



Damietta University
Faculty of Science
Geology Department



Geothermal Course

For

First Year Geophysics Program

Code: 103 Geoph

Lecture 5: Exploring for Geothermal Energy

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GEOHERMAL ENERGY

Trapping the Earth's Internal Heat

Exploring for Geothermal Energy

Geothermal & Hydrocarbon

- Geothermal energy is one of the cleaner sources of energy which are gaining importance as an alternative to **hydrocarbons**.
- An ideal conventional geothermal system requires **heat, permeability, and water**.

Geothermal & Hydrocarbon

The exploration of geothermal resource is different from the hydrocarbon exploration for these reasons:

- 1) Geothermal reservoirs can be found in highly varying geological environment mostly associated with volcanism.
- 2) The economically most interesting geothermal reservoirs are much hotter than any oil or gas reservoir.

Aims of geothermal exploration

- Delineate a geothermal resource.
- Outline a production field for geothermal system.
- Assess the general properties of geothermal system.
- Locate aquifers.
- Locate structures that may control aquifers in order to site wells.
- Develop a conceptual model.
- Evaluate the general properties of the geothermal system.
- Locate suitable drilling targets.

Physical parameters in a geothermal system are

- Temperature
- Porosity
- Permeability
- Pore Pressure
- Chemical composition of fluid
- Flow rate
- Water saturation

Take into account

- A deep exploration borehole in a high temperature field can **cost several million USD**.
- The total cost of geo-scientific exploration is only a **part of the cost** of one such well.
- Exploration requires considerable **up-front cost** prior to exploration drilling.

Therefore

- Exploration methods must be selected with respect to the site.
- Exploration must be carried out in professional manner.
- A stepwise approach نهج تدريجي is recommended, i.e. the strategy must be revised as the results appear.

Scales of Exploration

- **Regional exploration:** Exploration covering large area in order to identify possible geothermal resources and roughly assess their size.
- **Local exploration:** Exploration that concentrates on the interior of a known geothermal field in order to identify the best production sites and target for drilling to obtain maximum energy output with minimum cost.

Geothermal methods are divided into two groups

Direct Methods

- Thermal methods
- Resistivity Methods
- Self Potential Methods
- Remote Sensing

