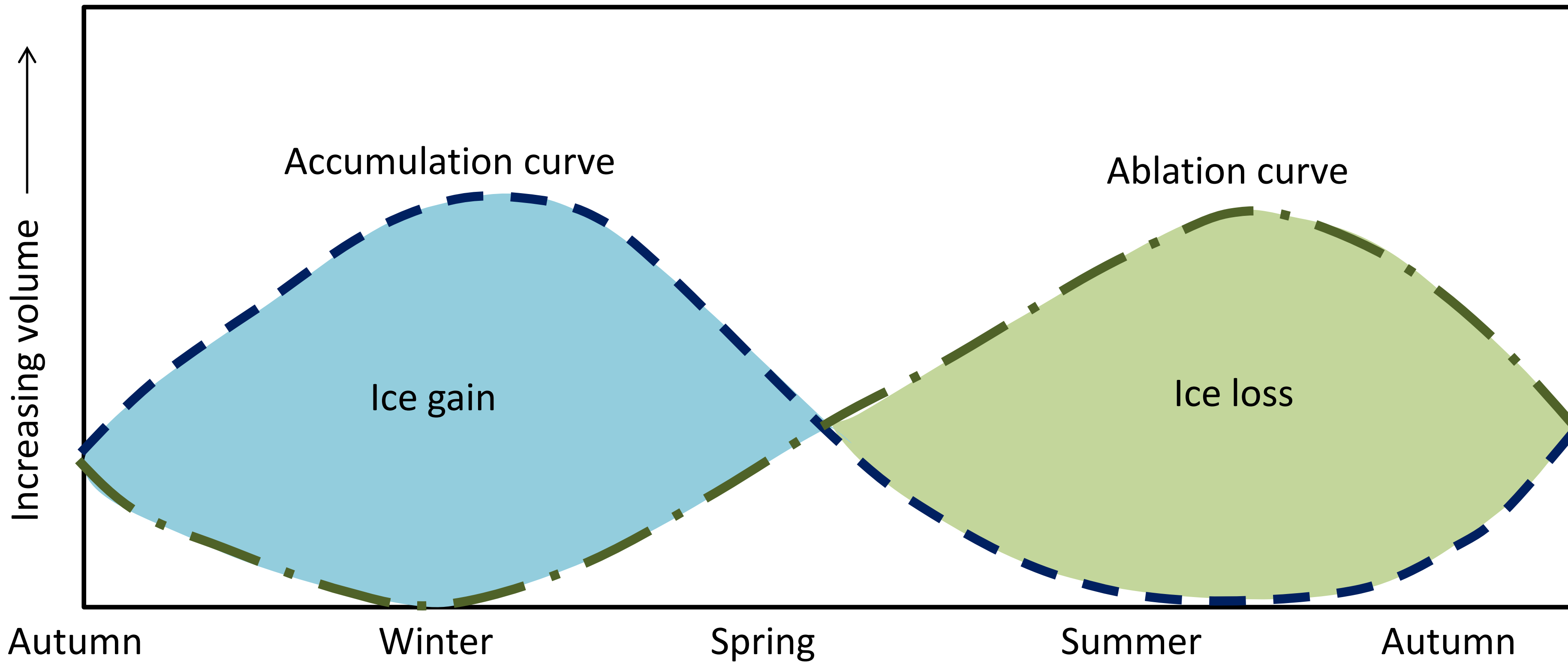
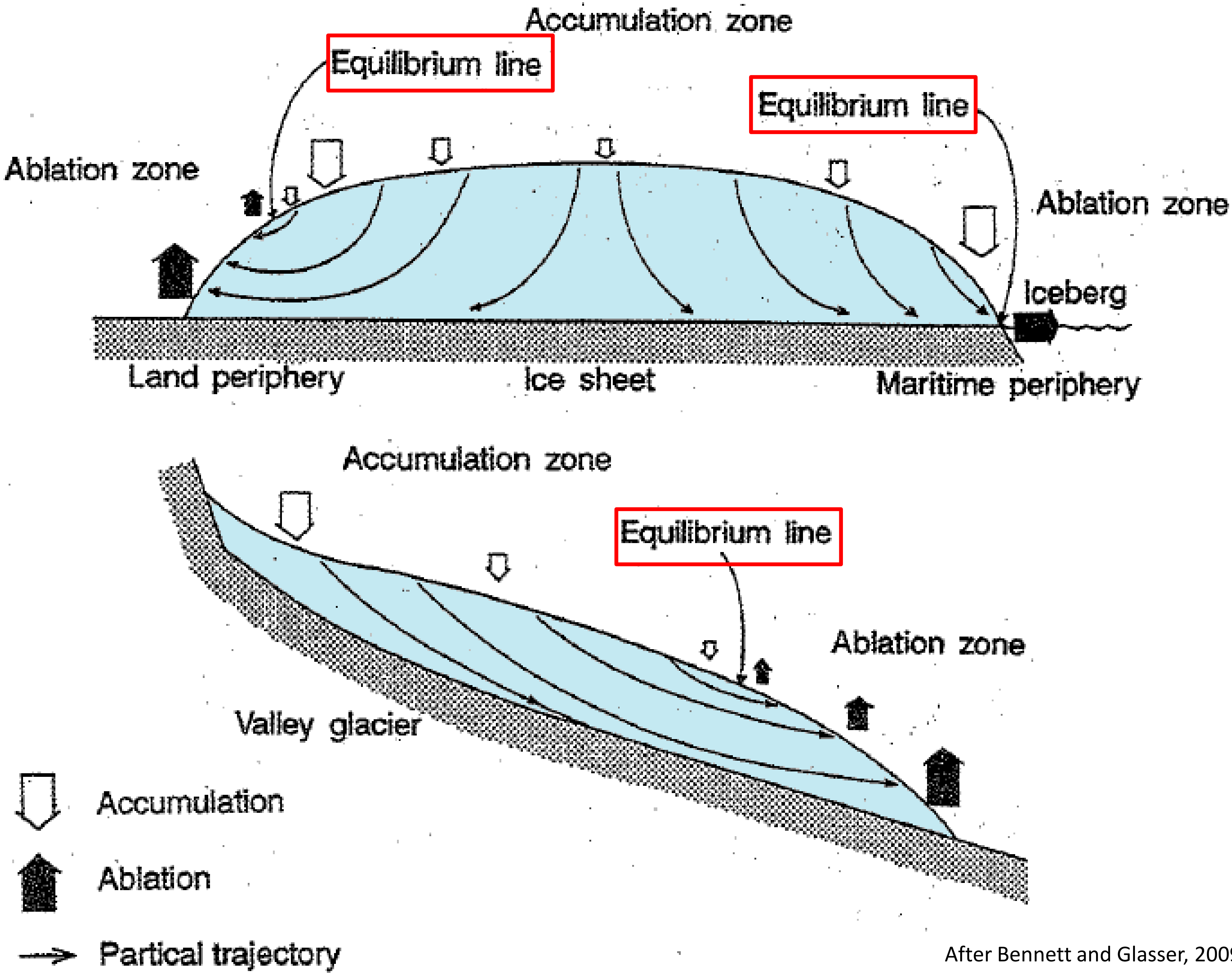
Mass Balance and Ice Flow Mechanisms

