



3-D MT model of the Laguna Colorada - Sol de Mañana geothermal field in SW Bolivia

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Three-dimensional magnetotelluric
inversion for the characterization of the
Sol de Mañana high-enthalpy
geothermal field, Bolivia

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In order to fight climate change...

...we need to invest in non-carbon energy like wind and sun and geothermal energy

The Andean countries have an enormous geothermal potential due to their subduction zone setting and resulting active volcanism.

But: Only a pilot plant in Bolivia (Laguna Colorada, 5 MW)...

...and only one power plant operating so far in neighboring Chile

Cerro Pabellon (Cordillera Occidental, northeast of Calama), 48 MW installed (81 MW end of 2023)

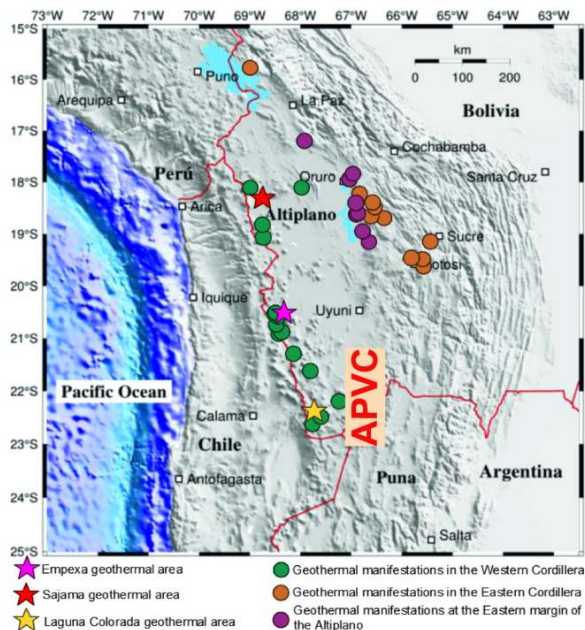
Compare with modern windmill: 5 MW

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Potential geothermal projects in Bolivia

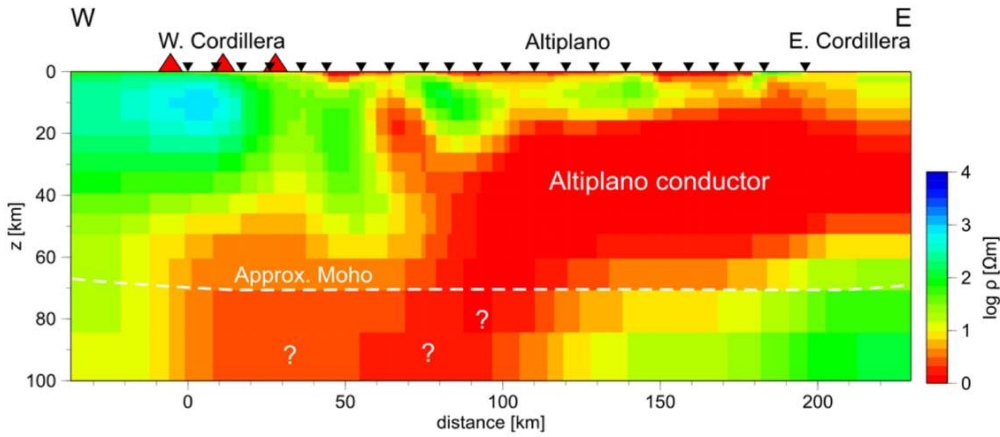


- Active volcanism in the Western Cordillera
- Extinct volcanism in the Eastern Cordillera
- Feasibility studies / reconnaissance in the 1970s: 42 sites with geothermal potential
- Drilling in the 1980
- High-enthalpy geothermal system
- APVC Altiplano-Puna Volcanic Complex (de Silva 1989)



