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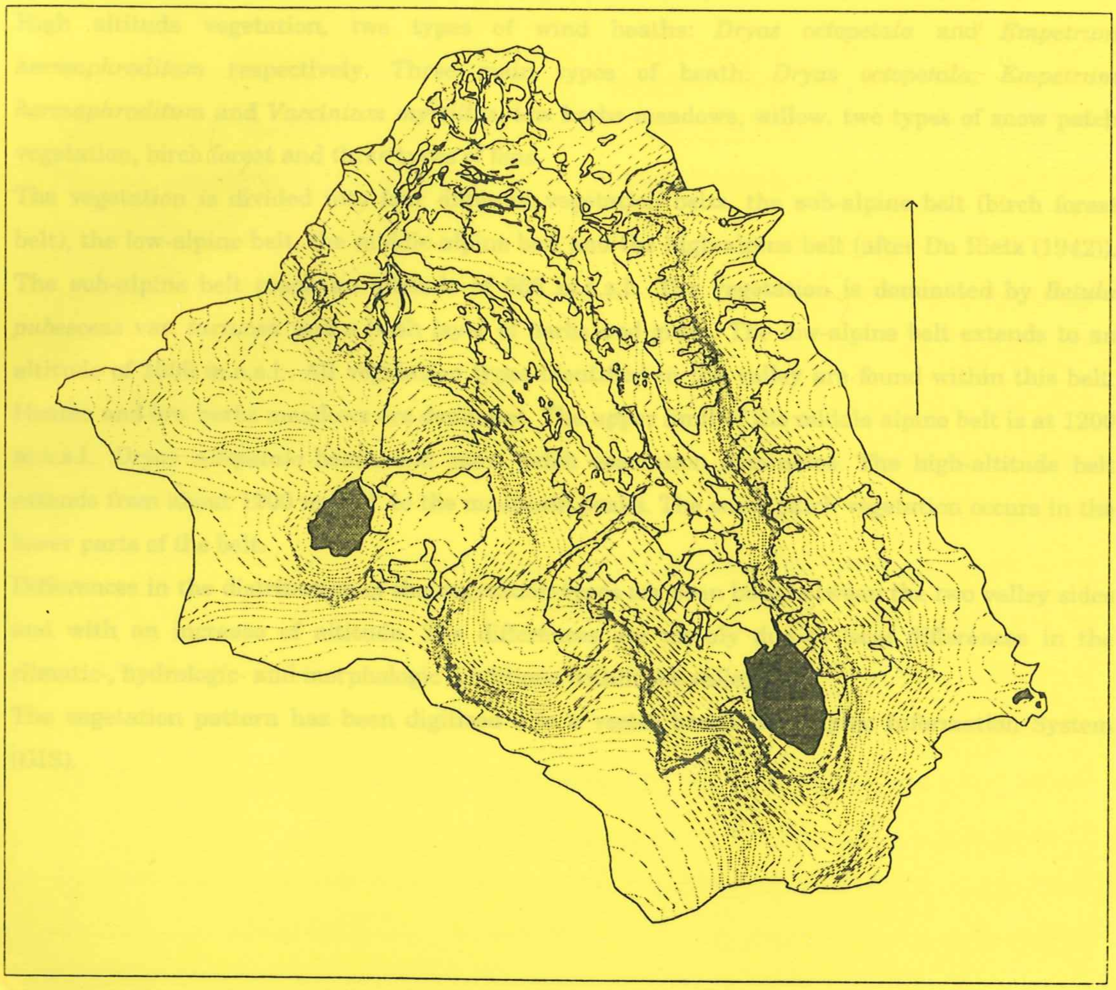

The Vegetation distribution in the Kärkevagge valley

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Abstract

A medium scale map of the vegetation-types and their distribution in the Kärkevagge valley, located in the northern Lapland has been made based on photo-interpretation of aerial infra-red colour photographs (scale 1 : 60 000). Following vegetation types have been identified:

High altitude vegetation, two types of wind heaths: *Dryas octopetala* and *Empetrum hermaphroditum* respectively. Three main types of heath: *Dryas octopetala, Empetrum hermaphroditum* and *Vaccinium myrtillus*, low herbs meadows, willow, two types of snow patch vegetation, birch forest and three types of fens.

The vegetation is divided into four different vegetation belts, the sub-alpine belt (birch forest belt), the low-alpine belt, the middle-alpine belt and the high-alpine belt (after Du Rietz (1942)). The sub-alpine belt reach an altitude of 550 m.a.s.l.. The vegetation is dominated by *Betula pubescens* var. *turtuosa* and a bush layer of herbs and grass. The low-alpine belt extends to an altitude of 1050 m.a.s.l.. All vegetation types identified in the valley are found within this belt. Heaths and low herbs meadows are dominant. The upper limit of the middle alpine belt is at 1200 m.a.s.l.. *Dryas octopetala*-heath and snow patch vegetation dominates. The high-altitude belt extends from about 1200 m.a.s.l. to the mountain peaks. The snow patch vegetation occurs in the lower parts of the belt.

Differences in the distribution of the vegetation-types are seen both between the two valley sides and with an increase of altitude. The differences are mainly due to local differences in the climatic-, hydrologic- and morphologic conditions within the valley.

The vegetation pattern has been digitised into a vector based Geographic Information System (GIS).

Acknowledgement

This paper would not have been what it is without the many advises and the constructive criticism from both Peter Schlyter and Peter Jönsson, Thank you for your patience. Peter Persson has supported with useful climate data recorded in the Kärkevagge valley, covering most of 1993. Finally I would like to give my special thanks to Jessika Hellberg, Anders Jerre, Camilla Jönsson, Magnus Karlsson and Per Lindegård for their assistance during the field surveys.

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1 Mapping of alpine vegetation by the use of remote sensing

The advantages, in terms of accuracy, over-view and work speed, of aerial photographs for medium scale vegetation mapping are well-known. The use of infra-red sensitive films have further improved the abilities of interpreting the vegetation (Arnberg & Wastenson 1973). The infra-red film reinforces the contrast between different vegetation-types compared to black and white photographs, and the infra-red film usually give a better image quality when used from higher altitudes owing to the ability to a better penetration of haze in the infra-red interval than in the visible.

In Sweden techniques and methods for vegetation mapping in alpine environments, using remote sensing, have been thoroughly investigated and developed by Ihse & Wastenson (1975). Ihse and Wastenson concluded that infrared aerial photographs in a scale of 1:50 000 or larger were most useful for medium scale mapping.

A vegetation map can be of use for land use planing and monitoring. In alpine regions e.g. when assessing different areas with respect to their value for the reindeer grazing, their need of protection or their ability to withstand the pressure from human activities. The distribution of different vegetation-types and species, may be used to indicate water availability, substrate stability, nutritional- and calcium richness etc. This is particularly true in areas with steep environmental gradients and with minimal human modification of the vegetation distribution e.g. alpine areas. Knowledge about the distribution of the alpine vegetation may be used to stratify alpine landscapes with regard to the geomorphic processes operating in it (Frank & Thorn 1985).

2 Objective

The aim of this examination paper is to analyse and present a medium scale alpine vegetation map based on medium scale colour infra-red aerial photographs. The Kärkevagge valley, about 20 km west of Abisko, was chosen as study area. The results will be presented in a map together with a written description of the different vegetation-types identified in the valley.

3 The study area

The Kärkevagge valley is situated about 20 km west of Abisko, lat. 68°23'N and long. 18°20'E (fig 1). The name Kärkevagge is from the Lapish language and means ”the stone valley” which is a suitable name for this area. Most of the valley centre is occupied by a large number of huge boulders forming an almost impassable rubble. The rubble is surrounded by slopes with rich herbs- and heath meadows (making the valley exciting and very inspiring to a phytogeographer). The Kärkevagge valley has been the target of a number of different scientific projects through the years. Sjögren (1909), Mannerfelt (1945) and Holdar (1957) have done investigations of both processes and the vegetation in the Torneträsk area, including Kärkevagge. During the 50´s the valley was in focus for a classical pioneers study covering all major geomorphic processes in the valley (Rapp 1960). A revitalisation of the process studies in the valley has recently been initiated (Schlyter 1993).

Figure 1. The Kärkevagge valley and surroundings. After (Rapp 1960)

4 An outline of earlier classification schemes for vegetation distribution in northern Lapland

The vegetation of northern Lapland has been described by a number of phytogeographers, for instance by (Wahlenberg 1812, Vestergren 1902, Nilsson 1907, Fries 1917, Smith 1920, Tengvall 1920, Engqvist 1933, Du Rietz 1942, Kilander 1965 and Rune 1965). They have all used systems based on descriptions of vegetation distribution in different altitudinal belts. In general alpine vegetation change with altitude. The number of sensitive low-land species decreases with an increasing altitude, being substituted by more resistant alpine species.

Wahlenberg (1812) used both phytogeographic and climatic indicators when he discerned three regions above the timber line. Wahlenberg named the lowest region *Regio alpina inferior*, defined as beginning just above the timber line and ending at the upper limit of the willow shrubs. The region is often called the willow region or the willow belt. The second region he named the *regio alpina superior* and delimited to reach up to the snow limit. The area above the snow limit was named the *Alpium cacumina glacialia*. This limit was important in Wahlenbergs scheme and it seems like he considered the snow line to have a constant position, which it has not. This limit has been criticised by later phytogeographers as the snow line is a geographic limit, depending on several different climatic variables, and as inappropriate for a phytogeographic line of demarcation (Rune 1965). Apart from this the main features of the region division carried out by Wahlenberg (1812) appears to be largely valid even today. Later phytogeographers have improved the originally vague region descriptions and delimitations made by Wahlenberg.

Nilsson (1907) and Fries (1917) divided, based on a geomorphologic criterion, the alpine region into two parts, *alpina prima* and *alpina secunda*. The limit between *prima* and *secunda* was drawn at the beginning of the boulder lands, i.e. the extensive fields of coarse boulders that cover large areas of the mountains at high altitude. This division-line was also used by Smith (1920) and by Tengvall (1920) who named the belts *regio alpina fertilis* and *regio alpina sterilis*. This division has subsequently been criticised as geological, and by that should not be used as a phytogeographical boundary. From a geomorphologic perspective, in view of present mountains as to the development and age of boulder fields the use of these features for the delineation of current vegetation seem inappropriate.

The first attempt to make a separation of the mountain regions based exclusively on plant communities was made by Vestergren (1902). He outlined a division of the vegetation in the alpine region into three zones, corresponding to the present definitions of the low-alpine, middle-alpine and high-alpine belts.

Du Rietz (1942) presented the system describing the distribution of Swedish mountain vegetation, which now is currently used by Scandinavian phytogeographers. As this system is widely used it is thoroughly described in chapter 4.1.

