

Volcano-ice interaction: The empirical constraints derived from eruptions in Iceland in the period 1918-2015

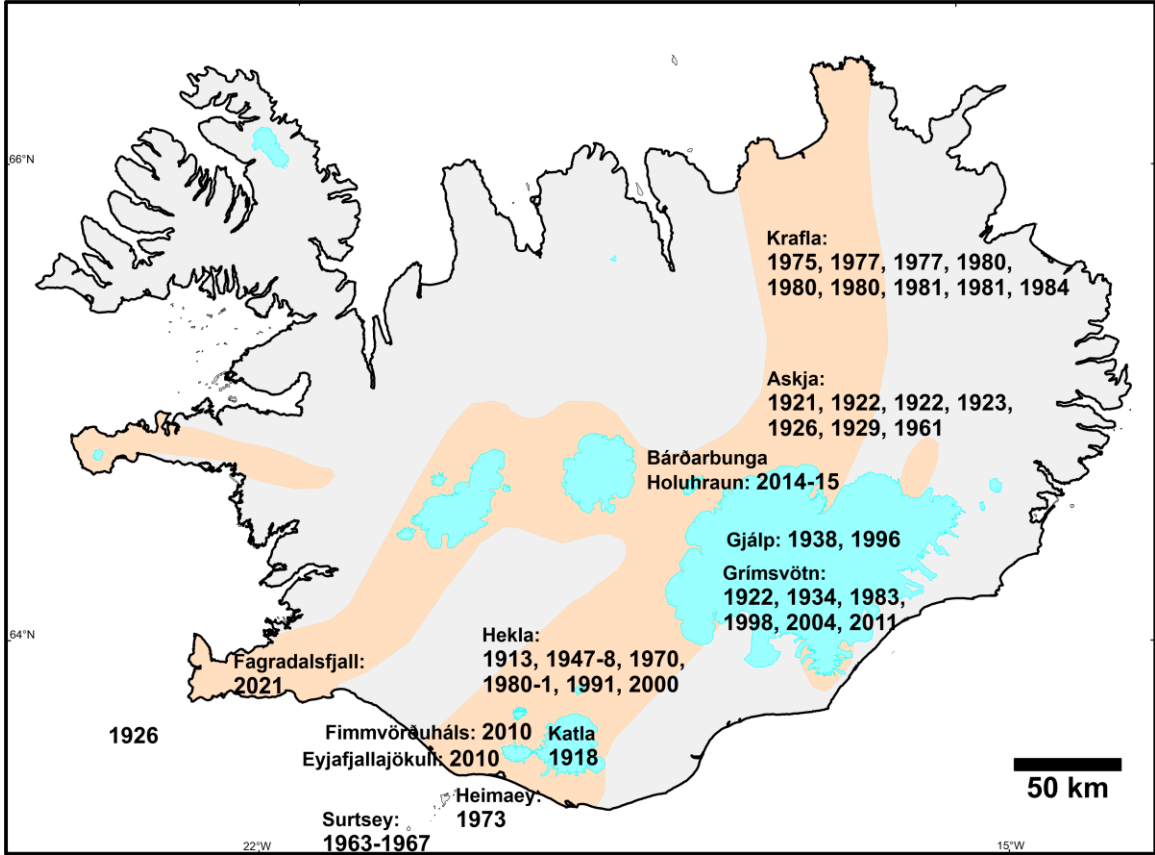
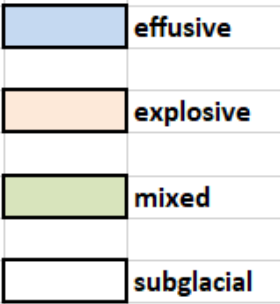


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Nordvulk, Institute of Earth Sciences, University of Iceland

