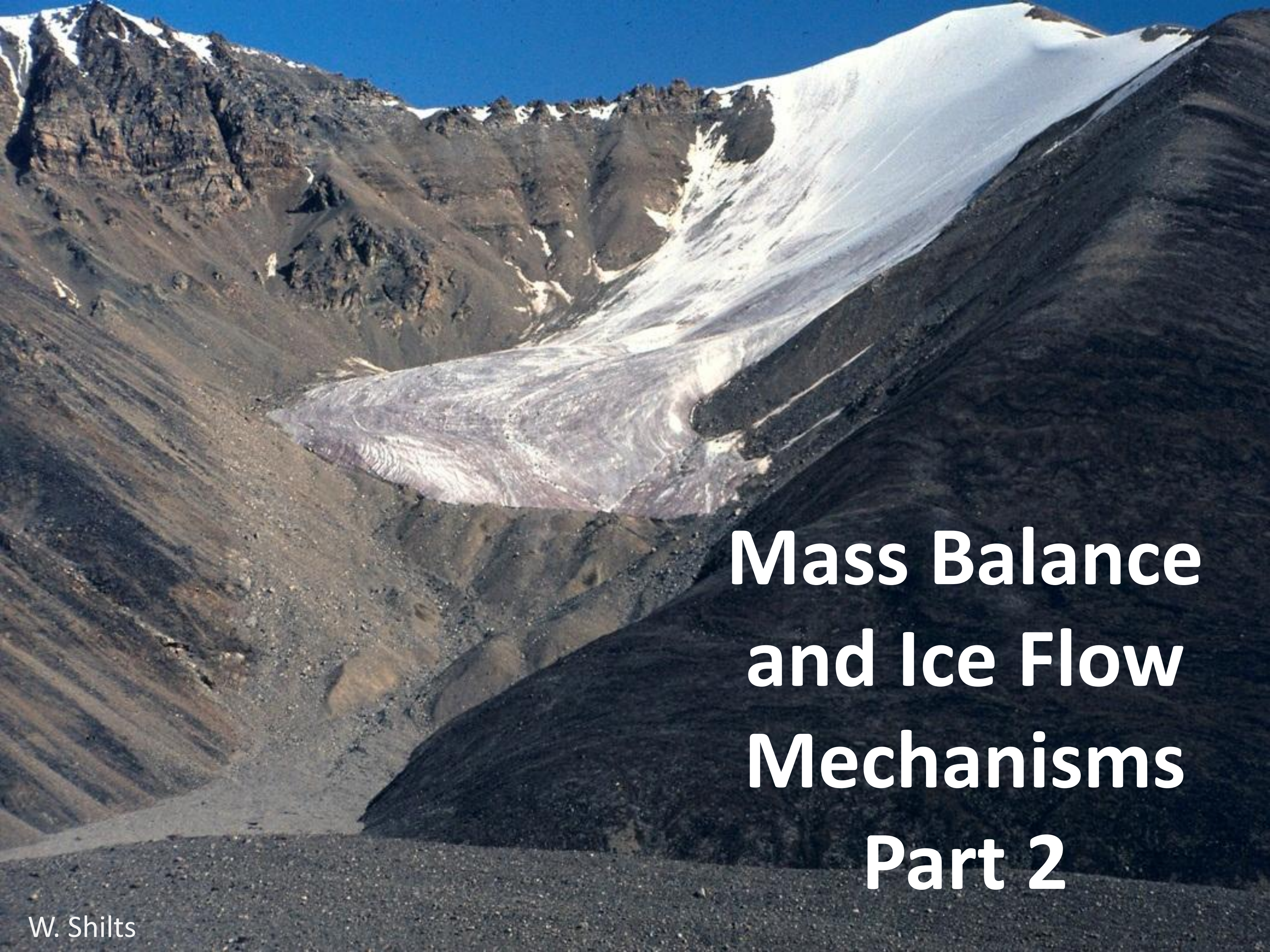


Mass Balance and Ice Flow Mechanisms Part 2

W. Shilts

Glacier Movement

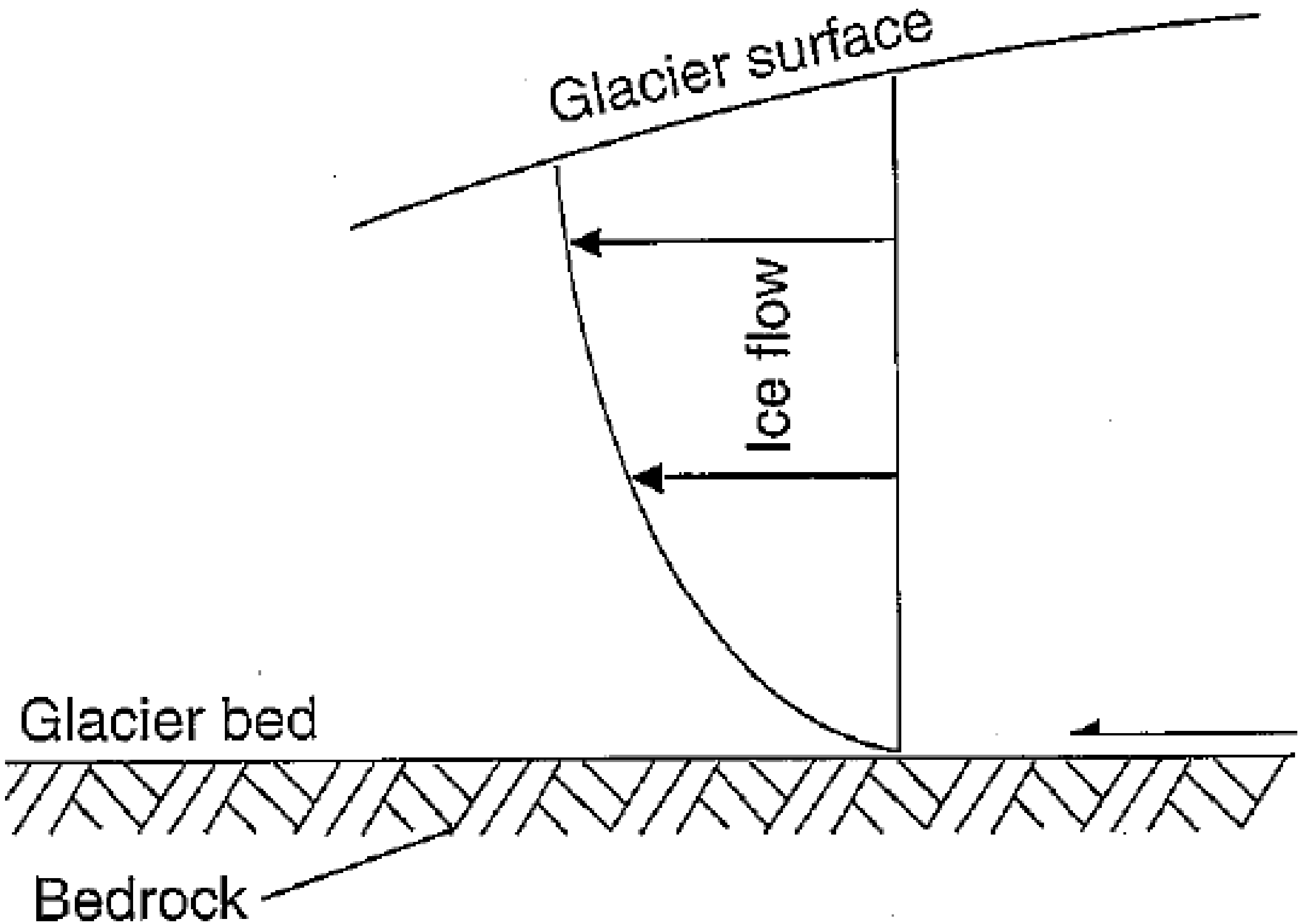
- Internal deformation (ice deforms through much of its thickness by creep and by folding and faulting)

- Basal sliding
  - Sliding at the ice – bed interface
  - Enhanced basal creep
  - Regelation slip

- Bed deformation

What makes glaciers move?

Internal flow only



After Bennett and Glasser, 2009

Estimation of the tendency for ice to deform

$$\tau = \rho g (s - z) \sin \alpha$$

τ = shear stress at a point within the glacier (kPa)

