The origin of ice-shelf channels revisited

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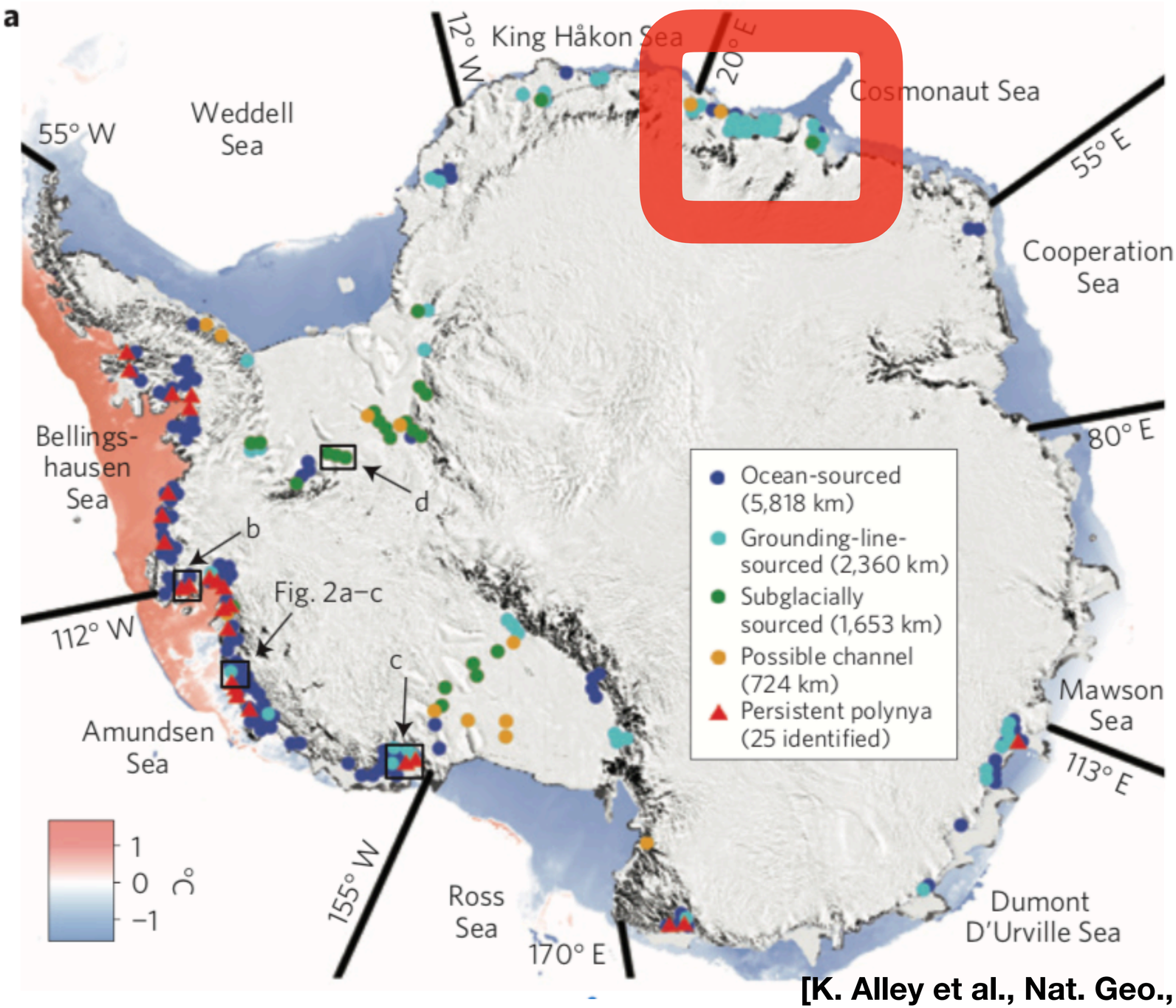
Questions Addressed

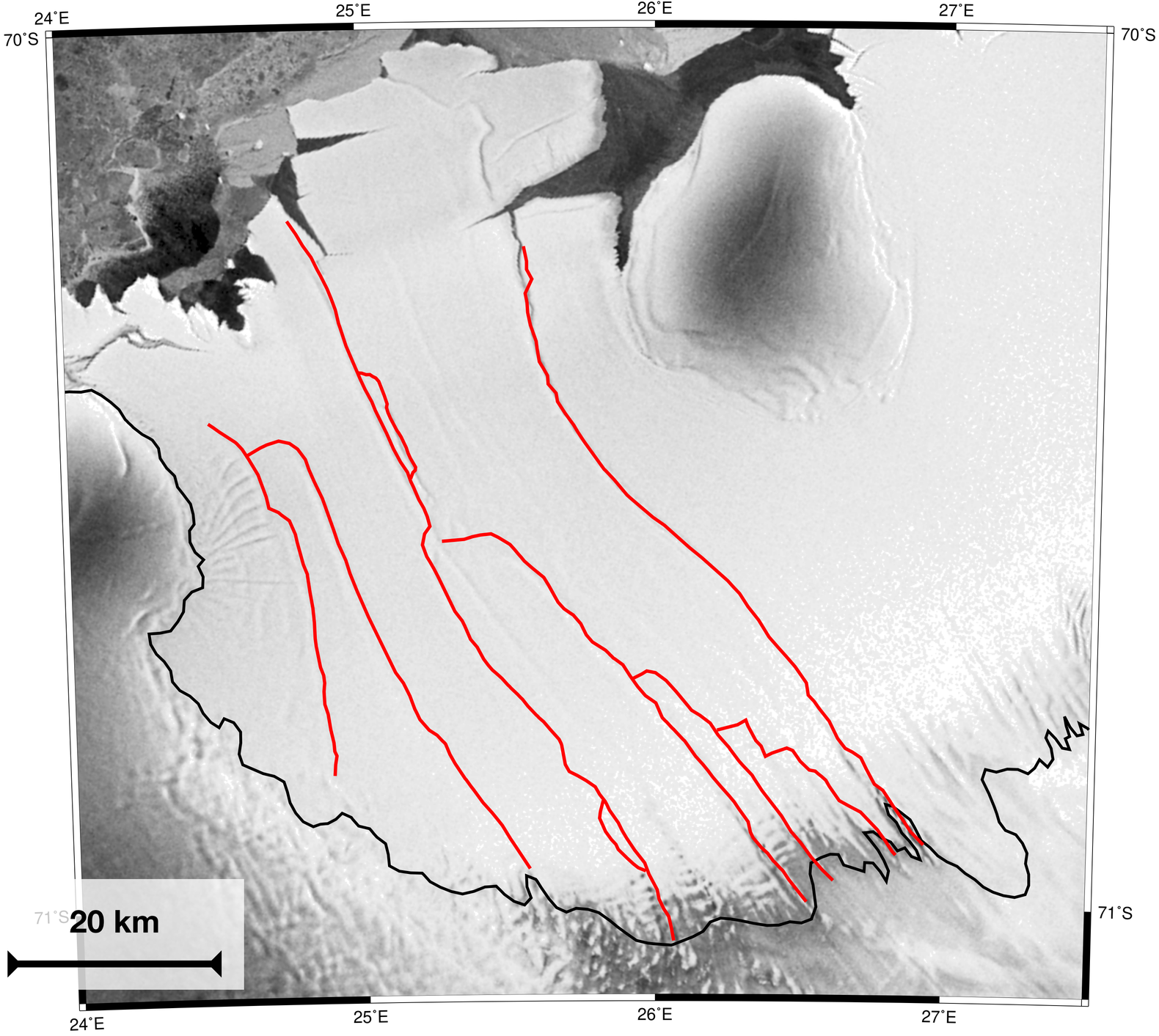
1. What defines ice-shelf channel morphology ?
2. What is the origin of ice-shelf channels ?

Study Area

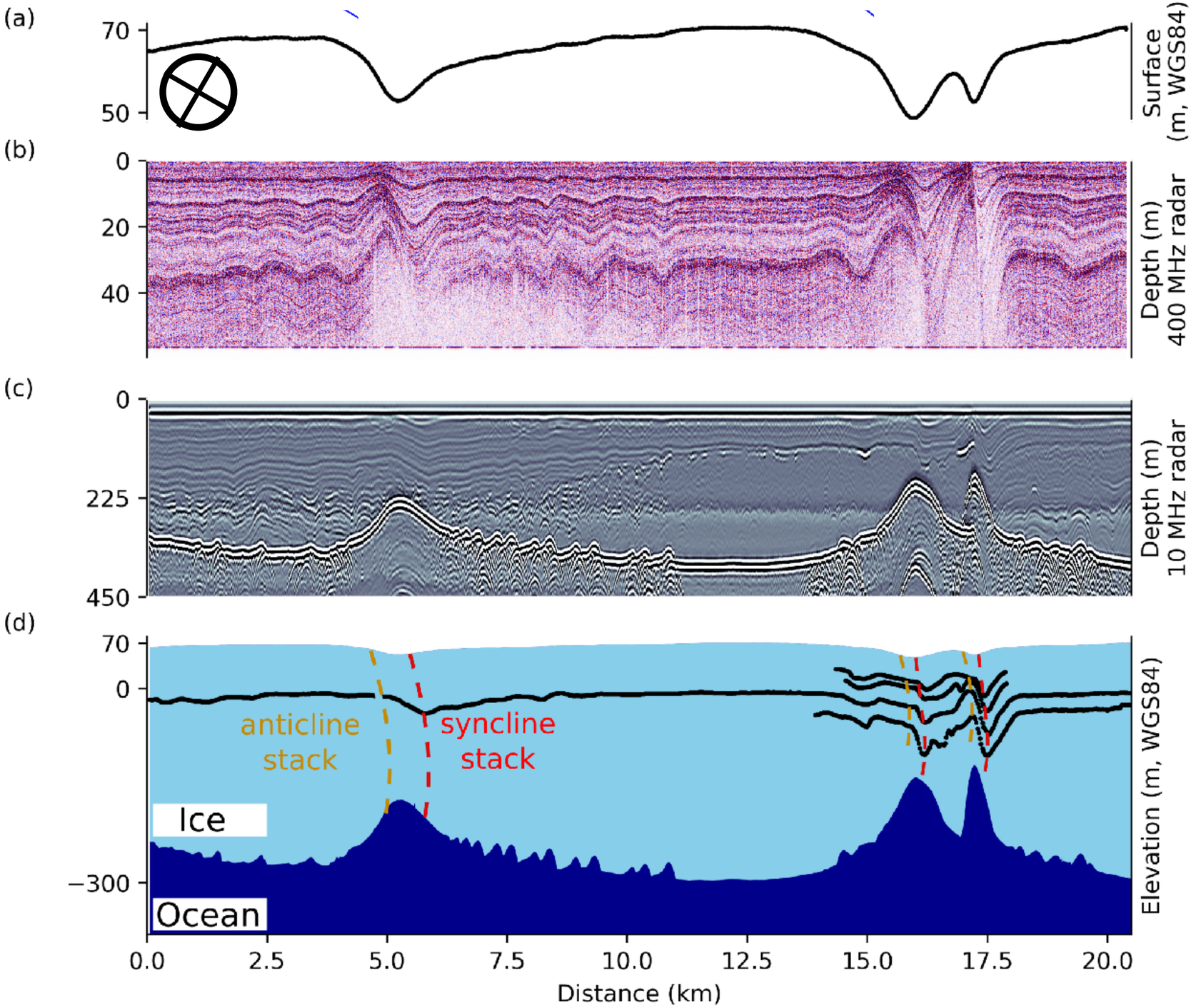


[K. Alley et al., Nat. Geo., 2016]

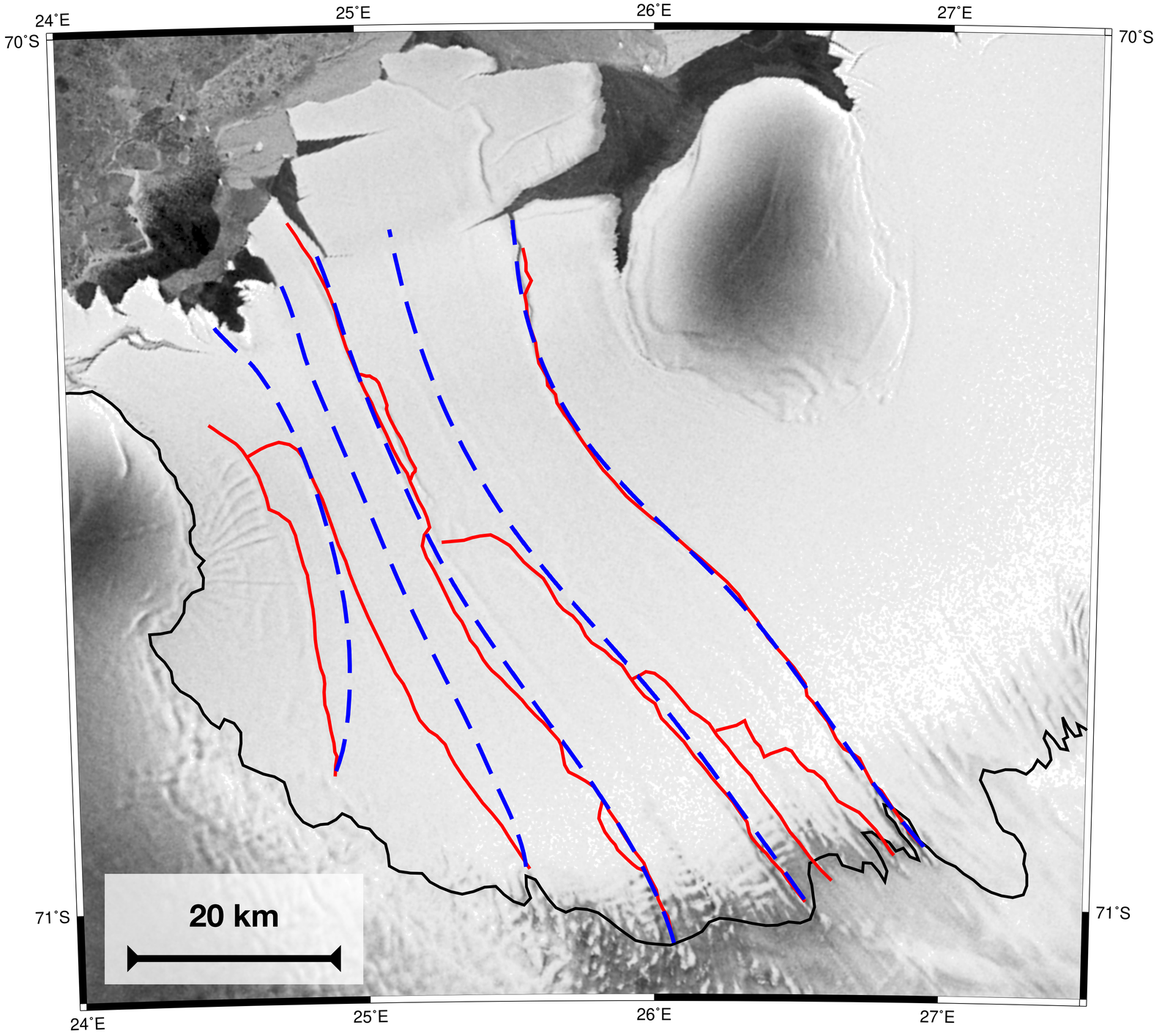
Study Area



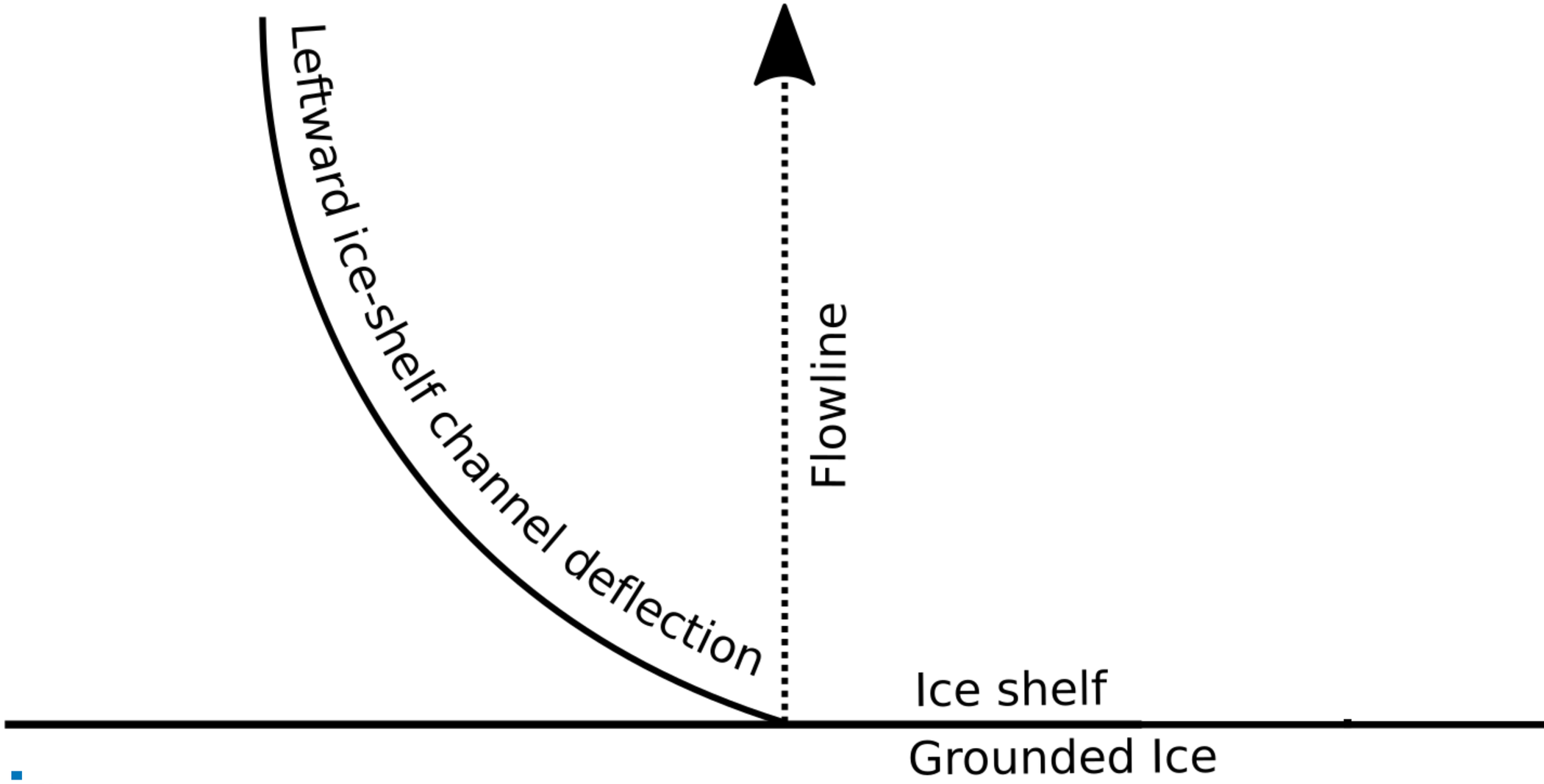
Ice-shelf channels



Ice-shelf channel morphology

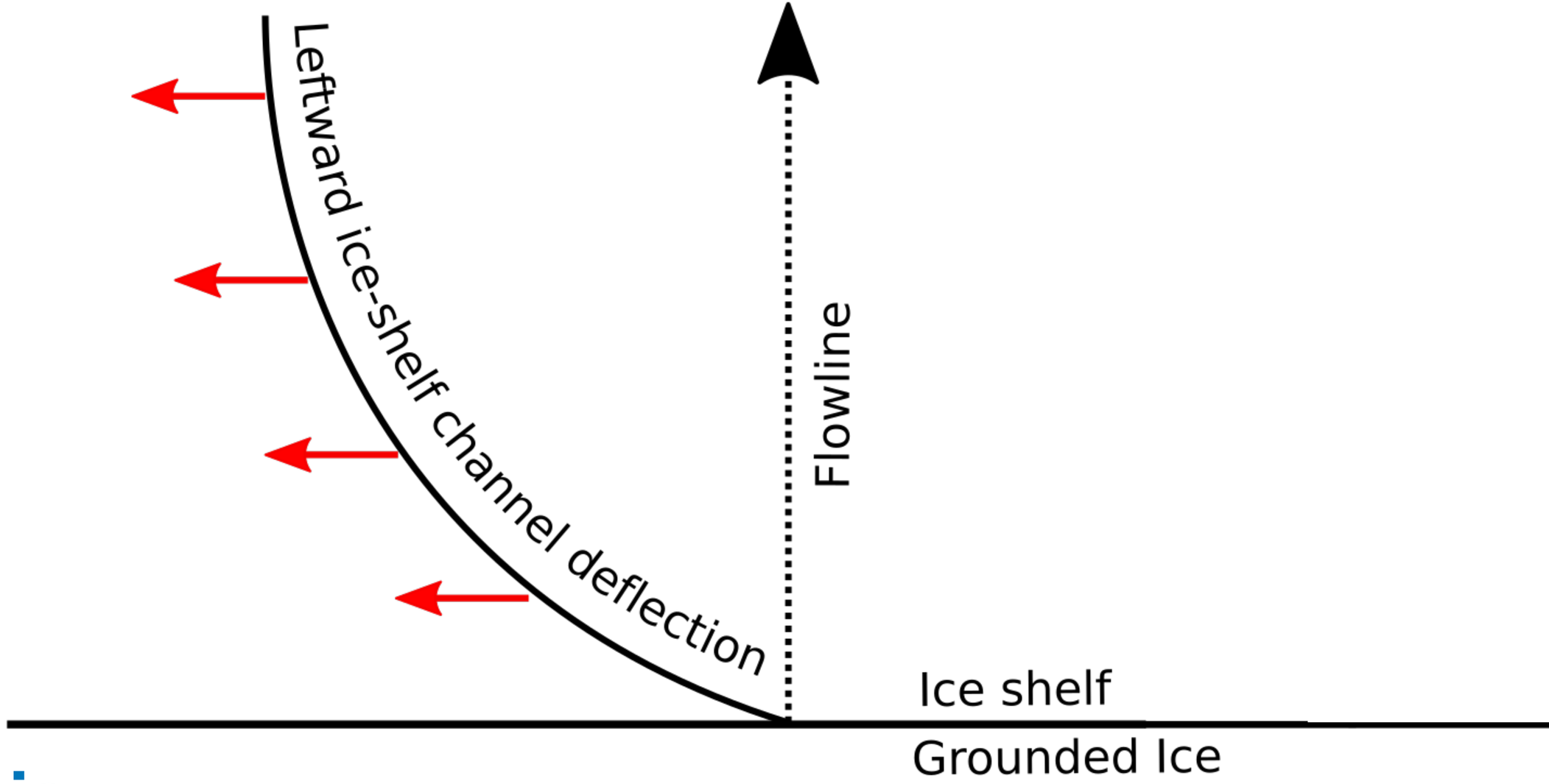


(a)



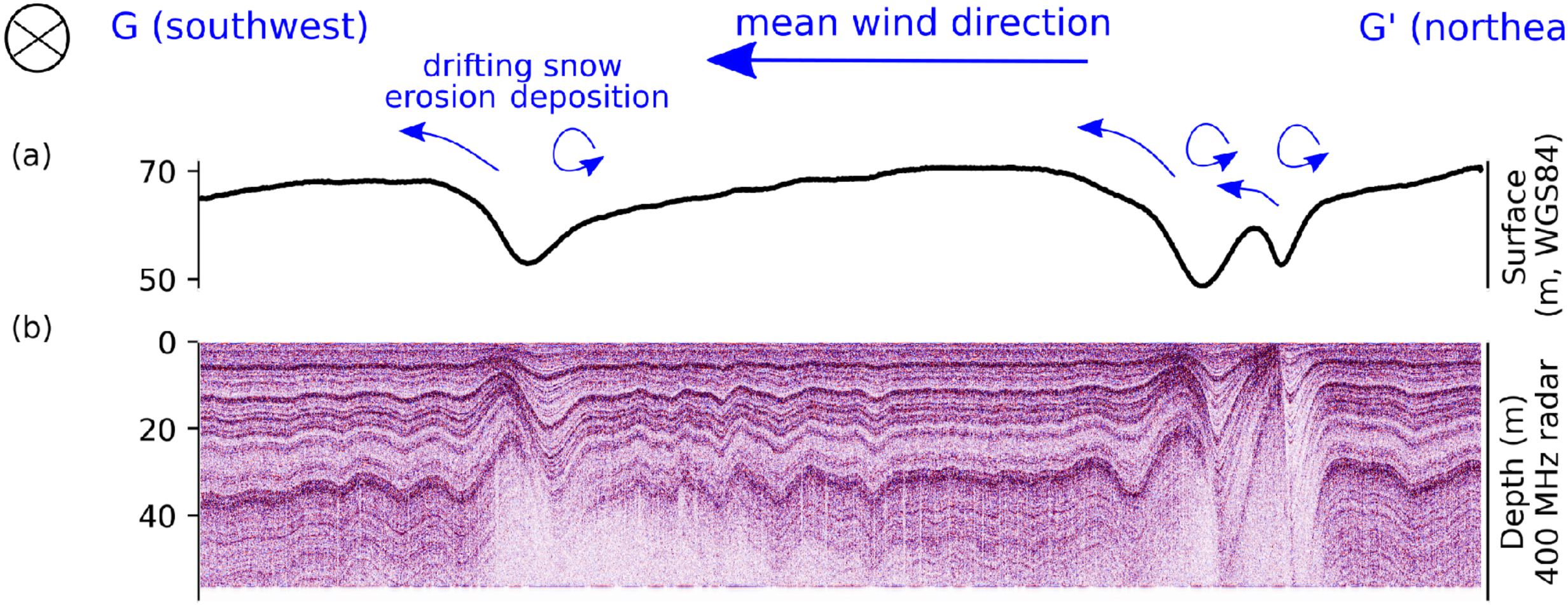
Hypothesis

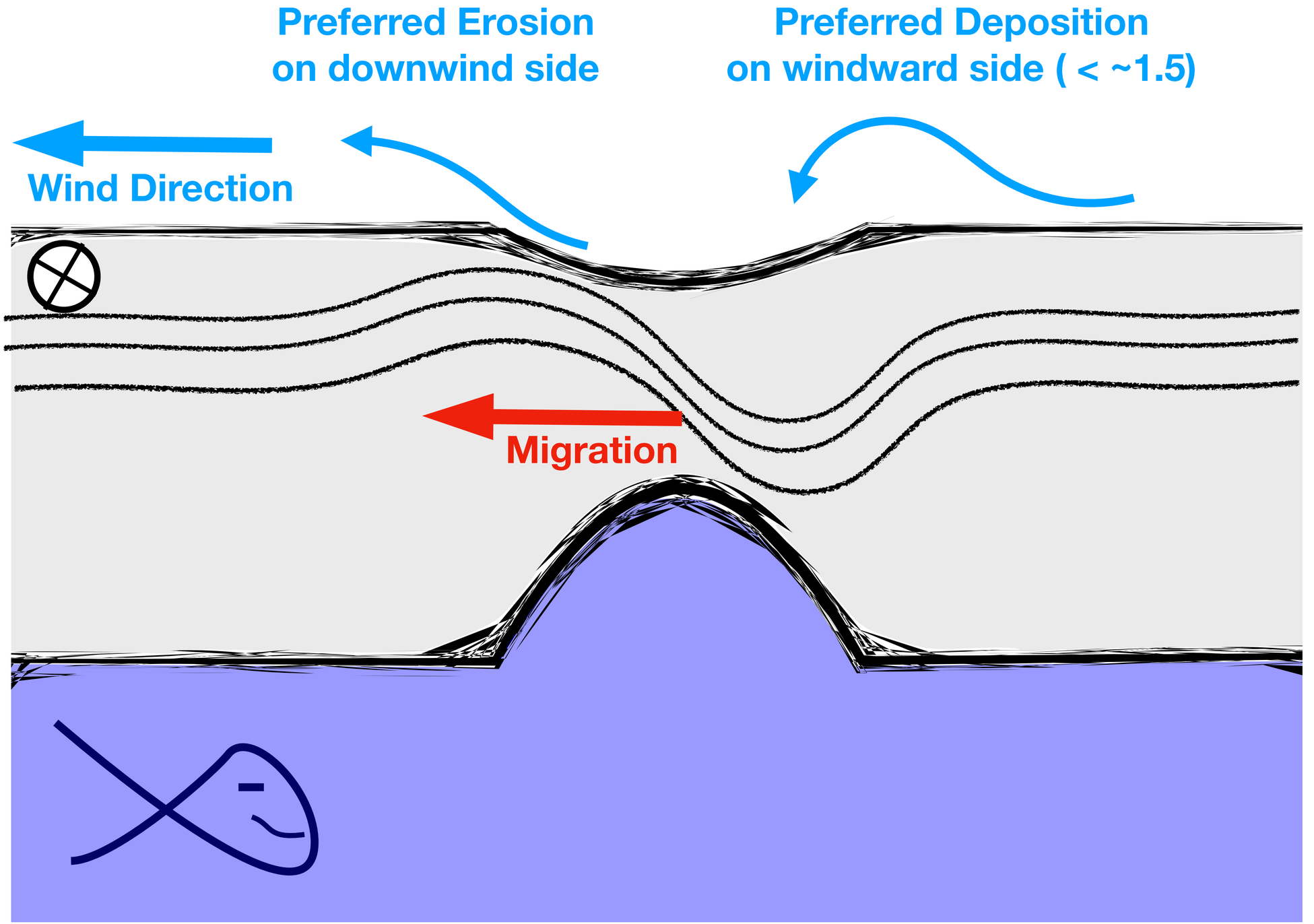
(a) Hypothesis 1: Left-biased ocean melting or surface mass balance



