UiT The Arctic University of Norway

Steindalen: Exploring a Glacier Valley

An idea book for teachers, guides, and other nature enthusiasts

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Table of Contents

Most valleys in the Nordic countries, including Steindalen ("The rock valley"), were shaped during and after the ice ages. I believe that natural phenomena are most effectively taught outdoors, where students can use all their senses and do not need to sit still. Most importantly, students experience real nature, not a digital high-gloss version from exotic places around the world, as so often used in textbooks and films. Therefore, this text is specifically aimed at teachers planning a trip to a glacier valley. It is focused on student-centered activities with thought-provoking questions that address several school science standards and might be used to connect impressive phenomena to geology, physics, ecology and climate-change.

Since Steindalen and its glacier, Steindalsbreen, are relatively easily accessible, they have long been a popular destination in the Lyngen Alps. In the valley, there are information boards explaining the physical geography, which are equally informative as: *The Trip to Steindalen*, by Geoffrey D. Corner, which this booklet builds further upon: http://geologiskolen.uit.no/lokalGeologiskolen/Nord-Norge/troms/storfjord/turen_gar_til_steindalen.pdf

Consider embarking on a virtual journey to Steindalsbreen at: https://glaciereducation.com/

The starting point for the trip is just an hour's drive from Tromsø Airport, or 30 minutes from Lyngseidet, see figure 1.