Indirect Methods

- Magnetic method
- Gravity method
- Active seismic method

Exploration Stages

Regional exploration

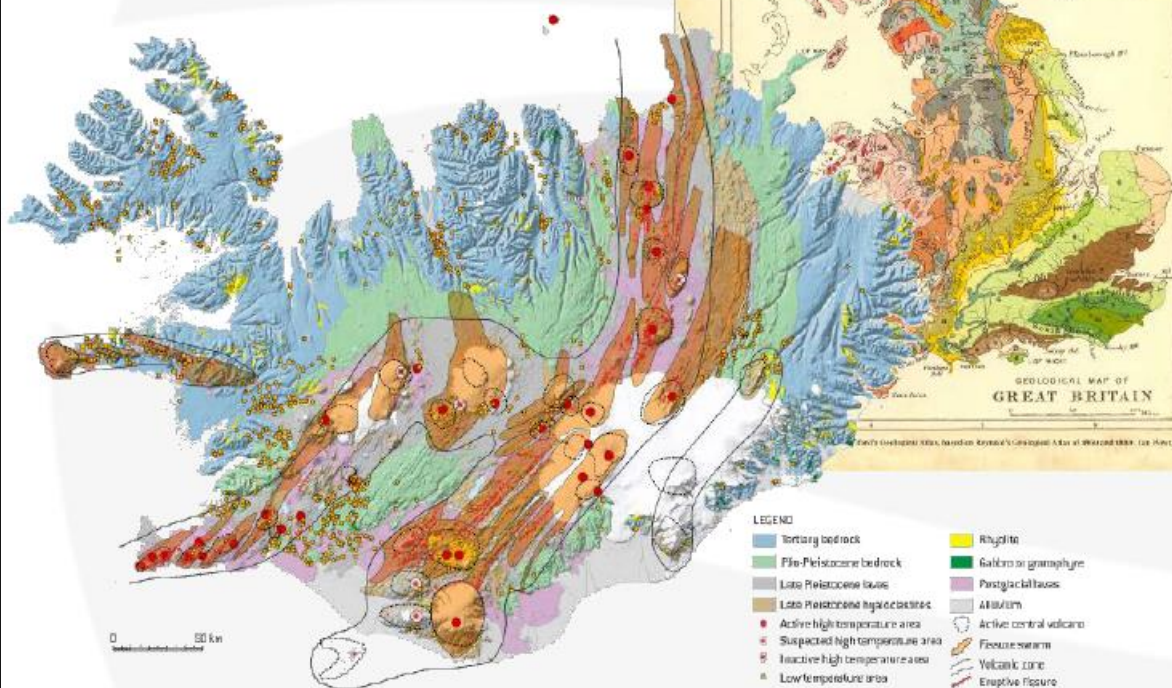
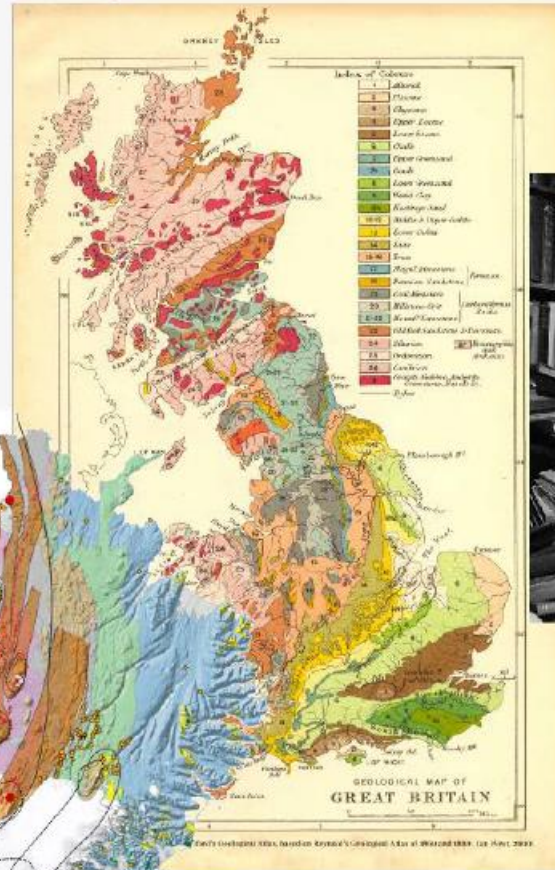
- Review of existing data
- Reconnaissance
- Geological Exploration

Local exploration

- Geophysical Exploration
- Exploration Drilling
- Preliminary Resource Estimate

Regional Exploration

Review and study all available existing data



Regional Exploration Reconnaissance الاستطلاع

- **Desktop study of all available data**
- **Field studies:**
 - Visual studies, maps, photographs (infra red).
 - Mapping of the manifestations الظواهر
 - Temperatures and flow rate
 - Mapping of soil temperatures
 - Fluid sampling and analyses (geo-thermometers, fluid chemistry)
 - Historical data on activity and utilization
- **Ownership and rights (licensing)**
- **Environmental aspects (EIA)**
- **Social aspects**
- **Market possibilities**

Regional Exploration

Reconnaissance الاستطلاع



Mapping of manifestations, temperature and flow-rate.

Mapping of soil temperatures

Chemical analysis of springs and gas from steam vents gives information on reservoir temperatures.

Regional Exploration Reconnaissance الاستطلاع

Geothermometers

If we have access to the geothermal fluid through hot springs, steam vents or borehole we can take samples for chemical analysis.

