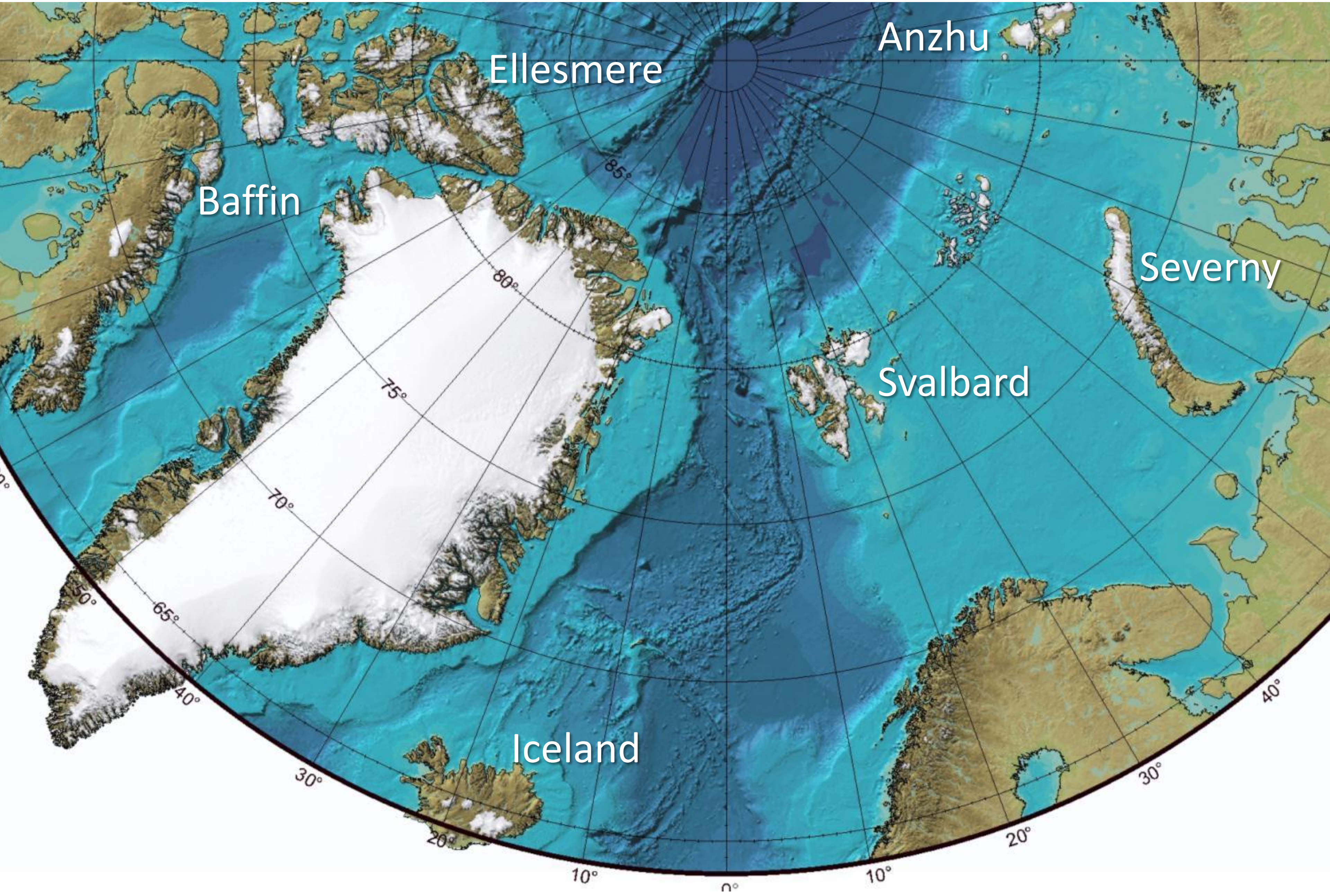
Ice Cap Glaciers in the Arctic Region

John Evans Glacier, Ellesmere Island (Robert Bingham, U. Aberdeen)

- **Iceland**
- **Svalbard**
- **Ellesmere and Baffin Islands**
- **Severny and Anzhu Islands**

Topics:

- Temperate vs non-temperate glaciers
- Tidewater glaciers
- Jökulhlaups
- Sandurs
- Surge behaviour


Anzhu
Ellesmere
Baffin
85°
80°
Severny
75°
Svalbard
70°
65°
40°
Iceland
30°
20°
10°
0°
10°
20°
30°
40°

Ice cap

- An ice cap is a relatively flat glacier (often occupying an upland area) that is less than 50,000 km^2 in area (<225 x 225 km)
- This is not an ice-cap!

- Many Arctic land masses north of 70° have ice caps
- Ice caps have outlet glaciers

Temperate vs non-temperate glaciers

- A temperate glacier is at its melting point, throughout its thickness, for most of the year
- A polar glacier is below its freezing point, from surface to base, through most of the year
- A sub-polar or polythermal glacier is intermediate between these extremes, with both temperate and polar ice depending on the ice thickness and the elevation
- Temperate glaciers are common in areas where there is a lot of precipitation, so that while it might not be that cold, there is plenty of snow accumulation in winter
- Iceland and Svalbard have temperate glaciers, largely because of their proximity to the Gulf Stream

Tidewater glaciers

- A tidewater glacier reaches the ocean, and therefore exists in an area that either has a great deal of precipitation (as snow) or is very cold
- Iceland does not have tidewater glaciers, but the other Arctic ice-caps do

Jökulhlaup

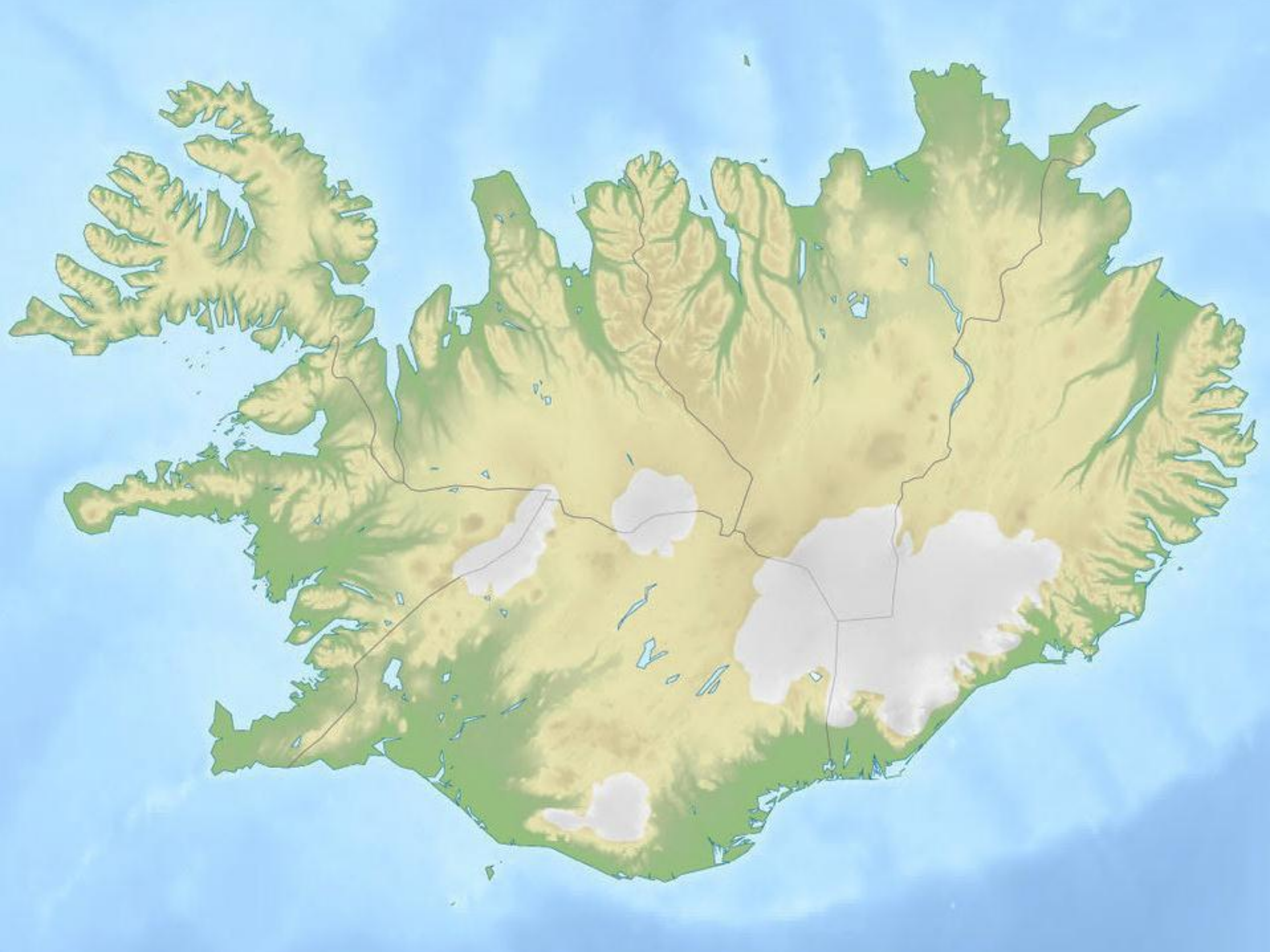
- A jökulhlaup is a large outburst of water that was stored either beneath, on or in front of a glacier
- Iceland is famous for jökulhlaups, most of which are related to subglacial melting by volcanism, but any glacial outburst flood is a jökulhlaup

Sandur

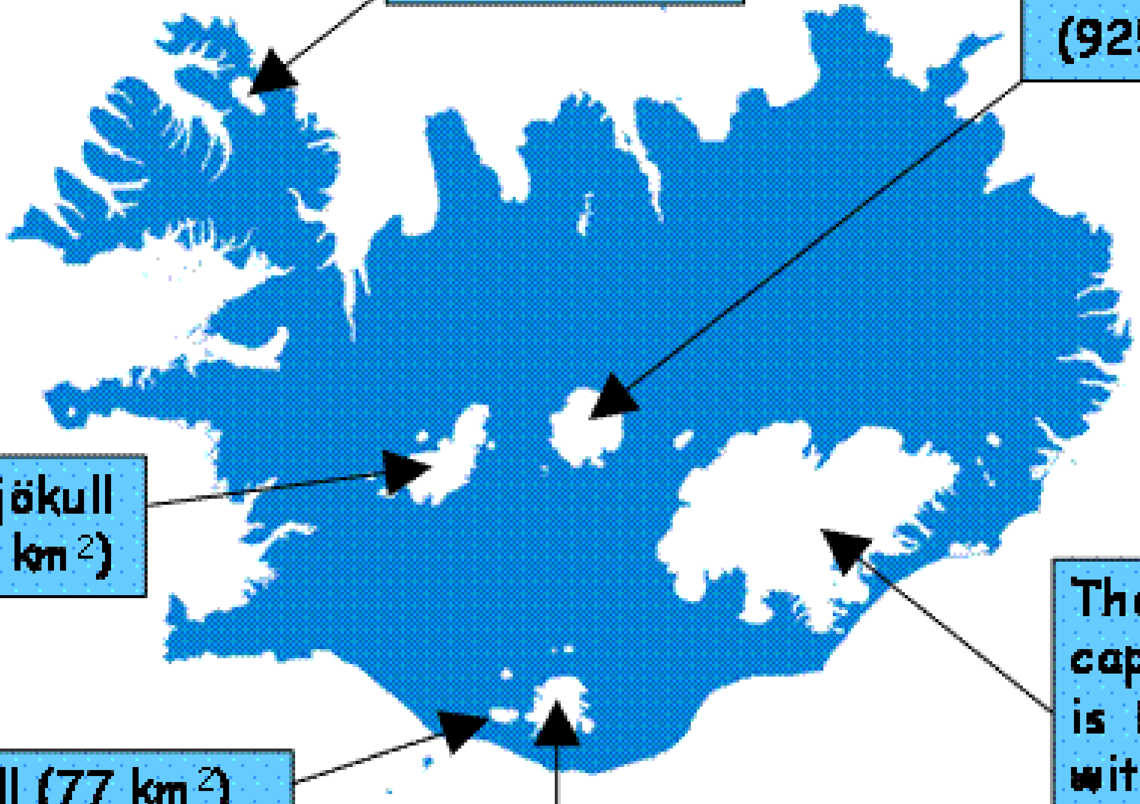
- A glacial outwash plain composed of sand and gravel – mostly as braided deposits
- Some sandurs are strongly affected by jökulhlaups

Surge glaciers

- Most glaciers move relatively steadily
- Some glaciers surge dramatically on time scales of months to years (with years to centuries of relative quiescence)
- Surging can be facilitated by changes in water flow (as we saw in Greenland), by temperature changes, or because of failure of the bed material
- Many of the Svalbard glaciers show surge behaviour



Icelandic glaciers



Drangajökull (160 km²)

