Chapter 7

1/ Glacial forms:

The majority of areas today characterized by this morphology were created by the movement of the great continental glaciers during the Quaternary glaciations. The Ice Age left a legacy of a series of forms that significantly connote many of the Park's environments (cirques, rock piles, moraine deposits), generally taking the form of large niches, crowned with steep slopes and whose vast bottom forms a plain or depression.

Glacier du Nadelhorn, au-dessus de Saas-Fee, Valais, Suisse

2/ Ice and Alpine glacier:

A glacier is a mass of ice of varying extent that is formed by the settlement of accumulated layers of snow. Crushed under its own weight, the snow gradually expels the air it contains, welds into a compact mass and turns into ice.

A glacier flows slowly down a slope or by creep due to gravity. Anthropogenic global warming has resulted in the melting of glaciers since the end of the twentieth century.

There are generally two zones in a glacier:

• The accumulation zone: this is the part of the glacier where snowfall turns into ice. It corresponds to the area of eternal snow and therefore the ice is rarely exposed. The accumulation zone is usually 60 to 70% of the surface area of an alpine glacier;

• The ablation zone: this is the part of the glacier where the significant melting causes the thickness of the glacier to decrease until it completely disappears at the level of the glacial front, which can take the form of a cliff, a hill, a disorganized mass of ice, etc.

The front of a glacier can be moved forward or backward in a valley. These movements are the result of an imbalance between snow supply and melting. During glacial retreat, the position of the glacial front gradually regresses upstream. Most of the world's alpine glaciers are now in a phase of rapid retreat:

• Swiss glaciers have lost 40% of their length, more than half of their mass and continue to lose fifty centimetres of thickness every year; about 100 disappeared between 1850 and 1999;

• The Gébroulaz glacier in Vanoise has retreated by 1.63 km since the mid-nineteenth century;

• The Furtwängler glacier (Kilimanjaro's local ice cap) lost 80% of its volume during the twentieth century and will disappear between 2040 and 2060.

Natural hazards associated with glaciers

Glaciers can cause disasters related to their nature (solid and liquid water), their characteristics (presence of seracs, crevasses, etc.) and their capacity (glacial surge, dam, etc.). Glaciers can cause:

• Avalanches caused by falling seracs or the glacial front;

• Flooding by excessive melting, jökulhlaup, the emptying of a subglacial, intraglacial, supraglacial or periglacial lake;

• Rockfalls from moraines;

• The destruction of forests, fields, villages, etc. by burial during a glacial advance or glacial surge;

• Land subsidence, landslides, etc. during a glacial retreat on the walls of valleys that are no longer maintained by the glacier (e.g. Ruins of Séchilienne) and on moraines, especially lateral moraines, which are no longer protected from erosion by the glacier.

3/ Alpine glaciers or confined glaciers

Alpine glaciers are an essential part of the mountain landscape throughout the world. Whether they are perched on the highest peaks or nestled at the bottom of deep valleys, these are glaciers whose morphology is dependent on the relief. They are usually found in the mountains and occupy the bottom of the talwegs.

Glaciers de type alpin, la Mer de Glace et le glacier du Géant (Massif du Mont-Blanc, France).

The transformation of snow into ice is a process that originates with the gradual accumulation of snow on high-altitude mountains from one year to the next. Over time, the fine, cold winter snow turns into coarse-grained spring snow. On the glaciers, the firn line, the mythical line of "eternal snow", is established around 3000 meters in the Alps, at the end of summer.

4/ An Ice Field:

Is an area of less than 50,000 km2 of ice that is often found in colder climates and at high elevations where there is sufficient precipitation. It is a vast area of interconnected valley glaciers whose highest peaks rise as nunataks. Ice fields are larger than alpine glaciers, smaller than ice sheets, and close to ice caps.

Large ice field : An ice field over 20 km across. *Medium ice field* : An ice field 15-20 km across. *Small ice field* : An ice field 10-15 km across.

Ice fields are formed by the accumulation of snow, which becomes ice by compression. Because of their mass, ice fields usually form over large areas that are above basins or shelves, allowing a continuum of ice on the landscape that is not interrupted by glacial channels. Glaciers usually form at the edges of fields and are used to remove excess ice by gravity.

image satellite du champ de glace Nord de Patagonie.

