The Fall of the Glaciers

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INTRODUCTION: DEEP TIME AND ETERNAL CHANGE

One June day in 1788 the Scottish geologist James Hutton visited a rugged promontory called Siccar Point on the south-east coast of Scotland, not far from Edinburgh. Hutton was that uncommon thing, a polymath. In 1740, at the age of just 14, he had embarked on the study of humanities and medicine at the University of Edinburgh, then gone on to study chemistry and anatomy in Paris before rounding off his education with a medical degree in Leiden, the Netherlands, in 1749. The following year, he inherited two farms in south-eastern Scotland, where he applied his all-round knowledge of the natural sciences to the advancement of agriculture.

It was an ageing Hutton who came to Siccar Point by boat, and the overview of its geology he gained by observing it from the sea sparked one of those rare eureka moments. It was an instant that didn't just change the history of geology, but also our notion of time. What a dizzying revelation it must have been when he suddenly grasped the significance of the stratified cliffs before him, their strata angled in different directions and clearly formed of different rock types. The cliff bore witness to an ancient sea bed transformed into rock, and to the vast but infinitely slow processes that had raised it. Rock had eroded into grains of sand, which had ultimately become river plains and deltas or sediment in the sea, reshuffling the geological strata. At Siccar Point, horizontal strata of sandstone lay over older, vertical rock. They showed that what was once sea bed had been hardened, pressed and tilted through different processes over vast periods of

time. Hutton's companion on that day, the Scottish mathematician and minister John Playfair, has described the moment thus: 'The mind seemed to grow giddy by looking so far into the abyss of time…'. And as they stared into the depths of time past, they caught a glimpse of the planet's evolution over millions of years.

With that, the concept of *deep time* was born, an insight that was controversial in its day. In 1788, the prevailing wisdom was that the earth's age could be established on the basis of an orthodox biblical conception of time as a limited and graspable period of roughly six thousand years dating back to the *creation* depicted in Genesis. With Hutton's eureka moment at Siccar Point, time was opened up, extending back towards endless eras that predated humanity's time on earth. In this new context, the span of a human life abruptly became insignificant. The discovery also paved the way for the realisation that everything is in a constant process of change, regardless how slowly the mill of time grinds. The past, which had hitherto stretched back over a manageable number of generations to Adam and Eve, now extended over enormous epochs that are difficult to grasp using a human life as a yardstick. Although, in the tradition of St Augustine's *De Civitate Dei* (The City of God) from around 426 CE, history became linear, it was still only stretched out further between Creation and the Fall. After Hutton, time stretched almost from one eternity to another in a world that was undergoing continuous change.

Hutton's insight, which the geologist Charles Lyell (1797–1875) further developed in his *Principles of Geology* (published in 1830–33), was also crucial to the understanding that life had evolved over endless periods of time, and that this, too, was a ceaseless process of change that would continue. The theology student Charles Darwin brought Lyell's book along with him as his 'second bible' on his voyage around the world on board the Beagle between 1831 and 1836. It enabled him to place the fossils of extinct animals and seashells that he found on his travels in an

understandable context. The world and life itself were not static: the horizons of time also expanded for life on earth, into both past and future. And, if we take a long enough view, Norway's Ivar Aasen—philologist, lexicographer, playwright and poet—was actually wrong: the old mountains on the horizon do *not* forever look the same. Fossilized marine animals in the highlands bear witness to extraordinary upheavals, showing that the mountains must once have been ocean bed. Meanwhile, enormous deltas and river plains were built up, one grain of sand after another, demonstrating that time tirelessly gnawed away at those same mountains, sending them back to the bottom of the sea.