Eruptions in Iceland 1913-2021

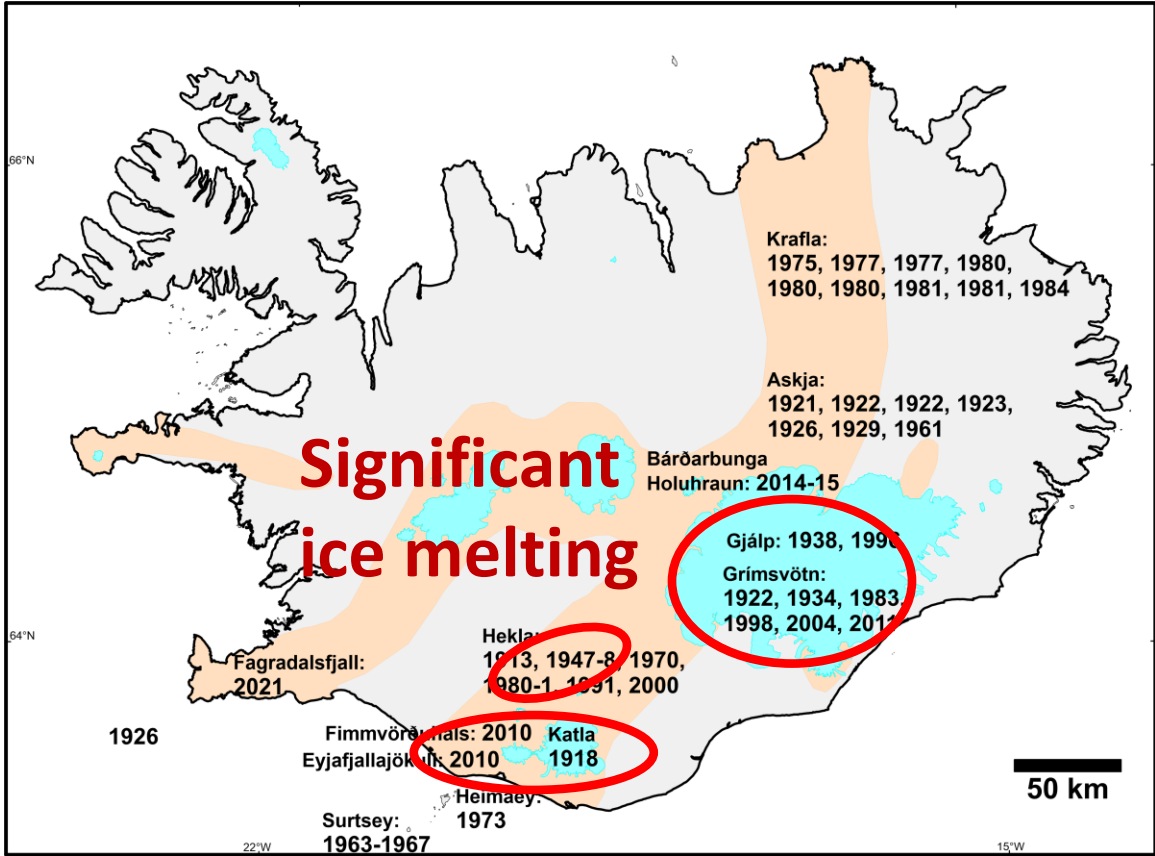
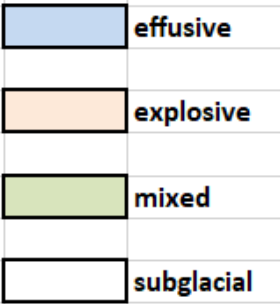
Effusive 21
Explosive 9
Mixed 6
Subglacial 2



Volcano	year	Lava area (km ²)	Volume tephra (km ³)	Volume subglacial (km ³)	Volume submarine (km ³)	Volume lava (km ³)	DRE (km ³)	VEI
Hekla, Mundafell	1913	10	0.000			0.060	0.060	1
Katla	1918		0.950	0.700		0.000	0.790	4
Askja	1921	0.2	0.000			0.001	0.001	1
Askja	1922	0.2	0.000			0.001	0.001	1
Askja	1922	2.2	0.000			0.010	0.010	1
Grímsvötn	1922		0.100	0.010		0.000	0.050	3
Askja	1923	0.2	0.000			0.001	0.001	1
Askja	1926	0	0.050			0.000	0.020	2
Askja	1929	25	0.000			0.130	0.120	1
Grímsvötn	1934		0.080	0.010		0.000	0.040	3
Gjálp	1938		0.000	0.500		0.000	0.300	subglacial
Hekla 1947-1948	1947		0.210			0.631	0.680	4
Askja	1961	11	0.004			0.090	0.090	2
Surtsey 1963-1967	1963		0.200		0.700	0.500	0.960	3
Hekla	1970	18.5	0.070			0.211	0.230	3
Heimaey	1973		0.010			0.250	0.240	2
Krafla, desember	1975		0.000			0.000	0.000	1
Krafla, apríl	1977		0.000			0.001	0.001	1
Krafla, sept.	1977		0.000			0.002	0.001	1
Krafla, mars	1980		0.000			0.003	0.002	1
Krafla, júlí	1980	6	0.000			0.025	0.024	1
Krafla, október	1980	11.5	0.000			0.035	0.030	1
Hekla 1980-1981	1980	24	0.060			0.170	0.190	3
Krafla, janúar-febrúar	1981	6.3	0.000			0.032	0.030	1
Krafla, nóvember	1981	17	0.000			0.050	0.050	1
Grímsvötn	1983		0.005	0.010		0.000	0.008	2
Krafla, sept.	1984	24	0.000			0.135	0.130	1
Hekla	1991	23	0.010			0.240	0.230	3
Gjálp	1996		0.010	0.800		0.000	0.500	2
Grímsvötn	1998		0.040	0.052		0.000	0.050	3
Hekla	2000	12	0.010	0.000		0.095	0.090	3
Grímsvötn	2004		0.027	0.028		0.000	0.030	3
Fimmvörðuháls	2010	1.3	0.000	0.000		0.020	0.020	1
Eyjafjallajökull	2010	0.6	0.270	0.010		0.040	0.150	3
Grímsvötn	2011		0.700	0.010		0.000	0.290	4
Holuhraun 2014-2015	2014	84	0.000	0.010		1.440	1.370	1
Fagradalsfjall	2021	4.85	0.00	0.000		0.150	0.140	1