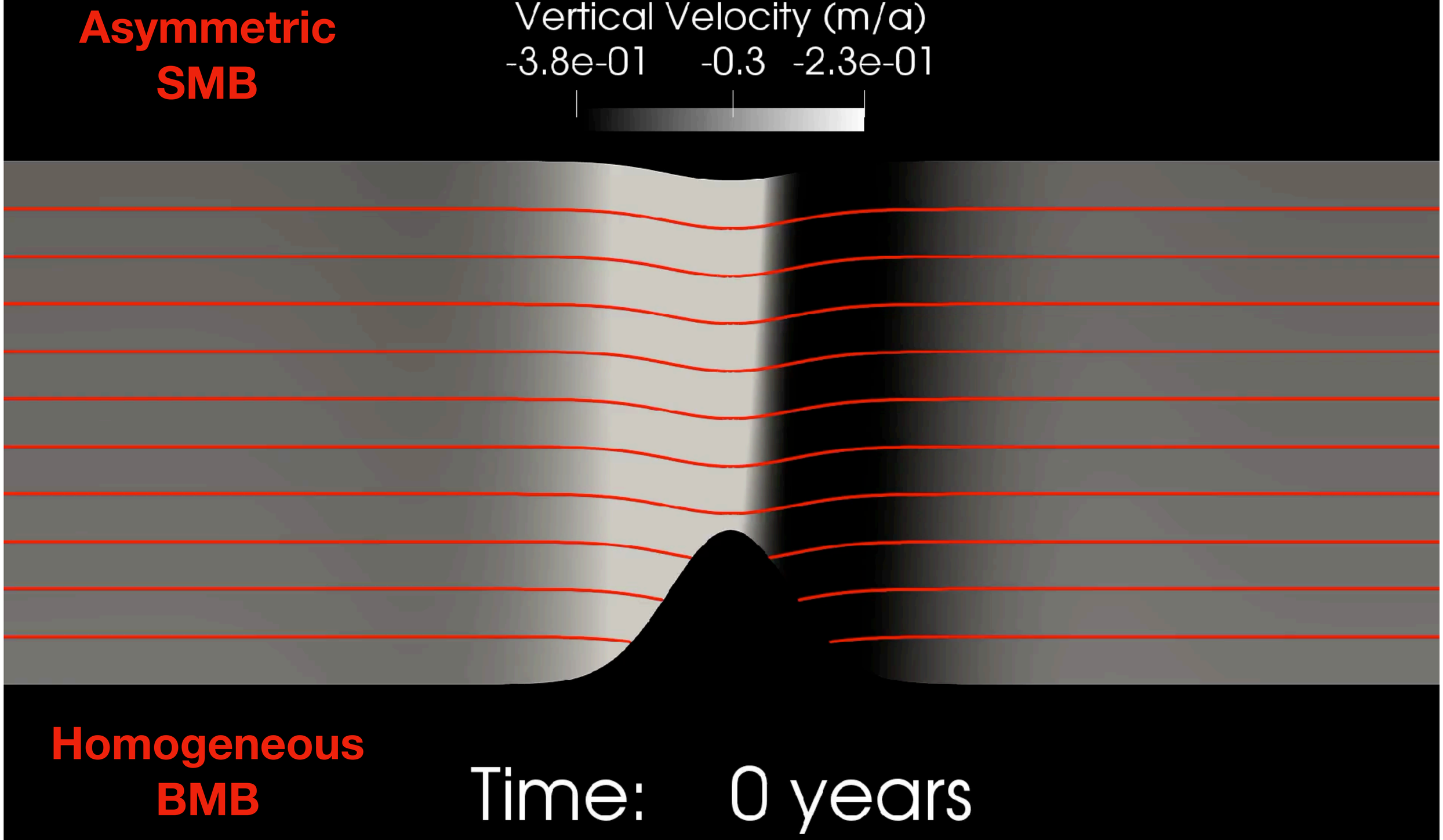
Hypothesis

Explanation of syncline/anticline pattern in stratigraphy




Preferred Erosion
on downwind side
Preferred Deposition
on windward side (< ~1.5)
Wind Direction
Migration

elmer ice


Asymmetric
SMB
Vertical Velocity (m/a)
-3.8e-01
-0.3
-2.3e-01
Homogeneous
BMB
Time: 0 years

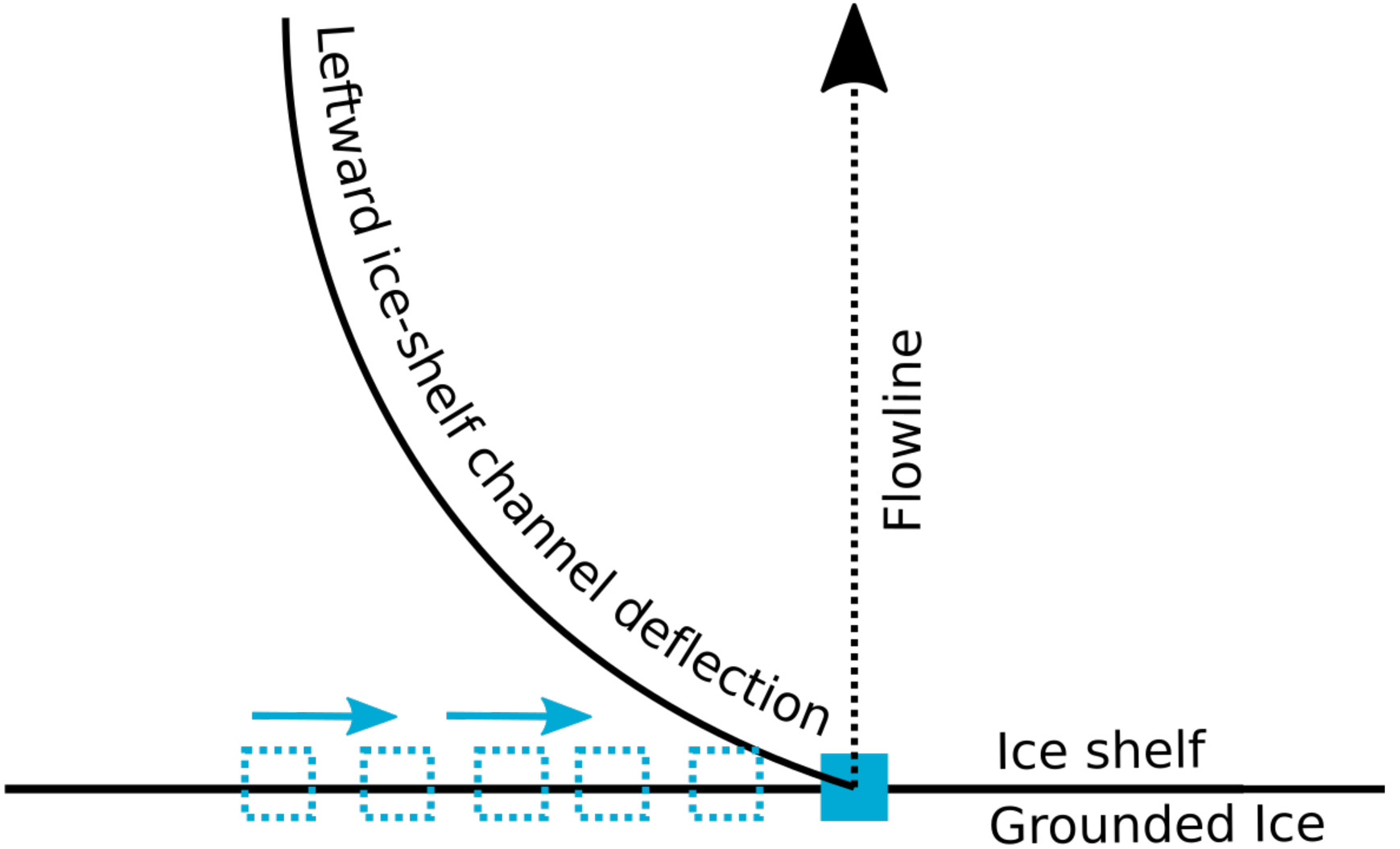
Questions Addressed

1. What defines ice-shelf channel morphology?

In part it is the surface mass balance.
(There are other factors)

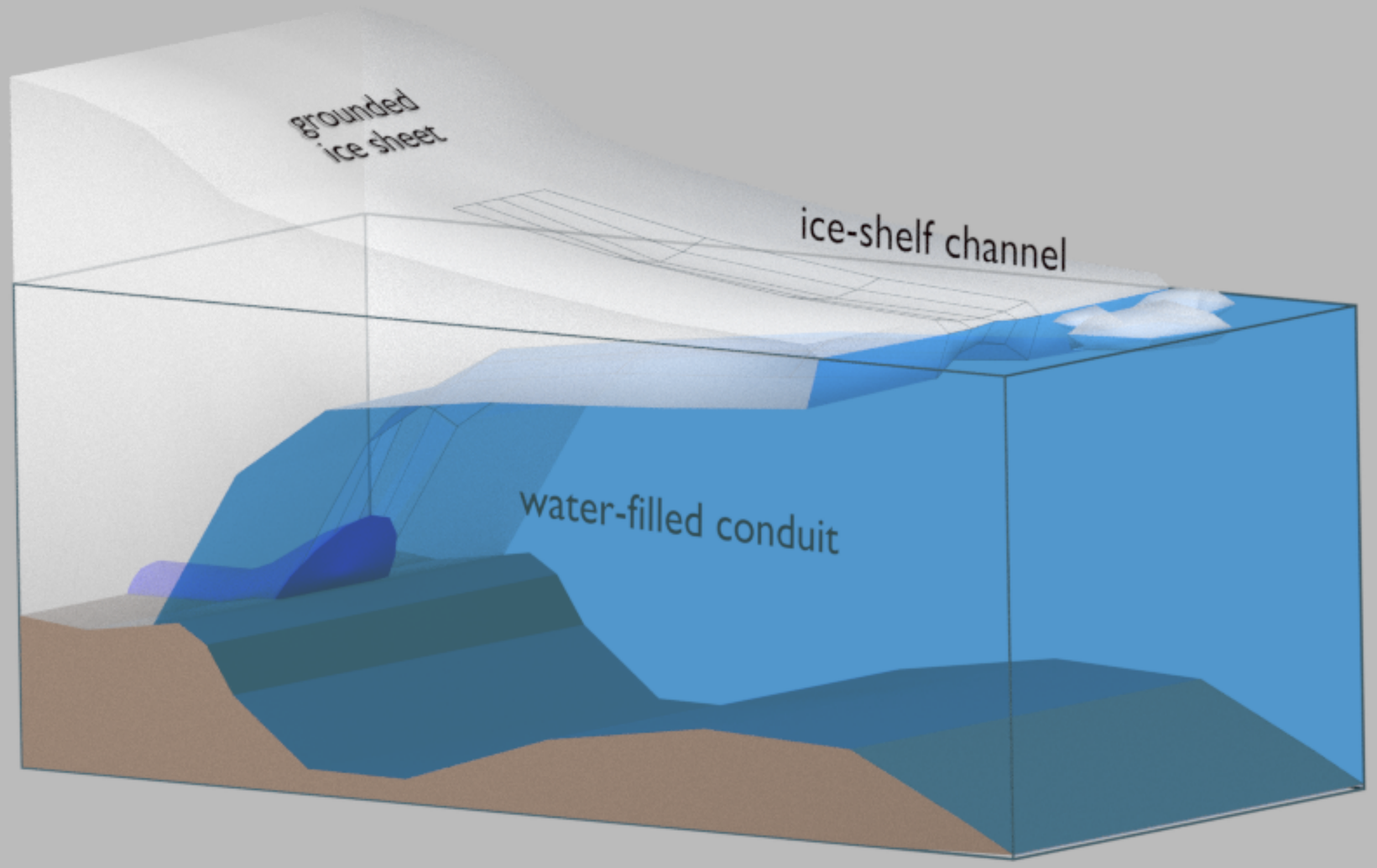
3. What is the origin of ice-shelf channels ?

(a)



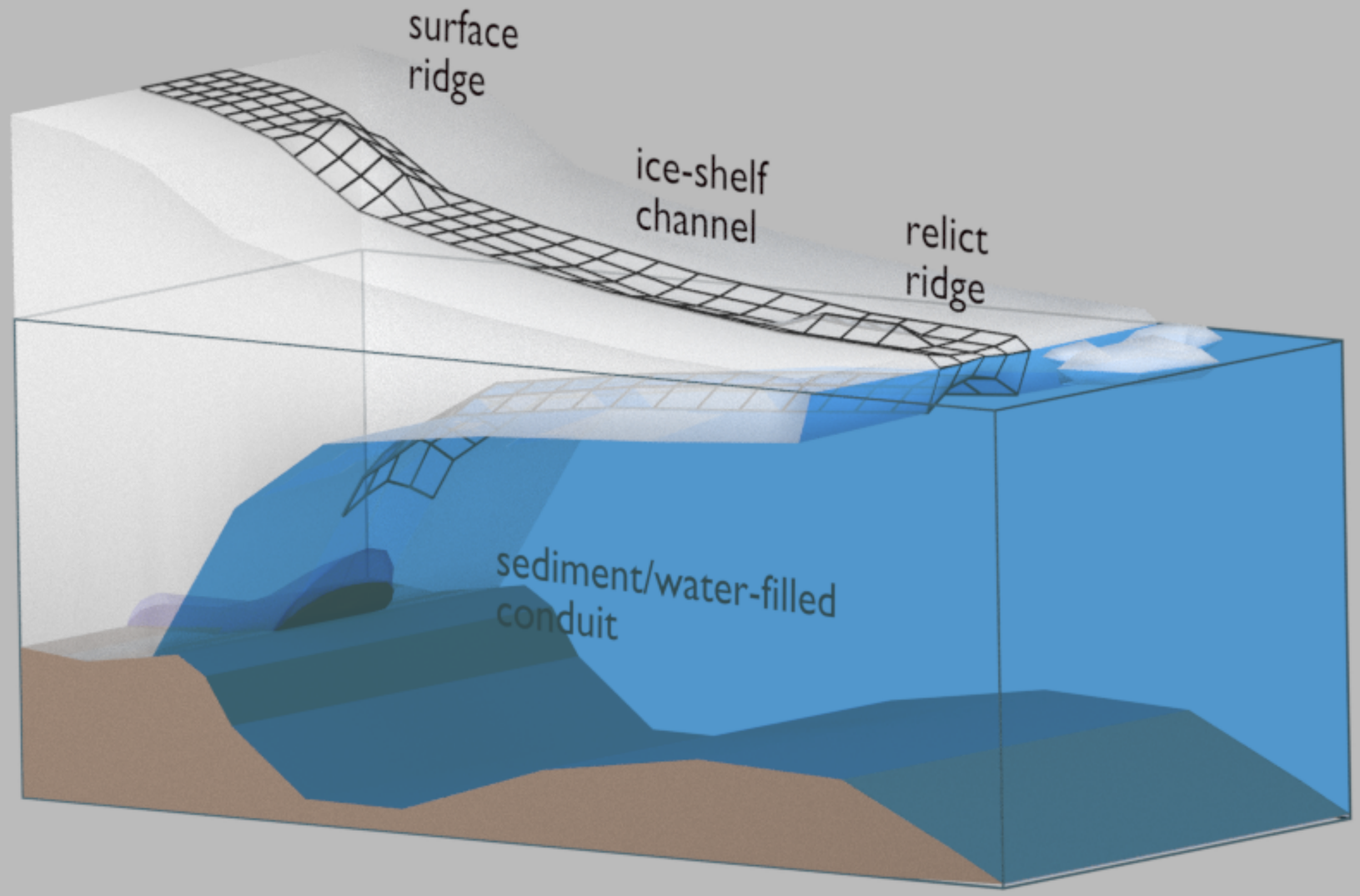
Hypothesis 2: Rightward migration of source at grounding line

Trumpeting of subglacial conduits

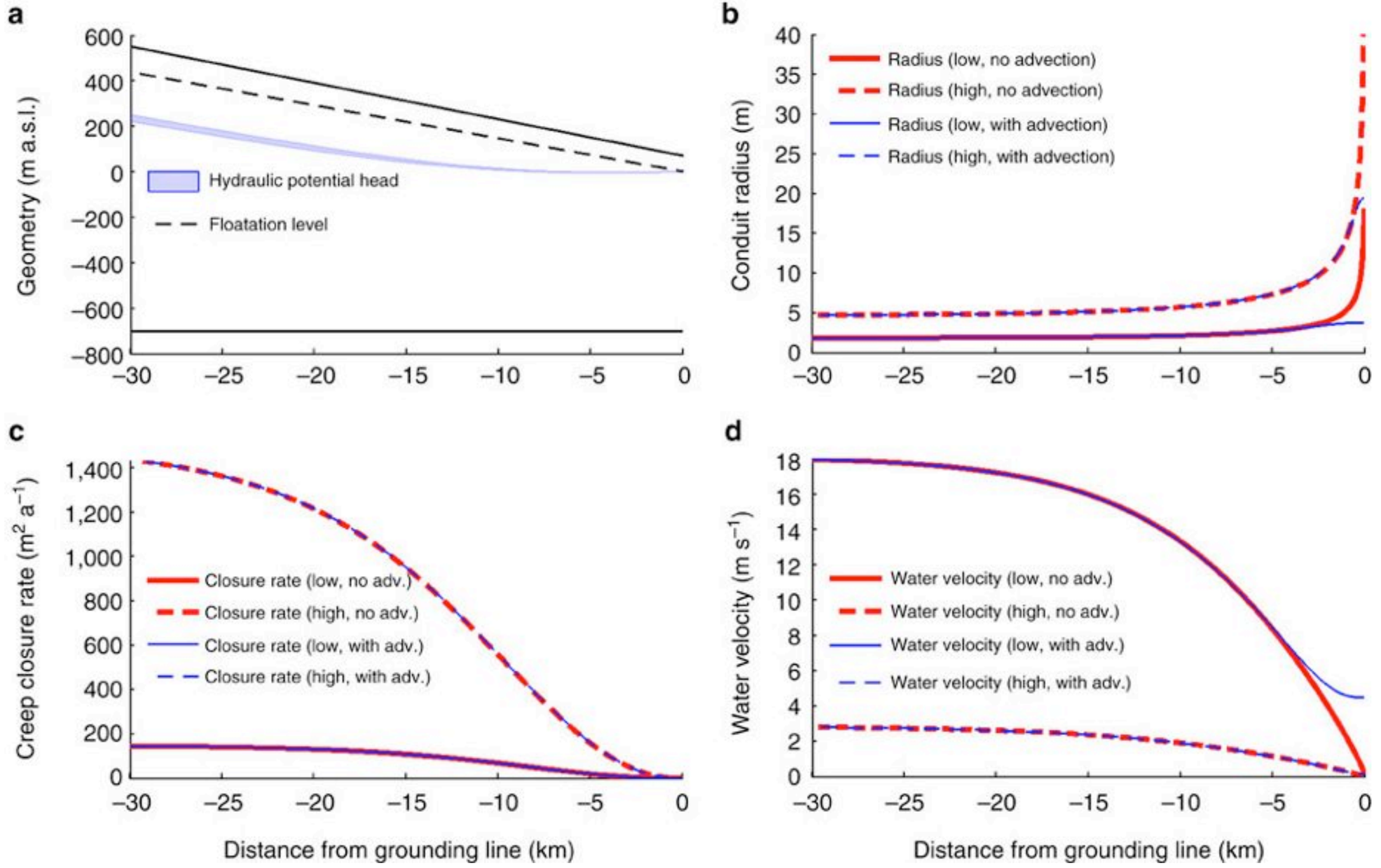


LeBrocq et al., 2013; Marsh et al., 2016
Drews et al., 2017

Trumpeting of subglacial conduits + sediment deposition

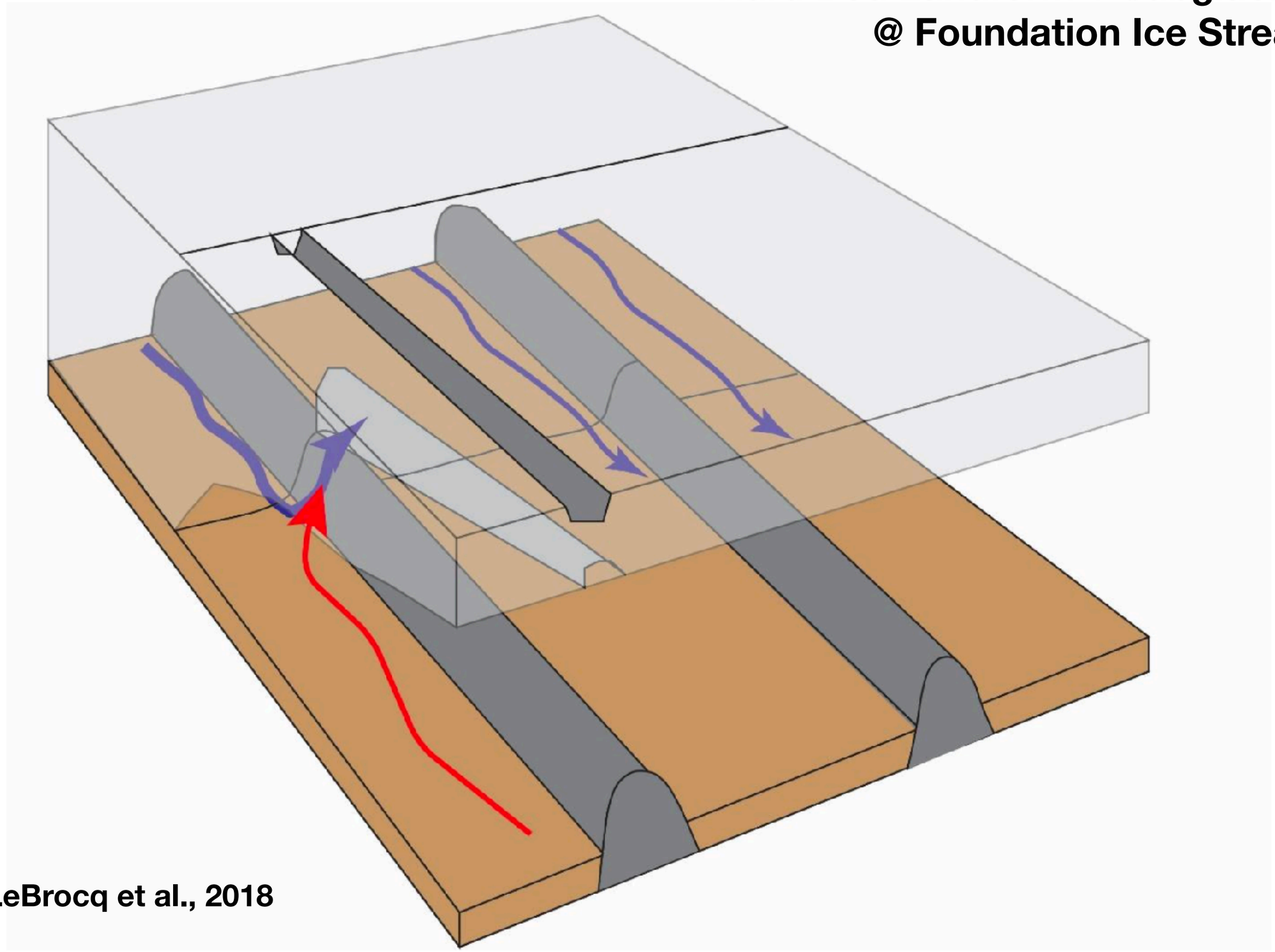


Drews et al., 2017



Drews et al., 2017

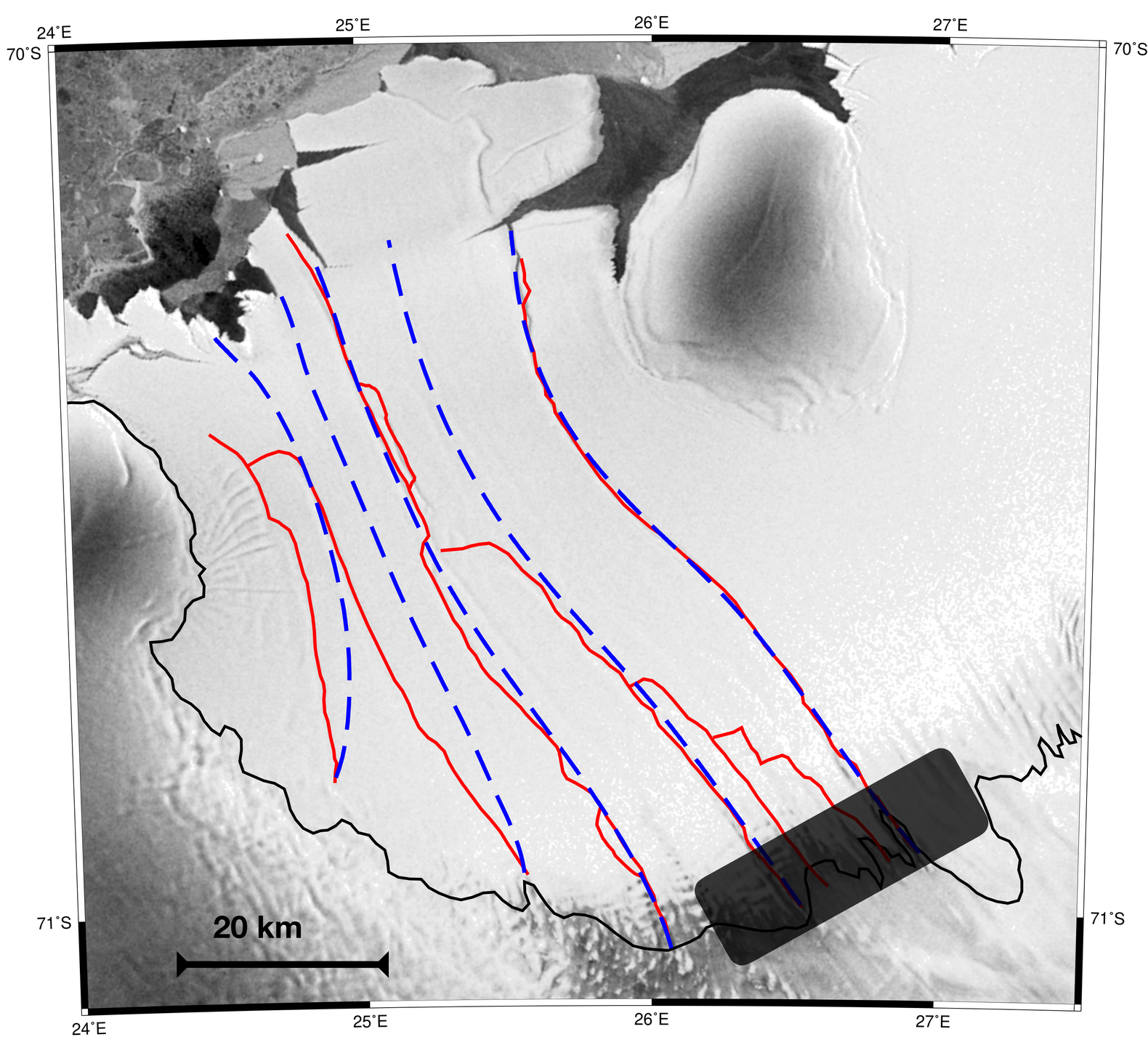
Hard Bed Landform + Subglacial Conduits @ Foundation Ice Stream

