

Ankara University
Faculty of Languages and History-Geography
Department of Geography

Glacial Geomorphology

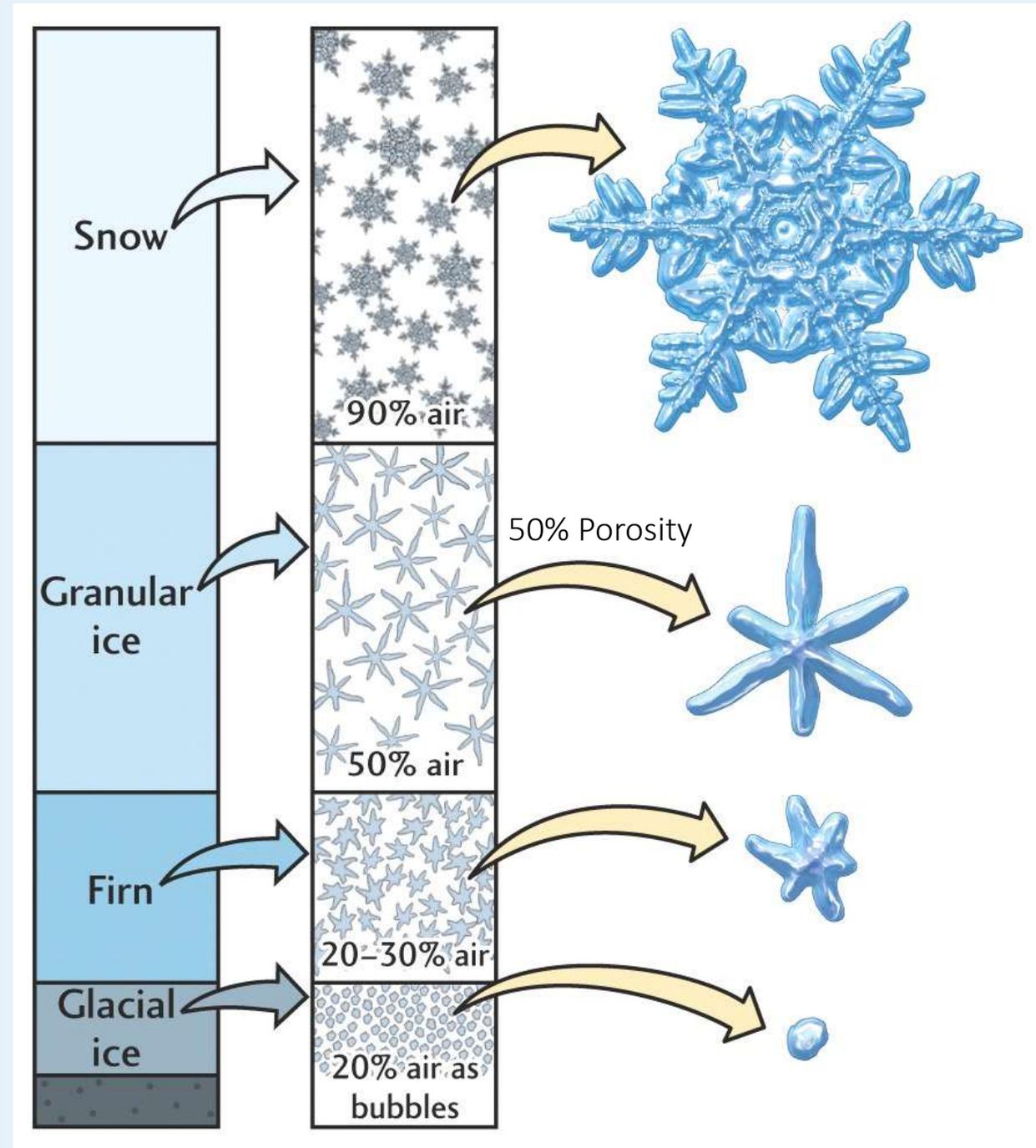
Dr. Serdar Yeşilyurt

What is a glacier?

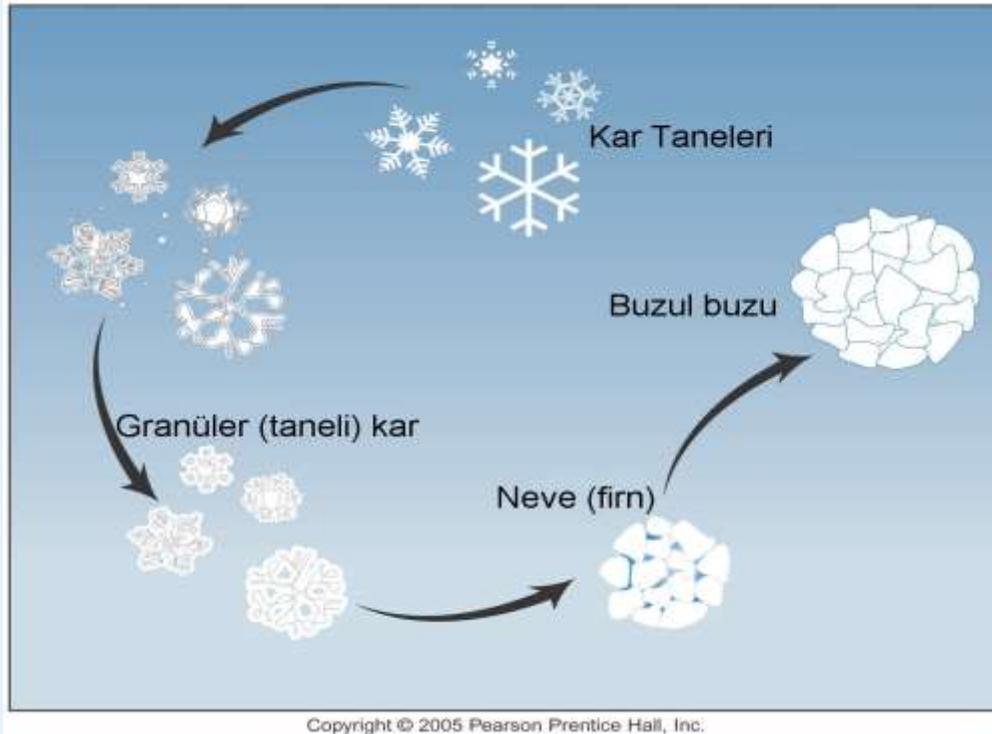
Glaciers are large ice masses formed through a long and complex series of processes, including the accumulation, compression, melting, refreezing, and recrystallization of snow.

