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Applicability of geophysical surveys in geothermal projects in Romania – status and potential value for reservoir de-risking: Beiuș and Oradea case study

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Norway grants

Case study introduction

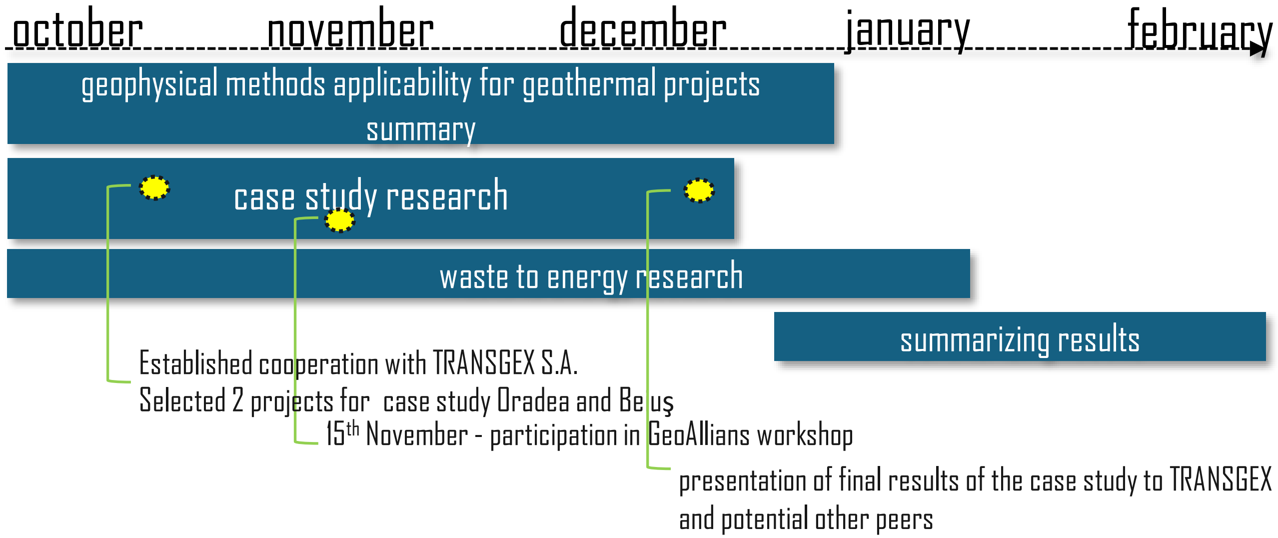
The project explores **applicability of geophysical technologies** to derisk potential exploration and production targets in geothermal projects with focus on **Romanian assets**

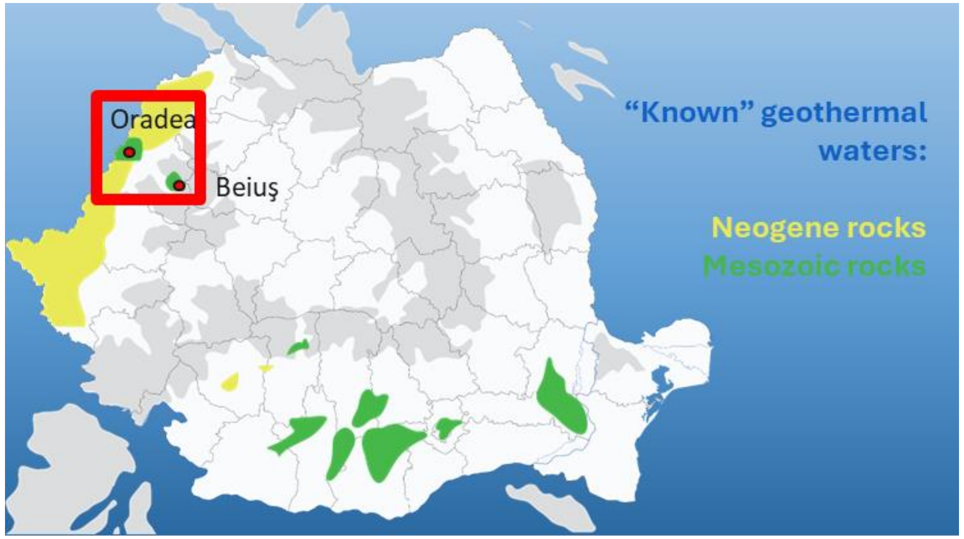
One of important goal **is to improve awareness about value of geophysical surveys in geothermal**

The project team established **cooperation with TRANSGEX S.A.** – the biggest geothermal producer in Romania and selected two case studies:

- Beiuş
- Oradea

The main addressed geophysical method is **seismic surveys**. Also potential of **electrical surveys** is being studied.

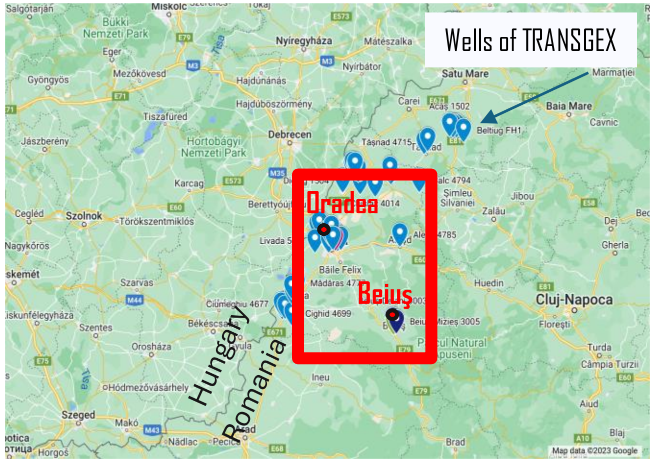




Beiuş, Oradea projects summary

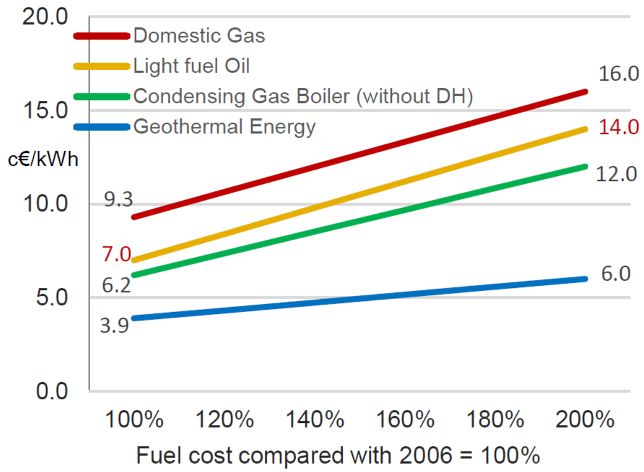
Since 1960 geothermal water started to be used in Romania for recreation purposes, geothermal industrial production started in 1980. Since 1990/1991 two companies operate geothermal: TRANSGEX S.A. (Bihor, Satu Mare counties, Pannonian Basin), FORADEX (Banat county, Olt Valley, and Bucharest region, Pannonian Basin)

