
The effect
of supraglacial debris
in permafrost regions

# The effect of supraglacial debris in permafrost regions

1: Environmental considerations

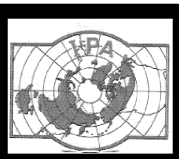
2: Thermal glacier types in permafrost regions

3: Source of supraglacial debris

4: Supraglacial debris: effects on ablation

5: Deglaciation in permafrost regions

# CIRCUM-ARCTIC MAP OF PERMAFROST AND GROUND-ICE CONDITIONS



| Extent of Permafrost (percent of area) | Ground-Ice Content (visible ice in the upper 10-20m of the ground; percent volume) | | | | |
|---|---|---|---|---|---|
| | Lowlands, highlands, and intra- and intermontane depressions characterized by thick overburden cover (f) (>5-10m) | | | Mountains, highlands, ridges, and plateaus characterized by thin overburden cover (<5-10m) and exposed bedrock (r) | |
| | High (>20%) | Medium (10-20%) | Low (0-10%) | High to Med. (>10%) | Low (0-10%) |
| Continuous (90-100%) | Chf (1)* | Cmf (5) | Clf (9) | Chr (13) | Clr (17) |
| Discontinuous (50-90%) | Dhf (2) | Dmf (6) | Dlf (10) | Dhr (14) | Dlr (18) |
| Sporadic (10-50%) | Shf (3) | Smf (7) | Slf (11) | Shr (15) | Slr (19) |
| Isolated Patches (0-10%) | Ihf (4) | Imf (8) | Ilf (12) | Ihr (16) | Ilr (20) |

*letters & numbers adjacent to color codes refer to polygon classes in ArcInfo database.

Glacier G (21) Current digital version does not include European and Asian glaciers. Outlines of the glacier margins will become crowded and appear black at small scales.

Deep relict permafrost (where known) R (22)

Lakes L (23)
Ocean/Inland Seas O (24)
(Incomplete coverage)

Land Ld (25)
(no country boundaries north of 50° latitude)

Limit of area within which subsea permafrost is known or presumed to occur

Northern limit of trees

Limit of the minimum sea-ice edge

30°

30°

70°

50°

Digital version based on USGS Circum-Pacific Map Series Map CP-45; compiled and edited by Jerry Brown, Oscar J. Ferrians, Jr., J. Alan Heginbottom, and Evgeny S. Melnikov.
Original digital version prepared by UNEP/GRID-Arendal, Norway

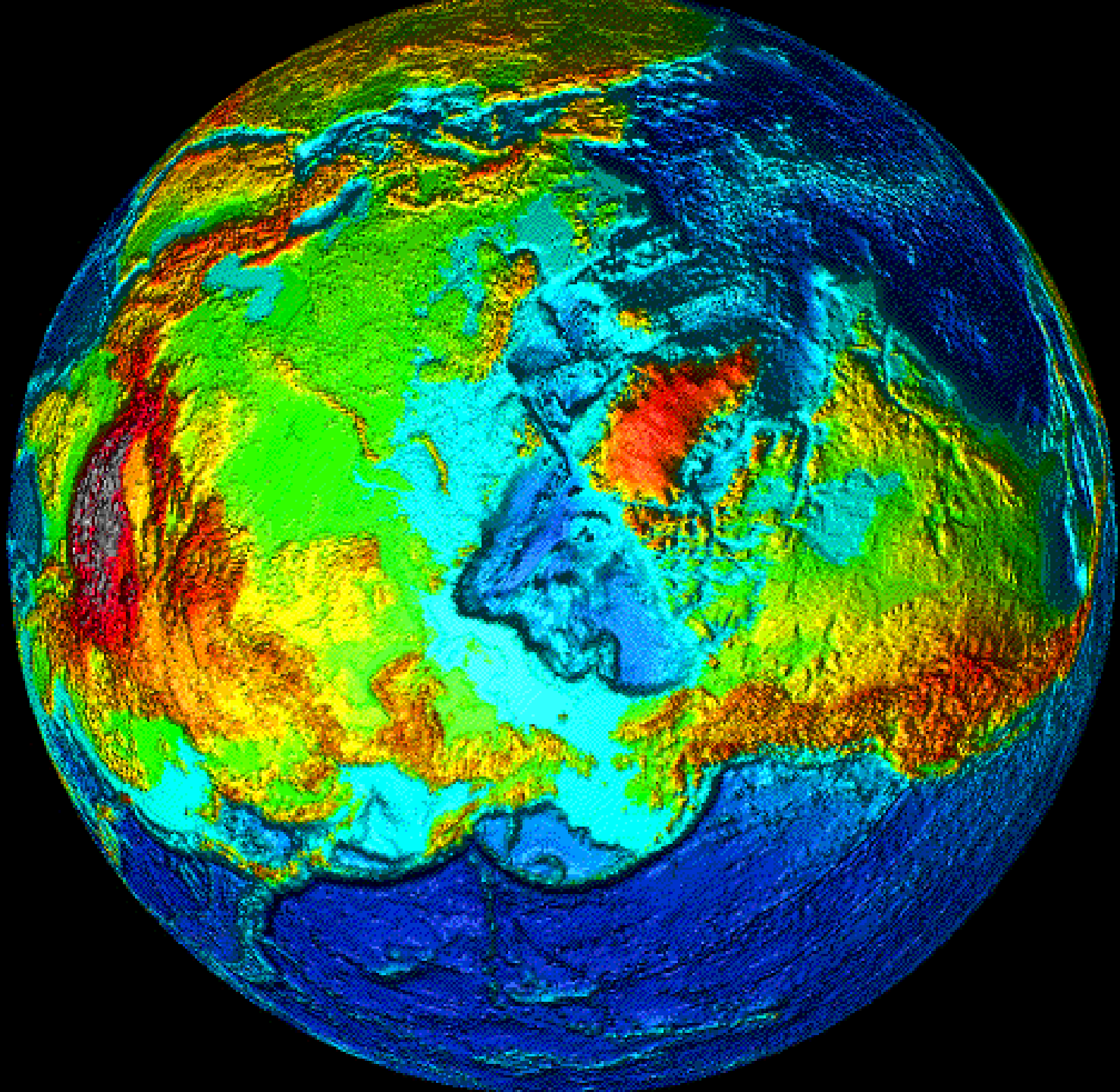
Source: International Permafrost Association, Data and Information Working Group, comp. 1998. Circumpolar Active-Layer Permafrost System (CAPS), version 1.0. CD-ROM Available from National Snow and Ice Data Center, nsidc@kryos.colorado.edu. Boulder, Colorado: NSIDC, University of Colorado at Boulder.

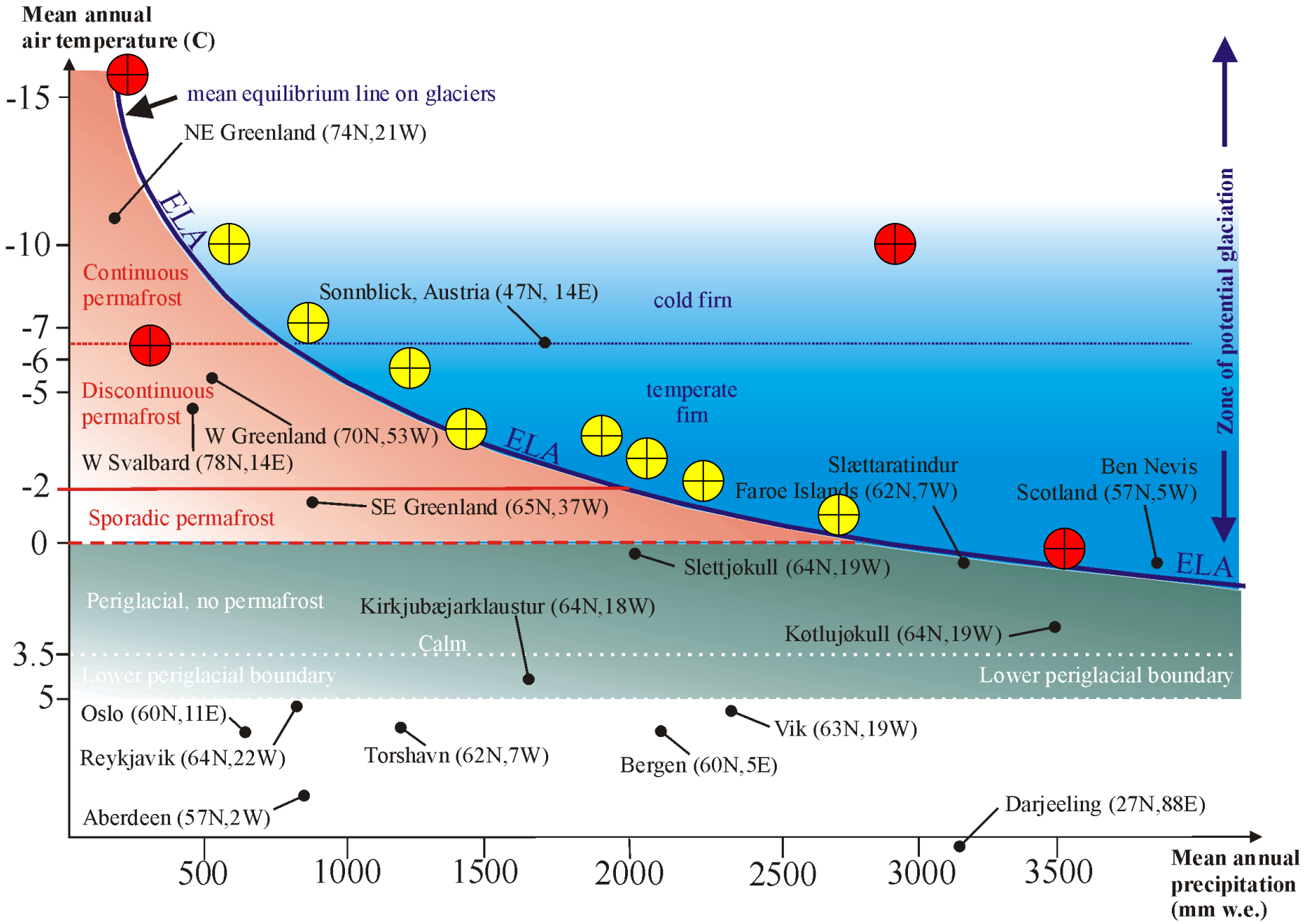
Lambert Azimuthal Equal-Area Projection
Map Center Point: North Pole
Scale 1:20,000,000