When the amount of snowfall in an area exceeds the amount that melts, accumulation occurs over time. Repeated accumulation over many years results in layered snow, which compresses under its own weight, increasing its density and eventually transforming into glacier ice.

Winter precipitation and summer temperatures are crucial factors in the formation of glaciers.



How do glaciers form?



Typical densities of snow and ice (kg/m³)

New snow	50-70
Damp new snow	100-200
Settled snow	200-300
Depth hoar	100-300
Wind packed snow	350-400
Firn	400-830
Very wet snow and firn	700-800
Glacier ice	830-917

Glaciers are masses of compressed snow and ice that move under their own weight due to gravity.

The first stage in the formation of glacier ice is the accumulation of snow on the glacier surface through precipitation. This process is typically long and complex.

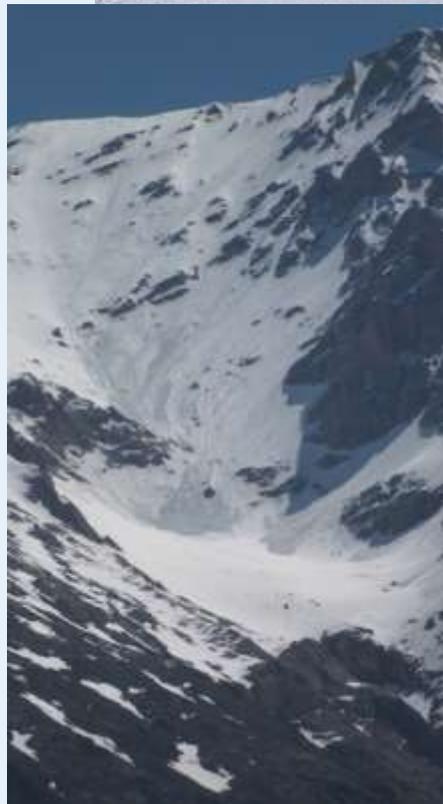
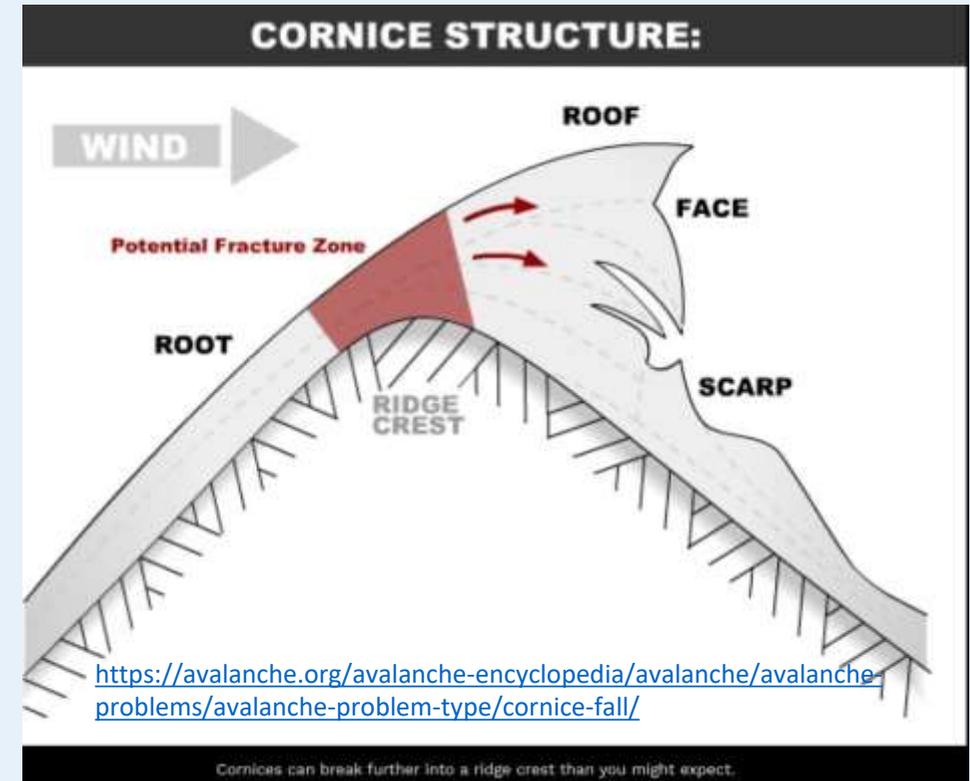
After snowfall, the snow accumulates in layers, compresses under its own weight, melts, refreezes, and recrystallizes. It first turns into firn, and eventually, with further compression, it transforms into glacier ice. As the density of the glacier ice increases, the amount of trapped air bubbles decreases.

Glacier ice absorbs some red light and reflects blue light, which is why glaciers appear blue. If a glacier appears white, it indicates the presence of fine air bubbles within the ice.

Transformation from snow to glacial ice

Snow accumulation occurs through snowfall, avalanches, and wind transport.

Snow layers



Avalanche



Transformation from snow to glacial ice

While melting during the ablation season plays a role in glacier formation in non-polar mountain ranges, the compaction of dry snow layers dominates in polar regions.