	Beiuş	Oradea
Capacity of power plant	21MW	35MW (under development to 50MW) +50kW electric
Annual production	17,000G Gcal/year	39,000 Gcal/year
Type of geothermal	Low-enthalpy, open-system	Low-enthalpy, open-system
Amount of wells	3 production +1 injection	11 production +1 injection
Wells production	60-70 l/s, av. 65 l/s	4-42 l/s, av. 19 l/s
Temperature of produced water	62-81 °C, av.73°C	70-105 °C, av. 88°C
Well design	Vertical	
Well completion	Open hole and ESP (electrical pump)	Open hole, cased hole and perforated (ESP + artesian)



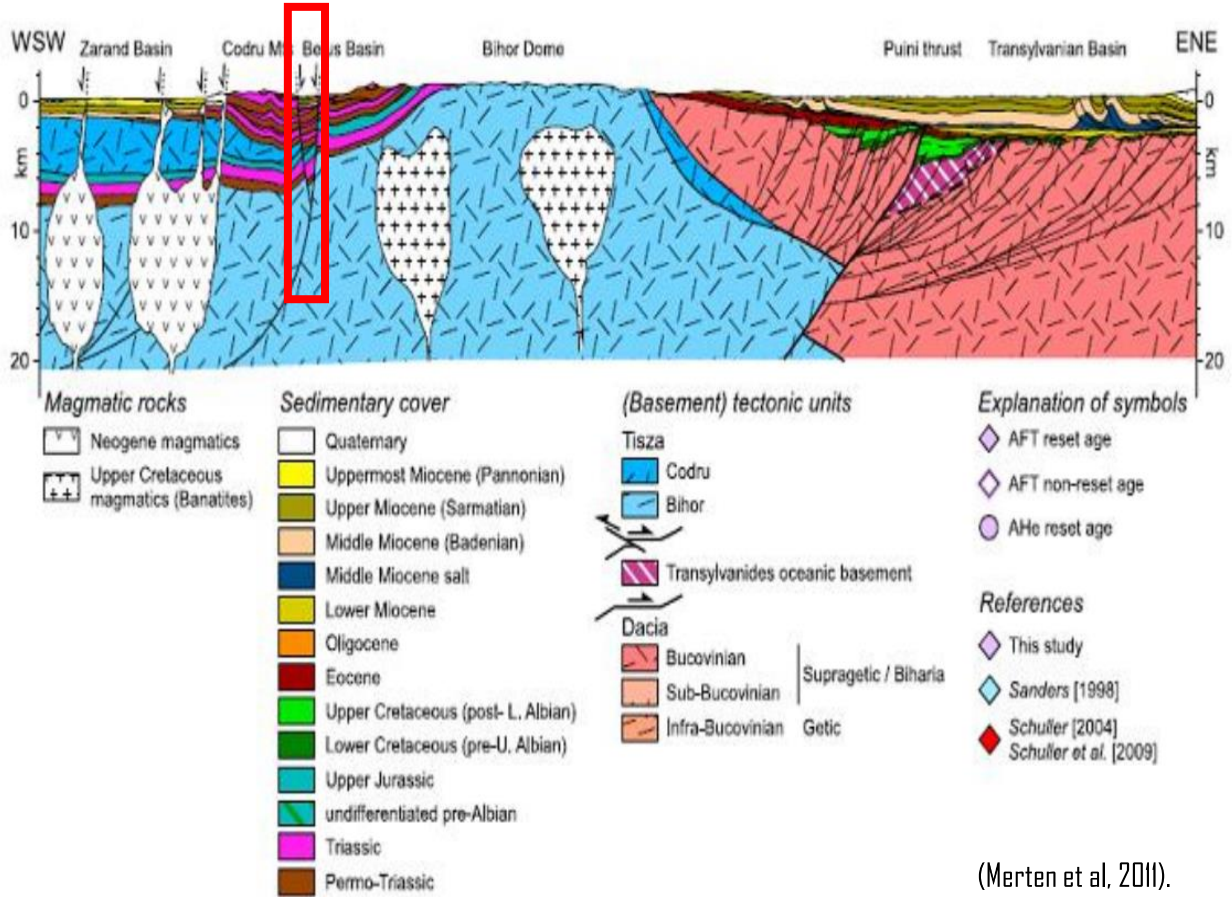
TRANSGEX Feasibility study, 2017
Source GeoDH 2014