Other forces also sculpted mountain and landscape with astonishing power and the aid of time. Lyell was on the trail of these forces in the sense that he observed the phenomenon, but he didn't understand what drove it. He wasn't the first person to notice that water sank over time – or was it land that rose? The areas around the Baltic Sea are among the places whose shorelines have shown the greatest changes. In many locations, old quays and boat houses now lay far inland, islands had become part of the mainland and old maps indisputably showed that the landscape had changed in mere centuries. Those who speculated about the causes, like Swedish scientist Anders Celsius (best known to posterity for his temperature scale), took it for granted that the sea must have sunk. And that is also what Lyell concluded because, of course, Scandinavia had an exceedingly stable geology: it was unthinkable that either earthquakes or volcanoes could affect the height of the land. On the other hand, it wasn't easy to find a plausible reason why the sea should have sunk precisely here – for this was not a global phenomenon.

Lyell took a trip from England to Sweden to study the question more closely. In 1834, he studied a massive oak outside Stockholm. The tree was estimated to be at least four hundred years old and stood up on a slope some forty metres from the edge of a lake. Since it and other large oaks were at

the same level whereas the only trees growing closer to the water were both smaller and younger, Lyell concluded that they had taken root as the land level was rising. This and other observations led him to conclude that it was, in fact, the land that rose and not the water that sank. Almost two hundred years later, the oak still stands there, but is now sixty metres from the lake. This is one of the few areas in the world where rising sea levels are not yet being registered. That is to say: the sea is rising, but the land is rising even faster. But why

Very few such aha moments ever come completely out of the blue; existing knowledge, prior observations of unexplained phenomena and perhaps earlier but incomplete hypotheses serve as the springboard to new knowledge. This was true for Hutton and Lyell, and it was also true for Darwin. Hutton's realisation about deep time and his eye for the geological characteristics in the landscape prompted him to speculate that the presence of the great granite blocks he observed in the calcareous Jura Mountains must imply that the glaciers in the Alps had once been mightier. Only they could have moved the enormous chunks of rock whose geological origins differed from the site where they now stood. Hutton was on the trail of the ice age. Many others had also wondered about the origins of these enormous blocks of stone, which diverged so dramatically in their geology from the local rock. Where did they come from and, above all, how did they end up there? And what had polished the rock in so many places, leaving those peculiar striations?

The Dano-Norwegian geologist Jens Esmark (1763–1839) found the answer. He was born in North Jutland and when his father, a parish priest, baptised him, the font in which Jens was christened was carved out of a large red block of granite. This was a stone type that did not naturally belong in Denmark, but back then neither the newly baptised child nor the priest had the faintest idea of the tale this block of stone could tell. The solution proved to be near at hand in both time and space: forty-five years after Hutton's eureka moment and eleven years before Lyell's

musings by the oak tree, Esmark had an aha moment of his own, which Geir Hestmark describes in his monumental biography of the man. It happened in the summer of 1823 on the old transport route from the west coast of Norway to the inner valleys. From the old summer farm at Sunndalen, the path climbs steeply towards the Kamperhamrene Pass at an altitude of 1,200 metres. At the uppermost point of the pass, they had to cross the front or terminus of the Raudal Glacier, the northernmost arm of Europe's largest glacier, Jostedalsbreen. The glacier had been melting in that period, giving up a couple of hundred metres of the advance it had made during the period known as the Little Ice Age, which ended in around 1750. It left behind it an area stripped of vegetation where large blocks – glacial erratics – lay strewn across the smooth-scoured rock. And this is where the pieces in an enduring puzzle finally fell into place. Suddenly, Esmark understood the relationship between the local forces he observed here and landscape formations that must have been caused by ice masses on an entirely different scale.

The previous year, Esmark had travelled around Western Norway, and along the way he had registered the steep, sometimes smooth-scrubbed mountainsides by the fjords. Something must have polished these rockfaces, but what? What natural phenomenon could be responsible? In the summer of 1823 he was in new terrain, now on the trail of copper deposits, a quest that took him to Lake Haukeli by Lysefjord. The water was naturally dammed by a strikingly large gravel ridge, locally known as Vassrygg. What could have placed such an enormous dam of gravel at the end of the long, narrow valley? Esmark then set off for the mouth of Sognefjorden, where there were said to be spectacular fossils. Although he found none of those, he did encounter a remarkable, smooth-scoured conglomerate. Again, it provoked the question: who or what had polished this rock to a sheen?