Eruptions in Iceland 1913-2021

Significant volcano-ice interaction



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Eruptions in glaciers in Iceland since 1918



Katla 1918

Katla 1918

Photo: Kjartan Guðmundsson



No photos or
observations

Grímsvötn 1922



Grímsvötn 1934

Photo: Niels Nielsen



Gjálp 1938

Photo: Pálmi Hannesson

**Last 40 years:
7 confirmed
eruptions in
glaciers**



Grímsvötn 1983

Photo: Helgi Björnsson



Gjálp 1996

Photo: MTG



Grímsvötn 1998

Photo: Þórdís Högnadóttir



Grímsvötn 2004

Photo: MTG



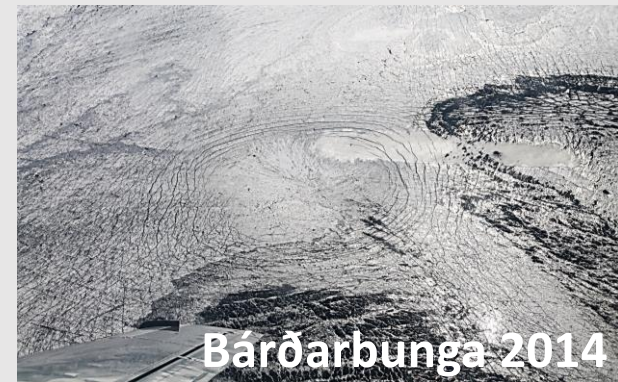
Eyjafjallajökull 2010

Photo: MTG



Grímsvötn 2011

Photo: MTG