ρ = density of the ice = 916.7 kg/m^3

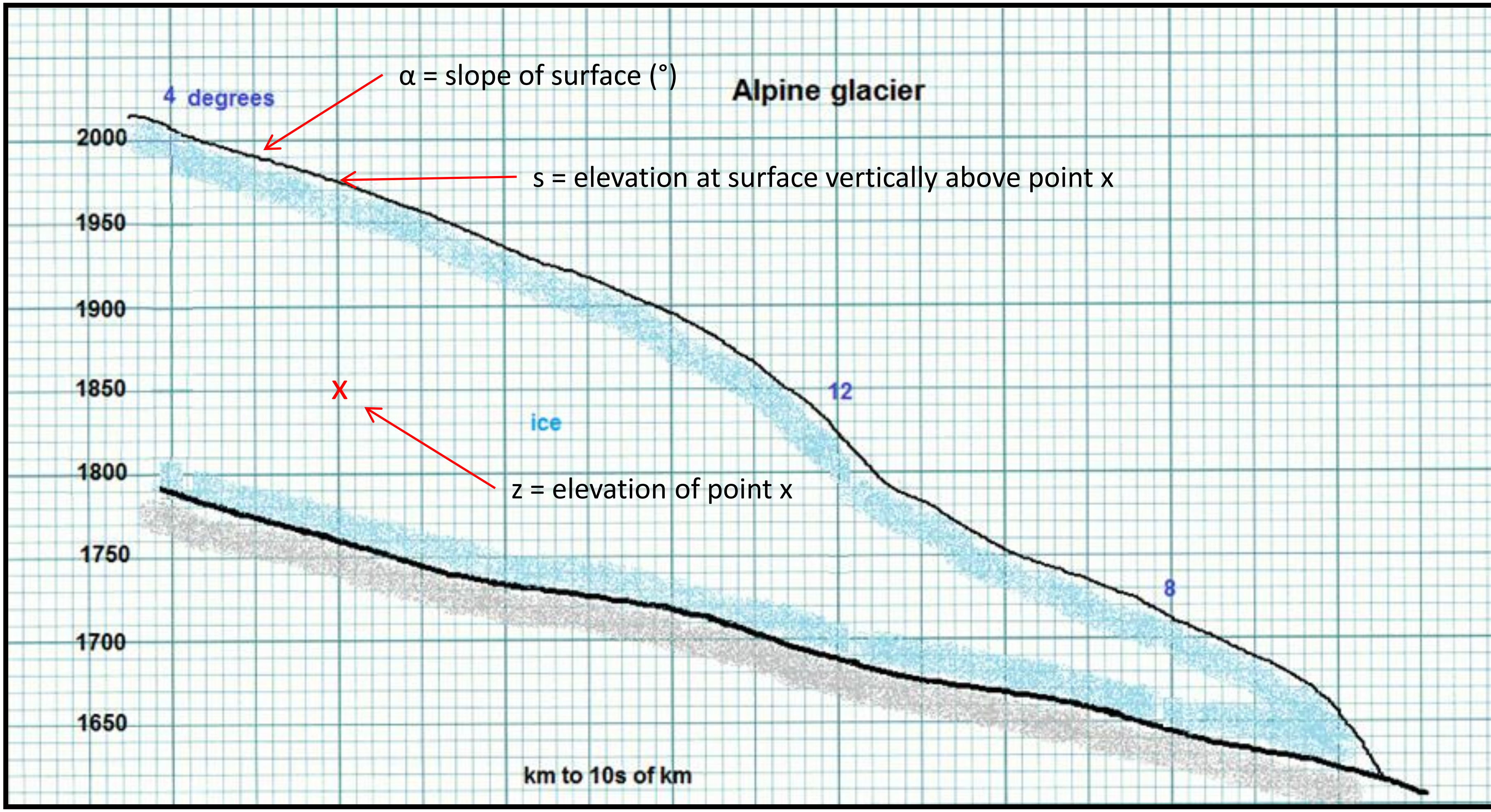
g = gravity = 9.8 m/s2

s = ice surface height above the base (m)

z = height at a point above the base (m)

α = slope on the ice surface (degrees)