With such questions rattling around in the back of his head, he made his way back towards the capital from the western coast, travelling east to Gudbrandsdalen. Along the way, close to the highest point of the journey, his party witnessed the glacier's ongoing work in the terrain. Its ability to deposit moraines as it advanced and retreated was well known and it was on this precise spot that Esmark realised that the glacier had delivered the proof before their very eyes: the smoothed rock, the glacial erratics and a moraine that was a miniature version of Vassrygg, the large moraine he had encountered on the western coast. Fjords and corries, vast moraines and gigantic glacial erratics dozens of miles away from their place of origin clearly demonstrated that this was not just a question of small glacial advances here and there: the whole of Northern Europe must once have been covered by vast ice masses. As Esmark put it, 'The similarity is so striking that anyone who has the occasion to make this comparison must have the same ideas.' When the pieces of a puzzle finally fall into place, the answer always seems obvious in hindsight, but for Esmark, this meant he had *discovered the ice age*, as his biography puts it.

Esmark didn't stop there but went on to develop the hypothesis of periodic glaciation caused by the earth's elliptical orbit around the sun. Once more, he emphasized that the earth was a place of change where climate and ice control both the biosphere and the lithosphere (rock and mountains), and even, in part, the atmosphere, over endless periods of time. Hutton achieved his dizzying realisation of deep time, eternity, and eternal change in a brief moment, and Esmark must have had much the same experience at the glacier's terminus on his way from west to east. Over long periods of time, the ice had come and gone on an alarming scale. The world was a changeable place, and the fact that the glaciers could expand or vanish demonstrated that the climate could undergo tremendous pendulum swings. From the perspective of eternity, even the mountains were transient. With the aid of endless time, the glacier could vanquish the mountain, gnaw out valleys, deposit peaks in between – and its glacial streams could carry vast amounts of finely ground rock

out into lakes and fjords. There they would rise once again in compressed form, as mountains of the kind Hutton had observed.

Darwin, who was interested in geology, embraced the theory at once when, in 1840, he attended a lecture by the Swiss zoologist, Louis Agassiz. Posterity would hail Agassiz as discoverer of the ice age, a theory he presented in 1837, a full fourteen years after Esmark. A few years earlier, Darwin had studied some remarkable terrace formations in Wales without grasping how they could have been formed. Agassiz gave him the answer: it was the ice. Deep time was also the answer to the origins and evolution of life. At some point or another, Darwin must also have gathered enough pieces of the puzzle to have *his* eureka moment, although it probably came more gradually. It seems likely that the realisation came in late September 1838 while he was reading Thomas Robert Malthus's *Essay on the Principle of Population*. Malthus's central point was that too many children were born in the world; not all of them could survive. Darwin saw at once that the same applied to life in general: only a few individuals, those that were best adapted, could reach adulthood. 'Finally got a theory by which to work,' he noted with satisfaction in his journal after reading Malthus.

But to return to Esmark: he was the first to posit the ice age, publishing his findings and a bold theory that large areas of the northern hemisphere had once been covered by a massive layer of ice. This was not just the obvious explanation for natural phenomena like glacial erratics, mountain ridges and fjords, but also for land uplift: liberated from the billions of tons of ice that had been crushing it, the land slowly began to rise as it had for close to 10,000 years. And by a stroke of poetic chance, the red granite of the font in which Esmark himself had been baptised had originated in the Norwegian landscape and been carried by the ice to North Jutland. The ice had brought more than blocks of stone, though: much of Denmark's landmass and large tracts of northern Germany were formed from sand and rock that originated in Norway. The ice age theory

solved many mysteries in one fell swoop. Yet few paid attention to Esmark's theory, which was published in a provincial journal in 1824.

Hutton, Lyell, Darwin, Esmark and Agassiz opened up the past, and it was a past formed by natural forces and climate in which the ice played a key role. Together, ice and time could both create and destroy mountains, and everything was in a perpetual process of change. Past catastrophes could also be future disasters. It was a dramatic realisation, but glaciers and ice also hold drama and fascination over more manageable periods of time.