500 0 500 1000 1500 2000 Kilometers

250 0 250 500 750 1000 Miles

April 1998

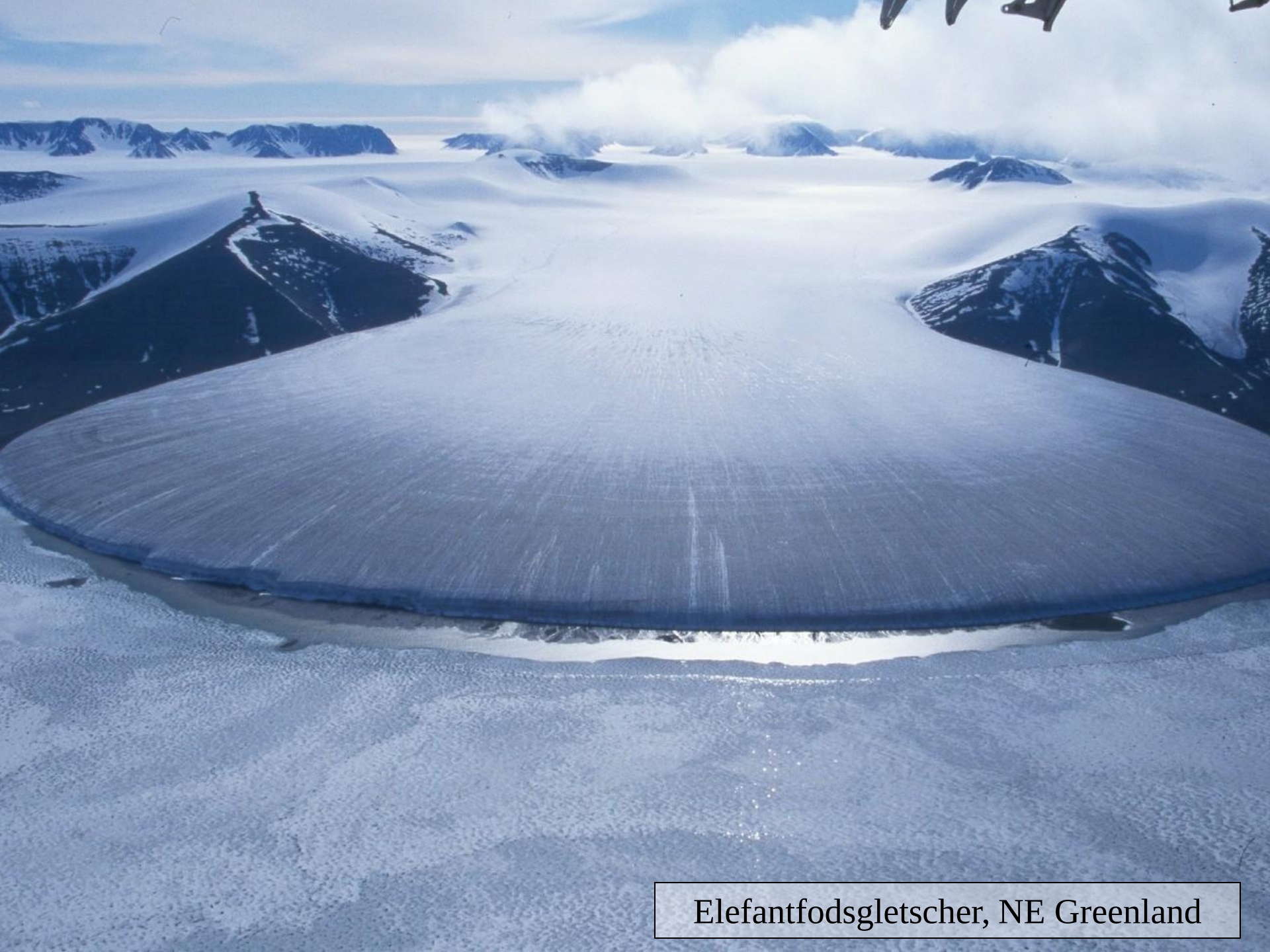



Mean annual
air temperature (C)
-15
-10
-7
-6
-5
-2
0
3.5
5
mean equilibrium line on glaciers
NE Greenland (74N,21W)
ELA
Continuous
permafrost
Discontinuous
permafrost
W Svalbard (78N,14E)
W Greenland (70N,53W)
Sonnblick, Austria (47N, 14E)
cold firn
temperate
firn
ELA
Sporadic permafrost
SE Greenland (65N,37W)
Slettjøkull (64N,19W)
Slættaratindur
Faroe Islands (62N,7W)
Ben Nevis
Scotland (57N,5W)
ELA
Zone of potential glaciation
Periglacial, no permafrost
Kirkjubæjarklaustur (64N,18W)
Calm
Køtlujøkull (64N,19W)
Lower periglacial boundary
Lower periglacial boundary
Oslo (60N,11E)
Reykjavik (64N,22W)
Torshavn (62N,7W)
Bergen (60N,5E)
Vik (63N,19W)
Aberdeen (57N,2W)
Darjeeling (27N,88E)
500
1000
1500
2000
2500
3000
3500
Mean annual
precipitation
(mm w.e.)

Ole Humlum

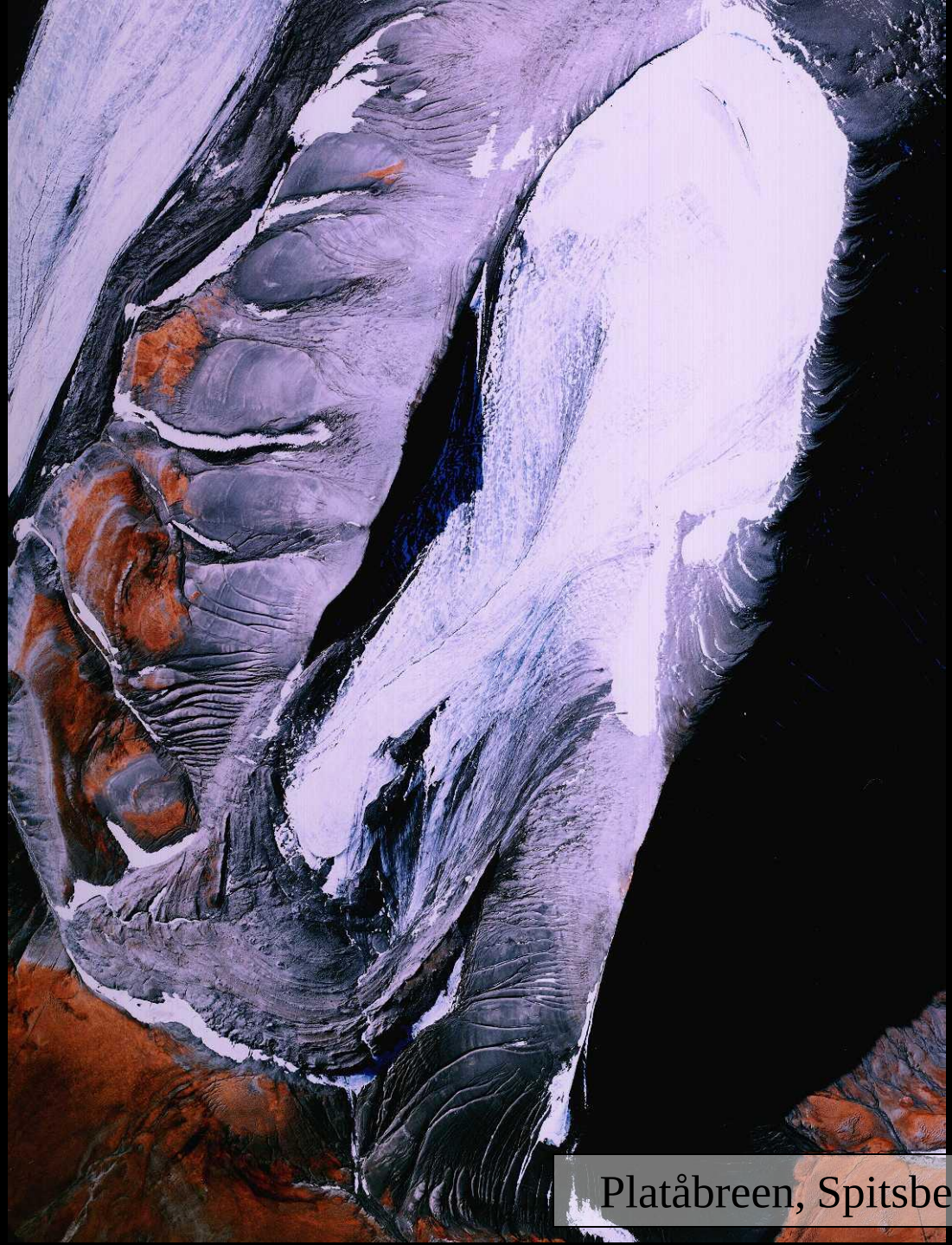
# Thermal glacier types in permafrost regions