$$\tau = \rho g\,(s-z)\sin\alpha$$



$$\tau = (916.7)(9.8)(1975-1850)\sin(4)$$

$$\tau = 78.3 \text{ kPa}$$

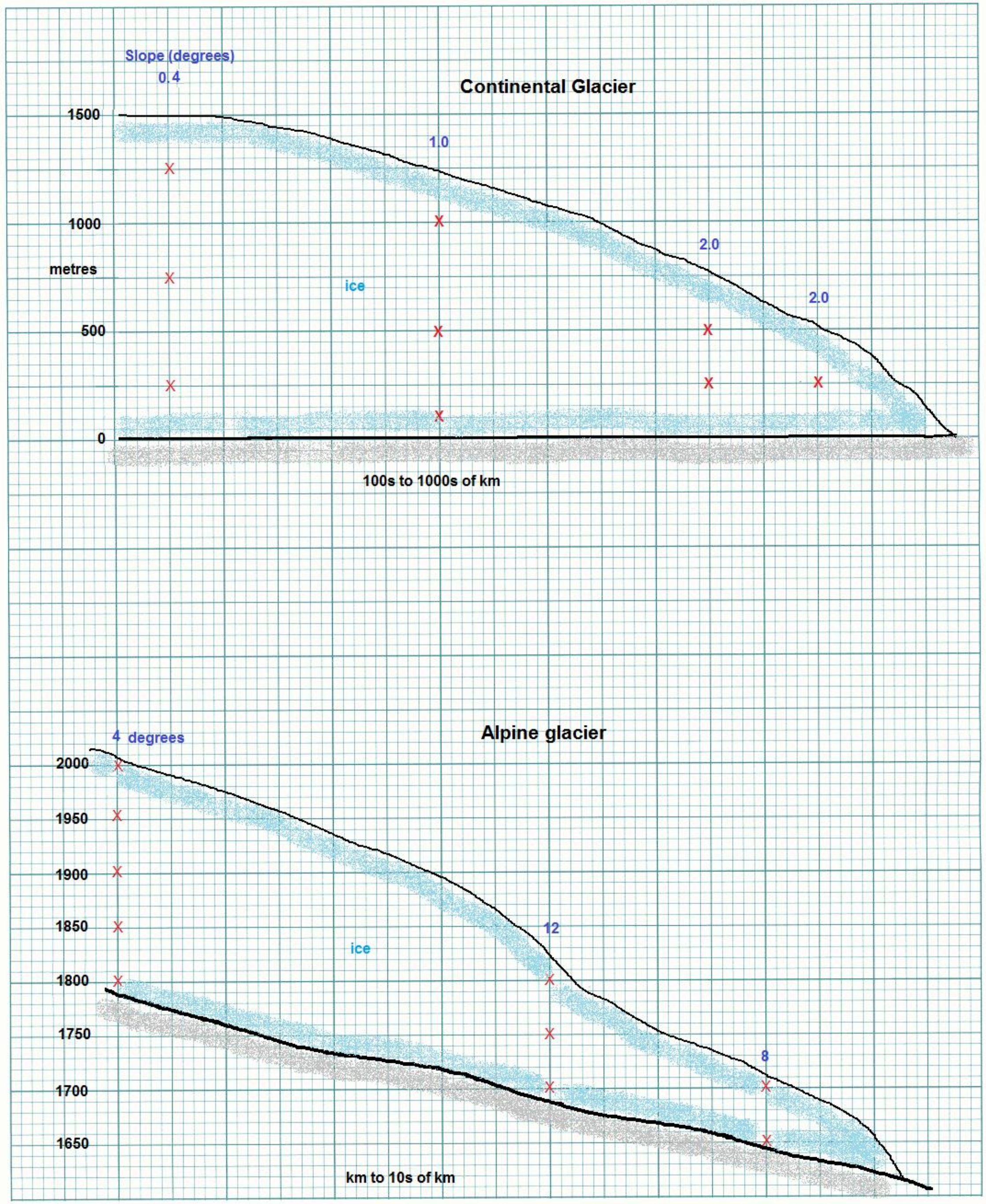
Ice will deform at shear stresses between 50 and 100 kPa, so it is likely that the ice at this point (x) in this glacier will “flow”.

Doubling the sheer stress will increase the creep rate by factor of 8.