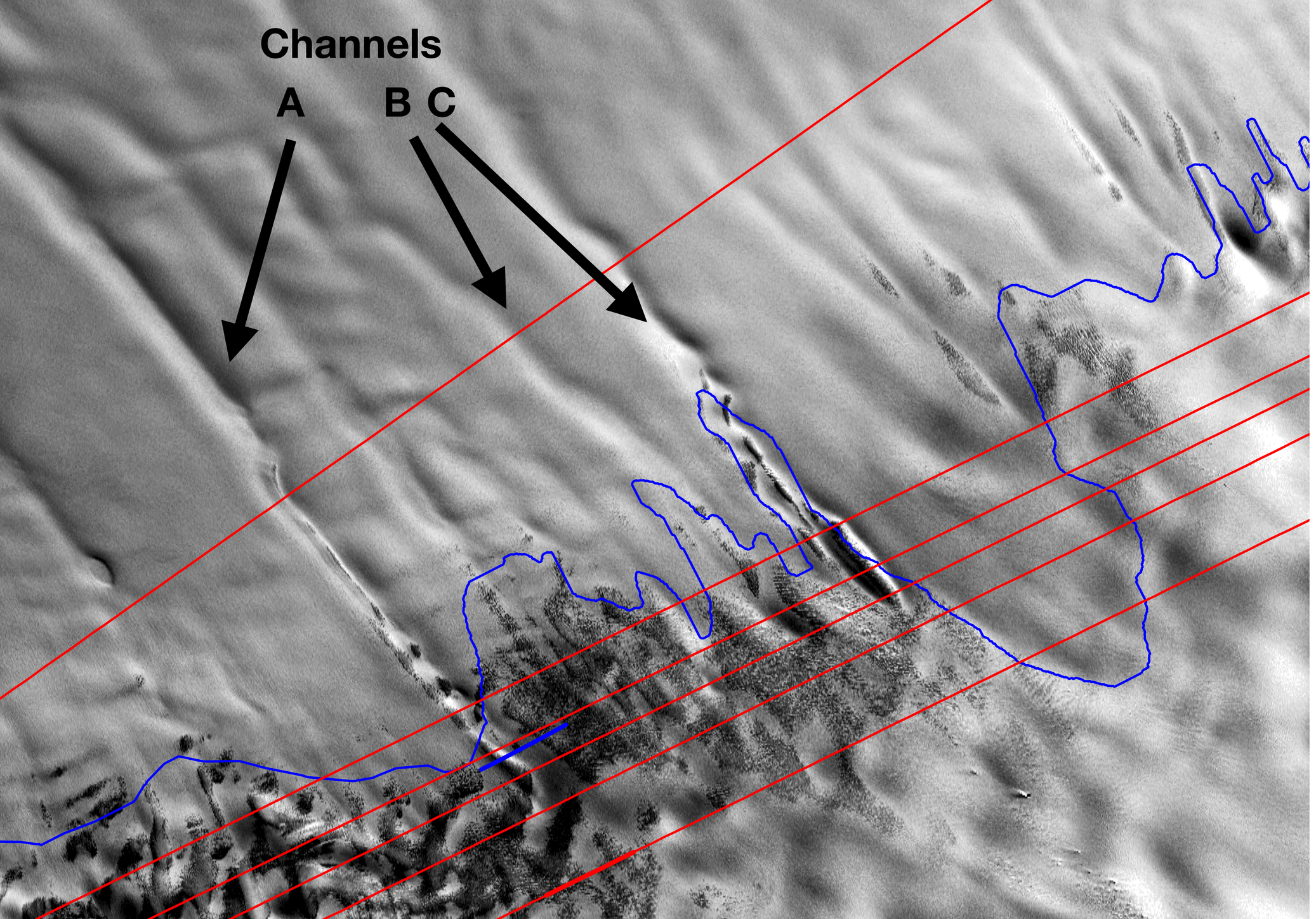


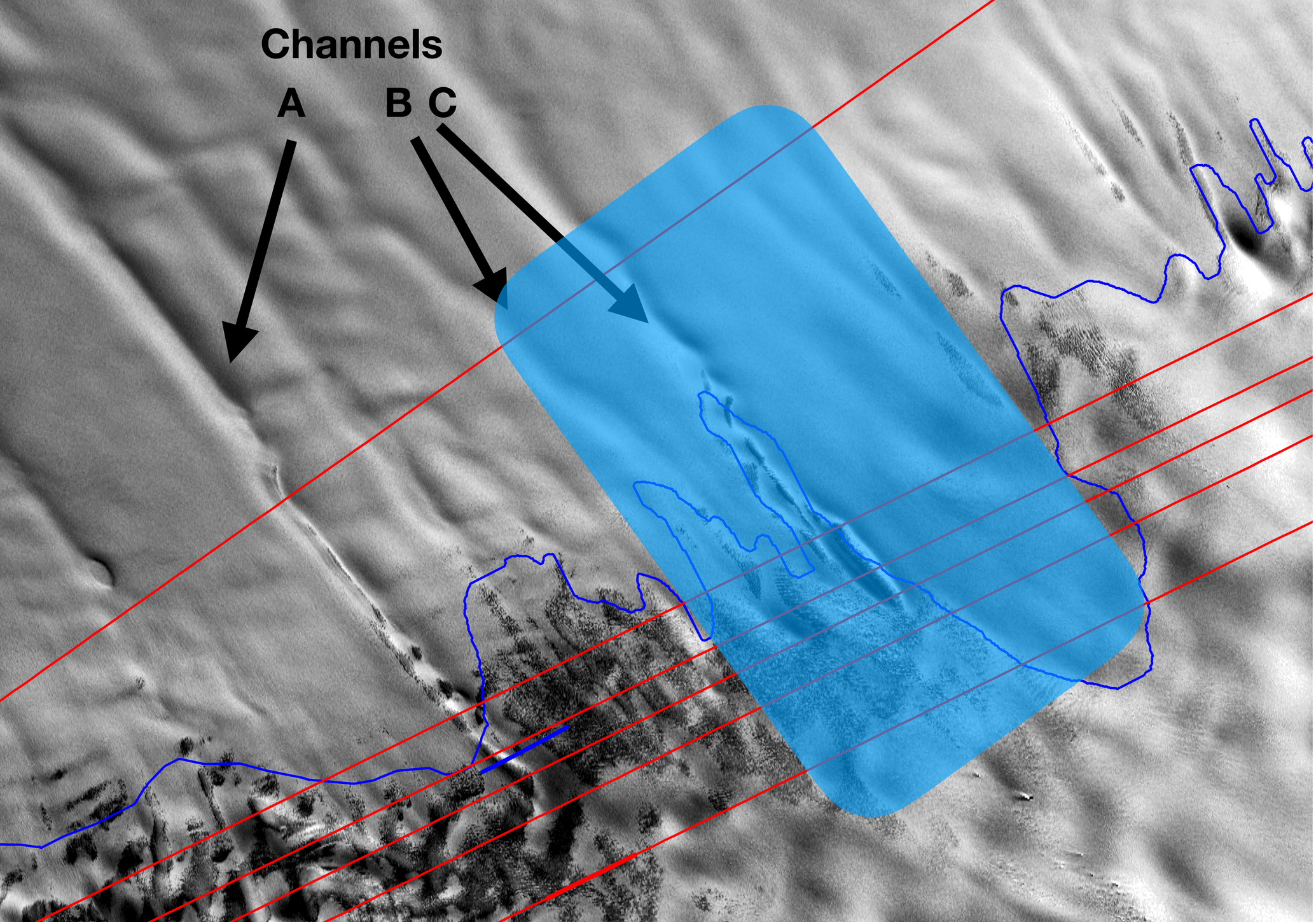
Jeofry & Ross & LeBrocq et al., 2018

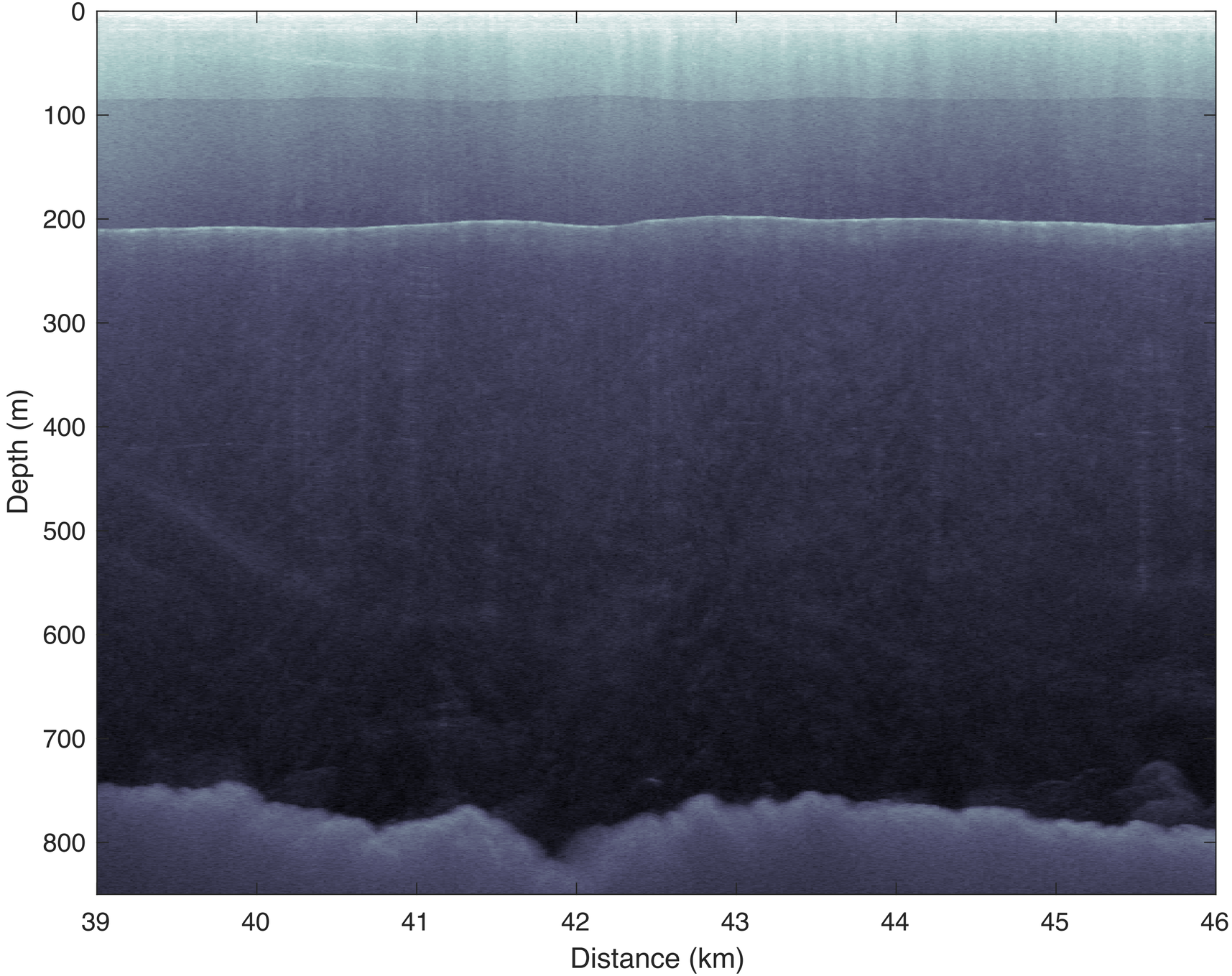

285
OUTDOOR EDUCATION
CREATION CENTER
285


Grounding
Line

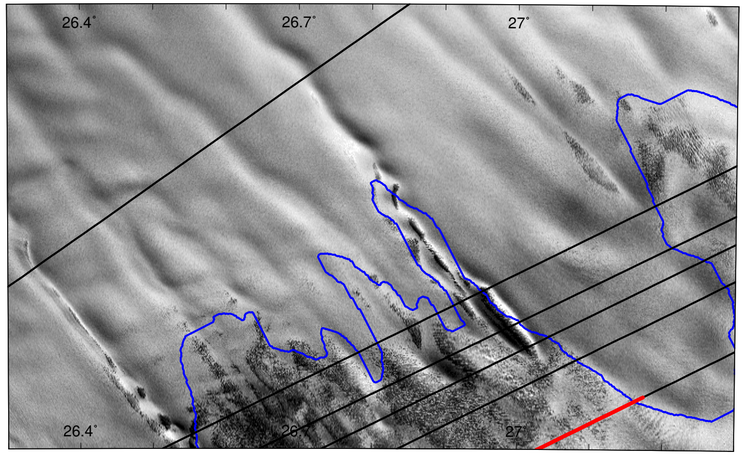

24˚E
25˚E
26˚E
27˚E
70˚S
71˚S
20 km

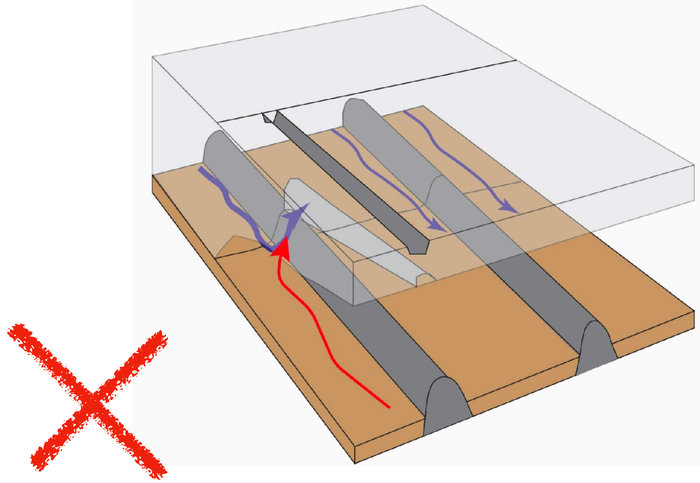

Channels
A
B C
5 km


Channels
A
B C
5 km

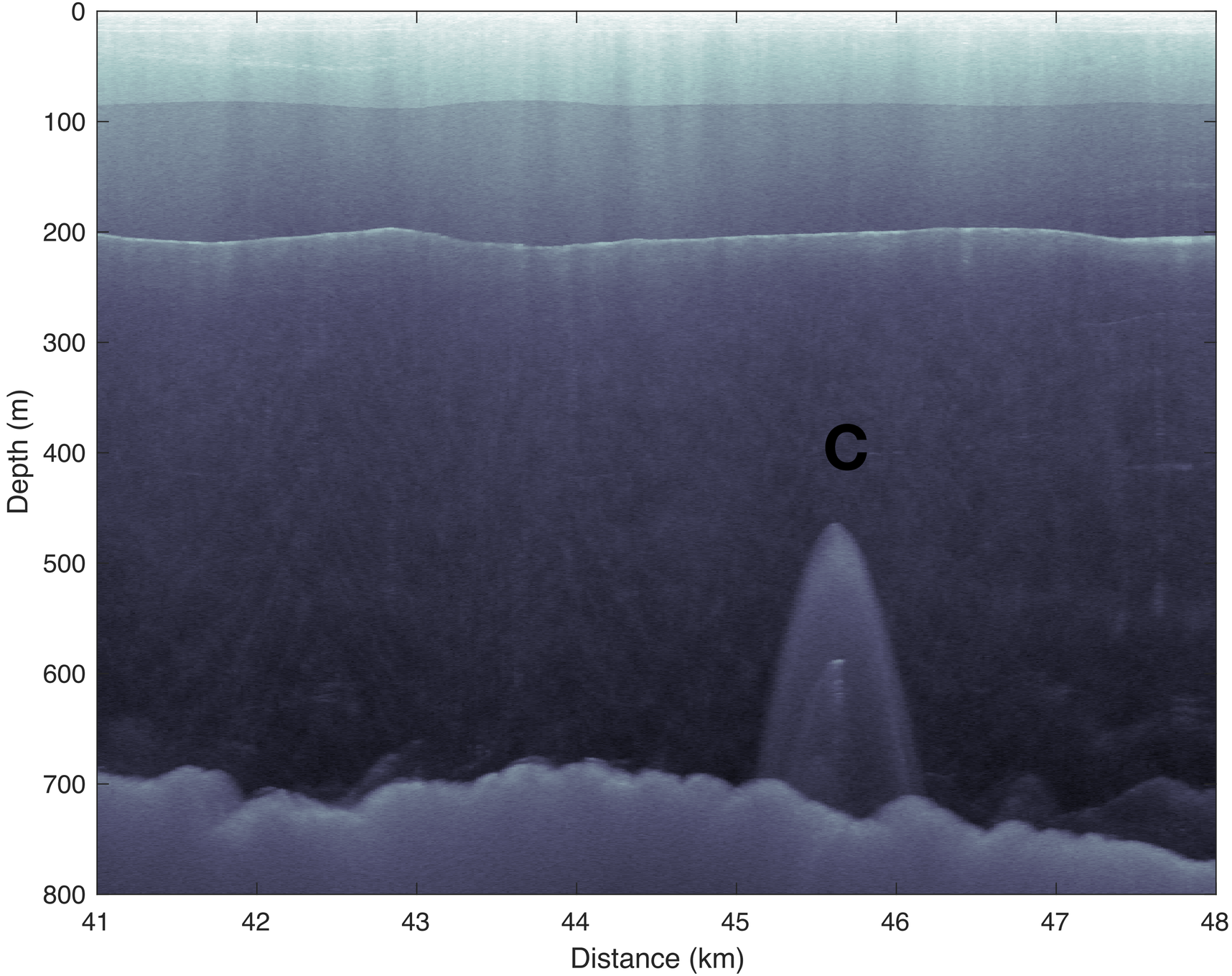


Grounded

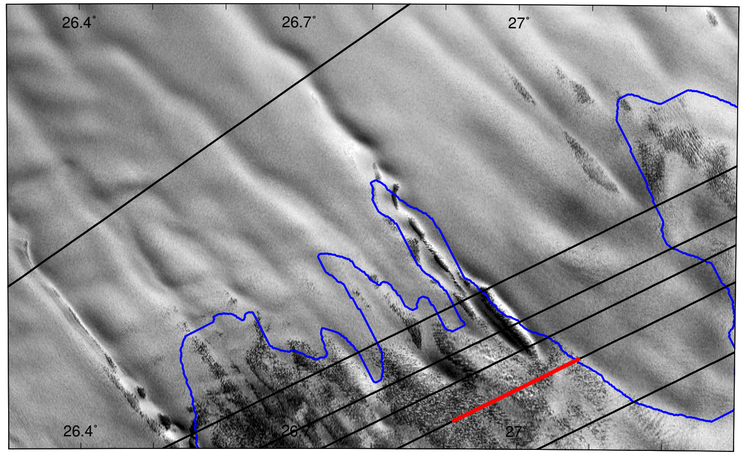


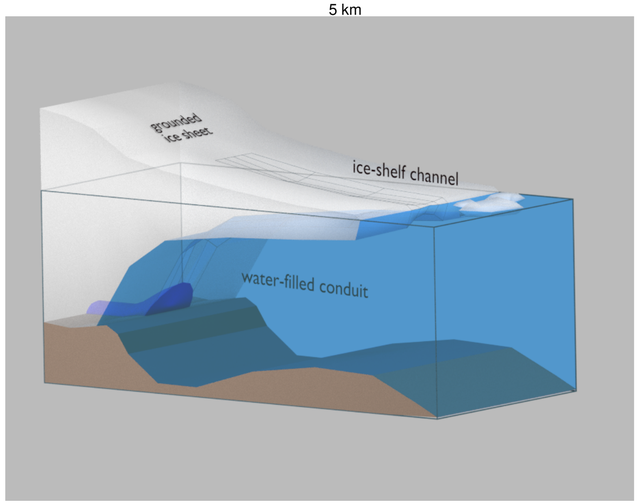


Not at Roi Baudoin Ice Shelf

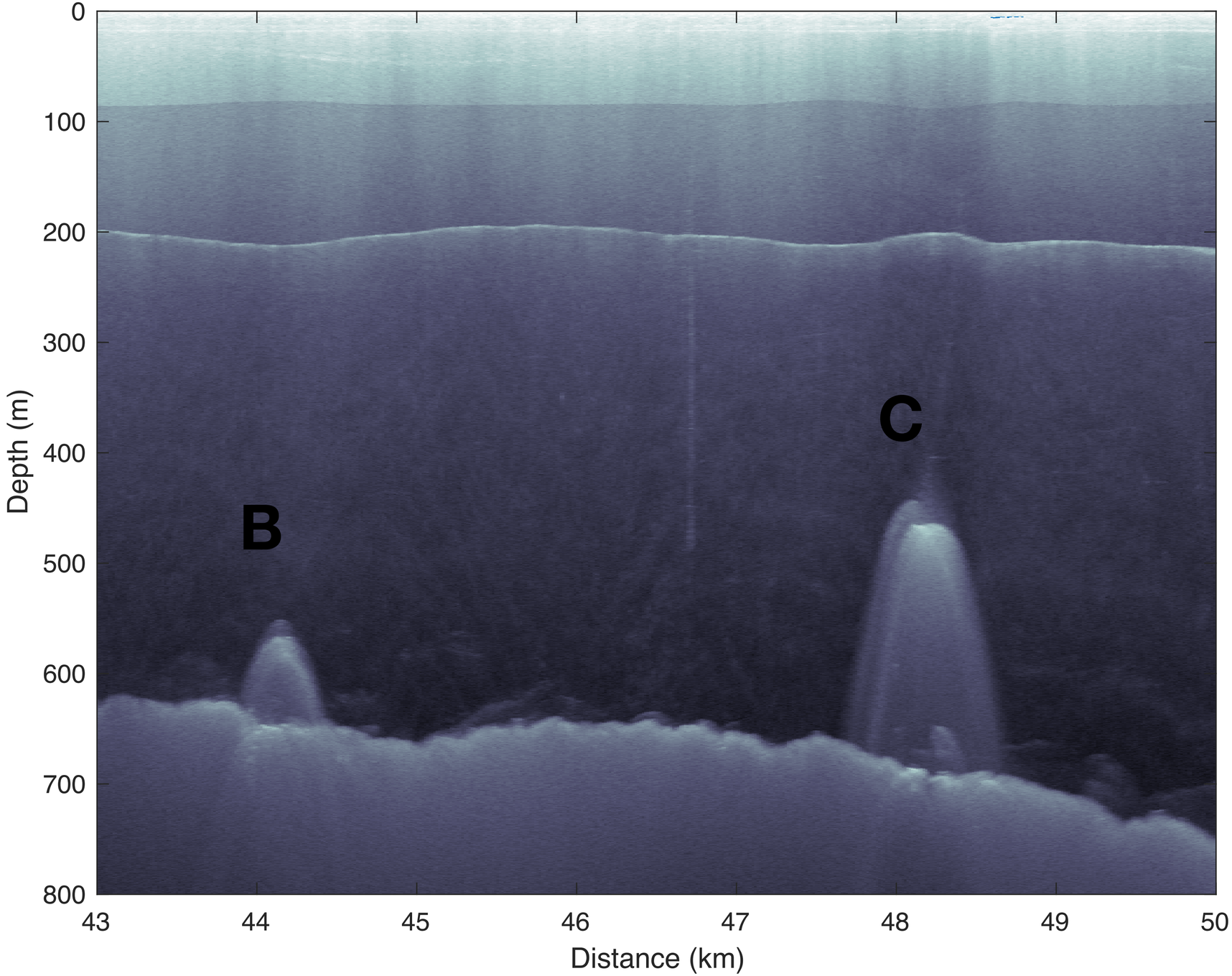


Grounded

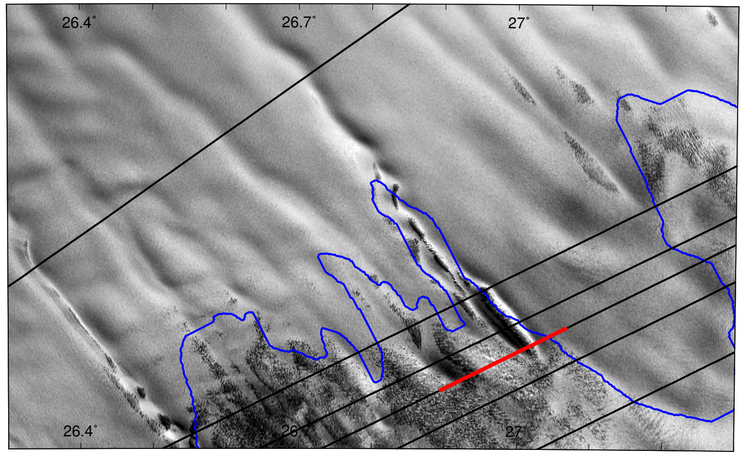


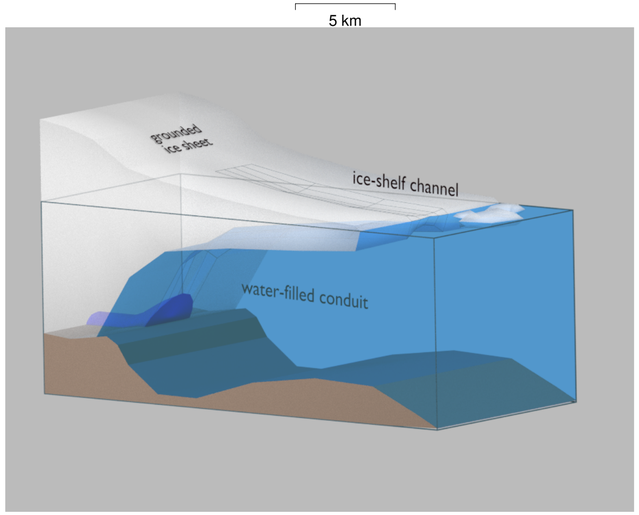


Englacial Conduit ?
Subglacial Conduit?



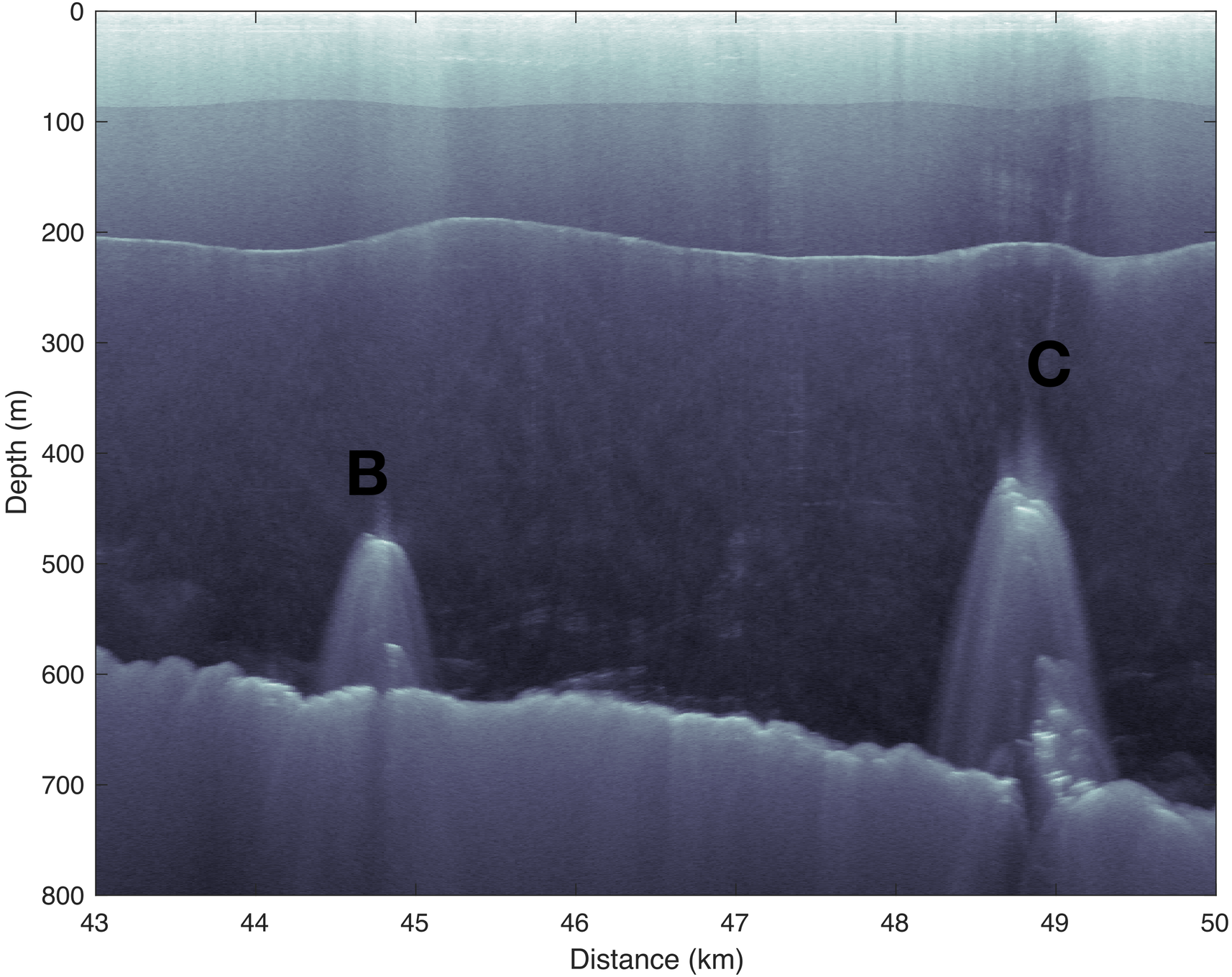
Grounded

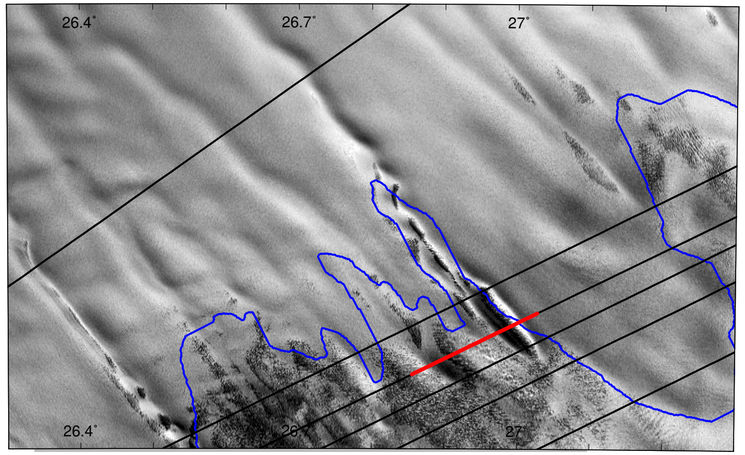


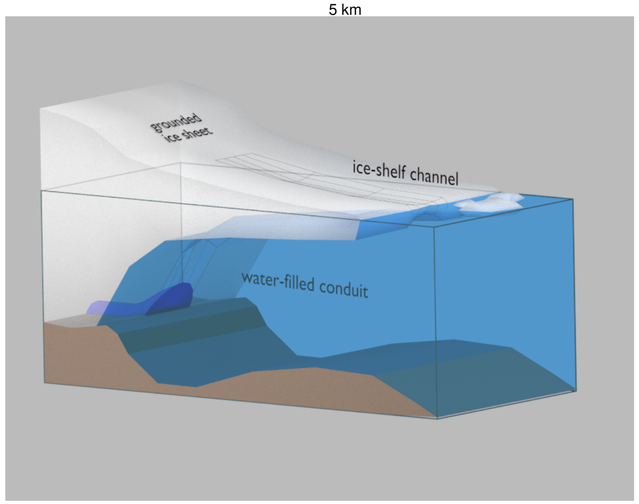


Englacial Conduit ?
Subglacial Conduit?

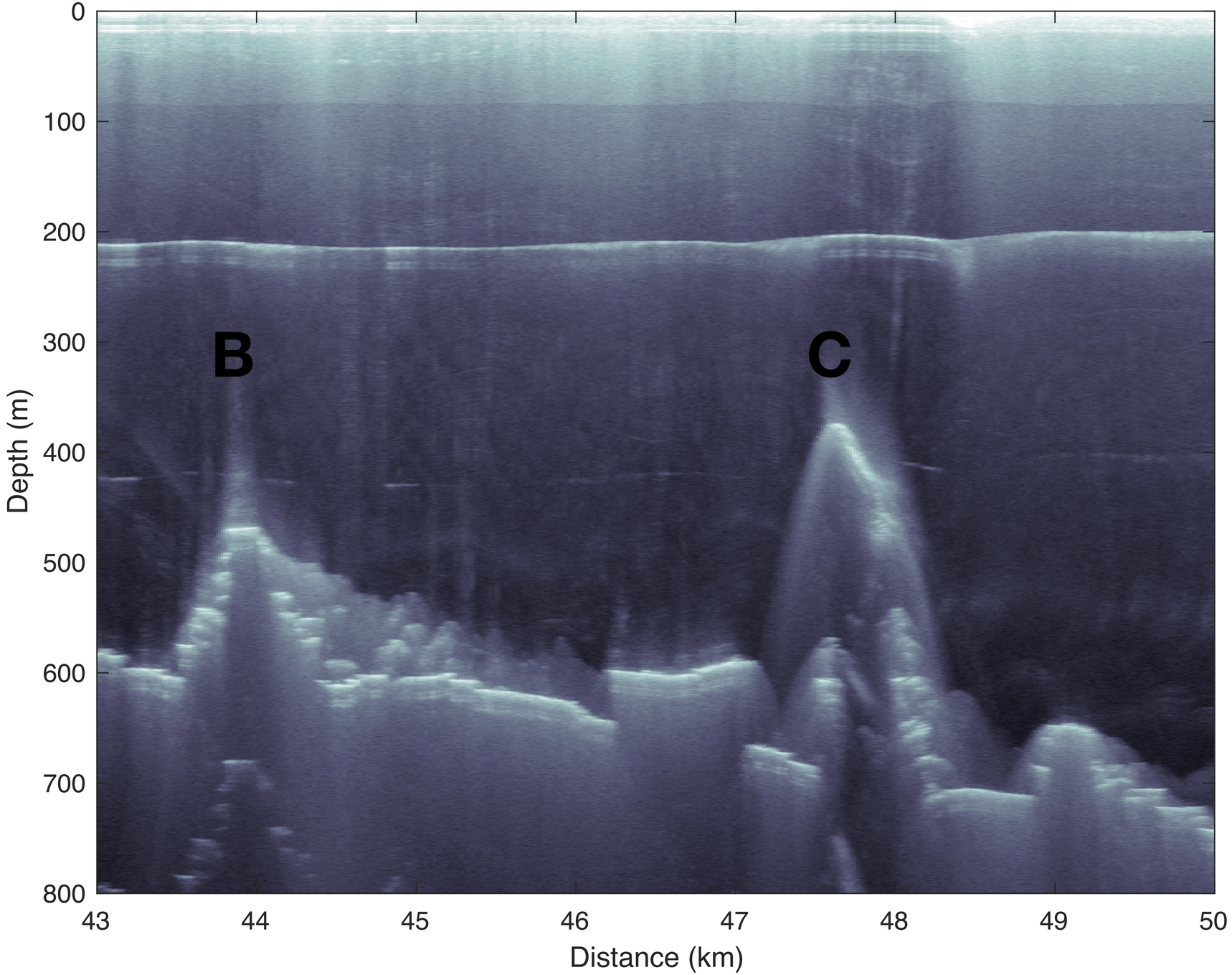
Grounding Line



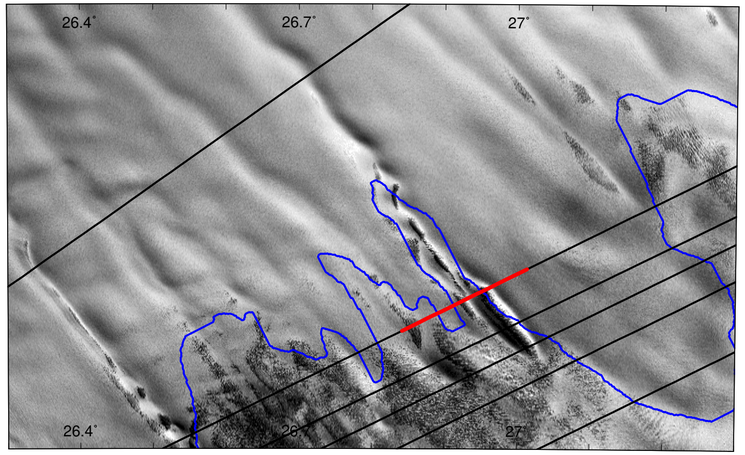




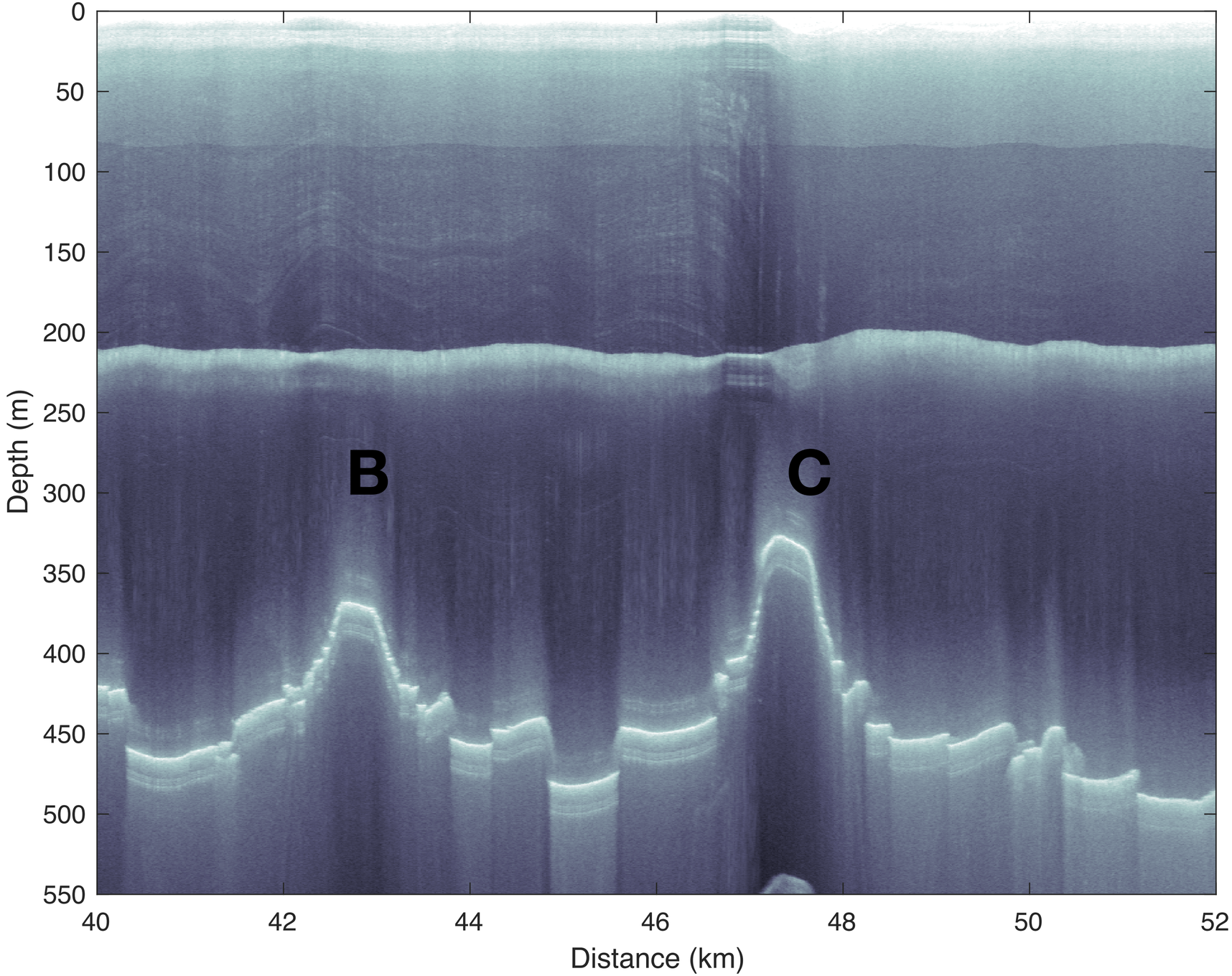
Englacial Conduit ?
Subglacial Conduit?
Sediments?

