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Interdepartmental Centre "Giorgio Levi Cases" for Energy Economics and Technology at University of Padova (Italy)

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

DIPARTIMENTO DI GEOSCIENZE

SUSTAINABLE GEOTHERMAL SOLUTION FOR THE DECARBONIZATION OF THE EUROPEAN ISLANDS: CASE OF VULCANO ISLAND IN ITALY

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Introduction

(https://originalmap.it/produit/mappa-italia/)

(https://www.infoeolie.com/mappa-delle-isole-eolie/)

About 22 km^2

About 1,000 permanent residents.

Approximately 15,000 during peak tourist season.

(Galderisi et al., 2013)

Main Efforts of Vulcano Island

ENERGY

MAIN POWER SOURCE

DIESEL GENERATOR SET

VULCANO

ELECTRICITY PROD. FOSSIL SOURCES

7.280 Mwhe/Anno

COMPANY: ENEL PRODUZIONE

DRINKING WATER

WATER SUPPLY MODE

VULCANO

DESALTER

TANKERS
FROM NAPOLI OR PALERMO

Biondo et al., 2020

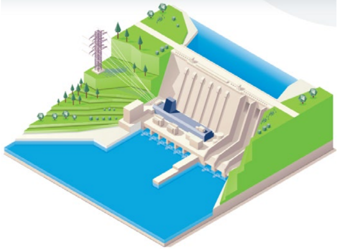
Renewable energy solutions

PHOTOVOLTAIC SYSTEM

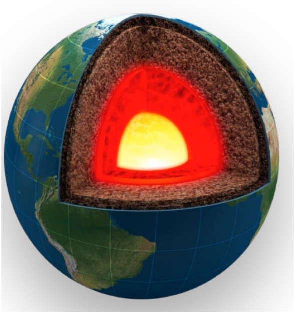
AEOLIAN SYSTEM

SOLAR THERMAL

HYDROPOWER



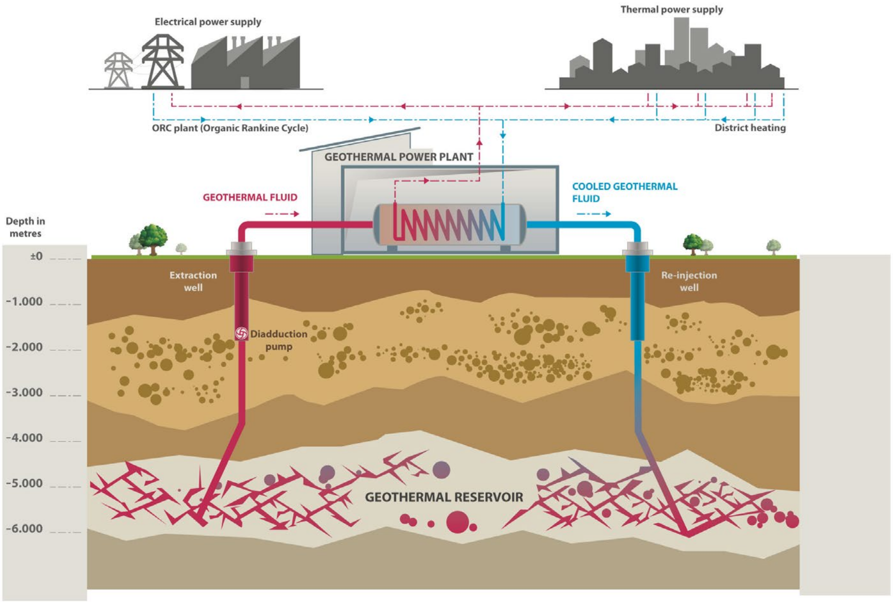
GEOTHERMAL ENERGY



Motivation

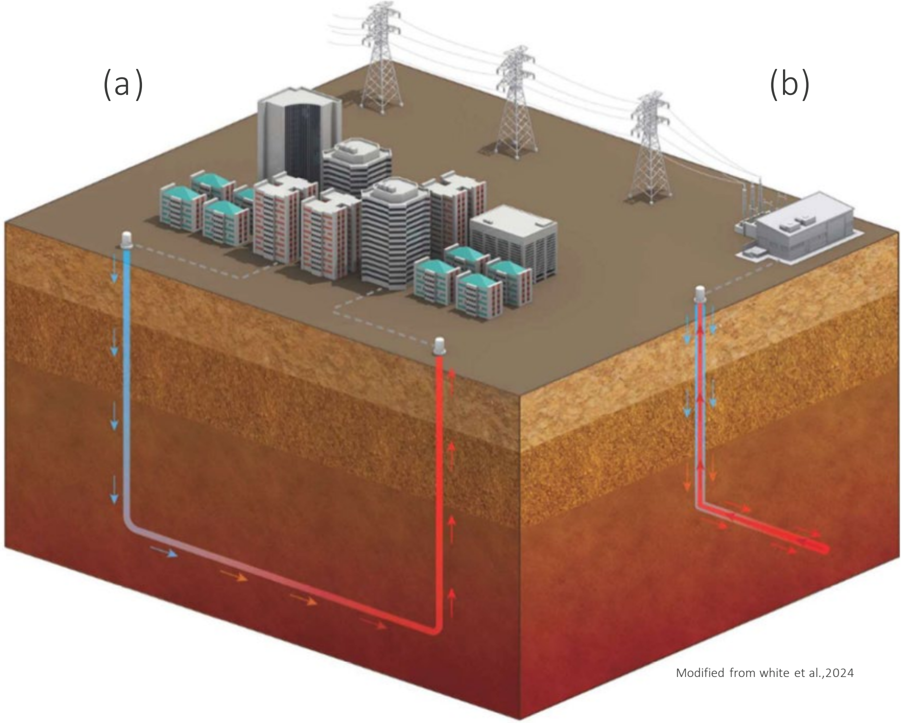
The purpose of this work aims to prove if, from the energetic point of view, Vulcano Island might be autonomous by using a “Single Flash and ORC Power Plant”. If it works, we can think, eventually, to implement this strategy to other islands involved in the Aeolian Arc as well.