Fig. 9.1.8. **Heat Generation Cost for District Heating Network by Fuel**

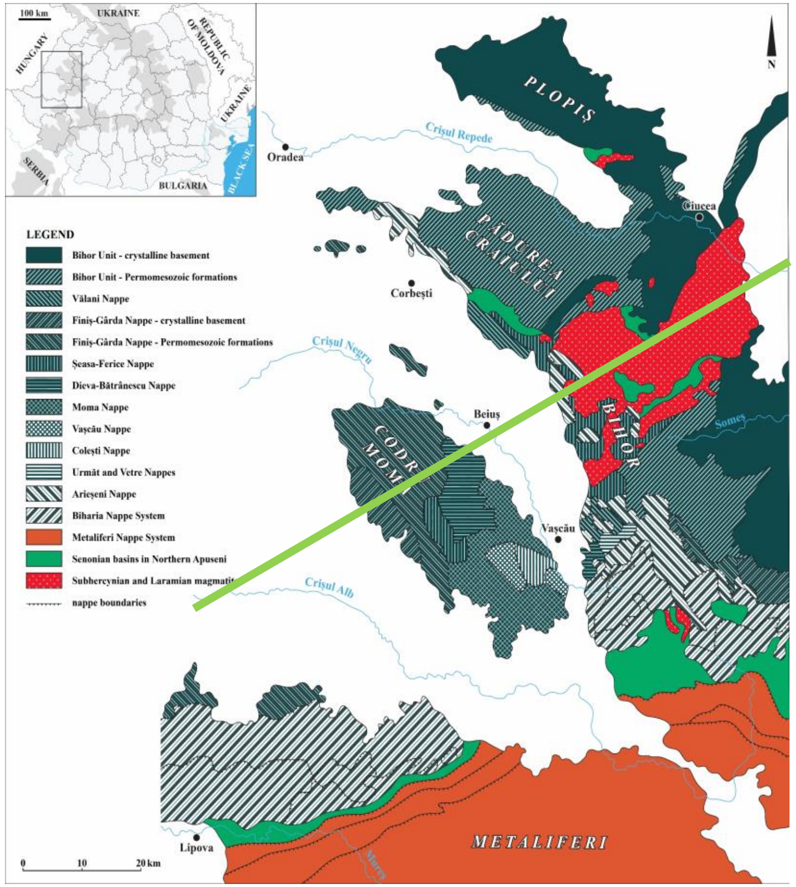


Beiuş geological settings

- Beiuş geothermal field is located within Beiuş Basin on eastern flank of larger back-arc Panonian Basin system, in proximity of surrounding orogens (Apuseni Mountains).
- Beiuş Depression is an opened towards basin half-graben formed as a result of extensional tectonics during U. Cretaceous - Miocene rifting and further fast subsidence of a Pannonian Basin.



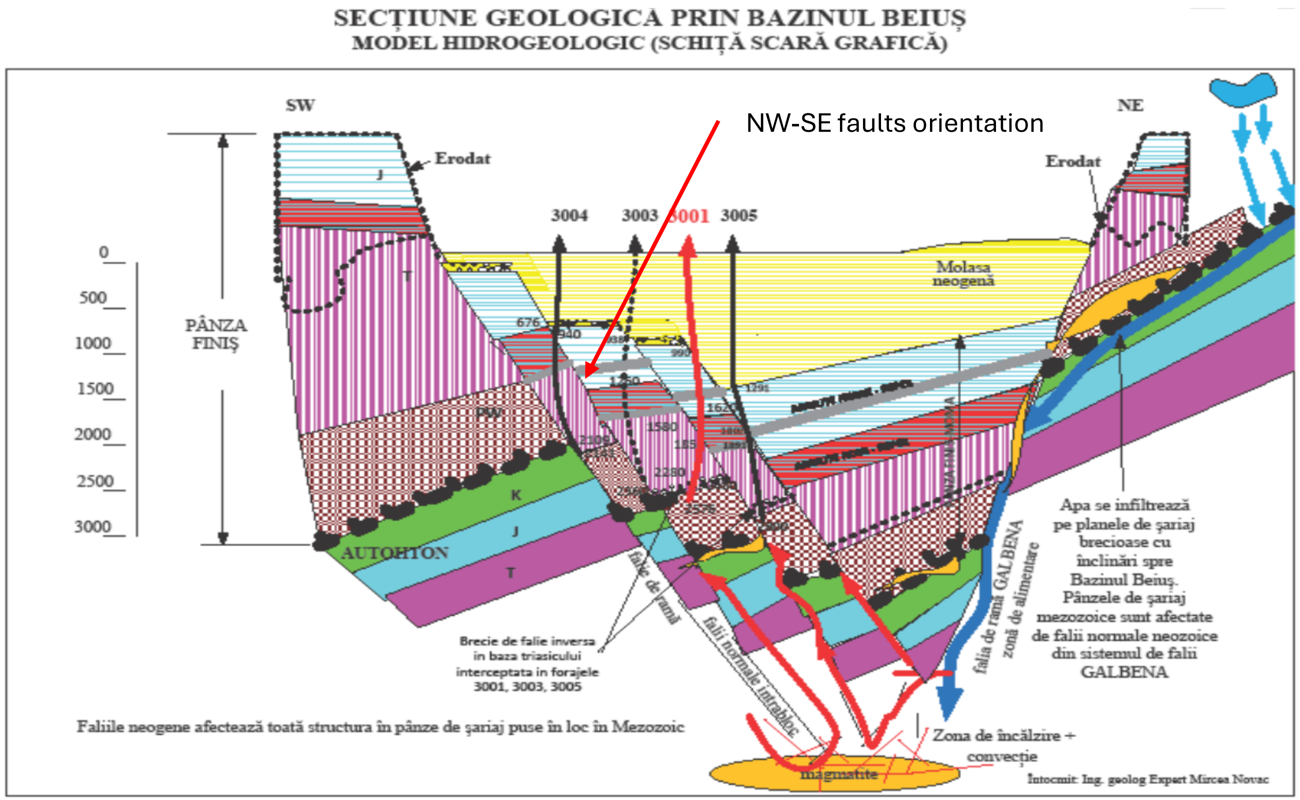
(Merten et al, 2011).



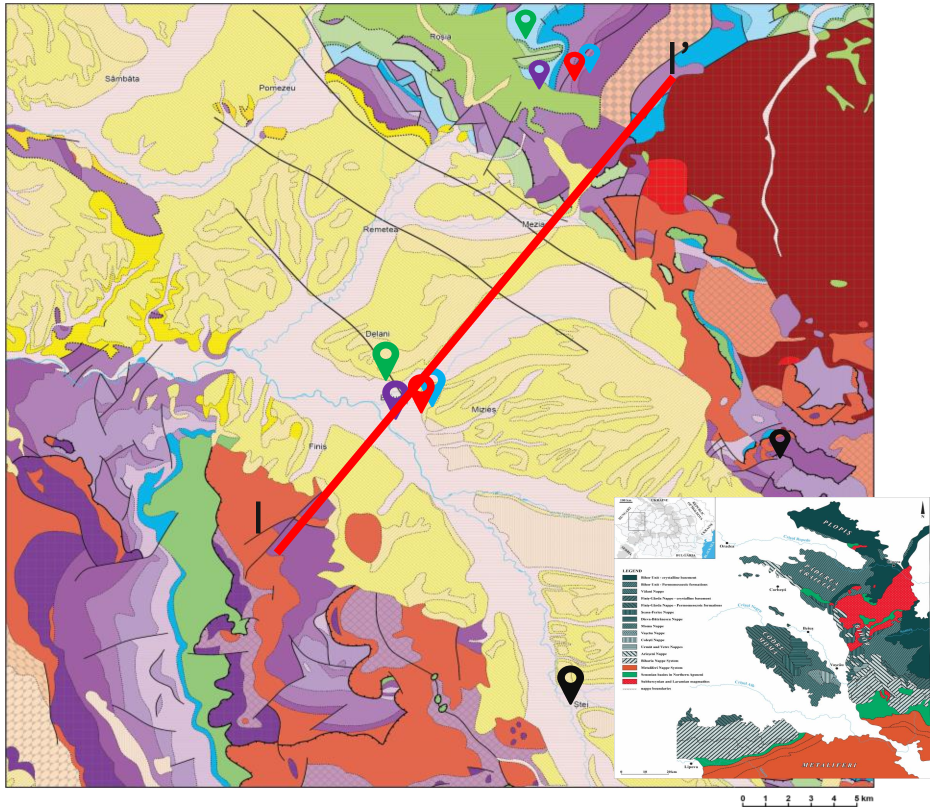
Balassa et all 2023 (modified after Bleahu et al., 1994)