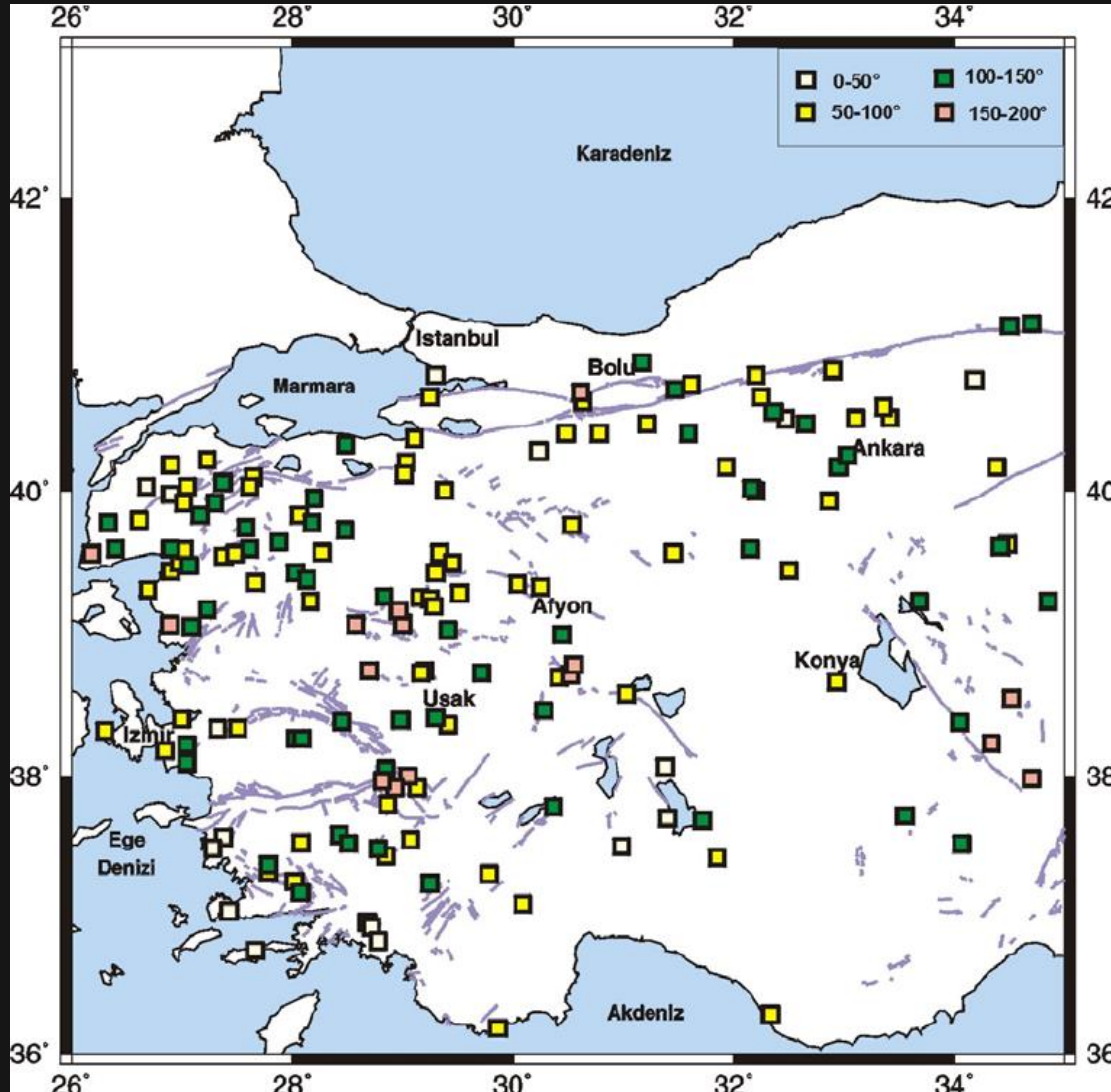
From the results of the analysis we can calculate and estimate the likely temperature in the underlying reservoir.



Regional Exploration

Reconnaissance الاستطلاع

Geothermometers



Regional Exploration

Geological Exploration

- Geological mapping (lithology).
- Structural geology (faults, fractures, dykes).
- Volcanology and volcanic history.
- Hydrogeology.
- Geo-hazards and environmental geology.

