# Changing Landscapes:

## Glaciated Landscapes

How do glaciers move?

# What you need to know

Differences between cold- and warm-based glaciers, their locations and rates of movement

Glacier ice movement including internal deformation, basal sliding, sub-glacial bed deformation, surge conditions, compressional/ extensional flow

# Why is ice temperature important?

It affects the impact of pressure on basal ice and therefore whether or not meltwater is present

It determines how easily the ice deforms internally: ice at 0°C deforms 100x more easily than ice at -20°C

Both of the above affect how, and how fast, the ice moves…and this affects the amount of erosion and transport done

# Glacier ice temperatures

Is usually close to the area's mean annual air temperature

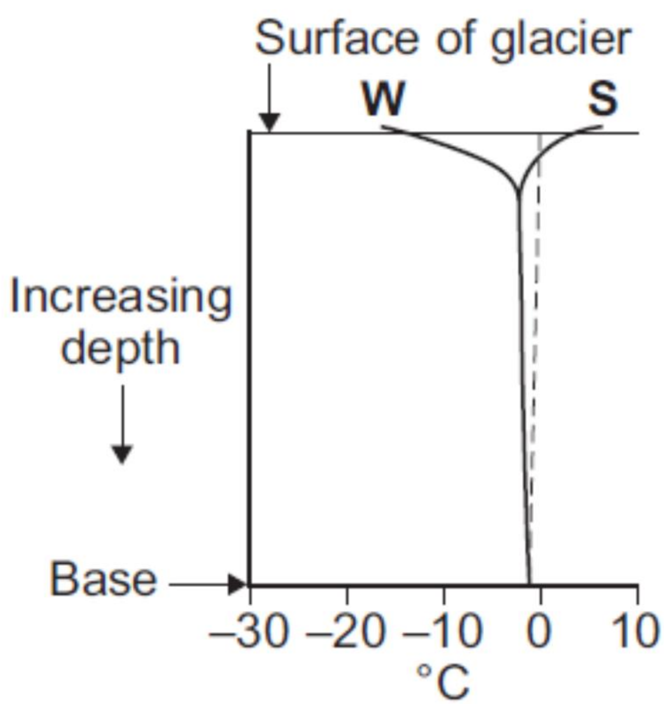
Polar ice is much colder than ice at lower latitudes – in Antarctica it can be -40°C

Reasons why ice temperatures vary within the glacier:

- Geothermal heat can warm basal ice
- Moving ice warms basal ice through friction
- As meltwater refreezes it releases latent heat
- Pressure melting, e.g. at 2000m the melting point is -1.6°C…

# Warm- and cold-based glaciers

**Warm based (temperate) glacier**




1. Describe how the temperature varies over the year and with depth through the ice
2. What is meant by the pressure melting point of the ice? How does this change with depth?
3. What do you notice about the ice temperature and the pressure melting point at the base of the glacier?
4. Why is this significant?