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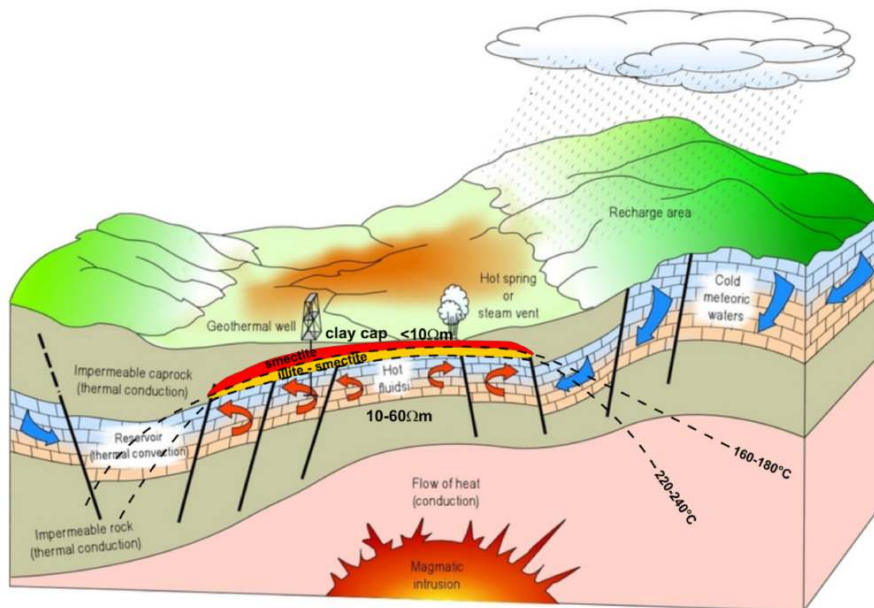
MT transect at 21°S (ANCORP)
Huge magmatic body in the backarc (Altiplano-Puna Magma Body APMB)



- No large magma chamber below volcanoes, but huge (magmatic?) body below Altiplano plateau. This "APMB" was also found by a more recent study of Comeau et al. (2015).
- Structure below Altiplano conductor unresolved due to extreme attenuation of electromagnetic fields. Melts rising from the mantle wedge? Too speculative...
- Fluids on/in downgoing plate compatible with data, but not required.

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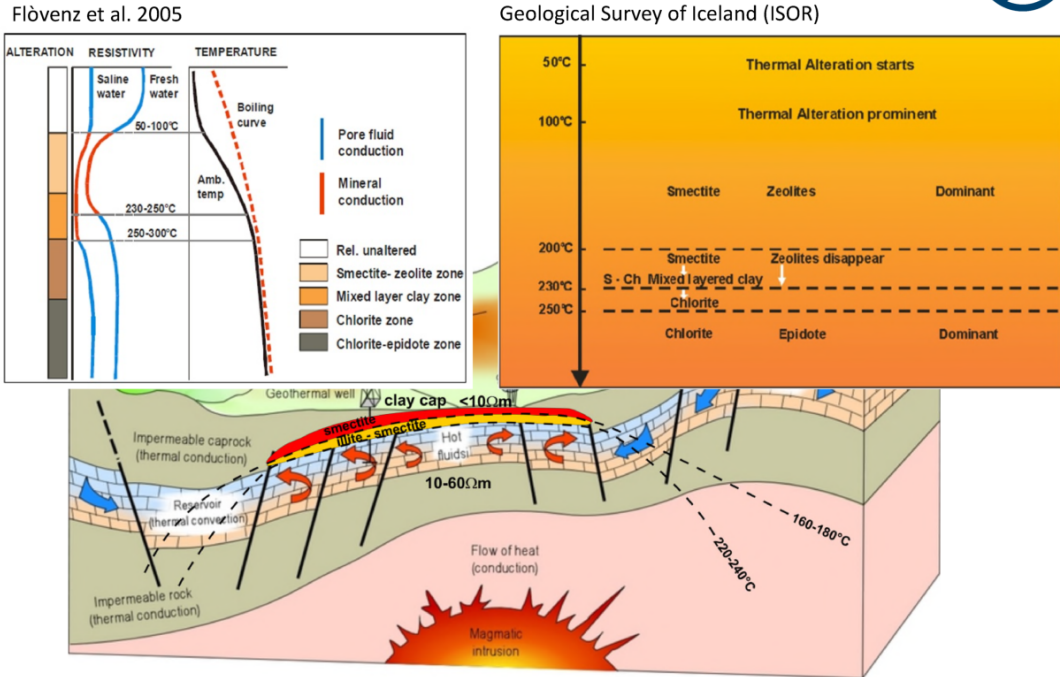
Sketch of a geothermal system



