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PLANT LIFE ON SERPENTINES AND RELATED ROCKS IN THE NORTH OF SWEDEN

BY

OLOF RUNE

UPPSALA 1953

ALMQVIST & WIKSELLS BOKTRYCKERI AB

SVENSKA VÄXTGEOGRAFISKA SÄLLSKAPET

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Contents

I. Introduction

From a strictly petrological point of view, serpentine is a hydrated silicate of magnesium and iron derived from a hydrothermal alteration of olivine. The term serpentine denotes the mineral itself as well as the rock consisting mainly of this mineral. In regard to the low-iron olivine, which usually occurs in the mountain district of N Sweden, this alteration follows the approximate formula (T. Du Rietz 1935 p. 255):

$$23\ Mg_{11}Fe\ Si_6O_{24} + 176\ H_2O + 38\ SiO_2 + 4\ O = 11\ H_{32}Mg_{23}Fe\ Si_{16}O_{72} + 4\ Fe_3O_4.$$

It has long been known that rock and soil of serpentine have a specific effect on vegetation and harbour a flora peculiar to itself. Actually, this effect is not restricted to serpentine only but is also to some extent connected with the other ultrabasic rocks, viz., peridotites and soapstones which have a rather similar chemical composition, being ecologically more or less equivalent to serpentine. Of all ultrabasic rocks, serpentine has the most striking effect on the vegetation and is, moreover, the one generally in contact with it. The ecological problems associated with these kinds of rock were therefore studied with particular regard to serpentine.

Ecologically, the meaning of the term serpentine has come to involve also other ultrabasic rocks equivalent to serpentine *sens. str.* Accordingly, the serpentine flora of North Sweden, which will be discussed in the present paper, includes also the plants on peridotites and soapstones. However, it should be stressed that this wider interpretation of the term serpentine will be used here in an ecological sense only, for example, as part of biological definitions such as *serpentine flora* or *serpentinicolous*, etc. (see p. 78). This does not rule out a strict mineralogical terminology in describing the different ultrabasic areas. In so far as the mineralogical composition of the various areas is established, a study of the differences in vegetation due to differences in mineralogical composition of the rock will facilitate dealing with the problems concerning the serpentine flora.

Ultrabasic rocks occur in different parts of the world: New Zealand, New Caledonia, South Africa, North and Central America, South and Middle Europe. In N Europe, they are chiefly found in the Caledonian mountain range. However, common ultrabasic intrusions are restricted only to some parts of this mountain range, e. g., some western, coastal districts of Norway, and a central mountain district comprising N Jämtland (Frostviken), S Lappland and adjacent parts of Norway (lat. 64° to 66° N). Being of the Lower Ordovician age, the ultrabasic intrusions are probably the oldest intrusions of the Caledonian igneous rock. As regards the Swedish part of the mountain range, they may occur both in the phyllitic, or so-called Köli, region in the west, and in the highly metamorphic, or so-called Seve, region in the east. The serpentines, as well as other ultrabasics, appear mainly as oval and lenticular outcrops, being from a few metres to some kilometres or more in length, their width being generally much less. They are generally seen as knobs above the surrounding rocks as they are less rapidly weathered. The serpentine outcrops of N Sweden may occur at altitudes ranging from about 400 to 1400 m. Although several are situated below the alpine belt, they all appear rather barren, the non-alpine ones being sparsely wooded. Moreover, they are easily recognized by the reddish-yellow tints of their weathered surfaces, sometimes accentuated by red lichens (*Caloplaca elegans*) or algae (*Trentepholia jolithus*). Most of the ridges are named after their reddish colour. T. Du Rietz (1935) monographed geologically the ultrabasic rocks of N Sweden.

Pančić, who described the flora of the serpentine mountains of Middle Serbia in 1859, was the first botanist to pay attention to the very peculiar vegetation of serpentine soils. Some years later, Milde (1867, 1868) stated that the fern *Asplenium adulterinum*, described by him two years earlier, might be a form of *A. viride* restricted only to serpentine soil. However, the problems connected with the serpentine flora were not discussed in detail until after 1920 when especially the serpentine floras of Middle Europe were described in several papers. Thus, Lämmermayer in a series of papers (1926, 1927, 1928 a b, 1934) dealt with the serpentine flora of the Austrian Alps. Nevole (1926) also contributed to this subject. In addition, Kretschmer (1931) described the serpentine flora at Gurhof in the Danube Valley. The flora and vegetation of the wide serpentine areas in Bohemia and Moravia were closely studied by Novák (1928, 1937) Suza, Nováček, Dvořák, and others (see Novák 1937). In Italy, the serpentine flora and vegetation were studied by Pavarino (1914), and by Pichi-Sermolli, who, in a recent informative paper (1948), described the serpentine flora of the upper Tiber Valley, and also treated the problems concerning serpentine floras in general. Outside Europe, the problems relating to serpentine vegetation were also investigated in N America, with special regard to the cause of the infertility of serpentine soils. From New Zealand, Cookayne (1921) gave a brief account of the vegetation of mineral belts that consist mainly of serpentine.

In N Europe, the serpentine vegetation has been largely overlooked by botanists, no doubt due to the rather sparse occurrence of serpentine rocks there and to their confinement to very distant and botanically more or less unexplored mountains and forest areas. Accordingly, so far only one paper on the Scandinavian serpentine vegetation exists, viz., that of B. Björlykke (1938) which was published posthumously, and deals with the vegetation of serpentine rocks in the district of Sumnöre at the west-coast of S Norway (about lat. 62° 30′ N). In Finland, M. J. Kotilainen studied the plant life on serpentine over a long period, with special regard to the bryophytes, and in 1944 presented some important results in an abstract from a lecture.

Apart from the above, the only contributions to the study of Fennoscandian serpentine vegetation are some brief notes in the vegetational monographs by Smith (1920), Nordhagen (1928), and Knaben (1952), and some short items published by Mikkola (1938), Danielsson (1948) and the present author (1947 and 1949).

During the summers of 1945–1950, in studying the mountain flora of S Lappland (Åsele and Lycksele Lappmarker), I travelled through the whole mountain district of that area. As it is rather rich in serpentine outcrops, I soon observed the peculiar and very interesting flora connected with that kind of rock. I therefore decided to visit every serpentine outcrop of importance within the area. Fortunately, this mountain district is mapped geologically (Backlund and Quensel 1929), and parts of it have also been more closely investigated by Kulling (1933), Beskow (1929), and T. Du Rietz (op. cit.). These geological data facilitated the fulfilment of my plans and I extended my serpentine studies to include adjacent parts of Jämtland, viz., the Frostviken parish which is also very rich in ultrabasic rocks. Thus, I visited the areas of Frostviken in 1947 and 1949, the last time together with M. J. Kotilainen who then studied the bryophyte flora of that area.

As the bulk of the Swedish ultrabasics occurs within the district of Frostviken – S Lappland, I was able to widen the range of my serpentine investigations to comprise all N Sweden by visiting only a few more localities in other parts of Jämtland and Lappland. Accordingly, in 1949 and 1950 I visited the serpentine areas south of Ånnsjön in W Jämtland, and in 1949 also some peridotite areas in Lule Lappmark (cf. map in Fig. 1). Thus, my investigation comprises all the outcrops of ultrabasic rocks in N Sweden of any importance with the exception of some in westernmost Lule Lappmark. For comparative studies, in 1948 I visited serpentine areas in N Finland, in 1950 serpentine areas in Helgeland, Norway (Hattfjelldal, and Rödön in Tjötta), and in 1951 some serpentine areas of E North America (cf. p. 91).

With regard to the Swedish ultrabasic rock areas, I have endeavoured to list the complete flora of each one visited. As most of the areas are moderate in size and have a rather scanty vegetation, the listing of all the vascular plants met with no obstacle. Still, as regards lichens and bryophytes I had the opportunity of studying but a few locallities more in detail.

Seeds were collected from some serpentinicolous plants and grown in the Botanical Garden of Uppsala University. Soil samples were collected in many of the areas visited and later analysed, by the following determinations: 1) pH value (by glass electrode in aqua dest. suspension); 2) Soluble phosphates according to the lactate method (Egnér, Köhler, and Nydahl 1938); 3) Soluble potassium by extraction with mono-chlor-acetic acid, and with a flame photometer (Egnér 1940). These analyses were all carried out by Statens Lantbrukskemiska Kontrollanstalt (State Service Station of Agricultural Chemistry). Some samples were also analysed with regard to the total content of CaO (by extraction with 20% HCl and precipitation with oxalate). The CaO analyses were carried out partly at the above-mentioned service station, and partly at the Mineralogical-Geological Institute of Uppsala University by Mrs Brita Collini. At the latter Institute, also the mechanical composition of some samples of serpentine soil was determined by elutriation analyses (Ekström 1927), and some rock slices were prepared.

I have the greatest pleasure in expressing my gratitude to those who have contributed in diverse ways to this paper in the course of my work.

Firstly, I am indebted to Professor Mauno J. Kotilainen, Helsingfors, for drawing my attention to the problems of the serpentine flora and also for the generous way in which he allowed me to benefit by his extensive experience in the study of this subject.

Professor G. Einar Du Rietz, Head of the Institute of Plant Ecology of Uppsala University, gave my work invaluable support by placing the resources of the Institute at my disposal, as well as personally by his unfailing interest and kindness in going through my manuscript.

Among the botanists and geologists with whom I have had the privilege of discussing my work I particularly wish to mention: Professor John Axel Nannfeldt, Professor Helge Backlund, Dr Nils Hylander, Dr Harry Smith, Dr Gunnar Lohammar, Mr Bengt Collini Fil. lic., Dr Axel Nygren, Dr Hugo Sjörs, Mr Bengt Pettersson Fil. lic., Mr Sven O. Björkman Fil. lic., Uppsala; Professor Eric Hultén, Stockholm; Dr Torsten Du Rietz, Boliden; Dr Erika Gaertner, Hamilton, Ontario, and Mr Marcel Raymond, Montreal.

Finally, I also wish to record my indebtedness to my faithful companions during field work in the serpentine mountains. My wife, Mrs Maj Rune, my brother Mr Sven Rune, Mr Tage Roos, Mr Volkmar Stoy and Mr Sven O. Björkman accompanied me during different periods. Professor Mauno J. Kotilainen accompanied me during excursions in N Finland and N Jämtland. During a visit to N America in 1951, Professor Edgar Wherry and Dr Francis Pennel, Philadelphia, were kind enough to show me the serpentine areas in Chester Co, SE Pennsylvania; Mr Marcel Raymond and Mr Jim Kucyniak, Montreal, supported my field work in Gaspé and organized an excursion in order to show me the serpentine areas of Megantic Co, Quebec.

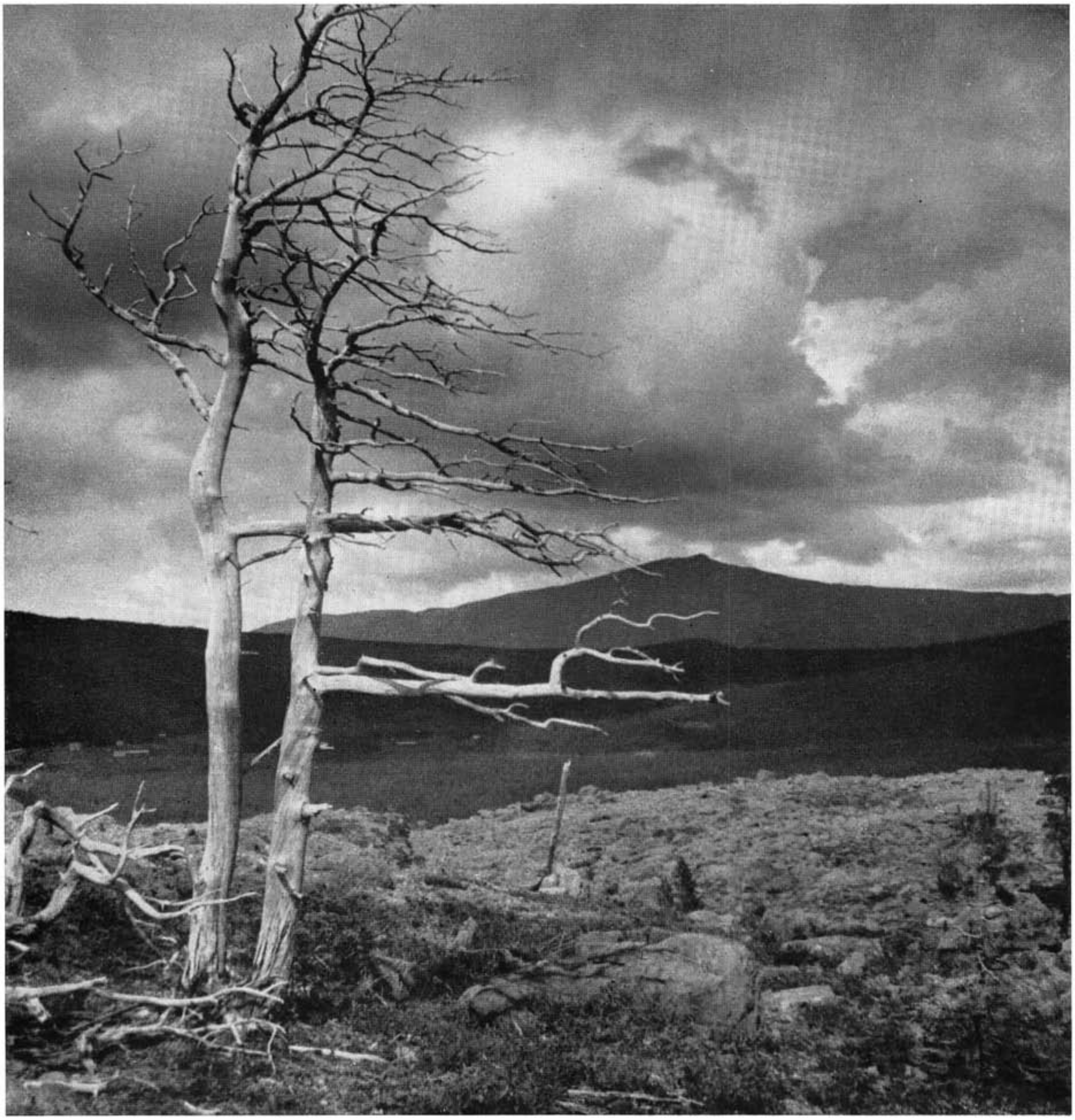
The Latin diagnoses were translated by Dr Nils Hylander, Uppsala.

In its English shape, the manuscript was revised by Mr David Smith, Oxford, and Mrs Ulla Schött, Stockholm.

Växtbiologiska Institutionen
(Institute of Plant Ecology)
Royal University of Uppsala,

December 27th, 1952.

Olof Rune



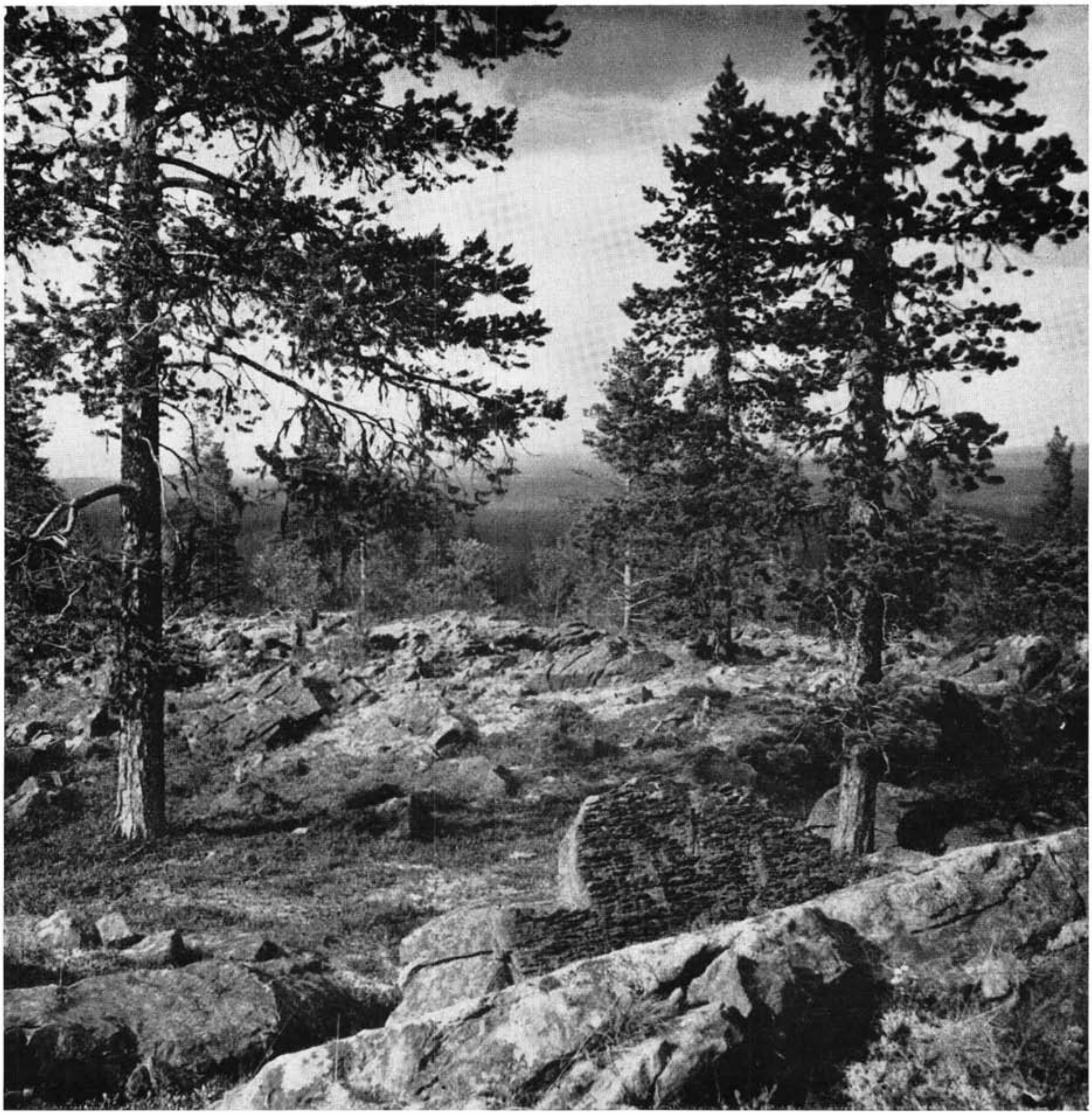
"The pine tree wastes which is perched on the hill,
nor bark nor needles shelter it;"
HAVAMAL.

From serpentine area at Kittelfjäll, Åsele Lappmark (cf. Fig. 14). Photo Olof Rune 6.7.1946. Quotation from an English translation of the Viking poem *Havamal* (OLIVE BRAY, London 1908).

Serpentine area south of Kittelfjäll village in Åsele Lappmark (No. 22), appearing as big, barren heaps of boulder and gravel almost destitute of vegetation, though only at about 500 m altitude. Photo Olof Rune 12.7.1946.

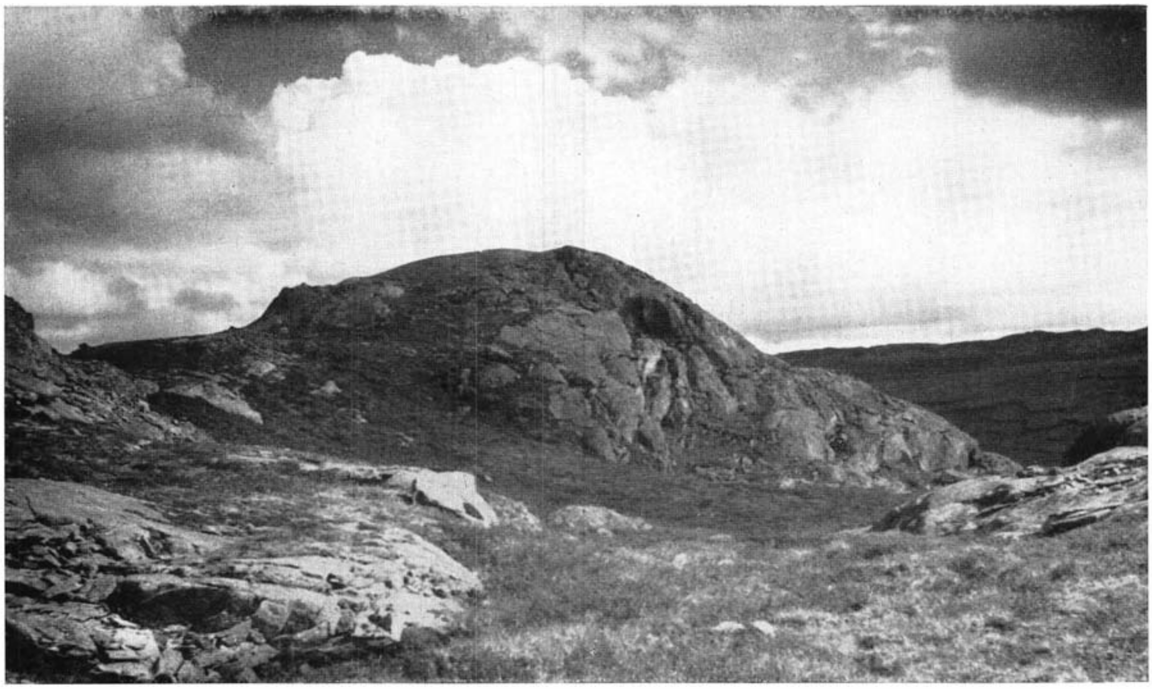
Mt Atoklinten — big serpentine protuberance on northern side of Södra Storfjällen (No. 36), west of Tärnaby near Norwegian border. Rises about 100 m above surrounding level, reaching 1 020 m, with characteristic profile easily recognized at great distance. Picture shows southwestern part of outcrop. Photo Olof Rune 27.8.1948.

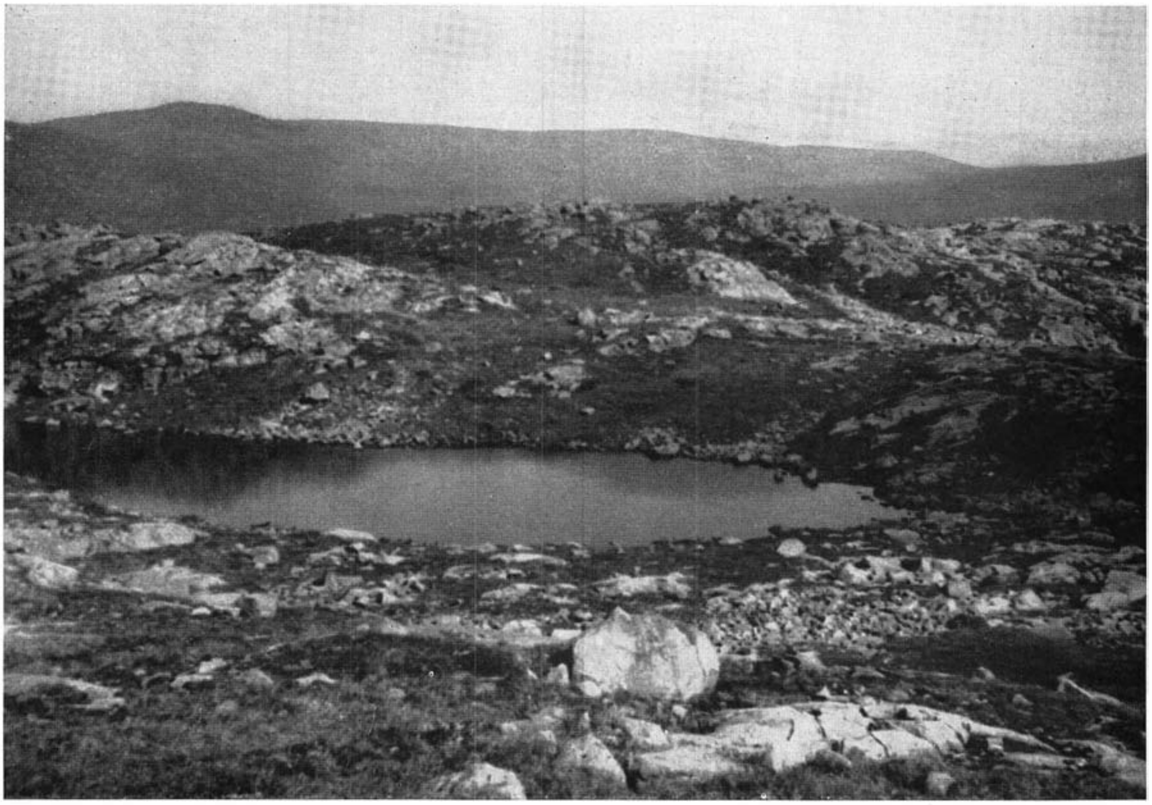
PLATE IV



Serpentine area at Lingonberget in parish of Gällivare (No. 41) is the only one outside the high mountain districts. Though surrounded by dense spruce forest, the serpentine is but sparsely forested with pine. In exposed parts, the ground is barren, harbouring but a few serpentinicoles; in less exposed parts, the ground is covered with dwarf shrub mats of *Empetrum hermaphroditum* and *Vaccinium uliginosum*. Photo Olof Rune 5.7.1949.

Slope in serpentine area at Lingonberget with pronounced solifluction. Vegetation consists of abundant *Asplenium viride* tufts and more sparse *Festuca ovina, Deschampsia flexuosa, Viscaria alpina* var. *serpentinicola*, and *Cerastium alpinum* ad var. *serpentinicola*. Photo Olof Rune 5.7.1949.





Above: Peridotite outcrop at about 900 m level due west of Lake Övre Ältsvattnet in parish of Sorsele, Lycksele Lappmark (No. 37). Photo Olof Rune 11.8.1949.

Below: Serpentine area of Mt Rautats in parish of Frostviken (No. 12), one of the largest in N Sweden, forming a wide mountain plateau with highly alpine character, though situated only at about 700 m. Mountain in background is Gilletsentjåkko. Photo Olof Rune 2.7.1947.

Above: Peridotite of Mt Aunevare in Åsele Lappmark (No. 21) forms an isolated, big mountain reaching 1265 m. Firm peridotite rocks crop out above about 1000 m, while below, the bedrock is mainly covered with moraine. Picture shows northwestern part of mountain. Photo Olof Rune 29.8.1947.

Below: Serpentine outcrop of Mt Lebbinjesnjounje, due west of Kittelfjäll village in Åsele Lappmark (No. 23) is extremely barren, being largely destitute of soil and vegetation. Mountain in background is Borkafjäll. Photo Olof Rune 6.7.1946.

Above: The wide top-plateau of Aunevare is a stony waste, extremely dry and poor in weathered material. In foreground sparse *Juncus trifidus - Silene acaulis* heath. See Pl. VII. Photo Olof Rune 19.7.1946.

Below: Close-up of *Juncus trifidus - Rhacomitrium lanuginosum* heath with *Silene acaulis* in foreground. Gurtatjåkko serpentine in Åsele Lappmark (No. 24). Note different vegetation of lichens on erratic boulder to the left. Photo Olof Rune 9.7.1946.

II. Flora and vegetation on serpentines and other ultrabasic rocks in North Sweden

1. Description of ultrabasic rock areas in North Sweden

In the following description the ultrabasic rock areas will be mentioned in their order from south to north. Adjacent areas are grouped together into districts, named after characteristic mountains, sometimes villages or lakes, within the district (see map in Fig. 1). References are given for each district including the numbers and names of the sheets of topographical maps, scale 1: 200 000.

Swedish and Lappish words forming part of place names have not been translated, e. g., Kyrkstensfjället (fjäll = high mountain), Övervattsberget (berget = mountain), Graipesvare (vare = high

Fig. 1. Situation of ultrabasic rock areas. Each dot represents a district comprising one or several adjacent areas.

1. District of Handöl
2. " " Kall
3. " " Muruhatten
4. " " Junstern
5. " " Lake Blåsjön
6. " " " Värgaren
7. " " N Burgfjällen
8. " " Graipesvare
9. " " Kittelfjäll
10. " " Gränssjö
11. " " Rönnbäck
12. " " Tärna
13. " " S Storfjällen
14. " " Lake Ältsvattnet
15. " " Ammarfjällen
16. " " Kvikkjokk
17. " " Gällivare

Fig. 2. Westernmost serpentine barren of Bunnerviken area. Scanty vegetation dominated by *Asplenium viride* in crevices, and *Arenaria norvegica* on loose gravel.
Photo Olof Rune 2.9.1949.

mountain [Lappish]), Häggsjön (sjön = lake), Smalsundstjärn (tjärn = tarn), Slipsikjaure (jaure = lake [Lappish]).

The terms *serpentinophyte, serpentinicolous,* etc., are defined on pp. 78—81. Some new varieties: *Cerastium alpinum* var. *serpentinicola, Melandrium rubrum* var. *serpentinicola* and var. *smithii,* etc., mentioned below are described on pp. 53—65.

JÄMTLAND

PARISH OF UNDERSÅKER

District of Handöl

(map 65 Duved).

1. Mt Täljstensberget.

South of Ånnsjön, a string of small serpentine outcrops runs eastward from Täljstenberget near the village of Handöl. The westernmost of these outcrops is situated on the northeastern side of Täljstensberget quite near the road to Bunnerviken, and forms an isolated knoll on the 600 m level. Its area is about 1.5 hectares.

According to T. Du Rietz (1935 p. 203) the composition of the rock is as follows (figures in parentheses are values given by T. Du Rietz in a personal communication):

	%	
SiO_2	38.53	
Al_2O_3	0.29	
Fe_2O_3	3.74	
Cr_2O_3	0.51	(0.35)
FeO	5.06	
NiO	–	(0.26)
MnO	0.11	
MgO	39.84	
CaO	1.45	
Na_2O, K_2O	0.05	
CO_2	1.80	
S	–	(0.1)
As	–	(0.03)

Actual composition (weight %)	
Olivine	36.4
Serpentine	43.8
Tremolite	11.3
Magnetite	4.9
Breunnerite	3.6

The calcium content of this serpentine rock is a little higher than usual because of the occurrence of tremolite and breunnerite. The vegetation is

Fig. 3. Exposed parts of Bunnerviken barrens with scanty vegetation, due largely to strong wind erosion and frost action during late winter. Growths in pictured area: *Asplenium viride*, *Arenaria norvegica*, *Deschampsia flexuosa*, *Rumex acetosa*, and, in foreground, *Rhacomitrium lanuginosum*. Ånnsjön in background. Photo Olof Rune 2.9.1949.

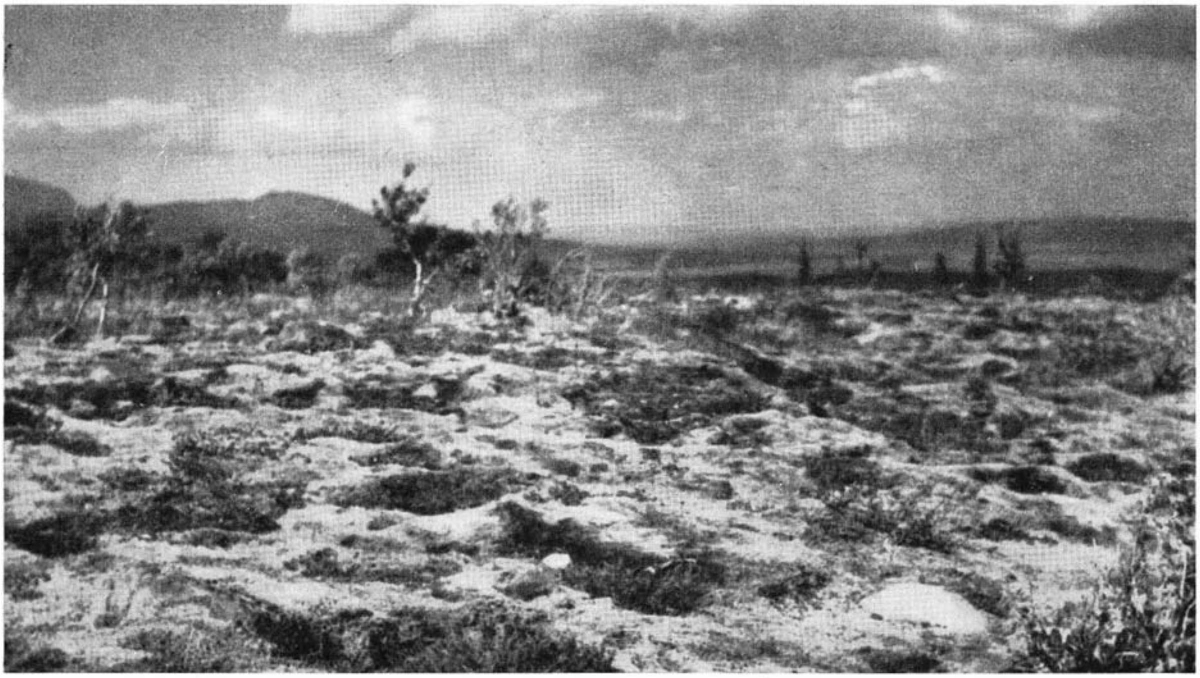


Fig. 4. Less exposed parts of Bunnerviken barrens covered with extensive *Rhacomitrium lanuginosum* mats, with interspersed dwarf shrub thickets of *Betula nana*, *Calluna vulgaris*, *Empetrum hermaphroditum*, and *Vaccinium uliginosum*. Photo Olof Rune 2.9.1949.

principally characterized by the great abundance of *Melandrium rubrum*, represented by a particular endemic serpentine race *M. rubrum* var. *smithii*.[1] *Asplenium viride* and *Rhacomitrium lanuginosum* are also particularly abundant there. In addition, the following were noticed: *Molinia coerulea*, *Deschampsia flexuosa*, *Rumex acetosa*, *Calluna vulgaris*, *Empetrum hermaphroditum*, and *Vaccinium uliginosum*. However, *Cerastium glabratum*, *Viscaria alpina*, and *Silene acaulis*, usually common on serpentine, were not observed.

2. **Bunnerviken** (Figs. 2, 3, 4).

At a distance of 1–2 km from the southern shore of Ånnsjön, and southeast of Bunnerviken farm, two small serpentine areas crop out about 1 km apart. They were mentioned by SMITH (1920) as very rich localities of *Arenaria norvegica*. The area of each outcrop amounts to approximately 0.5 hectare. They are both situated at the 600 m level, and composed of firm rocks, largely overlaid by weathered materials. Their surface is covered with *Rhacomitrium lanuginosum* mats, alternating with patches of barren soil in which particularly *Asplenium viride* and *Arenaria norvegica* occur rather plentifully. In addition, the following plants were observed: *Melandrium rubrum*, *Festuca ovina*, *Deschampsia flexuosa*, *Rumex acetosa*, *Juncus trifidus*, *Molinia coerulea*, *Empetrum hermaphroditum*, *Vaccinium uliginosum*, and *Juniperus communis*. However, the characteristic serpentinicoles, *Cerastium glabratum*, *Viscaria alpina* and *Silene acaulis* were lacking in this area.

3. **Mt Rödberget.**

The largest and most eastern of the serpentine outcrops within this district is Rödberget, situated about 3 km southeast of the southeastern part of Ånnsjön. Rödberget constitutes an isolated mountain top on the northern side of Kyrkstensfjället, and its highest point reaches 784 m. The area equals approximately 10 hectares. Large parts are covered by extraneous moraine; only the top and the steep southern parts consist of serpentine barrens. On these, *Calluna vulgaris* and *Rhacomitrium lanuginosum* are the most common plants. In rock crevices, *Arenaria norvegica*, *Silene acaulis*, and *Festuca ovina* appear rather frequently. Many characteristic serpentine plants, such as *Asplenium viride*, *Viscaria alpina*, *Cerastium glabratum*, and *Rumex acetosa*, are comparatively sparse. Actually, no characteristic serpentine vegetation exists on Rödberget except on the barren serpentine rocks. Instead, the usual low-alpine, acid soil heath with *Empetrum hermaphroditum*, *Vaccinium uliginosum*, *Loiseleuria procumbens*, *Juncus trifidus*, and *Carex bigelowii* is dominant.

[1] *Melandrium rubrum* var. *smithii* nova var. cf. p. 62.

PARISH OF KALL

District of Kall

(map 66 Åre).

4. **The Kall Peridotite.**

In the middle of the forest area between Häggsjön and the village of Sölsved, about 5 km northeast of the church village of Kall, quite a small occurrence of peridotite is noted. However, this is hardly at all serpentinized. This rock rises only a few metres above the ground, and its area does not equal more than a few hundred square metres. The surrounding rocks are mica-schists and gneisses, amphibolites, pegmatites, crystalline limestone and quartsites (T. DU RIETZ op. cit. p. 152). This Kall peridotite is mentioned by T. DU RIETZ (op. cit. p. 152), being characterized as a greenish-grey olivine rock, rich in actinolite and chlorite, sometimes also in mica. The same author reported the following analyses from the mica-bearing Kall peridotite:

	%
SiO_2	41.78
TiO_2	0.48
Al_2O_3	4.92
Fe_2O_3	1.60
Cr_2O_3	0.08
FeO	12.76
MnO	0.25
MgO	30.03
CaO	3.77
Na_2O	0.40
K_2O	0.35

Actual composition (weight %)	
Olivine	42.4
Actinolite	33.3
Chlorite	20.4
Biotite	3.1
Ore minerals	0.8

As compared with other peridotites, this one contains more Al, Fe, Ti, Na, and K, and less Mg and Cr than usual. Apart from a rather rich occurrence of *Asplenium viride* in crevices, not even traces of a serpentine vegetation are to be seen on this rock. All the flat parts are overgrown with the same xerophytic *Vaccinium vitis-idaea – Cladonia* communities as predominate in dry parts everywhere in the vicinity.

PARISH OF FROSTVIKEN

District of Muruhatten

(map 46 Frostviken).

About 10 km due west of the church village of Gäddede, quite near the Norwegian border, several large peridotite outcrops occur round the Stora Muruhattstjärn. They constitute distinct summits rising between 50 and 100 m above the general level, thus reaching an altitude of approximately 600 m.

The surrounding rocks are mainly mica-schists, injection-gneisses, and amphibolites. A detailed geological study of this district was made by T. Du Rietz (op. cit. p. 160).

5. Mt Muruhatten.

Muruhatten, with an area of about 20 hectares, is the biggest of these serpentine occurrences. It consists of a typical peridotite protuberance which rises about a hundred metres above the more easily eroded mica-schists and amphibolites. The rock is rich in talc and has been quarried as soapstone. The vegetation shows only a few features associated with serpentine. A common low-alpine heath vegetation with *Empetrum hermaphroditum*, *Arctostaphylos alpina*, *Deschampsia flexuosa*, *Rubus chamaemorus*, and *Juncus trifidus*, etc., is dominant. However, a relatively abundant occurrence of *Asplenium viride*, *Viscaria alpina* and *Rhacomitrium lanuginosum* may be regarded a typical serpentine character. Yet, real serpentine rocks occur only within the peripheral parts of Muruhatten. On its western side I found a place particcularly rich in highly serpentinized peridotite, where the vegetation consists of abundant occurrences of an angustifoliate *Melandrium rubrum* (ad var. *serpentinicola*), a serpentinicolous form of *Cerastium alpinum* (ad var. *serpentinicola*), *Rumex acetosa*, and *Silene rupestris*. See Table 1: 1 (p. 44).

The following analyses of peridotite from Muruhatten, quoted from T. Du Rietz (op. cit. p. 169), shows the high content of talc in this rock. (Figures in parentheses are values given by T. Du Rietz in a personal communication.)

	%
SiO_2	49.03
TiO_2	traces
Al_2O_3	0.73
Fe_2O_3	1.46
Cr_2O_3	0.34 (0.25)
FeO	6.46
MgO	34.06
CaO	3.19
Na_2O	0.05
K_2O	0.00
NiO	none (0.18)

Actual composition (weight %)	
Olivine	28.7
Actinolite	24.4
Talc	24.8
Serpentine (Antigorite)	18.7
Chlorite	1.3
Breunnerite	0.3
Magnetite	1.8

6. Mt Lillfjället.

Lillfjället, which is situated about 1 km northeast of Muruhatten, consists of some peridotite as well as mica-schists, injection-gneisses, and amphibolites. The peridotite crops out at Säterberget and at a small summit about 200 m north of Smalsundstjärn. The western part of Lillfjället is called Säterberget and consists of a peridotite outcrop about 500 m long, but not more than about 50 m broad. Its southern parts descend abruptly towards the Muruhattstjärn. This southern slope is the only part of Säterberget I had the opportunity to visit. The large boulders below the slope are covered with *Rhacomitrium lanuginosum* mats with tufts of *Asplenium viride* and a few interspersed individuals of *Cerastium glabratum*.

The peridotite summit north of Smalsundstjärn harbours several serpentinicolous plants. In addition to the aforementioned plants the following were established: *Cerastium vulgatum* var. *kajanense*, *Melandrium rubrum*, *Viscaria alpina*, *Silene rupestris*, *Calluna vulgaris*, *Agrostis canina*, *Deschampsia flexuosa*, *Molinia coerulea*, and *Rumex acetosa*. In this place, Professor M. J. Kotilainen found the moss *Weisia viridula* which is a very characteristic serpentine plant in Finland previously unobserved in any Swedish serpentine area.

7. Mt Övervattsberget.

Övervattsberget is the easternmost peridotite occurrence of the Muruhatten district. It is situated about 1.5 km east of Muruhatten. Its area may be estimated at about 10 hectares. Besides dunite (olivine + chromite), the rocks contain diopside (T. Du Rietz op. cit. p. 154). The considerable calcium content in this mineral has its effect on the vegetation, in that several exclusively calcicolous mosses grow on the moist rocks of the northern part of the mountain. The central parts of the mountain are covered by woods of birch (*Betula tortuosa*) and spruce (*Picea abies*), and the vegetation is rather similar to that on other kinds of rock in the vicinity. The eastern and western parts of this mountain descend rather steeply. However, on the boulders and screes of these parts several serpentinicolous plants occur, viz., *Asplenium viride*, *Cerastium vulgatum* var. *kajanense*, *Viscaria alpina* var. *serpentinicola*, and *Melandrium rubrum*.

District of Junstern

(map 46 Frostviken).

About 10 km north of the church village of Gäddede, on the isthmus between the lakes of Kvarnbergsvattnet, Jormsjön, and Kycklingvattnet, some ultrabasic rock areas appear quite near the northern highway running from Gäddede to Norway. Surrounding rocks are mica-schists with injection-gneisses and amphibolites.

8. Mt Junsterklumpen.

Junsterklumpen, the easternmost of these peridotite outcrops, is fairly big. Its area comprises about 75 hectares and the highest peak reaches the 577 m level. The rock is dunitic, consisting essentially of olivine, as is clear from the following analysis published by T. Du Rietz (op. cit. 141). (Figures in parentheses are values given by T. Du Rietz in a personal communication.)

	%		Actual composition (weight %)	
SiO_2	40.50	(38.1)		
TiO_2	none		Olivine	81.2
Al_2O_3	0.22	(0.54)	Serpentine	15.9
Cr_2O_3	0.40	(0.50)	Magnetite	2.9
Fe_2O_3	2.03	(3.3)	(Chromiferous)	
FeO	4.92	(2.5)		
NiO	–	(0.34)		
MnO	0.10	(0.33)		
MgO	49.34	(43.0)		
CaO	0.02	(0.39)		
$Na_2O + K_2O$	0.08			

The highest parts of this mountain form a large plateau where barrens appear in several places. On these outcrops a rather characteristic serpentine vegetation occurs with plants such as *Asplenium viride*, *Viscaria alpina* var. *serpentinicola*, *Melandrium rubrum*, *Rumex acetosa*, *Cerastium vulgatum* var. *kajanense*, *Agrostis canina*, *A. tenuis*, *Empetrum hermaphroditum*, and *Vaccinium uliginosum*. Of these, especially *Agrostis canina* is very abundant. Between the outcrops, where the rocks are covered with a considerable humus layer, the vegetation is of a trivial type with ericaceous dwarf shrubs such as *Calluna vulgaris*, *Vaccinium myrtillus*, *Empetrum hermaphroditum*, *Vaccinium vitis-idaea*, and scattered trees of spruce (*Picea abies*), pine (*Pinus silvestris*) and birch (*Betula tortuosa*).

9. Lermon Summits.

About 5 km northwest of Junsterklumpen, two ultrabasic outcrops appear quite close to each other near the Lermon farm. On the topographical map, they correspond to the two summits of 440 and 464 m. In both places the rock is almost completely transformed into soapstone which has been quarried, especially at the easternmost summit.

Some serpentinicolous plants were found on these soapstone summits, but on the whole the vegetation is not characteristic of serpentine. Thus, on the western summit the following plants were observed on the steep western slope: *Asplenium viride*, *Cerastium vulgatum* var. *kajanense*, *Arenaria norvegica*, *Rumex acetosa*, *R. acetocella*, and *Deschampsia flexuosa*. The flat plateau of the top is almost completely covered by carpets of *Rhacomitrium lanuginosum* with, e. g., *Draba norvegica*, *Viscaria alpina*, *Sedum annuum*, *Woodsia alpina*, and *Cystopteris fragilis* growing between them.

The eastern summit harbours a few serpentinicolous plants: *Viscaria alpina* and *Cerastium vulgatum* var. *kajanense* growing on the very top plateau. Among other plants growing there, *Silene*

Fig. 5. Several serpentine rocks appear at summit of Mt Klumpliklumpen. Vein structure of rock surface typical of serpentine. In crevices of rock: *Asplenium viride, Agrostis stolonifera, Cerastium glabratum,* and *Silene acaulis. Agrostis stolonifera* is particularly abundant, with real mats filling up the depressions seen in the central parts of the rock. Photo Olof Rune 28.8.1949.

rupestris, Sedum annuum, and *Agrostis canina* may be mentioned.

10. **Mt Norra Digerhösen.**

Another ultrabasic rock area, called Norra Digerhösen, crops out about 5 km further to the northwest, in a small peninsula of Kvarnbergsvattnet. This is only a small outcrop with an area of less than 0.5 hectare and situated at a height of 325 m. The rock consists of soapstone of a type similar to that at Lermon. Serpentine vegetation occurs only in the western part where the rocks have been laid bare by soapstone quarrying. Abundant occurrences of *Arenaria norvegica* and *Melandrium rubrum* ad var. *serpentinicola* appear particularly on the heaps of crumbled soapstone. Although less plentiful, *Asplenium viride, Ramischia secunda* and *Rumex acetosa* were also found there. The abundant occurrence of the alpine plant *Arenaria norvegica* at this rather low altitude is striking, as also the absence of *Viscaria alpina* and any *Cerastium* species.

District of Lake Blåsjön

(map 46 Frostviken)

About 15 km northeast of the Junstern district, another ultrabasic rock district occurs south and east of Stora Blåsjön. Within this district only two different outcrops occur, both, however, constituting large mountains reaching up to the alpine region. The surrounding rocks are mica-schists with injection-gneisses and amphibolites.

11. **Mt Klumpliklumpen** (Fig. 5).

Klumpliklumpen is an isolated and rather large mountain rising about 200 m above the general level of the isthmus between the lakes of Blåsjön and Jormsjön. The summit, situated at 776 m, reaches the alpine region. The area of its serpentine outcrops amounts to about 50 hectares. According to T. Du Rietz, the rock is much serpentinized (see Fig. 5). A real serpentine vegetation is only found on the very top, which mainly consists of barren serpentine rocks. In crevices, the following plants grow: *Asplenium viride, Agrostis stolonifera, Cerastium glabratum, Viscaria alpina, Silene acaulis,* and the moss *Campylium stellatum.* Of these, *Agrostis stolonifera* is particularly abundant forming continuous carpets especially in the moist crevices and cavities.

The slopes of the mountain, except the southern one, are mostly covered with extraneous moraine or humus. In these places trivial low-alpine dwarf

Fig. 6. In the northern part of Mt Rautats, schistose serpentine occurs in a limited area. *Arenaria norvegica* has its only station in the Rautats area on coarse, weathered material connected with this type of rock.
Photo Olof Rune 2.7.1947.

shrubs dominate, viz., *Empetrum hermaphroditum, Vaccinium uliginosum* and *V. myrtillus.* Parts of the southern slope are very steep and form real precipices. Below the biggest one, situated at about the 700 m level, the following plants were found to grow on the serpentine scree (in order of abundance): *Cerastium glabratum, Viscaria alpina, Minuartia biflora, Roegneria scandica, Poa glauca, Agrostis borealis, Silene acaulis, Melandrium rubrum, Geranium silvaticum, Rumex acetosa, Calluna vulgaris,* and *Solidago virgaurea.*

12. **Mt Rautats** (Fig. 6, Plate VI).

The high Rautats mountain (the spelling "Ruotats" is used in the topographical map) east of Blåsjön consists entirely of serpentine. With its area of about 10 square km, it represents one of the largest serpentine occurrences in Sweden. The shape of this mountain is rather flat and the highest peak reaches only to a height of 873 m. Serpentine crops out from about 670 m and upwards. As the timberline is situated at about 700 m, the main part of this serpentine area is situated within the low-alpine region. Especially at the higher levels, a great deal of space is taken up by serpentine outcrops with a very scanty vegetation (Pl. VI). This is confined to crevices and other places where weathered products have accumulated. *Cerastium glabratum, Silene acaulis, Agrostis stolonifera, Asplenium viride,* and within a limited area also *Arenaria norvegica,* are the most common plants within such localities (Fig. 6). Between the outcrops the moraine is mostly covered by a sparse dwarf shrub heath vegetation with the following dominant plants: *Empetrum hermaphroditum, Calluna vulgaris, Vaccinium uliginosum,* and *Deschampsia flexuosa.* In places with moist ground, the grasses *Molinia coerulea, Anthoxanthum odoratum,* and *Agrostis stolonifera* preponderate.

However, the heath vegetation is often interrupted by almost barren areas produced by deflation or frost action. These areas are colonized by clearly serpentinicolous plants, such as *Silene acaulis, Cerastium glabratum, Melandrium rubrum, Viscaria alpina, Rumex acetosa,* and *Agrostis stolonifera.* See Table 1: 2–3 (p. 44).

According to T. Du Rietz (op. cit. p. 149) the

Rautats peridotite consists of olivines and enstatites which are serpentinized up to 25–75 %, while chromiferous magnetite, chromite ore, tremolite, chlorite and talc occur as secondary minerals. However, no analyses are published from Mt Rautats. In a personal communication, the following values, in %, were provided by T. Du Rietz: Cr_2O_3, 0.5 (in chromite veins up to 47); FeO (soluble), 4.0; NiO, 0.22; CoO, 0.06; Pt, 0.1; S, 0.1. The chromium content is rather high, and the last time quarrying was undertaken was during the period 1941–1944. Near the miners' huts, several anthropochors have settled, viz., *Stellaria media, Rumex acetocella, Poa trivialis, P. annua*, and *Phleum pratense*.

District of Lake Värgaren

(maps 46 Frostviken and 47 Risbäck).

Lake Värgaren is situated about 20 km east of Blåsjön. Serpentine outcrops occur at the southern and northern parts of this long and narrow lake. The composition of these rocks is rather similar to that of Mt Rautats.

13. Mt Lejarklumpen.

Lejarklumpen forms a large isthmus between the lakes of Lejaren and Värgaren, near the northern end of the long lake of Värgaren. From the level of the lake at about 580 m, Lejarklumpen rises very steeply, reaching an altitude of 769 m. The higher parts of Lejarklumpen consist, within an area of about 1.5 square km, mainly of barren serpentine outcrops. On these, *Arenaria norvegica* is abundant in crevices and on weathered gravel, growing between tufts of *Asplenium viride* and *Silene acaulis*. Many other serpentinicoles were noticed, viz., *Agrostis stolonifera, Minuartia biflora, Rumex acetosa, Cerastium glabratum, Melandrium rubrum*, and *Viscaria alpina*. In addition, the following plants listed also on Lejarklumpen are all reported from several other serpentine areas: *Scirpus caespitosus, Luzula spicata, Juncus trifidus, Molinia coerulea, Anthoxanthum odoratum, Juniperus communis* var. *montana, Salix herbacea, Empetrum hermaphroditum, Vaccinium uliginosum*, and *Deschampsia flexuosa*. The three serpentinicolous mosses, *Rhacomitrium lanuginosum, Drepanocladus uncinatus*, and *Campylium stellatum*, were all seen in abundance on Lejarklumpen.

14. Serpentine areas at the settlement of Östra Värgaren (Fig. 7).

Several small serpentine outcrops occur near the small Lappish settlement of Östra Värgaren at the eastern end of Lake Värgaren. The northernmost outcrop is situated near the northeastern shore of Värgaren at an altitude of 600 m, and about 2 km northwest of the settlement Östra Värgaren. It forms a single barren rock about 10 m high with an area of about 0.25 hectare. In crevices and weathered gravels the following plants are found: *Arenaria norvegica, Agrostis stolonifera, Asplenium viride, Deschampsia flexuosa, Minuartia biflora, Rumex acetosa, Silene acaulis, Viscaria alpina, Salix herbacea, Vaccinium uliginosum, Empetrum hermaphroditum, Juniperus communis* var. *montana*, and small shrubs of *Betula tortuosa*. The following mosses appear in abundance: *Rhacomitrium lanuginosum, Drepanocladus uncinatus*, and *Campylium stellatum*.

At the southwestern shore of Värgaren, and due south of the settlement of Östra Värgaren, another serpentine rock of about the same size crops out. This forms a north-exposed flag with an inclination of about 30°, a length of about 150 m, and a breadth of only 5 m. The flat summit parts are covered with carpets of *Rhacomitrium lanuginosum*, and tufts of *Asplenium viride, Agrostis stolonifera, Deschampsia flexuosa, Viscaria alpina, Minuartia biflora*, and *Empetrum hermaphroditum*. The principal part of this outcrop is, however, a north-exposed slope where at least the lower parts are rather moist and shady (Fig. 7). Here *Molinia coerulea* and *Melandrium rubrum* ad var. *serpentinicola* are very abundant. Other plants noticed on this northern side are: *Agrostis stolonifera, Juncus trifidus, Anthoxanthum odoratum, Calluna vulgaris, Vaccinium uliginosum, Solidago virgaurea*, and some small *Betula tortuosa* bushes.

A third serpentine outcrop of about the same size occurs about 0.5 km east of the easternmost cove of Värgaren. Except for the two species *Cerastium glabratum* and *Silene acaulis* which are

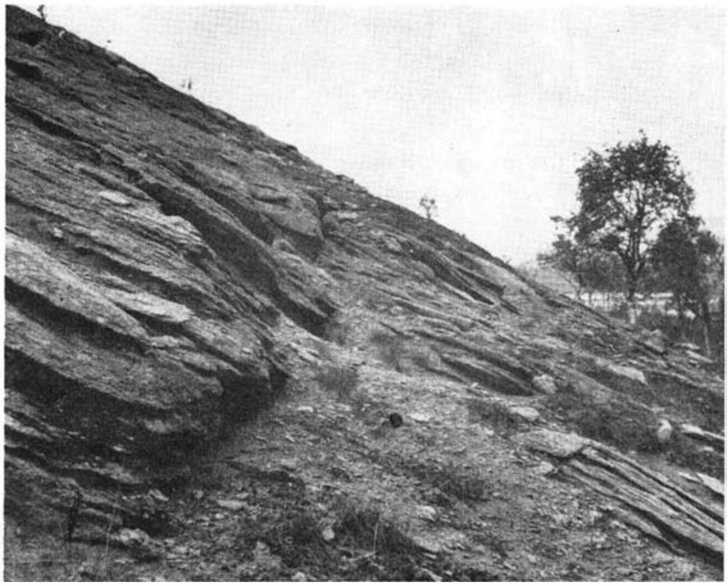


Fig. 7. Serpentine area south of the Östra Värgaren settlement forming a north-exposed flag partly covered with scree, and harbouring *Molinia coerulea, Deschampsia flexuosa,* and abundant *Melandrium rubrum* of a particular serpentinicolous race (ad var. *serpentinicola*), restricted to similar localities, i.e. serpentine scree at low altitudes.
Photo Olof Rune 6.7.1950.

Fig. 8. Serpentine outcrops at Lake Slipsikjaure, usually slightly arched but easily perceived owing to their yellow-brown colour, sharply contrasting with the dark brown low-alpine dwarf shrub heath. Vegetation in foreground consists of *Silene acaulis, Cerastium glabratum, Viscaria alpina, Minuartia biflora, Rumex acetosa, Juncus trifidus, Luzula spicata,* and the moss *Rhacomitrium lanuginosum.* Note different vegetation of lichens on erratic boulders to the right.
Photo Olof Rune 29.6.1947.

restricted to this latter locality, these two last-mentioned areas were found to have a similar flora.

15. **Lake Steurenjaure.**

DANIELSSON (1948) gave an account of some botanical excursions in the high mountains of N Frostviken, Jämtland. He mentioned a serpentine occurrence at the eastern side of the Steurenjaure tarn, about 3 km south of Östra Värgaren. This occurrence is situated in the low-alpine region at about the 800–900 m level. DANIELSSON's statement may be translated as follows: "On the eastern side of the Steurenjaure tarn lies an isolated olivine outcrop, visible at a great distance and having the same reddish yellow colour as Mt Rautats. Only the following 15 species were observed to grow there: *Arenaria norvegica, Asplenium viride, Calluna vulgaris, Cerastium glabratum, Deschampsia flexuosa, Empetrum hermaphroditum, Juncus trifidus, Juniperus communis* var. *montana, Minuartia biflora, Molinia coerulea, Rumex acetosa, Salix herbacea, Silene acaulis, Vaccinium uliginosum, Viscaria alpina.*"

LAPPLAND

Åsele Lappmark

PARISH OF VILHELMINA

District of Norra Burgfjällen

(maps 47 Risbäck and 40 Dikanäs).

Norra Burgfjällen is a wide, high mountain district extending along both sides of the border-line between Jämtland and Lappland. The western part, consisting mainly of mica-schists, is crossed by a chain of small serpentine outcrops which passes near the western end of Kultsjön in a southwestern direction.

16. **Serpentine areas at Lake Slipsikjaure** (Fig. 8).

Lake Slipsikjaure is situated about 10 km south of the village of Klimpfjäll, close to the border-line between Jämtland and Lappland. A chain of several small serpentine outcrops passes west and southwest of the lake, the area of each of the outcrops being about 1–2 hectares. The whole area lies at approximately the same level, viz., 900 m. The southernmost of the outcrops, situated beside the trail between the villages of Klimpfjäll and Raukasjö, differs somewhat from the others. It is high and steep with a greyish green colour, while the others are slightly arched and yellowish brown. A mineralogical examination revealed it to consist essentially of fresh olivine, while the others are largely serpentinized. While the flat outcrops are extremely dry, this southern one exhibits a moist, steep northern side which is relatively rich in plants not usually seen in serpentine, viz., *Saxifraga rivularis, S. stellaris, Ranunculus acris, Oxyria digyna, Carex lachenalii*, and *Salix herbacea*. The vegetation of this olivine outcrop does not differ so markedly from that of the surrounding mica-schists as does the vegetation of adjacent serpentine rocks. These are all very dry and deficient in weathered soil, so that plants can only thrive in a few crevices and cavities where soil has accumulated (Fig. 8). The only plants of this scanty vegetation are: *Silene acaulis, Cerastium glabratum, Viscaria alpina, Minuartia biflora, Rumex acetosa, Juncus trifidus, Luzula spicata* and, among mosses, *Rhacomitrium lanuginosum*. Se Table 1: 4–5 (p. 44).