**Key**

—— Temperature

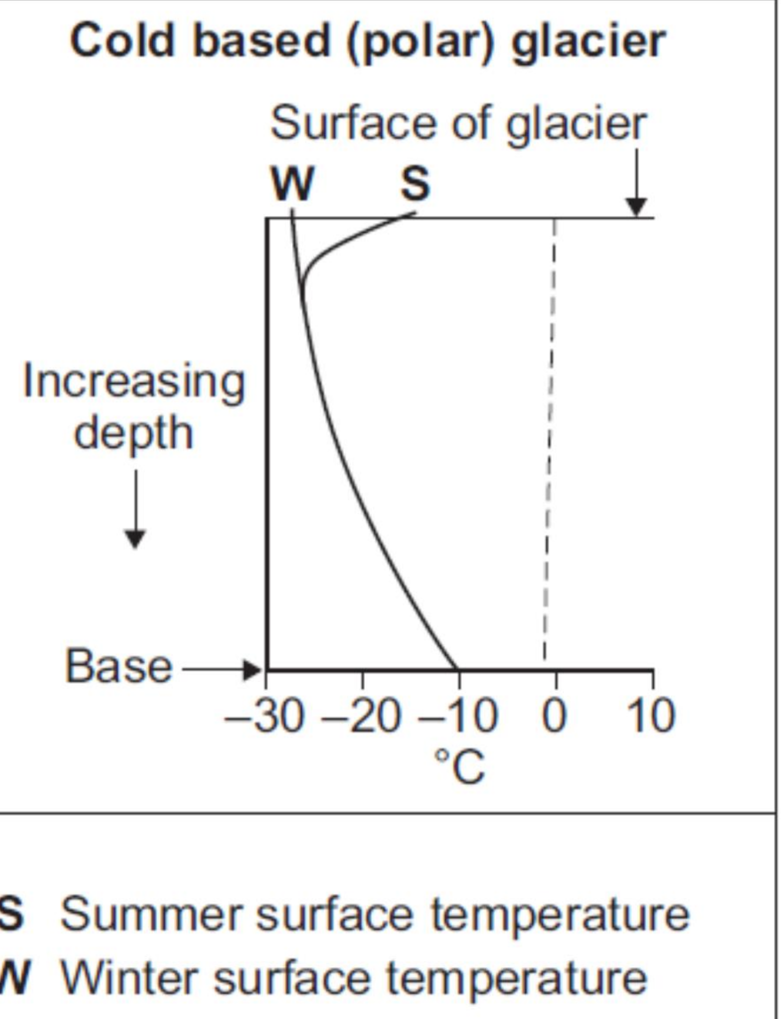
- - - - - Pressure melting point

**S** Summer surface temperature

**W** Winter surface temperature

# Warm- and cold-based glaciers

1. Describe how the temperature varies over the year and with depth through the ice
2. How are these different from a warm-based glacier?
3. What do you notice about the ice temperature and the pressure melting point at the base of the glacier?
4. Why is this significant?



# Glacial flow

Large glaciers and ice sheets can be cold-based in their upper regions and warm-based near their margins – *how*?

Ice thickness also affects the temperature at the base – *how*?

Normal flow rate for glaciers varies between 3-300m/yr

The world's fastest moving ice masses = outlet glaciers of W Greenland ice sheet: velocities > 12 km/yr.  Pressure of ice sheet pushes glaciers through mountain valleys.

Build-up of meltwater at glacier's base can cause <u>surges</u>: speeds 10-100x normal rates.  Surging glaciers tend to be found in Svalbard, Iceland, the Canadian Arctic and Alaska

# Glacier movement

In a typical glacier, two zones of movement may be seen:

- an upper zone of fracturing (up to 60m deep) where the ice is very cold and brittle – it shears under sudden changes of tension to form crevasses:
- a lower zone of flow, where more steady pressure and lubricating meltwater allow it to deforms plastically and move as a viscous body

Chikamin Glacier, Washington state

# Glacier movement

Glaciers flow in a number of ways:

- internal deformation
- basal sliding
- sub-glacial bed deformation
- compressional and extensional flow
- rotational flow (not named in the specification – but very important!)