modified from Dickson and Fanelli 2004; Pellerin et al., 1996

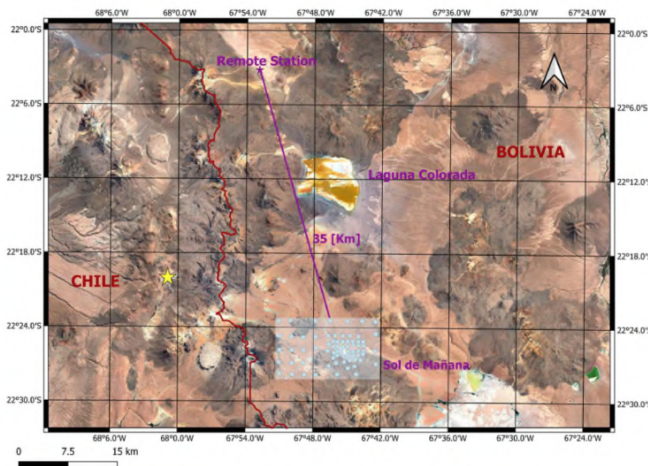
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Sketch of a geothermal system



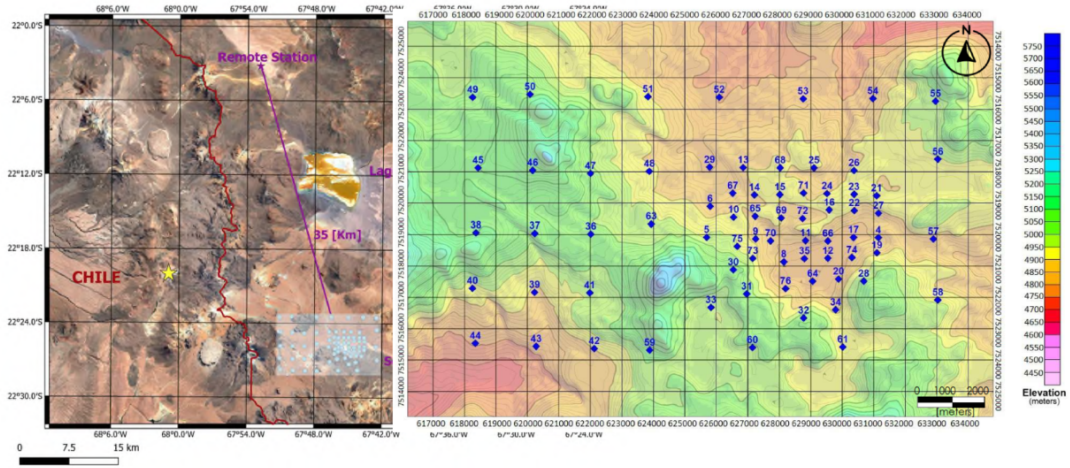
modified from Dickson and Fanelli 2004; Pellerin, 1996

MT sites in the Laguna Colorada-Sol de Manana geothermal area



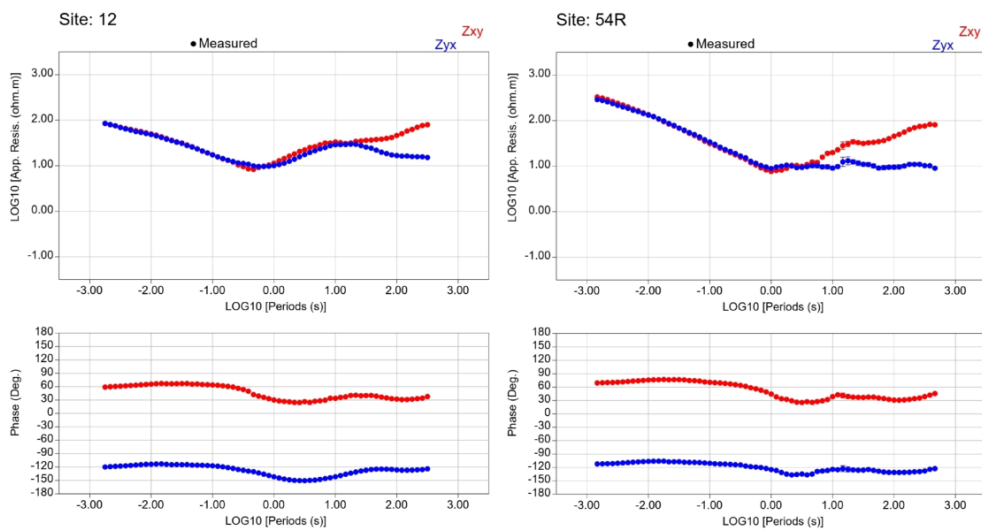
- French consulting company in a contract with ENDE (Empresa Nacional de Electricidad), Cochabamba
- Metronix (ADU7, MFS06)