17. **Mt Rupsentjårro** (Figs. 9, 10).

About 10 km northeast of Slipsikjaure, at Mt Rupsentjårro — a northwestern offset of Fiskonfjället — two rather small serpentine outcrops occur near each other. The area of each is about 1–2 hectares, and they are both situated at the 900 m level. The two outcrops are both strongly arched, with hardly any soil, except in crevices and beneath the cliffs where a yellowish brown, silty soil has

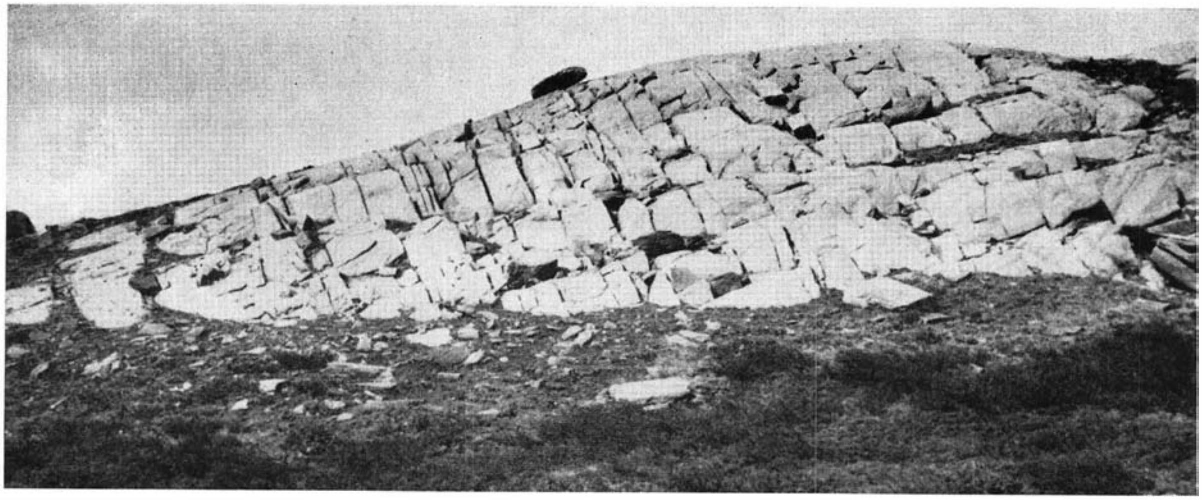


Fig. 9. North serpentine outcrop at Mt Rupsentjårro, strongly arched and exhibiting a steep south-side. Dwarf *Melandrium rubrum* is abundant in serpentine soil below. Border between serpentine and surrounding acid soil marks a sharp vegetation boundary; growth of dwarf shrub heath stops at serpentine soil border. A series of vegetational analyses was performed along a line perpendicular to the longitudinal axis of the outcrop. Fig. 10 gives the results. Photo Olof Rune 30.8.1948.

accumulated (Fig. 9). As always, these serpentine rocks are only sparsely covered with lichens, in this case chiefly *Caloplaca elegans* and *Physcia caesia*. At the time of my visit, the crevices were full of beautifully flowering *Cerastium glabratum* which occurs in abundance. In addition, the following plants were observed: *Asplenium viride*, *Festuca ovina*, *Juncus trifidus*, *Luzula spicata*, *Rumex acetosa*, *Oxyria digyna*, *Minuartia biflora*, *Viscaria alpina*, *Melandrium rubrum*, *Empetrum hermaphroditum*, *Vaccinium uliginosum*, the moss *Rhacomitrium lanuginosum*, and the lichens *Cetraria nivalis*, *Cladonia rangiferina*, and *C. sylvatica*.

The longitudinal axis of the northern outcrop has an almost east-western direction. The hillock therefore shows well-outlined northern and southern sides. In order to illustrate, firstly, the difference between the vegetation on the northern and the southern sides and, secondly, the sharp limit between the vegetation in serpentine soil and that in the vicinity, a series of vegetation analyses were carried out along a line perpendicular to the longitudinal axis. The results are given in Fig. 10 and Table 1: 6–10 (p. 44).

Surrounding the serpentine, a common low-alpine *Empetrum hermaphroditum* heath predominates, on the northern side rich in mosses and *Betula nana*, and on the southern side rich in lichens. On the northern side, the limit between the serpentine vegetation and this *Empetrum* heath is not at all sharp; a wide transition zone appears with *Betula nana*, *Salix herbacea*, *Carex lachenalii*, and *Juncus trifidus* growing among the typical serpentine plants (Fig. 10, stands 1, 2). The serpentine soil of the northern side is covered by a layer of humus. On the top, *Cerastium glabratum* is predominant (stand 3). The transition zone of the southern side is characterized by an abundance of dwarf *Melandrium rubrum*; this transition zone has no humus layer (stand 5). On the southern side the limit between the serpentine vegetation and the *Empetrum* heath is very sharp (notice the difference between stands 5 and 6). This limit is also illustrated in Fig. 9.

18. **Mt Tjarve.**

About 10 km further east of Rupsentjårro, and 5 km south of the village of Stornäs, another peridotitic area crops out. Its appearance differs, however, from that of the other more serpentinized outcrops within this district. It looks like a big sugar-loaf, rising about 100 m above the plateau level. The area equals about 8 hectares. The top of this mountain, named Tjarve, reaches an altitude of 772 m. The outcrop has a pronounced longitudinal axis with an east-western direction, which gives it clearly marked southern and northern sides. The rock, which has not been closely studied from a geological standpoint, is greyish black and very resistant to weathering. It seems to be rather similar to the peridotite of Röberget which occurs only about 10 km further to the northwest. The peridotite of Röberget is, according to T. Du Rietz (op. cit. p. 227), rich in carbonate (magnesite) and talc. No thoroughly typical serpentine vegetation appears on Tjarve. Serpentine plants only occur on the western side, where *Asplenium viride*, *Cerastium glabratum*, *Minuartia biflora*, and *Saxifraga nivalis* are rather abundant. The dry and warm southern side is rich in plants, thermophilous at this altitude, e. g., *Roegneria scandica*, *Poa glauca*, *Cystopteris fragilis*, *Lastrea dryopteris*, *Calamagrostis purpurea*, *Rubus saxatilis*, and *Silene rupestris*. See Table 1: 11 (p. 44).

District of Mt Graipesvare

(map 40 Dikanäs).

From about the middle of Lake Kultsjön, a ridge of serpentine stretches almost 20 km NNW. This ridge is most developed in the high mountains of Graipesvare, Murfjället and Aunevare. This is the largest serpentine district in Sweden, forming a large mountain ridge rising distinctly over the flat, low-metamorphic, phyllitic or Köli-rock level.

19. **Mt Röberget** (Fig. 11).

About 5 km east of the village of Lövberg, a steep peridotite cliff rises from the northern shore of Kultsjön. This mountain is called Röberget because of the red colour of the steep southern side, caused by the lichen *Caloplaca elegans*. Röberget, whose summit reaches the level of 680 m, rises 140 m above the surface of the lake and is visible at a great distance from the lake. According to T. Du Rietz (op. cit. p. 227), the rock is mainly olivine and serpentine but it contains also a great deal of carbonate (magnesite) and some talc. Just below Röberget lies a settlement where the grazing of the cattle has caused great injury to the mountain vegetation. Nevertheless, a typical serpentine vegetation was probably never confined to Röberget. Below the steep southern side, the following plants may be mentioned: *Roegneria scan-*

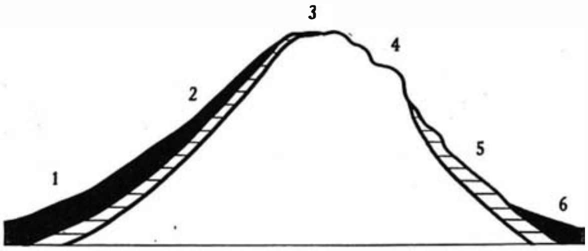


Fig. 10. Cross section through serpentine outcrop in Fig. 9 (perpendicular to longitudinal, east-west, axis) showing situation of a series of stands (1 m²) analysed with regard to vegetation. 1–2 north side, and 4–6 south side. White area in centre = firm serpentine rock; striped areas = mineral soil; black areas = humus-rich soil. The latter two on enlarged scale. Distance between each stand approx. 2 m. Ecological characteristics of stands given in Table 1, p. 44. Stands 1, 2, 3, 5, 6 in present Fig. correspond to stands 6, 7, 8, 9, 10, respectively, in Table 1.

1.
Humus layer 5 cm
Betula nana 5
Empetrum hermaphroditum 3
Vaccinium uliginosum 2
Phyllodoce coerulea 2
Juncus trifidus 2
Hylocomium splendens 4
Pleurozium schreberi 5
Dicranum sp. 1
cf. Table 1: 6

2.
Humus layer 3 cm
Festuca ovina 4
Betula nana 2
Viscaria alpina 1
Juncus trifidus 1
Salix herbacea 1
Carex lachenalii 1 –
cf. Table 1: 7

3.
Bare mineral soil
Cerastium glabratum 1
Festuca ovina 1
Juncus trifidus 1
Minuartia biflora 1 –
cf. Table 1: 8

4.
Firm rock
Caloplaca elegans 1
Physcia caesia 1

5.
Bare mineral soil
Melandrium rubrum 3
Minuartia biflora 1
Rumex acetosa 1
Viscaria alpina 1
Festuca ovina 1
Salix herbacea 1 –
Betula nana 1 –
cf. Table 1: 9

6.
Humus layer 0–4 cm
Empetrum hermaphroditum 5
Betula nana 2
Vaccinium vitis-idaea 1 –
" *uliginosum* 1 –
Arctostaphylos alpina 1 –
Loiseleuria procumbens 1 –
Juncus trifidus 1 –
Cladonia sp. 1
Dicranum sp. 1
cf. Table 1: 10

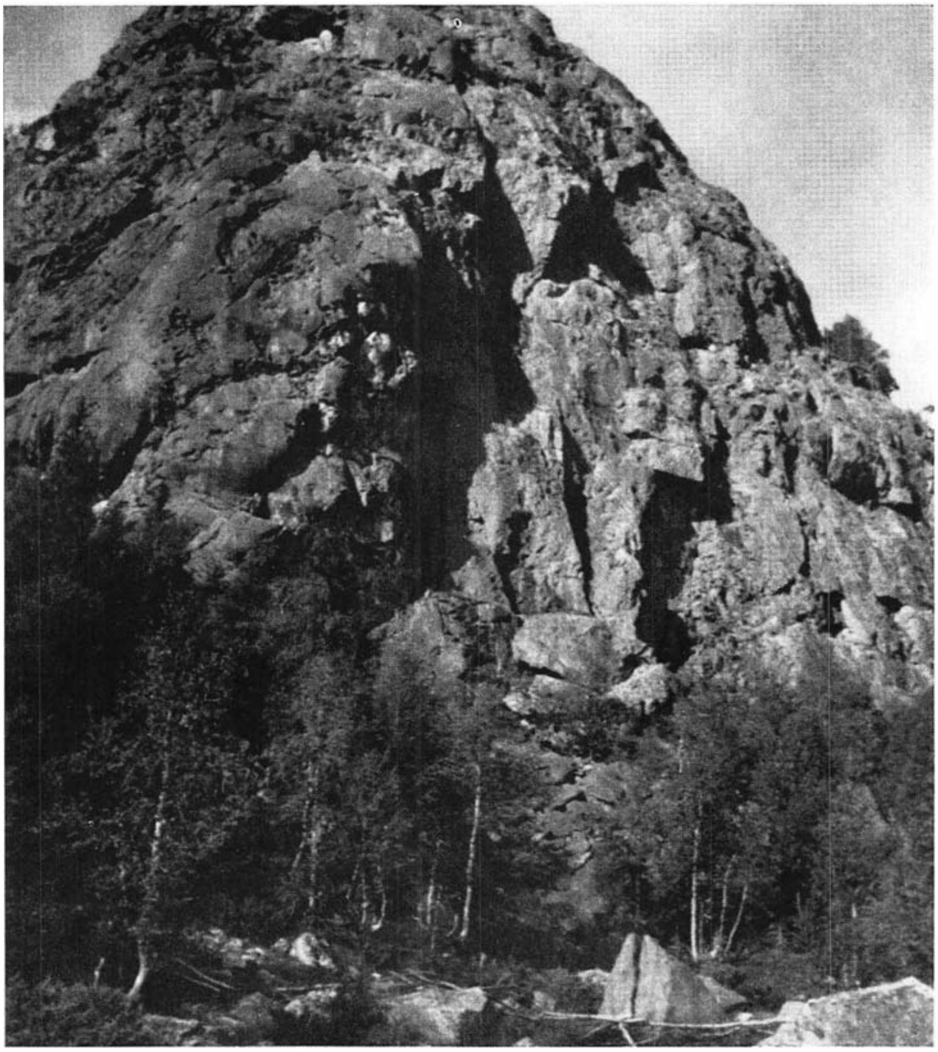


Fig. 11. Peridotite cliff of Röberget, rising steeply close to shore of Kultsjön. Its red colour is due to abundant occurrences of the lichen *Caloplaca elegans*. Below the southern bluff: *Roegneria scandica*, *Poa glauca*, *Silene rupestris*, and *Stellaria graminea*. The opposite side slopes gently and is covered with moraine. Photo Olof Rune 24.8.1946.

dica, *Poa glauca*, *Silene rupestris*, and *Stellaria graminea*. The following values from Röberget were obtained from T. Du Rietz in a personal communication:

	%		%
SiO_2	38.1	CaO	0.02
Al_2O_3	0.36	MnO	0.09
Fe_2O_3	8.29	NiO	0.29
Fe^{II}	1.4	Co	traces
Fe^{III}	4.6	Va	”
Cr_2O_3	0.43	S	0.059
MgO	39.3		

20. **Mt Graipesvare and Mt Murfjället** (Figs. 12, 13).

The two high mountains of Graipesvare and Murfjället together form a mountain ridge more than 10 km long between the two big lakes of Kultsjön and Ransaren. The summit of Graipesvare reaches 1 117 m above sea level (Fig. 12), and the summit of the more northern Murfjället 1000 m (Fig. 13). Almost the entire mountain ridge consists of serpentine rock. The Graipesvare district is distinguished by an irregular tectonic and a strong

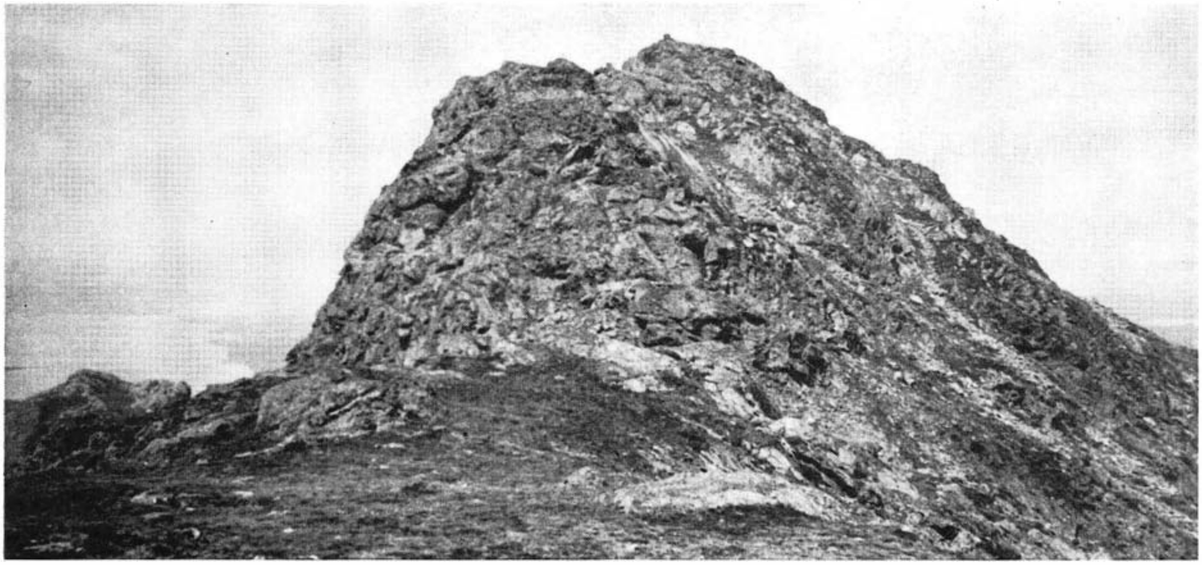


Fig. 12. Graipesvare top, reaching 1 117 m, consists of calcareous serpentine and harbours some calcicolous plants: *Dryas octopetala, Carex rupestris,* and *Gentianella tenella. Draba nivalis, Minuartia rubella,* and *Arenaria norvegica* have disjunctive localities on northern and eastern slopes of the top (to the right in the picture). Lake Ransaren discernible to the left.
Photo Olof Rune 24.6.1947.

Fig. 13. Murfjället top, 1000 m, with typical appearance of an ultrabasic rock protuberance. On tower *Dryas octopetala - Carex rupestris* heath, alternating with bare soil patches with *Minuartia rubella, M. biflora,* and *Arenaria norvegica.* Foreground slope harbours, inter alia, southernmost Swedish locality of *Euphrasia lapponica.* Skyline to the right is Graipesvare. Photo Olof Rune 24.6.1947.

isoclinal folding of the rocks. Thus, the serpentine ridge is interrupted in several places by other kinds of rock, viz., quartzite conglomerate, greywacke-quartzite, and quartzite. The geology of the Graipesvare district was studied and mapped by T. Du Rietz (op. cit. p. 222).

The southern parts of Graipesvare are largely covered by extraneous moraine on which a common low-alpine, acid soil *Empetrum* heath predominates. In several places, serpentine outcrops rise above the brown heath, like the grey towers of a fortress. These outcrops consist of fairly pure serpentine with a low content of lime ($<1\%$ CaO). On these towers, a typical serpentine vegetation is found with the following plants: *Asplenium viride, Festuca ovina, Rumex acetosa, Cerastium glabratum, C. alpinum* var. *serpentinicola, Viscaria alpina, Minuartia biflora,* and *Silene acaulis.* In one place, a small occurrence of *Carex glacialis* was observed, a very rare plant known from only a few localities in all S Lappland.

The northern part of Graipesvare and the main part of Murfjället are built up of a rather calcareous serpentine. T. Du Rietz did not publish any chemical analyses from Graipesvare–Murfjället. The value 14.2 % CaO was obtained from one of my own analyses. Microscopical examination of rock sections revealed the presence of a great deal of calcite, and an obvious effervescence was observed in treating the rock with hydrochloric acid. The values of chromium and nickel are 0.25 and 0.22 %, respectively (according to a personal communication from T. Du Rietz). The vegetation on this calcareous serpentine is considerably richer in species than is usual on serpentine. The flora of this calcareous serpentine is rather similar to that of pure limestone or dolomite. Thus, the most predominant plants are *Dryas octopetala* and *Carex rupestris.* In addition, *Festuca ovina, Silene acaulis, Minuartia biflora,* and *Salix reticulata* are quite abundant there. This *Dryas* heath is broken up into a network of bare soil patches formed by deflation or frost action. On these patches several rare plants were found, viz., *Minuartia rubella, Draba nivalis, Arenaria norvegica, Gentianella tenella,* and on Murfjället, also *Euphrasia lapponica.* See Table 1: 12–15 (p. 44).

21. **Mt Aunevare** (Plates VII, VIII).

Aunevare is situated about 5 km northeast of Murfjället. With its area of about 25 square km, it is the largest peridotite occurrence in Sweden. The shape of Aunevare is like the gigantic frustum of a cone, with a wide plateau-like summit at a level of 1200 m (Pl. VII). The highest peak reaches 1265 m. Except for the northern side which is partly well-covered with permanent snow, the whole mountain is very dry because of the rich occurrence of vertical systems of crevices. The vegetation is also very sparse, and the whole mountain looks extraordinarily barren. The rock consists mostly of a slightly serpentinized olivine and of diopside (T. Du Rietz op. cit. p. 154). T. Du Rietz reported the following values from Aunevare (personal communication), in %: Cr_2O_3 generally equalling 0.4; NiO, 0.27; Co, 0.02; S, 0.1; As, 0.03. This is a rock very resistant to weathering, and practically the whole plateau is a stony waste with hardly any weathered soil (see Pl. VIII). Cushions of *Silene acaulis* and meagre tufts of *Festuca ovina* are very common in all the crevices. Other typical serpentinicoles, viz., *Asplenium viride, Rumex acetosa, Viscaria alpina, Minuartia biflora,* and *Cerastium glabratum,* may be found, though sparsely. See Table 1: 16 (p. 44).

At the highest peak the following plants were noticed to occur within an area of about 200 square m: *Lycopodium selago, Carex bigelowii, Agrostis borealis, Trisetum spicatum, Luzula spicata, L. arcuata, Salix herbacea, Oxyria digyna, Silene acaulis, Cerastium alpinum, C. glabratum, Minuartia biflora, Saxifraga nivalis, S. rivularis,* and *Vaccinium vitis-idaea.*

On the northern side, which is kept moist by permanent snow, the vegetation is richer. In these stations, several mesophytes thrive which are otherwise excluded from serpentine because of the as a rule extremely dry character of that soil, viz., *Poa alpina, Poa alpigena, Salix lapponum, S. glauca, S. lanata, Cerastium cerastoides, Sagina intermedia, Ranunculus acris* var. *pumilus,* and *Erigeron uniflorum.*

On the northern side of Aunevare, just above the timberline, a section of a strongly calcareous serpentine appears like a socle. Just as at Mur-

Fig. 14. Serpentine area at Kittelfjäll village consists of big heaps of boulders and gravel, almost devoid of vegetation. Scattered tufts, visible in picture: *Asplenium viride, Agrostis stolonifera, Molinia coerulea, Deschampsia flexuosa, Rumex acetosa, Cerastium glabratum, Silene acaulis, Viscaria alpina, Minuartia biflora, Empetrum hermaphroditum, Vaccinium uliginosum,* and *Calluna vulgaris.* Kittelfjäll village discernible to the far left. Grönfjället in background.
Photo Olof Rune 6.7.1946.

fjället and at Graipesvare, the calcicoles *Dryas octopetala* and *Carex rupestris* are predominant. In one place, a large occurrence of *Euphrasia lapponica* was established — together with a small occurrence at Murfjället, these are the only stations known in S Lappland. It is evident that these two localities, at about lat. 65° 15′ N, constitute a new southern limit of *Euphrasia lapponica* in Sweden; the nearest Swedish locality is situated in the northern part of Lycksele Lappmark at about lat. 66° N.

East of Lake Vuokarjaure, a string of small serpentine outcrops form an offset from the northern side of Aunevare. In contrast to the Aunevare olivine, this is rather strongly serpentinized. The vegetation is very rich in typically serpentinicolous plants, particularly *Cerastium glabratum* which forms wide, nicely flowering carpets. Because of the folding of this rock, it is more easily weathered than the Aunevare olivine, and a richer supply of weathered soil seems, inter alia, to contribute to a more pronounced serpentine vegetation.

District of Kittelfjäll

(map 40 Dikanäs).

Near the small village of Kittelfjäll, in the valley of the Vojmån river, several serpentine outcrops occur. Actually, serpentine rock was first discovered in Sweden by A. E. TÖRNEBOHM, in 1877, at Kittelfjäll. The different outcrops within this district are rather small and are distributed over a large area. They are comparatively little serpentinized, though sometimes very strongly weathered, and yellowish brown in colour. According to T. DU RIETZ (op. cit.), the composition is rather similar to that of Mt Rautats in Frostviken. Recently, SUNDIUS (1949) published a note on the chromium content of olivine rock from Kittelfjäll (cf. p. 113). The surrounding rocks are mainly amphibolitic.

22. **Serpentine outcrops south of Kittelfjäll village** (Fig. 14, Plates I, II).

On the southern side of the Vojmån river, about 1 km south of the village of Kittelfjäll, olivine rocks, partly serpentinized, crop out within an area of about 0.5 square km. From the road passing through the village, some reddish, barren hillocks can easily be distinguished, which contrast sharply with the green, wooded bottom of the valley (Pl. I, II).

These hillocks consist of soils and boulders from the weathered olivine rocks, which are, contrary to what is usual, completely covered with weathered olivine and serpentine soil. The whole outcrop, which is situated at an altitude of approx. 500 m, is overgrown with a very sparse pine forest (*Pinus silvestris*), while beyond it the forests consist essentially of spruce (*Picea abies*) and mountain-birch (*Betula tortuosa* coll.). The field and ground layers of the vegetation are very scanty, and the yellowish brown soil is almost barren. Here and there on the barren soil tufts of serpentinicolous plants occur (Fig. 14), viz., *Asplenium viride*, *Agrostis stolonifera*, *Molinia coerulea*, *Deschampsia flexuosa*, *Rumex acetosa*, *Cerastium glabratum*, *Silene acaulis*, *Viscaria alpina*, *Minuartia biflora*, *Empetrum hermaphroditum*, *Vaccinium uliginosum*, and *Calluna vulgaris*.

According to a legend in the villages, the barren hillocks are the result of a fire started by the men who first broke ground near this village, more than a hundred years ago. Still, no marks of burning have been detected, though this might be due to the fact that no real forest has ever grown there. On the northern side of the Vojmån river, a few serpentine hillocks occur similar in appearance to those on the southern side. The field and ground layers of the vegetation on them are more continuous, forming a real *Calluna*-*Empetrum* heath in which some of the serpentinicolous plants from the southern side also occur. These parts have probably escaped burning, and show the original appearance of the vegetation in the serpentine field. It is, in fact, remarkable that plants should be so slow in colonizing the serpentine soil as not to be completed even after a hundred years.

T. DU RIETZ (personal communication) gave the following results from analyses of one locality at Kittelfjäll:

	%		%
SiO_2	39.1	CaO	0.36
Al_2O_3	0.36	MnO	0.31
Fe_2O_3	8.60 (Fe^{II} 5.9; Fe^{III} 0.3)	NiO	0.47
Cr_2O_3	0.56	Co	traces
MgO	47.0		

23. **Mt Lebbinjesnjuonje** (Fig. 15, Plate VII).

About 2 km west of the village of Kittelfjäll, a serpentine outcrop with an area of about 5 hectares occurs at Mt Lebbinjesnjuonje, a southern offset of Mt Kittelfjäll. The road westward from Kittelfjäll passes just below the outcrop, which lies between the altitudes of 640 and 710 m. Although the entire serpentine area lies completely within the region of the mountain-birch wood (Regio subalpina), only a few small birch shrubs grow there.

Fig. 15. Surface of Lebbinjesnjuonje serpentine gives impression of high-alpine region, though situated at about 700 m. Note large tufts of *Rhacomitrium lanuginosum* between boulders, mats of *Silene acaulis* to the right, and curtain of dense birch forest beyond serpentine area. Photo Olof Rune 9.7.1946.

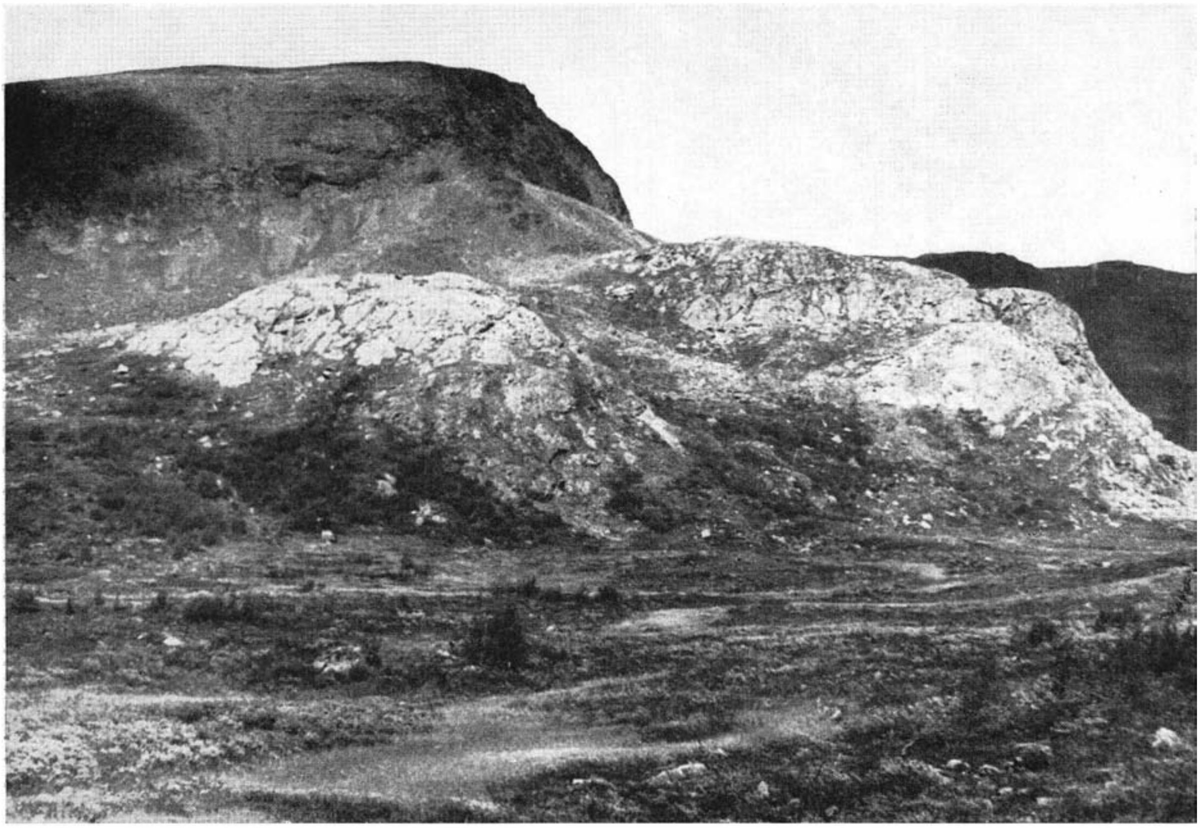


Fig. 16. Gurtatjåkko serpentines form south-exposed bluffs. On scree accumulated on shelves and below cliffs, inter alia: *Arenaria norvegica, Melandrium rubrum, Asplenium viride, Cerastium glabratum, Viscaria alpina,* and *Silene acaulis.* On summits: predominantly *Juncus trifidus - Rhacomitrium lanuginosum* heath (see Plate VIII). Sparse birch wood below serpentine. Bright scrubs in foreground: mainly *Salix lapponum.* Dark rocks of precipice above serpentine are amphibolite. Photo Olof Rune 10.7.1946.

Almost the whole area consists of rather barren rocks with hardly any soil (Pl. VII). The horizontal areas are overgrown with carpets of *Rhacomitrium lanuginosum* interspersed with tufts of the following plants, viz., *Asplenium viride, Festuca ovina, Agrostis stolonifera, Molinia coerulea, Juncus trifidus, Luzula spicata, Juniperus communis* var. *montana, Rumex acetosa, Cerastium alpinum, Cerastium glabratum, Viscaria alpina, Saxifraga oppositifolia, Arctostaphylos alpina, Calluna vulgaris, Empetrum hermaphroditum,* and *Vaccinium uliginosum.* The *Calluna vulgaris - Silene acaulis - Asplenium viride* association of this area is a very peculiar plant community in so far as *Calluna vulgaris* is considered to be calcifuge, while the other two are calcicolous.

24. **Mt Gurtatjåkko** (Fig. 16, Plate VIII).

About 6 km north of the village of Kittelfjäll, a rather large serpentine outcrop occurs on the western side of Grönfjället. It forms a rather highly arched dome at the base of the summit of Gurtatjåkko (Fig. 16). The serpentine field has an area of about 0.5 square km, and is situated between the altitudes of 800 and 900 m. Thus, it lies entirely within the alpine region. Microscopical examination of rock sections showed the rock to consist principally of serpentine (antigorite and some pyroxene). The largest part of the area constitutes a steep southern slope. On the weathered gravels that have accumulated on shelves and below the cliffs, rich occurrences appear of *Arenaria norvegica, Melandrium rubrum, Asplenium viride, Cerastium glabratum, Viscaria alpina,* and *Silene acaulis*; some calcicolous *Carex* species, viz., *C. rupestris,* C. *capillaris,* and *C. atrata* were also noticed.

The occurrence of some calcicolous plants is undoubtedly due to the content of calcium-bearing pyroxene. The horizontal areas above the steep slope are covered by *Rhacomitrium lanuginosum* mats with scattered tufts of *Silene acaulis* and *Juncus trifidus* in it (Pl. VIII). Sparse occurrences of *Phyllodoce coerulea, Rubus chamaemorus* and *Pedicularis lapponica* were also noticed. See Table 1: 17–19 (p. 44).

25. **Mt Rotikken.**

About 5 km northwest of Gurtatjåkko, in the northwestern parts of Grönfjället, another serpentine outcrop occurs, on the topographic map named Rotikken. It lies at the same level as the Gurtatjåkko area, and is of a similar size. However, the Rotikken serpentine is not inserted in the geological map drawn by BACKLUND and QUENSEL (op. cit.). The Rotikken serpentine is partly rather schistose which makes it more easily weathered. Thus, large areas consist of a scree rich in coarsely weathered material and with an abundance of *Arenaria norvegica* growing on it. In addition, *Festuca ovina, Agrostis stolonifera, Rumex acetosa, Cerastium glabratum,* and *Minuartia biflora* are common on this kind of soil. In more stable parts, an *Empetrum - Vaccinium uliginosum* heath including tufts of *Rhacomitrium lanuginosum, Asplenium viride,* and *Silene acaulis* predominates. See Table 1: 20 (p. 44).

District of Gränssjö

(map 40 Dikanäs).

In the high mountain district of Åsele Lappmark, two main chains of ultrabasic rocks occur: the aforementioned Graipesvare–Aunevare–Kittelfjäll chain, and a western one, much smaller and running close to the Norwegian border. The centre of this western chain is the serpentine mountain Rotikken situated near the settlement of Gränssjö at the eastern end of Lower Vapstsjön. The border-line between the districts of Åsele Lappmark and Lycksele Lappmark runs just south of Rotikken. Although Rotikken is situated within Lycksele Lappmark, it will be described in connection with the outcrops of this chain which all lie within Åsele Lappmark. The surrounding rocks are phyllitic, low-metamorphic Köli-rocks. The serpentines of the Gränssjö district are not included in T. DU RIETZ' study (op. cit.). However, O. KULLING has given a short description of them (KULLING 1933).

26. **Mt Rotikken at Gränssjö** (Figs. 17, 18, 19, 20).

As mentioned above, Rotikken is a serpentine mountain situated just north of the border-line between Åsele Lappmark and Lycksele Lappmark, and between the two lakes of Upper and Lower

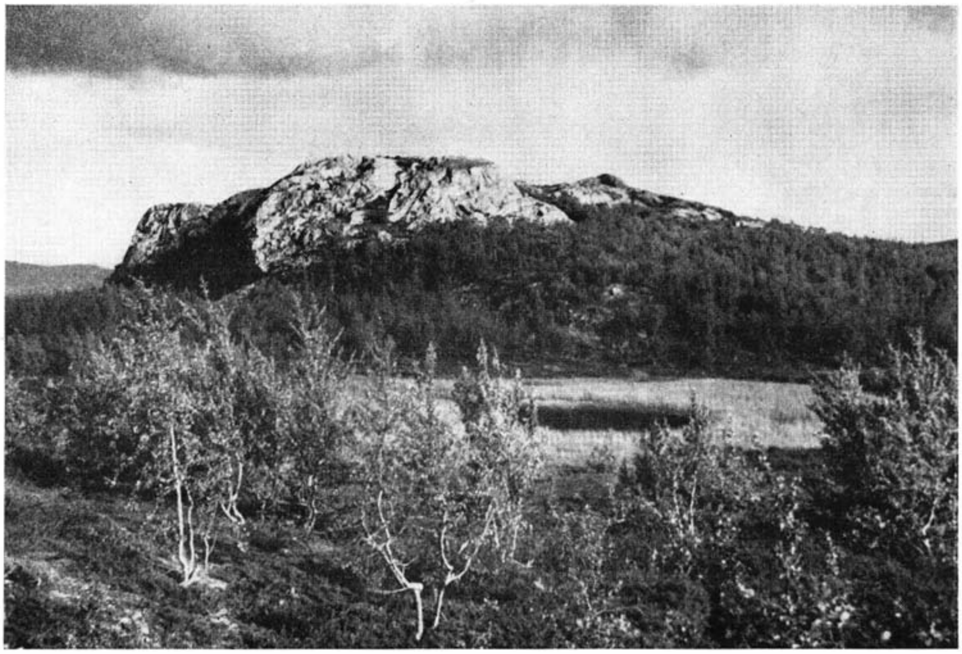


Fig. 17. Northern part of Gränssjö Rotikken rises abruptly above surrounding subalpine birch forest.
Photo Olof Rune 17.8.1946.

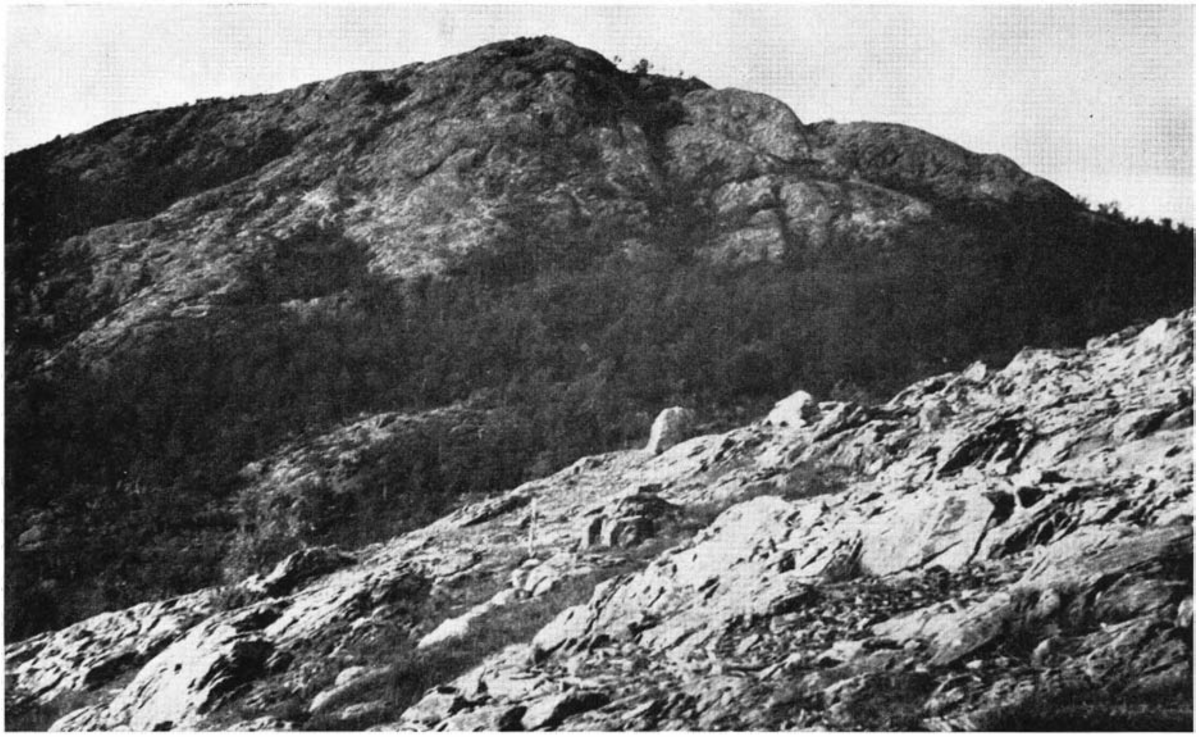


Fig. 18. Main part of Gränssjö Rotikken slopes southward into valley of Vapstälven river. As the timberline is lowered on serpentine, most of this area is unforested, though mainly situated below 700 m. In foreground, western side of southernmost part of the outcrop with schistose serpentine (cf. Fig. 19). Photo Olof Rune 19.8.1946.

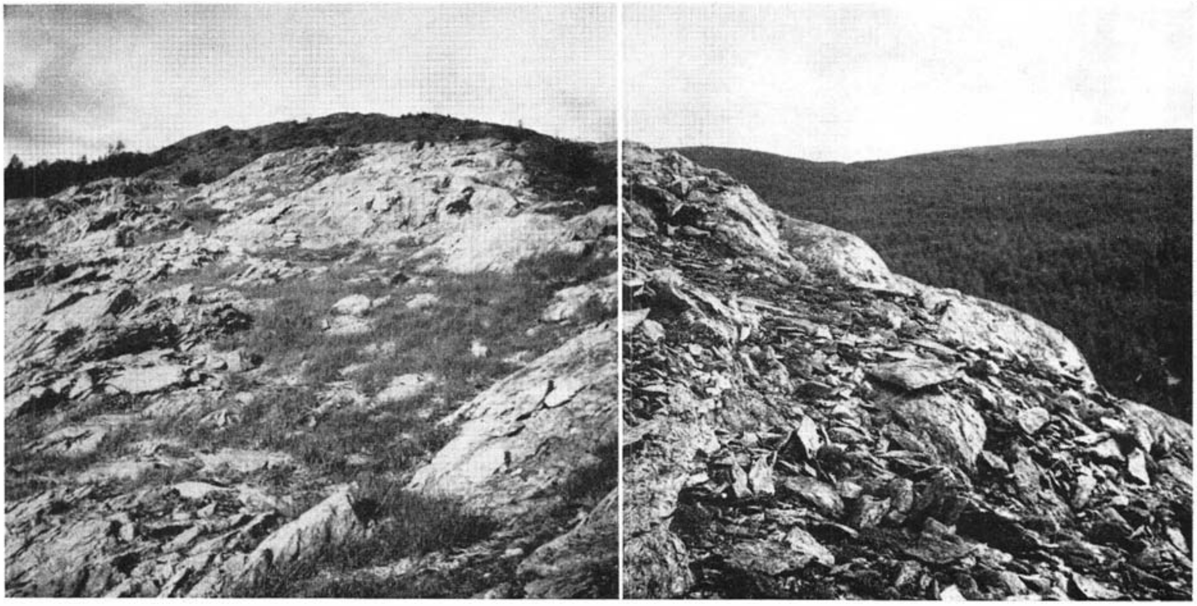


Fig. 19. Left: Close-up of the foreground of Fig. 18 showing abundant *Molinia coerulea*. The slope of the schistosity makes the ground rather stable on this side.

Right: Corresponding eastern side slopes perpendicular to the schistosity and is largely covered with unstable scree, harbouring abundant *Arenaria norvegica*. Photo Olof Rune 19.8.1946.

Vapstsjön. It constitutes a distinctly marked mountain ridge rising above the subalpine birch woodland (Figs. 17, 18). The highest point reaches the altitude of 747 m. The length of the mountain is about 3 km, while the breadth is much less, only about $^1/_2$ km. The upper limit of the mountain-birch wood (*Betula tortuosa*) reaches an altitude of only about 700 m, and the timberline is thus about 50–100 m lower on the serpentine ground than in the vicinity.

A lowered timberline on serpentine seems to be a general phenomenon observed also in the Alps (Schröter 1926, Lämmermayer 1926). Mineralogical examination of rock sections has shown the serpentine of the Gränssjö Rotikken to consist exclusively of antigorite and some ore (magnetite or chromite). Particularly in the southern parts the rocks are strongly folded. The schistose rock is easily subjected a mechanical weathering so that large areas are covered with gravel and splinters (Fig. 19). Such areas are, as mentioned in connection with Rotikken of the Kittelfjäll district, generally characterized by an abundance of *Arenaria norvegica*. In addition, *Cerastium glabratum*, *Viscaria alpina*, and *Rumex acetosa* are abundant in these habitats. On this serpentine mountain, *Molinia coerulea* is strikingly abundant. This grass is often completely dominant in crevices and other places with a comparatively deep soil.

It is a remarkable fact that *Silene acaulis* seems to be quite absent on this mountain, being probably due to competition from *Molinia coerulea* which seems to have conquered all habitats suitable for the former. Thus, a *Molinia*-rich *Vaccinium uliginosum* heath with *Rhacomitrium lanuginosum* in its ground layer is the most common plant community of the area. The summit of this mountain consists of rather flat rocks, rich in hollows and crevices which are more or less filled with soil. The district has a rather high precipitation, and the hollows are often very wet and overgrown by *Agrostis stolonifera* which alone may dominate over wide areas. Only in one place were a few individuals of *Carex canescens* and *Juncus filiformis* observed in the *Agrostis* carpet. See Table 1:21 (p. 44).

Fig. 20. Southernmost part of Gränssjö Rotikken forms a small precipice, harbouring, besides serpentinicoles, some thermophilous plants: *Poa glauca* and *Roegneria canina*. Though of moderate size, such southern bluffs of serpentine harbour same thermophilous elements as big southern bluffs of other kinds of rock, so-called "sydberg".
Photo Olof Rune 19.8.1946.

27. **Isthmus of Lake Bleriken.**

On the small isthmus between the two lakes Gottern (Gotajaure) and Bleriken, south of Vardofjällen, a chain of barren serpentine rocks rises some 20 m above the dense birch wood. The chain consists of three barren outcrops, each about 100 m long and about 50 m broad. The sparse vegetation is characterized principally by the following species: *Arenaria norvegica, Cerastium glabratum, Agrostis stolonifera,* and *Rhacomitrium lanuginosum.* The following are also abundant: *Festuca ovina, Deschampsia flexuosa, Viscaria alpina, Rumex acetosa, Melandrium rubrum,* and some ericaceous dwarf shrubs, viz., *Vaccinium uliginosum, Arctostaphylos alpina,* and *Empetrum hermaphroditum.*

Lycksele Lappmark

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District of Rönnbäck

(map 40 Dikanäs).

In the neighbourhood of the village of Rönnbäck, about 30 km southeast of the church village of Tärnaby, several serpentine outcrops occur. This district is situated at the eastern edge of the mountain range and the serpentine generally crops out at an altitude of about 400 m. They consequently occur exclusively within the conifer forest region, thus differing from all other ultrabasic rock occurrences within this part of Lappland (Fig. 22). This fact is reflected in the flora and vegetation of the Rönnbäck serpentine mountains.

Consequently, serpentinicoles with a strictly alpine character, such as *Arenaria norvegica, Cerastium glabratum,* and *Silene acaulis,* are lacking in these areas. Instead, certain lowland plants appear, all of them serpentinicolous, viz., *Cerastium vulgatum* var. *kajanense, Viscaria alpina* var. *serpentinicola,* and *Melandrium rubrum* var. *serpentinicola.* As to the mosses, *Rhacomitrium lanuginosum* is far less abundant than in the alpine and subalpine

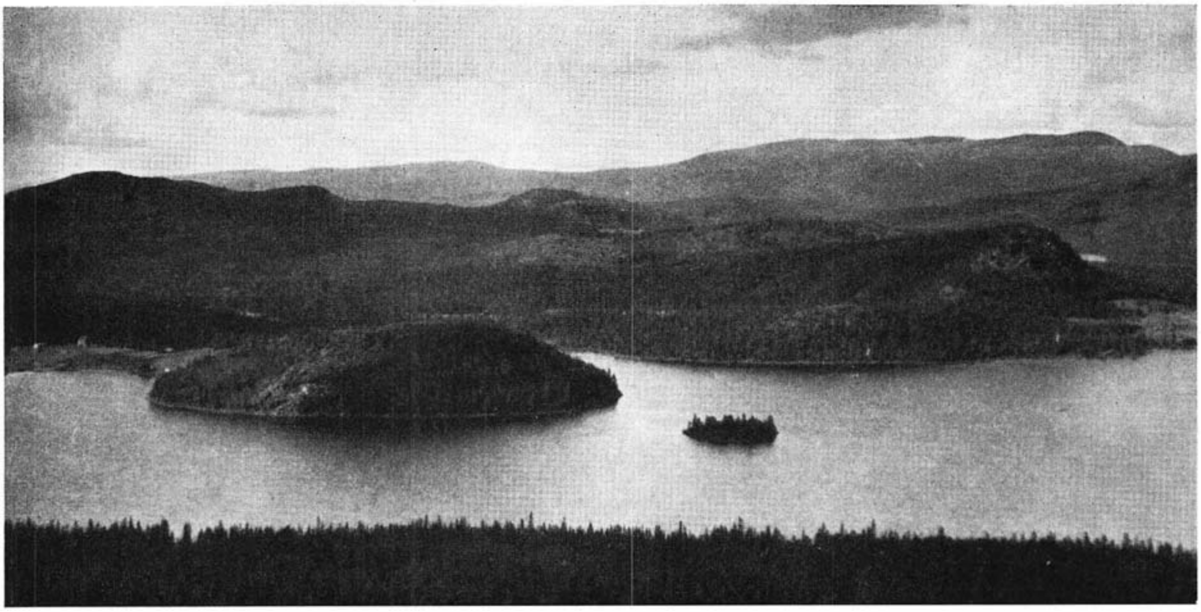


Fig. 21. Serpentine areas at Rönnbäck are situated at eastern edge of high mountain area, entirely in conifer forest region. View northward from top of Vinberget showing Rönnbäckssjön with Rönnbäck peninsula (area No. 29) and, beyond, Brandbergen (area No. 30). Utgårdsberget (area No. 31) on far left. Settlements of Rönnbäck village right and left. Highway to Björkvattnet and Tärnaby visible just above top of peninsula. Skyline formed by Brakkfjället.
Photo Olof Rune 19.8.1949.

areas. Instead, *Dicranum* species, particularly *D. muehlenbeckii*, appear very abundantly. In addition, *Campylium stellatum* and *Tritomaria quinquedentata* are very abundant.

In the Rönnbäck district, considerable serpentine occurrences are concentrated within a rather small area (see Fig. 21). Differences in position and topography make it necessary to describe different parts separately. The composition of the serpentine rock seems to be rather similar over the whole district. T. Du Rietz (personal communication) has given the following values, in %: Cr_2O_3, 0.4; NiO, 0.3; FeO, 3.6; As_2O_3, 0.03; CoO, 0.04. He pointed out the rocks of this district as having a particularly high content of nickel.

28. **Serpentine mountains south of Rönnbäckssjön** (Fig. 23).

On the northern slope of Vinberget, south of the eastern part of Rönnbäckssjön, three big serpentine cliffs rise about 30–50 m above the surrounding forest land. Owing to their barren surface, and light greyish-green colour, they are perceptible even from a great distance. These outcrops look much like towers with nearly vertical sides and plateau-like summits. It is possible to climb them only from the western and southern sides. The vegetation is nearly the same on all these three adjacent serpentine hillocks. The spruce forest of the vicinity changes into a sparse mountain-birch shrub (*Betula tortuosa*) vegetation. On the plateaus only a few species occur, viz., *Asplenium viride*, *Festuca ovina*, *Agrostis stolonifera*, *Deschampsia flexuosa*, *Rumex acetosa*, *Cerastium vulgatum* var. *kajanense*, *Melandrium rubrum* var. *serpentinicola*, *Viscaria alpina* var. *serpentinicola*, and *Vaccinium uliginosum* (Fig. 23). On the dry and warm southern sides some xero- and thermophilous plants were noticed, viz., *Cystopteris fragilis*, *Woodsia alpina*, *W. ilvensis*, and *Roegneria scandica*. The mountain walls of the northern sides are often coloured red by the lichen *Caloplaca elegans* and the alga *Trentepohlia jolithus*. Below the northern walls, where the humidity is greater, the vegetation is rather luxuriant with thickets of *Calamagrostis purpurea*,

Fig. 22. Serpentine precipice at southern point of Rönnbäck Peninsula harbours several ferns: *Asplenium viride*, *Cystopteris fragilis*, *Woodsia alpina*, *W. ilvensis*, and *Polypodium vulgare*. In scree on shelves: *Roegneria scandica*, and abundant *Melandrium rubrum* var. *serpentinicola*. Photo Olof Rune 19.8.1949.

Chamaenerion angustifolium, *Rubus idaeus*, and *Ribes spicatum*.

On the largest outcrop further to the south, several subfossil pine trunks were observed, though no pine is growing there in our days.

Near the top of Vinberget, at the level of 610 m, still another serpentine occurrence exists. However, it is rather diffuse and not so easily perceived as the others. Nevertheless, serpentinicoles, such as *Agrostis stolonifera*, *Cerastium vulgatum* var. *kajanense*, and *Viscaria alpina* var. *serpentinicola*, occur there sparsely. *Polypodium vulgare* and *Poa glauca* should also be mentioned from the dry parts of this locality.

29. **Rönnbäck peninsula** (Figs. 21, 22, 24).

At the tip of the large peninsula of Rönnbäckssjön, serpentine crops out within an area of about 5 hectares. This outcrop constitutes the connection between the serpentine areas south of the lake and the large outcrops further to the north, viz., Brandbergen. The most prominent part of this outcrop is the very steep southern side (Fig. 22), where several ferns were noticed, viz., *Polypodium vulgare*, *Cystopteris fragilis*, *Woodsia alpina*, *W. ilvensis*, and *Asplenium viride*. The first-mentioned is very rare in the high mountain districts of N Sweden, being a thermophilous relic, restricted to southern bluffs. *Roegneria scandica* and a very abundant occurrence of *Melandrium rubrum* var. *serpentinicola* were noticed on the dry shelves. Above the steep cliff a wide plateau extends in which barren rocks alternate with areas covered by a thin layer of soil. The only trees living on it are some small mountain-birch shrubs (*Betula tortuosa*) (Fig. 24).

In fact, the flora of this area is rather similar to that of the outcrops south of Rönnbäckssjön containing: *Festuca ovina*, *Agrostis stolonifera*, *Rumex acetosa*, *Cerastium vulgatum* var. *kajanense*, *Viscaria alpina* var. *serpentinicola* (cf. p. 56), and *Vaccinium uliginosum*. However, the occurrence of the apetalous type of *Viscaria alpina* var. *serpentinicola* is limited to the areas on the southern side of Rönnbäckssjön.

30. **Mts Brandbergen** (Figs. 25, 26).

North of the village of Rönnbäck, a large area extends, consisting entirely of serpentine (Fig. 21). The road through the village passes quite near the southern slope of a large serpentine mountain, sparsely forested with pine. North of this, two more serpentine mountains of the same size occur. These

Fig. 23. Close-up of typical serpentine vegetation in outcrops south of Rönnbäckssjön, showing abundant *Asplenium viride* tufts, even outside rock crevices. Apetalous *Viscaria alpina* var. *serpentinicola* is also abundant, though hardly discernible in the picture. Less abundant occurrences: *Agrostis stolonifera*, *Rumex acetosa*, and *Cerastium vulgatum* var. *kajanense*.

Photo Olof Rune 19.8.1949.

three serpentine mountains are arranged in a ring surrounding a tarn which is situated about 1 km northwest of the bridge over the sound at Rönnbäckssjön (Fig. 25). The area of these serpentine mountains totals about 5 square km, the highest points hardly reaching the 500 m level.

The whole area is covered with open pine forest. Spruce is almost completely absent and birch is very sparse. The pine forests of these dry mountains are often subjected to forest fires, and the last fire occurred about twenty years ago. The villagers of Rönnbäck have actually called these mountains, "Brandbergen" (meaning "The Fire Mountains"). On the high and very exposed parts of the mountains the pine forest is rather sparse. The trees are stunted or broken, and the great number of dead, whitening trunks illustrates the extent of the adverse conditions for forest growth (Fig. 26). As is usual on serpentine, the vegetation of the field and ground layers is rather sparse. In places with a closed vegetation, the most prominent species are (in order): *Calluna vulgaris*, *Empetrum hermaphroditum*, *Vaccinium uliginosum*, *V. vitis-idaea*, *Festuca ovina*, and *Molinia coerulea.* The first three are particularly common, and constitute a dwarf shrub heath community with a ground layer of *Rhacomitrium lanuginosum*, *Dicranum*, *Cladonia*, and *Stereocaulon* species. This community forms a thin humus layer which covers the serpentine soil.

The silty serpentine soil is highly congeliturbate, especially in places where the underlying rock is impermeable to water, resulting in the destruction of the heath vegetation and the formation of frost scars. These bare patches are rapidly colonized by special serpentine plants, viz., *Agrostis stolonifera*, *Viscaria alpina* var. *serpentinicola*, *Cerastium vulgatum* var. *kajanense*, *Rumex acetosa*, *Deschampsia flexuosa*, and *Melandrium rubrum* var. *serpentinicola*.

In places where the frost action is impermanent, the heath vegetation soon returns. Several serpentine plants, e.g., *Viscaria alpina* var. *serpentinicola* and *Rumex acetosa* may also remain in the heath vegetation. In places with permanent frost action the serpentinicoles, viz., *Agrostis stolonifera*, *Rumex acetosa*, *Cerastium vulgatum* var. *kajanense*, *Viscaria alpina* var. *serpentinicola*, and *Melandrium rubrum* var. *serpentinicola*, constitute the only vegetation. The same vegetation also prevails at similarly open deflation areas or on scree. See Table 1: 22–29 (p. 44).

Brandbergen also exhibit several steep rock faces, being, however, of a rather moderate height (Figs. 27, 28). Crevices of the rock faces are often filled up with *Asplenium viride*, in moist places occurring together with *Agrostis stolonifera* and the mosses *Campylium stellatum*, *Drepanocladus uncinatus*, and *Tritomaria quinquedentata*.

The mechanical composition of some soil samples from Brandbergen have been analysed, and the results are given on p. 115.

Fig. 24. On serpentine plateau of Rönnbäck Peninsula, barren rocks alternate with soil patches harbouring *Festuca ovina, Agrostis stolonifera, Rumex acetosa, Cerastium vulgatum* var. *kajanense, Viscaria alpina* var. *serpentinicola*, and *Vaccinium uliginosum*. Soil is not deep enough for other trees than birch bushes. Note abundance of *Agrostis stolonifera*.
Photo Olof Rune 19.8.1949.

31. **Mt Utgårdsberget** (Figs. 27, 28).

Near the settlement of Utgård, south of the village Björknäs and about 5 km northwest of Rönnbäck, another mountain, Utgårdsberget, occurs. This is of about the same size as all within the Brandbergen complex. As Utgårdsberget does not differ from Brandbergen, whether in regard to the kind of rock or the situation, the vegetation is quite similar.

