Geological Survey of Ethiopia

Federal Institute for
Geosciences and Natural Resources

Magnetotelluric measurements to explore deeper structures of the Tendaho geothermal prospect (Afar, NE Ethiopia)

by

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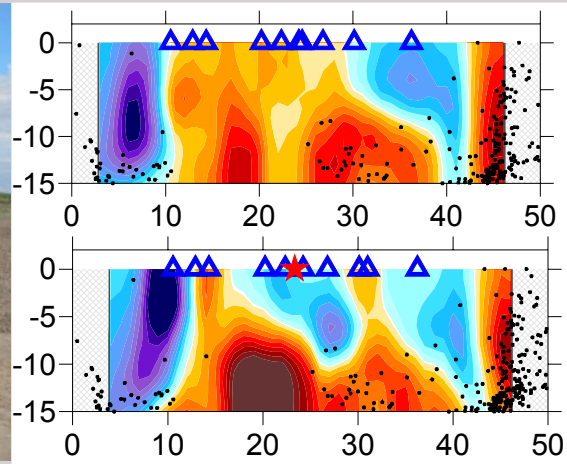
Outline

A Introduction

B The MT method

C MT results from Tendaho

A Introduction



Pilot projects reducing investment risks (feasibility studies, application of geoscientific methods for site evaluation)

Training

Policy advice and awareness raising

Goal:
Partner countries use their geothermal potential

GEF

UNEP

Networking and international cooperation

Projects

Uganda: Investigation of Buranga geothermal site

Eritrea: Training of geo -thermal experts in cooperation with the United Nations University

Yemen: Feasibility Study at Al Lisi as part of a GEF Project

Vietnam: Socio-economic analysis of framework conditions for direct use and electricity production

Rwanda: geothermal studies, training

Chile: Geothermal explora-tion at Térmas de Río Blanco, Training, EIA guidelines

Tanzania: Geothermal exploration, training, and awareness raising of decision makers

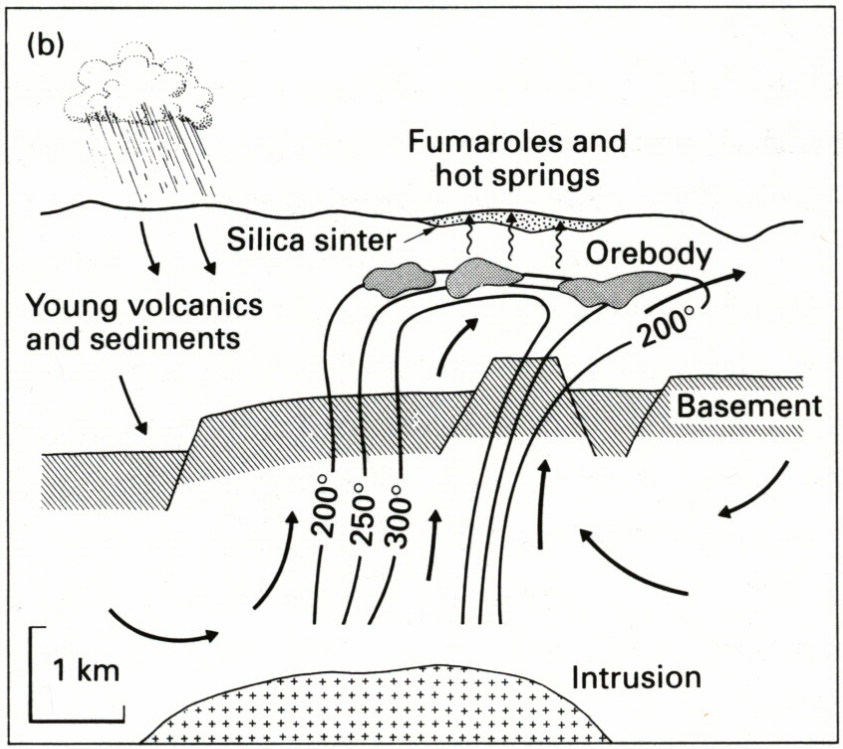
Kenya: Training in GIS, airborne thermal camera survey

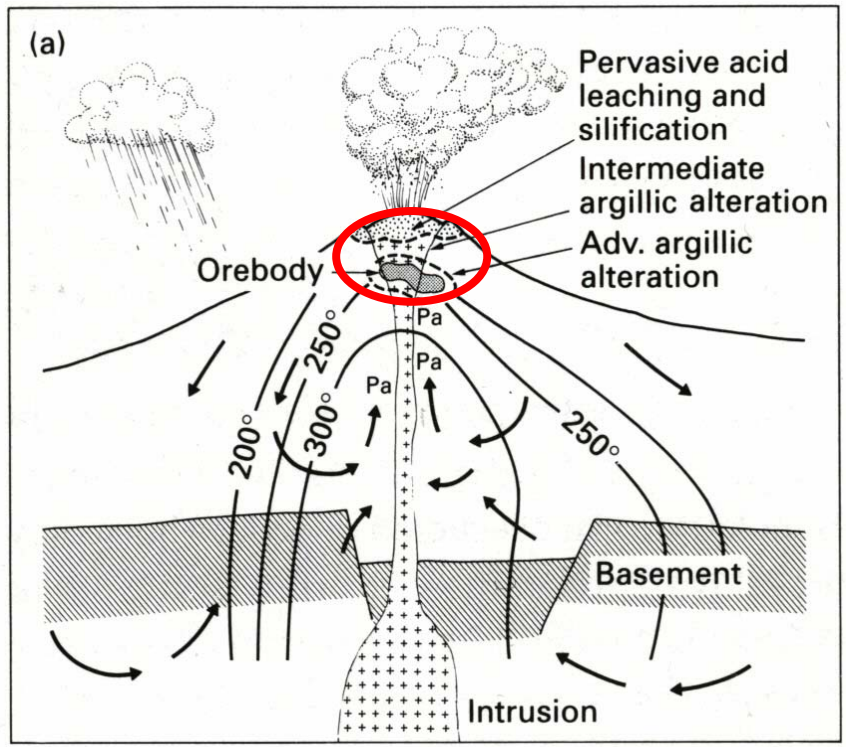
Ethiopia: geophysical exploration at Tendaho, Support to the African Geothermal Conference 2006

Main phases of surface exploration

- Literature survey (desk top study)
- Regional review (with prioritizing sites)
- Site selection (apply for concession of most promising site)
- Remote sensing (satellite images, aerial photographs, IR, InSAR)
- Geologic survey (rock units, tectonic setting, active faulting, age of youngest volcanic activity, surface manifestations, alteration zones)
- Hydrologic survey (meteorological data, discharge rates of springs, water table, hydraulic gradient, mean residence time)
- Geochemical survey (chemical and isotopic composition of fluids and gases, geo-thermometry, soil gas survey)
- Interim conceptual model (for geophysical survey planning)
- Geophysical survey (temperature gradient, resistivity methods, gravity, magnetics, micro-seismicity)
- Synthesis (final conceptual model with suggestion of sites for exploratory drilling)

