Notes

Use of vegetation types by Svalbard reindeer from Arctic winter to spring

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ABSTRACT. Svalbard reindeer were examined for their dependency on seasonal changes from January to May and their choice of certain vegetation types. Snow characteristics and accumulation appear to be the main factors for the changing use of vegetation types from open plains and wetland in January and February to slopes and areas with ridge and heath vegetation in April and May. The results confirm other studies of the grazing behaviour of reindeer and caribou on the Norwegian mainland and in North America.

Introduction

Svalbard reindeer (*Rangifer tarandus platyrhynchus*) comprise one of the northernmost reindeer populations. Their presence is restricted to Spitsbergen (76–81°N), where they are the only mammalian herbivores, and the population is not controlled by predators (Tyler 1987). The population is controlled, however, by weather conditions during winter, since increasing snow depth and snow hardness, as well as possible icing events, restrict forage availability (Reimers 1977, 1983; Aanes and others 2000). The vegetation cover is very sparse and mainly restricted to plains, river valleys, and bird cliffs (Berge 1998).

Svalbard reindeer are generalist herbivores. They feed for biomass and not for quality (Wegener and Odasz-Albrigtsen 1998; Van der Wal and others 2000). The low plant species richness and the limited number of species representing main vegetation biomass in high Arctic regions give herbivores fewer occasions to select for specific plant species (Klein and Bay 1994; Klein 1996). In addition, there is a reduction of food density in some patches due to competition, and a more aggregated patch distribution on a large spatial scale (MacArthur and Pianka 1966; Klein and Bay 1994).

Spitsbergen is an Arctic semi-desert compared to other reindeer habitats. Low precipitation (200–300 mm a^{-1}), cold winter temperatures ($\bar{T} = -16$°C), low humidity, and high wind speed result in a thin snow cover with a high temperature gradient, slow crystallisation processes, and a high snow sublimation rate (Førland and others 1997; Jaedicke 2001). Furthermore, wind transport breaks up the ice crystals, which results in very hard and dense snow layers (Jaedicke 2001). These difficult conditions mean that the feeding behaviour and patch choice of Svalbard reindeer during the winter may be different than those of other reindeer. Bjune (2000) provided the only description of Svalbard reindeer's diet during winter; these data were collected indirectly, by pollen analysis, from February to May.

Methods

This study on the use of vegetation types by Svalbard reindeer is part of a project on their general behaviour (Lindner 2001). It was conducted in winter, spring, and autumn 2000 in different areas of Nordenskiöld Land, Spitsbergen.

Reindeer were observed from January to May, independent of sex and age. The first group of reindeer containing at least three individuals was chosen for daily observations. The activity of reindeer was recorded every 10 min by scan-sampling (Altmann 1974). The number of useful grazing observations out of total scan samples (N_{scan}) varied with time, and only a few groups (n) observed could be used for the present analyses (January: $n = 6$, $N_{scan} = 95$; February: $n = 28$, $N_{scan} = 556$; March: $n = 14$, $N_{scan} = 439$; April: $n = 6$, $N_{scan} = 336$; May: $n = 28$, $N_{scan} = 580$). The positions of reindeer while feeding were estimated using GPS data of the observer's position and by considering distance and angle to the animals' positions.

To estimate the use of different vegetation types, the vegetation was roughly characterised in June and September 2000 at locations where reindeer groups were observed during winter. Vegetation diversity was characterised on a large scale by the dominant vegetation type, describing the winter feeding place. A slightly modified classification system, after Van der Wal and others (2000), was used for this purpose. All vegetation types used by the reindeer were grouped into a few main types (Table 1).

Snow accumulation was measured automatically with an ultrasonic distance sensor until the beginning of May. Snow characteristics were recorded for each sampling day, by classifying the snow as powder, wet, hard-packed, snow crust, or ice.

A chi-square test was carried out to test the hypothesis that reindeer use the described vegetation types independent of time of the season for feeding. The hypothesis applies to January until May.

Results

The reindeer mainly used five of seven accessible vegetation types: ridge vegetation, *Luzula* heath, graminoid sward, *Alopecurus–Equisetum*–wet-moss vegetation, and *Dupontia–Eriophorum* marshes. Reindeer fed on available vegetation types in different ways from January

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Table 1. Vegetation types from dry to wet, after Van der Wal and others (2000).