MT sites in the Laguna Colorada-Sol de Manana geothermal area



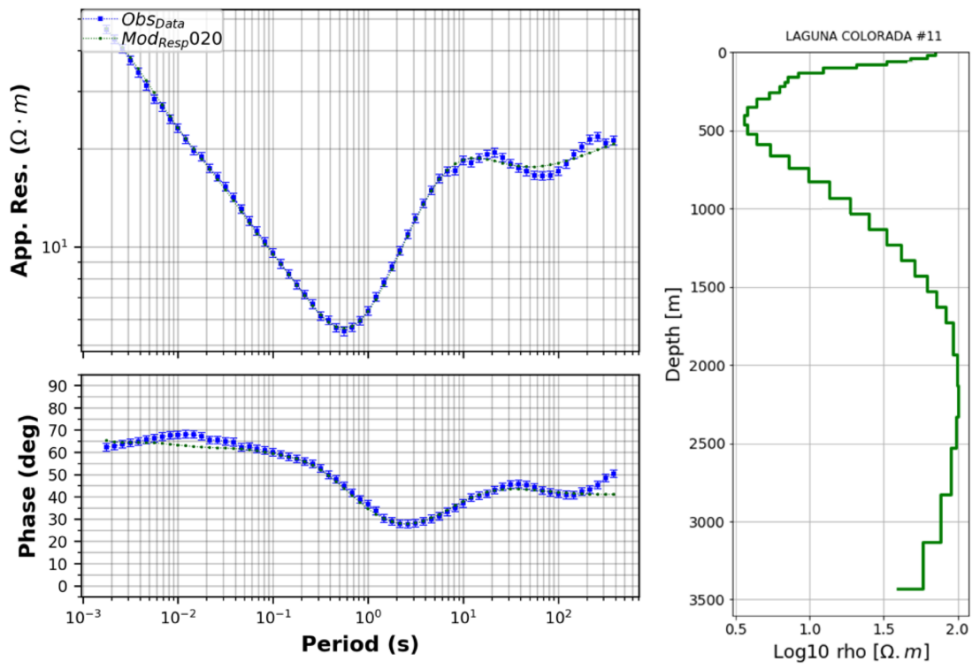
- Measurement grid:
- Outer area: ~2km
- Central area: several hundreds meters

Data examples



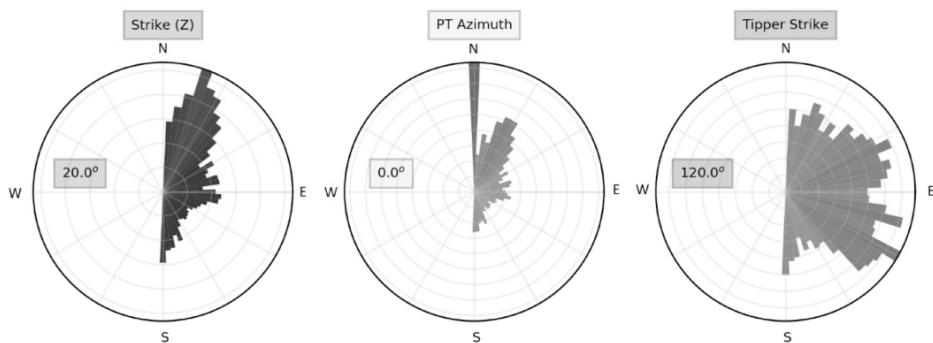
- Processing after Larsen carried out by CGG Milano
- Vertical magnetic field mostly very small, so not shown here.