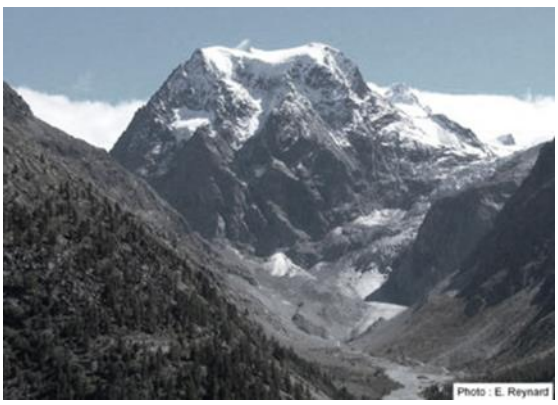
5/ The ice cap:

Is the thick mass of land ice cover. From a few hundred metres to 3 km thick, it is installed on a continental base. It was formed over several tens of thousands of years by snow consolidation and glaciation. This ice mass covers less than 50,000 km2 in area. It is also referred to as an ice sheet.

Le glacier Furtwängler au sommet de Kilimandjaro.

These are laciers that possess certain characteristics of ice sheets: a large surface area, a random shape, a great thickness, a relatively low slope of the bedrock, an evacuation of ice by large glacial fronts and/or by glacier emissions. Ice sheets (especially Antarctica) are not limited by topography But their dome is usually centered around the highest point of a mountain range.

The climate of an ice sheet is typical of the northern and southern polar ice caps. In winter, the ice remains permanently in shadow, while in summer, it is permanently illuminated by the sun. In the Antarctic climate, temperatures are the lowest in the world.



Le glacier de calotte du Mont Collon et le Bas Glacier d'Arolla qui est un glacier de type alpin (Val d'Arolla, VS).

6/ Piedmont Glacier :

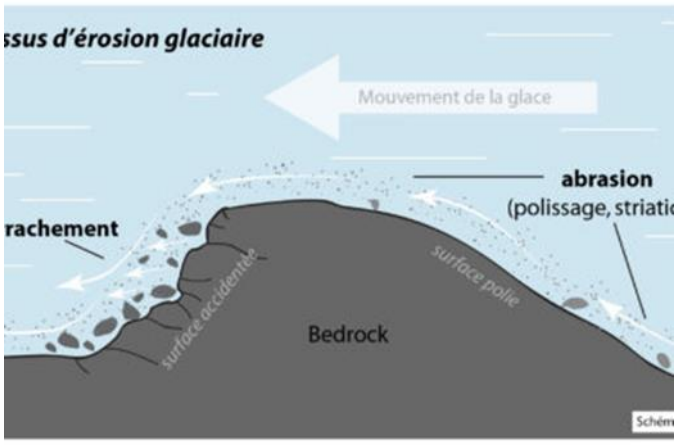

Le lobe glaciaire du glacier Malaspina en Alaska.

Piedmont glaciers emerge from a valley and spread out in the shape of a spatula over a plain. It is a valley glacier that reaches the plain at the foot of the mountain range. It has an accumulation zone and a classic transport zone, but its ablation zone spreads over the plain either in digitations or in a more or less extensive glacial lobe.

This lobe is 38 kilometres long, 32 kilometres wide and 3,900 km2 in the sandur. It is 600 metres thick in places and can be as low as 300 metres below sea level.

7/ Erosion processes and forms:

Glacial erosion acts at different scales. On rocks that have been in contact with ice, there are micro-shapes that testify to the direction and direction of movement of the glaciers. They are the result of abrasion and tearing processes. Moutonnée rocks are smooth and asymmetrical in shape: they are polished upstream, where the glacier is compressed on top of the rock, and angular downstream of the obstacles, where the glacier is detached from the rock and where by refreezing the subglacial waters, pieces of rock are torn off. The surface of a rock abraded by the glacier has various types of micro-shapes, such as streaks, resulting from the movement of the glacier over the bedrock.



Processus d'érosion glaciaire.

Abrasion

Wear produced by the friction of particles against each other or between two surfaces, at least one of which is abrasive. Mechanical abrasion is the result of the friction of material-laden ice on the bedrock; It takes place in two modes, striation, which is the digging of small furrows (in the order of a millimetre) – called glacial striations – parallel to the direction of ice flow, and polishing, which is a relatively uniform abrasion of the rock by the friction of the glacier.


Abrasion sur les flancs du glacier Perito Moreno en Argentine.