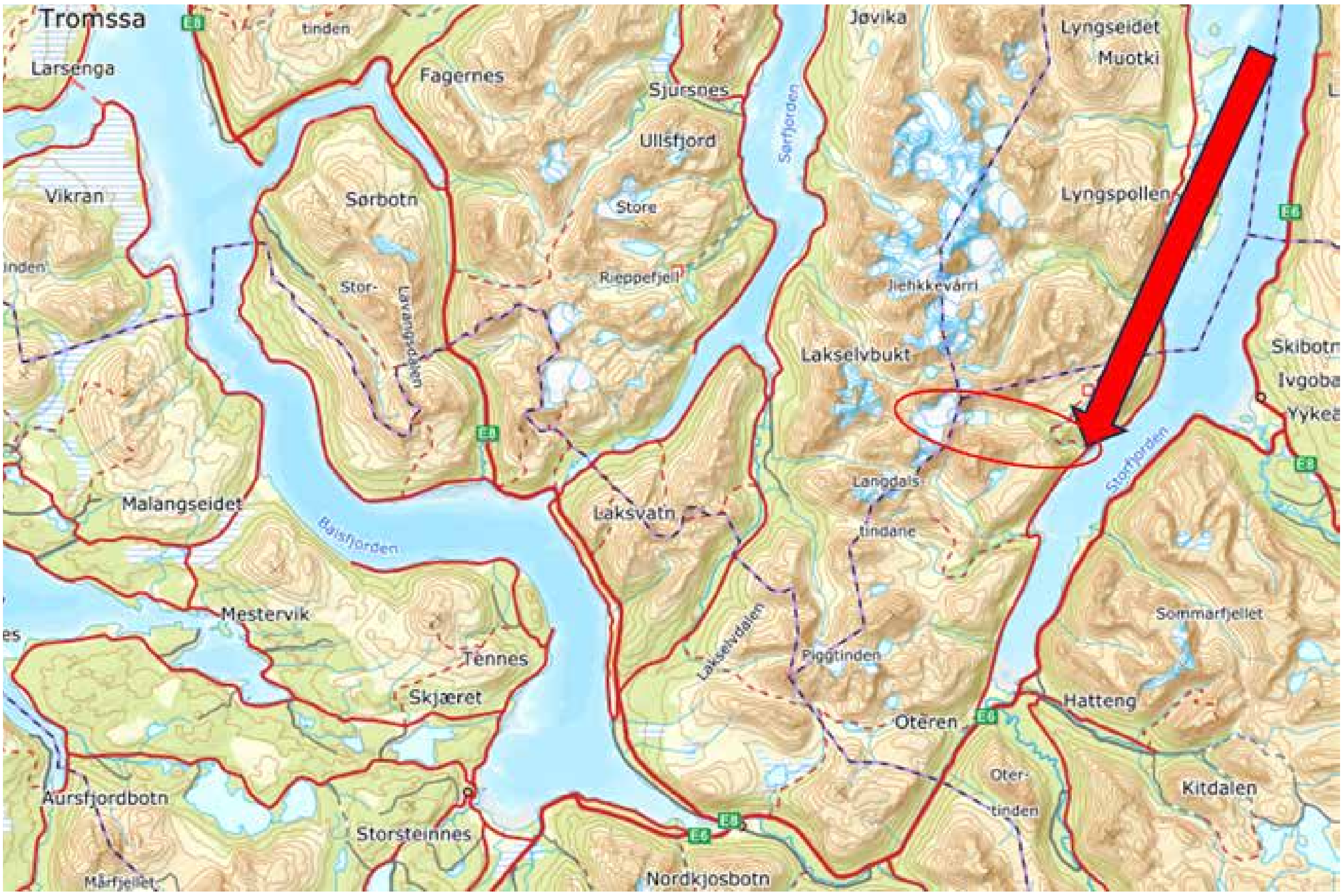

Figure 1: Overview map of the Lyngen Alps. Parking area for Steindalen marked with a red arrow, map excerpt from www.norgeskart.no.

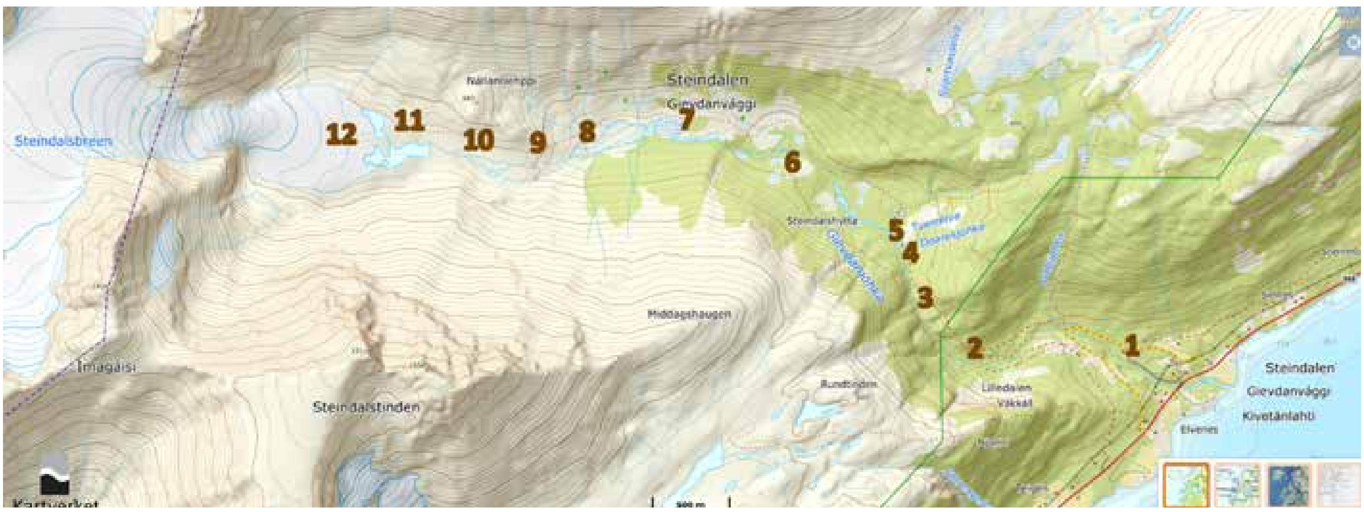

Figure 2: Map of the hike to the glacier. The numbers indicate the approximate locations described in the text, map excerpt from www.norgeskart.no.

Welcome to Steindalen, but Where is the Glacier?

It may be disappointing that the glacier itself is not visible at the hike's start. At the same time, we could use this as motivation to find indirect signs that there once was a glacier here. This brochure is intended as an inspiration to pick out what you want to focus on with your class, or ponder over yourself! Here are some suggestions for thematic excursions:

- Minerals and rocks
- Landforms
- Climate change and scientific practices and ways of thinking
- Succession - an ecosystem develops

As preparation, the class should have worked on how a glacier functions in principle and changes the landscape, forming U-shaped valleys. Good model experiments can be found here: https://www.earthlearningidea.com/Indices/contents_Norwegian.html

Figure 3: Information board at the parking lot.

1. Loose Rocks Everywhere

Steindalen is aptly named, the valley of rocks. We will see many rocks along the way. The one next to the information board in the parking lot is a good starting point for several activities, figures 3 and 4:

- Where does the rock come from?
- Take a closer look at the rock and describe its appearance. What does it tell us about its history?


Figure 4: A glacial erratic from the Ice Age next to the information board.

The advantage of such open questions is their suitability for differentiated teaching, as they do not ask for a definitive answer. Students can come up with many ideas. Perhaps it rolled down the mountainside? Perhaps it has always been there and the rest around it eroded away? Perhaps a previous glacier deposited it there after transporting it a distance? We will explore the latter further up the valley.