GEOTHERMAL ENERGY EXPLOITATION



Modified from white et al.,2024

Common type of open-loop geothermal system



Modified from white et al.,2024

Common types of closed-loop geothermal systems: (a) U-shaped design configuration and (b) coaxial design configuration

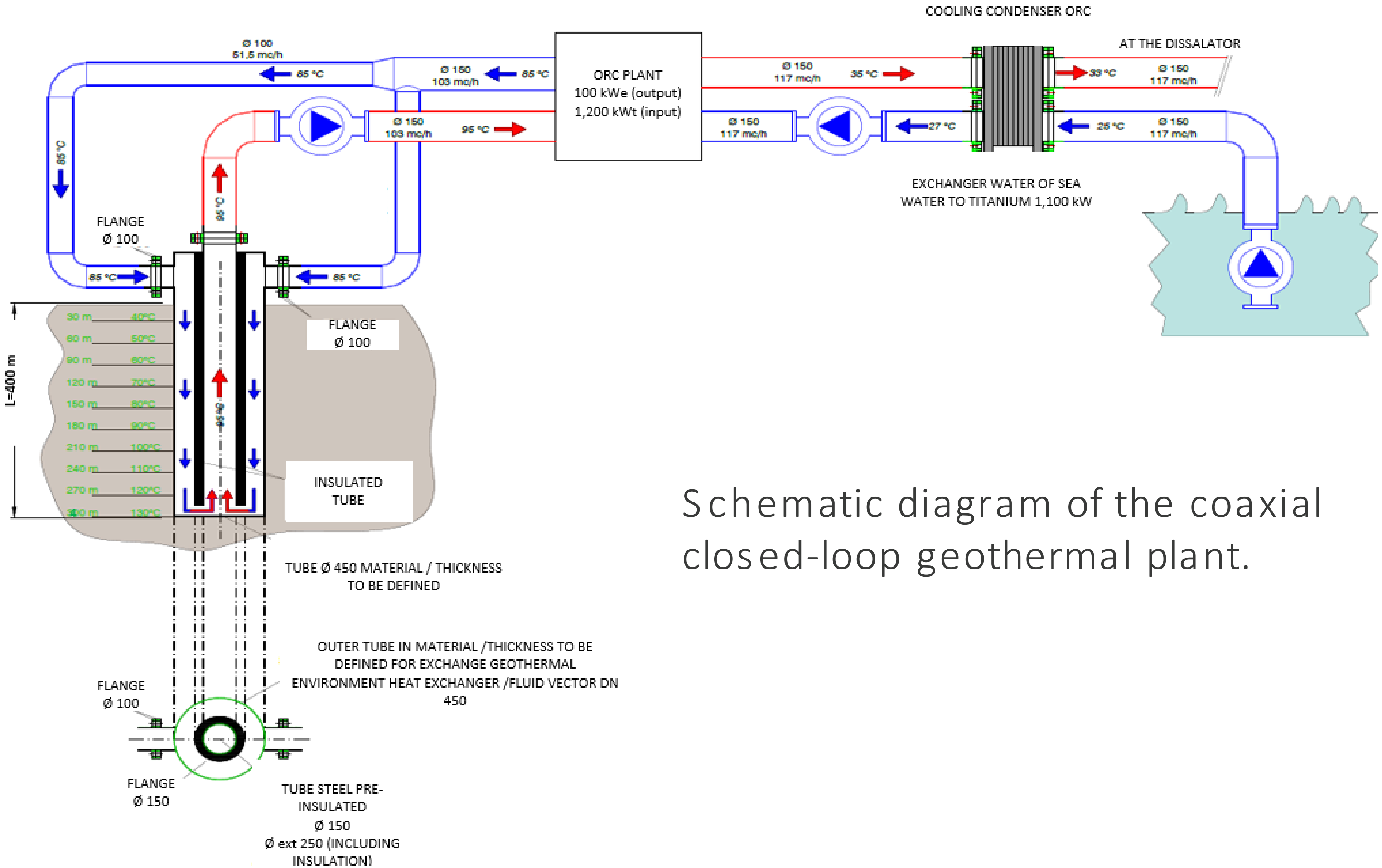
Geological Challenges

- High temperature,
- High pressures,
- Chemical aggressive fluids,
- Fluid managements problems

Corrosion

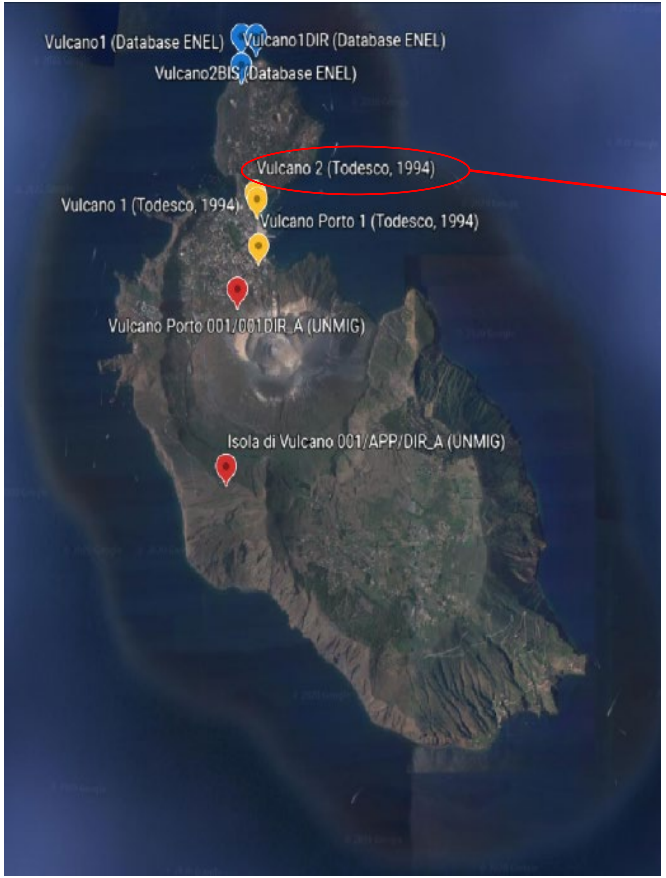
Scaling

Objectives: PILOT GEOTHERMAL PLANT

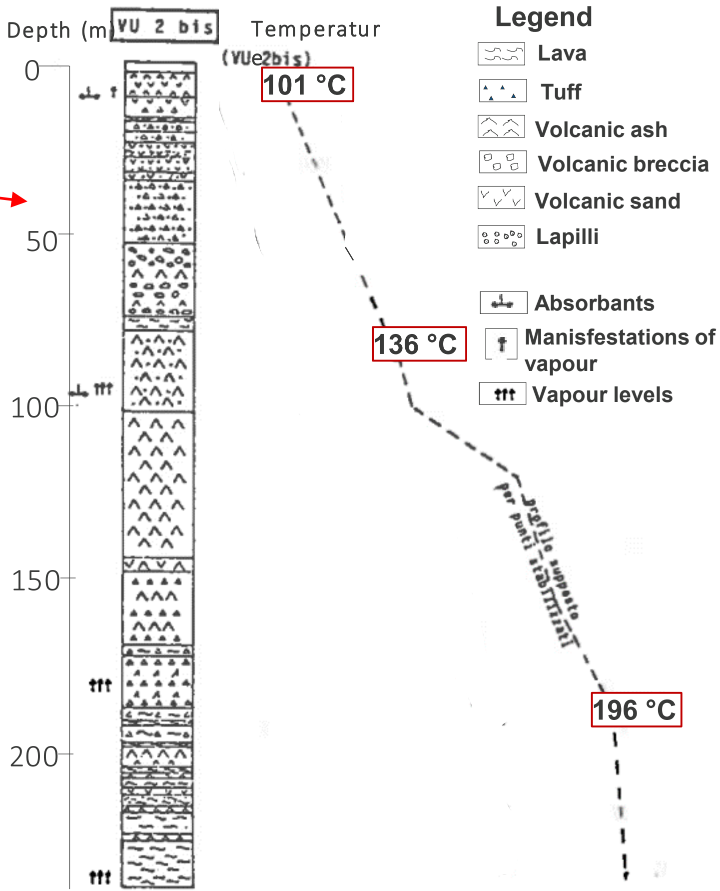


Schematic diagram of the coaxial closed-loop geothermal plant.