Schematical geothermal reservoir types

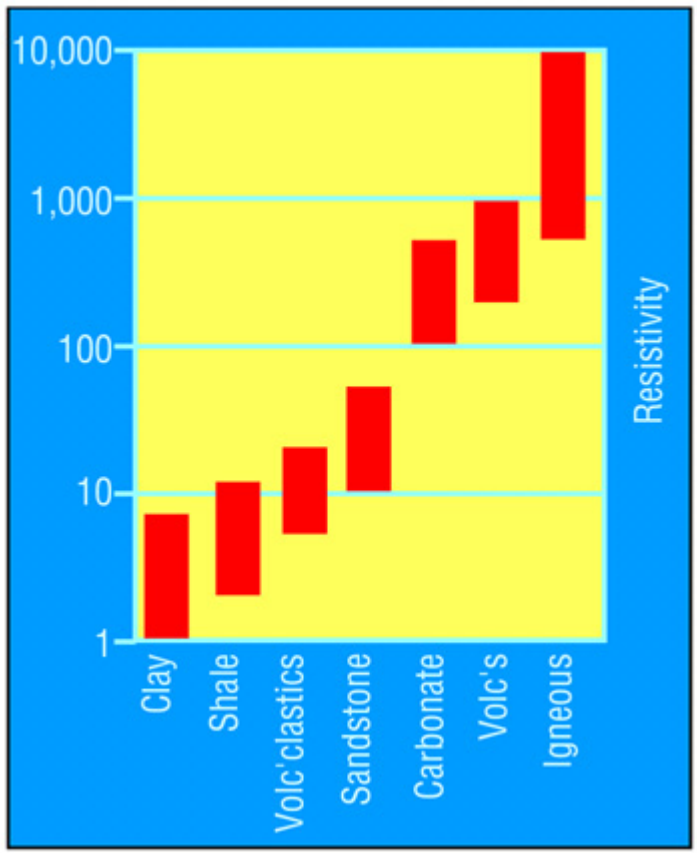


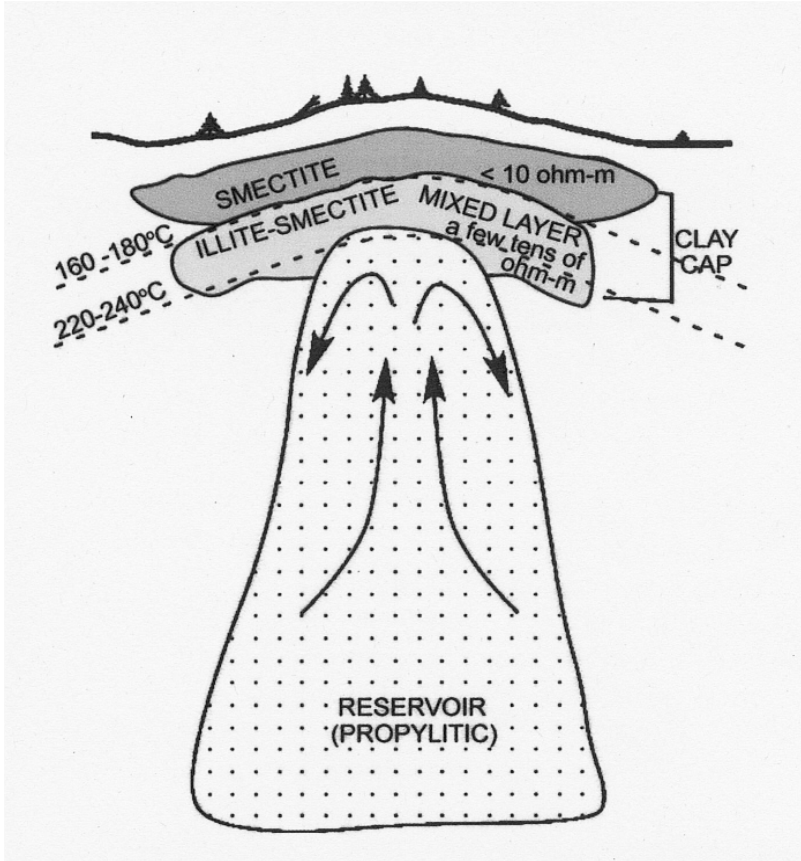


from: Evans 1997

A Introduction

Working model of a geothermal reservoir, produced by hydrothermal alteration

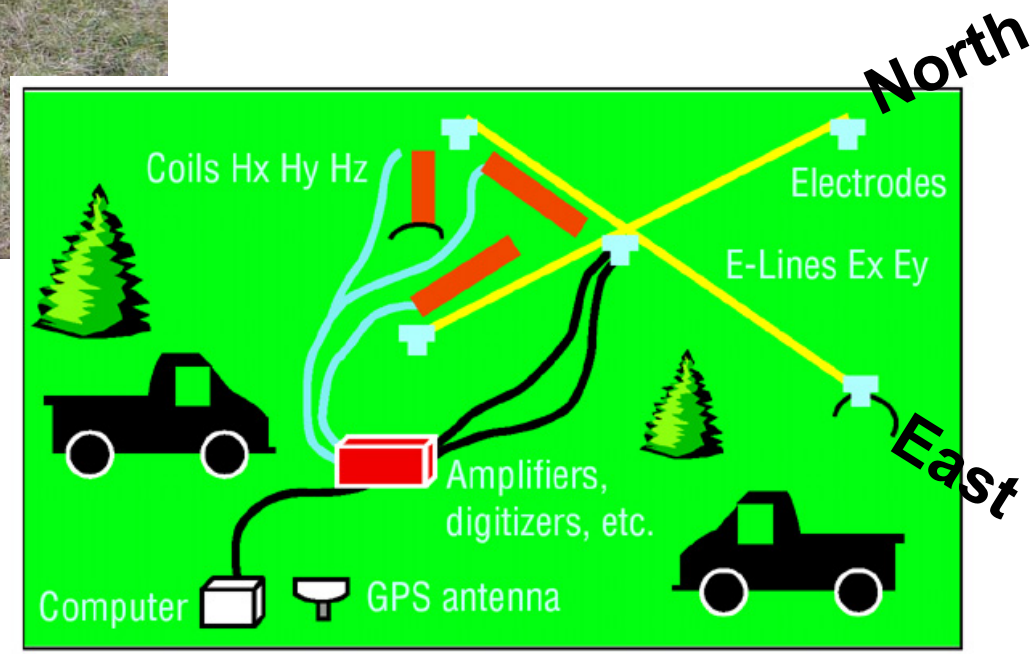




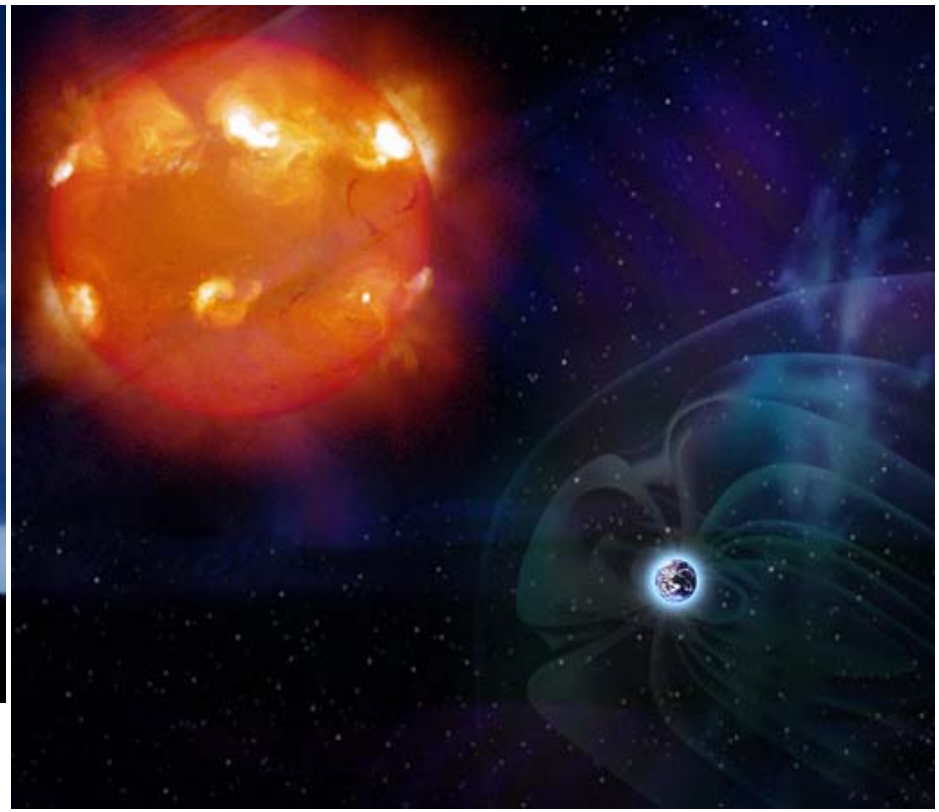
Modified after: Johnston et al. 1992

B The MT method

Two 5-channel stations (Ex, Ey, Bx, By, Bz)
Time synchronised recording
10 kHz bis 0,01 Hz (100 s)
Sensors: **Induction coil magnetometers**
Pb-PbCl electrodes, dipole length 100 m



No transmitter: passive method. What are the sources?



- Variations of the Earth‘s magnetic field cover a broad frequency range
- Lower frequencies penetrate deeper into the subsurface and thus allow conclusions on electrical conductivity structures at depth

B The MT method

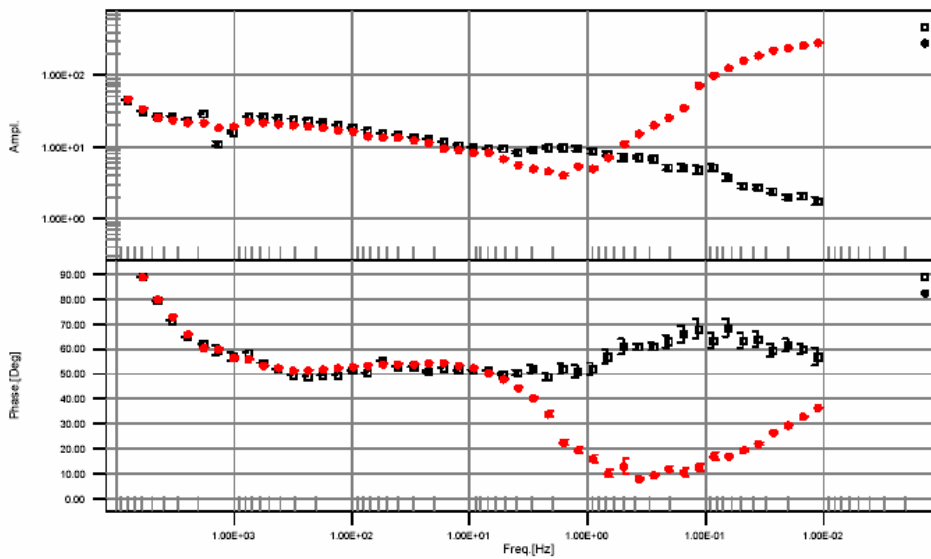
Exploration depth depends on frequency and conductivity of subsurface:

e.g.: 10 Ohm*m / 0.1 Hz
5 km depth of exploration

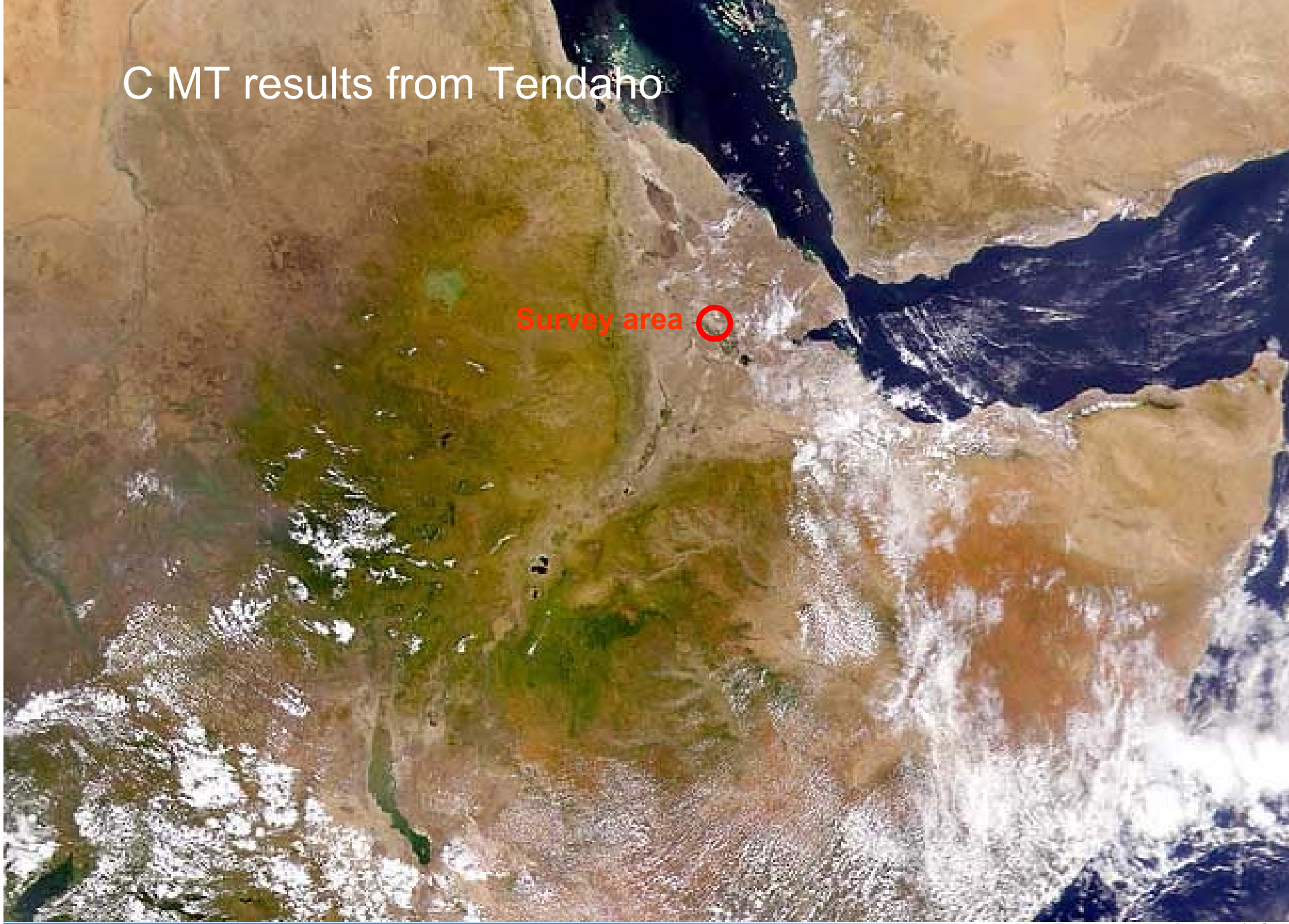
$$\delta \cong 0.5\sqrt{\frac{\rho}{f}}$$

The ratio of E- to H- field variations is used to calculate **apparent resistivities** for selected frequencies.