Bárðarbunga 2014

Photo: Þórdís Högnadóttir

Eruptions in glaciers – constraints on ice melting rates



Photo: Kjartan Guðmundsson

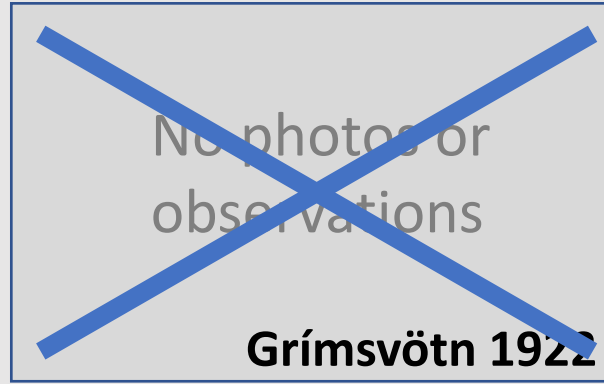


Photo: Niels Nielsen

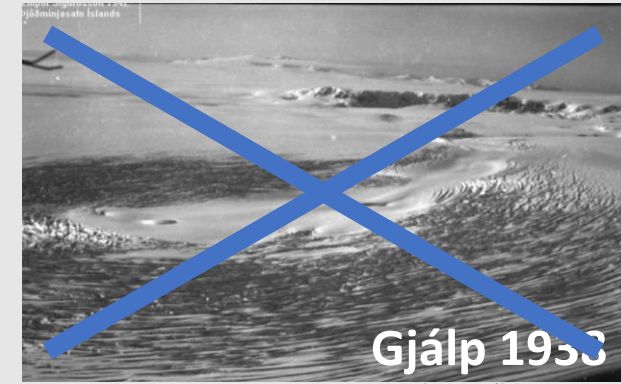


Photo: Pálmi Hannesson

**Last 40 years:
7 confirmed
eruptions in
glaciers**



Photo: Helgi Björnsson



Photo: MTG



Photo: Þórdís Högnadóttir



Photo: MTG



Photo: MTG



Photo: MTG

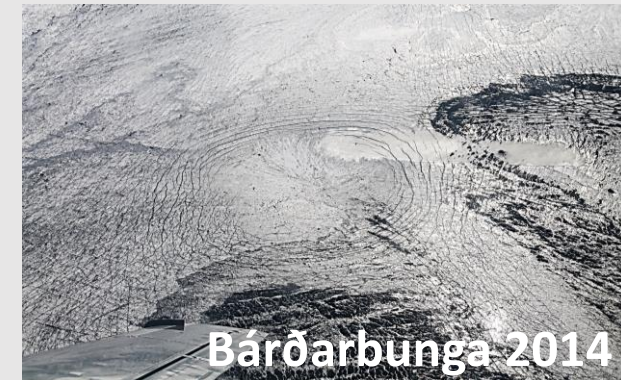


Photo: Þórdís Högnadóttir

Melting in eruptions – past events – empirical constraints

The Iceland record 1918-present:

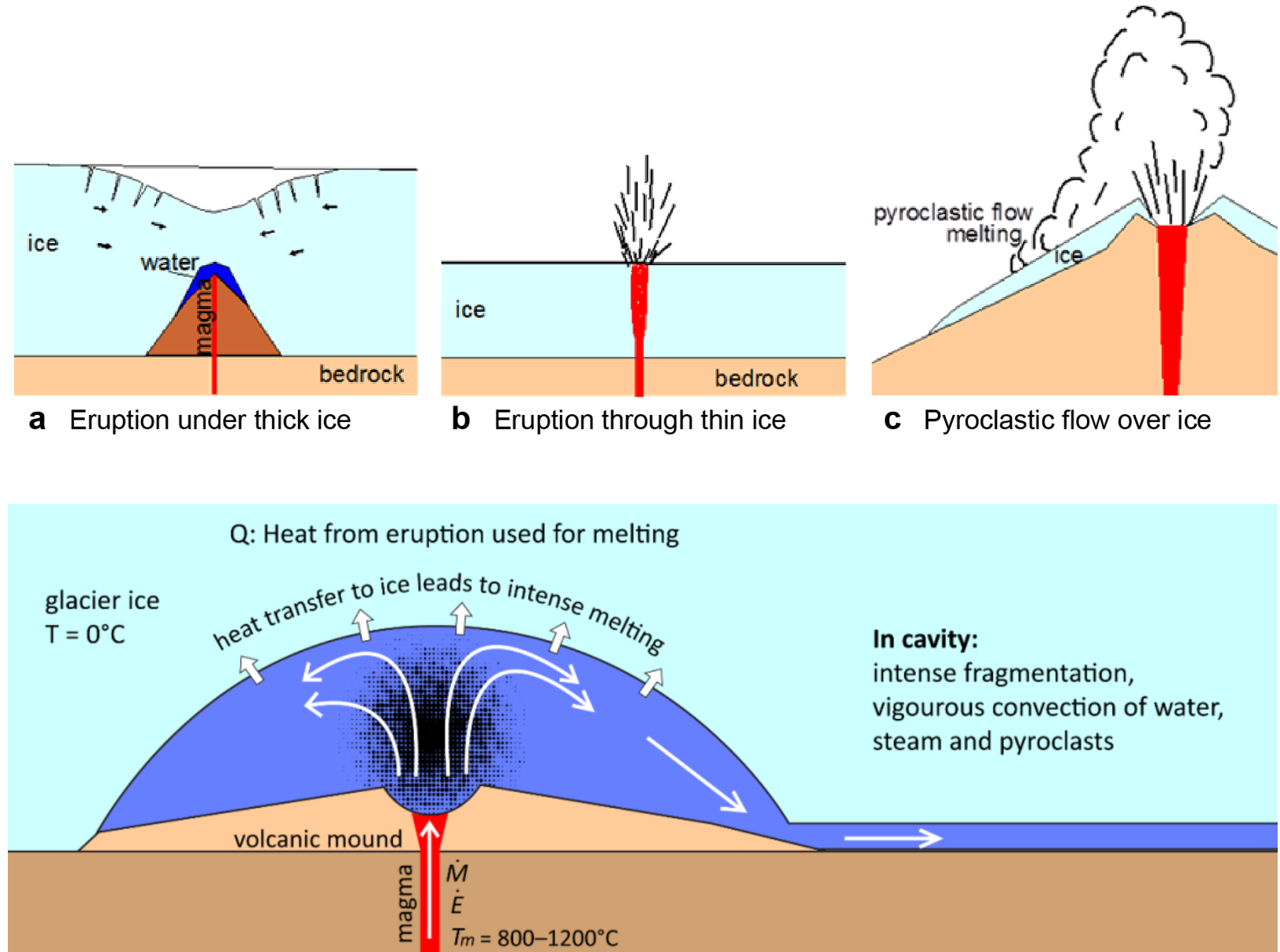
Under ice:

