SCEC Final Technical Report

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SCEC Community Earth Models (CEMs)	*None*

Institutional Affiliation	**Investigators**
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Field investigation of complex faulting across the San Diego Bay step-over
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We conducted field investigations of faults along the La Nacion Fault Zone (LNFZ) and faults south of San Diego Bay that were recently mapped in Lidar and aerial imagery data and that may link to the Rose Canyon fault zone (RCFZ) to the north, impacting the regional seismic hazard. The Holocene active RCFZ is a known hazard to the city of San Diego and is well mapped and studied where it trends onshore in San Diego, from La Jolla to downtown (Fig. 1). However, south of downtown, the fault zone splays into San Diego Bay and it remains unclear how slip is transferred between the RCFZ and faults to the south. In early models, the RCFZ was thought to link with the offshore Descanso fault, creating the San Diego Bay pull-apart basin through deformation on the cross-basin Spanish Bight (SBF), Coronado (CF), and Silver Strand faults (SSF) (Legg, 1985; Treiman, 1993; Kennedy and Clarke, 1996; Rockwell, 2010). More recently, a double pull-apart basin model was used to explain the faulting beneath San Diego Bay (Singleton et al., 2021; Singleton et al., 2024). In this model, the RCFZ-Descanso step explains faulting in the western part of the basin (SBF, CF, and SSF), while a step from the RCFZ to the San Miguel Vallecitos fault (SMVF) explains faulting beneath the southeastern Bay and the LNFZ. However, definitive evidence of faulting south of San Diego Bay to explain the RCFZ-SMVF connection has not been identified. Now, new fault mapping, based on Lidar and aerial imagery from south of San Diego Bay, including within the Tijuana River National Estuarine Research Reserve (TRNERR), revealed several potential fault strands that could elucidate connections between the San Diego Bay faults, the RCFZ, the LNFZ, and the SMVF (Fig. 1) (Mueller & Lopez, 2024). These data resulted in a new model where slip from the Salisipuedes fault, offshore northern Baja, Mexico, steps across the TRNERR to the LNFZ. This