Beiuş geological settings

- Main tectono-stratigraphic sequences include Proterozoic to Early-Permian basement tectonic unit (nappes), sedimentary cover including Mesozoic pre-rift sequence and Neogene syn rift and post-rift sediments



Materials from TRANSGEX, Mircea Novac



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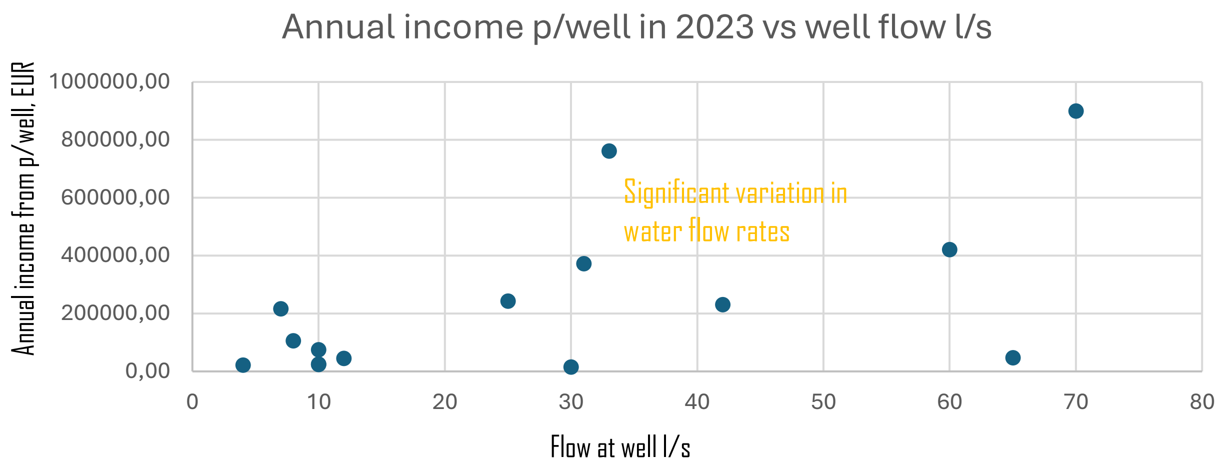
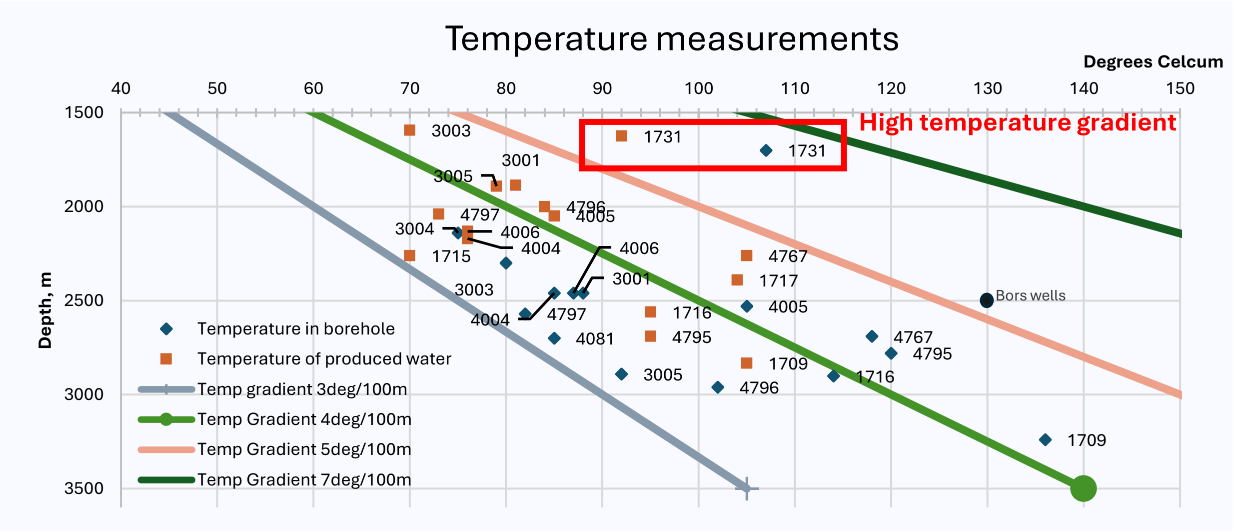
Beiuş geological settings. Reservoir

	Beiuş	Oradea
Reservoir age	Triassic	
Lithology	Dolomite, Limestone, Dolomitic limestone, brecciated dolomites, sometimes silicified dolomites	
Porosity type	Porosity in various reports: Matrix porosity ~2% Fracture porosity ~10% Mentioned vuggs developed along fractures, no information on vuggy porosity estimation	
Permeability	0.01mD average matrix permeability, 15mD average including fractures	
Fractures/fault type	Inverse (Mesozoic) W-E direction and normal gravitational fractures (Neozoic) NW-SE direction (Bratu, 2017)	
Depth of reservoir top	Av. 1680m	Av. 2300m
Reservoir gross thickness	480-1000 m	311-925 m
Temperature downhole measurements	75-92 °C av. 84 °C	82-136 °C av. 103 °C
Temperature lateral distribution	No local high temperature area have been identified	Proven areas with faults indicate 2-4°C higher temp/gradient
Water salinity	0.5 g/l TDS, no scaling.	0.9 – 1.2 g/l, no significant scaling.