Dry valley, Antarctic



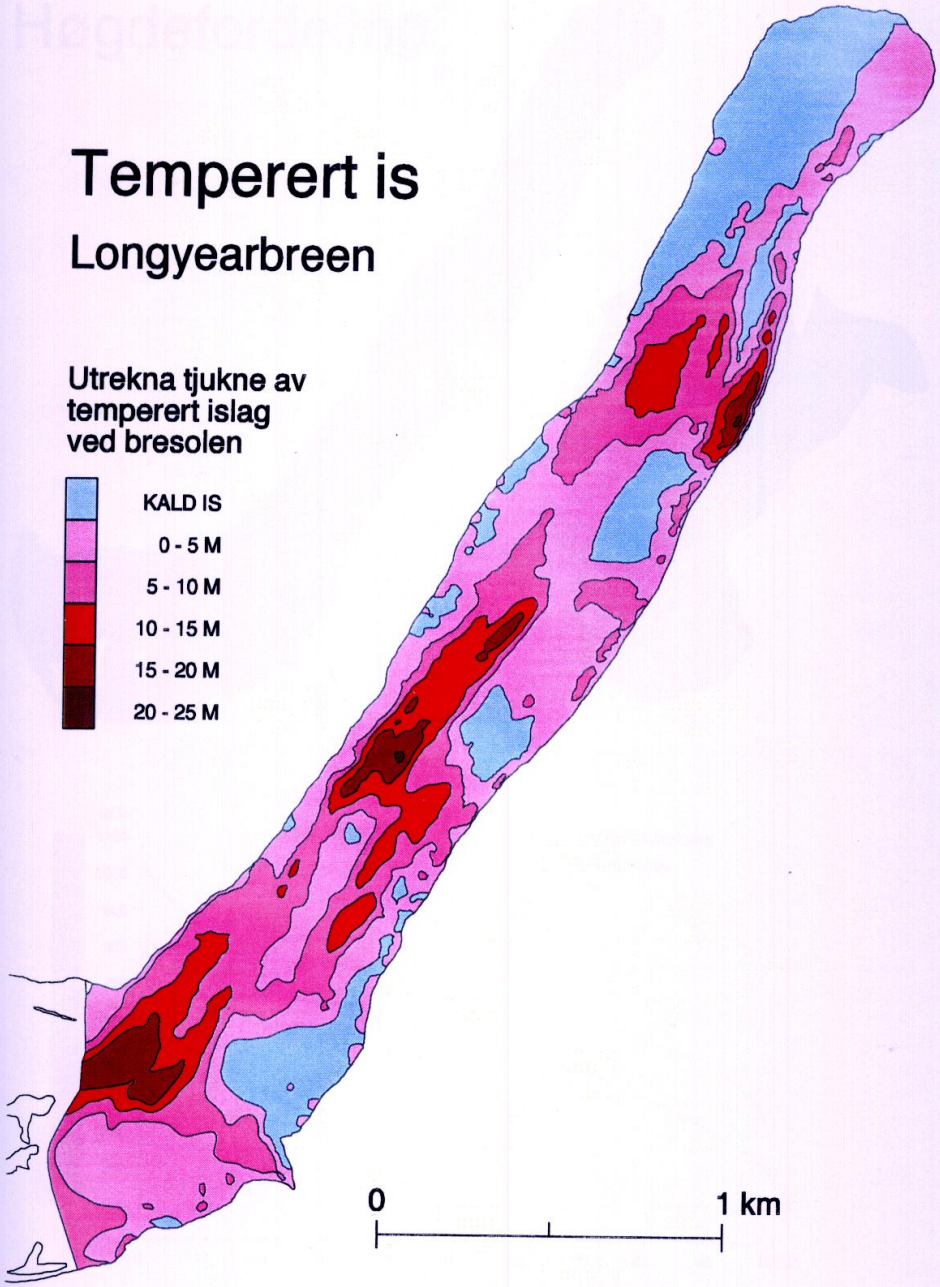
Elefantfodsgletscher, NE Greenland

Hofmannskees, Gross Glockner, Austria

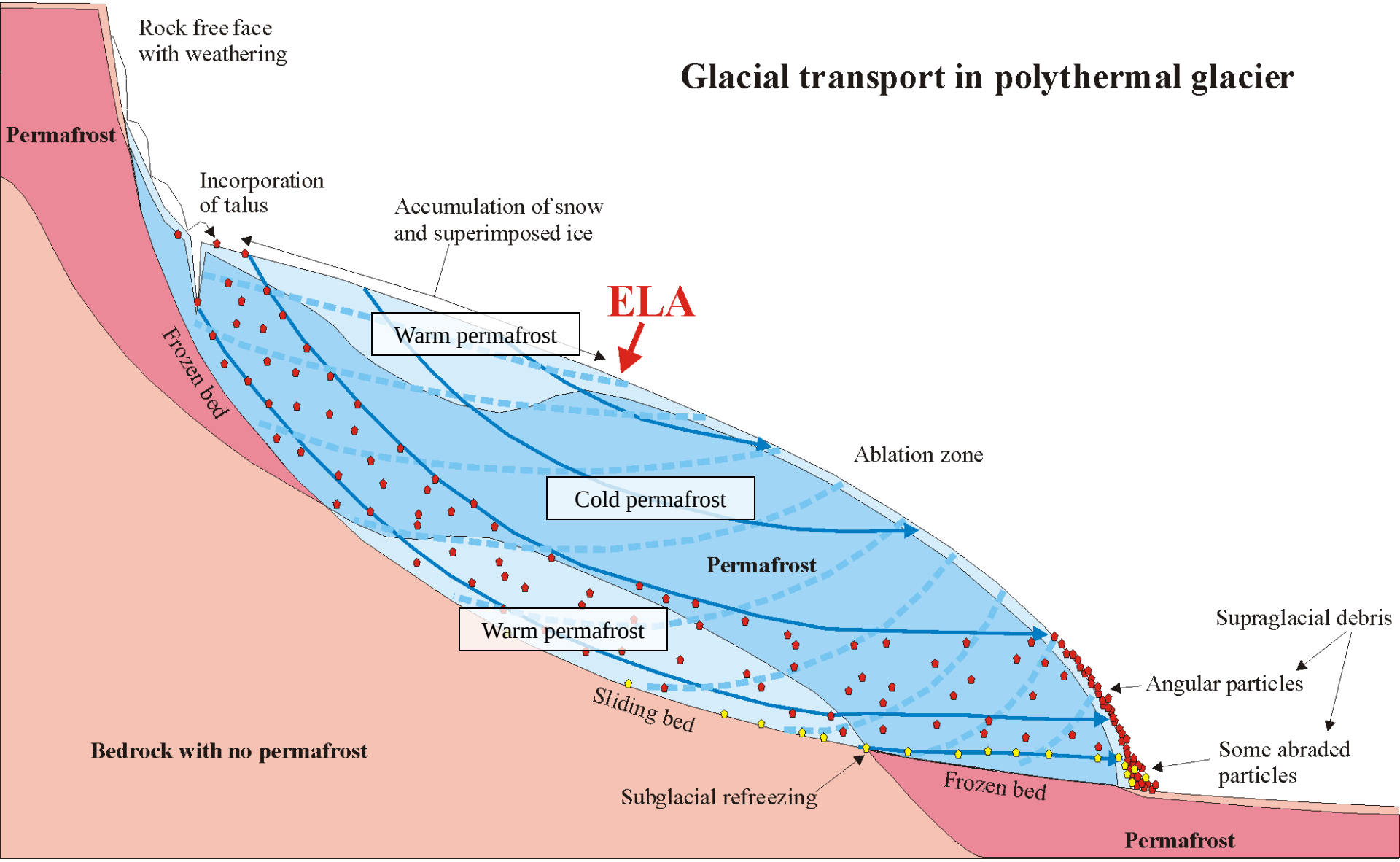


Platåbreen, Spitsbergen, Svalbard

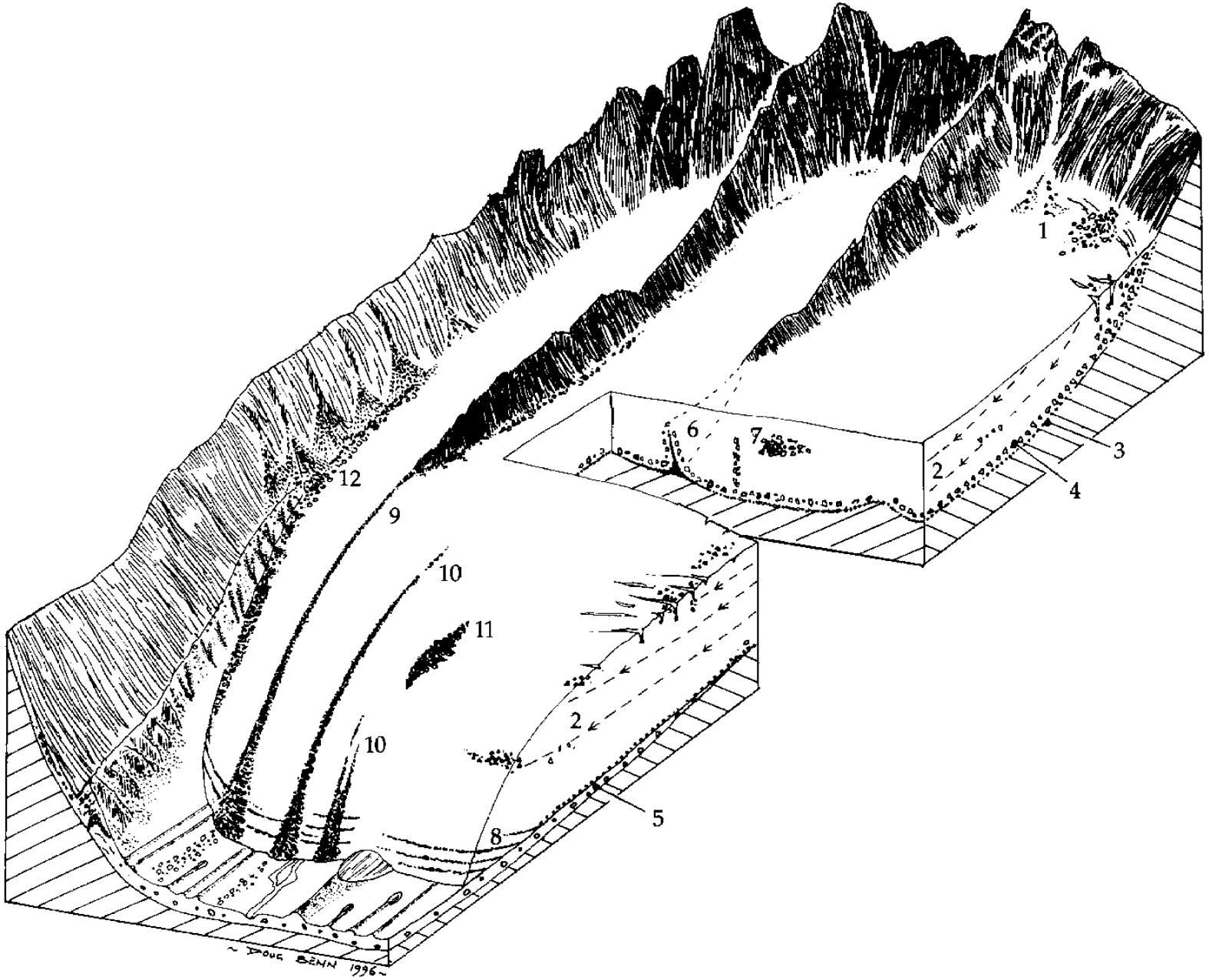

Longyearbreen, Spitsbergen, Svalbard




Figur 3.8: *I følgje radarmålingane har eit temperert islag under Longyearbreen ei utbreiing som synt over.*


Glacial transport in polythermal glacier
Rock free face
with weathering
Permafrost
Incorporation
of talus
Accumulation of snow
and superimposed ice
ELA
Warm permafrost
Frozen bed
Ablation zone
Cold permafrost
Permafrost
Warm permafrost
Supraglacial debris
Angular particles
Some abraded
particles
Sliding bed
Bedrock with no permafrost
Subglacial refreezing
Frozen bed
Permafrost

