Low potential for deep geothermal heat under Gothenburg

Axel Sjöqvist[ab], Mikael Tillberg[ab] and Johan Hogmalm[b]

[a]Axray Scientific AB, Vårgårda, Sweden, axel@axray.science; [b]Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden

District heating powered by geothermal energy is an attractive idea. Contrary to a conventional heat plant, a geothermal heat plant requires no fuel logistics and no chimneys in the city. Thus, the viability for geothermal district heating in Gothenburg was investigated, initiated by Göteborg Energi. The municipal district heating system in Gothenburg operates at a temperature of 120 °C during winter, which we set as the minimum requirement for a geothermal reservoir temperature.

To investigate the potential for extraction of geothermal heat from the bedrock for district heating in Gothenburg, we conducted a desktop study of the local lithosphere during 2020. The bedrock is dominated by two suites of 1.6 and 1.56 Ga metamorphic granitoid gneisses as well as a 1.3 Ga suite of granites that includes the actinide-rich RA Granite ("radioactive granite").

The corrected heat flow density, measured in a 550-m-deep drillhole in the city, is 58.6 mW/m^2 (Balling 1995). The calculated heat conductivity, based on average modal mineralogy, spans a range of 2.47–3.62 W/mK. Assuming a mean conductivity of the upper crust between 2.7 and 3.3 W/mK results in a mean calculated geothermal gradient between 17.2 and 21.3 °C/km (Angelbratt 2020). Thus, we expected that the target temperature of 120 °C could be found at a depth of 5.3–6.6 km, similar to St1's Otaniemi geothermal pilot project in Finland, which at the time was still ongoing.

We chose the RA Granite as the focus of geothermal research since we expected it to have the highest geothermal gradient with its mean heat production of 7 µW/m^3. To model the geothermal gradient more reliably, we had to acquire new data on the temperature of the bedrock. Thus, we decided to drill to 1 km depth, to minimise the influence of recent climate on the temperatures measured at depth.

In 2021, the deepest drillhole in Västra Götaland, GE-1, was drilled vertically down into RA Granite to a depth of 1 km. After resting, the temperature was logged down to the bottom of hole, resulting in a mean geothermal gradient of 15 °C/km between 100–1000 m (Hogmalm et al. 2021). The temperature curve could alternatively be interpreted to first stabilise on 17 °C/km at 100 m depth before decreasing to 14.66 °C/km 500–1000 m (Sjöqvist & Tillberg 2023).

A second hole, GE-2, was drilled in 2022 to 986.45 m depth with a -70° dip (vertical depth ≈ 860 m), to study fracture zones and to make a second measurement of the geothermal gradient, above the RA Granite. The geothermal gradient is stable from 200 m depth and is on average 16.94 °C/km between 200–856.7 m. The rock quality was good in both drillholes. Fractures occur localised in narrow zones separated by wider intersections of mostly unfractured crystalline rocks (Sjöqvist & Tillberg 2023).

We conclude that the RA Granite is not voluminous enough to raise the heat flow density significantly above average conditions in the Nordic crust. According to our investigations, the Gothenburg area is not prospective for high geothermal gradients (Hogmalm et al. 2021, Sjöqvist & Tillberg 2023). Extrapolating the measured geothermal gradients, a geothermal reservoir with 120 °C would be found at around 6.6 km depth, which is deeper than the failed Otaniemi geothermal pilot project. Therefore, the idea of an economically viable enhanced geothermal system in Gothenburg has been suspended.

Research about geothermal district heating in Gothenburg has been discontinued since 2023.

References

Angelbratt, A., 2020: *Feasibility Study – Gothenburg affordable and fossil free Enhanced Geothermal System.*

Balling, N., 1995: Heat flow and thermal structure of the lithosphere across the Baltic Shield and northern Tornquist Zone. *Tectonophysics 244*, 13–50.

Hogmalm, J., Tillberg, M. & Angelbratt, A., 2021: *GE-1 drilling – Geological report.*

Sjöqvist, A. & Tillberg, M., 2023: *Geological and geothermal characterisation of drillhole GE-2 in Gothenburg.* (Energimyndigheten, Dnr 2020-018376)