Looking closely at the rock in figure 5, it appears quite striped, it glitters in the sunlight, and it also has many red spots. You may need to guide the students a bit to look at the rock itself, and not the lichens growing on it in many places, for example in the upper right part of the image.


Figure 5: Close-up of the erratic showing the rock type garnet mica schist and some crustose lichens (red circle).

The explanation for the appearance is that the rock is a *garnet mica schist*. A rock that was formed more than 400 million years ago. Most rocks in the area were formed at this time when, what is now the American continent and Greenland collided with Europe. Here, this rock was subjected to so much pressure and heat deep in the Earth's crust that the original rock was compressed, creating the schistose structure.

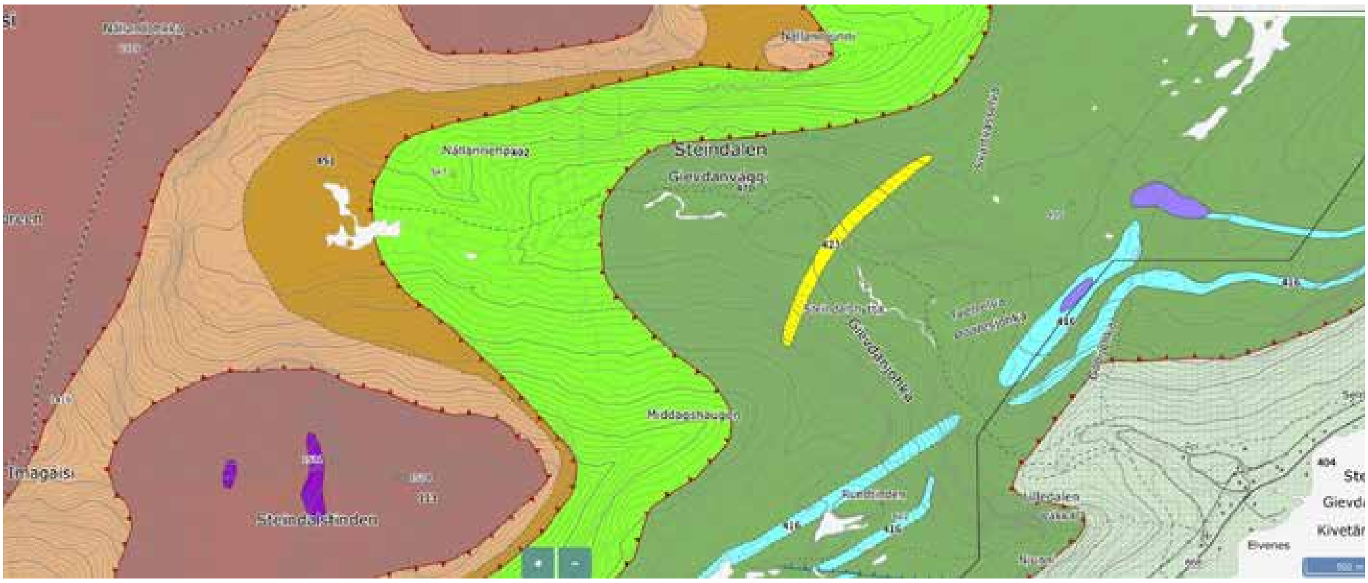

Figure 6: Bedrock map, excerpt from https://geo.ngu.no/kart/berggrunn_mobil/. Main rock types simplified: gray green: garnet mica schist, dark green: gneiss, light green: phyllite; brown tones: gabbro.

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2.
The Path Becomes Very Steep

Continuing along the path into Steindalen, we notice that it quickly becomes steeper. Looking back as in figure 7, one might think the explanation lies in the fact that we are now climbing up the side of the U-shaped valley created by Steindalsbreen, the glacier.

However, this does not explain why it becomes so steep so quickly. The reason is that we are now climbing up a so-called valley step, a threshold, where the glacier came out of the higher parts of the valley and flowed over this threshold into the lower valley. As we slowly approach the valley step, we pass solid rock, as shown in figure 8.

Let the students take a closer look at the structure of the rocks. Where the bedrock is not covered by mosses and lichens in figure 9, we see that the rock has even more pronounced stripes than the mica schist. This time there are alternating light and darker stripes, as well as various arches and folds.

One can almost imagine the enormous pressure that transformed a previous rock deeper than 10 km in the Earth's crust. It was flattened, folded, and tilted, so we can say that this is a metamorphic rock, figures 9 and 10. This one is called *gneiss*, and it is one of the most common rocks found in Norway (dark green on the bedrock map in figure 6). The gneiss is composed of much harder mineral grains and was therefore more resistant during the ice ages than the mica schist, both against erosion from the large glacier in the main valley and our little valley glacier, which could not dig as deeply into it.