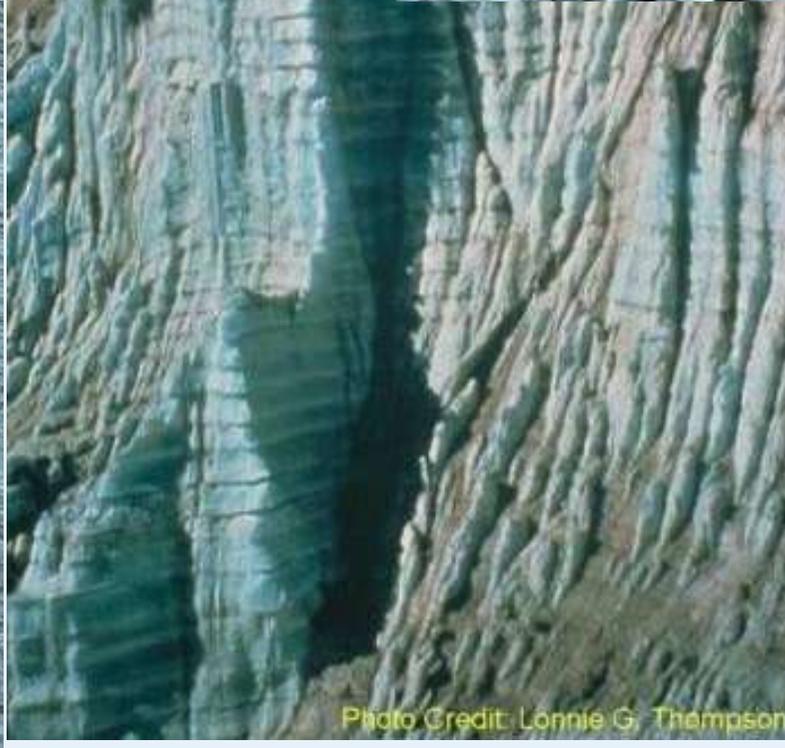


Compacted snow layers

Firn



Glacial ice layers



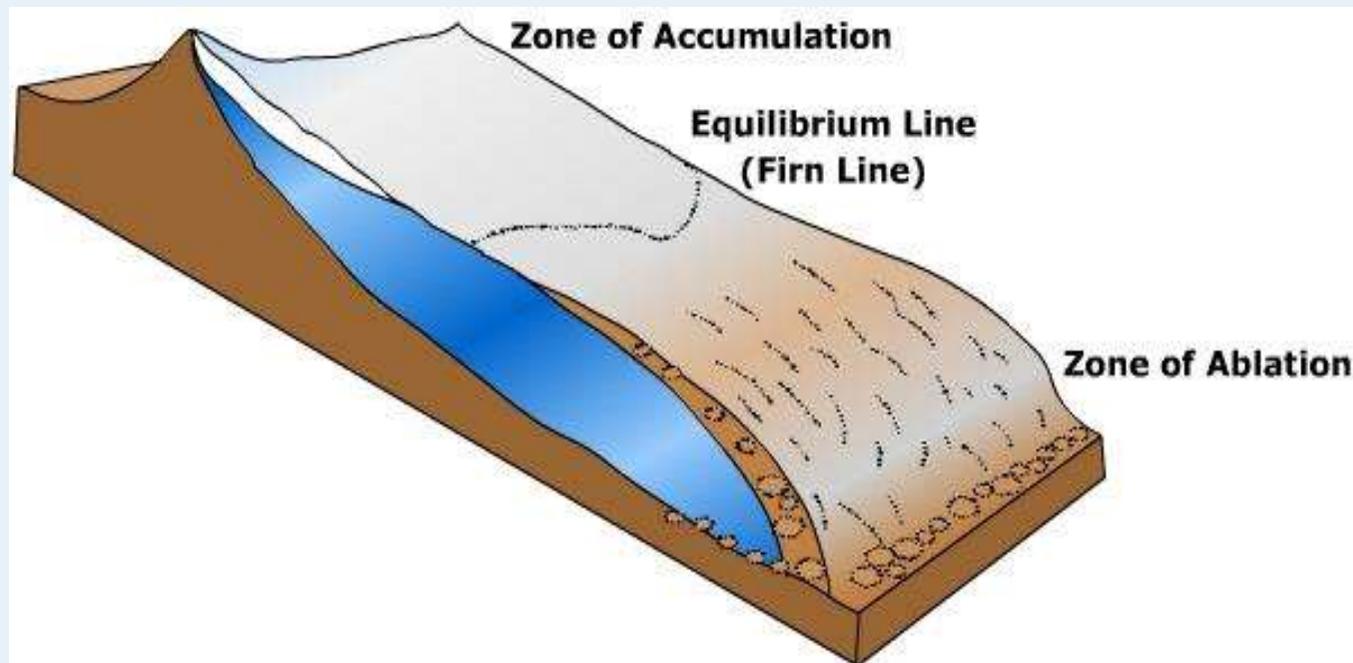
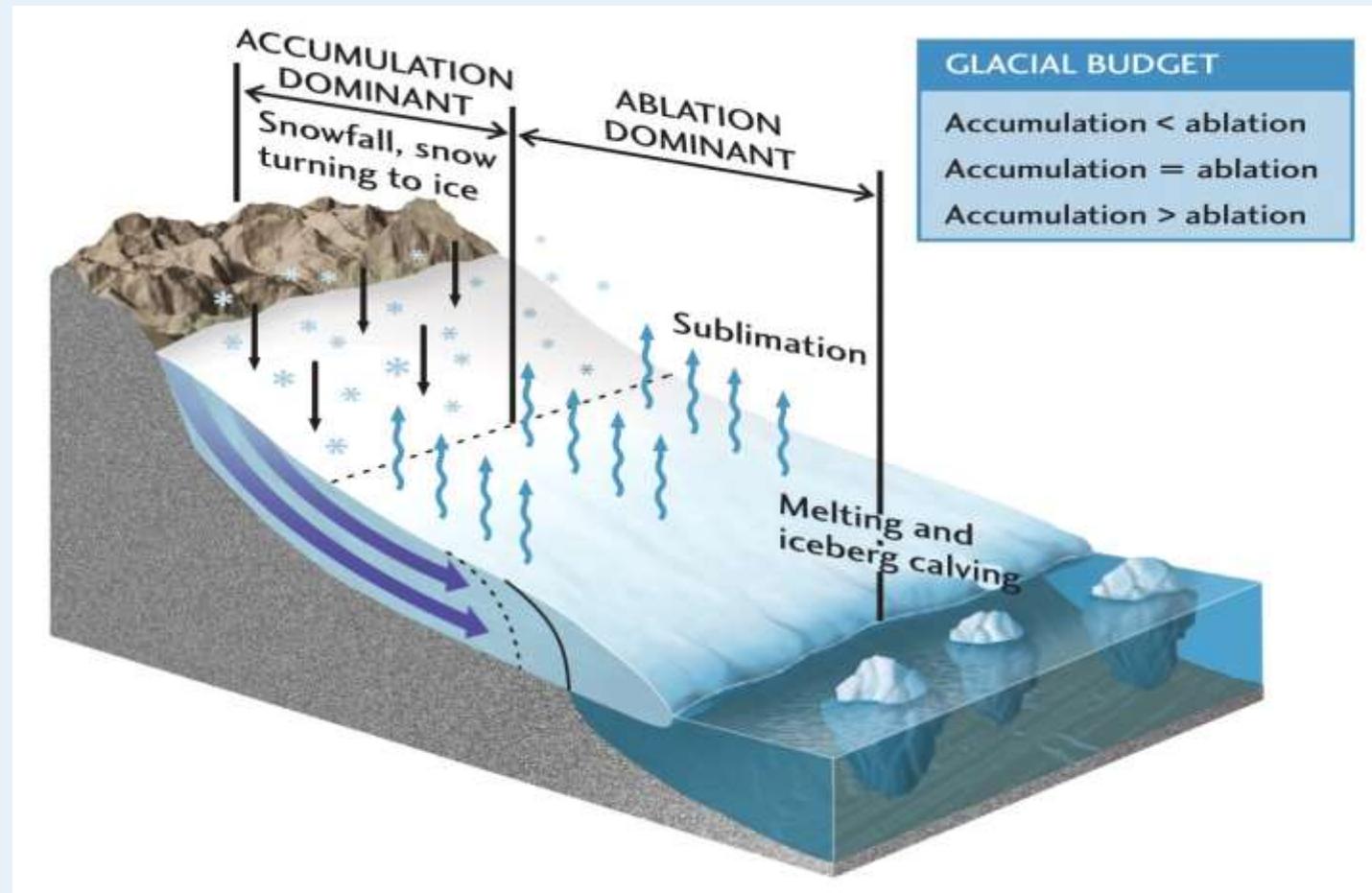
© Scott McGee