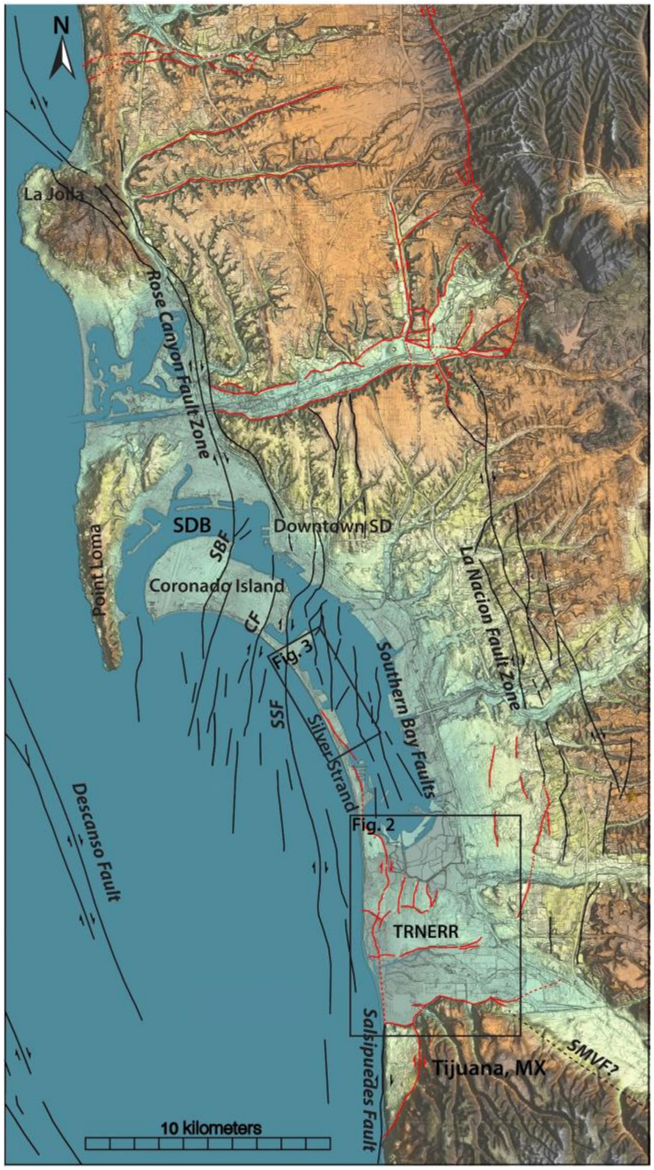

Fig. 1. Fault map of San Diego region. Black faults are previously mapped. Red are newly mapped by Mueller and Lopez (2024). SBF - Spanish Bight Fault; CF - Coronado Fault; SSF - Silver Strand Fault; SMVF - San Miguel Vallecitos Fault; SDB - San Diego Bay; TRNERR - Tijuana River National Estuarine Research Reserve.

would indicate that the LNFZ may potentially be more active than previously thought. We ground-truthed the Lidar mapped fault strands in the TRNERR and LNFZ by compiling existing geotechnical studies and conducting geophysical surveys across mapped fault strands in the TRNERR. The work supported an SDSU Masters thesis and was integrated into two SDSU undergraduate advanced field classes. The work was organized into six primary tasks, which are detailed in the following sections.

Tasks 1 and 2. The goal of these tasks was to collect existing geotechnical data from the region south of San Diego Bay and along the LNFZ to characterize the stratigraphy and search for evidence of faulting. Much of these areas are heavily developed making geologic fault zone studies difficult. However, geotechnical studies are often required by city governments prior to development and the reports may contain important information on the stratigraphy beneath the surface. To accomplish this task, we first georeferenced pre-development 1928 aerial photographs from the San Diego County library to identify geomorphic features within the study area that suggest faulting prior to land surface modifications. We also imported USGS 3D Elevation Program (3DEP) 1 meter digital elevation model (DEM) rasters (UGSS, 2021). The DEM represents a topographic bare-earth surface produced from lidar data sources with elevations referenced to the North American Vertical Datum of 1988 (NAVD88). Geotechnical reports prepared for land developments within the LNFZ were

