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# Integrated MT/Gravity geothermal exploration in Hungary: A success story

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21 ASEG Conference and Exhibition, Sydney
2010

# Integrated MT/Gravity geothermal exploration in Hungary: A success story

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Hungary is promising for utilization of low temperature (< 150°C) geothermal energy because of its high thermal gradient, reaching almost 50° C/km over most of the country. This high gradient is mainly caused by a relatively thin layer of the Earth's crust in that area and partly due to the non permeable lower Pannonian sediment layer that covers a large part of the country. Our geothermal evaluation project in Hungary has, since 2007, yielded over 30 possible well sites for geothermal energy production and utilization. The first drilled well was recently successful.

The correlation between resistivity and temperature is associated with the local degree of hydrothermal alteration. Most high-temperature hydrothermal systems are indicated by a low resistivity layer over the geothermal reservoir which is caused by clay mineral alteration. Electrical methods provide information about rock properties, temperature, and the degree of hydrothermal alteration. This information can be used to determine the geometry of hydrothermal reservoirs, its depth, location of fracture zones, and the permeability distribution. To complement the electromagnetic method of choice (magnetotellurics or MT), gravity surveys were acquired along the MT survey lines with higher density spacing to assist in detecting fault systems. Gravity data may be used to interpret the subsurface and to aid in locating prospective heat sources. Integrating the MT and gravity data reduces the ambiguity of either dataset and produces a more robust interpretation.

The distribution characteristics of the fault zones with relatively low resistivity and with boundaries outlined by cooperative constrained inversion of MT and gravity data indicate that the prospective zones for potential geothermal reservoirs in the survey area are along the mid-northern part of the AMT/MT survey line 1 and the middle part of AMT/MT survey line 2.

Based on integrated processing and interpretation of electromagnetic, gravimetric and seismic combined with stratigraphic information; the position of the first geothermal well site was selected and drilled in the Szentlőrinc survey area. Hot water with temperatures in excess of 85°C, estimated to have a peak heating capacity of 4 MW, was found at depths of 1,620 to 1,790 meters. This discovery was possible due to the utilization of different geophysical and geological methods to determine the best well location.

The integrated approach which uses different datasets has proven to be a very effective method for locating the most promising areas for geothermal exploration. Utilizing this method in Hungary, with the goal of supplying 700,000 homes with geothermal energy within the next decade, is readily possible.

# Introduction

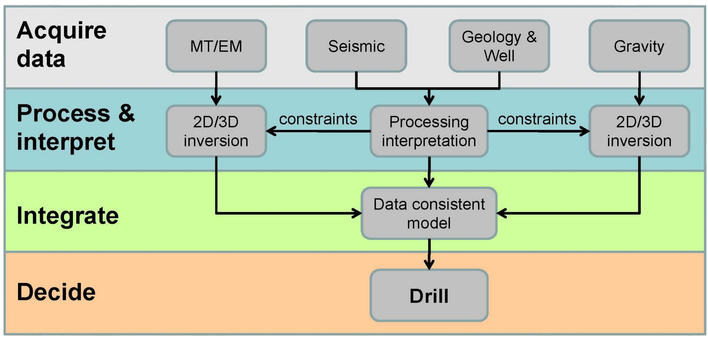
Hungary has low temperature (<150°C) geothermal energy due to high thermal gradient (50° C/km) over most of the country. Main geothermal reservoir systems are Mesozoic carbonate–karstic basement rocks and Pliocene-Upper Pannonian porous sedimentary formations.

***Project objectives:***

- Perform Magnetotelluric (MT)/Audio-magnetotelluric (AMT) & gravity surveys;
- Derive robust WORKFLOW;
- Outline potential geothermal reservoirs using resistivity and gravity data ;
- Understand better deep geothermal reservoir distribution;
- Provide critical input for drilling plan.

# Methodology

WORKFLOW for the integrated geothermal exploration:




WORKFLOW

***Magnetotelluric (MT)/Audi-magnetotelluric (AMT) method:***

- Acquire MT/AMT data (0.001 Hz ~ 10,000 Hz ) on each site;
- Resistivity characteristics to extract structural information;
- Resistivity to determine high-permeability & up flow hydrothermal systems.

***Gravity method:***

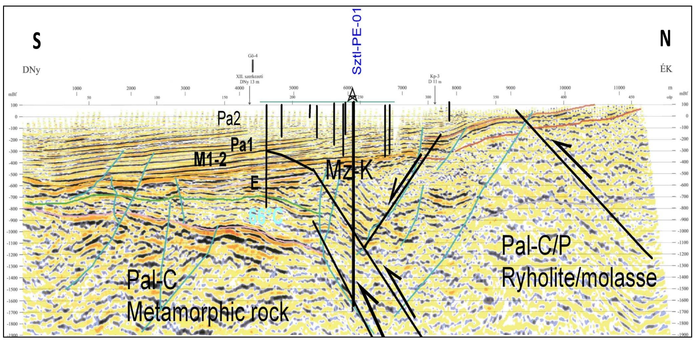
- Acquire gravity data along MT lines to measure density contrast;
- Help detect fault systems (penitential heat sources ) below subsurface;
- Help understand groundwater channels & water flow directions;

***Integrated interpretation (MT/AMT and gravity data):***

- Reduces intrinsic ambiguity of either dataset;
- Produces robust & reliable interpretation.