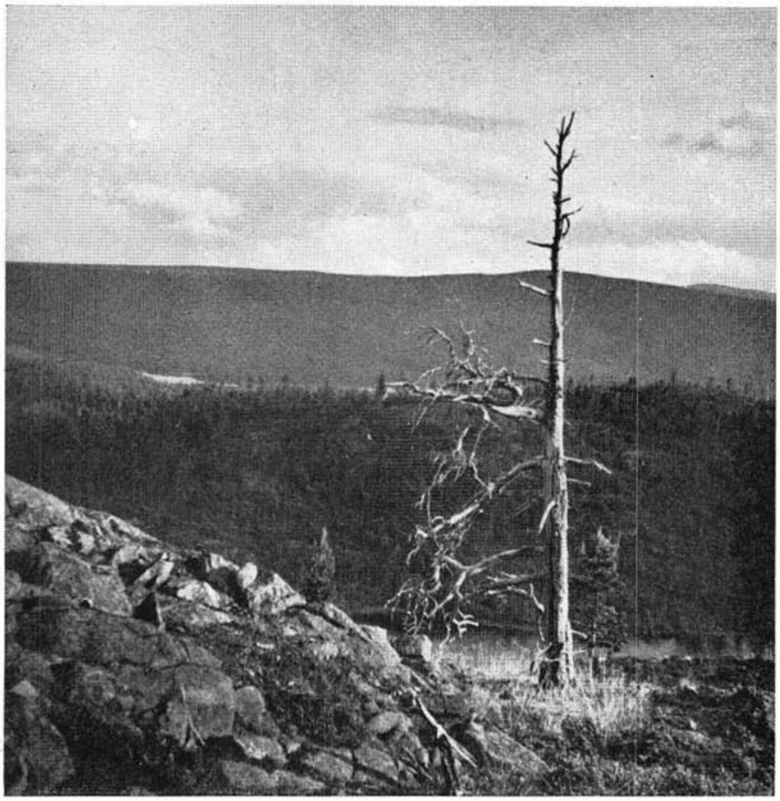
District of Tärna

(map 32 Tärna).

Northwest of the church village of Tärnaby, a small string of peridotites occur. This stretches from Laxfjället at Tärnaby towards the NNW, passing the Isle of Storholmen in Lake Laisan and reaching the vicinity of Laisholm village. All these peridotitic outcrops are small and often covered with moraine. The ultrabasic rocks of the Tärna district are surrounded by mica-schists, phyllites, and amphibolites. The first-mentioned area is situated at the 800 m level, the others at about 450 m.

32. **Mt Laxfjället.**

On the southwestern slope of Laxfjället, below its easternmost summit, some very small outcrops of peridotite are found (cf. T. Du Rietz op. cit. p. 154). One of these, which appears on the top of a small summit, is free from moraine and harbours a flora peculiar to itself. However, this area does not attain a size of more than some hundred square metres. As to the composition, this rock is different from the other ultrabasic rocks of the district. According to T. Du Rietz (op. cit. p. 154), diopside predominates entirely even though serpentine,



Figs. 25, 26. Waste serpentine area of Brandbergen with barren rocks and dead trees sharply contrasting with densely forested surroundings. Whitening trunks of dead trees indicate adverse conditions of forest growth. Forest fires, Fig. 25, and blizzards, Fig. 26, caused great injury to this dry and exposed pine forest. Foregrounds of both pictures show localities, bare soil and crevices, rich in serpentinicolous plants: *Asplenium viride*, *Agrostis stolonifera*, *Cerastium vulgatum* var. *kajanense*, and *Viscaria alpina* var. *serpentinicola*. In Fig. 26 abundant mats of depressed *Juniperus communis* var. *montana*. Photo Olof Rune 3.7.1948.

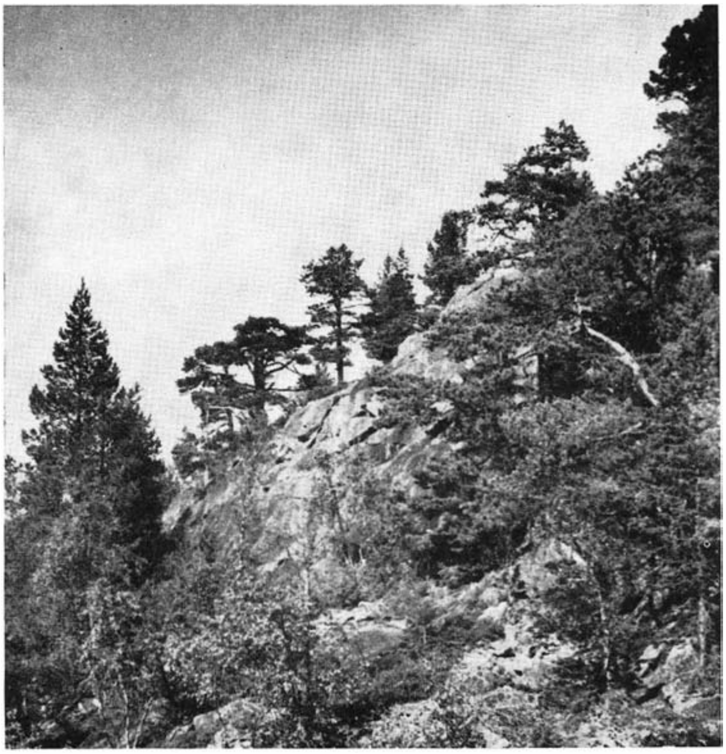


Fig. 27. Serpentine mountain at Utgård settlement, immediately north-west of Brandberget, harbours a more dense and vigorous pine forest. Vegetation of ground and field layers is rather similar, presenting *Asplenium viride, Agrostis stolonifera, Deschampsia flexuosa, Rumex acetosa, Cerastium vulgatum* var. *kajanense, Viscaria alpina* var. *serpentinicola*. Photo Olof Rune 19.8.1949.

chlorite and some magnetite are also present. The chemical composition of this rock was never established. However, because of the diopside, this rock may be assumed to be somewhat calcareous.

Above all, the vegetation of this outcrop is characterized by an exceptional abundance of *Minuartia biflora*. Other plants noticed in the area are (in order of abundance): *Cerastium alpinum, Gnaphalium supinum, Luzula spicata, Cerastium cerastoides, Polygonum viviparum, Carex bigelowii, Salix herbacea, Empetrum hermaphroditum, Arctostaphylos alpina, Salix reticulata, Poa alpigena, Salix lapponum, Lycopodium selago*. Still, all of these plants are far from being as abundant as *Minuartia biflora*.

33. **Isle of Storholmen** (Fig. 29).

At the southeastern tip of Storholmen in Lake Laisan, some peridotite rocks occur quite near the shore. These rocks constitute slightly arched flags which slope downward from the highest shore line into the water (Fig. 29). Above the highest shore line the rocks are covered with moraine. The barren peridotite rocks are accordingly submerged during the high water periods. This makes the vegetation quite different from that of the generally very dry serpentine localities.

With the exception of *Festuca ovina, Agrostis stolonifera, Molinia coerulea*, and *Campanula rotundifolia*, all the plants generally typical of serpentine are lacking. Instead, several shore plants appear on these rocks. Thus, *Prunella vulgaris* and *Primula stricta*, both common plants on the shores of big lakes in the N Swedish mountain region, occur here. The inundated zone of these lakes is rich in alpine plants (Regio alpina descensa, BJÖRKMAN 1939). Apparently, on these peridotite barrens of a low altitude, it is natural also to encounter such species as, *Trisetum spicatum, Poa alpina, Potentilla crantzii*, and *Leontodon autumnalis* var. *taraxaci*.

34. **Village of Laisholm.**

The ultrabasic outcrops at the village of Laisholm are situated beside a small brook at the

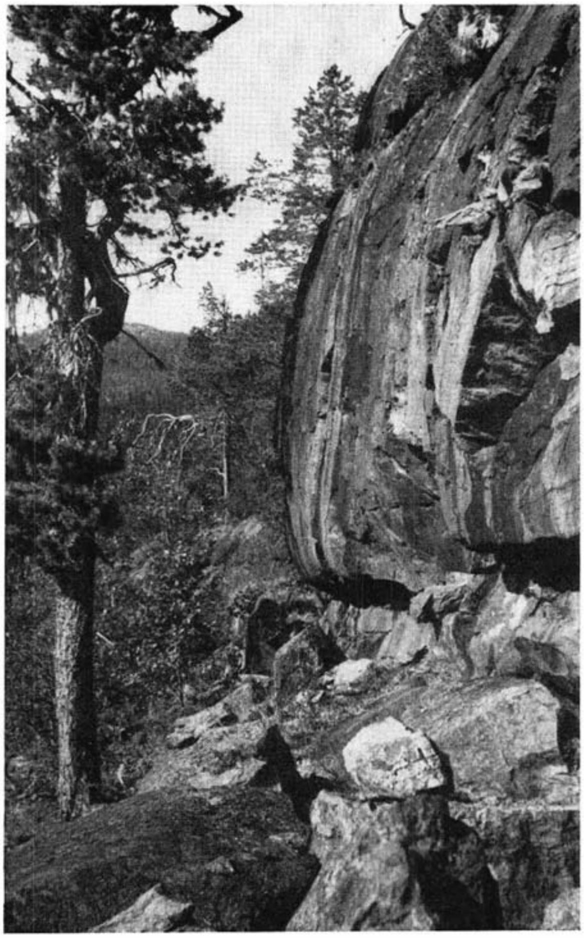


Fig. 28. Brandbergen and Utgårdsberget exhibit several steep rock faces of moderate height. Rock faces are largely red-coloured from lichen *Caloplaca elegans*, and crevices are filled up with *Asplenium viride*, *Agrostis stolonifera*, and mosses, viz., *Campylium stellatum*, *Drepanocladus uncinatus*, and *Tritomaria quinquedentata*. Picture from Utgårdsberget. Photo Olof Rune 19.8.1949.

northernmost farm, and at a tarn about 1.5 km south of the same farm. At the first locality where soapstone has been quarried, the rock is covered with extraneous moraine, and the locality is of little interest from a botanical point of view.

The other occurrence is a rather small but distinctly marked rock at the western shore of a small tarn, situated at the 500 m level. The area of this rock equals about 0.5 hectare. The following analysis cited from T. Du Rietz (op. cit. p. 210) shows the composition of this rock:

	%
SiO_2	38.12
Al_2O_3	0.20
Fe_2O_3	4.89
Cr_2O_3	0.45
FeO	4.97
MnO	0.23
MgO	44.94
CaO	0.30
$Na_2O + K_2O$	0.03

Actual composition (weight %)	
Olivine	62.9
Serpentine	28.9
Magnetite	6.7
Chlorite	0.9
Carbonate	0.6

From this it is clear that the rock consists mainly of unaltered olivine. This mineral resists weathering very well, and soil is almost completely lacking on this rock. The long axis of the rock which is situated on a small peninsula has an east-western direction. The southern side descends very steeply into the tarn, and is therefore strongly exposed. However, the rock rises only a few metres above the surface, and the southern slope is rather small. Rather typical serpentine vegetation occurs only in the crevices on this side. *Asplenium viride* is rather common, as well as *Rumex acetosa*, *Deschampsia flexuosa*, *Silene rupestris*, and *Sedum annuum*.

Other parts of the rock are almost totally barren, and only a few individuals of *Empetrum hermaphroditum* and *Vaccinium uliginosum*, may be seen here and there in crevices.

T. Du Rietz (personal communication) has given the following analysis values from Laisholm, in %: Cr_2O_3, 0.5; NiO, 0.2; Co, 0.06.

District of Södra Storfjällen

(map 32 Tärna).

West of the large and high mountain district of Södra Storfjällen, which lies west of the church village of Tärnaby, a wide area of serpentine stretches southward from the Hattfjelldal valley and northward to Lake Krutvattnet. Nearly the whole serpentine district is situated on the Norwegian side of the border. A small offshoot reaches the northwestern part of Södra Storfjällen. From about the boundary cairn No. 211 A, south of Krutvattnet, the serpentine area stretches northeast and forms a large serpentine mountain, Mt Atoklinten, situated about 10 km from the border-line. The serpentine chain continues and forms some small outcrops further to the northeast of Atoklinten.

Fig. 29. Southern point of Isle of Storholmen in Lake Laisan near Tärnaby, consisting of peridotite. Rocks are covered with moraine except in actual shore region. Besides a few serpentinicolous plants, viz., *Festuca ovina, Agrostis stolonifera, Molinia coerulea,* shore plants common to this lake have taken possession of the crevices of this rocky shore.
Photo Olof Rune 15.8.1948.

However, I have not visited all these outcrops personally. The rocks surrounding these serpentines are mainly Köli-schists.

35. Mt Skaritjåkko.

On the northern side of Mt Skaritjåkko, the high mountain with the boundary cairn No. 211 A, a serpentine outcrop of about 1 km in length appears at the 900 m level. It is only about 100 m broad and the height is about 30–40 m over the general ground level. Only the eastern third is situated on the Swedish side of the border-line. The rock is very resistant to weathering and seems to consist mainly of unaltered olivine. No analyses from this locality are to be found in the literature. Almost the whole outcrop consists of barren rocks. A sparse vegetation occurs in crevices where the following plants were noticed: *Asplenium viride, Agrostis stolonifera, Festuca vivipara, F. rubra* var. *mutica, Cerastium glabratum, Arenaria norvegica, Minuartia biflora, Viscaria alpina, Saxifraga nivalis, S. tenuis,* and *S. stellaris.*

36. Mt Atoklinten (Plate III).

Atoklinten is one of the largest serpentine mountains of S Lappland. Its length is about 2.5 km and its width 0.5–1 km. It looks like a large wall, rising about 100 m above the flat northern slope of Södra Storfjällen, with a summit that reaches an altitude of 1020 m. The long axis of the mountain has an east-western direction. Thus, Mt Atoklinten has a dry southern side and a moist northern side, rich in permanent snow. This makes different parts of Atoklinten vary considerably from an ecological standpoint. The flora of this serpentine area is therefore rather rich in species, and the composition of the vegetation varies.

Wide, cupola-like, barren rocks, with vegetation only in crevices, are most common (Pl. III). The most important species are: *Asplenium viride, Agrostis stolonifera, Arenaria norvegica, Cerastium glabratum, Minuartia biflora,* and *Silene acaulis.*

In places where the rock is somewhat schistose, weathering has been stronger, and soil and splinters cover the rocks. Here a sparse heath vegetation occurs with the following plants, viz., *Vaccinium uliginosum, Empetrum hermaphroditum, Cerastium glabratum, Silene acaulis, Juncus trifidus, Luzula spicata, Festuca ovina, F. vivipara, Solidago virgaurea, Campanula rotundifolia,* and, in the ground layer, *Rhacomitrium lanuginosum.* On steep parts where the vegetation cannot reach a climax stage because of the instability of the ground, the serpentinicolous plants are especially prevalent, viz., *Rumex acetosa, Cerastium glabratum, Silene acaulis,* and *Arenaria norvegica.*

In some places, the calcicole *Dryas octopetala* occurs together with the serpentinicoles. The total content of CaO in this serpentine soil is 1.15% (see Table 1: 30) which, for serpentine, is a little higher than usual. This results in the occurrence of other more or less calcicolous plants, viz., *Selaginella selaginoides, Festuca rubra* var. *mutica, Carex capillaris, Salix reticulata, Potentilla crantzii,* and *Thalictrum alpinum.*

On the snow beds of the northern side, several plants seldom seen elsewhere on serpentine have been noticed, viz., *Phippsia algida, Carex lachenalii, Cerastium cerastoides, Sagina intermedia, Ranunculus pygmaeus, Saxifraga stellaris* and *S. rivularis.* The rarity of these plants on serpentine is no doubt explained by the pronounced dryness of these soils.

PARISH OF SORSELE

District of Lake Ältsvattnet

(map 25 Nasafjäll).

37. **Mt Ruopsokvare** (Plate VI).

About 5 km southwest of Lake Övre Ältsvattnet in the western part of Sorsele parish, Lycksele Lappmark (about lat. 66° N), a rather large peridotite outcrop occurs. It forms two tower-like summits, about 1 km apart (Pl. VI). These summits rise about 50–100 m above the general ground level which lies at about 800 m and consists mainly of phyllites. The area of each is about 5 hectares, and they stand out clearly on the topographical map where they are given the name Ruopsokvare. The whole peridotitic area is situated within the alpine region. No data are available concerning the composition of these rocks. The rock is greyish — sometimes changing into red — and seems to consist chiefly of unaltered olivine.

The principal parts of the peridotitic area are occupied by barren cupola-like rocks. Below these parts, however, a fairly large amount of weathered soil has accumulated. Among the sparse plants growing there, the following are the most prominent: *Festuca ovina, Rumex acetosa, Viscaria alpina, Cerastium alpinum,* and *Minuartia biflora.* Others observed are: *Asplenium viride, Scirpus caespitosus, Carex rupestris, Juncus trifidus, Juniperus communis* var. *montana, Salix herbacea, Arenaria norvegica, Melandrium rubrum, Empetrum hermaphroditum, Diapensia lapponica;* and below a moist northern side: *Luzula wahlenbergii, Cardamine pratensis* ssp. *angustifolia, Saxifraga stellaris,* and *S. foliolosa.* See Table 1: 31 (p. 44).

It is remarkable that the common serpentinicoles *Cerastium glabratum* and *Silene acaulis* are completely absent there.

District of Ammarfjällen

(map 25 Nasafjäll).

Ammarfjällen form a rather large, high and isolated mountain district in the northern part of Lycksele Lappmark (about lat. 66° N). The area equals 200–300 square km, and the highest peaks reach the 1600 m level. Within this district several small peridotite outcrops occur. The serpentine content is, however, rather low, and no pronounced serpentine vegetation exists on these outcrops. The surrounding rocks are mainly amphibolites.

38. **Mt St. Ålke** (Fig. 30).

A small peridotite outcrop, with an area of about 500 square m, occurs on the very top of Mt St. Ålke at an altitude of 1454 m.

The composition of this rock is clear from an analysis of the adjacent peridotite at the tarn Stråttekjaure, given by T. Du Rietz (op. cit. p. 217). (Figures in parentheses are values obtained by personal communication).

	%	
SiO_2	37.91	
TiO_2	0.10	
Al_2O_3	5.96	
Fe_2O_3	5.58	
Cr_2O_3	0.22	(0.23)
FeO	5.12	
MnO	0.12	
NiO	–	(0.04)
MgO	36.18	
CaO	0.66	
Na_2O	0.03	
K_2O	0.06	

Actual composition (weight %)	
Chlorite	48.7
Olivine	29.6
Serpentine	8.5
Talc	5.5
Magnetite	3.5
Tremolite	3.0
Enstatite	1.2
Traces of breunnerite and pyrrhotite	

Fig. 30. Peridotite, cropping out near peak of St. Ålke in high mountains of Ammarfjällen, lies at about 1450 m. Only three species of phanerogamic plants, viz., *Ranunculus glacialis, Luzula arcuata,* and *Agrostis borealis* were found on this high-alpine outcrop. Similar vegetation established on surrounding amphibolites. Skyline formed by Spångfjället, highest peak of Ammarfjällen. Photo Olof Rune 28.7.1949.

According to T. Du Rietz, the peridotite of St. Ålke differs from that of Sråttekjaure by a higher content of tremolite. As may be expected, there is no typical serpentine vegetation on the peridotite of St. Ålke. Only three species were noticed there, viz., *Ranunculus glacialis, Luzula arcuata,* and *Agrostis borealis.* The small number of species is explained, however, by the high altitude of this locality. The first two species mentioned are by far the most prominent ones in the serpentine vegetation at this high altitude, where the phanerogamic vegetation as a whole is very sparse, that of the peridotite hardly differing from that of the surrounding amphibolites.

39. Mt Ruopskaisse.

Within the northeastern part of Ammarfjällen, near the summit of Ruopskaisse, several small peridotite outcrops occur. These are generally situated at altitudes between 1000 and 1100 m. Geological statements about these peridotite occurrences are lacking. However, the content of serpentine seems to be somewhat higher here than at St. Ålke.

Thus, the surfaces of the rocks have the yellowish brown colour generally characteristic of weathered serpentine. This colour has probably inspired the name Roupskaisse. The vegetation shows characteristic serpentine features, viz., a great abundance of *Rumex acetosa, Viscaria alpina,* and *Minuartia biflora.* The dominating vegetation is an *Empetrum hermaphroditum* heath, with scattered tufts of *Silene acaulis* and *Festuca ovina.* The following plants were also noticed in these serpentine fields: *Carex bigelowii, C. lachenalii, Juncus trifidus, Trisetum spicatum, Poa arctica, Cerastium cerastoides, Saxifraga rivularis, Oxyria digyna, Vaccinium vitis-idaea, Cassiope hypnoides, Phyllodoce coerulea, Lycopodium selago* and *Antennaria alpina.*

Lule Lappmark

PARISH OF KVIKKJOKK

District of Kvikkjokk

(map 19 Staika).

Within some parts of the high mountains of Lule Lappmark several small serpentine outcrops occur. Most of them are situated in the western parts near the Norwegian border, viz., south of Lake Virihaure and north of Lake Vastenjaure. Until recently, these districts were not explored geologically, and still no maps or descriptions are available from that part of Lappland. This, combined with

Fig. 31. On top of Vuoka-Ruopsok, unaltered olivine rocks crop out. Serpentine vegetation is confined to vicinity of these rocks, harbouring, inter alia, *Agrostis stolonifera, Festuca ovina, Silene acaulis.*
Photo Olof Rune 9.7.1949.

the great difficulties of approaching such isolated areas, has so far kept me from visiting these serpentine occurrences.

In the eastern parts of the high mountains of Lule Lappmark, two peridotitic occurrences have been known to geologists for a long time (Svenonius 1883). The first, Mt Säkok-Ruopsok, is situated about 30 km northwest of the church village of Kvikkjokk, and the second, Mt Vuoka-Ruopsok, SSW of Kvikkjokk. The latter occurrence is by far the largest in Lule Lappmark and it is the only one that I have visited.

40. **Mt Vuoka-Ruopsok** (Fig. 31).

Mt Ruopsok is a mountain summit about 15 km WSW of Kvikkjokk, and just west of the large and high mountain of Vuoka. Mt Ruopsok comprises an area of about 2–3 square km. The highest peak reaches up to about 1000 m. To a large extent the peridotite rocks are covered with extraneous moraine and only at the very top do the olivine rocks crop out (Fig. 31). The surrounding rocks are strongly schistose amphibolites, mica-schists, and mica-gneisses. The composition of the rock of Vuoka-Ruopsok is clear from the following analysis quoted from T. Du Rietz (op. cit. p. 143):

	%	Actual composition (weight %)	
SiO_2	43.10		
TiO_2	traces	Olivine	79.6
Al_2O_3	0.71	Enstatite	12.3
Fe_2O_3	1.42	Hornblende	6.4
Cr_2O_3	0.66	Chromite	
FeO	6.69	(Magnetite)	1.3
MgO	45.71	Breunnerite	0.4
CaO	0.69		
Na_2O (K_2O)	0.06		

The rock is characterized principally by unaltered olivine, and by a rather high content of chromium. Vegetation with "serpentine" features is restricted to places where the rocks crop out. Except for the particular serpentine race of *Agrostis stolonifera* which occurs in abundance, no other really serpentinicolous plants were found. Instead, an *Empetrum hermaphroditum* heath, with scattered tufts of *Festuca ovina* and *Silene acaulis* in it, predominates all over the area. In addition, the following plants were noticed at the top of Mt Ruopsok: *Lycopodium selago, Deschampsia alpina, Carex bigelowii, Luzula arcuata, L. spicata, Salix herbacea, Minuartia biflora, Cerastium edmondstonii, C. alpinum*, and *Cassiope hypnoides.*

PARISH OF GÄLLIVARE

District of Lingonberget

(map 22 Hakkas).

41. **Lingonberget** (Fig. 32, Plates IV, V).

In the southern part of the extensive parish of Gällivare, comparatively far from the high moun-

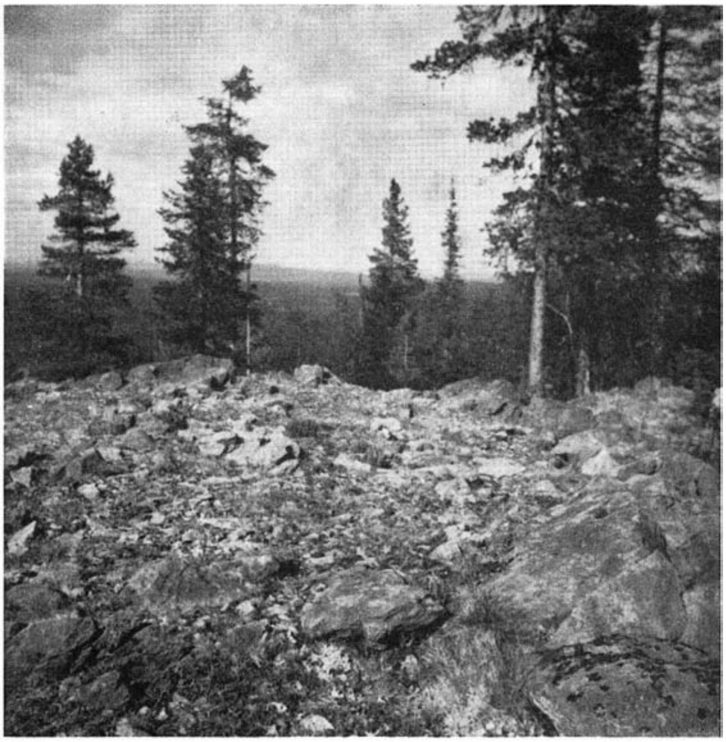


Fig. 32. Edge of serpentine outcrop at Lingonberget illustrates termination of spruce forest on reaching serpentine. Barren serpentine of foreground shows frost action pattern, with boulders arranged in rings and fine material in centres. This unstable ground harbours several serpentinicoles, viz., *Asplenium viride, Cerastium alpinum* ad var. *serpentinicola, Viscaria alpina* var. *serpentinicola.* Note different vegetation of lichens on erratic boulder in right corner.
Photo Olof Rune 6.7.1949.

tain district, a single occurrence of serpentine appears near the settlement of Lingonberget (the Finnish name is Poulalaki), in the village of Purnu. Lingonberget is situated at about lat. 67° N, and lies about 15 km northeast of the railroad station of Nattavara. During the past years quarrying has been undertaken, but only to a very small extent. For that purpose, a road was built from the Lingonberget settlement up to the quarries.

The serpentine outcrop at Lingonberget has a length of 700–800 m and a width of 20–50 m, and lies at about the 400 m level. The serpentine outcrop forms a sharply delimited zone on the northern side of a rather large mountain, and consists of several small, rather flat, barren rocks which appear on the similarly rather barren weathered soil.

The vegetation of the serpentine field differs clearly from that of the surroundings. The spruce (*Picea abies*) forest is dominant outside the serpentine, but on the serpentine it is replaced by a sparse forest of stunted pine (*Pinus silvestris*) (Pl. IV). The most prominent plant of the field and ground layers is *Asplenium viride,* which occurs everywhere — not only in crevices but also as tufts and carpets on bare weathered soil (Pl. V). *Viscaria alpina* var. *serpentinicola* and a glandulous type of *Cerastium alpinum,* rather close to the var. *serpentinicola,* are found in abundance there. Also the following plants were noticed: *Festuca ovina, Deschampsia fleuxosa, Empetrum hermaphroditum, Vaccinium vitis-idaea, V. uliginosum,* and *V. myrtillus.*

Hillock-tops and other exposed places exhibit almost bare deflation areas that harbour the abovementioned serpentinicoles, viz., *Asplenium viride, Cerastium alpinum,* and *Viscaria alpina* var. *serpentinicola,* and a few lichens: *Cetraria nivalis, Stereocaulon paschale,* and *Cladonia* species (Fig. 32). In depressions between the rocks a closed heath vegetation occurs with *Vaccinium uliginosum, V. myrtillus, V. vitis-idaea, Empetrum hermaphroditum,* and *Deschampsia flexuosa.* In Table 2 (p. 46) stand No. 10 illustrates the composition of the peculiar vegetation of this serpentine area, also pictured in Plates IV and V.

Number of stand	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
ECOLOGICAL CHARACTERISTICS																															
Size of stand m^2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Altitude 100 m	6	8	8	9	9	9	9	9	9	9	7	9	10	10	9	11	9	9	9	9	8	4	4	4	4	4	4	4	4	10	10
Exposure	S	L	L	E	L	N	N	L	S	S	L	L	N	E	W	L	L	L	L	S	S	L	L	L	L	L	L	L	S	S	L
Slope degrees	30	0	0	10	0	10	30	0	30	20	0	0	10	10	10	0	0	0	0	20	10	0	0	0	0	0	0	0	10	10	0
Wind exposure	0	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Minerals of substratum	st	s	s	o	s	s	s	s	s	s	so	s	sc	sc	od	sp	sp	sp	s	so	s	s	s	s	s	s	s	s	s	s	o
Mechanical composition (s=silt, g=gravel)	s	s	s	sg	s	s	s	s	s	s	s	s	s	sg	sg	s	s	s	s	s	sg	s	s	s	s	s	s	s	s	s	s
Thickness of mineral soil cm	25	15	20	20	20	30	20	10	20	30	15	20	10	30	40	10	20	20	20	40	40	10	20	20	20	20	20	15	15	20	25
" " humus layer "	0	0	0	0	0	5	3	0	0	0	0	2	0	0	3	0	0	0	0	0	0	3	0	0	0	0	0	0	5	0	0
Humus content of root horizon approx.%	0	0	0	0	0	25	25	0	0	0	0	25	0	0	25	0	0	0	0	0	0	25	0	0	0	0	0	0	50	0	0
Water " " " " "	d	d	d	n	vd	n	n	d	d	d	d	d	d	d	n	d	d	d	d	d	d	d	d	d	d	d	d	d	n	d	d
CaO total content %	-	12	11	10	0.8	-	-	-	-	-	-	0.6	1	14	3.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	-
pH of root horizon 1/10 x	65	71	72	67	66	65	64	-	-	68	68	67	68	75	75	63	63	-	-	62	71	72	-	-	-	-	-	-	69	68	68
Sol. phosphate mg/100 g dry soil. " "	02	00	00	00	00	06	05	-	-	03	03	-	03	01	01	02	07	-	-	03	01	05	-	-	-	-	-	-	25	00	02
" potassium " " " " " " "	45	55	45	30	30	90	55	-	-	50	35	-	45	45	45	60	65	-	-	63	75	65	-	-	-	-	-	-	350	45	25
FLORISTIC COMPOSITION																															
Serpentinicolous plants:																															
Asplenium viride	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Agrostis stolonifera	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	5	-	5	-	1	-	-
Luzula spicata	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Rumex acetosa	-	1	1	1	1	-	-	-	1	-	1	-	-	-	-	1	-	-	1	1	1	1	1	-	-	-	1	-	-	-	1
Cerastium alpinum v. serpentinicola[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
" glabratum	-	1	1	1	1	-	-	1	-	-	1	-	-	-	-	-	1	1	1	1	2	-	-	-	-	-	-	-	-	1	-
" vulgatum v. kajanense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	1	-	-	-
Minuartia biflora	-	-	1	1	1	-	-	1	1	-	1	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Arenaria norvegica	-	-	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-	1	-
Viscaria alpina	-	1	-	-	1	-	1	-	1	-	-	-	-	-	-	1	1	1	1	-	-	1	1	2	-	1	2	1	-	-	1
Silene acaulis	-	2	1	5	5	-	-	-	-	-	-	-	1	1	1	-	2	3	-	-	-	-	-	-	-	-	-	-	-	1	-
Melandrium rubrum	1	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	5	-	1
Serpentine-indiff. and -accident. plants:																															
Agrostis borealis	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deschampsia flexuosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	1	1	-	-	-	-
Trisetum spicatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Festuca ovina	-	-	-	-	1	-	4	1	1	-	-	1	-	1	1	1	1	1	2	1	-	-	-	-	-	-	-	3	2	-	-
Carex lachenalii	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
" canescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Juncus trifidus	-	2	-	-	-	2	1	1	-	1	-	-	-	-	-	2	1	2	-	-	-	-	-	-	-	-	-	-	-	1	-
Salix herbacea	-	1	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-
Betula nana	-	-	-	-	-	5	2	-	1	2	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyria digyna	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sedum rosea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Saxifraga nivalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Viola biflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Phyllodoce coerulea	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctostaphylos alpina	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium vitis-idaea	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
" uliginosum	-	-	-	-	-	2	-	-	-	1	-	-	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Calluna vulgaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	3	-	-	-	-	-	-	-	-	-
Empetrum hermaphroditum	-	-	-	-	-	3	-	-	-	5	-	-	-	-	-	-	1	-	-	-	-	5	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Solidago virgaurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	1	-	-	-	-
Calcicolous plants:																															
Carex rupestris	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
" glacialis	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tofieldia pusilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leuchorchis albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salix reticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Minuartia rubella	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum alpinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba norvegica	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parnassia palustris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dryas octopetala	-	-	-	-	-	-	-	-	-	-	-	2	5	3	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Saxifraga oppositifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphrasia lapponica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bartsia alpina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinguicula vulgaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mosses and lichens:																															
Bryum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Dicranum spp.	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drepanocladus uncinatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
Hylocomium splendens	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurozium schreberi	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhacomitrium lanuginosum	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Cetraria nivalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1	-	-	-	-	-	-	-	-
Cladonia pyxidata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
" rangiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-
" sylvatica	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	-
Stereocaulon paschale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Bare soil	5	5	5	4	2	-	3	5	4	1	5	3	3	3	-	4	2	-	4	5	5	-	5	5	5	5	5	5	5	5	5

Table 1. Analyses of vegetation and corresponding ecological characteristics from following ultrabasic rock areas N Sweden (No. of stand in paranthesis): 5 (1), 12 (2, 3), 16 (4, 5), 17 (6–10), 18 (11), 20 (12–15), 21 (16), 24 (17–19), 25 (20), 26 (21), 30 (22–29), 36 (30), 37 (31). Explanatory note on opposite page.

[1] No typical var. *serpentinicola*, but a distinct type rather similar to it (cf. p. 54).

2. Notes on the vegetation of serpentine in North Sweden

As is evident from the preceding pages, the vegetation of at least all these northern serpentine areas shows a superficial similarity. Their barren, rocky character gives the impression of highly arctic or alpine exclaves, sharply contrasting with their vicinity. Nevertheless, the serpentine vegetation is not uniform enough, even in as relatively limited an area as N Sweden, to constitute a single phytosociological unit. Considerable obstacles are to be met with in a study of the plant communities in typical serpentine vegetation. Firstly, the typical serpentine vegetation seldom forms closed communities, but rather consists of a few serpentinicolous species that alone colonize the wide, barren soil patches produced by frost action, deflation or simply by weathering. Consequently, the serpentine vegetation shows the same variation and instability as any other pioneer vegetation.

Actually, only few serpentinicolous plants occur in almost every serpentine area in N Sweden, e.g., *Asplenium viride* and *Viscaria alpina*. However, these plants are not characteristic only of the serpentine vegetation, and have already been used in Scandinavian phytosociology to characterize other plant communities.

Explanatory note to Table 1. Soil samples taken from rhizosphere in centre of each square analysed with regard to vegetation. Cover of species estimated according to five-parted scale of HULT-SERNANDER. Contents of humus and water, as well as main fraction of mechanical composition of soil, are estimated. Other determinations see p. 7. The following abbreviations, used in table, need explanation:

Exposure: L = level

Wind exp.: + = strong

Minerals: c = calcite; d = diopside; o = olivine; p = pyroxene; s = serpentine; t = tremolite. Correction: column 15 should be sc, and column 16 od.

Water cont.: vd = very dry; d = dry; n = normal (similar to other soils of vicinity)

Note: To obtain values of pH, soluble phosphate, and soluble potassium, respectively, the figures in the columns should be divided by ten. (Decimal points omitted from considerations of space.)

In dealing with the problems relating to serpentine plant communities in N Sweden, I soon became aware of the impossibility of keeping together, in one and the same alliance, even serpentine vegetation from similar altitudes. I found that some of the serpentine plant communities fitted those phytosociological alliances already recognized in Scandinavian alpine and subalpine vegetation by NORDHAGEN (1928, 1936, 1943) and G. E. DU RIETZ (1942 a and b, 1950). Within these large units they represent very special, depauperate associations. As phytosociology does not form any prominent part of my serpentine studies, this material is too small to allow further descriptions. Only some views on the connection between a few types of serpentine vegetation and corresponding types on soils of another lithological origin will be stated.

A. Plant communities of serpentine rock crevices, the Asplenion viridis subarcticum alliance.

NORDHAGEN (1936) described an alliance of Fennoscandian calcareous rock crevices — *Asplenion viridis subarcticum* — which is an equivalent to BRAUN-BLANQUET's *Potentilletalia caulescentis* from the Alps. The same author (1943) also mentioned (p. 568) that on olivine and serpentine this alliance appears in a particular form characterized by, e.g., the following plants: *Asplenium viride*, *A. adulterinum*, *A. adiantum nigrum*, *Viscaria alpina*, *Silene vulgaris*, *S. maritima*, and *Arabis petraea*. Apparently, this refers only to the coastal districts of SW Norway.

On calcareous rock, *Asplenium viride* seems to be totally confined to rock crevices. This is not the case on serpentine, where it sometimes forms tufts or small mats on plain, bare soil patches (see Pl. V). In serpentine rock crevices, especially the shady ones, *Asplenium viride* is very abundant in almost all Fennoscandian serpentine areas at altitudes from sea level up to about 1000 m. Thus, within the *Asplenion viridis subarcticum*, a very distinct

Table 2. Vegetational analyses of *Asplenion* communities from non-alpine serpentine areas. Size of stand: 1 m².

Number of stand	1	2	3	4	5	6	7	8	9	10
Asplenium viride	1	3	3	2	2	4	1	1	1	2
Arenaria norvegica				1 −						
Cerastium alpinum										1
" *vulgatum* *v. kajanense*		1	1 −	1 −		1 −	1 −	1 −	1 −	
Melandrium rubrum	1	1 −	1			1		1		
Rumex acetosa	1 −	1 −	1 −	1 −	1 −		1 −	1 −		
" *acetocella*				1 −						
Silene rupestris		1 −								
Viscaria alpina		1	1			1 −	1 −	1 −	1	1 −
Agrostis canina		1 −								
" *stolonifera*					1		1	1	5	
Deschampsia flexuosa		1		1		1 −	1			1 −
Festuca ovina										1
Molinia coerulea		1 −								
Poa glauca			1 −							
Scirpus caespitosus	1 −									
Empetrum hermaphroditum										
Vaccinium uliginosum										1 −
Pinus silvestris (15 cm high)										1 −
										1 −
Campylium stellatum	1	2	1	1 −	1	2	1	1 −	1 −	
Drepanocladus uncinatus	2	1	2	2	1 −	1	1 −	2	2	
Rhacomitrium lanuginosum					5 +					
Tritomaria quinquedentata	1 −	1 −	1 −	1 −	1 −	1 −	1 −	1 −	1 −	
Cetraria nivalis										1 −
Cladonia rangiferina										1 −
Stereocaulon paschale										1 −
Stand obtained from serpentine area No.	1	7	7	9	12	28	28	28	28	41

serpentine facies doubtless exists in all Fennoscandia, distinguished above all by an occurrence of *Asplenium viride* in much greater abundance than ever found on calcareous rock.

In N Sweden, the only area I really thoroughly studied, *Asplenium viride* is accompanied chiefly by some serpentinicolous mosses, viz., *Tritomaria quinquedentata, Campylium stellatum, Drepanocladus uncinatus*, and *Rhacomitrium lanuginosum*. In contrast to the aforementioned Norwegian coast facies of this serpentine-plant association, its alpine-subalpine facies in N Sweden contains some more or less alpine elements, viz., *Cerastium alpinum Silene acaulis, Juncus trifidus*, and *Luzula spicata*. Actually, all serpentinicolous plants listed on pp. 51–66 may appear more or less abundantly in this serpentine plant association of *Asplenion* which is, however, generally characterized by a very complete dominance of *Asplenium viride*. This serpentine facies of *Asplenion viridis* has a wide altitudinal amplitude, ranging from sea level to about 1000 m. However, the abundance of *Asplenium viride* decreases at increasing altitudes. Accordingly, the most typical *Asplenion* communities are found below the alpine region. (See Table 2.)

As the vegetational analyses of Table 1, p. 44, were made in order to show the vegetation connected with the analysed soils, they do not represent any communities from rock crevices. However, within some serpentine areas — mainly from rather low altitudes — some stands of *Asplenion* communities were analysed and the results are given in Table 2 on the opposite page.

B. Plant communities of serpentine scree, the Arenarion norvegicae alliance.

NORDHAGEN, in several papers (1935, 1936, 1943), pointed out the peculiar character of the vegetation which occurs on the debris of talus, and elsewhere on unstable calcareous ground (limestone, dolomite, and mica-schists). He discerned as a distinct alliance — *Arenarion norvegicae* — the pioneer vegetation on unstable, calcareous ground, especially talus, within the Scandinavian mountain area. This alliance may correspond to the *Thlaspeion rotundifolii* (BRAUN-BLANQUET 1926, JENNY-LIPS 1930) of the Alps. The *Arenarion* alliance is characterized by the following pioneer plants as characteristic species: *Arenaria norvegica*, *Braya linearis*, and *B. purpurascens.* Further, as differential species against the non-calcareous soil communities the following are mentioned: *Dryas octopetala*, *Saxifraga oppositifolia*, *S. aizoides*, *Astragalus* and *Oxytropis* spp., *Epipactis atropurpurea* and *Lastrea robertiana* (NORDHAGEN 1943). However, among these, both *Braya* species are very rare, *B. purpurascens* is confined to one single locality in northernmost Norway, and the two last-mentioned ones do not reach even to the subalpine region, except in very warm, south-exposed places. *Arenaria norvegica* is, therefore, by far the most important index species of the *Arenarion* alliance. As *Arenaria norvegica* grows in such great abundance on debris and bare soil patches in several serpentine areas, it seems reasonable to include much of the pioneer vegetation typical of serpentine in the *Arenarion* alliance.

On serpentine, *Arenaria norvegica* seems to have no preferences as to the calcium content but is always found in abundance in places where the serpentine rock is somewhat schistous, and gives rise, by mechanical weathering, to a large amount of coarse gravel debris. Such localities are found in the areas Nos. 12, 25, 26, 36 (cf. pp. 16, 28, 30, 39, resp.).

NORDHAGEN (1935) found the following to be constants of the *Arenarion* on calcareous scree at Junkerdalen in Salten, Norway: *Arabis alpina*, *Arenaria norvegica*, *Astragalus alpinus*, *Braya linearis*, *Campanula rotundifolia*, *Cerastium alpinum*, *Saxifraga aizoides*, *S. oppositifolia*, *Roegneria scandica*, *Poa alpina*, and *P. glauca*. The following were found to be constants in *Arenarion* communities at Duken, Mageröya, N Norway: *Arenaria humifusa*, *A. norvegica*, *Pinguicula alpina*, *Polygonum viviparum*, *Silene acaulis*, *Thalictrum alpinum*, *Tofieldia pusilla*, *Carex bigelowii*, *C. rupestris*, *Festuca ovina*, *Dryas octopetala*, *Salix reticulata.* Of these, *Arabis alp.*, *Braya linearis*, *Astragalus alp.* were never found on serpentine, while the others may occur more or less frequently on serpentine (cf. Table 1 p. 44 and pp. 51–76) — the bulk, it is true, confined to calcareous serpentine. However, *Arenaria humifusa*, *Silene acaulis*, *Campanula rotundifolia*, *Cerastium alpinum*, and *Festuca ovina*, are all abundant even on the pure serpentine. Besides, such plants as *Arenaria ciliata* ssp. *pseudofrigida*, *Minuartia rubella*, and *Arabis petraea*, which all favour calcareous debris, may also appear in abundance in the serpentine facies of *Arenarion.* This again is very clearly characterized by such serpentinicolous allies of *Arenaria norvegica* as *Cerastium glabratum* and *Rumex acetosa* which are certain constants of the serpentine facies of *Arenarion.*

The vegetational analyses on next page further illustrate the composition of these communities.

The coarsely weathered gravel, favourable for *Arenaria norvegica*, is as a rule not common in connection with serpentine which normally weathers to a silty soil. However, *Arenaria norvegica* may occur even in that kind of soil, though more sparsely. With the exception of *Arenaria norvegica*, none of the above serpentinicolous plants seem to have definite preferences with regard to the mechanical composition of the soil. As all plant communities of the *Arenarion* alliance are confined to unstable ground, on serpentine as well as on calcareous rock, a bottom layer of lichens and mosses is almost completely lacking. On calcareous ground the unstable soil is more or less confined to the scree below steep cliffs. However, this is not the case on serpentine where the instability of the ground may just

Table 3. Vegetational analyses of *Arenarion* communities on serpentine. Size of stand: 1 m².

Number of stand	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Arenaria norvegica		2			1 –	1 –	1	2	1	1	2	1	2	2
Asplenium viride						1				1 –	1 –			
Campanula rotundifolia									1 –					
Cerastium glabratum	1 –	1	1 –	1		1	1 –	2	1					1 –
Draba norvegica					1 –									
Melandrium rubrum											1			
Minuartia biflora		1 –	1 –	1			1 –							1 –
” *rubella*					1 –									
Rumex acetosa	1 –	1 –	1 –	1 –		1	1 –	1			1 –	1	1 –	1 –
Saxifraga oppositifolia					1 –									
Silene acaulis	2	1	5		1				1			2	1	
Viola biflora									1 –					
Viscaria alpina	1 –		1			1 –						1		1 –
Agrostis stolonifera	1	1						1 –				1	1	1 –
Festuca ovina			1		1	2	1							
Juncus trifidus	2								1 –					
Dryas octopetala					3				2					
Salix herbacea									1 –					
Salix reticulata					1									
Bare soil	5	5	2	5	3	4	5	5	5	5	5	4	5	5
Corresponds to following No. of Table 1	2	3	5	11	14	19	20	21	30	—	—	—	—	—
Stand obtained from serpentine area	12	12	16	18	20	24	25	26	36	10	2	13	14	27

as well be caused by frost action or deflation. Actually, the colonization proceeds very slowly on the serpentine soil, and a closed community will not be formed until a humus layer, produced mostly by *Rhacomitrium lanuginosum*, covers the mineral soil. Moreover, the closed communities on the serpentine soil may again easily be destroyed by frost action, etc., and then the recolonization has to start anew.

With a few exceptions, *Arenaria norvegica* is restricted to low-alpine and subalpine serpentine habitats and is thus lacking on areas within the conifer forest region. In some of the lowland areas it is replaced in similar types of localities by the typical serpentinophyte *Cerastium vulgatum* var. *kajanense*. However, some truly alpine members of the serpentine facies of *Arenarion*, e.g., *Viscaria alpina* and *Cerastium alpinum*, occur also in lowland serpentine areas far from the mountain region (cf. p. 43). Yet the lowland serpentine pioneer communities are in some ways different from the alpine and subalpine ones (cf. p. 31), and it is doubtful whether they can be included in the *Arenarion* alliance.

C. Climax communities on serpentine.

Although a closed mat of vegetation is never typical of serpentine, it may still be found in places protected from frost action and erosion, and where the ground is stable (cf. Braun-Blanquet 1951 p. 238). In fact, a closed vegetation will not be found on serpentine unless the serpentine soil is covered by a humus layer. This is formed mainly by *Rhacomitrium lanuginosum* which, when the ground remains sufficiently stable, slowly invades the bare soil patches. Accordingly, as a first stage towards a climax, a *Rhacomitrium* mat appears, at the beginning including most of the plants typical of the bare soil, viz., *Arenaria norvegica*, *Silene acaulis*, *Cerastium glabratum*, *Minuartia biflora*, *Viscaria alpina*, and *Rumex acetosa*. The next stage is the invasion by *Juncus trifidus* and some ericaceous shrubs, *Calluna vulgaris*, *Empetrum hermaphroditum*, and *Vaccinium uliginosum*.

Thus, on stable and rather dry ground climax communities appear which are dominated by *Calluna vulgaris*, *Empetrum hermaphroditum*, *Vaccinium uliginosum*, *Juncus trifidus*, and *Festuca ovina* in the field layer, and *Rhacomitrium lanuginosum* in the ground layer. Some serpentinicolous plants, remnants from the pioneer stage, may continue to exist also in these closed communities, viz., *Viscaria alpina*, *Silene acaulis*, *Rumex acetosa*, and *Asplenium viride*. Thus, within these communities the acidicolous *Calluna vulgaris* is, curiously enough, found to grow together with the calcicoles *Asplenium viride* and *Silene acaulis* (cf. p. 28).

In the Scandinavian mountains *Empetrum hermaphroditum* is, above all, characteristic of the low-alpine heaths on acid soils, especially the parts not protected by snow during winter. These *Empetrum* heaths constitute a very clear phytosociological unit of a high order — the *Empetrion* alliance (G. E. Du Rietz 1942 a and b, 1950) or *Loiseleurieto-Arctostaphylion* (Kalliola 1939, Nordhagen 1943). Most of the climax communities of alpine-subalpine serpentine soils are likely to be regarded as very special facies of the *Empetrion* alliance, characterized, above all, by the abundant occurrence of *Calluna vulgaris* and *Rhacomitrium lanuginosum*, and, in addition, serpentinicolous plants such as *Asplenium viride*, *Viscaria alpina*, *Silene acaulis*, etc.

The *Empetrion* alliance is the most xerophytic type of low-alpine vegetation which appears chiefly on crests, summits, and other, strongly exposed places. Naturally, the dry character of the serpentine outcrops is one of the main reasons why the serpentine climax vegetation largely falls within the *Empetrion* alliance.

In less exposed places where the vegetation is protected by a considerable layer of snow during winter, the *Empetrum* heath changes into a *Vaccinium myrtillus* heath which also contains several herbs and grasses, viz., *Solidago virgaurea*, *Cornus suecica*, *Trientalis europea*, *Melampyrum silvaticum*, *M. pratense*, *Pedicularis lapponica*, *Deschampsia flexuosa*, and *Anthoxanthum odoratum*. Besides *Vaccinium myrtillus*, other dwarf shrubs also occur there, viz., *Betula nana*, *Phyllodoce coerulea*, *Empetrum hermaphroditum*, and *Calluna vulgaris*. This type of heath vegetation constitutes another alliance of the acid soils of the low-alpine region, and has been named *Myrtillion* (G. E. Du Rietz 1942 a and b, 1950) or *Phyllodoco-Myrtillion* (Nordhagen 1936, 1943).

Although *Vaccinium myrtillus* itself is very rare in serpentine soil, the serpentine climax vegetation of shady or less exposed places seems most of all reminiscent of this alliance. In this case, the humus layer covering the serpentine mineral soil is quite considerable and the serpentine character of this type of vegetation is largely decreased. In this community, *Rhacomitrium lanuginosum* is to a certain extent replaced by *Pleurozium schreberi*, *Hylocomium splendens*, and *Dicranum* species. Among the dwarf shrubs the following are common: *Calluna vulgaris*, *Betula nana*, *Vaccinium uliginosum*, *Empetrum hermaphroditum*, and *Phyllodoce coerulea*. Some of the most characteristic herbs and grasses of the *Myrtillion* are also usual in this type of serpentine vegetation, viz., *Solidago virgaurea*, *Deschampsia flexuosa*, and *Anthoxanthum odoratum*. In fact, it is mainly the occurrence of these herbs and grasses that justifies looking for *Myrtillion* communities on serpentine.

It is an important fact that the serpentine vegetation is rather similar to that of acid soils, though the reaction of the serpentine soil itself is usually neutral or slightly basic (cf. Braun-Blanquet 1951 p. 238). However, when the serpentine contains calcium (cf. p. 114), *Dryas octopetala* and *Carex rupestris* will become dominant plants, and the vegetation as a whole will approach the *Dryadion* alliance (G. E. Du Rietz 1942 a and b, 1950) which is the calcareous soil equivalent of the aforementioned *Empetrion* and *Myrtillion*.

The climax communities on serpentine are far more complex and difficult to recognize than the typical serpentine communities within the *Asplenion* and *Arenarion* alliances, and the lack of further investigations does not allow of more than a mere indication of these outlines. Among the vegetational analyses in Table 1, p. 44, only very few are based on climax communities. Such are, indeed, stands Nos. 6, 10, 15, and 22, while Nos. 17 and 18 may be the first stages in forming closed communities. No. 6 may be a *Myrtillion*; 10 and 22 *Empetrion* communities, while No. 15 illustrates the *Dryadion* of the calcareous serpentine.

In conclusion, it may be stated that the plant communities of serpentine areas in N Sweden, which are mainly situated within the low-alpine and subalpine regions, may to a certain extent represent special associations within the ranges of the large vegetational units of the Scandinavian low alpine vegetation. Thus, it seems clear that the *Asplenion viridis subarcticum* alliance described by NORDHAGEN, and typical of calcareous rock crevices, is fully represented also in serpentine.

The most typical serpentine vegetation, i.e. where the maximal abundance of serpentinicolous plants occurs, is restricted to pioneer habitats — debris and bare soil patches generally produced by frost action. This typical serpentine vegetation, which as a rule covers wide areas of the serpentine outcrops, does not form closed plant communities. It is rather reminiscent of the pioneer vegetation of unstable calcareous ground distinguished by NORDHAGEN as the *Arenarion norvegicae* alliance. Thus, its most characteristic plant, *Arenaria norvegica*, is very abundant also on serpentine barrens. However, because of the rich occurrence of such serpentinicolous plants as *Rumex acetosa, Viscaria alpina, Cerastium glabratum*, etc., the serpentine facies of *Arenarion* is quite peculiar to itself.

Closed plant communities may occur on serpentine where the ground is stable enough to allow of the existence of a humus layer. Because of the dry character of most serpentine outcrops, the closed vegetation will constitute dwarf shrub heath communities which seem most closely related to the low-alpine, acid soil alliances *Empetrion* and *Myrtillion*. However, as is general on serpentine, some calcicolous plants may grow together with the acidicolous ones (cf. p. 88). As serpentine outcrops are very sparsely wooded, they may form alpine exclaves in the subalpine and even in the conifer forest region. The above types of serpentine vegetation, therefore, seem to have a very wide altitudinal range, even though the number of alpine plants decreases with increasing distance from the mountain district.

3. List of plants found on serpentines and other ultrabasic rocks in North Sweden

The following list of plants observed on serpentines as well as other ultrabasic rock areas of N Sweden is complete only as regards the vascular plants.

In regard to its affinity to serpentine, any species found on it may represent either of the following three categories:

A. *Serpentine-characteristic (serpentinicolous) plants.*[1]
Plants occurring more frequently or abundantly on serpentine than on other soils and rocks in the vicinity.

B. *Serpentine-indifferent plants.*
Plants occurring more or less frequently or abundantly on serpentine, though not more so than on other soils and rocks in the vicinity.

C. *Serpentine-accidental plants.*
Plants occurring incidentally, and usually more sparsely, on serpentine than on other soils and rocks in the vicinity.

Plants of the first category are very abundant

[1] The shorter term serpentinicolous will be used in the text.

and vigorous on serpentine, being probably ecologically distinct races of the species. Some of these races are morphologically distinguishable and will be referred to as individual taxa. However, several of them do not differ morphologically from the type race of the species and have, moreover, not been studied adequately with regard to their ecological amplitudes. Thus, when listing, e.g., *Rumex acetosa* as a serpentinicole, it must be borne in mind that this probably only refers to a special race of that plant.

Plants of the second category are not characteristic of serpentine. In general, they are common, ubiquitous plants with a wide ecological amplitude. They do not give the impression of being especially attached to serpentine as compared with soils of a different lithological origin.

Though few in number, the plants of these two categories are by far the most important on serpentine, forming the bulk of its scanty vegetation.

The preponderant part of the listed plants belongs to the third category, being plants found incidentally on serpentine. They are by no means characteristic of serpentine. To prevent the more important serpentine plants from being drowned in the long list of serpentine-accidentals, each of the above categories will be listed separately.

In the following list, also the non-serpentine occurrences of the listed plants are taken into consideration. Unless otherwise stated, these data refer to conditions in the mountain districts of S Lappland which harbour the main part of the Swedish serpentine areas. Each plant is characterized also with regard to its soil preferences outside serpentine. For this purpose the following well-known terms will be used: acidicolous — indifferent — calcicolous. With regard to altitudinal regions, the following abbreviations are used: Reg. alp. = Regio alpina = the alpine region; Reg. alp. inf. = Regio alpina inferior = the lowest part of the alpine region; Reg. subalp. = Regio subalpina = the mountain-birch forest region; Reg. conif. = Regio coniferina = the conifer forest region. In regard to the vascular plants, the nomenclature given by HYLANDER (1941 and 1945) is in principle followed.

A. Serpentine-characteristic (serpentinicolous) plants.

a. Vascular Plants.

Asplenium viride HUDS.

SERPENTINE: Very abundant in all serpentine areas except in extreme alpine situations, only lacking in areas Nos. 38, 39, and 40. Most abundant in crevices but forming also mats and tussocks in the bare patches of weathered serpentine soil. Very characteristic of serpentine in all Fennoscandia.

OUTSIDE SERPENTINE: Frequent in calcareous rock crevices, generally in the low-alpine and subalpine regions.

Agrostis stolonifera L.

SERPENTINE: Abundant in several widely distant areas at altitudes from 300–1000 m, viz., Nos. 11–13, 22, 26, 28–31, 35, 36, 40. Growing in both wet and dry habitats; in crevices or as mats on bare soil. This plant is one of the first to colonize the bare soil patches produced by frost action. Specimens from dry habitats seem to differ from those of wet stations, but when cultivated in normal soil they proved to be identical. This plant will be discussed also on p. 87.

OUTSIDE SERPENTINE: See p. 87.

Molinia coerulea L.

SERPENTINE: Abundant in several areas, viz., Nos. 1, 2, 6, 12–15, 22–26, 30, 31, 33; most of them at altitudes below 700–800 m. They occur in dry as well as wet habitats. Abundant on serpentine also outside Sweden (cf. p. 87).

OUTSIDE SERPENTINE: In the Scandinavian mountain district, frequent as a mire-plant; less frequent in other habitats.

Luzula spicata (L.) DC.

SERPENTINE: Abundant in several alpine areas, viz., Nos. 13, 14, 17, 22, 24, 32, 36, 40. It seems more abundant in serpentine than in soils of other lithological origin; restricted to alpine areas.

OUTSIDE SERPENTINE: Frequent on different kinds of rock; mainly alpine.

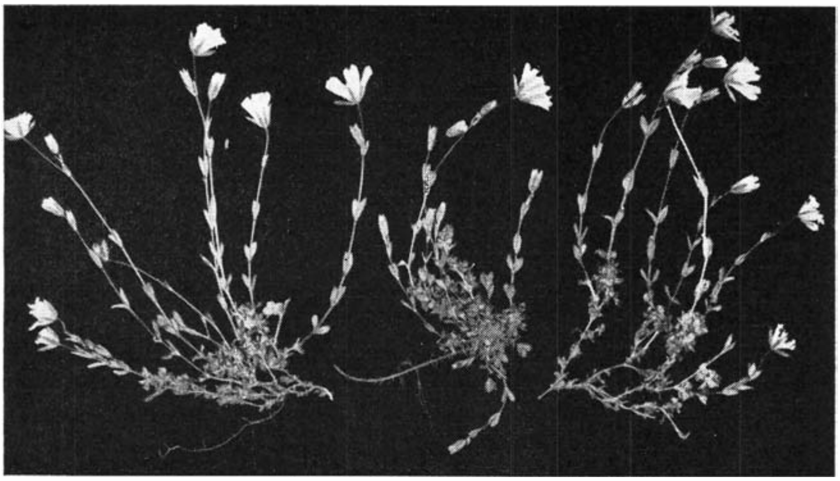


Fig. 33. *Cerastium glabratum* from Rupsentjårro serpentine (area No. 17). Specimens from serpentine are generally m•re slender and angustifoliate than others of the species. Photo Sven Eriksson 1948.