Figure 7: View down the valley showing the typical shape of a U-valley.

Figure 8: The bedrock protrudes on the steep valley threshold.

Figure 9: Close-up of a gneiss directly by the hiking trail, with the typical alternation between dark and light minerals.

Figure 10: Typical for metamorphic rocks is the striped appearance.

3.
The River Below the Path

Some students may be thirsty and want to drink from the river below the path, figure 11, which rushes violently down a deep gorge. WARNING: Do not let them drink from this river, but rather observe it. They will surely notice that it is milky and blue-green colored. This is a sure sign that the river comes from a glacier. It contains a lot of fine material, silt, and clay, which forms when the glacier moves over the bedrock, scraping and grinding the rock. We do not know how much heavy metals are in this water, and in addition, there may be various bacteria and other microorganisms.

After the valley step, the path suddenly descends again, and we end up on an old river plain. This was formed behind the valley threshold when the glacier melted away several thousand years ago. Here the river flows slowly through the landscape, and we soon reach a small hill where the group can gather for a rest.

Figure 11: Steindalselva, the "rock valley river" rises in the glacier and drinking is not recommended!

4.
A Meeting Point Between a Glacial and a "Normal" River

This place is well-suited for inquiry-based learning. Students may start by observing the different rivers. They will find that *Tverrelva* to the right looks quite normal, with clear, uncolored water, in contrast to *Steindalselva* to the left. Beyond that, we can use other senses and equipment to continue the quest and let them, for example, discuss: How warm do you think the rivers are?

Some students might suggest that the glacial river could be colder than the regular river since it comes directly from a melting glacier. At the same time, both flow through open landscapes for a few kilometers, and when it's warm, both are heated by the sun and cooled down if you visit on a cold day.

- To test the hypotheses, we need to go down to the rivers, figure 12, and the students can propose how they want to do it - hold their hand in the river and compare or take off their shoes and wade into them.
- Bring thermometers, either analog or digital, and measure the water temperature.
- If the school has invested in an IR camera, it can be used by the students to get strong visual impressions, both here and at the glacier. An infrared camera has several advantages. We can perform remote measurements, see many measurement points simultaneously, and compare different areas. We may even use it to raise awareness about the world appearing very different depending on what kind of senses animals have, where some are able to sense infrared parts light, hidden to us.

The surface temperature on a warm late summer day shows large temperature differences, presented in figure 13, which is the same section as figure 12.

The advantage of IR cameras is that the temperature becomes visible, so we see temperature differences as color differences, ranging from the warmest as white over yellow and red to dark purple as the coldest. The temperatures on the two pixels shown in the image may seem a bit high, and with cheap IR cameras, it's best to just look at the temperature difference instead of absolute numbers. Here we see that the water is in overall colder than the riverbank and the surrounding vegetation. Tverrelva, which comes from the left, is significantly warmer than Steindalselva, appearing in a dark violet color where streaming fast and turbulent, as the water is not warmed by the sun at the surface, yet. Measuring with thermometers inside the water bodies, the students will discover the different temperatures, with Steindalselva around 6.6 degrees Celsius, while the normal river shows 12.2 degrees.

Figure 12: The meeting point of both rivers shows the difference in water quality.

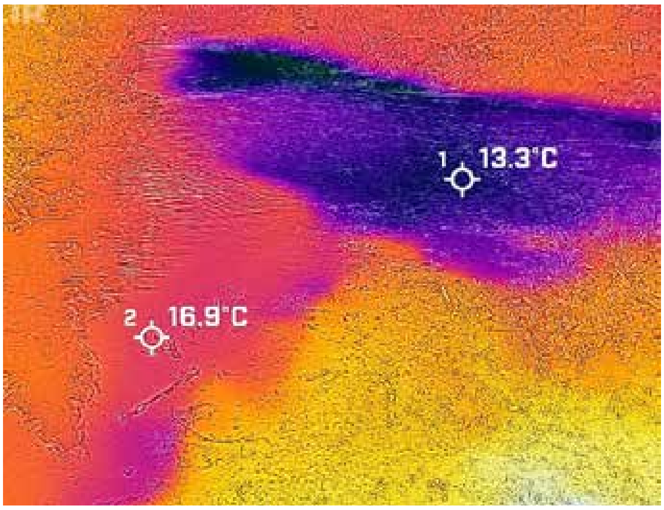

Figure 13: The same location as Figure 12, shown as a thermal image, whith white as the warmest and dark purple the coldest temperature.