Vegetation type	Characteristics
Polar desert	Virtually non-vegetated Characterised by *Papaver dahlianum*
Ridge vegetation	Low vegetation cover (generally less than 20%) *Dryas* sp., *Cassiope* sp., *Salix* sp., *Polygonum* sp., *Saxifraga oppositifolia*
Luzula heath sward	*Luzula* sp., *Salix* sp., *Poa arctica*, sometimes with *Alopecurus* sp. Graminoid *Poa arctica*, *P. alpigena*, *Festuca cryophila*, some *Alopecurus* sp.
Alopecurus–Equisetum– wet moss	Hummocky structure, moss dominated *Alopecurus* sp., *Equisetum arvense*
Phipsia (late snow melt)	*Phipsia* sp., *Saxifraga hyperborea*, *Ranunculus pygmaeus*
Dupontia–Eriophorum marshes	*Dupontia* sp., *Eriophorum* sp., *Ranunculus spetsbergensis*

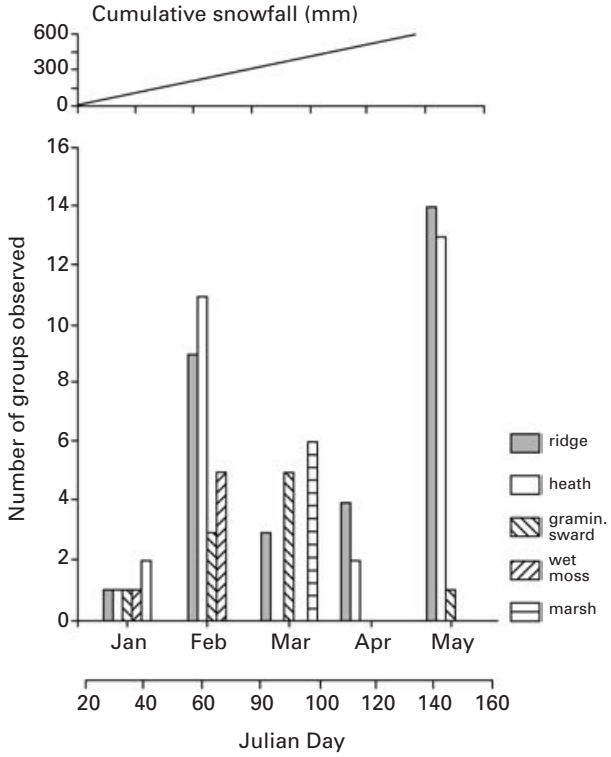


Fig. 1. Use of vegetation types by Svalbard reindeer throughout the winter–spring period. The upper figure shows the average snow accumulation.

to May. The chi-square test result showed a clear dependency on the use of vegetation type by reindeer during the winter season ($D = 53.96$, $df = 16$, $p < 0.01$). Figure 1 indicates a tendency, where moist-vegetation types (graminoid sward, wet-moss vegetation, and marshes) are more frequently used from the end of January until March. Dry-vegetation types, such as heath and ridge vegetation, are frequently used by reindeer in April and May.

As justified by a chi-square test, the snow characteristics also depend on the season ($D = 22.31$, $df = 8$, $p < 0.01$). Whereas hard-packed snow and ice prevail during January and February, March is characterised by hard-packed snow and snow powder in almost equal shares, and during April and May all classes occur except ice (Table 2).