Rumex acetosa L.

SERPENTINE: In serpentine areas of N Sweden the complex species *Rumex acetosa* is represented by a certain race, very abundant in most areas, only lacking in the following, Nos. 7, 18, 19, 24, 38, 40, 41. It may occur in all kinds of serpentine vegetation, and is often found in extremely dry habitats. This serpentine race seems to be morphologically more connected with the lowland population of ssp. *pratensis* (WALLR.) BLYTT & DAHL, than to the mountain population of ssp. *alpestris* (SCOP.) LÖVE, having a laciniate ochrea and basal leaves about 3–4 times longer than broad (cf. LÖVE 1944). The height varies between 15–60 cm, the root system is strongly developed and the inflorescence has usually a clearly red colour. Within the Rönnbäck areas some hairy specimens were also collected which may belong to forma *hirtulus* (FREYN) LÖVE, mentioned by LÖVE (op. cit.).

The population of *Rumex acetosa*, occurring within the serpentine areas of N Sweden seems to be an ecologically distinct race, reminiscent of the ssp. *pratensis*. However, the *Rumex acetosa* complex is highly variable and taxonomists have failed to recognize distinct races based on morphological characteristics. The serpentinicolous race of *Rumex acetosa* cannot as yet be distinguished taxonomically, since in spite of LÖVE's investigation (op. cit.) the Scandinavian mountain population of *Rumex acetosa* is still very little known.

Rumex acetosa is also mentioned from the serpentine areas of Sunmöre (BJÖRLYKKE op. cit.) and from the serpentine in the Danube Valley (KRETSCHMER op. cit.).

OUTSIDE SERPENTINE: In the Scandinavian mountain districts, *Rumex acetosa* is mainly represented by ssp. *alpestris* (SCOP.) LÖVE, which is a rather common plant within and below the low-alpine region, growing in meadows and other moist habitats.

Cerastium glabratum HARTM.

This plant was described as early as in 1820 by HARTMANN, but was later usually considered as a variety of *Cerastium alpinum*, (*C. alp.* var. *glabrum* RETZ.) from which it differs mainly by its glabrous leaves and stems, longer petals and narrower capsules. Recently, ARWIDSSON (1943) and SELANDER (1950) supported its rank of species. The peculiar distribution and ecology of this plant seem rather to justify a higher taxonomic rank than a variety. In N Sweden, *C. glabratum* is almost limited to serpentine when occurring south of Pite Lappmark (about south of lat. 66°–67° N). It grows in abundance in almost every serpentine area of the low-alpine and subalpine regions, viz., Nos. 3, 6, 11–18, 21–27, 35, 36, there being a physiognomically distinctive and constant feature of the vegetation. In serpentine, *C. glabratum* grows mainly in rock crevices and patches of barren soil where it often forms attractively flowering carpets. In fact, this is one of the most characteristic pioneer plants of the barren serpentine soil.

Serpentine-specimens of *C. glabratum* are often morphologically somewhat different from the non-serpentine ones in forming very large tufts and having a more slender growth (see Fig. 33). However, these differences do not appear distinctive enough for taxonomic separation.

Outside serpentine, *C. glabratum* is generally considered to be a calcicole. It is very common in N Norway and N Lappland. In the southern parts of the high mountains of Sweden it is found only outside serpentine in a few places within the high mountain district of SW Jämtland and NW Härjedalen (Mts Sylarna and Helags). ARWIDSSON (op. cit. p. 198) pointed out that within the northern districts (Lappland) *Cerastium glabratum* is totally glabrous, while further south (Jämtland, Härjedalen) the specimens might have a few hairs on shoots and leaves. It may be questioned, therefore, whether or not the southern specimens are really true *C. glabratum*. However, on serpentine *C. glabratum* is always totally glabrous, even in Jämtland and S Lappland. Yet semi-glabrous types can also be found on serpentine, but as they generally differ also in other respects — smaller size, etc., — the latter should rather be considered to belong to the serpentinicolous variety of *C. alpinum* (see below). *Cerastium glabratum* and *C. alpinum* do not seem to occur together either in serpentine or in other soils (cf. SELANDER 1950 II p. 78).

Cerastium alpinum var. *serpentinicola* nova var.

Planta sparse pubescens vel fere glabra, gracilis sed plerumque caespites magnos, densos formans, plerumque c. 5 (3–7) cm alta, caulibus stricte erectis plerumque unifloribus (raro bi- vel trifloribus); foliis caulinis pro specie manifeste angustis, 1.5–2 mm latis et plerumque duplo vel triplo longioribus (3–6 mm longis); sepalis c. 5 (4–6) mm, petalis c. 7 (6–8) mm longis; seminibus diam. 0.7—0.8 mm.

Habitat in serpentino regionis subalpinae et regionis alpinae inferioris alpium Scandinaviae.

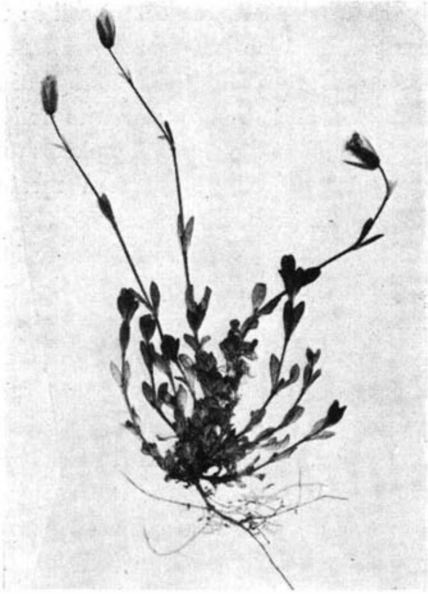


Fig. 34. *Cerastium alpinum* var. *serpentinicola* from serpentine outcrop east of settlement Gruben in Krutå, Hattfjelldal, Norway. Photo Sven Eriksson 1952.

Coll. orig.: Suecia, Lapponia åselensis, par. Vilhelmina, in saxis serpentini regionis alpinae c. 900 m s.m. montis Graipesvare prope Grundfors, leg. O. RUNE 24. VI. 1947 (typus in Mus. Bot., Uppsala).

var. *serpentinicola* differs from other races of this species mainly by its smaller size, approx. 5 cm, excluding the root system which may be 2–3 times that length. The stem leaves vary between approx. 3–6 mm in length and approx. 1.5–2 mm in breadth; the petals are approx. 7 (6–8) mm and the sepals approx. 5 (4–6) mm. The seeds are 0.7–0.8 mm in diameter. As regards the stem leaves, the variety is more angustifoliate than other races of the species. Though usually conspicuously slender, the floral shoots are very stiff and erect. Each stem has only one single flower (rarely 2–3). The pilosity varies from slightly pilose to nearly glabrous. Actually, this variety is intermediate between *C. alpinum* and *C. glabratum* in that respect.

var. *serpentinicola* usually forms dense and rather large tufts. It is restricted to serpentine areas of the lower alpine and upper subalpine regions and is found in four different stations in Scandinavia (see below).

I have in vain tried to cultivate this variety by growing seeds in normal soil in the Botanical Garden of Uppsala University. Actually, some seeds did grow, but the seedlings did not develop normally and died during the following winter. As the cultivation of alpine plants under unfamiliar climatic conditions often meets with difficulties, the failures in growing this variety does not preclude its capacity to thrive in normal soil. However, this can only be proved in its native area.

A small tuft of var. *serpentinicola* from the type locality at Graipesvare was growing well when planted in the Botanical Garden of Uppsala University. The original tuft increased considerably in size during the cultivation which lasted for several years. However, no morphological changes were observed during that time.

var. *serpentinicola* is usually very abundant in its localities. Besides, the populations are generally conspicuously uniform. No doubt, dwarfish individuals of *Cerastium alpinum* of the same size as var. *serpentinicola* may appear on soils of a lithological origin different from that of serpentine. In that case, either one or a few individuals constitute the extremes of a normal population that lacks the gracile shape of var. *serpentinicola.* In fact, the existence of large and uniform populations of the dwarfish var. *serpentinicola* clearly indicates its character of a distinct, independent race.

Typical var. *serpentinicola* has so far been established in four different stations in Scandinavia.

The only Swedish occurrence is the type locality, situated on Graipesvare in S Lappland. Here a rather uniform and abundant population of var. *serpentinicola* occurs on a small, barren outcrop of non-calcareous serpentine at the 900 m level. Within an area of some ten square metres, var. *serpentinicola* is very abundant. Being free from intermediate types, this population of a very small *Cerastium,* forming dense tufts and mats in crevices and on serpentine scree, looks confusingly like an *Arenaria.*

Another population, partly similar to that reported, appears in the serpentine areas near the settlement of Gruben southwest of Lake Krutvattnet in Hattfjelldal, Norway, adjacent to the Swedish border. var. *serpentinicola* appears abundantly on the crests of several serpentine outcrops at altitudes of 600–800 m. However, this large population is far less uniform than that of the type locality. Above all, the variation in size is considerable. Most of the specimens collected can hardly be distinguished from those of the type locality. Also larger specimens were encountered. They are of a size similar to that of the normal *C. alpinum* but have the gracile shape of var. *serpentinicola* and may probably be considered as "hybrids".

Knaben (1952) pointed out the existence of a peculiar type of *C. alpinum* on serpentines in W Norway, viz., an almost glabrous form from Möre, collected by R. Nordhagen, and a more variable one from the serpentine areas of Middle Sogn, collected by G. Knaben. In comparing my own material of var. *serpentinicola* with the herbarium specimens from these localities belonging to the Botanical Museum of Bergen University, I found the reference of the Norwegian material to this variety fairly justified.

No doubt, the description of var. *serpentinicola* does not by any means cover all the serpentinicolous populations of *C. alpinum* existing in Scandinavia. It includes only one of the types observed, viz., the most distinct one and the only one detected in more than one locality. For example, in the serpentine areas of N Sweden, three other different serpentinicolous local-populations of *C. alpinum* were established. Although they have some features in common with var. *serpentinicola*, they cannot rightly be identified with it, but may for the present be referred to as *ad var. serpentinicola.* Thus, in area No. 5, Muruhatten, a type of *C. alpinum* occurs which is rather similar to var. *serpentinicola* but is strongly glandular-pilose. Another glandular-pilose type, larger than the variety, appears abundantly in area No. 41, Lingonberget. Finally, a dwarfish type which, however, lacks the gracile shape of var. *serpentinicola* was found in area No. 37, Ruopsokvare.

The complete list of the stations of *Cerastium alpinum* var. *serpentinicola* runs as follows:

Norway: Sogn og Fjordarne, Vik hd, Arnafjell, Vetle-Rauberg 14/8 1941 and Rauberg 2/8 1942, leg. G. Knaben. Bot. Mus. Bergen.

Möre, Sunndalen hd, Kopungen in Gjeitådalen on serpentine 8/8 1929, leg. R. NORDHAGEN, Bot. Mus. Bergen.

Nordland, Hattfjelldal hd, serpentine outcrops east of the settlement Gruben in Krutå 30/7 1950, leg. O. RUNE. Bot. Mus. Ups.

Sweden: Lappland, Åsele Lappmark, Vilhelmina par., Grundfors, southern part of Graipesvare 24/6 1947, leg. O. RUNE. Type locality. Bot. Mus. Ups.

Cerastium vulgatum L. var. *kajanense* KOTIL. & VEERA SALMI

This typical serpentinophyte was recently described from Finland by KOTILAINEN and SALMI (KOTILAINEN & SALMI 1950). Earlier, this plant was referred to by KOTILAINEN as *Cerastium caespitosum* var. *angustifolium* KOTIL. & VEERA SALMI, ad interim. This variety differs from other Fennoscandian forms of *Cerastium vulgatum* chiefly by its slenderness and very narrow leaves. It is about 10–15 cm high with leaves about 5–15 mm long and 1.5–4 mm broad. In Finland, it is only found within a few serpentine areas in Ostrobottnia Kajanensis (Paltamo parish, about lat. 64° N). In N Sweden this serpentinophyte has been found in the serpentine areas (Nos. 28–31) of the Rönnbäck district (Lycksele Lappmark, Tärna parish, about lat. 65° 30′ N) and in some serpentine areas (Nos. 6–9) near Gäddede (Frostviken parish, N Jämtland, about lat. 64° 30′ N). The distance between its two Swedish distributional areas is about 150 km.

In all its localities, this plant is totally restricted to serpentine (in area No. 9 the rock is mainly soapstone). The stations are all situated within the conifer forest region, below an altitude of 500 m. The plant is quite frequent in its localities, growing most abundantly in patches of unstable ground where climaxes are slowly formed.

From Sunmöre, BJÖRLYKKE (op. cit.) reported *Cerastium vulgatum* from several serpentine areas. Since no remarks are added to his statement, it can hardly be a serpentinicolous variety. In the serpentine areas of the Isle of Rödön, in Tjötta, I myself noticed *Cerastium vulgatum*. Most of the collected material seems to conform to var. *glabrescens* (G. F. W. MEYER) HYL. This variety, recognized by its glabrous, or almost glabrous, leaves and one-sided pilose stem, seems to be a spontaneous coastal plant in NW Europe (cf. MÖSCHL 1948, the maps in Figs. 13 and 14). The variety seems to have a wide ecological amplitude and is not restricted to wet habitats, as is often stated in the literature. Specimens of dry stations are rather small in size and have very stiff, erect stems, being rather reminiscent of the serpentinicolous var. *kajanense*. Actually, the latter differs from the former only by its narrower leaves and slenderness. Further, as they also have a similar type of pilosity, var. *kajanense* may be assumed to be a serpentine race morphologically distinct from the var. *glabrescens* complex from which it differs by such typical serpentinomorphoses as stenophyllism and gracility. This will facilitate an understanding of the remarkable disjunctions of var. *kajanense*. As far as is known, var. *glabrescens* has never been observed near the stations of var. *kajanense*. In fact, the distribution of the different *Cerastium vulgatum* races in Scandinavia has not been studied to any particular extent. However, var. *glabrescens* seems to be a spontaneous coastal plant distributed, inter alia, along the coasts of the Baltic and, probably, also of the Bothnian Sea. It has already been mentioned that var. *kajanense* was found only in areas at a low altitudinal level (below 500 m). In addition, all its areas occur very close to great lakes and lake systems: the lake system of Ströms Vattudal at Gäddede (cf. p. 13); the lake system of Umeälven river at Rönnbäck (cf. Fig. 22); and the lake Uleträsk at Paltamo in Finland. These lake systems were all in much closer contact with the pre-Bothnian Seas of early postglacial times than with the Bothnian Sea of our days. Accordingly, during these epochs the serpentine areas concerned here might have been within easy reach of var. *glabrescens* — provided this was also a shore plant of the preliminary stages of the Baltic and the Bothnian Sea. Apparently, var. *kajanense* developed from the var. *glabrescens* complex independently within its three Fennoscandian centres. Specimens from the different centres also show slight differences in pilosity and in the shape of the leaves.

Another serpentinicolous variety of *Cerastium vulgatum* — var. *serpentini* (NOVÁK) GARTNER — was found in Central Finland and Bohemia. This type differs considerably from var. *kajanense* and seems to derive from other types of the species complex.

Minuartia biflora (L.) Sch. & Th.

Serpentine: Very abundant in alpine and subalpine areas (Nos. 11–18, 20–26, 32, 35–37, 39, 40); sparse or lacking at altitudes below about 500 m. Usually growing in crevices and on bare soil patches, but sometimes also in closed communities (cf. p. 37).

Specimens from serpentine are usually rather small, densely tufted, and with strongly developed root systems. Whether or not this type is genotypical cannot as yet be decided owing to the failure to cultivate this plant. From Sunmöre, *M. biflora* is mentioned by Björlykke only from a few areas. In N Finland, *Minuartia biflora* occurs very disjunctively in several serpentine areas far from alpine districts, thus appearing there as a serpentinicolous relic.

Outside serpentine: Frequent within the alpine region. Most abundant on calcareous rock, though not limited to this kind of rock.

Arenaria humifusa Wg.

Not found in N Swedish serpentine areas but occurs rather abundantly within the Norwegian serpentine areas, south and southwest of Lake Krutvattnet, which lie very close to the Swedish areas Nos. 35 and 36 (see p. 84).

Arenaria norvegica Gunn.

Serpentine: Very abundant in several low-alpine and subalpine areas (Nos. 12–15, 20, 24–26, 35, 36). In Jämtland abundant also in some areas of the conifer forest region (Nos. 2, 3, 9, 10). Very typical of unstable serpentine ground (cf. p. 47). Abundant on serpentine also in the Shetland Islands (Edmondston 1845).

Outside serpentine: Occasionally on unstable calcareous ground. Map in Fig. 48.

Viscaria alpina (L.) G. Don.

This plant is very abundant in serpentine areas of widely different altitudes (Nos. 1–9, 11–17, 20–31, 35–41). In some of these areas it is represented by a particular variety (see below). It appears in abundance in different types of habitats, e.g., dry or wet crevices, bare soil patches and closed heath-communities. Within alpine districts the plant is also rather common outside serpentine, even though it does not appear there in the same abundance as in serpentine. *Viscaria alpina* seems also to be connected with heavy metals in the soil (cf. p. 105).

In the district of Sunmöre, *Viscaria alpina* is very abundant within the serpentine areas, though it is almost absent on other kinds of rock (Björlykke op. cit.). In Finland this plant is also very typical of serpentine.

Viscaria alpina var. *serpentinicola* nova var.

Differt a formis ceteris speciei foliis angustioribus (rosalibus 0.1 cm latis, caulinis 0.2 cm latis et 2–4 cm longis), caule stricte erecto 5–15 cm alto et inflorescentia plus elongata et ramosa (parte inferiore ramis floriferis in axillis foliorum superiorum caulinorum ortis composita). — Petala 0 vel minuta (staminibus breviora); planta manifeste pollacantha.

Habitat in serpentino regionis coniferinae Scandinaviae borealis.

Coll. orig.: Suecia, Lapponia lulensis: Purnu, in saxis serpentini montis Lingonberget, leg. O. Rune 5. VII. 1949 (typus in Mus. Bot., Uppsala).

var. *serpentinicola* is characterized by its narrow leaves; its more or less reduced petals; its slender but very stiff, erect stem; the peculiar branching pattern of the raceme, usually highly branched and elongated owing to pedicels appearing from the bases of stem leaves far below the very tip; its ecological peculiarity and clearly pollacanthic character.

As regards the reduction of the petals there is a clinal variation from the absolutely apetalous type of area No. 28 to the nearly "normal-flowered" one of area No. 41. The various populations also differ in that respect; thus apetalous specimens were occasionally found in most populations (see below). When occurring, the petals are narrow and generally shorter than the stamina. The tendency of the raceme to increase in length owing to pedicels issuing from parts of the stem below the tip is especially pronounced in the case of luxuriant growth, e.g., by cultivation in normal soil (cf. Fig. 38).

All the characteristics have proved to persist

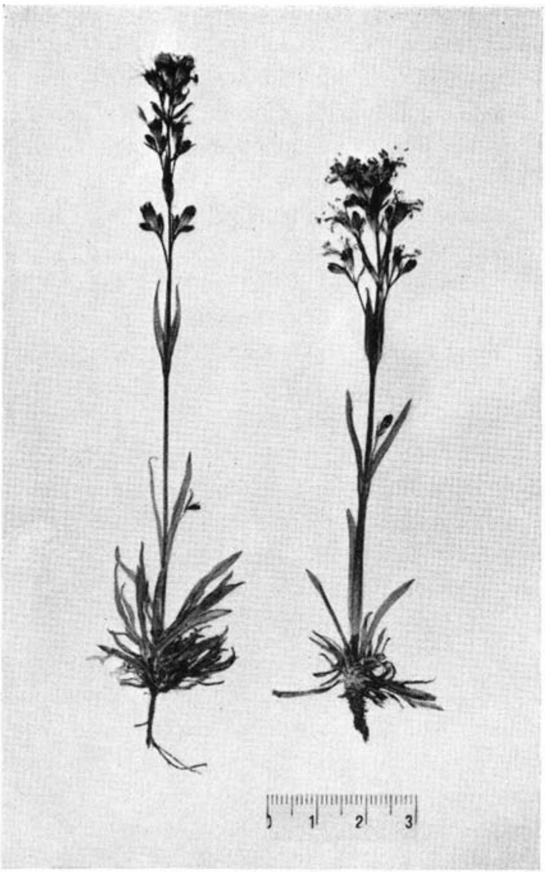


Fig. 35. Specimens from the holotype of *Viscaria alpina* var. *serpentinicola*. Serpentine area at Lingonberget, Parish of Gällivare. Photo Sven Eriksson 1952.

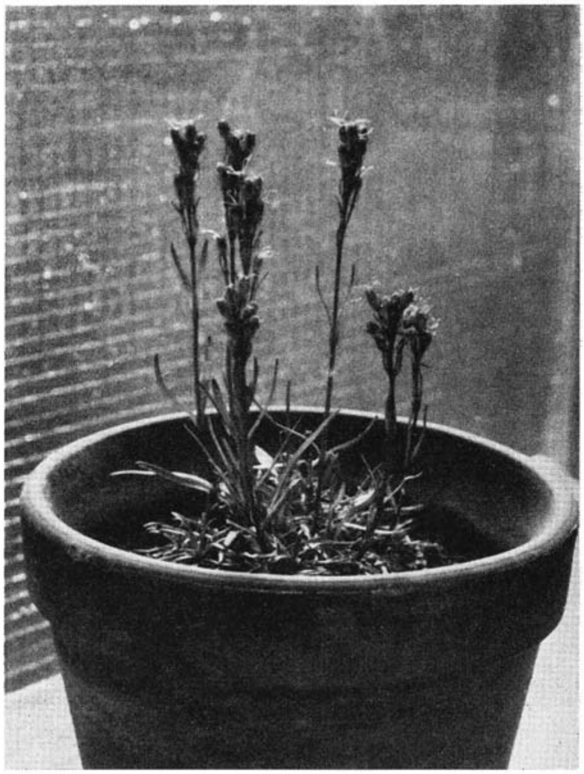


Fig. 36. Apetalous *Viscaria alpina* var. *serpentinicola* from Rönnbäck (area No. 28) cultivated in serpentine soil in Uppsala. Diameter of pot 10 cm.
Photo Olof Rune 25.5.1950.

under cultivation in normal soil in the Botanical Garden of Uppsala University for several generations. However, cultivation in normal soil seems to cause a more luxuriant growth — as regards descendants from the Rönnbäck areas the stem and the leaves increased in length by approx. 100 %. The stem leaves showed a corresponding increase also in breadth, while the basal leaves remained nearly constant in that respect — hence even more angustifoliate (Fig. 38).

In fact, *Viscaria alpina* is represented in Fennoscandia by several races (TURESSON 1927) which have never been closely studied. The main race of *Viscaria alpina* is essentially an alpine plant, rather abundant in the alpine and arctic parts of Fennoscandia. However, outside the northern area *Viscaria alpina* also appears sparsely in some isolated lowland areas of South and Middle Sweden, South Finland, etc. (cf. LID & ZACHAU 1929, HULTÉN 1950). Within its isolated lowland-stations *Viscaria alpina* is probably represented by races differing genotypically from each other and from the alpine race (cf. TURESSON op. cit.). Yet it is hard to find any clearly morphological differences between them.

Actually, var. *serpentinicola* differs clearly from the alpine race of *Viscaria alpina* by all the characteristics mentioned above. Thus, the latter always lacks the gracile shape of var. *serpentinicola* — its leaves are generally twice as broad as in this variety and its stem is also thicker. The flowers occur in a dense, head-like raceme; the petals are well developed and are always longer than the stamina. Moreover, the alpine race of *Viscaria alpina* does not seem to be as clearly pollacanthic as the variety, instead it is mainly hapaxanthic.

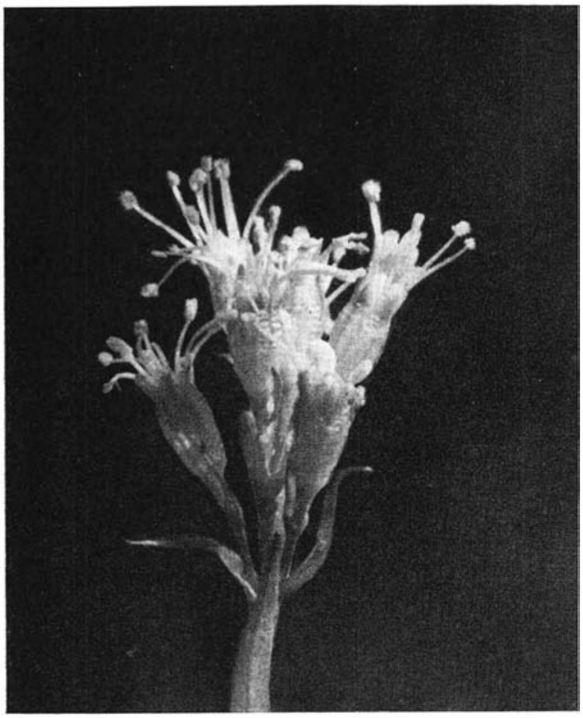


Fig. 37. Close-up of flowers from apetalous *Viscaria alpina* var. *serpentinicola* pictured in Fig. 36, enlarged approx. 10 ×. Photo Axel Nygren 1950.

Among the S Fennoscandian populations of *Viscaria alpina*, one described as var. *oelandica* (AHLQ.) STERNER is endemic of the calcareous steppe of the Isle of Öland. Although this plant is also a dwarfish pollacanthic plant, adapted to edaphical conditions comparatively similar to those on serpentine, it usually lacks the slender shape of var. *serpentinicola* and seems to have nothing to do with this type at all.

Among some other populations of southern and middle Sweden, viz., in the provinces of Blekinge and in Bergslagen, angustifoliate individuals may appear which are reminiscent of var. *serpentinicola* in that respect. However, they concern plants from extremely dry localities constituting extreme fenotypes. For example, on the ore heaps at the Stollberg mines in Bergslagen (cf. p. 105) a local-population of *Viscaria alpina* appears confusingly like var. *serpentinicola*. However, *Viscaria alpina* has also spread from this locality to secondary ones on roadsides of the close vicinity. In such localities the individuals are much taller and less angustifoliate than in the original locality. Seeds from the ore-heap plants were grown in normal soil in the Bot. Garden of Uppsala Univ. and they developed into plants similar to those from the roadsides. This type clearly differs from cultivated specimens of var. *serpentinicola* — mainly because it lacks the highly branched and elongated racemes typical of the latter (cf. Fig. 38).

Thus, var. *serpentinicola* differs from the S Fennoscandian races of *Viscaria alpina* by its tendency to reduced petals, by a genotypical stenophyllism pertinent to the entire populations and, above all, by a tendency to elongated and highly branched racemes that appears very clearly in culture. Yet, var. *serpentinicola* can be distinguished with certainty from certain lowland specimens of *Viscaria alpina* only after cultivation.

var. *serpentinicola* is found within six different serpentine areas in N Sweden, all situated in the conifer forest region (below 500 m). The variety is generally very abundant within its localities, and was never found there together with the main form. On the other hand, the latter may be abundant elsewhere on serpentine. Still, the main form seldom occurs in such great abundance as does the variety in, e.g., the areas Nos. 28, 29, 30, 41.

Each population of var. *serpentinicola* is fairly uniform in itself, while the separate populations differ from one another. The population of the isolated serpentine area at Lingonberget in the parish of Gällivare (area No. 41) has been chosen as the type of var. *serpentinicola*. This population is very uniform, but neither in regard to stenophyllism nor in the reduction of the petals does it show the same extreme characteristics as, e.g., the Rönnbäck populations (see below). However, as regards the size and other characteristics of the plants, the type population agrees with the majority of the populations referred to as var. *serpentinicola*. The type population is clearly angustifoliate. The flowers are not apetalous but have slightly developed petals. Above all, its members are characterized by their very extended and highly branched racemes and a stiff, erect stem.

The serpentine areas of the Rönnbäck district harbour by far the most abundant occurrences of this variety ever noticed. In one of these areas, No.

28, all the individuals are totally apetalous and very angustifoliate. In the other areas of this district, viz., Nos. 29, 30, 31, this plant is also very angustifoliate, though not apetalous. Apetalous flowers may be noticed, but as a rule they have some thin, narrow petals which are, however, shorter than the stamina. However, in all the areas of this district the individuals are smaller (approx. 10 cm heigh) and have more rich-flowering and dense racemes than is typical of var. *serpentinicola.*

var. *serpentinicola* was found also within some adjacent serpentine areas in the neighbourhood of Gäddede in Frostviken, N Jämtland: 1) Mt Övervattsberget, area No. 7, where this variety grows in abundance within a limited area (cf. p. 14). This locality is rather shady and some specimens which grew in extremely shady places behind boulders, etc., are rather tall (17 cm). In this locality the specimens are all angustifoliate. Some of them are apetalous; the bulk, however, seems to have small petals. 2) Mt Junsterklumpen, area No. 8, where var. *serpentinicola* occurs within some limited patches on the top plateau. This population is angustifoliate and some apetalous specimens appear within it. Yet, this population differs from the others by having rather few flowers in the racemes. 3) Lermon Summit, area No. 9, which is adjacent to Mt Junsterklumpen. A few specimens of the same type as on Mt Junsterklumpen were observed on each of the two summits included in this area (cf. p. 14).

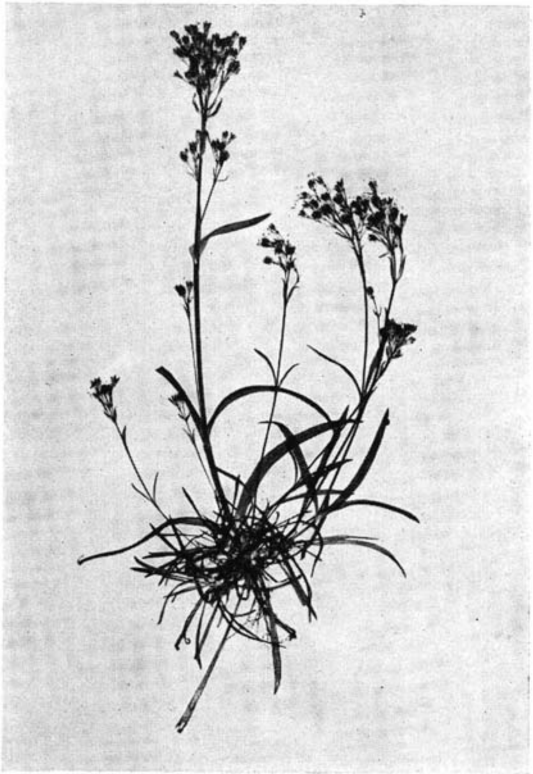


Fig. 38. Apetalous *Viscaria alpina* var. *serpentinicola* from Rönnbäck (area No. 28). This specimen was grown in normal soil in Uppsala from seed of original locality. Normal soil brings about a considerable increase in size and a richer flowering (cf. Fig. 36). Note peculiar branching pattern of raceme appearing very clearly at luxuriant growth. Photo Sven Eriksson 1952.

The material of *Viscaria alpina* collected within the serpentine area No. 22 — at the bottom of the Kittelfjäll valley — seems to belong to var. *serpentinicola.* This type is very angustifoliate but has larger petals than the other populations of this variety. As the serpentine areas of the Kittelfjäll district were visited at the beginning of my serpentine studies when I was unaware of the peculiar serpentine variety of *Viscaria alpina,* further information about its occurrence in this locality cannot be given. In any case, it is by no means so strikingly abundant there as in most of its other localities.

Björlykke (op. cit.) called attention to an angustifoliate form of *Viscaria alpina* from the serpentine area of Almklovdalen, Sunmöre. This plant, pictured in Björlykke's paper (op. cit. p. 115), seems to agree quite well with var. *serpentinicola.* As its characteristics proved also to be retained after cultivation in normal soil, it is no doubt identical with var. *serpentinicola.* In addition, *Viscaria alpina* forms which may rightly be considered as var. *serpentinicola* have been found in two Norwegian serpentine areas adjacent to S Lappland. Thus, I observed an abundant occurrence of *Viscaria alpina* covering an area of some ten square metres on the crest of the serpentine knob which crops out due east of the settlement Gruben near Krutå in Hattfjelldal. Although less pronounced, this local-population shows all the characteristics of var. *serpentinicola* and reference to this variety seems quite justifiable.

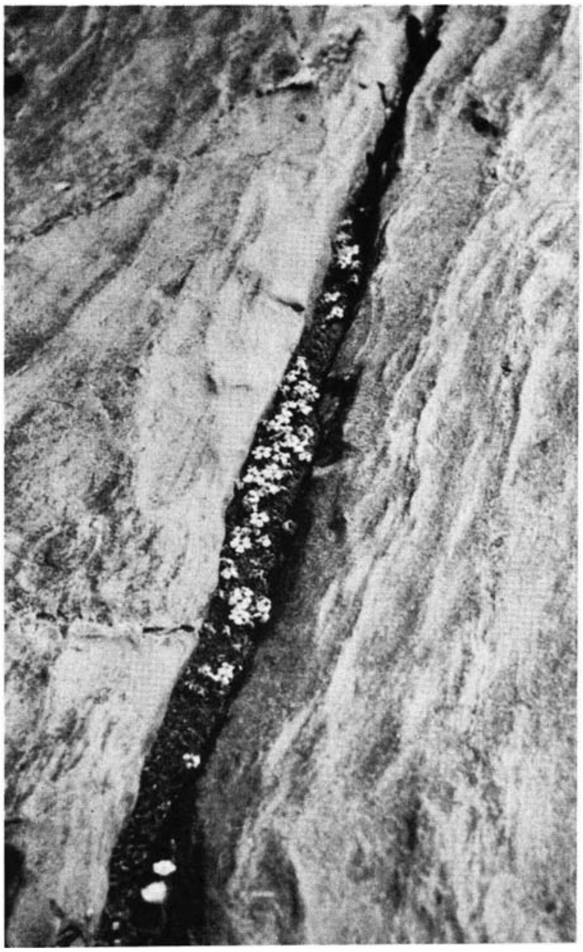


Fig. 39. *Silene acaulis* in a deep serpentine rock crevice. This plant is very characteristic of alpine and subalpine serpentine areas, growing usually on scree. Requires rather deep soil. Picture from serpentine of Fig. 8.
Photo Olof Rune 29.6.1947.

Within the wide serpentine area of the Isle of Rödön in Tjötta *Viscaria alpina* is rather frequent, though never abundant. Most specimens collected by me in this area agree very well with var. *serpentinicola*. These plants are usually tall, about 15 cm, angustifoliate, and with an elongated, highly branched raceme on the stiff stem. Since all plants had passed flowering at the time of my visit, I was unable to establish to what extent they are apetalous. Within this area also the alpine main form of *Viscaria alpina* was noticed — though never mixed with the variety. However, more or less intermediate types may appear in both populations.

In Middle Finland, Ostrobottnia Kajanensis, I collected a few specimens of *Viscaria alpina* within two different serpentine areas (see below). These plants are quite tall, approx. 20 cm high and extremely angustifoliate. Unfortunately, all plants had passed flowering at my visit and were, moreover, rather damaged by grazing. Thus, as far as can be decided from this meagre material, var. *serpentinicola* seems to occur also in Finland.

Viscaria alpina var. *serpentinicola* is found in the following localities in Fennoscandia:

Norway: Sumnöre, Almklovdalen (BJÖRLYKKE op. cit. p. 60, 115); Hattfjelldal, Gruben near Krutå, serpentine outcrop at about 400 m alt. 20/7 1950, leg. O. RUNE.

Tjötta, Rödön Trolandet, on serpentine rocks, 50–100 m alt. 18/7 1950, leg. O. RUNE.

Sweden: Jämtland, Frostviken par., Gäddede, 1) Övervattsberget, E precipice, 28/8 1949, leg. O. RUNE, 2) Junsterklumpen 23/8 1949, leg. O. RUNE, 3) Soapstone outcrop p. 440 28/8 1949, leg. O. RUNE. Lappland: Åsele Lpm., Vilhelmina par., Kittelfjäll 3/7 1946, leg. O. RUNE. Lycksele Lpm., Tärna par., Rönnbäck, 1) Serpentine hill south of Lake Rönnbäckssjön 22/8 1947, 19/8 1949, leg. O. RUNE, 2) Mt Brandbergen 3/7 1948, leg. O. RUNE. Within the Rönnbäck district, *Viscaria alpina* var. *serpentinicola* was noticed — though not collected — in some other adjacent areas (cf. p. 35). Lule Lpm., Gällivare par., Purnu, serpentine rocks at Lingonberget 5/7 1949, leg. O. RUNE. Type locality.

Finland: Ostrobottnia Kajanensis, Paltamo par., 1) Serpentine outcrop north of Lehmelampi 25/7 1948, leg. O. RUNE, 2) Serpentine outcrop at Jormua, 25/7 1948, leg. O. RUNE.

Herbarium material from the localities mentioned above in the Botanical Museum of Uppsala University.

Silene acaulis JACQ.

SERPENTINE: Very abundant in alpine and subalpine areas (Nos. 3, 11–17, 20–25, 36, 39, 40). Found in crevices or as large carpets on the weathered serpentine soil (Pl. VIII, Fig. 39). Prefers deep soil but, in other respects, its ecological amplitude is very wide. Thus, it may occur in dry or wet habitats, on hillock-tops as well as near snowbeds.

In the serpentine areas of Sunmöre, *Silene acaulis* seems quite abundant, but BJÖRLYKKE did not characterize it as serpentinicolous. VOGT (1942 b) pointed out its great abundance within the serpen-

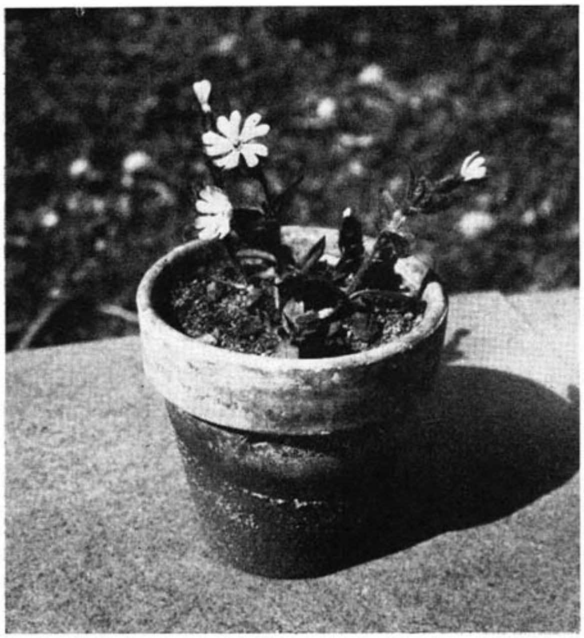


Fig. 40. Dwarf *Melandrium rubrum* from alpine serpentine area at Rupsentjårro (area No. 17). This plant is grown in normal soil in Uppsala from seed of original locality. Diameter of pot 10 cm. Photo Olof Rune 25.5.1950.

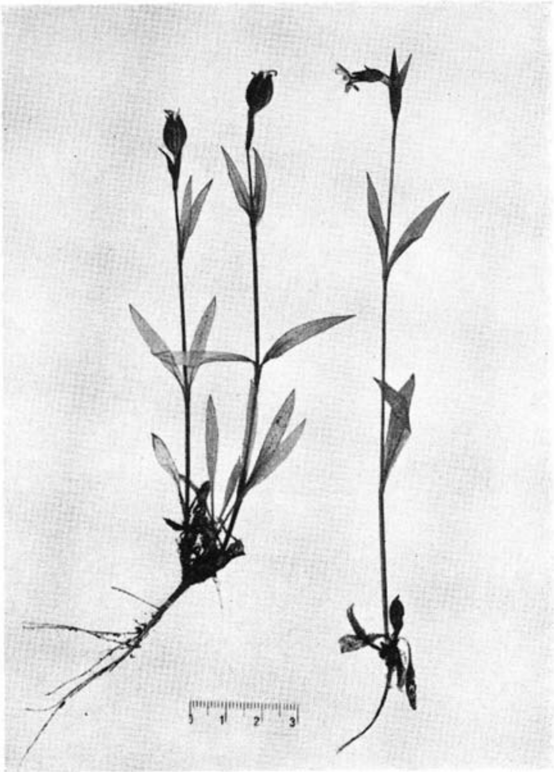


Fig. 41. Specimens from the holotype of *Melandrium rubrum* var. *serpentinicola*. Brandbergen, Rönnbäck, Parish of Tärna (left ♀, right ♂). Photo Sven Eriksson 1952.

tine areas of Röros. In N Finland, *Silene acaulis* appears, like *Minuartia biflora*, very disjunctively in lowland serpentine areas far away from alpine districts, and it may be considered a serpentinicolous relic in these areas.

OUTSIDE SERPENTINE: Abundant on calcareous rocks within the alpine and subalpine regions of Scandinavia.

Melandrium rubrum (WEIG.) GARCKE.

SERPENTINE: Very abundant in several serpentine areas mainly below the alpine region (Nos. 1, 2, 5, 6, 8, 10–14, 17, 27–31, 37). In some of these areas it is represented by particular varieties (see below). Among the rich populations that generally appear on serpentine, large variations can be observed. Thus, glabrous or white-flowered specimens are not uncommon and angustifoliate races are very typical of some areas (cf. below).

BJÖRLYKKE (op. cit.) noticed *Melandrium rubrum* in most areas at Sunmöre, but he did not consider it as serpentinicolous. According to VOGT (1942 b), *M. rubrum* is very abundant in the serpentine areas of Röros. Like *Viscaria alpina*, *Melandrium rubrum* seems to be connected with heavy metals in the soil (cf. p. 105).

Though not usually an alpine plant, *Melandrium rubrum* may yet appear in abundance also in exposed situations in alpine serpentine areas (900–1000 m, e.g., in areas No. 17 and 37). In that case, however, it concerns dwarf specimens of *Melandrium rubrum*, mainly 10–15 cm high (the smallest ones only 5–7 cm high). The root system of these dwarf specimens is usually longer than the stem. The flowers are of normal size, 1.5–2 cm, rendering these dwarfs very large-flowered. Seeds of these dwarfs, grown in normal soil in the Botanical Garden of Uppsala University, produced plants of the same small size. The serpentine-dwarfs of *Melandrium rubrum* therefore seem to be a distinct alpine serpentine-ecotype (Fig. 40). Still, dwarf-types of *M. rubrum* are occasionally found in the low-alpine region even outside serpentine, though

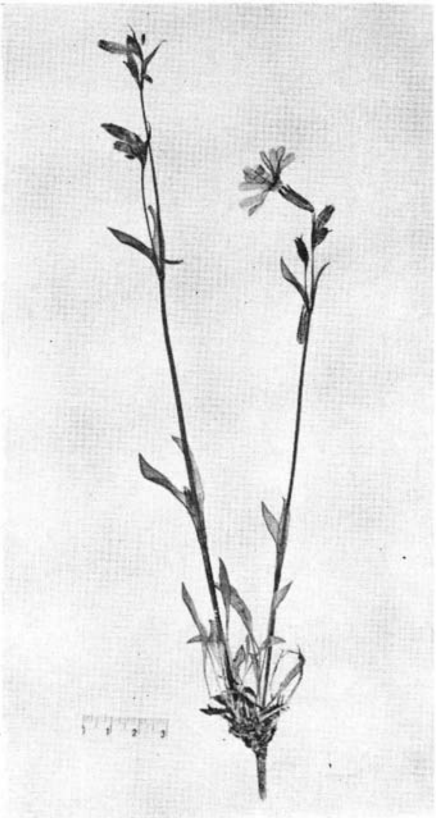


Fig. 42. Specimen (♂) from the holotype of *Melandrium rubrum* var. *smithii*. Täljstensberget, Handöl, Parish of Undersåker. Photo Sven Eriksson 1952.

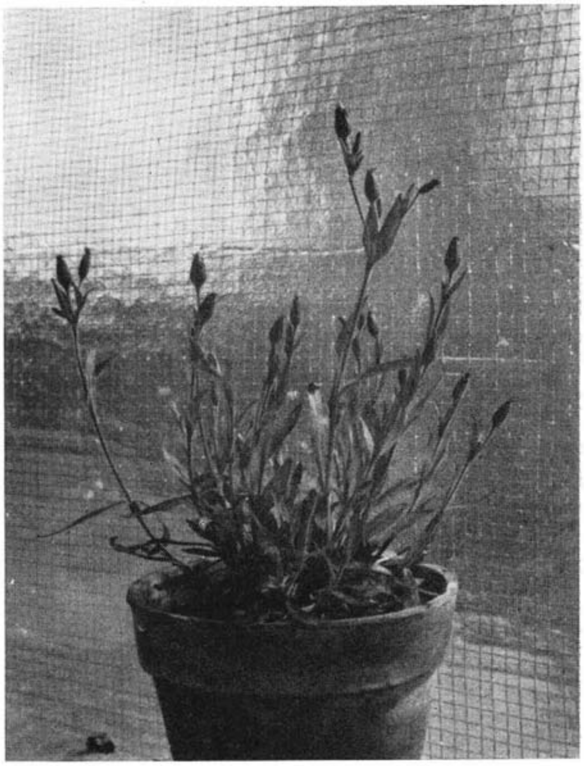


Fig. 43. *Melandrium rubrum* var. *serpentinicola* from type locality at Rönnbäck, grown in normal soil in Uppsala from seed of original locality. This is a female plant in early postfloral stage. Flower with small petals (similar to Figs. 44, 45) and swollen calyx. Diameter of pot 10 cm. Photo Olof Rune 25.5.1950.

never as abundantly as in the serpentine. Thus, NORMAN (1895) once described a dwarf race of *M. rubrum* from N Norway, viz., var. *subacaule*, which is only 10 cm high. Because of lack of sufficient material of alpine, non-serpentine dwarfs, I have so far not been able to compare the serpentine and non-serpentine alpine dwarf-races of this species.

Melandrium rubrum var. *serpentinicola* nova var.

Differt a formis ceteris speciei caule stricto erecto (12 –) 15 – 20 (– 25) cm alto et foliis angustioribus, (0.3 –) 0.5 – 1.0 (– 1.2) cm latis, (plerumque anguste) lanceolatis vel caulinis inferioribus et rosalibus ± anguste spathulato-lanceolatis, basin versus valde angustatis (rosalibus ± longe petiolatis), apicem versus valde elongatis. — Planta perennis (pollacantha), brevissime mollivillosa, radice valde elongata (saepe parti epigaeae plantae aequilonga), saepe multicaulis. Flores pauci, calyce in statu florendi parum inflato, in postfloratione sat manifeste inflato, 1.2–1.5 cm longo, petalis parvis, 2.0–2.5 cm longis.

Habitat in serpentino c. 400 m s.m. in Lapponia Sueciae.

Coll. orig.: Suecia, Lapponia åselensis, par. Tärna: in parte australi montium Brandbergen prope Rönnbäck, leg. O. RUNE 7. VII. 1950 (typus in Mus. Bot., Uppsala).

Melandrium rubrum var. *smithii*[1] nova var.

Differt a var. *serpentinicola* foliis paullo crassioribus sed angustioribus et basin ut apicem versus abruptius angustatis, anguste lanceolatis vel fere lineari-lanceolatis (in speciminibus macris ± linearibus), (0.3 –) 0.4 – 0.7 (– 0.9) cm latis. Flores numerosiores, petalis 2.5–3 cm longis, angustis et profunde bifidis. Calyx etiam in speciminibus femineis vix manifeste inflatus, 1.2–1.5 cm longus, dentibus sat elongatis. Planta

[1] Named after Dr Harry Smith, Uppsala, who first paid attention to this plant.

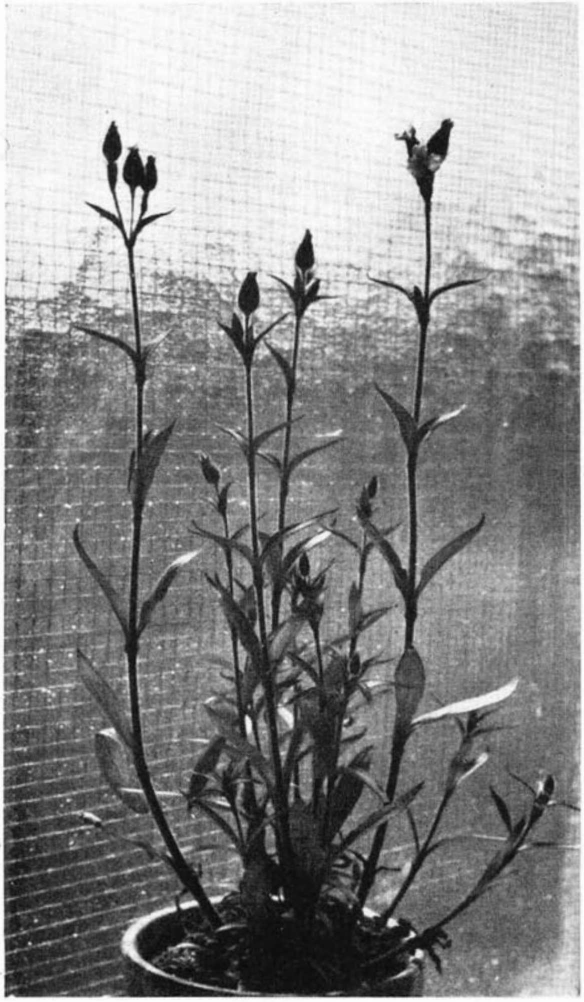


Fig. 44. *Melandrium rubrum* ad var. *serpentinicola* from Muruhatten near Gäddede (area No. 5) grown in normal soil in Uppsala from seed of original locality. This is a female plant with small petals (see flowers on right stem) and swollen calyx. Whole plant pilose and with dark purplish stems. Shape of leaves not typical of var. *serpentinicola*. Diameter of pot 10 cm. Photo Olof Rune 25.5.1950.

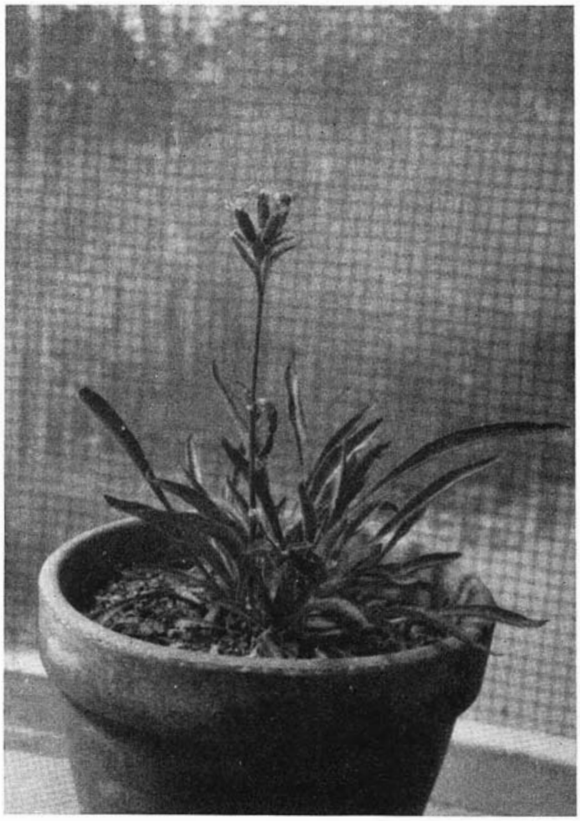


Fig. 45. *Melandrium rubrum* ad var. *serpentinicola* from N Digerhösen near Gäddede (area No. 10) grown in serpentine soil in Uppsala from small plant collected in original locality. This is a male plant with small petals and extremely narrow leaves. Whole plant pilose. Diameter of pot 10 cm. Photo Olof Rune 25.5.1950.

tota glaberrima, caule et foliis caulinis saepe purpurascente.

Habitat in serpentino c. 550 m s.m. in prov. Jemtlandia Sueciae.

Coll. orig.: Suecia, Jemtlandia, par. Undersåker: in declivi septentrionali-orientali montis Täljstensberget prope Handöl, leg. O. Rune 1. VII. 1950 (typus in Mus. Bot., Uppsala).

Melandrium rubrum var. *serpentinicola* and var. *smithii* are closely related to the common subalpine race of *M. rubrum* (var. *lapponicum* Simmons). They differ from this, above all, by their slender but always stiff, erect stems and narrow leaves. As is clear from Fig. 46 the stem leaves, as well as the basal leaves, are less than 1 cm in breadth. The root system is usually strongly developed; the central root may reach a length similar to (or even longer than) that of the stem. Both varieties are pollacanthic plants with a bunch of stems often proceeding from the central root (Figs. 43–45, 47).

All these characteristics persisted at cultivation in normal soil for several generations. However, their growth in normal soil seemed to be more vigorous — the plants increased in size by approx. 30 %. Even the strongly developed root system persisted during the cultivation. Thus, a pot, 10 cm deep,

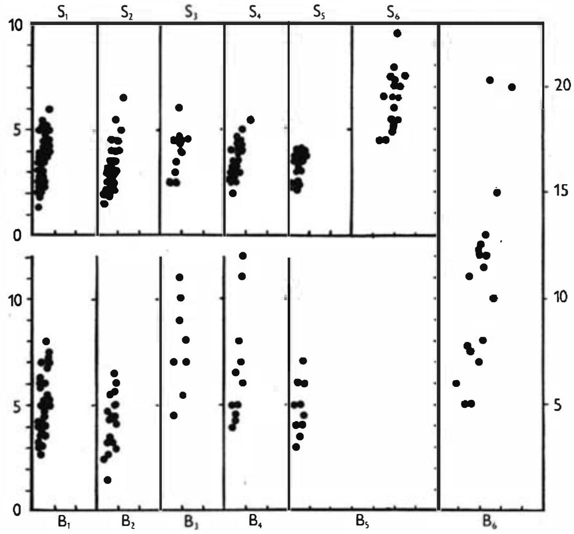


Fig. 46. Diagram showing length and breadth of leaves of serpentinicolous races of *Melandrium rubrum*. Vertical length, horizontal breadth. Length unit 1 cm. Upper row: stem leaves (middle pairs) S_1–S_6. Lower row: basal leaves (average value of each specimen) B_1-B_6.

The following populations are represented in the diagram:

1. (S_1B_1) *Melandrium rubrum* var. *smithii*, Täljstensberget (No. 1)
2. (S_2B_2) " " ad var. *serpentinicola*, Värgaren (No. 14)
3. (S_3B_3) " " var. " , Rönnbäck (No. 28)
4. (S_4B_4) " " " " " (No. 29)
5. (S_5B_5) " " " " " (No. 30)
6. (S_6B_6) " " " *lapponica*, non-serpentine population from subalpine meadow of Laxfjället, Tärnaby, Lappland, included for comparison.

Number of specimens measured in each population varies from about 10 to 30, depending on their abundance. Because of a lack of measurable basal leaves in some specimens, stem and basal leaves may be unequal in number.

was quite filled up by the root system of a single plant; the central root even grew out of the bottom hole and continued some 10 cm down into the sand layer.

Ecologically, var. *serpentinicola* agrees completely with var. *smithii*, both being confined to barren serpentine rocks and scree of low altitudes (below 600 m). Both varieties occur very abundantly in their localities.

Morphologically, var. *serpentinicola* and var. *smithii* differ in the following respects:

1) var. *serpentinicola* shows the same degree of pilosity as does the common subalpine race of the species (var. *lapponicum*), while var. *smithii* is totally glabrous. As a rule, the stems and leaves are purplish in the latter.

2) var. *serpentinicola* has only a few flowers on rather long pedicels (see Figs.), while var. *smithii* is rather rich-flowering, having several flowers in a dense raceme. This difference is striking at cultivation (cf. Figs. 43, 44, and 47).

The petals of var. *serpentinicola* are relatively similar to, or smaller than, those of the main form and they also conform in shape. The calyx of var. *serpentinicola* is always somewhat swollen or bladdery in the flowers of either sex (cf. Figs. 41, 43, 44).

The petals of var. *smithii* are relatively longer, narrower, and more deeply split than in other biotypes of the species. The calyx of var. *smithii* is long and narrow, rarely somewhat swollen in female specimens (Fig. 47).

3) Considering the whole populations, var. *smithii* is more markedly angustifoliate than var. *serpentinicola* (cf. Fig. 46). A difference in shape is also discernible, the leaves of the former being thicker and more linear than those of the latter which are narrowly lanceolate.

Apparently, these varieties are also distinguished from other types of *Melandrium rubrum* by the above-mentioned characteristics.

It is only natural that such a variable species as *Melandrium rubrum* will be found to have produced morphologically different serpentinicolous ecotypes in different stations. Thus, typical representatives of these varieties are to be seen only in their type localities.

The description of var. *serpentinicola* refers to the populations of the Rönnbäck district, which occur abundantly within three adjacent areas (Nos. 28, 29, 30). As emerges from Fig. 46 the population of No. 30 (type locality) is more angustifoliate than the others of the district. The plants of this locality are even smaller in size. These differences are probably due to local modifications, the type locality (No. 30) being situated on south-exposed scree which is dry and warm, while the others, on shelves etc., occur in partly shaded situations. In other respects, the three populations of this district conform well.

In Frostviken, Jämtland, different serpentinicolous local-populations of *Melandrium rubrum* occur within three different areas, viz., Nos. 5, 10, 14. Though not identical with var. *serpentinicola* they are rather similar to it and will be referred to as *ad var. serpentinicola.*

var. *smithii* is found in one single locality, viz., Täljstensberget at Handöl, where it grows in abundance. The population is rather uniform. Still, pilose individuals have been detected. As they are intermediate also with regard to other characteristics they may be considered as "hybrids". This peculiar plant has been observed and collected by several botanists and is also mentioned in the literature (HYLANDER 1947).

Melandrium rubrum var. *serpentinicola* and closely related forms have been established from the following localities:

Lappland, Åsele Lappmark, Tärna par., Rönnbäck: 1) Brandbergen, southern part 7/7 1949, leg. O. RUNE, 2) Serpentine area of the Rönnbäck Peninsula 7/7 1949, leg. O. RUNE, 3) Serpentine area south of Rönnbäckssjön 6/7 1949, leg. O. RUNE.

ad. var. *serpentinicola:* Jämtland, Frostviken par., 1) Muruhatten 3/7 1947, leg. O. RUNE, 2) Norra Digerhösen, not collected, 3) Serpentine area south of Värgaren settlement 6/7 1950, leg. O. RUNE.