Photo Credit: Lonnie G. Thompson

Glacier Mass Balance

The **equilibrium line (permanent snow line)** is considered the boundary between the accumulation and melting zones, where the mass balance is assumed to be zero.

Once a glacier has formed, its survival depends on the balance between accumulation and melting, which is controlled by **temperature, precipitation, and solar radiation.**



Snow accumulation occurs in the upper part of valley glaciers, which make up 2/3 of the total glacier mass.

The excess pressure at the base of the glacier breaks down the bedrock beneath it.

Equilibrium Line Altitude



The permanent snow line (**ELA**: equilibrium line altitude) corresponds to the altitude at which the amount of accumulated ice and the amount of melted ice are equal.

It is an important parameter in comparing paleoclimate with current climate conditions.

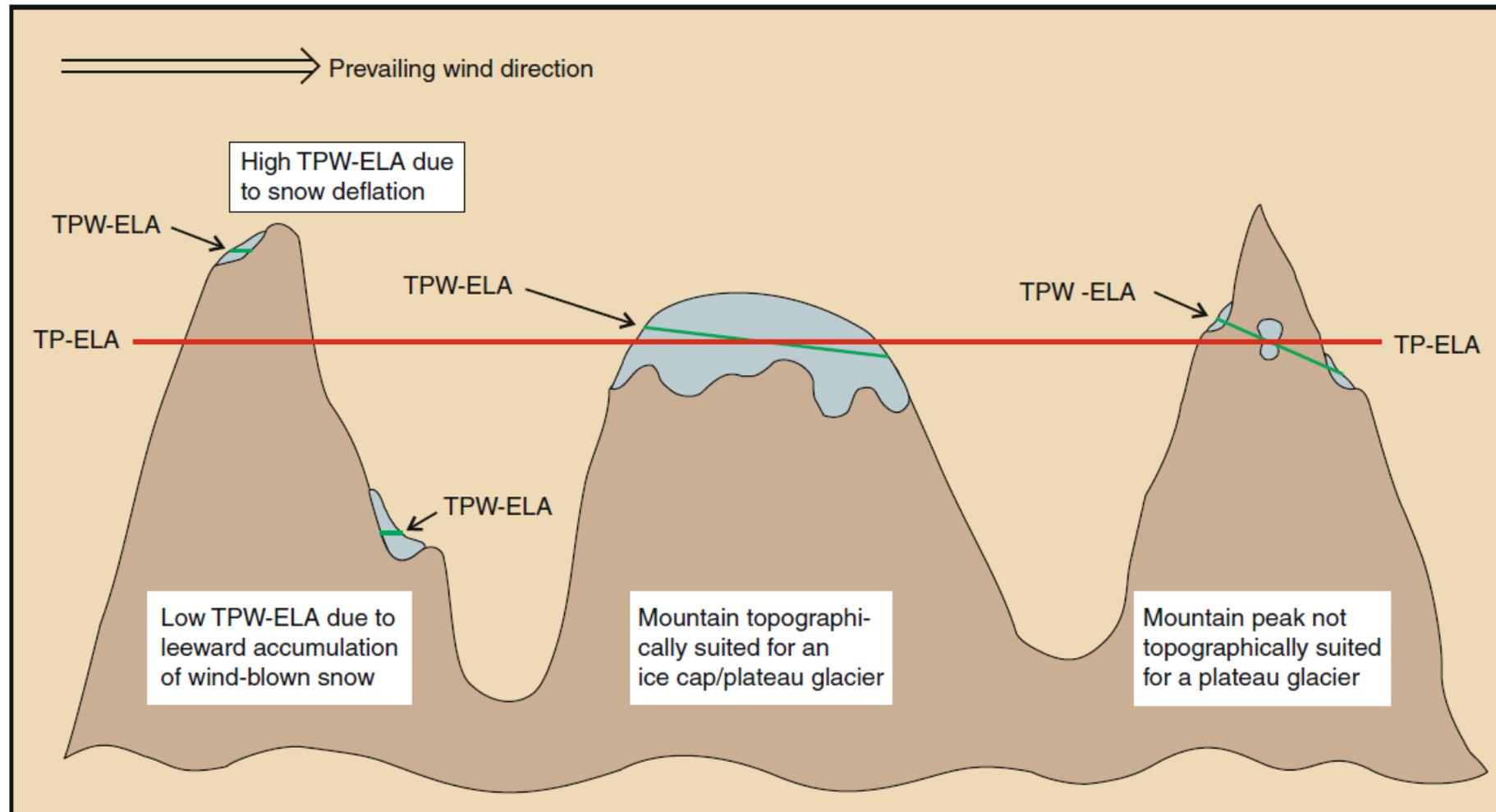
Equilibrium Line Altitude



Equilibrium Line Altitude

270

EQUILIBRIUM-LINE ALTITUDE (ELA)



Equilibrium-Line Altitude (ELA), Figure 2 The effect of windblown snow can on some glaciers contribute with a large amount of snow. Therefore, the term temperature-precipitation-wind (TPW) ELA can be useful when describing the altitudinal distribution of glaciers in an alpine terrain (Dahl and Nesje, 1997)