# The source of supraglacial debris


1
2
3
4
5
6
7
8
9
10
10
11
12
2
~ DOUG BENN 1996 ~

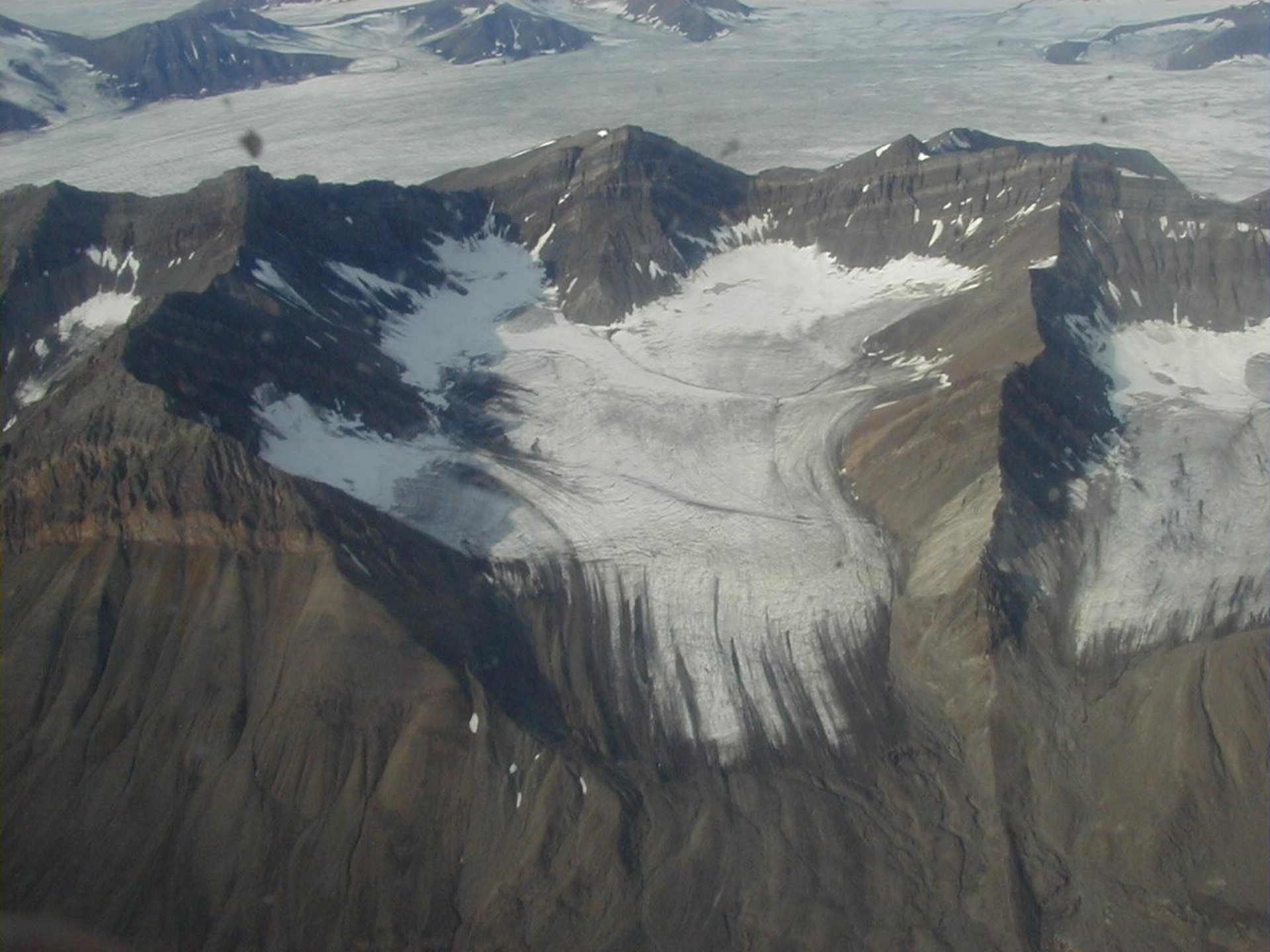
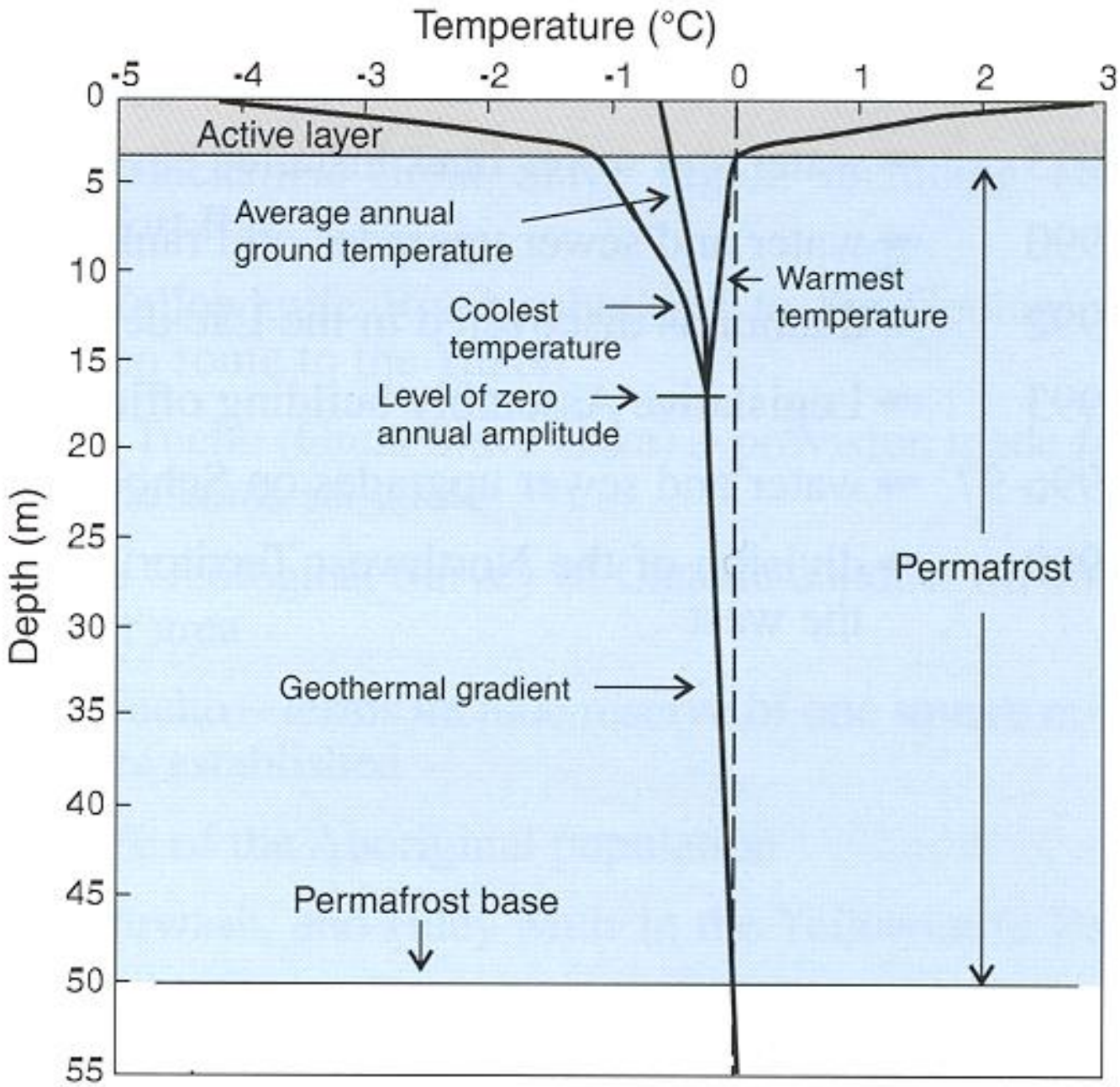
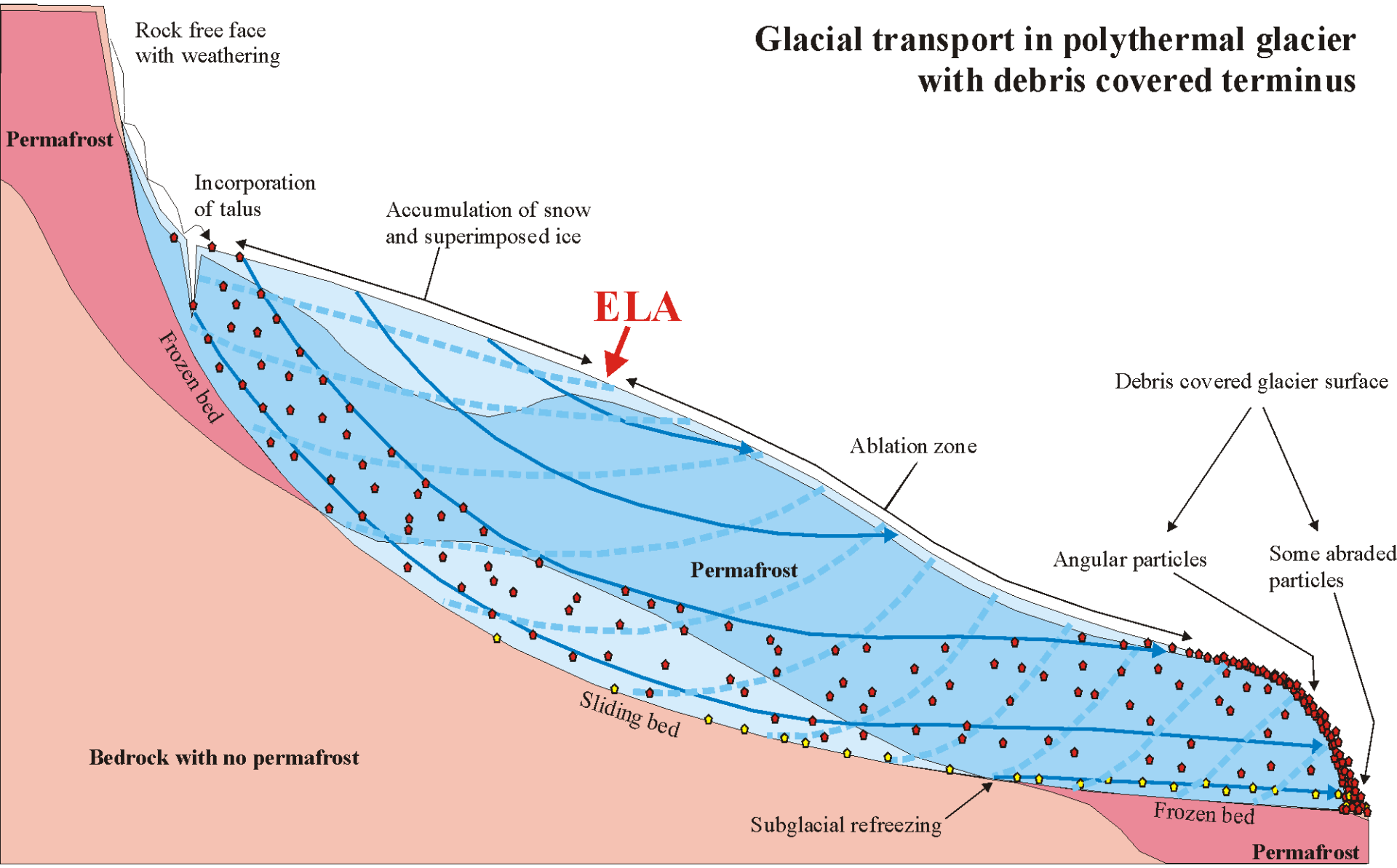
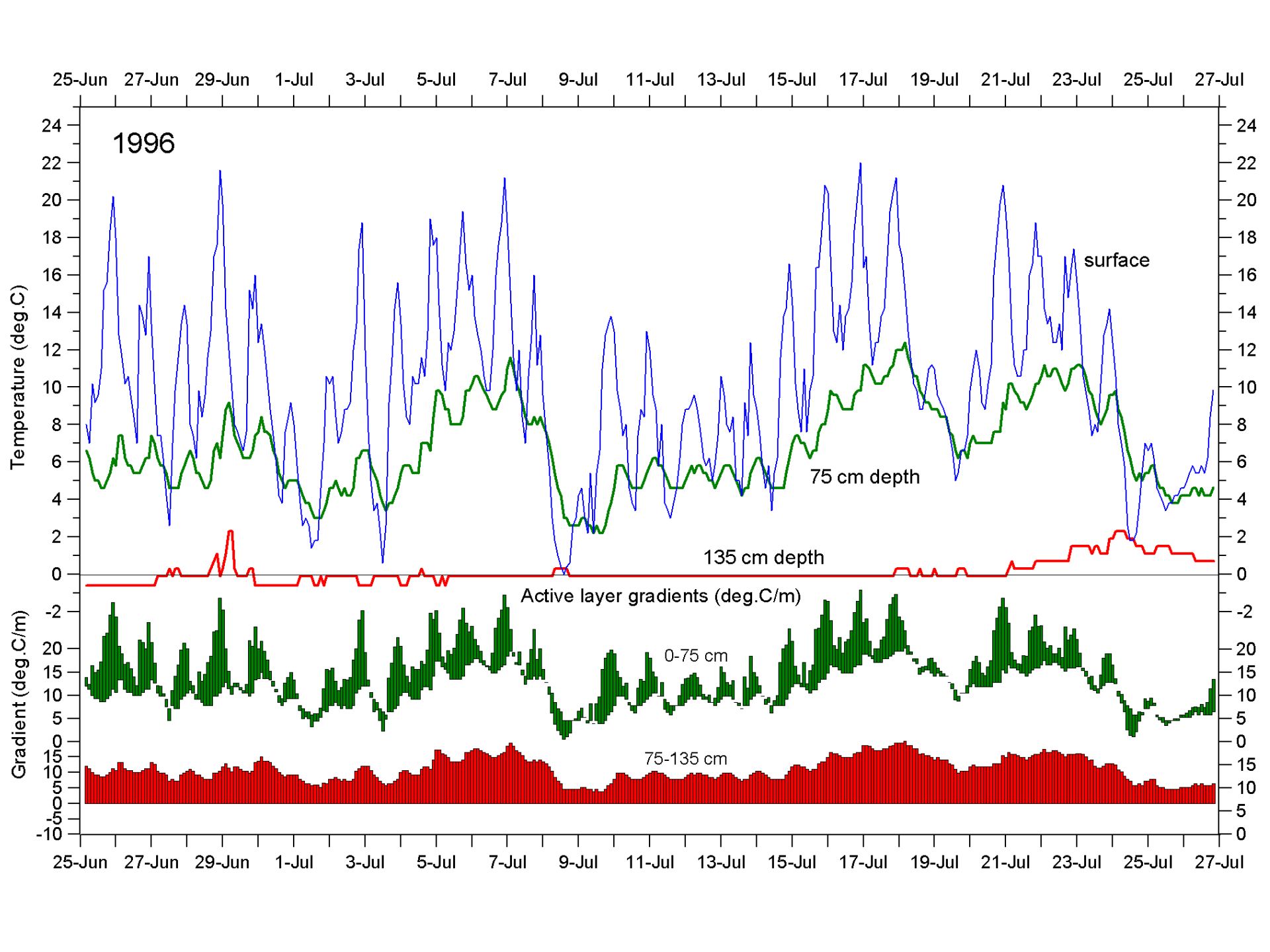