Basalt	8
Basaltic andesite	2
Trachyandesite	1

Pyroclastic flows over ice:

Andesite	1
Dacite	1

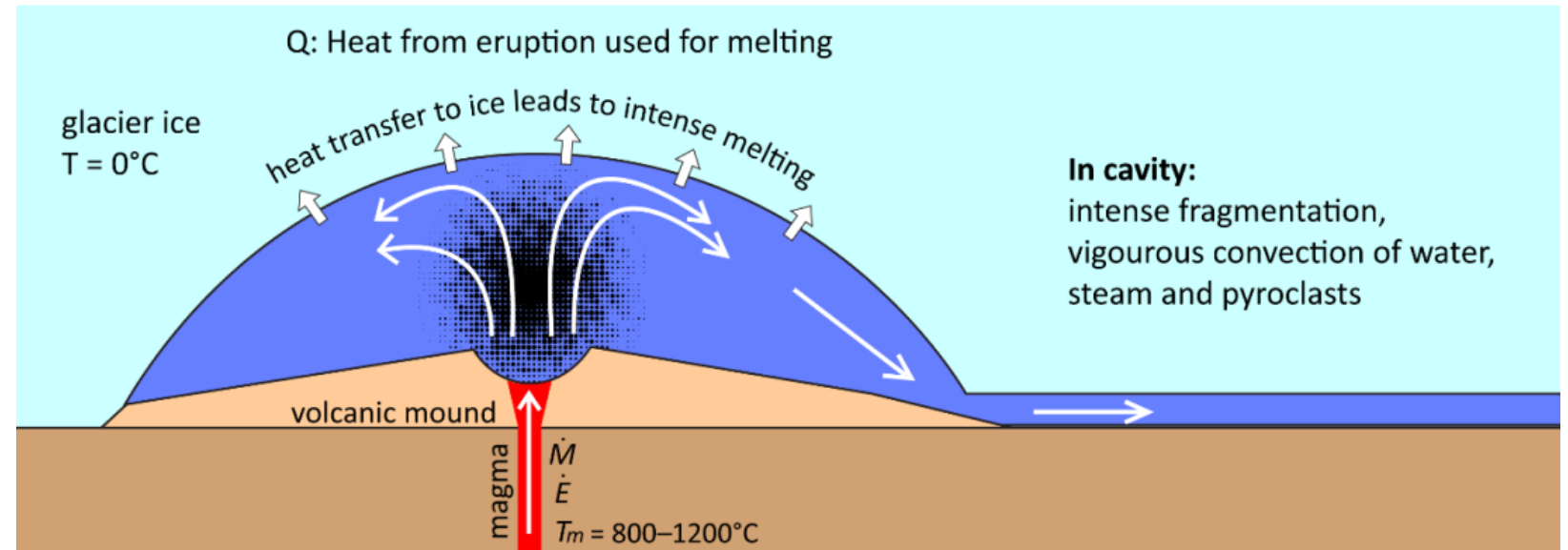
No rhyolite