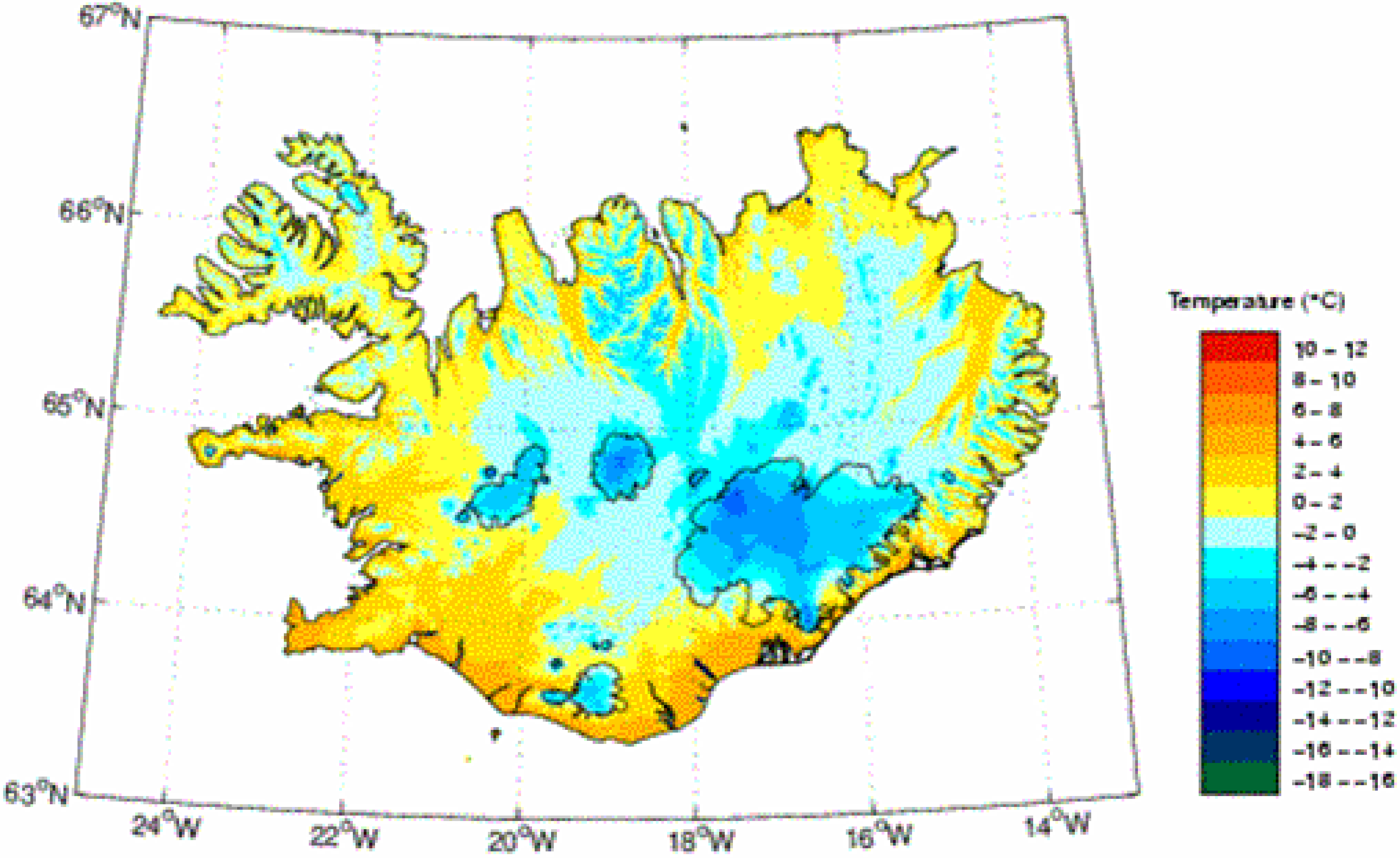
Hofsjökull (925 km²)

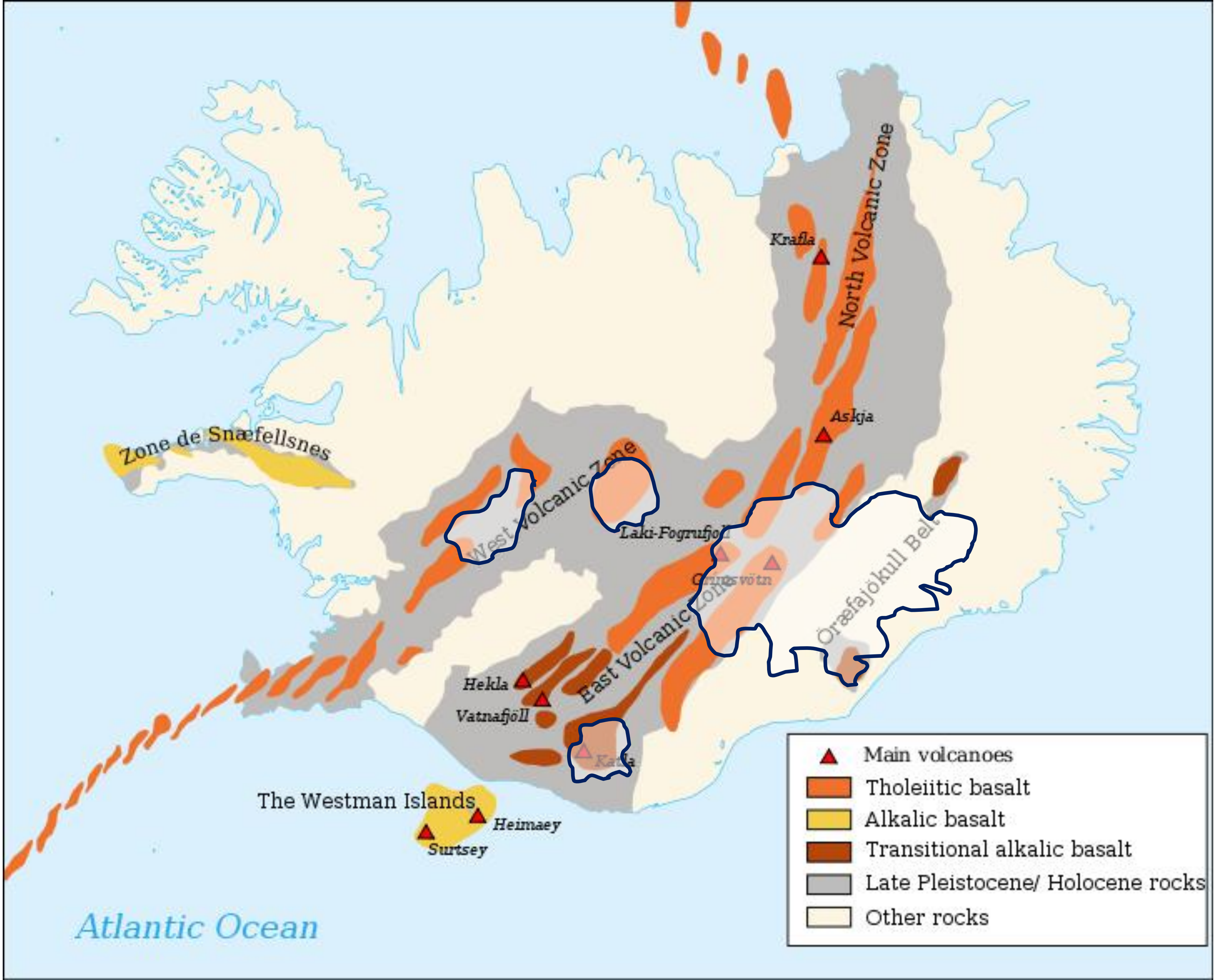
Langjökull (950 km²)

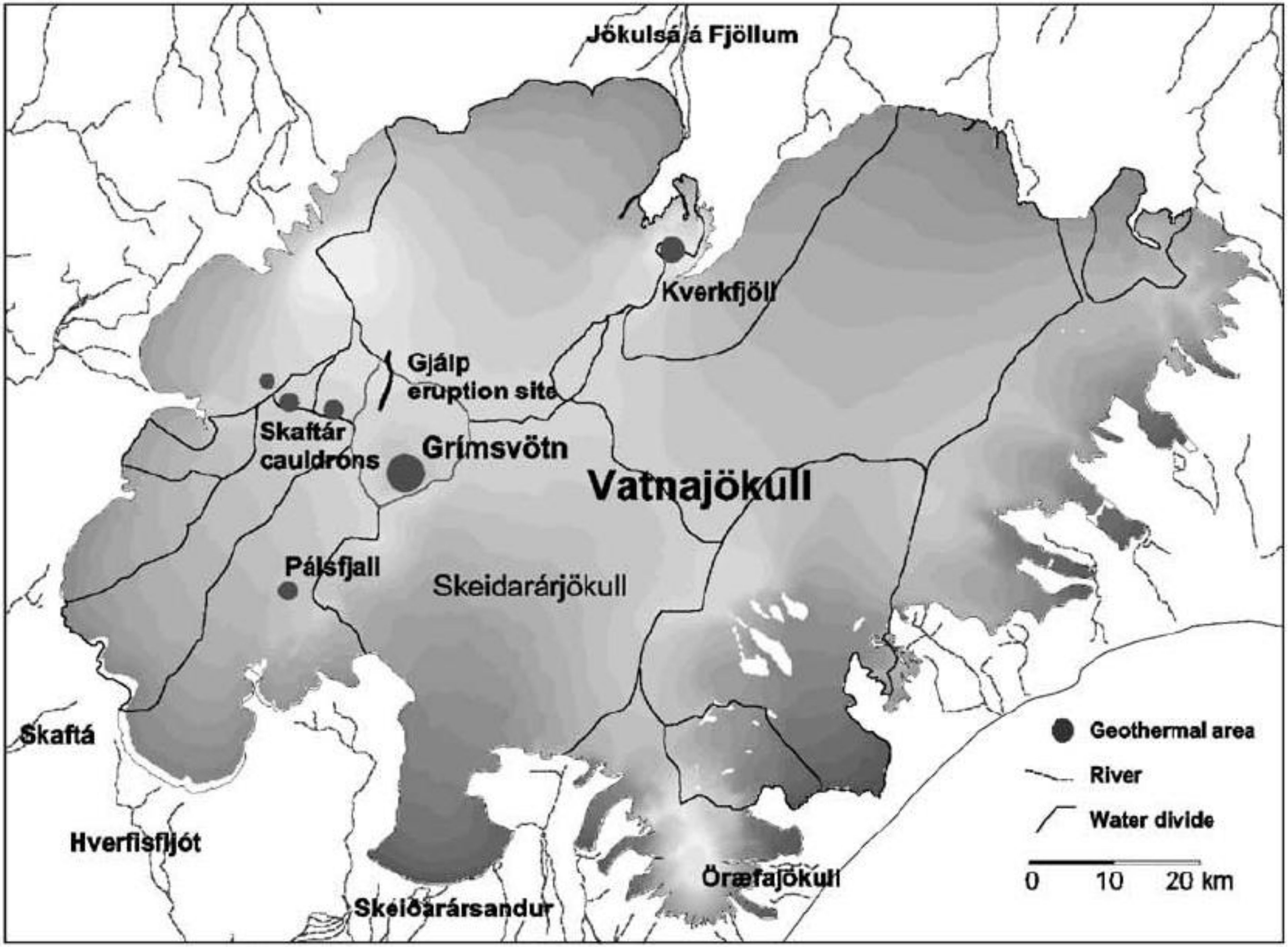
Eyjafjallajökull (77 km²)

Mýrdalsjökull (596 km²)

The largest ice cap on Iceland is *Vatnajökull*, with an area of 8,160 km². It reaches a thickness of >1,000 m.