Fig. 47. *Melandrium rubrum* var. *smithii* from Täljstensberget, Handöl, grown in normal soil in Uppsala from seed of original locality. This is a male plant, approx. 30 cm high and totally glabrous. Note rich flowering with flowers in dense head-like racemes, flowers with long, narrow petals. Photo Olof Rune 10.6.1951.

Melandrium rubrum var *smithii* has been established from the following locality:

Jämtland, Undersåker par., Handöl: Täljstensberget, noth-east slope, 11/7 1946 leg. J. A. NANNFELDT, and 1/7 1950 leg. O. RUNE.

Herbarium material from all the above localities in the Botanical Museum of Uppsala University.

b. Bryophytes, Lichens, and Algae.

Among the lower cryptogams—bryophytes, lichens and algae—a similar poorness in species prevails on serpentine as among the vascular plants. However, certain species were invariably found in abundance in almost every serpentine area, such as the mosses *Rhacomitrium lanuginosum, Drepanocladus uncinatus, Campylium stellatum, Tritomaria quinquedentata,* and the alga *Trentepohlia jolithus.* These are all common and widespread in the mountain district of N Sweden also on rocks of a different lithological origin. However, they occur so frequently and abundantly on serpentine as to justify, apparently, their being considered as serpentinicolous.

The lichen *Caloplaca elegans* is also very common on serpentine, especially on dry south-exposed bluffs, where the rock faces are sometimes red in colour from this lichen. However, such abundant occurrences of this lichen are not restricted to serpentine only but characteristic of all basic rocks.

According to KOTILAINEN (verbal information) the moss *Weisia viridula* is highly characteristic of the serpentine areas in Finland. It has so far been found in one single Swedish serpentine area, viz., Lillfjället near Gäddede, by KOTILAINEN. As I am no specialist in bryology, it is quite possible that this moss may have been overlooked by me in other serpentine areas of N Sweden. Even so, it is quite clear that in N Swedish serpentine areas *Weisa viridula* must be by far less frequent than the serpentinicolous mosses mentioned above. In contrast with E Fennoscandia, it is not particularly serpentinicolous in Sweden. Also the specific serpentine type of *Brachythecium velutinum* mentioned by KOTILAINEN (1944) as typical of some serpentine areas of Middle Finland has been searched for in vain on the serpentines of N Sweden. Thus, the only serpentinicoles of N Sweden among the lower cryptogams seem to be the following species:

Bryophytes.

(nomenclature according to JENSEN 1939).

Tritomaria quinquedenta (HUDS.) BUCH.

Abundant in moist and shady crevices of the serpentine rocks. Lacking only in extremely dry areas.

Rhacomitrium lanuginosum HEDW.

Extremely abundant in most of the western alpine and subalpine areas, forming carpets on rocks and weathered soil; more sparse in the low-altitude areas of the eastern mountain districts. Abundant on serpentine also in E Canada and in the Austrian Alps (LÄMMERMAYER 1926 p. 385).

Drepanocladus uncinatus (HEDW.) Warnst.

Abundant in crevices and on moist boulders in areas of different altitudes.

Campylium stellatum (SCHREB.) BRYHN.

A particular type of this variable species is very abundant in crevices and on wet serpentine soil in most serpentine areas (cf. p. 46). This type of *Campylium stellatum* has been observed by KOTILAINEN (1944) to be strongly characteristic of serpentine in Finland.

Algae.

Trentepohlia jolithus (L.) WALLR.

Abundant on serpentine boulders and rock walls in moist or shady places, notably, near snowbeds. According to KNABEN (1952), abundant on serpentine in Sogn, W Norway. Abundant also in the Alps on serpentine, magnesite, and dolomite (LÄMMERMAYER 1928 a, BRAUN-BLANQUET 1951 p. 236).

B. Serpentine-indifferent plants.

a. Vascular Plants.

Lycopodium selago L.

SERPENTINE: Occasional in some alpine areas (Nos. 12, 21, 32, 39, 40). In N Finland found also in lowland serpentine areas (cf. MIKKOLA 1938). According to BJÖRLYKKE, abundant in the serpentine areas of Sunmöre; occurring also in serpentine areas of Central Europe (cf. BJÖRLYKKE op. cit. p. 118). Probably more connected with serpentine outside Sweden.

OUTSIDE SERPENTINE: Rather frequent in the alpine region on soils of a different lithological origin.

Juniperus communis L. var. ***montana*** AIT.

SERPENTINE: Abundant in areas of low altitudes (below 700 m); occasional at higher altitudes, hardly reaching above 900 (Nos. 1–3, 6, 12, 14, 15, 18, 19, 22–31).

OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.–reg. conif.

Pinus silvestris L.

SERPENTINE: Areas of low altitudes (below c. 600 m) are usually covered with sparse pine forests. Pines are the only trees to form forests in the serpentine areas of N Sweden. Yet even the pine grows slowly in serpentine soil. The trunks of the trees are often stunted or broken. A large number of subfossil trunks have been noticed in areas without pine forest today (No. 28). In the serpentine areas of Sunmöre and in Middle Europe, *Pinus silvestris* is the only tree to form forests (BJÖRLYKKE op. cit., LÄMMERMAYER 1926, 1928 a, KRETSCHMER 1931). Pine is found in areas Nos. 1, 2, 4, 6–8, 22, 28–31, 41.

OUTSIDE SERPENTINE: Abundant, though unequally distributed in the mountain districts; indifferent. Reg. conif.

Anthoxanthum odoratum L. (mainly ***A. alpinum*** Löve & Löve).

Serpentine: Abundant, especially in alpine areas; preferential of not too much exposed habitats (Nos. 12, 13, 16, 17, 21, 24, 25, 36, 37). Abundant also in the serpentines of Sunmöre.

Outside serpentine: Very abundant; indifferent. Reg. alp.–reg. conif.

Agrostis canina L. var. ***arida*** Schlecht.

Serpentine: Frequent in some areas at low altitudes (areas Nos. 6–9, 12, 33). Very abundant in area No. 8, Mt Junsterklumpen. *Agrostis canina* s. lat. is frequent in the serpentine areas of Sunmöre (Björlykke) and, according to my own observations, also in the serpentine of the Isle of Rödön, Nordland.

Outside serpentine: Occasional, dry rocks in reg. conif.; indifferent.

Deschampsia flexuosa (L.) Trin.

Serpentine: Abundant in almost every area, lacking only in shore area No. 33 and in the rather extreme, alpine areas Nos. 38–40. Abundant also in the serpentine areas of Finland (Mikkola op. cit.), Norway (Björlykke op. cit.), Central Europe Kretschmer op. cit.). Very abundant on serpentine also in E Canada.

Outside serpentine: Very abundant, reaching in S Lappland the 1 200 m level. Preferential of acid soils. Found on extremely acid soil near the outcrops of copperpyrite, e.g., at Remdalen, Åsele Lappmark, and accordingly also very resistant to the injurious effects of a high copper content in the soil.

Deschampsia flexuosa is often denoted as acidicolous. This does not, however, seem adequate, considering the rich occurrence of this plant on serpentine which has a slightly basic soil reaction.

Festuca ovina L.

Serpentine: Very abundant in most areas, at altitudes ranging from 300 to 1 200 m. Only lacking in the high alpine area of Mt St. Ålke (No. 38). Particularly abundant in very dry habitats, viz., parts of south-exposed rocks, etc. Abundant also in serpentine of N Finland (cf. Mikkola op. cit.). In South and Middle Europe, several races of *Festuca ovina* are very abundant on serpentine (cf. Kretschmer op. cit., Suza 1928, and Pichi-Sermolli 1948).

Outside serpentine: Very abundant; indifferent. Reg. alp.–reg. conif.

Scirpus caespitosus L. ssp. ***austriacus*** (Palla) Brodd.

Serpentine: Frequent in moist crevices in some alpine areas (Nos. 12, 24, 36, 37, 40). According to Björlykke (op. cit.) abundant on the serpentine of Sunmöre. Rather abundant on serpentine also in E Canada.

Outside serpentine: Very abundant as a mire-plant; on firm rock never as frequent as on serpentine; indifferent. Reg. alp.–reg. conif.

Juncus trifidus L.

Serpentine: Very abundant in the areas of the alpine and subalpine regions. At low-alpine and subalpine altitudes, *Juncus trifidus* is more abundant on serpentine than outside, disclosing the same abundance as generally seen in the mid-alpine region. Only lacking in areas Nos. 4–10, 28–34, 41.

Outside serpentine: Very abundant in the alpine region, especially in the mid-alpine region (1 200–1 400); indifferent.

Cerastium alpinum L.

Serpentine: Besides *Cerastium glabratum*, which may be considered to belong to the *C. alpinum* complex, also other races of it occur on serpentine. A serpenticolous variety of *C. alpinum* has been described previously on p. 53. However, also the type-race of *Cerastium alpinum* is rather frequent in alpine serpentine areas. It was observed in the following areas, Nos. 19, 23–25, 32, 36.

Outside serpentine: Frequent in the alpine region, occasional at lower altitudes; indifferent.

Minuartia rubella (Wg) Hiern.

Serpentine: Rather frequent in some localities in the area of Graipesvare–Murfjället (No. 20), where the serpentine is partly rather calcareous (cf. Rune 1947).

Outside serpentine: Frequent in the northern parts of Lappland (Torne and Lule Lappmark), very rare in S Lappland (Pite, Lycksele and Åsele Lappmark); calcicolous. Reg. alp.

Saxifraga nivalis L.

Serpentine: Frequent in several areas at different altitudes (areas Nos. 16, 18, 20, 21, 24, 25, 27, 29, 30, 35, 36). *Saxifraga nivalis* is also mentioned by Ove Dahl (1915 p. 102) as abundant in the serpentine areas southeast of Lake Rösvatn (Hattfjelldal, Nordland). It is also mentioned by Knaben (1952) from the alpine serpentine areas of W Norway (Sogn). However, this plant does not seem to have been found in the serpentine areas of Sunmöre (Björlykke op. cit.). Nevertheless, I myself have seen it growing rather frequently on the coastal serpentine of N Norway (Rödön in Tjötta, Nordland). *Saxifraga nivalis* also appears very disjunctively in several low-altitude serpentine areas of Finland (cf. p. 91). This species might probably as well be characterized as serpentinicolous.

OUTSIDE SERPENTINE: Frequent in reg. alp. and subalp., occasional in reg. conif.; indifferent.

Ramischia secunda (L.) GARCKE.

SERPENTINE: Frequent in a few areas at low altitudes (Nos. 10, 28–31, 33). In Sunmöre, this plant seems also to occur quite abundantly in some areas at low altitude (BJÖRLYKKE op. cit.). At Mt Taberg, in the province of Småland, *Rasmischia secunda* grows abundantly in the soil derived from magnetite-olivinite. In Finland, *Ramischia* seems also to be rather frequent on serpentine, and might perhaps be characterized as serpentinicolous.

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. subalp.–reg. conif.

Arctostaphylos uva-ursi (L.) SPRENG.

SERPENTINE: Occasional in some areas at widely different altitudes (areas Nos. 3, 20, 30).

OUTSIDE SERPENTINE: Occasional; indifferent. Restricted to very dry habitats; unevenly distributed in the mountain district. Reg. alp.–reg. conif.

Vaccinium uliginosum L.

SERPENTINE: Noticed in all the visited areas, except in Nos. 4 and 38. *Vaccinium uliginosum* occurs abundantly on serpentine and is undoubtedly one of the most important plants of this substratum. However, as this plant is also very abundant on other kinds of soil, it cannot properly be considered to be serpentinicolous.

OUTSIDE SERPENTINE: Abundant in all altitudinal regions. The alpine race seems to be somewhat calcicolous.

Calluna vulgaris (L.) HULL.

SERPENTINE: Abundant in most areas below the alpine region (areas Nos. 1–15, 22, 23, 26, 28–31, 34, 41). Statements in the literature disclose *Calluna vulgaris* as a common serpentine plant also in Sunmöre (BJÖRLYKKE op. cit.) and in the Austrian Alps (LÄMMERMAYER 1926). Though *Calluna* is known to be acidicolous, it is one of the most important plants on the slightly basic serpentine soil.

OUTSIDE SERPENTINE: Frequent (locally abundant); calcifuge. Reg. alp. inf.–reg. conif.

Empetrum hermaphroditum HAGERUP.

SERPENTINE: Noticed in all areas, except No. 38 — often in great abundance.

OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.–reg. conif.

Campanula rotundifolia L.

SERPENTINE: Frequent in several areas at different altitudes (areas Nos. 12, 19–24, 28–31, 35–36). Also outside N Sweden, *Campanula rotundifolia* seems to be a common serpentine plant. It is mentioned as common in serpentine areas of Sunmöre (BJÖRLYKKE), Finland (MIKKOLA), and Central Europe (LÄMMERMAYER, KRETSCHMER, and others). Also in the serpentine areas of E Canada, *Campanula rotundifolia* occurs in abundance. Many different serpentine races may of course exist in this variable species. Though very typical of serpentine, *Campanula rotundifolia* is by no means serpentinicolous. In N Sweden, it is not more preferential of serpentine than, e.g., of limestone.

OUTSIDE SERPENTINE: Frequent; especially on calcareous rock. Reg.alp.–reg. conif.

b. Bryophytes and Lichens.

As a rule, the lower cryptogams are not included in my study of the serpentine flora. Apart from my observations concerning the serpentinicolous representatives of these plant groups reported earlier (cf. p. 65), further contribution to the knowledge of the cryptogamic serpentine flora consists only of some odd notes from a few areas which had also been investigated slightly with regard to these plant groups. Thus, the collections, mainly from areas Nos. 18, 22, 29, 30, and 36, were determined by O. MÅRTENSSON (bryophytes) and S. AHLNER (lichens). As it is impossible to decide, on the basis of this fragmentary material, which species are serpentine-indifferent and which are accidentals, they will all be included in the list below.

Bryophytes.

(nomenclature according to JENSEN 1939).

Sphenolobus minutus (CR.) STEPH.

Area No. 30, frequent in tufts of *Dicranum fuscescens*.

Blepharostoma trichophyllum (L.) DUM.

Area No. 30, occasional in moist crevices.

Ptilidium ciliare (L.) HAMPE.

This common and widespread hepatic seems to occur as abundantly on serpentine as on any other kind of soil. Occasionally found on serpentine rocks, though abundant only in the ground layer of the dwarf shrub heaths which occurs where the serpentine soil is covered with a humus layer.

Sphagnum nemoreum SCOP.

Area No. 30; a single tuft in a wet cavity on the rock.

Dicranum bergeri BLAND.

Area No. 34, occasional.

Dicranum fuscescens TURN.

Areas Nos. 29, 30, 31, abundant.

Dicranum majus TURN.

Area No. 30, occasional.

Dicranum muehlenbeckii Br. eur.

Areas Nos. 29, 30, 31, rather abundant. This moss is considered by KOTILAINEN (verbal information) to be very characteristic of serpentine in Finland. Found also on serpentine in Central Europe (LÄMMERMAYER 1927).

Dicranum scoparium (L.) HEDW.

Areas Nos. 29, 30, abundant; area No. 36, occasional.

Ceratodon purpureus (L.) BRID.

Areas Nos. 18, 29, 30, 36, rather abundant in rock crevices.

Distichium capillaceum (HEDW.) Br. eur.

Areas Nos. 18, 30, occasional.

Ditrichum flexicaule (SCHLEICH.) HAMPE.

Areas Nos. 18, 36, sparse.

Tortula norvegica (WEB. fil.) LINDB.

Area No. 36, sparse.

Tortula ruralis (L.) EHRH.

Area No. 18, occasional on a south-exposed precipice.

Tortella tortuosa (L.) LIMPR.

Areas Nos. 18, 29, 30, 31, 36, occasional. This moss which is considered to be a calcicole is observed also on serpentine free from calcium (29–31).

Schistidium apocarpum (L.) Br. eur.

Areas Nos. 18, 36, occasional.

Tetraplodon bryoides (ZOËGA) LINDB.

Area No. 30, sparse on pieces of reindeer bones.

Webera cfr ***nutans*** HEDW.

Area No. 36, sparse.

Bartramia ityphylla BRID.

Area No. 18, occasional on a south-exposed precipice.

Leucodon sciuroides (L.) SCHWAEGR.

Area No. 18, rather frequent on a south-exposed percipice.

Thuidium abietinum (L.) Br. eur.

Area No. 18, occasional on a south-exposed precipice.

Lichens.

Ionaspis odora (ACH.) TH. FR.

Area No. 22, occasional.

Nephroma arcticum (L.) TORSS.

Areas Nos. 29–31, occasional on serpentine covered with humus.

Lecidea lapicida ACH.

Area No. 22, occasional on serpentine boulders.

Lecidea sorediza NYL.

Area No. 22, occasional on serpentine boulders.

Rhizocarpon geminatum (FLOT.) KBR.

Area No. 26, sparse on a south-exposed precipice.

Cladonia rangiferina (L.) WEB.

Occasional in places where the serpentine soil is covered with humus.

Cladonia pyxidata (L.) FR.

Same as above.

Cladonia sylvatica (L.) HOFFM.

Same as above.

Stereocaulon paschale (L.) HOFFM.

Same as above.

Lecanora polytropa (EHRH.) RABH.

Area No. 22, occasional.

Cetraria nivalis (L.) ACH.

Frequent in places where the serpentine is covered with humus.

Caloplaca elegans (LINK) TH. FR.

Areas Nos. 3, 8, 9, 11, 18, 19, 21, 24, 26, 29–31, 35, 37. Rather abundant on dry south-exposed precipices.

Caloplaca sorediata (VAIN.) DR.

Area No. 26, same as above.

Physcia caesia (HOFFM.) HAMPE.

Abundant on tops of exposed boulders, etc. (bird-perches).

Physcia lithotodes NYL.

Same as above.

C. Serpentine-accidental plants.

Lycopodium alpinum L.

SERPENTINE: Rare, a few individuals noticed in one area: Mt Rautats (No. 12).

OUTSIDE SERPENTINE: Rather frequent; indifferent. Reg. alp.–reg. conif.

Selaginella selaginoides (L.) LINK.

SERPENTINE: Occasional in some areas (Nos. 20, 24, 33, 36).
OUTSIDE SERPENTINE: Rather frequent; somewhat calcicolous. Reg. alp.–reg. conif.

Athyrium alpestre (HOPPE) MILDE.

SERPENTINE: Rare, only a few individuals noticed at Mt Rautats (No. 12).
OUTSIDE SERPENTINE: Abundant; indifferent. Reg. alp.–reg. conif.

Cystopteris fragilis (L.) BERNH.

SERPENTINE: Occasional on southern bluffs in the Rönnbäck district (areas Nos. 28, 29), also No. 9.
OUTSIDE SERPENTINE: Occasional; probably somewhat calcicolous. Reg. alp.–reg. subalp.

Woodsia ilvensis (L.) R. BR.

SERPENTINE: Occasional on some southern bluffs of the Rönnbäck district (areas Nos. 28, 29).
OUTSIDE SERPENTINE: Occasional, mainly on southern bluffs; indifferent. Reg. subalp.–reg. conif.

Woodsia alpina (BOLTON) S. F. GRAY.

SERPENTINE: Rather frequent in one of the areas (No. 29) of the Rönnbäck district, growing on serpentine boulders below a southern bluff. Sparsely also in area No. 28.
OUTSIDE SERPENTINE: Occasional; probably somewhat calcicolous. Reg. alp.–reg. conif.

Polystichum lonchitis (L.) ROTH.

SERPENTINE: Rare, only a few, very small individuals in one single locality: a southern bluff of Graipesvare (No. 20) at a remarkably high altitude (1000 m).
OUTSIDE SERPENTINE: Occasional; somewhat calcicolous. Reg. subalp.–reg. conif.

Lastrea dryopteris (L.) BORY.

SERPENTINE: Occasional on the southern bluff of Mt Tjarve (No. 18).
OUTSIDE SERPENTINE: Very abundant in woods; indifferent. Reg. subalp.–reg. conif.

Polypodium vulgare L.

SERPENTINE: Occasional on dry cliffs of the Rönnbäck area (Nos. 28, 29).
OUTSIDE SERPENTINE: Rare, in the high mountain district, limited to the southern bluffs of the reg. conif. Indifferent.

Picea abies (L.) KARST.

SERPENTINE: Rare; the spruce always seems to avoid serpentine, and even when surrounded by spruce-forests, the serpentine areas are almost devoid of this kind of tree.
OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. conif.

Phragmites communis TRIN.

SERPENTINE: Growing very sparsely in a small pool of the Kittelfjäll serpentine (No. 22).
OUTSIDE SERPENTINE: Occasional and calcicolous in the mountain region (reg. subalp. and upper reg. conif.). Abundant and indifferent at lower altitudes.

Phleum pratense L.

SERPENTINE: Rare, only as a weed near the miners' huts at Mt Rautats.
OUTSIDE SERPENTINE: Only hemerophilous around settlements, in lumbering places, etc.

Agrostis borealis HARTM.

SERPENTINE: Rather frequent in alpine and subalpine areas (Nos. 12, 16, 18, 21, 23, 26, 28–30, 33, 34–38).
OUTSIDE SERPENTINE: Frequent at different altitudes and on different kinds of rock.

Agrostis tenuis SIBTH.

SERPENTINE: Occasional in some areas at low altitude (Nos. 8, 9, 33).
OUTSIDE SERPENTINE: Occasional in the mountain district. Restricted to lower regions, doubtful whether indigenous; indifferent.

Calamagrostis purpurea TRIN.

SERPENTINE: Occasional among boulders below steep bluffs (Nos. 18, 28).
OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.–reg. conif.

Calamagrastis neglecta (EHRH.) G., M. & SCH.

SERPENTINE: Occasional, growing mostly round bird-perches in alpine areas (Nos. 21, 36).
OUTSIDE SERPENTINE: Abundant; indifferent. Reg. alp.–reg. conif.

Deschampsia alpina (L.) R. & S.

SERPENTINE: Rare, only few individuals in two alpine areas (Nos. 12, 40).
OUTSIDE SERPENTINE: Frequent in the alpine region; indifferent.

Deschampsia caespitosa (L.) PB.

SERPENTINE: Occasional in two different habitats:

a serpentine rock on the shore of Lake Laisan (No. 33), and near the top of Mt Rautats (No. 12).

OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.–reg. conif.

Trisetum spicatum **(L.) RICHT.**

SERPENTINE: Occasional in some alpine areas (Nos. 20, 21, 36) and on a serpentine rock on a lake shore (No. 33).

OUTSIDE SERPENTINE: Frequent in the alpine region; indifferent.

Poa alpigena **(FR.) HIIT.**

SERPENTINE: Occasional in some areas (Nos. 12, 19, 32, 33, 36).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.–reg. conif.

Poa alpina **L.**

SERPENTINE: Occasional in a few areas (Nos. 19, 36).

OUTSIDE SERPENTINE: Abundant; somewhat calcicolous. Reg. alp.–reg. subalp.

Poa annua **L.**

SERPENTINE: Hemerophilous round the miners' huts on Mt Rautats (No. 12).

OUTSIDE SERPENTINE: In the mountain district, only hemerophilous on roads, etc.

Poa arctica **R. BR.**

SERPENTINE: Occasional in an area of Ammarfjällen (No. 39).

OUTSIDE SERPENTINE: A complex species with bicentric distribution in the Scandes. Frequent in N Lappland. S limit in Sweden at Ammarfjällen; indifferent. Reg. alp.

Poa glauca **VAHL.**

SERPENTINE: Rare, only on dry, south-exposed rocks (areas Nos. 11, 18, 28).

OUTSIDE SERPENTINE: Occasional on southern bluffs and dry rocks; indifferent. Reg. alp.–reg. conif.

Poa trivialis **L.**

SERPENTINE. Rare, only as a weed near the miners' huts on Mt Rautats (No. 12).

OUTSIDE SERPENTINE: Not indigenous in the mountain district. Hemerophilous round settlements, etc.

Phippsia algida **(SOL.) R. BR.**

SERPENTINE: Occasional only in one area: the peak of Mt Atoklinten (No. 36), at 1000 m altitude.

OUTSIDE SERPENTINE: Frequent on snowbeds in reg. alp., indifferent.

Festuca vivipara **(L.) SM.**

SERPENTINE: Frequent in the alpine serpentine areas of Södra Storfjällen (Nos. 36, 37), but not seen elsewhere in the serpentine areas of N Sweden. According to BJÖRLYKKE (op. cit.), abundant in the serpentine areas of Sunmöre.

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Reg. alp.

Festuca rubra **L. var. *mutica* HARTM.**

SERPENTINE: Occasional in the same areas as *F. vivipara.* According to BJÖRLYKKE (op. cit.), very abundant in the serpentine of Sunmöre.

OUTSIDE SERPENTINE: The var. *mutica* HARTM. is an alpine, calcicolous race of *Festuca rubra* which is rather abundant in the northern parts of the mountain district of N Sweden, but becomes very sparse towards the south.

Roegneria canina **(L.) NEVSKI.**

SERPENTINE: Occasional on serpentine scree below a southern bluff (area No. 26).

OUTSIDE SERPENTINE: Frequent below cliffs and in rich woods; somewhat calcicolous. Reg. alp.–reg. conif.

Roegneria scandica **NEVSKI.**

SERPENTINE: Occasional on serpentine scree below southern bluffs (areas Nos. 18, 29).

OUTSIDE SERPENTINE: Occasional; dry and warm habitats on calcareous ground. Reg. alp.–reg. conif.

Eriophorum scheuchzeri **HOPPE.**

SERPENTINE: Occasional near ponds in two alpine serpentine areas (Nos. 36, 37).

OUTSIDE SERPENTINE: Abundant in the alpine region, occasional at lower altitudes; indifferent.

Eriophorum angustifolium **HONCK.**

SERPENTINE: Rare, growing sparsely near a small pond at Mt Rautats (No. 12).

OUTSIDE SERPENTINE: Abundant; indifferent. Reg.alp.–reg. conif.

Carex rupestris **ALL.**

SERPENTINE: Very abundant on calcareous serpentine (area No. 20), occasional on pure serpentine rock (Nos. 21, 24).

OUTSIDE SERPENTINE: Very abundant; calcicolous. Reg. alp.–reg. subalp.

Carex lachenalii **SCHKUHR.**

SERPENTINE: Frequent in moist places in several alpine areas (Nos. 12, 16, 17, 20, 21, 36, 37, 39).

OUTSIDE SERPENTINE: Abundant; indifferent. Reg. alp.

Carex canescens L.

SERPENTINE: Occasional in two areas, growing near small ponds (Nos. 26, 29).
OUTSIDE SERPENTINE: Abundant; indifferent. Reg. alp.–reg. conif.

Carex bigelowii TORR.

SERPENTINE: Occasional in a few alpine areas, growing only in soil rich in humus (Nos. 12, 16, 17, 24, 32, 39).
OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.

Carex atrata L.

SERPENTINE: Occasional on calcareous serpentine (Nos. 20, 24).
OUTSIDE SERPENTINE: Frequent; calcicolous. Reg. alp.–reg. conif.

Carex glacialis MACK.

SERPENTINE: This rare plant was found in one alpine area, Graipesvare (No. 20), growing in weathered serpentine soil. Yet the calcicole *Carex glacialis* was not found among the other calcicoles which occur on the calcareous serpentine of Graipesvare, but on rather pure serpentine.
OUTSIDE SERPENTINE: Rare; calcicolous. Reg. alp.

Carex capillaris L.

SERPENTINE: Rare in a few areas of calcareous serpentine, Nos. 20, 24, 36.
OUTSIDE SERPENTINE: Frequent on calcareous soil. Reg. alp.–reg. conif.

Juncus filiformis L.

SERPENTINE: Sparsely in one area, No. 26, growing near a small pond.
OUTSIDE SERPENTINE: Abundant; indifferent. Reg. alp.–reg. conif.

Luzula wahlenbergii RUPR.

SERPENTINE: Occasional on rock ledges of a moist north-exposed cliff (area No. 37).
OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.–reg. subalp.

Luzula arcuata (WG) SW. s. str.

SERPENTINE: Occasional in the markedly alpine areas (Nos. 21, 36, 38, 40).
OUTSIDE SERPENTINE: Very abundant at high altitudes (c. 1400–1800 m); indifferent.

Tofieldia pusilla (MICHX.) PERS.

SERPENTINE: Occasional on the calcareous serpentine (c. 25 % $CaCO_3$) of Murfjället (No. 20).
OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Reg. alp.–reg. conif.

Leucorchis albida (L.) E. MEY.

SERPENTINE: Rare, a few individuals seen in the same locality as *Tofieldia pusilla* (see above).
OUTSIDE SERPENTINE: Occasional; somewhat calcicolous. Reg. alp.–reg. conif.

Salix reticulata L.

SERPENTINE: Rare and only in a few areas with ± calcareous serpentine (Nos. 20, 22, 32, 36).
OUTSIDE SERPENTINE: Frequent on calcareous rocks. Reg. alp.–reg. subalp.

Salix herbacea L.

SERPENTINE: Rare but is to be found in most alpine areas. Only lacking in the low-altitude areas Nos. 1,2, 4–10, 22, 26–32, 34, 41.
OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.

Salix lapponum L.

SERPENTINE: Small shrubs of grey willows, *Salix lapponum*, *Salix glauca* and their hybrids, occur sparsely in most areas at altitudes between approx. 500 and 1000 m. Lacking only in areas Nos. 4–10, 28–32, 38, 41.
OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.–reg. conif.

Salix glauca L.

SERPENTINE: See *Salix lapponum*.
OUTSIDE SERPENTINE: Very abundant; Indifferent. Reg. alp.–reg. conif.

***Salix lapponum* × *glauca*.**

SERPENTINE: See *Salix lapponum*.
OUTSIDE SERPENTINE: Abundant; indifferent. Reg. alp.–reg. conif.

Betula tortuosa LED.

SERPENTINE: Trees of the mountain-birch occur up to a level of about 600 m, and small shrubs up to about 700 m. Thus, in the serpentine areas the timberline is about 100 m lower than outside. As may be seen from Pl. VI, the wide plateau of Mt Rautats at the 700 m level has a totally alpine character. Many serpentine areas (cf. Figs. 17, 18, Pl. VII) are also forming alpine islands in the subalpine birch-forest region. Even in the low-altitude serpentine areas, the birch-trees are restricted to favourable habitats with deep soil. Usually, a clear contrast is noted between the scattered birch-bushes within the serpentine area and the dense birch-forest beyond it. A similar lowering of the timberline, here formed by the spruce, is also reported from the serpentine areas of the Alps (SCHRÖTER 1926, LÄMMERMAYER 1926). This phenomenon is no doubt due to unfavourable conditions for forest-growth, as offered by the serpentine, and provides a good example of a timberline, which is orographically conditioned, i.e. not influenced by climatic factors only.

OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. subalp.–reg. conif.

Betula nana L.

SERPENTINE: Occasional in most areas, especially when the serpentine soil is covered by a humus layer. Lacking only in areas Nos. 4, 15, 32, 38, 41.

OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.–reg. conif.

Rumex acetocella L. s. lat.

SERPENTINE: Rare, only as a weed near the miners' huts at Mt Rautats.

OUTSIDE SERPENTINE: Only hemerophilous round settlements, etc.

Oxyria digyna (L.) HILL.

SERPENTINE: Occasional in alpine areas, especially on moist northern sides (areas Nos. 12, 13, 16–25, 35–40).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.

Polygonum viviparum L.

SERPENTINE: Occasional in one single area (No. 32).

OUTSIDE SERPENTINE: Frequent; calcicolous. Reg. alp.–reg. conif.

Chenopodium album L.

SERPENTINE: One single individual in one of the Rönnbäck areas (No. 29); escaped from the adjacent settlement.

OUTSIDE SERPENTINE: Only as a weed in the gardens of settlements.

Stellaria media (L.) VILL.

SERPENTINE: Only as a weed near the miners' huts at Mt Rautats (No. 12).

OUTSIDE SERPENTINE: Only as a weed near settlements.

Stellaria graminea L.

SERPENTINE: Occasional in a single locality: the boulder heaps below Röberget (No. 19).

OUTSIDE SERPENTINE: Occasional; indifferent. Reg. subalp.–reg. conif.

Cerastium cerastoides (L.) BRITTON.

SERPENTINE: Occasional; near snowbeds in some alpine areas (Nos. 12, 21, 32, 36).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.

Cerastium edmondstonii (WATS.) MURB. & OSTF.

SERPENTINE: Occasional in one alpine area (No. 40).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.

Sagina intermedia FENZL.

SERPENTINE: Occasional near snowbeds in two alpine areas (Nos. 21, 36).

OUTSIDE SERPENTINE: Occasional; indifferent. Reg. alp.

Sagina saginoides (L.) KARST.

SERPENTINE: Occasional in a single locality, the serpentine rock at the shore of the Isle Storholmen in Lake Laisan (No. 33).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. subalp.–reg. conif.

Sagina normanniana LAGERH.

SERPENTINE: Rare, occurrring as a weed near the miners' huts at Mt Rautats (No. 12).

OUTSIDE SERPENTINE: Rare, only in Frostviken; indifferent. Reg. subalp.–reg. conif.

Silene rupestris L.

SERPENTINE: Rare, only on south-exposed cliffs below the alpine region (areas Nos. 5, 9, 18, 19, 34).

OUTSIDE SERPENTINE: Rare, only on southern bluffs of the subalpine and conif. forest regions; indifferent.

Thalictrum alpinum L.

SERPENTINE: Rare, only in some areas with calcareous serpentine (areas Nos. 20, 36).

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Reg. alp.–reg. conif.

Ranunculus pygmaeus WG.

SERPENTINE: Occasional in moist and shady crevices and on north-exposed rock-sides in alpine areas (Nos. 16, 21, 36, 39).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.

Ranunculus acris L. coll.

SERPENTINE: Occasional in a few alpine areas (Nos. 12, 16, 21).

OUTSIDE SERPENTINE: Very abundant; indifferent. Reg. alp.–reg. conif.

Draba norvegica GUNN.

SERPENTINE: Occasional in calcareous serpentine (area No. 20). Sparse in area No. 9.

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Reg. alp.

Draba nivalis LILJEBLAD.

SERPENTINE: Rare, found only in one locality: on calcareous serpentine near the peak of Graipesvare (No. 20).

OUTSIDE SERPENTINE: Frequent in the northern parts of Lappland (north of about lat. 67° N), rare in the southern parts — apart from the serpentine locality only very few are known in all S Lappland; calcicolous. Reg. alp.

Sedum rosea (L.) SCOP.

SERPENTINE: Occasional in a few areas of calcareous serpentine (Nos. 20, 36).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.–reg. subalp.

Cardamine pratensis L. ssp. **angustifolia** (HOOK) O. E. SCHULTZ.

SERPENTINE: Rare, only a few individuals on the moist northern side of area No. 37.

OUTSIDE SERPENTINE: This alpine race of the complex species occurs occasionally in the alpine region of Lappland; indifferent.

Sedum annuum L.

SERPENTINE: Rare on a few south-exposed cliffs below the alpine region (areas Nos. 9, 18, 19, 34).

OUTSIDE SERPENTINE: Occasional; restricted to southern bluffs below the alpine region.

Parnassia palustris L.

SERPENTINE: Rare, only a few individuals in three different areas (Nos. 12, 20, 33). The habitats are all rather wet; in only one of them the serpentine is calcareous (No. 20).

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous Reg. alp.–reg. conif.

Saxifraga aizoides L.

SERPENTINE: Rare, only a few individuals in two areas (Nos. 12, 22).

OUTSIDE SERPENTINE: Frequent; calcicolous. Reg. alp.–reg. conif.

Saxifraga foliolosa R. BR.

SERPENTINE: Rare, only a few individuals in one area (No. 37).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.

Saxifraga groenlandica L.

SERPENTINE: Rare, only in some strictly alpine areas (above 1100 m). Areas Nos. 20, 21.

OUTSIDE SERPENTINE: Occasional; somewhat calcicolous. Reg. alp.

Saxifraga oppositifolia L.

SERPENTINE: Occasional in some alpine areas (Nos. 21, 23, 24). Frequent when the serpentine contains some calcium (area No. 20).

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Mainly alpine.

Saxifraga rivularis L.

SERPENTINE: Occasional in moist habitats in some alpine areas (Nos. 16, 21, 36, 39).

OUTSIDE SERPENTINE: Occasional; indifferent. Reg. alp.

Saxifraga stellaris L.

SERPENTINE: Occasional on the moist northern slopes of some alpine areas (Nos. 16, 32, 35, 36).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.

Saxifraga tenuis (WG) H. SM.

SERPENTINE: Rare, only moist northern slopes of strictly alpine areas (Nos. 20, 21, 36).

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Reg. alp.

Rubus chamaemorus L.

SERPENTINE: Occasional round bird-perches on the tops of some alpine areas (Nos. 5, 12, 21, 36).

OUTSIDE SERPENTINE: Very abundant, though mainly as a mire-plant. Acidicolous. Reg. alp.–reg. conif.

Rubus saxatilis L.

SERPENTINE: Rare, only a few individuals in one locality, the south bluff of Mt Tjarve (No. 18). According to BJÖRLYKKE, abundant in the serpentine areas of Sunmöre.

OUTSIDE SERPENTINE: Abundant, mostly in dry habitats, e.g., south-exposed slopes; indifferent. Reg. alp. inf.–reg. conif.

Rubus idaeus L.

SERPENTINE: Occasional in one area of the Rönnbäck district (no 28), growing among boulders below a north-exposed precipice.

OUTSIDE SERPENTINE: Very abundant; in the mountain district mostly below southern bluffs; indifferent. Reg. subalp.–reg. conif.

Potentilla crantzii (Cr.) G. Beck.

Serpentine: Occasional in three different areas (Nos. 12, 20, 33); at least in one of these the serpentine is somewhat calcareous (No. 20).

Outside serpentine: Frequent; somewhat calcicolous. Reg. alp.–reg. conif.

Dryas octopetala L.

Serpentine: Abundant in the area of Graipesvare-Murfjället (No. 20) where the serpentine contains a relatively great amount of calcite (10–15 % CaO). A few individuals are found also on Mt Atoklinten (No. 36) where the calcium content (CaO) equals only about 1.5 %.

Outside serpentine: Very abundant; strictly calcicolous. Mainly alpine.

Geranium silvaticum L.

Serpentine: Rare, only a few individuals in one locality: Mt Rautats (No. 12).

Outside serpentine: Very abundant; indifferent. Reg. alp. inf.–reg. conif.

Viola montana L.

Serpentine: Occasional in one area: the shore locality of the Isle of Storholmen near Tärnaby (No. 33).

Outside serpentine: Occasional; somewhat calcicolous. Reg. subalp.–reg. conif.

Viola biflora L.

Serpentine: Occasional in two areas (Nos. 20, 36), both of which have ± calcareous serpentine.

Outside serpentine: Abundant; indifferent. Reg. alp.–reg. conif.

Chamaenerion angustifolium (L.) Scop.

Serpentine: Frequent, though in one locality only (area No. 28), growing among the boulders below a steep north-exposed precipice.

Outside serpentine: Abundant; indifferent. Reg. subalp.–reg. conif.

Loiseleuria procumbens (L.) Desv.

Serpentine: Occasional in one area only (No. 3).

Outside serpentine: Abundant; indifferent. Reg. alp.

Phyllodoce coerulea (L.) Bab.

Serpentine; Occasional in a few alpine areas (Nos. 12, 24, 39).

Outside serpentine: Abundant in the alpine region, occasional at lower altitudes; indifferent.

Cassiope hypnoides (L.) D. Don.

Serpentine: Rare, only a few individuals in some alpine areas (Nos. 39, 40).

Outside serpentine: Frequent in the alpine region; indifferent.

Andromeda polifolia L.

Serpentine: Frequent in one area — Mt Rautats (No. 12) — but never seen elsewhere on serpentine.

Outside serpentine: Abundant; indifferent. Reg. alp.–reg. conif.

Arctostaphylos alpina (L.) Spreng.

Serpentine: Occasional in a few areas — not all alpine (Nos. 5, 20, 23, 32).

Outside serpentine: Very abundant; indifferent. Reg. alp.–reg. subalp.

Vaccinium vitis-idaea L.

Serpentine: Occasional in serveral areas at widely different altitudes (areas Nos. 4, 8, 17, 20, 21, 26, 28–31, 41).

Outside serpentine: Very abundant; indifferent. Reg. alp.–reg. conif.

Vaccinium myrtillus L.

Serpentine: Rare, only rather few individuals noticed in some areas (Nos. 8, 11, 12, 28). Hence, *Vaccinium myrtillus* seems clearly serpentinifuge, and the widely extending *Vaccinium myrtillus* heath ceases abruptly on reaching serpentine areas.

Outside serpentine: Very abundant; indifferent or somewhat calcifuge. Reg. alp.–reg. conif.

Diapensia lapponica L.

Serpentine: Rare, a few individuals in one area only (No. 37).

Outside serpentine: Frequent; indifferent. Reg. alp.

Primula stricta Horn.

Serpentine: Rare, a few individuals in one area only: the shore locality of the Isle of Storholmen, Tärnaby.

Outside serpentine: Occasional, mostly on shores of great mountain lakes; somewhat calcicolous. Reg. alp. inf.–reg. conif.

Gentiana nivalis L.

Serpentine: Rare, a few individuals in two areas with ± calcareous serpentine (Nos. 20, 36).

Outside serpentine: Frequent; somewhat calcicolous. Reg. alp.–reg. conif.

Gentianella tenella (Rottb.) H. Sm.

Serpentine: Rare, a few individuals on the very calcareous serpentine of Graipesvare (No. 20).

OUTSIDE SERPENTINE: Rare; calcicolous. Reg. alp.

Prunella vulgaris L.

SERPENTINE: Rare, a few individuals in the shore locality of the Isle of Storholmen, Tärnaby (No. 33).

OUTSIDE SERPENTINE: Occasional; indifferent. Indigenous only on the shores of large mountain lakes. Reg. subalp.–reg. conif.

Euphrasia frigida PUGSL.

SERPENTINE: Occasional in a few areas (Nos. 12, 33, 36). BJÖRLYKKE (op. cit.) mentioned *Euphrasia officinale* among plants common in the serpentine areas of Sunmöre. However, in this case probably also other species of *Euphrasia* than *E. frigida* may be concealed under the collective name "*officinale*".

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.–reg. conif.

Euphrasia lapponica TH. FR. j:r.

SERPENTINE: Occasional in two adjacent areas in Åsele Lappmark: 1) Murfjället (No. 20), where it grows rather sparsely, and 2) the northern side of Aunevare (No. 21) where it is rather abundant. In both localities the serpentine is very calcareous (about 25 % calcite). These localities, are very isolated and situated about 120 km south of the nearest non-serpentine station of *Euphrasia lapponica* in Sweden.

OUTSIDE SERPENTINE: Bicentric distribution in the Scandes, frequent in the northern parts of Lappland; calcicolous. Reg. alp.–reg. subalp.

Bartsia alpina L.

SERPENTINE: Rare, only in the calcareous serpentine of Murfjället (No. 20; in the same locality as *Euphrasia lapponica*).

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Reg. alp.–reg. conif.

Pedicularis lapponica L.

SERPENTINE: Rare in one single area (No. 24).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.–reg. conif.

Pinguicula vulgaris L.

SERPENTINE: Occasional in two areas with more or less calcareous serpentine, Nos. 20, 22.

OUTSIDE SERPENTINE: Frequent; somewhat calcicolous. Reg. alp.–reg. conif.

Solidago virgaurea L.

SERPENTINE: Frequent in some areas at low altitudes (areas Nos. 18, 20, 24, 28–31).

OUTSIDE SERPENTINE: Abundant on acid soils. Reg. alp. inf.–reg. conif.

Erigeron uniflorum L.

SERPENTINE: Rare, only a few individuals on the northern side of Aunevare (No. 21).

OUTSIDE SERPENTINE: Frequent in reg. alp; occasional in lower regions; indifferent.

Antennaria alpina (L.) GAERTN.

SERPENTINE: Rare, only a few individuals in one area (No. 39).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.

Antennaria dioica (L.) GAERTN.

SERPENTINE: Rare in a few areas at different altitudes (Nos. 20, 22, 32).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp.–reg. conif.

Gnaphalium supinum L.

SERPENTINE: Rare in one single area, No. 32.

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp. Occasional on snowbeds and trails also at lower altitudes.

Leontodon autumnalis L. var. ***taraxaci*** (L.) HARTM.

SERPENTINE: Rare, a few individuals in two different areas (Nos. 20,22).

OUTSIDE SERPENTINE: Frequent, mostly in reg. alp.; indifferent.

Hieracium alpinum L. coll.

SERPENTINE: Rare, a few individuals in one area only (No. 20).

OUTSIDE SERPENTINE: Frequent; indifferent. Reg. alp. inf.–reg. subalp.

III. Problems of the serpentine flora

1. General characters of the serpentine flora

The unique character of the flora of serpentine rocks has been stressed by all students of these problems. According to my own observations in Sweden, Norway, Finland and E North America, and data from the literature, it seems clear that all the characteristics denoting the serpentine flora are about the same in different parts of the world. The composition of the serpentine flora may differ from one place to another, but the general character seems invariably the same.

Thus, the following characteristics of the serpentine flora of N Sweden are no doubt common to at least all the northern serpentine floras: 1. The serpentine flora is relatively poor in individuals as well as in species. 2. In serpentine localities, several species are represented by certain races (ecotypes) differing ecologically and, sometimes, also morphologically from their original types. 3. Many plants appear very disjunctively in serpentine localities. 4. The serpentine flora contains basicolous as well as acidicolous plants which often grow together. 5. The serpentine flora has a relatively xerophytic character. 6. The serpentine flora is often dominated by certain families or genera, e.g., Caryophyllaceae in N Europe and E North America. In the present chapter these general characteristics will be discussed with special reference to N Sweden.

The waste and barren nature of serpentine areas is always emphasized by botanists and geologists. To a non-botanist, serpentine areas — especially in the northern districts — seem practically destitute of vegetation.

A very vivid impression of a serpentine area is given by A. P. Low, a Canadian geologist, who in 1883 explored the big serpentine mountain, Mt Albert, in the Gaspé Peninsula, Quebec (Figs. 49–51). This description is of particular interest to us in our study of the northern serpentine flora. The following may be quoted (Low 1884): "The top of Mt. Albert is nearly flat and is rent by a deep gorge on the east side, which near its head, splits into several smaller ones. The sides of these gorges are quite destitute of vegetation and the bare serpentine rocks are weathered to a light buff color. On the top of the mountain, blocks of serpentine are scattered around, and are partially covered by a thick growth of mosses (chiefly *Rhacomitrium lanuginosum*) and lichens. Sheltered places are occupied by a stunted growth of black spruce (*Abies nigra*[1]), which rarely attains a height of ten feet. The branches interlace near the ground and form an impenetrable thicket. The whole surface has a dead appearance and reminds one of pictures of the moon."

Similar descriptions have been given by various authors from different parts of the world.

The border-line between serpentine and surrounding non-serpentine soil is always distinctly marked by a clear difference in vegetation (Fig. 49). Thus, the vegetation of the serpentine soil is always very poor, as compared with that of the vicinity, and the number of species as well as of individuals is smaller. However, this difference in number has never been subjected to a close analysis requiring as it does a thorough knowledge of the flora of the surrounding district. In one of

[1] Both *Picea mariana* and *Abies balsamea* constitute these thickets, cf. Fig. 49).

his papers, FERNALD (1907) discussed the soil preferences of certain alpine plants in E North America, comparing the number of alpine species growing on certain kinds of rock. FERNALD distinguished a group of 21 plants localized to the serpentine area of Mt Albert in the Gaspé peninsula equalling only 8 % of the 258 alpine and subalpine plants of that district.

BJÖRLYKKE (op. cit.), who studied the flora of 30 different serpentine areas in the district of Sunmöre on the west coast of Norway (about lat. 62° N), found 289 vascular plants. This high number is, however, due to the fact that these localities represent altitudes from sea level up to the alpine region (600 m).

This number can be estimated at less than one third of the total number of the flora in the district.

In N Sweden I studied the flora of different serpentine areas, representing altitudes from about 350 to 1400 m above sea level. Approximately 140 different species of vascular plants were found, but about 40 were observed very sparsely in one single locality where they occurred only incidentically. As the total number of species growing in the vicinity of these serpentine areas can be estimated to be about 400 (excluding the microspecies of the genera of *Taraxacum* and *Hieracium*), it is clear that only about 25 % of the flora can grow in the serpentine of N Sweden.

Serpentine soils are generally dry, and this fact no doubt limits the occurrence of meso- and hygrophytes. However, some serpentine areas in N Sweden are situated in high mountain districts with a damp climate, and at least the north-exposed parts of the serpentine outcrops are continually moist. Though relatively sparse, meso- and hygrophytes are far from totally excluded from serpentines in N Sweden: among the 140 vascular plants mentioned above, several belong to these categories. In serpentine areas at low altitudes, the flora is much more scanty than at high altitudes as compared with that of the vicinity. This is probably caused partly by a higher precipitation at the higher altitudes, and partly by the fact that truly alpine plants seem more tolerant to serpentine soil.

The question of the existence of plants strictly limited to serpentine soils has been much discussed in earlier papers. Long ago it was observed that several species of plants are represented in serpentine soil by particular races differing, morphologically as well as ecologically, from the typical species. In many cases they were described as new species, subspecies, varieties or forms. In the literature, plants preferring serpentine soils are variously referred to by the following terms: serpentine plants, serpentinicolous plants, serpentinophytes, serpentine endemics, or serpentinomorphoses. In the present paper, principally the nomenclature proposed by PICHI-SERMOLLI (1948 p. 243) is used. Accordingly, any plant with an affinity for serpentine soil, i.e. growing more abundantly on it than on other soils of the vicinity, will be referred to as *serpentinicolous*.

The term *serpentinophyte* is used in a more specific sense, i.e. to designate a serpentine race morphologically differentiated to such an extent as to be distinguished as an individual taxon, even a new species, thus being more or less restricted to that substratum. Serpentinomorphoses imply only the morphological changes characteristic of serpentinophytes (see further p. 108).

NOVÁK in a paper from 1928, — "Quelques remarques relatives au problème de la végétation sur les terrains serpentiniques" — compiled a comprehensive list of plants, essentially from Bohemia, Moravia and the Balkan Peninsula, which he considered to be serpentinophytes (les types serpentiniques).

NOVÁK obviously considered all serpentinicolous plants to be serpentinophytes, i.e. differentiated within serpentine areas and strictly limited to these habitats. From a taxonomic point of view they represent, according to him, three different categories:

"Au point de vue systématique, il faut souligner que la notion de types serpentiniques est très large, puisqu'elle embrasse, d'une part, des espèces systématiquement et géographiquement bien caracterisées pour lesquelles nous ne connaissons pas (du moins avec sûreté) le type originaire non-serpentinique (par ex. *Halacsya sendtneri*, *Sempervivum pittonii* . . . *Euphorbia serpentini*, etc.), d'autre part, des races ou variétés dont nous connaissons bien les types non-serpentiniques les plus apparentés (vraisemblement le type originaire), mais les différences entre les deux sont très frappantes et dont l'aire d'extension coïncide avec des limites des serpentines a l'intérieur de l'aire d'extension de leur type originaire (par ex. *Asplenium adiantum nigrum* var. *cuneifolium*, *Potentilla crantzii* var. *serpentini*), et, enfin, elle comprend des types serpentiniques qui quantitativement diffèrent peu du type originaire, mais dont la différence apparaît de façon constante sur les serpentines et qui sont susceptibles, une fois transportées sur un autre substrat, de retourner, au cours d'une seule génération, au type" (l.c. p. 44).

LÄMMERMAYER, in several papers (1926–1934), denied the existence of plants which grow exclusively on serpentine soil. He pointed out that according to his own observations several plants, referred to by NOVÁK as serpentinophytes, did occur in other magnesian soils and, in a few instances, also in non-magnesian soils. This applied especially to the two serpentine ferns, *Asplenium adulterinum* and *A. cuneifolium*. LÄMMERMAYER's criticism was justified in so far as many serpentinophytes may also occur more or less sparsely or incidentally in other kinds of soil.

In a later paper (1937), NOVÁK divided the serpentinophytes into two groups: *obligate serpentinophytes*, i.e. plants found only in serpentine soils; and *facultative serpentinophytes*, i.e. plants preferential of serpentine but sometimes found in soils of another lithological origin. He also pointed out the existence of some pre-glacial relics in the latter group.

Many serpentinophytes growing under natural conditions only in serpentine soils have, during cultivation, proved capable of growing also in normal garden soil. So far, it has not been clearly demonstrated that any serpentinophytes exist that cannot be cultivated in normal soil. NOVÁK (1937) tried to grow seeds of *Euphorbia serpentini* NOVÁK in normal garden soil, but failed. As pointed out by PICHI-SERMOLLI (op. cit.), this experiment proved nothing, as NOVÁK had made no control experiments by sowing the same sort of seed in serpentine soil.

Recently, PICHI-SERMOLLI (op. cit.) contended that also NOVÁK's last attempt to group the serpentine plants was incorrect. PICHI-SERMOLLI states that many serpentinicolous plants must be regarded as relics, now growing on serpentine soils only because of the specific, edaphic conditions created by the serpentine rocks. He strongly emphasized that the *serpentinicolous relics* must not be confused with the real *serpentinophytes* which have arisen within serpentine areas and seldom occur outside them. Thus, serpentinicolous relics are plants that have occurred outside serpentine during earlier epochs, or still occur in other kinds of soil within other parts of their distribution areas. Therefore, serpentinicolous relics are plants which are becoming extinct. They have totally, or partly, died out over their whole area of distribution, except in certain serpentine areas where they have been conserved owing to specific, edaphic conditions.

Like NOVÁK, PICHI-SERMOLLI also divides the serpentinophytes into two groups: serpentinophytes only observed in serpentine soils; and serpentinophytes growing also in other magnesian soils (magnesite, diabas, etc.). The first group is named "typical serpentinophytes" (*serpentinofite tipiche*), the second one, "preferential serpentinophytes" (*serpentinofite preferentiale*).

PICHI-SERMOLLI's introduction of a new category of serpentinicolous plants seems important in offering a classification of the serpentine flora from a phytogeographical standpoint. A serpentinicolous relic must be understood as an edaphic relic. Like geographical relics (CAIN 1944 p. 150) the edaphic ones are associated with the existence of a refugium, according to CAIN (op. cit. p. 150) defined as follows: "A refugium consists of some locality which, for one reason or another, has not been as drastically altered climatically or otherwise as the region as a whole."

Serpentine areas are no doubt refugia created by the edaphic conditions of the serpentine soil rather than by climate conditions. In serpentine habitats the soil factor is dominant enough to cause small climatic changes to have hardly any effect on the vegetation. The essential factor is a capacity to withstand the toxic effect of serpentine soil. As only a limited part of the surrounding flora seems to have this capacity, serpentine areas are always more or less barren and they are seldom invaded by closed communities. Thus, plants thriving in serpentine live there almost without any actual competition. This factor has a conserving effect on the serpentine flora, as the waves of new climaxes following climatic changes (cf. CLEMENTS 1916, 1934) have never been able to wash over the serpentine areas to any noteworthy extent.

In this connection some remarks by CAIN may be quoted which give a good idea of the nature of the serpentinicolous relics (op. cit. p. 223): "A study of relics in general provides valuable clues to vegetational history, as ably pointed out by CLEMENTS (1934), because each major climatic shift produces a corresponding clisere and leaves behind relics of each climax type in formerly occupied regions. Such relics, however, are seldom endemic to their station, but are merely disjunct from the major area of the community or species population which has moved on elsewhere."

According to CAIN (op. cit. p. 213), plants restricted to strongly marked habitats, e.g., serpentine soils, can be regarded as endemics. The concept of endemism, however, includes two different types of organisms: endemics *sens. str.*, which are relatively young species, and epibiotics, which are relatively old relic species. These concepts are applicable to groups other than species (RIDLEY 1925; CAIN op. cit. p. 213).

"Since the term endemic signifies that the organisms live with their own people, RIDLEY (1925) proposed the term *epibiotic* signifying survivors, to distinguish those endemics which are relics of a lost flora. If we follow him, the term endemic would be reserved for those organisms which are related to, or evolved from other plants in the same area. If circumstances permit, there would appear to be no a priori reason why endemics could not spread and become ordinary, widespread, successful plants. He considers them to be 'newborn' species. In contrast, epibiotics are relics of an earlier flora which has nearly disappeared from the region as a result of climatic or other environmental vicissitudes" (CAIN op. cit. p. 213).

Both these categories are represented among the plants endemic to serpentines. Thus, serpentinophytes must be regarded as endemics *sens. str.* (neoendemics), while serpentinicolous relics are perfect examples of epibiotics.

No doubt, the group of serpentinicolous relics is rather complex, consisting of plants of different age and origin. For example, old serpentinicolous relics may once have been more or less morphologically distinct serpentine races, thus even serpentinophytes which were later the only surviving populations of a species, or group of species. Today they appear as puzzling, morphologically isolated endemics.

The actual existence of such a plant was demonstrated by CLAUSEN (1951). In the inner Coast Range of central California he found a plant belonging to *Compositae* and "so unlike anything previously named that it was thought to belong to an undescribed genus". It occurs "as a small colony of some 300 individuals on a hillside of unfertile serpentine soil". CLAUSEN showed by cultivation and crossing experiments that "the new form is a subspecies of *Layia glandulosa*, probably an edaphic race adapted to the serpentine soil and possibly an ancient relict" (CLAUSEN op. cit. pp. 80, 82).

On the other hand, serpentinicolous relics from the northern areas which were covered by the Pleistocene ice sheets are all comparatively young in their serpentine habitats. They are therefore seldom endemic to their stations but merely disjunctive from their major areas of distribution. Usually they do not differ morphologically[1] from their main populations, but probably often constitute particular, ecological races.

Apparently, the connection between serpentinophytes and serpentinicolous relics is more complicated than assumed by PICHI-SERMOLLI. Since a serpentinicolous relic, i.e. a serpentine ecotype geographically isolated from the main populations of the species, probably always differs ecologically, sometimes even morphologically, from the main population of the species, it is actually also a serpentinophyte in its initial stage. In addition, a serpentinophyte, i.e. a morphologically distinct serpentine race distinguished as an individual taxon,

[1] Small morphological differences may exist, though not sufficiently clear for taxonomic separation (cf. pp. 52, 108).

may appear also as a serpentinicolous relic when geographically isolated from its original type. It should be emphasized, therefore, that the characteristics of the serpentinicolous relics do not exclude those of the serpentinophytes, and the classification must be based on the dominant character.

No doubt, serpentinicolous plants exist which cannot properly be considered either as serpentinicolous relics or as serpentinophytes, since they are rather indifferent in these respects. This implies that the serpentinicolous populations do not differ morphologically from other populations of the species, and do not even appear geographically isolated from them. Such *serpentinicolous ubiquists* are frequent in the serpentine flora of N Sweden.

It was stated previously (p. 50) that any member of the serpentine flora in N Sweden may represent either of the following categories:

A. Serpentine-characteristic or serpentinicolous plants.
B. Serpentine-indifferent plants.
C. Serpentine-accidental plants.

