GFZ Helmholtz Centre POTSDAM

EarthShape – Earth Surface Shaping by Biota – A German-Chilean Research Initiative

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New insights into the DeepEarthShape project (Chile) by comparison of 2D and 3D inversion results of RMT data using GoFEM and ModEM

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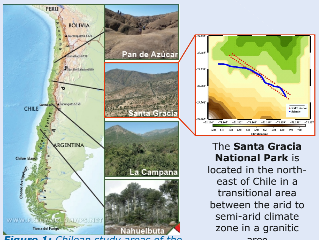
Earthshape project

The Earthshape project focuses on how biologic processes form soil, influence topography, and thereby **shape the Earth surface** over time scales from the present-day to the distant geologic past. All the field research is conducted in the **Chilean Coastal Cordillera** that features one of Earth's most spectacular vegetation gradients and is controlled by climate ranging from arid to humid temperate. It is a **natural laboratory** to study how biology, topography and the near-subsurface interact (Earthshape, 2023).
Within this framework, **DeepEarthshape** project has emerged to focus on the following challenges using **seismics** and the **Radio-Magnetotelluric** method to accompany shallow drilling projects:

1. Depth of **weathering zone**
2. Determine the depth of the water table
3. Image **faults**
4. Image the presence of **fluid**

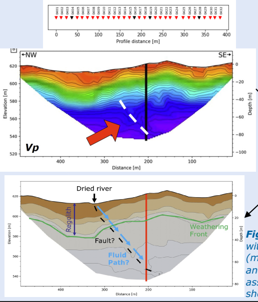
(all points in 2D & 3D)

Study Area & Dataset



The **Santa Gracia National Park** is located in the north-east of Chile in a transitional area between the arid to semi-arid climate zone in a granitic area

Figure 1: Chilean study areas of the EarthShape project (Earthshape, 2023) and the selected Santa Gracia RMT profile



2D Conceptual model is derived from P-wave velocity model along seismic profile in Fig. 1

Figure 2: P-wave velocity model with integrated borehole location (middle) (Trichandi et al., 2022) and 2D Conceptual model (lower) of the weathering structure and the suggested fault/fluid path underneath and the associated receiver line of the RMT profile P2 from Fig. 1 (upper) with dark triangles indicating the receiver positions shown on the right (apparent resistivity and impedance phase curves for TE and TM mode)

2D Inversion

2D inversion performed by:

- Mare2DEM (Key, 2016): TE and TM mode of dataset (Fig.3)
- WinGLink: Rotated TE and TM mode of dataset (Fig.4)

Starting model 1000 Ωm, Error settings: ρ_a 10%, φ 2%

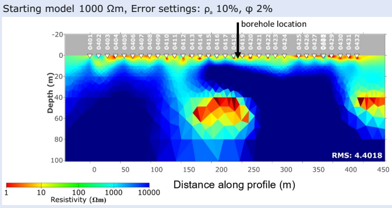


Figure 3: 2D inversion model [Mare2DEM (Key,2016)] using selected stations (Fig. 2)

Inversion model shows the **thickness and extent of regolith layer** (depth of weathering front) as a conductive layer and a conductive **fluid pathway** below stations 411 and 412 (Fig. 2)

Starting model 10000 Ωm, Error settings: ρ_a 10%, φ 2%

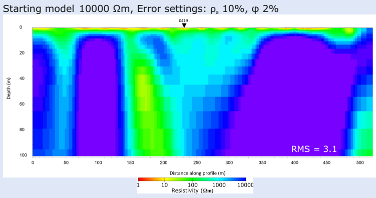


Figure 4: 2D inversion model [WinGLink] using selected stations (Fig.2)

Inversion model illustrates the conductive **weathering structure** and the **fluid** as conductive pathway

New inversion attempt with rotated dataset

2D inversion approaches with processed dataset

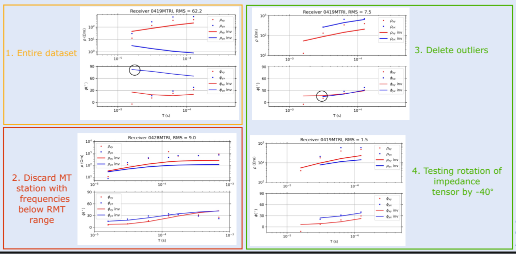
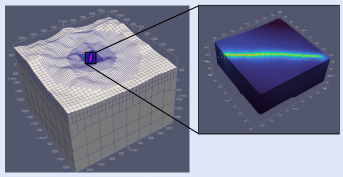


Figure 5: 2D inversion results for different dataset versions (apparent resistivity and impedance phase curves for TE and TM mode)

3D Inversion

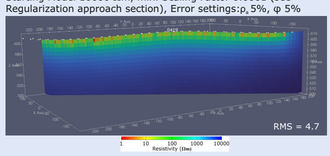


3D inversions performed by:

- GoFEM (Grayver et al., 2015): Rotated full impedance tensor dataset (Fig.7)
- ModEM (Kelbert et al., 2014): Full impedance tensor dataset

Both 3D inversion results have in common features: weathering layer imaged, but no fluid/fault path or conductive body as present in borehole log (Fig. 7)

Starting Model 10000 Ωm, min. Scaling Factor 0.0001 (see Regularization approach section), Error settings: ρ_a 5%, φ 5%



Starting Model 100 Ωm

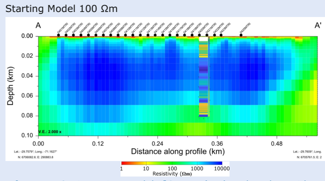


Figure 7: 3D inversion models [GoFEM (top) and ModEM with inserted resistivity borehole log (bottom)]

Regularization approach for 2D and 3D inversion

Inversion by GoFEM and the implemented cooling approach on the regularization parameter by: $\beta = \frac{\gamma \tilde{\partial}_{L_2}}{n_{iter}^c}$ (with $\gamma \in [0,1], c > 0$), where the regularization parameter will be decreased by the scaling factor β_{L_2} after every n_{iter}^c iteration (see Grayver et al. 2013 for more information)

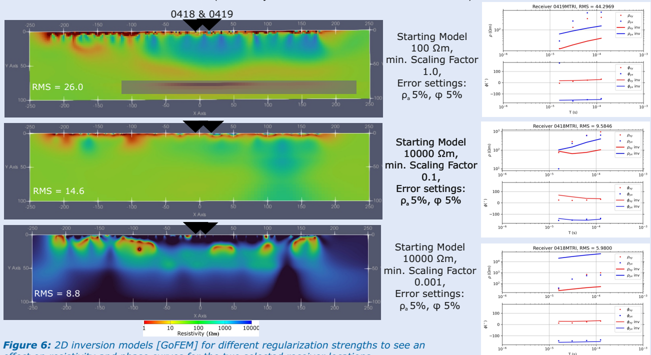


Figure 6: 2D inversion models [GoFEM] for different regularization strengths to see an effect on resistivity and phase curves for the two selected receiver locations

Inversion models include **weathered conductive top layer** (10-20 m) & **resistive basement** (> 1000 Ωm)

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