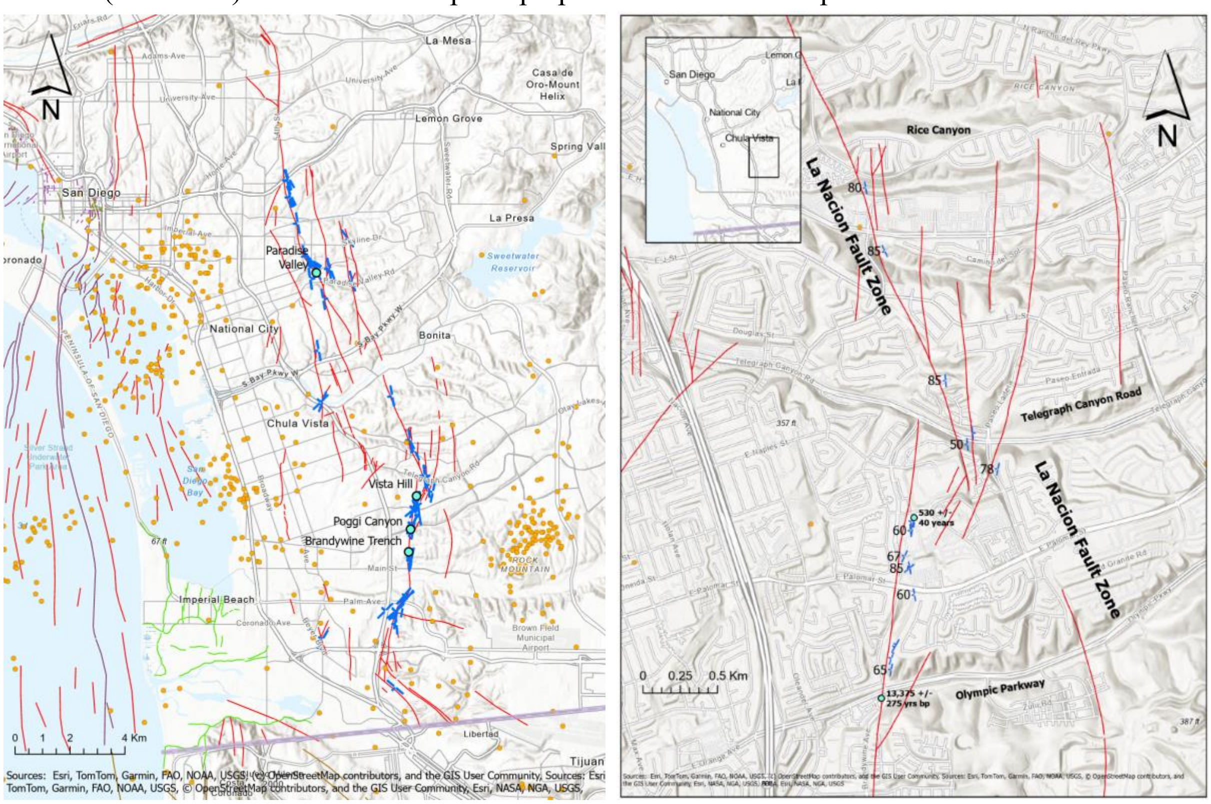

Figure 2: Left - Map of the LNFZ and newly mapped potential faults in the Tijuana River Estuary. Faults are shown as lines, color coded as follows: red-potentially active faults (CGS); purple-active faults (CGS); tan-Baja California faults (CICESE); green-new potential faults proposed by Mueller (2024). Teal dots represent soil samples that have undergone C-14 dating. Yellow dots represent earthquake locations (USGS). Right - Zoomed in map on LNFZ at Chula Vista with blue strike and dip symbols plotted for geotechnical reports compiled in the project.

acquired from various sources, including private geotechnical firms and the Cities of San Diego and Chula Vista. Where traces of the LNFZ were observed in fault trenches, the fault map was georeferenced. A georeferenced dataset was then created with the strike and dips of each of the observed faults, and a separate layer indicated the locations of any fault offset that had been previously dated (Fig. 2). Results showed a generally N-S striking fault zone with an average strike of N1°W (Fig. 3). Fault dip was primarily to the west and ranged from 33° to 85°. All reports indicated vertical slip, primarily down to the west, and little evidence of lateral offset was observed in DEMs or historical aerial imagery to suggest a major strike-slip component of faulting. There were two Holocene ages previously proposed for the LNFZ, but one is not reliable due to bioturbation and mixing of the dated sediment and the other was not reproducible on subsequent field efforts. Therefore, we did not identify any conclusive evidence of Holocene earthquakes on the LNFZ

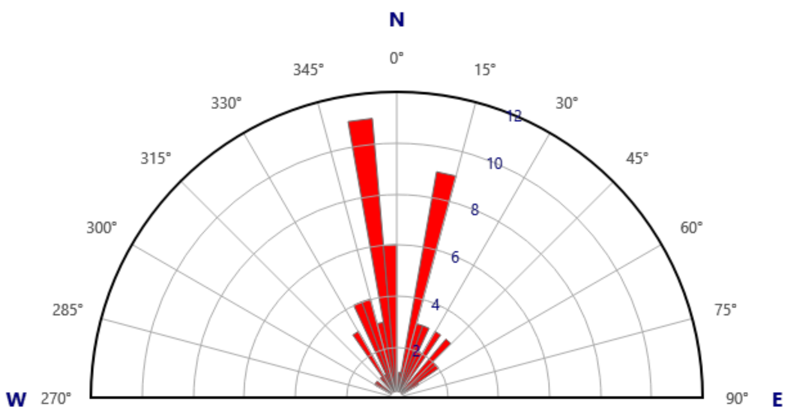

Fig. 3: Rose diagram of LNFZ fault strike compiled from previous field studies and geotechnical reports. Overall orientation is consistent with a N-S striking normal fault, dipping west, with down to the west slip.