This classification is based on the relative abundance of the plants on serpentine as compared with other kinds of rock in the vicinity, and has a general applicability.

The serpentine-characteristic plants may be classified as follows:

a. Serpentinophytes.
   Morphologically recognizable serpentine races distinguished as individual taxa. Not geographically isolated from allied races or species.
   1. Typical serpentinophytes.
      Exclusively serpentinicolous.
   2. Preferential serpentinophytes.
      Preferentially serpentinicolous.
b. Serpentinicolous relics.
   Any serpentinicolous plant appearing disjunctively in serpentine areas, thus geographically isolated from allied races or species.
c. Serpentinicolous ubiquists.
   Serpentinicolous plants not appearing as morphologically recognizable races and not geographically isolated from allied races or species — being probably morphologically unchanged serpentine races of ubiquitous plants of the surroundings.

When comparing NOVÁK's "systematical" classification of the serpentinicolous plants (cf. p. 78) with the phytogeographical one given above, certain points of agreement are to be noted. It will be seen that the first of NOVÁK's categories corresponds to the serpentinicolous relics and the second to the serpentinophytes. Plants of the third of NOVÁK's categories may be serpentinicolous relics as well as serpentinicolous ubiquists.

As a rule epibiotics seem to be more or less restricted to habitats with a low competition, i.e. where vegetation is kept at the pioneer stage. Apart from serpentine soils, this happens also in places where the ground is unstable for some reason or other, e.g., on shores, and on talus or faces of easily weathered rocks. The similarity between serpentine and other such habitats of a low competition seems rather evident in the flora of the Gaspé Peninsula, Quebec, which is very rich in epibiotics. However, this will be discussed more closely further on in this chapter (p. 97).

In this connection it should be emphasized that the recognition of serpentinicolous relics must be based chiefly on their present occurrence distant from their main population as epibiotics in isolated habitats outside of which they cannot survive. The question whether such a relic is really a remnant from a once wider distributional area, or the result of long distance dispersal, cannot be determined with accuracy, even though the latter alternative seems to concern only the plants with very light diaspores.

The existence of two different types of serpentinicolous endemics was recently demonstrated experimentally by KRUCKEBERG (1951), who grew seeds of serpentine and non-serpentine plants from the Central Coast Range reciprocally on serpentine and non-serpentine soils in the Botanical Garden of the University of California. He tested the complex species *Streptanthus glandulosus* HOOK., the forms of which are clearly serpentinicolous; most of them grow exclusively on serpentine. However, non-serpentine localities for some of the infraspecific units are occasionally encountered.

KRUCKEBERG states: "It might be supposed that the few non-serpentine forms are merely migrants from serpentine populations and have soil-tolerance ranges like those of the serpentine forms. However, such is not the case. All the non-serpentine strains of this species-complex tested on serpentine proved to be serpentine-intolerant." From this the author draws the conclusion that the serpentine endemics within the section *Euclisia* of the genus *Streptanthus* have arisen by biotype depletion. Thus, with a few exceptions, the serpentine biotypes should be the only survivors of a once richer set of biotypes. Apparently, this serpentine endemic, which is mentioned by KRUCKEBERG as belonging to the "*depleted species*" type (STEBBINS 1942), will probably be classified as a serpentinicolous relic, according to the nomenclature used in the present paper.

The other type of endemics mentioned by KRUCKEBERG (citing STEBBINS 1942) is the insular species, viz., "those which have developed on an island or an isolated ecological habitat on a continent . . ." The three best known indicator species for the serpentine habitats in this area — *Quercus durata*, *Ceanothus jepsonii*, and *Cupressus sargentii* — are mentioned as good examples of the "*insular type*" of endemic. Apparently, they are typical serpentinophytes, as stated in this paper.

However, KRUCKEBERG did not deal only with narrow endemics. His cultivation experiment included ubiquitous plants growing on serpentine. He reports the results from experiments with *Gilia capitata* DOUGL., a complex species in which GRANT (1949) recognized six ecogeographical subspecies. KRUCKEBERG tested a type of *Gilia capitata* which grows in serpentine as well as non-serpentine soil. He states: "Beginning with the seedling stage, the reaction of serpentine and non-serpentine strains of *Gilia capitata* diverges into two distinct classes: serpentine-tolerant and serpentine-intolerant types. By maturity only the serpentine strains are seen to be doing well on the serpentine medium. Usually, even a serpentine strain fares better on the more fertile non-serpentine soil than on its native serpentine substratum. However, with *Gilia*, there is no such diminution of vigor." (KRUCKEBERG op. cit. p. 413.) Thus, the yields of dry matter of a serpentine-tolerant type on serpentine are quite similar to the yields on more fertile, non-serpentine soil. It is evident that in *Gilia* serpentine and non-serpentine races exist even on an infraspecific level.

Finally, KRUCKEBERG also tested the herbaceous perennial *Achillea borealis* BONG., well known for its ecotypic responses to climatic gradients (CLAUSEN *et al.* 1948). He states: "It occurs on serpentine throughout the central inner Coast Range areas, as well as on soils of almost all possible lithological origin . . . Consistent with the results presented above for the two annuals, the *Achillea* strains can be readily separated into serpentine-tolerant and serpentine-intolerant types . . . As with *Streptanthus* and *Gilia*, strains from serpentine localities are far more successful than non-serpentine strains when grown on the serpentine medium."

However, in the case of *A. borealis* the situation seems to be more complex: "Some non-serpentine strains of *A. borealis* show a partial tolerance to serpentine in that a few scattered individuals are able to perform just as well on serpentine as do the plants of a serpentine-tolerant strain. This sporadic tolerance of certain non-serpentine individuals suggests that some populations of *A. borealis* are more variable than others: That is, they may include biotypes that are potentially adapted to the more severe, selective serpentine habitat." Still more striking is the case of a coastal, non-serpentine strain showing an even more uniform tolerance to serpentine.

Thus, it seems probable that most of the plants thriving well on serpentine are true serpentine races, whether they show morphological differences or not, for in this case the fundamental problem must be physiological rather than morphological. However, KRUCKEBERG's results do not allow of any further general conclusions concerning the serpentine flora of, e.g., N Sweden since this is largely arctic-alpine and consists mainly of perennials. In regard to such plants, *Achillea borealis* showed that the problem is rather complex.

I have not, as yet, been able to make any corresponding cultivation experiments with the serpentine plants of N Sweden, which would have been very valuable. In our case, the difficulties connected with such an enterprise are considerable, because serpentine areas are only to be found in remote mountain districts far up in the North. Besides, the arctic-alpine origin of the serpentine plants in N Sweden makes it impossible to carry out cultivation experiments in botanical gardens in southern parts of the country where the climate differs a good deal from what is normal to these plants.

The serpentine floras of Central and South Europe are very rich in serpentinicolous endemics. Many of them have a clear epibiotic character and should be classified as serpentinicolous relics, e.g., *Forsythia europea*, *Halacsya sendtneri* (belonging to the borage family), and *Potentilla visiani*. The last one, a representative of the *Tanacetifoliae*-group, has quite an isolated position in Europe with regard to the morphology (Pichi-Sermolli op. cit., Braun-Blanquet 1951 p. 239).

Other serpentinicoles are likely to be neoendemics and should be classified as serpentinophytes. In addition to the two serpentine ferns already reported, *Asplenium adulterinum* and *A. cuneifolium* (*A. adiantum nigrum* var. *cuneifolium*), occasionally found outside serpentine and thus belonging to the category of preferential serpentinophytes, the following typical serpentinophytes from S Central Europe should be mentioned: *Dianthus capillifrons*, *Sempervivum pittonii*, *S. hillebrandtii*. (Braun-Blanquet op. cit. p. 239.)

In the serpentine areas of N Sweden we find, as always in serpentine, certain plants growing more abundantly and, sometimes also, more luxuriantly than anywhere else. Some of these serpentinicolous plants are easy to group in the categories of Pichi-Sermolli. Thus, the following distinct serpentine races may be characterized as typical serpentinophytes: *Cerastium vulgatum* var. *kajanense*, *Cerastium alpinum* var. *serpentinicola*, *Melandrium rubrum* var. *serpentinicola* and var. *smithii*, and *Viscaria alpina* var. *serpentinicola*.

Of these, the first may probably also be considered as a serpentinicolous relic — provided it has really evolved from the indigenous coastal race of *Cerastium vulgatum*, viz, var., *glabrescens* (cf. p. 55). However, since the different races of the *Cerastium vulgatum* complex are but little known, it is probably better to leave the question open as to the origin of var. *kajanense* and consider it as a serpentinicolous variety of the ubiquitous species complex only. In that case, it should be characterized as a serpentinophyte. The other serpentinophytes mentioned are serpentinicolous races of common species which are also represented on serpentine by other types than the varieties concerned here.

It is evident that northern serpentine areas, e.g., in N Sweden, are very poor in serpentinophytes as compared with more southern areas, e.g., in South and Middle Europe. While the serpentinophytes of northern areas differ only to a small extent from their original species, thus representing mere varieties, the southern ones are often so different that they are liable to be treated as new species or subspecies. This difference is easily realized by the fact that northern serpentine areas have been totally glaciated during the Pleistocene glaciations. Thus all serpentinophytes specific to these areas must have been differentiated in postglacial time. On the other hand, serpentinophytes from southern unglaciated areas may, in many cases, have grown in their present stations since the Tertiary (Pichi-Sermolli op. cit. p. 245).

The serpentine flora of N Sweden contains no representative of preferential serpentinophytes. A very typical representative of this category, the fern *Asplenium adulterinum*, the best known and most widespread of all European serpentinophytes, reaches N Europa but is not found in N Sweden. In Norway, *Asplenium adulterinum* is found on serpentine as far north as lat. 66° N. This locality is, however, situated near the sea level. As *Asplenium adulterinum* is limited to low altitudes at these northern latitudes, one cannot expect to find it in any serpentine area of N Sweden which are all situated above 300 m.

Except for the morphologically distinguishable serpentine races mentioned above, no other serpentinicolous plants within the whole of N Sweden are strictly limited to serpentine. However, many of them conform with the criteria of serpentinicolous relics, disclosing 1) disjunctive occurrences in serpentine localities, and 2) restriction to serpentine in certain areas but not in others. This holds true for the following plants: *Arenaria humifusa*, *Arenaria norvegica*, *Cerastium glabratum*, and *Agrostis stolonifera* (as regards its indigenous occurrences in the high mountains of Scandinavia). The reasons for considering them as serpentinicolous relics may be stated as follows, beginning with the most obvious example, *Arenaria humifusa*. Actually, this plant was never found on serpentine in N Sweden. Nevertheless, it will be discussed here since it was found on serpentine very close to the Swedish border.

The distribution of *Arenaria humifusa* comprises arctic N America from Alaska to Newfoundland, NW and S Greenland, Spitsbergen, and a few localities in Scandinavia. Its occurrence in Scandinavia was recently clarified by NORDHAGEN (1935). *Arenaria humifusa* was first collected by WAHLENBERG, in 1807, on the small mountain Unna Tuki south of Lake Virihaure in S Lule Lappmark, and a few years later described by him as a new species. This new species was later confused with other types of *Arenaria* and then vanished from the floristic literature. Accordingly, when next found in Scandinavia (on the Isle of Mageröya in northernmost Norway), this plant was first identified with the American *Arenaria cylindrocarpa* FERNALD. NORDHAGEN, the discoverer of this new plant, made clear the identity of *A. humifusa* WAHLENBERG and *A. cylindrocarpa* FERNALD. By revising herbarium collections of related species, NORDHAGEN was able to establish some more localities in N Norway.

For the present, ten localities of *A. humifusa* are known within Scandinavia. The bulk of them is situated in Finnmark, N Norway (mostly north of lat. 70° N). One locality, the Isle of Stjernöy, is characterized by gravels of olivine or gabbro. Most localities in this district are, however, situated on calcareous rock. The most eastern localities are situated on the Peninsula of Fiskarhalvön in Lapponia tulomensis (Russian Lappland). The two most southern localities in Scandinavia are very disjunctive and, contrary to all others, not situated in coastal districts.

Among specimens of *Arenaria norvegica* GUNN., collected by DAHL on Mt Krutvattsröddiken, a serpentine mountain near the church village Hattfjelldal in Nordland, Norway (lat. 65° 30′ N), NORDHAGEN also found specimens of *A. humifusa*. Krutvattsröddiken is situated in a large serpentine chain, stretching from Hattfjelldal to Lake Krutvattnet near the Swedish border, a distance of about 15 km.

In this area I found abundant occurrences of *Arenaria humifusa* south of Krutvattnet, about 7 km east of Krutvattsröddiken, very close to the Swedish border, and also southwest of Krutvattsröddiken, near the settlements of Krutå. This last locality is situated in the subalpine belt at an altitude of about 400 m. In all likelihood, more finds of *A. humifusa* will be made in this wide serpentine area in the future. On the Swedish side of the border, I have searched very carefully, though in vain, for this plant on the serpentine of Mt Atoklinten.

The only Swedish locality of *Arenaria humifusa* is Mt Unna Tuki in S Lule Lappmark. Apparently, this rare plant disappeared from WAHLENBERG's original locality where it has never been found again. In 1939 DAHLBECK found a new locality on a hillock below the southwestern slope of Mt Unna Tuki. About a hundred individuals were observed growing in weathered soil from calcareous "schist" (SELANDER 1943 and 1950 II).

Serpentine outcrops are rather common south of Mt Unna Tuki, but their flora is still uninvestigated. SELANDER (1950 p. 132) assumed the station of *A. humifusa* on Unna Tuki to be secondary, the primary ones being probably situated on the adjacent serpentine hills. However that may be, we maintain with certainty that *A. humifusa* in its southern, isolated, and very abundant area northeast of Hattfjelldal is strictly limited to serpentine.

In E North America a parallel exists. We also find there a southern, isolated area of distribution with an abundant occurrence restricted to the serpentines of Mt Albert and W Newfoundland. In Gaspé a few localities also exist outside serpentine, in so far as *A. humifusa* grows very sparsely on moist, alpine, calcareous cliffs. One locality in the lowland is of particular interest, viz., at Coppermine in the valley of York River (DANSEREAU & RAYMOND 1949). As is evident from the name, this locality is connected with an outcrop of copper ore. This is an interesting phenomenon which will be discussed in a later chapter (p. 105). Outside this southern centre, the nearest localities are situated in N Labrador, at the east coast of Hudson Bay, and in the district of Lake Mistassini. These abundant, isolated occurrences on serpentine of a very rare plant with doubtless epibiotic character (cf. NORDHAGEN 1935) are very good illustrations of the conception of serpentinicolous relics.

In the Scandinavian mountain flora another, more common and widespread representative of the genus *Arenaria*, occurs—*A. norvegica* GUNN., which I am placing also in the category of serpentinicolous relics. The Scandinavian distribution of this plant is clear from the map in Fig. 48 (next page).

This plant is rather characteristic of unstable ground, and is generally limited to calcareous weathered gravels (limestone, dolomite and calcareous schists). In addition, it also occurs in serpentine soil growing there almost more abundantly and luxuriantly than anywhere else (cf. p. 47). In some serpentine areas local-populations exist differing from the type race by a more slender growth, a bright green colour, and by forming large, dense tufts (cf. p. 108).

As is clear from the map, the Scandinavian distribution of *Arenaria norvegica* has a bicentric tendency. A more or less bicentric distribution is characteristic of many Scandinavian alpine and subalpine plants and is considered to be characteristic of glacial survivors (cf. HULTÉN 1950). When only other localities than serpentine are considered, the bicentric distribution becomes even more apparent. In other words, *Arenaria norvegica* is mainly restricted to serpentine in the area including Jämtland and S Lappland. This constitutes the gap between the two centres of the bicentric plants. The occurrence of *Arenaria norvegica* in that area in serpentine is not particularly remarkable since this kind of rock is rather common there. However, the fact that hardly any locality is to be found on other kinds of rock, though parts of this area are very rich in calcareous schists (Köli-schists), is more noteworthy. Even more remarkable is, perhaps, the finding of *Arenaria norvegica* in Jämtland, south of Ånnsjön and in the parish of Frostviken in very small, isolated serpentine outcrops in the conifer forest region.

The assumption of an earlier continuous distribution in the Scandinavian mountain range seems more probable than a long distance dispersal to these small, isolated areas. In early postglacial time, when large areas of "new soil" hastily appeared through the melting of ice and the draining of ice-dammed lakes, a plant like *Arenaria norvegica* with claims to bare soil must have had a good chance of a wide distribution. Through an invasion of climax vegetation, this pioneer may have become extinct from large areas, except in a few localities where it survived thanks to certain edaphic conditions. This would suggest that mainly the serpentine populations survived there.

The map of the recent distribution of *Arenaria norvegica* shows a much more abundant occurrence of this plant in the northern parts of the Scandes than in the southern. Thus, *Arenaria norvegica*, with a few exceptions, is restricted to serpentine south of lat. 66° N. The northern non-serpentinous area of *A. norvegica* coincides well with the area of the northern unicentric and the northern area of the bicentric plants. Like many bicentric plants, *Arenaria norvegica* is rather sparse in S Norway (see Fig. 48).

The increasing difficulties of survival of this plant in the southern parts of the Scandes may be due to intense competition in late postglacial time. In view of the fact that *A. norvegica* is mainly a low-alpine plant, it is clear that the strong invasion of forest communities and southern plants during warm postglacial periods must have created highly unfavourable conditions for *Arenaria norvegica* in the southern parts of the Scandes (cf. NORDHAGEN 1935, p. 141).

A similar type of distribution is also shown by *Cerastium glabratum*. This plant is rather common in N Norway (Troms and Finnmark) and in N Lappland (Torne and Lule Lappmark) where it is mainly calcicolous (cf. ARWIDSSON 1943 and SELANDER 1950 II). In S Lappland (Åsele and Lycksele Lappmark) and Jämtland, *C. glabratum* occurs very constantly and abundantly in almost every alpine serpentine outcrop. Also in this case the serpentine populations are characterized by a markedly slender growth (cf. p. 52). In this area, *C. glabratum* is not found outside serpentine, except in a few stations

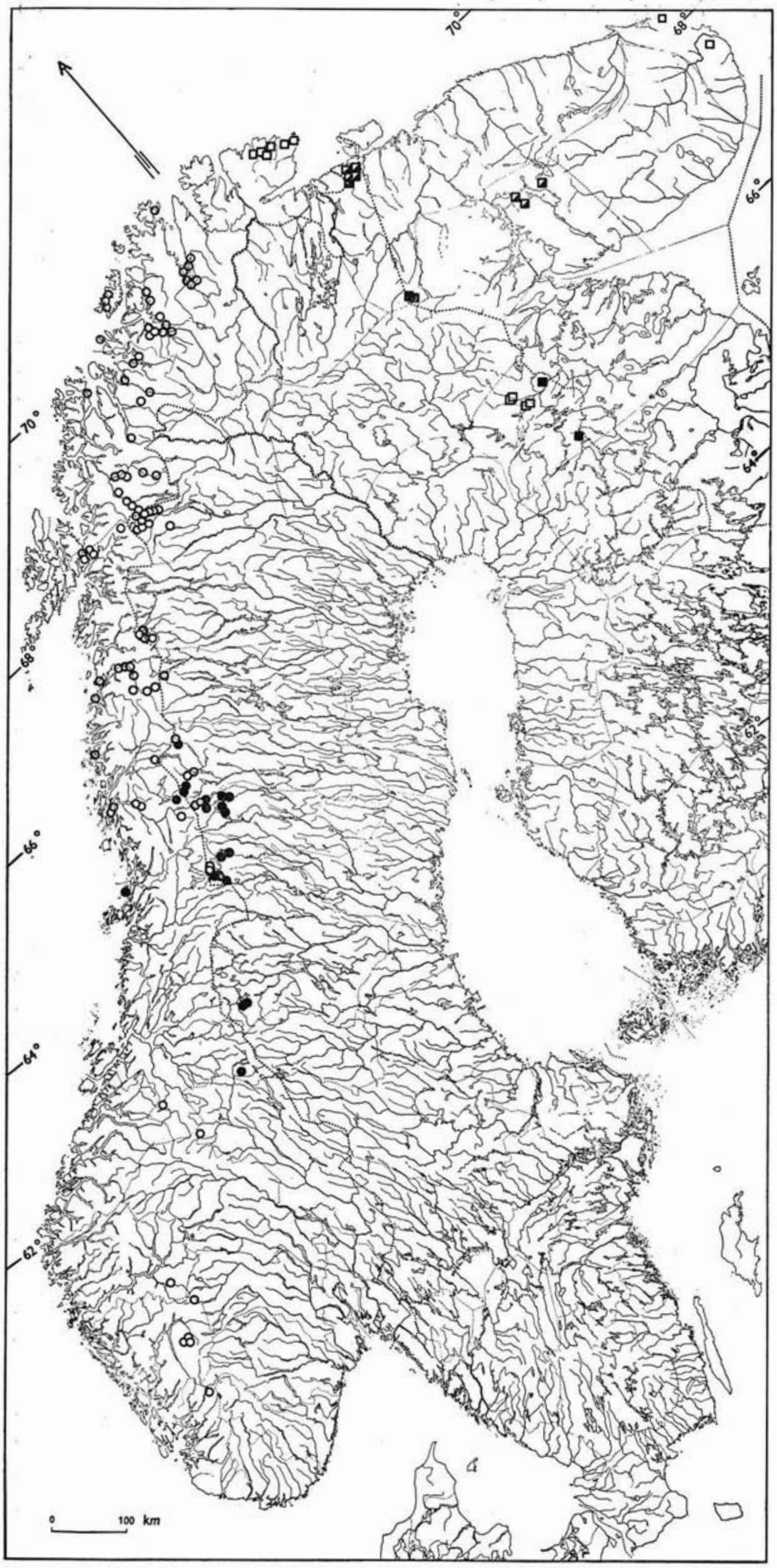


Fig. 48. Distribution in Fennoscandia of *Arenaria norvegica* (dots and circles) and *A. ciliata* ssp. *pseudofrigida* (squares). Dots and black squares denote occurrences on serpentine and peridotite, open circles and squares occurrences on other rocks. Half-filled squares denote occurrences of *A. ciliata* ssp. *pseudofrigida* on basic eruptives other than ultrabasics. Distribution of *Arenaria norvegica* revised and supplemented after NORDHAGEN (1935); *A. ciliata* ssp. *pseudofrigida* according to information from M. J. KOTILAINEN.

of the high mountain districts of SW Jämtland and adjacent parts of Härjedalen, viz., Mt Helags and Mt Sylarna (cf. ARWIDSSON 1943 p. 199). In the high mountain districts of S Norway this plant seems to reappear on other soils. In Finland, *C. glabratum* has a very isolated station on the periodotite of the district of Panajärvi (E Finland at about lat. 65° N), now USSR territory. It also appears disjunctively in the serpentine areas of the lowlands of Finnish Lappland (cf. p. 91).

Agrostis stolonifera may be mentioned as a fourth representative of the serpentinicolous relics of the serpentine flora in N Sweden. In the high mountains of Scandinavia, this plant was earlier known to grow indigenously only on the shores of a few large lakes in Lappland (Torneträsk and Virihaure). This type has been named, *in schedis*, var. *arctica* by WESTERGREN and ssp. *inundatum* by SELANDER (cf. SELANDER 1950 II p. 8).

When listing the flora of the serpentines of N Sweden, I noticed very rich occurrences of certain biotypes of *Agrostis stolonifera* in several serpentine areas from different parts of Lappland and N Jämtland. In connection with a caryo-systematic study of the genus *Agrostis*, S. O. BJÖRKMAN, Uppsala, has cultivated and examined also the serpentine biotypes of *Agrostis stolonifera*. His results have not as yet been published, but according to verbal information the serpentine biotypes can hardly be distinguished from the aforementioned shore biotypes. The only ecological factor common to these two types of localities is the relatively feeble competition. The shore localities are situated in N Lappland, far from serpentine areas, thus rendering quite impossible any direct communication between serpentine and shore localities via water streaming from surrounding mountains.

If we consider the *Agrostis stolonifera* populations from the serpentines and the mountain-lake shores to be identical from a taxonomic point of view, their occurrence in these two extreme types of localities can be explained only by assuming them to be epibiotics surviving only in localities with a low competition. Many other shore and coastal plants are known to appear disjunctively in serpentine areas far from shores and coastal districts, respectively, viz., *Asplenium adiantum nigrum*, *Sagina nodosa*, *Armeria maritima*, *Silene maritima*, *Plantago maritima*, and others, cf. pp. 90, 91.

The possibility of classifying the above-mentioned serpentinicoles of N Sweden according to PICHI-SERMOLLI's system is fairly evident. The status of the remaining plants seems more doubtful. Such plants as *Asplenium viride*, *Molinia coerulea*, *Viscaria alpina* s. str., *Silene acaulis*, *Melandrium rubrum* s. str., *Minuartia biflora*, and *Luzula spicata*, are clearly serpentinicolous. Yet, they do not fit into either of the categories mentioned above. Their serpentine populations do not differ morphologically from other ones of these species, nor are any considerable distributional disjunctions manifested by these common plants. These plants seem to belong to a category of their own, for which I have proposed the name *serpentinicolous ubiquists* (cf. p. 81). However, this holds true exclusively with regard to N Sweden. Such plants as *Molinia coerulea* and *Minuartia biflora* appear disjunctively on serpentine outside Sweden and may be classified as serpentinicolous relics there (cf. pp. 56, 90).

Although the character of a narrow disjunction does not necessarily differ in principle from that of a wider one, a true serpentinicolous relic always presupposes a considerable disjunction. However, as regards the narrow disjunctions of several relatively ubiquitous plants on serpentine, they may be referred to as local serpentinicolous relics. Thus *Molinia coerulea* is a rather ubiquitous and abundant plant in all Fennoscandia. However, it seems to show a preference for serpentine within different parts of Europe. I have ascertained this in N Finland, Sweden and Norway. The literature gives similar information from Italy (PICHI-SERMOLLI op. cit.), the Danube Valley (KRETSCHMER op. cit.), and Bosnia (CONRATH 1887). In the serpentine of N Sweden, *Molinia* is also very common, even in very dry localities.

However, outside serpentine, *Molinia* occurs in the mountain districts as an exclusive mire-plant. On the large serpentine area of the Isle of Rödön on the west coast of Norway (Tjötta, at lat. 66° N), *Molinia* is extremely abundant, though, as far as I was able to see during my short visit, totally lacking in the vicinity. Accordingly, *Molinia* appears locally as a serpentinicolous relic in Fennoscandia. Still, it should not actually be considered as such, in view of its marked frequency and the narrow disjunctions.

Another type of local disjunction is shown on serpentine by plants which are not usually serpentinicolous but appear incidentally — generally with a comparatively small disjunction — in one (or a few adjacent) serpentine areas. This is illustrated by e.g. *Minuartia rubella* which has two large occurrences on the two adjacent serpentine mountains, Murfjället and Graipesvare in Åsele Lappmark (about lat. 65° N). This plant has a bicentric distribution in Scandinavia with a large northern area reaching southwards to about lat. 66° N and a southern area in S Norway. These isolated serpentine localities, being the southernmost in Sweden, are situated more than 100 km from the nearest stations on calcareous ground.

Two other bicentric plants, *Draba nivalis*, and *Euphrasia lapponica* present the southernmost occurrences of their northern areas on calcareous serpentine at Graipesvare and Murfjället, respectively. With the exception of another locality on calcareous serpentine about 10 km north of Murfjället, *Euphrasia lapponica* also has its nearest occurrence about 100 km further north. *Draba nivalis*, however, occurs about 50 km north of Graipesvare.

From Finland another example could be mentioned, viz., *Dianthus superbus*, which has an isolated locality on serpentine rock in N Karelia about 200 km from its nearest localities. Still another example can be given from Norway. The fern *Asplenium adiantum nigrum*, which occurs within the outermost coastal districts of the west-coast of S Norway, has an isolated locality in the district of Sunmöre, growing on serpentine quite distant from the sea (Björlykke op. cit.).

In several papers (1926, 1927, 1928a) on the flora of serpentine in the Austrian Alps, Lämmermayer pointed out the fact that the serpentine flora contains basicolous as well as acidicolous plants. He calls particular attention to the remarkable fact that the acidicolous heather, *Calluna vulgaris*, is common on serpentine together with the basicolous *Erica carnea*. A similar condition is noted in regard to *Alnus viridis* and *Pinus montana*. The *Calluna-Erica* association has also been described from other parts of S Europe, Serbia (Pančič 1859) and Italy (Pavarino 1914). Lämmermayer mentioned that serpentine soil, being poor in mineral nutrients and having an alkaline-neutral reaction, combines the properties of non-calcareous and calcareous soils, and he presents this fact to explain the above circumstances. These problems will be discussed further on, but the distribution of acidicolous and basicolous plants within N Swedish serpentines will be treated briefly here.

It emerges from the list of plants on pp. 50–76 that the preponderant part of all plants found on serpentines in N Sweden has a wide ecological amplitude and must be regarded as nearly indifferent to soil reaction. However, several plants characterized as calcicolous are also included in the serpentine flora. It is a simple matter of observation that in localities with serpentine mixed with calcite the number of calcicolous plants has on the whole increased. This is true, for example, in several parts of Graipesvare, where plants such as *Dryas octopetala*, *Draba nivalis*, *Minuartia rubella*, *Euphrasia lapponica*, *Carex rupestris*, *Carex atrata*, *Carex capillaris*, and *Selaginella selaginoides* are more or less abundant. Of these, *Dryas octopetala*, *Carex rupestris*, *Carex atrata*, *Carex capillaris*, and *Selaginella selaginoides* are found in localities with a calcium content in the soil of only approx. 1 % CaO. However, none of these were found in serpentine soil where the calcium content is as a rule very low (< 1 % CaO). In this pure serpentine soil with hardly any calcium content, several plants commonly characterized as calcicolous are also to be seen, e.g. *Asplenium viride*, *Carex glacialis*, *Silene acaulis*, *Arenaria norvegica*, *Cerastium glabratum*, and *Campylium stellatum* among bryophytes, and *Caloplaca elegans* among lichens.

On the other hand, markedly acidicolous plants are abundant in the alkaline-neutral serpentine soil, viz., *Calluna vulgaris*, *Deschampsia flexuosa* and the bryophyte *Rhacomitrium lanuginosum*. These plants very often grow side by side with the calcicoles *Asplenium viride*, *Silene acaulis*, and *Cerastium glabratum*.

Whether this divergence from the usual behaviour shown on serpentine by several plants is due to the existence of particular races is a complex problem that cannot be solved without extensive cultivation experiments.

The xerophytic character of the serpentine flora is emphasized by many authors. This character is comparatively independent of climatic conditions, and is due to the serpentine rock and soil which creates a dry and warm micro-climate. As to the serpentines of N Sweden, the dry character is caused by the most markedly convex arching of the serpentine outcrops, and the rich occurrence of vertical systems of crevices (cf. Fig. 9). The warmth is moreover due to some extent to the pronounced arching which subjects at least the south exposure to strong irradiation by the sun. To this may be added the high heat capacity of the serpentine rock (according to RINNE 1908, serpentine and dolomite 0.24, sandstone 0.21, basalt 0.20, granite 0.19).

For example, the vegetation of the serpentine areas in Moravia consists mainly of a steppe with *Festuca glauca*, *Stipa capillata*, and *Sesleria calcarea* (SUZA 1928). Xerophytes are also dominant within the serpentine area in the Danube Valley described by KRETSCHMER (op. cit.), viz., *Festuca glauca*, *F. ovina*, *Genista pilosa*, etc. PICHI-SERMOLLI (op. cit.), in his comprehensive paper on the vegetation of the serpentine areas of the upper Tiber Valley in Tuscany, described several markedly xerophytic plant communities.

LÄMMERMAYER (1927) pointed out that, in the Austrian Alps, the thermophilous plants, *Potentilla arenaria*, *Teucrium chamaedrys*, and *Tunica saxifraga*, reach much higher altitudes in serpentine habitats than is usual. Still another example may be given: the northernmost localities in Europe of the thermophilous mediterranean fern *Notholaena maranthe* are situated in serpentine areas in the Danube Valley and at Mohelno in SW Moravia.

The typical serpentine vegetation of N Sweden has also a xerophytic character. The most extreme serpentine vegetation is found in localities with a dry micro-climate, viz., at low altitudes and at the summits and south-exposed parts of the rocks. In moist localities, e.g., north-exposed sides of the rocks, the serpentine soil is usually covered by a layer of humus or peat, varying from a few to some 10 cm in thickness (Fig. 10). This enables several plants which cannot grow in pure serpentine soil to grow in serpentine localities. However, typical serpentine vegetation is always characterized by more or less xerophytic plants, e.g. ericaceous shrubs, viz., *Calluna vulgaris*, *Empetrum hermaphroditum*, *Vaccinium uliginosum*; xerophytic graminids, viz., *Festuca ovina*, *Molinia coerulea*, *Juncus trifidus*; and also herbs with deeply descending root systems, viz., *Silene acaulis*, *Rumex acetosa*, and *Viscaria alpina*.

The tendency of serpentine to maintain thermophilous plants is clear from the fact that south exposures of rather small serpentine cliffs often harbour the same thermophilous elements as the big south-bluffs of other rocks, so-called sydberg. Among plants which are more or less thermophilous within the mountain district of N Sweden and found on south-exposed slopes of serpentine hills (not alpine), the following may be mentioned: *Polypodium vulgare*, *Woodsia ilvensis*, *W. alpina*, *Silene rupestris*, *Sedum annuum*, and the mosses *Leucodon sciuroides*, *Thuidium abietinum*, and *Tortula ruralis*.

It is noteworthy that the serpentine floras of N Sweden and other parts of N Europe are rich in representatives of the family *Caryophyllaceae*. No other families are nearly so well represented in the serpentine floras there. A similar condition seems to prevail in the serpentine areas of E Canada. In the serpentine areas of E Quebec, Gaspé Peninsula, and W Newfoundland, there are no less than 8 clearly serpentinicolous representatives of the Caryophyllaceae: *Arenaria humifusa*, *Minuartia* (*Arenaria*) *rubella*, *M. marcescens*, *M. biflora*, *Viscaria alpina*, *Silene acaulis*, *Stellaria longipes*, and *Cerastium arvense*. In more southern serpentine areas, viz., in Central and South Europe, the dominance of the family *Caryophyllaceae* seems far less striking. This is mainly due to the increasing importance of such large families as *Leguminoseae* and *Compositae* in these parts.

2. Flora of other, mainly northern, serpentine areas outside Sweden

A. Norway.

Practically all the serpentine areas of N Sweden are situated in the Scandinavian Mountain Range (the Scandes), and the serpentine flora of N Sweden therefore derives from an alpine flora. Serpentine areas also occur in the Norwegian part of the Scandes. The flora of these alpine serpentine areas of Norway does not differ essentially from that of similar areas in N Sweden.

In Norway serpentine also occurs in several places in the coastal districts. For example, considerable serpentine areas occur in the district of Sunmöre (S Norway at lat. 62° N). The flora of these areas, which was described by B. Björlykke (op. cit.), differs in composition in some respects from the serpentine flora of N Sweden. Thus the serpentine flora of Middle Europe is represented by the serpentine fern *Asplenium adulterinum* which grows together with other representatives of the genus *Asplenium*, viz., *A. adiantum nigrum*, *A. trichomanes*, and *A. viride*.

Arabis petraea Lam. is a very common plant in the serpentine areas of Sunmöre, occurring there in no less than 13 different areas. Outside serpentine, this plant has only one locality at Sunmöre. It has a rather peculiar distribution in Fennoscandia: a main area in S Norway (Rogaland to Möre and Romsdal, east to Opdal) and further some other, disjunctive occurrences, viz., at the coast of the Bothnian Sea (Sweden, province of Ångermanland, approx. lat. 63° N), and at the northern part of Lake Onega in East Fennoscandia. Outside Fennoscandia, *Arabis petraea* is known from Scotland, Iceland, and the mountains of Middle Europe. In Russia, closely related species occur east of the Petschora river (Hultén 1950). This scattered distribution points to an epibiotic character and, at least in Scandinavia, this plant grows exclusively in localities with low competition — shore or river gravels and scree. Thus *Arabis petraea*, being very abundant in the serpentine of Sunmöre, can no doubt be characterized as a serpentinicolous relic in this area. The serpentine areas of Sunmöre also have some serpentinicolous plants in common with the serpentine areas of N Sweden, viz., *Asplenium viride* and *Viscaria alpina* var. *serpentinicola.* According to Björlykke, *Molinia coerulea* is also very characteristic of these serpentine areas.

I had the opportunity to visit a more northern serpentine area on the Norwegian coast, the Isle of Rödön (Tjötta in Nordland, lat. 66° N), where serpentine rocks emerge from the sea level up to an altitude of about 300 m. This serpentine area is situated at the same latitude as the majority of the serpentine of N Sweden. The flora, however, has but a few species in common: *Asplenium viride*, *Molinia coerulea*, *Viscaria alpina* var. *serpentinicola*, *Cerastium alpinum*, *Calluna vulgaris*, and the moss *Rhacomitrium lanuginosum.* The vegetation of the Rödön serpentine is above all characterized by *Molinia coerulea* and *Rhacomitrium lanuginosum*, with *Lotus corniculatus* and *Polygala vulgaris* forming a richly coloured pattern in the uniform mat. Some shore plants, *Plantago maritima*, *Armeria maritima*, *Sagina nodosa* and *Silene maritima*, although far from the sea shore, are also common there. In this serpentine area *Asplenium adulterinum* has its northernmost occurrence in Europe.

B. Finland.

An arctic-subarctic serpentine lowland-flora is also recorded in North and Middle Finland where rather small serpentine outcrops occur in Lapponia Kemensis, Lapponia Inarensis, Ostrobottnia Kajanensis (about lat. 64° N), and N Karelia (about lat. 63° N); all situated at an altitude of 100–400 m.

The flora of some serpentine areas of Finnish Lappland has been briefly described by Mikkola (1938). The characteristic plants of these serpentine areas are also common on serpentine in N Sweden, viz., *Asplenium viride*, *Viscaria alpina*, *Cerastium alpinum*, *Minuartia biflora*, *Campanula rotundifolia*, and *Molinia coerulea.* Mikkola also mentions a very disjunctive occurrence of *Arenaria ciliata* from a serpentine area near the Russian border in the district of Tuntsajoki. *Arenaria ciliata*, in this case no doubt identical with *A. ciliata* ssp. *pseudofrigida* OSTENF. & DAHL, is a very rare, arctic plant restricted in Fennoscandia to the far northeastern parts (see map Fig. 48). As shown in Fig. 48 this plant appears disjunctively on serpentine not only in Finnish Lappland but also in Kuusamo. According to KOTILAINEN (verbal information), who later visited some of these areas, MIKKOLA's statement concerning *Cerastium alpinum* probably refers to *C. glabratum* which is abundant there.

In the Karelian serpentine areas the southern serpentinophyte *Asplenium adulterinum* was found (KOTILAINEN 1921). Another serpentinophyte from E Central Europe (Moravia) has been found in some serpentine areas of the province of Ostrobottnia Kajanensis, *Cerastium vulgatum* var. *serpentini* (NOVÁK) GARTNER. Another serpentinicolous race of this species, *C. vulg.* var. *kajanense* KOTIL. & VEERA SALMI was recently described from this district (KOTILAINEN & SALMI 1950).

This second variety was also found in two different places in N Sweden, viz., Rönnbäck in S Lappland and Gäddede in N Jämtland. Some of the most abundant plants of the serpentines of Middle Finland are also common to the serpentine areas of N Sweden: *Asplenium viride*, *Viscaria alpina* var. *serpentinicola*, *Molinia coerulea*, and the mosses *Campylium stellatum* and *Weisia viridula*. Another moss, *Brachythecium velutinum*, is also characteristic of the serpentine in Finland (KOTILAINEN 1944). However, it has not as yet been found in the serpentine areas of N Sweden. Besides the very typical serpentinicolous relic of N Karelia, *Dianthus superbus*, mentioned earlier in this paper (p. 88), some more plants with a similar disjunctive occurrence on N Karelian serpentines might be mentioned, viz., *Sedum telephium*, *Sagina nodosa*, and the alpine plants *Cerastium alpinum* and *Saxifraga nivalis*. In this connection also two arctic mosses may be mentioned, *Bryum nitidulum* and *B. arctogaeum* occurring in lowland serpentine areas in the province of Ostrobottnia Kajanensis (KOTILAINEN 1944).

Apparently, the similarity between the serpentine floras of N Sweden and North and Middle Finland seems more marked than that between N Sweden and the coastal districts of Norway.

C. North America.

Another serpentine flora from an area with a climate much like that of N Fennoscandia is found in E Canada. The largest and best known serpentine area there is Mt Albert in the Gaspé Peninsula (E Quebec, about lat. 49° N). The flora of this serpentine mountain was described by FERNALD (1907), RAYMOND (1949), SCOGGAN (1950), and others. In the summer of 1951, I personally visited Mt Albert and was able to compare its serpentine flora with that of Scandinavia.

Next to Table Top, Mt Albert is the highest and broadest mountain top of the Shickshocks, which in the Gaspé Peninsula form the northernmost region of the Appalachian mountain system. Mt Albert consists of serpentinized peridotite surrounded by dark amphibolite. The very wide plateau-like summit (about 5 km in breadth) varies in elevation from approx. 1 100 to 1 230 m. The border between amphibolite and the serpentine appears distinctly as a sharp vegetation boundary (Fig. 49). Thus, amphibolite is everywhere covered by a close growth of low shrubby spruce and balsam fir, while the wide barren serpentine area possesses an arctic-alpine flora quite peculiar to itself; the ground as well as the vegetation is reminiscent, above all, of the arctic tundra or high alpine areas. The ground shows a very typical congeliturbation pattern (BRYAN 1946), viz., stone polygons with fine materials in their centres (Fig. 50).

On the highly congeliturbate soil in the centre of the polygons, *Arenaria humifusa*, *Minuartia* (*Arenaria*) *rubella*, *M. marcescens*, and *Artemisia borealis* grow in abundance. At peripheral, more stable, parts, *Rhododendron lapponicum*, *Vaccinium uliginosum* var. *alpina*, *Carex scirpoidea*, and sometimes *Silene acaulis* are very common. In places less exposed to the wind and therefore protected by snow during winter, the intensive frost action decreases; in the places where the soil does not dry out as extremely, a tundra-like vegetation will prevail. The soil is covered by mats of *Rhacomitrium lanuginosum* in which occur especially, *Viscaria*

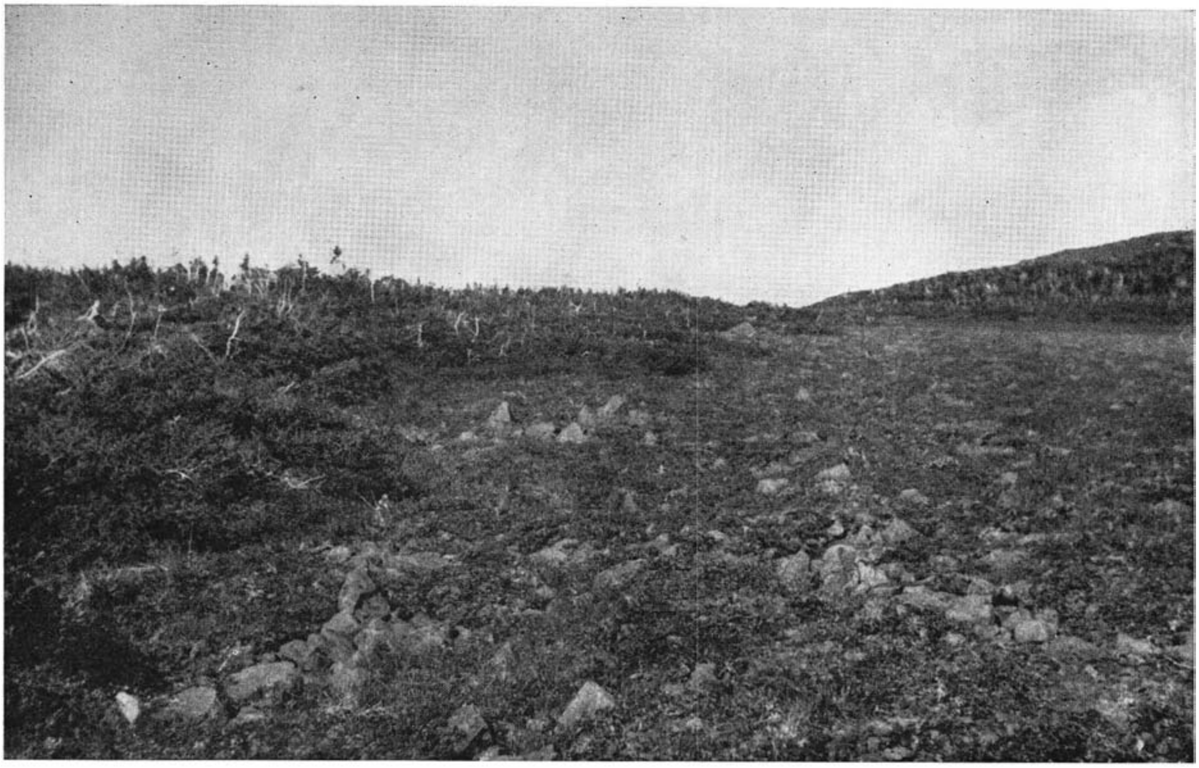


Fig. 49. In the northern part of the Mt Albert top plateau, the border-line between amphibolite and serpentine appears as a sharp vegetation boundary. Dense mats of low shrubby spruce and balsam fir covering amphibolite cease directly on reaching serpentine. This serpentine harbours a vegetation rather reminiscent of arctic tundra with, *Arenaria humifusa, Minuartia marcescens, M. rubella, M. biflora, Armeria scabra* ssp. *labradorica, Artemisia borealis, Betula glandulosa, Carex scirpoidea, Ledum groenlandicum, Rhododendron lapponicum, Vaccinium uliginosum* var. *alpina, Viscaria alpina,* etc. Note congeliturbation pattern of boulder rings. Gaspé, Que., Canada. Photo Olof Rune 29.7.1951.

alpina, Armeria scabra ssp. *labradorica, Scirpus caespitosus, Deschampsia caespitosa, Campanula rotundifolia, Ledum groenlandicum, Betula glandulosa,* and *Salix brachycarpa.* Thus, on the serpentine plateau a tundra-like vegetation extends with arctic plants predominating. Many of these occur very disjunctively on Mt Albert and similar serpentine areas in W Newfoundland; beyond these places they are not found south of N Labrador.

The extreme alpine character of the Mt Albert serpentine tableland is edaphically conditioned, mainly because of its extremely congeliturbate soil. The mechanical composition of the serpentine soil, combined with its scanty vegetation, seems always to cause a considerable congeliturbation in alpine serpentine areas. On Mt Albert this tendency is largely increased because of the horizontal serpentine bedrock situated a few feet below the surface of the soil. Thus, the bedrock there plays a role similar to the permafrost of the arctic tundra, which delays the disappearance of the water.

From the southern edge of the serpentine tableland a deep gorge — Devil's Gulch — stretches towards the centre (Fig. 51). Its steep walls and talus harbour a serpentine flora different from that of the plateau. Three very interesting ferns, *Polystichum mohroides* var. *scopolinum, Cheilanthes siliquosa,* and *Adiantum pedatum* var. *aleuticum,* can be found in crevices and behind boulders. The two grasses *Festuca scabrella* and *Danthonia intermedia,* also seen there, are of particular interest as regards distribution.

Finally, there is one plant growing abundantly everywhere on the serpentine of Mt Albert, viz., a very distinct, angustifoliate serpentine race of *Cerastium arvense*, which may possibly correspond to *C. arvense* f. *serpentini* Novák from E Central Europe. It is difficult to decide from the meagre description given by Novák (1928 p. 48) to what extent these races are similar. Except on Mt Albert the American serpentine race is found also in the serpentine areas of Megantic Co, S Quebec. Yet it is not found in the serpentine areas of W Newfoundland. In the more southern serpentine areas of E North America, e.g., the Conowingos of SE Pennsylvania, it is replaced by another serpentine race of *Cerastium arvense*, *C. arvense* var. *villosissimum* Pennel.

The serpentine variety of *Cerastium arvense* mentioned above is the only typical serpentinophyte of the Mt Albert serpentine. However, *Minuartia marcescens* (Fernald) House, extremely abundant on the Mt Albert serpentine may probably be considered a preferential serpentinophyte, closely related to *M. obtusa* of the West (cf. Fernald 1925). It is a St. Lawrence Gulf endemic found only on Mt Albert serpentine and in W Newfoundland, growing on serpentine and magnesian limestone barrens.

Most of the plants typical of the Mt Albert serpentine can be characterized as serpentinicolous relics. Thus, one group includes the arctic plants, reaching its southern limit in E North America in the serpentine areas of Mt Albert and W Newfoundland. Such plants are: *Armeria scabra* ssp. *labradorica*, *Viscaria alpina*, *Minuartia biflora*, *Artemisia borealis*, *Arenaria humifusa*. The four first-mentioned, in particular, appear very disjunctively in the serpentine areas of Mt Albert and W Newfoundland, which are their only localities in E North America outside the arctic region. Apparently, these plants, occurring together with other arctic-alpine plants of wider distribution, e.g. *Carex scirpoidea*, *Minuartia rubella*, *Rhododendron lapponicum*, *Ledum groenlandicum*, *Vaccinium uliginosum* var. *alpina*, grow there on account of the edaphic, "arctic" conditions created by the serpentine soil.

However, there is also another group of plants on Mt Albert, showing another type of disjunctive distribution. It comprises the members of what was called the Cordillera-group by Fernald (Fernald 1925). This group consists of species with a generally wide western distribution, ranging mostly from Alaska to the Rocky Mts, and represented in E North America in but a few localities in the St. Lawrence Gulf region. The fern *Polystichum mohroides* var. *scopolinum* has its only E North American locality on Mt Albert. This fern has a scattered distribution in the West, ranging from Idaho and Montana to S California. However, it is a very rare plant known only from about ten localities. This variety represents one of the geographic races of the subantarctic species *Polystichum mohroides*, which is distributed northward along the Andes of S America.

Another fern of the Mt Albert serpentine, *Adiantum pedatum* var. *aleuticum* occurs mainly from Kamtchatka and Alaska to California and the Rocky Mts, where it is rather typical of alpine basic rocks. However, in its E North American area, ranging from Newfoundland to N Vermont, it is restricted to peridotites (serpentine, asbestos). In W Newfoundland it also has a few localities on other magnesian rocks.

The third serpentine fern of Mt Albert also belongs to this group of distribution. Thus, *Cheilanthes siliquosa*, which is rather sparse on Mt Albert but more abundant in the Black Lake serpentine area of S Quebec, is a Cordilleran plant ranging from S British Columbia to NW Wyoming, N Utah and S California, generally growing on magnesian or limestone rocks (Fernald 1950, St. John 1937). Like many other plants belonging to this distributional group, it also has an isolated station in the Great Lakes region, viz., at the Bruce Peninsula, Ontario, growing on dolomitic limestone.

All three ferns mentioned above are, undoubtedly, typical serpentinicolous relics. The question whether these ferns are relics from a once wider eastern area of distribution, or whether the eastern serpentine stations result from long distance dispersal, cannot be easily decided. As these ferns are also represented by serpentine populations in the West and, like all ferns, have very light diaspores, the latter possibility cannot be excluded. However, this problem does not affect their status as serpentinicolous relics, because this concept refers mainly to

Fig. 50. The Mt Albert top forms a wide serpentine plateau at about 1200 m altitude. Its scanty vegetation is extremely alpine including several arctic plants, reaching the southernmost outposts of E North America in this locality, viz., *Arenaria humifusa*, *Minuartia biflora*, *Armeria scabra* ssp. *labradorica*, *Artemisia borealis*, *Viscaria alpina*. The alpine character is edaphically conditioned, and is largely due to pronounced solifluction and frost heaving effects in soil, producing conditions in ground similar to arctic and high-alpine areas. Note congeliturbation pattern of boulder rings. Gaspé, Que., Canada. Photo Olof Rune 29.7.1951.

their present existence in isolated, ecologically very specific areas outside which they cannot survive (cf. p. 81).

Besides these ferns, also some other serpentine plants on Mt Albert belong to the same distributional group. Thus the tall, beautiful grass *Festuca scabrella*, rather abundant on Mt Albert, is widely distributed in the Cordillera from British Columbia and Alberta to Oregon, N Dakota, and Colorado. It also occurs disjunctively in the Great Lakes region. In Gaspé, it is also found sparsely in two localities outside the serpentine. In W Newfoundland, it is found on serpentine and limestone barrens. In addition, its E North American area comprises a rich occurrence in the Black Lake serpentine area in Megantic Co, S Quebec.

A rather similar distribution is shown by another grass, *Danthonia intermedia* VASEY, which extends from Kamtchatka, Alaska, Yukon, and Manitoba southward to California and New Mexico, and with isolated areas in the Great Lakes and the St. Lawrence regions. In Gaspé only one locality exists outside the Mt Albert serpentine, viz., in a calcareous subalpine meadow at Table Top, adjacent to Mt Albert. In W Newfoundland, *Danthonia intermedia* is confined to serpentine and magnesian limestone. However, in E Labrador it is found in meadows as well as on peats and gravel (FERNALD 1950).

Another example is the small grey-pubescent willow, *Salix brachycarpa* NUTT., which grows in abundance on the Mt Albert serpentine. Furthermore, this willow is also found in this region on limestone gravels on Anticosti Island. However, its wide main area extends from Ungava to N British Columbia, and southward to Manitoba, Saskatchewan, Colorado, Utah, and Oregon (FERNALD 1950).

In the Longe Range Mts in W Newfoundland, some large serpentine areas occur, i.e. southwest of the port of Corner Brook. FERNALD (1911) once botanized there and mentions the flora of this serpentine area as being much the same as on Mt Albert. This is confirmed by recent studies by E. ROULEAU. Thus, *Armeria scabra* ssp. *labradorica*, *Viscaria alpina*, *Arenaria humifusa*, *Minuartia marcescens*, *M. rubella*, *Silene acaulis*, *Artemisia borealis*, *Festuca scabrella*, *Carex scirpoidea*, and *Adiantum pedatum* var. *aleuticum* are common to both areas. However, some plants very typical of Mt Albert serpentine are lacking on the serpentine of W Newfoundland, e.g. the ferns *Polystichum mohroides* var. *scopolinum* and *Cheilanthes siliquosa*, as well as the serpentine race of *Cerastium arvense*, and *Salix brachycarpa*.

Fig. 51. Devil's Gulch, the deep gorge stretching from the southern edge towards the centre of the Mt Albert table-land. Its steep walls harbour several endemic and disjunctive plants restricted to this part of the mountain, e. g., three ferns with main distribution in the West: *Polystichum mohroides* var. *scopolinum*, *Cheilanthes siliquosa*, and *Adiantum pedatum* var. *aleuticum*. Bottom of valley is forested with shrubby spruce and balsam fir. Gaspé, Que., Canada.
Photo Olof Rune 12.8.1951.

In the northernmost parts of the Appalachians, serpentine also occurs in S Quebec, viz., at Black Lake in Megantic Co, about 160 km E of Montreal. Unlike Mt Albert these areas, which I visited in 1951, are not alpine at all. Outside the serpentine, spruce forests (*Picea alba* and *P. mariana*) dominate; but as is usual on serpentine, pine is by far the most common tree, being represented here by the red pine (*Pinus resinosa*). Although rather sparse in this district, it occurs abundantly in the serpentine areas. In this district the serpentine outcrops form rather small isolated and steep summits. They are, apart from cliffs and talus, more or less wooded. The most typical serpentine vegetation appears on the scree and among boulders in the steep talus parts. The following plants are found there: *Cheilanthes siliquosa*, *Adiantum pedatum* var. *aleuticum*, *Carex scirpoidea*, *Festuca scabrella*, *Stellaria longipes*, *Campanula rotundifolia*, and *Juniperus communis* var. *depressa*. In the crevices of the cliffs are found *Minuartia rubella* (= *Arenaria rubella*), and also the same serpentine race of *Cerastium arvense* as is common on Mt Albert. This latter plant is the only typical serpentinophyte within this district, and, as on Mt Albert, the bulk of the serpentinicolous plants is likely to be composed of serpentinicolous relics.

Thus, we find in the Black Lake district some of the members of FERNALD's Cordillera-group discussed above in connection with Mt Albert, viz., *Cheilanthes siliquosa*, *Adiantum pedatum*, var. *aleuticum*, and *Festuca scabrella*. The three arctic or arctic-alpine plants *Carex scirpoidea*, *Minuartia rubella* and *Stellaria longipes* within this comparatively low and southern district, are, invariably restricted to serpentine, and are very good examples of serpentinicolous relics.

When comparing the vegetation and flora of the serpentine areas of E Canada and N Sweden, the following points become evident:

1) *Superficially, a great resemblance exists between the vegetation of, e.g., the alpine serpentine area of Mt Albert and any corresponding area of N Sweden.* This resemblance is, above all, due to the very abundant occurrence of *Rhacomitrium lanuginosum* and to the intensive frost action in the soils, together causing physiognomically rather similar plant communities in both areas.

2) *The following serpentinicolous plants of Mt Albert are also more or less serpentinicolous in Scandinavia:*

Viscaria alpina, occurring as a serpentinicolous relic on Mt Albert and W Newfoundland, is clearly serpentinicolous in Scandinavia, though it is a rather common and widespread alpine plant here. The American population of *V. alpina* was distinguished by FERNALD as a var. *americana*. However, the difference is only due to the size (var. *americana* is somewhat taller), and does not seem very distinctive.

Arenaria humifusa and *Minuartia rubella* (= *Arenaria rubella*) are serpentinicolous relics in the serpentine area of Mt Albert. Both occur in N Scandinavia as serpentinicolous relics, though much more sparsely (cf. pp. 84, 88). *Minuartia rubella* is a very polymorphous species in N America, and, according to my own observations, the Mt Albert specimens are rather different from what I have observed in Scandinavia. To a certain extent this is true also of *Arenaria humifusa*.

Silene acaulis may probably be characterized as a serpentinicolous relic on Mt Albert and in W Newfoundland, but it does not seem to be as important on serpentine there as in Scandinavia. On the whole, this plant is far more common in Scandinavia. The E American population belongs to var. *exscapa*.

Armeria scabra ssp. *labradorica* is a very typical serpentinicolous relic on Mt Albert and in W Newfoundland. According to IVERSEN (1940), this plant is identical with *A. scabra* ssp. *sibirica*, which is, for instance, known from Mt Peldsa in northernmost Scandinavia. This arctic race is monomorphic and differs in that respect from the common Scandinavian sea shore plant *Armeria maritima* (MILL.) WILLD. which shows a marked pollen and style dimorphism. However, the latter seems to grow abundantly in Norwegian coastal serpentine areas, even quite far from the sea shore (cf. p. 90).