4.1 Zones of the alpine vegetation in northern Lapland

As was mentioned above, Du Rietz (1942) presented a classification system which divides Swedish alpine vegetation into different belts based on the varying distribution of different species with respect to altitude (figure 2). Du Rietz defined five different vegetation belts of the Swedish mountain vegetation:

A. The coniferous forest belt
B. The birch forest belt
C. The low-alpine belt
D. The middle-alpine belt
E. The high-alpine belt

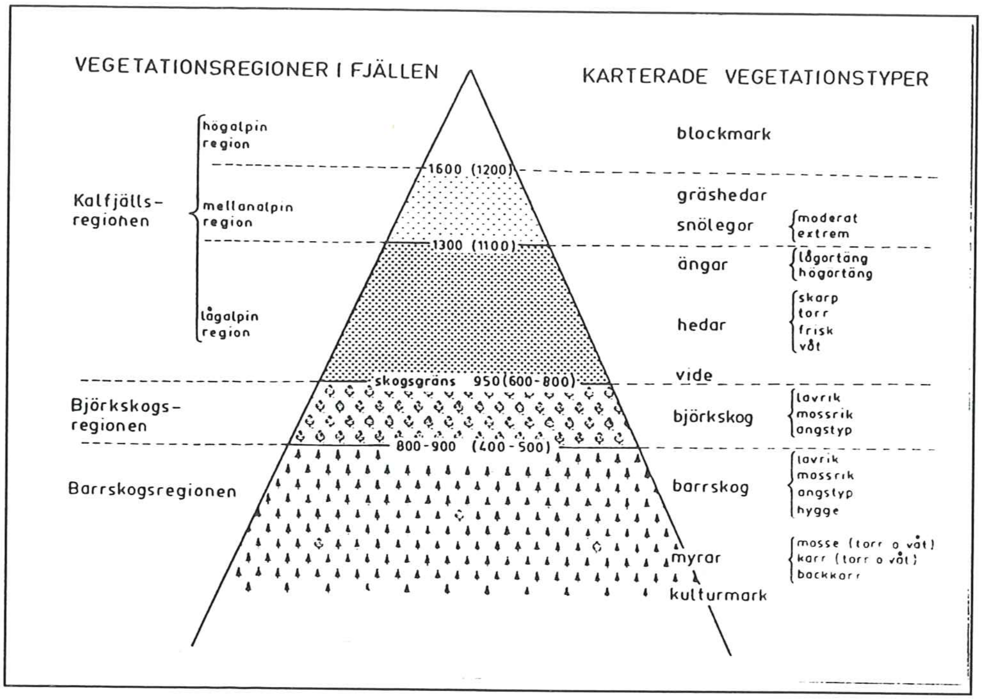

Figure 2. An "ideal mountain" showing the division-system frequently used for alpine vegetation mapping. The altitudes within brackets are valid for the northern parts of Lapland. After (Ihse et al. 1977)

A. The coniferous forest belt

The alpine conifer forest may be considered as the lowest vegetation belt of the mountains, or as a pre-alpine sub region of the conifer forest region of northern Sweden (Du Rietz 1942). The upper limit of the continuous conifer belt corresponds by definition to the upper limit of natural reproduction by seeds. This limit lies at about 500 m.a.s.l. in the eastern parts of northern Lapland and falls towards the west (Rune 1965).

A comparison between the conifer forest belt of the western mountain area and the eastern woodlands in northern Lapland reveals an increase in the occurrence of herbaceous plants to the west. This is due to the dominating westerly winds which bring warm and moist air from the Atlantic ocean (Rune 1965). This maritimity results in a higher amount of precipitation and a lower amplitude between the winter and summer temperatures in the western parts of the mountain range. The fact that the soils are more calcareous in the western region, compared to the soils in the eastern woodlands, is probably a factor that further contributes to the increase of herbaceous plants.

B. The birch forest belt

In northern Lapland *Betula pubescens* ssp. *tortuosa* is the most dominant tree species. In shelter, on fertile soils, this birch often grow with a straight trunk and may reach a height of 10-12 m. In exposed positions, or on dry infertile soils, the birch seldom gets taller than a few meters. The trunks are often twisted and bent. Lack of lichens on the lower trunk owing to snow pressure and snow drift may be used as an indicator of average snow depth in the area. Several definitions of the upper limit of the birch forest belt have been presented. Smith (1920) and Engqvist (1933) defined the uppermost birch tree as the delimiter. This definition using extreme out-layers makes it difficult to determine the limit in the field. The most commonly used definition is that made by Fries (1917) and Tengvall (1920), who defined the limit as the level of the uppermost birch groves.

The highest birch woods in northern Lapland reach an approximate altitude of 750 m.a.s.l., and in the extreme north the woods reach about 600 m.a.s.l.. The belt has a vertical extension of about 200 m in the western parts of Lapland.

C. The low-alpine belt

Above the timberline the landscape is open, less sheltered, and strong winds leave their marks on the vegetation. Tall herbs become restricted to more sheltered places, like stream valleys and depressions. In the unsheltered areas the vegetation is dominated by low plants. The vegetation is either of alpine plants or dwarfed alpine ecotypes of common lowland plants ascending into the low-alpine belt. The snow cover is unevenly distributed in the landscape accenting topographical and edaphic conditions creating a varied vegetation pattern. Steep environmental and vegetation gradients occur within small spaces; tortured dwarf shrubs may be struggling on the bare-blown ridges while luxurious grows occur in more sheltered places, and where the snow is not melted out until late in the summer the snow patch vegetation is predominant. Willow shrub is abundant in the lower parts of the belt, found in sheltered places on moist heaths and often close to streams. The upper limit of the willow is irregular, and the upper most occurrences usually consist of single individuals standing wide apart (Kilander 1965).

The most extensive vegetation-type in the low-alpine belt is the dwarf-shrub heath. In areas with noncalcareous and intermedient soils *Vaccinium myrtillus* is one of the most important dominants. This heath is used as an indicator of the upper limit of the belt. The upper limit of *V. myrtillus* is located at an altitude of about 1050 m.a.s.l. in northern Lapland (Rune 1965).

Independent of the soil type the vegetation changes at this altitude, because of the unfavourable climatic conditions, the vegetation being almost totally dominated by the true alpine plants (Kilander 1965).

D. The middle-alpine belt

The vegetation pattern of the higher vegetation belts are influenced by a number of factors. In the middle-alpine belt and at higher altitudes, snow may fall during the summer and the final winter snow comes early in the autumn. The snow is unevenly distributed because of strong winds, leaving patches of the ground without any snow cover at all. The ground is exposed to pronounced frost penetration, and frost action for long periods in spring and early autumn. Intense solifluction may prevent the establishment of closed plant communities, and limits in places the vegetation to species adopted to exist on an unstable substratum. On wet slopes, where solifluction is intense, dwarf shrubs as *Cassiope hypnoides* and *Salix herbacea* are generally found. The vegetation is low, reaching a few centimetres above the ground. Different types of heaths are abundant, their differentiation depending on the soil properties. *Dryas octopetala* is common where the soil is calcareous while *Cassiope hypnoides* is more dominant in areas with poor acid soils. Compared to the low-alpine belt, the number of species in the middle-alpine belt are fewer.

The upper limit of the middle-alpine belt is located at an altitude of about 1200-1350 m.a.s.l. in northern Lapland. The limit is defined by the patches of heath vegetation, which have generally ceased to occur at an altitude of 1350 m.a.s.l. (Rune 1965).

E. The high-alpine belt

In this belt the climate is severer. The mean summer temperature is commonly just a few degrees above freezing. Frost cycles occur in the soil even during the summer. This causes an up-freezing of stones and boulders which accumulate in great numbers on the soil surface. Vegetation is only found in small single patches. Above all the high-alpine vegetation is dominated by lichens and mosses. Vascular plants are restricted to micro-environments of shelter, often facing towards the south.

5 Classification of alpine vegetation for medium-scale mapping - a general overview

There is a number of principal different classification systems, which can be used during a medium scale vegetation mapping. The vegetation is classified and presented in different ways depending on which part of the world and what kind of vegetation that is studied.

A medium scale vegetation map is most often describing the different vegetation societies, i.e. the different combinations of different species in the area of investigation. Two other aspects which are commonly investigated are the ecology, i.e. the relation between the vegetation-type and the environment, and the physiognomy, the over all impression of the vegetation. The physiognomy has been the basis of the mapping of the vegetation-types of the world, made within International Biological Program, IBP (Fosberg 1967).

Ihse & Wastenson (1975) used a classification system based on a combination of the three aspects mentioned above. They divided the vegetation societies into five main groups (series), heath-, meadow-,mire-, willow and birch series. The physiognomy of the willow and birch forest is so important that they are represented as main groups, although they do not constitute proper groups. The main groups are further divided into sub groups defined by environmental factors as the soil moisture and the composition of nutritious substances.

6 Regional background

The geology, morphology and climate of the region is briefly described to provide a background for the understanding of the vegetation distribution. This chapter is not completely outlining these topics, but the major factors influencing the distribution of the vegetation will be described. According to Lundqvist (1968) the most important factors acting on the vegetation in a limited area are:

A. Bedrock and soil,

B. Morphology (Topography, altitude, supply of water), and

C. Climate

6.1 Bedrock and soil conditions

Bedrock conditions are of importance for the distribution of vegetation-types in several ways, e.g. as parent material for soils through its chemical composition, and its importance for slope morphology.

The Abisko mountains are part of the Caledonian orogenic belt, in Scandinavia often referred to as the Scandes. The Scandes were formed through a process involving great eastward overthrusts of nappes, partly covering various older rocks. The overthrust created two nappe-complexes, the Köli and the Seve. The Köli is lying on top of the Seve, which is resting on the autochtonous bedrock. The autochtonous rock is exposed in the Vassijaure window north of Kärkevagge.

The Seve-nappes are found in the eastern Abisko mountains. They consist of wide, very thick massives of alkaline magmatic rock which have been heavily metamorphosed, resulting in a slate, green-black amphibolite, forming dark coloured and steep mountains.

The Köli-nappes consist of sedimentary- and volcanic rocks. Where these rocks have been exposed to high pressures and temperatures they have been metamorphosed into soft black schists, quartz-rich grey mica-schist and grey Njulla marble (Sjögren 1909). The rocks in Kärkevagge originate from the Köli-nappes and are of an intermediate standard, consisting of a schist and limestone sequence. Garnet rich mica-schist occurs in nearly horizontal beds above 1300 m.a.s.l.. The garnet rich mica-schist forms a cap rock over a grey mica-schist and a black, phyllitic mica-schist occurring in layers from one to a few meters thickness. Bluish crystalline limestone, marble, occurs below the mica-schists (Rapp 1960). Rock in the valley floor consists of a banded sericite-quartzite and schist, the hardschist series (Sjögren 1909).

The majority of soils in the Scandes are rather nutrient poor, though usually better than the soils in the eastern and southern, Pre-Cambrian parts of Fennoscandia (Sjörs 1965). In general the soils in Kärkevagge are intermediate, neither rich or poor, with a thin organic layer. The soil shows distinct podzol horizons at least up to 100 m above the birch forest limit (Rapp 1960). In higher altitudes do the soil often consist of a moraine with a thin organic layer. In the lower parts of the valley, among the ridges described below (see 6.2), the soil seems to be of *in situ* weathered rocks. There seems to be a slight difference between the soils of Mt. Kärrketjåkko and Mt. Vassitjåkko. The talus of Mt. Kärketjåkko is more fine grained and the soils being slightly richer, as the stones in the melt water streams are coated with white precipitate of $CaSO_4$ (gypsum) which has been dissolved from the rocks (Dixon et al. subm.). The slopes of Mt. Vassitjåkko have a higher percentage of black schist (Rapp 1960).

