Mapping geothermal reservoir using broadband MT survey in Þeistareykir, Iceland.

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Outline

• Introduction
• Project objectives
• Data acquisition
• Data processing
• Modeling & inversion
• Interpretation
• Conclusions
Introduction

- Much of Iceland’s energy supply is geothermal energy;
- Geothermal power station site selection to build new aluminum mills;
- Geothermal field E&D are key elements for sustaining development;
- Existing TEM has very limited depth penetration (<800 m);
- Using MT to explore deep geothermal reservoirs.
Introduction
Introduction

(Trønnes, 2002)

Armannsson 2000

Þeistareykir geothermal & geology maps
Geological section in NW-SE direction across Krafla hydrothermal system

Jonasson, 1994
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Project objectives

• Confirm TEM survey findings of a high temperature reservoir under survey area;

• Outline better boundaries of the reservoir;

• Provide basis to map temperature & permeability variation.
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Magnetotelluric (MT) method

Measures natural variation of EM field
source: ionosphere & world wide thunderstorm activity;

Source field can be handled as vertical incident plane wave,
influenced by ground conductivity.

Impedance: \[ \frac{E}{H} \]
\[ \rightarrow \] Resistivity of ground
Planned MT survey sites

Completed MT survey sites
Field MT data acquisition
Raw MT data display (I-104)
High level noise in I-103, I-102, & I-101
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MT data processing flowchart

1. Copy calibrating files to computer
2. Check calibrating files
3. Copy data to PC
4. Check the Parameter
5. View files
6. Verify, Editing Parameter
7. Check time
8. Setup Robust Parameter
9. Process data
10. Edit Data
Cross power editing

Editing is done through deleting or restoring individual cross powers in the two graphs on the right.
Comparison of noise editing

Comparison of before (Left) & after (Right) auto editing

Comparison of before (Left) & after (Right) manual editing
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Resistivity model for the survey area

- 500 m, 500 Ohm-m
- 500 m, 10 Ohm-m
- 1000 m, 80 Ohm-m
- 2000 m, 300 Ohm-m
- 4000 m, 80 Ohm-m
- 2000 m, 30 Ohm-m
- 10 Ohm-m

Offset (Meters)

Depth (Meters)
Continuous media & nonlinear conjugate gradients inversion result

2D (MTIS) Inversion Result of Res-xy

NLCG Inversion Result of Res-xy
Comparison of NLCG (Emage-2D) & continuous media inversion (MTIS)

Result of Emage-2D

Result of MTIS
Þeistareykir MT survey profile layout
MT inversion result of Section 01

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MT inversion result of Section 02
MT inversion result of Section 04
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TEM inversion result of profile 307

Forward modeling

Data

Inversion

Model

Subsurface resistivity
MT inversion result of Section 02
MT inversion result of Section 04
Upper (sea level) geothermal reservoir distribution range (~ 32 km²)
Lower (1,500 m below sea level) geothermal reservoir distribution range (~ 46 km²)
Deep (5,000 m below sea level) conductive geothermal reservoir distribution range (~ 54 km²)
MT inversion (cross well section)
3-D resistivity inversion result (northwest)
3-D resistivity slices in Z (depth), X (E-W) & Y (N-S) directions
3-D data volume shows contribution of moderate (6 ~ 15 Ωm, left, & 15 ~ 25 Ωm, right) resistivity volume
Model for resistivity data interpretation

- Fracture zone defined by lower resistivity within high resistivity host rock;
- Clay cap occurs above hydrothermal system & heat source below;
- Resistivity contrasts below clay cap causes polarization & splitting in MT data.
Comparison of geologic cross-section in SW Iceland with observed resistivity
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Conclusions

- MT is an effective method for hydrothermal exploration;
- Geoelectric structure in NW corner is a 4-layer model up to 7,000 m;
- Hydrothermal reservoir consists of two parts:
  - Upper part reservoir to 1,000 m is water saturated with a mean T ~205 °C;
  - Main aquifers in lower part link to fissures & intrusives with T from 300 °C to 350 °C or more;
  - Bottom of upper thermal part is 900 m ~ 1,200 m with coverage ~32 km²;
  - High potential hydrothermal zone is from 3,200 m to 3,400 m & covers ~46 km²;
  - A deep conductive geothermal reservoir with coverage of more than 54 km² from 4,000 m to 7,000 m, & T may be more than 500 °C.
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