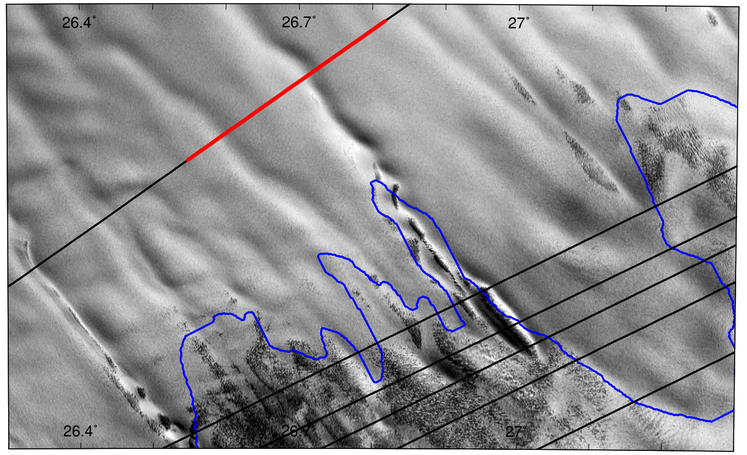


Floating



Basal terracing develops just downstream of grounding line



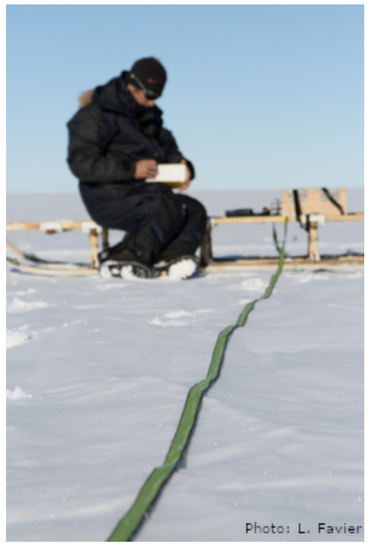


Incision decreasing away from GL, Basal terracing maintained.

Can we observe a temporal evolution of the reflectors ?

@IPF

2012

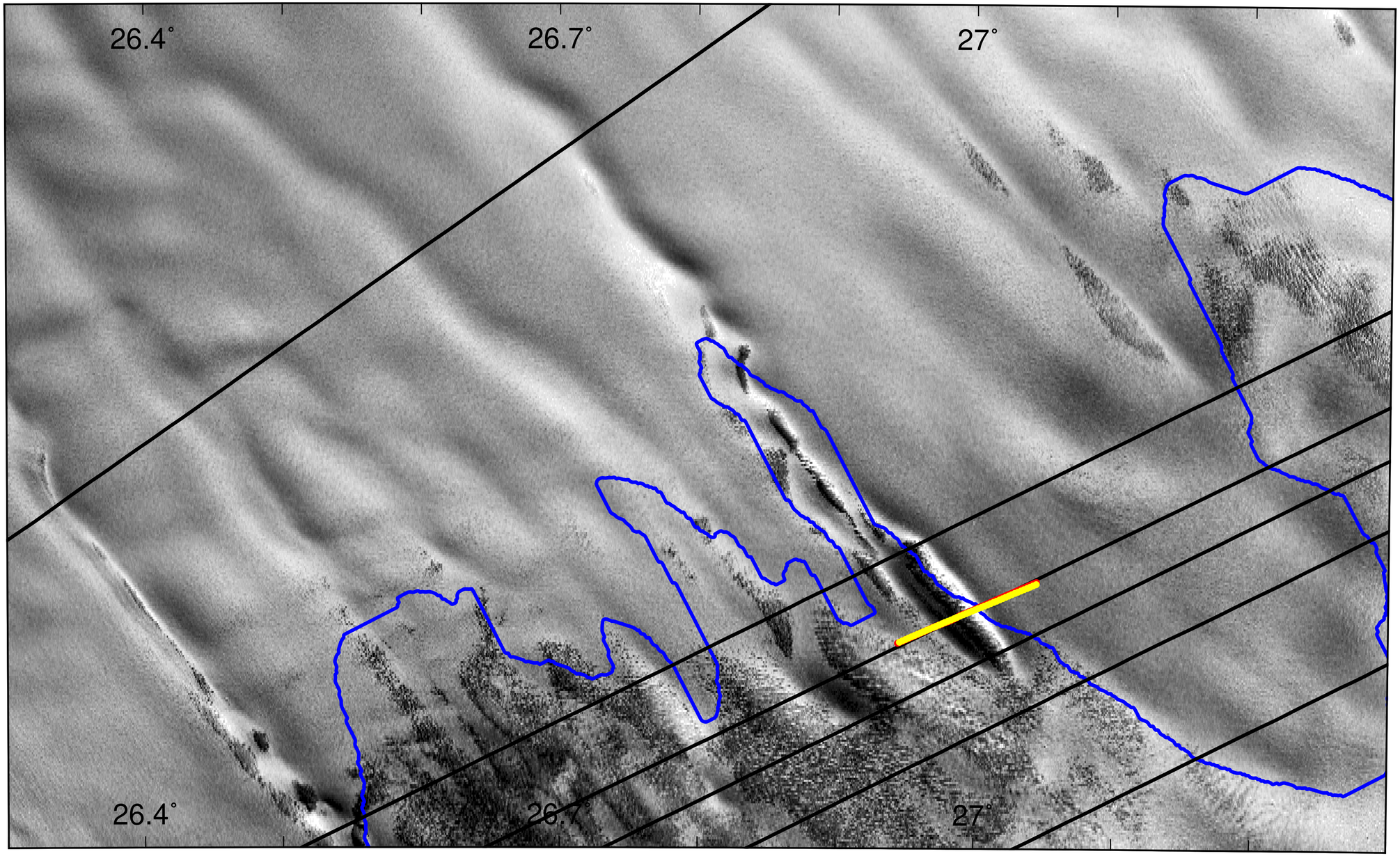


@Favier

2014

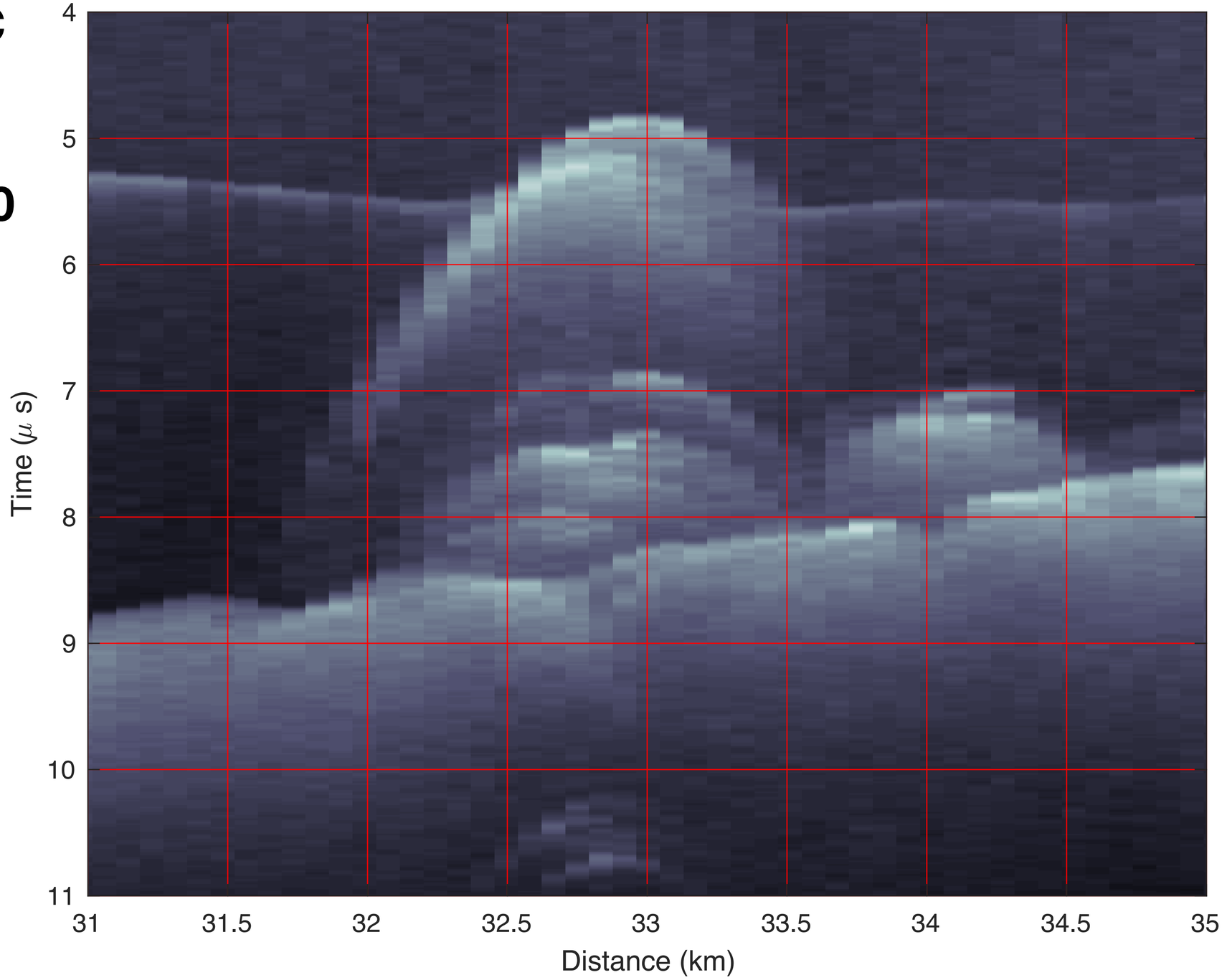
@Gehrmann

2019


26.4˚
26.7˚
27˚
26.4˚
26.7˚
27˚
5 km

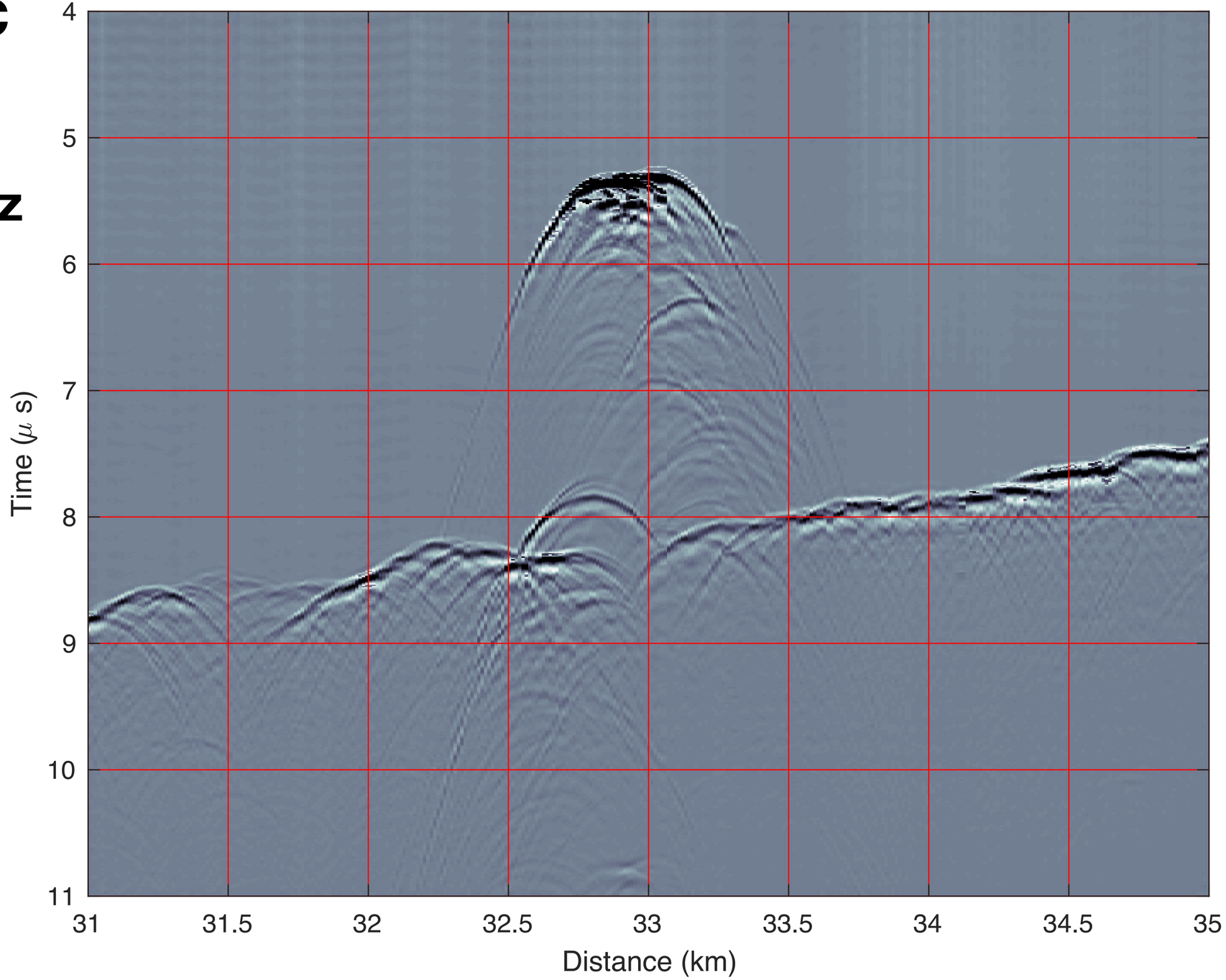
Reflector C 2012

Old AWI 150 MHz



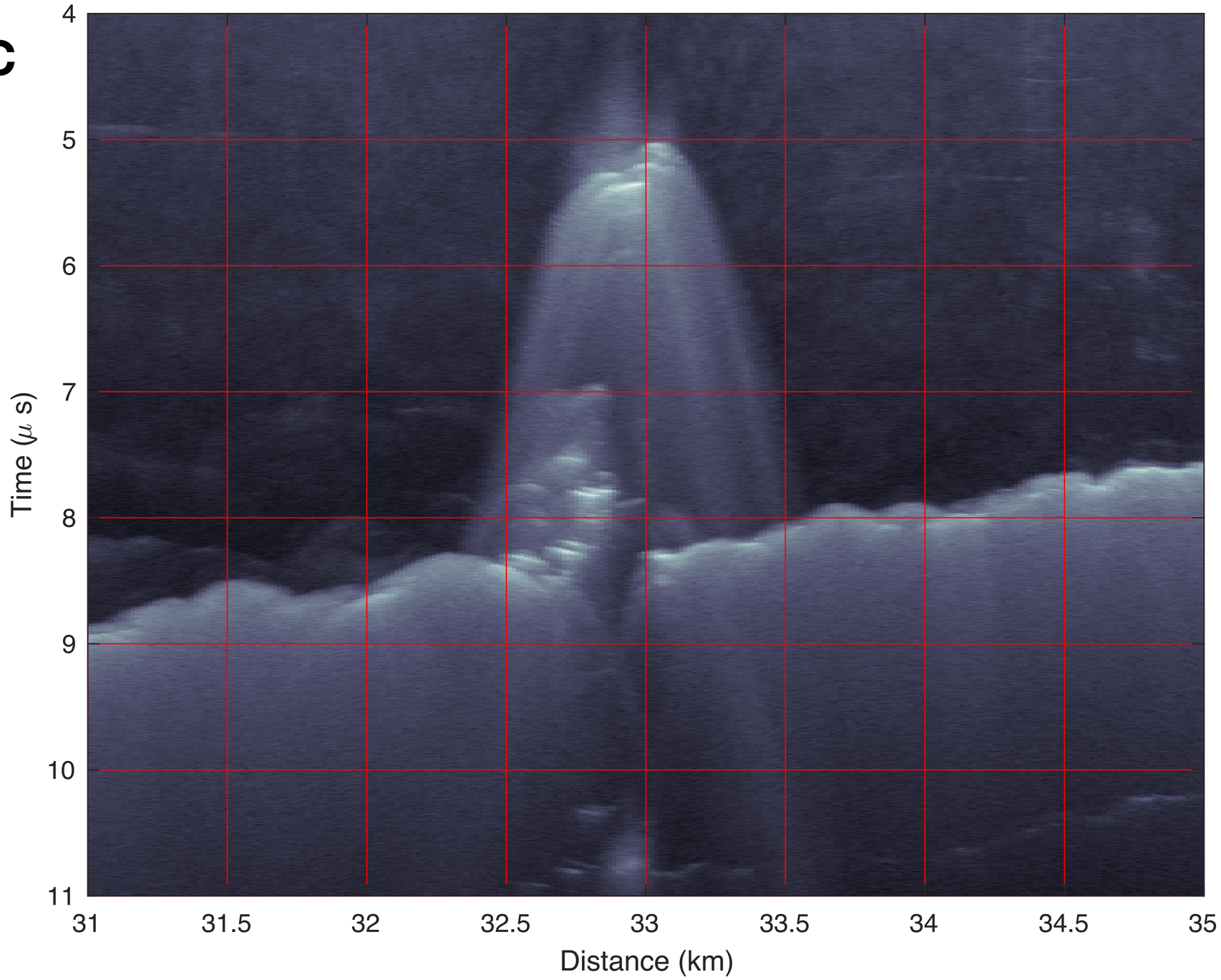
Reflector C
2014

GPR 10 MHz



Reflector C
2018

AWI UWB



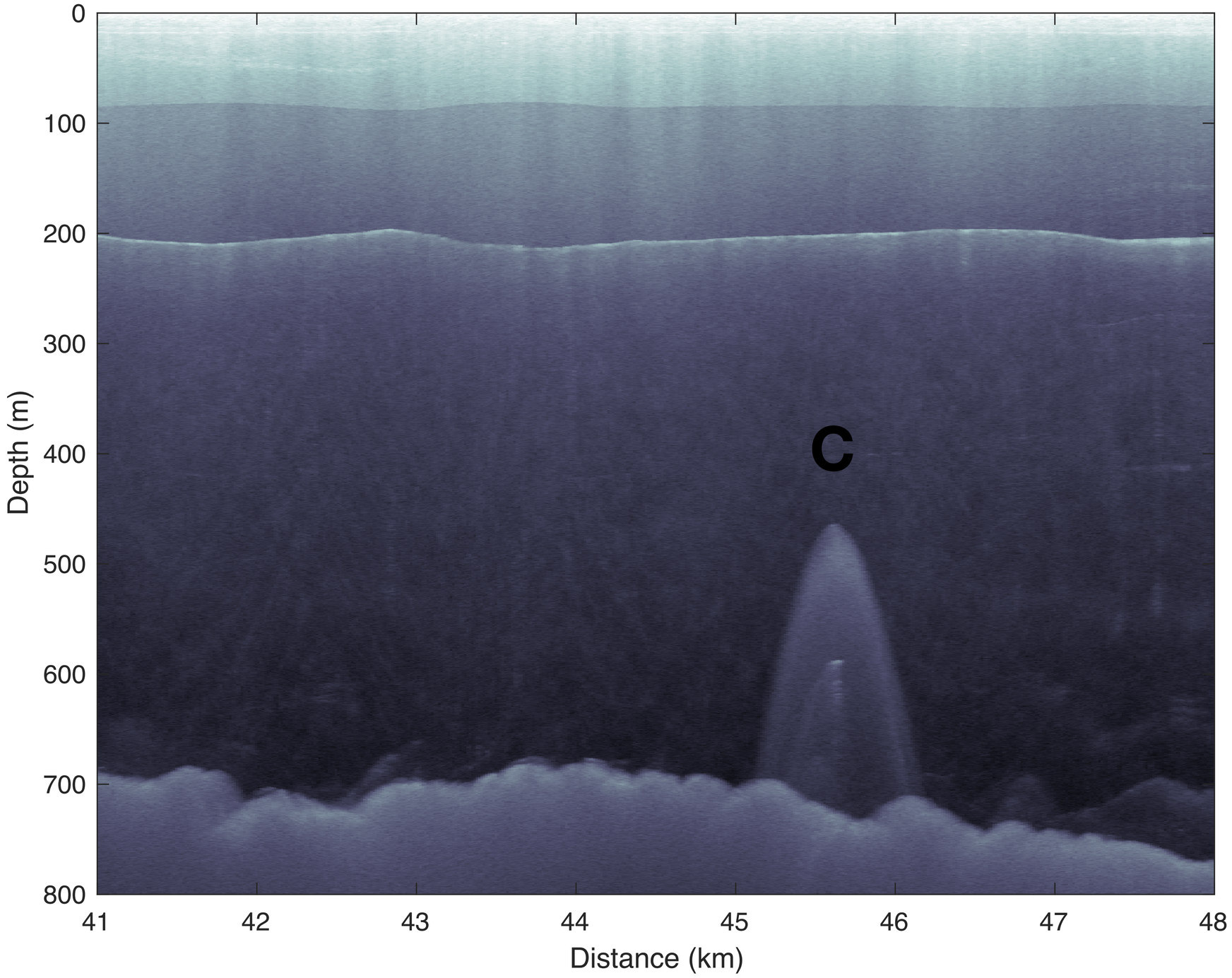
Questions Addressed

1. What defines ice-shelf channel morphology?

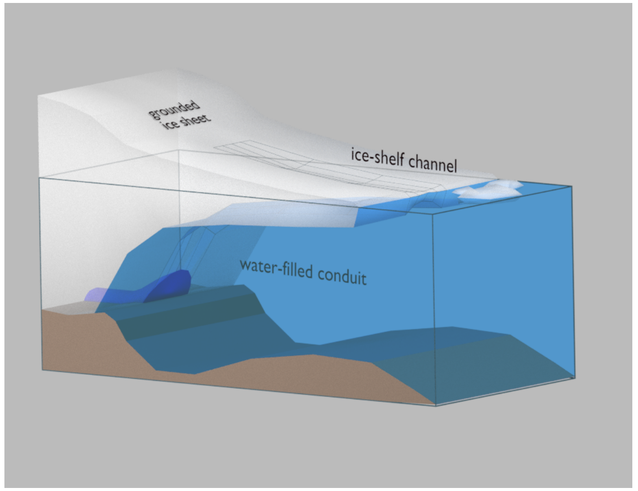
→ In part it is the surface mass balance.
(There are other factors)

3. What is the origin of ice-shelf channels ?

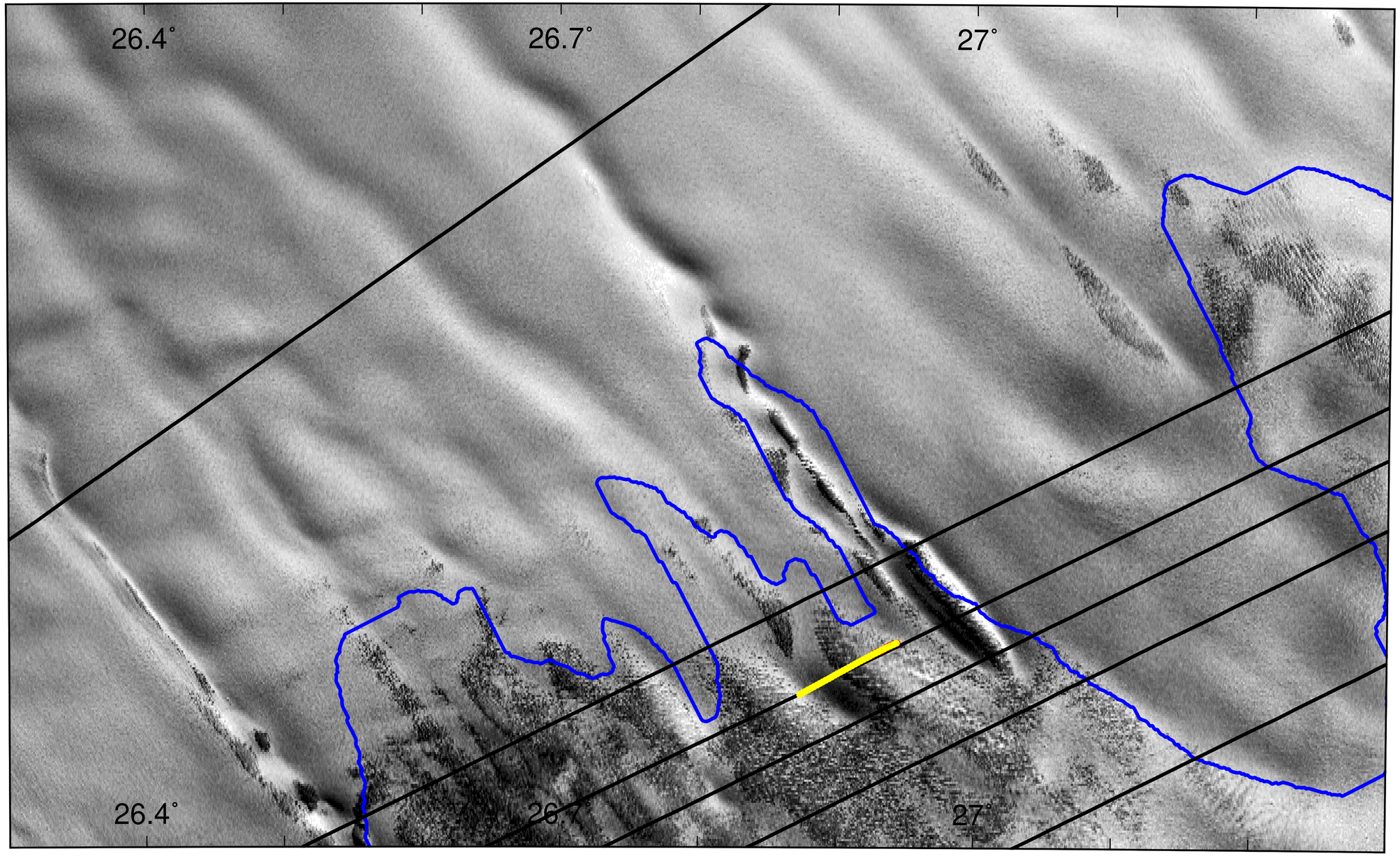
→ Cavities 3- 5 km upstream of the GL growing in height & maintained by high melt rates from mixing of ocean/subglacial water + local sediment deposition.