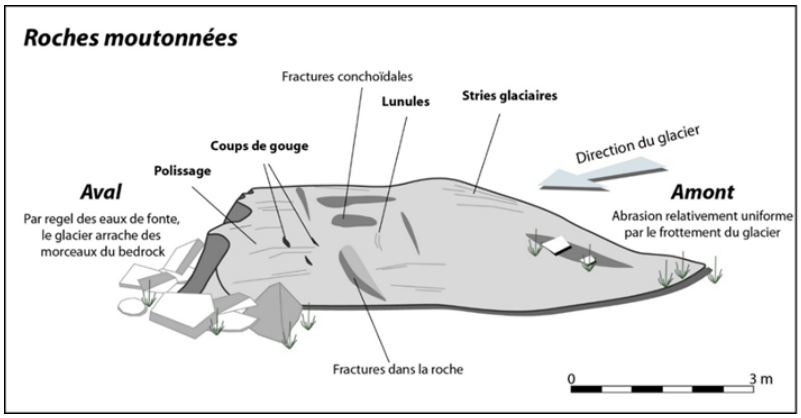
Extraction:

A steep drip is a protruding part of the bedrock whose downstream face has a break almost perpendicular to the passage of the glacier, Steep slopes can reach large dimensions and form cliffs. The glacier tears off pieces of the bedrock that will be incorporated into the bottom moraine. The tearing gives the moutonné rocks an asymmetrical morphology:

They are polished upstream, where the glacier is compressed on the rock, and angular downstream of the obstacles, where the glacier is detached from the rock and where by refreezing of the subglacial waters, pieces of rock are torn off.

Sheepish rocks

Are a widespread form of glacial erosion resulting from the combination of these two processes. Moutonnée rocks are a bedrock that has acquired a bumpy surface that looks like a wool fleece. Moutonné rocks can stretch for miles.



Dissymétrie des roches moutonnées liées à l'arrachement à l'aval de l'obstacle (adapté de Maisch et al., 1993)

Fluvio-glacial erosion :

Subglacial waters, in temperate glaciers, sometimes under pressure, constitute a third factor of erosion.

Glacio-karst erosion:

A special case is constituted on calcareous bedrock, the ablation is partly due to typical are of the order of 0.01 mm/a for polar glaciers; of 1 mm/year for temperate glaciers from chemical dissolution processes.

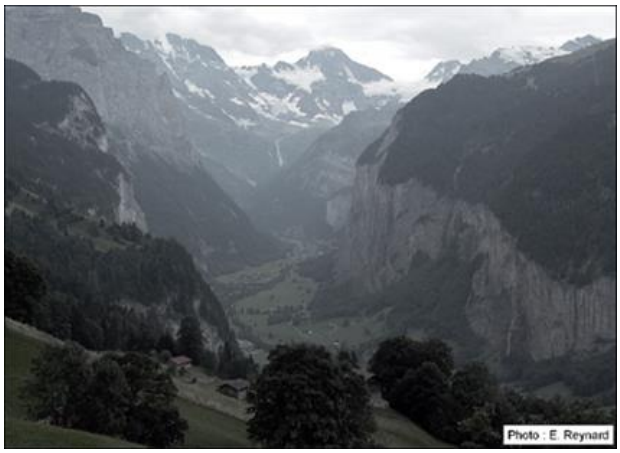
Valley Glacier:

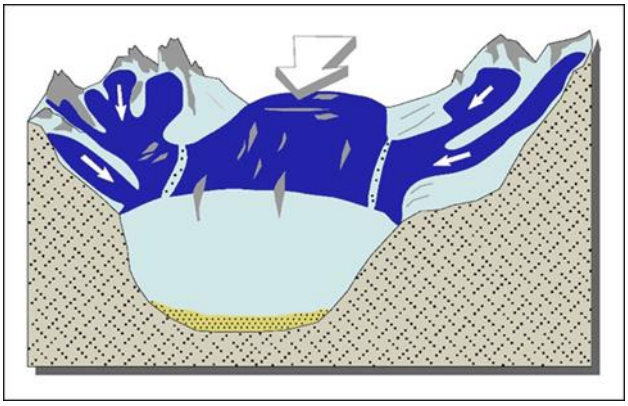
Le glacier d'Aletsch en Suisse.

Valley glaciers are the classic image of a glacier: a cirque-like catchment basin at the base of peaks protruding from the snow, an elongated mass of ice occupying the entire width of a valley, and a glacial front giving rise to a torrent.

