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Greenland Country Update

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ABSTRACT

The research for geothermal energy in Greenland is still at an early stage. Currently, geothermal water is used in natural spas in one or two places for bathing, balneology and tourism with little economic return. Surface manifestations of geothermal activity exist in several places. They are mainly found in the basaltic areas at Scoresbysund and Disko. A single geothermal spring in Uunartoc South Greenland is used for bathing. The Greenland Glacier covers over 80% of the country and the majority of all hot springs and geothermal sites are believed to be ice covered. The highest spring temperatures are found on the east coast, north and south of Scoresbysund. The warmest spring (61,5°C) there is near Cap Tobin, near the small town Ittorqqortoormiit. Geothermometers indicate around 90°C deeper in the system. The temperature of one of the warmest springs in Disko, near the town Qeqertarsuaq, is around 18°C. There, geothermometers indicate 50-70°C deeper down. Recent investigations of the geothermal gradient in Greenland have been reported. A compilation of heat flow recordings indicate the existence of geothermal anomalies beneath the ice sheet that could explain high glacial ice flow areas in some places, especially in north east Greenland.

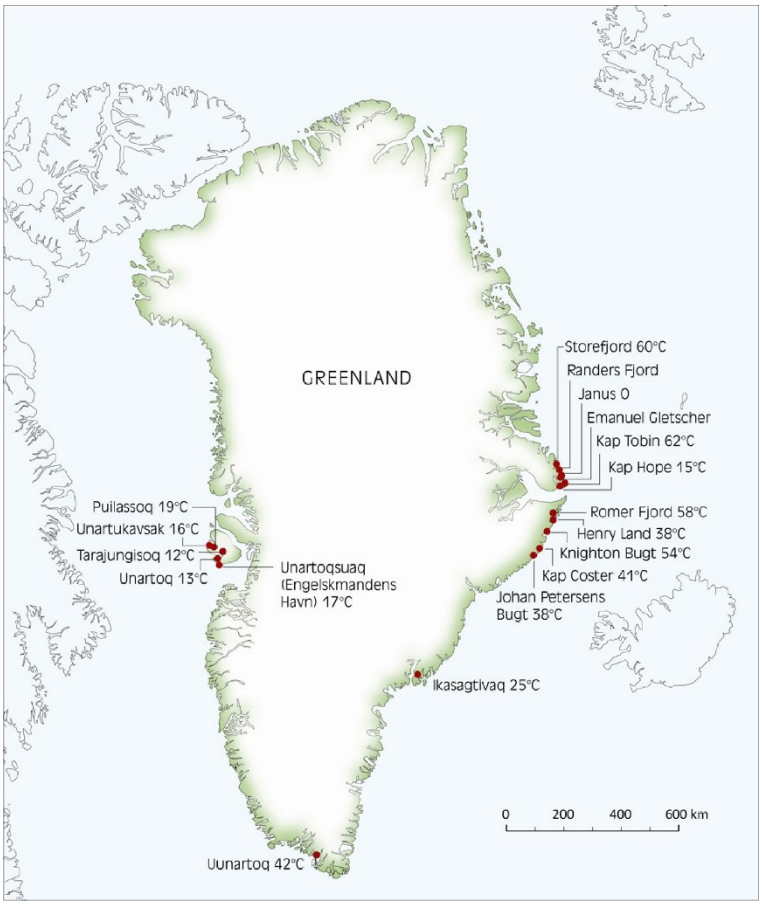

Figure 1: Geothermal sites in (> 10°C) Greenland. See also Table 1.

1. HEAT FLOW AND GEOTHERMAL GRADIENT

Direct measurements of heat flow in Greenland are very rare. These measurements, however, along with model estimates suggest a considerable regional difference with values ranging from 20 to 40 mW m^{-2} in the south to 140 mW m^{-2} in the central northern Greenland (Rysgaard et al. 2018). Locally, high melt rates indicate heat flow 15 to 30 times higher than continental background values. This could strongly influence basal hydrology and many geological processes (Petrunin et al. 2013).