<u>*Tasks 3 and 4.*</u> The goal of these tasks was to collect new data across Lidar mapped fault strands in areas that are undeveloped to characterize stratigraphy and look for evidence of faulting. The largest undeveloped area is the TRNERR where Mueller and Lopez (2024) mapped the N-S trending Salsipuedes fault continuing north from the US-MX border and a normal fault just north of the border that may connect the Salsipuedes fault with the LNFZ (Fig. 1). Several potential transects across fault segments were identified for geophysical survey. Due to permitting restrictions and accessibility, we identified a primary and secondary transect for geophysical data collection in the TRNERR (Fig. 3). These transects crossed a newly proposed fault mapped in Lidar data by collaborator Karl Mueller, and interpreted to be a possible extension of the Salsipuedes fault. At profile 1, a suite of geophysical instruments were employed including seismic refraction using a hammer and steel plate source, a magnetometer, a gravimeter, and a resistivity system. These data reveal changes in subsurface properties that could indicate a fault zone. Due to permitting restrictions, originally planned vibracores could not be collected along the transect. Following data collection, the geophysical data were processed and interpreted using software available at SDSU. The seismic refraction, magnetometer, and partial gravity surveys were conducted as part of the SDSU Advanced Field classes in Sedimentology and Stratigraphy and Geophysical Methods, taught by Jillian Maloney and Kim Olsen, respectively (Fig. 4). SDSU M.S. student Jen Morton and collaborator Tom Rockwell led the collection of subsequent high resolution ERT surveys and gravity

surveys along profile 1. An ERT survey was also conducted across profile 2, located south of profile 1 to identify the possible continuation of a proposed fault.

The northern ERT profile (profile 1), indicated a subvertical change in resistivity at around 160 m along the transect from the east (Fig. 5). This aligns roughly with the potential fault mapped by Mueller & Lopez (2024), which is represented in Lidar data as a linear ridge. A shorter, higher resolution ERT survey across the feature along the same profile replicated the same conditions (Fig. 6). A gravity survey across the same profile indicates a relatively high anomaly coincident with the change in resistivity (Fig. 6), however the magnetic survey did not indicate a magnetic anomaly at this location, although a large negative magnetic anomaly was observed slightly to the west (Fig. 5). In the southern ERT profile, the same resistivity change was not observed (Fig. 7). This could indicate that the feature at profile 1 is a local, non-fault related feature, or it is possible the fault bends farther east than we were able to survey due to access restrictions. Unfortunately, the seismic reflection data were collected prior to the ERT profile and it did not extend across the resistivity change at 160 m.

