Anniversaries

Discovery of the Ice Age 200 years ago

HOW JENS ESMARK DISCOVERED THE ICE AGE IN 1823 – SERENDIPITY AND A PREPARED MIND

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When Jens Esmark (1762–1839) (Fig. 1) in mid-June 1823 set out from the Norwegian capital on a three month long voyage, he certainly had no intention of discovering the Ice Age. And when as a result of observations made on this voyage he in April the following year published a paper (Esmark 1824, 1826) where he claimed to present incontestable evidence that Norway and Northern Europe had once been covered by large ice sheets, enormous glaciers carving out valleys and fjords, polishing cliffs and transporting erratic boulders, only a few savants took his claim seriously (Krüger 2013, Hestmark 2017).

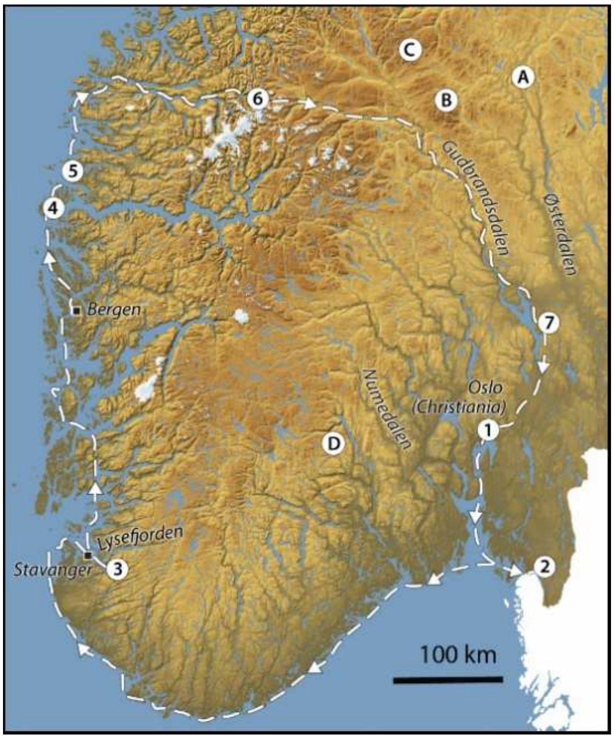

Fig. 1. On left, portrait Jens Esmark. Courtesy of Norwegian Geological Survey. On right map of southern Norway, with white dotted line showing his voyage from June to September 1823. 1 = Christiania (Oslo); 2 = Rød, the home of Otto Tank; 3 = Enighed Copper Works and the site of the Esmark Moraine close to sea level; 4 = Steinsund, with polished Devonian conglomerate at sea level, Sula Islands; 5 = Grimeli Copper Works; 6 = Northern tip of Jostedalsbreen glacier, Rauddalsbreen with Otto Tank's Moraine at 1040 m above sea level.; 7 = Mjøsa boulder terrain. The letters refer to high peaks ascended and measured by Esmark between 1800 and 1810: A = Tronfjell; B = Rondane; C = Snøhetta; and D = Gausta. Source: Hestmark 2018.

The son of a Danish country parson, Esmark received his education at the University of Copenhagen and the mining seminars and academies at Kongsberg, Freiberg and Schemnitz. From 1798 he served as one of the top administrators in the Oberbergamt at the silver town of Kongsberg in Norway, where he also taught at the Royal School of Mines. In 1814 he accepted a position as professor of mining science at the recently established university in Christiania (now University of Oslo), and remained in this position until his death (Hestmark 2017).

The purpose of his 1823-voyage was to survey an abandoned copper mine close to sea-level at Forsand by Lysefjorden, not far from Stavanger, on the south-west coast of Norway (map locality 3). He was accompanied by two young students, Niels Otto Tank (1800-1864) and Jan Theodor Kielland (1803–1844). The mine proved a disappointment, but following a suggestion from locals that the copper vein might surface on the other side of a steep hill, they there stumbled over a mysterious big ridge of gravel and boulders damming a lake (Haukalivatn) (Fig. 2) in a narrow valley. They pondered how such a ridge could have been created but had no immediate answer (Esmark 1824, 1826).