6.2 Topographic conditions

The morphology in Kärkevagge has been described by, for instance (Högblom 1906, Sjögren 1909, Mannerfelt 1945, Holdar 1957 and Rapp 1960). The Kärkevagge valley is surrounded by Mt. Kärketjåkko, 1400 m.a.s.l., to the east and Mt. Vassitjåkko to the west. With its height of 1591 m.a.s.l., Mt. Vassitjåkko is the highest peak in the area. North of the valley, towards lake Torneträsk, the terrain on the Pre-Cambrian window is fairly gentle.

The Kärkevagge valley, with its mouth facing to the north, is glacialy shaped with a typical U-shaped cross-profile. The mouth is at an altitude of 500 m.a.s.l., giving a height ratio of about 1000 m from the bottom to the peaks within the catchment.

The valley is about 5 km long in a north / south direction and, in the central and inner parts, about 800 m wide. The valley walls are steep and reach between 400 and 600 m above the valley floor. The total area of the catchment basin is about 25 sqkm.

Two cirques are present in the catchment, both on Mt. Vassitjåkko. The Kärkereppe niche is located in the middle of the valley and the remnants of a smaller niche occurs further north. None of the cirque-glaciers showing any evidence of being currently active. A small plateau-glacier covers the top of Mt. Vassitjåkko, with its lower limit at an altitude of 1400 m.a.s.l..

Two lakes are present in the valley, the largest of them, Lake Rissajaure is located at an altitude of 814 m.a.s.l., where the valley ends in a cirque-like *cur de sac*. The other lake occupies a cirque beneath the smaller, glacial niche on Mt. Vassitjåkko. Small streams are abundant on both mountain sides, joining the main stream Kärkejokka in the centre of the valley. The slopes in the lower parts of Mt. Vassitjåkko are wet and solifluction lobes are ample.

Talus and traces of rock falls and debris flows are abundant on both slopes. A large alluvial fan is located on the plain beneath the Kärkereppe niche, dividing the Kärkejokka stream into two semicircles encircling the plain. Avalanche transported debris is deposited on top of the fan.

A giant boulder accumulation is located north of Lake Rissajaure. A similar accumulation is situated in the centre of the valley, concentrated in a 350 m wide, and 2.5 km long strip with the largest boulders nearest to Mt. Vassitjåkko (figure 3). The accumulation is believed to origin from a rock slide accumulation (originally deposited onto a valley glacier surface).

A large moraine ridge is located north of the boulder accumulation. This moraine ridge has been described by (Holdar 1957). A number of ridges and hills are present in a 500 m wide zone north of the moraine ridge. The material in these ridges seems to be *in situ* weathered rock.

Fig. 3 The boulder landscape in the centre of the Kärkevagge valley. The rock is a tough mica-schist (photo M. Karlsson)

6.3 Climate conditions

The temperature climate in northern Sweden is characterised by a decreasing annual average temperature with an increasing latitude and altitude, resulting in a shortening of the vegetation season. In the northern Lapland the vegetation period is 2 months shorter at the timberline and the snow free season is about three months shorter compared to conditions at "*limes Norlandicus*" (Sjörs 1965).

The climate in Kärkevagge can be considered to be of a local maritime type. The climate is generally characterised by humid weather and the area receives a relatively large part of the annual precipitation as snow.

The climate is here described by climate data from Katterjokk recorded by the Swedish Meteorological and Hydrological Institute (SMHI). Conditions in the valley, at an altitude of about 800 m.a.s.l., and the Katterjokk meteorological station are compared for 1993. Katterjokk is the nearest official climate station 10 km west of the valley.

Seen from a phytogeographic point of view, the following climatic variables are of interest:

A. The annual temperature fluctuations
B. The length of the frost free period
C. Annual precipitation and snow depth
D. The length of the snow free season

A. Temperature

During 1961-1990 the mean annual temperature at Katterjokk was -1.29 °C and the monthly mean precipitation was 70,6 mm. The monthly average temperatures during 1993 at Katterjokk and in Kärkevagge are presented in table 1. The temperature registrations in the valley were made once every hour during the year.

In Kärkevagge temperatures over 0 °C were recorded several times during the winter of 1993, even in January and February, which are the coldest months of the year. In general the monthly mean temperatures are relatively high during the winter compared to other locations at the same latitude but further to the east. This is probably an effect of the relative proximity to the Norwegian sea and the Gulf stream which creates a local maritimity.

B. Length of the frost free period

The length of the frost free period influences the distribution of some species. In an alpine environment the length of the period decreases rapidly with increasing altitude. This results in large differences in the composition of the vegetation, even within small areas like the Kärkevagge valley.

According to the temperature record obtained during 1931-60 at the Katterjokk meteorological station the average length of the frost free season is about 100 days, lasting from the beginning of June to the middle of September. 1993 the frost free season in Kärkevagge lasted for 81 days, between 16/6 and 5/9, (fig 4). It is important to keep in mind that the number of frost free days in the valley may differ depending on where the measurements are made. The temperature measurements were made at an altitude of about 800 m.a.s.l.. Lower in the valley the frost free season will be longer, allowing less frost resistant species to survive.

Table 1. Average monthly temperature and number of frost days in Katterjokk and Kärkevagge. Precipitation, 1961-1990, and snow depth during 1993 in Katterjokk (SMHI 1993 &1994). Publish of climate data from Kärkevagge permitted by P. Persson.

Month	*Monthly temp (C) Katterjokk*	*Monthly temp (C) Kärkevagge*	*Monthly precipitation (mm)*	*Snow depth (cm)*	*Frost days Katterjokk*	*Frost days Kärkevagge*
Jan.	-11,9	-6,3	76	136	31	31
Feb.	-11,2	-6,2	66	207	27	28
Mar.	-9	-3,3	51	265	30	31
Apr.	0,2	-4,4	46	229	28	30
May	1,4	1,1	42	215	22	26
Jun.	7,2	3,2	57	0	5	13
Jul.	10,5	10,6	78	0	0	0
Aug.	9	7,5	87	0	0	0
Sept.	4,2	1,0	83	0	14	13
Oct.	-0,8	-4,0	107	64	30	31
Nov.	-5,9	-2,8	75	58	28	30
Dec.	-9,2	?	79	78	31	31
Total			847		246	264

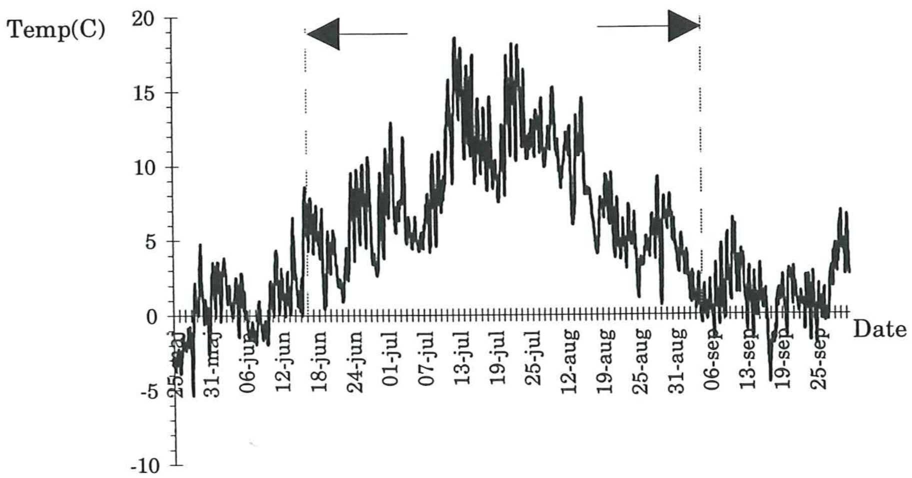

Figure 4. Hourly mean temperature recordings during 25/5 and 30/9-1993 in Kärkevagge (800 m.a.s.l.). The frost free season lasted for 81 days this year, between 16/6 and 5/9. (Publishing permitted by P. Persson)

C. Precipitation

Unfortunately no precipitation measures were made in the valley during 1993. The amounts presented here have been recorded at the Katterjokk meteorological station by SMHI. The annual amount of precipitation is about 850 mm of which about 75 % falls as snow (figure 5). 1993 the maximum snow depth was 230 cm. The snow forms a large water reservoir which is released in the spring during a relatively short period, resulting in the spring-flood.

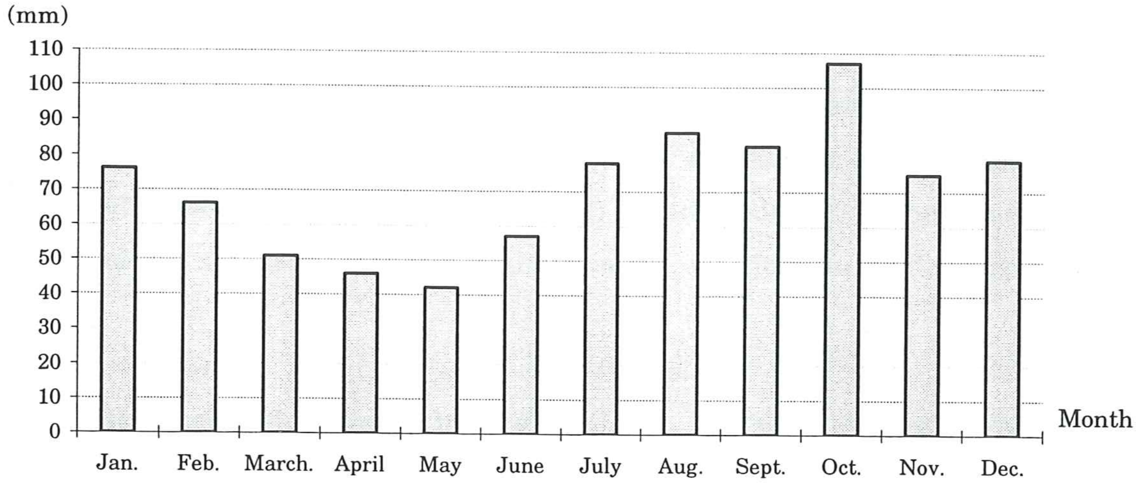

Figure 5. The monthly average precipitation at the Katterjokk meteorological station during 1993 (SMHI 1993 &1994)

D. The snow free season

The snow free season is important as it controls the length of the vegetation period. During the winter the snow cover insulates the ground and protects the vegetation from frost damage. An example of this is the distribution of *Vaccinium myrtillus* as the plant requires snow protection during the winter to survive. If the snow cover is to deep it will take to long to melt in the summer resulting in a shorter vegetation period and a water saturated soil through most of the summer, making it impossible for most of the heaths and herbs to establish themselves and survive.

The length of the snow free season depends on the amount of precipitation falling as snow, temperature, the altitude and aspect, dominating wind-direction and the relief of the landscape. If the ground is bare-blown the cold wave will be able to penetrate deeper into the soil. Some plants will be damaged by this lower winter temperature. As the ground is bare during the spring the activity in the surviving plants might start to early, increasing the risks of frost and drought damage. The snow is often blown away from the open fields and accumulated in sheltered places. In Kärkevagge, during the winter, the winds are often of a westerly origin. This results in large accumulations of snow on the east facing slopes of Mt. Vassitjåkko.