Geographical settings

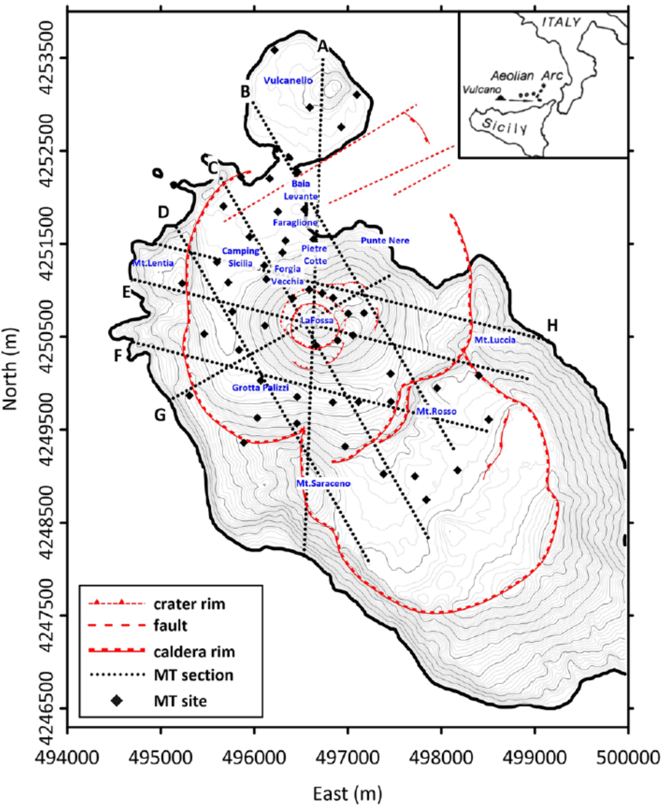


Geothermal wells in Vulcano Island (INGV)



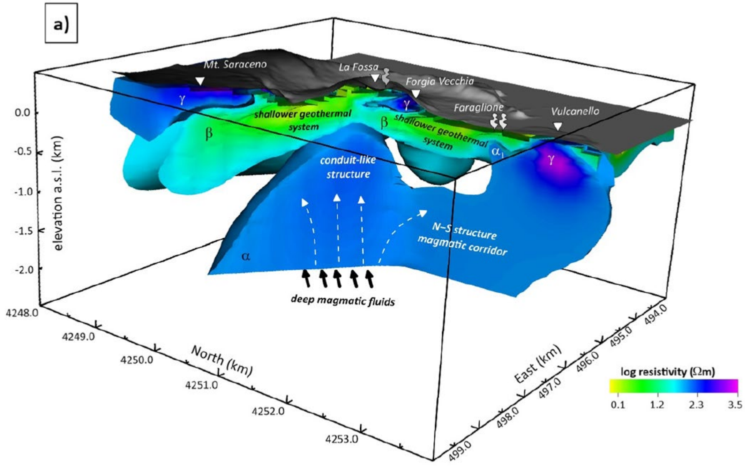
Modified by Sommaruga (1994)

Site knowledge - Magnetotelluric survey (by INGV)

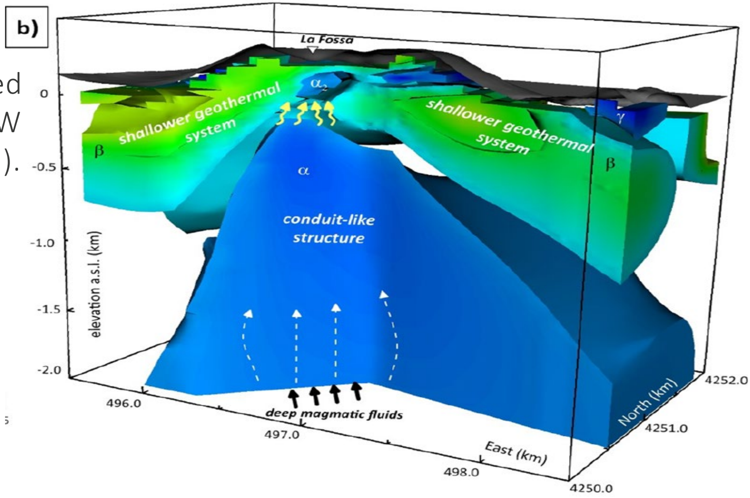


Locations of the 51 MT soundings carried out and the traces of the 2D resistivity sections extracted from the 3D model

a) shows a visualization (view from the east) showing the depth trend of the most resistive bodies aligned in the N–S direction.

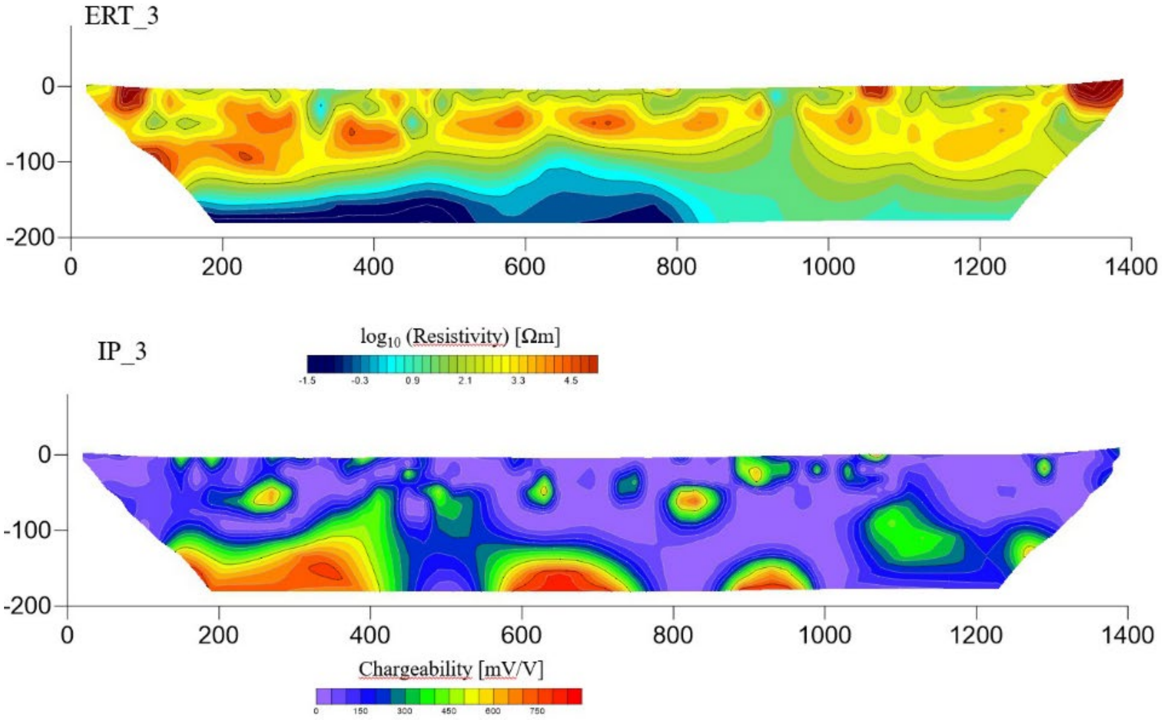


b) Shows the detected anomalies along an E–W alignment (view from the south).