5.
A Large Pile of Boulders Blocks the Path

Figure 14: The path crosses a pile of rocks, just before Steindalshytta.

As we approach a local cabin, which is barely visible in the center of Figure 14, the path is suddenly blocked by a large pile of boulders. A new mystery! Where did all these rocks come from?

The students may immediately observe that these boulders are merely barren, compared to the surrounding area, which is filled with forest and heath. We need to find out why.

Find a place where the original minerals are visible beneath the weathered surface, as shown in Figure 15. These rocks are obviously not striped like everything else so far. Here we see many small crystals, mostly black or white. Such speckled rocks form when magma cools slowly, for example, in a volcano. But we don't see any volcanoes around us.

According to the bedrock map, we are still in an area with a lot of gneiss. We actually need to look around a bit, and then we notice that behind the soft, rounded mountains, we can see some of the high and pointed peaks characteristic of the Lyngen Alps. These are of volcanic origin and consist mostly of gabbro, which is the name of the rock we just studied.

This means that the boulders must have been transported here, and a possible explanation is that during the last ice age, a large landslide occurred over the glacier further up the valley. The glacier then transported the landslide all the way here, and when the glacier melted away, the rocks were left behind.

At the cabin, we may take a break with our group and drink from Tverrelva before continuing the journey. If the weather is good, attentive students may catch a glimpse of the glacier for the first time (back left of center in Figure 16), increasing motivation for the second part of the hike.

To see the glacier properly, we need to walk a bit through the forest, and a natural next stop is a place called *Šalbmedievvá* in Sami language, Figure 17.

Figure 15: Close-up of a rock showing the rock type gabbro, the typical rock of the high mountains in the Lyngen Alps.

Figure 16: The rest area at Steindalshytta offers a glimpse of the glacier.

6.
Moraines – Natural Viewpoints

In Figure 18, we finally see the real glacier, partially hidden by some large gravel mounds.

Now it's time to wonder about all the ridges, shattered across the valley. This also applies to the point we are standing on, which is a small elevation. It is almost not visible due to all the vegetation.

Like the other ridges in Figure 18, we are standing on a moraine, more specifically an end moraine. These formed when the glacier front stayed in one place for an extended period, and the glacier transported new material over many years, accumulating at the front. Alternatively, the climate became colder, causing the glacier to grow larger and push deposits in front of it like a bulldozer.

Let the students investigate the ridge in open areas like in Figure 19. Typical of a moraine is that it consists of loose materials and contains rocks of all sizes. Both large boulders, gravel, sand, but also silt and clay particles. Glaciers do not sort by size, as a flowing river would do depending on how fast it flows. The glacier scrapes loose the surface it slides over, and everything freezes into the ice and is carried along, regardless of size.

Figure 17: Šalbmedievvá - a small moraine ridge left by the glacier.

Figure 18: The view of Steindalsbreen from Šalbmedievvá.

Figure 19: The hiking trail erodes the vegetation and moraine material becomes visible.

7.
The River Branches and Meanders Wildly

VIf you want to delve into how flowing water behaves, the flat area is a good opportunity. This is an old glacial river plain between the moraine ridges, Figure 20.

Near the path, there is a river bend that students can investigate, Figure 21. The difference between the outer and inner bend becomes clear.

The river flows fastest at the outermost point and digs deeper and deeper into the edge. There it carries away loose materials, which are then deposited in the next inner bend, where the river flows slowly or is almost stagnant. In this way, the river builds up large gravel plains.

Figure 20: Glacial river plain below the large moraine ridges.

Figure 21: A typical river bend, in which the water flows quickly on the outer side, with sand and gravel banks on the inner side.

8.
Large Moraines Tower in the Valley

Behind the river plain, large moraines block the view of the glacier, Figure 22. These date from the *Little Ice Age*, which lasted from about 1750-1920. The reason they are so massive is that the climate before this period had been much warmer for a long time. The glacier was most likely completely gone, and when it formed again, there were huge amounts of weathered rocks, which could be eroded by the glacier, resulting in these large moraines.

Figure 22: Moraine ridges from the "Little Ice Age."

9.
Exciting Rocks in the Large Moraines

While most rocks look rather gray, one type stands out, Figure 23. These cinnamon-colored ones are something quite special and are called *serpentinite*. They originate in the Earth's interior, the mantle, and are very dark. However, you only see this if you find a rock that has recently been broken into several pieces, Figure 24. The surface becomes light when it weathers, which is a type of rust that occurs when the dark minerals react with oxygen.

Figure 23: Cinnamon-colored rocks that come from the Earth's mantle.

Figure 24: Close-up of the interior shows the rock type serpentinite.