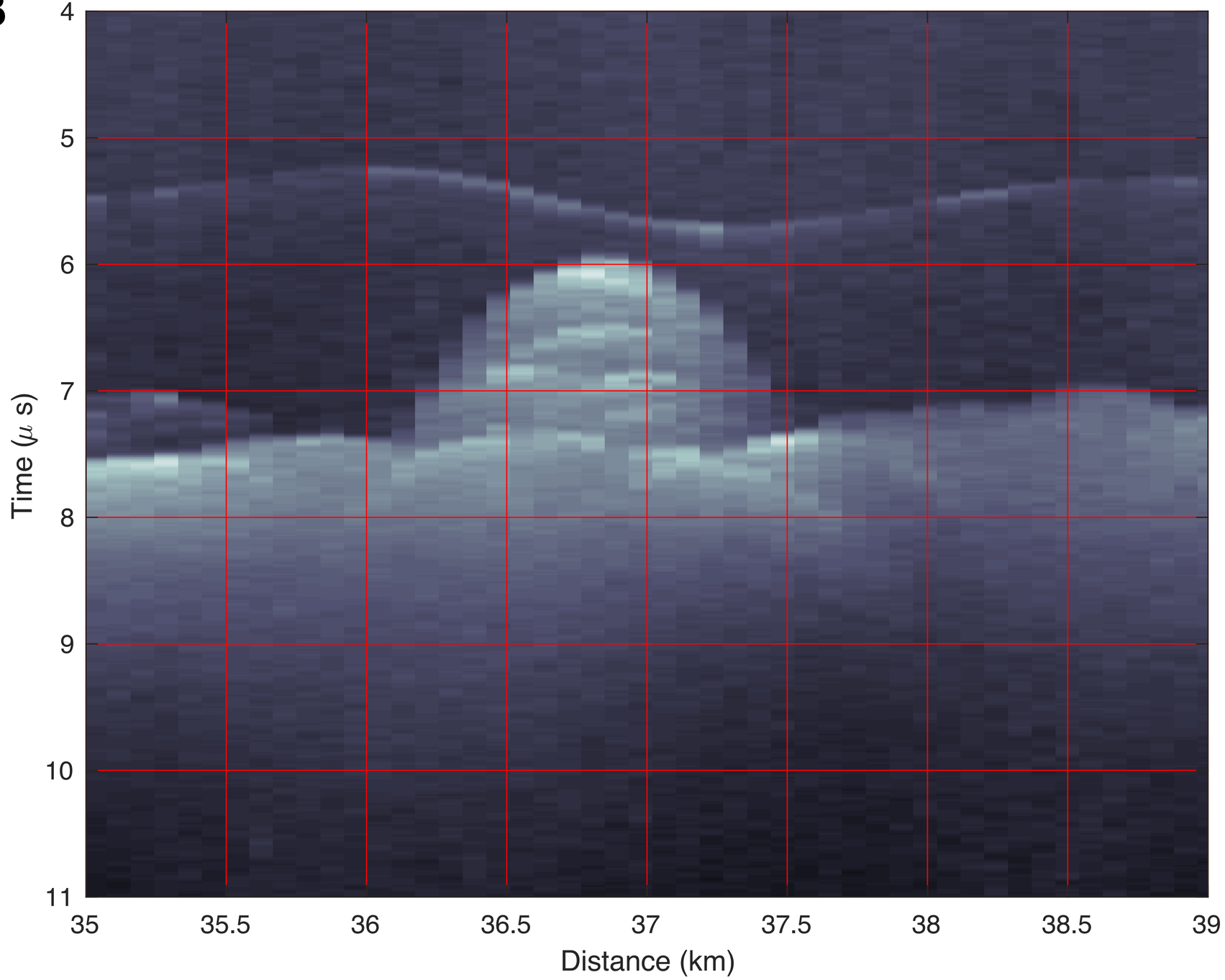
Grounded



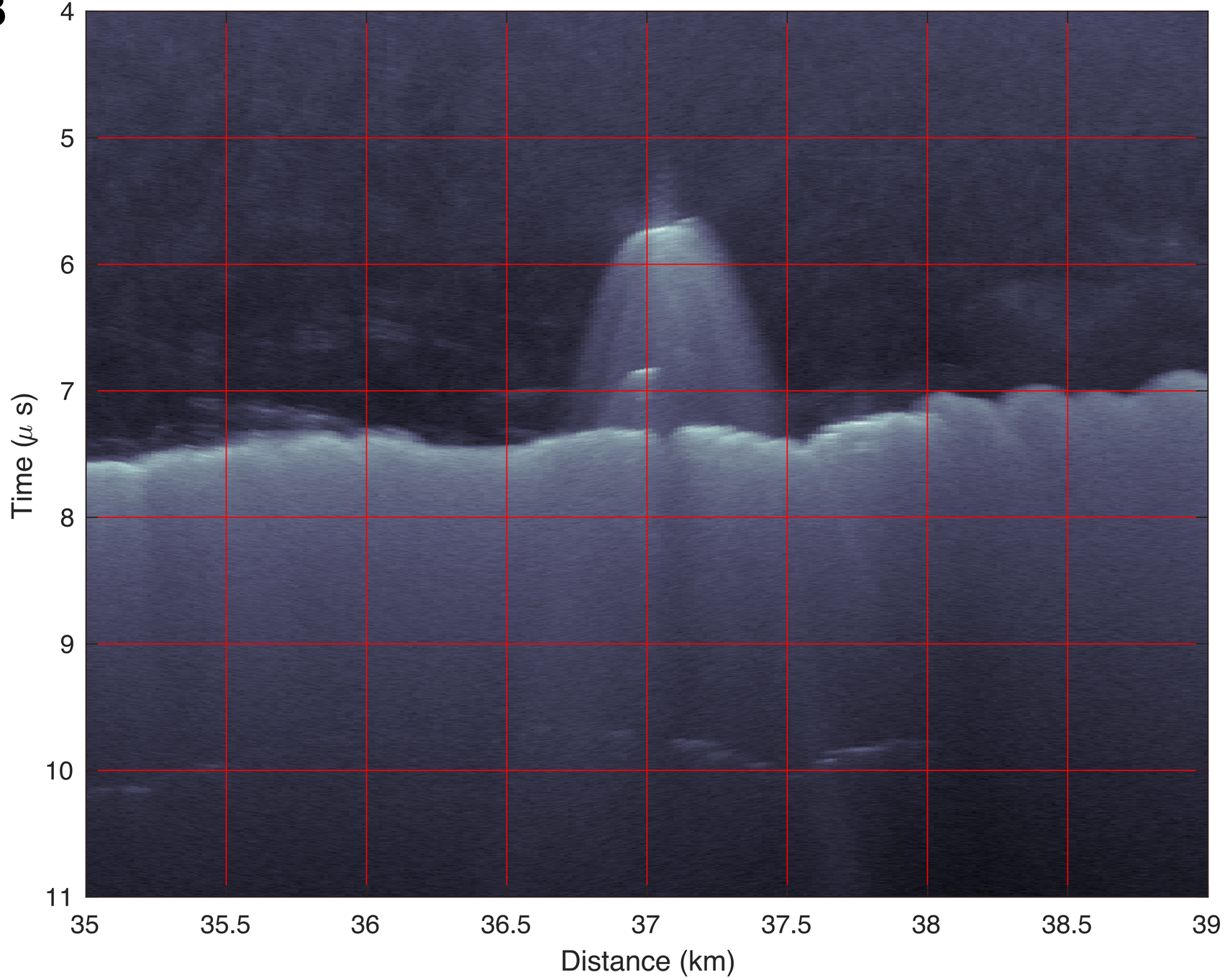
Englacial Conduit ?
Subglacial Conduit?

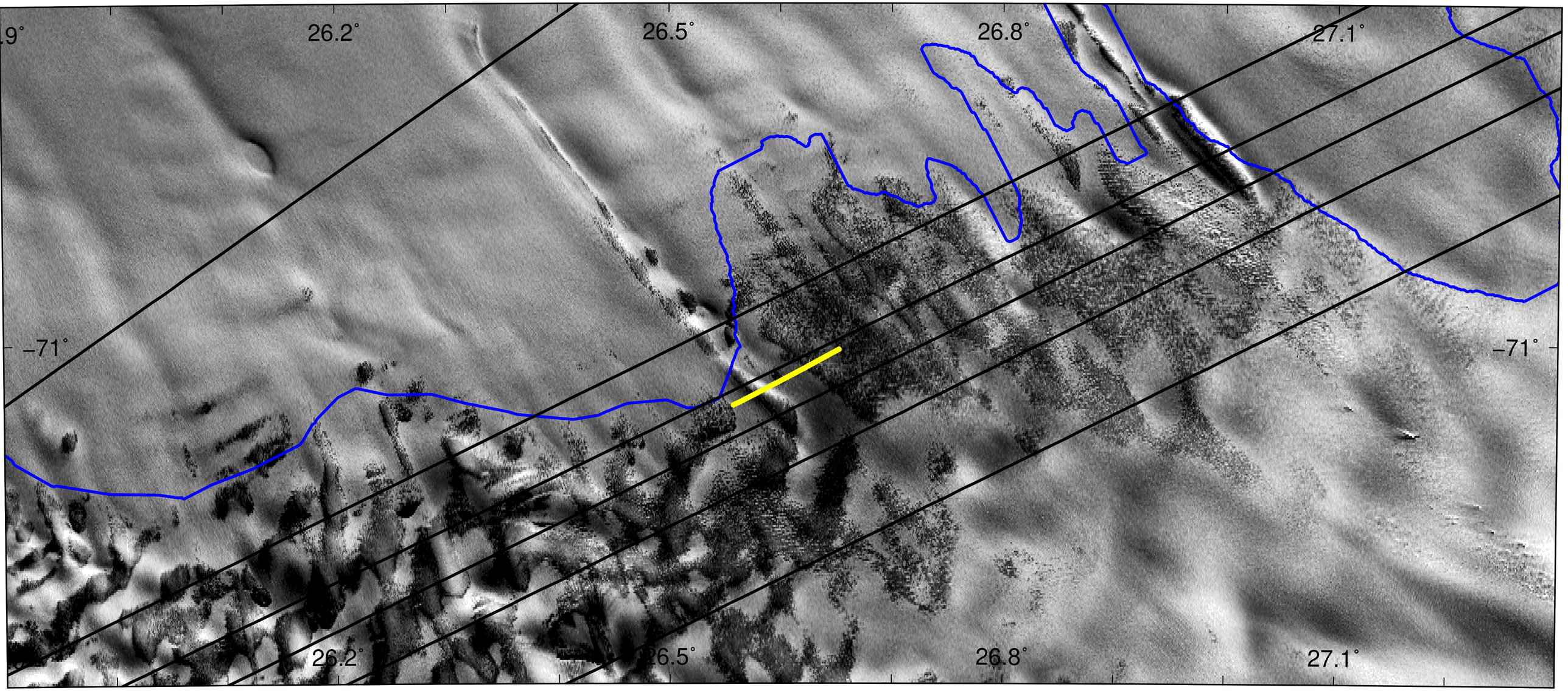

26.4˚
26.7˚
27˚
26.4˚
26.7˚
27˚
5 km

Reflector B

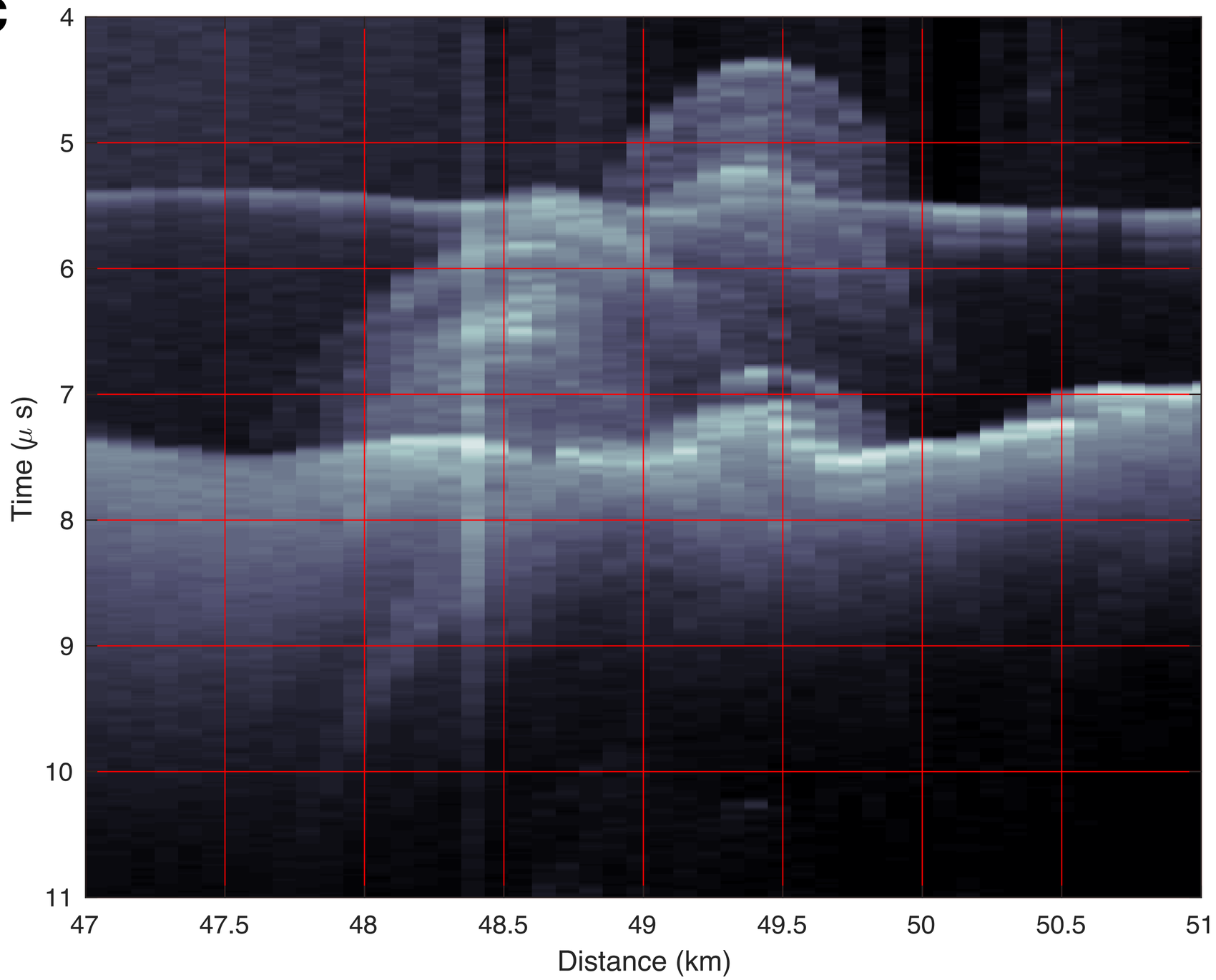


Reflector B

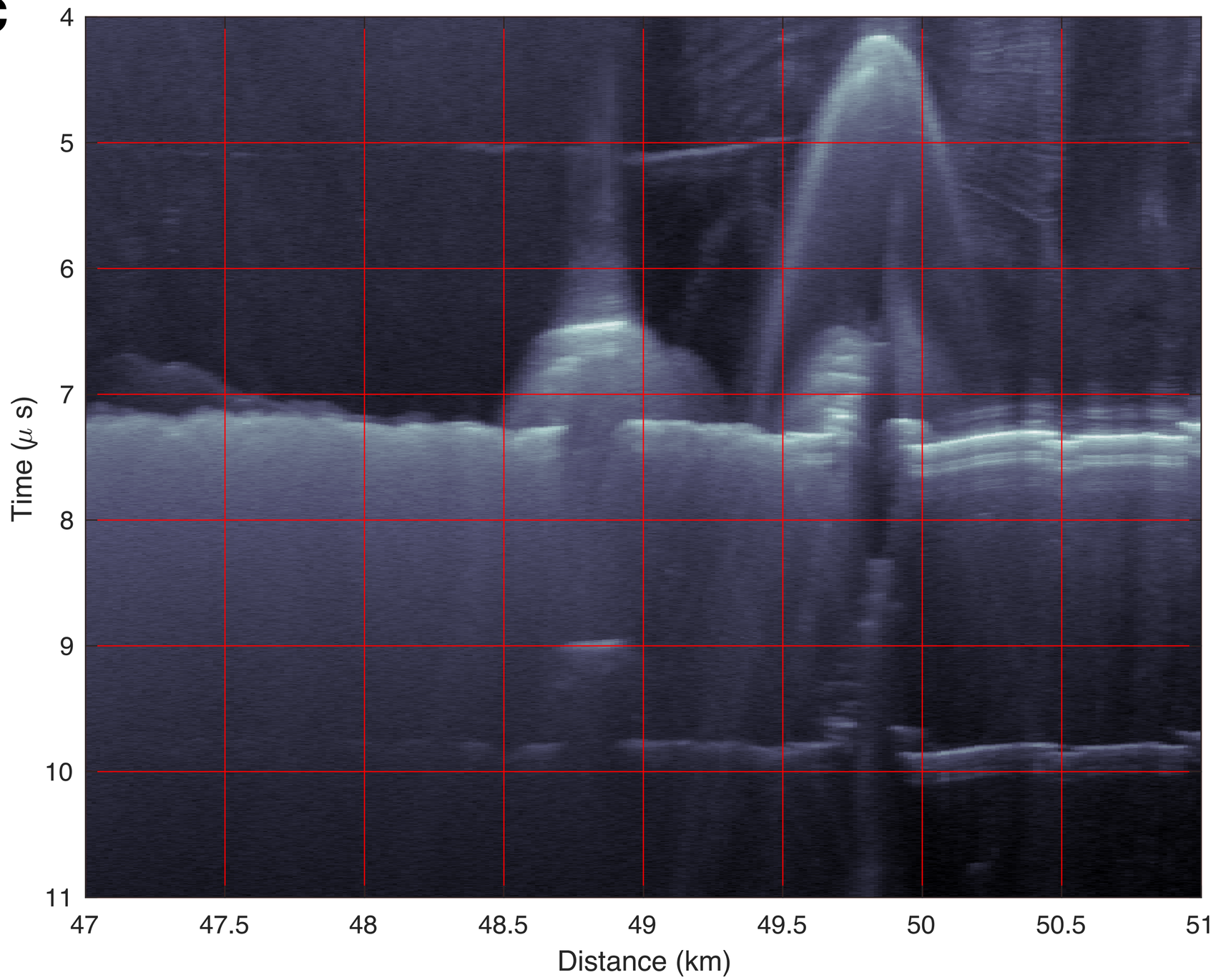



9˚
26.2˚
26.5˚
26.8˚
27.1˚
−71˚
−71˚
26.2˚
26.5˚
26.8˚
27.1˚
5 km

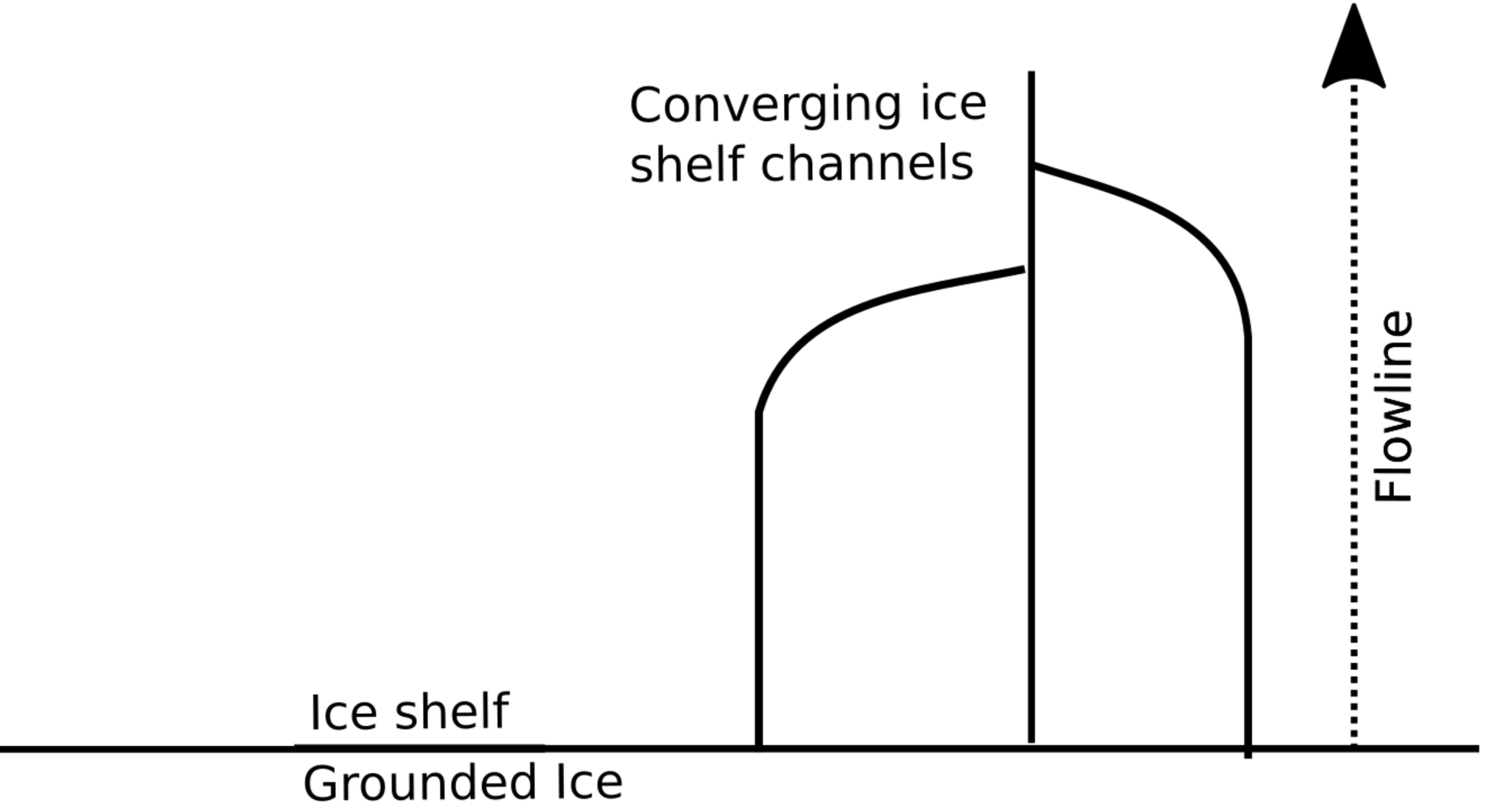
Reflector C



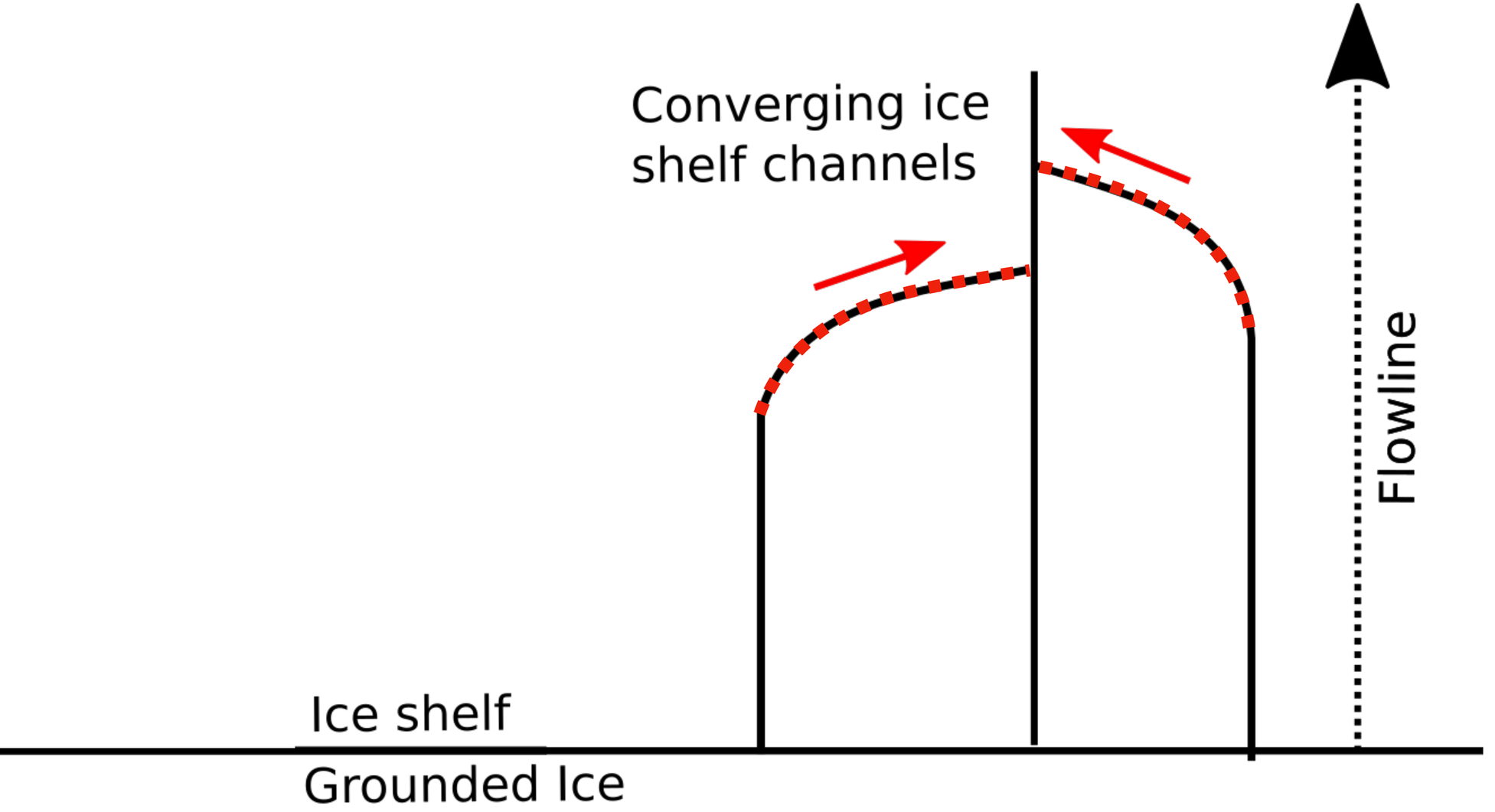
Reflector C



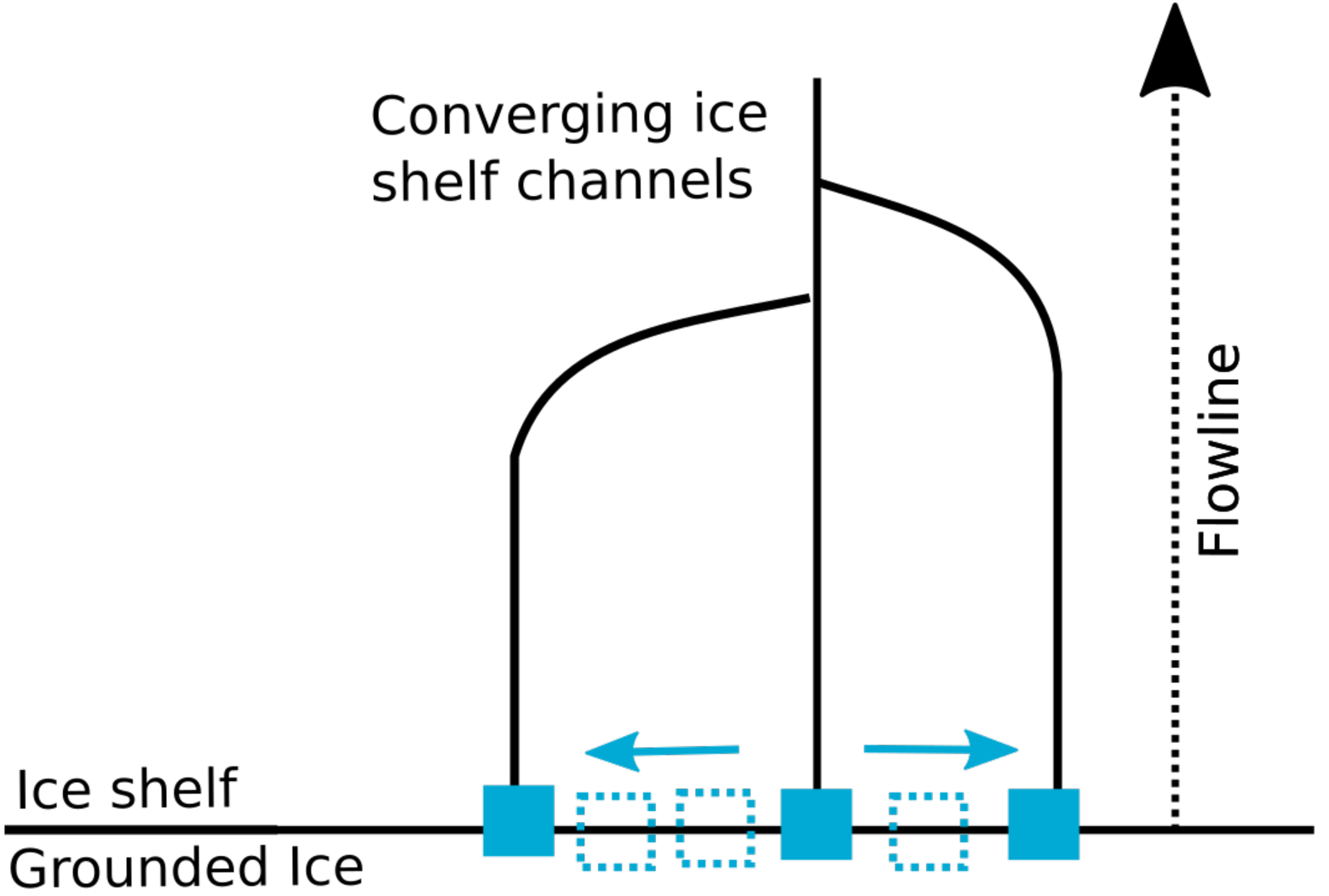
(b)


Converging ice
shelf channels
Flowline
Ice shelf
Grounded Ice

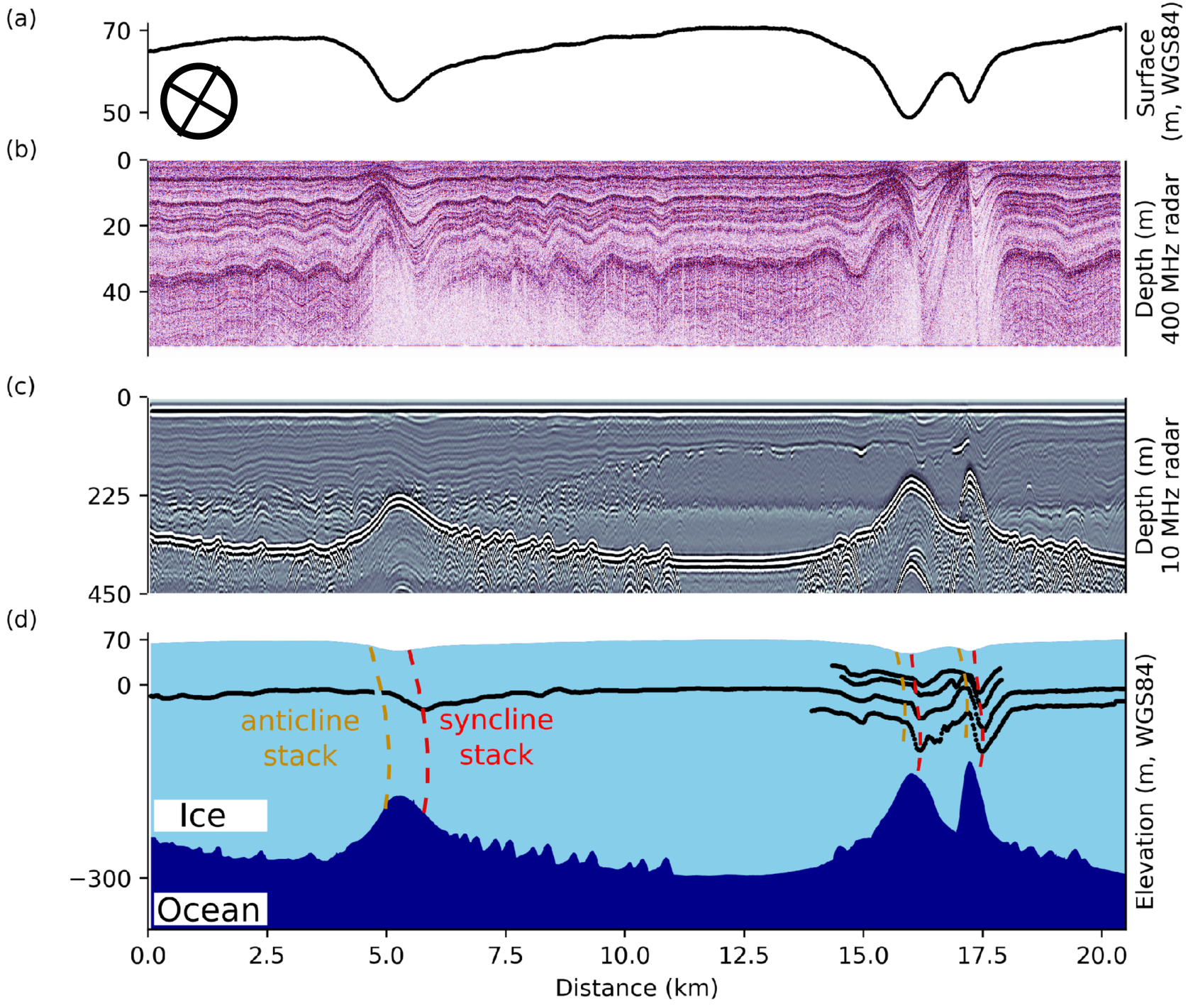
(b) Hypothesis 1: Convergence by ocean melting