Discussion

Even during winter, reindeer have certain preferences in their choice of foraging places. They look for wet-ground vegetation from January to March, when there are almost unchanging snow characteristics. At the beginning of the year, precipitation is still low, and strong winds keep the plains open where wetland vegetation mainly occurs. When snow starts to accumulate and becomes hard-packed around February, the windblown ridges, with sparse vegetation, become alternative feeding grounds, although they are low in available forage (LaPerriere and Lent 1977; Nellemann and Fry 1995; Ferguson 1996; Nellemann 1996). Skogland (1984) observed that the Norwegian wild reindeer population (*R. t. tarandus*) was restricted to chionophobe vegetation types during the period with highest snow accumulation. The same is true for the Peary caribou (*R. t. pearyi*, Adamczewski and others 1988). While wind speed decreases towards spring, snow accumulates mainly as powder during March, and the open plains again become used by reindeer. In contrast to the mainland, the snow depth at Spitsbergen is shallow enough for the reindeer to be able to dig through it (Skogland 1974). At the end of winter (April–May) sunshine releases snow-free patches for feeding reindeer on ridges and slopes by sublimation and melting processes. Places with ridge and heath vegetation are preferred foraging habitats. These findings are consistent with the data of Sørmo and others (1999), in which reindeer were shot in April and the gastrointestinal contents examined. At this time the first protein-rich buds are available below the thin ice crusts or a thin snow cover. Solar radiation is able to penetrate the thin layer and warms the soil, inducing the growth of the first vegetation (Bjune 2000).

Even though the snow-accumulating mechanism at Spitsbergen differs from other reindeer habitats in that there is little snow cover and a hard and dense snow layer (Jaedicke 2001), and Svalbard reindeer differ greatly from other *Rangifer* spp. in behaviour, anatomy, and physiology

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Table 2. Snow characteristics on the observation days. The data of January–February and April–May are pooled, because of too few samples during January and May.

Number of days with defined snow characteristics					
Month	Powder	Wet	Hard-packed	Snow crust	Ice
Jan–Feb	2	0	15	1	3
March	4	0	3	0	0
April–May	4	4	3	2	0

(Skogland 1989; Cuyler and Øritsland 1993; Sørmo and others 1999), they show the same foraging strategies as their relatives in regions with high snow cover. They use snow-poor plains at the beginning of winter and, later, when snow accumulation increases, they shift to windblown ridges.

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Carl von Ditmar, 1822–92: a geologist in Kamchatka

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ABSTRACT. From 1851 to 1855, the Baltic-German geologist Carl von Ditmar explored and made scientific observations of Kamchatka. This area had first been scientifically investigated by Georg Wilhelm Steller and Stepan Petrovich Krasheninnikov in the 1730s and 1740s. However, until the last decade of the nineteenth century, little was added to the studies by Steller and Krasheninnikov, despite almost all of the Russian circumnavigations having gone through Kamchatka. It was only in 1890 that Ditmar's detailed investigation of the natural history and peoples of the Kamchatka peninsula was published. Although Ditmar remains little known to the broader public, his investigations are still used by those investigating Kamchatka.

Life

Carl von Ditmar (often Karl von Ditmar) was born 22 August 1822 (old calendar) into the family of Woldemar von Ditmar of Vana-Vändra (Alt-Fennern) estate, private senior lecturer of Roman, Livonian, and criminal law at the University of Tartu (Dorpat). The education of the younger Ditmar was carried out at the newly opened private gymnasium of Krümmer in the town of Võru (Werro) from 1832 to 1840. He then attended the University of Tartu, first in economics and later in geology. In 1846, shortly after his graduation, Ditmar defended the academic degree of candidate. Hermann Abich, a renowned geologist and explorer of the Caucasus, encouraged him to begin work in geology and invited him to the Caucasus (Schrenck 1892: 312). However, Ditmar instead decided to continue his studies as an auditor student at Leipzig and Berlin universities and at the famous Academy of Mining in Freiberg, as well as to travel in Germany, Italy, France, and Russia (1846–49). In Germany, one of his teachers was the geologist Gustav Rose, who had travelled in Russia with Alexander von Humboldt (Tammiksaar 1995: 130).

In 1850, Count Maximilian von Leuchtenberg, president of the St Petersburg Mining Institute (who had also carried out geological investigations), asked Alexander Theodor von Middendorff, the famous explorer of Siberia, to find a geologist to go into the service of Vasiliy Stepanovich Zavoiko, military governor of Kamchatka, with the aim of carrying out investigations into local natural resources. Middendorff recommended Ditmar, whom he had met in St Petersburg in 1848 through the auspices of Alexander von Schrenck, senior lecturer of the University of Tartu (Schrenck 1848). Ditmar soon received an official invitation from von Leuchtenberg.