7 Materials and Methods

7.1 Instruments

The vegetation distribution has been interpreted from stereoscopic aerial infra-red colour photographs in a scale of 1 : 60 000, taken in 29-07-79. A Wild B8 Aviograph was used for the interpretation, in the field was a Wild field stereoscope used for field checks. During the field checks the orientation was supported by a Global Positioning System (GPS).

7.2 Brief description of the used classification system

A classification system must be adapted to the intended scale of the map and the type of heterogeneity of the vegetation. The classification system that have been used is the one defined by NMR (1984). A few modifications have however been made to adjust the system to the special conditions in Kärkevagge, see below.

The NMR classification system is very similar to that used by Ihse & Wastenson (1975), described in chapter 5 above. It is based on a combination of physiognomy and different vegetation series (societies) with an addition of environmental factors such as soil moisture and composition of nutritive substances. The classification system is presented in table 2.

Table 2. Classification system of alpine vegetation, modified after (NMR 1984).

Vegetation-type	*Main group*	*Code*	*Sub group*	*Other units*
Alpine	nonvegetated/ high altitude vegetation	100		
	Wind heath	1213r		ridges
		1231	*K. myosuroides / D. octopetala*	
	Heath	1213	*E. hermaphroditum*	
		1213b		boulders
		1232	*D. octopetala*	
		1311	*V. myrtillus*	
	Low herbs meadow	1341	Low herbs meadow	
		1341s		Solifluction
	Willow	1373	*Salix* spp. *Vaccinium* spp.	
	Snow patch vegetation	141	Snow patch vegetation	Unstable ground
		1423	*R. nivalis*	
	Birch forest	2241	*B. pubescens* var. *turtuosa*	
	Fen	366	Rich	
		366	Intermediate	
		3651	*Eriophorum*	

To better represent the vegetation in Kärkevagge some modifications have been done to the classification system. The letters r, b and s have been added to indicate the occurrence of ridges, big boulders and solifluction lobes. The sub groups 1213 and 1232 are defined as wind heaths by NMR (1984), but have here been transferred to the main group heath. The reason for this is that the vegetation in Kärkevagge that corresponds to these vegetation-types is richer and denser then what is usually expected in a wind heath.

7.3 Interpretation

A preliminary photo-interpretation of the vegetation was made according to the standard procedures of remote sensing, excellently described by Ihse & Wastenson (1975). The location of the different vegetation classes were drawn simultaneously onto the topographic base map over the area (Kärkevagge Catchment Map 1993). The smallest mapable area was determined to be 900 sq. m (approximately 0.5*0.5 mm in the photography). Smaller areas have been generalised to the surrounding vegetation class. A preliminary vegetation map was made during the spring of 1993. This map was field checked during the field work in 280793-130893, and compared to the vegetation-types in the valley. The different vegetation-types were documented. The species identification and nomenclature according to Lid (1976). Vegetation communities have been classified according to NMR (1984), see chapter 7.2. A modified photo-interpretation of the vegetation was made, based on the preliminary map and on the field experiences.

7.4 Evaluation of the interpretation

To obtain a measure of the accuracy of the map it has been field checked twice (which usually isn't necessary). The first attempt was performed in September 1993 but it was interrupted by a snow storm. In August 1994 the field check was finally accomplished. Point observations were made along randomly selected transects through most of the central parts of the valley.

8. Results

The final results of the interpretation, the occurrence and distribution of different vegetation-types in the Kärkevagge valley, are presented as thematic maps for the major vegetation-types as well as a complete region map, c.f. appendix 2. The accuracy of the vegetation interpretation is presented. The vegetation-belts identified in the valley are described with emphasis on the vegetation-types occurring in the belts. The altitudinal extents of the belts are compared with the generalised definitions of vegetation belts by Du Rietz (1942).

8.1 Description and location of the different types of vegetation

The descriptions of the vegetation-types are based on the definitions made in NMR (1984) together with observations made in the study area. The number in front of each vegetation-type refer to the NMR (1984) classification code. While reading this and the following chapters the reader is adviced to look at the vegetation map in appendix 2.

100 Non vegetated surfaces and high altitude vegetation

This vegetation-type is represented in dry streams and other unvegetated areas. The high alpine vegetation is also included. The reason for this is the spars occurrence of vegetation at higher altitudes, cf. figure 18. Above 1200 m.a.s.l. are lichens almost the only vegetation represented on otherwise bare rock. Mosses and a few vascular plants, for instance *Ranunculus glacialis* occurs sparsely. Patches of heath and herbs may be found in small protected environments, but they are generally to small to be mapped. The vegetation-type occupies 51 % of the interpreted area.

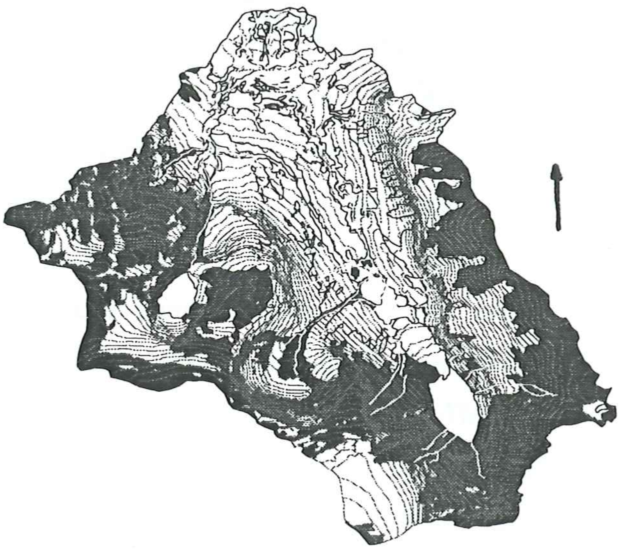

Figure 6. Distribution of non vegetated areas and high altitude vegetation (100)

1213 Empetrum hermaphroditum heath

This type of vegetation occur in the sub-alpine to low-alpine belts. The *E. hermaphroditum* heath is the most common heath in the western parts of Lapland. The class occupies most of the central parts of the Kärkevagge valley. As the name implies *E. hermaphroditum* is the dominating species but lichens are also generally well represented. In contrast to the *V. myrtillus* heath the *E. hermaphroditum* heath does not demand any snow protection.

The vegetation-type occupies 3,3 % of the interpreted area.

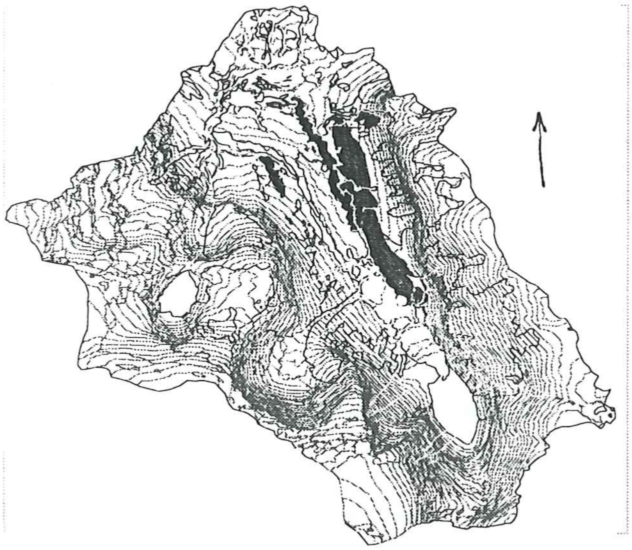

Figure 7. Distribution of *E. hermaphroditum* heath (1213)

1213r E. hermaphroditum wind heath

This sub-type of vegetation is found in the low alpine belt, on ridges and other surfaces which are exposed to severe wind, and indirectly temperature conditions. The soils are poor and generally dry with a very thin organic layer due to the wind erosion. The vegetation cover follows an environmental gradient from the exposed ridge top towards the more protected foot. Both the species distribution and vegetation density change with exposure. On the top of the ridges is the vegetation cover often broken with a thin cover of mosses, lichens and *Empetrum hermaphroditum*. On the margins of the ridges *E. hermaphroditum* is dominant mixed with some *Vaccinium myrtillus*, followed by *Salix herbacea, Betula nana* and herbs, cf. figure 22. The upper limit of the *V. myrtillus* indicates the limit of consistent snow cover, as it does not survive without snow protection. Snow patch vegetation may be found on the lee-sides of ridges, where large amounts of snow accumulates during the winter. This mosaic of small environments are presented as one class in the map as they are too small to be separated in more detail.

The vegetation-type occupies 0,1 % of the interpreted area.

1213b <u>E. hermaphroditum</u> heath vegetation among big boulders

The vegetation is the same as in 1213 but a physiologic distinction is made based on the special, and in extreme substrate conditions among the big boulders in the centre of the valley. *E. hermaphroditum* dominates but the snow patch vegetation is more frequent and environmental gradients are generally steeper than in 1213. The snow is accumulated during the winter, and preserved far into the summer, in the shelter between the boulders. As the vegetation season is generally shorter in this region the number of plants demanding a longer vegetation season is less compared to 1213.

The vegetation-type occupies 2,9 % of the interpreted area.

Figure 8. Distribution of *E. hermaphroditum* heath within the boulder landscape

1231 <u>Dryas octopetala, Kobresia myosuroides</u> wind-heath

This wind heath is generally found in the low- middle alpine belts forming small, creeping societies of *Dryas octopetala*. The severe wind exposure and the poor snow protection during the winter separates this vegetation from the more common *D. Octopetala*-heath (1232). The vegetation cover is often broken due to wind erosion. In Kärkevagge this class is only found upon a few ridges above the *D. Octopetala* heath on Mt. Kärketjåkko.

The vegetation-type occupies 0,05 % of the interpreted area.

1232 Dryas octopetala heath

This heath is present on more lime-rich substratum in the low- to middle alpine belt. The vegetation cover is dense and the vegetation is totally dominated by *Dryas octopetala,* cf. figure 20. Some other heaths as *Salix rugosa* and *Salix herbacea* is present but not as dominant as *D. octopetala*. A relatively large number of different herbs are found. The number of herbs varies, depending on the micro-topography of the slopes. Herbs are most abundant near streams and in lower, sheltered spots in the slopes. Where the ground is drier and the climate is more demanding, on ridges, the number of vascular plants decreases and the *D. octopetala* covers the ground completely.

The vegetation-type occupies 5,1 % of the interpreted area.

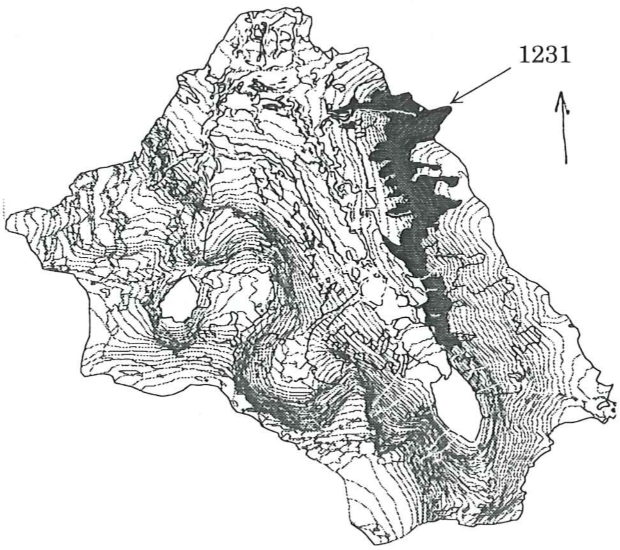

Figure 9. Distribution of D. octopetala wind heath (1231) and heath (1232)

1311 Vaccinium myrtillus heath

This class is found in the low alpine belt, just above the tree-line. *Vaccinium myrtillus* is dominant but *E. hermaphroditum* is present.