A glacial valley is a valley that was once occupied by a glacier (in this case, a valley) and whose latitudinal section reveals a "U" shaped profile known as a "trough". Alpine valleys are another example of glacial macroforms. But there are also V-shaped glacial valleys (e.g. the Mer de Glace), not least due to subglacial torrential over-deepening.

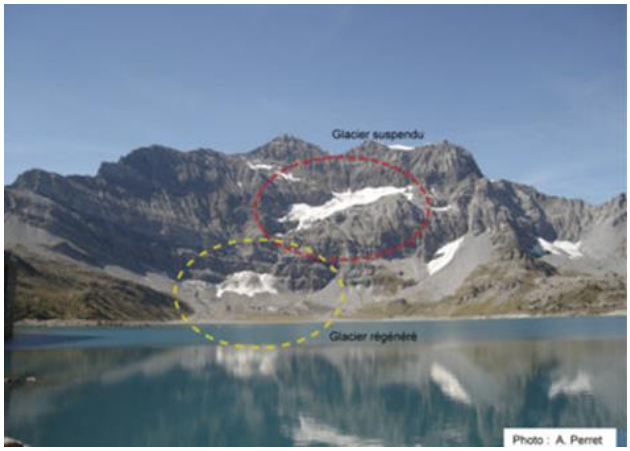
The U-shape is sometimes due to post-retreat glaciofluvial filling, which can completely cover a profile of the bedrock approaching a V-shape. By regressive erosion of the side streams, they will first be connected to the main valley by a waterfall





Vallée glaciaire en auge : la vallée de Lauterbrunnen Profil transversal d'une vallée alpine

Hanging Glacier :



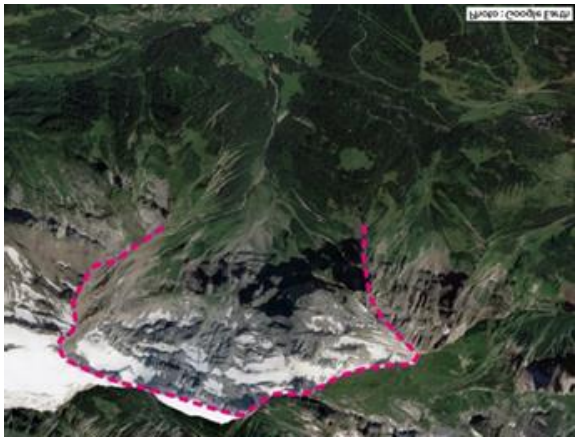
Le glacier de la Verte sur la face ord de l'aiguille Verte en France. Le Glacier Noir, un glacier suspendu dans sa partie haute et un glacier régénéré dans sa partie basse (Salanfe, VS, 2011). A hanging glacier is usually small in size and is perched on the sides of a mountain. It is composed of only an accumulation zone, sometimes a short transport zone but very rarely an ablation zone. The ice is evacuated by sublimation or by falling seracs, which can give rise to a regenerated glacier below.

Regenerated Glacier:

It is a glacier whose snow supply is provided by serac falls from a hanging glacier. Since a hanging glacier is usually small, snow supplies are limited and regenerated glaciers are often small and fail to form valley glaciers. Their ice is evacuated by sublimation or melting. The regenerated glacier is a kind of ablation zone of a hanging glacier.

Circus Glacier:

The glacial cirque is the simplest form of glacial over-deepening It is a "wide depression, with a flat bottom and a slight slope, with steep sides, which cuts into the side of a mountain generally a little below the ridges" When a summit is bordered at its base by a series of cirques of different orientations, a horn is formed, a pyramidal summit sculpted by glaciers flowing in several directions.



Cirque glaciaire de Creux de Champs (VD). Le glacier Stubaier sur le Jochdohle en Autriche

This is actually the part corresponding to the accumulation zone of a valley glacier. It has an accumulation zone, a reduced transport zone and an ablation zone. Glacier ablation areas can create cirques if erosion is sufficient to accentuate the mountain slopes.

