LANDFORMS AND SEDIMENTS

Bjørndalen-Vestpynten, Svalbard

Landforms and sediments tell the story of how the land was formed, and how different processes act over time.

Lena Rubensdotter et al. 2015

Photo: H.H. Christiansen

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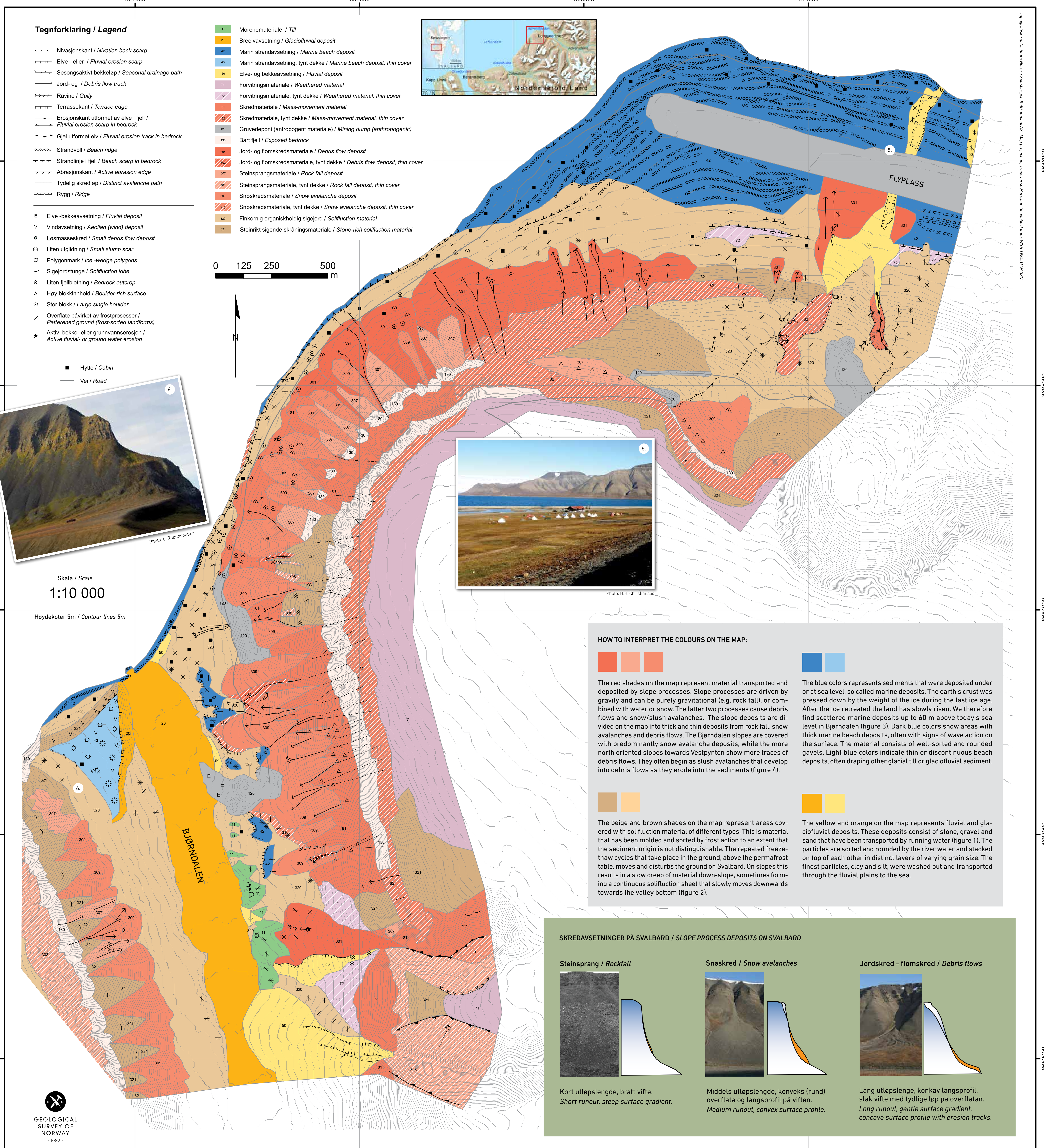

Photo: L. Rubensdotter

Photo: H.H. Christiansen

HOW TO INTERPRET THE COLOURS ON THE MAP:

The red shades on the map represent material transported and deposited by slope processes. Slope processes are driven by gravity and can be purely gravitational (e.g. rock fall), or combined with water or snow. The latter two processes cause debris flows and snow/slush avalanches. The slope deposits are divided on the map into thick and thin deposits from rock fall, snow avalanches and debris flows. The Bjørndalen slopes are covered with predominantly snow avalanche deposits, while the more north oriented slopes towards Vestpynten show more traces of debris flows. They often begin as slush avalanches that develop into debris flows as they erode into the sediments (figure 4).