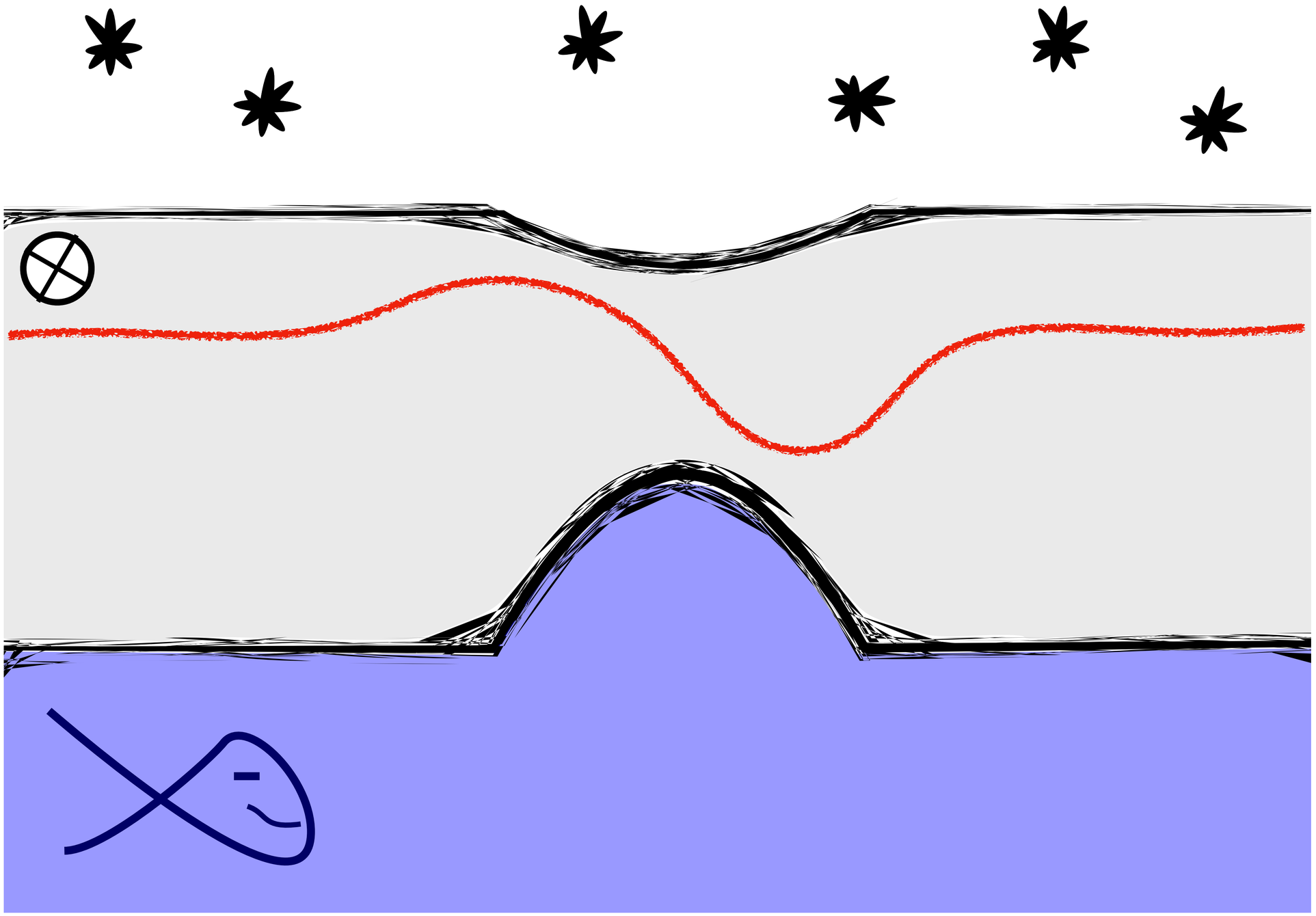


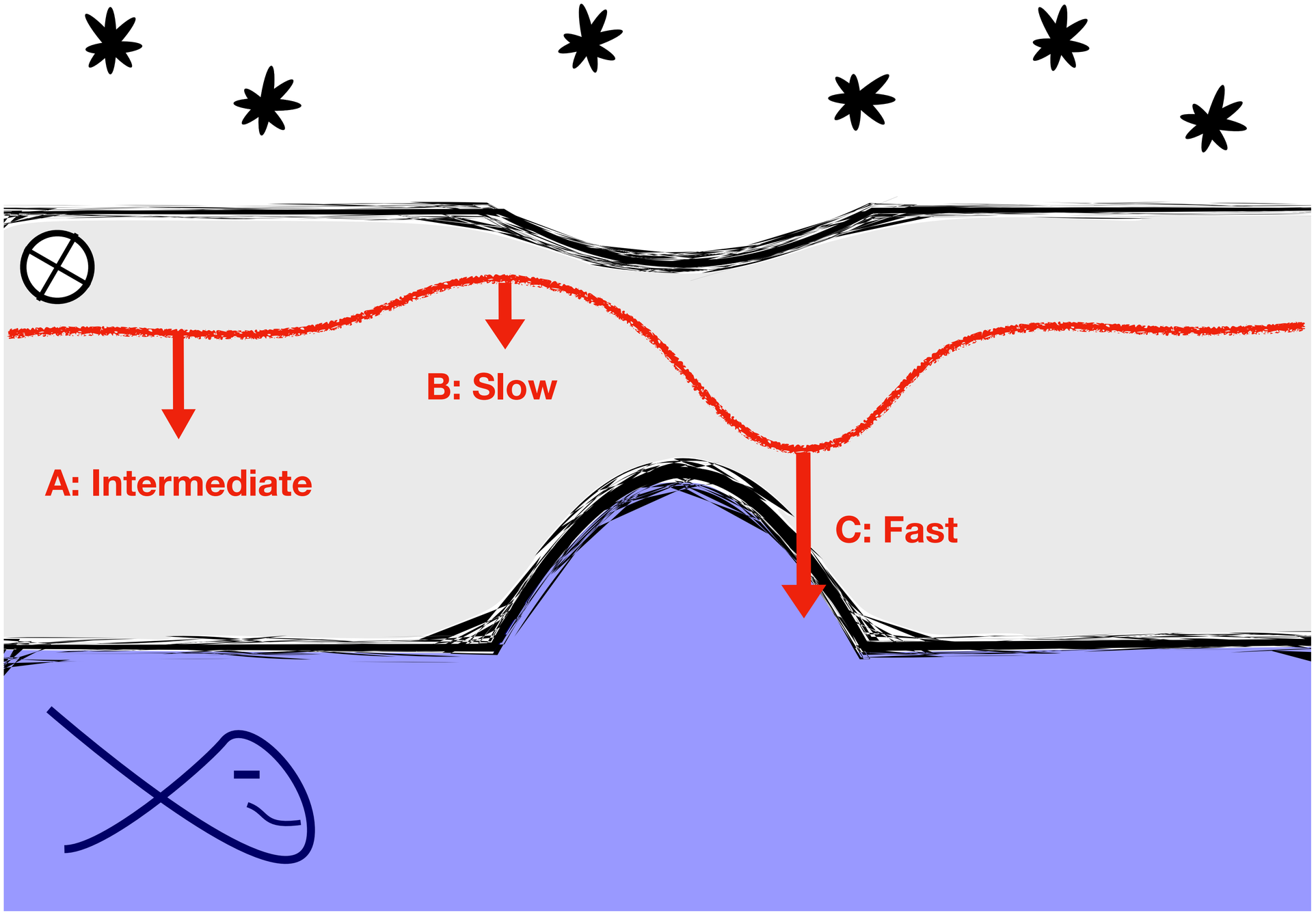
(b)



Hypothesis 2: Splitting of sources
at grounding line


(a)
70
50
Surface
(m, WGS84)
(b)
0
20
40
Depth (m)
400 MHz radar
(c)
0
225
450
Depth (m)
10 MHz radar
(d)
70
0
−300
anticline
stack
syncline
stack
Ice
Ocean
Elevation (m, WGS84)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Distance (km)




A: Intermediate
B: Slow
C: Fast

Column Adjustment
Atmosphere + Ocean

$$u_z(z) = \dot{a}\frac{\rho_i}{\rho_w} + \dot{b}(1 - \frac{\rho_i}{\rho_w})$$

Ice Dynamic Deformation

$$+ \left(H(1 - \frac{\rho_i}{\rho_w}) + (z - z_s) \right) \frac{\partial u_x}{\partial x}$$

(For 2D plug-flow + Hydrostatic Equilibrium)

Atmosphere + Ocean

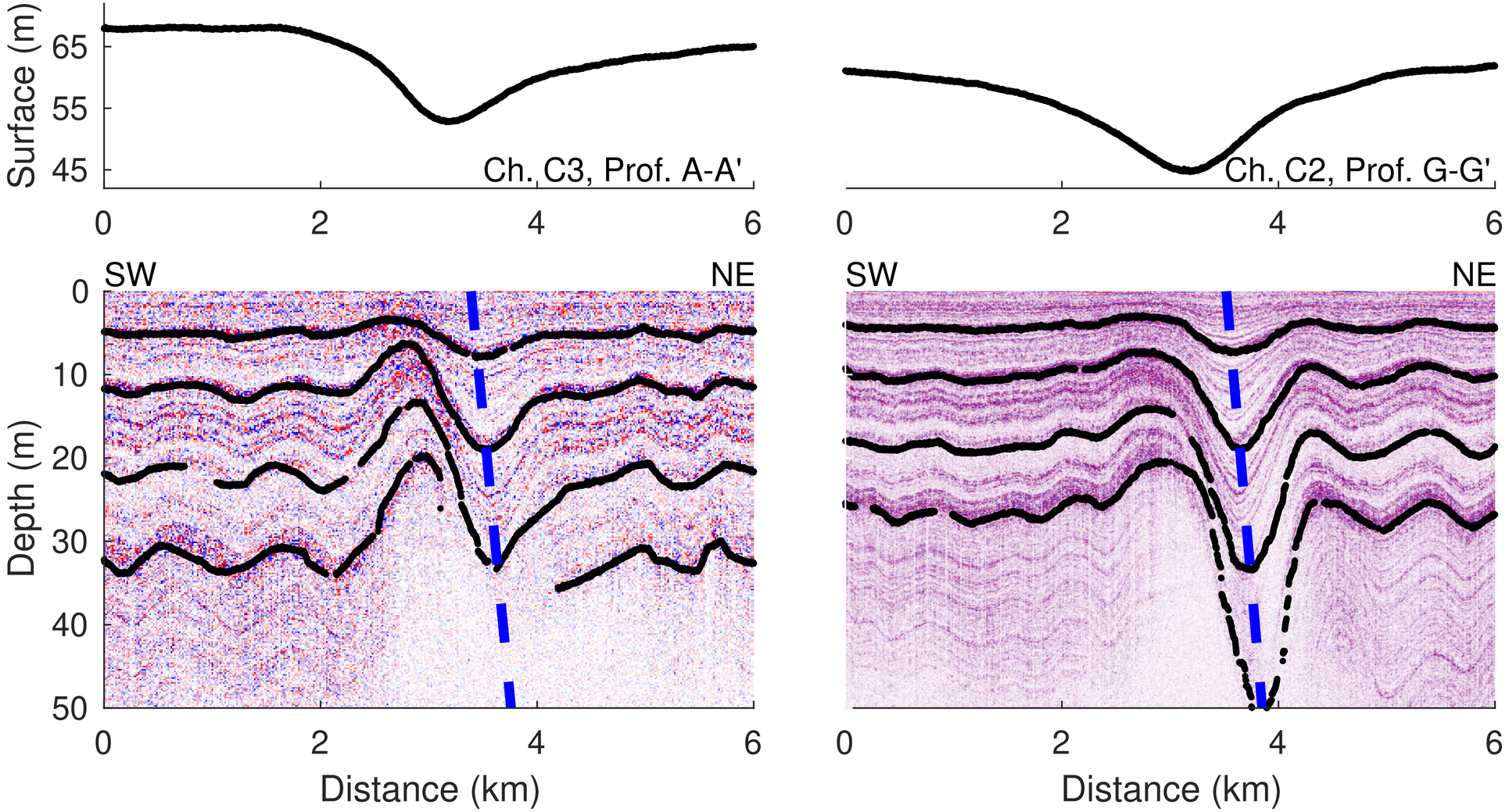
$$u_z(z) = \dot{a}\frac{\rho_i}{\rho_w} + \dot{b}(1 - \frac{\rho_i}{\rho_w})$$

~0.9 ~0.1

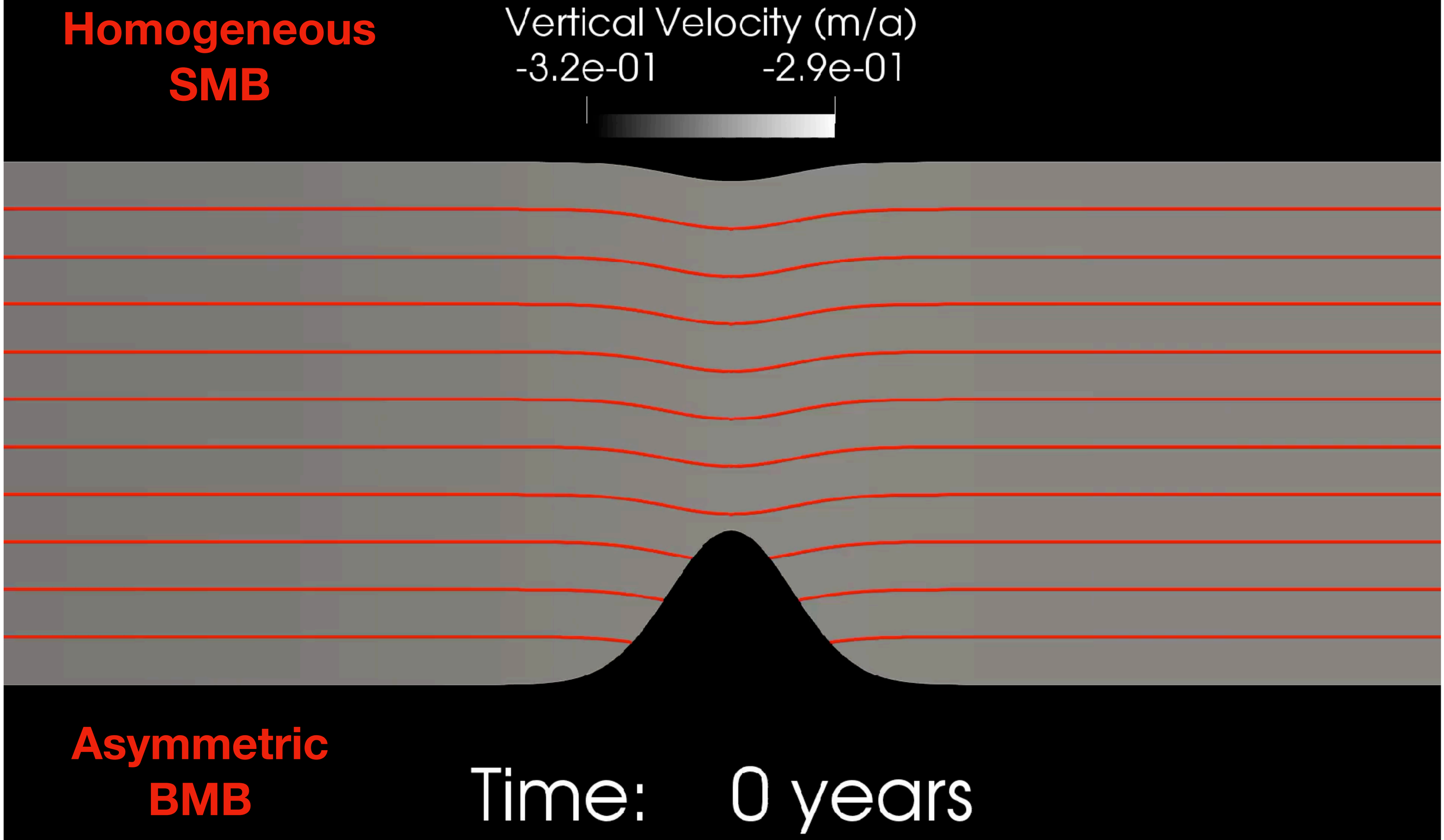
Ice Dynamic Deformation

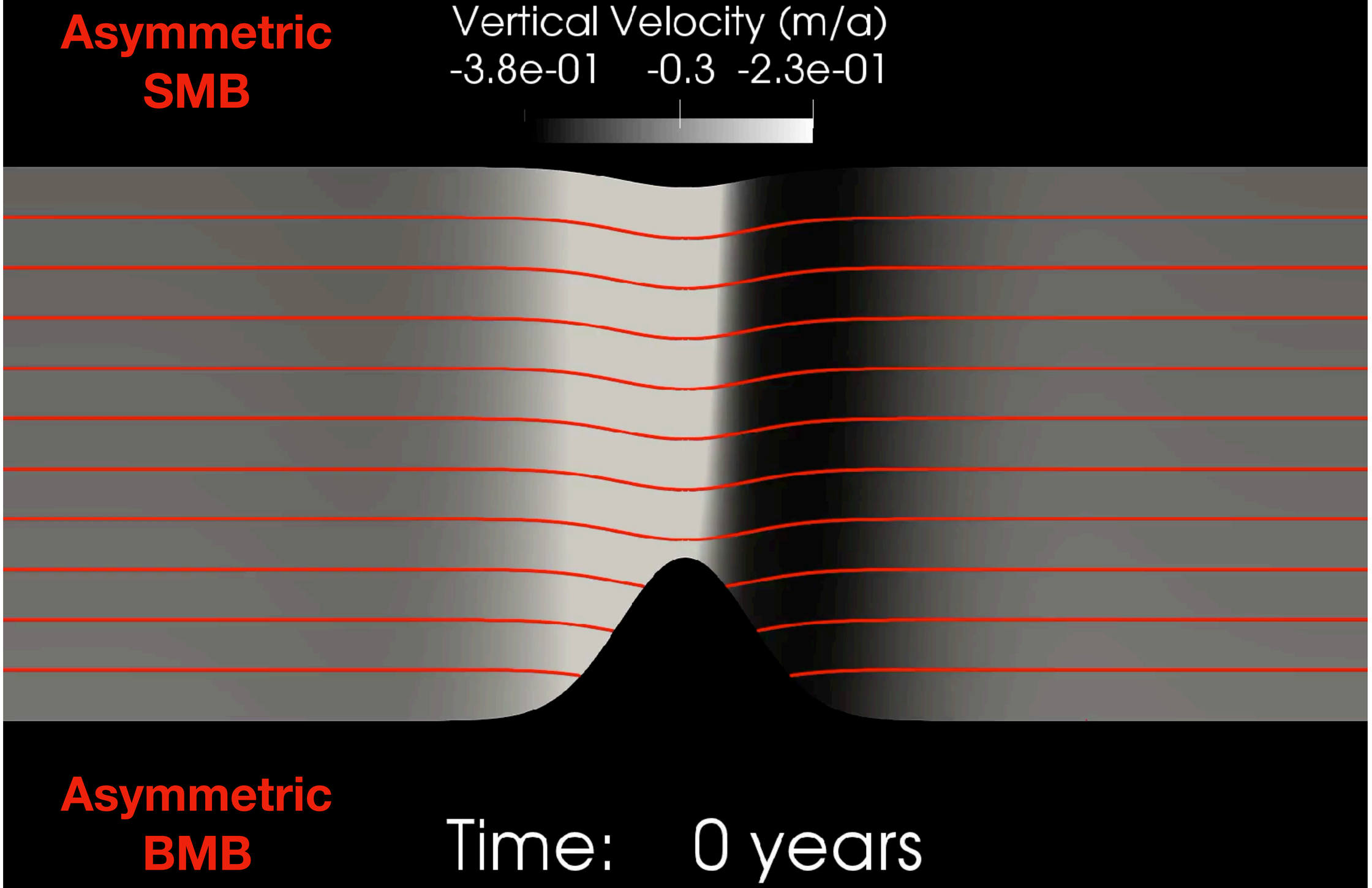
$$+ \left(H(1 - \frac{\rho_i}{\rho_w}) + (z - z_s) \right) \frac{\partial u_x}{\partial x}$$

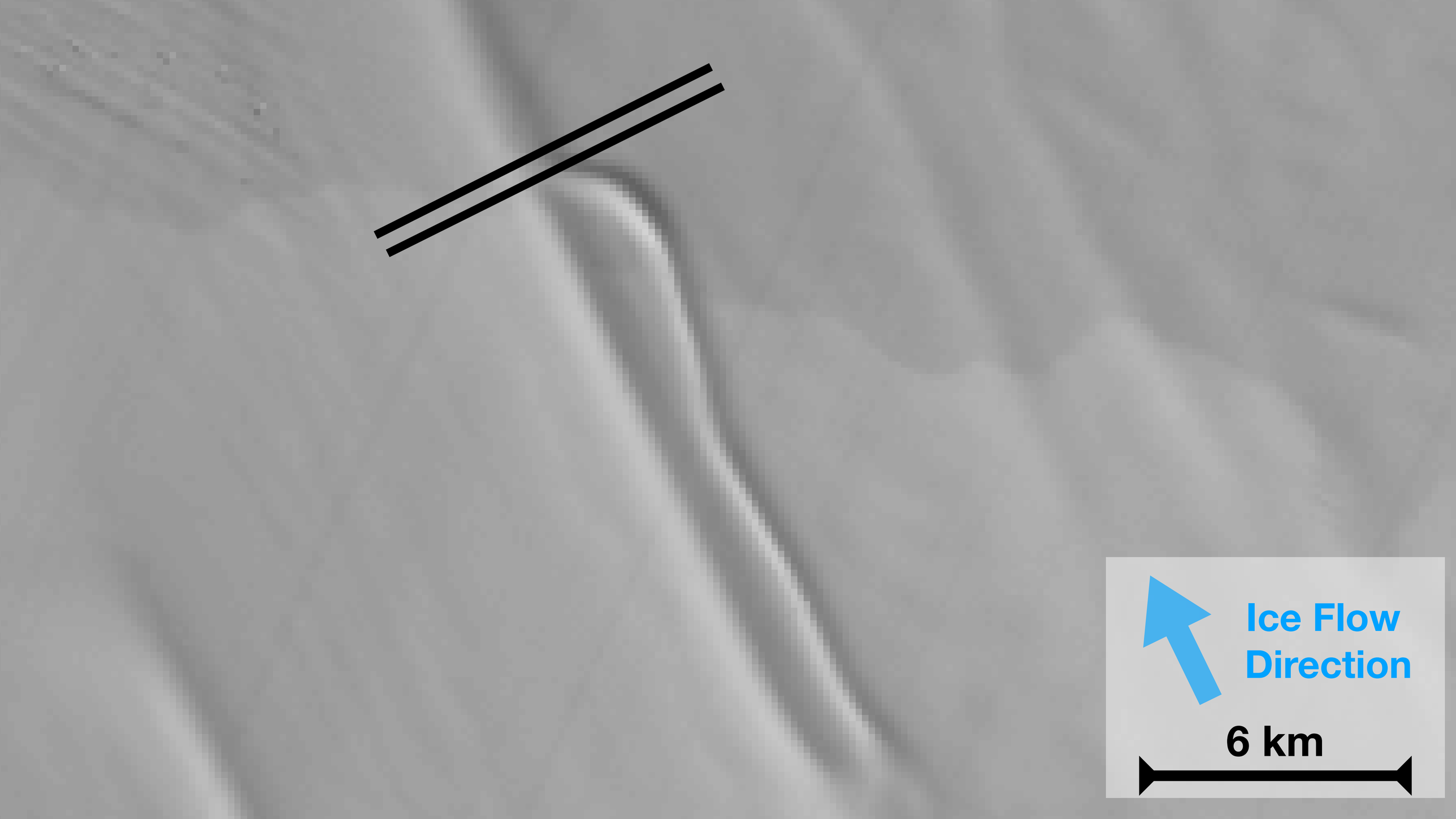
(For 2D plug-flow + Hydrostatic Equilibrium)

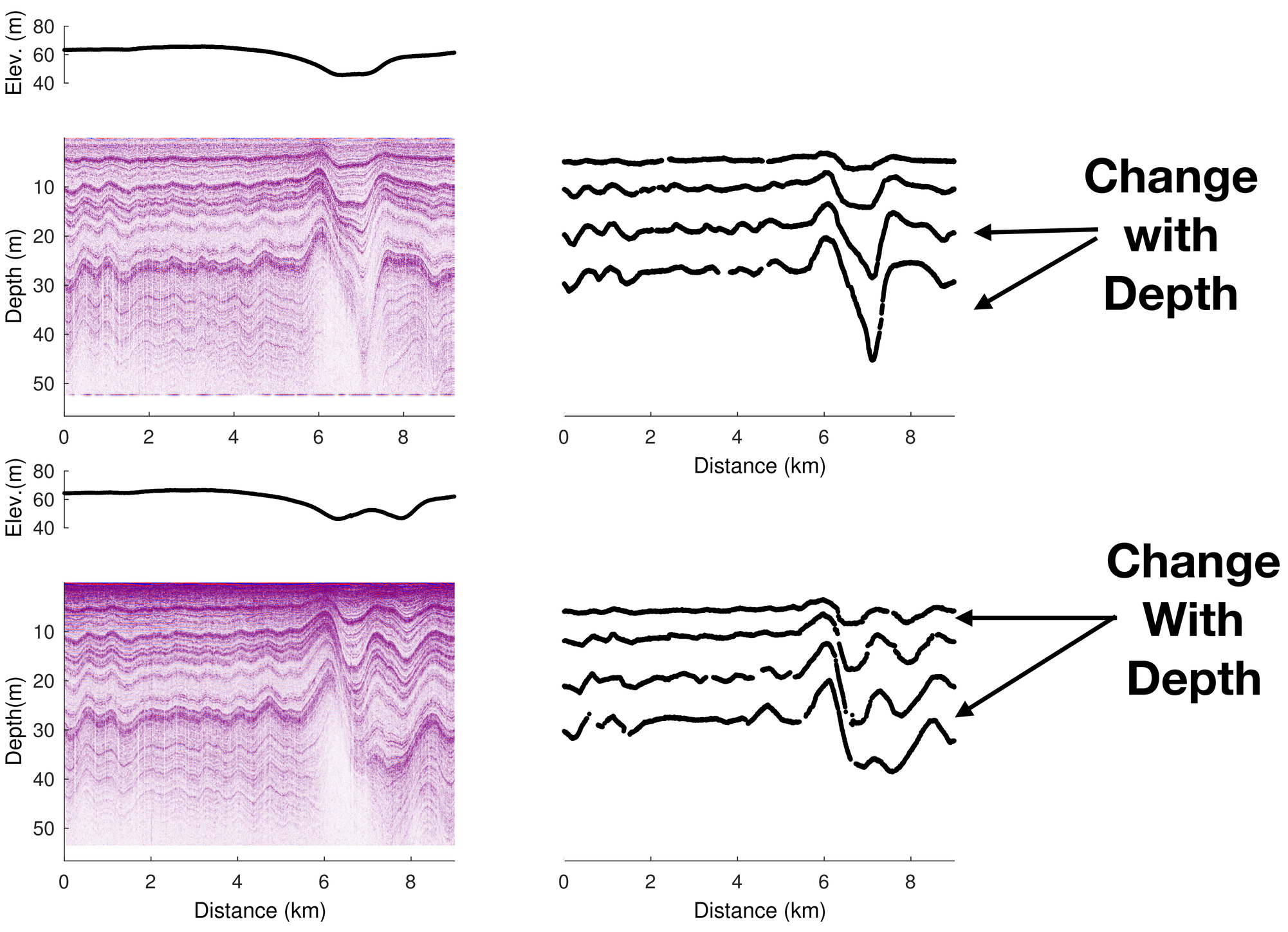


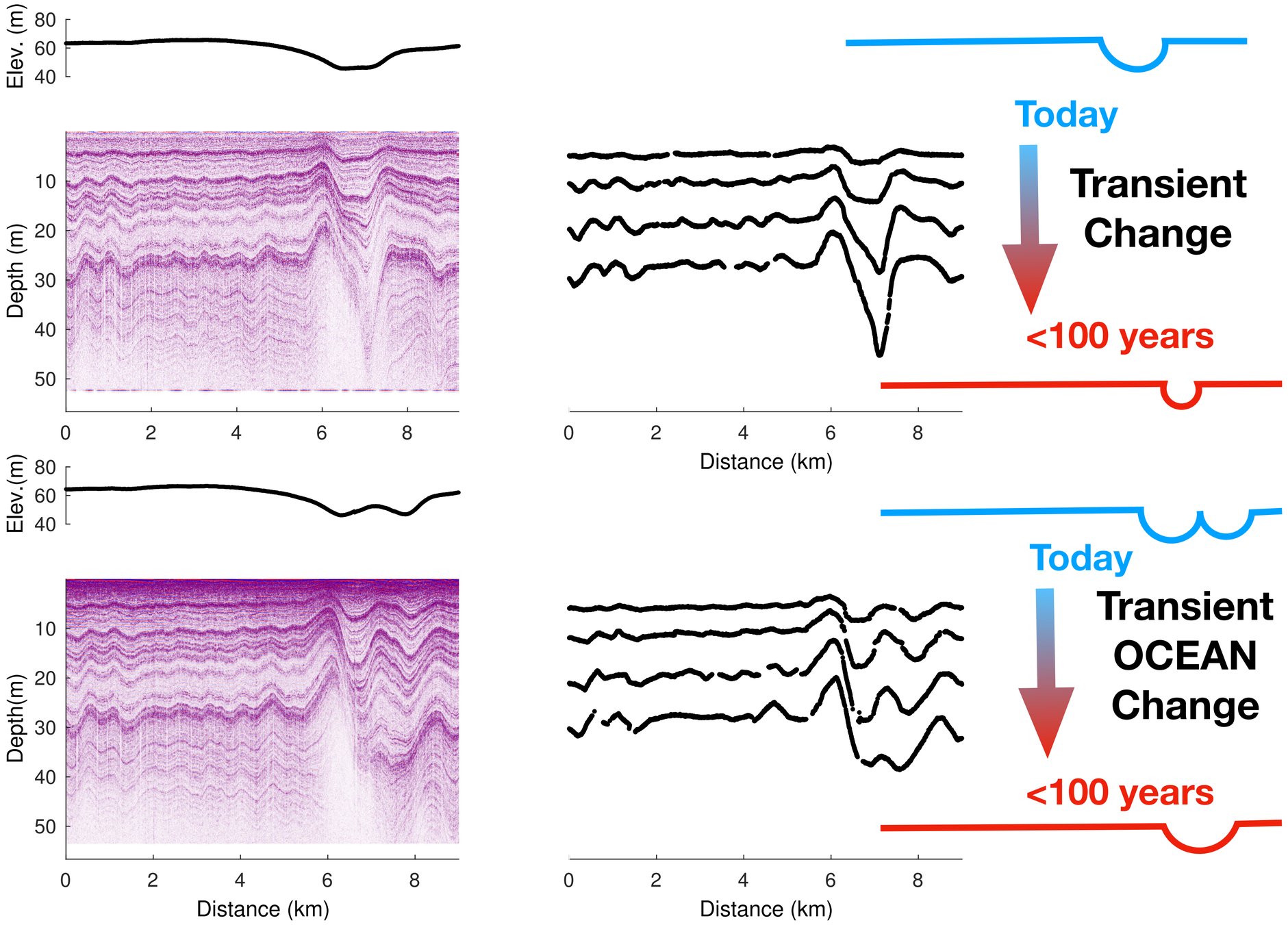
- **Tilted Syncline / Anticline Stacks**
- **Amplification, but no change in shape with depth**