https://link.springer.com/rwe/10.1007/978-90-481-2642-2_140

Glacial Ice



Glacial Ice



Glacial Ice

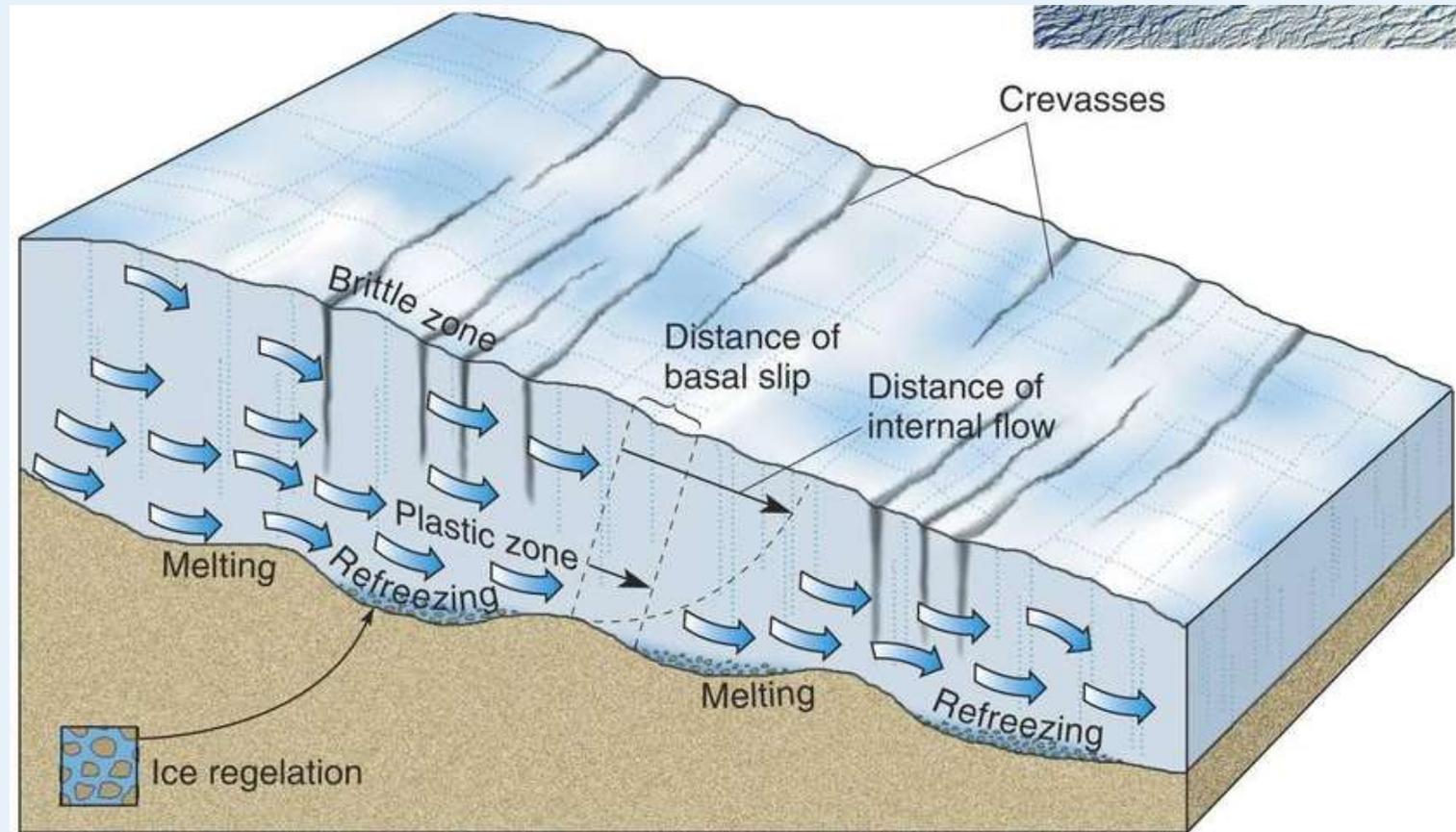


Glacial Ice



Glacier Movement

- Glaciers are dynamic and fragile ice masses in continuous motion due to the stress from gravity and their own weight.
- Once a glacier's ice reaches a thickness of approximately 20 meters, it begins to move under its own weight.
- This movement transfers snow and ice from the accumulation zone to the ablation zone through glacial flow.
- Glacial flow occurs through various processes, including **internal deformation** (viscous flow / the deformation of ice crystals), **basal sliding**, and **subglacial bed deformation**. Additionally, **meltwater** at the glacier's base acts as a lubricant, allowing the ice to slip over the ground below.
- In mountain and valley glaciers, this movement typically occurs from higher to lower altitudes, while in ice sheet glaciers, it flows from central ice domes outward toward the edges.