Figure 2: The geothermal spa in Uunartoq Island S-Greenland. See figure 1 for location. There are three naturally heated springs which run together to a small stone-dammed pool 37-38°C. Here people have gone bathing for 1000 years. (From Wikipedia. Photo. Svíčková).

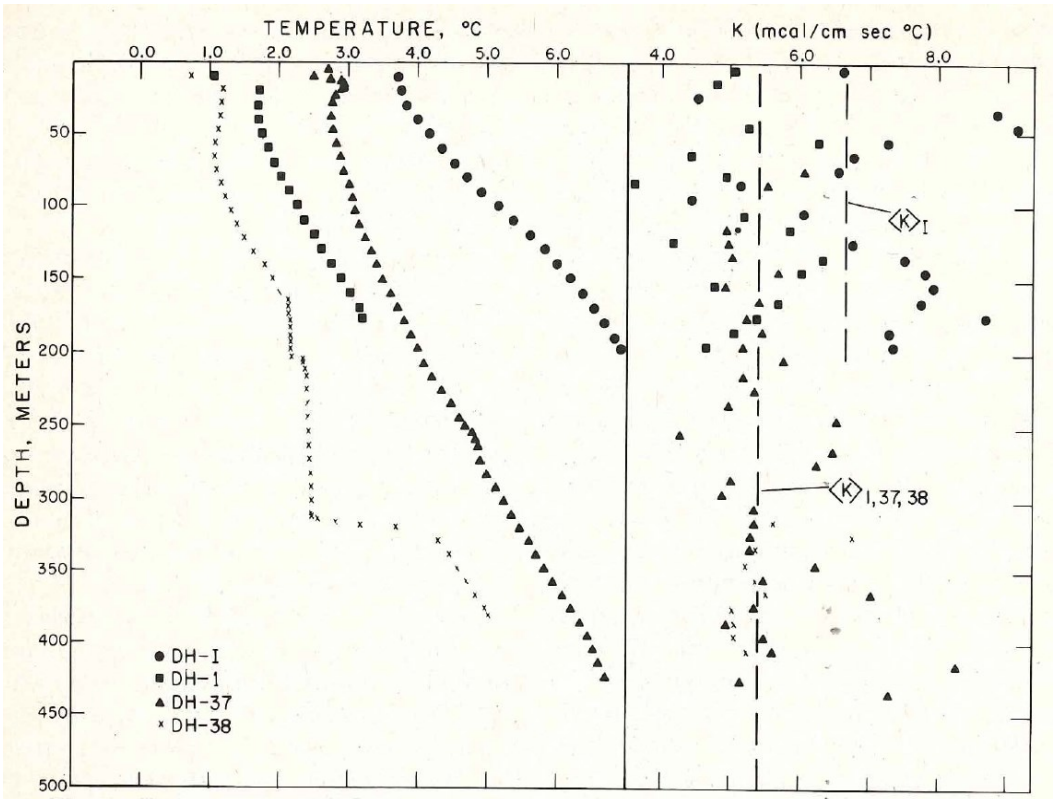

Figure 3: Temperature and thermal conductivity versus depth in boreholes in SW-Greenland (Sass et al. 1972).

Table 1: Hot springs in Greenland. (Based on Halliday, Kiim-Nielsen & Smart 1974 and Hjartarson & Ármannsson 2005).