10.
Finally: The Glacier Itself

In Figure 25, there are many geological features we could examine more closely. We can start by letting the students describe what they see and how they think the glacier forms and moves. The main glacier must stretch invisibly further up between the mountains. Then we see a long icefall, where the glacier flows about 300 meters down over a valley step, somewhat similar to what we passed at the start of the hike. The difference is that here the glacier still is active, so we do not know exactly what it looks like under the glacier. The lower part is the remainder of the valley glacier that previously filled the entire valley, but where the glacier front (in 2023) lies only a few hundred meters in front of the icefall.

It is important to get the students to understand that the ice flows slowly but surely downward, with only a few centimeters per day. Therefore, we do not see it flowing, but the shape can perhaps be compared to something thick and flowing. Syrup, slime, or rubber, which comes down from the mountain and spreads out where it gets space.

Many want to know how quickly the glacier is melting. It is not easy to see for someone visiting the glacier only once. Fortunately, some signs were put up, and the students may try to find them and do the math themselves. The newest sign is from 2010 and stands a bit away from the large glacial lake that has formed since then, Figure 27. It becomes clear that the glacier front is far from the sign, and we can calculate that the glacier is currently shrinking by 10-30 meters per year (Nielsen, 2016), while having melted a record 76 meters during the warm summer of 2024.

Those visiting a glacier for the first time are often surprised by how cold it is when approaching the glacier, despite the sun shining. Here, an IR camera is useful again to illustrate how the temperature differs, near and on such a large ice mass at the end of the valley, Figure 26. Since the air above the glacier cools significantly, and cold air sinks, there are often cold winds coming down the glacier.

Figure 25: The entire glacier becomes visible once you have crossed the large moraine ridges.

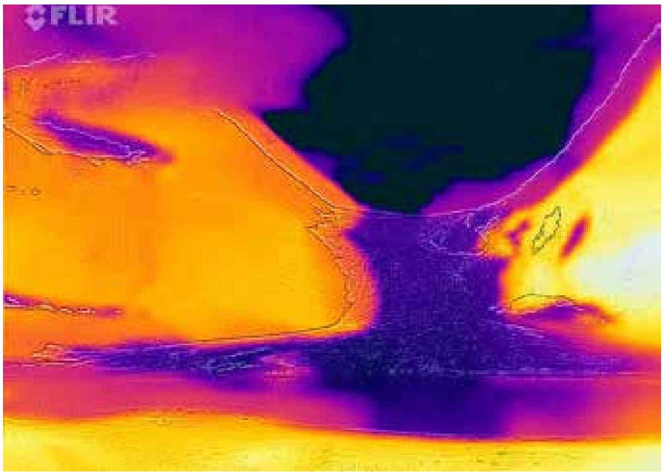

Figure 26: A thermal image of the glacier and surroundings shows temperature differences from purple as the coldest to white as the warmest.

Figure 27: Signs show how much the glacier has melted over a few years.

11.
In Front of the Glacier

Near the glacier, at some places bedrock is exposed, Figure 28, and we can observe two exciting features created by the glacier.

"Sheepbacks" and Striations

Ask the students to describe the shape of such rocks and ponder about their origin. We see that these rocks have a characteristic, asymmetric form, cracked and a steep edge on the left side, while on the right side, polished smooth and rising in a rounded arc. Here, the glacier came from the right side, so the ice under high pressure polished the rock, and at the same time, the ice melted due to the high pressure. On the left side, when the ice mass suddenly had more space, it froze, and the glacier could pluck pieces that became loose due to frost weathering. If you look closely at the surface, you may find grooves or lines running in the same direction, which were scratched by rock-fragments under the glacier, so-called striations in Figure 29.

Figure 28: The typical landscape form roche moutonnée, or sheepback showing that the glacier came from the right side.

Figure 29: Close-up of striations on the surface.

Glacial Lake

Why has a lake formed in front of the glacier? If we look at the glacial lake from the side, as in Figure 30, we might guess the reason.

During the Little Ice Age, the glacier deposited so much loose material on the left side down the valley that it blocks the path for the meltwater. Today, the glacier front lies lower than the end moraine to the left in the picture. Therefore, the meltwater cannot drain away as quickly as the glacier melts.

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Figure 30: The glacial lake, which has grown in recent years. The glacier to the right.

12.

On the Glacier (Note: Only with an Experienced Guide and Proper Security Measures!)

Figure 31: A group of middle school students walking on the glacier with necessary safety equipment: harness, safety rope, helmet, ice axe, crampons, and a professional glacier guide.