Preliminary 1-D Occam inversion of invariants



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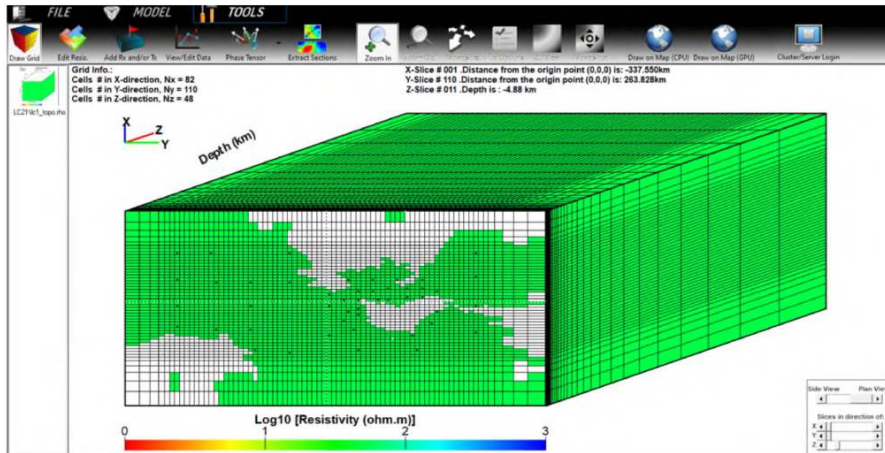
Dimensionality and electrical strike



- No clear preference direction
- Phase tensor analysis hints at 3-D for longer periods (not shown here)
- → 3-D modeling/inversion necessary
- ModEM code from Kelbert et al. 2012
- Parallel code, run time several days per model

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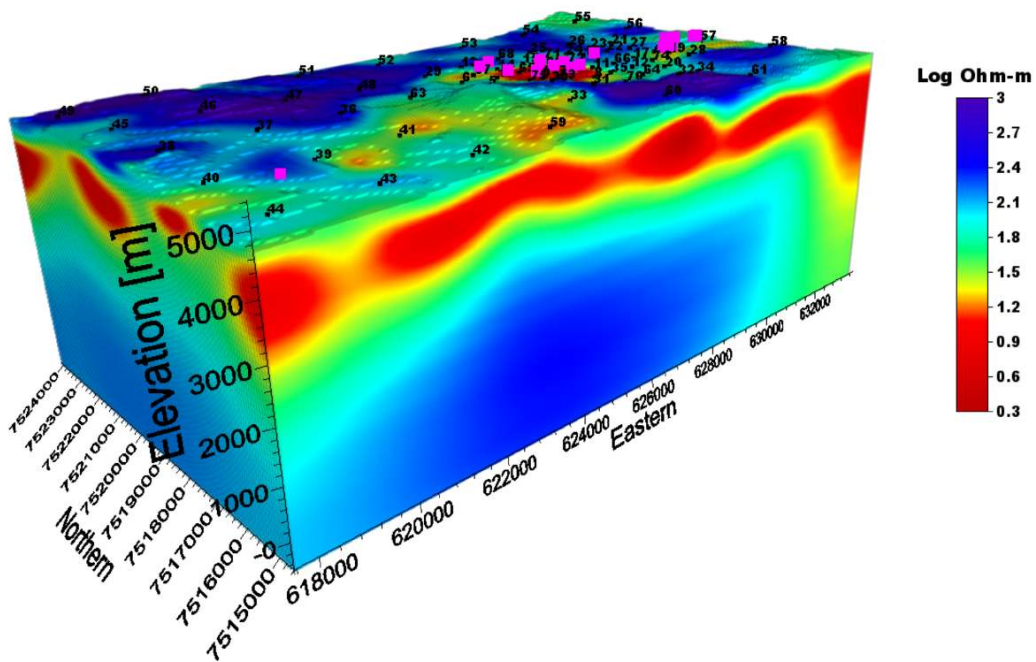
3-D Inversion



- ModEM
- Grid: 82 x 110 x 48 cells
- Cell dimension 200 x 200m (central part)
- SRTM Topography included
- Starting model: 50 Ohmm
- Error floor: $Z_{xy}=Z_{yx}=5\%$, $Z_{xx}=Z_{yy}=10\%$, Tipper=only minor influence