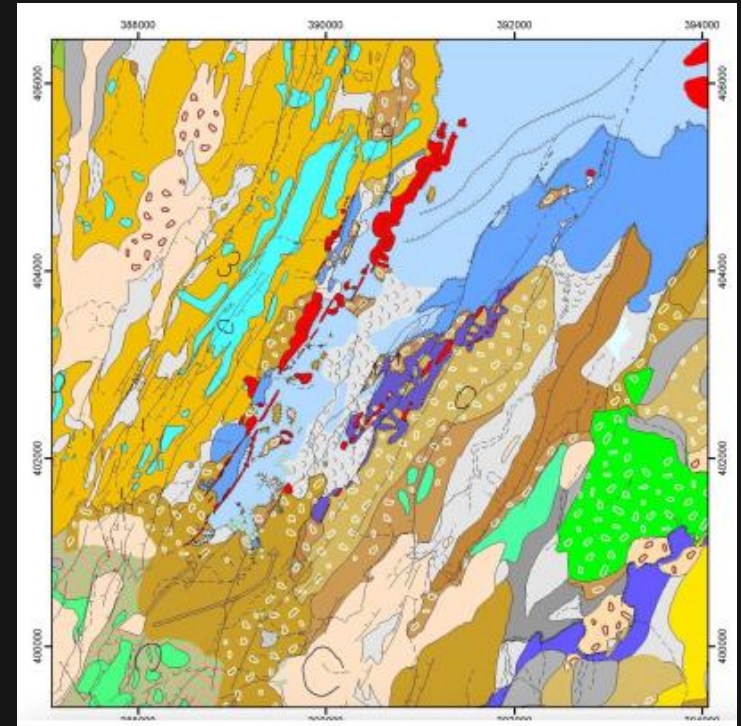
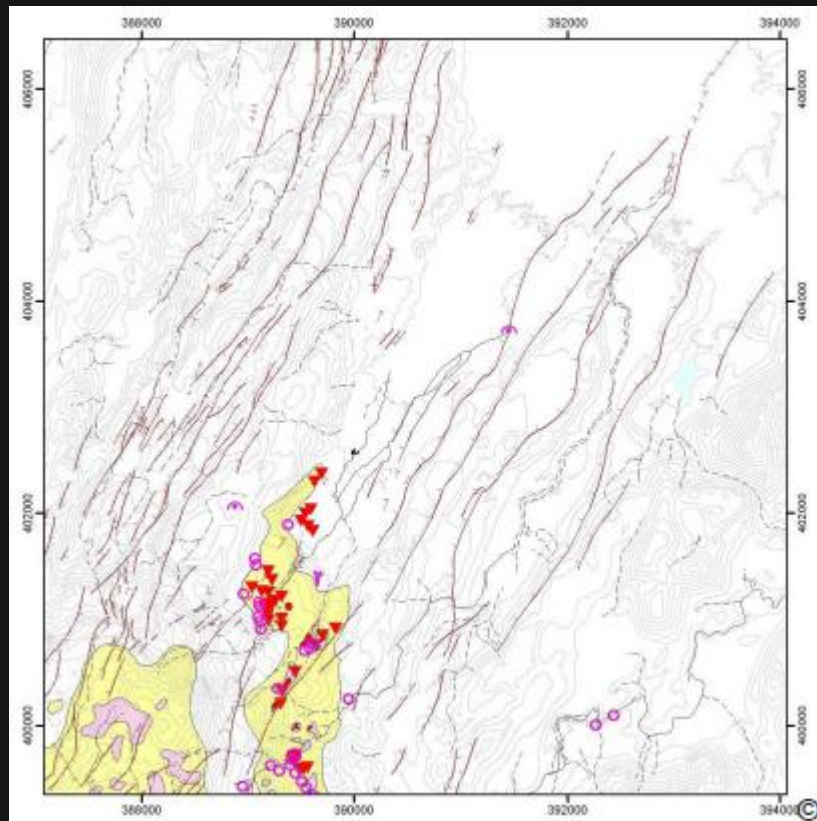


Does the surface activity relate to geological structures ?