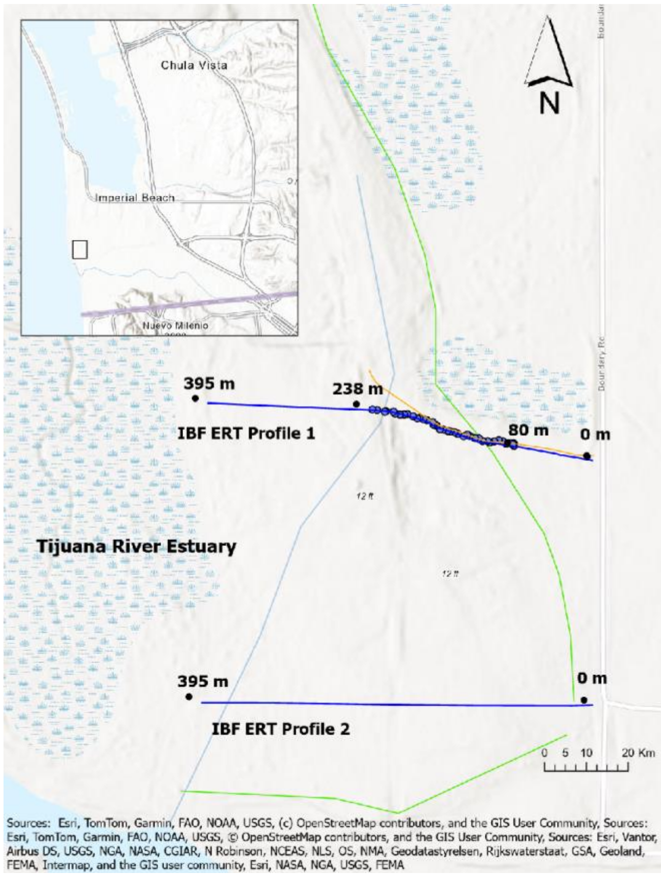

Fig. 3: Map showing location of geophysical surveys in the TRNERR. Green lines are newly proposed faults from Mueller and Lopez (2024). Blue lines are ERT profiles, yellow line is magnetic survey profile, and blue dots are gravity survey locations.

Task 5. The work conducted for this proposal forms the basis of Jen Morton's M.S. thesis. She has elected the thesis option offered by SDSU to submit her thesis for peer reviewed publication. She is finishing her thesis for submission in May 2026. Although data were not available to present at the SCEC 2025 annual meeting, Morton presented her results at the spring San Diego Association of Geologists meeting. Additionally, undergraduate students from the field classes gained experience in field data collection and data processing, and they used the data to generate reports for their courses.

Task 6 is the composition of the final report and publication of the data. The geodatabase is currently being finalized and will be made available through Zenodo. We anticipate publication of Morton's thesis in May 2026, with subsequent submission to a peer-reivewed journal in summer 2026.

Fig. 4: Photos from the Advanced Field classes collecting resistivity and seismic reflection data in the TRNEER.

Conclusions

Data from the previously mapped LNFZ indicate primarily N-S trending faults with normal slip, down to the west. The lack of laterally offset features is also consistent with a primarily normal fault. This agrees with the double pull-apart basin model where the LNFZ accommodates subsidence across the pull-apart basin between the Rose Canyon and San Miguel Vallecitos fault zones (e.g., Singelton et al., 2021), rather than the pull-apart basin model between the Salsipuedes and LNFZ (Mueller and Lopez, 2024). We did not identify any new evidence of Holocene offset along the LNFZ, which means the fault is still considered "potentially active."

The geophysical data collected across the newly proposed extension of the Salsipuedes fault in the TRNERR indicate the possible presence of a fault in the subsurface. In particular the ERT profile shows a strong vertical change in the resistivity at the location of the mapped feature. A coincident gravity anomaly is also consistent with a fault interpretation, possibly reflecting a more cemented fault core. The lack of a magnetic anomaly could indicate that there isn't a strong change in the magnetic content of the units offset by the fault. Future work is needed to trace the extent of this fault to the north and south as it was not identified in the southern ERT profile.

The presence of the Salsipuedes fault extension into the TRNERR could support both of the pull-apart basin models tested here, at least partially. The model of Mueller and Lopez (2024) includes an E-W trending fault along the U.S.-Mexico border that accommodates subsidence and rollover into the San Diego Bay basin. The data collected in this research support that interpretation, but we suggest that the Salsipuedes-LNFZ step-over is not required to create this feature. Alternatively, the Salispuedes fault zone may continue north and connect with faults in the southern San Diego Bay, potentially forming the eastern boundary of the Rose Canyon-San Miguel Vallecitos pull-apart basin. Future geophysical surveys across the E-W border fault would greatly enhance our understanding of this complex geologic region.