The **phase** shift between E- and H-fields is also indicative for changes in subsurface resistivity



C MT results from Tendaho



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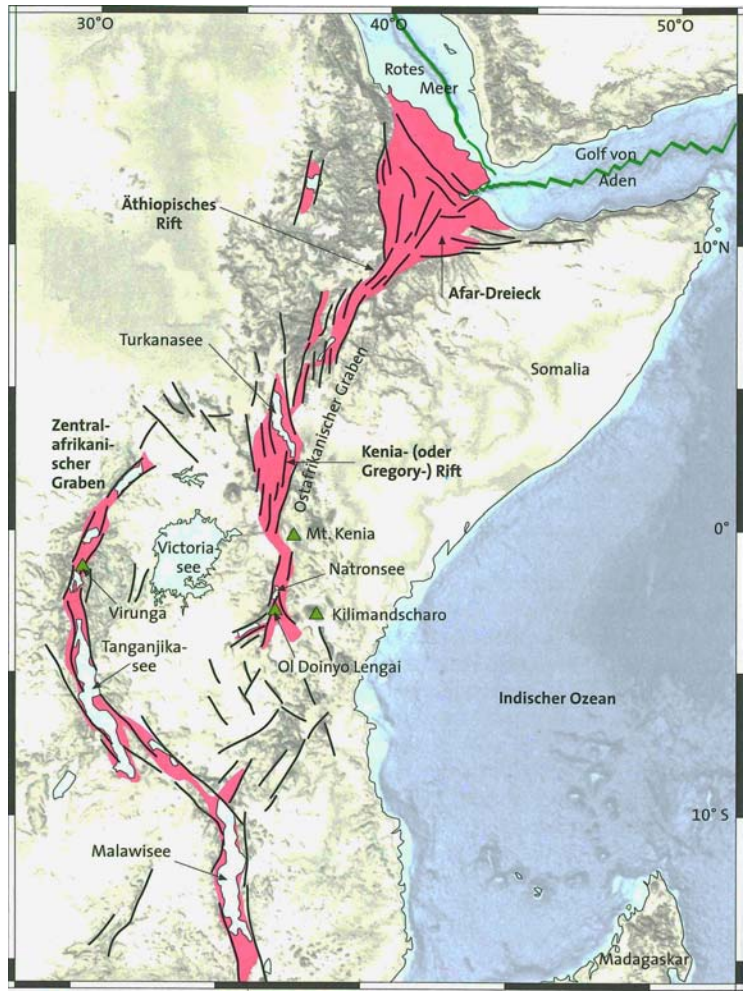
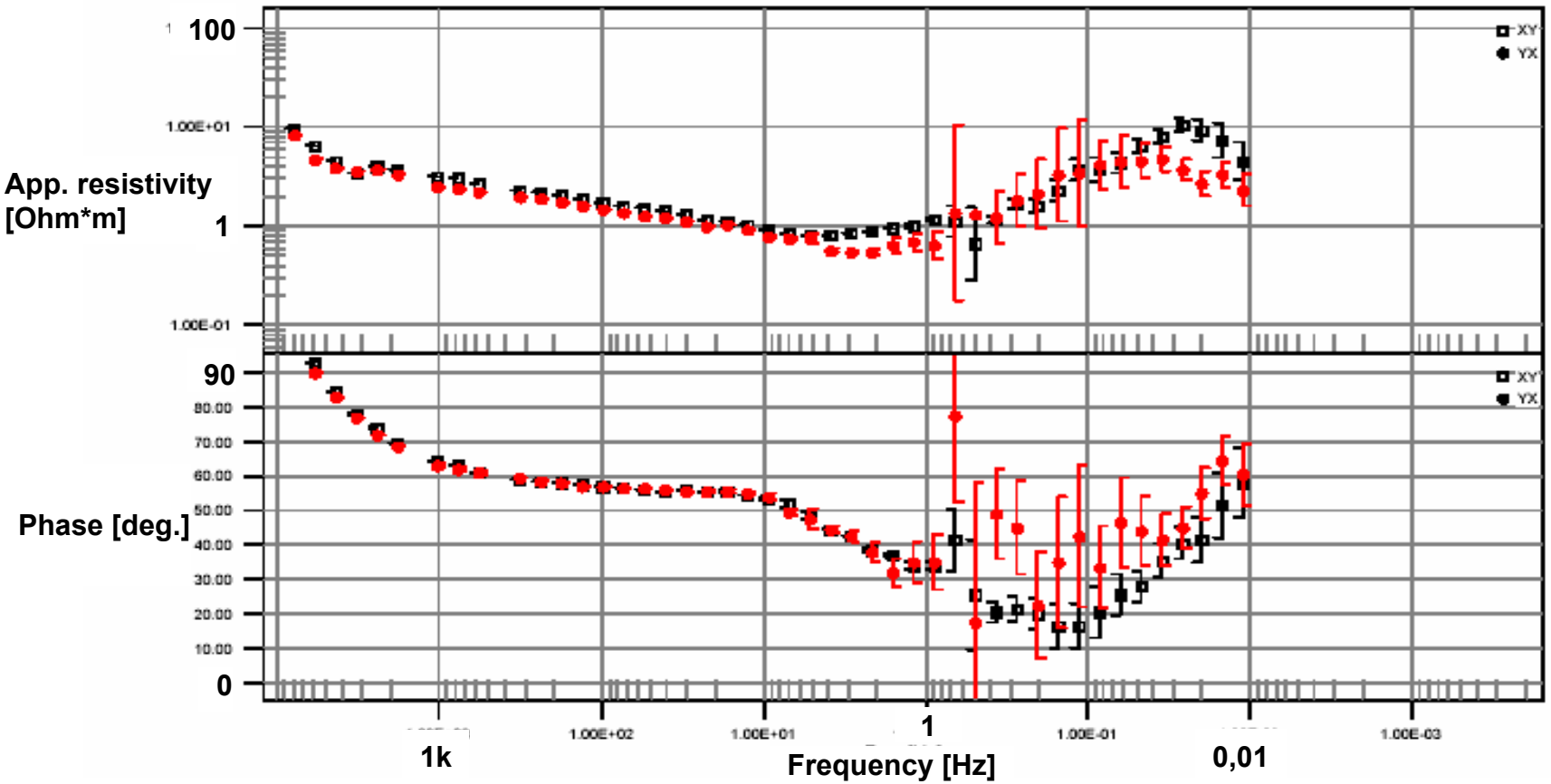