Glaciers are time capsules. They don't just contain drama from the recent past but also carry within themselves vestiges of those who had business in the mountains hundreds, even thousands of years ago. They have taken good care of these artefacts from times gone by and, once in a while, even the people who carried those items into the mountains. Glaciers contain not only dead insects, lemmings and reindeer, but also an unknown number of climbers, glacier hikers, hunters and travellers from the past, some from the *truly* distant past. Death in the ice can even have heroic elements if it results from an attempt to conquer new heights or insights. The Norwegian philosopher Peter Wesser Zapffe elevates death in the ice to new poetic and heroic heights in the conclusion of his essay, 'Why Did Scott Die?'. There he writes that, with his heroic death in the merciless embrace of the ice in the South Pole, Robert Falcon Scott '…offers his people's youth an almost blazing display of heroic death… that is why the eyes of humanity also seek out his remote, vanished tomb, where the deadly cold itself preserves his form. Until, that is – a long, long time from now – it breaks loose with a thunderous roar and sails with the storm out towards the deep, dark-blue sea in a vast, sarcophagus that glitters in the sun.'

The glacier itself has an eternal perspective. The frozen depths that still conceal Scott contain ice that fell as snow many hundreds of thousands of years ago. They contain ice that is several millions of years old. This ancient ice is also a time capsule and an archive of the climate and even the life of the past. And the ice conceals more powerful forces than even the glaciation of Europe might suggest. Some 700 million years ago, the earth almost became locked in the deadly grip of cold. Ice was in the process of covering the entire planet and snuffing out the life that had slowly evolved over 2.8 billion years – in perhaps the only home life has in the universe.

There is unquestionably something *monumental* about ice, about the glacier, which can be colossal and dangerous. It has, with good reason, been a source of fear. Yet its colossal nature is simultaneously fascinating– especially the icefall, with its wildness, its beauty and its play of colours in countless shades of blue. Ice is dead but it is also life in so many ways. Some people resort to words like *sublime* when faced with the ice; there is something so lofty about it (and sublimation is what happens when it transitions directly to water vapour without going via water). The glacier captivates many of us – once a glacier always a glacier – but why?

I have always thought that my writing should have utility value, even, on a good day *meaning*. But is it meaningful to write about glaciers? Is it important? There is, of course, good popular education to be had from describing the traits of glaciers: how they grow and shrink, their physics and physiology, how the crevasses form and why the white ice turns blue under pressure. There is, naturally enough, a wealth of glaciological facts available to write about. Yet there is more to the glacier than its physical manifestation, in symbolic, cultural and mythological terms. The experience of the glacier is personal. Many of the world's glaciers have acquired the status of climate victims. And, as with everything else, our consciousness of the value of the glaciers increases as they melt away; what's more, as an image of the effects of climate change, before-and-

after photographs of glaciers are trumped only by polar bears on melting ice floes. This moves us, at any rate many of us, even people who've never set foot on a glacier.

It is difficult to offer any easy explanation for the strength of my feelings about glaciers and mountains without falling into cliché. All I know is that I always get the urge to dust off my rope, ice axe and crampons and get climbing whenever I see a glacier; and that it's a genuine yearning. Although it's personal, it's also a feeling that will be familiar to many. The magnificence of the glacier or the peace of mind that comes when surveying the world from above on a mountaintop don't need to be understood: it's enough that they exist. Not everyone feels this, not to the same extent, but it is still a common denominator for many. Any history of the glacier will therefore necessarily be a personal history, and the personal aspect also revolves around the eco-grief that strikes us when the reencounter with a glacier feels like seeing an old friend on their deathbed.