The class occupies 7,2 % of the interpreted area.

Figure 10. Distribution of *V. myrtillus* heath (1311)

1213 / 1311 Transition zone between V. myrtillus- and E. hermaphroditum heath

Just above the *V. myrtillus*-heath, the landscape is varying between small hills and hollows, the vegetation cover is divided into small patches of *E. hermaphroditum* and *V. myrtillus* mixed with patches of low herbs meadow, willow and snow patch vegetation. This mosaic of vegetation is mainly owing to differences in the micro-topography and hydrology.

The vegetation-type occupies 3,9 % of the interpreted area.

1341 Low herbs meadow

This vegetation is present in the sub- to middle-alpine belts. The vegetation is relatively low (10-15 cm), cf. figure 21. Different combinations of herbs dominates in small areas, owing to varying micro-environmental conditions, mosses dominate the field layer. In general this vegetation demands some snow protection but an early melt out. Low herbs meadows are found on both sides of the boulder-landscape in the centre of the valley and on the alluvial fan beneath the Kärkereppe niche.

The vegetation-type occupies 4,7 % of the interpreted area.

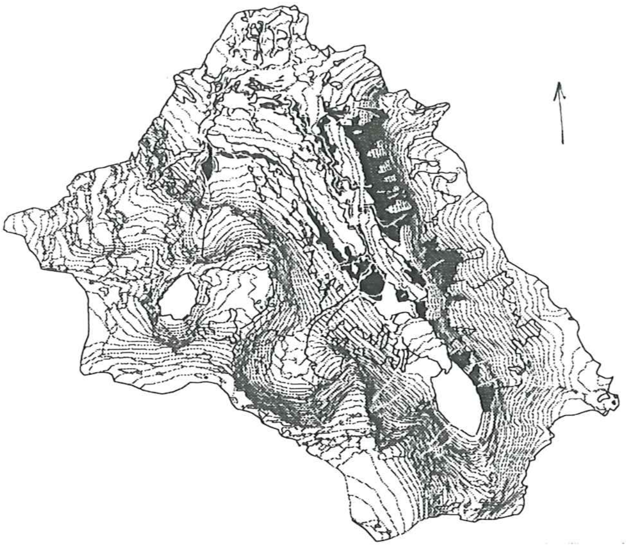

Figure 11. Distribution of Low herbs meadow (1341)

1341s Low herbs meadow, solifluction

This class is present in the low- middle-alpine belts. The vegetation is characterised by a dense vegetation cover of low herbs and mosses. The number of species tolerating moist conditions and a long lasting snow cover is high. This type of vegetation is often located on the slopes below snow patches and melt-water springs. The vegetation-type is represented on the moist western slopes, where solifluction lobes are frequent, above the common low herbs meadows, cf. figure 19.

The class occupies 7,9 % of the interpreted area.

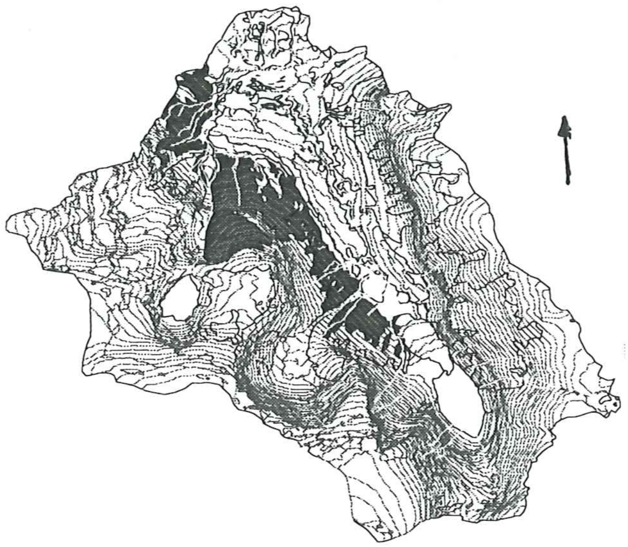

Figure 12. Distribution of Low herbs meadows with solifluction (1341s)

1373 Willow shrub (Salix spp. Vaccinium spp.)

The willow shrubs are found in the sub- and low-alpine belts. The shrubs reach a height of between 0.5 and 2m and occurs in areas with moist soils and close to streams, cf. figure 23. The stems are often bent because of the snow pressure.
The class occupies 1,4 % of the interpreted area.

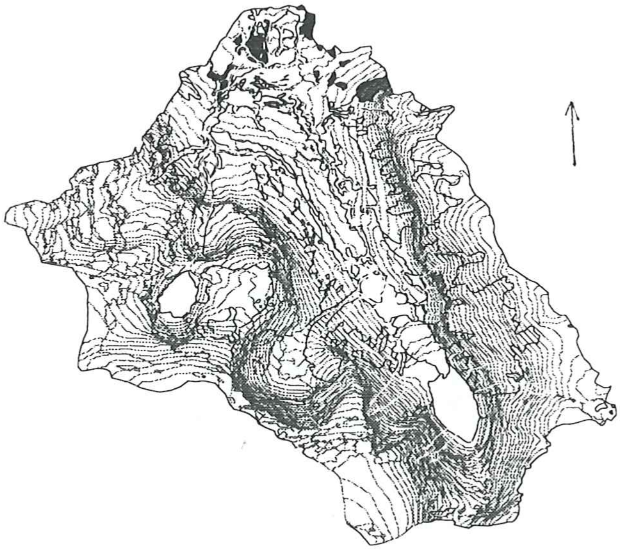

Figure 13. Distribution of willow (1373)

141 Snow patch vegetation on unstable ground

This type of vegetation is found in the low-, middle- and high-alpine belts, often just above the central parts of the snow patches. The vegetation has the character of a heath vegetation with a relatively large number of lichens. *Salix herbacea* is often dominant in a dark and dense moss-carpet.
The soil is poor with just a thin organic layer. The melting snow makes the soil saturated during the spring and early summer. When all snow is melted the ground usually dries up, resulting in a dry crust. The ground do often show evidence of solifluction and traces of erosion.
The class occupies 10,1 % of the interpreted area.

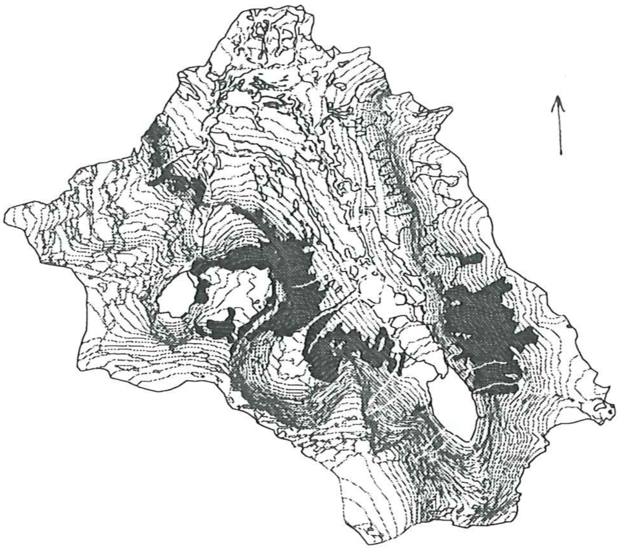

Figure 14. Distribution of snow patch vegetation (141)

1423 Snow patch vegetation (Ranunculus nivalis)

This vegetation is found in the low-alpine belt. The vegetation is dominated by mosses with a few vascular plants. The ground is kept moist/wet the whole summer by melt water from snow patches or springs. The soil layer is generally thin. The vegetation-type do exist on both rich and poor substrata. The ground often show evidence of solifluction and some traces of erosion.

The class occupies 0,3 % of the interpreted area.

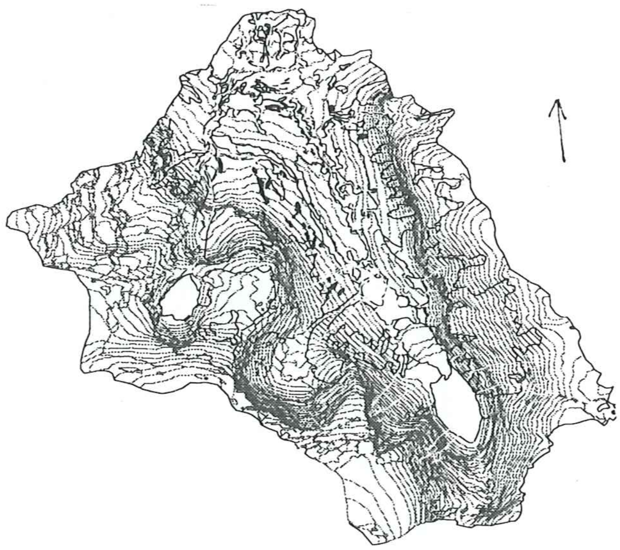

Figure 15. Distribution of snow patch vegetation, *R. nivalis* (1423)

2241 Alpine birch forest (Betula pubescens var. turtuosa)

The alpine birches reach a height between 4 and 7 m. The bush layer is sparse and the field layer vegetation is dominated by herbs and grass. Mosses are more common than lichens. The stems are often bent and lacks lichens due to the snow cover and pressure. The birch forest is represented only in the lowest northernmost parts of the valley.

The class occupies 0,7 % of the interpreted area.

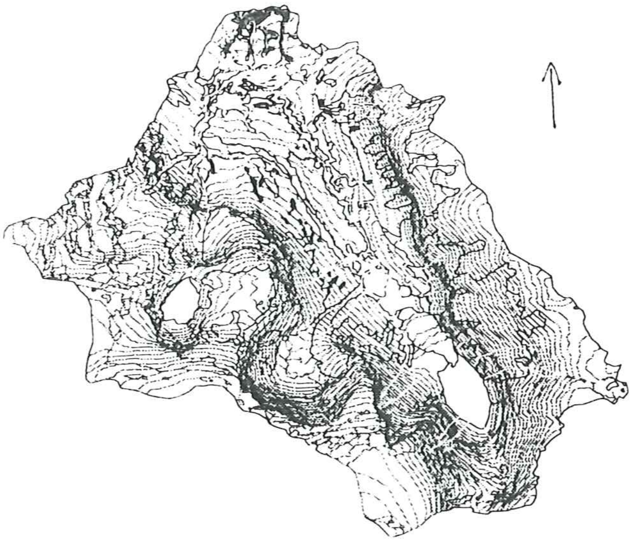

Figure 16. Distribution of Alpine birch forest (2241)

366, 3651 Fen vegetation

Fen vegetation is found in all of the vegetation belts in the valley. The class can sometimes be a combination of both fen- and snow patch vegetation. The fens are not covered by snow for as long period as the snow patch vegetation. The fens are characterised by waterlogged soils, saturated by melt water from springs and snow fields.