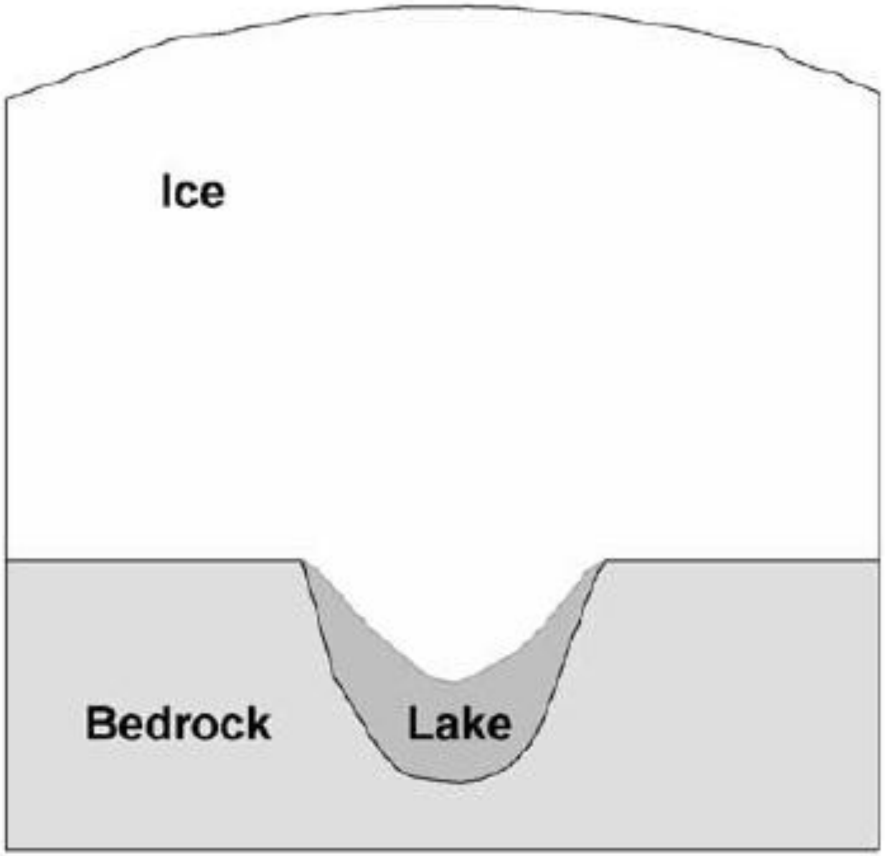

67°N
66°N
65°N
64°N
63°N
24°W
22°W
20°W
18°W
16°W
14°W
Temperature (°C)
10 – 12
8 – 10
6 – 8
4 – 6
2 – 4
0 – 2
−2 – 0
−4 – −2
−6 – −4
−8 – −6
−10 – −8
−12 – −10
−14 – −12
−16 – −14
−18 – −16

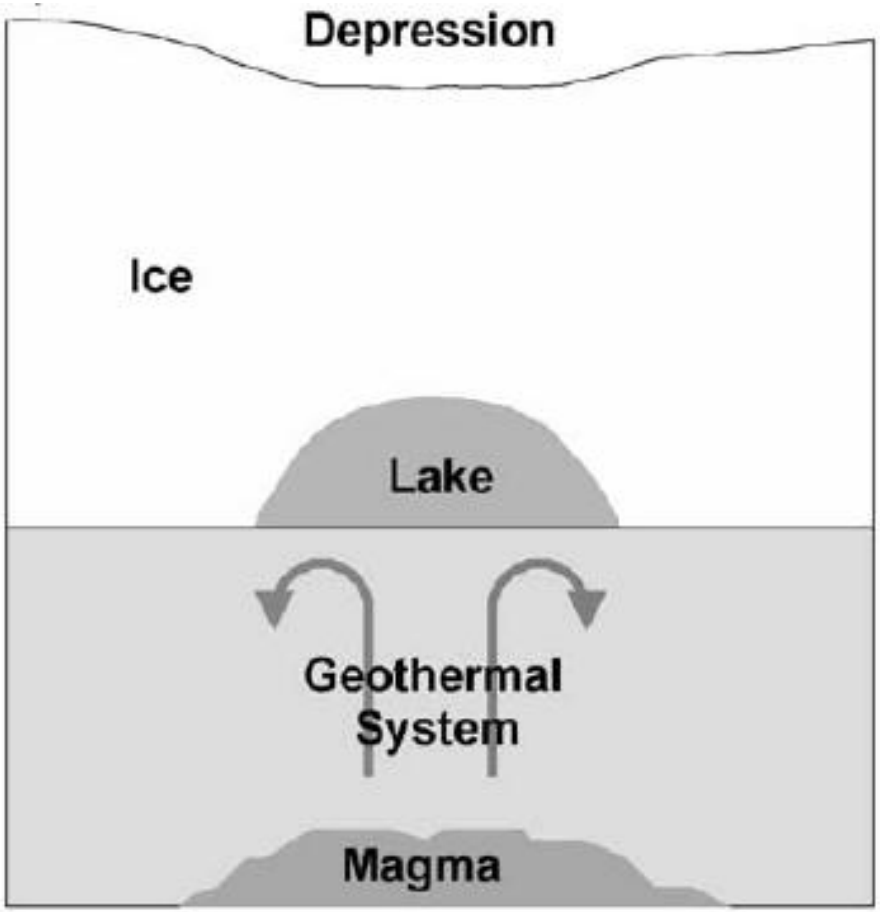

North Volcanic Zone
Krafla
Askja
Zone de Snæfellsnes
West Volcanic Zone
Laki-Fogrufjoll
Grimsvötn
East Volcanic Zone
Öræfajökull Belt
Hekla
Vatnafjöll
Katla
The Westman Islands
Heimaey
Surtsey
Atlantic Ocean
Main volcanoes
Tholeiitic basalt
Alkalic basalt
Transitional alkalic basalt
Late Pleistocene/ Holocene rocks
Other rocks



H. Björnsson, 2002, Global and Planetary Change, V. 35.

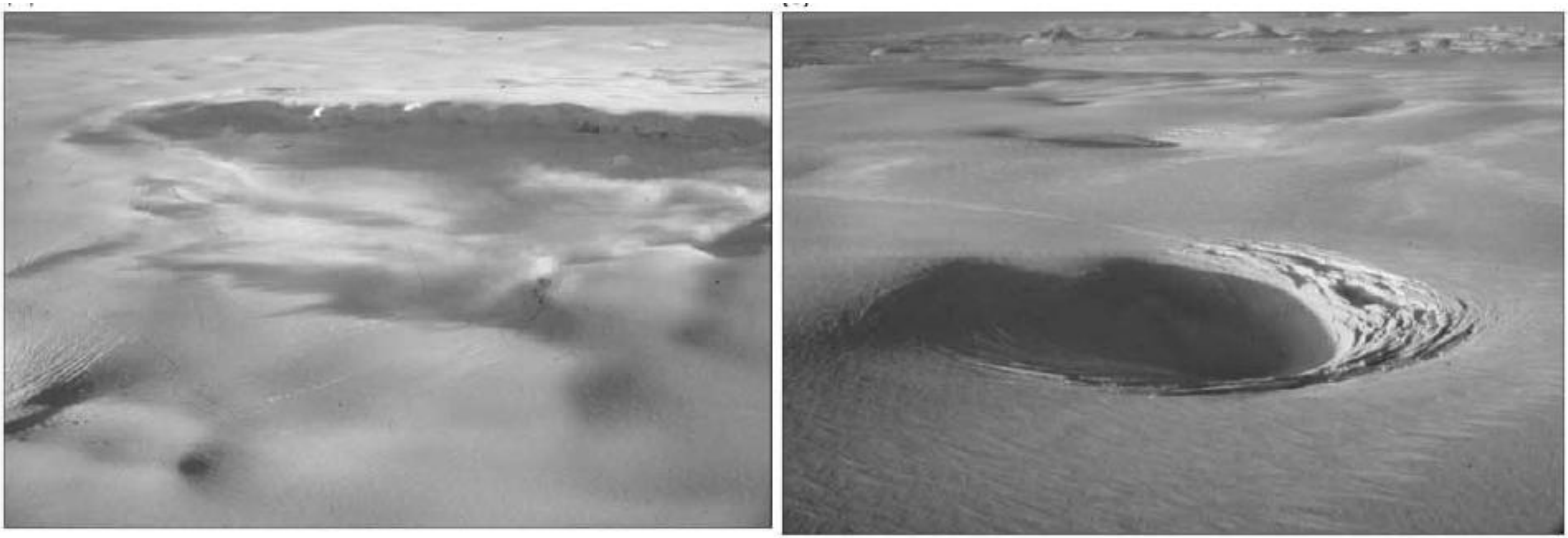
Two different types of sub-glacial lakes. The one on the left is relatively stable. The one on the right is unstable.





H. Björnsson, 2002

Ice-surface subsidence above sub-glacial lakes that have been drained by jökulhlaups

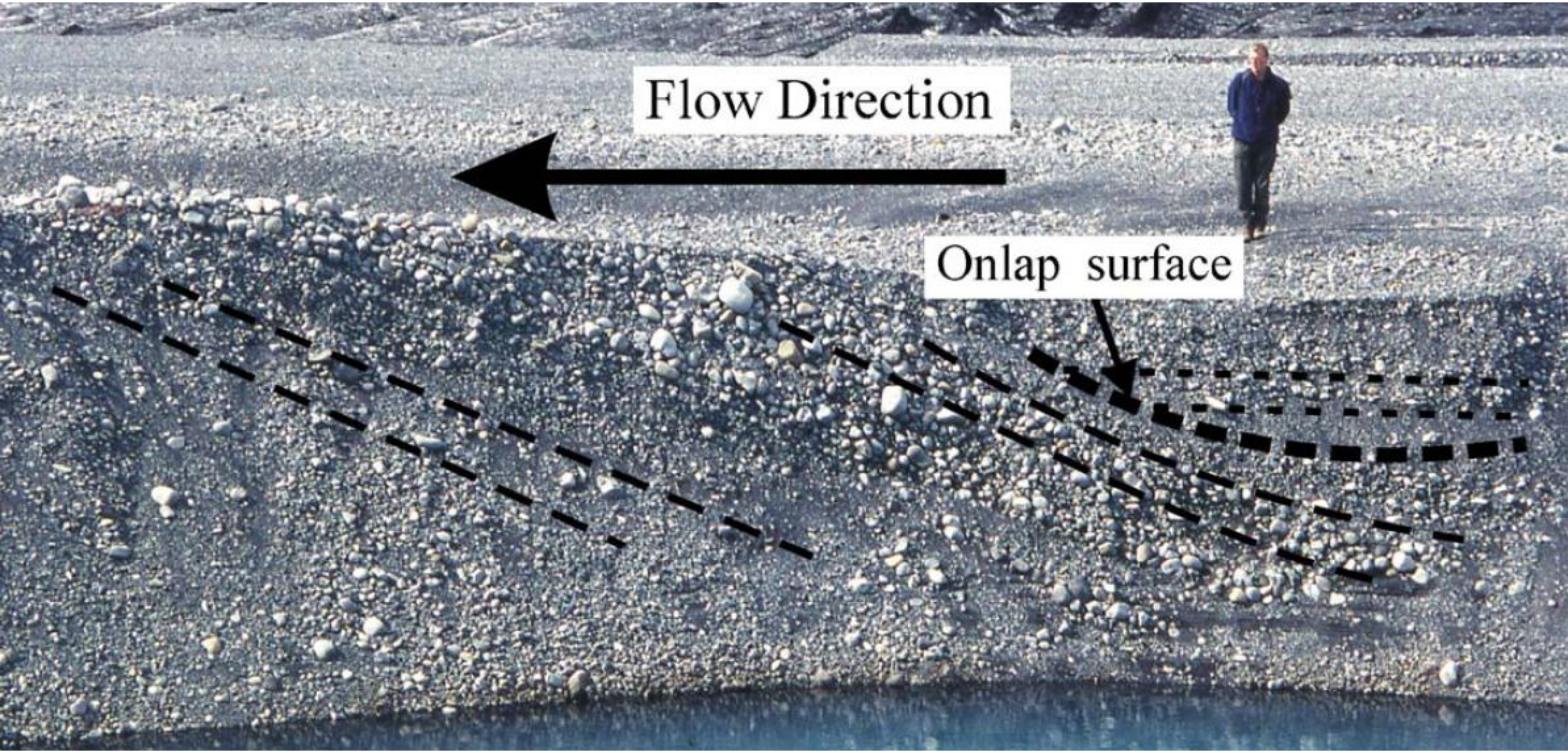


H. Björnsson, 2002

The Skeidara´ sandur (outwash plain) from Vatnajokull to the coast. Dykes control the river on the left hand side. The bridge across the river is 900 m long.