# Geological cross sections

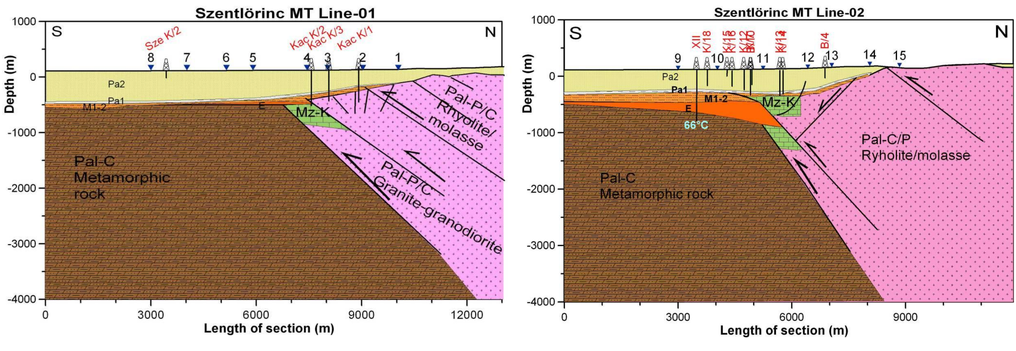
In the SEISMIC SECTION, lower structural belts below old Paleozoic micaceous schist.




SEISMIC SECTION

GEOLOGICAL SECTIONS are well-based structural profile along lines 1 (left) and 2 (right).

- Southern part (Line-01): polimetamorphic rocks, palingene granite & granodiorite;
- Northern part (Line-02): continental rhyolite & continental molasse of Permian age;
- Paleozoic rock slope changes in depth profile indicates tectonical zones.



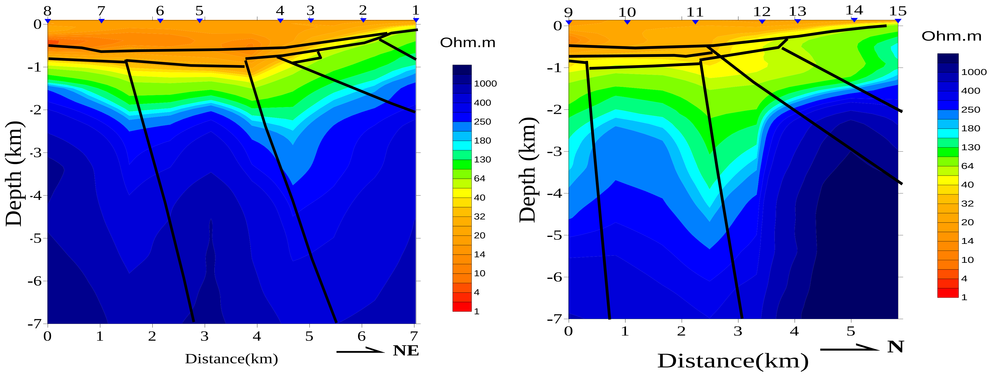

GEOLOGICAL SECTIONS

## Data acquisition

- MT/AMT site spacing 1,000 m & gravity station spacing 250 m (~ 450 MT/AMT sites);
- MT/AMT measurement on each site with different induction coils;
- MT measurement: 0.00025 Hz to 400 Hz;
- AMT measurement:0.35 Hz to 12.5 kHz.

## Data processing & integrated interpretation

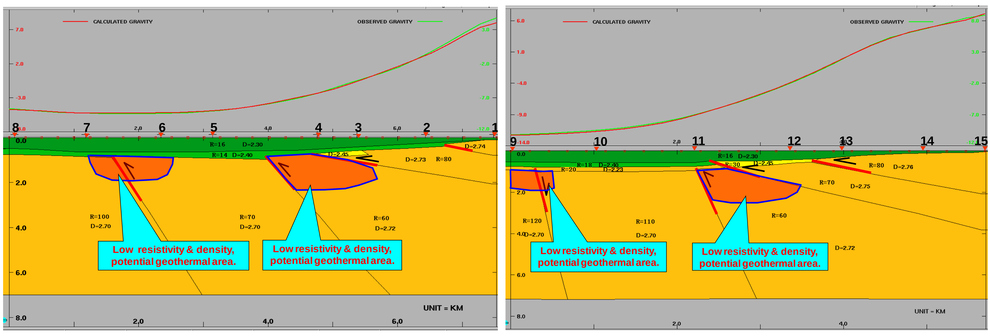
MT/AMT INVERSION along lines 1 (left) & 2 (right). Pre-survey structural interpretation superimposed on inversion profile.




MT/AMT INVERSION & A PRIORI GEOLOGY

- Structural interpretation from MT consists with wells;
- Supported by & correlated to gravity derived tectonic interpretations;
- Integrating gravity /MT honors observed data at same time/location;
- Produce a more robust & unique interpretation;
- Lower resistivity/density areas correspond to structurally advantageous zones.

INTEGRATED MT/AMT & GRAVITY INTERPRETATION identified potential geothermal reservoir locations. Lower resistivity/density area is structurally advantageous positions for geothermal reservoir.




INTEGRATED MT/AMT & GRAVITY INTERPRETATION

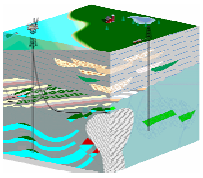
- Select 1st well from integrated interpretation;
- Successfully drilled 1st geothermal well in the Szentlőrinc area in 2009;
- Estimated 4 MW peak heating capacity with 85°C hot water;
- Production depth from 1,620 to 1,790 meters (interpreted fracturing/faulting zone).

WELL TEST at Szentlörinc, HUNGARY

## Conclusions

- MT/AMT resistivity anomalies supported by gravity data interpretation;
- Integrated interpretation to map potential geothermal reservoirs;
- Use geophysical/geological methods to determine optimum drilling location;
- Derived integrated & optimum WORKFLOW;
- Successfully drilled 1st geothermal well with 4 MW peak heating capacity.

Based on these surveys and integrated interpretation of geology, seismic, well logging, gravity and MT/AMT data, client is currently conducting an ongoing drilling program in Hungary.



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