A glacier is more than a dead mass of frozen water. It is also a living thing in its way, with specialised ecosystems of microscopic life that scrapes out a meagre existence in the ice. And since ice has the conserving properties of the freezer, everything that vanishes beneath the snow inside the glacier or into the deep blue crevasses will someday reappear when the snow and ice thaw, or it will follow the slow flow of the mass of ice towards the glacier's terminus, where it will be revealed once more. In the meantime, the glacial mill will have done its job. Scott will not reach the ocean in his sarcophagus with a smile of redemption upon his lips – he will barely be recognisable at all; but he will certainly end up in the ocean one day, along with the 1911-vintage ice.

It is all these contrasting facets of glaciers that are worth conveying: time, space, eternity, future and meaning. Life and death, facts and feelings, beauty and disquiet, but above all, our own personal relationship to the glacier – the aspect that is most difficult to explain and justify, but is all the more fascinating for precisely that reason. The glacier may contain the deep past but, as a

mirror of the past, it also encompasses the future. Time frames the tale of ice. One of the arguments the social sciences have frequently offered to justify the study of history is that it's important to know the past in order to be prepared for (and influence) the future. This definitely holds true for ice and glaciers. Glaciers, ice and climate have driven the earth's evolution and will also decide its future.

PART 1: THE BASIS OF THE GLACIER

The First Encounter

My first encounter with a glacier was in 1969. Our class was due to spend a week at the most exciting camp and spirits were high on the bus ride from Lillehammer to Spiterstulen amid the mountains and glaciers of Jotunheimen. Truth be told, I don't remember very much else from that week apart from the one day on the glacier and above all *inside* the glacier. On the other hand, I *do* remember that day extremely vividly. It was a long approach, but as we passed a mighty moraine and saw the bubbling glacial stream before us, the glacier guide, Eiliv Sulheim, pointed up to the right. There, high above us, on top of a slab of rock, was a blue ice castle with towers and spires. I felt a rush of terror mingled with intense joy. I recall that a photo was taken of me inside the brilliant blue of the ice tunnel. Ice towers loomed around us. We were inside Svellnosbreen, the fairytale glacier. I had seen a lot of spectacular nature on my family's annual visits to Western Norway: precipitous mountain roads, waterfalls and gorges where I'd lain on the edge and felt my stomach drop. I'd climbed a few peaks too. All that was impressive, for sure, but my encounter with the glacier was something else entirely, an experience that seared itself into my memory. The icefall was monumental. The walls of ice rose up, shot through with blue hollows and grottos. The deeper they were, the more intense the blue. There was a rumbling far inside the glacier and I felt these deep sounds set off a strange resonance inside me. The masses of ice stretched from the foot of Norway's highest mountain by way of the splendid icefall to a smooth-scoured slab down towards the valley where the glacial stream tumbled, sometimes accompanied by thundering blocks of ice. I had a feeling of insignificance but at the same time a sense of grandeur and belonging, the feeling we sometimes get in nature, at the foot of a mighty mountain or alone beneath the stars on a winter night. It's at moments like these that I've felt as if I'm standing on the outermost edge of something, gazing into a profound revelation that

always eludes me at the last minute. I wanted to go up on the glacier, into the ice, to feel it. One day I would come back. I would challenge the glacier, but also become its intimate.

EIliv Sulheim was referred to as a *real mountain man*. He *knew* the mountain and the glacier, and spoke of them in his local dialect with its echo of ore-pine and waterfalls. This glacier guide could tell us about *everything*, from the humblest heather blooms to why the ice was blue. Following his instructions and linked to each other with a glacier rope, we wound our way like a millipede through the narrow passages, the blue ice tunnel and around the ice tower inside the icefall itself. Then we came up in the transition between the white flat glacier that stretched into the mountains and the icefall below. Here the glacier formed deep transverse crevasses where the ice tried to follow the mountain below. Sulheim played out the rope so that, one by one, we were able to stand on the very edge of the crevasse and stare down into the depths, where the blue gradually gave way to a black chasm.