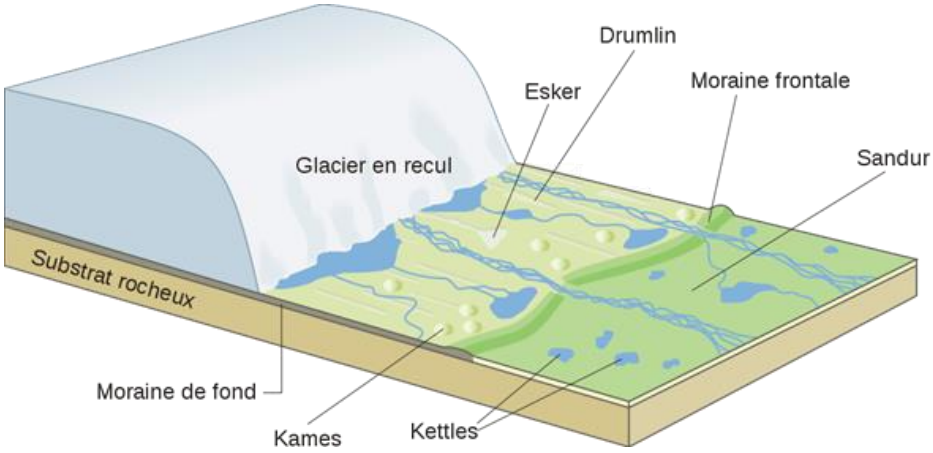
Coastal Glacier:

L'Engabreen en Norvège.

A glacier with one tongue joining the sea or ocean is generally referred to as coastal. These situations occur only in high latitudes

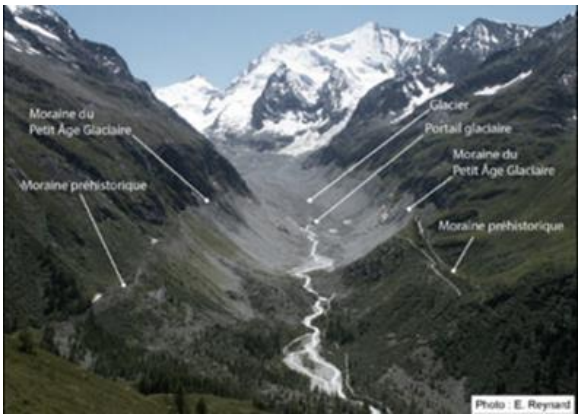
8/ Forms of accumulation:

Glacial deposits are loose materials accumulated by a glacier or directly influenced by the presence of a glacier. They are observed either in shapeless accumulations, up to several hundred metres thick, or in the form of the relief generally delimiting a glacier's parking position.



Lateral moraines:

develop on the sides of the glacier and form when ice transports and accumulates sediment as it slides along the walls of the glacial valley. They can take the form of long ridges parallel to the flow of the glacier. It is a mass of mineral debris carried by a glacier or ice sheet. A moraine also refers to a mountain range or till mantle



Marge proglaciaire du glacier de Zinal, délimitée par le complexe des moraines préhistoriques

The drumlins is an elongated hill formed by the remains of the bottom moraine of an ancient glacier. This whale-back relief is usually found on the bottom of glacial valleys.

The drumlins are thought to be either small median moraines deposited during a short stagnation of the glacier as it retreats from the valley or advances, or a moraine deposit found in a large notch in the length of the glacier formed by a river on the surface of the glacier

Erratic

Is a piece of rock that differs in several ways from the rocks of the surrounding landscape. Such rocks are transported by glaciers over long distances and are deposited in land where such rocks are not present. The size of the erratics varies from pebbles to massive boulders.

• Glacial polish: A glacial polish is a rocky surface, sometimes of large surface area, that has been completely flattened and worn to the point of becoming practically smooth.

• Glacial striations: Glacial striations are notches and grooves in the rock formed either by the passage of a rock embedded in the ice and acting like a chisel, or by the passage of a subglacial stream that has worn away the rock.

Polis, stries glaciaires et blocs erratiques à Central Park, New York

9/ Fluvio-glacial deposits :

Glaciofluvial processes occur when glacial deposits are reshaped by meltwater.

Sandur (Icelandic meaning "sand").