Finally, the following plants may be mentioned: *Scirpus caespitosus*, *Deschampsia caespitosa*, *D. flexuosa*, and *Vaccinium uliginosum*. They are rather abundant on Mt Albert, but cannot be considered as particularly serpentinicolous, being, no doubt, omnipresent plants in this area. Thus, they have much the same mode of occurrence as in Scandinavia (serpentinicolous ubiquists).

3) *The following serpentinicolous plants of Mt Albert occur in Scandinavia, but only as non-serpentinicolous ones:*

Rhododendrom lapponicum, which is extremely abundant on Mt Albert, is also found, though very sparsely, on two other adjacent mountain tops in Gaspé. Although *Rhododendron* is a rather common alpine plant, at least in the northernmost parts of Scandinavia (about north of lat. 66° N), it is not found on serpentine. Actually, most serpentine areas in Scandinavia are situated south of the distribution area of *Rhododendron*. Still, the distance is comparatively inconsiderable and in view of the serpentinicolous character of this plant in E Canada it is remarkable not to find it as a serpentinicolous relic also in Scandinavia like, e.g., *Arenaria humifusa* and *Minuartia rubella*.

Furthermore, *Carex scirpoidea*, which is rather serpentinicolous in E Canada, has a single locality in Scandinavia, though not on serpentine.

Stellaria longipes appears to be serpentinicolous in the Black Lake district of E Quebec. In Scandinavia, this complex species is represented by a certain type, distinguished by HULTÉN (1943) as an individual species, *Stellaria crassipes* HULTÉN. However, this very rare plant was never found in connection with serpentine.

Finally, *Cerastium arvense*, which is represented in serpentine areas of E North America by some special serpentine races, appears in Central Europe as a highly serpentinicolous plant. Still, this species hardly reaches N Fennoscandia as an indigenous plant.

4) *The following serpentinicolous plants of Fennoscandia occur as non-serpentinicolous plants in E Canada:*

Asplenium viride, the most common and widespread of all serpentinicolous plants in Fennoscandia, is completely lacking in the serpentine areas of E Canada, even though it occurs on calcareous rock in the arctic-boreal parts of America. Actually, this fern seems to be more common and widespread in Europe than in America, and the European population is apparently richer in biotypes. In Europe, *Asplenium viride* lives under a variety of climatic conditions, because its area comprises all N Europe as well as the mountains of Middle Europe. In N Europe it is strictly basicolous (serpentine, calcareous rocks), while in Middle Europe it is classified as indifferent (HEGI I p. 27). The American distribution is mainly arctic and alpine (Alaska to Labrador and Newfoundland, and in the West along the mountains to Colorado, Utah, and Washington, with isolated outposts southward to Vermont, New York, Ontario, and Wisconsin).

Cerastium alpinum seems to be quite a parallel. In N Europe it is a very common alpine plant which sometimes occurs in the lowland as a "glacial relic". As a whole, it is a very polymorphous species with a wide ecological amplitude. Some of its races are highly serpentinicolous (cf. pp. 52–54, 67), and representatives of *C. alpinum* sens. lat. are seldom lacking in any alpine serpentine area of N Sweden. In N America this species is strictly arctic, and in the East it does not occur south of Newfoundland (cf. FERNALD 1950). Thus, it does not reach Gaspé. However, it is represented there by its close ally, *Cerastium beeringianum* (*C. alpinum* var. *beeringianum*) which is found in a few localities, all outside serpentine.

In this connection also *Minuartia biflora* could be mentioned. This circumpolar species is highly serpentinicolous in Fennoscandia. In America, where usually referred to as *Arenaria sajanensis*, it is widely distributed in the Arctic and Mt Albert has been recorded as its southernmost outpost in the East. I found only very few individuals of *Minuartia biflora* (*A. sajanensis*) on Mt Albert and in spite of its disjunction it gave the impression of being far less serpentinicolous here than in Fennoscandia.

To sum up: a comparison between the serpentine floras of Fennoscandia and E Canada demonstrates fairly clearly the well known fact that a certain species may have different ecological claims or amplitudes, in different (or at least sufficiently remote) parts of its distributional area. This apparently also holds true concerning such homogeneous species as *Asplenium viride* and *Rhododendron lapponicum*. More light is shed on these problems when the results obtained by KRUCKEBERG (1951) are taken into account. As mentioned previously he demonstrated, by cultivation experiments with *Streptanthus* sp. and others, that the ability to grow on serpentine was confined to a certain "biotype". The offspring of specimens which had not grown on serpentine did not thrive when cultivated in serpentine soil. However, the results from other cultivated plants were not so informative (for a further discussion, cf. p. 82). In the light of this fact, the varying ability of a plant to grow on serpentine in one part of its distributional area, but not in another, may be explained by the distribution of its serpentine-tolerant biotypes. After all, not so few species show a similar inclination towards serpentine within two widely remote parts of their distributional range, e.g., *Viscaria alpina*, *Arenaria humifusa*, *Minuartia rubella*, and *Silene acaulis*. It is remarkable that all these, though ecologically similar, are morphologically somewhat different in Scandinavia and E North America.

Actually, the serpentine of Mt Albert is not the only area in Gaspé which harbours rare plants with a disjunctive distribution; some of them are also found on a few other mountains, e.g., on Table Top and Mt Logan, on the calcareous sea-cliffs of the north shore, and on the gravels of river flats near the mouths of the great rivers of the south coast (e. g., Cascapedia, Bonaventure, and Grand River). Moreover, plants with a similarly disjunctive distribution (FERNALD's Cordillera-group) also occur on Anticosti and Mingan Islands. As a whole, the area all around the Gulf of St. Lawrence seems to be a centre of plants with a disjunctive distribution.

In a classical phytogeographic study — "Persistence of plants in unglaciated areas of boreal America" — FERNALD (1925) explained the rich flora of the Gaspé Peninsula as the result of an incomplete glaciation of the Gaspé mountains during the Wisconsin glaciation. However, this nunatakk-theory of FERNALD was founded on incomplete botanical and geological evidence, and further investigations do not seem to confirm his theory (cf. WYNNE-EDWARDS 1939). This complex problem cannot be dealt with here. Only a few points relating to serpentine will be briefly considered.

Mt Albert is by far the richest locality of Gaspé for the many arctic and Cordilleran plants which appear there more or less disjunctively as serpentinicolous relics. Since serpentine areas everywhere in boreal and subarctic areas — and even in once heavily glaciated districts — are rich in serpentinicolous relics, it is not necessary to assume incomplete glaciation as the cause of the very particular flora of Mt Albert. Moreover, the serpentine areas of Black Lake, which are situated in a once heavily glaciated district, also harbour serpentinicolous relics, some of which are found also on Mt Albert (cf. p. 95).

As mentioned above, rare plants occur in Gaspé, not only on serpentine but also in some other types of localities, as follows: 1) calcareous, easily weathered schists in alpine situations, e.g., Table Top and Mt Logan (on Table Top the rare plants are not found on the very top, which is granitic, but on the surrounding tops which are built up of schists); 2) bluffs and talus of limestone, calcareous schists or conglomerates on the steep north coast of the peninsula, e.g., Mt St. Pierre, Anse Pleureuse, Cape Bon Ami, Percé, and Bonaventure Island; 3) river flats and delta deposits of the rivers of the south coast. In W Newfoundland the rare plants are found on limestone and magnesian limestone barrens as well as on serpentine. On Mingan and Anticosti Islands, limestone cliffs and gravels harbour the interesting elements.

Besides a basic soil reaction, these different types of localities have a certain property in common — a property which is also characteristic of serpentine: they are not occupied by closed plant-communities. The vegetation is kept at the pioneer stage by the instability of the soil — combined with the infertility in the case of serpentine. In a study of the ecology of rare plants, GRIGGS (1940) declared that "rare plants are rare, because they cannot compete". He states that epibiotics can only survive in localities free from hard competition. According to him, the St. Lawrence Gulf region has numerous such localities, which would account for the many rare plants there. However that may be, the rare Gaspé plants are undoubtedly concentrated to pioneer habitats without a closed vegetation. At all events, the Gaspé flora, so rich in epibiotics, demonstrates that serpentinicolous relics are quite equivalent to other epibiotics in that they are all confined to habitats with a low competition.

In E North America, serpentine areas also occur at more southerly latitudes. Thus, along the Piedmont Plateau, from New England to N Carolina, a series of serpentine outcrops are to be seen, the Conowingo Barrens. PENNEL (1911, 1912) studied the flora of the Conowingo Barrens within Chester Co in SE Pennsylvania, and I had personally the opportunity to visit these areas in July 1951. As they were never reached by the Wisconsin ice, these serpentine areas look rather different from what I have seen in more northern districts. The serpentine rock is almost everywhere covered by weathered soil. However, the serpentine is distinguishable from its vegetation. The surrounding hardwood forest ceases as soon as it reaches the serpentine which is either totally destitute of trees, or sparsely forested by pine (*Pinus rigida*) and bushes of *Quercus marylandica*. Besides, the vegetation is above all characterized by the big tussocks of *Deschampsia caespitosa*, between which a more or less bare soil occurs. The bare soil patches are sometimes attractively coloured by a beautiful little plant, *Phlox subulata*, which is characteristic of some of these serpentine areas.

PENNEL (1912) found a group of 17 species restricted to serpentine in this section of the Piedmont area. According to him, the following elements are represented in this group: 1) northern or Alleghanian plants appearing disjunctively or reaching their southern limit in the Conowingo Barrens, viz., *Sporobolus heterolepis, Atheropogon curtipendulus, Galium boreale, Deschampsia caespitosa, Carex bicknellii*; 2) southern, coastal plain species reaching their northern limit here, viz., *Quercus marylandica, Asclepias verticillata, Phlox subulata*; 3) plants with very disjunctive localities in the Conowingo Barrens, occurring in widely remote areas over most of the Eastern States, viz., *Panicum annulum, Sphenopholis obtusata* var. *pubescens, Scutellaria parvula* var. *ambigua*; 4) *Talium teretifolium* and *Cerastium arvense* f. *oblongifolium* (TORR) PENNEL, which are practically confined to serpentine in the East, but are adapted to other xerophytic habitats within the western parts of their range, Minnesota to Colorado. Finally, at least one typical serpentinophyte is endemic in one of the serpentine barrens of Chester Co, viz., *Cerastium arvense* var. *villosissimum* PENNEL. This variety is very long-haired, of depressed growth, and forms widely spreading mats (cf. p. 110).

As might have been expected, the serpentine flora of the Conowingo Barrens differs considerably from that of E Canada. Considering that the Conowingo flora has only a few endemics but many serpentinicolous relics, we may add that there is a clear resemblance to the northern serpentine floras. This may seem remarkable since the Conowingo Barrens in question are situated south of the range of the Wisconsin ice. However, the distance is rather inconsiderable (some hundred km) and the area has certainly undergone great changes in climate.

As mentioned before, a recent report on the serpentine flora of the Central Coast Range in California is given by KRUCKEBERG (op. cit.). He characterizes these serpentine areas as very rich in endemics. Further, he states that these serpentine endemics represent two major types, and, as discussed previously (p. 82), they probably correspond to serpentinophytes and serpentinicolous relics, respectively. According to KRUCKEBERG (op. cit.), the three best known indicator species for the serpentine habitats of this district — *Quercus durata*, *Ceanothus jepsonii*, and *Cupressus sargentii* — may be interpreted as good examples of the "insular type" of endemics which correspond with our concept of the serpentinophytes. Examples of the other type of endemics, the "depleted species" type, may be found in the section *Euclisia* of the cruciferous genus *Streptanthus*. According to our nomenclature, this type of endemic may belong to the serpentinicolous relics.

The vegetation of the Coast Range serpentine areas is of the chaparral type and dominated by the above-mentioned serpentine-endemic shrubs, such as *Ceanothus jepsonii*, *Quercus durata*, and *Garrya congdonii*, as well as by the non-endemics, *Adenostema fasciculatum*, *Photinia arbutifolia* and *Pinus sabiniana* (KRUCKEBERG op. cit.).

In this connection, some remarks may be made on the large serpentine areas of the northeastern parts of Cuba, since they will be referred to in later pages (p. 118). A paper on the vegetation of the large serpentine mountain, Sierra de Nipe, in that area was published by CARABIA (1945). He mentions that from this area sixteen endemic genera and a large number of species have been described, representing about 80 % of the total flora.

Many of these are characterized as relics, "but there is no doubt that here, also on this serpentine soil, we are in the presence of a great center of neo-endemic or vicarious species being mainly selected by local edaphic phenomena" (CARABIA op. cit. p. 325). Apparently, the number of serpentinophytes on the tropical mountain of Sierra de Nipe is enormous as compared with northern areas. To a certain extent, this high number of endemics may also be explained by the geographical isolation of these mountains. In other southern serpentine areas the number of endemic serpentine plants is far less.

From Italy and Albania, PICHI-SERMOLLI mentioned about twenty serpentinophytes and about the same number of serpentinicolous relics (PICHI-SERMOLLI op. cit.). From E Central Europe and the Balkan Peninsula, NOVÁK mentioned about sixty species, varieties and forms which he considers "certainement rigoureusement liées pour leur existence et leur développement favourable au sol des roches serpentiniques ou magnesitiques" (NOVÁK 1928, p. 57).

From this it is clear that the flora of serpentine strikingly emphasizes the general fact that the lands of the northern hemisphere, which were covered by the Pleistocene ice sheets, are conspicuously poor in endemics (cf. CAIN 1944, p. 216).

D. East Asia.

Finally, some very recent notes on the serpentine flora in Japan (KITAMURA & MOMOTANI 1952, and KITAMURA & MURATA 1952) will be considered where an interesting serpentine flora is outlined which, apparently, has several general features in common with the serpentine floras mentioned previously.

In the serpentine area of Sugashima Island, Prov. Shima, the dominant species are dwarf *Pinus thunbergii* and *Buxus microphyllus* var. *japonicus*. *Salvia isensis* is mentioned as a serpentine plant common in the area, though not as yet found outside serpentine, appearing as a distinct species with villose petioles and stems. *Thymus quinquecostatus* is abundant on the serpentine rocks of this area, situated at about 100–200 m. In Hondo, the same species occur on denudated rocks at 1000–2000 m. *Enkianthus perulatus* var. *japonicus* is mentioned as a relic in this area. Other dominant species are *Pertya glabrescens*, *Dicranopteris dichotoma*, *Miscanthus* *sinensis, Swertia japonica, Atractylodes japonica, Rhododendron sanctum, Malus toringo, Chrysanthemum makinoi, Wikstroemia sikokiana, Berberis thunbergii, Lilium japonicum, Viburnum erosum,* and *Fraxinus sieboldiana.*

In the serpentine area of Awa, Shikoku, *Spirea blumei* is mentioned as an indicator of serpentine, being very abundant on this kind of rock, though not restricted to it. This plant is rare elsewhere in Japan. In the same areas, *Saussurea nipponica* ssp. *yoshinagi* and *Lilium japonicum* var. *abeanum* are mentioned as endemic serpentine races. "The former seems to be a relic and deformed in this area. The latter seems to have been selected in this area" (loc. cit. p. 122). The authors especially studied the association dominated by *Pinus densiflora* and *Enkianthus perulatus* var. *japonicus*, in the area near Sakushiu village. In this area, situated at 650 m, *Sciadopitys verticillata, Thujopsis dolabrata,* and *Pinus parviflora* are found as relics. *Buxus microphyllus* var. *japonicus, Pertya glabrescens, Wikstroemia trichotoma, Berberis thunbergii, Smilax china, S. sieboldii, S. oldhami, Rhododendron reticulatum, R. metternichii, R. macrosepalum* and *Pieris japonica* are common in this area.

From the above, we may conclude that, even in this part of the world, pine is the dominant tree on serpentine. In principle, this particular serpentine flora is rather reminiscent of the others mentioned above, being rich in relics, neoendemics, and disjunctive elements. However, it differs from the serpentine floras of Europe and E North America by a lack of caryophyllaceous plants among its characteristic species.

3. Flora of different kinds of magnesian rock

It was previously mentioned that the unique flora of serpentine is more or less common to all ultrabasic rocks. In the upper Tiber Valley, Pichi-Sermolli (op. cit.) found that the flora of other ultrabasic (ofiolitic) rocks than serpentine disclose serpentine features, though to a less pronounced degree. In the previous chapter the flora, as well as the principal rock composition, of the ultrabasic rock areas of N Sweden, studied by the author, were reported. From this it became clear that differences exist between different ultrabasic rocks as regards their effect on plant life. The following may be briefly deduced from these observations.

Among the ultrabasic rocks of N Sweden some do not harbour a characteristic serpentine vegetation. They are as follows:

1) *Serpentine rocks containing considerable amounts of calcium.* When the serpentine rocks contain calcium as carbonate, the serpentine character of the vegetation will be largely decreased. Calcium as silicate is far less effective (cf. p. 114).

2) *The Kall peridotite* (p. 12), which holds olivine and some biotite, but no serpentine. Furthermore the chromium content in this rock is very low.

3) *The peridotites of Ammarfjällen,* especially the areas near the peak St. Ålke and the tarn Sråttekjaure, which consist of unaltered olivine, chlorite, tremolite, and some carbonate, etc. (cf. p. 40). The nickel content is very low, while the chromium content is normal of serpentine. It must be emphasized that these areas are situated at a comparatively high altitude (1400 and 1200 m, resp.), a fact which probably may alone prevent the occurrence of many serpentinicolous plants.

4) *Mt Aunevare and Mt Vuoka-Ruopsok,* two of the largest peridotitic outcrops in N Sweden (cf. pp. 24, 42), consist mainly of unaltered olivine and do not harbour a typical serpentine flora. The same applies to some small olivine outcrops (cf. pp. 19, 37, 40).

5) *The soapstone occurrences of N Frostviken* which do not generally harbour a typical serpentine vegetation. Still, as in olivine, serpentinicolous plants may also be found there, though less abundantly (cf. pp. 13, 14).

As a general observation it may be stated that the "serpentine character" of the vegetation on peridotitic rocks seems to increase with increasing serpentinization of the rock. To a certain extent, this is due to differences in weathering. Thus, with increasing serpentinization the rock usually weathers more easily, and gives rise to a serpentine soil which harbours the typical serpentine flora. On the other hand, the unaltered olivine is extremely resistant to weathering, and the olivine rocks often seem nearly destitute of soil and vegetation (see Pl. VIII). However, also another difference between serpentine and olivine rocks, of definite importance to vegetation, may be considered. The solubility of nickel and probably also chromium compounds seems to increase with increasing serpentinization. The effect of these factors will be discussed in greater detail in a later chapter (cf. p. 119).

Soapstone also has a chemical composition rather similar to that of serpentine and olivine. As to the vegetation, soapstone is much like olivine rock; it is very resistant to weathering and does not produce any considerable amount of soil. However, when soil occurs, e.g., in talus parts below steep cliffs or where the rock has been crushed by quarrying, serpentinicolous plants and even serpentinophytes may be found (cf. pp. 14, 15).

In addition to the ultrabasics, another mineral rich in magnesium, viz., magnesite, may be discussed in this connection. This is composed of a rather pure magnesium-carbonate. In nature, magnesite occurs in about the same way as serpentine, though more sparsely. The flora of the magnesite rocks has not been studied to any great extent. However, LÄMMERMAYER, in connection with his studies of the serpentine flora of the Austrian Alps, also directed his attention to the flora of magnesite. In his last papers (1928a,b, 1934), he made a comprehensive comparison of the floras of serpentine and magnesite. He pointed out that magnesite occurs much more sparsely than serpentine in his area, and that the vegetation of many magnesite outcrops was destroyed by quarrying. For this reason the flora of the magnesite was not studied as closely as that of serpentine.

LÄMMERMAYER arrived at the result that the flora of magnesite does not correspond to that of serpentine, though they have several features in common. According to him, the flora of magnesite is intermediate between that of serpentine and that of limestone. In his area the majority of the serpentinicolous plants, e.g., *Asplenium adulterinum, Asplenium cuneifolium, Dianthus capillifrons, Sempervivum pittonii* (cf. p. 83), and many other are found also in magnesite, even though *very sparsely.* As in serpentine, basicolous and acidicolous plants, e.g., *Calluna vulgaris* and *Erica carnea* also grow together in magnesite. The flora of magnesite differs from that of limestone by a decrease in the number of species and by containing acidicolous plants as well. It differs from the serpentine by harbouring serpentinicolous elements only occasionally, and to a limited extent.

Dolomite rocks (carbonate of calcium and magnesium) have a flora which is generally quite reminiscent of the limestone flora (cf. BRAUN-BLANQUET 1951 p. 235). However, in the mountains of Spain and in the S Alps several plants occur which seem restricted to dolomite. This chiefly applies to epibiotics of the Tertiary age, occurring within very limited areas only. They are all confined to stations on debris or barren soils and rocks where they have no doubt survived owing to edaphic conditions created by the dolomite rocks. Hence, these dolomite relics should be compared particularly to the serpentinicolous relics. The epilithical vegetation of cryptogams (notably lichens and algae) on dolomite rocks differs in general from that of limestone, and harbours communities peculiar to the dolomite (BRAUN-BLANQUET op. cit. p. 236).

Some of the plants which appear as serpentinicoles in the serpentines of Gaspé and W Newfoundland may occasionally be encountered also on the dolomite barrens of W Newfoundland or in the Great Lakes region (cf. p. 93). Such plants are, e.g., *Adiantum pedatum* var. *aleuticum, Cheilanthes siliquosa, Danthonia intermedia, Festuca scabrella, Minuartia marcescens.* But for the last one, they are all clear epibiotics.

In N Sweden, G. BJÖRKMAN (1937) studied the flora of a magnesite outcrop at Mt Äpartjåkko in the national park of Sarek in N Lule Lappmark, N Lappland (about lat. 67° N). His short paper is of great interest in this connection because it is

Fig. 52. Limestone barrens at northern end of Lake Ältsvattnet in parish of Sorsele, Lycksele Lappmark, are seemingly reminiscent of serpentine outcrops. This may be due to scanty vegetation with comparatively few species viz., *Dryas octopetala* and *Carex rupestris*, being the only dominant plants. Lappland, Sweden. Photo Olof Rune 12.8.1949.

the only statement on the magnesite flora from Scandinavia, and affords an opportunity to draw a superficial comparison between the floras of serpentine and magnesite in the mountain districts of N Sweden.

It is evident from BJÖRKMAN's study that the magnesite flora of Äpartjåkko is more similar to that of limestone than to that of serpentine. The resemblance to the latter is limited to the occurrence of the following rather ubiquitous plants: *Festuca ovina*, *Juncus trifidus*, *Silene acaulis*, *Vaccinium uliginosum*, and *Rhacomitrium lanuginosum*. In addition, this magnesite locality maintains a very rare plant, *Carex incurva* LIGHTF., which appears there rather disjunctively. In Scandinavia, it is mainly an Atlantic sea-shore plant, in Norway occurring also on sandy river flats in the high mountains. Apart from a recent anthropochorous dispersal from the Norwegian coast along the railroad to Abisko, the Äpartjåkko magnesite is the only locality of *Carex incurva* known in the high mountains of N Sweden.

On the other hand, several typically serpentinicolous plants are lacking in the magnesite locality, viz, *Asplenium viride*, *Rumex acetosa*, *Cerastium glabratum*, *Viscaria alpina*, *Calluna vulgaris*, and many more. Besides, several calcicolous plants also occur in the magnesite locality which, according to BJÖRKMAN, contains about 10 % calcium carbonate. Such are, e.g., *Carex rupestris*, *Dryas octopetala*, *Rhododendron lapponicum*.

Magnesite is very rare within the mountain districts of N Sweden. Apart from this occurrence in the national park of Sarek, there is, as far as I know, only one more occurrence of importance in Lappland, situated at Mt Tarrekaise about 100 km south of Mt Äpartjåkko. The flora of this magnesite area has never been closely studied. However, some observations of SELANDER, who studied the flora of that district, makes probable that the flora of the Tarrekaise magnesite, too, resembles that of limestone.

I have not had the opportunity to study the flora of magnesite personally, but impressions gained from BJÖRKMAN's paper convince me that it is very similar to that of pure limestone, such as I have found it in the district of NW Lycksele Lappmark, S Lappland (about lat. 66° N). There the crystalline limestone crops out in the same way as serpentine, forming arched domes at the 800 m level (Fig. 52). These limestone rocks are very dry and barren, and their vegetation consists mainly of *Dryas octopetala* and *Carex rupestris*, and also of sparse *Saxifraga aizoides*, *S. oppositifolia*, *Festuca ovina*, *Vaccinium uliginosum*, *Asplenium viride*, *Euphrasia lapponica*, and *Draba norvegica*. This flora is also very reminiscent of that on dolomite. (See G. E. DU RIETZ 1925 b, Plate 23 b.)

The outcrops of ultrabasics, magnesite, dolomite, and crystalline limestone generally form so-called barrens, i.e. dry, strongly exposed ridges or rocks with scanty vegetation. The floras of all such barrens seem to have a superficial resemblance, caused by a relative poverty of plants, species as well as individuals. This poverty may be explained partly by the dry character of all these habitats, and partly by the one-sided composition of these rocks, causing a deficiency in several elements necessary to plants. Yet the meagre floras of the above barrens often contain rare plants, being epibiotics appearing disjunctively or as endemics. All these rocks have a high heat capacity (cf. p. 89) that may contribute to a warm micro-climate, and they all produce basic soils.

However important these factors may be for epibiotics, the main thing for these plants is the occurrence of bare mineral soil.

Similar traits between the floras of serpentine, magnesite, dolomite, and limestone no doubt exist, the most important one being caused by the ability of these rocks to harbour epibiotics owing to a resistance to the invasion of a climax vegetation.

4. Plants connected with other specific minerals

It is a well known fact among geologists and mining engineers that certain minerals can be traced by the occurrence of certain plants. This seems particularly to apply to ores containing heavy metals, e.g., copper, lead, zinc, nickel, etc. Such plants have been known for a long time in Central Europe. In the German literature, they are called "schwermetallhold", and are chiefly associated with zinc ores, especially calamine (zinc carbonate and silicate).

In the calamine soils of Europe, i.e. in Belgium, Poland, Germany, and Austria, a certain violet, *Viola calaminaria* LEJ. (*V. lutea* var. *multicaulis* KOCH), grows in abundance. This plant is not entirely restricted to calamine soil, but is always plentiful there, occurring in such localities very disjunctively. Another calamine plant with a similar distribution is *Thlaspi calaminare* LEJ. et COURT. Both these plants may be regarded as chemomorphoses derived from *Viola lutea* and *Thlaspi alpestre*, respectively, and may correspond to the serpentinophytes (serpentinomorphoses) within the serpentine flora (cf. p. 108). Also some other plants, viz., *Minuartia* (*Alsine*) *verna*, *Silene inflata* var. *glaberrima*, and *Armeria maritima*, occur abundantly in certain calamine areas (cf. HEGI 1918 V p. 607, SCHIMPER 1898).

SCHWICKERATH (1931) studied the vegetation of calamine soils near Aachen (cf. BRAUN-BLANQUET 1951 p. 240). He found a strange calamine vegetation on soils containing 0.35–4.57 % Zn, and 0.06–1.7 % Pb. However, the ash analyses did not show any Pb content in the calamine plants, while, e.g., 21.3 % ZnO was found in *Thlaspi calaminare*. It was demonstrated that the content of lime in the calamine soil also affected the vegetation. The calamine soils near Aachen are high in lime and have a basic soil reaction, while those at Mt Hartz are low in lime. The real calamine soils near Aachen are destitute of trees and shrubs but have a closed climax vegetation which is rather similar to the *Bromion* alliance. Because of the occurrence of special calamine plants, viz., *Viola calaminaria, Thlaspi calaminare, Armeria maritima* var., *Silene vulgaris, Minuartia verna, Festuca ovina*, SCHWICKERATH (op. cit.) described this calamine vegetation as a distinct alliance (*Violion calaminariae*).

The calamine vegetation at Mt Hartz differs from the above by the absence of *Viola calaminaria. Armeria maritima* is represented here by a particular race, var. *halleri*, restricted to heavy-metal soils and, apparently, more closely related to the coastal type-race of *A. maritima* than to the more continental var. *elongata* (IVERSEN 1940). At Mt Hartz, *Minuartia verna, Armeria maritima* var. *halleri*, and *Cardaminopsis halleri* are also reported from other ores than calamine, viz., slag and ores of copper and lead (HEGI 1918 V:3 p. 1890). However, these ores may probably hold also small amounts of zinc.

In Finland, *Minuartia verna* was found in an isolated locality at Impilahti. KOTILAINEN (1944) assumed this locality to be connected with the veins of skarn-minerals occurring in this area. In Derbyshire, England, *Thlaspi alpestre, Minuartia verna* and similar calamine plants grow on the lead veins (holding small amounts of zinc) of the fluorspar occurrences. *Minuartia verna* followed the fluorspar imported to Norway from this district, now thriving on zinc ore at the loading place of a melting mill at Odda, SW Norway (NORDHAGEN 1930). *Minuartia verna* is a rather polymorphous species and the ore plants certainly represent a distinct race of this large species.

It is an interesting fact that some calamine plants — or related species — simultaneously seem to be more or less serpentinicolous (cf. LÄMMERMAYER 1927 p. 49). Thus, different races of *Armeria maritima* s. lat. appear as serpentinicoles in Scandinavia (p. 90), Austria, SW Moravia and E Canada (p. 92). *Thlaspi alpestre*, which is the original type of *Th. calaminare*, is abundant on serpentine in Austria and Bosnia. *Silene inflata* var. *glaberrima* is a calamine plant (see above), while *S. inflata* var. *glauca* is a serpentinicole from Austria (LÄMMERMAYER 1926). *Molinia arundinacea* is a calamine plant in Austria, while *Molinia coerulea* often appears as a serpentinicole (cf. p. 51).

ROBYNS (1932) described a particular vegetation connected with the copper fields of Upper Katanga in Congo. Trees of any kind are lacking on these copper soils, holding 8–14 % Cu, which are colonized by open stands of herbs, 50–60 cm in height. At places with a lower copper content, a more closed vegetation appears with shrubs and herbs, approx. 1 m high. The following plants are characterized as specific for copper soils in Upper Katanga (cf. BRAUN-BLANQUET 1951): *Uapaca robynsi* and *Acalypha cupricola* (*Euphorbiaceae*), several species of *Triumfetta* (*Tiliaceae*), *Barleria variabilis* and *Justicia cupricola* (*Acanthaceae*), *Buchnera cupricola* (*Schrophulariacea*), several species of *Iconum* and *Tinnea obovata* (*Labiatae*), *Guttenbergia cupricola* (*Compositae*).

Among the bryophytes, some rare species are encountered which are considered to be associated with copper ores, viz., *Merceya ligulata, Mielichhofera elongata, M. nitida, Dryoptodon atratus*, and the hepatics *Gymnocolea acutiloba* and *Cephaloziella* sp. (GAMS & MORTON 1925, PERSSON 1948).

In a short paper, BUCK (1949) recently compiled a list of plants from different parts of the world which are considered to be associated with heavy metals in the soil. From this list it emerges that in N America zinc carbonate, too, is indicated by certain plants, viz., *Populus deltoides* and *Ambrosia* species. In N America, *Silene* species are considered to indicate copper, and in Australia this is valid for the whole family of *Caryophyllaceae* (notably *Polycarpaea spirostyles*). This is of great interest because the family of *Caryophyllaceae* is strikingly well represented also in serpentine, at least in the northern areas.

In Scandinavia two representatives of the family *Caryophyllaceae* are to be found which undoubtedly show an "affinity" to heavy metals, viz., *Viscaria alpina* and *Melandrium rubrum*, These plants are, however, clearly serpentinicolous. *Viscaria alpina* was pointed out by several Scandinavian authors as characteristic of the outcrops of copper ore (copper pyrite) (NORDHAGEN 1930, TIBERG 1931, VOGT 1942 a, LUNDMARK 1948). In the district of Petsamo, N Finland, this plant was used as a good indicator of nickel ore deposits (Tanner 1930). The ore consists of pyrite, copper pyrite, and pentlandite, chiefly representing sulphides of Fe, Cu, and Ni.

In Middle Sweden (the district of Bergslagen, Dalecarlia), *Viscaria alpina* occurs very abundantly and disjunctively on ore and slag deposits. This plant is especially abundant on minerals containing copper, lead, and zinc at the Garpenberg mines. At the Stollberg mines in the parish of Norrbärke, which I visited in 1949, I found *Viscaria alpina* accompanied by another serpentinicolous plant, *Rumex acetosa*, growing together with *Agrostis canina* which is characteristic of some serpentine occurrences (cf. p. 67). Apart from these three species, no other plants were noticed on the ore heaps. Thus, I came across a plant community confusingly like one from serpentine. The ore of the Stollberg mine is a complex iron-lead-zinc-ore, holding about 25–28 % Fe, 4–6 % Mn, 1.5–2 % Pb and 3.5–5 % Zn (Geijer & Magnusson 1944).

Melandrium rubrum may also be defined as a so-called copper plant. Vogt (1942 b) demonstrated the abundance of this plant in soils with a toxic content of copper at the mining district of Röros, S Norway. Besides *Melandrium*, the following plants proved their ability to endure a high copper content in the soil: *Salix herbacea*, *Betula nana*, *Salix glauca*, *Salix reticulata*, *Oligotrichum hercynicum* (bryophyte), *Agrostis canina*, *Juncus trifidus*, *Eriophorum vaginatum*. Except for the moss, all these plants are found on serpentine, though more or less sparsely.

Vogt and Braadlie (1942) carried out chemical analyses of this poisonous soil, containing sulphides of iron, copper, and zinc. They found that *Melandrium* could grow even at a copper content of 650 mg Cu/100 g dry soil, which is about 300 times as great as the concentration of copper in normal soil. The pH values varied between 4 and 5, which is not low enough to suggest H_2SO_4 as the toxic factor. In this case, the authors consider copper and, perhaps, ferrous iron or zinc as the essential toxic factors.

In Czechoslovakia, at Piesky, in Slovakia, Prát (1934) found *Melandrium rubrum* growing abundantly in soil rich in copper as copper-hydroxy-carbonate. *Agrostis alba* L. (probably *A. stolonifera*) is also common in this copper soil and even grows in places where the copper content reaches 39 %. *Melandrium rubrum* is found at a maximum content of 1.8 % Cu. By cultivation experiments Prát demonstrated that the ability to endure a high concentration of copper in the soil is limited to plants from this copper soil and their descendants. *Melandrium rubrum* from other localities did not grow in copper soil. No morphological changes could, however, be observed in this "copper-race" of *Melandrium rubrum*.

A recent report (Bradshaw 1952) on *Agrostis tenuis* shows that also this species of the genus *Agrostis* is resistant to heavy metal poisoning. This grass was found in a disused lead mine near Aberystwyth in Wales. The soil of the mine contains about 1 % Pb and 0.03 % Zn, mostly as sulphates and sulphides, and carries no plant life except *Agrostis tenuis*. It was proved by cultivation experiments which included *A. tenuis* biotypes from the vicinity of the mine that resistance to the poisonous soil is restricted to the particular population of the mine which, moreover, seemed to be less vigorous in normal soil.

In the district of Remdalen, Åsele Lappmark, S Lappland, I had the opportunity of studying the vegetation near an outcrop of copper pyrite. *Melandrium rubrum* is also extremely abundant there (Fig. 53). Within these populations glabrous specimens are in the majority, but otherwise no morphological difference could be noticed. Apart from *Melandrium* only a few species grow on the slope below the outcrop, viz., *Juncus trifidus*, *Deschampsia flexuosa*, *D. caespitosa*, *Euphrasia frigida*, and *Equisetum pratense* (Fig. 54). All these are to be found in serpentine. Finally, the aforementioned occurrence of *Arenaria humifusa* at Coppermine in Gaspé should be remembered (cf p. 84).

Whether or not certain ecotypes of the above plants are common both to serpentine and soils rich in heavy metals, is an important question which remains to be answered. Still, a link between these two ecologically extreme types of habitats may be assumed to exist for the very reason that *several species* are common to both of these habitats.

Fig. 53. Copper soil near outcrop of copper pyrite in Remdalen, parish of Vilhelmina, Åsele Lappmark, harbours only *Melandrium rubrum* which is abundant. Some tufts of *Deschampsia flexuosa* occur to left. Note dense birch forest which ceases on reaching copper soil. Lappland, Sweden.
Photo Olof Rune 8.8.1950.

A problem relating to serpentine vegetation is the phenomenon of gypsocolous plants growing in soils of pure hydrated calcium sulphate, or soils rich in this mineral, and more or less restricted to the substratum. The gypsum flora of some Mexican deserts was recently studied by Johnston (1940) who enumerated a number of species that tolerate or require gypseous soils. From Europe, gypsum vegetation is described from Central Europe and Spain (Meusel 1939, Braun-Blanquet 1951). Gypsocolous endemics are known only from Spain where they represent gypsum formations of extremely arid areas. These habitats harbour several gypsocolous Tertiary relics, viz., *Gypsophila hispanica*, *Herniaria fruticosa*, *Lepidium subulatum*, *Helianthemum squamatum*, *Ononis tridentata*, which occur, inter alia, together with some semi-desert plants with main distributions in N Africa and Central Asia (*Lygaeum spartum*, *Artemisia herba-alba*, *Ermopyrum cristatum*) only reaching isolated outposts there. The gypsum formations south of Mt Hartz harbour, inter alia, several arctic-alpine relics growing on "gypsum barrens" (cf. Meusel op. cit.).

In this connection the sulphur springs or solfataras may be mentioned. No vegetation at all exists in close proximity to these volcanic springs, but, at a distance, a few, often very specific plants may be seen. The flora round sulphureous springs has been studied in Java, in particular. In a recent paper, Persson (1948) drew attention to a very rare moss, *Merceya lingulata*, occurring sparsely in different parts of the world. It is an interesting fact that this plant seems to be localized to volcanic springs as well as to copper ores.

From Iceland, Ostenfeld (1899) gave some information concerning vegetation near sulphur springs. There is one plant actually limited to such places, *Ophioglossum vulgatum* L. var. *polyphylla* A. Br. Other plants which may be found in the neighbourhood of the solfataras are *Agrostis stolonifera*, *Sagina procumbens*, *Cerastium vulgatum*, *Plantago major* f. *pygmaea*, and *Stellaria media*. The first three of these plants are also found on serpentine in Scandinavia.

Other examples of plants associated with certain minerals can no doubt be given, but the above suffice for a comparison with the problems con-

Fig. 54. From outcrop of copper pyrite in Fig. 53. Copper has leached downward along slope producing an infertile belt several hundred metres long, harbouring only *Juncus trifidus* and *Deschampsia flexuosa*. Bright zone at base of tufts derives from preceding year's dead shoots, so rich in copper as to become light blue in colour and resist decay. Lappland, Sweden.
Photo Olof Rune 8.8.1950.

cerning serpentine flora. As the minerals are rather insoluble in the above instances, it must be emphasized that these problems should not be mixed up with those connected with halophytic plants and vegetation which are related to high concentrations of soluble salts in the soil.

In minerals or soils particularly characterized by peculiar vegetation or plants, there is actually one factor in common, viz., their toxic effect on the bulk of the surrounding plants. It is an important fact that the floras of the soils mentioned above are very poor in species containing as a rule only species considered to be associated with the specific mineral. The few species resistant to the toxic effect of the mineral are left without severe competitors. They will therefore occur very abundantly. In many cases it has been demonstrated that the resistance is restricted to a particular race which does not usually differ morphologically from the type race.

There is no reason to assume that certain plants are associated with certain minerals, e.g., copper and zinc ores, because of the need of large amounts of certain elements, viz., copper and zinc. This seems clear from the few cultivation experiments made in this field. With a few exceptions, these plants do not, even in nature, appear exclusively restricted to a certain metal soil. Thus, so-called copper plants may occur on serpentine, zinc and lead ores, near sulphur springs, etc. In this connection it should be borne in mind that there are probably no serpentinophytes that cannot also grow in normal soil. Furthermore, PRÁT succeeded in cultivating the copper-race of *Melandrium rubrum* in normal soil. I have grown, inter alia, *Viscaria alpina*, *Agrostis canina*, and *Rumex acetosa* from some mines in Bergslagen (Garpenberg and Stollberg) in normal soil; the only difference noticeable in the cultivated plants was, perhaps, a slightly more vigorous growth.

However, it must be admitted that cultivation in normal soil with high nutritional contents does not clearly disclose the effect of these heavy metals on the plants in nature. Actually, the soils of serpentine, calamine, copper ore, etc., to which certain plants seem to be restricted are characterized by a low nutritional content — even a deficiency in important elements — combined with high concentrations of nickel, zinc, copper, etc.

It was assumed that the serpentinophyte *Alyssum bertolonii* might be capable of compensating a deficiency in certain necessary elements by excess quantities of nickel, an element which occurs in a comparatively high concentration in serpentine and is shown to be accumulated in this plant (MINGUZZI & VERGNANO 1948 p. 62). However that may be, this is a rather complex matter and no conclusive proof can be derived from the present observations owing to the lack of more comprehensive inquiries.

To sum up, it can be stated that plants restricted to, e.g., dolomite, magnesite, and gypsum are probably mostly epibiotics, having survived there owing to specific, edaphic conditions. They may be compared to the serpentinicolous relics. On the other hand, plants restricted to calamine, copper soil or similar substrata, seem to be neoendemic races or species having become differentiated in the peculiar substratum to which they are adapted. Apparently, they correspond to the serpentinophytes of the serpentine. The fact that chemical properties of magnesian as well as "heavy metal" soils are combined in the serpentine soil is reflected in the serpentine flora (cf. chapter IV).

5. Serpentinomorphoses

As mentioned before, certain plants are represented on serpentine by distinct races characterized by definite morphological changes. These morphological changes are so evident as to render several serpentine races distinguishable as definite taxonomic units (species, subspecies, varieties, and forms). These changes, represented within different genera and rather uniform, are called serpentinomorphoses. NOVÁK (1928) was the first to use the term in a similar sense.

Much earlier, however, NEGER, in his Biologie der Pflanzen (1913), introduced the concept *ecomorphose* to comprise any irreversible adaption of a plant to a habitat as against the reversible adaption called *ecologism.* The neo-Lamarckian viewpoint underlying the concept of ecomorphoses has probably affected the interpretation of serpentinomorphoses in so far as they have been largely looked upon as mere adaptions to the serpentine habitats.

Thus, LÄMMERMAYER (1926) established by photometric measurement that the serpentinophyte *Asplenium adulterinum* requires more light than its close ally, and probably its original type, *Asplenium viride.* He concluded that the increased light on the barren serpentine areas plays an important part in forming serpentinomorphoses.

On the other hand, NOVÁK (op. cit.) considered the chemical peculiarity of the serpentine substratum to explain the serpentinomorphoses. "Les serpentinomorphoses appartiennent au groupe des chémomorphoses, c'est-à-dire au groupe des phénomènes dans lesquels la plante réagit à une certaine composition chimique du sol par une changement de la forme de son corps "(loc. cit. p. 43). — This question will be discussed more in detail below, but it should be emphasized that in the present paper the term serpentinomorphose covers any morphological characteristic distinguishing a serpentinicolous race from other races of the species, irrespective of whether this characteristic is an adaption or not.

The nature of the serpentinomorphoses of phanerogamic plants has been closely studied by PICHI-SERMOLLI (op. cit.). According to him, these serpentinomorphoses mainly constitute the following changes: 1. stenophyllism, 2. glabrescence, 3. plagiotropism, 4. nanism, 5. a greater development of the root system, 6. glaucescence. In some cases anatomical and embryological changes have also been established.

The observations of PICHI-SERMOLLI include only vascular plants, but SUZA (1930) has also established serpentinomorphoses among lichens, and KOTILAINEN (1944) has presupposed serpentinomorphoses among mosses. Serpentinomorphoses include hereditarily fixed changes, persisting at cultivation in normal soil, as well as nonhereditary modifications (cf. PICHI-SERMOLLI op. cit. p. 292).

However, only a few serpentinomorphoses have been thoroughly studied in this respect by cultivation for a long period. Thus, the hereditary nature of the serpentinomorphoses within the serpentine races of *Cerastium vulgatum* described by KOTILAINEN and SALMI (1950) is established by cultivation for several generations. This is true also of the serpentinomorphoses of *Viscaria alpina* and *Melandrium rubrum* described in the present paper.

As early as in 1871, SADEBECK (1871, 1887) cultivated the well-known serpentine fern *Asplenium adulterinum* which proved to be constant in normal soil for three generations. The fifth generation, however, seemed to be similar to *A. viride.* In cultivating *A. viride* in serpentine soil, SADEBECK did not find any changes even after six generations. Although never verified, SADEBECK's results were later called in question.

As previously mentioned, the N Swedish serpentine flora is very poor in serpentinophytes and gives only few opportunities for studying serpentinomorphoses. For this purpose only the following will come into consideration: *Cerastium vulgatum* var. *kajanense*, *Cerastium alpinum* var. *serpentinicola*, *Viscaria alpina* var. *serpentinicola*, and *Melandrium rubrum* var. *serpentinicola* and var. *smithii*. They all belong to the family *Caryophyllaceae.*

These varieties all differ from the main types of the corresponding species by a more or less pronounced stenophyllism. The gracility is not restricted to the leaves alone; also the stems and the pedicels are extremely slender in these varieties. Yet, in spite of their slenderness these varieties are always very stiff and erect. Morphological changes in the flower were observed, above all, in the case of *Viscaria alpina* var. *serpentinicola* which shows a trend to reduced petals. Trends to glabrescence were observed in two serpentinophytes, the type races of which are pilose: *Cerastium alpinum* var. *serpentinicola* and *Melandrium rubrum* var. *smithii.* However, they only show a clinal trend to glabrescence that never appears as a constant feature within an entire population.

PICHI-SERMOLLI (op. cit.) demonstrated that glabrescence as a serpentinomorphose was combined with an increased thickness of the cuticula as a protection against high transpiration. Thus, this type of glabrescence should be ecologically equivalent to a high pilosity. Whether this holds true with regard to our northern serpentinophytes was never established and seems rather doubtful. Not a few serpentinophytes of southern areas are highly pilose, and SUZA (1928) as well as PAVARINO (1914) considered the increased pilosity to be a serpentinomorphose. To this PICHI-SERMOLLI (op. cit.) raised the objection that a pronounced pilosity is a general xeromorphism, not typical of the serpentine only. An increased pilosity was never observed in the northern serpentinophytes, nor was the plagiotropism and glaucescence mentioned by PICHI-SERMOLLI (op. cit.). However, in addition to the serpentinomorphoses mentioned by him, the tendency of several northern serpentinophytes to become purplish in colour may also be considered a serpentinomorphose.

A very pronounced nanism — as typical of the serpentinophytes of the serpentine steppe at Mohelno, SW Moravia (DVOŘÁK 1935) — is not pertinent to the northern serpentinophytes. Yet all the serpentinophytes of the Fennoscandian flora show a decrease in size as compared with the main type of the species, and in some stations the specimens of *Cerastium alpinum* var. *serpentinicola* are so small that one can really speak of nanism.

A strongly developed root system is usually typical of the N Swedish serpentinophytes, although considerable differences exist from one station to another. Above all, the unstable serpentine soil, scree etc., seem to favour the enlargement of the root system. Yet the strongly developed root systems of the serpentinicolous varieties of *Melandrium rubrum* were retained even under cultivation in normal soil. Obviously, the perennial character of the serpentinicolous varieties of *Viscaria alpina* and *Melandrium rubrum* is connected with the strongly developed root systems.

As regards the serpentinomorphoses of the bryophytes *Campylium stellatum* and *Brachythecium velutinum*, assumed by KOTILAINEN (1944), too little is still known of them to justify inclusion in the present discussion.

In conclusion, it may be stated that under fairly equal climatic conditions, the serpentinomorphoses of the phanerogamic plants will run on similar lines. Thus, in Fennoscandia the phanerogamic serpentinophytes are all distinguished by narrow leaves and slender, but very stiff, erect stems and pedicels. A trend is noticed to smaller size and relatively larger root systems, as well as a tendency of the whole plant to become glabrous and purplish in colour. Serpentinomorphoses similar to these appear in another area with a rather similar climate, viz., E Canada.

In more southern areas, such serpentinomorphoses as plagiotropism, glaucescence and increased pilosity may play an important role (cf. pp. 98, 99).

The parallelism of the serpentinomorphoses demonstrates clearly the fact that different species may evolve parallel ecological races in similar environments. This fact was proved earlier by TURESSON (1922), CLAUSEN (1951), and others with regard to other environmental factors.

Many serpentinophytes are true endemics, having arisen in a single area only. However, more often the same serpentinophyte seems to have evolved in different places independently. This was assumed by KOTILAINEN (1944), who explained the large disjunction of the serpentinicolous varieties of *Cerastium vulgatum* (cf. pp. 55 and 91) as resulting from a parallel evolution. Since all but one of the N Swedish serpentinophytes appear in several different stations geographically more or less isolated from each other, the polytopic origin of these serpentinophytes cannot be doubted.

Also PICHI-SERMOLLI (op. cit. p. 292), mentioning LÄMMERMAYER's results, considered the serpentinomorphoses to be adaptions to the intense light (esp. the stenophyllism), the dry micro-climate, and the low nutritional content, all of these factors being highly characteristic of serpentine habitats. However, it is often difficult to decide which characters are adaptive or not. To this end, superficial observations are far from enough. "If we are ignorant of the life history, development, and ecological relationships of a species we must maintain a completely open mind and an agnostic position concerning the adaptiveness or nonadaptiveness of its distinguishing characteristics. Even in the case of better-known species, neither the adaptive nor the nonadaptive quality of a particular character should be assumed unless definite evidence is available concerning that character." (STEBBINS 1950 l.c. p. 119.)

From the above, the following may be stated with regard to the N Swedish serpentinophytes.

Morphological changes essentially similar to the serpentinomorphoses can also be seen in plants living in other distinct habitats where edaphic conditions are characterized by nearly the same factors. In N Europe, this is true of the calcareous steppe (the Alvar) of the Isle of Öland (cf. WITTE 1906). Actually, these habitats have some factors in common with the serpentine soils — intense light, dry micro-climate, frost heaving, basic soil reaction, low nutritional content of the soil, etc. The morphological changes shown by the alvar-plants correspond partly to serpentinomorphoses and constitute, inter alia, nanism, a strongly developed root system, plagiotropism, increased pilosity, etc. By comparing the relative effect of different serpentine habitats on the development of serpentinomorphoses, I came to the conclusion that the nanism and the strongly developed root system are more or less adaptive characters. On the other hand, I have become convinced that the stenophyllism, and even the glabrescence, are not adaptions to the intense light but, instead, relatively nonadaptive characters. This is evident from the fact that serpentinophytes with even the most pronounced stenophyllism are not restricted to habitats where the light is the most intense and the micro-climate the driest. True, all serpentinophytes are more or less restricted to open areas without a closed vegetation. In spite of this they may be found on dry and sunny southern sides as well as in more moist and shady parts of the serpentine outcrops. The whole plant increases and the root system decreases in size in the last type of locality, but there is only small changes with regard to the stenophyllism. Not even cultivation in normal soil changes this character. Moreover, most serpentinophytes occur in the serpentine areas of the lowest altitudes. Alhough these areas are rather sparsely wooded, there are still enough trees to lower considerably the light intensity in the field layer.

However, provided that stenophyllism as a serpentinomorphose is not simply an adaption to light conditions, another explanation has to be found. This is a rather complex problem that calls for further studies. Presumably the stenophyllism of the serpentinophytes may be linked to physiological characteristics of these plants, with a high selective value and developed by means of what has been mentioned as an adaptive compensation (STEBBINS 1950 p. 122).

Actually, not only the serpentine but many other extreme habitats harbour ecological races which may differ morphologically from the type races of the species. However, only the serpentine habitats seem to cause such an increased evolution as to produce a great number of morphologically distinctive races and even neoendemic species. An exhaustive analysis of this process cannot be made at present. Here only a few aspects of the problem will be ventilated.

The tendency of the serpentine to further an increased evolution presupposes the existence of a very effective isolation mechanism in these habitats. According to the nomenclature proposed by STEBBINS (1950 p. 196), the isolation mechanisms operating in the serpentine habitats are both spatial and physiological (ecogeographical). The spatial isolation is due to the very distinctive cropping out of the serpentine areas either individually or in isolated chains or clusters. Serpentine areas, with their specific flora, will therefore form islands in the surrounding vegetation. Because serpentine outcrops are mostly rare and restricted to certain districts, the flora of each serpentine area will have a very isolated position.

As regards the physiological isolation, the investigations of KRUCKEBERG (op. cit.), previously mentioned on p. 82, should be borne in mind. He clearly proved the existence of distinct, physiological races of several species with different degrees of tolerance to serpentine. In ecological races of a species, such a physiological differentiation precedes the development of morphological and genetical discontinuities (cf. CLAUSEN 1951 p. 90). Apparently, the tolerance to serpentine (cf. pp. 82 and 115), limited to rather a few species, or races and biotypes of a species, is a very strong ecological barrier that acts as a very effective isolation mechanism.

It may be questioned to what extent the serpentine substratum also furthers an increased variation. SALISBURY (1940) has noticed that species of open habitats are frequently more variable than species of closed communities. He suggests that "the increase in variability which a wild species frequently shows when brought under cultivation and protected from competition is due not to a change in inherent conditions but to the preservation of forms which, in nature, would be rapidly eliminated" (quotation from CAIN 1944 p. 232). Since in serpentine single species often occur over wide areas with hardly any competitors, conditions are, no doubt, favourable for an increased variability.

PICHI-SERMOLLI (op. cit.), who had a larger material for studying serpentinomorphoses than the author, mentions the following genera as especially rich in serpentinomorphoses: *Cerastium*, *Silene*, *Dianthus*, *Alyssum*, *Potentilla*, *Euphorbia*, *Armeria*, *Stachys*, and *Galium*. Serpentinomorphoses seem particularly common and widespread within the genus *Cerastium* (esp. *C. vulgatum* and *C. arvense*). Obviously, variable genera or species are highly disposed to serpentinomorphoses. Most of the above-mentioned genera are more or less characterized by polyploidy and variable chromosome numbers. These problems of serpentinomorphoses have not as yet been studied from a cytogenetic point of view and offer a wide field for further studies.

IV. Serpentine soil and its effect on plant life

1. Chemical and mechanical composition of serpentine soils

Only a few statements are to be found in the literature on the pedological nature of serpentine soils. Botanists, who have discussed the effect of serpentine soil on vegetation, have drawn their conclusions merely from data on the chemical composition of the parent rock (LÄMMERMAYER, NOVÁK, etc.). As far as I know, only one comprehensive study of serpentine soils exists, viz., that of ROBINSON, EDGINGTON and BYERS (1935). They studied in detail the chemical composition of a number of serpentine soils from different parts of of the United States in order to discover the reason for their infertility.

Although their investigation falls entirely within the range of pedology and contains no statements on vegetation, it is an important contribution towards the solution of the problems concerning serpentine vegetation. It was demonstrated that the chemical composition of soils derived from serpentine rocks may differ considerably, depending on the climatic conditions under which weathering has taken place. In a humid and rather cold climate (Pennsylvania, Maryland), only comparatively small changes occur in the composition of the soil, as compared with the parent rock. Some magnesium may be lost, and iron, chromium, and silica gained, but the changes are small. "It would seem as though the constituents were being carried away by the ground water in much the same proportions as they occur in the rock" (op. cit. p. 19). In a warm and humid climate (Cuba and Puerto Rico), serpentine weathers to a laterite soil from which nearly all the magnesium of the parent rock has been leached away. On the other hand, sesquioxides (iron and chromium) accumulate. This may be illustrated by the examples on top of opposite page, cited from ROBINSON *et al.* (op. cit. p. 11).

The chemical composition of the parent rocks of these areas is, of course, not quite identical. Even so, the striking difference in the chemical composition of the Nipe clay does not correspond to a similar difference in the parent rock.

PICHI-SERMOLLI (1948), in his comprehensive paper on the vegetation of the serpentine area in the upper Tiber Valley in Tuscany, gives the following values for the chemical composition of the serpentine soil:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO
Parent rock	38.7	0.58	3.19	7.26	tr	36.44
Soil	42.05	0.73	14.12		tr	32.39

From the serpentine area at Gurhof in the Danube Valley, KRETSCHMER (1931 l. c. p. 173) found the following constituents of the serpentine soil to be *soluble in hydrochloric acid* (1:1). I is characterized as a light soil and II as a heavy one.

	SiO_2	Al_2O_3	Fe_2O_3	Cr_2O_3	FeO	MgO	CaO	MnO	K_2O
I	0.34	5.75	4.69	1.24	4.99	27.5	3.2[illegible]	tr	0.04
II	0.62	3.53	3.68	1.70	5.38	28.15	1.11	tr	0.11

Unfortunately, the nickel content was not determined in these analyses.

No chemical analysis was carried out on the soils of N Sweden, but the climatic conditions under which weathering occurs would indicate the unlikelyhood of any considerable difference between the soil and the parent rock. The rock analysis made by T. DU RIETZ (1935) may, therefore, approximately represent the chemical composition of

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	Cr_2O_3	NiO	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	N
Nipe clay, Nipe Bay, Oriente, Cuba	11.05	1.03	14.58	55.23	3.60	0.28	0.59	0.04	0.60	0.10	0.17	0.06	0.29	0.11
Mt Tamalpais, Marion Co., Calif.	40.28	0.12	2.36	9.31	0.29	0.25	0.13	—	36.42	—	0.02	0.02	0.08	—
Conowingo, Oxford, Penn.	51.49	0.18	7.52	8.33	0.36	0.064	0.08	—	25.01	0.12	0.03	0.04	0.08	—

Chemical composition of serpentine soils from America according to ROBINSON, EDGINGTON and BYERS (1935). See opposite page.

the soils. Some of these analyses were quoted in connection with a description of the areas (pp. 9–43). In general, the N Swedish serpentine rocks (and peridotites) have the following approximate composition:

SiO_2 c. 40 %; Al_2O_3 1 %; Fe_2O_3 mostly 5 %; Cr_2O_3 c. 0.4 %; FeO c. 5 %; NiO c. 0.2 %, MnO traces, MgO c. 40 % CaO traces, $Na_2O \cdot K_2O$ traces.

For further discussion, it is important to obtain a knowledge of the contents of chromium and nickel. According to information obtained from T. DU RIETZ, all peridotites and serpentine rocks in the mountain district of N Sweden contain chromium, averaging about 0.4 % Cr_2O_3 (the chromite veins of Mt Rautats 47 %), and 0.1–0.4 % nickel, averaging 0.2 % NiO. Nickel occurs partly as silicate and partly as sulphide; in the latter form particularly at increased serpentinization. The content of cobalt is much lower than that of nickel, and does not exceed 0.1 % CoO.

The chromium and nickel contents of olivine rocks from Kittelfjäll (cf. p. 26) were studied by SUNDIUS (1949) who found 0.43 % Cr_2O_3 and 0.26 % NiO. He further demonstrated that the chromium content did not only occur as a chromite but to a large extent also as silicates while, in his case all nickel occurred as silicates.