In 1851–54, Ditmar made nine exploratory trips in Kamchatka and the peninsula of Taigonos. An extensive expedition took place via boat along the eastern coast of Kamchatka, from Petropavlovsk to the mouth of the river Kamchatka, in summer 1852. From there the expedition moved upstream as far as the wellsprings, and then back to Petropavlovsk. The route of another longer trip in summer 1853 covered the western coast of Kamchatka and the peninsula of Taigonos. During these expeditions Ditmar carried out a thorough investigation of Kamchatka, excluding only the most southern and northern areas of the peninsula because of the local complications of the Crimean War (Ditmar 1890). In 1855–56, Ditmar explored the Priamurye (as the middle and the lower courses of the Amur River were called in Russia in the nineteenth century) and then returned through Siberia to St Petersburg. He did not remain in the capital long, however, as his mother — born Charlotte von Stackelberg — had bought him the Estate of Käru (Kerro) in Livonia in 1851 and it was waiting for its master (Ditmar 1890).

The estate was not in good condition, and it took 30 years and a great deal of effort to improve it to Ditmar's desired condition. He built new manor houses, founded a kindergarten and a school, and introduced steam engines into the agrarian practices (Schrenck 1892: 313). Ditmar was so busy with the estate that he did not find time to prepare his expedition diaries for publication, so he published shorter accounts of the expeditions in St Petersburg and Gotha (Ditmar 1856b, 1860).

In the mid-1880s, symptoms of heart disease appeared, and Ditmar began to spend his winters in Tartu. The ethnographer Leopold von Schrenck (the brother of Alexander von Schrenck) — a member of the St Petersburg Academy of Sciences, an aquaintance from student years, and a colleague with whom Ditmar had for a short time explored the Priamurye — suggested that Ditmar publish his expedition diaries (Schroeder 1921: 135–136). These were published in 1890 under the title *Reisen und Aufenthalt in Kamtschatka in den Jahren 1851–55* in the serial publication *Beiträge zur Kenntniss des Russischen Reiches und der angränzenden Länder Asiens*. The expeditions to the Amur were omitted from the publication, because after this region had been incorporated into the Russian Empire, it had been investigated by the Baltic-Germans L. von Schrenck, Carl Maximowicz, and Richard Maack, as well as the German naturalist Gustav Radde.

The book was received positively by scholars, as Ditmar's information was quite 'fresh' by comparison with that available from the eighteenth century, which was the last other time scientific data had been collected. In 1854, during the Crimean War, a British–French flotilla had attacked Petropavlovsk. Despite a successful defence, in March 1855 the main port of the Russian Far East had been transferred from Petropavlovsk to Nikolayevsk in the mouth of the Amur River (Ditmar 1890). After this, the next naturalist to make a serious study of Kamchatka

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Fig. 1. Carl von Ditmar (Estonian National Museum 866: 85).

did not reach it until 1908–09. This lack of information led to the first volume of the monograph also being published in Russian (Ditmar 1901). Ditmar had started compiling a systematic account of the expedition, but he could not finish it, and it was published in an incomplete state.

In Ditmar's final years in Tartu (1887–92), his old love for science returned (Anonymous 1892). He was active and participated in the Estonian Learned Society, the Naturalists' Society of Tartu, and in the Geographical Society of Tartu (Tammiksaar 1995). He also gave financial support to the network of stations measuring precipitation in Estonia, Livonia, and Kurland. He died in Tartu on 15 April 1892.

Scientific contribution

The beginning of the scientific investigation of Kamchatka is associated with Vitus Bering's second expedition (1733–43), which in Russian literature is called the Great Polar Expedition. On this expedition, the German Georg Wilhelm Steller, an adjunct of the St Petersburg Academy of Sciences (1737), and a student, Stepan Petrovich Krasheninnikov (an adjunct of the same academy in 1745), made the first serious studies of Kamchatka that reached the academic community. Even as late as the middle of the nineteenth century, their descriptions (Krasheninnikov 1755, 1766; P[allas] 1798) were the basis of scholarly information on Kamchatka in Russia, as the other potential sources — the Russian circumnavigators, including Adam Johann von Krusenstern, Otto von Kotzebue, Ferdinand von Wrangell, and Friedrich Benjamin — had made only short stops there and, other than bringing back botanical collections, added little to Steller's and Krasheninnikov's writings. Only the German geophysicist Adolph Erman (1848), who had travelled through Russia in 1828–30 and had made a lengthy stop in Kamchatka, had published more thorough data on the peninsula. Thus, Ditmar's expedition, during which he detailed climate, orography, botany, fauna, and ethnography, as well as describing the cartography of Kamchatka, was of great importance scientifically.