Three different kinds of fens have been distinguished in the valley: *Eriophorum* fen (3651), rich fen (366) and intermediate fen (366). The rich fen is located in the eastern slope, close to the lake Rissajaure. The intermediate fen is located in the northern part of the western slope, shadowed from sunlight by a steep rock wall. Snow has been observed there as late as in August, which results in a combination of both snow patch- and fen vegetation (as described here). The fen in the middle of the plane beneath the niche has been classified as an *Eriophorum* fen. The field layer has got both marsh- and moist meadow species.

The rich fen occupies 0,3 %, the intermediate 0,2 % and the Eriophorum fen 0,5 % of the interpreted area.

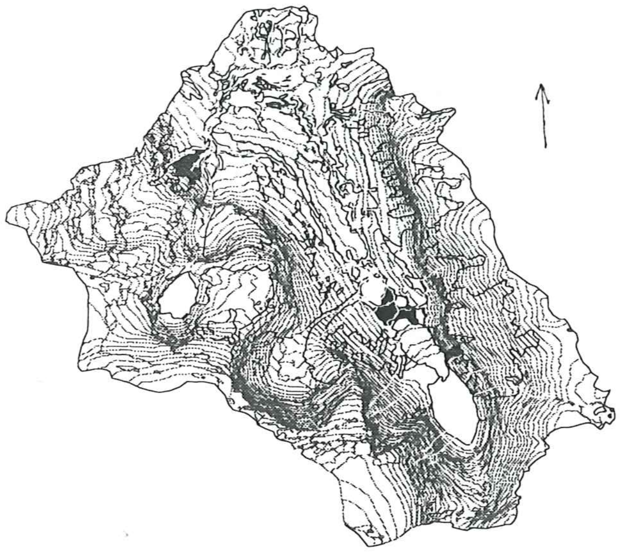

Figure 17. Distribution of the rich and intermediate fens (366) and the *Eriophorum* fen (3651). The *Eriophorum* is found in the centre of the valley.

Figure 18. High altitude vegetation on Mt. Vassitjåkko. Picture is taken towards the north at an altitude of 1160 m.a.s.l.

Figure 19. The wet slopes beneath the Kärkereppe niche. The vegetation is a low herbs meadow with solifluction lobes (1341s). In the plain the vegetation-type changes into low herbs meadow (1341). The picture is taken from the *E. hermaphroditum* heath (1213) on Mt. Kärketjåkko. (Photo by P. Klintenberg)

Figure 20. *Dryas octopetala* (Photo by P. Klintenberg)

Figure 21. Low herbs meadow (1341). (Photo by P. Klintenberg)

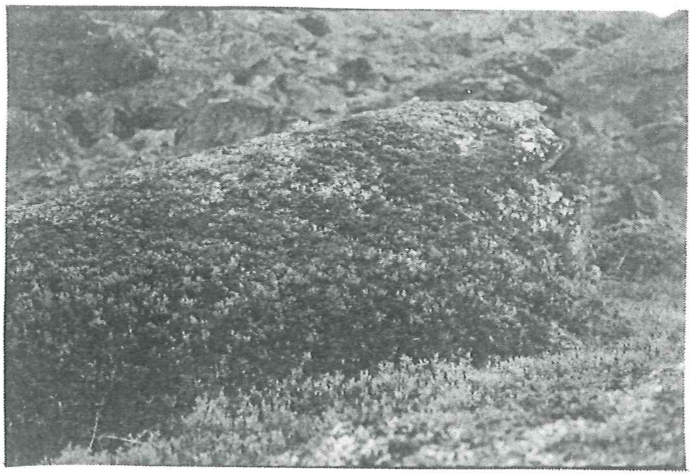

Figure 22. The vegetation distribution on a ridge. Note the almost bare-blown top and the increased density of vegetation towards the foot. (Photo by P. Klintenberg)

Fig 23. Willow 1373) following the stream Kärkejokka. The ridges with *E. hermaphroditum* heath (1213r) are seen in the background (Photo by P. Klintenberg)

8.2 The vegetation distribution in figures

The total area covered by each class have been calculated (table 3). The calculations are based on the orthogonal projection of the map which results in an under-estimation of the area calculations of steep slopes. An attempt to illustrate the difference in vegetation between the two valley sides, Mt. Vassitjåkko and Mt. Kärketjåkko, is presented in table 4. The values have been obtained by drawing an imaginary line in a north/south direction through the centre of the valley.

Mt. Vassitjåkko has a NE aspect and Mt. Kärketjåkko has a SW aspect. The major differences between the two mountain sides in the valley are:

-Low herbs meadows with solifluction lobes (1341s) are only identified on Mt. Vassitjåkko.

-Snow patch vegetation (141) is found at lower altitudes on the slopes of Mt. Vassitjåkko than on Mt. Kärketjåkko.

-Low herbs meadow (1341) and *E. hermaphroditum* heath (1312) are more abundant on the slopes of Mt. Kärketjåkko.

-*D. octopetala* heath (1232) is only identified on the slopes of Mt. Kärketjåkko.

Table 3. The area-coverage of the different vegetation-types identified in the valley.

Type	*Vegetation class*	*Area (ha)*	*%*
Non vegetated	100	1081	51
Wind heath	1213r	2	0,1
	1231	1	0,05
Heath	1232	108	5,1
	1311	168	7,2
	1213/1311	83	3,9
	1213	69	3,3
	1213b	61	2,9
Low herbs meadow	1341	99	4,7
	1341s	168	7,9
Willow	1373	29	1,4
Snow patch vegetation	141	214	10,1
	1423	7	0,3
Birch forest	2241	14	0,7
Fen	3651	10	0,5
	366	9	0,5

Table 4. Comparison of the vegetation distribution on the two valley sides (SW / NE aspect)

Class	*Slope of Mt. Vassitjåkko NE aspect (coverage in %)*	*Slope of Mt. Kärketjåkko SW aspect (coverage in %)*
100	60,2	40
1213r	0,2	0
1231	0	0,2
1232	0	15,9
1311	3,2	7
1213/1311	4,9	2,5
1213	1,1	8,1
1213b	0,2	0
1341	1,8	11,1
1341s	12,5	0
1373	0,8	1,9
141	10,3	11,1
1423	0,4	0,2
2241	0,4	1
3651	0,4	0,7
366	0,5	0,3

8.3 Acceptance of the interpretation

The results of the evaluation of the interpretation are presented in table 5a and 5b below. The total number of check points (N) is 740, of which 612 are correctly mapped (SUM A). The total accuracy of the entire interpretation is 83%. The accuracy in the positioning is crucial for the validity of the results. When a Global Positioning System is used the accuracy depends on the number of satellites detected by the GPS, and the quality of the signals transmitted and received. Non of the registrations were made with less than four satellites detected. The accuracy of the GPS device used is under normal conditions about +/- 25 m.

The high altitude vegetation and nonvegetated surfaces (100), the two wind heaths (1213r) and (1231) and the heath (1213b) have been excluded from the evaluation. The high altitude vegetation (100) was thoroughly investigated during the field period 1993. The vegetation cover is sparse and homogenous, which makes it easy to separate in the aerial photographs. It is by that assumed that the vegetation-type is represented accurately in the map. The two wind heaths have been excluded as they cover very small areas. They are easily distinguished in the aerial photographs and can by that also be considered to be interpreted with a satisfactory accuracy. The *E. hermaphroditum* heath in the boulder landscape (1213b) was excluded due to the physical risks and the impossible task of orientation among the boulders. This class is also easy to separate in the aerial photographs.

Five different values are needed to calculate the accuracy of each class (vegetation-type) and the total accuracy of the map: N = the total number of control points, A = The number of correct mapped control points for each class, SUM A = total number of correct mapped control points in all vegetation classes, B = The number of control points in the field for each class, and C = total number of control points in the map for each class.

Following expressions have been used for the calculation of the accuracy:
1. The interpretation accuracy, (A/B)*100
The ratio gives the percentage of collected field points of a specific class, which belongs to the same class at the same position in the map.

2. The object accuracy, (A/C)*100
The ratio gives the percentage of the control points in the map, of a specific class, that belongs to the same class in the same position in the field.

3. Area difference, ((C-B)/B)*100
The ratio gives the percentage of the over (+) or under (-) representation of the area covered by a class in the map in relation to the area of the class in the field.

4. Average accuracy, (2A/(B+C))*100
The ratio gives the percentage of the control points in the field and the control points in the map which are in a corresponding position and belongs to the same class.

5. The total accuracy, (SUM A/N)*100
The ratio gives the percentage of all the control points, all classes included, which, in a given position, belongs to the same class both in the map and in the field.

Table 5a. Matrix describing the distribution of the check points in the field and in the map. B = number of check points in the field for each class, C = Total number of control points for each class in the map. N = 740, SUM A = 612.

Class	*1213*	*1341*	*1341s*	*1232*	*141*	*1423*	*1373*	*2241*	*366*	*1311*	*1213/1311*	B
1213	**87**	2										89
1341	10	**130**		17							11	168
1341s	2	2	**103**		15		2					124
1232	6	4		**42**								52
141			28		**48**							76
1423						**7**						7
1373							**27**					27
2241								**5**				5
366		1	3	3					**35**			42
1311							9			**108**		117
1213/ 1311	7									6	**20**	33
C	112	139	134	62	63	7	38	5	35	114	31	

Table 5b. Accuracy of the interpretation, in percent, the calculations of the ratios are explained above.

Class	*Name*	*Acc. of interpretation*	*Object accuracy*	*Area difference*	*Average accuracy*
1341	Low herbs meadow	77	94	-17	87
1341s	solifluction	83	77	8	80
1213	*E. hermaphroditum*	98	78	26	87
1311	*V. myrtillus*	84	95	-11	90
1232	*D. octopetala*	81	68	19	74
141	Snow patch vegetation	63	76	-17	70
1423	*R. nivalis*	100	100	0	100
1373	Willow	100	71	41	71
2241	Birch	100	100	0	100
366-3651	Fen	83	100	-17	91
1213/1311	Transition zone	61	65	-6	62

8.4 Vegetation zones in the Kärkevagge valley

The generalised altitudinal distribution of vegetation-types defined by Du Rietz (1942) is compared with the observations made in the field and the mapped distribution. The reader have to keep in mind that the altitudinal limits of the belts defined by Du Rietz are generalisations based on a large number of observations made in northern Lapland. Deviations are observed in the Kärkevagge valley.

Four of the five vegetation belts described by Du Rietz (1942) are represented in the Kärkevagge valley. The coniferous forest belt is missing as it does not reach the altitude of the valley mouth (approximately 500 m.a.s.l.).

Table 6. Comparison between the ranges of the vegetation belts defined by Du Rietz (1942) and observations made in the field and the map. Note that the averages of the observed limits corresponds to them defined by Du Rietz (1942), except the sub-alpine belt. The area coverage of the different vegetation belts within the valley are presented.