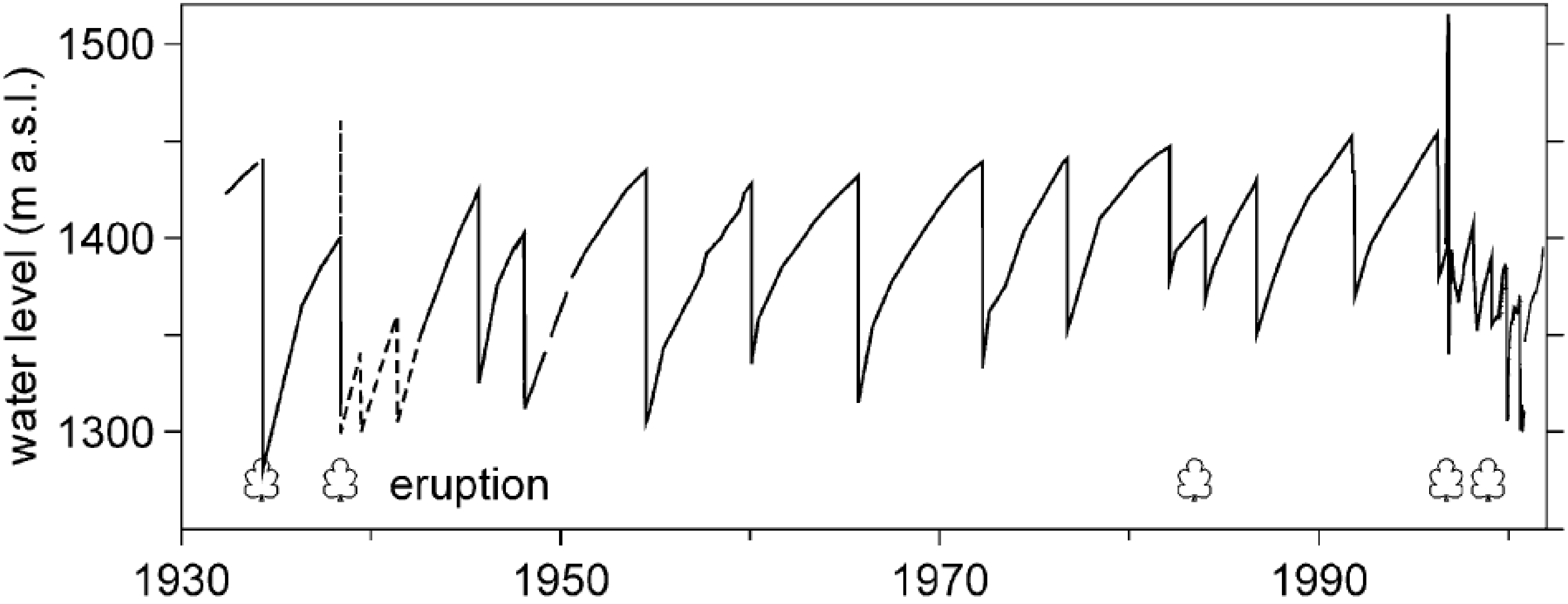
H. Björnsson, 2002

Major jökulhlaup outflows often produce large-scale cross beds, either normal, or reverse like these (because of standing waves). Vatnajokull

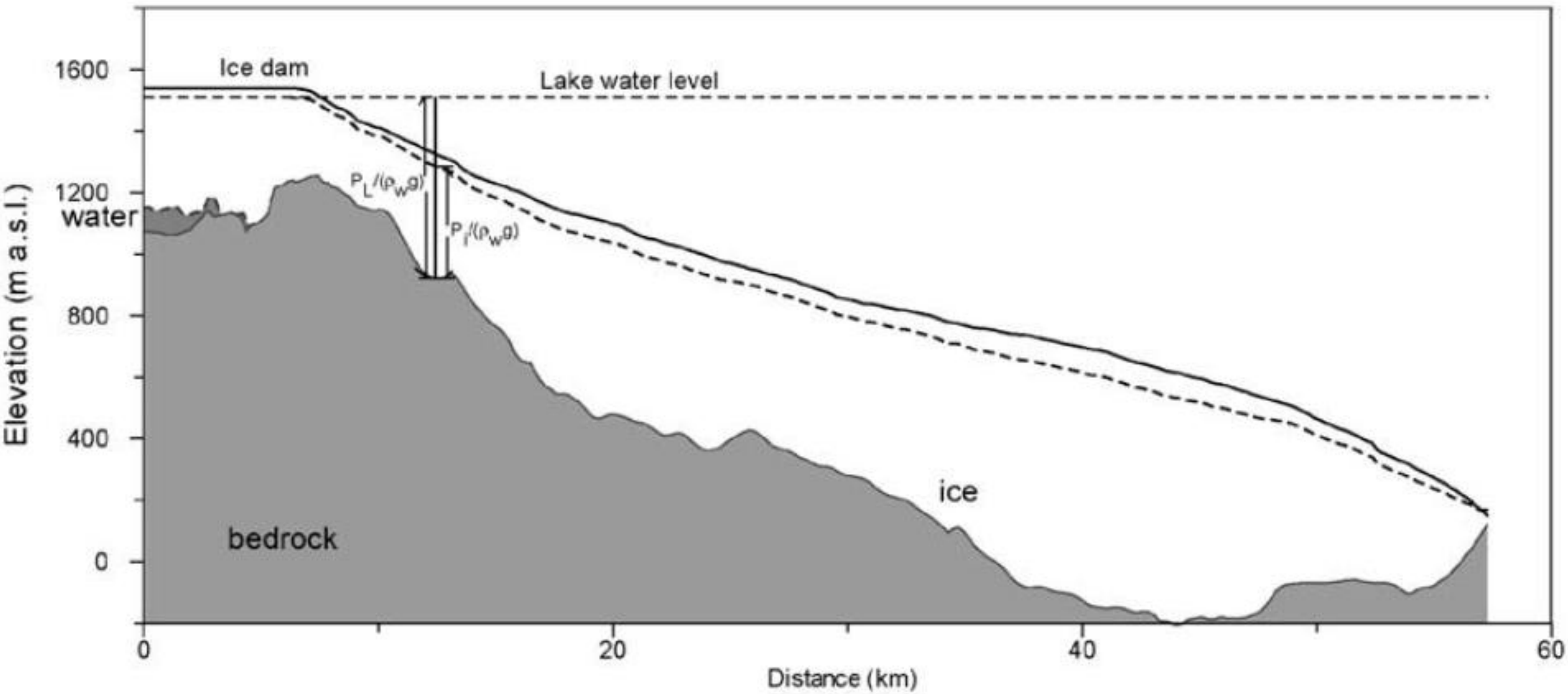


Russell, et al., 2006, Geomorphology 75, 33–64

The lake level of Grımsvötn 1930– 2000. The lake level ascends until a jökulhlaup takes place. In 1996 the lake rose to the level required for floating of the ice dam. The average interval is about 4 years, although many are around 6 years.



H. Björnsson, 2002

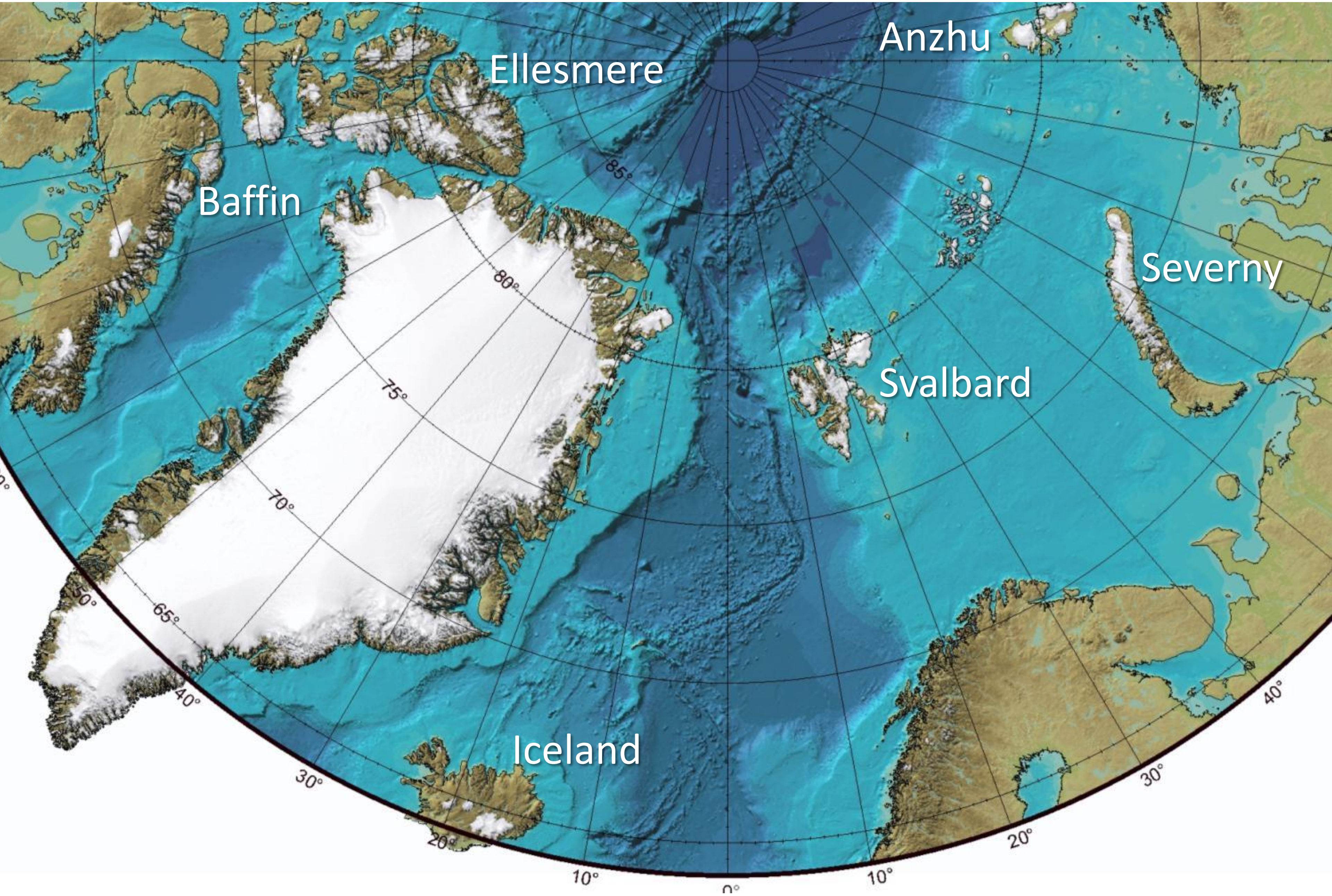


H. Björnsson, 2002

http://daveslandslideblog.blogspot.com/2010/04/extraordinary-video-of-jokulhlaup-in.html

Jökulhlaup cascading off the margins of the Eyjafjallajokull volcano, Iceland, on 14th April 2010

Ice-cap and outlet glaciers on Svalbard


Anzhu
Ellesmere
Baffin
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Svalbard
Iceland
85°
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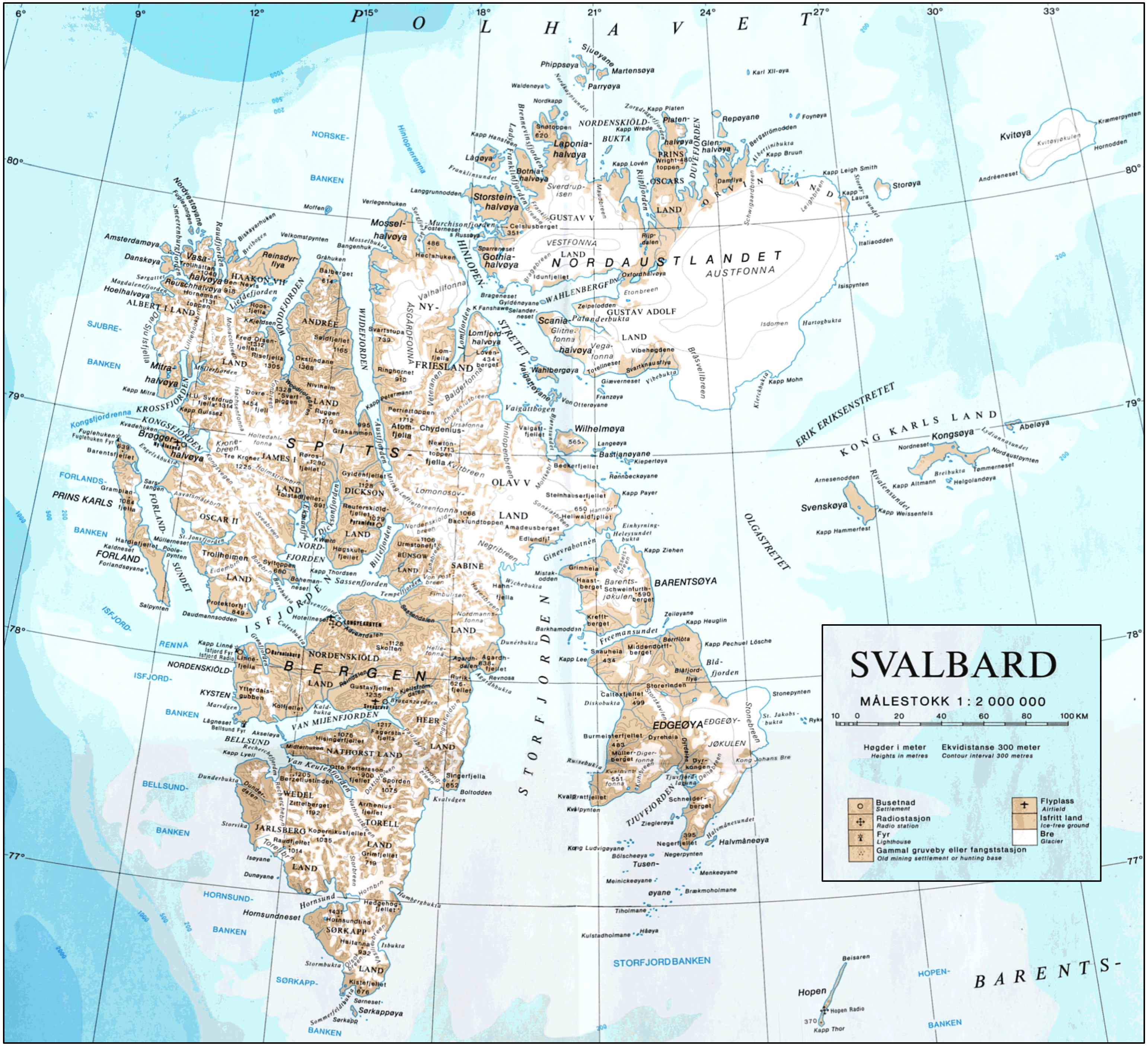