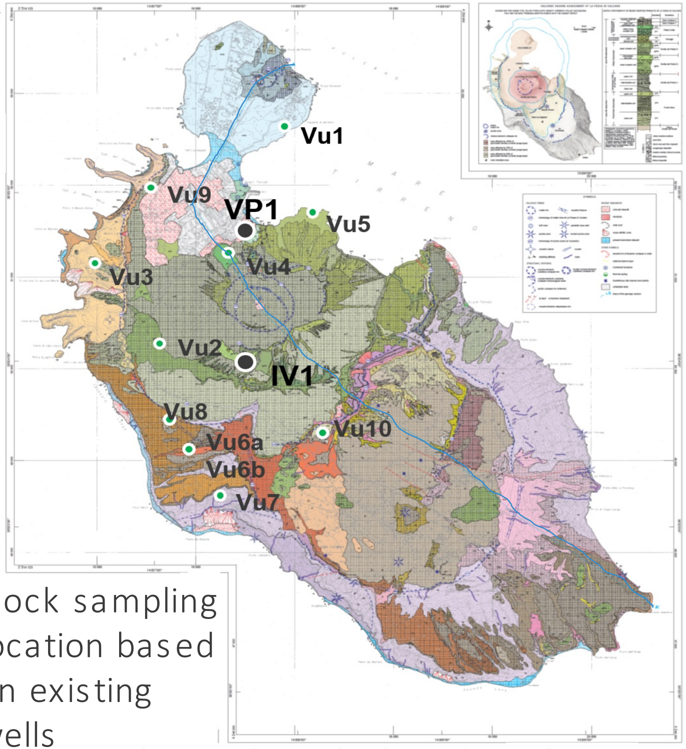
Field survey - ERT Survey (INGV-UNIPD-CNR)

Location of electrical surveys: the red dots indicate the positions of the electrodes used for the individual profiles (INGV)

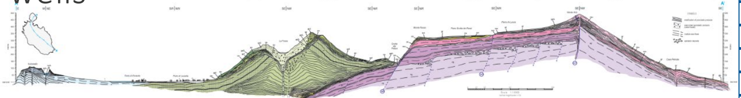


Electrical resistivity (ERT) and chargeability (IP) tomographs for profile 3 (INGV)