W. Shilts

Glacier accumulation and ablation curves (annual mass-balance)

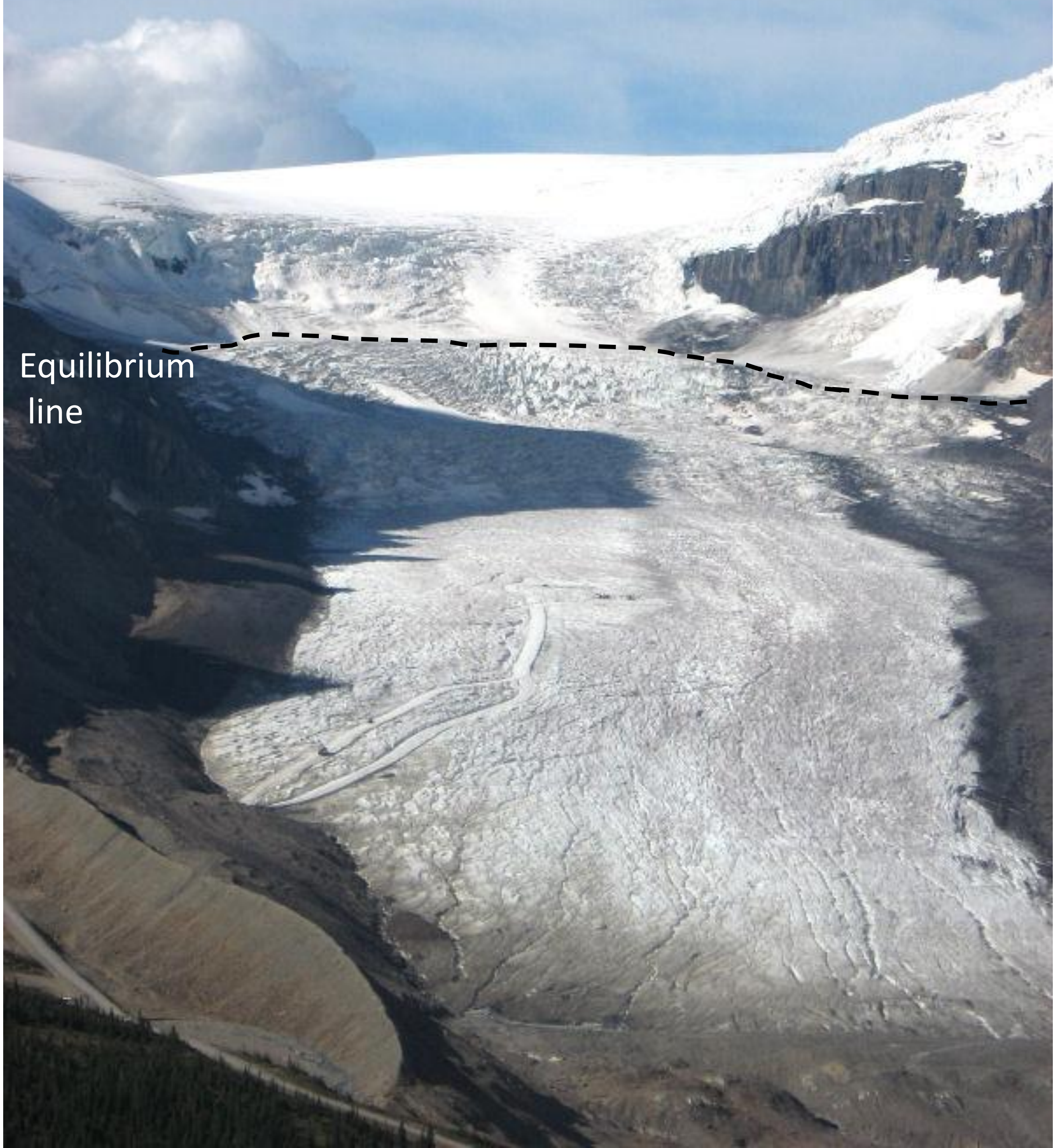


After Bennett and Glasser, 2009

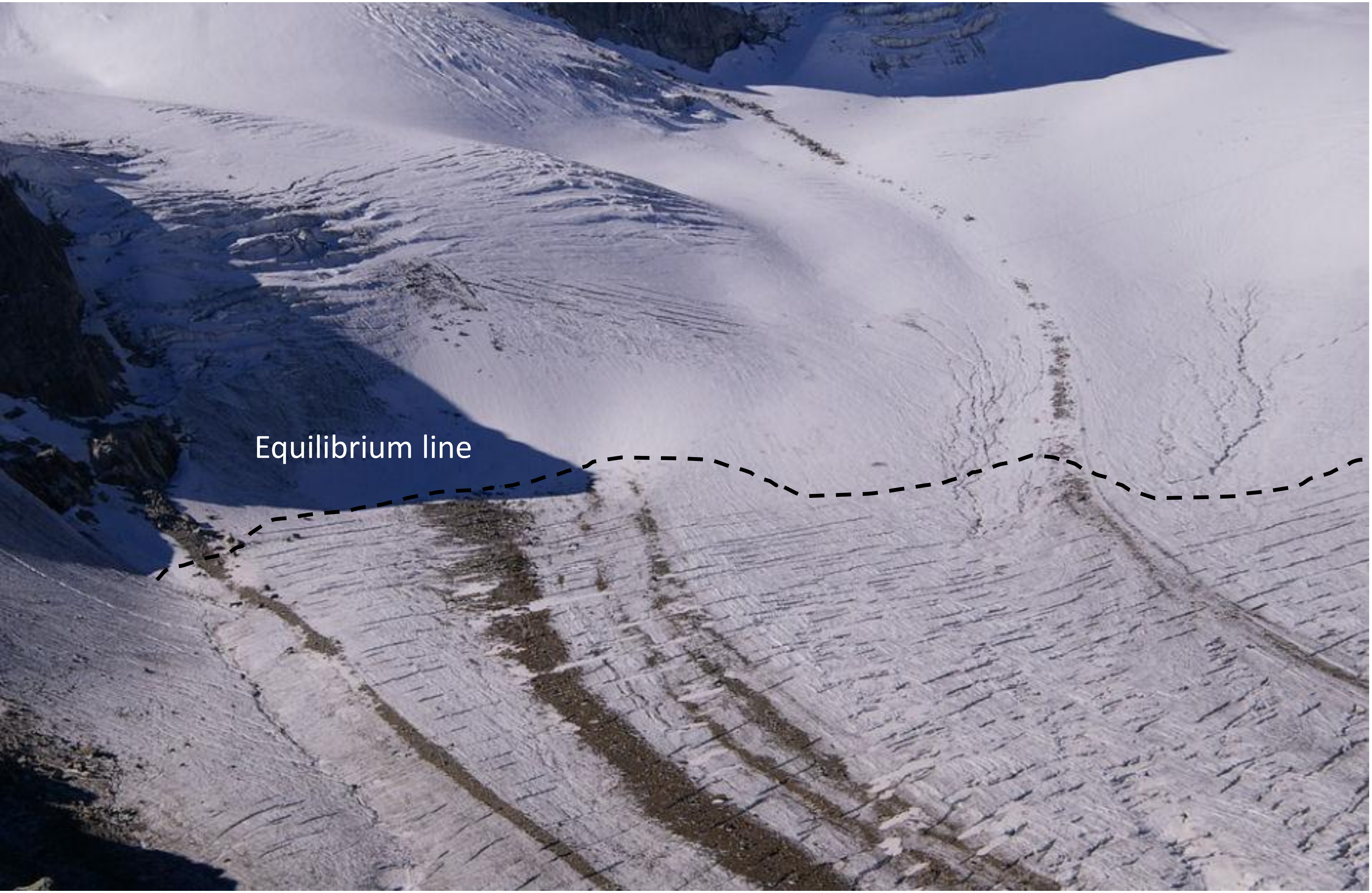


After Bennett and Glasser, 2009


Equilibrium line