Belt	*Extension by Du Rietz*	*Observed in the valley*	*Area (ha)*
Sub-alpine	<600	<(530-580)	112
Low-alpine	<1050	<(980-1100)	963
Middle alpine	<1200	<(1120-1300)	451
High-alpine	>1200	>(1120-1300)	598

The sub-alpine (birch-forest) belt

This belt is extending to an altitude of about 530 m.a.s.l.. Some scattered birch stands follows the Kärkejokka river, reaching an altitude of 580 m.a.s.l.. The general limit in the region is at an altitude of 600 m.a.s.l.. The forest is an open mountain birch forest (*Betula pubescens* var. *turtuosa*). Other vegetation-types represented in the belt are: Willow(1373), and *V. myrtillus* heath (1311).

The low-alpine belt

The upper limit of the low-alpine belt, in northern Lapland, is generally considered to be at 1050 m.a.s.l.. In Kärkevagge the limit is found in a range between 980 (in the shadowed southern parts) and 1100 m.a.s.l (on the west facing slope).

All vegetation-types identified in the valley are represented within the range of this belt. Grey willow shrubs (1373) and scattered shrubs of alpine birch (2241) cover the moist ground in the lower parts of the belt. Above the willow shrubs are heaths and meadows dominating. *Vaccinium myrtillus* (1311), *Empetrum hermaphroditum* (1213) and *Dryas octopetala* (1232) are the most abundant heath species. *V. myrtillus*-heath covers most of the ground just above the willow shrubs. As the altitude increases the vegetation changes into *E. hermaphroditum*-heath through a transition zone where both types are mixed. A large number of ridges are found within the transition zone, the vegetation-type on them is referred to as 1213r. *Dryas octopetala* is totally dominating the west facing slopes of Mt. Kärketjåkko. Low herbs meadows (1341) are present beneath the mountain slopes and in protected spots in the centre of the valley. Low herbs meadow with solifluction lobes (1341s) are common above the low herbs meadows in the east facing slopes of Mt. Vassitjåkko. The number of moist resistant species increases. In the wetter parts of the slopes is *R. nivalis*-snow patch vegetation (1423) found.

The middle-alpine belt

In Northern Lapland the upper limit of this belt is generally found at about 1200 m.a.s.l.. In Kärkevagge the limit is found within the range of 1120-1300 m.a.s.l..

High-altitude vegetation (100), *Dryas octopetala* heath (1231) and snow patch vegetation (141) dominates. The *D. octopetala* heath reaches about 1190 m.a.s.l. and the snow patch vegetation about 1300 m.a.s.l.. The vegetation is denser in the west facing slopes compared to the east facing. A general decrease in plant density is clearly seen, both in the number of different species and in the total biomass, compared to the low-alpine belt.

The high-alpine belt

In this belt the vegetation is sparse and dominated by lichens and mosses. The snow patch vegetation (141), in which the dwarf willows *Salix herbacea* and *Salix polaris* occurs, is found in scattered patches in the lower parts of this belt, the high-altitude vegetation is totally dominating. The highest reaching vascular plant in the valley is *Ranunculus glacialis* which has been found at a height of 1475 m.a.s.l. (Rapp 1960).

Table 7. The area coverage (in hectare) of the vegetation-types identified within the vegetation-belts

High- alpine belt		*Middle- alpine belt*		*Low- alpine belt*		*Sub-alpine belt*	
Class	Area	Class	Area	Class	Area	Class	Area
100	571	100	319	100	192	1311	90
141	28	141	92	1341s	163	2241	12
		1232	30	141	94	1373	10
		1341	5	1341	94		
		1341s	5	1213/1311	83		
				1311	79		
				1232	78		
				1213	69		
				1213b	61		
				1373	19		
				3651	10		
				366 (r+i)	9		
				1432	7		
				2241	2		
				1213r	2		
				1231	1		

9 Discussion

9.1 Why make a vegetation map?

Why do we make a vegetation map? As was mentioned in the beginning of this paper, cf. chapter 1, the use of aerial photographs have improved the ability to, in a rational way, make vegetation inventories and mappings within the alpine environment. The infra-red film with its superior representation of different vegetation-types has been a revolution for medium scale mapping.

Obviously most of the information about the vegetation is found in the aerial photographs, but not all. The photographs can be seen as the unaltered raw material and the map as the result of the interpretation and analysis of them. It is difficult to make exact delimitations of different vegetation-types just based on unchecked interpretations of aerial photographs. A vegetation map is the final product of a number of generalisations of the information in the aerial photographs, ideally accompanied by extensive field checks.

A map presents the often complex mosaic of different features identified in the aerial photographs, in a systematic and scientific manner. Vegetation maps may provide a useful material reference for future medium scale alpine vegetation mappings. The Kärkevagge vegetation map may hopefully be used as a reference for future vegetation studies in the valley or adjacent areas.

The unaltered information in the aerial photographs are potentially more useful than the information obtained from a map, for instance when change studies through time are made. The map is based on a number of more or less subjective generalisations, depending on the interpreter's ability to distinguish different features in the aerial photographs. This will most often have a negative influence on the accuracy of any comparison between different maps, especially if the interpretations have been done using different classification schemes. If change studies are to be made using aerial photographs without field checks / field data more detailed classification and comparisons are likely to be complicated and maps from smaller areas e.g. Kärkevagge, may in this context provide a "key" to vegetation interpretation of larger areas. The accuracy of the map is thus of critical importance.

9.2 Comment to the evaluation of the accuracy of the map

Snow patch vegetation (141), the transition zone (1213 / 1311), willow (1373) and *D. octopetala* heath (1232) are the vegetation-types with lowest accuracy of the evaluation, c.f. table 5a. The snow patch vegetation (141) has an accuracy of interpretation of 63 %, an object accuracy of 76 % and an average accuracy of 70 %. The area difference is -17 %. It is evident in table 5a that field points recorded as low herbs meadow with solifluction (1341s) have been mapped as snow patch vegetation and vice versa. All together the class has been under-represented in the map. This indicates a problem with finding the correct delimitation between these two classes in the aerial photograph. Even in the field it is difficult to find the exact line of demarcation between these two classes as they tend to be mixed in a transition zone / mosaic.

The transition zone (1213 / 1311) has an accuracy of interpretation of 61 %, an object accuracy of 65 % and an average accuracy of 62 %. The area difference is -6 %. The low interpretation accuracy of this vegetation-type is also an example of the difficulty of finding the exact delimitation between adjacent vegetation-types. In this case field points recorded as belonging to the type (1213 /1311) have been mapped as *E. hermaphroditum* (1213) or *V. myrtillus* heath (1311), resulting in an under-representation of the class in the map.

The willow vegetation (1373) has an accuracy of interpretation of 100 %, an object accuracy of 71 % and an average accuracy of 71 %. The area difference is 41 %. Field points recorded as *V. myrtillus* heath (1311) and low herbs meadows with solifluction (1341s) have been mapped as willow. The vegetation-type is largely over-represented in the map. The willow occurs in small scattered stands in the landscape, which explains the over-representation. A compromise have been done between a correct area representation and the visibility. If the small stands had been presented in there correct size some of them would not have been distinguishable in the map. As this class is an important indicator for both hydrologic and phytogeographic factors, c.f. chapter 4, this compromise has been necessary. The high interpretation accuracy makes future comparisons of vegetation change in terms of new establishment easy to identify.

The *D. octopetala* heath (1232) has an accuracy of interpretation of 81 %, an object accuracy of 68 % and an average accuracy of 74 %. The area difference is 19 %. A number of check points recorded as low herbs meadows (1341) in the field have been mapped as *D. octopetala* heath. Problems with the positioning may be contributing to this, as the low herbs meadow follow small runnel tracks on the slopes of Mt. Kärketjåkko. The width of these strips are sometimes smaller than the precision of the GPS-device (about +/-25 m).

9.3 Distribution of the vegetation

Changes in the distribution of vegetation-types are observed both in a north / south-, and west / east direction. These changes are mainly due to local differences in the climatic-, hydrologic and morphologic conditions within the valley.

The change in the composition of the vegetation with increasing altitude is probably the most obvious (table 7, chapter 8.4). This change is mainly due to the changing climatic conditions. The altitudinal difference between the valley mouth and the peak of Mt. Vassitjåkko is about 1000 m (chapter 6.2). This is equivalent to a decrease in temperature of about 10 °C, (if we assume a dry adiabatic temperature decrease of 1 °C / 100 m).

The area south of Lake Rissajaure (> 814 m.a.s.l.) is almost totally unvegetated. The main reason to this is that the inner, southern parts of the valley are shadowed by the steep rock walls most of the day permitting a snow cover until late in the summer, some of it is perennial.

The difference in vegetation composition of the two mountain sides are mainly owing to climatic and morphologic factors. In the map (and table 4, chapter 8.2 and Appendix 1) it may be seen that the vegetation on the Southwest facing slopes of Mt. Kärketjåkko is dominated by low herbs meadows and *Dryas octopetala* heath while the Northeast facing slopes of Mt. Vassitjåkko have a much sparser ground cover, dominated by snow patch vegetation and low herbs meadows characterised by solifluction movements. There are a number of factors which can explain this difference in the vegetation distribution. The most important is probably the climate. The aspect of Mt. Vassitjåkko, facing Northeast, makes these slopes more shadowed than the slopes of Mt. Kärketjåkko. Most of the winds during the winter are westerly and about 75 % of the annual precipitation falls as snow, c.f. chapter 6.3. Large amounts of snow accumulates on the lee-slopes of Mt. Vassitjåkko. This in turn shortens the vegetation period.

The soil properties are another important factor influencing the distribution of the vegetation. The snow accumulations on the slopes of Mt. Vassitjåkko make the soil moister (saturated) compared to the slopes of Mt. Kärketjåkko. The soils of Mt. Kärketjåkko being slightly richer, as the stones in the melt water streams are coated with white precipitate of $CaSO_4$ (gypsum) which has been dissolved from the rocks (Dixon et al. subm.). This favours *D. octopetala* which demands a richer substratum, c.f. chapter 8.1.
The black-schists in the talus of Mt. Vassitjåkko produces a soil with a low pH, which generally is unfavourable for the growth of vegetation (cf. chapter 6.1 and Rapp 1960).

9.4 Vegetation belts

The definitions and delimitations of different traditional vegetation belts have been reviewed. However, how reliable are the delimitations of the vegetation belts obtained by the interpretation of aerial photographs? If we examine the definitions of the different vegetation belts we see that the upper limit of the sub-alpine belt is defined by the highest occurrence of alpine birch stands. Single trees are identified in the aerial infra-red colour photographs (even in a scale of 1 : 60 000), making this line of demarcation easily distinguished in the aerial photographs, usually without any need of complementary field observations.

The low-alpine belt is defined by the occurrence of a specific heath, *V. myrtillus,* and a ceasing of low land species. The middle alpine belt is defined by a decrease in both the diversity of vegetation-types and the density of ground coverage compared to the low-alpine belt. It is almost impossible to distinguish different species of heath from one or the other by just studying the aerial photographs. As the texture is the same, the only difference, if any at all, between them is a slight difference in colour tone. It is also difficult to decide where to draw the line based on the definition of diversity and density. A thorough field study is needed to out-line the limit between these two belts.