SVALBARD
MÅLESTOKK 1 : 2 000 000
10 0 20 40 60 80 100 KM
Høgder i meter
Heights in metres
Ekvidistanse 300 meter
Contour interval 300 metres
○ Busetnad
Settlement
Radiostasjon
Radio station
Fyr
Lighthouse
Gammal gruveby eller fangststasjon
Old mining settlement or hunting base
Flyplass
Airfield
Isfritt land
Ice-free ground
Bre
Glacier
POLHAVET
BARENTS-
6° 9° 12° 15° 18° 21° 24° 27° 30° 33°
80° 79° 78° 77°
NORSKE-BANKEN
SJUBRE-BANKEN
FORLANDS-BANKEN
ISFJORD-RENNA
ISFJORD-BANKEN
BELLSUND-BANKEN
HORNSUND-BANKEN
SØRKAPP-BANKEN
STORFJORDBANKEN
HOPEN-BANKEN
Hinlopenrenna
Kongsfjordrenna
Sjuøyane
Phippsøya
Martensøya
Parryøya
Karl XII-øya
Waldenøya
Nordkapp
Repøyane
Foynøya
Kvitøya
Kvitøyjøkulen
Kræmerpynten
Hornodden
Andréeneset
Storøya
Kapp Leigh Smith
NORDENSKIÖLD-BUKTA
Platen-halvøya
Laponia-halvøya
Botnia-halvøya
Storstein-halvøya
Lågøya
Franklinsundet
Glen-halvøya
PRINS OSCARS LAND
DUVEFJORDEN
Rijpfjorden
Sverdrup-isen
GUSTAV V LAND
ORVIN LAND
Mossel-halvøya
Murchisonfjorden
Gothia-halvøya
VESTFONNA
NORDAUSTLANDET
AUSTFONNA
Isispynten
Isdomen
Hartogbukta
Etonbreen
WAHLENBERGFJ.
GUSTAV ADOLF LAND
Scania-halvøya
Palanderbukta
Vega-halvøya
Bråsvellbreen
Wahlbergøya
HINLOPENSTRETET
Vaigattøyane
Wilhelmøya
Bastianøyane
Kapp Mohn
ERIK ERIKSENSTRETET
KONG KARLS LAND
Kongsøya
Abeløya
Svenskøya
Kapp Hammerfest
OLGASTRETET
Moffen
Verlegenhuken
Velkomstpynten
Nordvestøyane
Amsterdamøya
Danskøya
Vasa-halvøya
Reinsdyr-flya
HAAKON VII LAND
Hoelhalvøya
ALBERT I LAND
WOODFJORDEN
ANDRÉE LAND
WIDJEFJORDEN
NY-FRIESLAND
ÅSGÅRDFONNA
Mitra-halvøya
KROSSFJORDEN
KONGSFJORDEN
Brøgger-halvøya
SPITSBERGEN
JAMES I LAND
Atomfjella
Chydeniusfjella
OLAV V LAND
Lomonosovfonna
Newtontoppen 1713
PRINS KARLS FORLAND
FORLANDSUNDET
OSCAR II LAND
DICKSON LAND
BUNSOW LAND
SABINE LAND
NORDFJORDEN
Trollheimen
ISFJORDEN
Sassenfjorden
Tempelfjorden
Longyearbyen
NORDENSKIÖLD LAND
BARENTSØYA
Barentsjøkulen
Freemansundet
STORFJORDEN
Kapp Linné
VAN MIJENFJORDEN
HEER LAND
NATHORST LAND
Van Keulenfjorden
WEDEL JARLSBERG LAND
TORELL LAND
EDGEØYA
EDGEØYJØKULEN
Stonebreen
Kong Johans Bre
TJUVFJORDEN
Halvmåneøya
Tusenøyane
Hornsund
SØRKAPP LAND
Sørkappøya
Hopen
Hopen Radio
Kapp Thor
Beisaren

Surge Glaciers

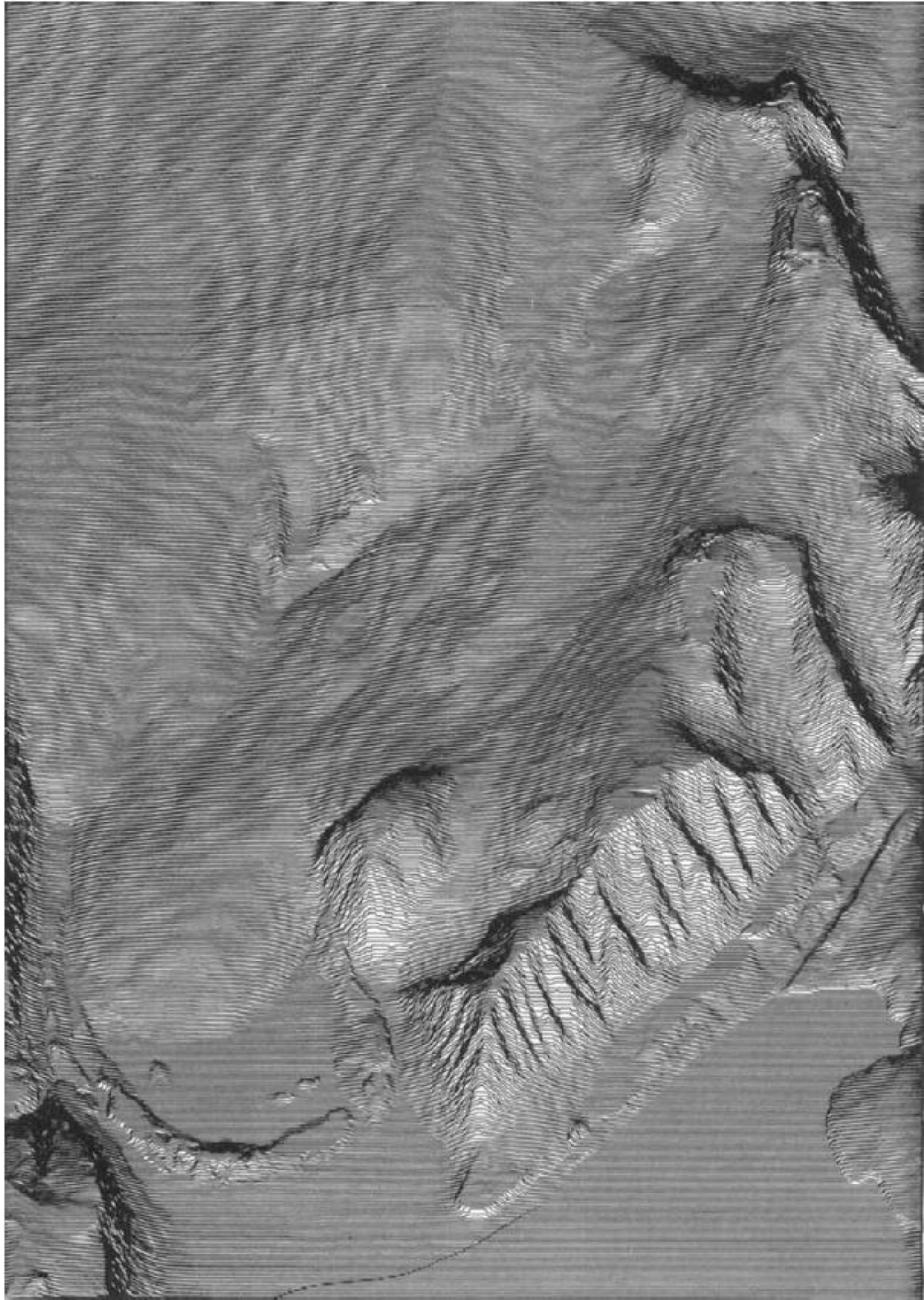
- ~1% of glaciers on earth show surge behaviour (13 to 90% of Svalbard Glaciers)
- Glacier becomes decoupled from its base
- On Svalbard most surge glaciers are in areas where the bed is soft sedimentary rock (and therefore the till is soft and clay-rich)
- Base temperature also appears to be an important factor

Hagen, J. 0. 1987: Glacier surge at Usherbreen, Svalbard. ***Polar Research 5 p. 239-252.***

Usherbreen started to surge in 1978, and the front has advanced 1.5 km and covered an area of 4.5 km'. During the first two years the front advanced more than 1 m/d, and the front was still advancing 0.15-0.20m/d in 1985, seven years after the start. The mean gradient of the lower 7km decreased from 3.3 grad. to 1.8 grad. during the surge. The volume of ice transported down the glacier from higher to lower parts during the surge was 815 x 10hm3. which is almost 20% of the total glacier volume.

Old ice-cored ridges in front of the glacier were reactivated, and the whole ridge system was pushed forward, in the summer of 1985 at a speed of about 0.05 m/d. Parts of the ridge system were moved 200 m during this surge. New ridges were developed on the flat sandur in front of the old ridge system. This demonstrates that the glacier advanced further than in any previous surge.

Jon Oue Hagen. Norsk Polarinstitun. Oslo Lufthavn, Norway;



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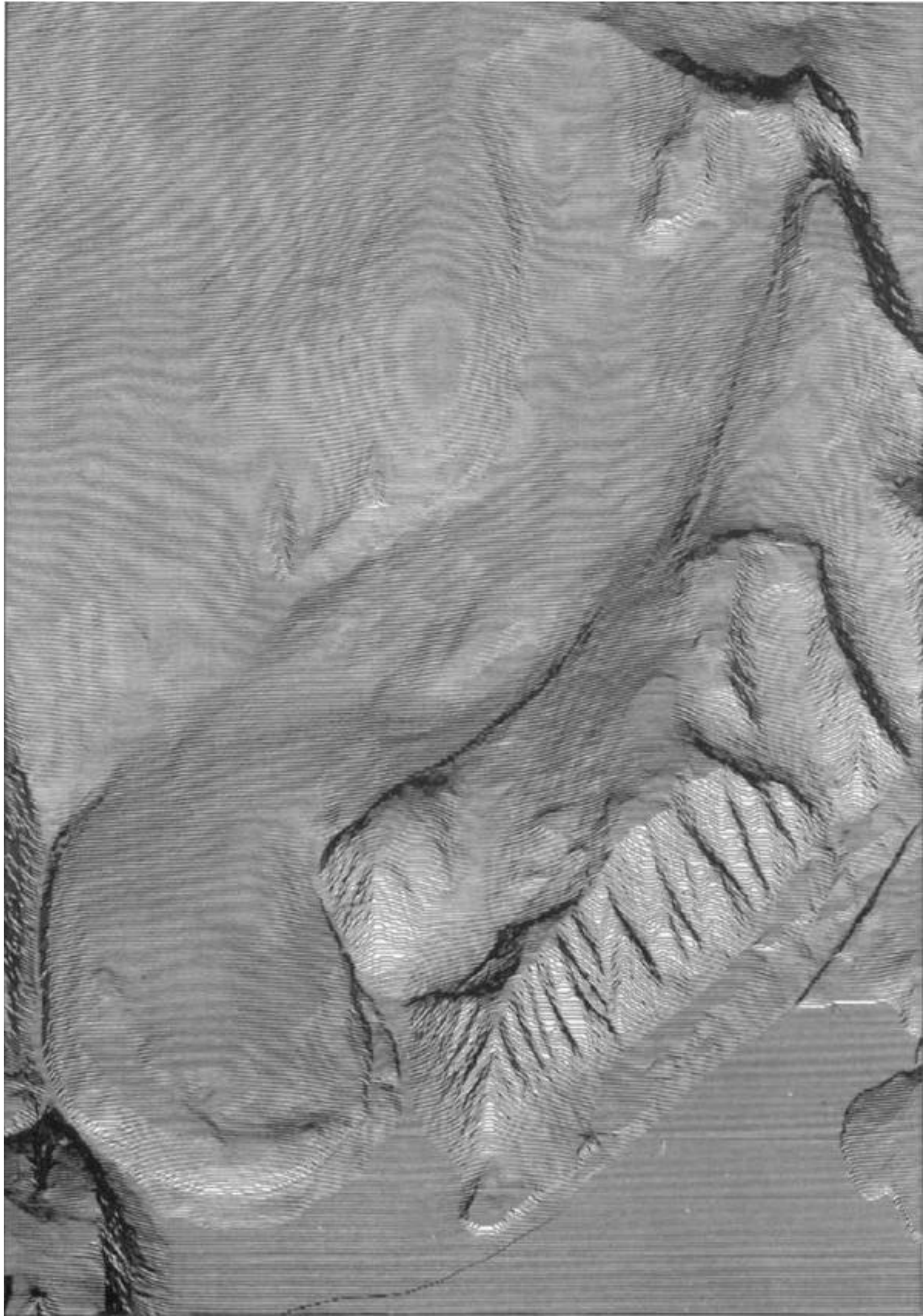