The main objective of Ditmar's expedition had been the study of the geological structure of Kamchatka, since Russian state officials did not have information on the natural resources of the region. Petropavlovsk was a very costly port, and the discovery of significant natural resources would have expedited the development of the desolate peninsula, thereby decreasing the expenses for the port's management. However, Ditmar did not find noteworthy deposits. Instead, he presented a theory of the origin of Kamchatka, produced the first geological map of the area, and compiled a list of active and extinct volcanoes of Kamchatka (17 volcanoes were mentioned for the first time) (Ditmar 1856b, 1860, 1891). According to the Russian geologist Vladimir A. Obruchev (1937: 456, 483–484), Ditmar's geological investigations of Kamchatka and Priamurye provided accurate conclusions regarding the geology of the Far East and Siberia. According to these theories, the age of the rock increased from the Far East to the inner regions of Siberia. However, Ditmar was unable to write a systematical account of the geology of the area, as he had sent his collections to Humboldt and Rose in Berlin (Tammiksaar 1995: 132). The latter, however, died before they could work on the collection. Ditmar's manuscript 'Materialien zur einer geologischen Beschreibung Kamtschatka's' also remained unpublished, since L. von Schrenck had given it to the geologist Konstantin Khrushchev who was to use it to write a petrological paper (Schmidt 1900: iv–v). There is no information available concerning the fate of the paper.

Ditmar's most important results regarding the physical geography of the area were the description of the Central Mountain Range (Sredinnyy Khrebet) of Kamchatka (a name he introduced), a list of geographical points of the peninsula (65 pages), and the completion of the mapping of Kamchatka's coastal line. He also proved that the high mountain range did not go through the isthmus of Parapol, which connected Kamchatka with the continent, as was depicted in the Russian maps of that time. However, his conclusion (like that of Erman) that the Itcha volcano in the centre of the mountain range (3621 m) was the highest point in the peninsula was erroneous.

Ditmar's conclusions regarding the primary factors influencing the climate of Kamchatka — the great height of its mountain range, its extent from north to south, and the effect of the cold Bering and warm Kuroshiwo

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streams — were correct. He also confirmed hypotheses put forward by Karl Ernst von Baer: that permafrost could be found in the northern part of Kamchatka (Tammiksaar 2001: xlii, 2002), and that the presence of permafrost had an effect on the local climate. In addition, Ditmar was one of the first investigators to study aufeis — which is characteristic of river sections with rapid currents in areas of permafrost, where ice forms and thickens on the bottom of a river; as a result, large valleys filled with ice come into being — and its origin in eastern Siberia. He erroneously considered river sections with slow currents and rich in snow-bound winters as the prerequisites for the origin and development of aufeis (Ditmar 1853). In the course of botanical investigations, Ditmar was also the first to discover indigenous woods in the midst of Kamchatka.

Ditmar was very interested in the life of local natives and was exceptionally understanding and humane towards them (Schrenck 1892: 314). He reacted painfully to the russification of Itelmens and Koryaks. He differentiated five national groups of Koryaks according to their language, the acceptance of the ways of land cultivation introduced by Russians, the decrease of hunting as the means of providing themselves with food, and relative numbers of them living in one place. He compiled the first map of the distribution of the nations and their language dialects (Ditmar 1856a), and he found evidence of the kinship of the Chukchi and Koryak languages. In his investigations proving the theory of palaeo-Asiatics, Schrenck drew general conclusions on the ethnography of the natives of Kamchatka on the basis of the material collected by Ditmar (Tammiksaar 1995).