Next to the glacier tongue, the journey ends for most people. Do not proceed without an expert and proper equipment, and not even "just a little." Figure 31 shows what a proper glacier hike looks like. Anything else means risking your or other's lifes.

Cryoconite and Albedo Effect

Various materials accumulate on the glacier's surface, either because they thaw from the ice or fall onto the ice. The black clumps in Figure 32 are called cryoconite and are a mixture of dust, organic material, and bacteria. We do not know if they contain harmful bacteria at this particular place, but they are one reason for not drinking glacier water. Another thing we notice is that the dark clumps are located a few centimeters into the ice. Let the students ponder why this happens.

Black materials absorb light, while white reflects light. This reflection is called Albedo-effect. Therefore, the clumps become warmer than their surroundings and melt into the ice. Using a thermal camera, we can easily measure the temperature difference. Here, we may also draw a connection from a local phenomenon to the global climate. The warmer it gets, the less ice and snow there is. The less white on the Earth's surface, the more heat is absorbed, and the temperature rises-a vicious cycle.

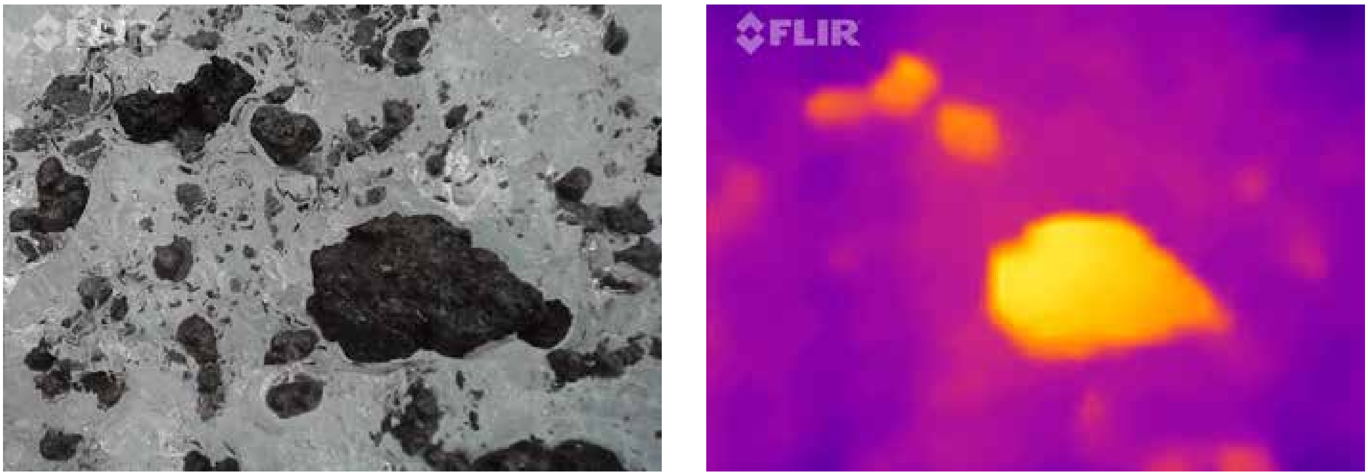

Figure 32: Dark material heats up faster than the ice and partially melts into the glacier.

New Moraines Under Formation

We don't need to walk on the glacier to see that a lot of rocks of all sizes have accumulated at the melting glacier front. These are rocks that were mainly transported inside or under the glacier, now coming into view after having traveled with the ice all the way down from the mountain.

Walking on these areas makes this even more intuitive, as seen in Figure 33, but it is not recommended with students. The ice on the sides begins to collapse, and there might always be more melting ice, mud or air hidden under these fresh moraines near the glacierfront.

Figure 33: When the glacier melts, we see that it has transported material of various sizes, which remains as moraine.

13.
On Your Way Back: Impressive Primary Succession

If you are interested in ecology and want to explore with your students how an ecosystem develops (succession), the way back is a good opportunity. There is not much green visible near the glacier in Figure 30 unless we take a closer look. A bit away from the glacier front, we find small algae and other microscopic organisms forming so-called biofilms, Figure 34. Soon small mosses and liverworts appear, Figure 35.

We also find some hardy flowering plants. Grass with special adaptations to reproduce quickly, where the new generation of plants grows out of the seed already on the parent plant, a process called *vivipary*. Small willow shrubs sprouting between the rocks are the first woody plants, Figure 36.

On the rocks, crustose lichens appear, Figure 37. These are specialist organisms, algae and fungi growing together in a symbiosis, surviving on bare rock. Initially only millimeters in size, they grow so slowly that it takes decades for the rocks to be fully covered.