Glacier Movement

1. Internal deformation

Internal deformation occurs through processes such as ice creep, large-scale folding, and faulting. Ice creep involves the gradual displacement of ice crystals relative to each other in response to applied shear stress, resulting in slow forward movement along the ice-surface slope. Folding and faulting occur when ice creep alone cannot accommodate the stresses within the ice quickly enough, helping the glacier adjust to these internal forces.

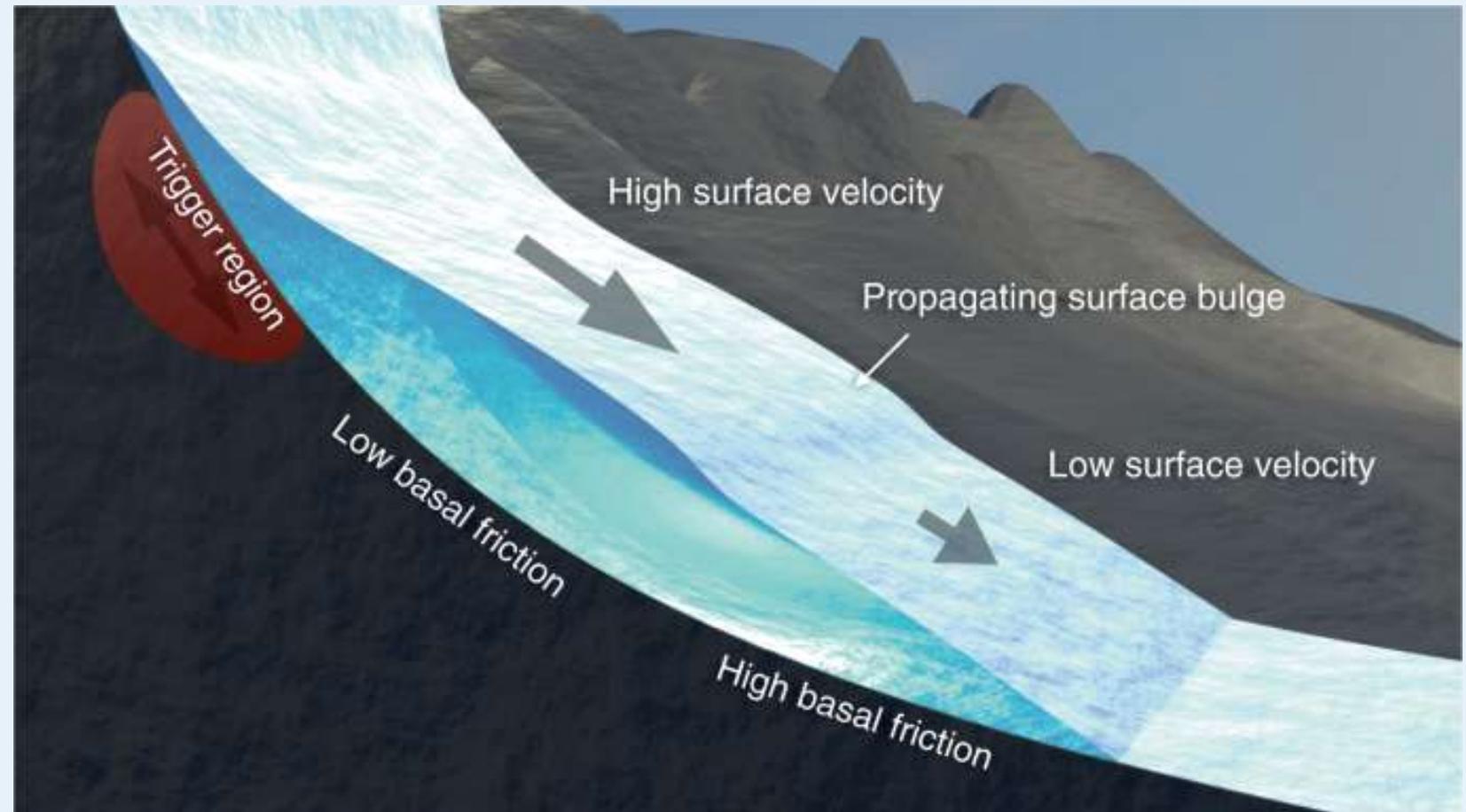


Glacier Movement

2. Basal sliding

Glacier moves over its bed, often aided by a thin layer of lubricating meltwater. This sliding occurs through a combination of enhanced basal creep and regelation (refreezing)

Increased pressure causes the melting temperature to decrease. Melting waters have a sliding effect. Geothermal heat also helps melting.