Name	*Place*	*N*	*W*	*°C max*	*Q L/min*	*Aths*
Nörrefjord				57		
Storefjord	South side	70°04'	21°54'	60		
Kap Thermopilæ	(Store Fjord?)	70°04,5'	21°44,5'	54,2	100	Several vents
Randers fjord		70°58'	21°42'			
Janus Island, N hot spring		70°52,3'	21°41'			
Janus Island, S hot spring		70°51,5'	21°40'			
Emanuel Glacier		70°51,6'	21°44,5'			
Unarteq	Kap Tobin	70°24,4	21°58'	61,8	40	
Unarterajik	Kap Tobin	70°25,2	21°54'	30-33		
Moskilden	Kap Hope	70°27,6	22°21,0	2		
Mosekilden	Kap Hope	70°28'	22°22'	15		400 m north of Kap Hope
Römer Fjord, north	Blosseville coast	69°44	23°38'	30		
Römer Fjord, south	Blosseville coast	69°43'	23°42'	58		Tidal springs
Henry Land	Blosseville coast	69°33'	23°41'	38		
Knighton Bugt	Blosseville coast	69°22'	24°43'	54		20 springs on a 250 m line
Kap Koster	Blosseville coast	68°59'	25°30'	41		
Johan Pedersen Bugt	Blosseville coast	68°48'	26°15'	38		
Unartorsuaq	Disco Island	69°16'	53°34'	16,2	120-180	Gneiss
Unartoq	Disco Island	69°26'	53°53.5'	11,1	90-120	Basalt
Angujartutit	Disco Island			(3-12)		Basalt
Tarajungitsoq	Disco Island	69°33'	53°36'	11,5	120	Gneiss
Unartuarak	Disco Island			14,5		Basalt
Kuanit	Disco Island			(3-12)		Basalt
Qeqertarssuk	Disco Island			(3-12)		Basalt
Puilassoq	Disco Island	69°40'	54°23'	17,6	120	Basalt
Kildedalen	Disco Island			14,5		Basalt
Unartukavsak	Disco Island			15,4	180-240	Basalt
Ikasagtivaq	Near Kulusuk	65°51'	37°29'	25		
Uunartoq	S-Greenland	60°30,5'	42°20'	42		

2. GEOTHERMAL SITES

Warm springs are rare in Greenland. They are found primarily on the east coast at a number of locations north and south of Scoresbysund and in several locations in Disko Island, West Greenland. Outside these regions only two occurrences of geothermal springs are known, that is at Uunartoq Island in South-Greenland and Ikasagtivaq on the southeast coast near Ammassalik (Fig.1). The Greenland Glacier covers over 80% of the country and the majority of all hot springs and geothermal sites are believed to be ice covered.

3. HOT SPRINGS NORTH AND SOUTH OF SCORESBYSUND

The geology around Scoresbysund is in some respects similar to the geology of Iceland, especially NW-Iceland, it is an ancient volcanic region made of a thick pile of flood basalt lavas. However, the basaltic pile is considerably older or around 60 Ma (Larsen et al. 1992) whereas the basaltic region of NW-Iceland is 14-16 Ma.

Hot springs are found in a number of locations along the shore both north and south of Scoresbysund (Fig. 1). The distance between the northernmost and southernmost sites is 350 km. Among them is the warmest geothermal spring of Greenland, the Unarteq hot spring at Cape Tobin. The maximum temperature is 61,8°C. The runoff is estimated to be 40 L/min. Close by is the smaller Unarterajik hot spring, 33°C. The place is 7 km south of the small town Ittoqqortoormiit. The main industries are fishing and hunting. In Cape Tobin there are some summerhouses and an abandoned weather and radiotelegraph station that was run for some decades during the 20th century. The geothermal site has little economic importance. It is visited by tourists and the hot water has been used for cooking and cleaning musk ox skulls. Chemical analyses in the Iceland GeoSurvey data collection indicate high salinity and total dissolved solids (Table 2) (Kristmannsdóttir 1998). Geothermometers indicate around 90°C deeper in the system. The relations of the geothermal system with the local and regional tectonics have not been studied. This is the only geothermal area in East Greenland located near to a settlement and that could possibly be harnessed for energy production and space heating.