The blue colors represents sediments that were deposited under or at sea level, so called marine deposits. The earth's crust was pressed down by the weight of the ice during the last ice age. After the ice retreated the land has slowly risen. We therefore find scattered marine deposits up to 60 m above today's sea level in Bjørndalen (figure 3). Dark blue colors show areas with thick marine beach deposits, often with signs of wave action on the surface. The material consists of well-sorted and rounded gavels. Light blue colors indicate thin or discontinuous beach deposits, often draping other glacial till or glaciofluvial sediment.

The beige and brown shades on the map represent areas covered with solifluction material of different types. This is material that has been molded and sorted by frost action to an extent that the sediment origin is not distinguishable. The repeated freeze-thaw cycles that take place in the ground, above the permafrost table, moves and disturbs the ground on Svalbard. On slopes this results in a slow creep of material down-slope, sometimes forming a continuous solifluction sheet that slowly moves downwards towards the valley bottom (figure 2).

The yellow and orange on the map represents fluvial and glaciofluvial deposits. These deposits consist of stone, gravel and sand that have been transported by running water (figure 1). The particles are sorted and rounded by the river water and stacked on top of each other in distinct layers of varying grain size. The finest particles, clay and silt, were washed out and transported through the fluvial plains to the sea.

SKREDAVSETNINGER PÅ SVALBARD / *SLOPE PROCESS DEPOSITS ON SVALBARD*

Steinsprang / *Rockfall*

Kort utløpslengde, bratt vifte.
Short runout, steep surface gradient.

Snøskred / *Snow avalanches*

Middels utløpslengde, konveks (rund) overflata og langsprofil på viften.
Medium runout, convex surface profile.

Jordskred - flomskred / *Debris flows*

Lang utløpslenge, konkav langsprofil, slak vifte med tydlige løp på overflatan.
Long runout, gentle surface gradient, concave surface profile with erosion tracks.

Reference to this map:
L. Rubensdotter, A. Romundset, W.R. Farnsworth and H.H. Christiansen, 2015: Landforms and sediments in, Bjørndalen-Vestpynten. Svalbard. Quaternary geological map, 1:10 000. Geological survey of Norway.
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Lower sea level during the ice age - but all the same higher than today

A large ice sheet covered Svalbard during the last ice age. This ice sheet continued over the Barents Sea onto mainland Scandinavia and all the way down to today's Germany, Poland and southern England. Large ice sheets were developed on most continents covering up to a fourth of all landmass on earth, compared to a tenth today. The ice retained enormous amounts of water, lowering the global sea level down to roughly 130 m below today's level. This global change is called a *eustatic* sea level lowering. Nevertheless we find marine deposits high above today's sea level on both mainland Norway and on Svalbard. This is due to the enormous weight of the large ice-sheet pressing down the earths crust. This process is called *isostatic* depression and this could be up to several hundreds of meters where the ice sheet was thickest. When the ice melted, the earth's crust was still very compressed, and it took a long time for it to bounce back again. Earth's crust is still rising in Scandinavia and Svalbard, which means the land is still recuperating from the last ice age, ending 10,000 years ago.

Simultaneous with the uplift of the land resulting from the removed ice-loading, there has been a rise of the global sea level. While this eustatic sea level rise has occurred similarly in all oceans, the uplift of the land has varied substantially depending on the previous ice-thickness. The sum of these two variables (land uplift and global sea level rise) is what we can observe as different patterns of sea level change, imprinted on the landscape. The area at Bjørndalen-Vestpynten has experienced an almost continuous sea level fall since the melt of the last glacial ice-cover (Figure 3).

Photo: W.R. Farnsworth

Figure 3. Photo from the beach towards the high marine terrace located in the outermost of Bjørndalen. The arctic shoreline is a harsh environment that shapes the landscape through wave erosion, deposition and sea-ice abrasion.

Marine deposits in Bjørndalen-Vestpynten

The highest marine deposits on this map lie at 60-70 m above present sea level, showing where the coastline stood directly after the last ice-age. This level is called the upper marine limit. The precise elevation of this is difficult to pinpoint due to the severe modification of the landscape by frost action and other processes.

To distinguish material deposited below sea level we look for signs of marine life (shells or similar) or morphological traces of wave sorting, beach ridges or beach cuts. On this map we find these signs particularly in the Vestpynten area, around the airport. Here we see a lot of beach-ridges, forming series due to the continuous lowering of the sea level. In Bjørndalen we find scattered terraced marine deposits with signs of old wave action on top and steep sides towards the valley bottom (Figure 3). The material inside the deposits vary in composition and may have been deposited as till or glaciofluvial material at the last ice-retreat. They have however been strongly modified by beach-processes and are therefore mapped as marine deposits with blue colors. The total area of marine deposits in Bjørndalen was most likely larger from

Photo: L. Rubensdotter

Figure 4. Large Debris flows have repeatedly come down the slope and deposited coarse material in a fan that has eroded flow tracks and large levées on the surface. Note person for scale (2m).