Field survey

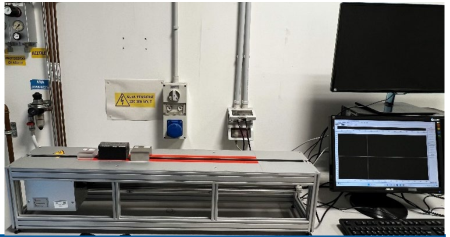


Rock sampling location based on existing wells



Modified from Arrighi et al.,2006

Thermal conductivity scanner



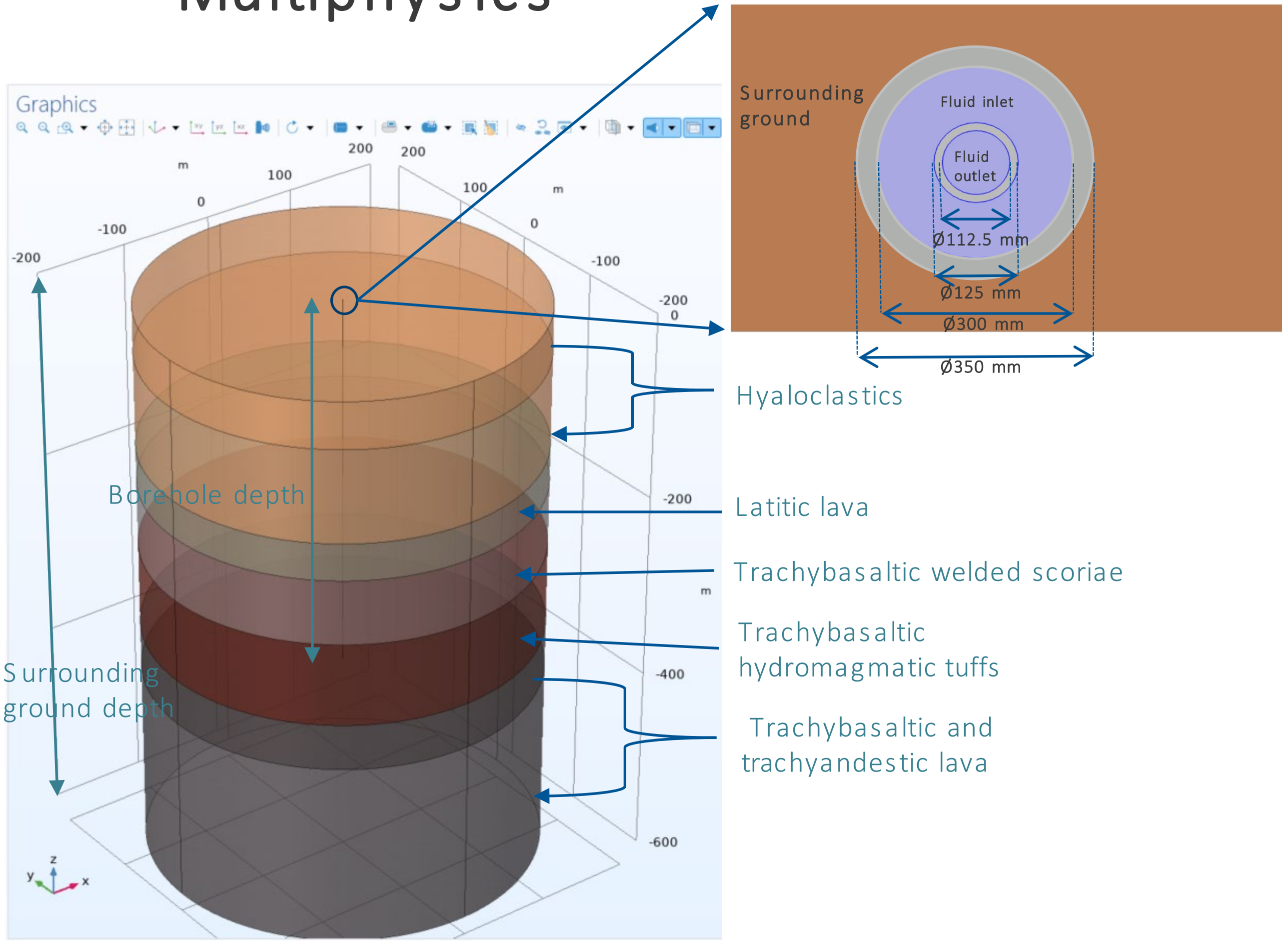
Laboratory results

Sample name and direction of measurement	Dry condition						Wet condition					
	Thermal conductivity (W/m*K)			Thermal diffusivity (m^2/s)			Thermal conductivity W/(m*K)			Thermal diffusivity (m^2/s)		
	TCmean	TCmin	TCmax	TDmean	TDmin	TDmax	TCmean	TCmin	TCmax	TDmean	TDmin	TDmax
Vu1 Massive lava with altered layers direction1	0.992	0.872	1.093	0.551	0.459	0.629	1.365	1.221	1.485	0.836	0.646	0.954
VU1 Massive lava with altered layers direction2	1.003	0.918	1.122	0.536	0.470	0.615	1.376	1.291	1.450	0.840	0.756	0.975
VU2 Pyroclastic rock direction1	0.342	0.316	0.364	0.223	0.193	0.242	1.105	0.983	1.249	0.241	0.157	0.368
VU2 Pyroclastic rock direction2	0.340	0.308	0.369	0.225	0.209	0.255	1.148	1.052	1.246	0.513	0.452	0.642
VU3 Massive lava rock direction1	1.473	1.400	1.509	0.726	0.664	0.780	1.453	1.405	1.491	0.910	0.876	0.941
VU3 Massive lava rock direction2	1.387	1.200	1.449	0.709	0.634	0.826	1.410	1.169	1.490	0.846	0.669	0.886
VU4 Ryolite direction1	1.023	0.856	1.094	0.599	0.564	0.632	1.193	1.003	1.389	0.675	0.566	0.912
VU4 Ryolite direction2	1.166	1.070	1.229	0.607	0.582	0.635	1.064	1.027	1.105	0.746	0.639	0.916
VU5 Trachite lava block direction1	0.441	0.412	0.492	0.318	0.279	0.377	0.956	0.841	1.054	0.531	0.456	0.600
VU5Trachite lava block direction2	0.429	0.394	0.455	0.280	0.245	0.321	0.974	0.863	1.046	0.528	0.471	0.600
VU6a Trachybasaltic hydromagmatic tuff direction1	0.768	0.670	0.862	0.490	0.411	0.592	0.865	0.749	0.980	0.669	0.601	0.778
VU6a Trachybasaltic hydromagmatic tuff direction2	0.697	0.642	0.771	0.518	0.442	0.611	0.865	0.780	1.017	0.635	0.583	0.684
VU6b Trachybasaltic welded scoriae direction1	1.356	1.411	1.454	0.685	0.601	0.775	1.431	1.309	1.535	0.755	0.636	0.866
VU6b Trachybasaltic welded scoriae direction2	1.242	1.100	1.386	0.655	0.588	0.750	1.433	1.268	1.563	0.916	0.844	0.988
VU7 Hyaloclastics direction1	0.366	0.319	0.406	0.241	0.201	0.292	1.468	1.124	1.420	0.430	0.345	0.576
VU7 Hyaloclastics direction2	0.376	0.345	0.411	0.242	0.212	0.281	1.181	1.077	1.345	0.444	0.311	0.728
VU8 Manzodioritites direction1	2.158	1.936	2.348	0.945	0.844	1.042	2.358	2.176	2.553	1.269	1.076	1.590
VU8 Manzodioritites direction1	2.075	1.776	2.341	0.919	0.733	1.001	2.412	2.229	2.598	0.975	0.893	1.061
VU9 Latites lava direction1	1.028	0.920	1.114	0.533	0.456	0.612	1.392	1.248	1.473	0.760	0.649	0.892
VU9 Latites lava direction2	1.077	0.967	1.148	0.562	0.478	0.636	1.350	1.238	1.295	0.846	0.675	0.931
VU10 Trachybasaltic and trachyandestic lava direction1	1.990	1.879	2.079	0.862	0.770	0.926	2.055	1.896	2.154	0.918	0.840	0.991
VU10 Trachybasaltic and trachyandestic lava direction2	2.027	1.891	2.135	0.886	0.820	0.985	2.069	1.931	2.152	0.985	0.929	1.038

Numerical simulations COMSOL Multiphysics

Model geometry and definition

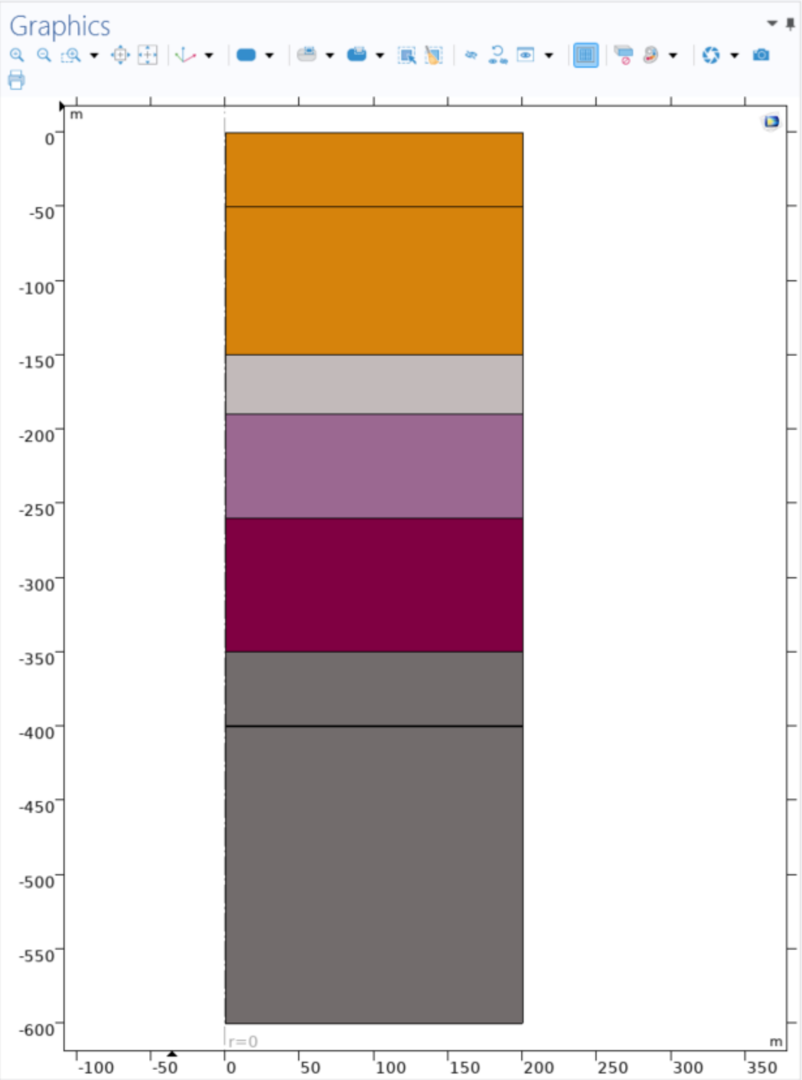
- Material parameters:
  - Fluid: water, in built properties
  - Inner Pipe: air inbuilt software material
  - Outer pipe: steel inbuilt software material properties
  - Grout: Concrete inbuilt software material properties
  - Ground: laboratory results properties