Table 2: Chemical analyses from East and West Greenland (for comparision)

Locality	*Unarteq, Cape Tobin*	*Unartorssuaq, Disco Island*
Date	1996-06-01	2005-08-28
No.	19962001	20050230
Temperature [°C]	61	13,8
Acidity [pH]	7,22/25°C	8,16/21°C
Carbonate, CO_2 [ppm]	26,18	55,2
Hydrogen sulphide, H_2S [ppm]	0,06	< 0,03
Bohr, B [ppm]	0,696	0,10
Silica, SiO_2 [ppm]	67,5	14,4
Natrium, Na [ppm]	2070	83,8
Potassium, K [ppm]	56,7	1,58
Magnesium, Mg [ppm]	11,3	0,48
Calcium, Ca [ppm]	1270	47,3
Fluoride, F [ppm]	2,73	1,5
Chlorite, Cl [ppm]	5339	146
Bromide, Br [ppm]	13,5	
Sulphate, SO_4 [ppm]	249,3	89,3
TDS [ppm]	10040	420

4. DISKO ISLAND

Disko Island is around 20.000 km^2. It belongs to the basaltic region of West Greenland. The basalts rest on a much older basement of Cretaceous sandstone and Precambrian gneiss. Geothermal activity is known in several places on the south coast of Disco, for example near Qeqertarsuaq and farther north such as in Diskofjord and in Akugdlit fjord (Mellemfjord) (Hansen et al. 1988). In all places the temperature is below 18°C and the water discharge is rather small. The source of the geothermal heat and its relation to the stratigraphy and tectonics are unknown but it seems reasonable to suggest that it is somehow connected to early Tertiary volcanism.

The main settlement is Qeqertarsuaq (Godhavn), about 1000 people. The town lies north of the Arctic Circle, 600 km north of Nuuk, near to latitude 69. The main industries are fishing and hunting but tourism is increasing. The town gets its space heating and electricity from diesel generators. The University of Copenhagen has since 1906 run the Arctic Station near the town carrying out comprehensive natural research.

The geothermal springs (≥ 10°C) are confined to the south western part of Disko. Eleven locations are known (Table 1). Most of these places are extremely remote and far away from inhabited areas. Unartorsuaq (Engelskmandens Havn) near the town Qeqertarsuaq is the only exception.

Some chemical analysis have been carried out (Hjartarson and Ármannsson 2005). Using geothermometers the temperatures in the roots of the geothermal systems were calculated along with some practical characteristics of the warm water. It is concluded that Unartorssuaq and Tarajornitsoq are the most promising sites on Disco. There, geothermal water with temperature 50-70°C might be expected in boreholes.

The warm springs of Unartorssuaq are the only ones located near an inhabited area. They are ca. 2 km outside the town Qeqertarsuaq (Godhavn). They seem to be connected to prominent fissures and faults found in the field which can be traced towards the town. If this is the case the geothermal system itself might also extend to the town. That cannot be proved without drilling. Boreholes are needed to investigate the geothermal gradient and the size and orientation of the geothermal system. Until drilling nothing more can be stated about the possibilities of geothermal utilisation in Qeqertarsuaq.

5. UUNARTOQ AND IKASAGTIVAQ HOT SPRINGS

The warm springs in Uunartoq and Ikasagtivaq are outside the basaltic regions of Greenland. They are single and do not belong to a group of geothermal springs as the thermal springs near Scoresby Sund and on Disco Island.

On Uunartoq Island there are geothermal springs which run together to a small stone-dammed pool, 37-38°C. Here people have gone bathing for 1000 years. The first written information on geothermal activity and utilisation in Greenland goes back to the medieval Greenland description of Ívar Bárðarson, written after his stay in the Norse settlement sometime around 1300 AD. He mentions warm springs in the small islets of the old Hrafnsfjörður (Ravensfjord), that is now known as the Island of Uunartoq. He also describes their annual temperature fluctuations and their therapeutic properties. He writes: "In these islets there is a lot of warm water. In winter it is so hot that no one endures it but in summer it is suitable for bathing. There many people have got holistic treatment and good healing and remedy of illnesses." (Halldórsson 1978, p. 135). Archaeological research has revealed ruins of a nunnery built near the hot springs after the Norse settlement in Greenland was converted to Christianity around 1000 A.D.