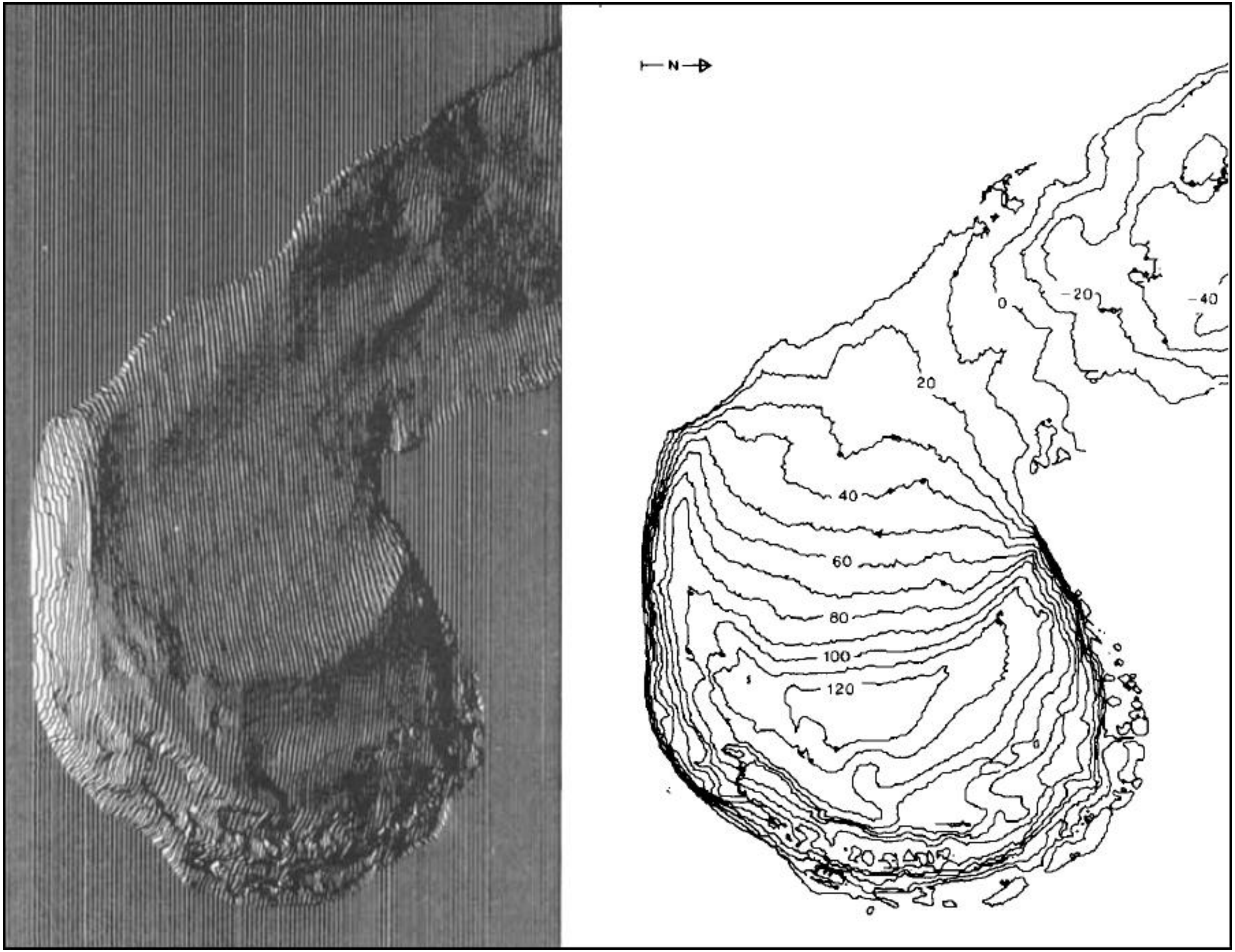
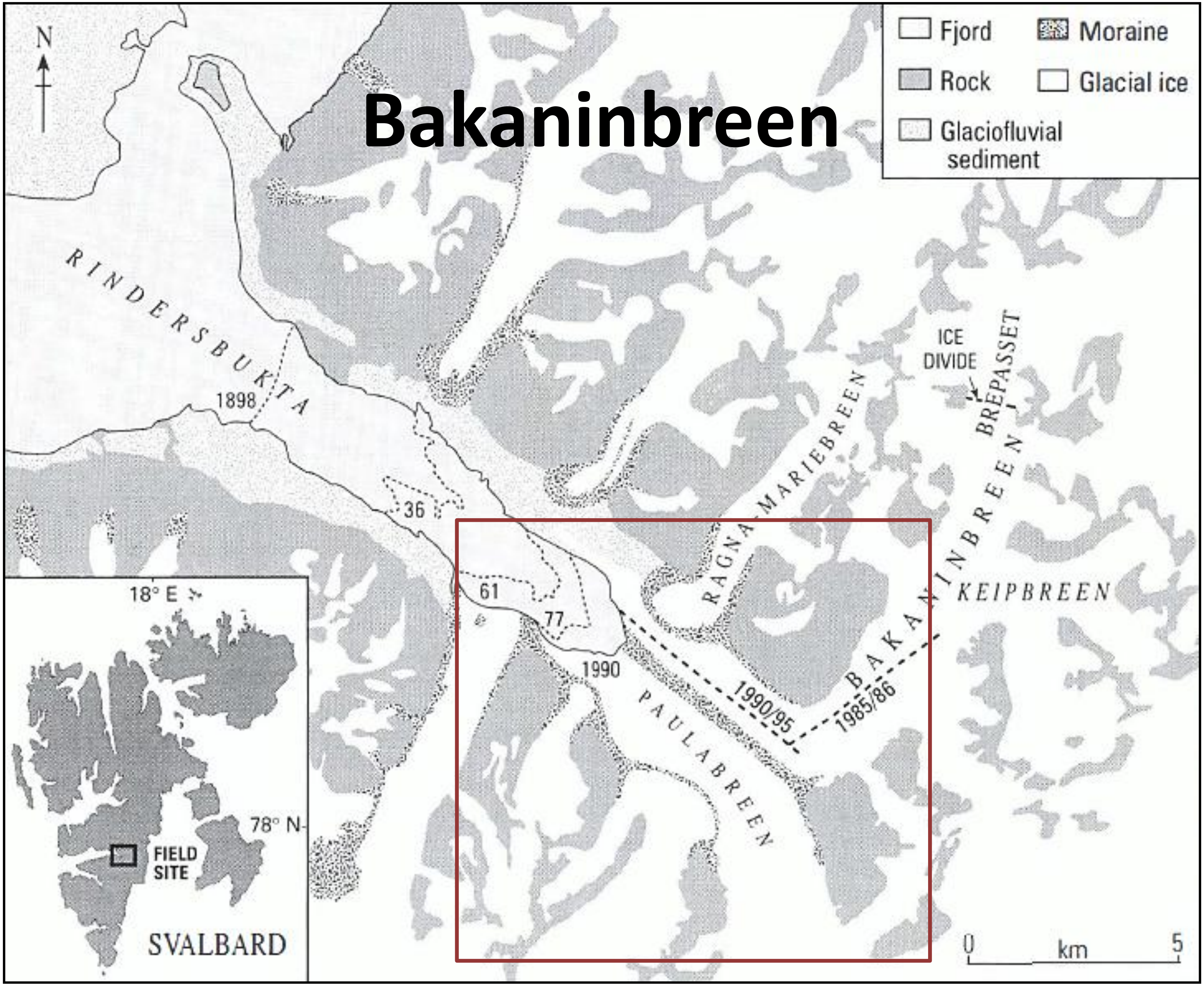
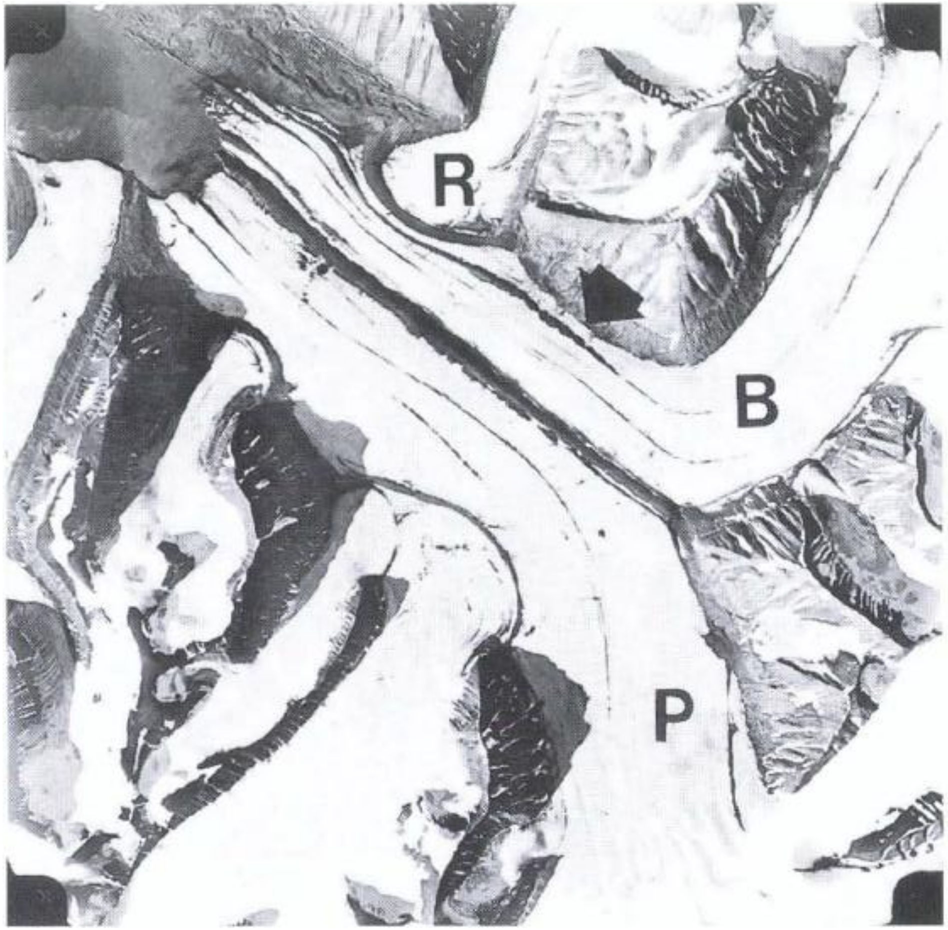

N
0
-20
-40
20
40
60
80
100
120

Fig. 2. The front of Usherbreen after the surge in August 1985. Photo direction is south–north. Note the steep front and the folded moraine ridge systems.

Bakaninbreen



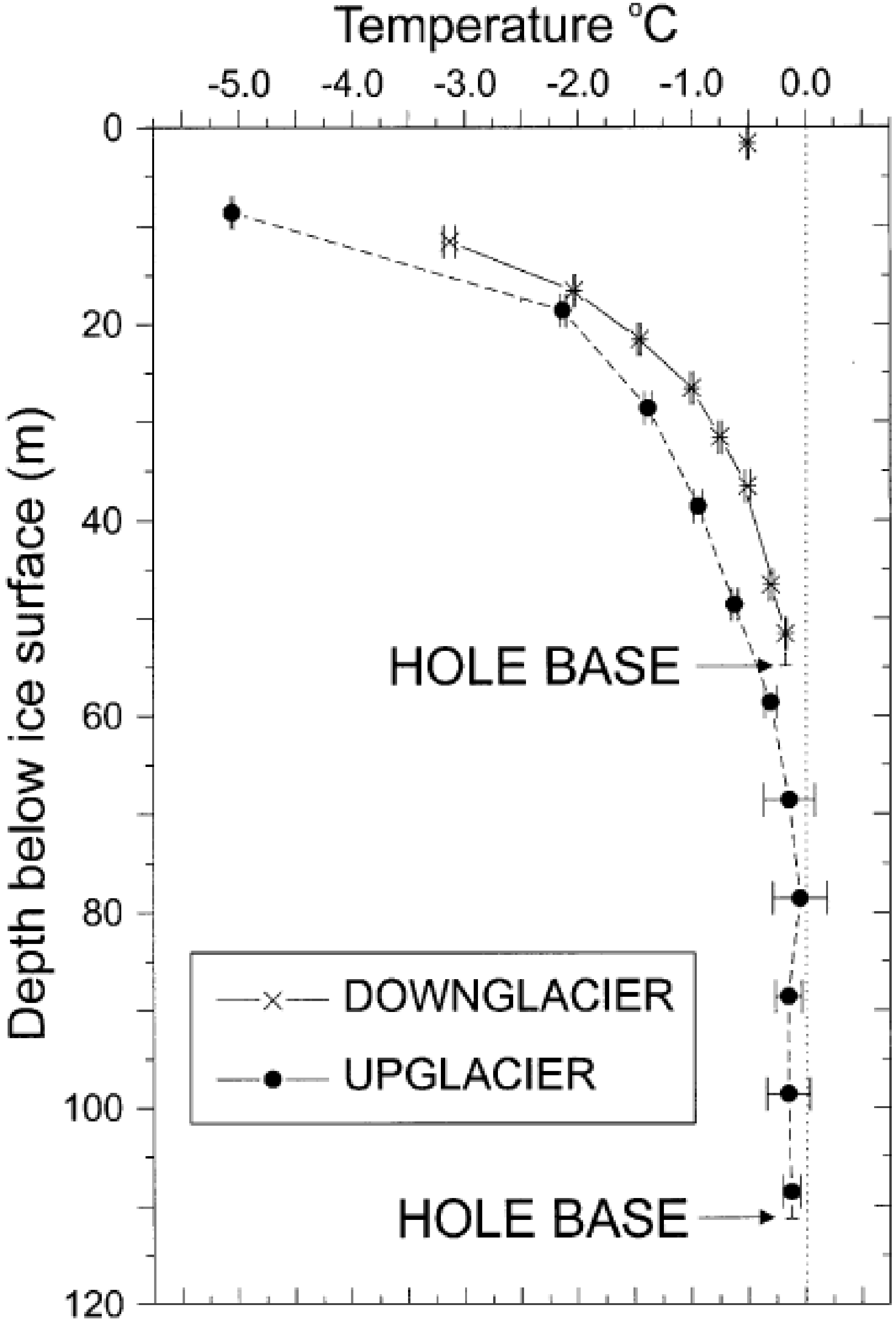
Murray et al, 1998, J. Glaciology, V. 44