- Operational parameters :
  - Defined base on literature

Model geometry and definition

Axisymmetric representation

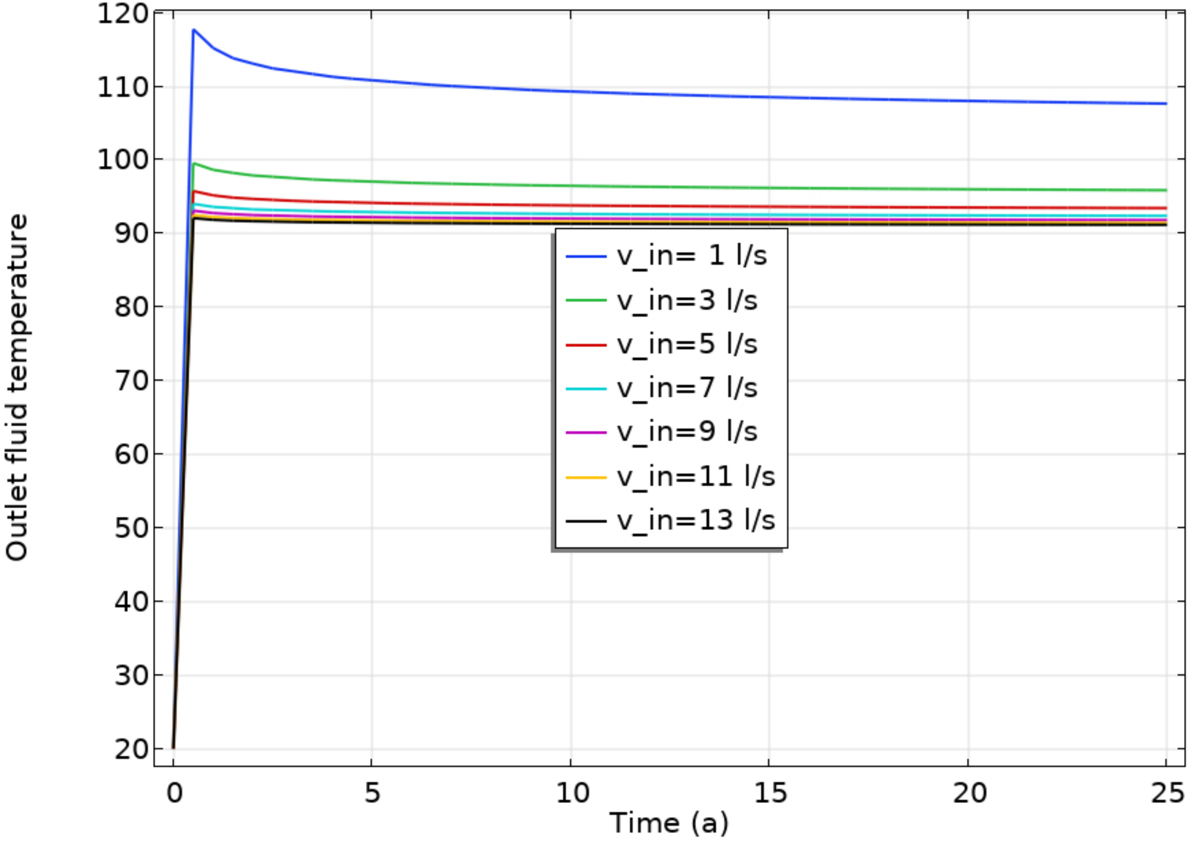


Results

Outlet fluid temperature

After 25 years of heat extraction for different fluid flow rates

Outlet temperature	
Vin=1 l/s	107°C
Vin=3 l/s	96°C
Vin=5 l/s	93°C
Vin=7 l/s	92°C
Vin=9 l/s	92°C
Vin=11 l/s	91°C
Vin=13 l/s	91°C