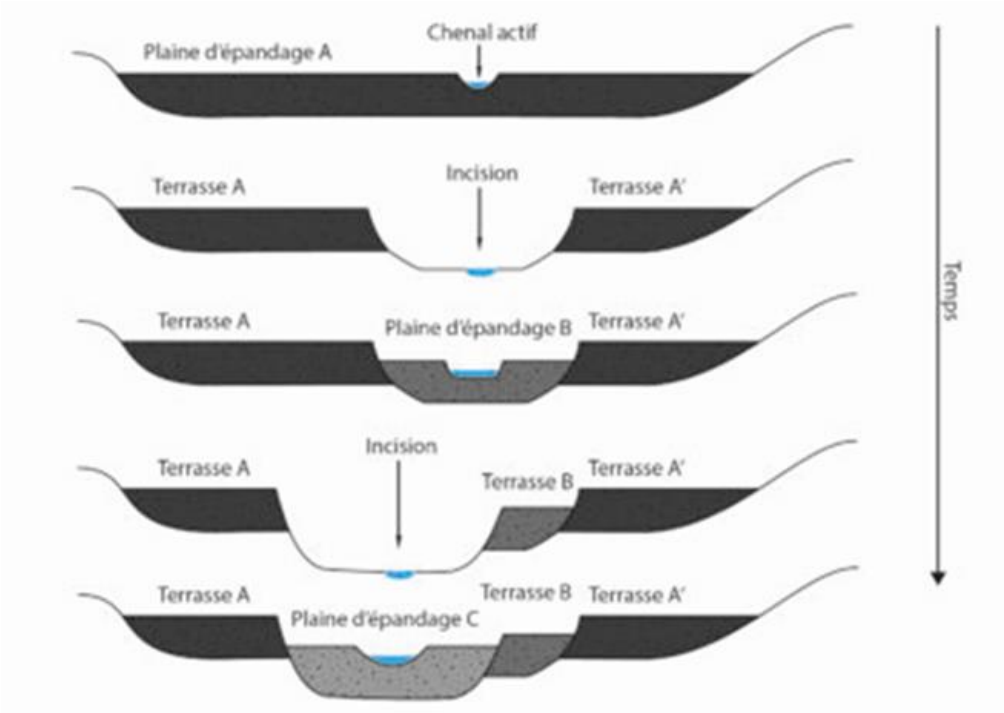
It is a glaciofluvio-land outwash plain located downstream of a glacier and may occupy all or part of the proglacial margin. In the polar regions, the sandur is often very extensive, while at the front of the Alpine glaciers, It can be reduced to a few hundred square meters. Due to variations in the flow of the proglacial stream and the large volumes of sediment that can be mobilized, the course of the sandur streams is usually braided

Un sandur au Vatnajökull (Islande) Cours d'eau tressé dans le sandur du glacier de Tourtemagne

With the retreat of the glacier and/or variations in flows and sediment load, the sandur can be incised, which leads to the formation of terraces.

Terraces

The initial postglacial filling is generally subsequently eroded, giving rise to a so-called fluvio-glacial terrace, which is markedly unevenly in relation to the altitude of the current riverbed and in relation to the so-called alluvial terraces nested in the fluvio-glacial terrace (e.g. in the Saane valley, VD/FR). Among the forms that characterize a proglacial margin, we can also distinguish



Formation de terrasses fluvio-glaciaires (modifié d'après Lowe et Walker, 1984).

The Kames

Which are steep-sided sandy-gravelly accumulations formed by supra- or paraglacial deposits. Kames are often associated with kettles, small depressions in glacial sediments that are sometimes filled with water, resulting from the melting of dead ice. The formations known as kame terraces are accumulations of sediment that have been deposited between the side of a valley and the edge of a glacier, Another characteristic form of proglacial margins are the eskers, are sedimentary ridges resulting from the filling of intra- or subglacial tunnels.

10/ Glacio-lacustrine deposits:

Glacio-lacustrine sedimentation concerns lakes influenced by glacial dynamics. This influence can be direct, as in the case of lakes in contact with the glacier, or indirect, as in the case of lakes fed by glacier water.

In the first case, the sedimentation corresponds to that of any lake (e.g. with the formation of deltas). However, these deposits will often be deformed by glacial dynamics. The second group concerns all lakes that originate in depressions over-dug by the glacier (umbilicus lakes) or behind frontal moraine arcs.

The granulometry of sediment inputs depends on variations in fluvio-glacial dynamics. These alternations give rise to laminins, which result either from daily variations or from seasonal variations in inputs. In the latter case, these levels, called varves, alternate between fine deposits (in winter, when flows are very low) and coarser deposits (deposited in summer when flows are greater).

Marge proglaciaire fortement aménagée du glacier de Moiry - Sédimentation glacio-lacustre avec formation d'un delta dans la marge proglaciaire du glacier du Mont Miné