Debris Flows - rocks in motion

Debris flows and debris floods are partly overlapping terms that describe the failure and collapse of material on a slope. The different terms are primarily related to varying water content in the moving mass. They often start in, or are channeled into, gullies, channels or other drainages paths. A debris flow is commonly composed of mix sediments (stones, gravel, sand and soil), vegetation and water. The material will combine to form a rapid mass movement down slope. The starting point is usually on inclinations over 30° but can also occur on more gentle slopes depending on the percentage water. Imagine fast moving wet cement, with boulders and vegetation, running down the slope and continuing over the more gently sloping valley bottom. The more water or snow in the moving mass, the longer the outrun will be before the flow stops. Most of the debris is deposited in lobes or tongues at the bottom of the slope but a significant amount of material is also left alongside the path of the debris flow forming elongated ridges on the flanks of the track called levees (Figure 4). Debris flows often occur on slopes already covered with other types of slope process deposits, such as snow avalanche or rock fall deposits. The debris flows then act a secondary transport agent that brings the material further out into the valley. As debris flows are recurring events, the continued process of erosion and deposition over time leads to the development of debris flow gullies and debris flow fans.

In Bjørndalen-Vestpynten we see many debris flow fans and tracks on the slopes. The tracks come in all sizes from the decimeters scale up to several meters wide. Signs of debris flows can be seen as everything from sheets of debris flow deposits on the slopes, to deeply incised tracks with high leveés, to large deposits with lobes and leveés reaching nearly to the valley floor. The deposits consist of everything from sands to large boulders. It can also be noted that several cases of debris flows in this area originated as slush avalanches released in over saturated snow, which further down the slope eroded into the ground and incorporated stones and sediments and thus became a debris flow.

The development of the landscape

The Svalbard landscape is formed through a combination of tectonic uplift and subsequent denudation. The sedimentary rocks that form the mountains were moved to their present places in the landscape through tectonic processes. Unconsolidated sediments are formed as the mountains are worn down (eroded) through weathering, river erosion and slope processes. Valleys incised into wide mountain plateaus are the primary landscape features. River erosion was the primary process for valley formation before the large-scale ice ages commenced ca. 2.5 million years ago. Glaciers have since then moved through the valleys through the ice ages, widening them and giving them U-shaped profiles (Figure 1). The small V-shaped valleys seen today are either younger than the last ice age, or are positioned in a geographic direction protected from the linear erosion of the main ice-movement. When the last remnants of the ice sheet melted away from the mouth of Bjørnadalen, more than 10,000 years ago, it deposited glacial till and glaciofluvial river sediments.

Permafrost has been present in the Svalbard landscape since the last ice age, and so-called periglacial weathering and slope processes have therefore dominated. The result of these processes is present in the vast areas of weathered sediments on top of the mountain plateaus, as well as in the talus fans and extensive solifluction material draped over the valley slopes. The talus fan material originates as rocks weathered from the bedrock and transported with rock-fall and snow avalanches. Slush-flows and debris flows have in many places eroded and redistributed the fan sediments further out on the valley floors. The different slope processes result in different types of slope fans with different types of sedimentology, geometry and grain size distribution.

Photo: L. Rubensdotter

Figure 1. View into Bjørndalen from the coast, clearly showing the U-shaped valley profile and wide glaciofluvial riverbed. On the left, two V-shaped valleys feed fluvial and debris flow sediments into the valley.

Permafrost and related landforms

Permafrost is ground or bedrock that remains below 0˚C for at least 2 consecutive years. It is found in all non-glaciated parts of Svalbard. The permafrost thickness in Svalbard varies from a few meters, close to major rivers, lakes and sea-shores, to several hundred meters in the higher mountains. The ground overlaying the permafrost, which thaws every summer to an average depth of 1-2 m and refreezes during winter, is called the active layer. Repeated freezing and thawing will make particles of different sizes move differently in the soil column. Over time these movements in the uppermost soils will cause a sorting of particles on the surface, resulting in patterns of rings and polygons on flat ground and steps, stripes or lobes on the slopes. The sorted landforms that are developed from these processes are dependent on grain-size distribution and organic content in the soils and vegetation cover. The low winter temperature also causes thermal contraction of the ground, forming polygonal networks of frost-cracks with ice-wedges. Frost activity also causes a continuous creep of material down slopes, called solifluction, which may form large solifluction sheets.

In Bjørndalen-Vestpynten we find frost sorting, thermal contraction cracking of the ground (ice-wedge polygons) and solifluction landforms on the mountain plateau, marine terraces and gentle slopes. A clear example of a solifluction sheet can be seen on top of the marine terrace in the mouth of Bjørndalen, where coarse-grained material on the slope has moved onto the finer-grained marine terrace, forming a well defined solifluction sheet (Figure 2).

Figure 2. Coarse material from slope processes soliflucting (creeping) down onto a more fine-grained marine terrace forming a coherent solifluction sheet. →

Photo: W.R. Farnsworth