The high-alpine belt is defined by a very sparse vegetation cover of mainly lichens. Owing to this the spectral reflectance of the underlying materials (soil and rock) are clearly seen in the photographs, making this belt easily separated from the middle-alpine belt. Complementary field observations are advisable as the occurrence of bare rocks and talus in the middle-alpine belt can lead to an underestimation of the extension of the middle-alpine belt.

To summarise, the ability to recognise the upper limit of the sub-alpine belt is very good, mainly because of the large difference in texture between the trees and the surrounding vegetation-types. The limit between the low- and middle-alpine belts is almost impossible to distinguish without a supplementary field survey. The limit between the middle- and high-alpine belts is fairly simple to out-line due to the very sparse vegetation cover and the spectral signature from the underlying material.

A solid knowledge about the factors determining the distribution of different vegetation-types can be a powerful tool within the other fields of research in the alpine environment. The identification of different vegetation-types can than be used as an indicator of micro climate, hydrology, nutritious conditions etc. An example of this is the distribution of the alpine birch. As the occurrence of alpine birch stands are easily distinguished in the aerial photographs we can assume that they are represented with a high accuracy in the vegetation map. An increased annual mean temperature would probably result in migration of alpine birch stands into higher altitudes. The monitoring of birch stands might be used as an indicator, among others, of a change in climatic conditions. The possibility to identify the birch stands without any field observations would make this a powerful method when large areas are to be monitored.

In chapter 7.3 the extensions of the different vegetation belts defined by Du Rietz (1942) were compared with observations in the valley. The average altitudinal distribution of the different vegetation belts in the valley correspond to those defined. Thus the detailed vegetation map supports previous, and general, definitions of altitudinal belts in a surprising degree. The extensions of the belts varies between different parts of the valley. The differences are due to the same local climatic and morphologic factors as those influencing the distribution of individual vegetation-types. The birch forest does not reach as high as might be expected. The slightly lower limit of the sub-alpine belt in Kärkevagge is probably an effect of the substantial tree felling during the construction of the rail road in the beginning of this century (Rapp 1960 and Schlyter et al. 1993).

9.5 Future use of the material

Now when a medium scale vegetation map has been made, showing the distribution of the different vegetation-types in the Kärkevagge valley, it is time to think of the future use of the material. I believe that the knowledge about the vegetation-distribution can be of a future help when we tries to understand not only the factors of vegetation growth but also other environmental issues of a study area, e.g. morphology, hydrology, micro-climatology etc.

Some studies may achieve more reliable results if the vegetation is more often included in the investigations. As have been out-lined above, some vegetation-types can be used as indicators of different environmental conditions, c.f. chapter 9.4.

To make this a useful tool to obtain a greater understanding of the environment we have to clarify the properties of the vegetation-types which are identified, and believed to be of relevance, within the area. Important morphologic and climatic indicators are e.g. the vegetation's demands on; soil properties (e.g. nutritious content and pH), water availability, length of the vegetation-period (snow free season) and demands of protection from both frost and winds.

To solve this task we will probably need help from experts in the adjacent fields of ecology, plant physiology and pedology, e.t.c..

10 Summary

Distribution of the vegetation-types identified in the valley

16 different vegetation-types have been identified in the Kärkevagge valley, They are distributed between the following main-types of vegetation: Birch forest, willow, heath, wind heath, low herbs meadow, snow patch vegetation, fen, and high altitude vegetation.

Changes in the vegetation distribution is observed both owing to the altitude and the aspect. The climate is believed to be the major factor, but differences of soil properties, length of the snow free period and hydrology between the two valley sides are also of importance.

Accuracy of the map

The total accuracy of the map is 83 %. Most of the classes are represented with a higher total accuracy than 75 %.

The reason for the lower accuracy in the interpretation of the transition zone between the *Vaccinium myrtillus*- and the *Empetrum hermaphroditum* heaths (1213/1311), and for the snow patch vegetation (141), is manly owing to problems with the delimitation between adjacent vegetation-types. The problems with the interpretation accuracy of the *Dryas octopetala* heath is due to difficulties with the positioning. The small areas covered by willow shrubs have been enlarged to make them distinguishable, this has resulted in an overrepresentation of the type in the map.

Vegetation belts

Four of Du Rietz vegetation belts are represented in the valley. The coniferous belt is not present. The average altitudinal extensions of the low, middle and high-alpine belts corresponds well to the general altitudes defined by Du Rietz (1942), The sub-alpine belt do not reach as high as it was predicted to.

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Appendix 1

Sampling of vegetation

Vegetation samples were collected at five locations along an east-westerly transect (fig 24). Four squares measuring 0.25*0.25 m were cut clean of vegetation at each location. The vegetation was sorted into four different groups: herbs, heath, mosses and grass. The samples were dried and weighed in order to obtain a measure of the biomass of the different life forms (table 8).

Figure 24. The location of the five sample sites

Table 8. The frequency of heath, herbs, moss and grass in the five sample sites. The values are averages based on the dry weights of four samples from each site.

Site	*Vegetation-type*	*% Heath*	*% Herbs*	*% Moss*	*% Grass*
1	*D. octopetala* (1232)	25,2	44,3	23,5	7,1
2	*E. hermaphroditum* (1213)	23,5	29,1	7,4	40,1
3	Low herbs meadow (1341)	0	87,5	2,1	10,5
4	1341 solifluction	3	70,5	15,4	11,2
5	1341 / 141	4,7	65	12,8	17,5

Site 1 and 2 are located in the slopes of Mt. Kärketjåkko. Site 1 is located in the *D. Octopetala* heath (1232) which is drier and at a higher altitude than site 2 in the *E. Hermaphroditum* heath.

Site 3 is located in the middle of the alluvial fan in the centre of the valley, beneath the Kärkereppe niche. The vegetation is of a low herbs meadow-type (1341).

Site 4 is located on the western slope in the moist low herbs meadow with pronounced solifluction (1341s).

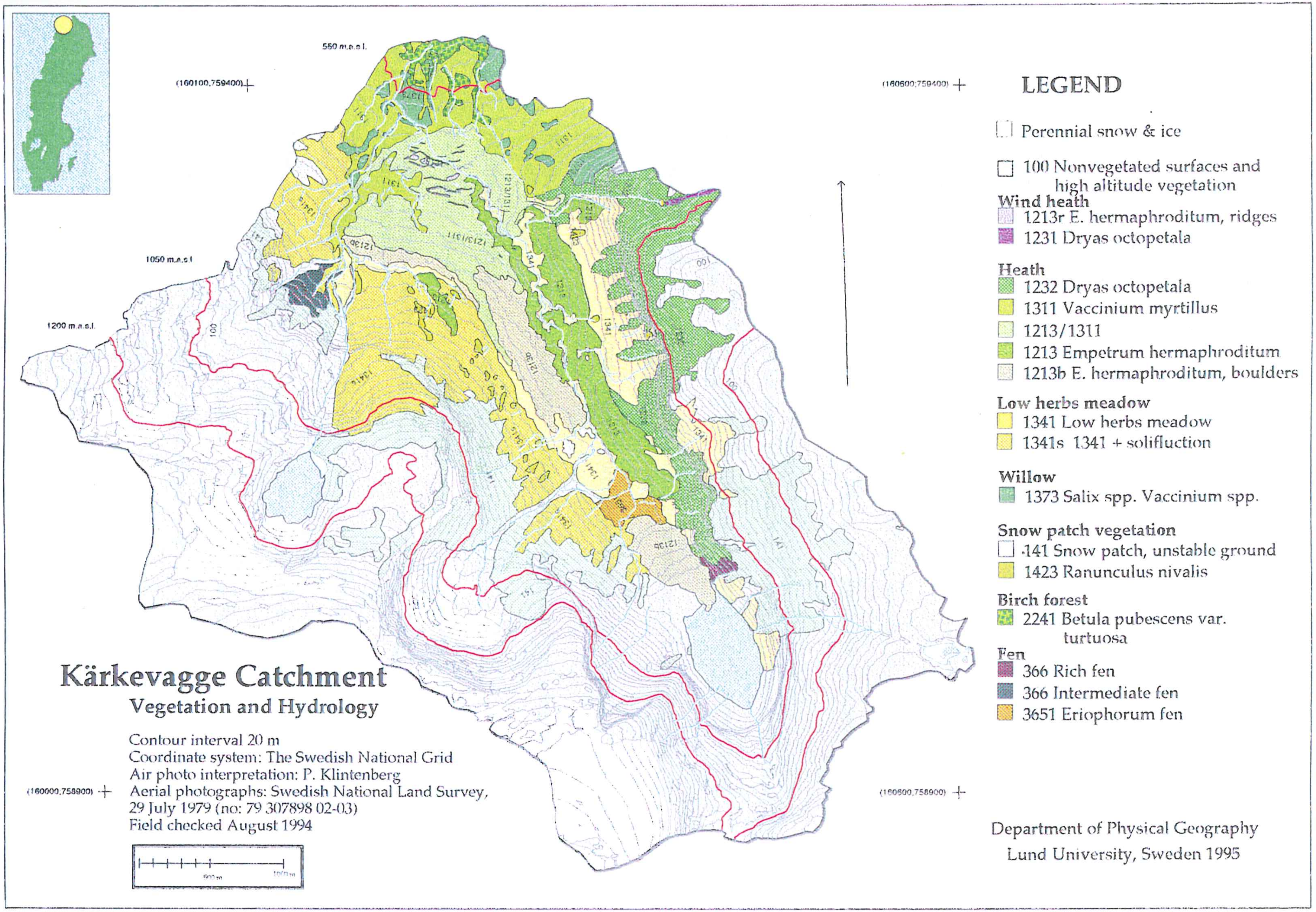
Site 5 is above site 4, just in the transition zone between (1341s) and the snow patch vegetation (141).

Appendix 2

The vegetation map

The vegetation distribution in the Kärkevagge valley is here illustrated on a colour map in a approximate scale of 1 : 35 000. The base map, the topographic iso-lines and the hydrology have been digitalized from the Kärkevagge base map (1993). The contour interval is 20 m (the original resolution is 10m). The Swedish National Grid has been used as coordinate system.

The extensions of the vegetation-belts defined by Du Rietz (1942) are presented as red coloured topo-lines.


Kärkevagge Catchment
Vegetation and Hydrology
Contour interval 20 m
Coordinate system: The Swedish National Grid
Air photo interpretation: P. Klintenberg
Aerial photographs: Swedish National Land Survey,
29 July 1979 (no: 79 307898 02-03)
Field checked August 1994
LEGEND
Perennial snow & ice
100 Nonvegetated surfaces and high altitude vegetation
Wind heath
1213r E. hermaphroditum, ridges
1231 Dryas octopetala
Heath
1232 Dryas octopetala
1311 Vaccinium myrtillus
1213/1311
1213 Empetrum hermaphroditum
1213b E. hermaphroditum, boulders
Low herbs meadow
1341 Low herbs meadow
1341s 1341 + solifluction
Willow
1373 Salix spp. Vaccinium spp.
Snow patch vegetation
141 Snow patch, unstable ground
1423 Ranunculus nivalis
Birch forest
2241 Betula pubescens var. turtuosa
Fen
366 Rich fen
366 Intermediate fen
3651 Eriophorum fen
Department of Physical Geography
Lund University, Sweden 1995
550 m.a.s.l.
1050 m.a.s.l
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