Ikasagtivaq hot spring is on the southeast coast near Ammassalik and Kulusuk. The max. temperature is 25°C, the discharge is unknown.

CONCLUSIONS

Geothermal exploration in Greenland has mainly aimed at establishing the influence of the warm springs on the flora and fauna (Kristensen 1987, 2000). The flora and fauna around the thermal springs are noted for the large element of southern species, which in many cases have their northern limits in these areas.

A limited investigation has been made into the possibility of geothermal utilisation in Disko, West Greenland on possible utilisation for space heating or power production. Research drilling has been suggested in Qequertarsuaq but no action has been taken because of nature conservation (Hjartarson and Ármannsson 2005, 2010).

The use of geothermal energy in Greenland is negligible. Currently, geothermal water is used in natural spas in one or two places (Uunartoq and Cape Tobin) for bathing, balneology and tourism with little economic return. No official plans for geothermal research or utilization have been made.

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APPENDIX. WGC 2020 GREENLAND TABLES

Table A1: Present and planned production of electricity

	Geothermal		*Fossil Fuels*		*Hydro*		*Nuclear*		*Other Renewables (wind)*		*Total*	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	0	0	95	274	92	263	0	0			187	538
Under construction in December 2019	0	0					0	0				
Funds committed, but not yet under construction in December 2019	0	0					0	0				
Estimated total projected use by 2020	0	0	92	265	95	272	0	0	1	3	188	540

Table A2: Utilization of geothermal energy for direct heat as of 31 December 2019 (other than heat pumps)

	Maximum Utilization					*Capacity[3)]*	*Annual Utilization*		
Locality	Type[1)]	Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity Factor[5)]
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	
Unartoc	S-Greenland B	2	37	25			0,1	2	3,2	1
TOTAL		2					0,1	2	3,2	1

Table A3: Summary table of geothermal direct heat uses as of 31 December 2019

Use	*Installed Capacity*[1)]	*Annual Energy Use*[2)]	*Capacity Factor*[3)]
	(MWt)	(TJ/yr = 10^{12} J/yr)	
Individual Space Heating[4)]	0	0	0
District Heating[4)]	0	0	0
Air Conditioning (Cooling)	0	0	0
Greenhouse Heating	0	0	0
Fish Farming	0	0	0
Animal Farming	0	0	0
Agricultural Drying[5)]	0	0	0
Industrial Process Heat[6)]	0	0	0
Snow Melting	0	0	0
Bathing and Swimming[7)]	0,1	3,2	1
Other Uses (specify)	0	0	0
Subtotal	0	0	0
Geothermal Heat Pumps	0	0	0
TOTAL	0,1	3,2	1

Table A4: Wells drilled for electrical, direct and combined use of geothermal resources from 1 January 2015 to 31 December 2019 (excluding heat pump wells)

Purpose	*Wellhead Temperature*	*Number of Wells Drilled*				*Total Depth (km)*
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	0	0	0	0	0
Production	>150° C	0	0	0	0	0
	150-100° C	0	0	0	0	0
	<100° C	0	0	0	0	0
Injection	(all)	0	0	0	0	0
Total		0	0	0	0	0

Table A5: Allocation of professional personnel to geothermal activities (restricted to personnel with University degrees)

Year	*Professional Person-Years of Effort*					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	0	0	0	0	0	0
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
2019	0	0	0	0	0	0
Total	0	0	0	0	0	0

Table A6: Total investments in geothermal in (2019) US$

Period	*Research & Development Incl. Surface Explor. & Exploration Drilling*	*Field Development Including Production Drilling & Surface Equipment*	*Utilization*		*Funding Type*	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0	0	0	0	0	0
2000-2004	0,1	0	0	0	0	100
2005-2009	0	0	0	0	0	0
2010-2014	0	0	0	0	0	0
2015-2019	0	0	0	0	0	0