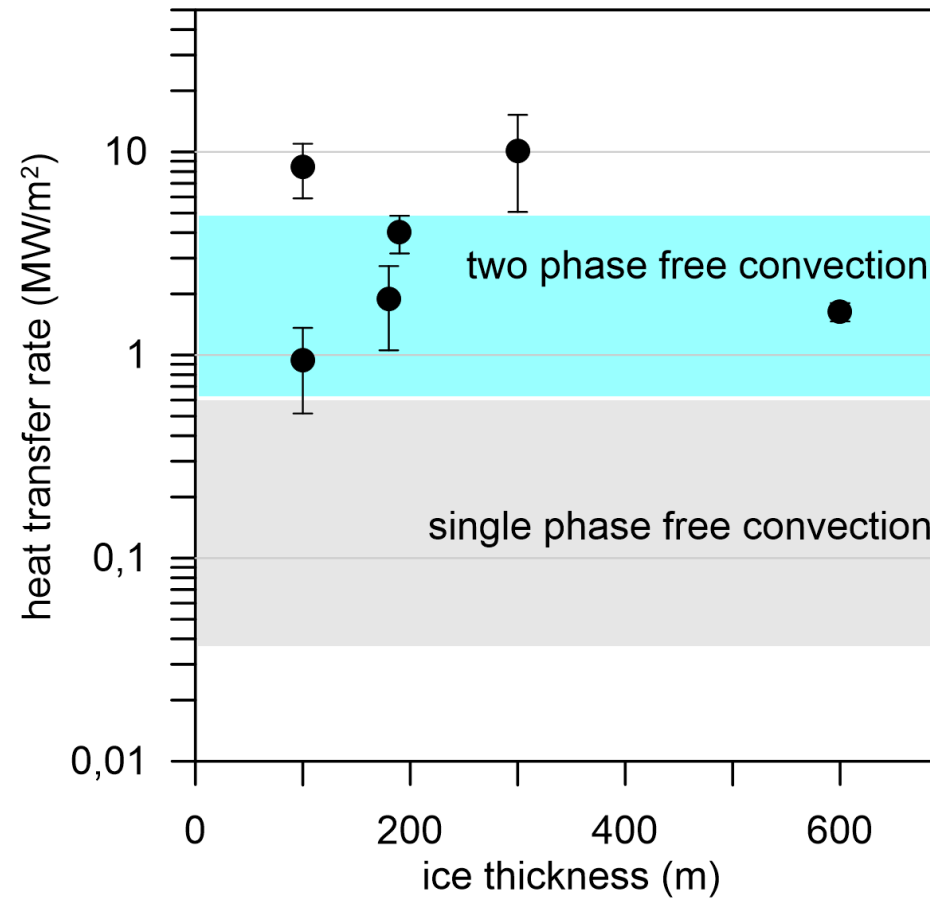
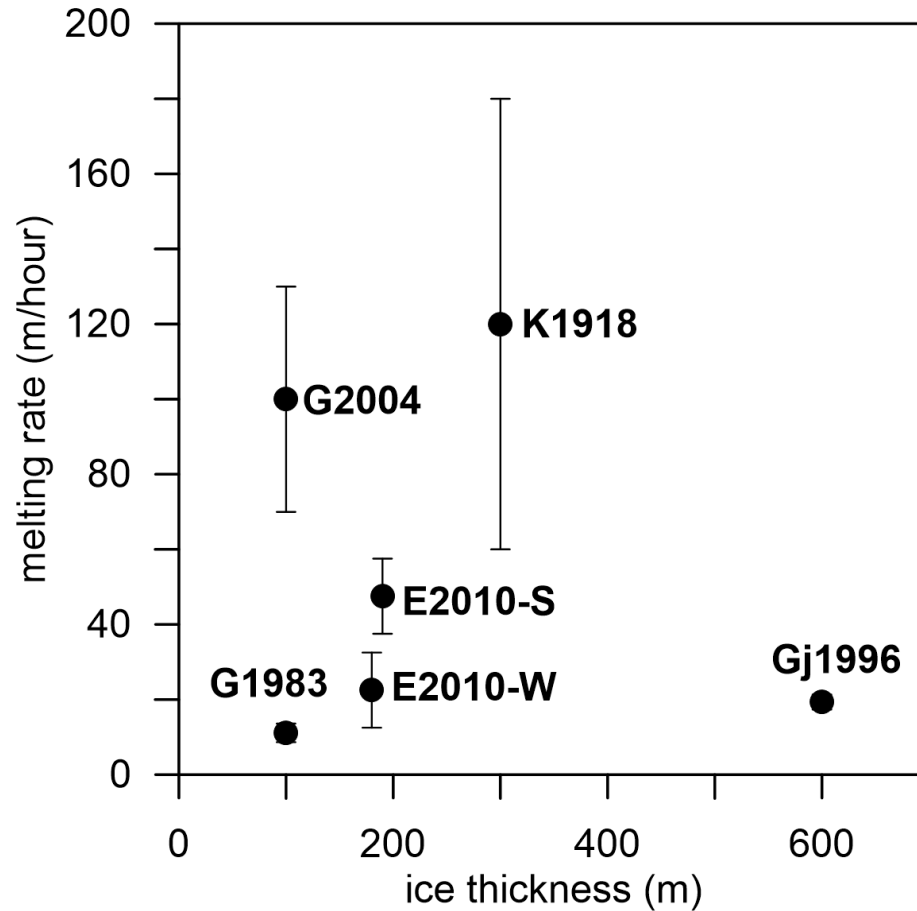
Six eruptions – ice thickness – subglacial phase – melting rates