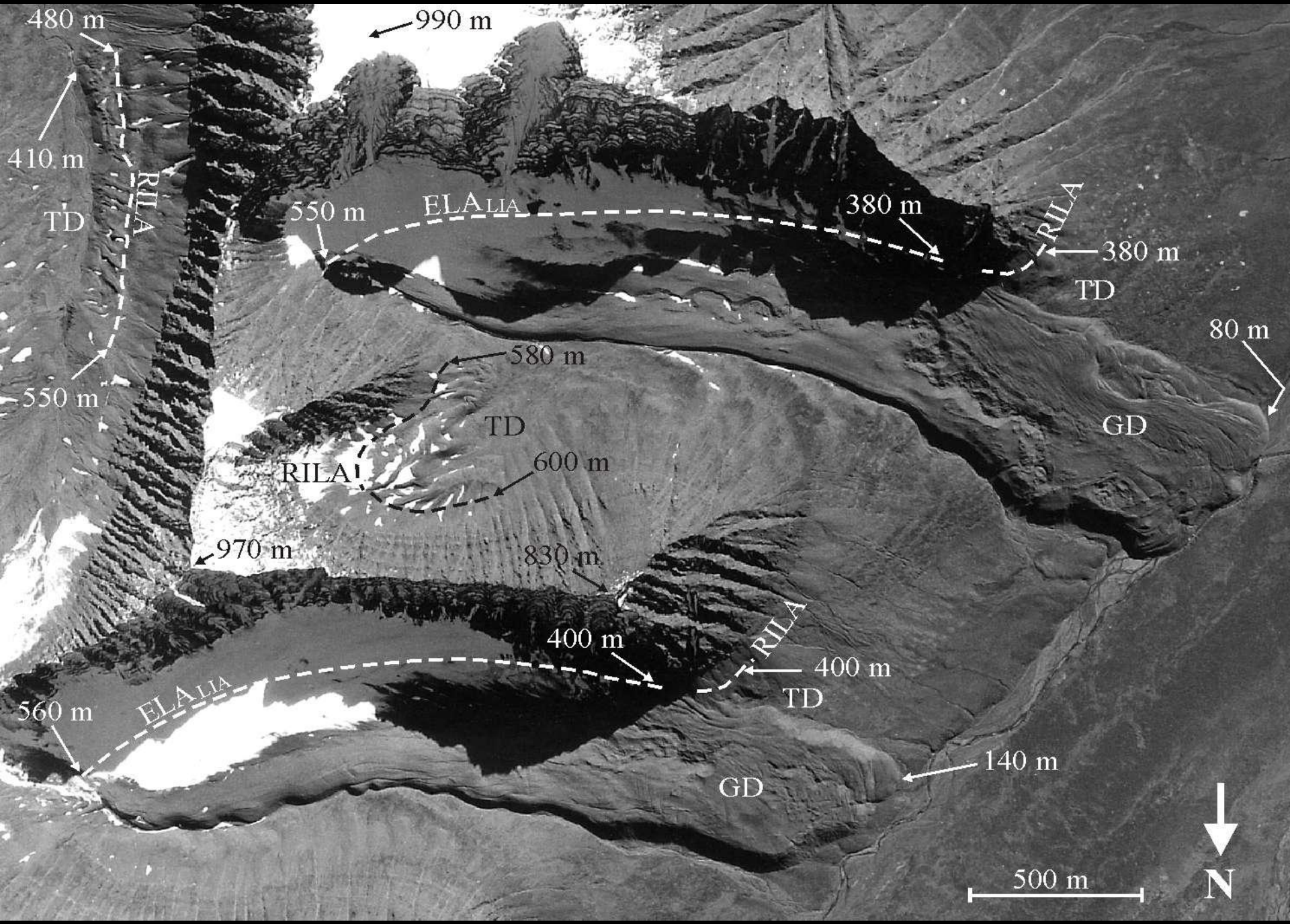

Photo: Doug Ben

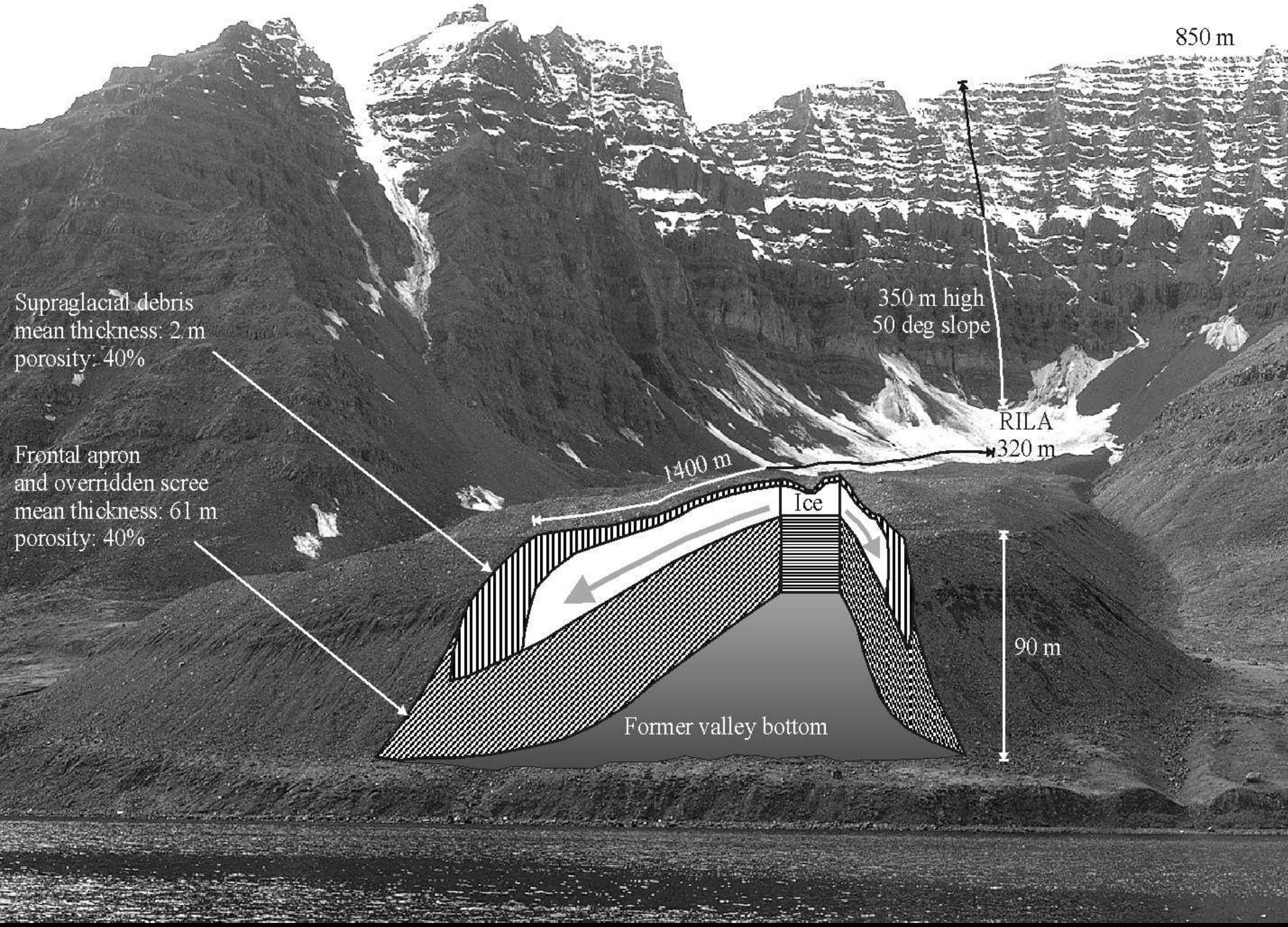
# The effect of supraglacial debris on ablation in permafrost regions

