Geothermal energy in the Faroe Islands, NE Atlantic Ocean

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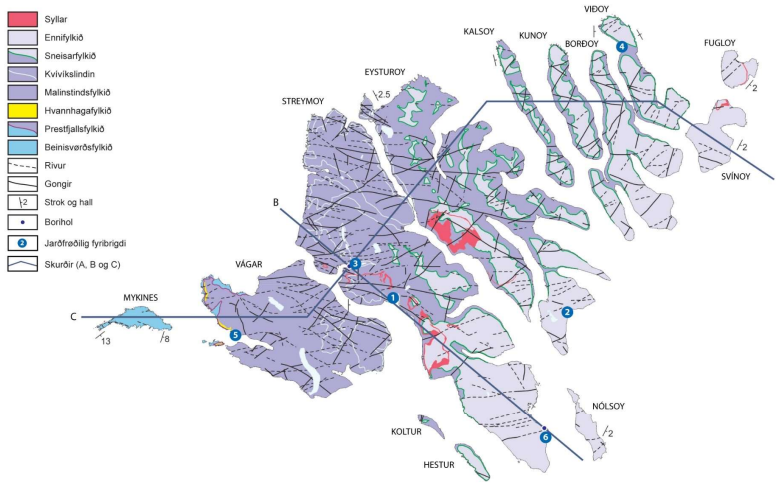
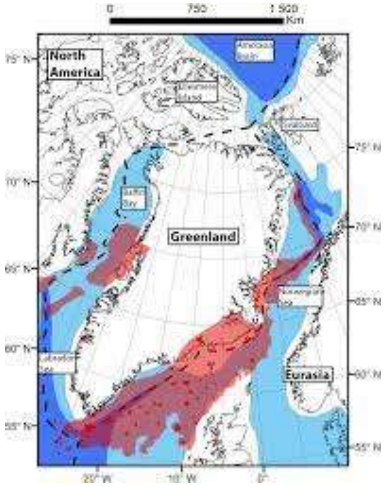
The Faroe Islands
(the sheep islands)

- A small archipelago situated in the NE Atlantic Ocean on the passive volcanic margin of the Mid-Atlantic Ridge between Iceland and Norway
- Consisting of 18 small islands with a total surface area of 1400 km2 and a population of just below 55.000 people – mostly natives but the rest is a mixture of 80 different nationalities (and 70.000 sheep)
- No point on the islands is more than 5km (3 miles) away from the sea
- A self-governing nation, not part of the EU, with a high degree of autonomy belonging to the Kingdom of Denmark (together with Greenland)
- The country has exclusive rights to legislate and govern independently in a wide range of areas, including:
    - The conservation and management of living marine resources within the 200-mile fisheries zone
    - Protection of the environment and sub-surface resources
    - Trade, fiscal and industrial relations
    - Taxation and customs
    - Energy and transport
    - Communications and social security
    - Culture, education and research

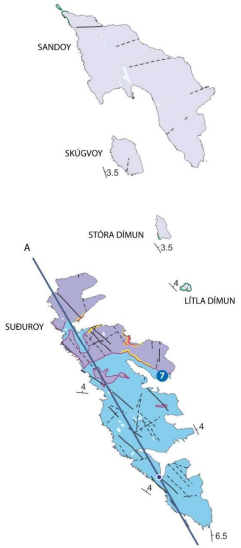
Geological context

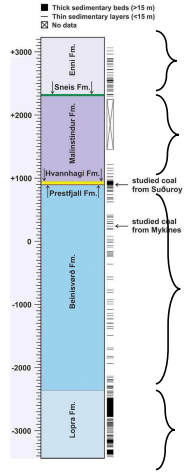
- The islands are part of the > 6,5 km thick volcanic succession called the Faroe Islands Basalt Group (FIBG)
- Which is part of the much larger North Atlantic Igneous Province (NAIP) - one of the largest igneous provinces (LIP's) in the world
- It stretches from Baffin Bay in Canada, across Greenland, Iceland, Faroe Islands, all the way to the west coast of Norway and down to Scotland and Ireland in the south
- The province is a result of volcanism connected to continental breakup and seafloor spreading between Greenland and Eurasia in early Paleocene to Eocene times
- This continues on the Mid-Atlantic Ridge and onshore Iceland still today





www.largeigneousprovinces.org





www.jf.fo

Upper basalt series

Middle basalt series

Lower basalt series

Lopra Fm. basalt series (only found in drillings)