Bylot island, Canada, W. Shilts

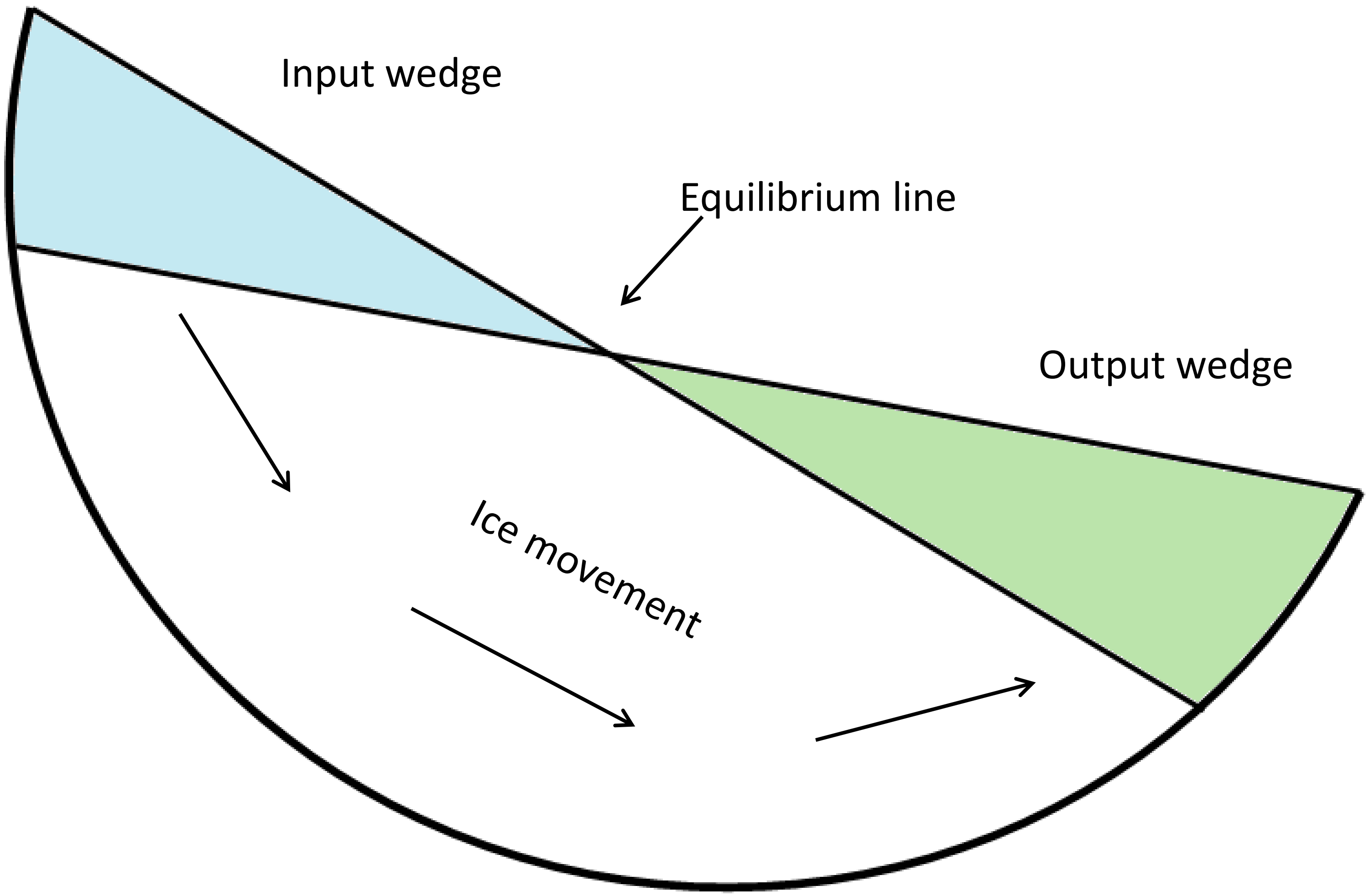


Athabasca
Glacier



Somewhere in the Swiss Alps

Glacier mass balance diagram



After Bennett and Glasser, 2009

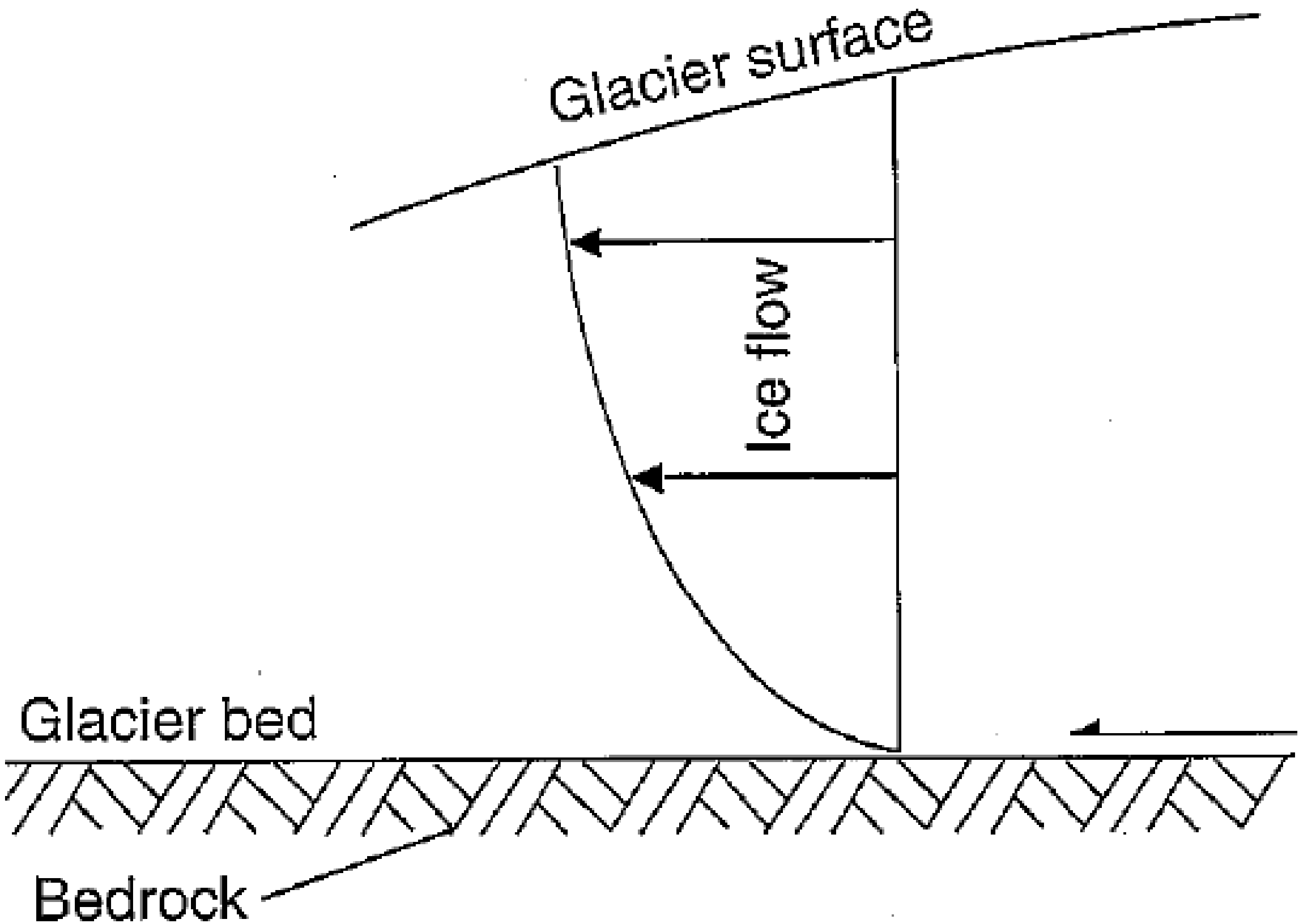
Glacier Movement