Regional Exploration

Geological Exploration

Geological mapping (lithology)



Geothermal map: Tectonic fractures, surface manifestations and alteration

Local Exploration

Geophysical Exploration

Resistivity Methods

Time-domain Electromagnetic (TEM)

Magnetotelluric (MT)

Micro seismicity

Heat flow

Gravity

Magnetics (dykes, faults)

Seismic reflection (only in sedimentary rock)

Local Exploration Geophysical Exploration

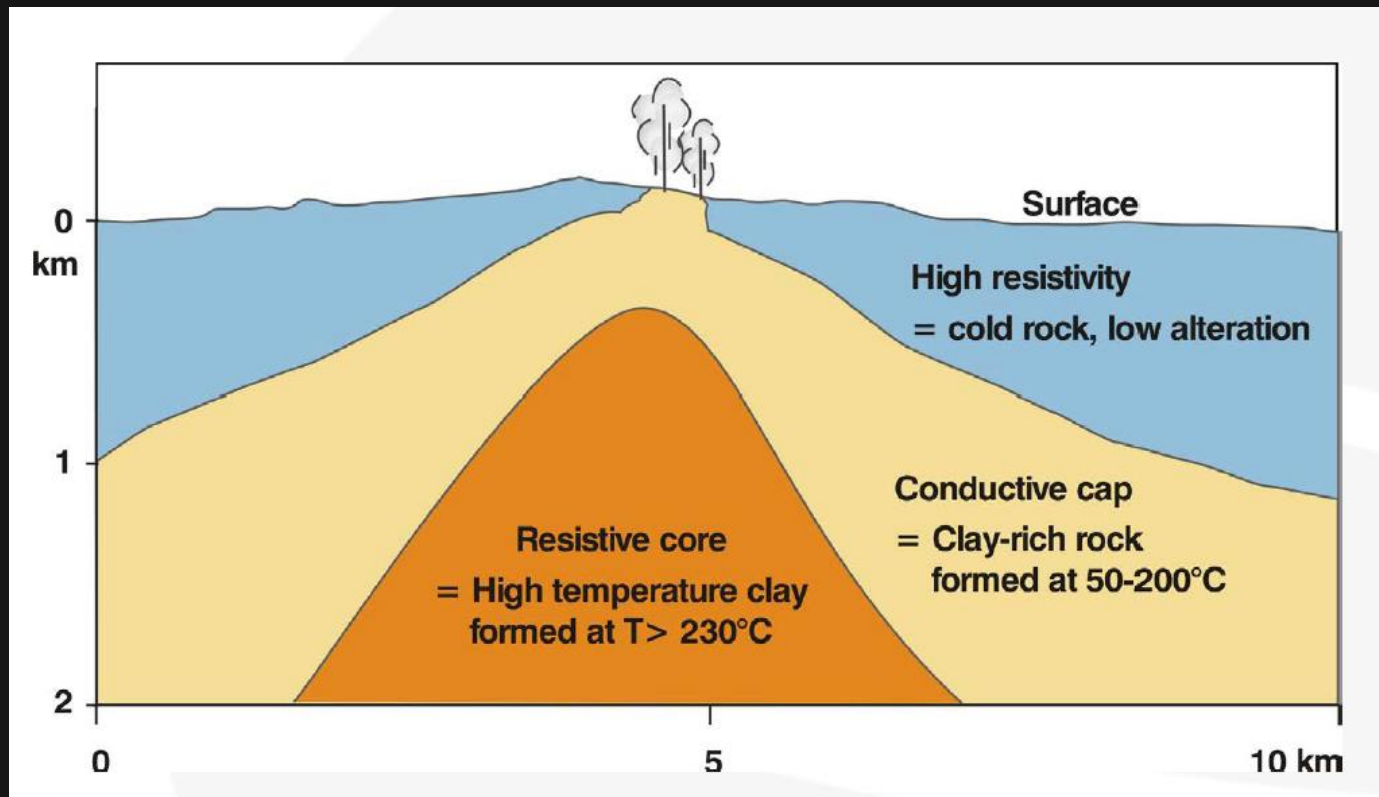
The important resistivity measurements

- The best available geophysical method.
- The only method that is sensitive to geothermal properties of rock.
- Two main types, TEM and MT, should be used together.