Esmark now decided to sail further up the west coast to inspect another abandoned copper mine (locality 5 on map). This also provided an opportunity to examine a famous fossil locality at the Sula islands described and depicted in the *Natural History of Norway* by Bergen-bishop Erik Pontoppidan in 1752 (locality 4 on map). They found no fossils but a smoothly polished conglomerate at sea level, and wondered what natural agent had abraded the cliffs (Esmark 1824, 1826).

By late August their voyage had already lasted longer than anticipated, and to arrive back to the university in time for his fall lectures, Esmark decided to cross from the west coast over the central Norwegian mountain chain to reach the fast coach service in Gudbrandsdalen valley. This was a fateful decision. They sailed through the Nordfjord to Stryn, and from here walked up to Oppstryn, and up the valley Sunndalen where many of the Stryn farms have summer farms (Hestmark 2018). From here a steep track leads up to a pass at approximately 1300 m above sea level, situated at the dividing point between western and eastern weather systems.

Reaching the pass, 60-year old Esmark must have been quite exhausted. And in front of him the route was apparently blocked: A big glacier tongue called Rauddalsbreen spread out over the track, from the south side of a valley to its north, the northernmost tip of continental Europe's largest extant glacier, the mighty Jostedalsbreen glacier (map locality 6). During the so-called 'Little Ice Age' (LIA) Norwegian glaciers expanded substantially reaching their maximum extension at around 1750. By 1823 the glacier had receded some 150-200 m from the LIA maximum, leaving a rim of recently exposed areas, a glacier foreland exhibiting many of the phenomena associated with glacial action (Hestmark 2018). Esmark had read about such phenomena; now he could observe and experience them up close, indeed the terrain is a lesson in glaciology: Most prominent was the sharp border of the foreland itself, between vegetated and barren terrain. They stepped from grass to gravel, from green to grey in a single step. This highlighted the glacier as a dynamic body of ice, advancing and retreating. At this western border of the foreland several large rounded single boulders rest directly on clean-swept rock surfaces. They look remarkably detached, like the big boulders (erratics) scattered all over Northern Europe. By 1823 the problem of the transport of erratic boulders was heavily debated among European geoscientists, and a number of moving agents had been proposed, such as strong floods, ice floes or volcanic eruptions (Rudwick 2008; Krüger 2013). To Esmark, upon seeing these boulders scattered in the foreland in front of the glacier it was immediately clear that the moving agent was ice. Polished cliff surfaces emerged everywhere from the gravel and boulder fields, swept free of debris, with sculpted surface forms unrelated to the structure and veins in the bedrock. The polishing agent was obviously the glacier, with its rock debris included to abrade the surface.

The track now continued over the flat glacier itself. They stepped onto the ice and walked eastwards a little more than a kilometre to the other side. Stepping down into the small foreland on the eastern side they hit upon a large ridge of gravel and boulders parallel to the glacier front — an end moraine (Fig. 2). With the glacier front just some 150 m behind it, the ridge was obviously pushed in place by the glacier. Deposited at LIA maximum around 1750 it had an uncanny resemblance to the big ridge they had seen close to sea level at Forsand, although scaled down to 25% size – being 4-5 m high rather than 20-30 m. Like the ridge at Forsand it stretched across the valley and consisted of an unsorted mixture of boulders, pebbles, sand and clay — a diamicton. Furthermore, in front of the moraine there is a glacial outwash plain, a sandur, similar to a plain in front of the ridge at Forsand.

Fig. 2. Photo above: Otto Tanks' Moraine at c. 1040 m above sea level, seen from the east towards west. The locality is situated in Breheimen national park, Skjåk municipality, Innlandet County (61°43’26’’ N, 7°26’43’’ E). The moraine was deposited around 1750, at the glacial culmination of the ‘Little Ice Age’. The northernmost tip of the Jostedalsbreen glacier can be seen in the background. Locality 6 in map. Source: Hestmark 2018. – Photo below: The Esmark Moraine and the sandur plain in front. Old arial photograph from the early 1940s before the moraine was planted with pine and the plain in front completely cultivated, Norway, Rogaland county, Sandnes municipality (58°54’14’’N, 8°08’14’’E). Deposited ca. 11500 years ago, 30-50 m above sea level. Lake Haukalivatn in the background now cover the valley where once the big glacier pushing up the moraine was situated. Locality 3 in map. Source: Photograph by Widerøe, courtesy of D. H. Djuv.