Bakaninbreen (B) before (1970) the 1985 to 1990 surge

Bakaninbreen after (1990) the 1985 to 1990 surge

Murray et al, 1998, J. Glaciology, V. 44



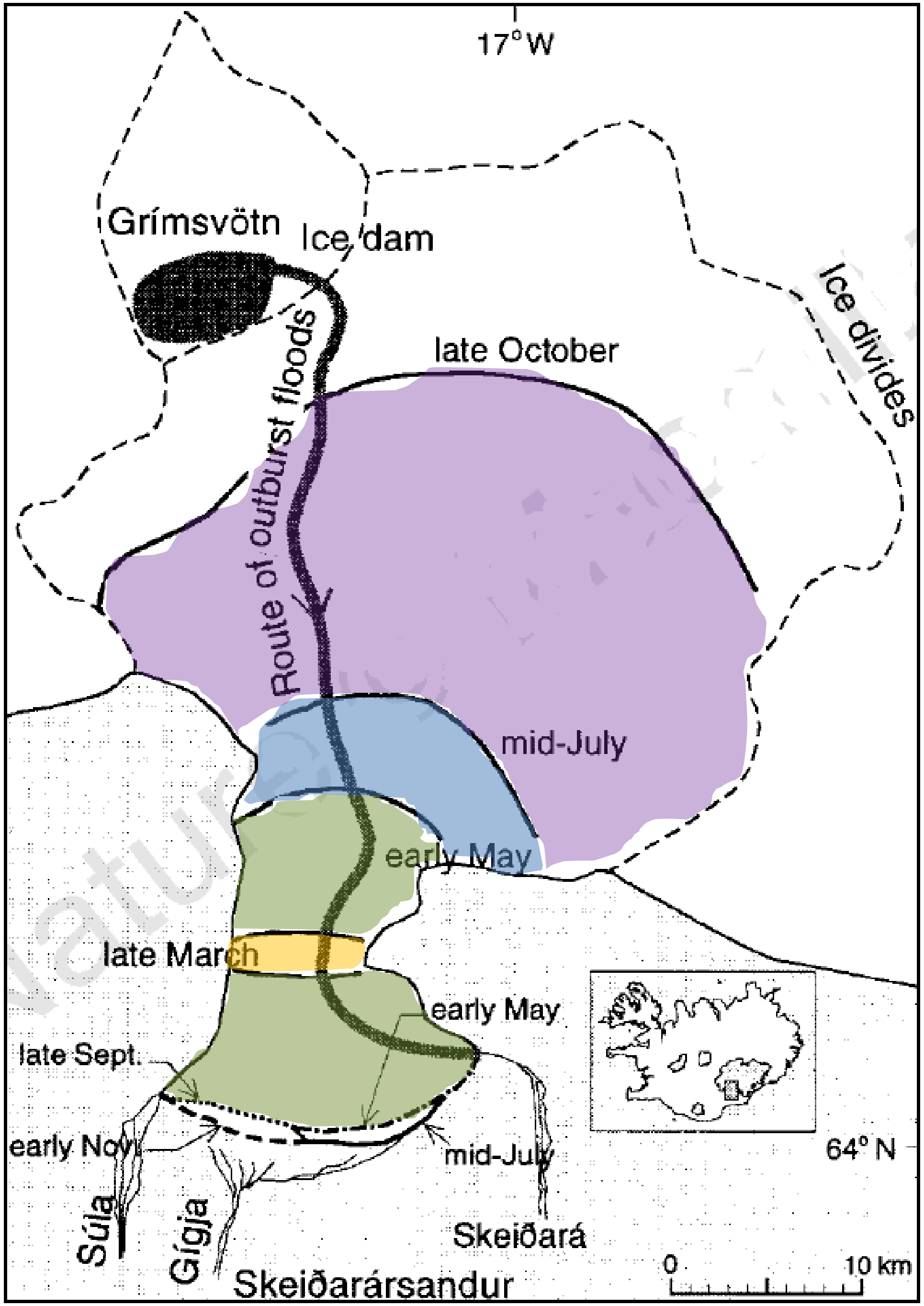
In the surge area (upglacier from the surge front) the ice-sheet base is warm (at the freezing point). Downglacier from the surge front the basal ice is cold.

Murray and Porter, 2001, Quat. International, V. 86

Mechanism

- The Bakaninbreen surge (1985-1990) took place in an area with a warm base
- The front of the surge was at the warm-cold boundary, and that boundary moved ahead during the surge (because the melting front moved)
- Part of the movement in the warm-cold boundary was due to heat created by sliding
- Eventually the movement stopped because there wasn’t enough heat to warm any more of the base

Murray and Porter, 2001, Quat. International, V. 86



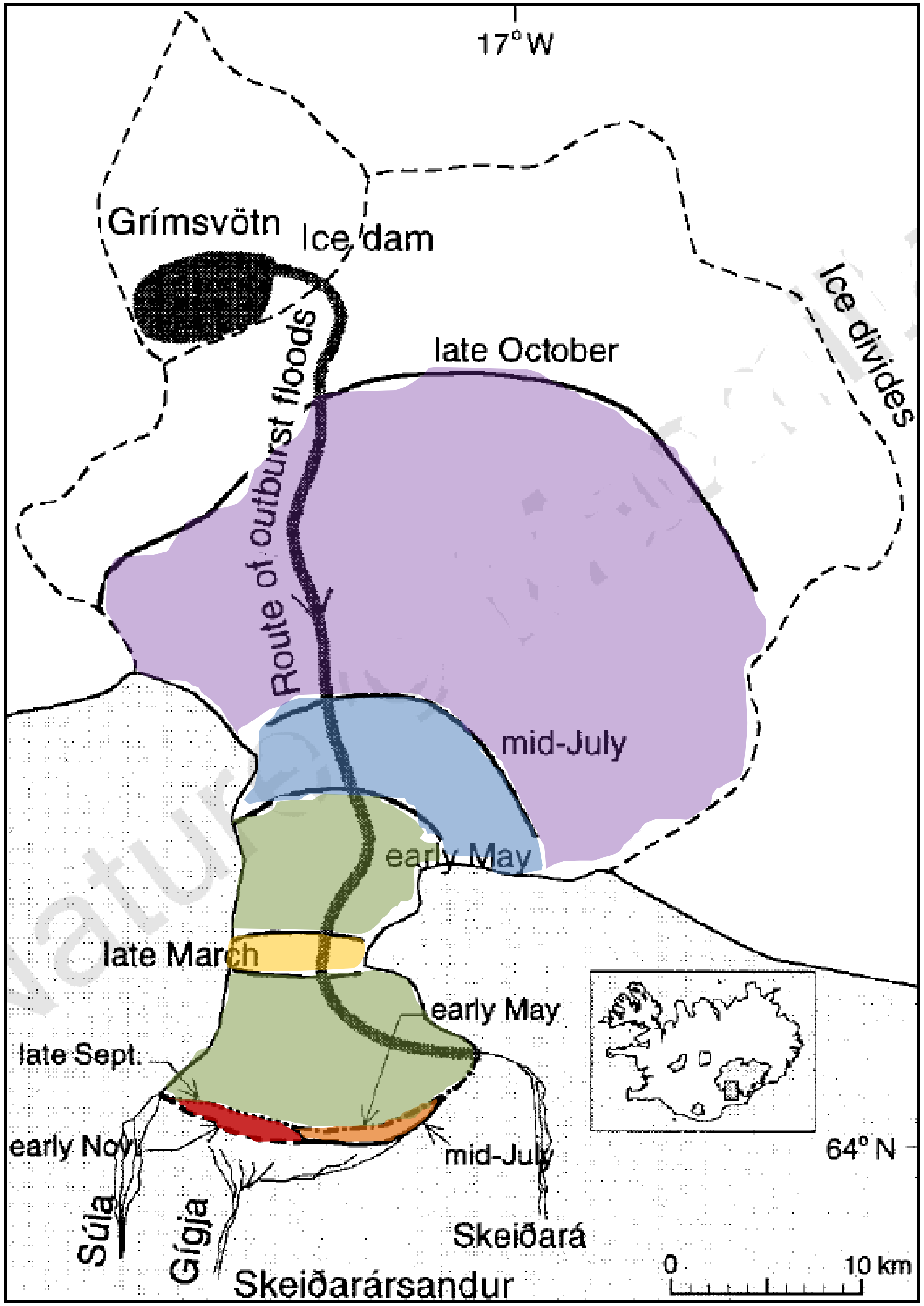
Surge-affected drainage from Skeiðarárjökull in 1991

In late March 1991, Skeiðarárjökull began to surge. The surge motion was not measured but deduced from the formation of abundant new crevasses, which was monitored from the air. Crevasses initially formed 10 km up-glacier from the terminus and propagated up- and down-glacier.

The area affected by increased sliding, producing crevasses, continued to expand up-glacier until the end of October. It ultimately extended some 45 km upwards from the front to within 5 km of the centre of the ice dam containing the Grımsvötn lake.

Bjornsson, 1998, Nature, V. 395

Surge-affected drainage from Skeiðarárjökull in 1991

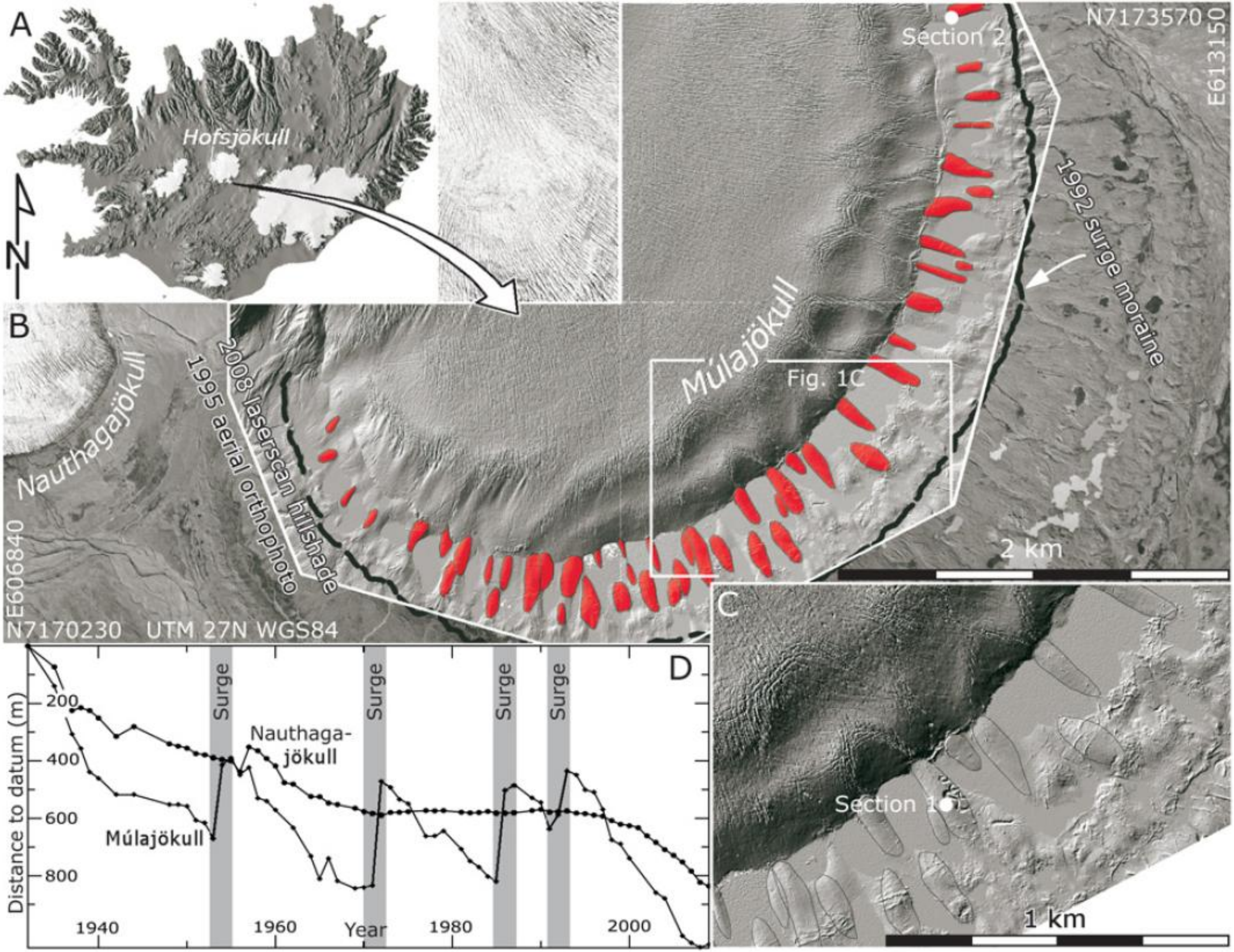


In early May, a 50-m-high surge front reached the eastern part of the terminus and, after having advanced 450 m, stopped in mid-July.