- 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 (basal ice deforms around obstacles)
  - Regelation slip (thawing and freezing)

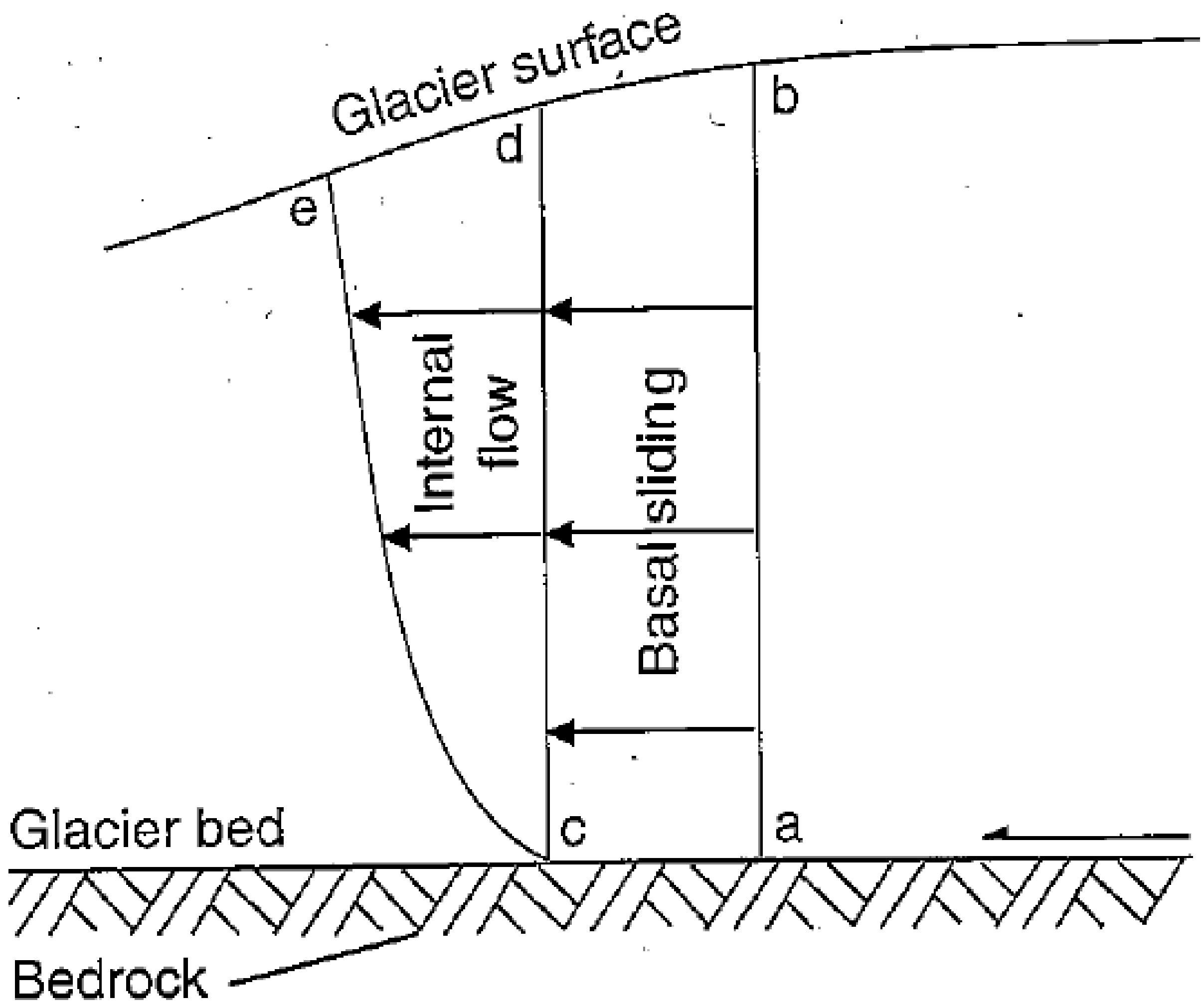
- Bed deformation (deformation of the sediments or rock beneath the glacier)