Eruption	Date	MER (kg/s)	ice thickness (m)	subglacial eruption start	subaerial eruption start	melting time (hours)	melting rate m/h	Power MW/m ²
Katla 1918	12.10.	6.00E+07	300	12:00-12:30	15:00	2.5	120	10
Grímsvötn 1983	28.5	1.00E+05	100	12:00	<21:00	9	11	1
Gjálp 1996	30.9.-2.10.	2.00E+06	600	22:00	04:47	31	19	2
Grímsvötn 2004	1.11.	4.60E+05	100	21:50	<22:50	1	100	8
Eyjafjallajökull 2010 - south cauldron	14.4.	5.00E+05	190	01:30	04:30-05:30	4	47.5	4
Eyjafjallajökull 2010 - west cauldron	15.4.	5.00E+05	180	>~10	~18	8	22.5	2

Cavities liquid dominated



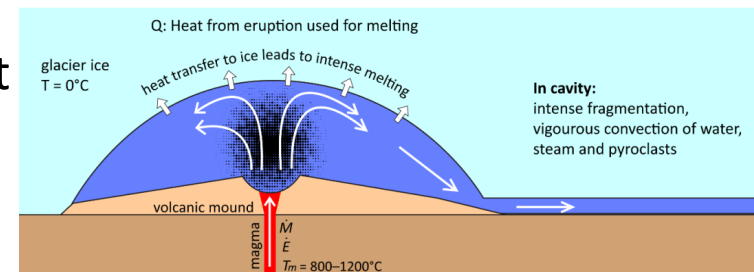
Melting rates and heat transfer rates



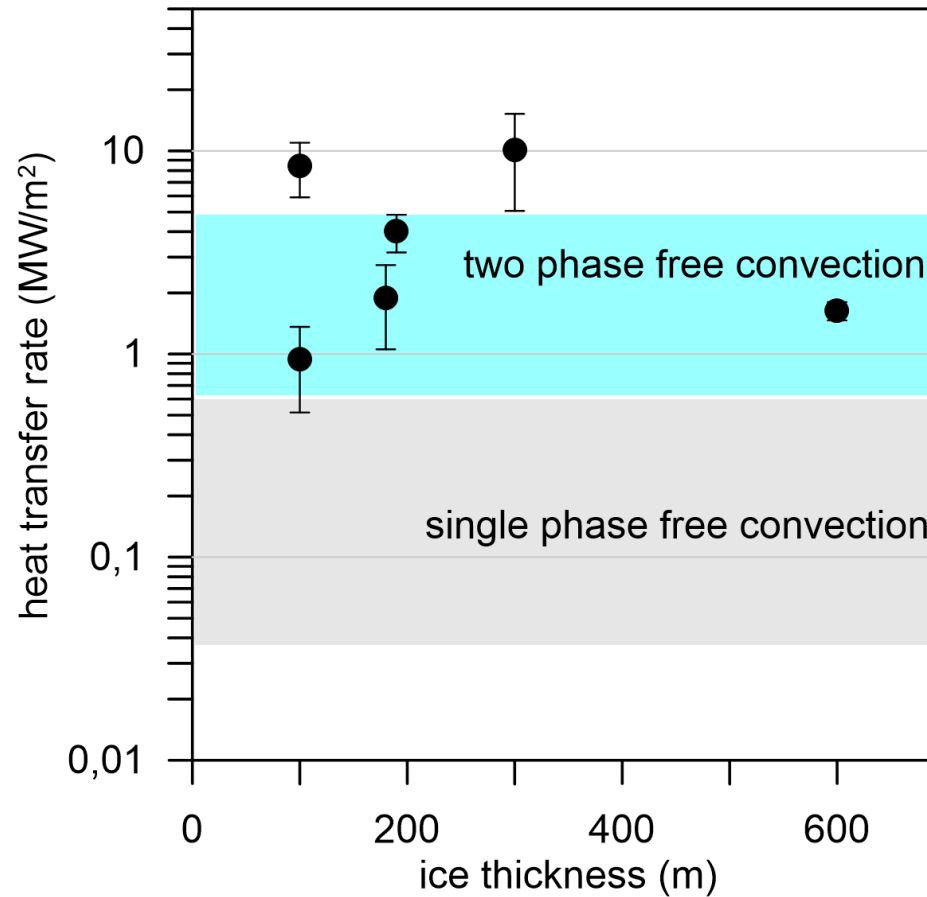
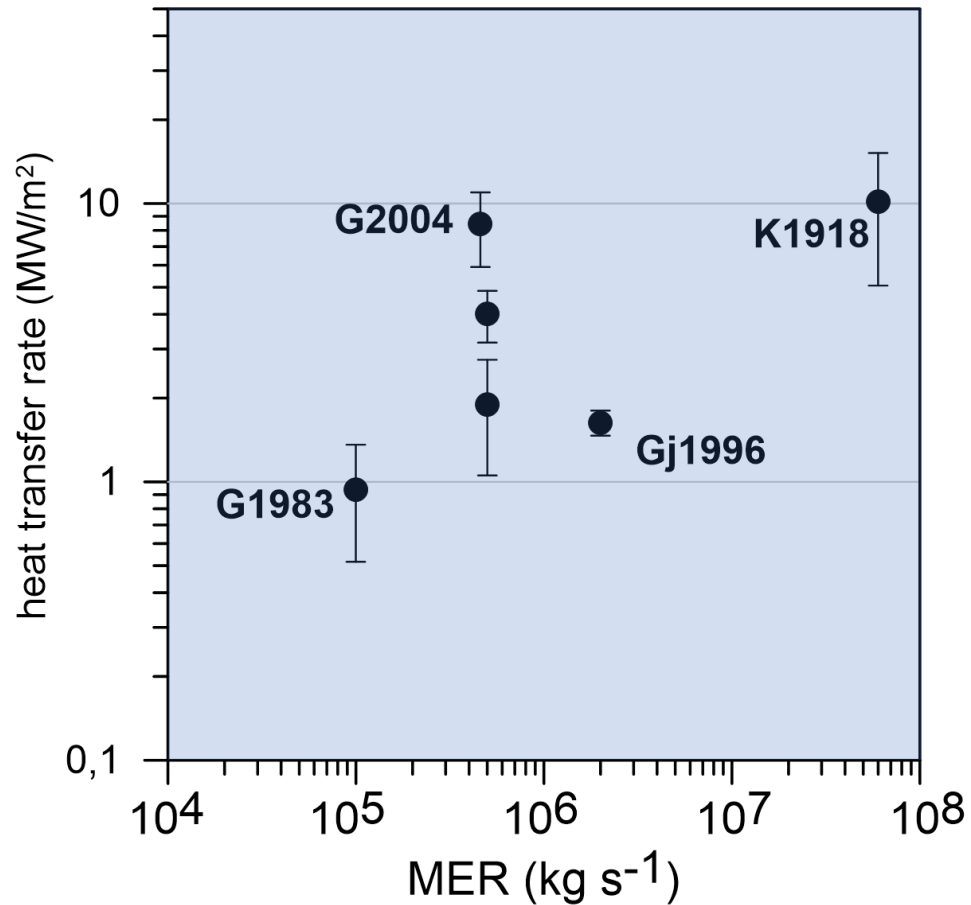
K: Katla
G: Grímsvötn
Gj: Gjálp