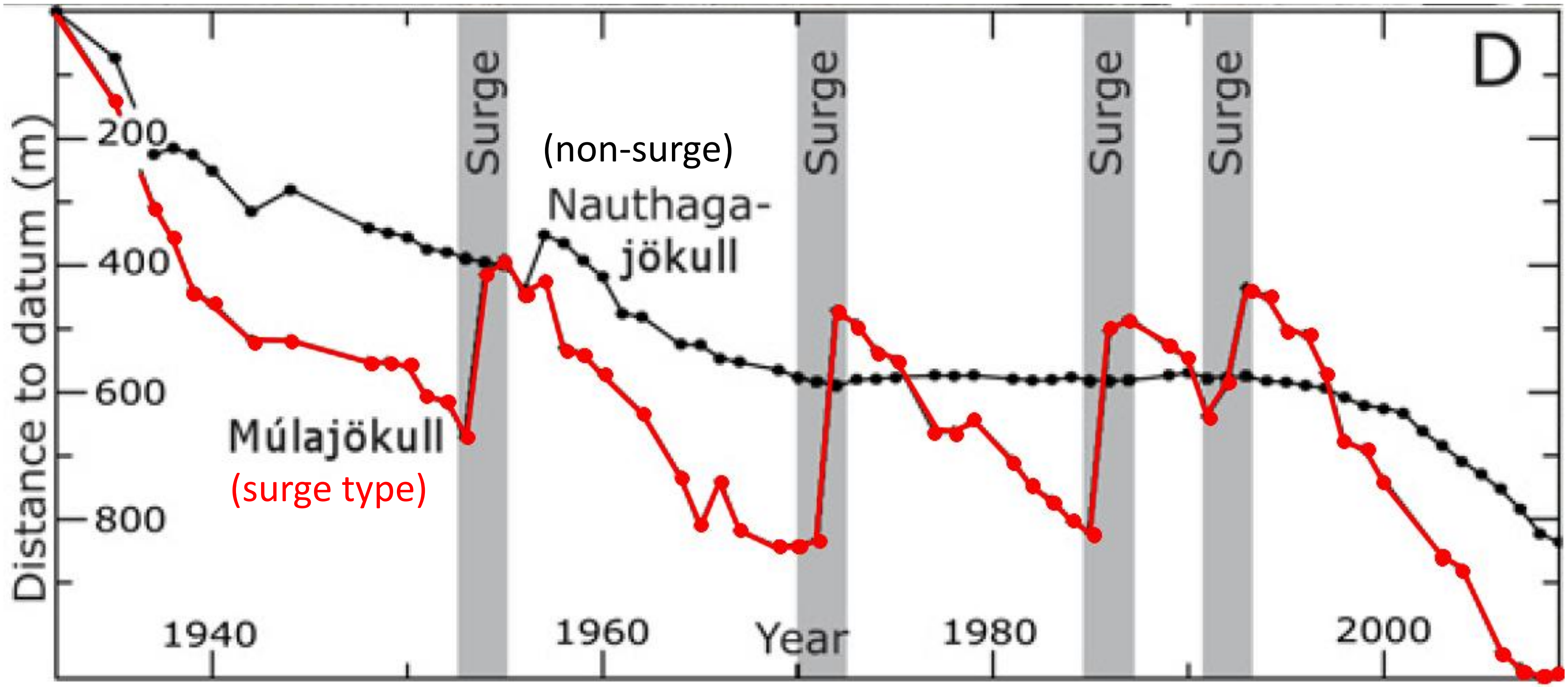
In mid-September drainage began from Grımsvötn lake. The discharge of the lake water increased approximately exponentially and then fell rapidly; this may be explained as drainage through a single tunnel from the lake. The drainage, however, failed to develop into a normal outburst flood and terminated when less than a quarter of the lake volume had drained .

In late September, the western half of the terminus started to advance, and moved forward about 1,000m before halting in early November.

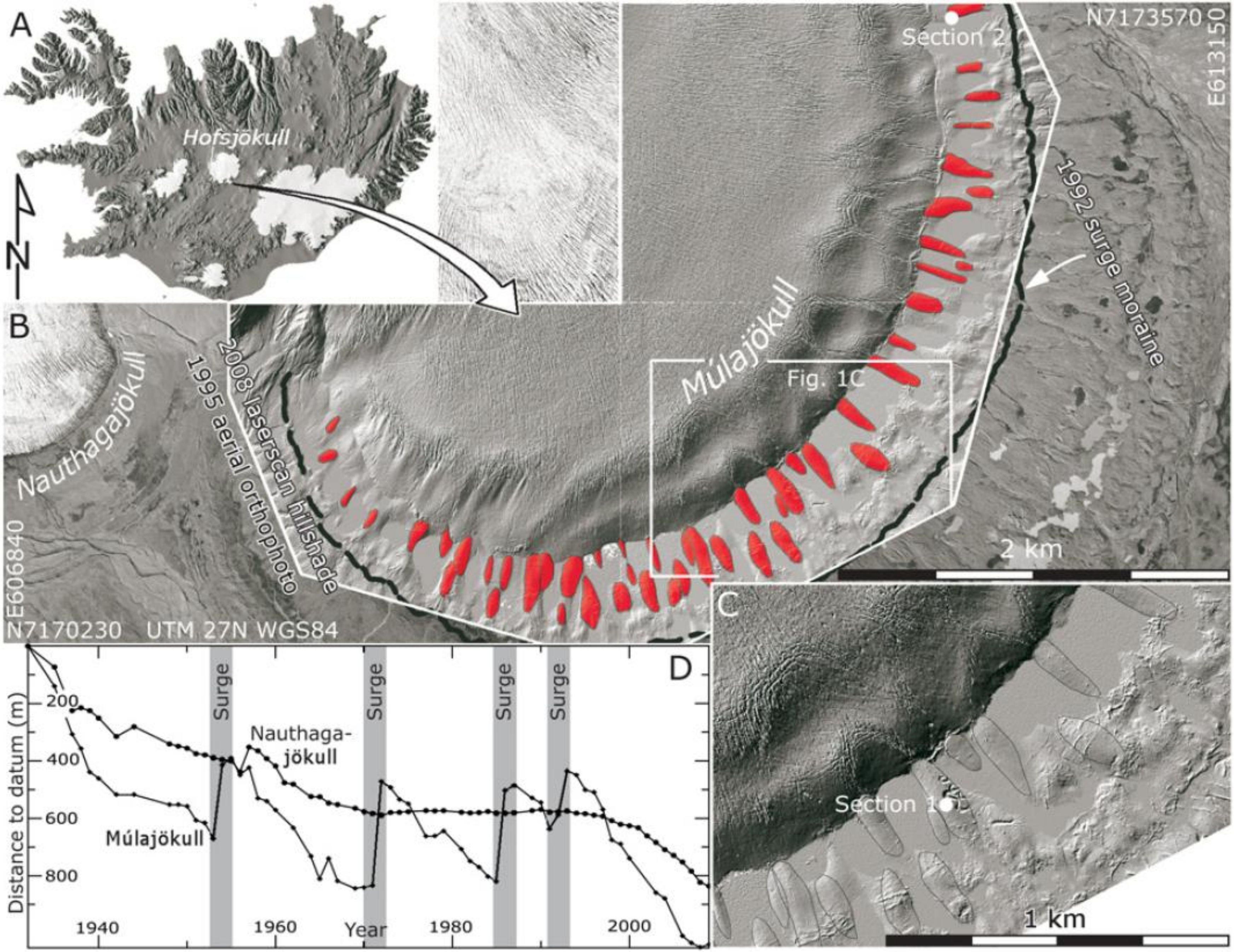
Bjornsson, 1998



Johnson et al., 2010, Geology, V. 38



Johnson et al., 2010, Geology, V. 38



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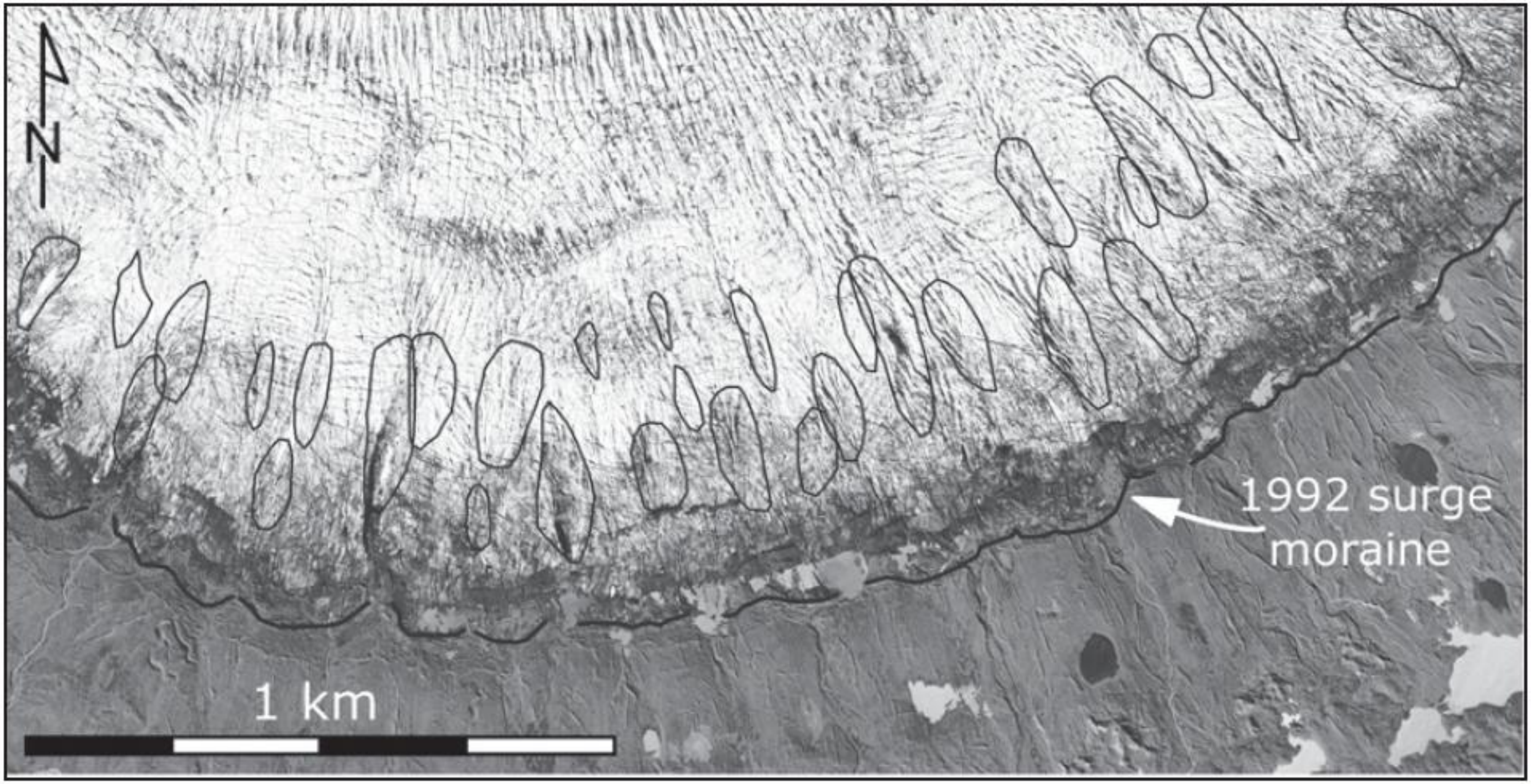

Figure 5. Drumlins from Figure 1 superimposed on 1995 air photo, showing that most drumlins are located below deep longitudinal crevasses or crevasse swarms near glacier margin.

Johnson et al., 2010, Geology, V. 38