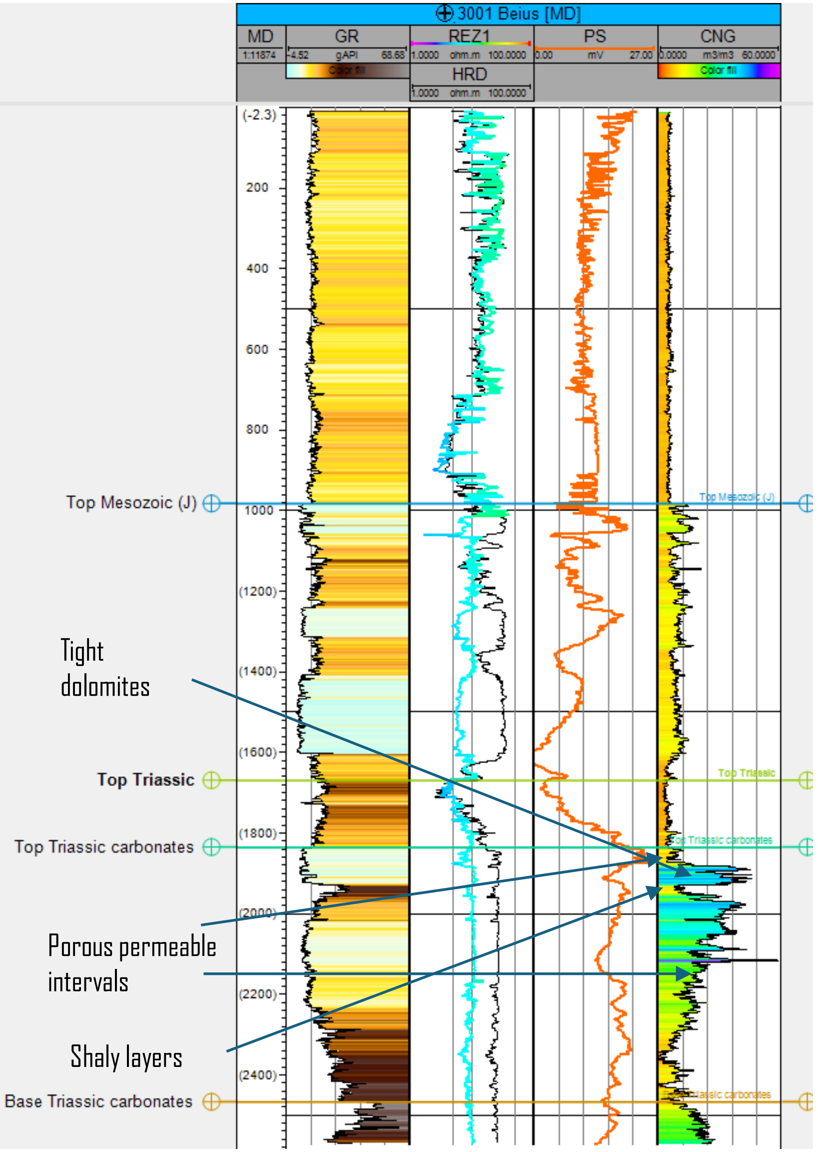


There are existing not successful wells due to low permeable Triassic rock (Cotiglet 4008, Stei 3002)



Current status of well geophysics use for exploration and appraisal purposes

Well	Available log data
4005	Resistivity, lithology description
4006	
4004	Resistivity, GR, NGR
4081	SP, Resistivity, GR, NGR, Density
4767	Microresistivity, GR, Neutron, CALI, Resistivity, SP, lithodescription
4796	
4797	GR, NGR, Density, SP, Resistivity, litho description
4795	GR, Resistivity, litho description
1715	SP, GR, rock description, Resistivity, NGR, Density
1716	SP, GR, petro interp, resistivity, CALI
1717	SP, Resistivity
1709	SP, GR, CALI, Resistivity, NGR, Density, petro intepretation
1731	GR, CALI, Resistivity, SP (relatively new log suite but not relevant because well did not penetrate Triassic)
3001	SP, CALI, Resistivity, GR
3005	
3004	Weatherford (ILL, Neutron, Density, GR, MPD – Compact photodensity)
3003	



- Well log data is used at time of well completion decision making, some interpretation is done by logging contractors for individual wells. Log data is not digitized to be actively used in interpretation.
- Core data is not available for The Operator
- Well data can be used more extensively for purpose of creating more detailed geological concept. It may help to derisk reservoir performance.

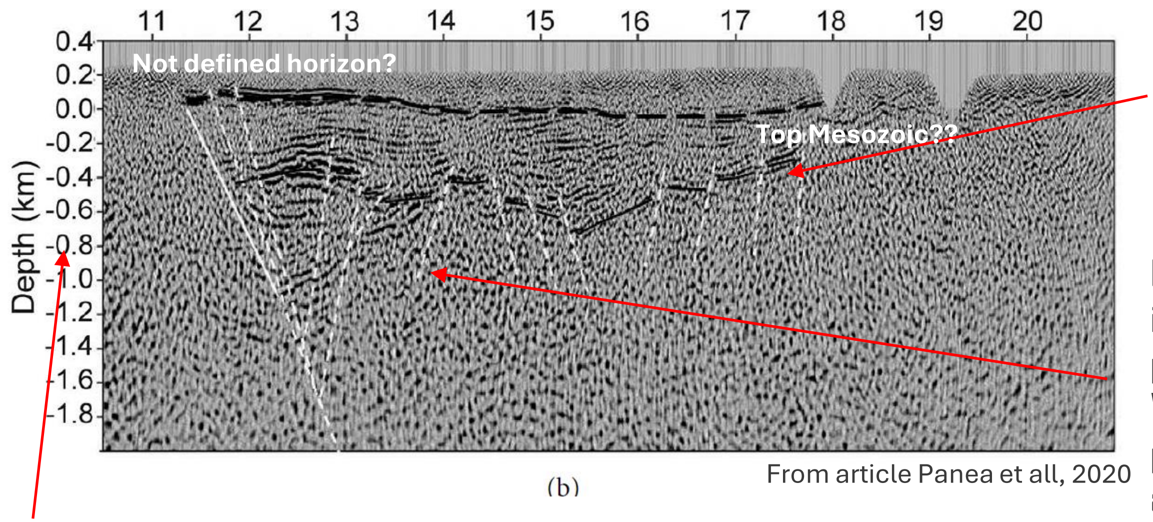
Current status of geophysics use for exploration and appraisal purposes

