TEM at breathtaking heights: Investigating fumaroles on Lastarria Volcano, Chile

T. Vondenhoff[1], B. Blanco-Arrué[2], J. Roas[1], B. Tezkan[1], D. Diaz[3] & P. Yogeshwar[1]*

[1]Institute of Geophysics and Meteorology, University of Cologne, [2]LIAG, [3]University of Chile
*Contact: tvonden1@uni-koeln.de, www.geomet.uni-koeln.de

Introduction

Chile is a country known for its seismic activity. One of the biggest deforming zones is the Central Volcanic Zone of the Andes. Here the Nazca Plate subducts underneath the South American Plate, which causes the region to uplift. Although the area houses more than 40 volcanos that are considered as active, to this date, the connection between the uplift and the volcanos magmatic systems are poorly understood. Since active volcanoes in fault zones are associated with hydrothermal fluids, clay minerals and magmatic structures, which are often characterized by high electrical conductivity, this makes it very suitable for the use of geophysical exploration methods.
In March 2023 we conducted TEM measurements on Lastarria Volcano with the aim of understanding fumarolic activities and their connection to the underlying magmatic system.
All results presented in this Poster are preliminary and thus might be subject to change in the following months as part of my upcoming MSc Thesis.

Survey Area & Geological Model

Lastarria-Cordon del Azufre volcano complex (Lazufre region)
- Located in the Western Cordillera of the Central Volcanic Zone (CVZ) of the Andes
- On the border to Argentina.
- Covers area of more than 1000 km²

recent volcanoes:
- Cordón del Azufre
- Lastarria Volcano
- Cerro Bayo Complex

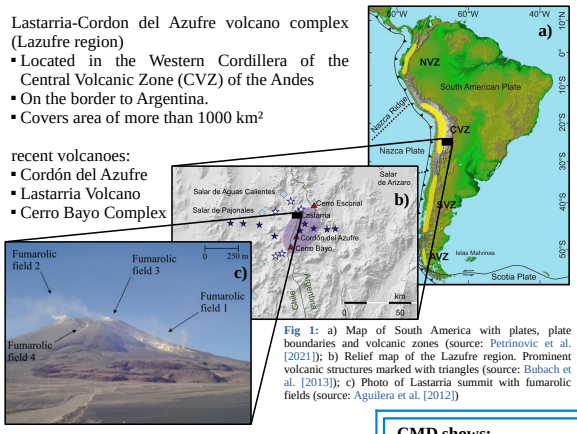

Fig 1: a) Map of South America with plates, plate boundaries and volcanic zones (source: Petrinovic et al. [2021]); b) Relief map of the Lazufre region. Prominent volcanic structures marked with triangles (source: Bubach et al. [2013]); c) Photo of Lastarria summit with fumarolic fields (source: Aguilera et al. [2012])

Lastarria Volcano of interest for scientists for more than 40 years.
- Numerous geological explorations
- Examination of the area using Interferometric Synthetic Aperture radar (InSAR) [Pritchard and Simons, 2002; Froger et al., 2007]
- Extensive geochemical research by analyzing the composition of fumarolic gases [Aguilera et al., 2012].

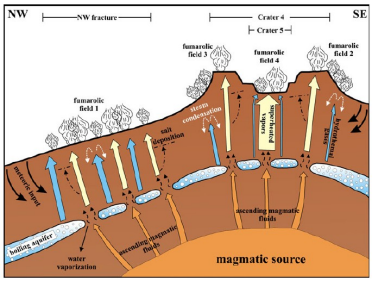

Fig 2: Geochemical conceptual model of Lastarria's fumarole system with a deep magmatic source and a shallow boiling aquifer. (source: Aguilera et al. [2012])

Aguilera et al. [2012] used prior knowledge and insights gained form compositional analysis to construct a conceptual model of Lastarria's magmatic system

Methods: TEM & CMD

- ABEM WalkTEM was used in an in-loop configuration with a transmitter loop size of 40 m x 40 m and a receiver loop size of 10 m x 10 m
- 17 TEM stations measured
- 2 Profiles were established to enable a later interpretation in 2D
- CMD Explorer was deployed to measure conductivities close to the surface
- 1 transmitter coil, 3 receiver coils
  → 3 depths (2.2 m, 4.2 m, 6.7 m)
- More than 4 km were covered by walking