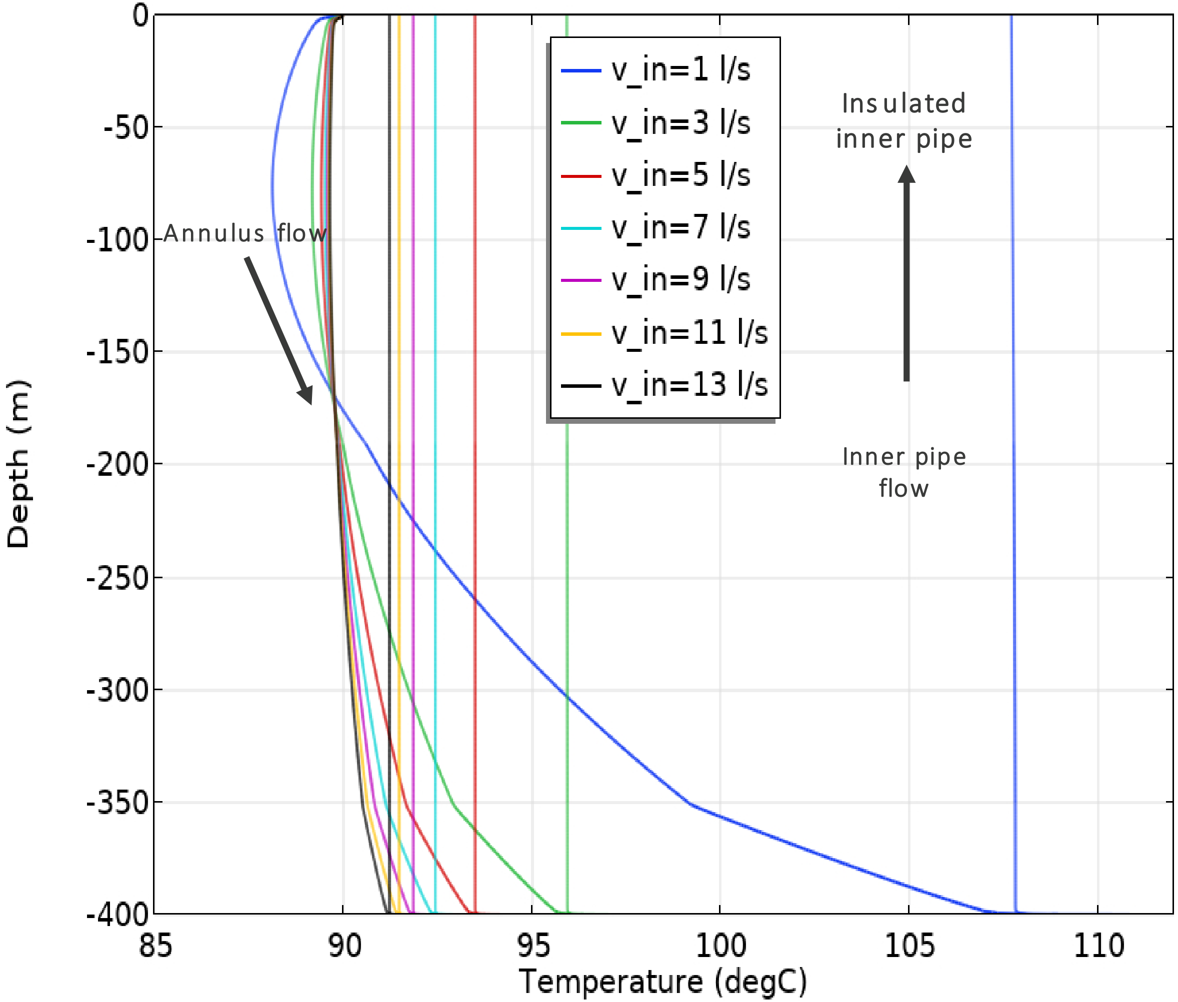


Evolution of outlet fluid temperature from the CBHE

Results

Thermal Performance

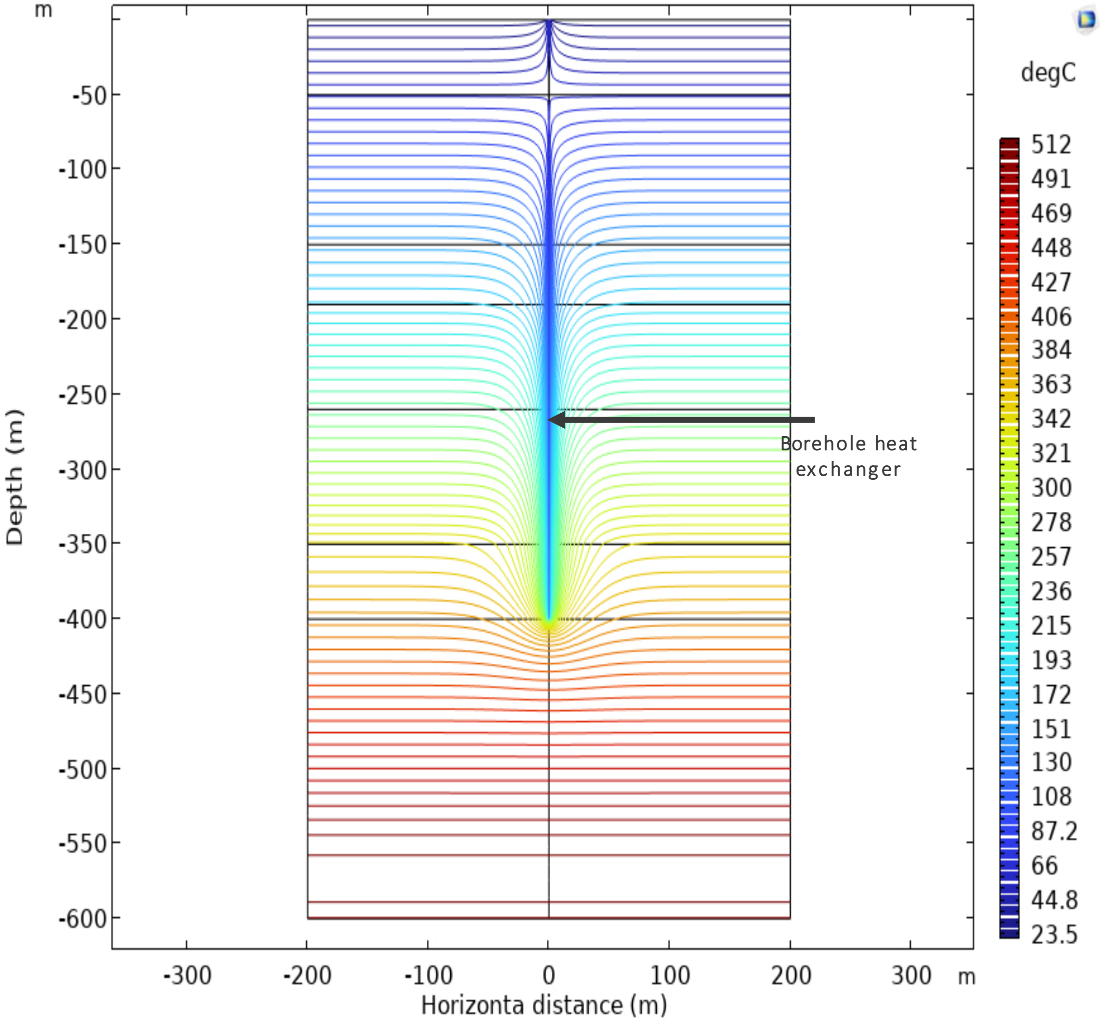
After 25 years of operation and under the conditions of various inlet flow



Results

Temperature contours distribution showing the cooling effect after 25 years of operation