source: Frisch & Meschede 2007

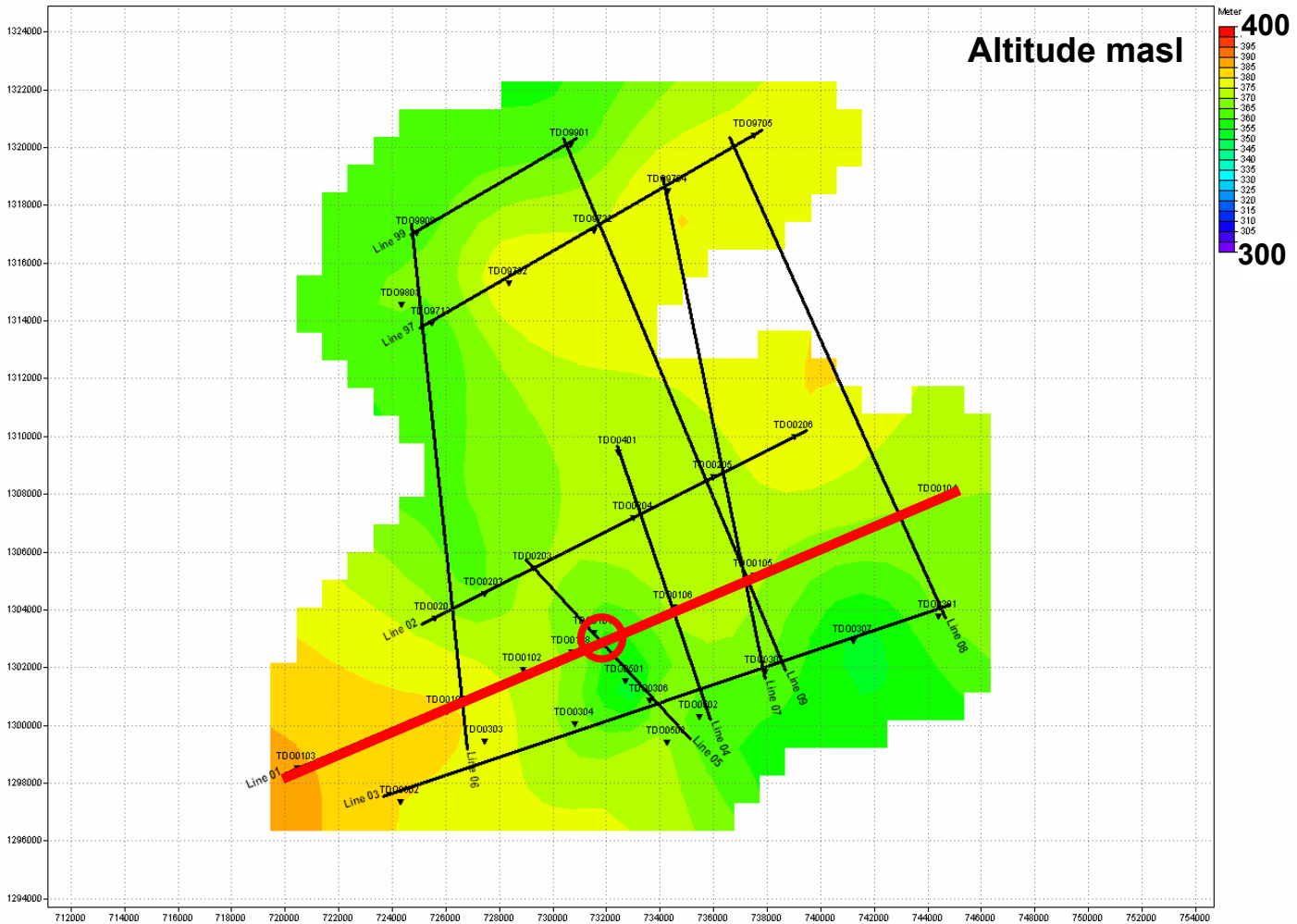
C MT results from Tendaho

Geothermal manifestations in the survey area

C MT results from Tendaho



C MT results from Tendaho



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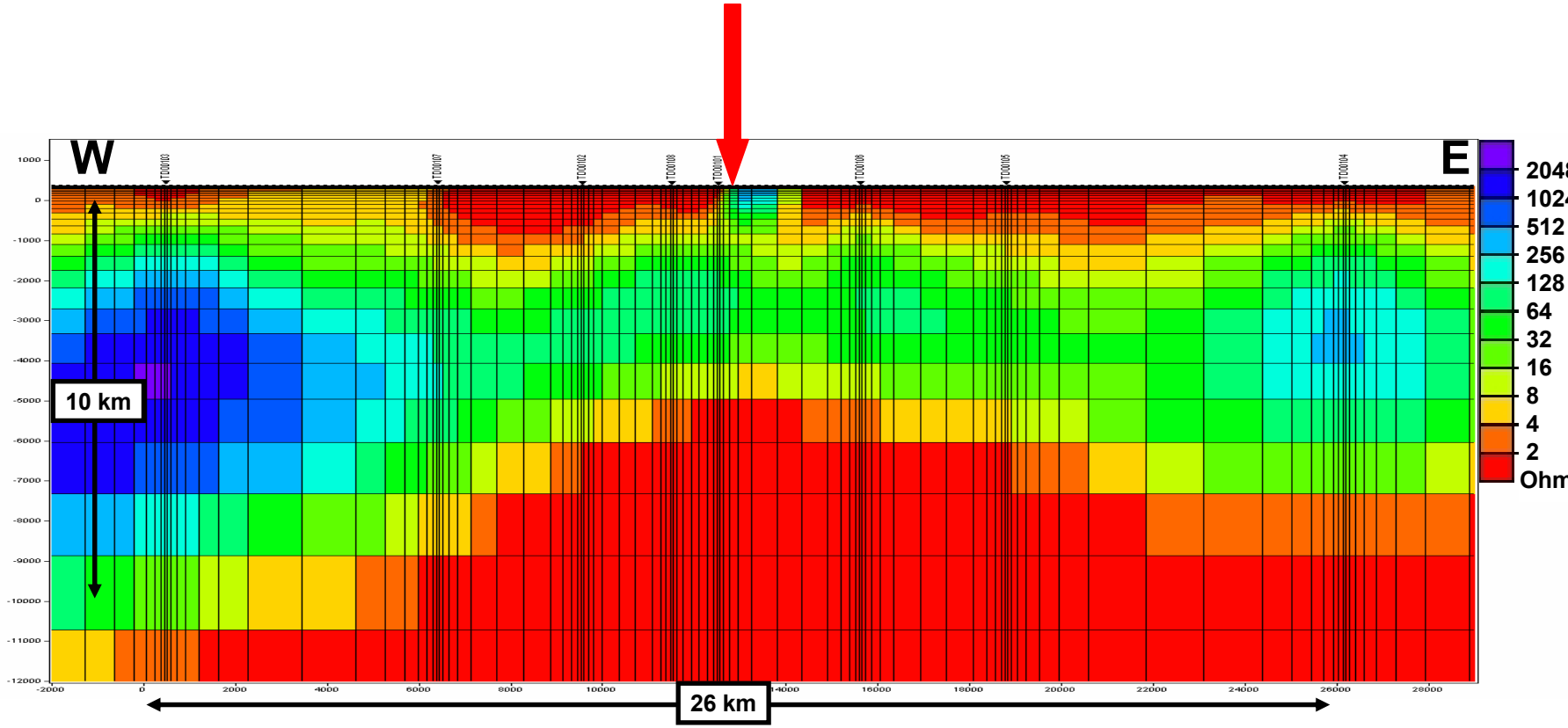
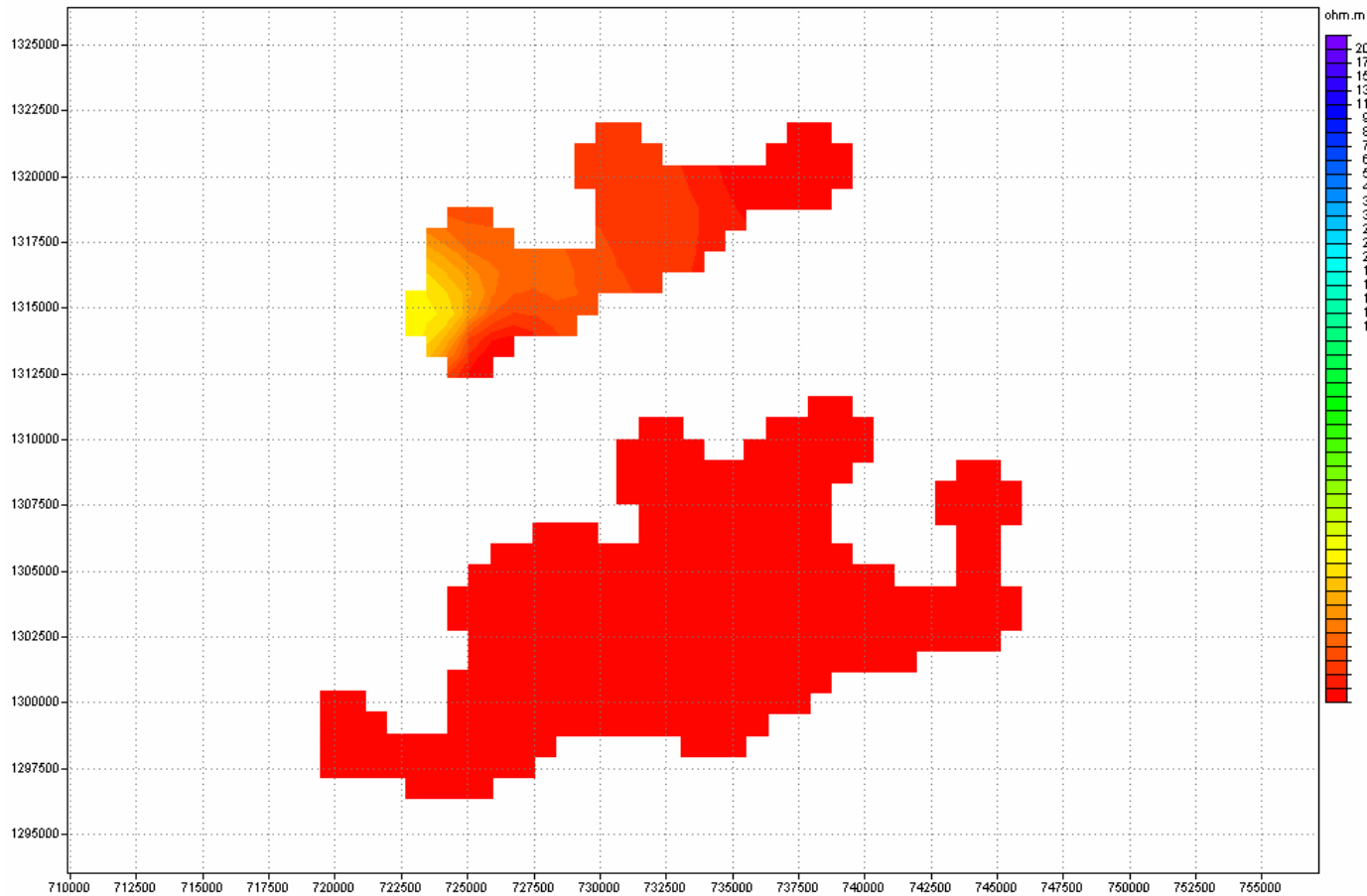


