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# Geophysical methods in geothermal exploration at NEA

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# GEOPHYSICAL METHODS IN GEOTHERMAL EXPLORATION AT NEA

The National Energy Authority (NEA) has been applying surface geophysical methods in geothermal exploration since the late forty's. The role and success of geophysical exploration has been steadily increasing as a result of development in exploration techniques and data interpretation.

Geothermal exploration is a multi disciplinary process and the choice of geophysical methods depends on the specific task at hand. The most frequently used geophysical methods by NEA are:

- Resistivity measurements.
- Magnetic Measurements.
- Gravity measurements.
- Soil temperature measurements.
- Self potential measurements.
- Thermal gradient and heat flow measurements.

Other methods have also been used, such as seismic methods, both passive (micro earthquake and ground noise studies) and active methods (seismic refraction and seismic reflection).

The capability of NEA to apply the above listed methods will now be described shortly. For further evaluation of the methods, refer to the enclosed paper "Evaluation of Physical Methods in Geothermal Exploaration of Rifted Volcanic Crust" by Árnason and Flóvenz.

## RESISTIVITY METHODS

Resistivity measurements are probably the most useful geophysical methods in geothermal exploration and NEA has almost 50 years of experience in applying these methods. NEA has up to date equipment and data processing and interpretation software to apply the following methods:

**DC methods**

This includes any geometrical configuration such as Schlumberger soundings, dipole-dipole (equatorial and coaxial) and head-on resistivity profiling.

*Interpretation*:
1D inversion and 2D modeling or inversion.

**Transient ElectroMagnetic methods** (TEM)

TEM with loop source and both in-loop and out-off-loop receiver (e.g. for profiling). Central-loop sounding is the most commonly used configuration and has been found to be especially suitable in difficult terrain and arid environment.

*Interpretation*:
1D inversion and 3D modeling.

**Magneto Telluric method** (MT)

The MT equipments at NEA cover the frequency range of $10^{-3}$ - 20 Hz. The telluric shift problem, inherent in the MT method, is addressed by applying central-loop TEM soundings at the MT sites to correct the MT data for effects of near surface inhomogeneities.

*Interpretation*:
1D inversion and 2D modeling or inversion.

## MAGNETIC MEASUREMENTS

NEA possesses proton precession total field magnetometers and has in cooperation with the University of Iceland access to airborne total field magnetometer.

*Data processing and interpretation*
Standard data processing such as filtering, upward or downward continuation. Data presentation as profiles, contour maps or 3D plots. Directional filtering and trend analysis. 2D modeling.

## GRAVITY MEASUREMENTS

NEA possesses one Lacost & Romberg gravity meter and state of the art geodetic instruments for measuring station elevation.

*Data processing and interpretation*
Standard data processing producing free air and bouger gravity field, filtering, upward or downward continuation. Data presentation as profiles, contour maps or 3D plots. Directional filtering and trend analysis. 2D or 3D modeling. Analysis of high precision gravity data for monitoring mass changes in geothermal reservoirs.

## SOIL TEMPERATURE MEASUREMENTS

NEA owns several termistor temperature measuring sticks.

*Data processing and interpretation*
Data presentation as profiles, contour maps or 3D plots. Directional filtering and trend analysis.

## SELF POTENTIAL MEASUREMENTS

NEA uses non polarizing electrodes and high precision voltmeters for SP surveying.

*Data processing and interpretation*
Data presentation as profiles, contour maps or 3D plots. Directional filtering and trend analysis.

## THERMAL GRADIENT AND HEAT FLOW MEASUREMENTS

NEA possesses several temperature measurement reels for measuring temperature in shallow bore holes as well as equipment for measuring thermal conductivity in core samples, using the divided bar method.

*Data processing and interpretation*
Data presentation as profiles, contour maps or 3D plots of temperature at different depths, thermal gradient and heat flow. Trend analysis and 2D modeling.

## ACTIVE SEISMIC METHODS

NEA owns 24 channel seismic recording system and cables for small scale seismic refraction and seismic reflection surveys.

*Data processing and interpretation*
NEA has a generalizeed reciprocal method interpretation software for seismic refraction processing and a complete software for large scale seismic reflection processing both for land and marine data.

## PASSIVE SEISMIC METHODS

NEA has in cooperation with the University of Iceland access to three component seismograms with digital data storage for earth quake monitoring.

*Data processing and interpretation*

Standard processing including epi- and hypocentral location and focal resolution.