- G&G work is based on wells and regional studies available in the area. Used well information generally include stratigraphy, macro core and cuttings description, observations during drilling
- Water properties measurements are more regulated, detailed water composition analysis have been done in frame of several recent researches [1, 3] and as part of process addressing scaling issue work in neighbor Borş geothermal field [2].
- Geophysical surveys are not currently used or considered by The Operator in G&G modelling of future well planning.
- Number of recent studies addressing use of seismic 2D surveys and Magnetotelluric electrical surveys. Most of them are involving University of Bucharest. The outcome of the studies include processed seismic lines and structural interpretation of main surfaces. Information about well use during seismic interpretation have not been in the articles. None of found works is addressing directly Beiuş or Oradea geothermal projects

[1] Balassa et all: DOI:10.35925/j.multi.2023.4.6
[2] STĂNĂŞEL et all 2005
[3] Petrescu-Mag et all 2009

Current status of geophysics use for exploration and appraisal purposes

1

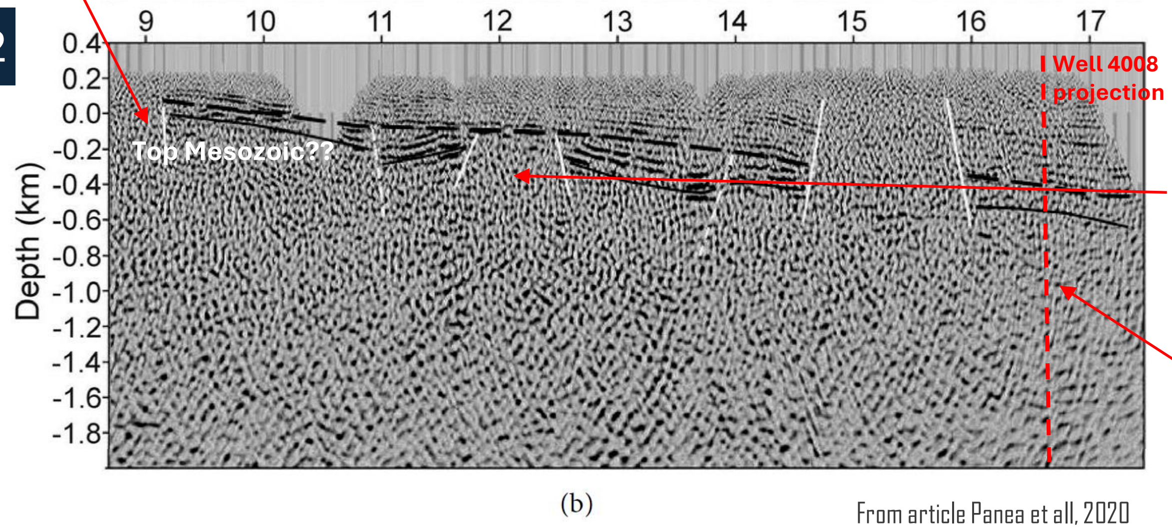


From article Panea et all, 2020

Uncertain depth conversion

For main geothermal unit - Triassic

2



From article Panea et all, 2020

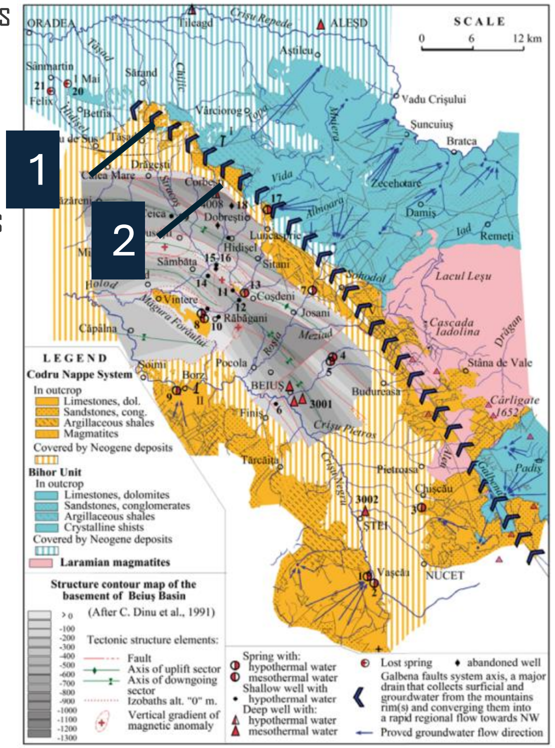
Seismic sections even with applied standard processing workflow allow to achieve image of Mesozoic sequence top and observe major faults

Certain reflectors can be observed in target interval. Most of producing Mesozoic interval has poor image

Very important to test more advanced processing technologies (selective multiples attenuation, selective noise filtration) to understand possibility of better imaging of within target Mesozoic interval for legacy data.

Provided in articles seismic sections illustrate complexity of Top Mesozoic morphology with reversed fault blocks, normal faults.