Line 1: resistivity section

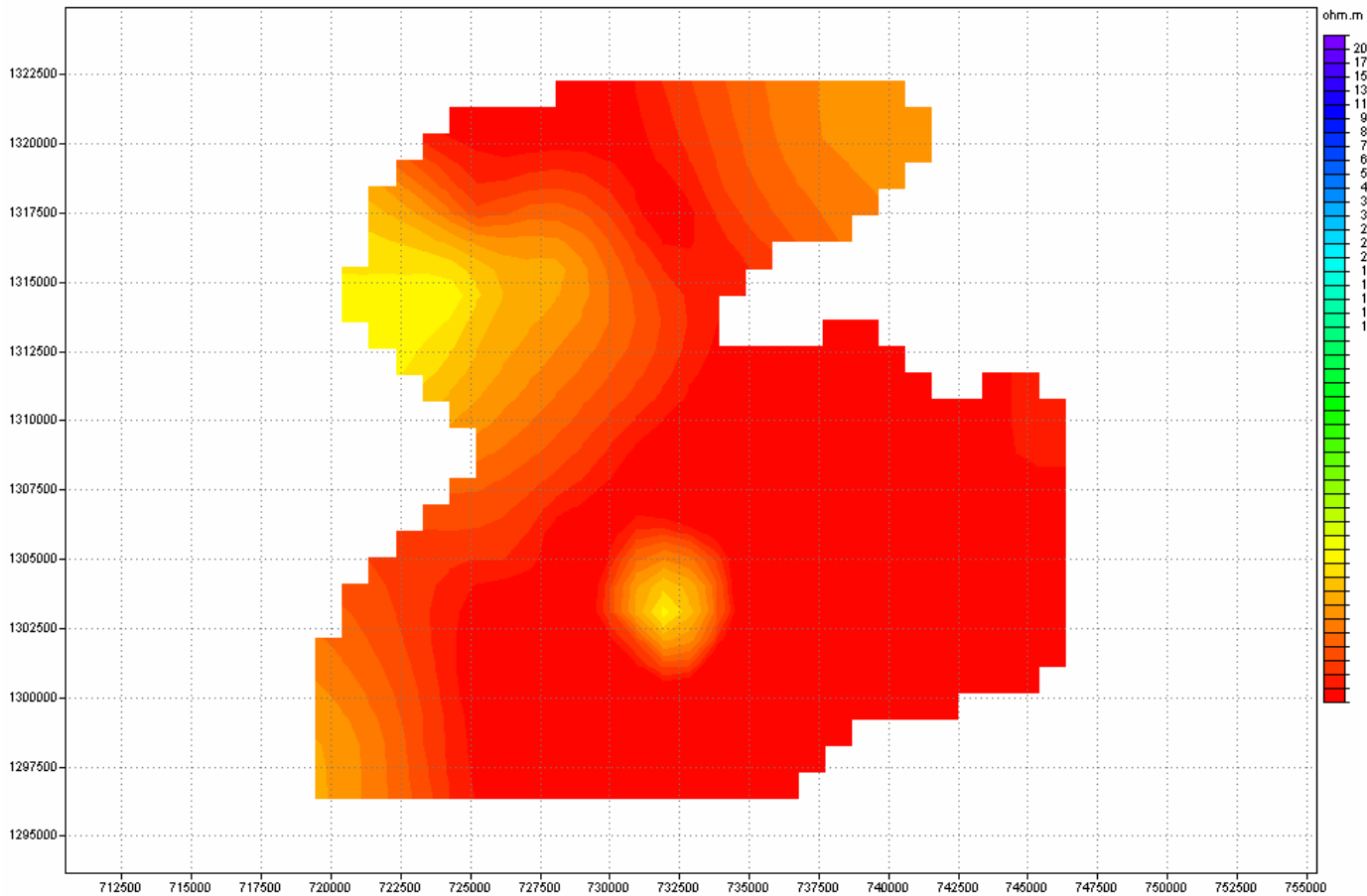
C MT results from Tendaho

Resistivity map at 200 masl



C MT results from Tendaho

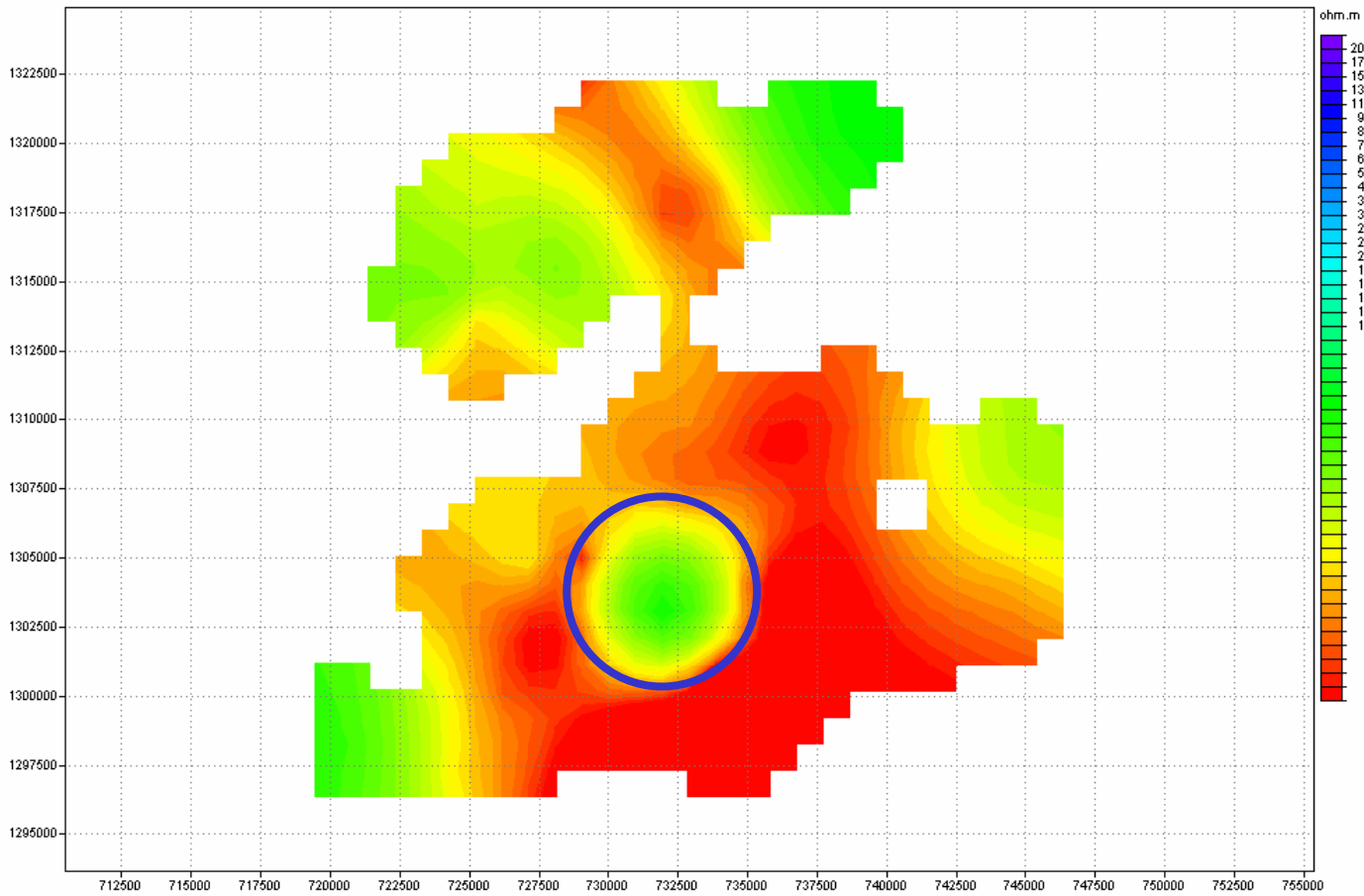
Resistivity map at 300 mbsl



C MT results from Tendaho

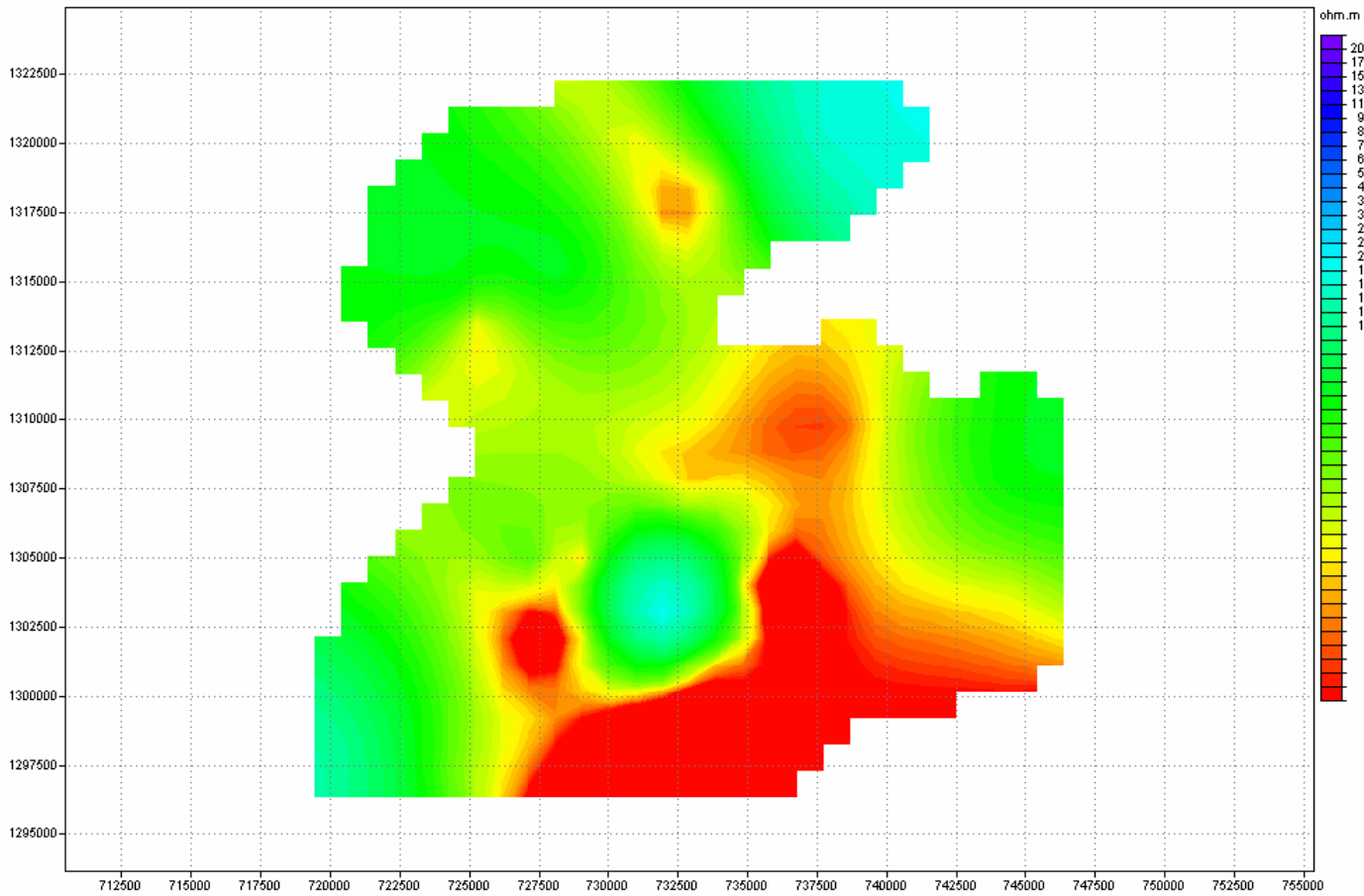
Resistivity map at 1000 mbsl

deep reservoir at approx. 1400 m depth?