A leading nation in sustainable electricity

- The Faroe Islands is one of the world's leading nations in producing sustainable electricity with over 50% of the nation's electricity deriving from renewable energy sources
- The aim is that the nation's electricity will be sourced solely from renewable energy by 2030
- Electricity today is produced by oil, hydropower, tidal and wind farms, mainly by SEV, which is owned by all the municipalities of the Faroe Islands
- The Faroe Islands are not connected by power lines with continental Europe, and therefore the country cannot import or export electricity

Geothermal energy

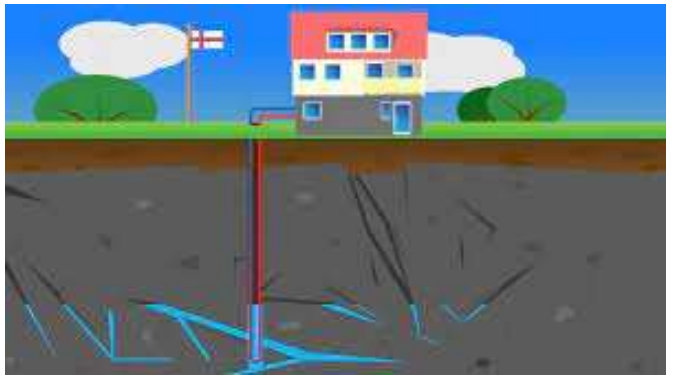
- Due to the isolated placement of the islands, it is difficult to get access to renewable energy from neighbouring countries
- Until 2008 the only method used for heating of private houses and larger buildings in the Faroe Islands was with oil-boilers
- Since then more than 1000 shallow geothermal (< 400m) wells have been drilled on the islands
- The wells are mostly used for heating of private houses, schools and other public buildings
- Regulations are not very strict – you have to apply for a drilling-permit, use one of the authorized drilling companies and the well has to be at least 20 meters from the neighbouring well
- Other than that not many restrictions are in place and only a small amount of research exists on the subject yet

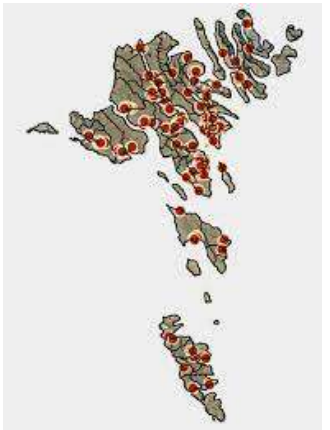
(Source: Umhvørvisstovan/www.us.fo)

Ground source heat pump (GSHP) wells

- Mostly low temperature water found in the wells (8-15^{o}C)
- Although a few wells and natural springs have anomalously high temperatures
- All wells are drilled vertically, ranging from about 140-300 metres in depth
- The wells function as a closed-loop systems, continously circulating a heat-transfer solution through plastic pipes submerged in the borehole
- Because the water-temperatures are relativily low, all wells are ”ground-source-heat-pump (GSHP) wells” used in combination with a heat-pump on the surface
- And therefore there is no connection or disturbance of the clean groundwater in the subsurface – and no clogging of wells
- There are future plans for deeper wells and therefore also the possibility to connect more than one building to one GSHP well

(Source: Orkuskiftið/www.os.fo)





What is gained by GSHP wells?

- The many installed GSHP systems decrease the use of oil in the Faroe Islands by a significant amount
- But instead they use around 9 GWh of electricity per year
- At the moment that is a problem because a large part of the electricity production on the islands still comes from oil – which leads to an extra import of heavy-oil at around 600 tonnes per year
- The already installed windmill park plus the 3 windmill parks that are being installed in 2022 and 2023 will change that number significantly
- Every private household with an installed GSHP system decreases the import of oil by 2-3 tonnes per year

(Source: SEV/www.sev.fo)

Precipitation and groundwater resources

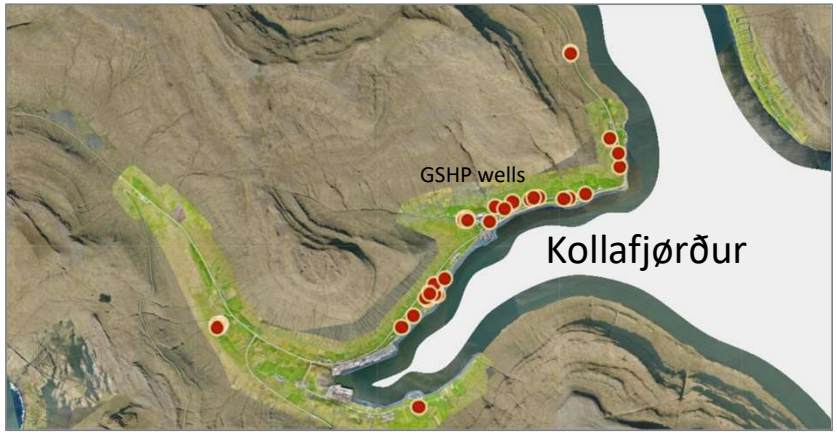
- Annual precipitation on the islands is high: Ranging from 823mm to 3261mm with an average of 1757mm for the entire country
- Mean yearly surface air temperature of 6,5°C and a monthly max mean of 12,4°C in Aug and min mean of 1,5°C in Jan (measured in a 30-year period from 1961-1990, Cappalan & Laursen 1998)
- Data from the many GSHP wells show evidence of a highly active and relatively young groundwater system (Eidesgaard et al. 2020)
- GW is most likely flowing through a complex interconnected network of large near-vertical fractures, smaller scale cooling fractures and weathered lava-bedding surfaces (Ólavsdóttir et al. 2021; Ellefsen et al. 2021; Eidesgaard et al 2019)