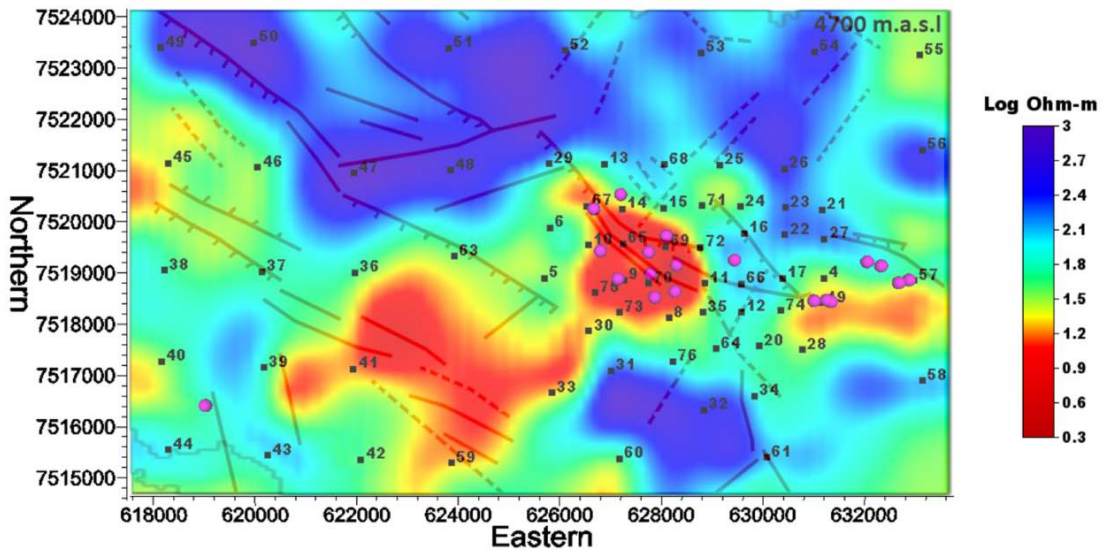
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3-D model block view



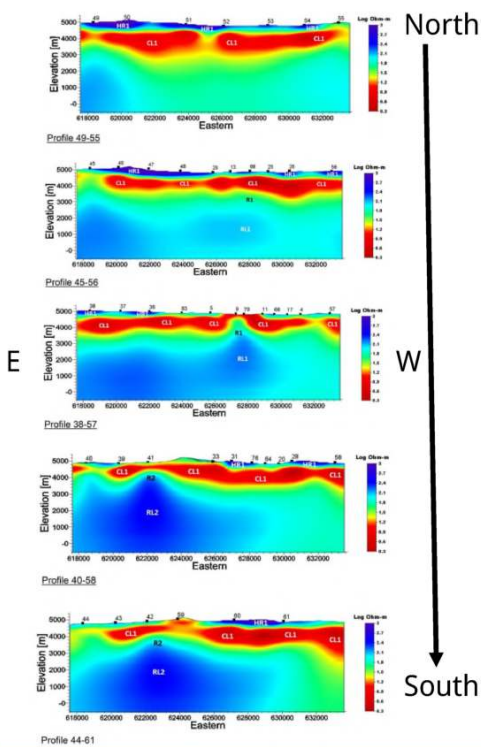
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3-D model, plan view, near-surface