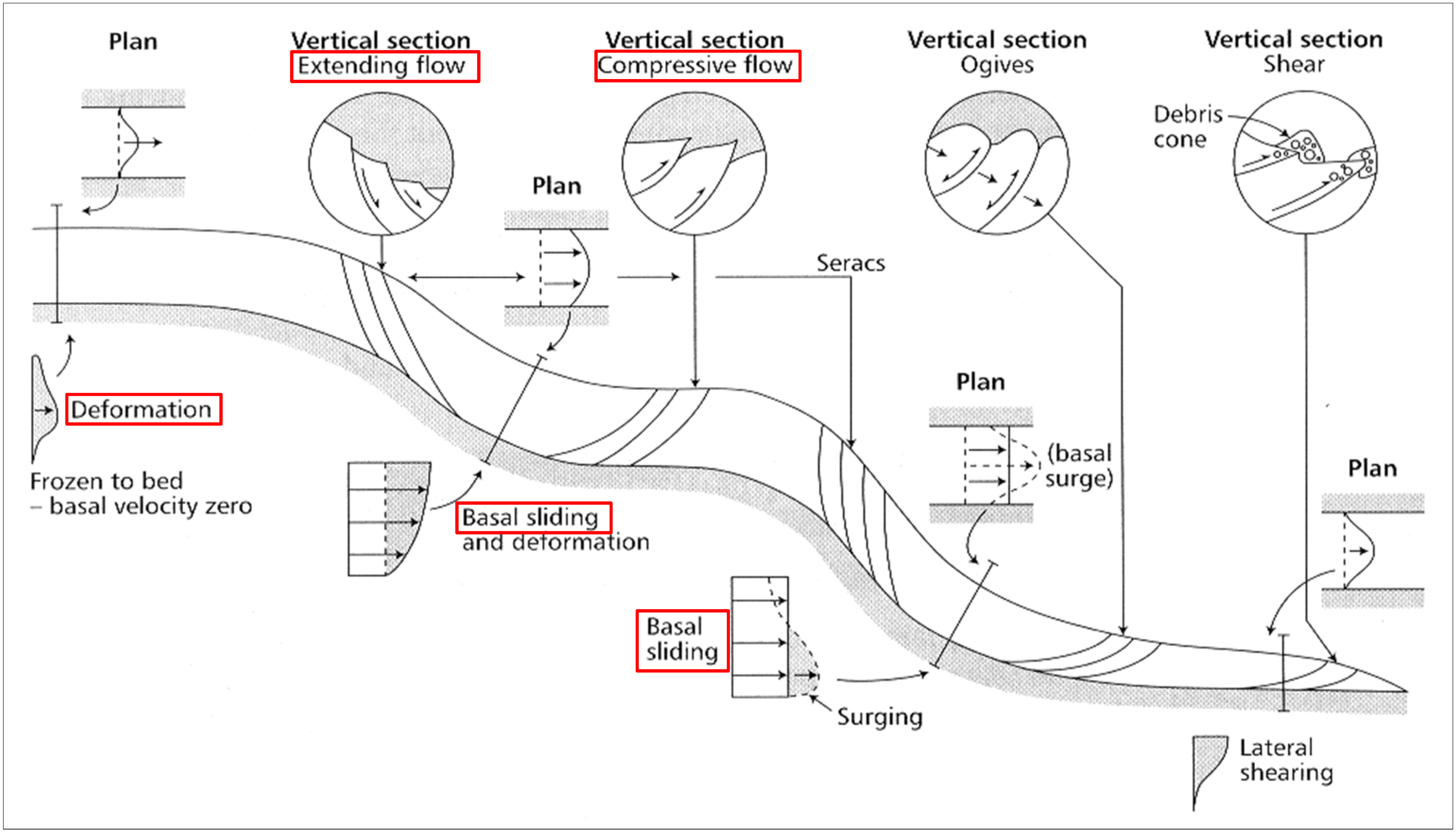
Time-lapse video of Franz Josef Glacier, NZ:
https://www.franzjosefglacier.com/about-us/blog/watch-2-years-of-glacier-retreat-in-15-seconds/

Time-lapse videos of Fox glacier, NZ:
https://vimeo.com/133626869 and https://vimeo.com/119312940

Time lapse movie of ice flow from underneath:
https://www.youtube.com/watch?v=njTjfJcAsBg

BSG pdf resource on glacial flows and rates:
http://geomorphology.org.uk/sites/default/files/ice_movement.pdf

# Glacier movement



# Glacier movement

Internal deformation:

- The crystal structure of individual grains of ice deforms as pressure squashes and elongates them
- Also grains may slide past each other, lubricated by intergranular film
- Can account for up to 2-3cm/day
- Cold-based + warm-based
- Higher ice temperatures aids greater deformation

# Glacier movement

Basal sliding:

- Meltwater acts as a lubricant at the ice/rock interface…so this doesn’t happen in cold-based glaciers
- A few mm of meltwater can significantly reduce friction
- Flow rates can be 1-2 m/day
- Contribution to total movement of ice can vary from 20-80%
- Most effective on steep slopes in summer
- Two components:
  - *Enhanced basal creep* – where basal ice deforms around irregularities on the bedrock surface
  - *Regelation slip* – localised increase in pressure in front of an irregularity causes pressure melting – the ice refreezes after the irregularity has been passed and pressure drops again