Varying geothermal gradient

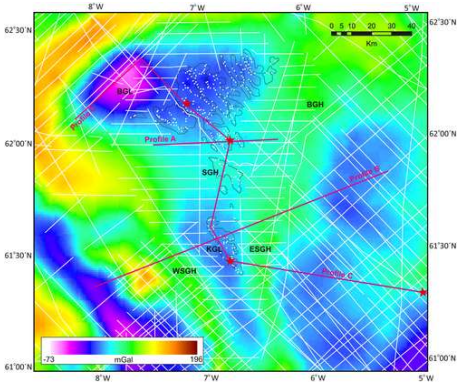
- Temp and EC measurements from GSHP wells give interesting insights into varying geothermal gradients
- Temperatures of groundwater measured in the wells range from as low as 8-10^{o}C in some places (mostly in the area of Tórshavn) to as high as 27-29^{o}C in the village of Kollafjørður, only about 12 km from Tórshavn
- Geothermal gradients vary from below 25^{o}C/km to 45^{o}C/km (using mean surface air temp and bottomhole temp)

The geothermal system of Kollafjørður – an anomaly?

- A study done by Eidesgaard et al. (2019), examining several wells drilled in the geothermal system of Kollafjørður, indicates that the high-temperature groundwater can most likely be explained by topography-driven vertical convection as an effect of the high terrain surrounding the well area
- This is confirmed by more recent studies by Ólavsdóttir et al. (2021) and Eidesgaard et al. (2020), concluding that the most likely explanation for the high-temperature geothermal waters in some areas of the Faroe Islands is caused by sub-vertical permeable pathways of open fracture zones that allow for a deep recharge and recycling of meteoric waters, of up to 1000 meters below surface
- Ólavsdóttir et al. (2021) also propose the idea (using gravity anomaly maps) that an uplifted horst-block buried deep below the Faroe Islands/or the Faroe plateau could be the cause of the elevated temperatures of the deep-circulating groundwater



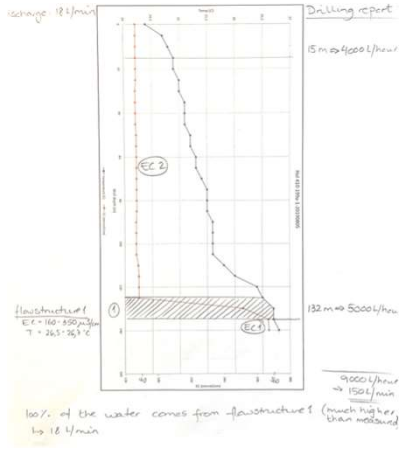
The village of Kollafjørður, Faroe Islands, with GSHP wells shown (Eidesgarrd et al. 2019)

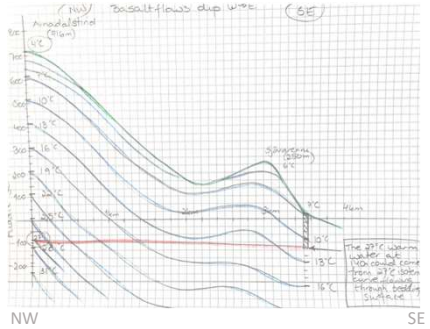


Gravity anomoly map of Faroe Islands and surrounding offshore area (Ólavsdóttir et al. 2021)

Are there other explanations for the variations in geothermal gradient?