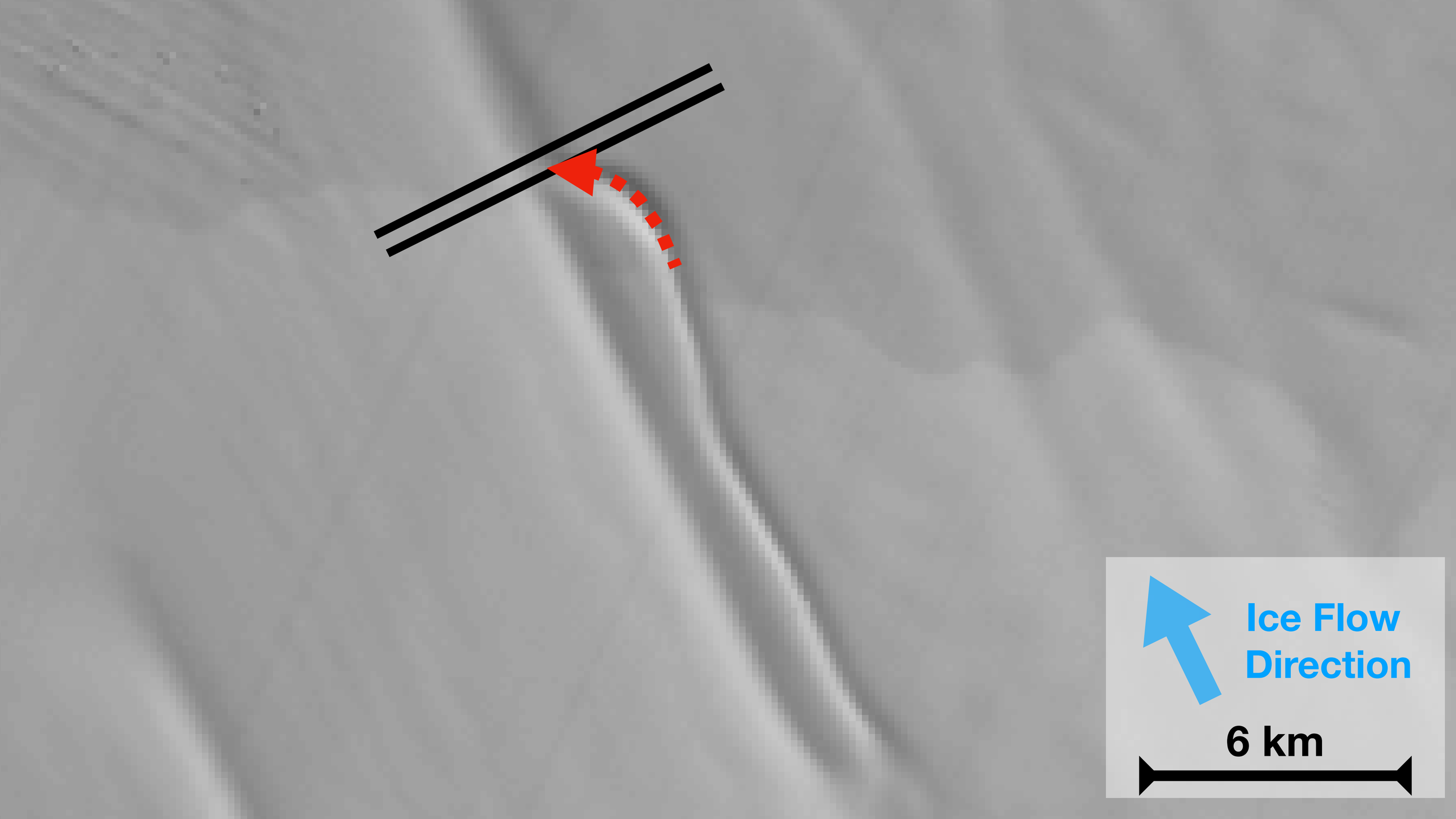

Homogeneous SMB
Vertical Velocity (m/a)
-3.2e-01
-2.9e-01
Asymmetric BMB
Time: 0 years

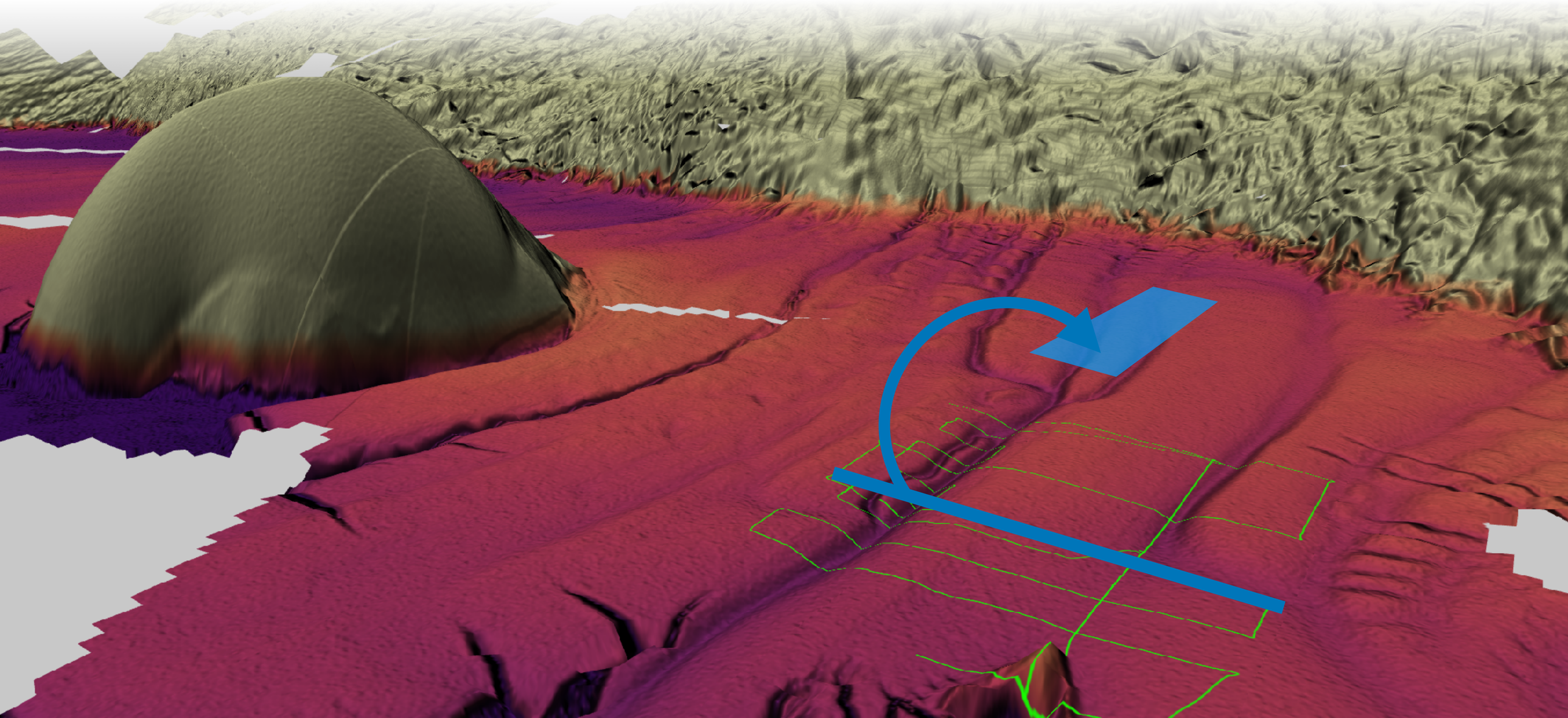

Asymmetric
SMB
Vertical Velocity (m/a)
-3.8e-01 -0.3 -2.3e-01
Asymmetric
BMB
Time: 0 years


Ice Flow
Direction
6 km

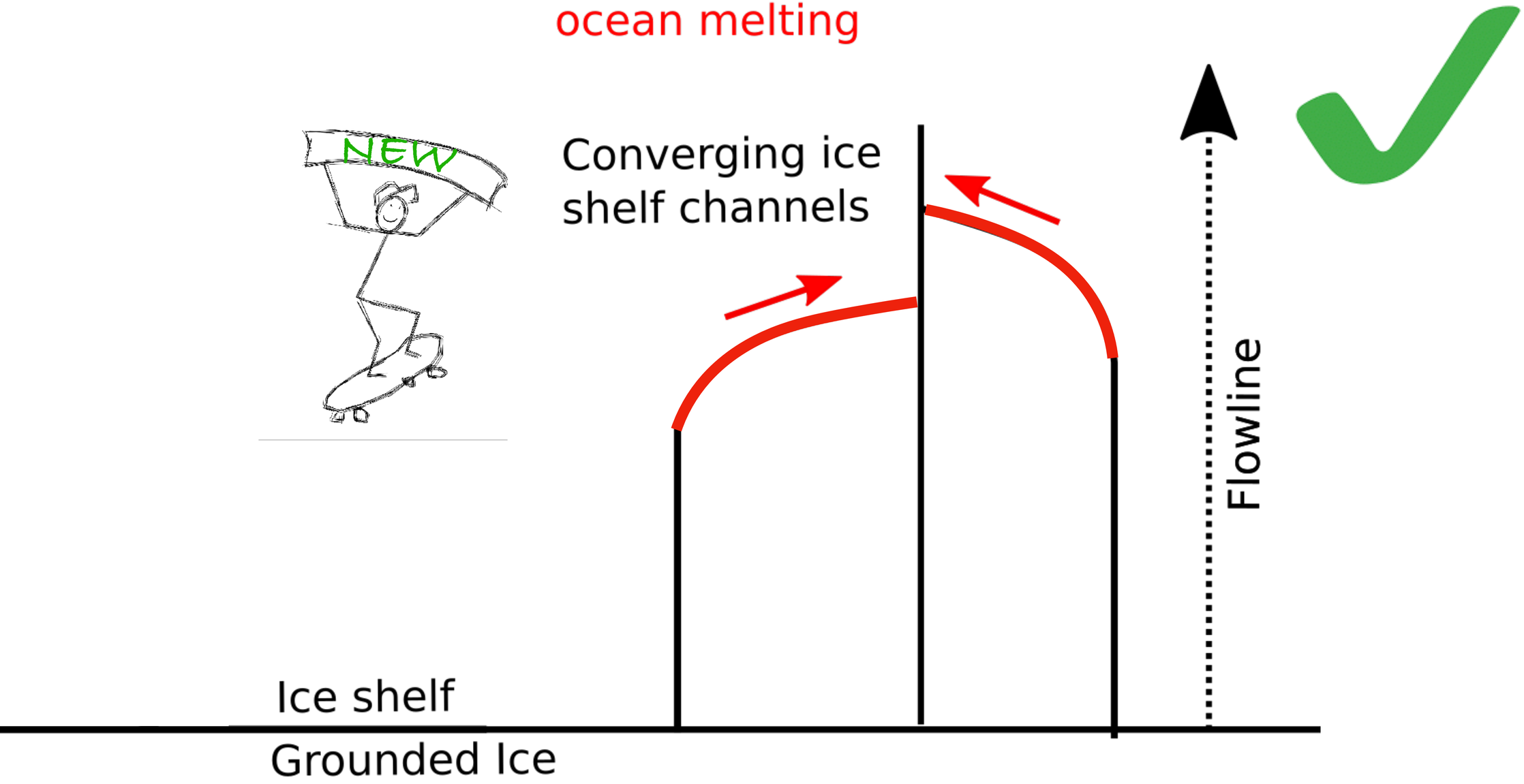

Elev. (m)
80
60
40
Depth (m)
10
20
30
40
50
0
2
4
6
8
Change
with
Depth
Distance (km)
Elev.(m)
Depth(m)
Change
With
Depth
Distance (km)

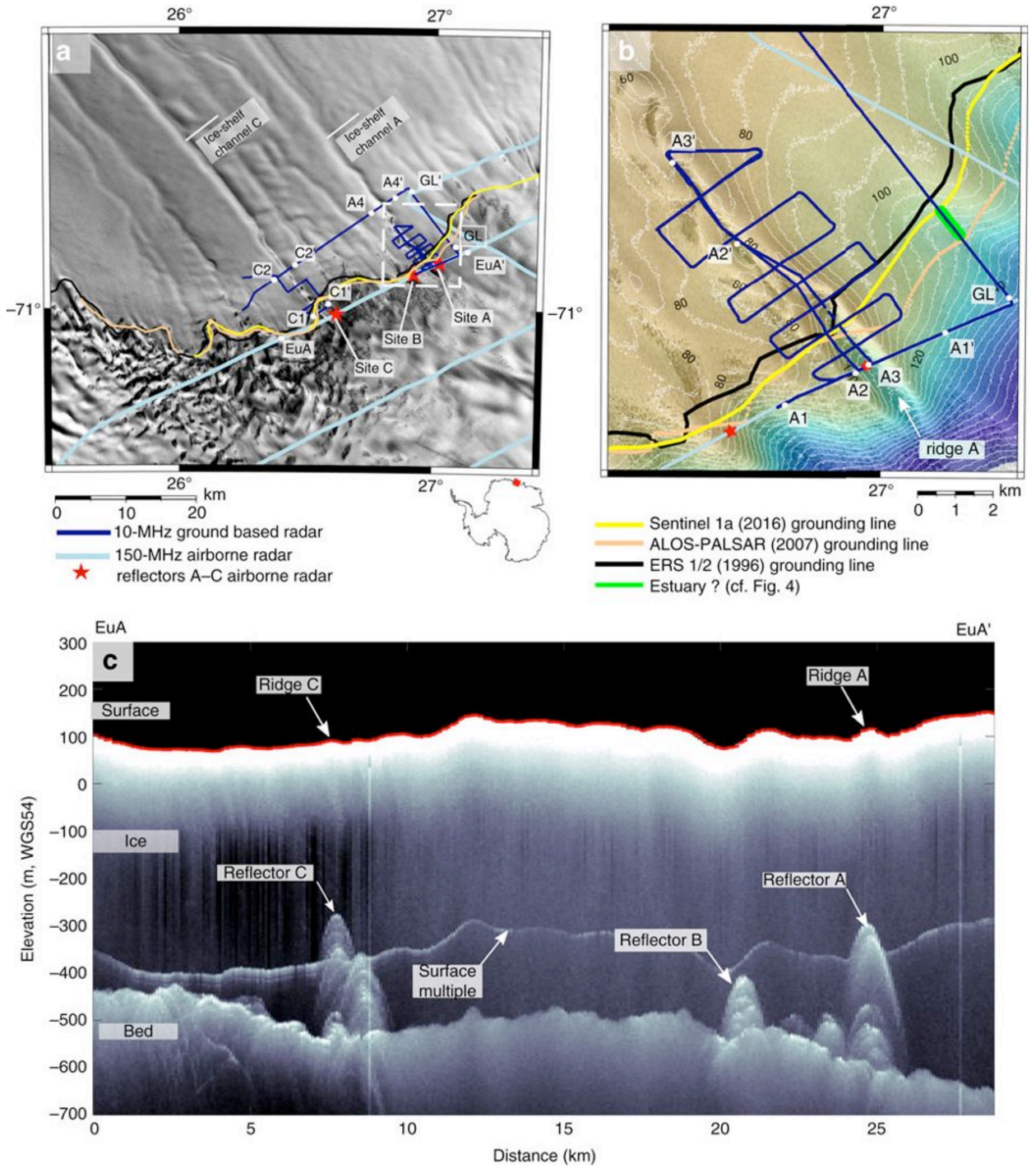

Elev. (m)
80
60
40
Depth (m)
10
20
30
40
50
0
2
4
6
8
Today
Transient
Change
<100 years
Distance (km)
Elev.(m)
Depth(m)
Today
Transient
OCEAN
Change
<100 years
Distance (km)

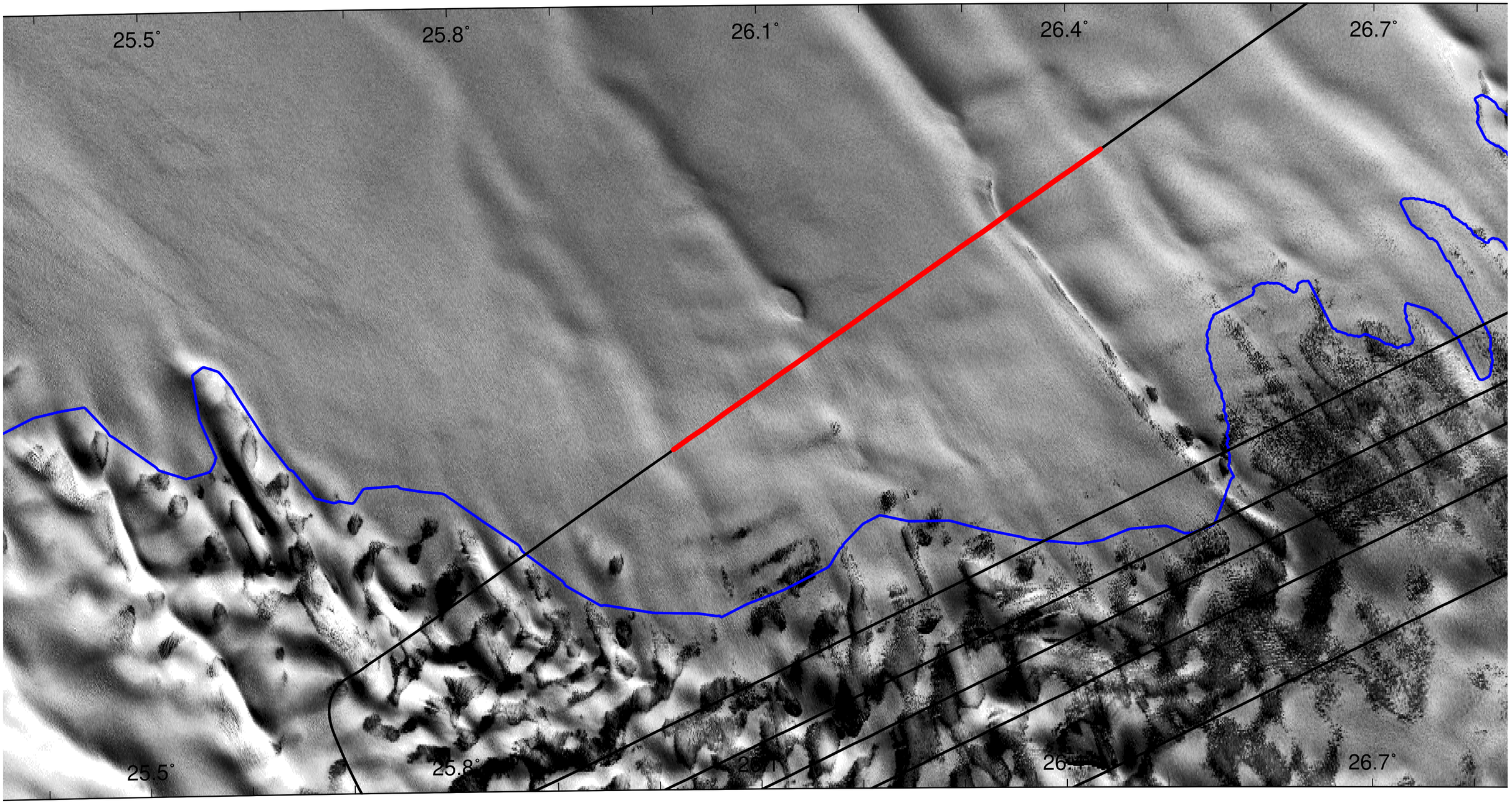

Ice Flow
Direction
6 km

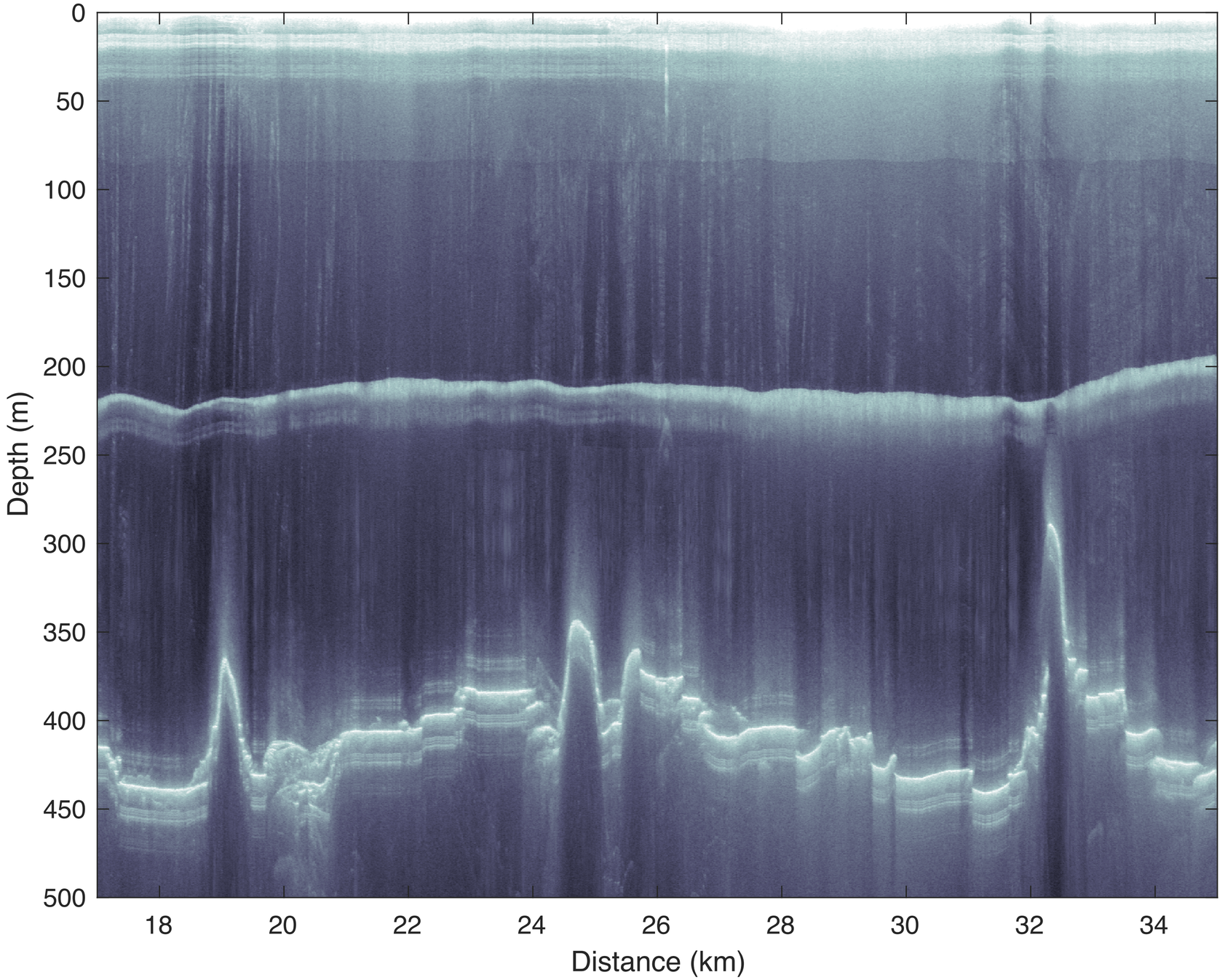


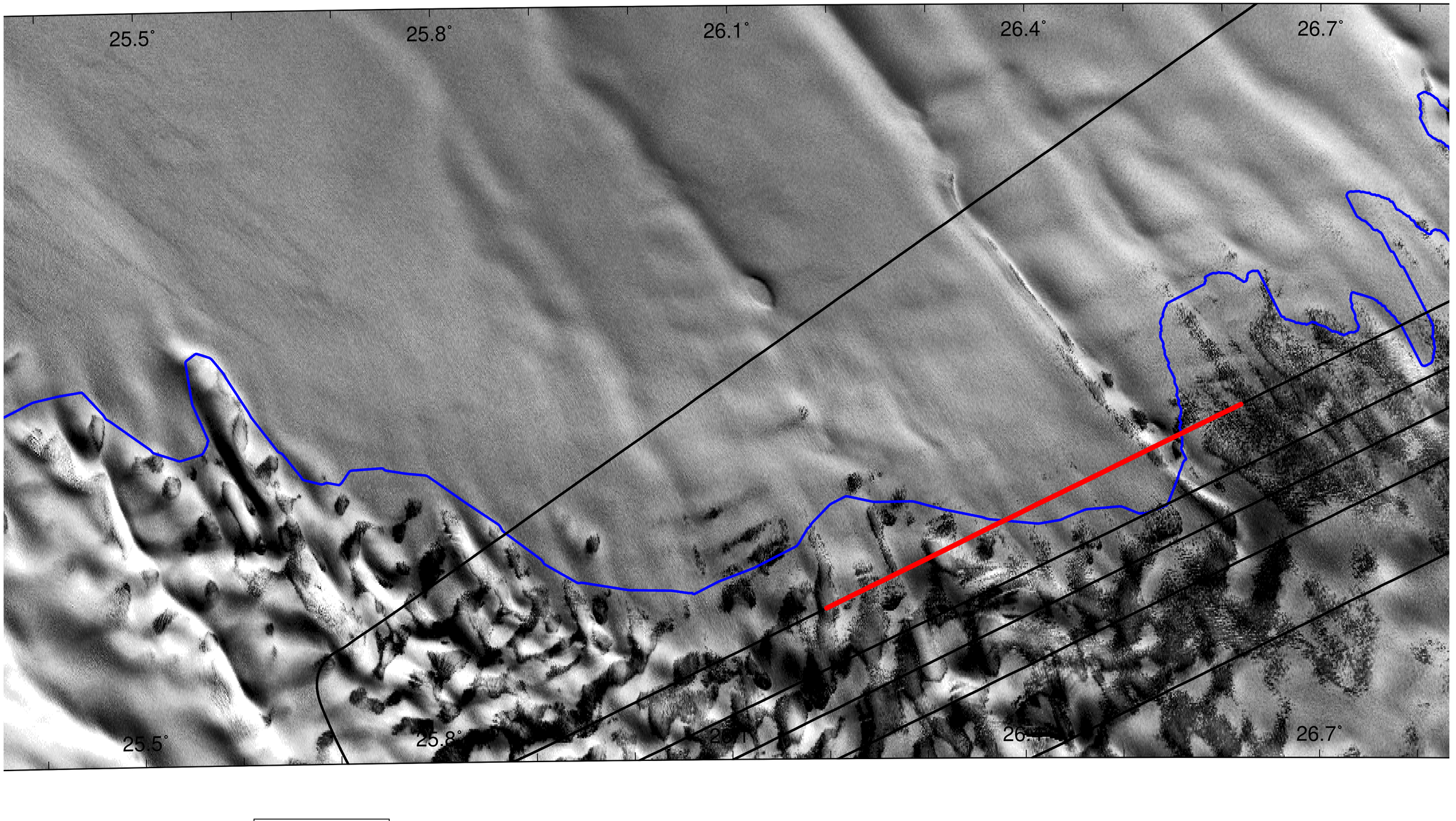
(b) Hypothesis 1: Convergence by ocean melting

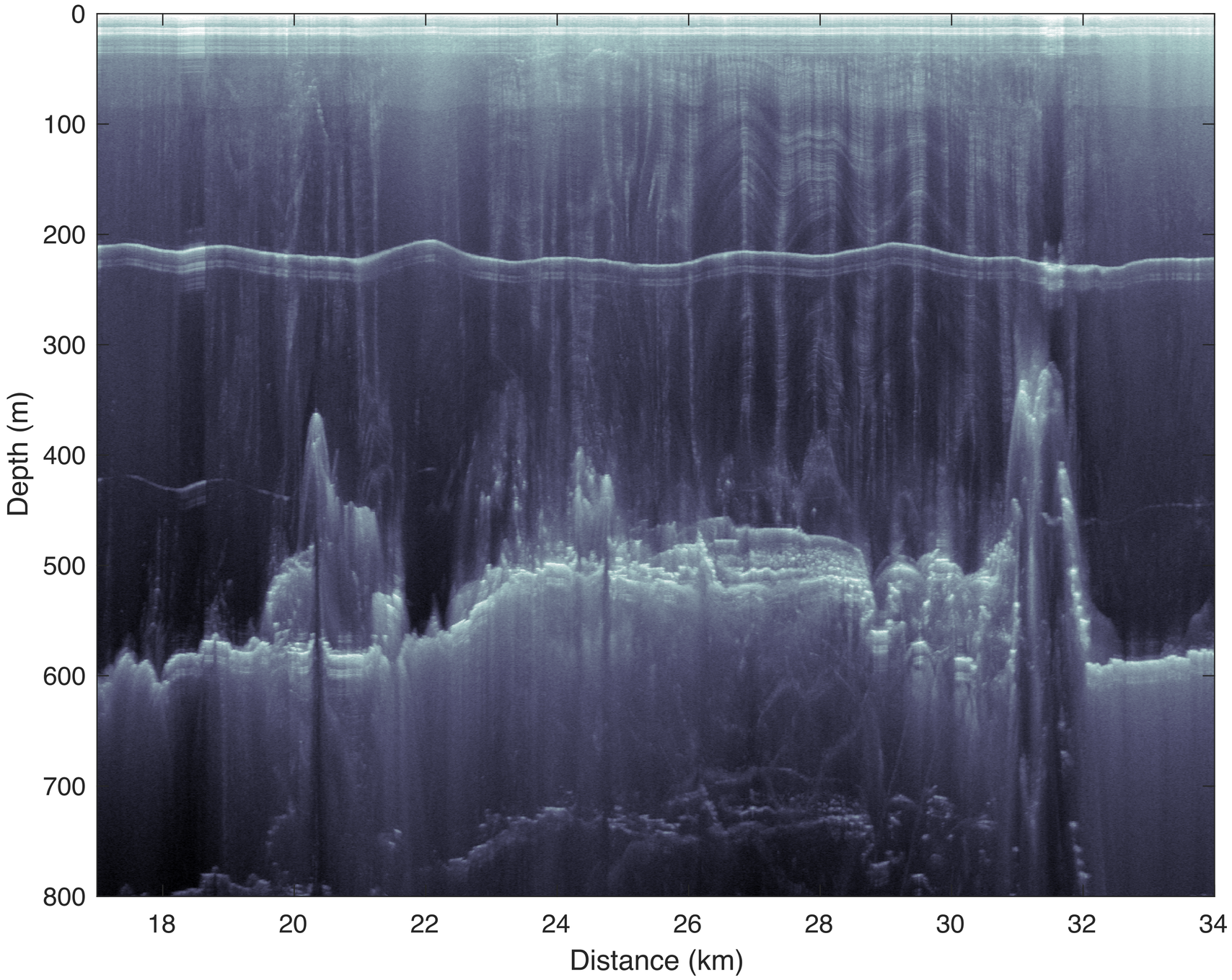


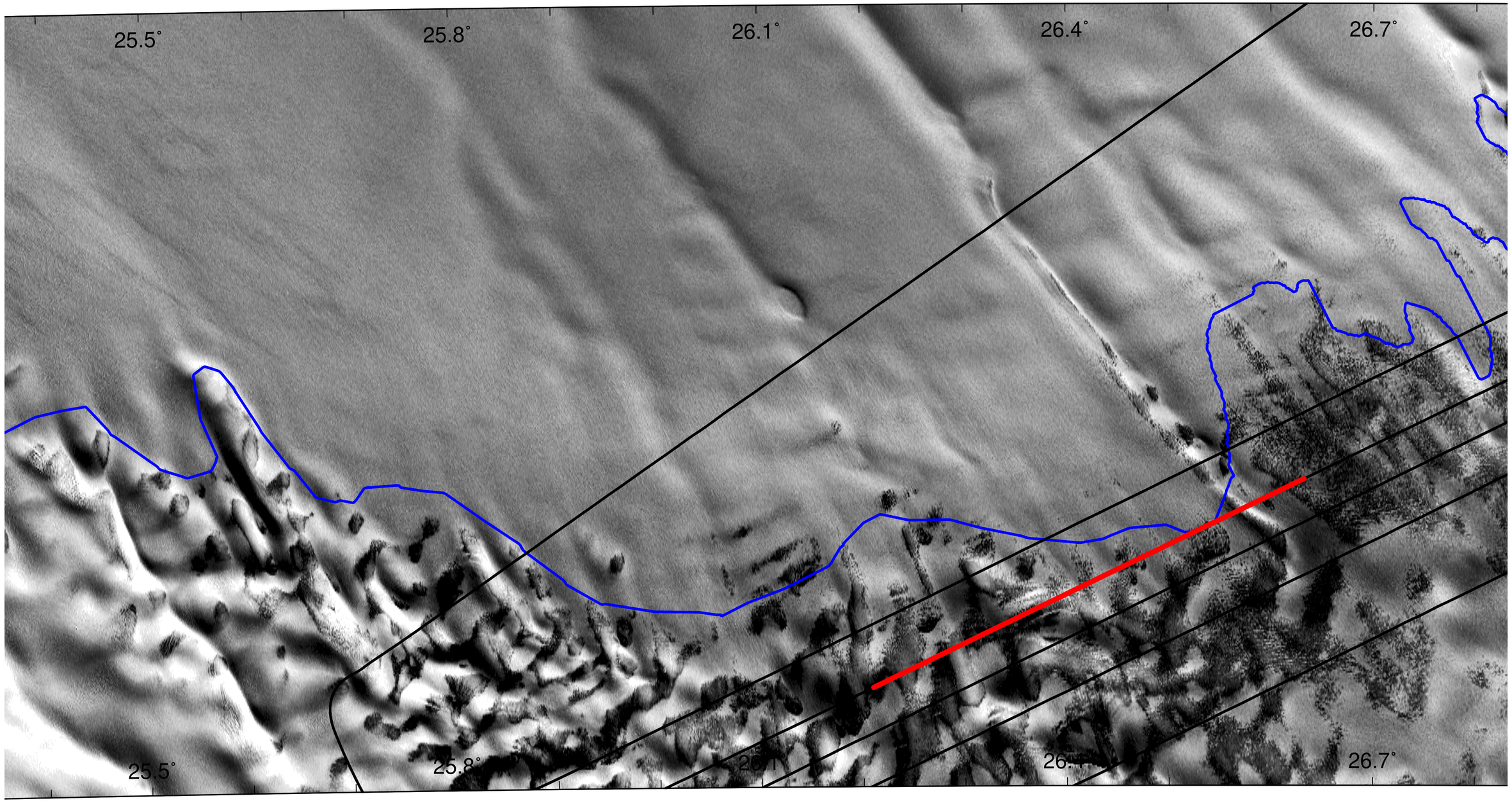

a
26°
27°
−71°
Ice-shelf channel C
Ice-shelf channel A
A4'
GL'
A4
GL
C2'
C2
EuA'
C1'
C1
Site A
Site B
EuA
Site C
km
0 10 20
10-MHz ground based radar
150-MHz airborne radar
reflectors A–C airborne radar
b
A3'
A2'
GL
A1'
A3
A2
A1
ridge A
0 1 2
Sentinel 1a (2016) grounding line
ALOS-PALSAR (2007) grounding line
ERS 1/2 (1996) grounding line
Estuary ? (cf. Fig. 4)
c
EuA
EuA'
Ridge C
Ridge A
Surface
Ice
Reflector C
Reflector A
Reflector B
Surface multiple
Bed
Elevation (m, WGS54)
Distance (km)