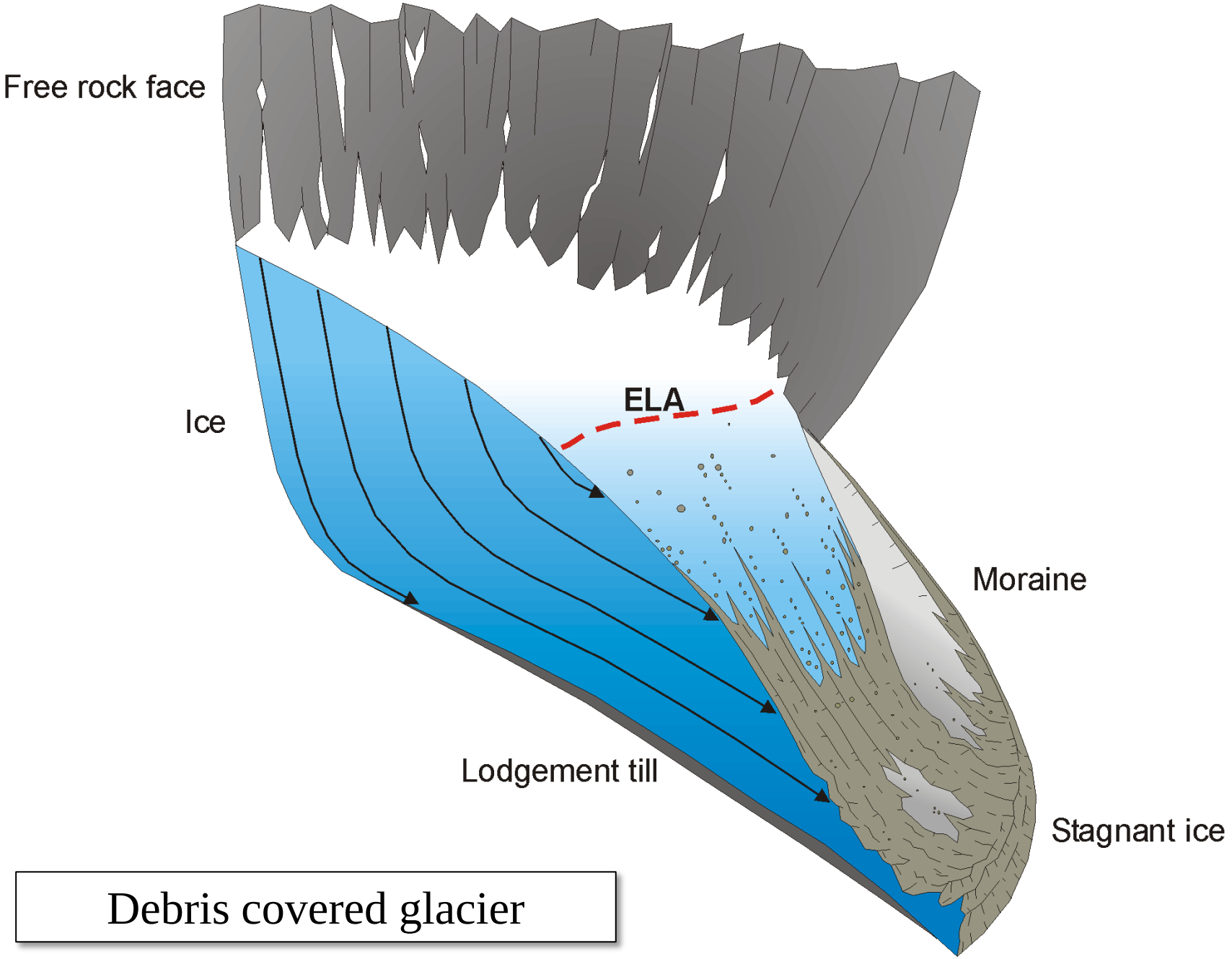

Temperature (°C)
-5
-4
-3
-2
-1
0
1
2
3
0
5
10
15
20
25
30
35
40
45
50
55
Depth (m)
Active layer
Average annual ground temperature
Coolest temperature
Warmest temperature
Level of zero annual amplitude
Permafrost
Geothermal gradient
Permafrost base


Glacial transport in polythermal glacier with debris covered terminus
Rock free face with weathering
Permafrost
Incorporation of talus
Accumulation of snow and superimposed ice
ELA
Frozen bed
Debris covered glacier surface
Ablation zone
Angular particles
Some abraded particles
Permafrost
Sliding bed
Bedrock with no permafrost
Subglacial refreezing
Frozen bed
Permafrost

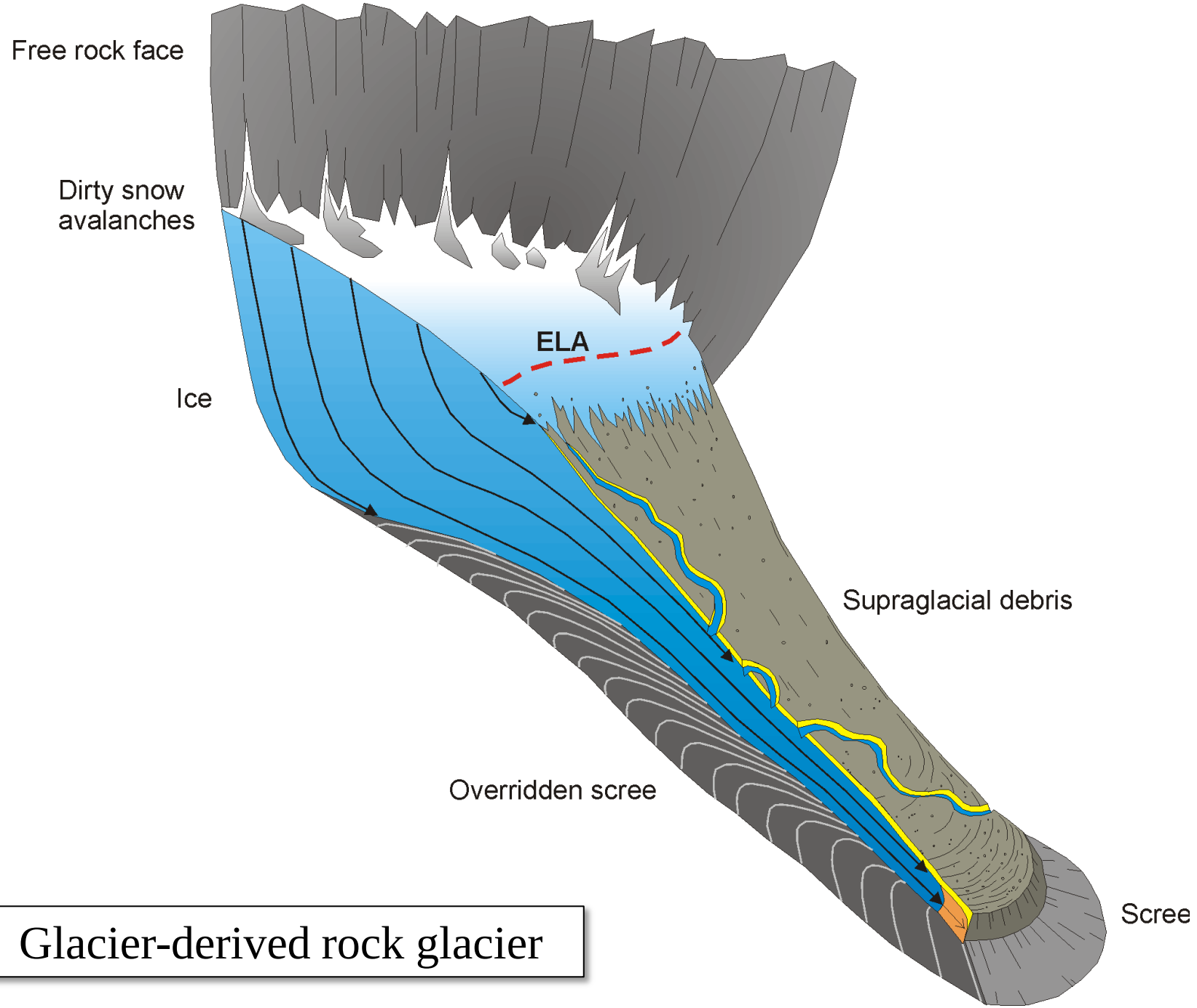

1996
Temperature (deg.C)
surface
75 cm depth
135 cm depth
Active layer gradients (deg.C/m)
Gradient (deg.C/m)
0-75 cm
75-135 cm
25-Jun
27-Jun
29-Jun
1-Jul
3-Jul
5-Jul
7-Jul
9-Jul
11-Jul
13-Jul
15-Jul
17-Jul
19-Jul
21-Jul
23-Jul
25-Jul
27-Jul


480 m
990 m
410 m
RILA
TD
550 m
ELALIA
380 m
RILA
380 m
TD
80 m
580 m
550 m
TD
GD
RILA
600 m
970 m
830 m
RILA
400 m
400 m
TD
560 m
ELALIA
140 m
GD
500 m
N


850 m
Supraglacial debris
mean thickness: 2 m
porosity: 40%
350 m high
50 deg slope
RILA
320 m
Frontal apron
and overridden scree
mean thickness: 61 m
porosity: 40%
1400 m
Ice
90 m
Former valley bottom