Temperature is a factor as well. Creep rate at -1° C will be approximately 1000 times that at -20° C.

Ice compared with other rocks

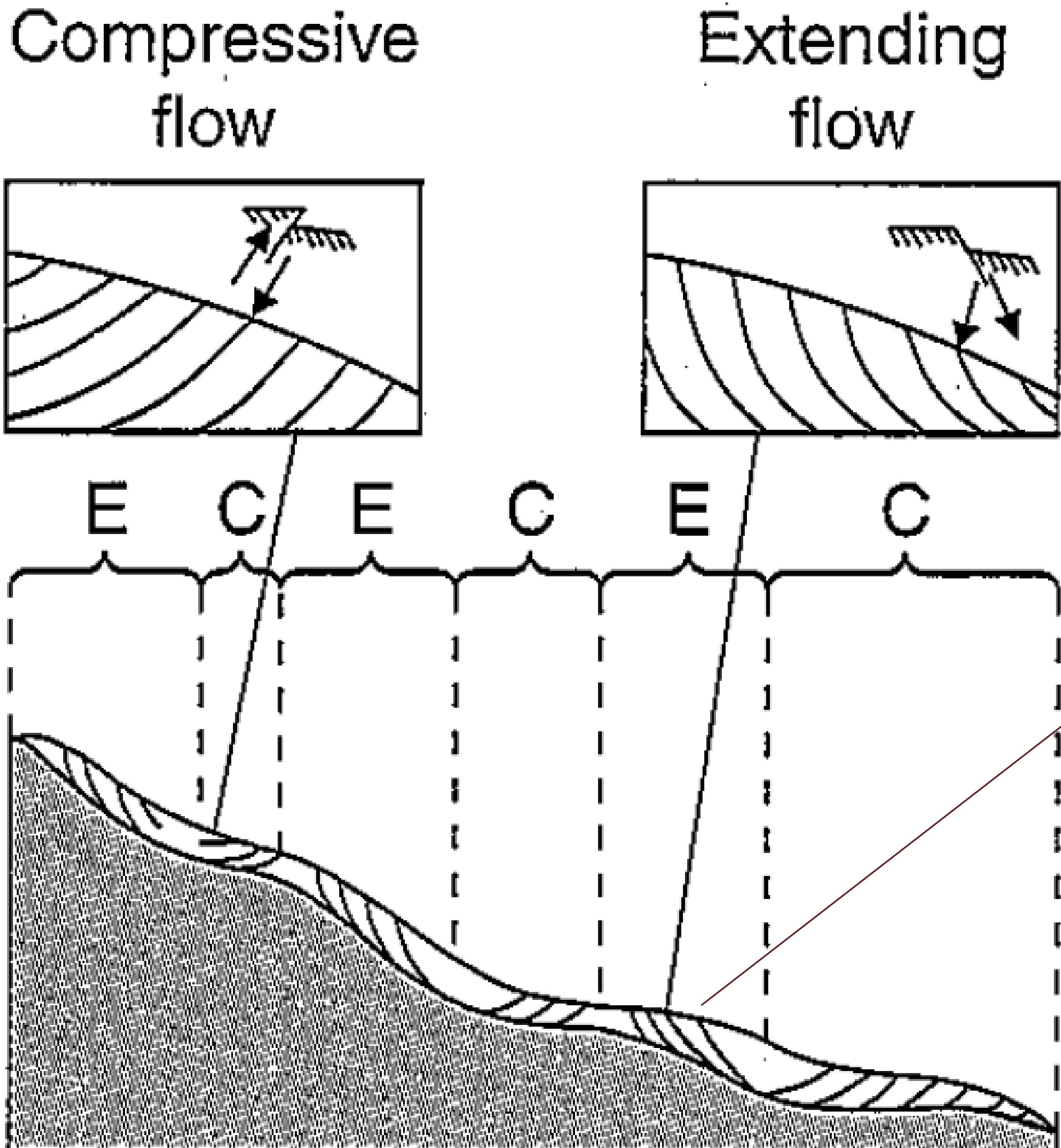
	Shear strength	
Rock	kPa	MPa
Granite	30648	31
Basalt	38302	38
Marble	21547	22
Sandstone	22960	23
Limestone	27718	28
Shale	700-2800	.7 - 2.8
Chalk	419	0.5
Ice	~100	0.1