And it is at this stage, at this site, 1040 m above sea level, they suddenly realize what they had seen close to sea level at Forsand:

> ‘The resemblance is so striking, that anyone who has an opportunity of making this comparison, must form the same ideas. I must put forward as proof of this, that Mr. *O. Tank*, a

> skilful young mineralogist, who with me observed the here described rampart [at Forsand] and afterwards travelled [with me] to the glaciers mentioned, immediately exclaimed to me, without me giving him any pretext, that that rampart by Stavanger had to be a glacier rampart.' (Esmark 1824, transl.).

And the implication? Enormous glaciers must once have covered Norway and reached down to sea level at Stavanger, implying a climate significantly colder than the present. Here a scientific revolution took place, a completely new way of reading the landscape. Given Otto Tank's exclamation, it seems appropriate to name this moraine Otto Tank's Moraine in memory of Esmark's enthusiastic young student (Hestmark 2017, 2018). The big gravel ridge at Forsand has been known informally as the Esmark Moraine for many years, and is now considered to have been deposited by an enormous valley glacier tongue at the end of the cold Younger Dryas, ca. 11 500 years ago, at the end of the last Ice Age (Weichselian).

Having traversed the mountain range in 36 hours, Esmark and his students proceded down to Gudbrandsdalen valley and by coach south to the capital. On the east side of lake Mjøsa they observed large erratic boulders in the middle of spruce forest quite similar to boulders they had seen in front of the Rauddalsbreen glacier (locality 7 on map). They realized that big glaciers had once covered the eastern parts of Norway too.

Esmark spent the winter of 1823-24 working out the implications, reading up on glaciers and erratics (Hestmark 2017). His main achievement was one of *synthesis*: Several of the geomorphological phenomena he realized to be caused by a single agent – former enormous glaciers – were well recognized and studied separately before 1823-24 (Rudwick 2008). Esmark brought them together in one unified story. The very same landscape features – moraines, polished rock surfaces, erratic boulders – were also the main clues to the former extent of Alpine glaciers noted by Swiss savants Ignaz Venetz, Jean de Charpentier, and eventually Louis Agassiz and his German friend Karl Schimper a few years later (Krüger 2013). The discovery of Ice Ages took place in two countries with extant glaciers – Norway and Switzerland. This is no accident. By observing up close what glaciers do to the landscape scientists were able to recognize similar effects in places where currently no glaciers exist, and thus trace the former much greater extent of glaciers in Northern Europe, the Alps and North America. To explain the former colder climate Esmark suggested it might be caused by changes in the eccentricity of the Earth's orbit.

Although Esmark's Ice Age paper has often been seen as coming right out of the blue, recent studies document that his discovery was a result of his learning and prepared mind: 1) he had a profound and life-long interest in climate and meteorological measurements, and in effect was the first Norwegian state meteorologist (Hestmark & Nordli 2016); 2) inspired by the 'physiographic' alpine researches of de Saussure, de Luc, Ramond and von Humboldt, Esmark from 1798 onward made altitude measurements of treelines, snowlines and several of the highest peaks in Norway (Hestmark 2009); 3) Esmark supplied encouragement and his own handcrafted instruments, notably mercury barometres for altitude measurements, to numerous explorers of Scandinavian glaciers before 1823 (Hestmark 2017). This is not to deny that Esmark's discovery involves serendipity and a coincidence of favorable circumstances. He stumbled over the Ice Age. What if copper had not been discovered at Forsand, the mine never established, or Esmark not been asked to survey it? What if he had not walked around the hill to pursue the copper vein? What if Esmark had not decided to extend the voyage north, or chosen another track for their mountain traverse? What if the 'Little Ice Age' had not occurred, producing the Tank moraine and the instructive foreland at the Rauddals glacier? What if the Esmark and Tank moraines had not been so uncanny similar? What if Otto Tank had not accompanied Jens Esmark?

Further Reading

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