# Glacier movement

Extending and compressional flow:

- Former occurs where bed gradient increases – causing the ice to accelerate, making it thinner and forming crevasses at the surface through shearing
- Latter happens where bed gradient decreases – causing the ice to slow, thicken and shear upwards.  Can also happen at glacier’s snout as moving ice rides up over stagnant ice

# Glacier movement

Subglacial bed deformation:

- The weight of the ice deforms unconsolidated or weaker rock at the bed
- Needs high pore water pressure: from weight of ice + meltwater
- Presence of water reduces friction between individual grains
- Can account for up to 90% ice movement (in Icelandic glaciers)

# Glacier flow

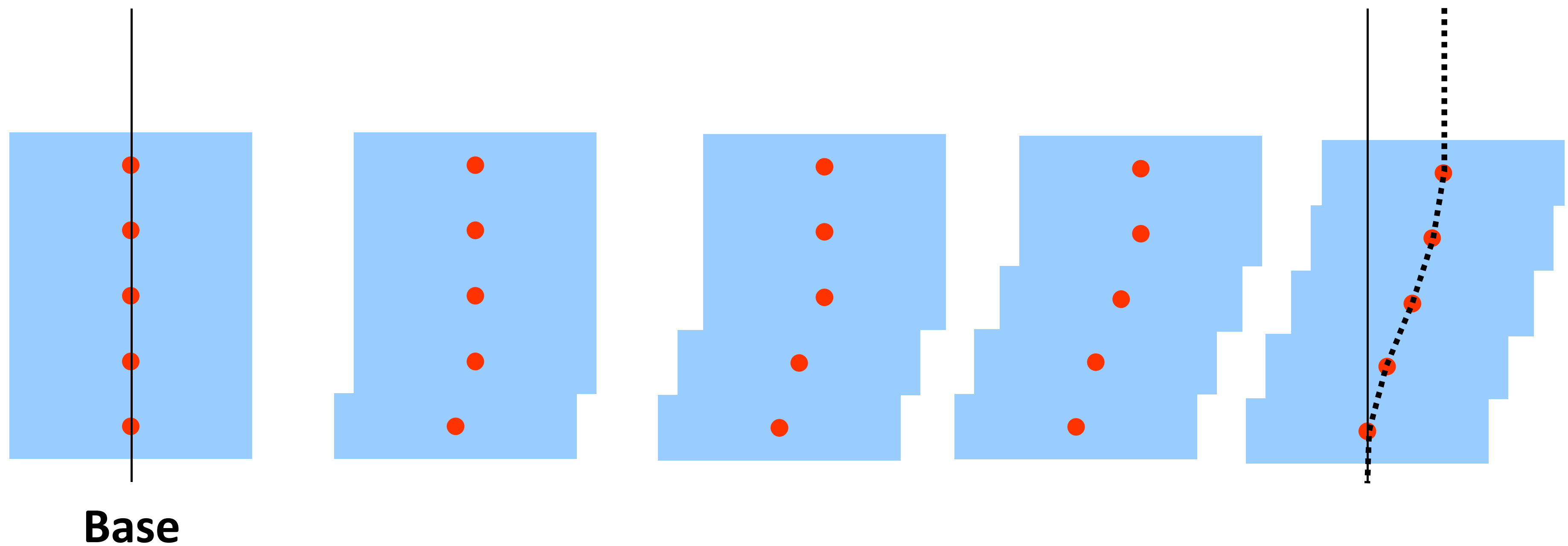
- is mostly slow and regular (average is < 1m/day, but can be 50m/day)
- Is usually fastest around the equilibrium line as ice is usually thickest here
- decreases from the surface to the base
- is fastest in the middle
- varies with the weather and seasons

The speed of a glacier's flow is controlled by:

- the gradient of the rock floor
- ice thickness and its impact on the temperature of the ice
- the internal temperatures of the ice

# Glacier flow

**Why ice displacement is fastest at the surface of the glacier:**



# Glacier flow