E: Eyjafjallajökull

Convective regimes according to Woodcock et al. (2016)

Highest rates call for additional mechanisms for heat transfer – e.g. erosion of ice roof by pyroclasts

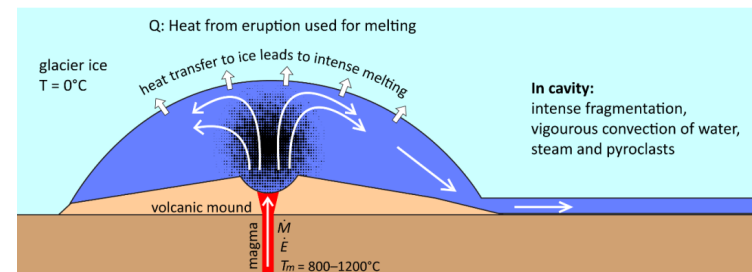


Heat transfer rates, ice thickness and mass eruption rate



K: Katla
G: Grímsvötn
Gj: Gjálp
E: Eyjafjallajökull

Some correlation between MER and heat transfer rates – but data is sparse



Concluding remarks – 1918-2022 - constraints

- We have learned a great deal in the last 25 years of higher activity in Iceland
- Thick ice, water-filled cavities – several observations
- Surface melting by pyroclastic flows – no recent
- Melting rates of 10-100 m/hour observed



Photo: MTG



Photo: Helgi Björnsson



Photo: MTG