With a nutrient base in place, we also discover some animals in this limited ecosystem, Figure 38. Students might want to go on a track hunt. Which animals have visited the riverbank?

As soon as there are plants, parasites follow, such as gall midges, which have their larvae in so-called galls, the yellow balls in Figure 39. Let the students cut open a gall and see if the larva has already transformed into a gall midge, ready to hatch.

Eventually, woody plants begin to dominate in the succession, Figure 40, unless the grazing pressure is too high. It starts with a few small birch trees and willow thickets.

Finally, a birch forest forms as the climax stage - and we get a last glimpse of the glacier beside the forest in Figure 41, before the journey goes back.

In a time when artificial intelligence gives us quick answers that are not fact-checked, and misinformation spreads rapidly on social media, it is important for students to see with their own eyes, feel with their whole bodies, that the climate is changing, and that it has always changed. It was warmer before, and there was the Little Ice Age, when it was colder than today, but never in human history has the temperature increased as rapidly as now. All this, Steindalen can show us. By using the valley, we give children firsthand experiences they will not forget. They experience the declining glacier with their senses, helping them to understand that climate change is real. At the same time, we don't want to scare them. Such a glacier valley is a perfect opportunity, as these changes happen gradually, and we humans are quite good in adapting and finding solutions when changes happen.


Figure 34/35: Bacteria and other microscopic organisms form so-called biofilms, the slippery surface we slide on when walking on wet rocks, as well as small green algae (Figure 34) and mosses (Figure 35).



Figure 36: Some hardy flowering plants like alpine rockcress, viviparous alpine meadow grass, and willow species sprout between the rocks.

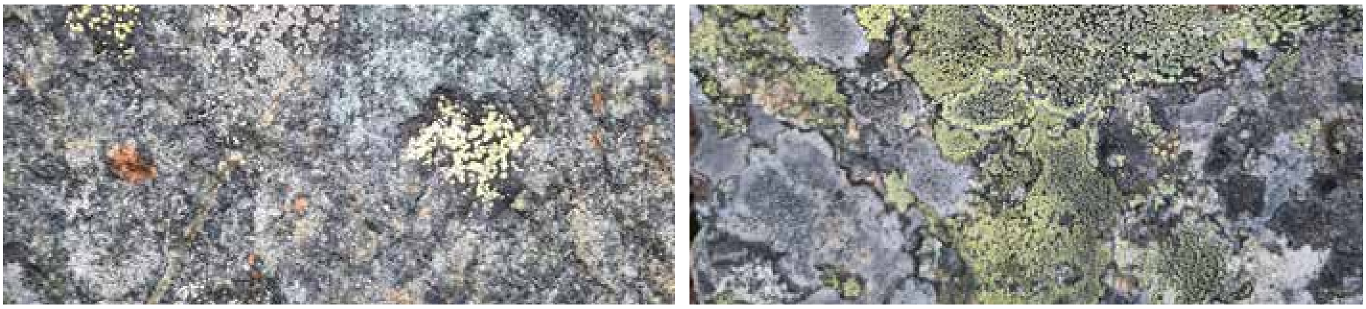

Figure 37: The map lichen (light yellow-green) on rock is easy to recognize because it resembles a map when it grows larger, as on the right rock further from the glacier.

Figure 38: Both insects and birds are animals we encounter on the hike or find their tracks.

Figure 39: Gall midges lay their eggs in leaves, then the larva grows, and the plant forms special tissue around the larvae, called galls.

Figure 40: Small birch trees, willow thickets, alternating with grassland, grazed by sheep.

Figure 41: Thick birch-forest as the climax stage of succession in these nordic regions.

Final Comment

In this brochure, I have tried to simply explain a selection of phenomena visible in such a glacier valley and provided some suggestions for curiosity and inquiry-based activities. The selection is based on trips with family, students, and pupils and their questions about phenomena along the path to the glacier. Some activities and facts may be so simplified that they may sound incorrect to researchers. If you believe something was scientifically incorrect, I would be happy if you contact me. Anyone who wants to dig deeper, will find scientific research related to Steindalsbreen at the Department of Geosciences at UiT. Specific claims about the moraines and the glacier's retreat are based on Carina Nilsen's master's thesis from 2016, titled: "*Glacier Retreat History and Landforms in Front of Steindalsbreen, Lyngen, Troms.*"

A big thank you to everyone in the schools and at the university who contributed to this brochure through inspiring conversations. Special thanks to my colleagues from the EU project GlacierXperience (https://glaciereducation.com/) for intense days in Steindalen in 2023 and the opportunity to walk on the glacier with students. All photos, except for the maps, are taken by the author.

Tromsø, Spring 2025
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