Conclusions

The results of Ditmar's expedition to Kamchatka had great scientific value and were so prized by scholars that even 35 years after the expedition, Carl von Diener, a professor of geography in Vienna, collected a scanty amount of Ditmar's expedition results and published it (Diener 1891). The fact that Alexander von Humboldt used Ditmar's results in his *Kosmos* (1858: 391) proves the great value attributed to them. Ditmar should be considered the first geologist, geographer, and ethnographer to have worked in Kamchatka. His collections and diaries are still used today. In his honour, the name Ditmar was given both to a volcano (height 1297 m) by Russian scientists in the twentieth century, and to a species of orchid (*Platanthera ditmariana*) in Kamchatka.

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Interaction of fluvial and gravitational processes in Laagkolldalen, Nathorst Land, central Spitsbergen, Svalbard

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ABSTRACT. At three localities in Svalbard, there are unusual geomorphological features, where solifluidal sediment bodies were at first eroded at the bottom and not at the top, as should normally be expected. It is suggested that the thermoerosion of the refrozen solifluidal sediment is caused by water running down the valleys or gullies it blocks. Thermoerosion affects the lower part of the frozen sediment, whereas the upper part remains frozen, thus creating a bridge-like feature and, consequently, subsurface drainage over shorter distances. As all three localities have a similar lithology in common, this seems to be a significant factor.

General area description

The small valley Laagkolldalen is situated in Nathorst Land, central Spitsbergen, at 77°40′N, 15°E (Fig. 1). The area is under the climatic influence of the Spitsbergen Current and thus has a maritime Arctic climate. The annual mean temperature at Isfjord Radio, 55 km north, is –4.6 °C, with average temperatures of –12.2 °C in March, the coldest month, and +4.7°C in July (Åkerman 1980).

Laagkolldalen stretches approximately 5 km in a northeast–southwest direction from Van Mijenfjord in the north, reaching maximum heights of less than 200 m above sea level at the watershed with its southern counterpart, Forkastningsdalen, which drains to the south into Bellsund. Laagkolldalen has mostly steep slopes with inclination angles of up to 40°. Geologically, the area is characterized by the mid-Jurassic Janusfjellet Formation, which belongs to the Adventdalen Group (Hjelle and others 1986; Dallmann and others 1990). The Janusfjellet Formation 'consists mainly of bioturbated, dark grey to black bituminous shales, green-grey siltstones' (Dallmann and others 1990: 26) deposited in a marine environment. Due to the combined convergent and strike-slip tectonics that occurred mainly in the Palaeocene and Eocene, the area is strongly deformed, and thus the thickness of the Janusfjellet Formation can only roughly be estimated at about 500 m. Faulting and folding on different scales occur in Laagkolldalen, and dip angles vary. Generally, structural elements tend to have a NNW–SSE direction.

Description of the observed phenomena

Laagkolldalen was visited in April 2000. The author was a member of a private ski expedition to the area, which is rarely visited. During the visit, geomorphological phenomena were observed that, from the author's field experience from various parts of Svalbard, must be regarded as rare. As far as is known to the author, these have not been described previously.

As shown in Figures 2 and 3, a part of the valley that is approximately 2 km south of Van Mijenfjorden is partly blocked with material identified as being derived from mass movement from upper parts of the slope. The type of destruction of the original sedimentary structure of the material suggests flow-like characteristics of the mass movement and not block-sliding. Thus it is inferred that originally the river must have been dammed by the mass movement. An overflowing of the resulting lake, leading to erosion of material derived from mass movement, would be the process to be expected normally.

However, in the case of Laagkolldalen, the material was stabilized by permafrost, which prevented fluvial erosion. The lower parts of the slopes are to a large degree protected from direct solar radiation, which contributes to conditions favourable for quick permafrost development in young solifluidal sediments. Thus, thawing from the surface is effectively prohibited. Thermoerosion takes place due to energy transported to the lowermost part of the frozen material by means of meltwater. The river has thermoeroded the lower part of the mass movement, resulting in subsurface drainage for short passages of the valley. This phenomenon was observed twice in Laagkolldalen within a distance of a few hundred metres.