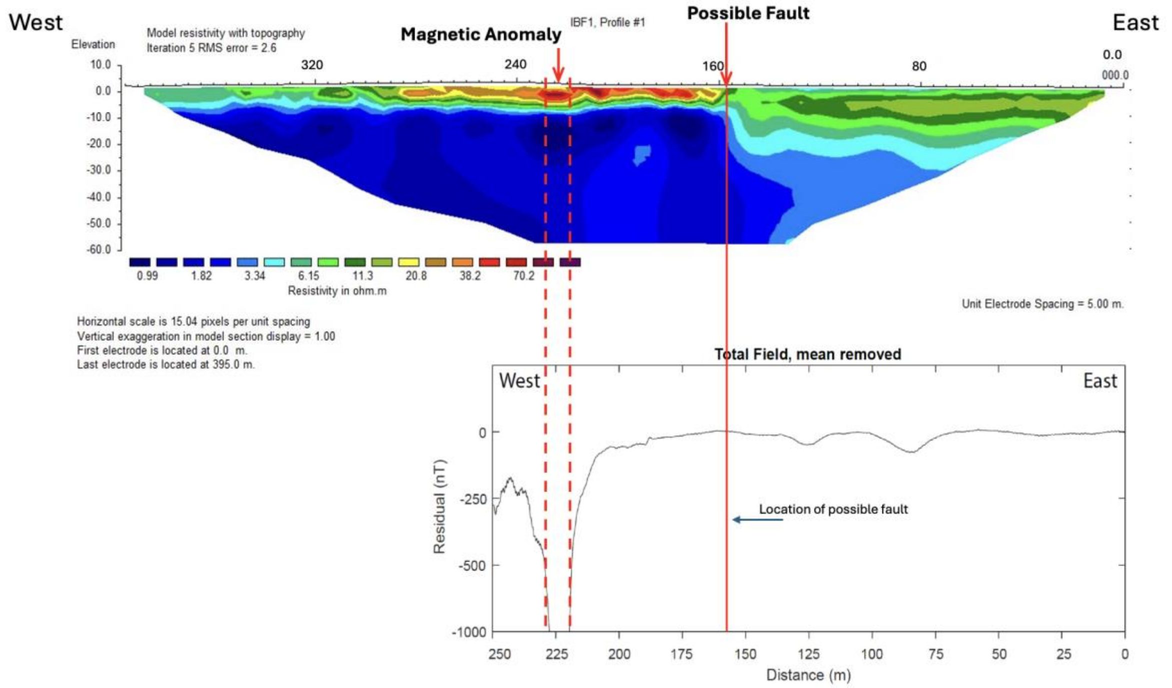

Fig. 5: Top - ERT profile along entire length of northern Profile 1 (see Fig. 3 for location) with 5 m electrode spacing. Note a strong, vertical change in resistivity ~160 m along the profile, as indicated by the red arrow, which may be caused by a fault in the subsurface. Bottom – Magnetic survey data across part of Profile 1 (see Fig. 3 for location). Note the absence of a magnetic anomaly at the location of the resistivity change, but a large anomaly to the west of the resistivity change.