Internal flow only



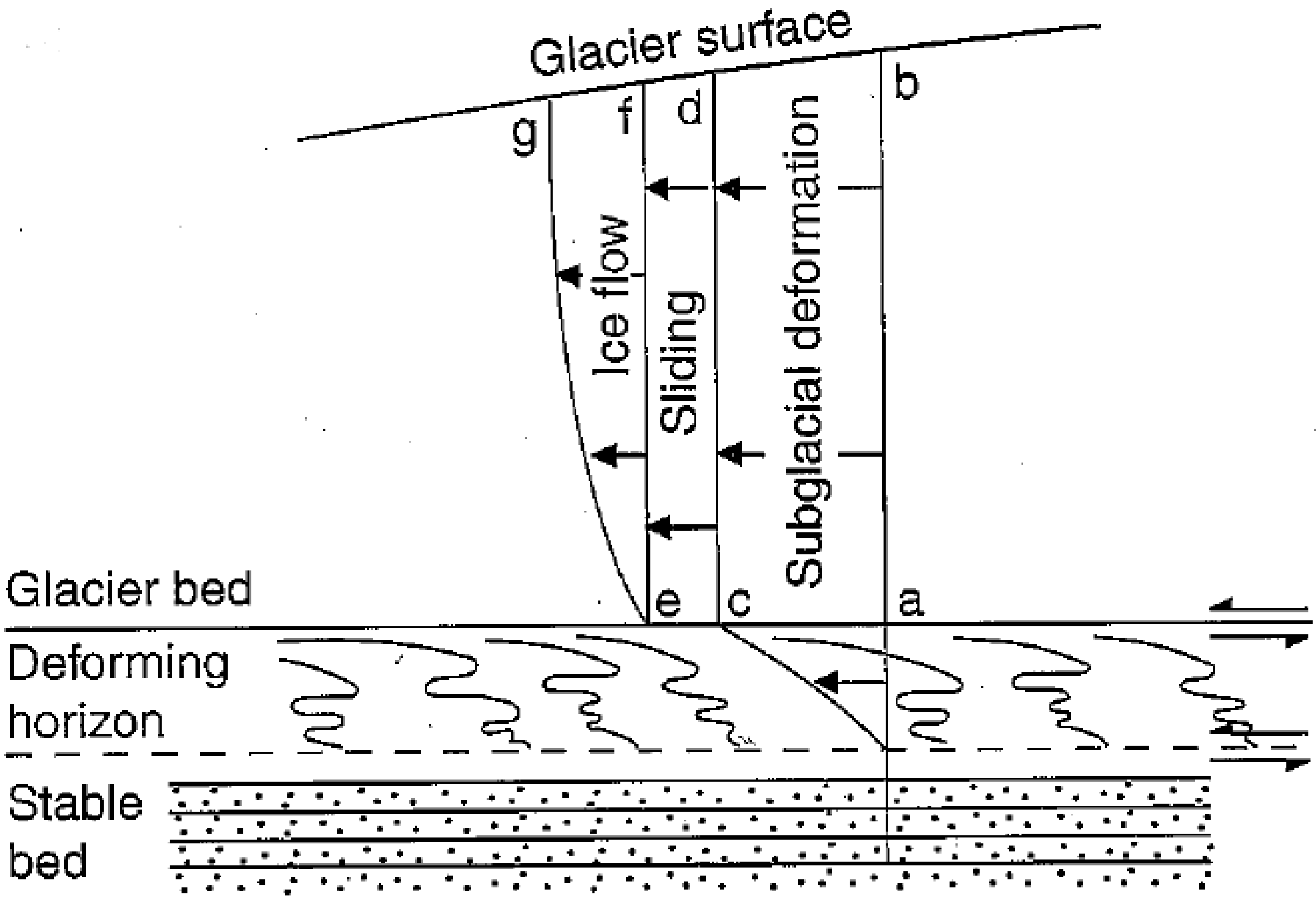
After Bennett and Glasser, 2009

Internal flow and basal sliding



After Bennett and Glasser, 2009

Internal flow, basal sliding and bed deformation

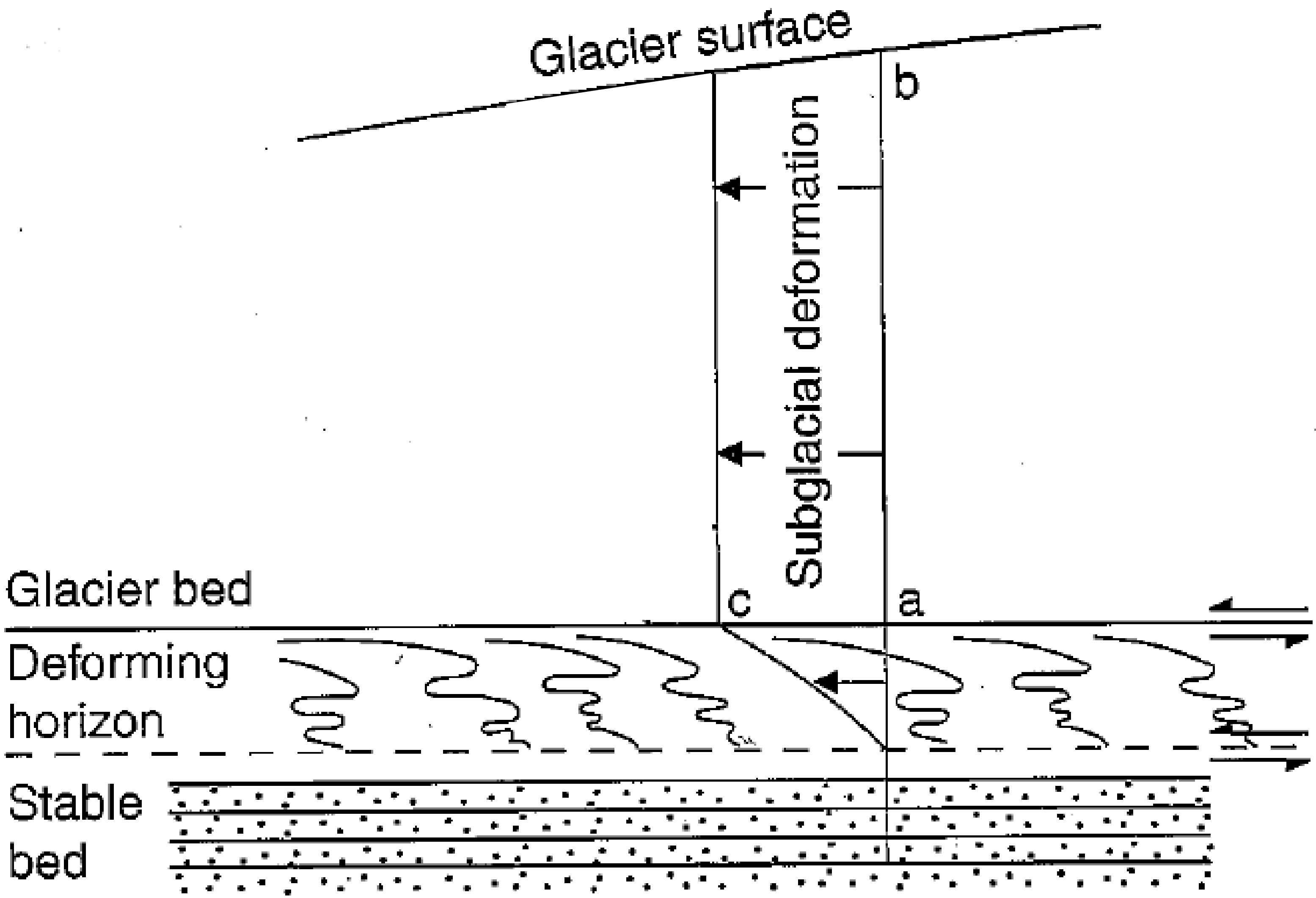


After Bennett and Glasser, 2009

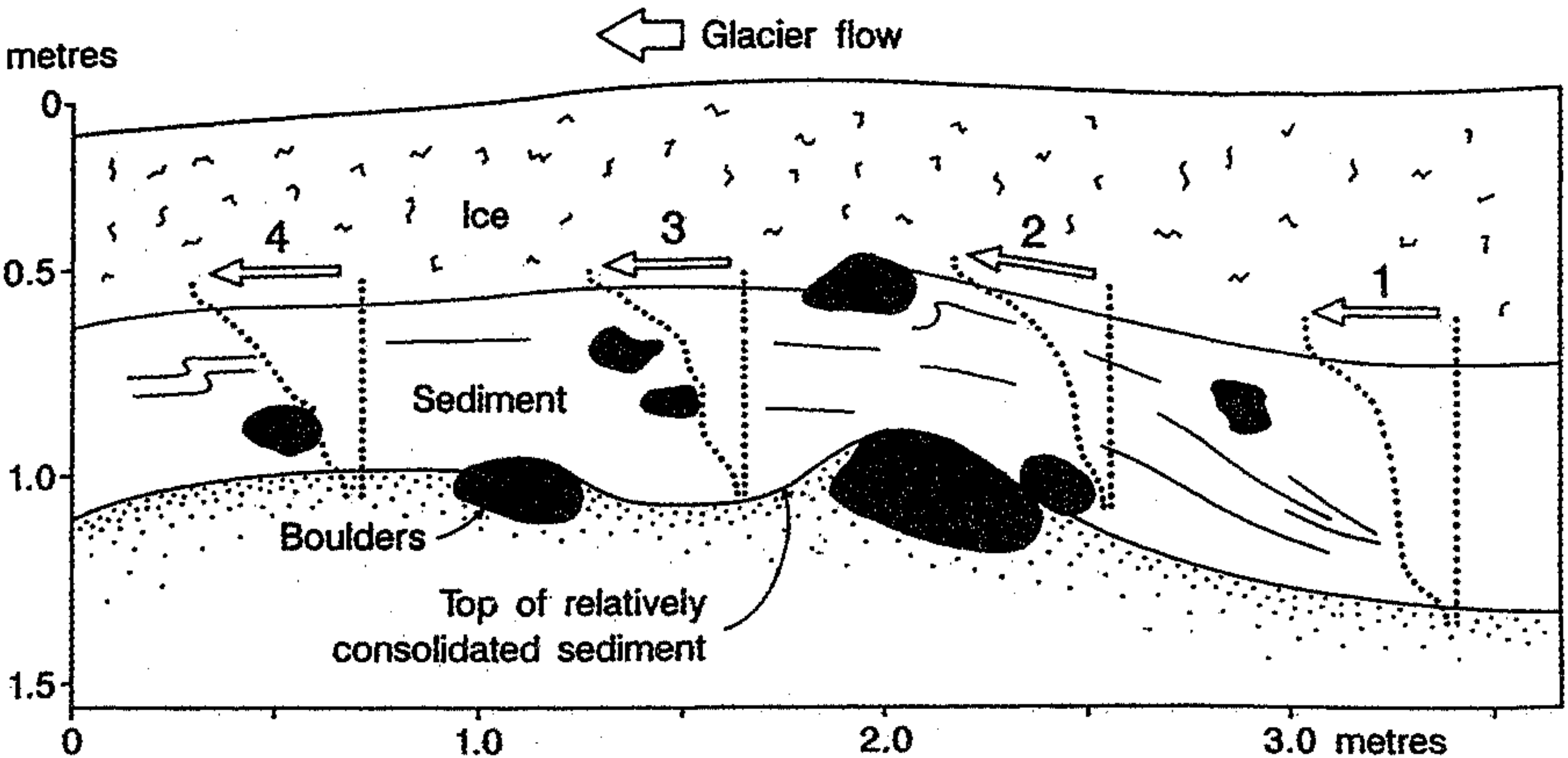
Deformed till

Factors that contribute to weakness in the material underlying a glacier

- **Temperature** (frozen sediments tend to be quite strong no matter what they're made of)
- **Composition** (clay minerals tend to be much weaker than other silicates)
- **Degree of lithification** (lithified materials are obviously stronger than unlithified ones)
- **Water content** (most materials, especially clay-bearing materials, are weaker when they are wet)



After Bennett and Glasser, 2009



After Bennett and Glasser, 2009

Basal sliding

Sliding at the ice – bed interface

- Most effective on smooth hard rock
- Presence of water enhances sliding
- Stick-slip motion is likely

Enhanced basal creep

- basal ice deforms around obstacles
- Stress is greatest on the up-ice side of an obstacle so there is a greater tendency for deformation near to an obstacle than where the base is flat