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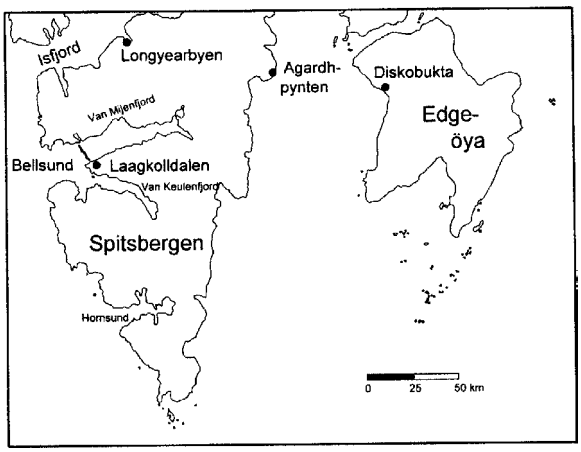


Fig. 1. Map of the southern part of the archipelago of Svalbard. The locations mentioned in the text (Laagkolldalen, Agardhpynten, Diskobukta) are marked with black squares.

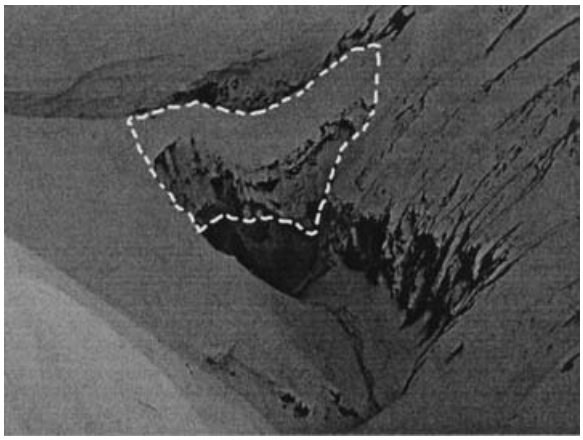


Fig. 2. The southern location in Laagkolldalen, photographed with a telephoto lens from an oblique position from the north at a distance of approximately 800 m. Dashed line indicates solifluidal sediment, thickness approximately 5 m.

The southern location shows a morphology resembling a bridge above a hole approximately 6–7 m high and 10 m long (Figs 2, 3).

At the second location, several hundred metres to the north of the first, the river disappears into a smaller hole with a diameter of less than 3 m at the entrance, where the thickness of the covering sediment is a few metres. The river remains below the surface for several hundred metres, being visible only through a few small holes in the covering sediment.

Similar phenomena at other locations in Svalbard

Close to Diskobukta on Edgeøya, a canyon steeply incised between Blanknuten and Drivdalsryggen (77°58′N, 21°18′E) is blocked in a similar way. In this case the origin of the blocking material could not be clearly material, it is thought to originate from mass-movement. Small-scale solifluction has covered the surface, thus making it

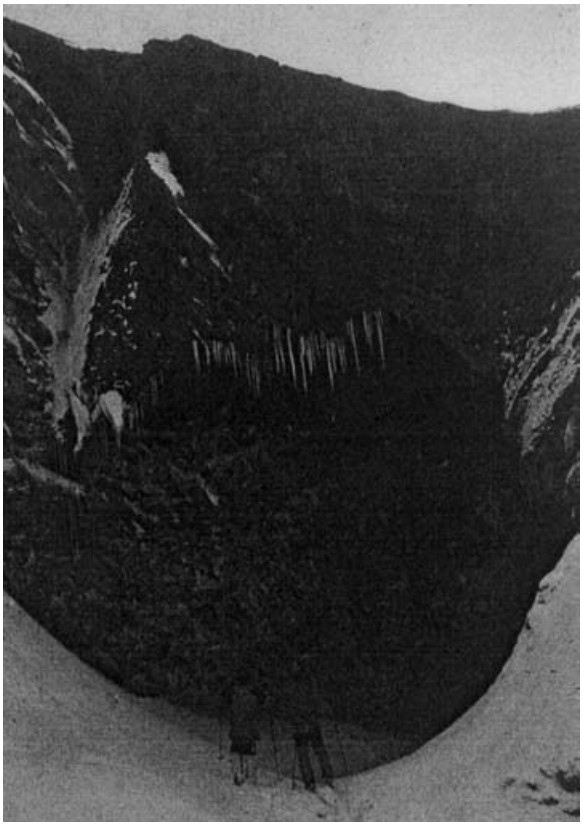


Fig. 3. The same location as shown in Fig. 2, seen from a short distance from the south. Persons indicate scale.

more difficult to see sedimentary details. The river flows beneath the surface for a distance of 30–40 m.