Well information can be integrated in interpretation workflow

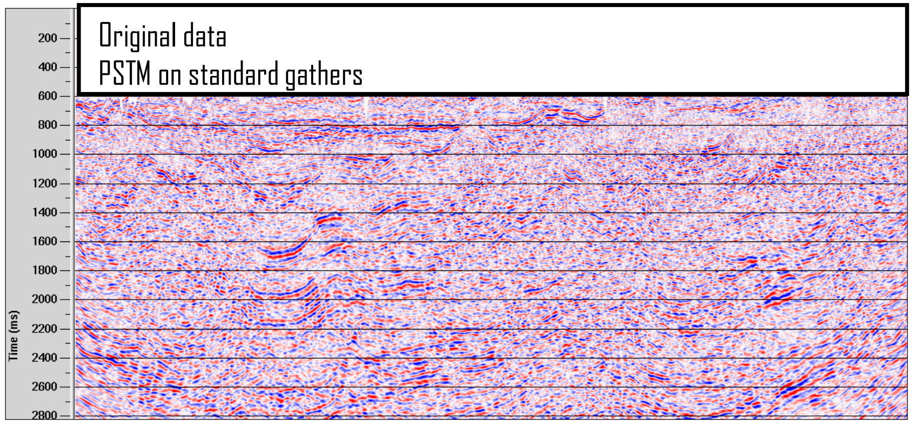


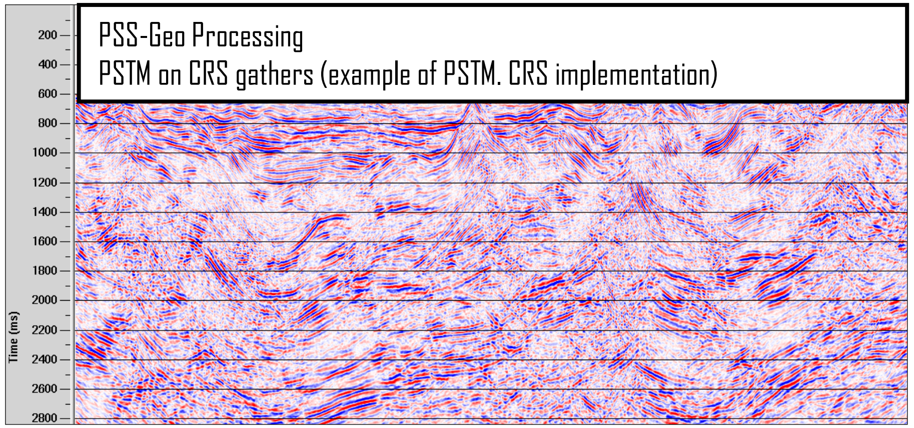
Hydrogeological map of Beiuş Basin, Iancu Orăşeanu

Potential improvement from using 2D seismic surveys based on previous studies

PSS-Geo
transgex

Addressed parameter	Importance for geothermal project	Expected accuracy	Possibility to achieve results in Beiuş, Oradea
Mapping of structural surface for Top Mesozoic	critical	20-50m	Available legacy 2D seismic data
Mapping of structural surface for Top Triassic in inner Triassic morphology	critical	30-60m	Processing technologies need to be tested to achieve interpretable image of Mesozoic sequence
Major faults	critical	certain for major faults (more then 30-70m amplitude)	
Faults with high heat flow	important, but value is not yet proven	can not be defined by seismic directly unless geological concept is developed	A regional concept for high heat flow faults should be developed as a part of regional project
Small scale fractures	good to have	Indirect indicators on seismic attributes Certain mapping possible using 3D seismic, or near well VSP	Most likely quality of legacy seismic will not allow to achieve accurate results Acquisition of new seismic data should be financially evaluated.
Reservoir properties (porosity, permeability)	good to have	2-5%, requires well data for calibration	





PSS-Geo processing examples for 2D legacy data

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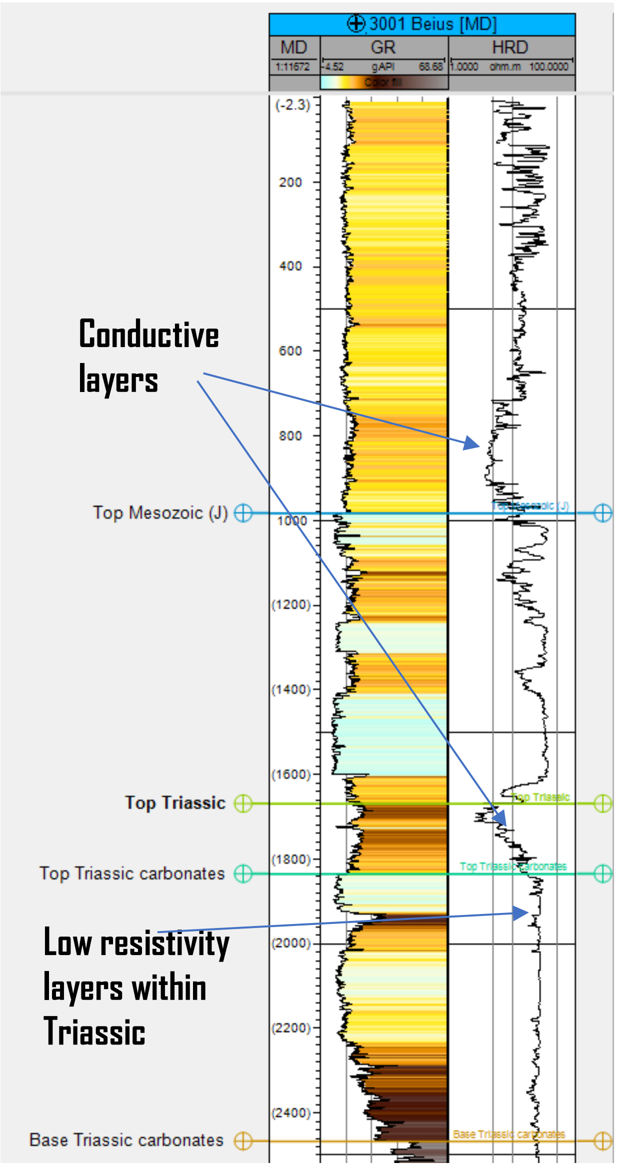
Potential for use of electric surveys

- Based on studied wells section can be characterized as medium resistivity contrast, which means that identification of thick layers is possible
- Several conductive layers are on top of Mesozoic and target Triassic which will likely allow to map both Top Triassic and
- Within Triassic shaly conductive intervals are obstacle for mapping of best reservoir zones

- Two main methods are usual to use in geothermal: Magnetotelluric (MT) and Transient of the electromagnetic field (TEM/TDEM)



Example of different methods outcomes (CSAM) and TEM. Modelling Yang Yang, Bin Xiong et all, 2022