Regelation slip

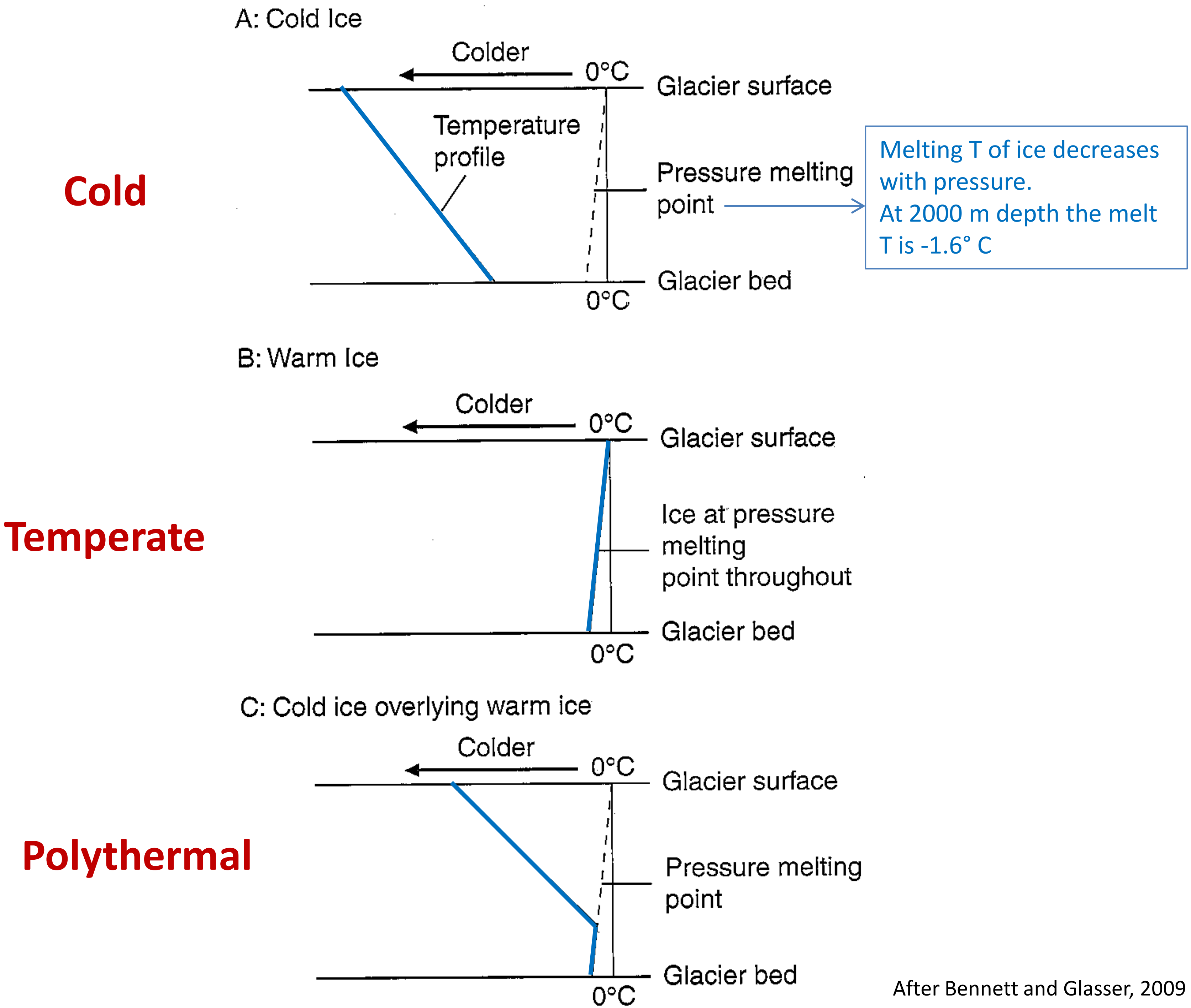
- The greater P on the up-ice side of an obstacle may lead to melting
- The water then flows around to the low side (where the P is less) and refreezes

If the base of the ice-sheet is very cold then the likelihood of basal sliding is very low. The ice will likely be frozen to the substrate, and will not move.

Controls on basal ice temperature

Factor	Effect
Ice thickness	Provides insulation from the cold air above. The greater the thickness the warmer the base
Accumulation rate	Rapid accumulation of cold snow leads to a cold base Rapid accumulation of warm snow leads to a warm base
Ice surface T (a function of the air T)	Cold surface contributes to a cold base (degree for degree)
Melt water	Warm melt water warms the basal ice. Melt water that re-freezes at depth warms basal ice even more (1 g of water that re-freezes can raise the T of 160 g of ice by 1° C)
Geothermal heat	Warms the basal ice – much greater in some areas than others.
Friction	Greater ice velocity contributes to a warmer base. (Ice velocity of 20 m/y is equivalent to the average geothermal heat flux)

Which conditions are likely to lead to the warmest basal ice, and which the coldest?