In this case the surrounding bedrock belongs to the Triassic Kongressfjellet Formation, which consists of dark grey shales and silty shales in the lower part, and mainly black paper shales in the upper (Flood and others 1971), lithologically similar to the Jurassic Janusfjellet Formation in Laagkolldalen. The area is not affected by tectonics.

At Agardhpynten on the east coast of Spitsbergen (78°05′N, 19°E), fluvial erosion has cut several little gullies a few metres deep into east-facing slopes. At several locations, subsurface drainage of the gullies could be observed.

The bedrock at Agardhpynten has a similar stratigraphical position as in Laagkolldalen, being determined as Agardhfjellet Formation belonging to the Janusfjellet Subgroup by Miloslavskij and others (1993). Thus, the lithology is similar to Laagkolldalen, whereas faulting and folding are not apparent.

Conclusions

Together with special lithological and geomorphological circumstances, a combination of permafrost and thermoerosion is able to create subsurface drainage on a spatial scale of several hundred metres. Permanently frozen material derived from mass movements seems in some cases to be vulnerable to the following sequence of

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processes. Thermoerosion is thought to be an important initial factor to weaken the sediment sufficiently to allow fluvial erosion to take place. Both processes cannot be decoupled, but seem to be dependent on each other in that thermoerosion weakens the previously frozen material, which then is ready for fluvial transport. Lithological factors are thought to be of major importance, as the author has observed similar phenomena only at two other locations in Svalbard, both of them with similar lithologies.

Lithologies particularly vulnerable to this type of erosion seem to be lower and mid-Mesozoic fine-grained marine sediments.

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Travels with mules: Antarctica 1912

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ABSTRACT. Seven pack mules were taken from India to the Antarctic in 1912. Their preparations for the voyage and for use in exploration are described. The names of the animals and of their leaders are recorded from the account of their expedition from winter quarters to find the last camp of Scott's Polar Party.

It may not be generally known that seven Indian pack mules were taken to the Antarctic in *Terra Nova* for use in exploration during the southern summer of 1912. They had been obtained from the Indian authorities by Captain Robert Falcon Scott on the advice of Captain L.E.G. Oates.

For a considerable period before embarkation the mules were exercised daily in a specially constructed box, which reproduced the rolling and pitching of the vessel, in order to strengthen their shoulder muscles. Their gear and equipment had been designed for the snow at about 7000 feet in the Himalayas. These proved equally effective in the Antarctic. Their clothing was made of canvas, lined inside with felt; snowshoes enabled them to pull well over bad surfaces.

The mules arrived at Cape Evans in May 1912 and were given into Bill Lashley's care for the winter. Unlike their predecessors, the Manchurian ponies, the mules were always eager to get out during the winter for exercise. They were also found to be more tractable than the ponies (Lyons 1924).

After the winter, eight men and the seven mules made a search southwards for the bodies and records of Scott and the Polar Party. Charles Wright was in charge as skilled navigator. The mules and their leaders were: Khan Sahib, led by Edward Nelson; Lal Khan, led by Tryggve Gran; Pyaree, led by Lashly; Rani, led by Tom Crean; Gulab, led by Thomas Williamson; Begum, led by Patrick Keohane; and Abdullah, led by F.J. Hooper. Two dog teams followed the mules.

Snow goggles provided by the Indian authorities were worn by the mules while on their lines, helping them to avoid snow blindness. Their ration of oil cakes and oats was unpopular. 'They would eat man or dog biscuits, tea-leaves and tobacco, ash and various portions of garments, with the greatest relish, but they needed the utmost care and coaxing to be induced to touch their rations at all' (Atkinson 1913: 342). Two animals had to be shot on the return when their condition deteriorated and in order to provide food for the dogs (Atkinson 1913: 348). The remainder returned to Cape Evans, after a journey of nearly 400 miles.

There are many 'ifs' and 'buts' about Scott's last expedition. Had Indian mules, rather than Manchurian ponies, been taken south, perhaps he and his companions would have returned alive.

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