Local Exploration Geophysical Exploration

Resistivity structure of a typical simple high temperature field

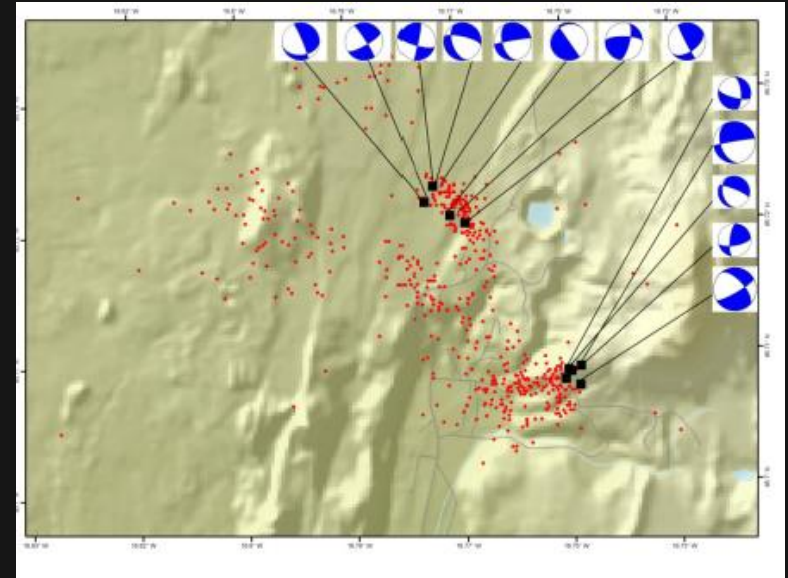


Local Exploration

Geophysical Exploration

Micro-seismicity

- Gives information about location of active faults.
- Helps to define drilling targets.
- Can show location of magma bodies.
- Can give information on the elastic crust.
- Can show fluid flow in fractures.



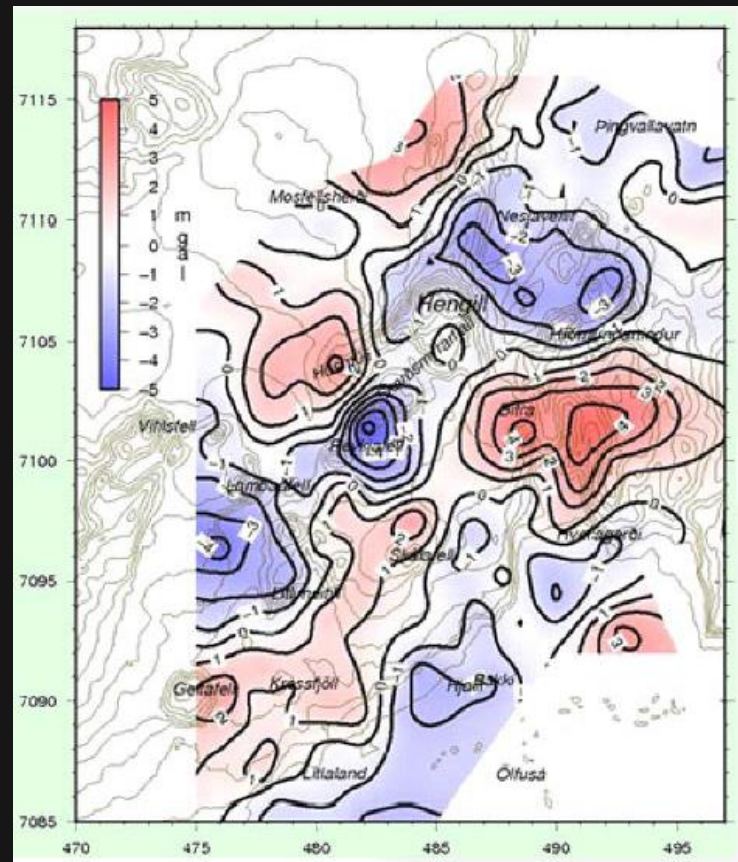
Distribution of microearthquakes and focal planes in Krafla geothermal field, Iceland