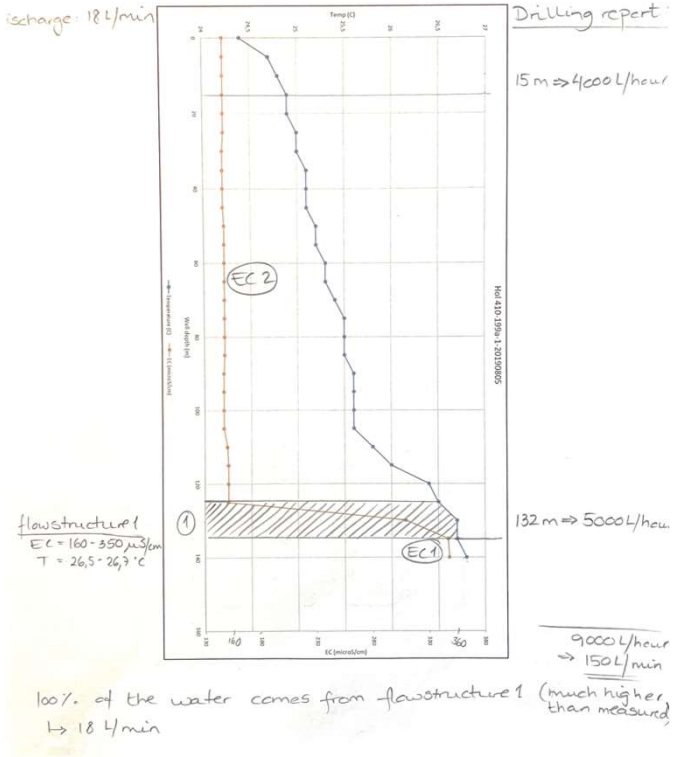
- Perhaps some of the anomolously high water temperatures around the Faroe Islands can be explained by a more simple reason
- The fresh GW is also found in sub-sea tunnels connecting the islands – indicating that the Faroe plateau and the outcropping islands are one single connected GW reservoir
- The GW is believed to flow in a network of fractures and weathered lava bedding surfaces in the lava-succession
- Can topography around the wells explain for the variations in geothermal gradient in a simpler way than the previous mentioned papers suggest?
- Some of this work is being explored in more detail in my ongoing industrial-PhD

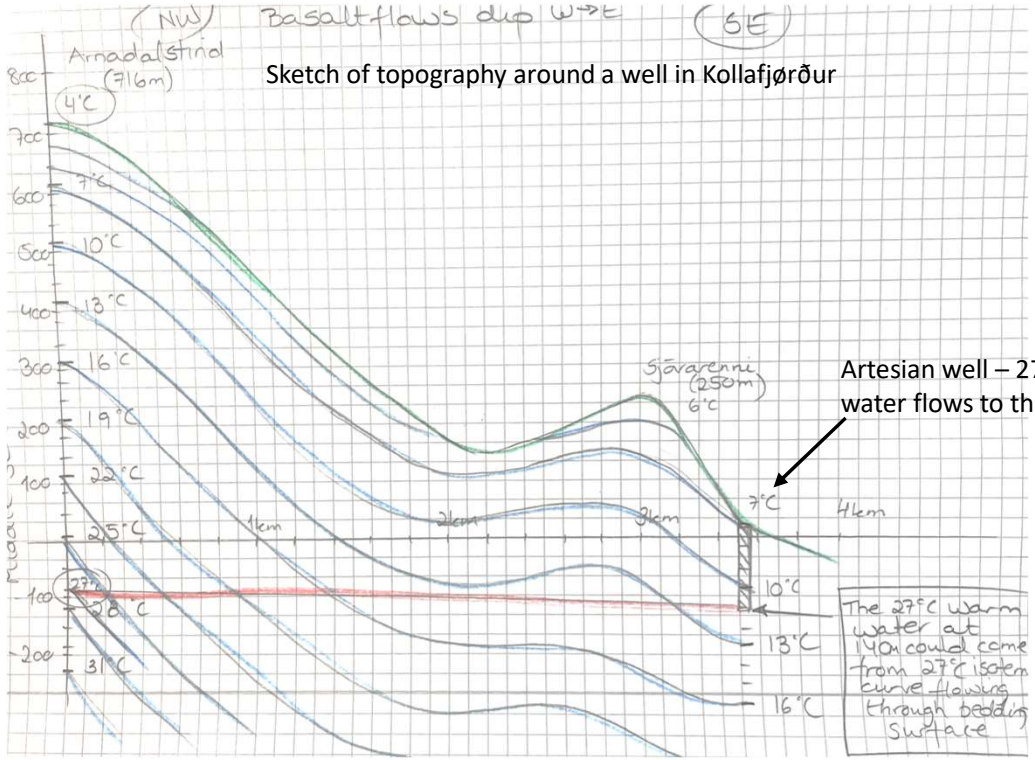




Are there other explanations for the variations in geothermal gradient?

Temp and EC measured in well





Sketch of topography around a well in Kollafjørður

Artesian well – 27°C warm water flows to the surface

Thank you for listening!

If you have questions feel free to email me:
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