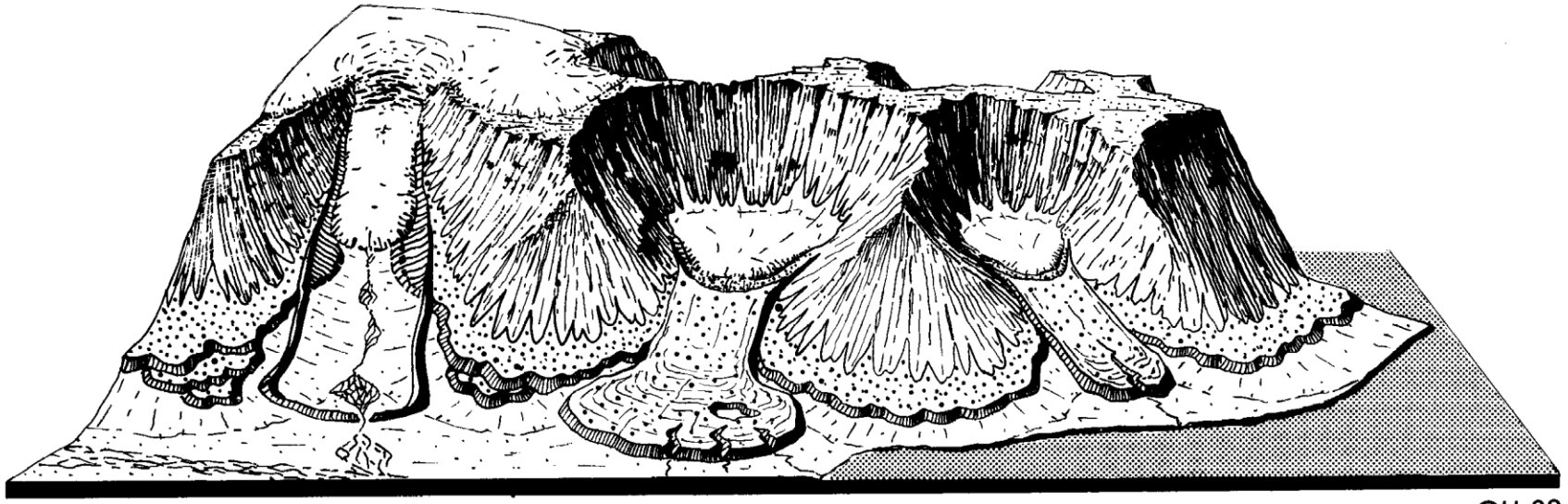

Debris covered glacier




# Glacier-derived rock glacier

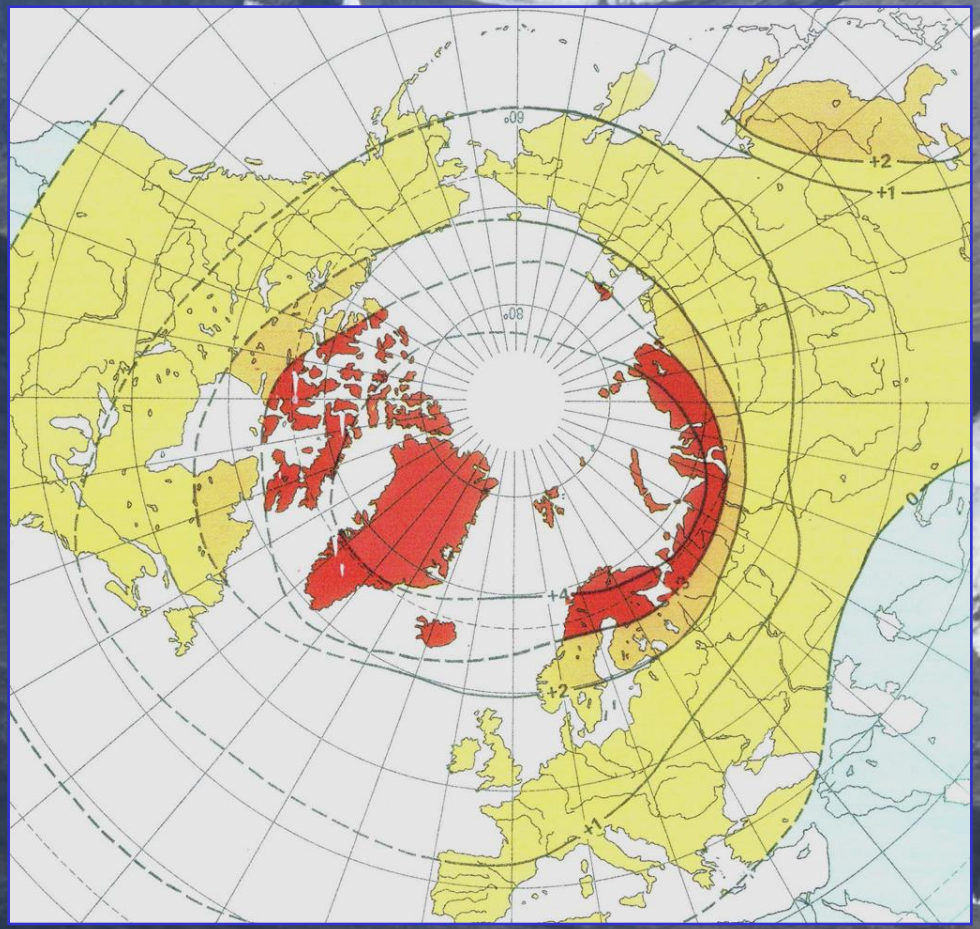
GREENLAND

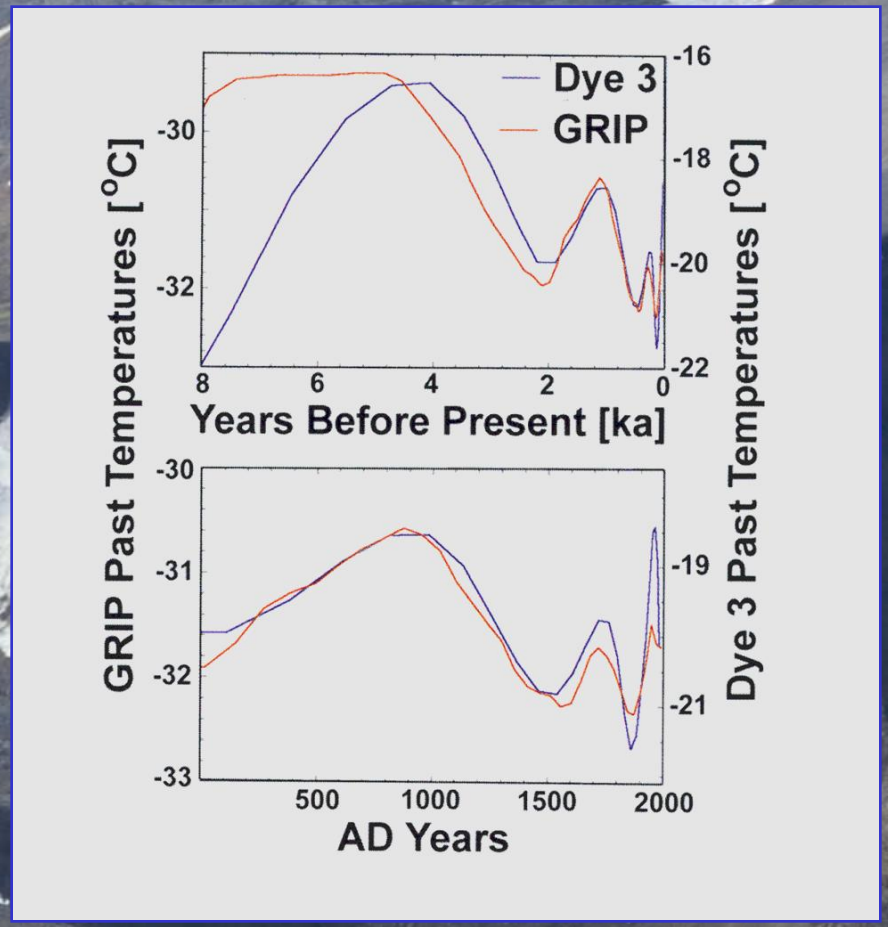
ROCK GLACIER TYPES, DISKO



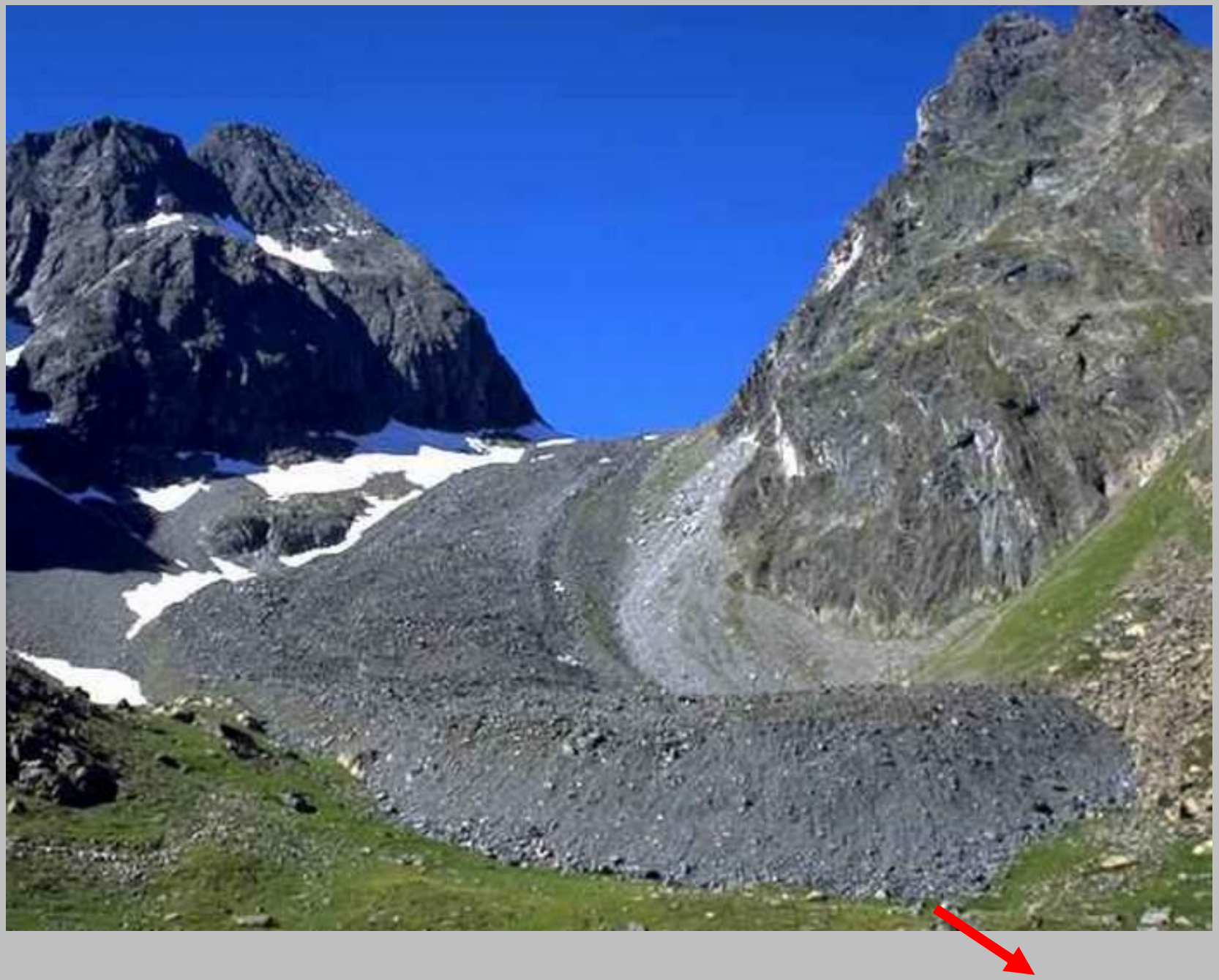
OH 82

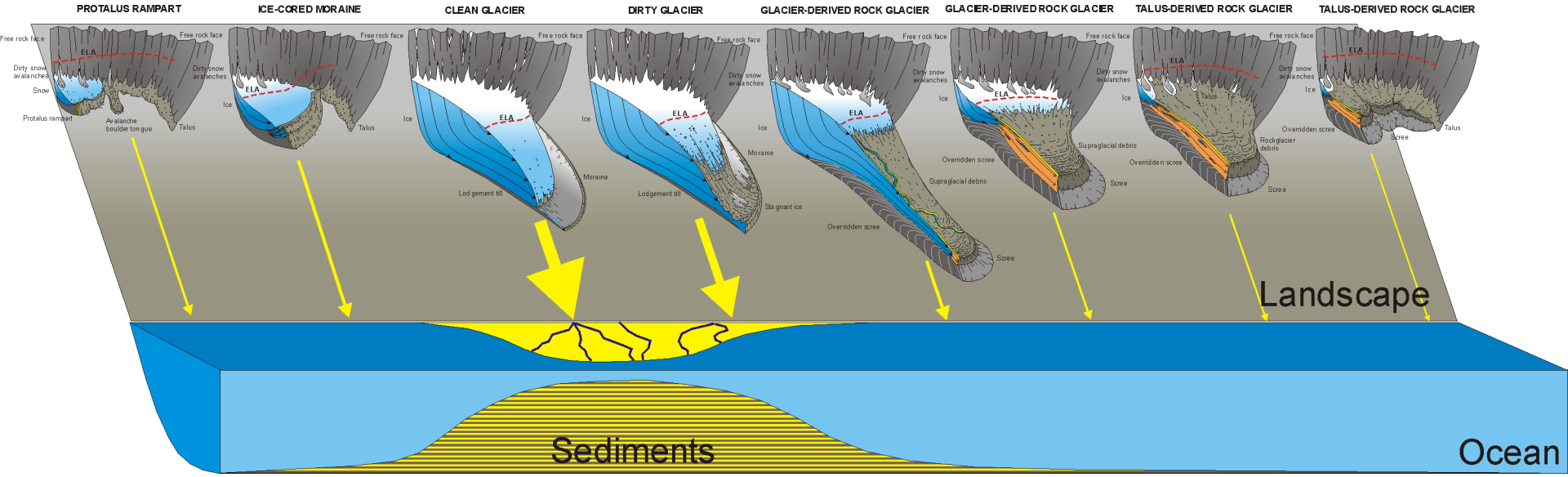
The relation between glaciers and rock glaciers