Local Exploration

Geophysical Exploration

Gravity and Magnetic

- Give structural information.
- Gravity anomalies show distribution of abnormal masses in the underground.
- Magnetic maps can reflect thermal alteration of rock.
- Should rather be used on local scale than regional.

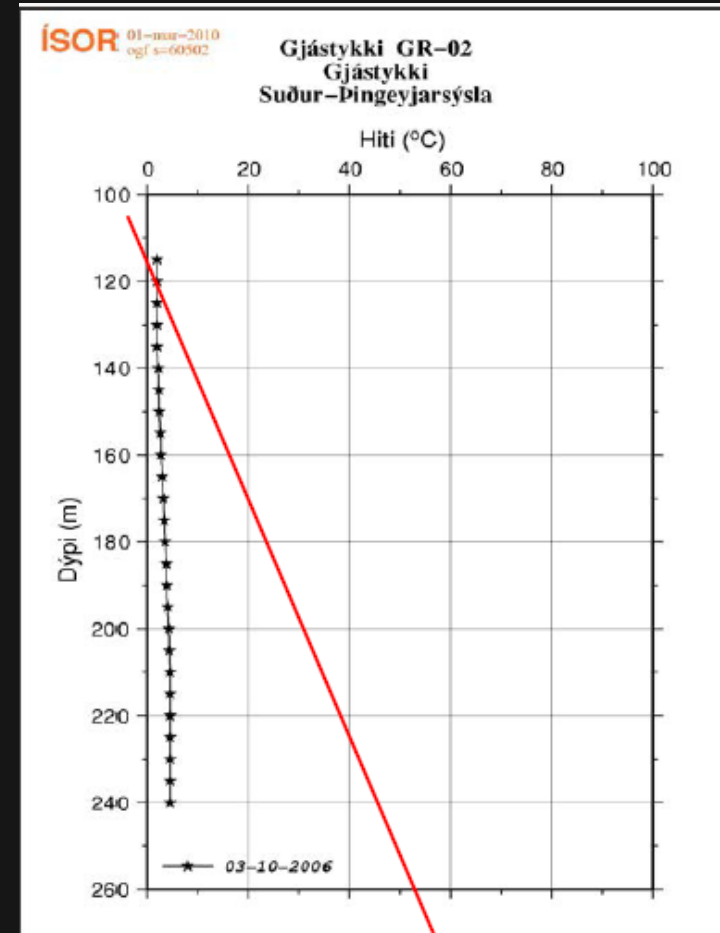


Hengill, Iceland. Gravity map

Local Exploration Geophysical Exploration

Heat Flow

- Measurement of temperature gradient in shallow boreholes.
- The heat flow must be conductive not convective



Temperature logs from a high temperature reflecting fluid flow in permeable rock. The red line show the expected conductive heat flow if 240°C is expected at 1 km depth

Result from the first four steps:

- Preliminary conceptual model.
- Selected site and design of exploration wells (shallow, intermediate or deep wells).

If all results are positive we go for the next step, the exploration drilling.

Exploration Drilling (sub-surface exploration)

- Testing the results of the resistivity exploration
- Confirming/updating the conceptual model
- Confirming the temperature estimation of surface sampling
- Confirming the chemical composition of the brine
- Confirming the existence of a geothermal resource
- Flow-testing the reservoir
- Update the reservoir model