2D-Plan representation

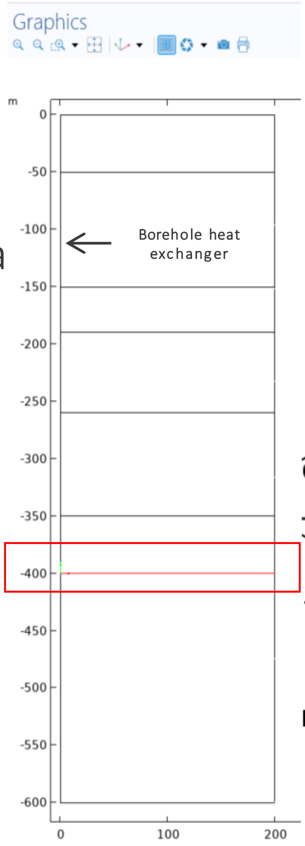


Results

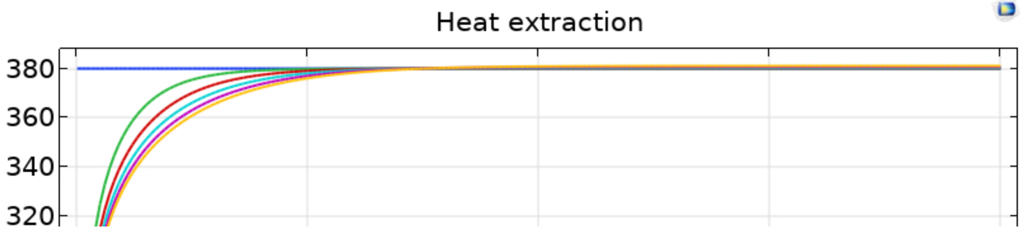
Ground temperature recovery

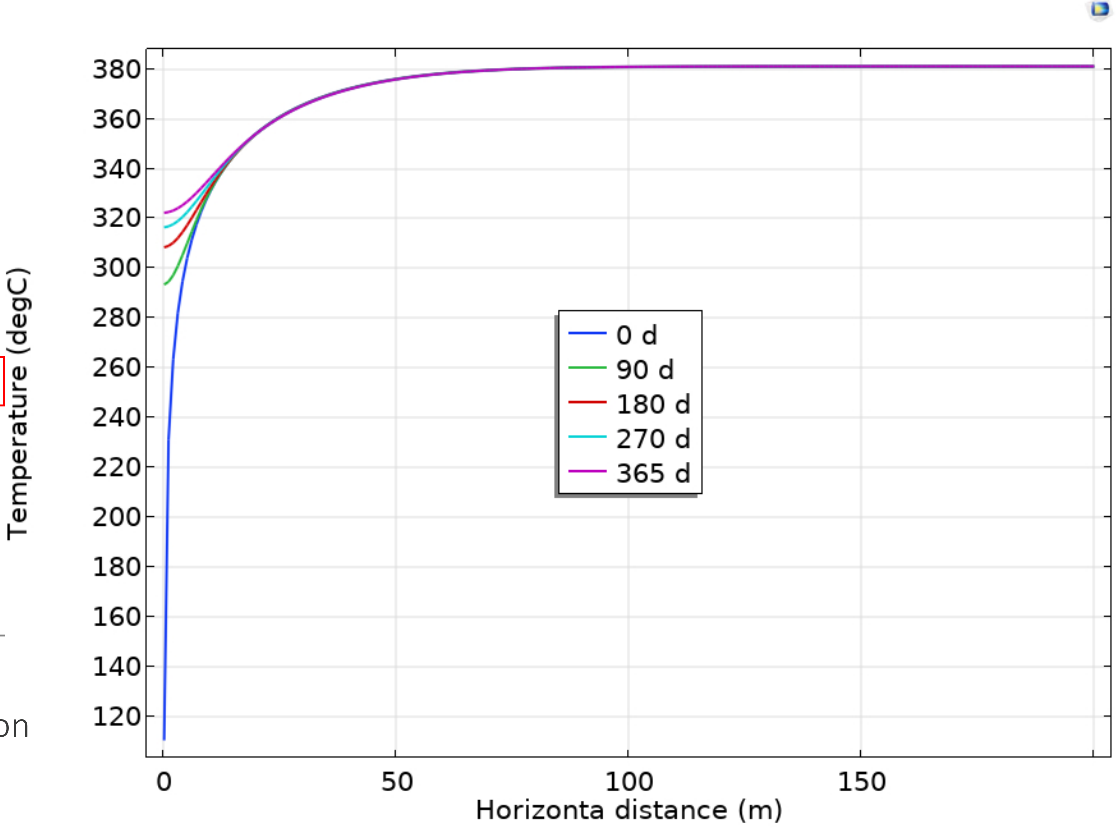
After 1 years of no hea extraction for different fluid flow rates.

Control point at the bottom of the borehole heat exchanger



Axisymmetric representation





Work in progress

❖ Enhanced heat exchange with the surrounding ground

- Testing of fin outer tube

- Testing corrosion-resistant coatings

- Investigate forced convection flow in fractured layers.

PTFE hollow tube

Fins tube

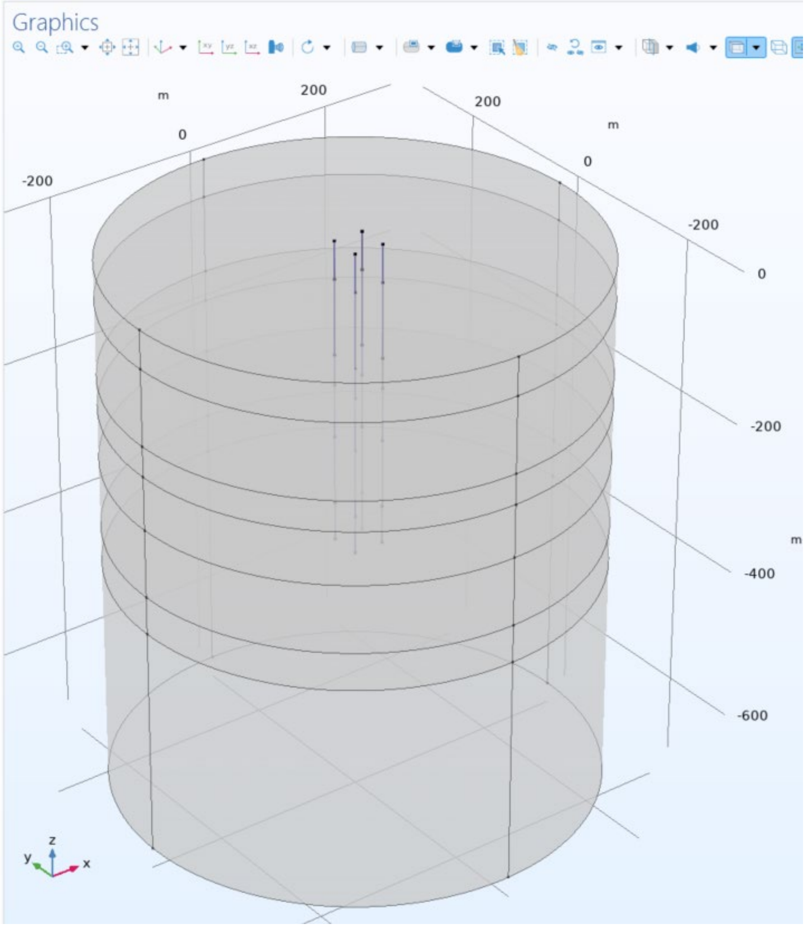
Helical tube

Work in progress

- Parametric sensitive analysis of the model, validation and calibration of the model.

- Optimisation of the geothermal plant operational mode.

- Application of the geophysical and technical approach to **Panarea Island Pilot Plant**



Conclusion

- Efficient exploitation geothermal energy from Vulcano Island to meet the island's energy demands.

- Optimal configurations and parameters for the geothermal system to maximize energy output.

- How do varying geological conditions on Vulcano Island impact the performance and sustainability of the geothermal system.

- What are the long-term impacts on the local environment due to continuous geothermal energy extraction.


Thank you for your keen attention
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