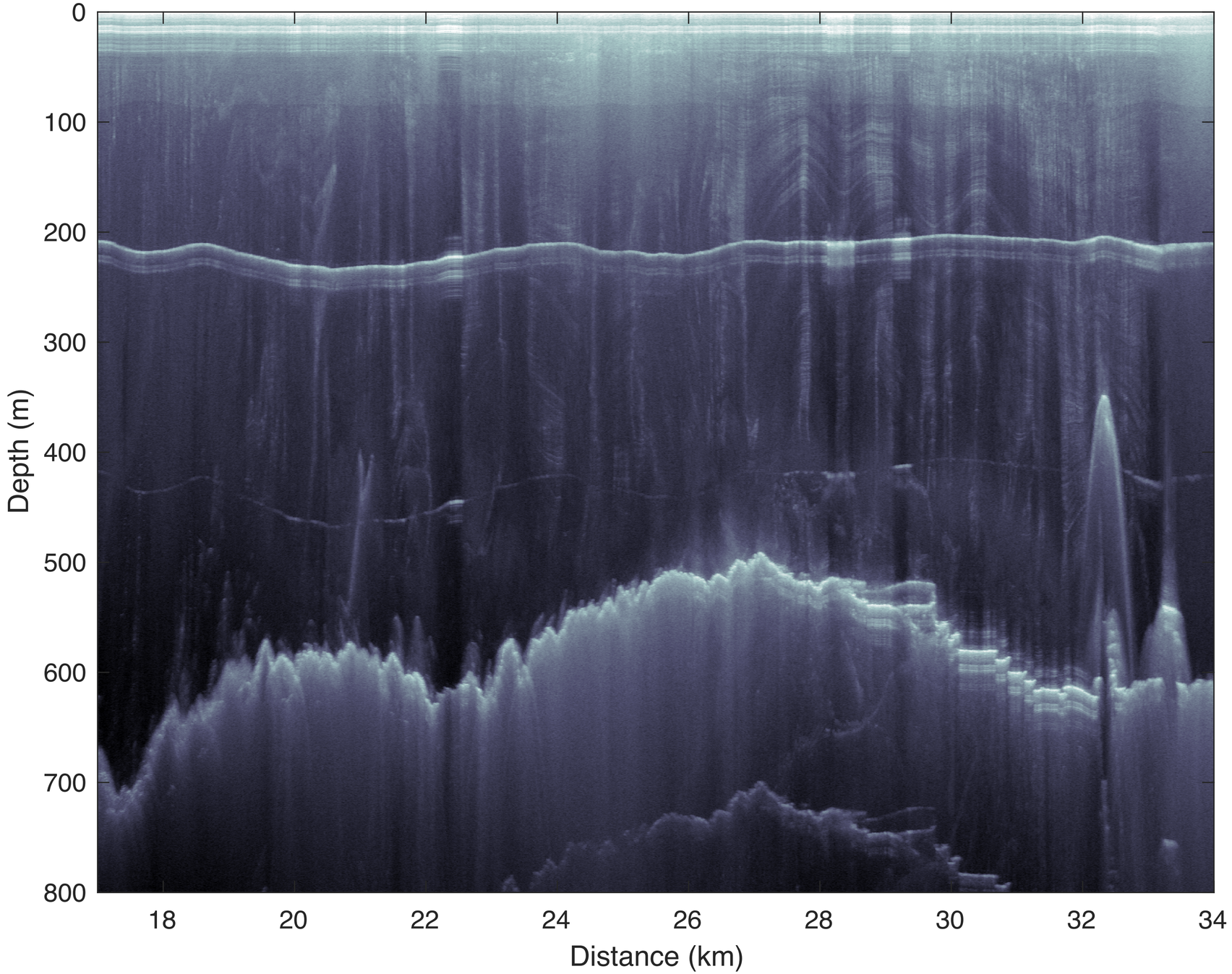

25.5˚
25.8˚
26.1˚
26.4˚
26.7˚
25.5˚
25.8˚
26.7˚
5 km

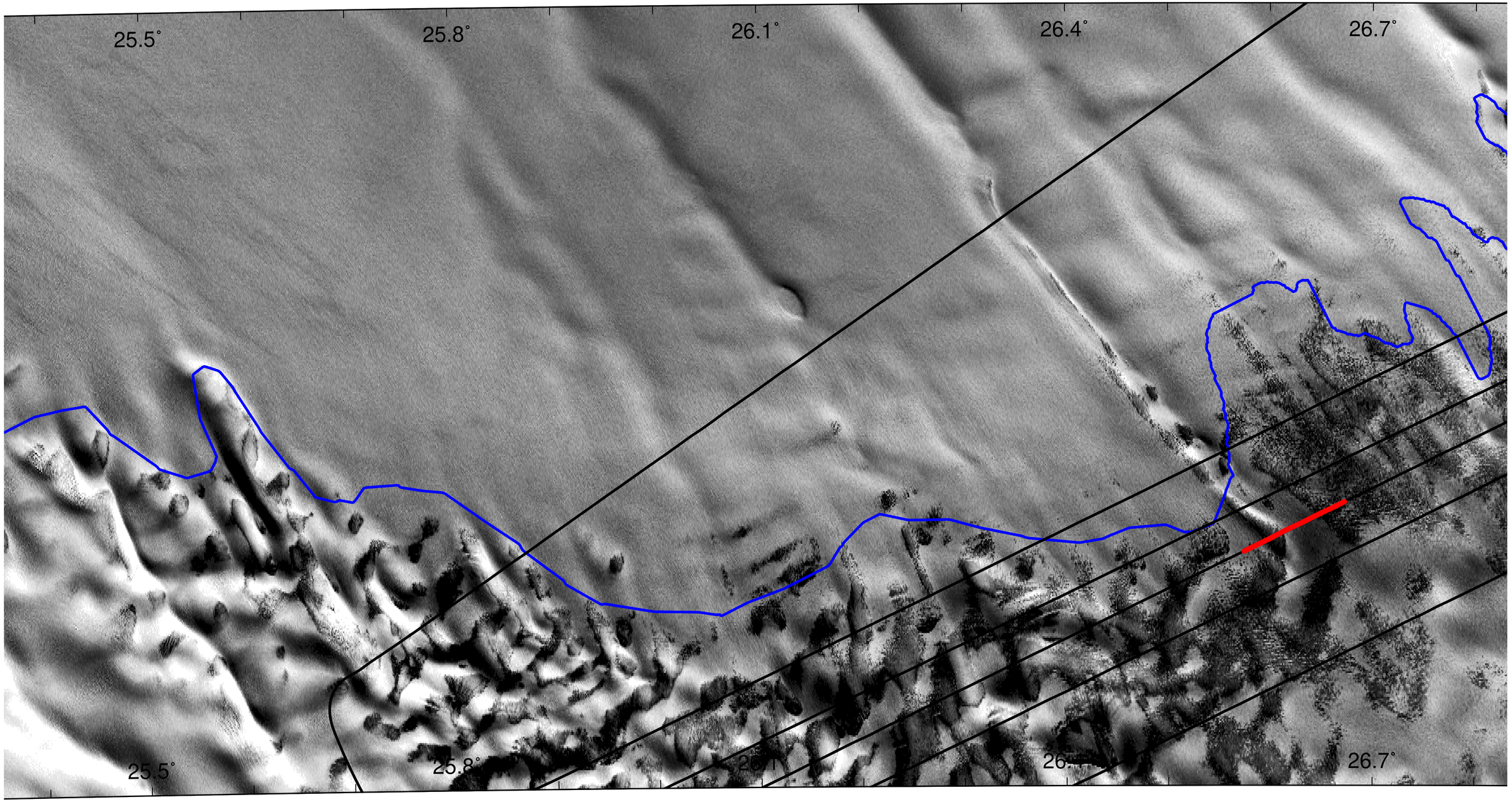

0
50
100
150
200
250
300
350
400
450
500
Depth (m)
18
20
22
24
26
28
30
32
34
Distance (km)

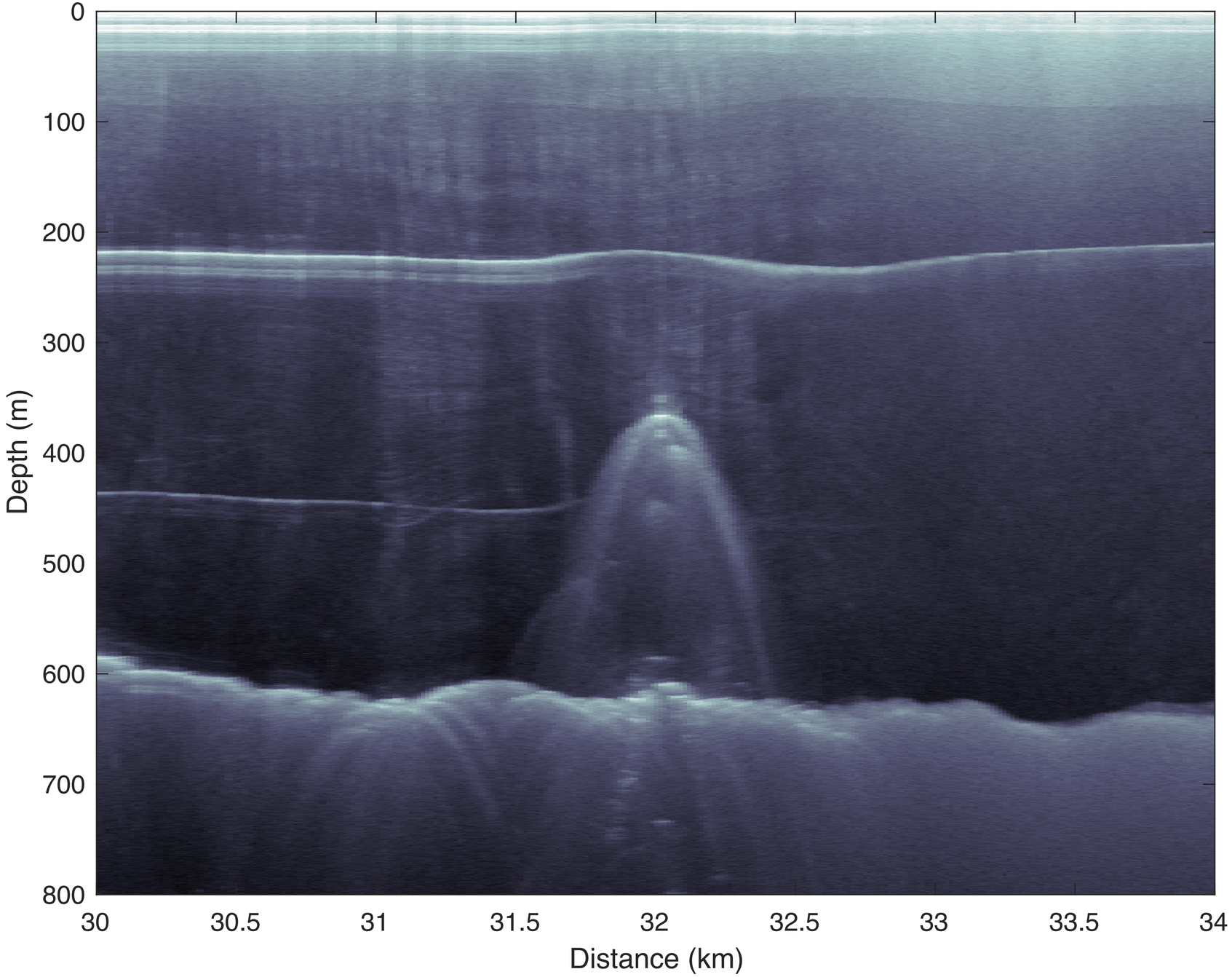

25.5˚
25.8˚
26.1˚
26.4˚
26.7˚
25.5˚
25.8˚
26.7˚
5 km

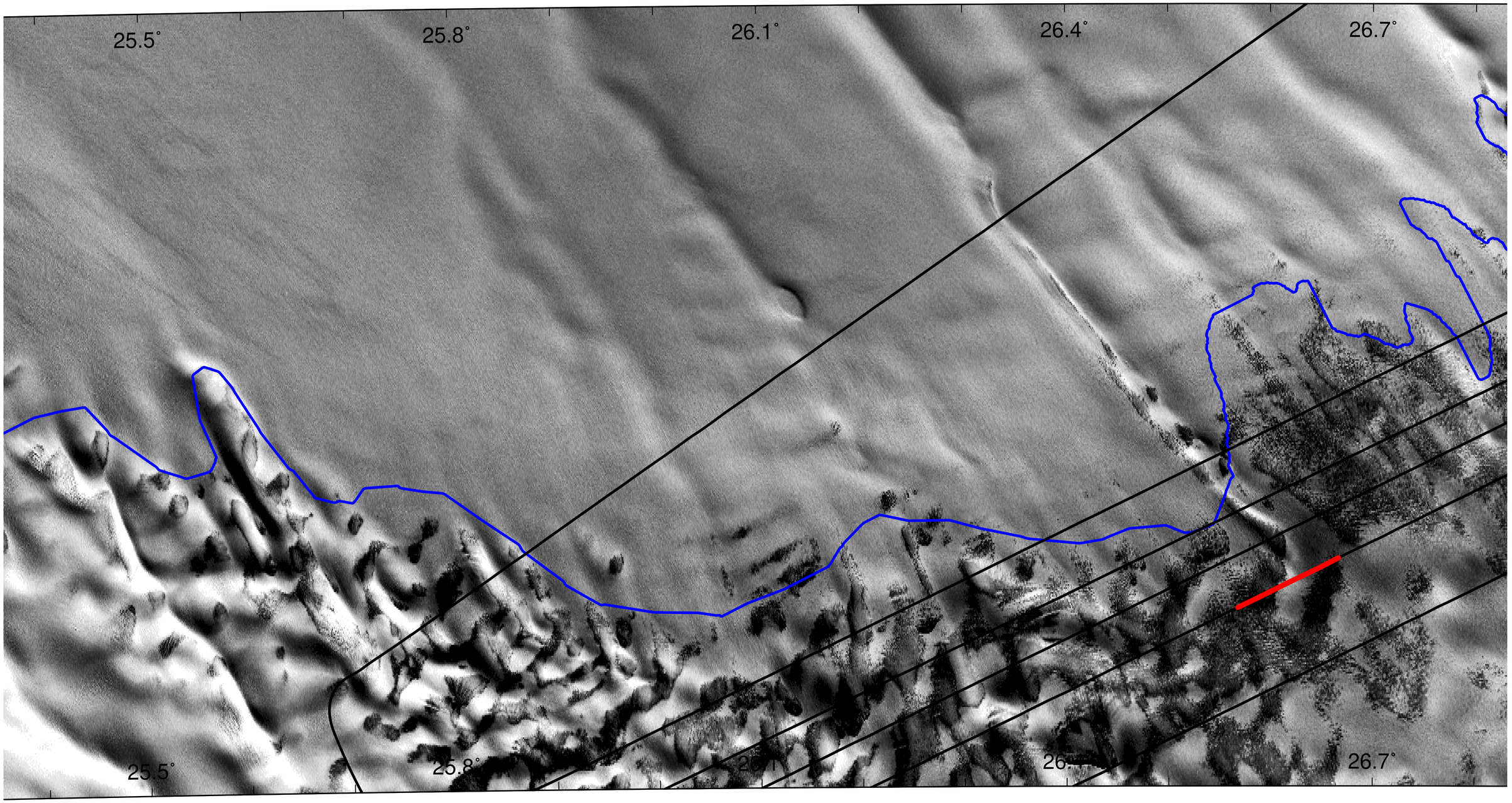

0
100
200
300
400
500
600
700
800
Depth (m)
18
20
22
24
26
28
30
32
34
Distance (km)

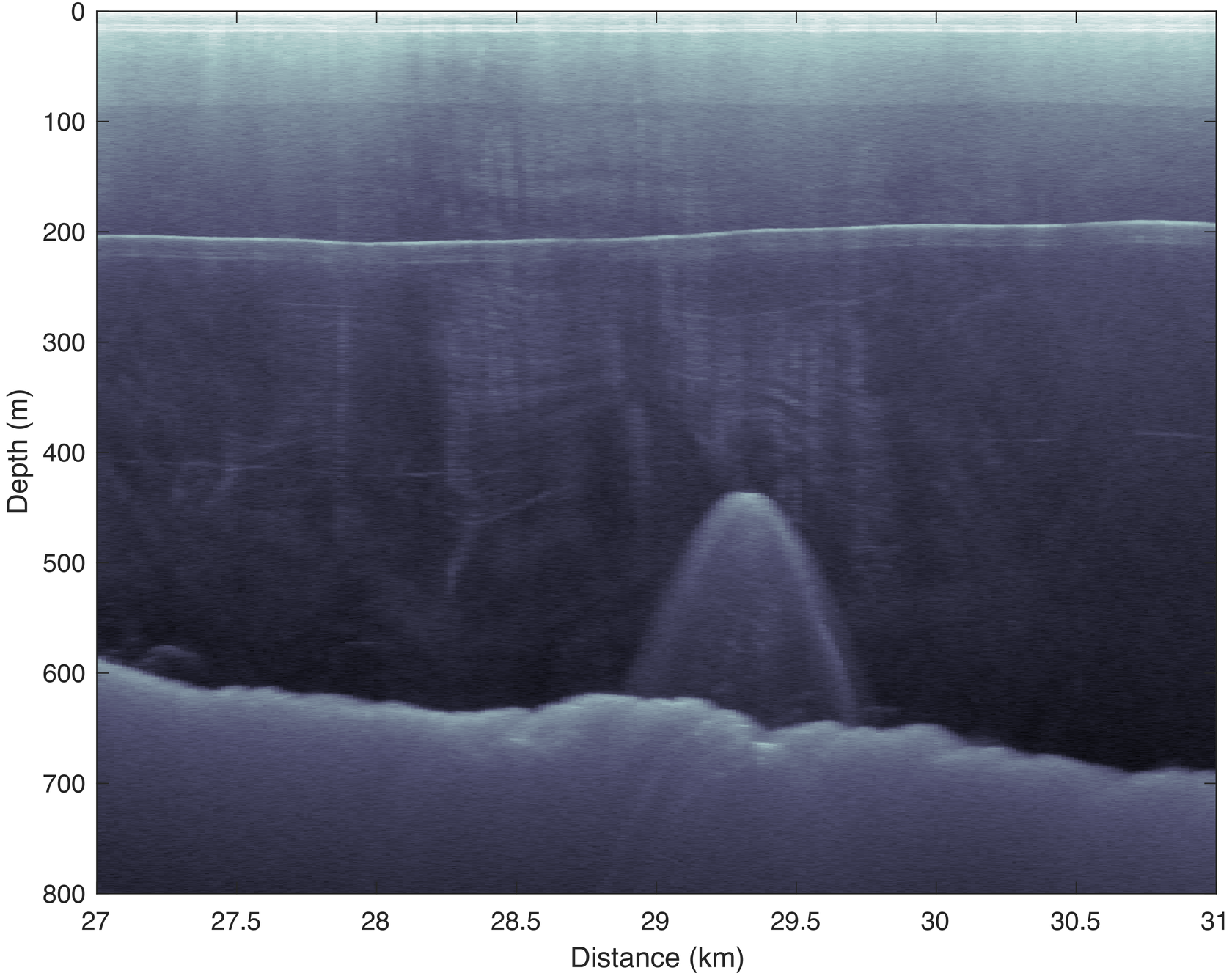

25.5˚
25.8˚
26.1˚
26.4˚
26.7˚
25.5˚
25.8˚
26.7˚
5 km

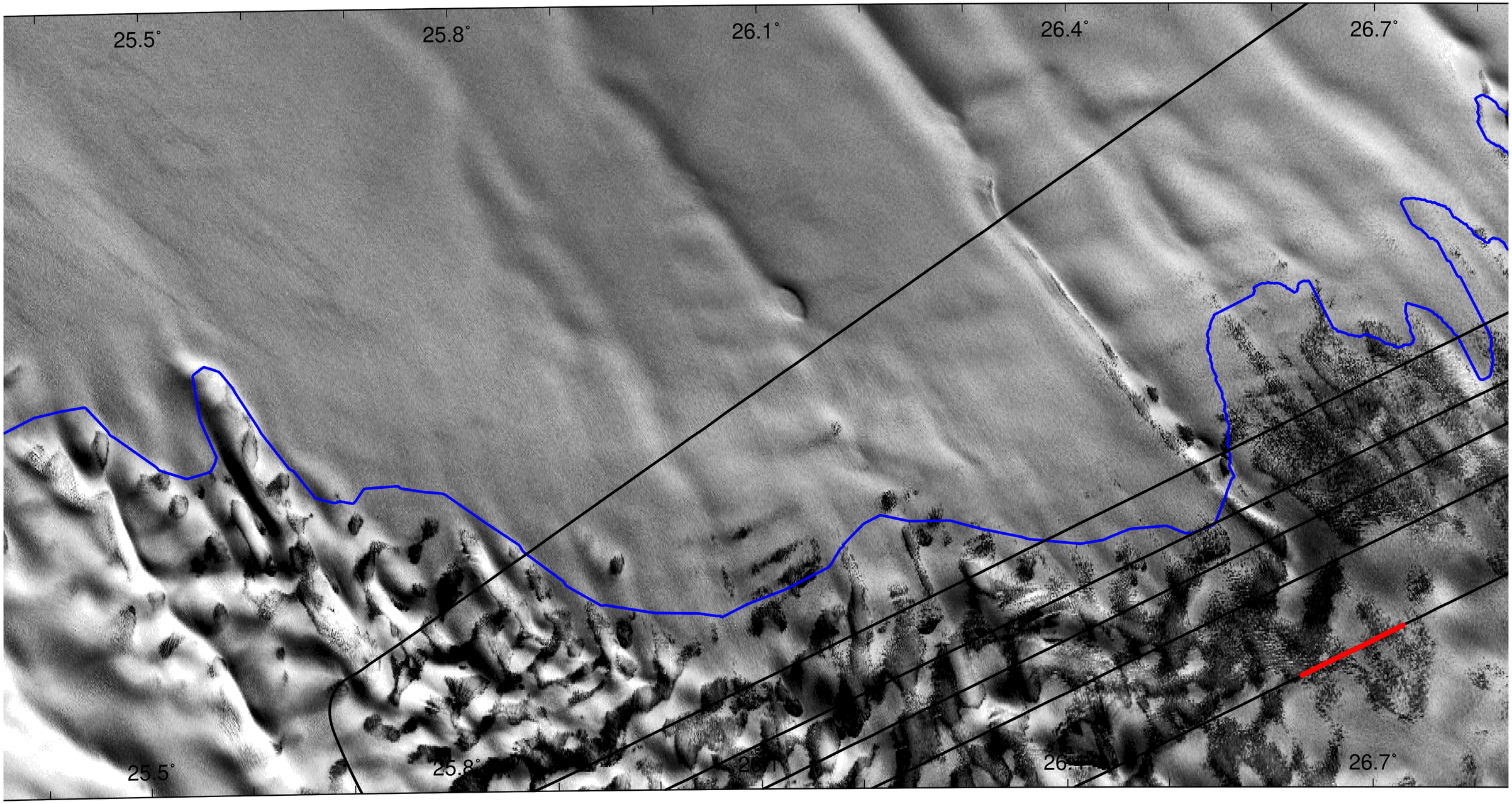

0
100
200
300
400
500
600
700
800
Depth (m)
18
20
22
24
26
28
30
32
34
Distance (km)

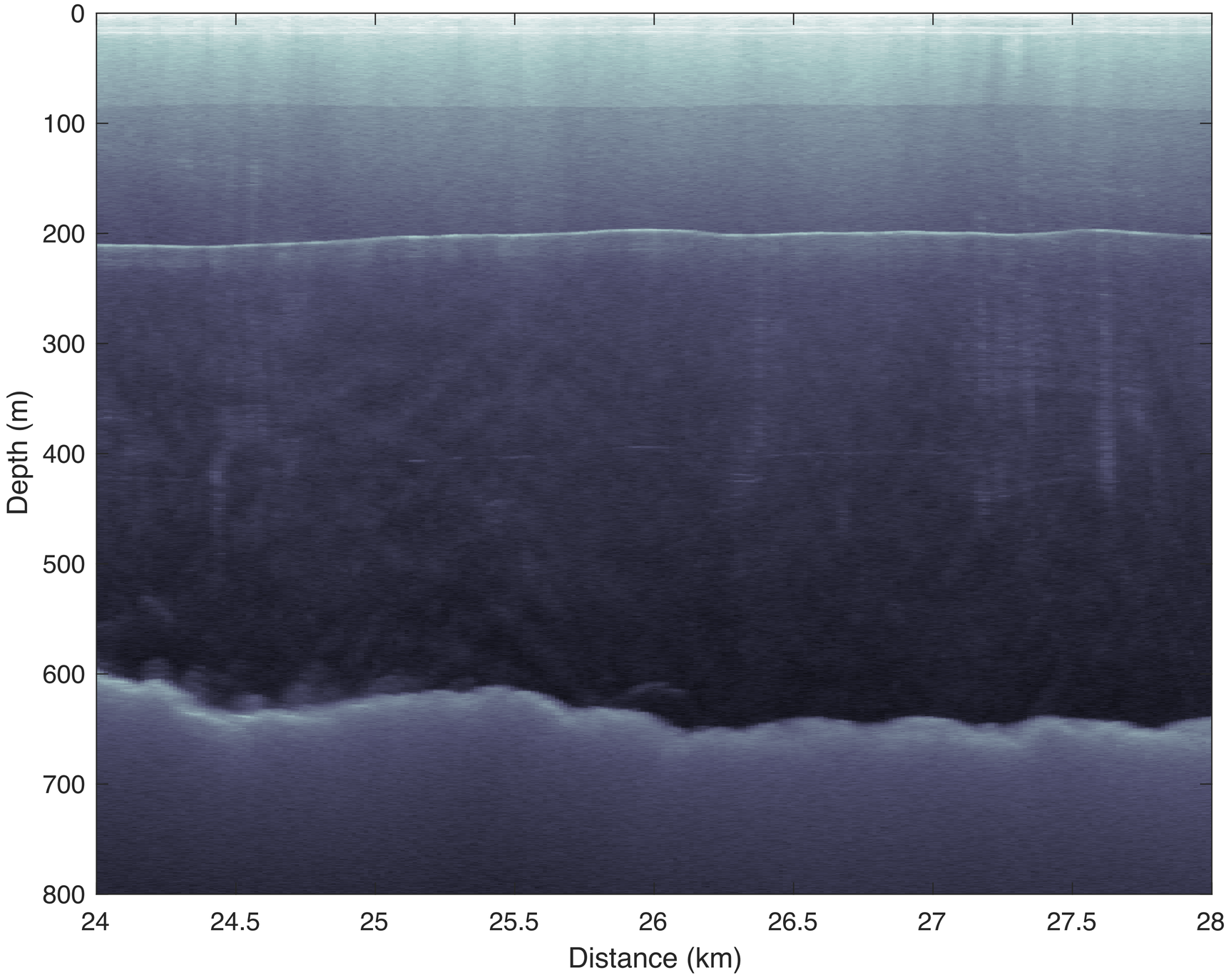

25.5˚
25.8˚
26.1˚
26.4˚
26.7˚
25.5˚
25.8˚
26.7˚
5 km


0
100
200
300
400
500
600
700
800
Depth (m)
30
30.5
31
31.5
32
32.5
33
33.5
34
Distance (km)


25.5˚
25.8˚
26.1˚
26.4˚
26.7˚
25.5˚
25.8˚
26.7˚
5 km


0
100
200
300
400
500
600
700
800
Depth (m)
27
27.5
28
28.5
29
29.5
30
30.5
31
Distance (km)


25.5˚
25.8˚
26.1˚
26.4˚
26.7˚
25.5˚
25.8˚
26.7˚
5 km


0
100
200
300
400
500
600
700
800
Depth (m)
24
24.5
25
25.5
26
26.5
27
27.5
28
Distance (km)