Above this area of crevasses lay an expanse of snow that stretched all the way in towards the peaks beyond. This was the flat glacier, Sulheim told us; certain glaciers are not afforded their own rugged icefall, they are simply flat glaciers. It has to be said that this part of the glacier is lacking in personality, being little more than a large tract that is usually covered in snow. That doesn't mean it isn't magnificent, not least because it often frames views that offer the drama its own content lacks. This is true of the inner expanse of snow at Svelnossbreen, with Galdhøpiggen to the north, Storjuvtinden peak in the west and Terråtinden peak in the south. The flat glacier may also have crevasses that are both large and deep, but they are often concealed by snow bridges. That is why this stretch is treacherous and dangerous in the late summer when the bridges are weakened by the melt but still cover the crevasses.

Given a certain inclination in the terrain, any glacier will flow downwards. Wherever it meets steep terrain or a knickpoint – an abrupt alteration in the steepness of the bedrock – it will be broken up. This is where the icefall forms, revealing the blue interior of the glacier. If the ice masses survive the icefall and continue to flow downwards in gentler terrain, they are often called a glacier tongue. For many glaciers, the transition between flat glacier and glacier tongue is unclear. Glacier tongues may be flat and rather boring, and the lower icefall often consists of nothing but dirty ice in the summer; but they also have their crevasses, and imposing glaciers may also have imposing glacier tongues. All this Eiliv Sulheim taught us on that day. He pointed out the glaciers and the mountains, told us what they were called and also sometimes explained how they came by their peculiar names.

Ten years later I met him again during those years that separate childhood and adulthood. At last the time had come to get to know the glacier and I came directly to Spiterstulen from a glacier course at the Smørstadbreen glacier. For several sun-filled days in July 1977, we were lowered into deep crevasses. Before that, we had mugged up on techniques that would enable us to bring ourselves and our party back up again. This was the first time I'd descended into the very depths of the ice and its utter silence. The crisp crackling sound, indeed the very feeling of crampons on ice gave a sense of security and a firm grip. In a few places, I cut steps in the ice with my axe. Where the glacier flattened out, I found what I was looking for: a blue crevasse down in the depths. Here, I screwed three large ice screws in a row, all the way down to the head of the screw, then secured the rope with slings and dropped it into the crevasse. Next I fastened the rope to the harness and slowly lowered myself into the crevasse. Some metres down there was a lengthwise snow-covered ice shelf. I sat down there in the blue – high above me chink of azure sky, deep beneath me the gurgle of water. Otherwise: absolute silence, utterly blue and utterly cut off from the outside world. Then I used slings, crampons and axe to climb back up again, relishing the joy that always comes from the feeling of mastering the elements.

I rounded it all off with a splendid time in the rugged Hurrungane mountain range, where we climbed and traversed a spectacular route amid the steepest peaks in Norway. The next day, feeling pretty off-colour after a rousing farewell party at Krossbu and carrying a lead-heavy backpack, I crossed the Smørstab Glacier to Leirvassbu, where I spent the night in a tent. Then I headed back to Spiterstulen where I tried to summon up the knowledge and enthusiasm that the glacier guide Eiliv Sulheim had conveyed ten years earlier.

I relived my first assignation with the glacier when I heard the spontaneous responses of the rope party as we came to the deep, blue crevasses. You'd always hear a gasp from the people who found themselves standing on the edge and peering down into the abyss for the first time. And it was even more spectacular to wander through blue grottoes and passages, to be inside the ice.

Glaciers have their personalities and come in an infinity of shapes and sizes determined by the underlying bedrock and their surroundings. At the same time, the glacier is subject to its mass balance, just as we are subject to our own weight or our bank account is dependent on deposits and withdrawals. A glacier's deposits are known as *accumulation*, and its withdrawals as *ablation*. The glacier has its equilibrium line, which is the place where the account is balanced. When this moves upwards and the glacier is dominated by ablation, the account dwindles. Temperature and precipitation determine where the equilibrium line lies. When accumulation is low, lower temperatures are needed, so the equilibrium line lies at a higher altitude for the glaciers in parts of the Jotunheim mountains where precipitation is scarce – and lower for glaciers in coastal regions with high winter precipitation.