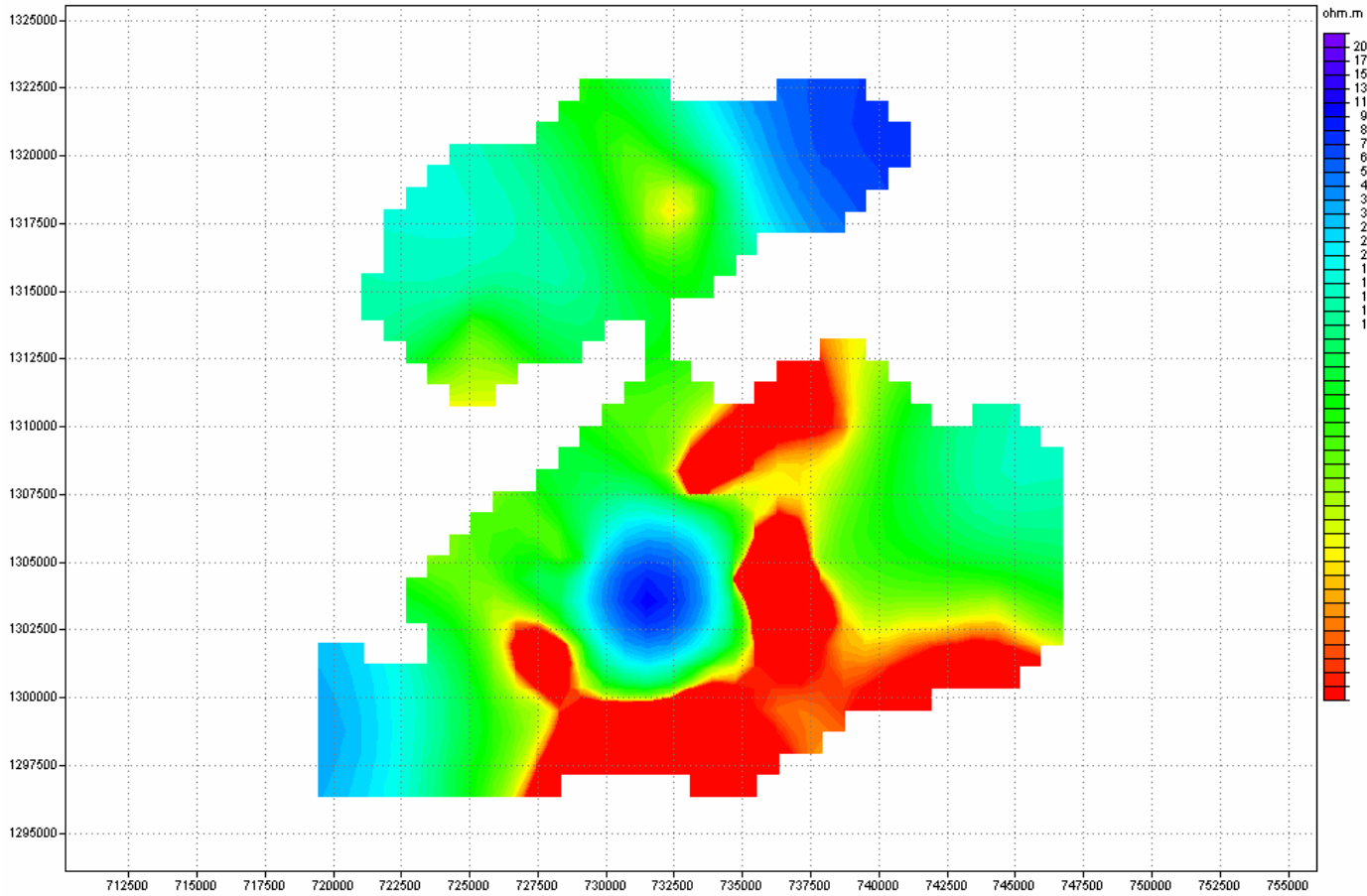
C MT results from Tendaho

Resistivity map at 1500 mbsl



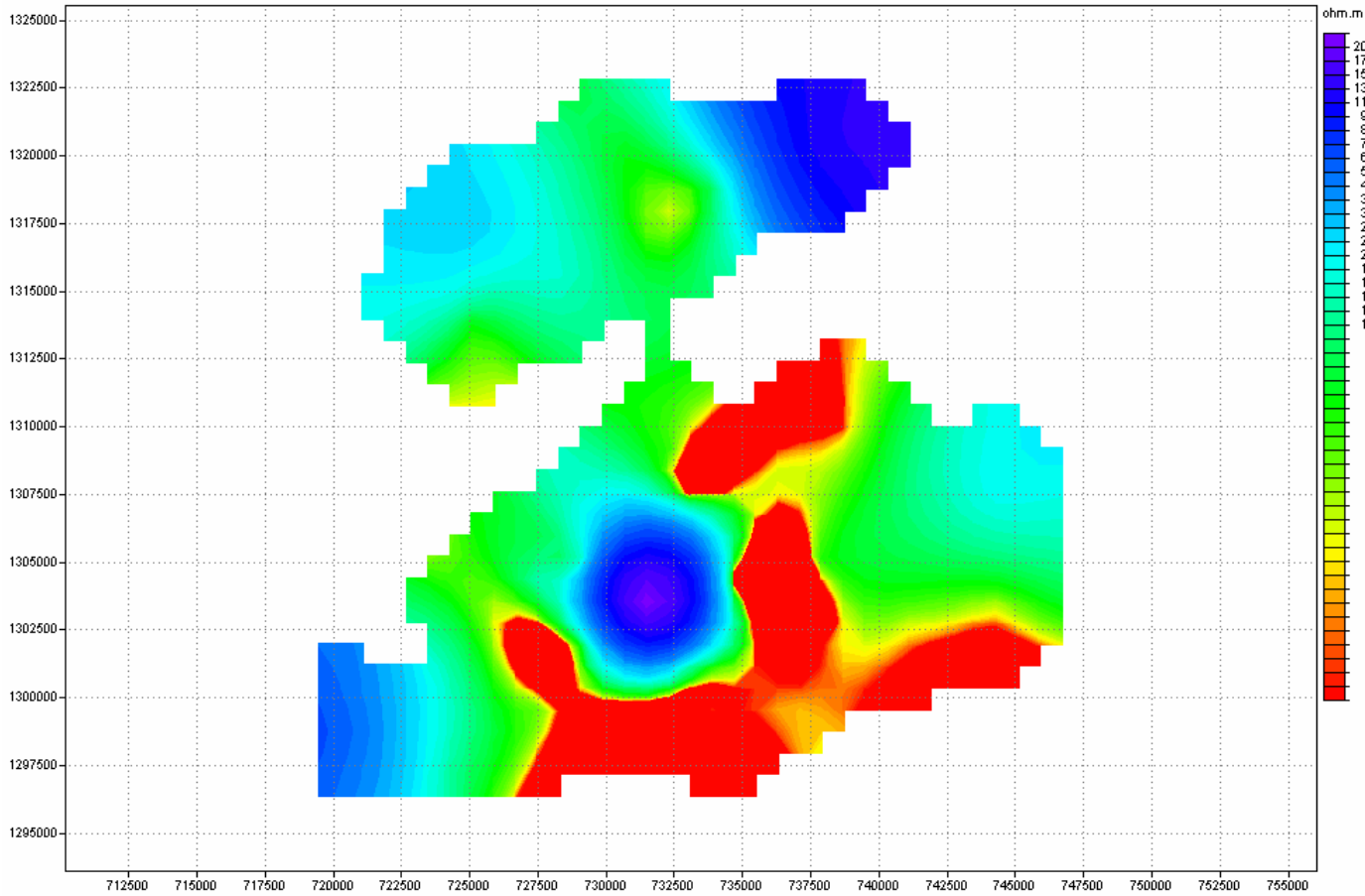
C MT results from Tendaho

Resistivity map at 2500 mbsl



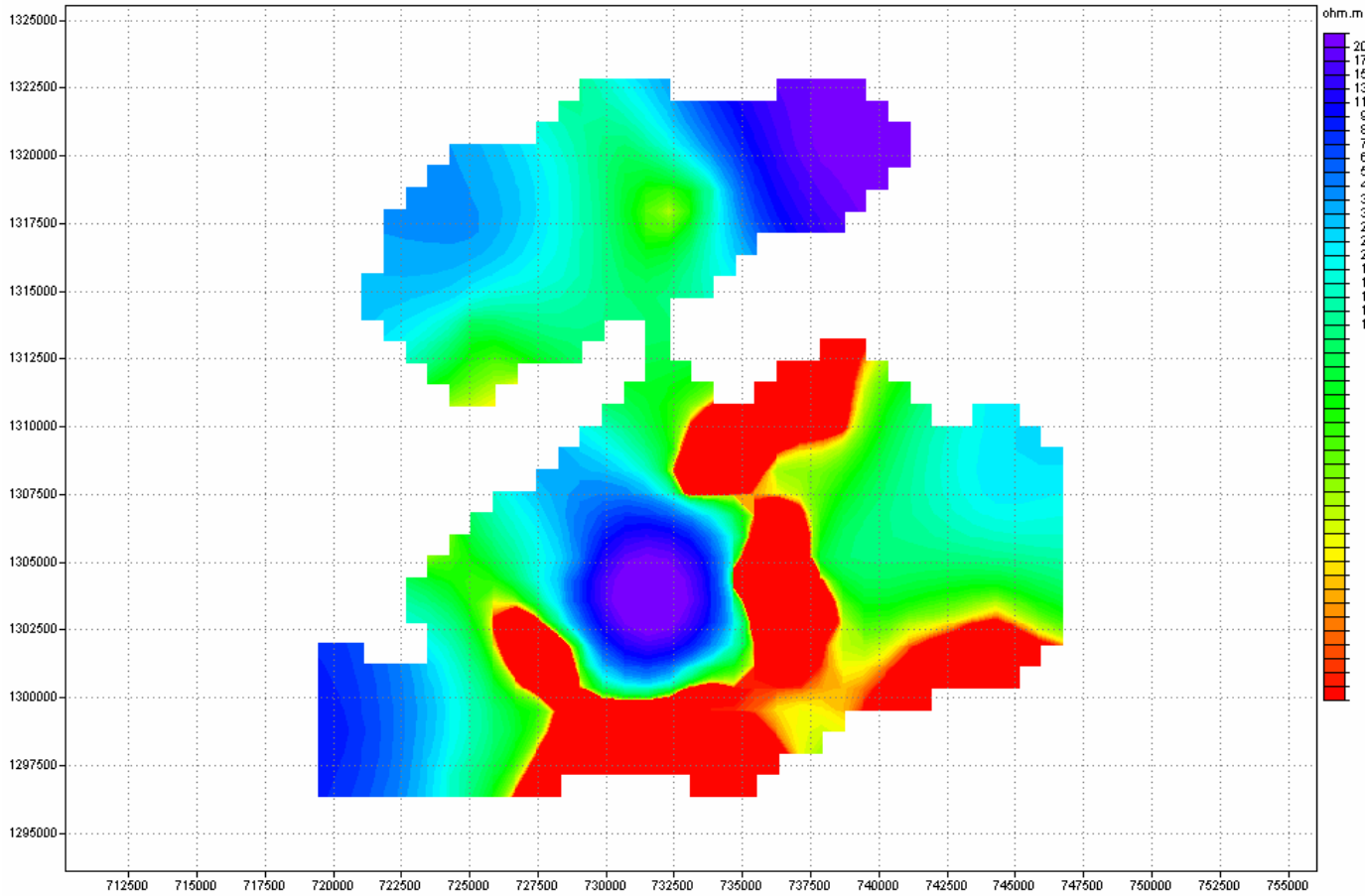
C MT results from Tendaho

Resistivity map at 3000 mbsl



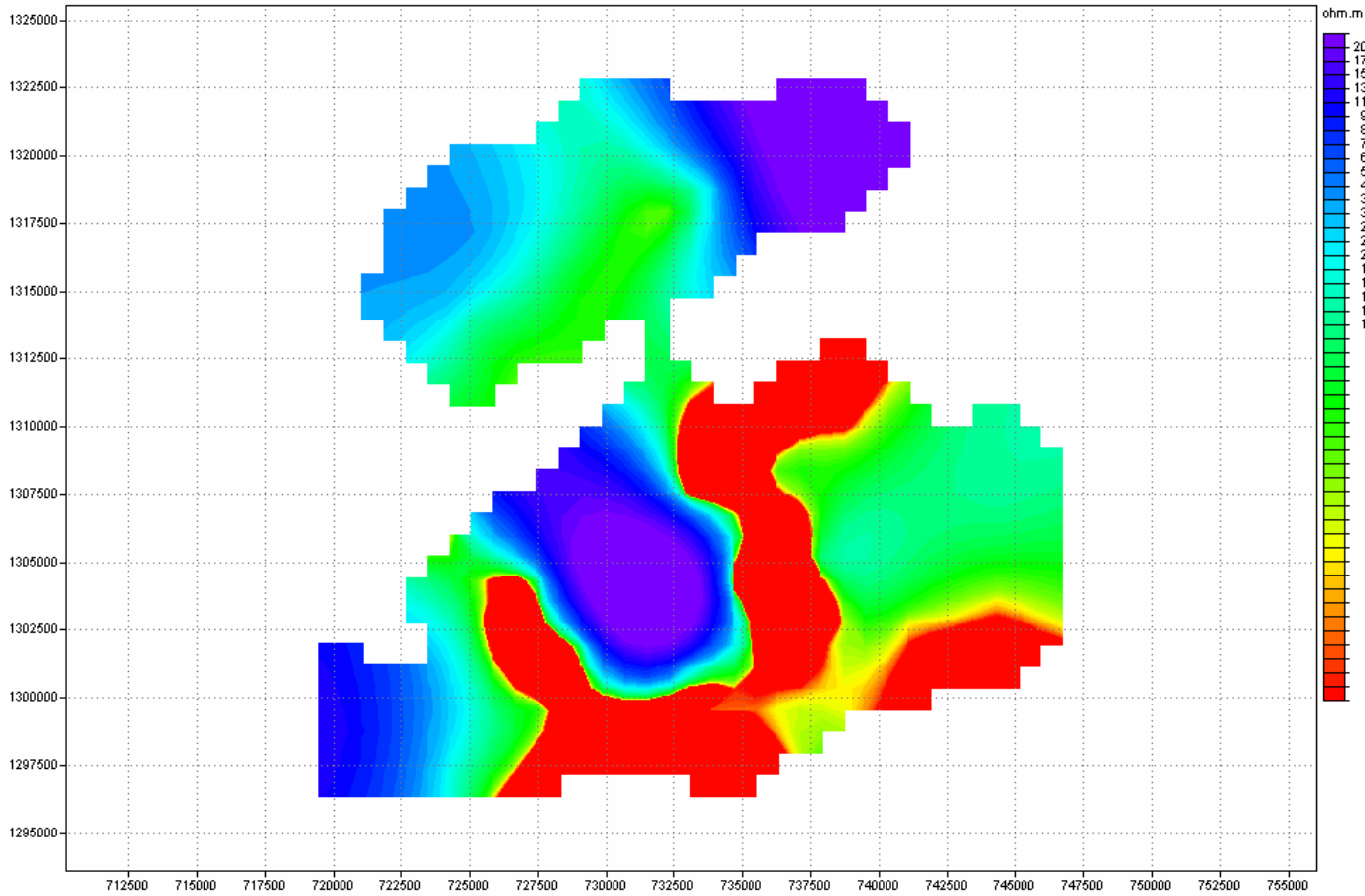
C MT results from Tendaho

Resistivity map at 4000 mbsl



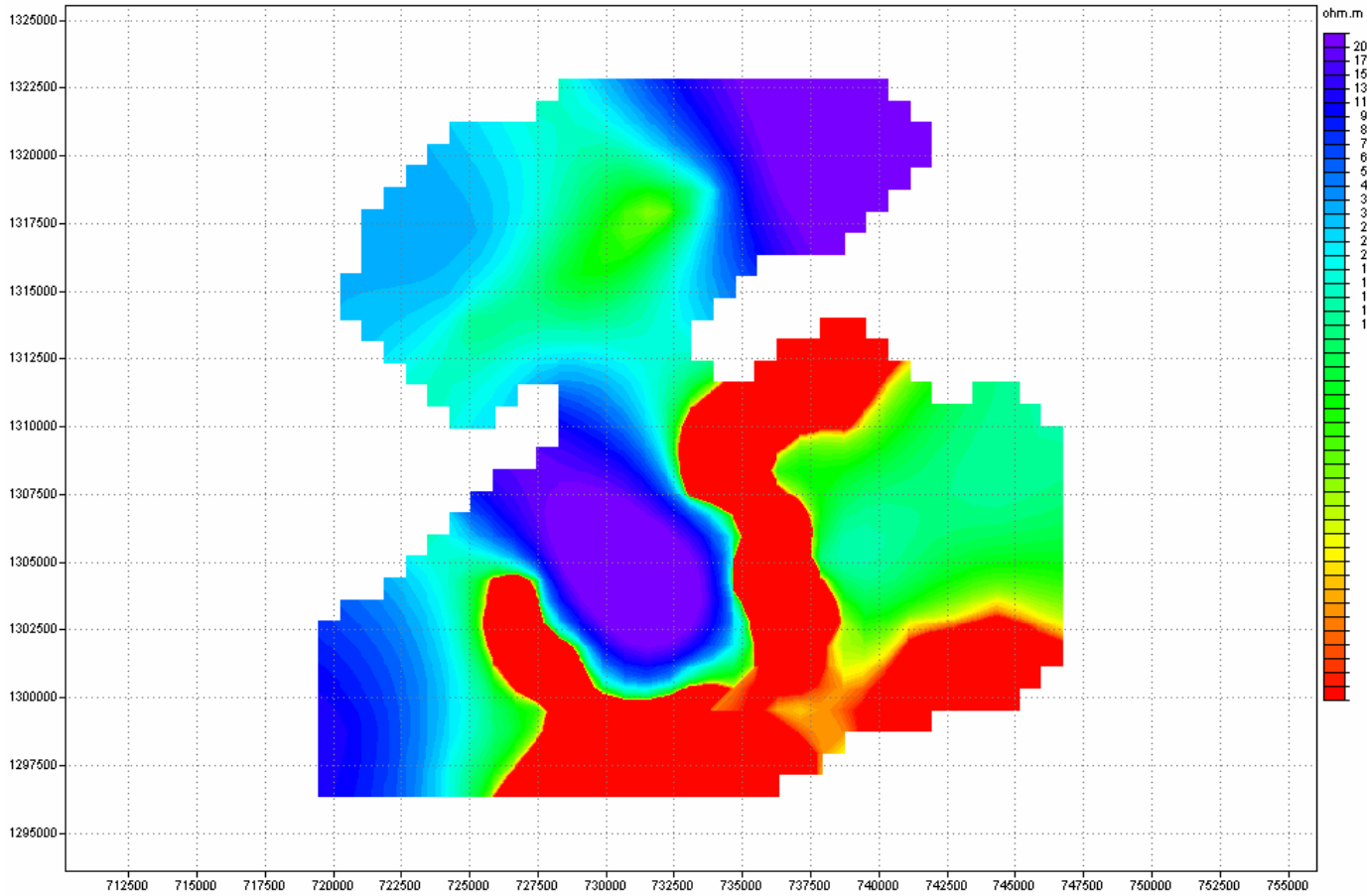
C MT results from Tendaho

Resistivity map at 5000 mbsl



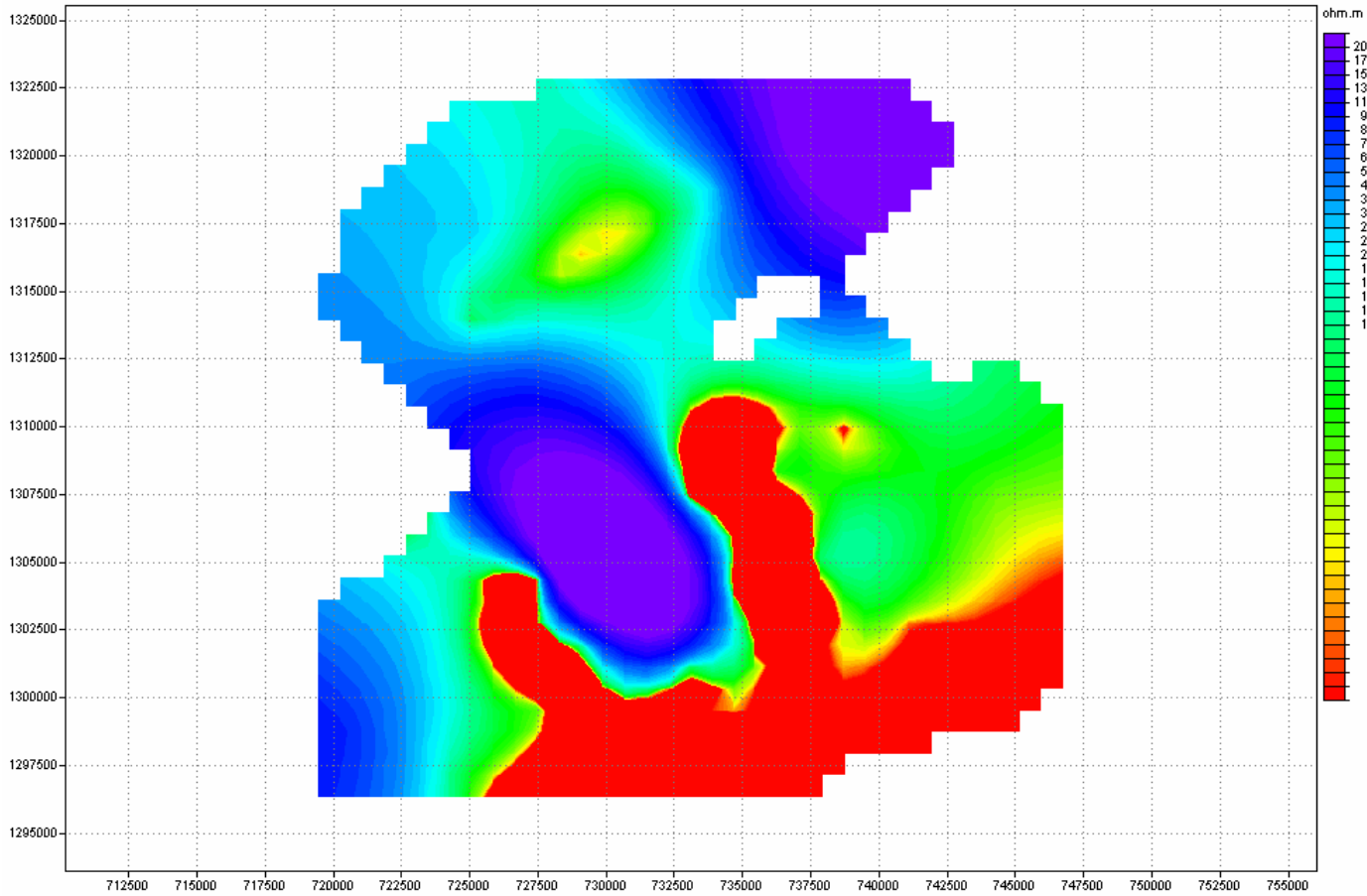
C MT results from Tendaho

Resistivity map at 6000 mbsl