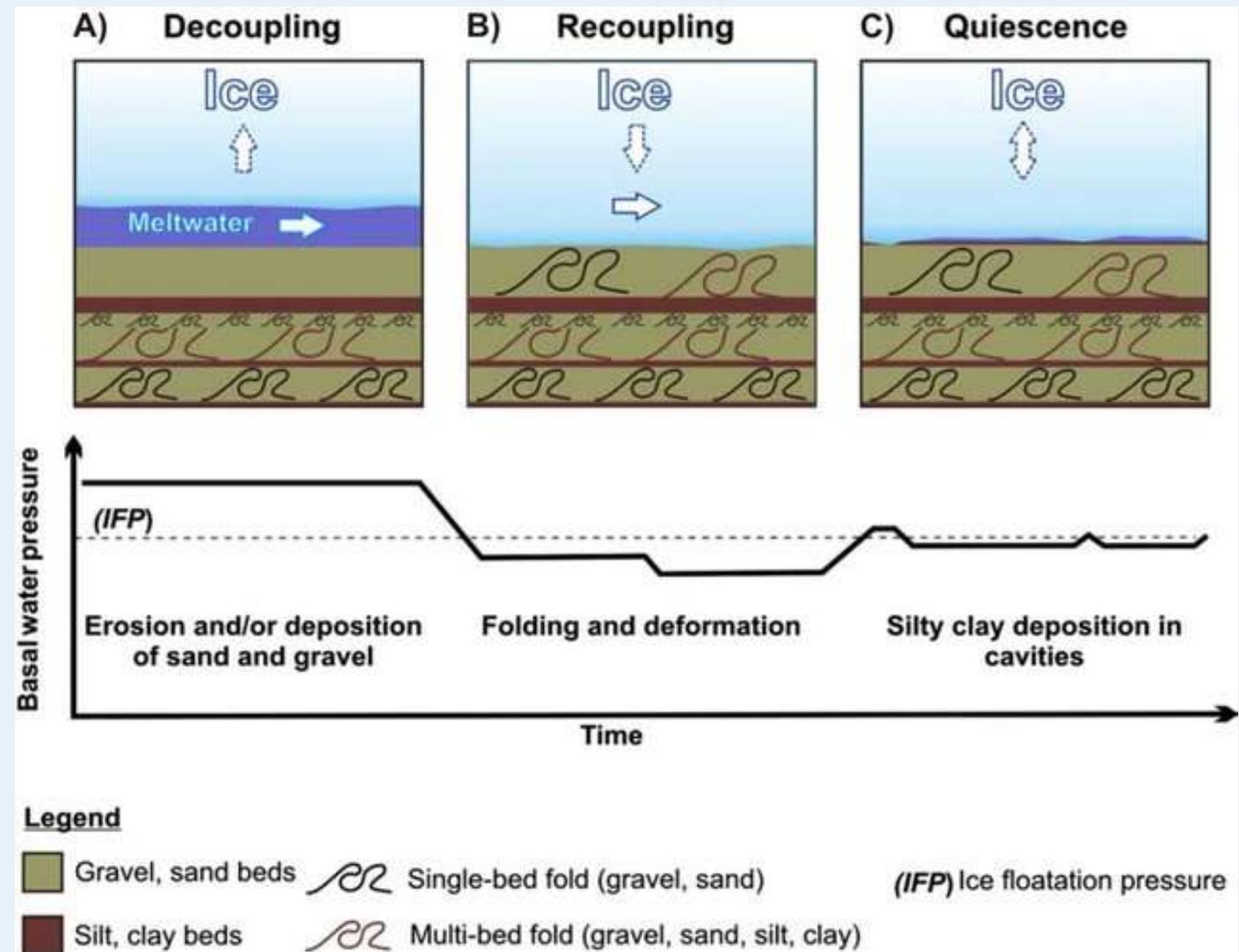
<https://youtu.be/ghC-Ut0fW4o?t=52>

https://youtu.be/he5QzhE7_g4?t=22

Glacier Movement

3. Subglacial bed deformation

Unfrozen sediment beneath the glacier deforms under the weight of the overlying ice. This deformation happens when water pressure in the pore spaces between sediment grains increases enough to overcome the friction between them, allowing movement between grains. This process is especially significant beneath temperate glaciers resting on loosely consolidated sediments.



https://www.researchgate.net/publication/262934436_Subglacial_deposition_and_deformation_of_glaciofluvial_sediments_during_episodic_glacier-bed_decoupling_events/figures?lo=1

