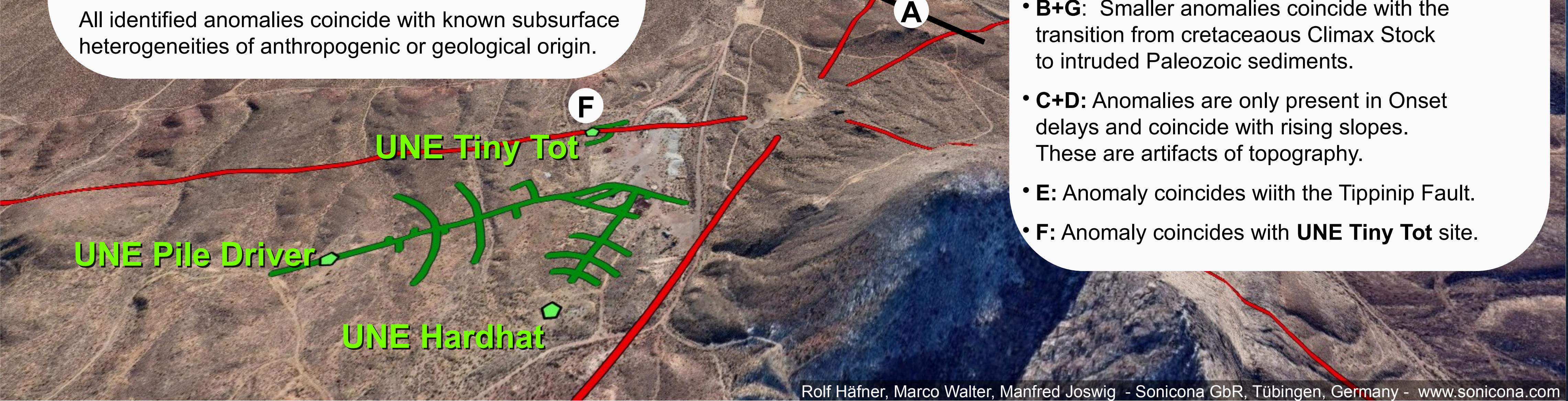
# Results: Subsurface anomalies near UNE Tiny Tot




All identified anomalies coincide with known subsurface heterogeneities of anthropogenic or geological origin.




A comparison of each anomaly located by Resonance Seismometry methods with known geology and UNE test information shows:

- **A:** Strongest anomaly in the survey area, coincides with the Boundary Fault
- **B+G**: Smaller anomalies coincide with the transition from cretaceaous Climax Stock to intruded Paleozoic sediments.
- **C+D:** Anomalies are only present in Onset delays and coincide with rising slopes. These are artifacts of topography.
- **E:** Anomaly coincides wiith the Tippinip Fault.
- **F:** Anomaly coincides with **UNE Tiny Tot** site.

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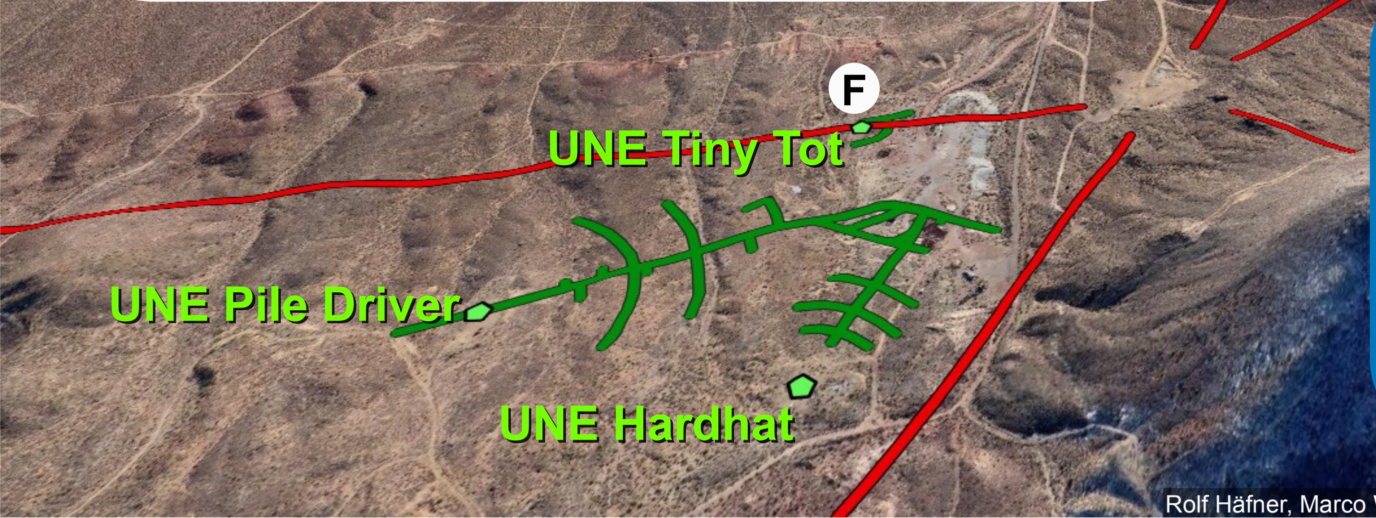
# Conclusion: Forensic approach to Resonance Seismometry

- Distant earthquakes provide sufficient signal power for horizontal **anomaly mapping** without the use of active sources.
- The improved, interactive **Onset Delay Method** provides a sensitive way of mapping weak subsurface anomalies.
- A **combination of methods** allows to discern large scale heterogeneities from point like anomalies.
- The approach of **Forensic Seismology** enables passive seismic methods to fulfill the requirements of Resonance Seismometry.

**Forensic Seismology**

- No dependance on a-priori information and model parametrization.
- Passive methods; no active sources.
- Enhancement and control of automated methods by interactive input.
- Interpretation of parameters directly derived from data.

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**Thank you for your attention!**

We're looking forward to meet you at the Sonicona booth in front of the Prinz Eugen Saal and discuss our findings.



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