Norway's glaciers are typically located west of the Langfjella mountains, but not too far west, because that would require lower temperatures than the mild coastal climate can offer. Norway's westernmost glacier is Ålfot, which is shared by the municipalities of Bremanger, Kinn and Gloppen.

The southernmost – for now – is Breifonn in Suldal, Rogaland. The easternmost and also the northernmost is Seilandsjøkelen in Loppa municipality, between the counties of Troms and Finnmark. The latter, incidentally, has no glaciers. The reason for the absence of glaciers in the county's Rondana mountains, with their high peaks and harsh winter cold, is that there simply isn't enough winter precipitation there in the shadow of the mountains that neighbour them to the west. That said, if we're feeling a bit generous, we could perhaps say that there is one glacier: Skriufonna. It has existed for 3,500 years and I have to admit that even though I've done a lot of hiking there, I'd never seen or heard of it. That's hardly surprising since it has, strictly speaking, ceased to be a glacier but is, rather, a snowdrift, a small remnant of snow-covered ice. That was the case in 2016, at least, but it is very possible that now, ten years on, even these final vestiges are gone.

By comparison with the surrounding mountains, which stand there for eternity (from a human perspective), glaciers are more variable. Like most other things in nature today, they are directly or indirectly affected by human activity. It is important to show this impact.

Our short collective memory draws a veil of oblivion not only over lost glaciers and lost landscapes, but also lost language and culture—indeed, over most things. The most striking way of demonstrating change is always via the visual, and photographs tell their stark tale. No one has documented the changes in the Norwegian landscape better than landscape geographer and photographer Oskar Pushmann. After seeking out old landscape photographs from the late 19th century, he went on to photograph precisely the same sections of the same landscapes as they had now become. When, at one point, I was writing a book that dealt with this very subject of changing landscapes and was looking for a cover image, I chose the double photographs of the Enga glacier in Norland, perhaps the best known arm of Svartisen. The glacier was photographed by Aksel Lindahl in 1889 and Pushmann's photograph was taken from exactly the same spot. My book wasn't about

glaciers, but that was the most striking example I came across of a total transformation in the landscape over little more than a century.

In the image from 1889, a man sits surrounded by some large glacial erratics and a lake in front of the icefall – which shows that the glacier was retreating even then. Yet the icefall is still mighty, it calves into the lake and there is barely any vegetation. In Pushmann's image from 2010, the glacial erratics are still there and a person sits on the same stone as in the earlier photograph, but the rocks and the lake are now surrounded by a well-grown birch forest. The remains of the glacier can be seen high up on the mountainside, but this is an utterly changed landscape. Sixteen years later still, the glacier can barely be seen from this spot.

The Norwegian Energy Regulatory Authority (NVE) has a unique time series of photographs from many Norwegian glaciers, many of which cover a period of more than a hundred years. One of the longest series shows the Enga glacier, which has also had some advances during its long retreat since the end of the 18th century. The photographs cover the period from 1885 to 2025, demonstrating that it has truly become a different landscape and a different glacier over the course of these 140 years.

Glaciers have both symbolic and concrete value. It is worth recalling how little water we actually have on this blue planet of ours – blue against the backdrop of the cold, dark universe; blue because 71 per cent of the surface is covered in water that is, overwhelmingly, salt. Yet if we measure it by volume, only 0.01 to 0.02 per cent of the planet is water: even though ocean trenches can descend to depths of close to 11,000 metres, the average depth is only 2,700 metres, which is modest in relation to the earth's radius of 6.37 x 10^6 metres. What's more, fresh water accounts for only 2.5 per cent of that total, and 68 per cent of this again is in the form of ice. Thirty per cent is groundwater, so rivers and lakes account for just one per cent of the world's freshwater. In many part of the world, this

scarce but utterly vital freshwater comes from glaciers. There are something like 275,000 glaciers in the world and these, together with the truly enormous ice masses—Greenland and the Antarctic—account for this 70 per cent of the world's freshwater.