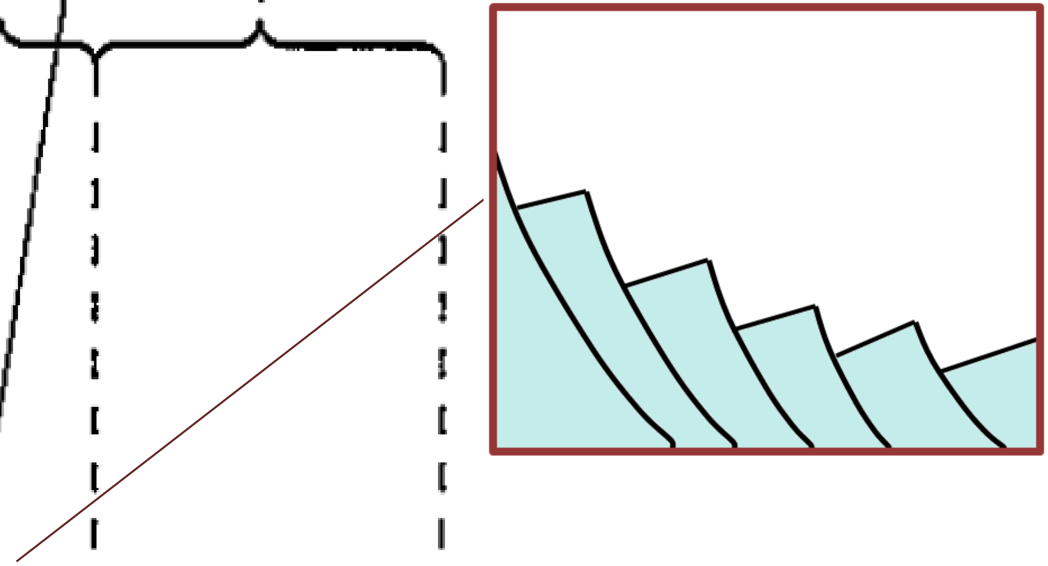


Slope (degrees)
0.4
Continental Glacier
1500
1.0
1000
2.0
metres
ice
2.0
500
0
100s to 1000s of km
4 degrees
Alpine glacier
2000
1950
1900
1850
12
ice
1800
1750
8
1700
1650
km to 10s of km

Flow under extensive versus compressive conditions

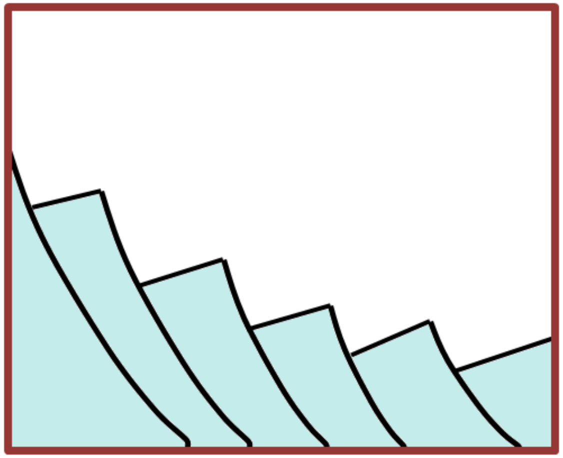
If a glacier is accelerating (e.g., on a steep incline) the flow will be extensive. If it decelerating (e.g., where the slope is getting flatter or something is constricting ice motion) the flow will be compressive.



