

Glacier Movement: Glaciers flow downhill in response to the gravitational forces generated by their own weight. Movement occurs by one, or a combination of three processes

Boyabreen, western Norway, with rapid ice flow velocities on the icefall with descends 1000 metres from the plateau Jostedalbreen ice cap



1. Internal deformation:

this is the slow creep of ice due to slippage within and between the ice crystals. The rate of internal deformation is greatest at the base of the glacier where pressures are at a maximum. This type of flow can occur in both polar and temperate glaciers

2. Basal sliding: this involves the sliding of a glacier over its rocky base. The sliding is accomplished in three ways.

basal slip: when a thin layer of water builds up at the ice-rock interface and the reduction in friction enables the ice to slide forward.

enhanced basal creep: ice squeezes up against a large (>1m wide) bedrock obstacle the increase in pressure causes the ice to plastically deform around the feature.

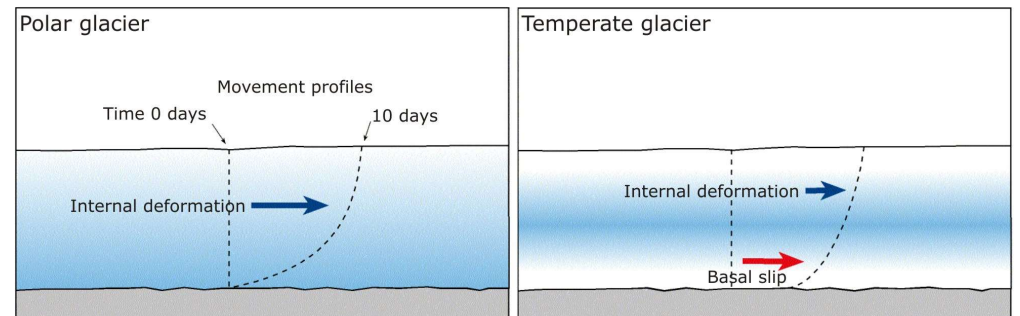
regelation flow: when ice presses up against a small (<1m wide) bedrock obstacle, and rather than deforming the ice melts and re-freezes on the lee side where pressure is lower. This process only occurs around obstacles that are small enough to enable the latent heat released by lee side re-freezing to be effectively conducted to stoss side and promote further melting.

3. Bed Deformation: this is movement accomplished by the deformation of soft sediment or weak rock beneath a glacier.

The type of movement exhibited by a glacier is closely related to the temperature of the ice. For instance, basal sliding is more efficient as a process if water is present at the base of a glacier and lubricates the ice/rock interface. Similarly, bed deformation is more effective beneath temperate glaciers, since the underlying sediment and rock will be saturated with water, which in turn reduces the strength of these materials. In contrast, the absence of water at the base of polar glaciers limits the effectiveness of basal sliding and bed deformation, and movement within these cold-based glaciers is mainly by internal deformation.



Base of a temperate glacier, the elongated grooves in the the ice were scoured out as the glacier flowed over a rocky protubance. This demonstrates that the glacier is moving by



Components of ice movement with a polar and temperate glaciers

Educational Resources—Glacial Environments

Causes and consequences of variations in the velocity of glacier flow:

Rates of ice movement vary enormously from one glacier to another, but generally lies in the range 3 to 300m a⁻¹. Glacial velocity depends on a number of factors;

thickness: a glacier moves because pressure generated by its own weight causes it to deform and/or slide, consequently, thick glaciers often flow faster than thinner glaciers. This also explains why high velocity glaciers tend to occur in areas of high snowfall.

temperature: in general, temperate and polythermal glaciers flow at greater velocities than polar glaciers. This is because temperate and polythermal glacial ice is warmer and is therefore able to deform more easily and, further, the presence of meltwater at their base promotes basal sliding.

bedrock: more rapid movement occurs over easily deformable rock, such as clay or shale, because bedrock deformation increases the rate of basal sliding. Greater velocities also occur over impermeable rock surfaces as compared to permeable since the percolation of meltwater into permeable rock masses will reduce lubrication at the ice/rock interface and retard flow.

gradient: glaciers with steep surface gradient flow faster than those with more gentle gradients, since the former are affected by greater gravitational forces.