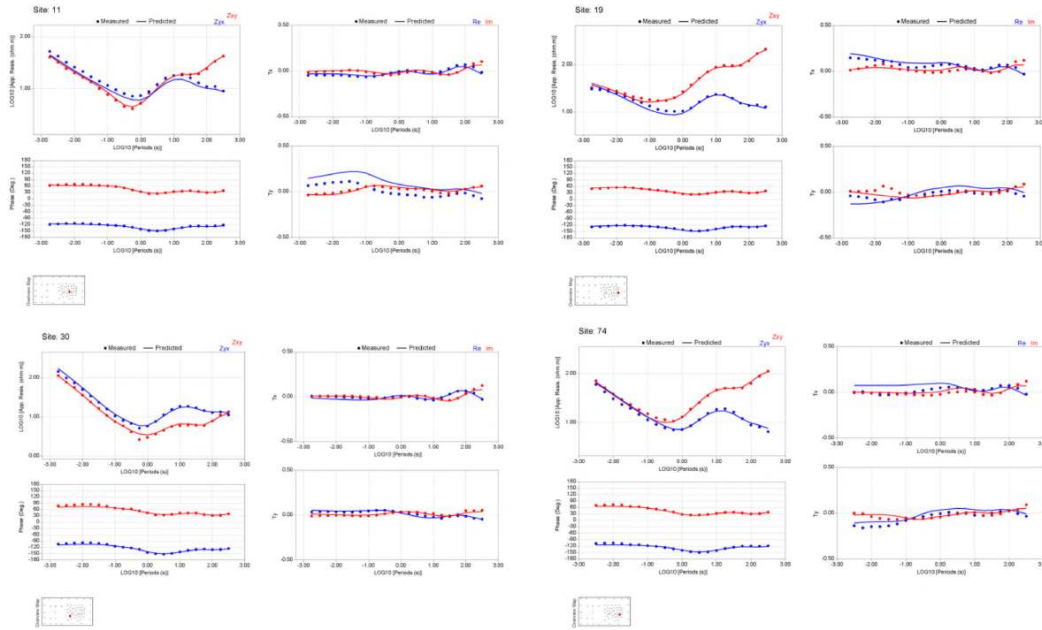
- Resistivity distribution in plan view at 4700 m.a.s.l., i.e. slightly beneath the surface. Pink dots denote geothermal surface manifestations.

3-D model sections (W-E)

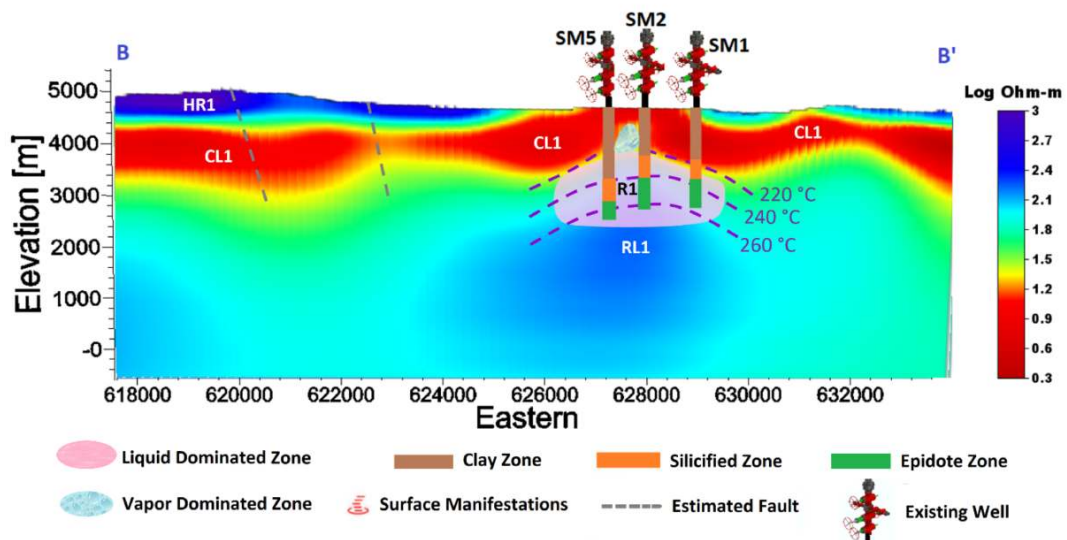


- Clay cap with high conductivities clearly resolved as contiguous cover layer
- Reservoir with intermediate resistivities
- Resistive basement
- Heat source (volcanoes of WC or APMB)?
- Several sensitivity studies to test most significant features

Data fit, total rms = 1.2



Conceptual model based on MT data





Conclusions

- 3-D MT study carried out in the Sol de Manana geothermal field
- Clay cap clearly resolved throughout the study area
- Correlation with drillings determines the hydrothermal reservoir
- Heat source unclear (APMB or volcanoes) ?
- MT provides valuable contribution to delineate the geothermal system
- Good potential for power generation

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