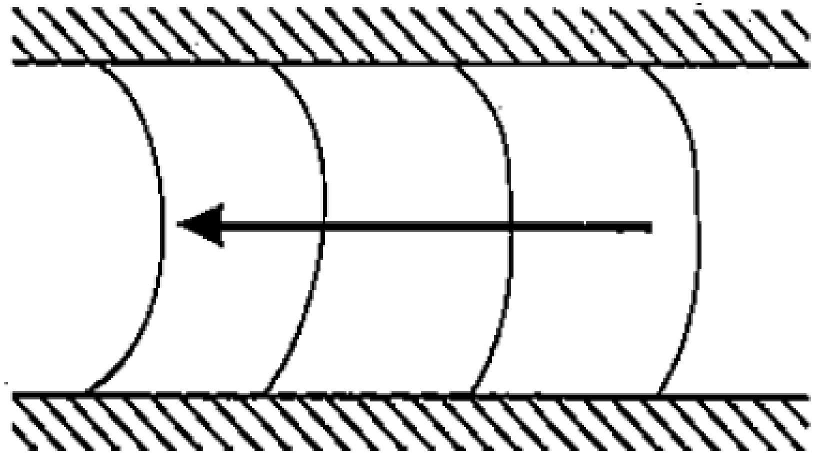


Bennett and Glasser, 2009

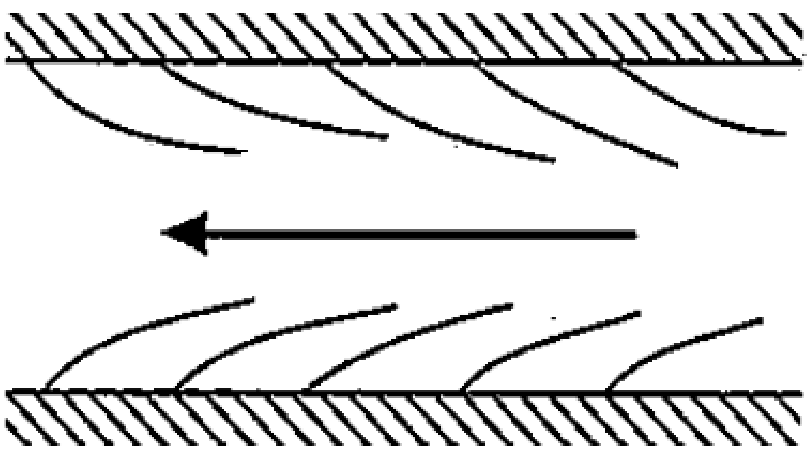
Extending-flow crevasse fields



Transverse crevasses: extending flow

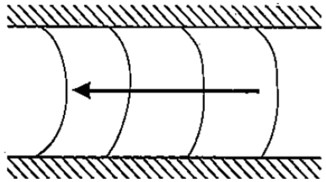


Radial crevasses: compressive flow