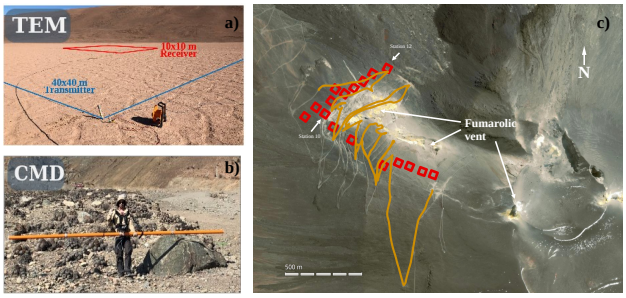

Fig 3: a) ABEM WalkTEM setup with transmitter and receiver loop, b) CMD Explorer setup, c) overview of Lastarria edifice with TEM stations (red squares) and the CMD path (yellow line) marked.

Preliminary Results

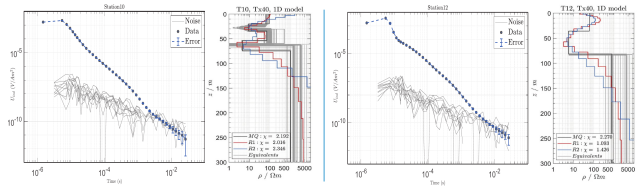

Fig 4: TEM data for two stations. Left shows the raw transient as induced Voltage. Right shows the corresponding 1D inversion

CMD shows:
- Strong conductor around the fumaroles
- More resistive subsurface the further away from fumarolic vents
- Good agreement of resistivity distribution at all 3 depths of investigations

CMD Expl., HCP-3, z*=6.7 m

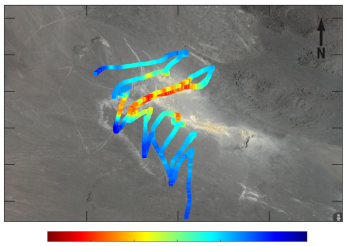

Fig 5: Picture of Lastarria's fumarolic field 1 with the CMD data overlayed. (Data provided by J. Roas)

TEM inversion shows:
- Conductive layer in shallow subsurface
- Resistive basement reached at most of the stations
- Good agreement of resistivity distribution across all 10 stations

Note
- Most stations show a conductive **double layer** at shallow depths
  - For now unclear if artifact from inversion or subsurface feature

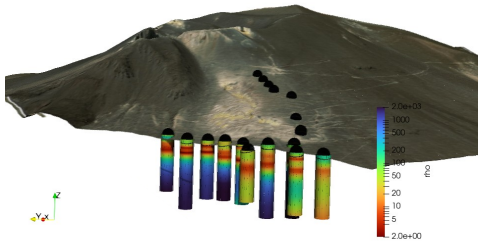

Fig 6: 3D view of Lastarria Summit with stations maked and 1D inversion results displayed at their corresponding position. (Data provided by B. Blanco-Arrué)

Conclusion & Outlook

- Successful geophysical survey
- Preliminary inversion results of TEM data look promising
- Preliminary CMD data in good agreement with prior geological knowledge

What's to come in the future?
- Full data evaluation including data processing and inversion with conventional 1D inversion techniques
- Interpretation of each station and combined in quasi 2D
- Combined interpretation with MT where possible

Acknowledgments

DFG, CRC1211 and Ckelar. D.Diaz for providing the TEM equipment and all assistants during the field campaign. Especially Prof. E. Campos for logistical support.

References

[1] M. N. Nabighian and J. C. Macnae. Time domain electromagnetic prospecting methods. In Electromagnetic methods in applied geophysics: Volume 2, Society of Exploration Geophysicists, 1991. **[2] M. E. Pritchard and M. Simons.** A satellite geodetic survey of large-scale deformation of volcanic centres in the central andes. Nature, 2002. **[3] J.-L. Froger, D. Remy, S. Bonvalot, and D. Legrand.** Two scales of inflation at lastarria-cordon del azufre volcanic complex, central andes, revealed from asar-envisat interferometric data. Earth and Planetary Science Letters, 2007. **[4] F. Aguilera, F. Tassi, T. Darrah, S. Moune, and O. Vaselli.** Geochemical model of a magmatic–hydrothermal system at the lastarria volcano, northern chile. Bulletin of volcanology, 2012. **[5] D. Diaz, W. Heise, and F. Zamudio.** Three-dimensional resistivity image of the magmatic system beneath lastarria volcano and evidence for magmatic intrusion in the back arc (northern chile). Geophysical Research Letters, 2015.