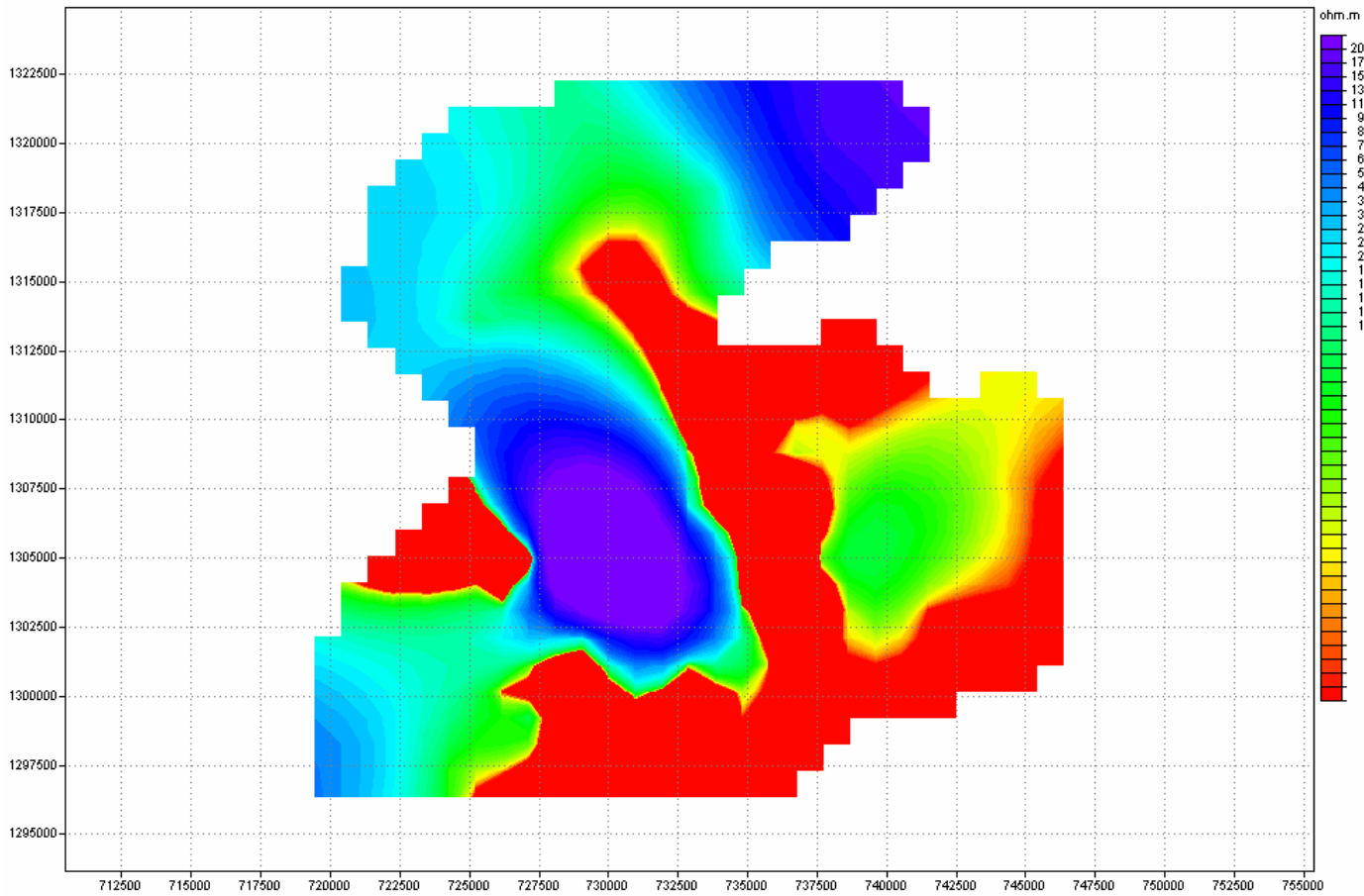
C MT results from Tendaho

Resistivity map at 7000 mbsl



C MT results from Tendaho

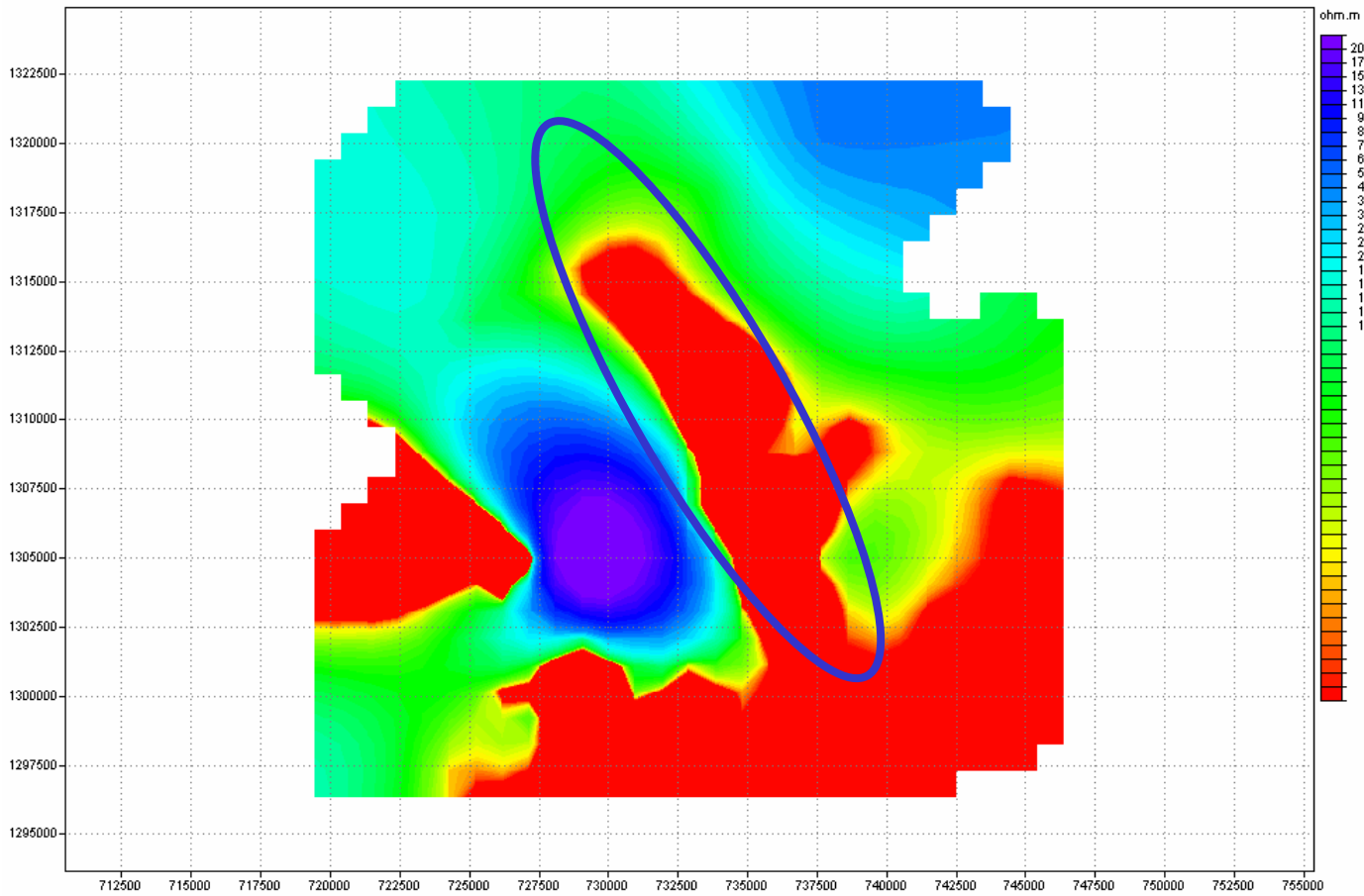
Resistivity map at 8000 mbsl



C MT results from Tendaho

Resistivity map at 9000 mbsl

magma?



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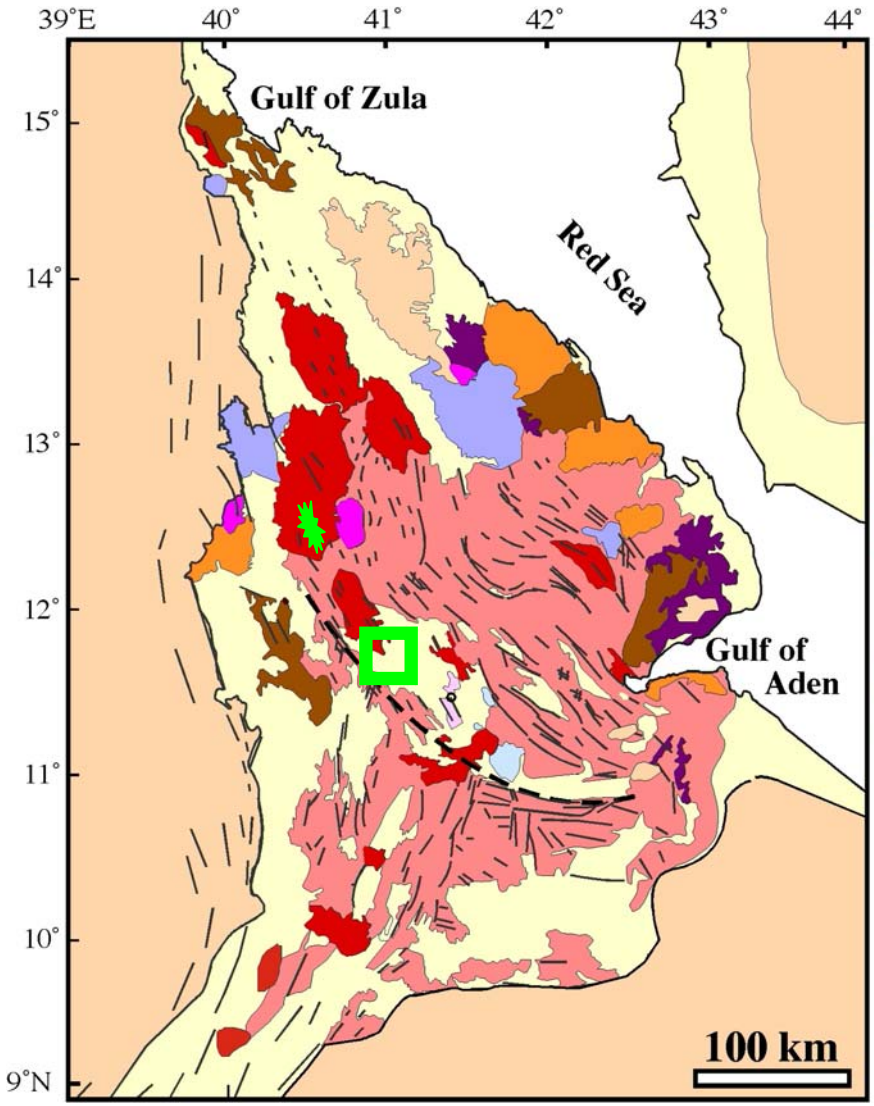


Quaternary
- Sediments
- Volcanics < 1 Ma
- Marginal centers < 4 Ma

Pliocene - Pleistocene
- Transverse volcanics <4 Ma
- Afar stratoid Series 1 - 4 Ma

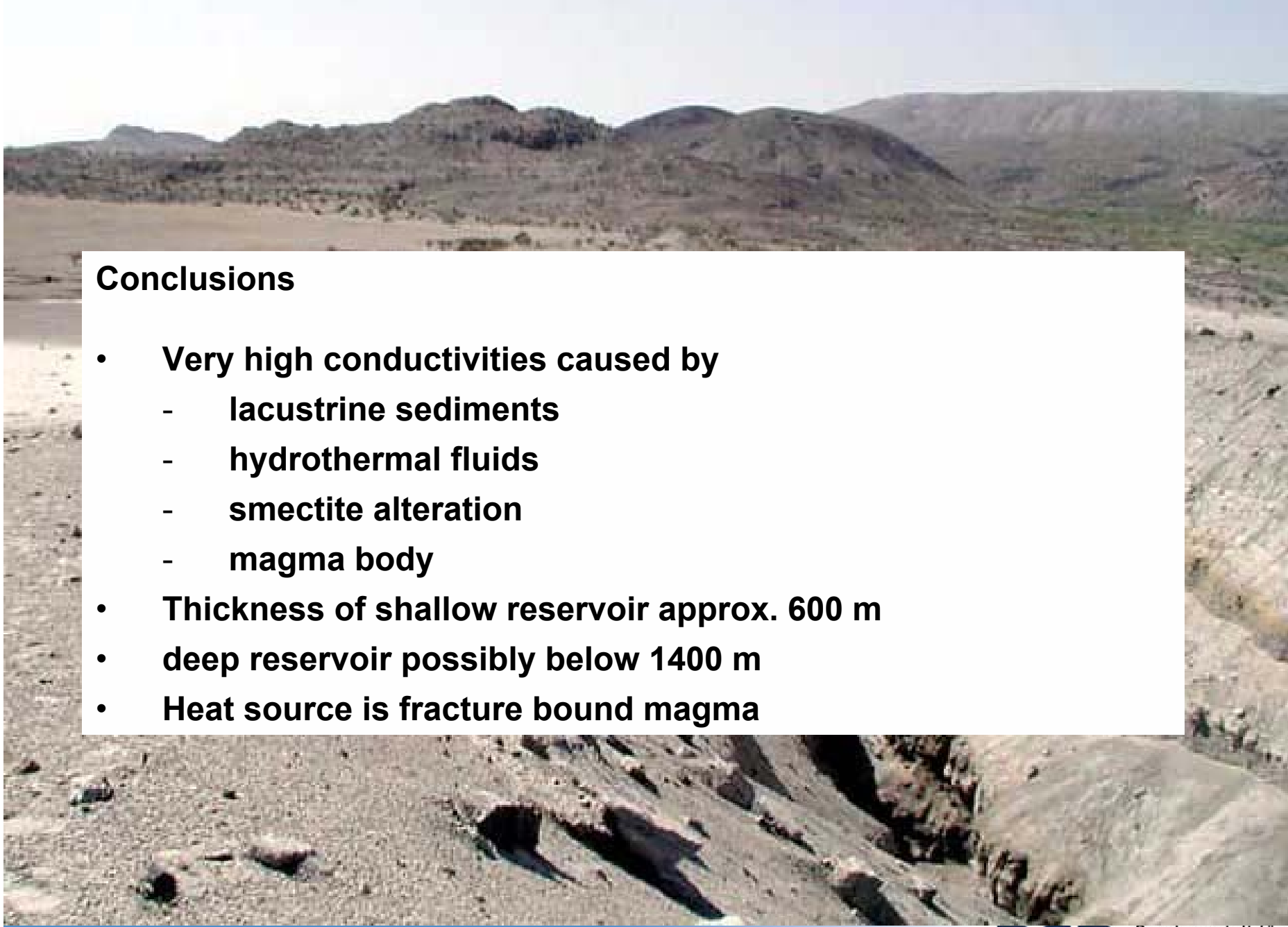
Miocene
- Dalha Series 6 - 8 Ma
- Mabla rhyolites Series 10 - 14 Ma
- Peralkaline granites 22 - 26 Ma

Pre-rift group
- Neoprotorozoic Basement
- Mesozoic sediment
- Eocene-Miocene basalt

C MT results from Tendaho

Boina vent (Dabbahu rift structure), developed approx.100 km NW of survey area, autumn 2005

C MT results from Tendaho



Conclusions

- Very high conductivities caused by
  - lacustrine sediments
  - hydrothermal fluids
  - smectite alteration
  - magma body
- Thickness of shallow reservoir approx. 600 m
- deep reservoir possibly below 1400 m
- Heat source is fracture bound magma

Thank you!


Thank you for your attention