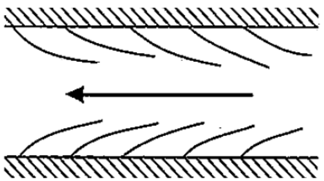


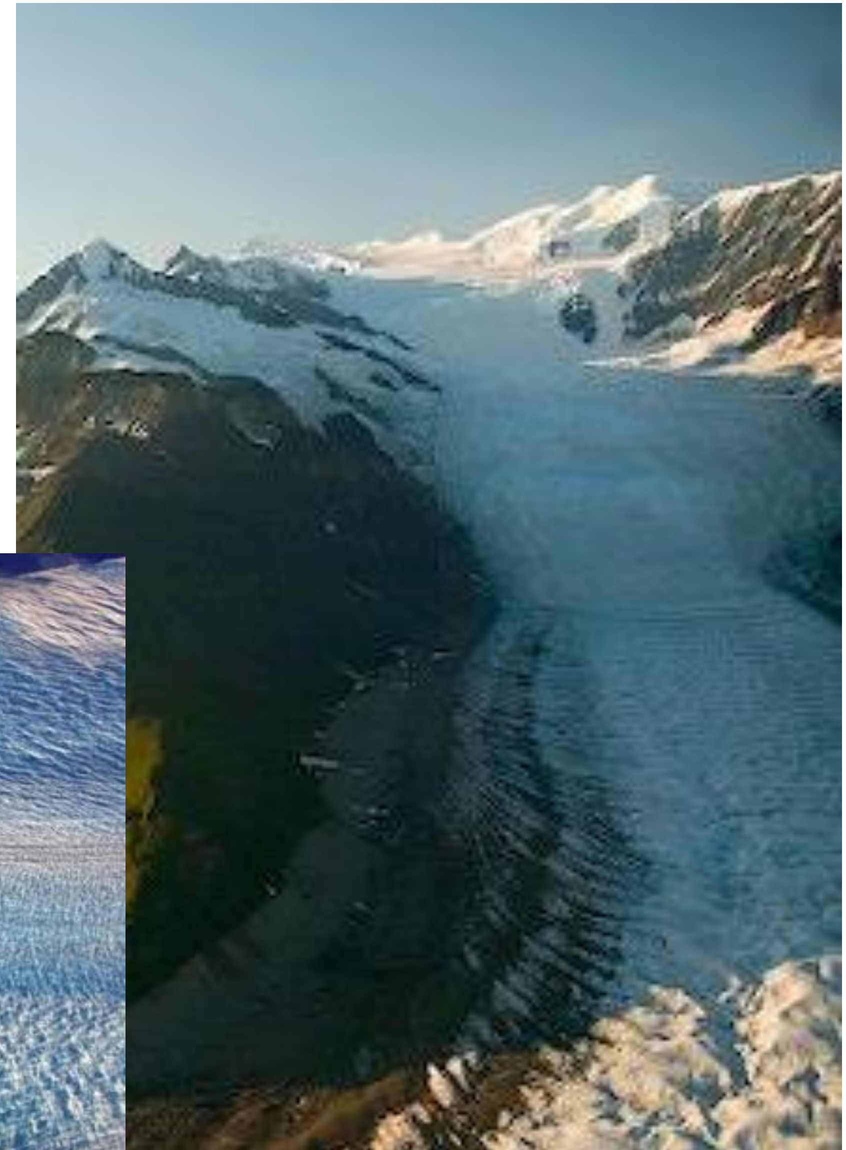
Bennett and Glasser, 2009

Transverse crevasses: extending flow

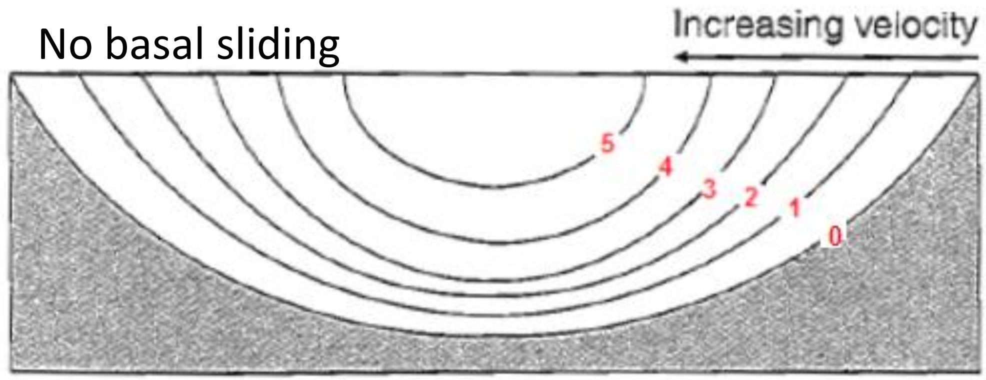


Radial crevasses: compressive flow

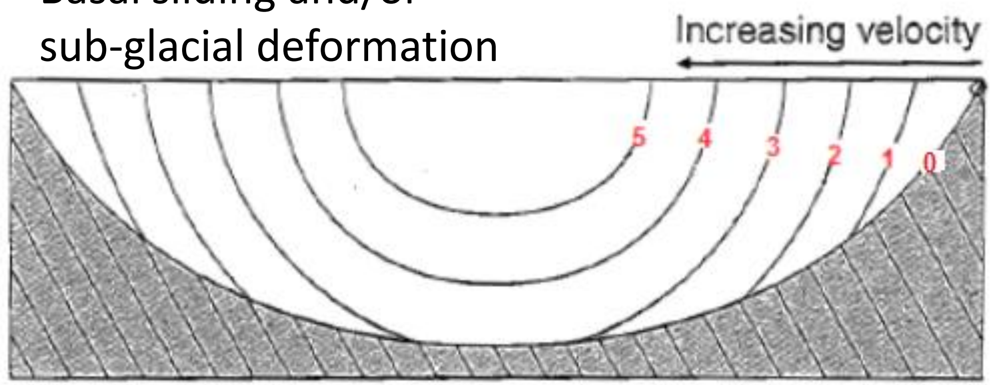