After Bennett and Glasser, 2009

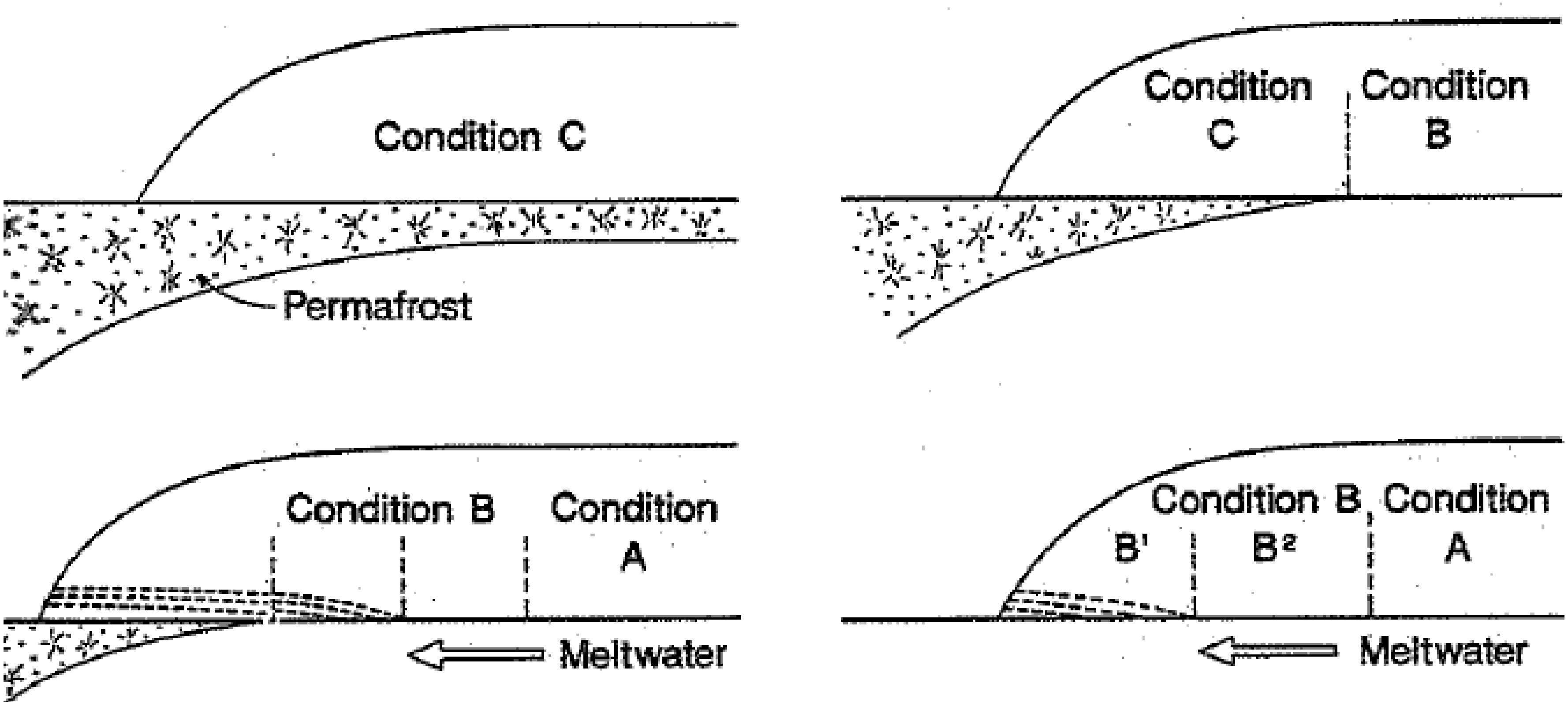
Boundary Conditions

- **A – Net basal melting** (more heat is generated at the base than can be conducted away)

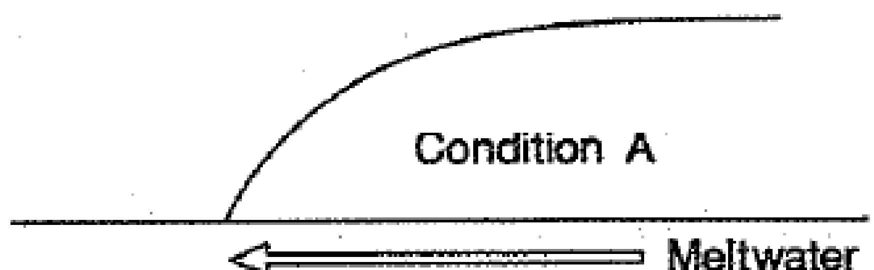
- **B – Equilibrium** between melting and freezing

- **C – Net basal freezing** (Heat generated at the base of the glacier is removed efficiently and the ice remains frozen on the bed)

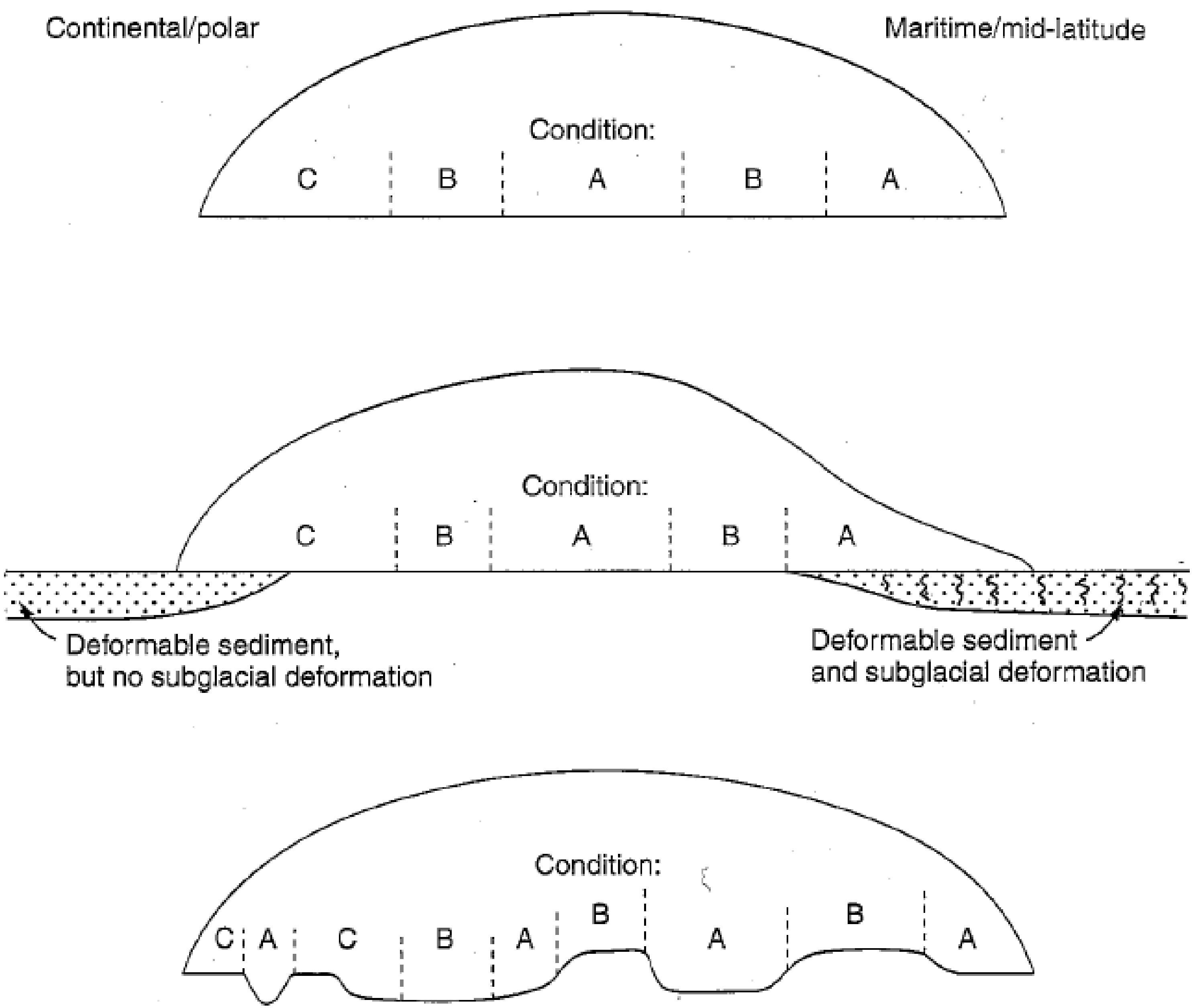
After Bennett and Glasser, 2009



B2 is transitional between A and B



After Bennett and Glasser, 2009



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