<https://youtu.be/ghC-Ut0fW4o?t=52>

https://youtu.be/he5QzhE7_g4?t=22

Glacier Movement

https://www.youtube.com/watch?v=njTjfJcAsBg&ab_channel=Peace



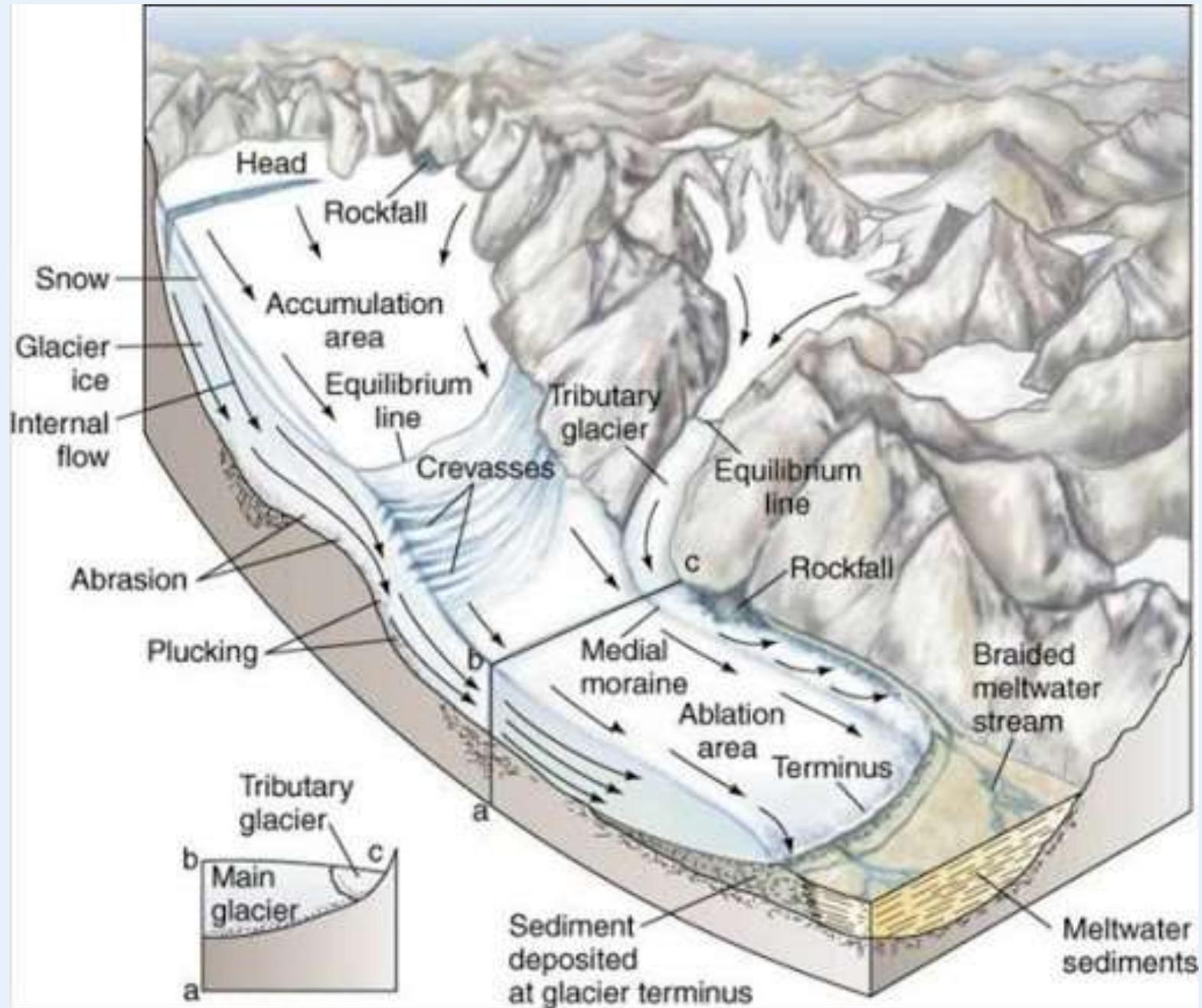
Glacier Movement

Hareket hızı düzenli olmayıp bazı buzullarda buzul dalgası (ice surge) olarak adlandırılan dönemlik ve ani hareketler görülebilir.

https://youtu.be/he5QzhE7_g4?t=117



Glacier Movement



Crevasse (yarık, krevas)

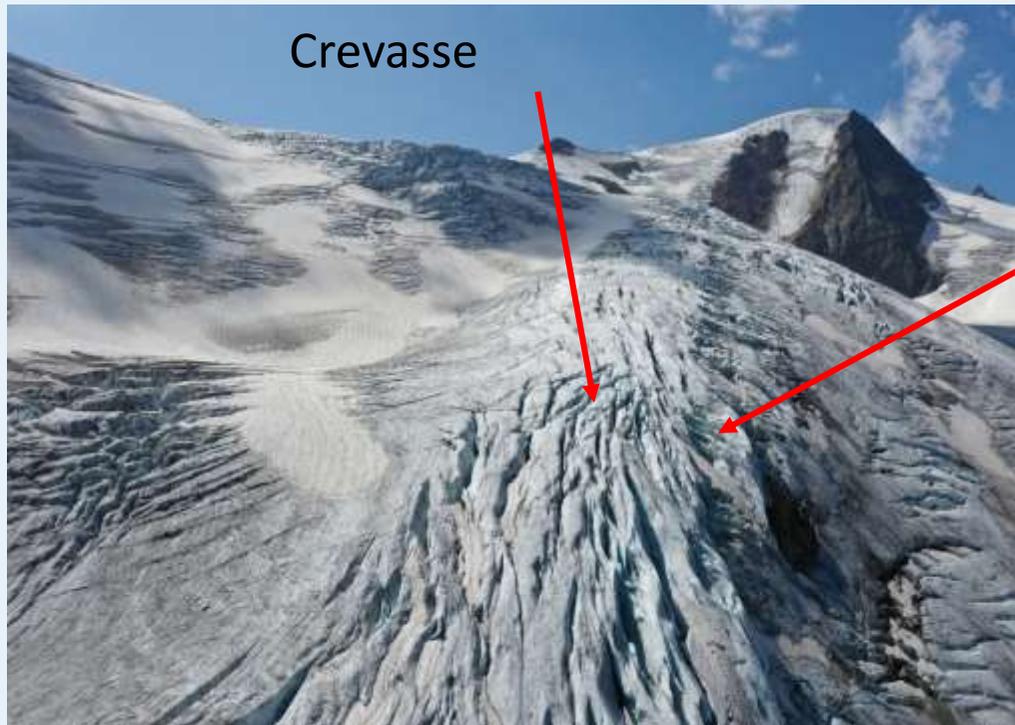
Crevasses are striking fractures or cracks in glacier ice, ranging from a few tens to thousands of meters in length, up to several meters wide, and extending tens of meters deep. These crevasses cut through the surfaces of most glaciers, and some may be concealed or bridged by snow, making them difficult to detect.

Crevasses form as a result of tensional stresses. Crevasses form when the maximum tension is greater than the cohesive strength of the ice.

In an air-filled crevasse at the glacier surface, the net longitudinal stress results from a combination of tensile stretching stress, which works to open the crevasse, and weight-induced lithostatic stress, which tends to close it. The depth of a crevasse can be estimated by finding the point at which lithostatic stress balances the tensile stress, resulting in a net longitudinal stress of zero. For a tensile stress of 150 kPa, this balance occurs at approximately 30 meters deep.



Crevasse (yarık, krevas)



Crevasse

Topographic
bulges



Crevasse (yarık, krevas)



Crevasse (yarık, krevas)



Crevasse (yarık, krevas)



Crevasse (yarık, krevas)



Serac (Buzul Kuleleleri /Seraklar)



Serac (Buzul Kuleleri /Seraklar)



Serac (Buzul Kuleleri /Seraklar)



Moulin (Buzul Yüzeyindeki Dikey Mağaralar)



<https://eos.org/research-spotlights/tremors-reveal-the-structure-of-deep-glacial-shafts>