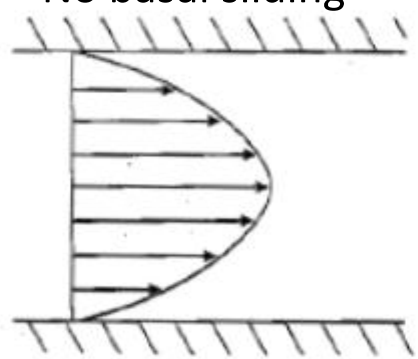
No basal sliding



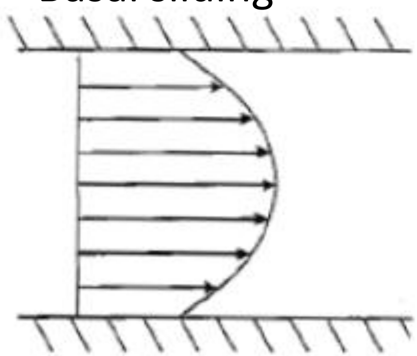
Basal sliding and/or sub-glacial deformation



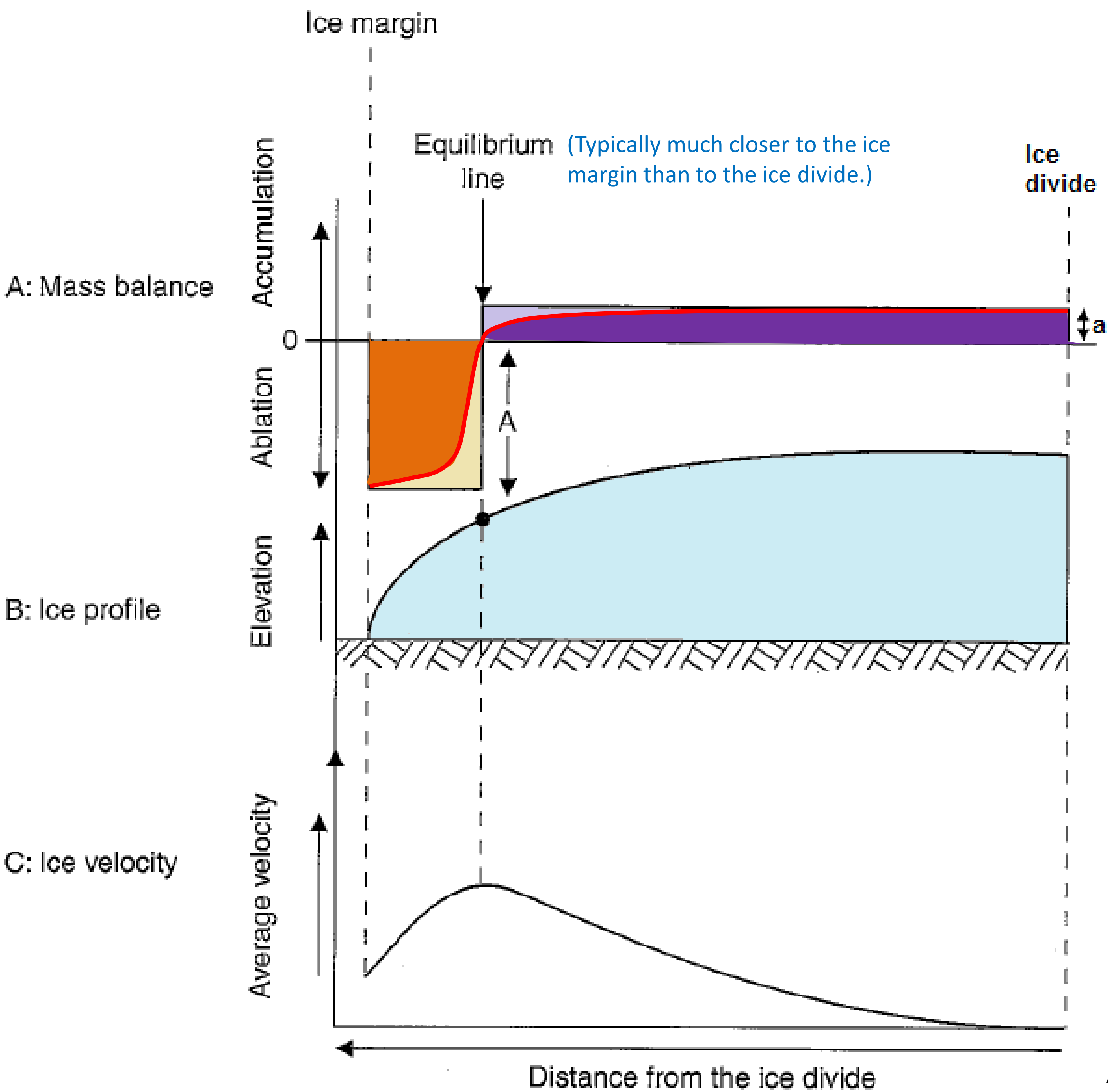
No basal sliding



Basal sliding



After Bennett and Glasser, 2009



After Bennett and Glasser, 2009