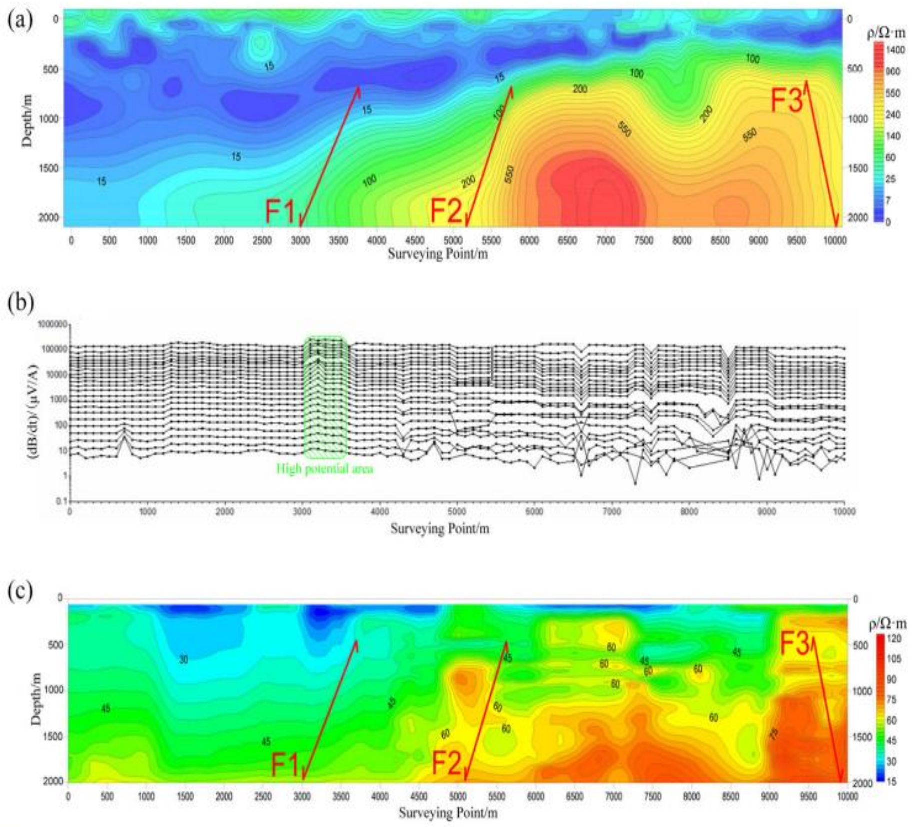


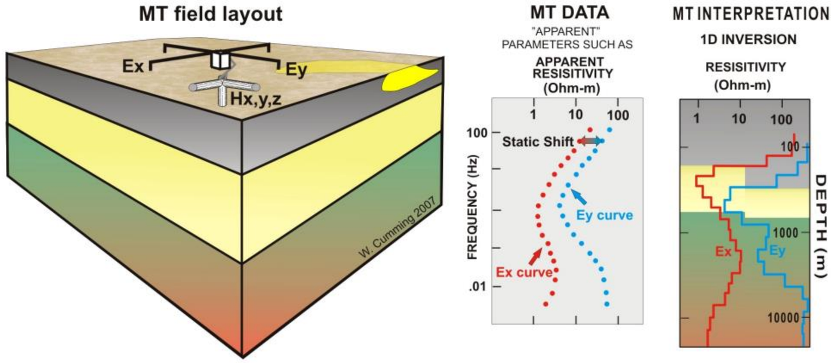
Figure 11. (a) Resistivity profile of CSAMT with a line number of 60. (b) Secondary field potential profile of TEM with a line number of 60. (c) Resistivity profile of TEM with a line number of 60.

https://doi.org/10.1080/10916466.2022.2060256

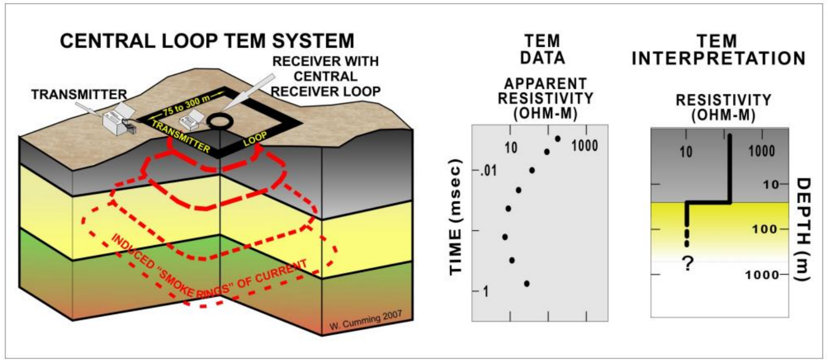
Potential improvement from using electric surveys (MT, TEM)

Addressed parameter	Applicability of TEM	Applicability of MT
Geoelectric section	High with high resolution	Medium resolution to greater depth
Base Neogene sequence mapping	high	high
Mapping of Triassic top	medium	Low (low resistivity contrast within Mesozoic section)
Faults mapping	high	medium
Mapping of faults with high temperature fluids	medium	low
Mapping of zones with high porosity and therefore higher water content within target interval	medium	medium
Identification of deep heat sources (intrusions, granitic bodies)	not possible because of low depth of investigation	medium

- MT surveys are easier in execution with low cost 1K – 2.5KEUR per km, low mobilization fee



Cumming W., Mackie R. 2010



- To achieve 3-4km depth is required to use linear system, size of transmitter loop must be 500x500m and 1000x1000m to achieve 4-6km depth

Recommended workflow for integrated analysis of geophysical data

PSS-Geo
transgex

wells

- Wells logs digitizing
- Integrated petrophysical interpretation

→ Lithology model
Estimated porosity

seismic

- Getting field seismic data
- Seismic re-processing of legacy data targeting Mesozoic sequence

→ Interpretable image of target Mesozoic sequence

- Seismic structural interpretation
- Wells integration
- Seismic inversion and Lithology prediction

→ Structural maps
Faults location
Interpreted sections with horizons, tectonic elements, predicted reservoir lithology

electric surveys

- Getting quotation from local electric surveys company for MT and TEM
- Select between MT and TEM
- Approval from The company and confirmation from local stakeholders
- Electric survey planning and acquisition
- Processing and Interpretation of results

→ Faults location
Resistivity sections, interpreted depth of aquifers, zones of higher water content and heat flow

1-3 weeks → 1-4 months → 4-8 months → 1 – 1.5 years

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Key challenges for The Operator to apply geophysics in geothermal projects on example of Beiuş and Oradea

- Challenging process to access data base for legacy seismic data
- Different license owners for oil & gas and geothermal projects, with potential to streamline sharing of information
- Evaluation of the value of geophysical surveys as part of the planning phase for the geothermal exploration process
- Opportunity to assess in-country availability of service-providers of geophysical surveys and benchmark the cost versus value of information

Aknowledgments

- This work has developed in the frame of the project: "Driving Sustainable Urban Futures: A Romanian-Norwegian Innovation Geophysical Alliance for Green Transition and SMART City Development" granted by Innovation Norway, Pre Stack Solution-Geo and University of Bucharest
- The data for case study as well as knowledge of the Romanian geothermal field was provided by TRANSGEX S.A.

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Technical challenges of applying TEM for deep reservoirs