+2
+1
+4
+2
+1

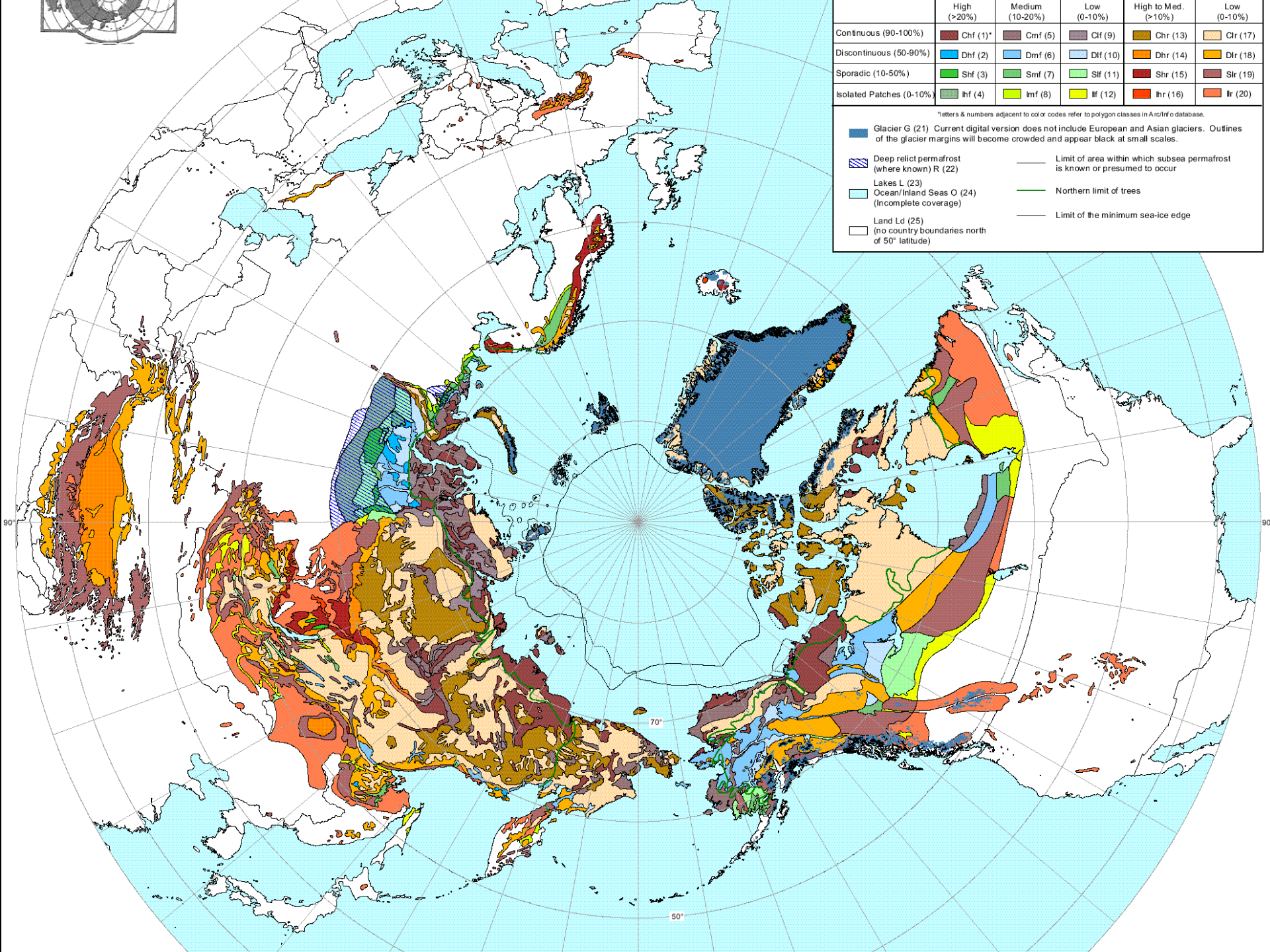

Dye 3
GRIP
-16
-18
-20
-22
-30
-32
8
6
4
2
0
Years Before Present [ka]
GRIP Past Temperatures [°C]
Dye 3 Past Temperatures [°C]
-30
-31
-32
-33
-19
-21
500
1000
1500
2000
AD Years

# Rock glaciers
# as efficient transport agents

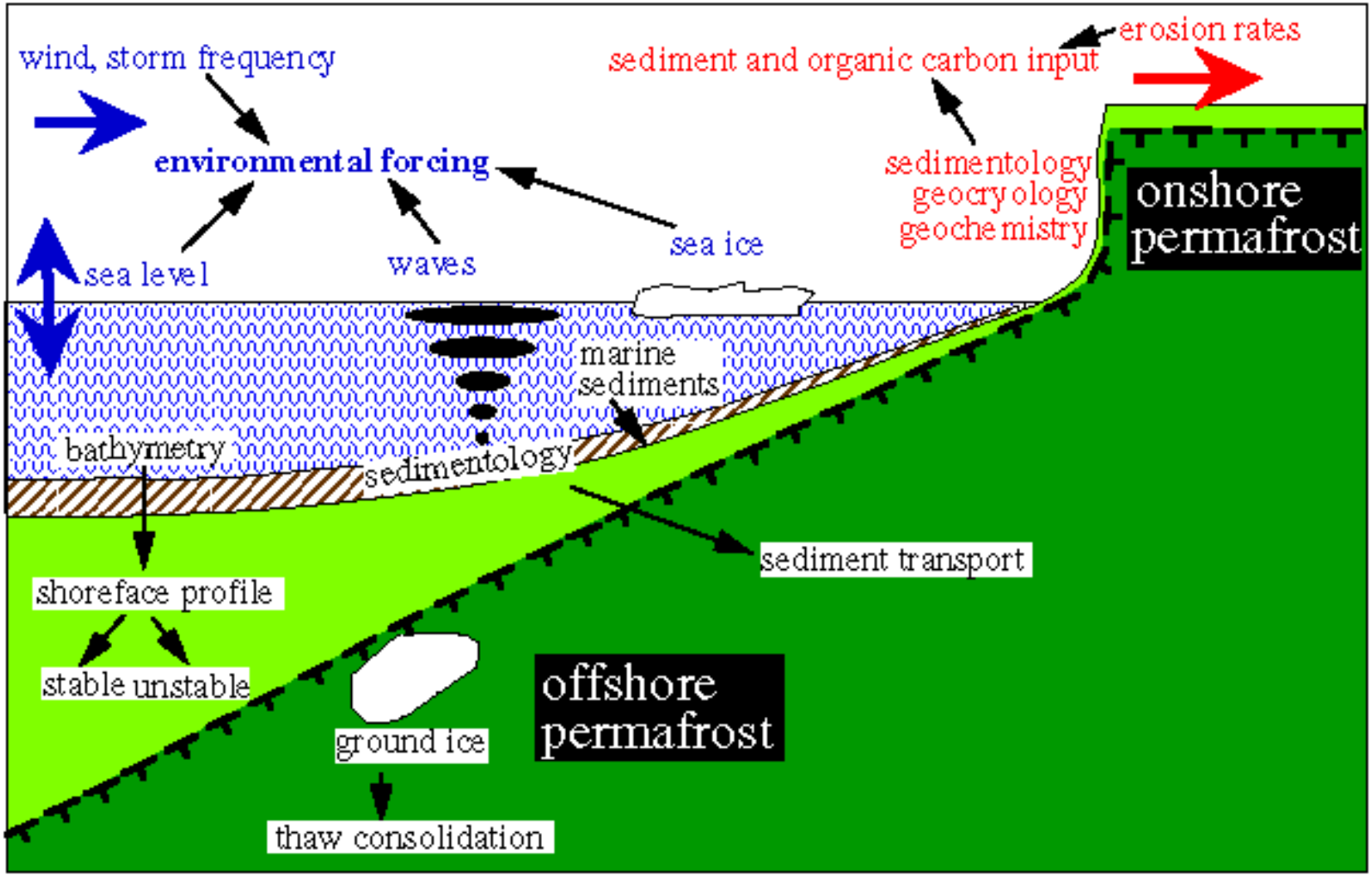



PROTALUS RAMPART
ICE-CORED MORAINE
CLEAN GLACIER
DIRTY GLACIER
GLACIER-DERIVED ROCK GLACIER
GLACIER-DERIVED ROCK GLACIER
TALUS-DERIVED ROCK GLACIER
TALUS-DERIVED ROCK GLACIER
Free rock face
Dirty snow avalanches
Snow
ELA
Protalus rampart
Avalanche boulder tongue
Talus
Ice
Moraine
Lodgement till
Stagnant ice
Overridden scree
Supraglacial debris
Scree
Rockglacier debris
Landscape
Sediments
Ocean

# Deglaciation
# in permafrost regions


High (>20%)
Medium (10-20%)
Low (0-10%)
High to Med. (>10%)
Low (0-10%)
Continuous (90-100%)
Chf (1)*
Cmf (5)
Clf (9)
Chr (13)
Clr (17)
Discontinuous (50-90%)
Dhf (2)
Dmf (6)
Dlf (10)
Dhr (14)
Dlr (18)
Sporadic (10-50%)
Shf (3)
Smf (7)
Slf (11)
Shr (15)
Slr (19)
Isolated Patches (0-10%)
Ihf (4)
Imf (8)
Ilf (12)
Ihr (16)
Ilr (20)
*letters & numbers adjacent to color codes refer to polygon classes in Arc/Info database.
Glacier G (21) Current digital version does not include European and Asian glaciers. Outlines of the glacier margins will become crowded and appear black at small scales.
Deep relict permafrost (where known) R (22)
Lakes L (23)
Ocean/Inland Seas O (24) (Incomplete coverage)
Land Ld (25) (no country boundaries north of 50° latitude)
Limit of area within which subsea permafrost is known or presumed to occur
Northern limit of trees
Limit of the minimum sea-ice edge
90°
90°
70°
50°

Ice complex, Lena Delta (Foto A. Sher)


wind, storm frequency
environmental forcing
sea level
waves
sea ice
sediment and organic carbon input
erosion rates
sedimentology
geocryology
geochemistry
onshore permafrost
marine sediments
bathymetry
sedimentology
sediment transport
shoreface profile
stable unstable
ground ice
offshore permafrost
thaw consolidation

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Quaternary Research 64 (2005) 125 – 137

QUATERNARY RESEARCH

www.elsevier.com/locate/yqres

# Basal processes beneath an Arctic glacier and their geomorphic imprint after a surge, Elisebreen, Svalbard

Poul Christoffersen[a,*], Jan A. Piotrowski[b], Nicolaj K. Larsen[b]

[a]*Centre for Glaciology, Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, Ceredigion SY23 3DB, UK*
[b]*Department of Earth Sciences, University of Aarhus, C.F. Møllers Allé 120, DK-8000, Aarhus C, Denmark*

Received 24 March 2004
Available online 15 July 2005

PERMAFROST AND PERIGLACIAL PROCESSES
*Permafrost Periglac. Process.* **9**: 107–120 (1998)

# Thermal Regimes Beneath Coarse Blocky Materials

*Stuart A. Harris* and David E. Pedersen*

Department of Geography, The University of Calgary, 2500 University Dr. N. W., Calgary, Alberta T2N 1N4, Canada