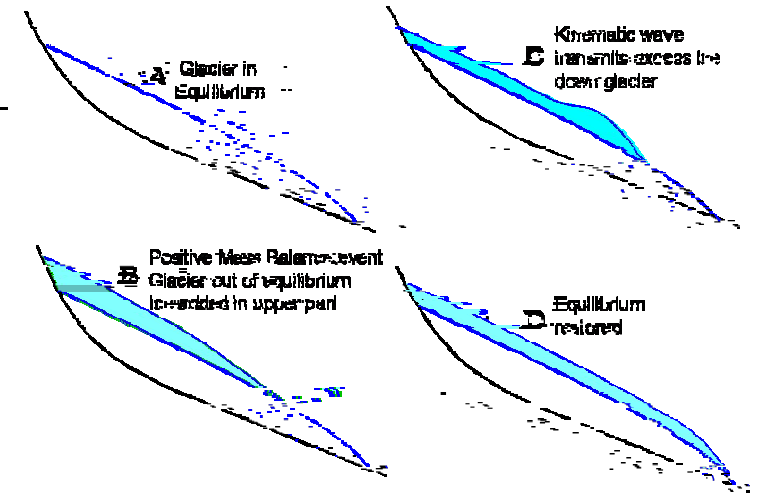
At present the world's fastest moving ice masses are the outlet glaciers of the West Greenland ice sheet. For example, velocities of over 12 km a⁻¹ have been recorded on Jakobshavn Isbrae; these exceptional rates are caused as the glaciers are pushed through mountain valleys by the pressure of the ice sheet behind. Most of the time glaciers flow at constant speeds, however, dramatic increases in velocity can occur in response to fluctuations in mass balance (kinematic waves) or increased basal meltwater (glacial surges)

Time lapse movies show the speeds of movement [Click here](#)

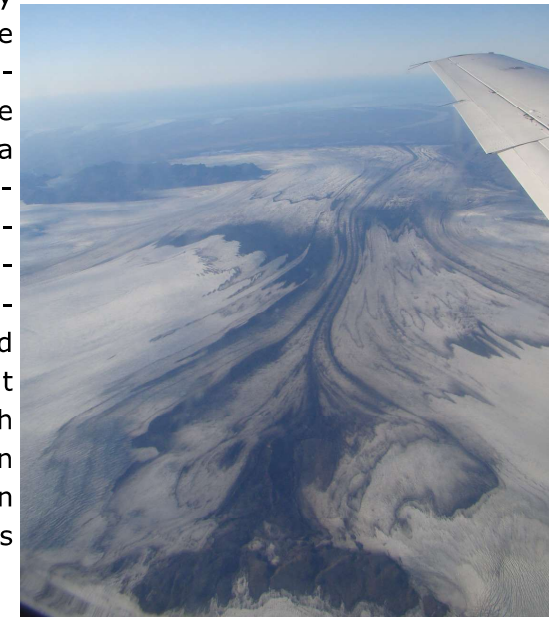
Kinematic

Waves are

bulges in the glacier surface, up to 10m high, caused by an increase in ice accumulation during a period of cool snowy weather. Over time the bulge moves from the accumulation zone towards the snout at a greater than average velocity, since the thicker ice under the bulge generates higher pressures.



Glacial surges are spectacular increases in velocity during which rates of flow may reach 10 to 100 times their normal value, whereas, glaciers usually flow at 3-300m a⁻¹, surging glaciers move at speeds of 4 to 12km a⁻¹. Some surges may trigger rapid advance of the snout. For instance, when Bruarjokull in Iceland, surged the snout moved forward 45km at a rate of 5m every hour. The precise cause of surging is unknown, but it is generally, considered to be caused by enhanced basal sliding triggered by the build-up of meltwater at the ice/rock interface. Black ash layers in Iceland volcanoes can reveal significant variations in ice velocity across the glaciers e.g. Skeidarajokull (photo)



Velocity also varies greatly in a single glacier.

Rates tend to be greatest at the equilibrium line since ice is usually thickest here. In contrast, glaciers move more slowly in the upper parts of the accumulation zone where ice is colder and more rigid, and along the highly crevassed and thin snout. Rates are also relatively slow along the lateral flanks and at the glacier base because flow is retarded by friction. Indeed, the velocity at the flanks and base of polar glaciers is zero since ice is frozen onto the bedrock. In most glaciers, variations in the rate of flow are caused by compressive and extensional flow. Light (winter) – dark (summer) banding, called ogives, formed at the base of ice falls show the velocity variation across a glacier e.g. Austerdalsbreen, western Norway.



Compressive and extensional flow: The gradient of bedrock surfaces beneath glaciers is often highly irregular owing to spatial variations in the resistance of rock to withstand glacial erosion. The resultant undulating subsurface exerts a strong control on the flow of the glacier above. For example, where the gradient of the underlying rock surface steepens, the glacier responds by accelerating and becoming thinner, this is known as extending flow. Areas of extending flow usually show large tensional cracks called crevasses (e.g. eastern Iceland). In contrast, where there is a reduction in the subsurface gradient the glacier slows down and thickens due to the build up of ice, this is



known as compressive flow. Once an extending / compressive flow regime becomes established it controls partially the nature of erosion at the base of the glacier. For example, maximum rates of erosion will occur at the transition zone from the extending to the compressive flow regime, since pressure at the base is increasing due to the thickening of the glacier, and velocity remains relatively high. (see below)

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