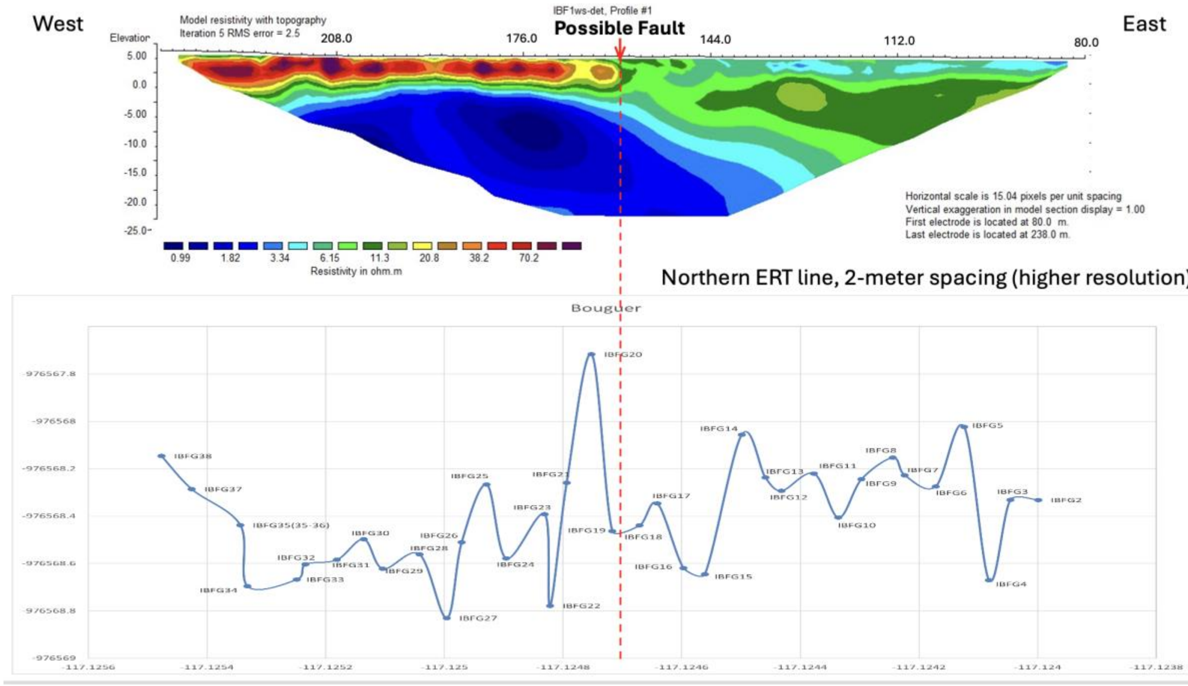

Fig. 6: ERT profile along partial length of northern Profile 1 (see Fig. 3 for location) with 2 m electrode spacing. Note a strong, vertical change in resistivity ~160 m along the profile, as indicated by the red arrow, which may be caused by a fault in the subsurface. Bottom – Gravity survey data across part of Profile 1 (see Fig. 3 for location). Note the large gravity anomaly slightly west of the resistivity change.

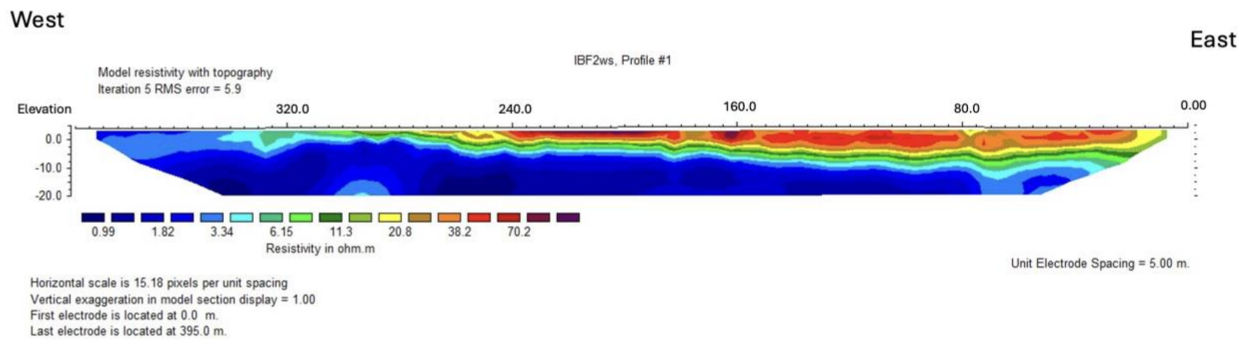

Fig. 7: ERT profile along the southern Profile 2 (see Fig. 3 for location) with 5 m electrode spacing. Note the absence of a change in resistivity, different from the northern Profile 1.

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