The occurrence of two different forms of chromium in serpentine was noticed also by ROBINSON *et al.* "Chromium apparently occurs in two forms in the parent rocks and the soils formed from them. One form, chromite or ferrous chromite is not attacked by fusion with sodium carbonate and potassium nitrate and is left as a brownish black insoluble residuum when the products of fusion are treated with hydrochloric acid." (l. c. p. 20.) To furnish evidence as to whether or not these forms of chromium and nickel were sufficiently soluble to have an influence on the plants, ROBINSON *et al.* tested the solubility and exchangeability of chromium and nickel from serpentine soils by leaching with acetate according to the method of SCHOLLENBERGER and DREIBELBIS (1930). They found "appreciable quantities of available chromium in all of the soils and the presence of available nickel in all but one of the soils tested" (op. cit. p. 21).

It was demonstrated in Table 1 (p. 44) that the pH, the contents of soluble potassium and phosphates, and in a few cases also of calcium, were determined in soils representing the majority of the serpentine areas of N Sweden. The pH values of mineral soils vary between 6.1 and 7.2, but are usually a little less than 7.

According to ROBINSON *et al.*, the pH of the serpentine soils of N America varies considerably. Many of the surface soils are quite acid, pH 4.5, and others are alkaline, pH 8.3. The bulk, however, seems to have pH values between 6 and 7. These soils, indeed, represent areas with greatly differing climates. KRETSCHMER (op. cit.) found that the pH in the serpentine area at Gurhof in the Danube Valley was between 6 and 7. The same author also determined the pH values in KCl solution in order to obtain the exchangeable hydrogen-ion concentration. These values were not much different from those in water solution. However, this is not unexpected when bearing in mind the low content of colloids in serpentine soils.

The quantities of soluble potassium and phosphates in serpentine soils are very low ($P_2O_5 < 1$ and $K_2O < 10$ mg per 100 g soil). Similar analyses (obtained by the same methods) from forest soils in S Lappland are given by ARNBORG (1943) who found values of the same proportions in the bleached zone (A-horizon) of the podsol soils. In the climate of the mountain district of N Sweden, the leaching of phosphates and potassium is considerable in all the mineral soils. Thus, the corresponding values of P_2O_5 and K_2O from weathered soil of calcareous phyllites (Mt Gräskevardo in *Dryas octopetala - Carex glacialis* community) are 0 and 14, respectively. From weathered soils of quartzite (Mt Mieskattjåkko) the values are 0.1 and 11.8; from limestone (Mt Seinestjåkko) 0.5 and 10, and limestone (Strimasund) 0.5 and 5.5, respectively. True, these few examples will not allow any drawing of conclusions. However, on account of the results of analyses by ARNBORG (op. cit.), it can probably be assumed that there is no considerable difference with regard to the contents of soluble potassium and phosphate between serpentine and many other soils of the mountain district in N Sweden. ROBINSON *et al.* (op. cit.) reported that the contents of potassium and phosphate in the serpentine soils of N America are extremely low but, on the other hand, not lower than in many fertile soils.

Serpentine rocks and soils of N Sweden are generally very low in calcium, mostly less than 1 % CaO. In some samples, however, a calcium content of more than 10 % was established (Kittelfjäll and Mt Rautats). In these soils, calcium occurs as silicate, due to the occurrence of, e.g., calcium-bearing pyroxene in the parent rock. Such pockets with a high calcium content may appear strictly locally, and the high calcium content cannot be considered as representative of the whole area. Calcium occurring as silicate seems to have only a rather limited effect on vegetation (cf. Table 1 p. 44).

In the serpentine soils of N America the quantity of calcium varies widely. "In the Conowingo soils it is generally low, but in some it is abnormally high. The lowest horizon of the Belmont Conowingo, no. 6175, shows nearly, if not quite, the maximum calcium content of any carbonate-free soil. There is some indication that the high-lime Conowingo soils are less infertile than the low-lime Conowingo soils. The difference in lime is due to the difference in the parent rock. The presence of hornblende and pyroxene accounts for the high calcium content." (ROBINSON *et al.* op. cit. p. 13.)

In the serpentine areas of Graipesvare and Murfjället in Åsele Lappmark, S Lappland, the serpentine is mostly rather calcareous (1–14 % CaO). There, the calcium occurs as carbonate (calcite), and the rock shows signs of effervescence when treated with hydrochloric acid. A few slices studied under the microscope showed about 25 % calcite. Calcium occurring as carbonate has a marked effect on the vegetation, and a rather rich flora with several calcicolous plants was observed (cf. p. 24). As to the peridotites of N Sweden, the chemical composition in one case differs considerably from that of the others, viz., the mica-bearing peridotite of Kall, Jämtland. "Compared with other peridotites, this one exhibits higher percentages of alumina, iron, titanium and alkali metals, and lower percentages of magnesium and chromium." (T. DU RIETZ op. cit. p. 153.) The vegetation in this locality shows no typical "serpentine features" (cf. p. 12).

Some other ultrabasic rocks in N Sweden mentioned in this paper are not serpentines in a strict sense, and the chemical and physical properties of their soils may differ from those of typical serpentine soils. This applies, e.g., to the soapstones of Frostviken (Muruhatten, Lermon, etc., cf. pp. 13, 14), which contain less chromium and nickel than does serpentine (cf. T. DU RIETZ op. cit. p. 182), and seem more resistant to weathering. The peridotite of Aunevare, consisting of diopside and unaltered olivine, appears hardly weathered at all and the whole mountain is nearly destitute of weathered soil (cf. p. 24 and Pl. VIII). Some peridotites of Ammarfjällen, viz., St. Ålke and Sråttekjaure, consist — apart from olivine — mainly of chlorite (cf. p. 40). This rock has a low nickel content, 0.04 % (according to information from T. DU RIETZ), and the vegetation is not typical of serpentine. This, however, may be due to a certain extent to the high altitude, 1400 and 1200 m, resp. Serpentine rocks generally weather slowly and weathered materials are relatively sparse in serpentine areas. At least in areas of N Sweden, the weathering seems to increase with the degree of serpentinization.

The serpentine rock may sometimes be somewhat schistose or folded, a condition that favours weathering and provides especially a rich occurrence of coarse weathered materials (cf. Figs. 6, 19).

These splinter materials will be accumulated in the surface layer by frost heaving. Among such splinters *Arenaria norvegica* generally grows in abundance (cf. p. 47). Usually, however, the serpentine soil is very poor in coarse material. This may result in a poor drainage, at least within the lower horizons, which will result in an increasing quantity of ferrous iron. Such a reduction phase has been noticed in some serpentine soils of N America by ROBINSON *et al.* (op. cit. p. 10) who noticed a gain in weight on treating the soil with hydrogen peroxide.

The mechanical composition of two serpentine soils from Rönnbäck has been determined. Sample I represents a soil without coarse material, and sample II a soil from a place with coarse material.

	Coarse gravel 20–6 mm	Fine gravel 6–2 mm	Coarse sand 2–0.2 mm	Fine sand 0.2–0.02 mm	Silt 0.02–0.002 mm	Clay < 0.002 mm
I	1.36	7.63	16.5	44.92	30.77	8.80
II	14.10	4.62	13.56	29.40	24.29	15.15

In these localities the mechanical composition explains the pronounced congeliturbation tendency, which is actually characteristic of all the serpentine soils of N Sweden. This tendency may be accentuated by other factors, e.g., the scanty vegetation and the fact that the bedrock, lying only some 10 cm below the surface, is permeable by water to a limited extent only. Thus, a frost heaving occurs there much like that of the so-called alvar areas on the isles of Öland and Gotland, which has been studied from an ecological point of view by HESSELMAN (1908), DU RIETZ (1925 a), STERNER (1925, 1926), ALBERTSON (1946), and others. The pronounced solifluction tendency of the serpentine soils is an important ecological factor contributing to the prevention of closed communities (cf. p. 48).

ROBINSON *et al.* (op. cit.) studied the mechanical composition of several American soils and all of them showed a maximum in the silt fraction (international silt: 0.02–0.002 mm diam.). As mentioned above, ROBINSON *et al.* found indications of poor drainage in some soils, but concluded that the infertility of serpentine soils cannot be attributed to the mechanical composition.

2. Views on the causal connection between vegetation and chemical composition of serpentine rocks

It seems clear that the peculiar vegetation of serpentine soil is due to the unique chemical composition of the parent rock. Serpentine vegetation is actually composed of a very small number of species. Serpentine soils impress us as very unfavourable to most plants. This infertility may be the result of a direct toxic effect, an unfavourable balance between different ions, or a deficiency of necessary elements. In the following, these possibilities will be more thoroughly discussed and the opinion of other specialists on the subject will be reported.

One of the first attempts to explain the influence of serpentine on vegetation was made by NOVÁK (1928) who stated that the following qualities in serpentine rock affect vegetation:

1. A considerable excess of magnesium.
2. The ratio MgO/CaO > 1 which NOVÁK considers to prevail in all serpentine soils.
3. A total lack of chlorides.

NOVÁK's theory is founded on observations from Moravia and statements from the literature. On the basis of available geological data, he proved that the above conditions are fulfilled whenever typical serpentine vegetation occurs.

However, his theory appears to be principally an application of data obtained some ten years earlier by LOEW (1901), who studied the effect of the ratio Mg/Ca on certain cultivated plants. By means of extensive cultivation experiments, LOEW showed that an excess of magnesium as against calcium generally has an injurious effect on plant growth. The optimum ratio varies from one species to the other, but general indications show it to be about Mg/Ca = 4:5, counted in mols.

The difficulty of applying LOEW's results to natural soils was emphasized by ROBINSON *et al.* (op. cit.). Usually only the total concentration of Mg and Ca is known, while only the quantities occurring as exchangeable cations are available for plants. This criticism definitely concerns NOVÁK who used only total analyses of the parent rock. LÄMMERMAYER (1928 b) criticized NOVÁK's theory stating as a main argument that the flora of magnesite differs from that of serpentine, though the Mg:Ca ratio is in both cases about the same.

In agricultural-chemical quarters in the U.S.A, much attention has been directed to the problems of the infertility of serpentine soils. Thus, GORDON and LIPMAN (1926) stated that the infertility of serpentine soil depends on a deficiency of nitrogen, potassium and phosphates. The alkaline soil-reaction (pH = 8. 2) and the poorness in colloid substances were also considered to contribute to the infertility. "They state positively that the excess of magnesium has no relation to the infertility of serpentine soils, basing this statement on two experiments. 1) They cite GERICKE's experiment of successfully growing plants in solutions, the salt constituent of which was seven-eighths magnesium salts. 2) GORDON and LIPMAN added magnesium salt to some of their culture solutions, without rendering them toxic or more toxic thereby." (ROBINSON *et al.* op. cit. p. 3.)

A weighty objection may be made to the experimental results arrived at by GORDON and LIPMAN. The solution obtained by extracting minerals of a serpentine soil in water only does not correspond to the amount of elements available to plants. Plants are able to take up exchangeable cations carried by colloid particles and, perhaps also, to etch the mineral particles.

Recently, cultivation experiments with serpentine soil have been carried out by VLANIES and JENNY (1948), and WALKER (1948). The former described a bad growth in serpentine soil cultures due to a calcium deficiency. The latter found, in addition, a lack of a certain minor element, molybdenum, which produced a diseased condition in the experimental plants. As these data are available only in an abstract form in a preliminary publication, it is hard to judge whether they can be used also in a wider sense.

ROBINSON *et al.* (op. cit.) studied the chemical composition of several infertile serpentine soils from different parts of the United States. They found them to contain a comparatively large quantity of chromium and nickel (cf. p. 113). "Whereas poor mechanical composition, causing poor internal drainage, an excess of magnesium, and lack of plant-food elements may be frequent causes of infertility in the soils studied, the only general and dominant cause of infertility in soils derived from ferromagnesian rocks is the comparatively high percentages of chromium and nickel" (ROBINSON *et al.* op. cit. p. 26). This was deduced by them from investigations of the toxicity of chromium compounds carried out by KOENIG (1910).

By cultivating different plants in water cultures, in sand cultures, and in humus soils to which various chromium compounds had been added, the latter demonstrated, that chromium in all but small concentrations is toxic to plants. The chromates proved to be the most toxic, and the highly insoluble chromite was toxic to more sensitive plants in the heaviest applications only. Small applications of chromous salts, and very small applications of chromates, as well as rather high concentrations of chromite, had a stimulating effect. Germination was prevented by a small concentration of chromium, and the roots of the plants in the chromium cultures contained more chromium than other parts of the plants. In sand cultures, 50 parts per million of chromium as dichromate were toxic. It took higher concentrations to produce toxicity in humus soils. Lime counteracted chromium toxicity. (cf. ROBINSON *et al.* op. cit. p. 23.) To this may be added that KOENIG found that plants containing much silicic and oxalic acid were more resistant to chromium toxicity.

ROBINSON *et al.* cite the results of SCHARRER and SCHROPP (1933) with regard to the toxicity of nickel. "Nickel in sand cultures in quantities of about 50 parts per million was somewhat stimulating, but was toxic at higher concentrations. Cobalt at concentrations less than 1 part per million was stimulating to corn and barley but toxic to other plants, and in higher concentrations was toxic to all plants. The earlier works reviewed by SCHARRER and SCHROPP show, in general, that nickel and cobalt are toxic to plant-growth and particularly toxic to yeast." (ROBINSON *et al.* op. cit. p. 25.)

In an abstract from a lecture, M. J. KOTILAINEN (1944), who studied the serpentine flora of Finland, assumed, probably without being aware of the study by ROBINSON *et al.*, that the "serpentine effect" is due to a high content of chromium, or other minor elements. This he concluded from the following facts: 1) Rock analyses from some serpentine areas in Finland with pronounced serpentine vegetation show a rather high chromium content (0.48–0.22 % Cr_2O_3). 2) Spectrographical analyses proved that *Arenaria pseudofrigida* from a serpentine locality contained rather much chromium. The "serpentine moss" *Campylium stellatum* was also very rich in chromium. 3) In N Karelia peridotitic outcrops exist without characteristic serpentine vegetation; geological investigations from these areas proved some of them to have a very low chromium content.

KOTILAINEN assumed a connection between these phenomena, but he had no opportunity to enter more thoroughly into the subject.

PICHI-SERMOLLI (op. cit.), in discussing the relation between serpentine vegetation and chemical soil factors, refuted the ideas of ROBINSON *et al.* He admitted, however, that chromium toxicity may play a certain part in the infertility of serpentine soils without being of any essential significance. On the whole, PICHI-SERMOLLI is far from inclined to consider that it is only the chemical composition of serpentine soils that causes the unique character of its vegetation. He emphasized the importance of taking other factors such as micro-climate, the mechanical composition of the soil, etc., into consideration.

Two studies on the chemical composition of ash from serpentinicolous plants may also be referred to in this connection. WHERRY (1936) analysed ash from several plants of the Conowingo Barrens in SE Pennsylvania; in some cases he found extremely high contents of magnesium. Later, MINGUZZI and VERGNANO (1948) published analyses from the ash of *Alyssum bertolonii* DESV., a typical serpentinophyte known from Italy and the western Balkans. They found a varying but always considerable content of nickel in the different organs of the plant (up to 10 % NiO). Within these organs the sum Ni + Mg and the ratio Ca:Ni were always constant, and the authors assumed nickel to play an extraordinary part in the metabolism of this plant.

In KRUCKEBERG's paper (1951), reported in an earlier chapter (p. 82), a short account is given of his chemical approach to the serpentine problem. "It seemed likely that mineral-nutrition studies could point to some of the physiological differences between serpentine-tolerant and serpentine-intolerant races of a given species. To follow up this aspect of the problem, serpentine soils were reconstituted with varying amounts of calcium, a nitrate-phosphate-potassium mixture and molybdenum. Of these (added singly), only calcium was able to bring about 'normal' growth of a non-serpentine strain on serpentine soil. A complete analysis of these nutritional studies, as well as further tolerance tests, are to be presented elsewhere (KRUCKEBERG, in manuscript.)" (KRUCKEBERG op. cit. p. 415.)

In conclusion, my own observations from N Sweden, regarding the causal connection between serpentine soil and vegetation, will be described and discussed with reference to earlier theories already mentioned.

The deficiency of plant nutrients (potassium, phosphate, calcium, etc.) in serpentine soil is, no doubt, an important factor which may favour, to a certain degree, the poorness of serpentine vegetation. However, this factor does not totally explain the "infertile" nature of serpentine rocks. As mentioned above, the experimental results of GORDON and LIPMAN cannot be accepted. Moreover, ROBINSON *et al.* demonstrated that there are many other soils with a similar nutritional deficiency, but without the same "infertility".

The serpentine soils of N Sweden proved to have very low contents of potassium and phosphates. On the other hand, many other soils of the mountain district of N Sweden show similar low values. My own observations support the conception that the infertile nature of serpentine soils must be due to the toxic effect of the elements from serpentine rock. Consequently, the elements of the serpentine rock should all be examined separately in order to ascertain the toxic ones.

As is apparent from several analyses mentioned earlier in this paper, serpentine rocks are rather rich in silicon. However, this is a quality common to most other types of rock and may be excluded from further discussion.

Next to silicon, magnesium is the element with the highest concentration in the serpentine rock, and is often discussed in relation to the toxicity of serpentine. The toxicity of magnesium may be discussed from two different points of view: 1) whether or not the absolute high Mg concentrations are toxic; 2) whether or not the balance between Mg and other cations — Ca, above all — is unfavourable.

With regard to the first question, the phenomenon that many serpentine plants accumulate Mg in their tissues (EBNER 1861, WHERRY 1936) may be interpreted as an indication that serpentinicolous plants are distinguished by an extreme tolerance to high Mg concentrations (cf. LUNDEGÅRDH 1950 p. 447). The theory that the serpentinicoles should be plants with an affinity for soils rich in magnesium compounds was denied by LÄMMERMAYER (1928 a, b). He pointed out that magnesite and dolomite rocks are mostly covered by a flora differing from that of serpentine. Other evidence is given by ROBINSON *et al.* (op. cit.) who demonstrated that the serpentine rocks of Cuba weather into a laterite soil from which nearly all magnesium is lost by leaching. The vegetation of these soils has nevertheless a marked serpentine character (cf. CARABIA 1945).

As regards the unfavourable balance between Mg and Ca ions, NOVÁK's theory and LOEW's investigation, mentioned earlier in this chapter (p. 115), must be borne in mind. Also in this connection the comprehensive study of ROBINSON *et al.* has shown that the high Mg/Ca ratio is probably not the main cause of the infertility of serpentine soils. Out of 15 serpentine soils studied by ROBINSON *et al.*, 11 were found to have an unfavourable Mg/Ca ratio (>1). The other 4 soils were classified as infertile although they had no unfavourable Mg/Ca ratio. These authors did not deny that the occurrence of unbalanced Mg may be conducive to infertility but, in their opinion, other factors are more likely to be responsible. During my studies in N Sweden, I noticed how the serpentine character of the vegetation decreases when the serpentine rock is calcareous. In that respect calcium occurring as carbonate gives a much greater effect than silicates of calcium. However, even in the areas of Graipesvare and Murfjället, where the Mg/Ca ratio is mostly rather low, the serpentine character of the vegetation is to a certain extent retained, even when typically serpentinicolous plants are lacking.

Similar observations were made by ROBINSON *et al.* who found high-lime Conowingo soils that were less infertile than low-lime. KRUCKEBERG, moreover, made serpentine soil fertile for serpentine-intolerant plants by adding calcium (cf. p. 117). Still, it must be emphasized that calcium also counteracts the toxic effect of other elements (e.g., chromium; cf. p. 116). Therefore a decreasing serpentine character, as related to the occurrence of calcium in the serpentine, gives no true indication of the effect of the increasing Mg/Ca ratio.

Besides magnesium, serpentine also contains a considerable amount of iron. The parent rock has an iron content of about 10 %. A variable and, sometimes, considerable part of the iron occurs in the ferrous form. In a temperate climate the serpentine soil has nearly the same iron content as the parent rock. In tropical areas, e.g., Cuba and Puerto Rico, the serpentine rock weathers into a laterite soil very rich in iron sesquioxide (more than 50 % Fe_2O_3 according to ROBINSON *et al.*).

KRETSCHMER (1931) disclosed the presence of a considerable content of ferrous iron (cf. p. 112) in serpentine soils from the Danube Valley. ROBINSON *et al.* found a gain in weight when treating some serpentine soils with hydrogen peroxide, and attributed this to an oxidation of the ferrous iron. However, a determination of the actual content of ferrous iron in a certain serpentine soil must involve many difficulties, for the redox equilibrium between ferric and ferrous iron will, no doubt, change as soon as the spade is put into the soil.

NOVÁK (1928) assumed that the iron content probably contributes to the strange character of serpentine soils. However, he did not give any further explanation. Also KRETSCHMER (op. cit. p. 174) believed that the high iron content might possibly explain the effect of serpentine on vegetation. However, in opposition to this theory, which she calls "a bribing assumption", she cited GÖHLERT's (1928) Die Flora über Eisenkarbonat. On the basis of anatomical and histochemical studies carried out on plants grown in iron quarries in Austria, GÖHLERT demonstrated that a high iron content in the soils does not influence the plants. Iron occurs there as a carbonate together with lime, and the vegetation consists mainly of calcicolous plants, *Saxifraga aizoides*, etc. (According to HAYEK [1923], the flora of the siderite in Styria is rather similar to that of limestone.) GÖHLERT's conclusions are therefore based on facts inapplicable to serpentine. My own observations show that other kinds of rock rich in iron, e.g., different magnetite ores do not manifest the same type of vegetation as serpentine. The occurrence of the two serpentinicolous ferns *Asplenium adulterinum* and *A. viride* and other serpentine characters of the vegetation of Mt Taberg (prov. Småland, S Sweden), which consists of magnetite-olivinite, is more likely due to the olivine content of the rock (RUNE 1950).

In the preceding pages (p. 105), the abundant occurrence of *Viscaria alpina*, *Melandrium rubrum*, and other serpentinicolous plants near pyritic outcrops has been mentioned. It is true that iron is common to serpentine and pyrite, but on the other hand pyrite also holds many other elements, e.g., copper and other heavy metals, known to be highly toxic to plants in high concentrations. As an example of "iron vegetation", BRAUN-BLANQUET (1951), citing GOLA (1910), mentioned the barren soils round the pyrite mines of Italy which are colonized by only a few plants, viz., *Calluna vulgaris*, *Agrostis canina*, *Silene rupestris*, and *Molinia coerulea*. The same author (op. cit. p. 239) also referred to VIELLARD who reported that the "red soils" of New Caledonia have a flora characterized by particular plants. In both these instances, other elements besides iron, viz., copper, chromium, etc. may be responsible for the effect.

From Finland, KOTILAINEN (1944) maintained that the occurrence of ferrous phosphates (vivianite) at the bottom of swamps gives rise to a special type of vegetation, with birch (*Betula alba* coll.) and the rare, beautifully yellow-flowering *Saxifraga hirculus* as the most characteristic components. The same author draws attention to the fact that in Westfalen v. LINSTOW (1928) was able to trace a vein of siderite (ferrous carbonate) by following the vegetation; only the birch (*Betula alba*?) grew on the ore vein which was avoided by oak and beech (*Quercus* and *Fagus* sp., respectively).

In regard to the iron content of the serpentine soil, the following remarks may be made. Iron in the ferric form has probably no effect on plants. When the internal drainage of the soil is poor, ferrous iron is easily produced. This form of iron is known to be unfavourable to plant growth and may, in some cases, give rise to a specific vegetation. The mechanical composition, no doubt, makes the serpentine soil tend towards easy reduction. This was demonstrated by ROBINSON *et al.* (op. cit.). The occurrence of ferrous iron in serpentine soil may therefore sometimes be associated, to a certain extent, with the infertility (cf. ROBINSON *et al.* op. cit. p. 13).

Finally, some minor elements occurring in serpentine in relatively large quantities, viz., chromium and nickel, will be discussed.

Chromium occurs in most serpentine rocks and amounts to about 0.5 % Cr_2O_3. The quantity may, however, be much larger in the chromite veins (in N Sweden about 47 %, cf. p. 113).

All the serpentine soils of N America studied by ROBINSON *et al.* proved to contain mostly less than 1 % chromium, but in lateritic serpentine soils, where sesquioxides are accumulated, the chromium content amounted to 3–5 %. As mentioned earlier in this chapter, the chromium content occurs, partly, as highly insoluble chromite and, partly, as more soluble silicates (cf. p. 113). ROBINSON *et al.* stated that serpentine soils contain quantities of chromium, classified by KOENIG as toxic (cf. p. 116).

Besides chromium, ROBINSON *et al.* found relatively large quantities of nickel (max. 0.45 % NiO) in all the infertile soils. They stated that this element is also conducive to infertility (cf. p. 116). This theory derives support from the observations made by MINGUZZI and VERGNANO (op. cit.), who found that the organs of the serpentinophyte *Alyssum bertolonii* accumulate considerable quantities of nickel (cf. p. 117).

Practically all the serpentine and peridotite rocks of N Sweden show rather similar contents of chromium and nickel (approx. 0.4 % Cr_2O_3 and 0.2 % NiO, cf. p. 113). These values are of the same proportions as those found by ROBINSON *et al.* in American serpentine soils and considered as toxic. However, there are two exceptions: 1) The Kall peridotite which has an extremely low chromium content (cf. p. 114). Unfortunately, the nickel content is unknown. 2) The peridotites of Ammarfjällen (cf. p. 114) which are low in nickel but normal in chromium content. None of these peridotites show a real serpentine character with regard to the vegetation. However, this is not conclusive, because the Kall peridotite holds mica which may likewise contribute to diminishing the serpentine effect, and the peridotites of Ammarfjällen are probably too alpine (1400 m) for a typical serpentine vegetation.

In the previous chapter (p. 101) it was stated that highly serpentinized peridotites show a more pronounced effect on vegetation than do the unaltered olivine rocks. This may, to some extent, be explained by the increased weathering that results from serpentinization. However, the differences in vegetation are generally so clear that also another factor must be considered.

Earlier, chromium was stated to occur in serpentine, partly as insoluble chromite and, partly, as more soluble silicates. SUNDIUS (op. cit.) showed that the more soluble form mainly occurs in the serpentinized minerals of the rock.

Nickel occurs as silicate and sulphide, in the latter form, which is comparatively more soluble, particularly at increased serpentinization. Apparently, the solubility of chromium and nickel seems to be accentuated by increased serpentinization. Thus, the theory propouned by ROBINSON *et al.* is strongly borne out by the difference in vegetation observed in relation to the degree of serpentinization of the peridotitic rock.

These authors discussed the chromium toxicity as the main cause of the infertility of serpentine soils. However, they also considered the high nickel content of the serpentine soils to be an important factor.

In fact, some of the observations reported in the present paper seem to prove that nickel has an even greater significance than chromium.

Firstly, the serpentinicolous plants *Viscaria alpina* and *Melandrium rubrum* are also typical so-called copper plants; *V. alpina* is to be found abundantly in connection with nickel ore and ores containing zinc (cf. p. 105). Many other plants which have proved their tolerance of high concentrations of copper in the soil are often found also on serpentine. Actually, members of the *Caryophyllaceae* family show a particular "inclination" both to serpentine and copper (cf. pp. 89, 104).

In addition, the peculiar flora of calamine soils is essentially like the serpentine flora (e.g., the existence of certain neoendemics restricted to each of these particular habitats). Plants typical of calamine soils — or plants closely related to them — are sometimes found on serpentine or in connection with high concentrations of copper or other heavy metals in the soil (cf. p. 104). However, the soils rich in "other heavy metals" (mainly Pb) harbouring specific "ore plants" seem to contain also Cu and (or) Zn, though in a concentration of but a few percentages.

It may be assumed that serpentine, copper soils, and zinc soils have a rather similar effect on plants, though without any elements in common.[1] The most probable link between these three different substrata appears to be the three metals Ni, Cu, and Zn, occupying the order numbers 28, 29, and 30, respectively, in the Periodic System. These three elements all belong in the group of true minor elements, essential in small concentrations for normal plant development. In small concentrations they act as stimulants and seem essential to plant growth, but are injurious in higher concentrations. However, the biochemical effect of these elements has been closely studied only in relation to Cu and Zn, while hardly anything is known concerning Ni in this respect (cf. LUNDEGÅRDH 1950). Actually Ni and Cu have some chemical properties in common which may be of a biochemical significance, namely a pronounced catalytic effect and a great tendency to form complexes with ammonium.

Nickel is definitely the element in serpentine which has a physiological effect most closely resembling that of copper and zinc. In view of the existence of plants associated with copper and zinc ores, it should be natural to assume that nickel might connect certain plants to serpentine. This assumption derives support from investigations by MINGUZZI and VERGNANO. They maintained that the serpentinophyte *Alyssum bertolonii* accumulates excess quantities of nickel, possibly similar to the zinc accumulation of the zinc plants (cf. p. 103, SCHARRER 1941, CAMP 1945). True, ash analyses of plants from serpentine have also shown high contents of magnesium and chromium (cf. p. 117). However, the high magnesium content appeared variable (cf. WHERRY op. cit.), and data concerning the chromium content are very sparse (cf. p. 116).

Finally, my observations may be said to confirm the theory presented by ROBINSON *et al.*, that the rather high content of chromium and, above all, nickel in serpentine soils constitutes the general and dominant cause of infertility. Still, it must be emphasized that the effect of these elements on serpentine depends on several other properties of this rock, i.e. low nutritive content, low calcium content, high magnesium content, pH value, mechanical compositon, etc.

ROBINSON *et al.* carried out their investigations on serpentine soil in order to find out the cause of

[1] Small amounts of nickel (approx. 0.01 %) may often follow the sulphide ores of copper and zinc.

its infertility, particularly relating to cultivated plants. They did not, however, deal with the scanty but unique flora that actually exists in serpentine soils. A mere ascertainment of the cause of the infertility will not suffice to solve all the problems concerning the serpentine flora. Nevertheless, the infertility probably still marks the peculiar character of the serpentine flora whose members are left, on the whole, without any serious competitors.

Apparently, all plants thriving well on serpentine are indirectly favoured by the high nickel and chromium contents. However, these minor elements (especially Ni) probably also act directly; the abundance and vigour of many serpentinicolous plants may justify the assumption that these plants are stimulated by the high nickel (and perhaps chromium) content, even at concentrations toxic to other plants. In this case, we may have to deal with typical serpentinophytes which may be considered as nickel plants, corresponding to zinc and copper plants (cf. p. 103). All these plants accumulate large quantities of the minor element in question, and it is not improbable that excess quantities of these minor elements, i.e., Ni, Zn, Cu, may play a special part in the metabolism of such plants (MINGUZZI and VERGNANO, op. cit. p. 62).

The high nickel and chromium contents must not be considered as the only, deciding factors underlying the existence of serpentinicolous plants. Many serpentinicolous relics are probably confined to serpentine because of other factors, such as the physical properties of the serpentine soil, the particular micro-climate, the low competition, etc.

As shown on p. 103, the serpentine flora also has some properties in common with the floras of magnesite and dolomite, e.g., the tendency to harbour epibiotics. This is probably explained by the similar physical properties of these rocks rather than by the high contents of magnesium, for a similar tendency is to be found in the limestone and gypsum floras (cf. pp. 106, 108). Concerning the serpentine flora of the upper Tiber Valley, PICHI-SERMOLLI (op. cit.) considered the physical properties of the serpentine rock, micro-climate, etc., to be factors more important than high contents of chromium and nickel.

It would seem as though the answer to the question of which factor in serpentine is the main cause of the peculiar effect on vegetation may certainly differ with climate, local topography, age of the flora, etc.

Apparently, the causal connections between serpentine soils and vegetation are too complex to be given a general explanation based on conditions in one limited area. A further discussion of these problems is, moreover, beyond the scope of a comparative ecological study. Conclusive proof of the infertility of the serpentine soils as well as answers to other questions mentioned above, can be obtained only after continued investigations, also within the fields of physiology, biochemistry, and genetics.

Summary

Rocks and soils of serpentine — a hydrous ferromagnesium silicate formed from olivine by hydrothermal alteration — are known all over the world to have floras quite peculiar to themselves. A similar effect, though less pronounced, is shown also by other ultrabasic rocks. The serpentine flora has been studied in Central and South Europe, and North America, in particular. In N Europe serpentines occur, though rather sparsely, in the northern parts of Fennoscandia.

While the serpentine flora has earlier been studied to some extent in Norway and Finland, these problems were not investigated in Sweden. This is no doubt due to the fact that serpentines occur in Sweden mainly within botanically rather unexplored parts of the northern mountain districts. During the summers of 1946–1950, the author visited 41 different ultrabasic rock areas in the mountain district of N Sweden, and made a relatively complete inventory of their flora.

In chapter II pp. 9–76 an account is given of the flora and vegetation of each area visited. In several areas soil samples were collected, which were analysed with regard to pH, soluble potassium and phosphates. The results are given in Table 1, p. 44.

Flora and vegetation on serpentines in N Sweden.

The flora of the serpentine areas of N Sweden is very poor in species and usually also in individuals. In fact, only about 140 species of vascular plants were found within all the serpentine areas of N Sweden, though the altitudinal level varies from 350 to 1 400 m. In addition, this number includes many species occurring incidentally in one single area.

As regards their affinity to serpentine, the plants observed on this substratum can be grouped into three categories: *serpentine-characteristic* (*serpentinicolous*) plants, *serpentine-indifferent* plants, and *serpentine-accidental* plants. Each plant growing more abundantly or frequently on serpentine, as compared with other rocks and soils of the vicinity, may be classified as serpentine-characteristic or serpentinicolous. Although the serpentinicolous plants are not particularly numerous, they play by far the most prominent role in serpentine vegetation. According to my observations the following plants are serpentinicolous in N Sweden: *Asplenium viride*, *Agrostis stolonifera* (considering its indigenous occurrence in the mountain districts of N Sweden), *Molinia coerulea*, *Luzula spicata*, *Rumex acetosa*, *Arenaria norvegica*, *Cerastium alpinum* var. *serpentinicola*, *Cerastium glabratum*, *Cerastium vulgatum* var. *kajanense*, *Viscaria alpina* (including *V. alp.* v. *serpentinicola*), *Melandrium rubrum* (including *M. rubr.* v. *serpentinicola* and *smithii*). Besides, the mosses *Rhacomitrium lanuginosum*, *Campylium stellatum*, *Drepanocladus uncinatus*, *Tritomaria quinquedentata*, and the alga *Trentepohlia jolithus*, may be characterized as serpentinicolous.

Of these, *Cerastium vulgatum* var. *kajanense* is a distinct serpentine race — probably evolved from the coastal *C. vulg.* var. *glabrescens* — restricted to serpentines of Finland and N Sweden. *Cerastium alpinum* var. *serpentinicola*, *Viscaria alpina* var. *serpentinicola*, and *Melandrium rubrum* var. *serpentinicola* and *smithii* are morphologically recognizable serpentine races described in this paper (pp. 53, 56, 62).

Rumex acetosa is represented in serpentine by a distinct, ecological race. It is, however, difficult to distinguish it morphologically, because of the great number of different races existing within this complex species.

Although very abundant on serpentine, the other serpentinicoles are not restricted to this kind of rock. Thus, *Asplenium viride*, *Arenaria norvegica* and *Cerastium glabratum*, are more or less frequent on calcareous rock. *Molinia coerulea*, *Luzula spicata*, and the serpentinicolous mosses are all rather common and widespread outside the serpentine, and are not so clearly serpentinicolous as the others. Apart from the aforementioned races, also *Viscaria alpina*, *Melandrium rubrum*, and *Cerastium alpinum*, are rather common and widespread plants on soils of a lithological origin different to that of serpentine soil.

The group of serpentine-indifferent plants includes all those found on serpentine — whether abundantly or rarely — which do not occur in greater abundance or frequency on serpentine than in soils of another lithological origin in the vicinity. They are usually common and widespread plants with a very wide ecological amplitude, occurring rather abundantly also in serpentine soil, e.g., *Empetrum hermaphroditum*, *Festuca ovina*, and *Juncus trifidus*.

Finally, the third category comprises plants found

incidentally on serpentine, growing sparsely in one or a few areas only. Although constituting the bulk of the plant list, these plants are the least important of the serpentine flora.

As the serpentine soil seems rather unfavourable to most plants, the vegetation will very slowly colonize this kind of soil. In addition, the lack of a closed vegetational mat, combined with the pronounced frost action in the silty serpentine soil, makes the ground very unstable. The serpentine areas of N Sweden, therefore, usually seem very barren, being almost destitute of vegetation, even at altitudes far below the alpine region. The typical serpentine vegetation consists of pioneer communities formed by one or a few serpentinicolous plants, generally occurring in great abundance. However, it is impossible to keep together the different types of serpentine vegetation even from similar altitudes in the same phytosociological unit (alliance). Some serpentine plant communities seem rather to be closely connected to phytosociological alliances already recognized in Scandinavian alpine and subalpine vegetation. However, in these large units they would represent very special and depauperated associations. The most typical serpentine vegetation, i.e. where the maximal abundance of serpentinicolous plants occurs, is restricted to pioneer habitats: debris and bare soil patches, generally produced by frost action. Because of the abundant occurrence of *Arenaria norvegica* in many of these habitats, this type of serpentine vegetation seems rather reminiscent of the pioneer vegetation of unstable calcareous ground distinguished by NORDHAGEN (1935, 1936, 1943) as the *Arenarion norvegicae* alliance. Moreover, the great abundance of *Asplenium viride* in serpentine rock crevices shows the *Asplenion viridis subarcticum* alliance — described by NORDHAGEN (1936) and characteristic of calcareous rock crevices — to be a very common community of serpentine rocks.

Closed plant communities may occur on serpentine rocks where the ground is stable enough to allow the existence of a humus layer. Because of the dry character of most serpentine outcrops, the climax vegetation under such circumstances is dwarf-shrub heath communities which seem most closely related to the low-alpine acid soil alliances *Empetrion* and *Myrtillion*. The humus layer covering the serpentine soil is as a rule formed by *Rhacomitrium lanuginosum* which slowly invades the bare patches, provided the ground remains sufficiently stable. Therefore, as a first stage towards a climax, a *Rhacomitrium* mat appears, including at the outset most of the serpentinicolous plants characteristic of bare soil. The next stage is the invasion by *Juncus trifidus* and some ericaceous dwarf shrubs: *Calluna vulgaris, Empetrum hermaphroditum,* and *Vaccinium uliginosum.* Also some serpentinicolous plants, remnants from the pioneer stage, may continue to exist in the closed communities. The pioneer plants growing in the pure mineral soil of serpentine are all more or less basicolous (serpentini- or calcicolous), while the climax communities on serpentine are dominated by acidicoles. The fact that basicoles grow together with acidicoles, e.g., *Asplenium viride* and *Calluna vulgaris* in the case of N Sweden, is a striking feature of serpentine vegetation.

General character of serpentine flora.

In chapter III (pp. 77–111) the general problems concerning the serpentine flora are discussed. In comparing my own observations on the serpentine floras of N Sweden, Finland, Norway, and North America with statements from the literature, I found the following features to be common to at least all the serpentine floras of the North: 1. The serpentine flora is relatively poor in individuals as well as in species. 2. On serpentine, several species are represented by particular races (ecotypes) differing ecologically and sometimes also morphologically from the type races of the species. 3. Many plants occur very disjunctively on serpentine. 4. The serpentine flora contains basicolous as well as acidicolous plants which often grow together. 5. The serpentine flora has a relatively xerophytic character. 6. The serpentine flora is often dominated by a certain family or certain genera, e.g., *Caryophyllaceae* in N Europe and E North America.

As emphasized by botanists and geologists who have described outcrops of serpentine, the waste and barren surface clearly indicates this kind of rock. The number of species occurring in serpentine areas is as a rule strikingly low. Thus in the 41 areas visited in N Sweden, only 140 species of vascular plants are found, this being only 25 % of the total number of species within the district.

It has for long been observed that several plant species are represented in serpentine soils by particular races, differing morphologically as well as ecologically from the typical species. In many cases they have been described as new species, subspecies, varieties, and forms. In the literature, the plants more or less restricted to serpentine soils have been variously characterized as serpentine plants, serpentinicolous plants, serpentinophytes, serpentine endemics, or serpentinomorphoses. Though many of these plants were found exclusively in serpentine soils, all the tested ones could be cultivated in normal soil. NOVÁK (1928) listed a great number of plants from South and Central Europe which he considered to be restricted to serpentine soil. He considered these so-called serpentine types (les types serpentiniques) to have become differentiated in the serpentine areas, and never to have occurred outside them. However, in several papers Lämmermayer (1926–1934) pointed out that, according to his own observations, several of the plants mentioned by Novák as exclusive serpentinophytes occurred in other magnesian soils and, in a few instances, also in non-magnesian soils. This applied especially to two well-known serpentine ferns — *Asplenium adulterinum* and *A. cuneifolium*. Later, therefore, Novák (1937) divided the serpentinophytes into two groups: obligate and facultative serpentinophytes.

Recently, Pichi-Sermolli (1948) made clear that all plants that are serpentine endemics need not be considered as neoendemics produced in serpentine areas. He stated that many serpentine endemics and other serpentinicolous plants are actually relics (epibiotics), now more or less restricted to serpentine, since they are enabled to survive only under the specific edaphic conditions created by the serpentine rocks. These serpentinicolous relics are plants that have occurred at earlier epochs, or still occur in other kinds of soil in other parts of their area of distribution. Thus, among the serpentinicolous plants two different categories exist: 1) *serpentinophytes* which are neoendemics differentiated within the serpentine areas, and 2) *serpentinicolous relics* which are epibiotics more or less restricted to serpentine habitats since they became extinct outside.

Pichi-Sermolli's opinion (op. cit.) derives support from a recent experimental study by Kruckeberg (1951) who grew seeds of serpentine and non-serpentine plants of the same species from the Central Coast Range on serpentine and non-serpentine soils in the Botanical Garden of the University of California. Using the terminology of Stebbins (1942), Kruckeberg stated that among the serpentine endemics of the Central Coast Range areas, both the "insular species" type (neoendemics) and the "depleted species" type (epibiotics) exist. He demonstrated that the highly serpentinicolous section *Euclisia* of the cruciferous genus *Streptanthus* may probably have originated in a biotype depletion, i.e. the serpentine biotypes are the only survivors of a once richer set of biotypes.

The existence of serpentine-tolerant and serpentine-intolerant biotypes within ubiquitous species was propounded by Kruckeberg. However, the physiological and ecological differences did not necessarily correspond to morphological changes. Although Kruckeberg's results do not allow of such wide, general conclusions including also our mainly arctic and alpine serpentine floras, they nevertheless point out the existence of distinct serpentine races with very particular ecological requirements. In the event of such a population being the only to survive within a species, it would appear as a serpentinicolous relic.

The main condition for the survival of epibiotics seems to be rather low competition (Griggs 1940), this being exactly what characterizes the serpentine habitats. In this respect the serpentine habitats are the equivalents of shores, scree and the faces of easily weathered rocks, which are the types of locality usually harbouring epibiotics. This is, for instance, evident from the fact that many shore and alpine plants appear in serpentine areas far away from water and high mountains. — A good example of this may be seen in the flora of the Gaspé Peninsula which is very rich in epibiotics, all more or less restricted to serpentine, shores, and debris of talus.

Serpentinicolous plants in the flora of N Sweden.

In the serpentine flora of N Sweden, as in other northern floras, the number of serpentinophytes is very small. From a taxonomic viewpoint, those manifested have hardly differentiated further than to varieties. However, in the serpentine areas of the South, e.g. in S Europe, the number of serpentinophytes is considerable, and many of them have been distinguished as individual species. This difference is explained by the fact that all northern serpentine floras are comparatively young, and their serpentine races did not have more than the postglacial period in which to differentiate. Thus, in the flora of N Sweden the only members of the serpentinophyte group are the serpentinicolous races of *Cerastium alpinum*, *C. vulgatum*, *Viscaria alpina*, and *Melandrium rubrum*. However, some of the most common and widespread serpentinicolous plants of N Sweden are likely to be considered as serpentinicolous relics. Such are: *Arenaria humifusa*, *A. norvegica*, *Cerastium glabratum*, and *Agrostis stolonifera* (when indigenous in the high mountains of Scandinavia). These plants are not restricted to serpentine throughout Scandinavia. In some parts of the mountain areas they may appear abundantly on serpentine, though they were never observed there on soils of another lithological origin. The distribution of these plants is discussed more in detail on pp. 84–87. The bulk of the serpentinicolous plants of N Sweden, viz., *Asplenium viride*, *Molinia coerulea*, *Silene acaulis*, *Minuartia biflora*, and *Luzula spicata*, can hardly be classified as serpentinophytes or as serpentinicolous relics. Although clearly serpentinicolous, they are seldom restricted to this kind of rock over extensive areas. These plants are still too common and widespread outside serpentine to be classified as serpentinicolous relics. The term *serpentinicolous ubiquists* characterizes this group more adequately. Still, the borderline between these two categories is rather diffuse. For example, *Minuartia biflora*, which is a serpentinicolous ubiquist in N Sweden, appears as a serpentinicolous relic in Finland.

Several plants — not necessarily serpentinicolous

— appear very disjunctively in serpentine habitats. They may be alpine plants appearing in serpentine areas below the alpine region, or shore plants appearring in serpentine areas far from the sea (cf. p. 87). Northern plants may have their southernmost outposts, and southern plants may have their northernmost outposts, even in the same serpentine area, e.g., Mt Albert in the Gaspé Peninsula (cf. p. 93). In Sweden the southernmost stations of the northern distributional areas of *Draba nivalis*, *Euphrasia lapponica*, and *Minuartia rubella*, are found on serpentine. Apparently, the vast areas of barren soil on serpentine are favourable stations for alpine and shore plants.

Several thermophilous plants are restricted to the south-exposed parts of serpentine cliffs. The high heat capacity of the serpentine rock (similar to limestone and dolomite) and the protruding shape of the outcrops contribute to a warm local climate on the south-exposed parts of the serpentine cliffs. Such habitats harbour a thermophilous flora and many plants may be found there at unusually high altitudes or latitudes.

Several serpentinicolous plants of N Sweden are also calcicolous — or rather basicolous — e.g., *Asplenium viride*, *Silene acaulis*, and *Arenaria norvegica*. However, some very important serpentine plants, viz. *Calluna vulgaris* and *Deschampsia flexuosa*, are also typical acid soil plants. The notable fact that basicoles and acidicoles are found together on serpentine is reported also from the Alps (LÄMMERMAYER 1926).

In the serpentine flora of N Sweden — and all Fennoscandia — no family is so well represented as the *Caryophyllaceae*. Actually, most plants typical of serpentine belong to this family, e.g., the genera *Cerastium*, *Viscaria*, *Melandrium*, *Arenaria*, and *Minuartia*. Within the serpentine areas of E Canada a similar predominance of the *Caryophyllaceae* was established. However, in S Europe the important families *Leguminosae* and *Compositae* seem also to dominate in serpentine areas.

Serpentine flora in Norway and Finland.

As the Swedish serpentine areas are situated within high mountain districts, their flora derives from the arctic-alpine mountain flora of the Scandes. In the high mountain districts of Norway serpentine areas with a flora greatly resembling that of Sweden are to be seen. In Norway, however, large serpentine areas occur at low altitudes in the coastal districts, viz., at Sunmöre and S Nordland. This serpentine flora is rather different from the corresponding one in the high mountain districts.

Thus, a serpentinicolous fern typical of the serpentine flora of Middle Europe is found here, viz., *Asplenium adulterinum*, having its northernmost outpost in the serpentine area of the Isle of Rödön, S·Nordland. In addition, from the Sunmöre district *Arabis petraea* may be mentioned, an epibiotic element with a scattered distribution in Europe and, probably, a serpentinicolous relic in Sunmöre. Some shore plants, viz., *Plantago maritima*, *Armeria maritima*, *Sagina nodosa*, and *Silene maritima*, occur abundantly on the serpentine of the coastal district, even comparatively far from the sea. However, some typical serpentine plants actually occur both in the serpentine areas of the coast and of the high mountains, viz., *Asplenium viride*, *Molinia coerulea*, *Viscaria alpina*, *Cerastium alpinum*, and *Calluna vulgaris*.

Although situated at a rather low altitude — mainly below 400 m — the serpentine areas of N and Middle Finland have a flora which contains several arctic-alpine elements as serpentinicolous relics: *Arenaria ciliata* ssp. *pseudofrigida*, *Minuartia biflora*, *Cerastium glabratum*, *Viscaria alpina*, and *Saxifraga nivalis*. Two serpentinicolous races of *Cerastium vulgatum* were recently described from Finland: *C. vulg.* var. *kajanense* and *C. vulg.* var. *serpentini*. The former is found also in N Sweden, the latter only in Moravia. The serpentinicolous fern *Asplenium adulterinum* also reaches the serpentine areas of Middle Finland. The serpentine vegetation in Finland is dominated by the same plants as in N Sweden, viz., *Asplenium viride*, *Molinia coerulea*, and *Calluna vulgaris*. Considering the serpentine flora of all Fennoscandia, most of the serpentinicolous plants seem to be restricted only to certain parts of it. However, two plants occur almost constantly, as well as abundantly, in practically every serpentine area of Fennoscandia: *Asplenium viride* and *Viscaria alpina*.

Serpentine flora in E North America.

For comparison, the flora of some serpentine districts of E Quebec is discussed in this connection. Mt Albert is a wide serpentine mountain situated in the Shickshock mountains within the central parts of the Gaspé Peninsula. Its very wide plateau-like summit varies in altitude from 1 100 to 1 230 m, and constitutes a barren serpentine table land which possesses on arctic-alpine flora quite peculiar to itself. On the bare patches of extremely congeliturbate soil the following plants are to be found: *Arenaria humifusa*, *Minuartia marcescens*, *M. biflora*, *M. rubella*, and *Artemisia borealis*. At peripheral, more stable, parts of the solifluction polygons are found: *Rhododendron lapponicum*, *Vaccinium uliginosum* var. *alpina*, and *Carex scirpoidea*. At places with a more stable ground, a tundra-like vegetation prevails. The soil is covered by mats of *Rhacomitrium lanuginosum* in which occurs in particular: *Viscaria alpina*, *Armeria scabra* subsp. *labradorica*, *Scirpus caespitosus*, *Des-*

champsia caespitosa, Campanula rotundifolia, Ledum groenlandicum, Betula grandulosa, and *Salix brachycarpa.* Thus, on the serpentine plateau of Mt Albert an arctic flora prevails, and many of the species appear very disjunctively there. From the southern edge of the table land a deep gorge stretches towards the centre. Its steep walls and talus harbour a serpentine flora, differing in some respects from that of the plateau. Thus, three ferns, *Polystichum mohroides* var. *scopolinum, Cheilanthes siliquosa,* and *Adiantum pedatum* var. *aleuticum,* and two grasses, *Danthonia intermedia* and *Festuca scabrella,* appear very disjunctively there. They all belong to FERNALD's Cordillera-group, i.e. plants with a main distribution in the West, and disjunct stations in the St. Lawrence Gulf region in the East. This distributional type was explained by FERNALD (1925) as a result of the incomplete glaciation of the St. Lawrence region during the Wisconsin glaciation. However, recent investigations have proved the problem to be more complex. The abundance of disjunct occurrences on Mt Albert may be due to the serpentine itself, which always seems to harbour disjunctive plants even within once heavily glaciated areas. Most of the rare plants of Mt Albert are probably serpentinicolous relics which have survived the post-glacial changes of climate because of the edaphic conditions created by the serpentine rock, irrespective of whether they are remnants of once richer eastern populations or whether they arrived there by long distance dispersal. The latter seems conceivable only with regard to the serpentine ferns. Besides, some of the plants appearing disjunctively on Mt Albert — members of both the arctic and the Cordillera-group — also appear as serpentinicolous relics on the serpentine hills of the Black Lake district in Megantic Co, E Quebec, an area which was heavily glaciated by the Wisconsin Ice.

Mt Albert harbours only one true serpentinophyte (serpentine neoendemic), viz., a very distinct, though not yet described, serpentine race of *Cerastium arvense.* As mentioned before, this poorness in serpentine neoendemics in the northern serpentine areas may be explained by the fact that their flora is of post-glacial age only. The flora of the serpentine of Mt Albert, therefore, does not bear out the theory that the top of this mountain was never covered by the Wisconsin Ice.

A comparison between the serpentine flora of Mt Albert and the corresponding alpine serpentine flora of Scandinavia throws some interesting light on the arctic-alpine plants common to N America and NW Europe. Some of these are serpentinicolous in both places, viz., *Viscaria alpina* and *Arenaria humifusa.* However, the most typical serpentinicole of all in Fennoscandia, viz., *Asplenium viride,* also occurs in the northern areas of North America, though never on serpentine. *Cerastium alpinum* and *Minuartia biflora* are similar examples. On the other hand, plants that are serpentinicolous in N America may occur in Scandinavia though never on serpentine, e.g., *Rhododendron lapponicum* and *Carex scirpoidea.* The latter is, however, very rare in Scandinavia, being found only in one locality. Such ecological differences may be due to an unequal distribution of serpentinicolous biotypes within the species.

Effect of different magnesian rocks on vegetation.

As regards the ultrabasic rock areas studied in N Sweden, differences are to be noted in the composition of the rock. These differences may sometimes correspond to differences in vegetation. Thus, the serpentine character of the vegetation is less marked in areas where the serpentine contains considerable amounts of calcium. Calcium has a far more pronounced effect in the form of carbonate than in the form of silicate. A mica-bearing peridotite with a low chromium content did not show a serpentine character in regard to its vegetation; nor did the peridotites of Ammarfjällen (Nos. 38–39) which are rather high in calcium but low in nickel. However, most of these last-mentioned areas are situated at altitudes sufficiently high to prevent most of the typical serpentinicoles from growing there. Nor do some outcrops of unaltered olivine (Mt Aunevare and Mt Vuoka-Ruopsok) and soapstones (Mt Muruhatten and the Lermon Summits) disclose a typical serpentine flora. This may partly be explained by the lack of weathered material which makes these rocks nearly destitute of vegetation. In addition, it may be stated as a general observation that the serpentine character of the vegetation increases with increasing serpentinization of the rock.

In the Austrian Alps, LÄMMERMAYER (1928 a, b, 1934) made a comparative study of the floras on serpentine and magnesite. He found serpentinicolous plants growing occasionally also on magnesite, and he considered the flora of this kind of rock to be intermediate between that of serpentine and that of limestone. Within the mountain district of N Sweden, magnesite occurs very sparsely, and I have never had the opportunity myself to study the magnesite flora. However, thanks to BJÖRKMAN's (1937) study of the flora of a magnesite outcrop in the Sarek National Park area, the flora of this kind of magnesian rock can be compared with that of serpentine in the mountain district of N Sweden. It appears, from BJÖRKMAN's paper, that this magnesite flora is rather different from that of serpentine, and that it is more reminiscent of the limestone and dolomite floras.

Plants connected with specific minerals.

For a further comparison, plants connected with other specific minerals will also be discussed. From

Europe, a few plants connected with calamine soils (zinc carbonate and silicate) are known, viz., *Viola calaminaria* and *Thlaspi calaminaria*, which may be considered as special calamine races of *Viola lutea* and *Thlaspi alpestre*, respectively. Moreover, *Minuartia* (*Alsine*) *verna*, *Silene inflata* var. *glaberrima*, and *Armeria maritima* also appear in abundance in calamine soils. Some of the calamine plants, especially *Minuartia verna*, seem to be connected with ores of lead and copper. However, considering the fact that the lead ores, in particular, usually contain zinc, it is difficult to judge which is the metal responsible for the effect on plant life.

Some bryophytes are known to be associated with copper ores, viz., *Merceya ligulata*, *Mielichhofera elongata*, *M. nitida*, *Dryoptodon atratus*, *Gymnocolea acutiloba*, and *Cephaloziella* sp. From N America, the following plants are known to indicate ores (Buck 1949): *Populus deltoides* and *Ambrosia* species which are associated with zinc carbonate, and *Silene* species associated with copper. In Australia another member of the *Caryophyllaceae*, *Polycarpaea spirostyles*, is used as a copper indicator.

In Fennoscandia at least two members of the *Caryophyllaceae* are known to appear abundantly in connection with copper ores, viz., *Viscaria alpina* and *Melandrium rubrum*. The latter, in particular, has proved able to endure very high concentrations of copper in the soil, and is found in abundance even in localities where the soil is too poisonous for other plants to grow. In N Finland, *Viscaria alpina* was also found in abundance on the nickel ores of Petsamo. It is noteworthy that these copper plants are very typical of serpentine in Fennoscandia. A similar affinity both to copper ores and serpentine is shown by several members of the *Caryophyllaceae* in other parts of the world.

A very specific flora is found also on certain gypsum soils and near volcanic sulphur springs. It is interesting to note that the aforementioned so-called copper moss, *Merceya ligulata*, is to be found near volcanic springs. All the cases referred to here concern relatively insoluble minerals. The particular problems involved should, therefore, not be confused with those of halophytic plants and vegetation which concern high concentrations of soluble salts in the soil.

Minerals or soils characterized by a certain vegetation or certain plants seem to have one factor in common, i.e. a toxic effect on the bulk of the surrounding plants. It should be borne in mind that the floras of these minerals — like the serpentine flora — are markedly poor in species and contain on the whole only such species as may be connected with the mineral in question. The few species capable of tolerating the toxic effect of the minerals are left without any strong competitors and will therefore occur very abundantly. There is no reason to assume that certain plants are associated with certain minerals, e.g., copper or zinc ores, because of their need of large amounts of the elements in question. This seems evident from the cultivation experiments made in this field. With but a few exceptions, these plants do not, even in nature, appear exclusively restricted to a certain metallic soil. Thus, "copper plants" can occur on serpentine or on lead ores, as well as near volcanic springs. However, no further conclusions can be drawn owing to the lack of detailed investigations.

Serpentinomorphoses.

It was mentioned previously that many serpentine races show distinct morphological changes, sometimes ranking as individual taxa. These changes, which are represented within different genera and rather uniform, are called serpentinomorphoses. Pichi-Sermolli (1936, 1948) discussed the serpentinomorphoses of vascular plants and found that they disclose the following changes: 1. Stenophyllism; 2. glabrescence; 3. plagiotropism; 4. nanism; 5. a greater development of the root system; 6. glaucescence. In some cases, anatomical and embryological changes have been ascertained. Suza (1930) noted serpentinomorphoses among lichens, and Kotilainen (1944) assumed their existence among bryophytes.

Pichi-Sermolli (1948) contended that the serpentinomorphoses are adaptions to intense light, dry micro-climate, and low nutrient content, all these factors being characteristic of serpentine localities. Serpentinomorphoses include hereditarily fixed changes which persist at cultivation in normal soil, as well as non-hereditary modifications.

As the serpentine flora of N Sweden is very poor in serpentinophytes, few opportunities are obtained for studying them. However, stenophyllism, and tendencies to glabrescence, nanism, and a greatly developed root system, are characteristic of all the Fennoscandian serpentinophytes. Of these, nanism and the greatly developed root system seem to be adaptive characters — xeromorphoses — typical of plants in dry habitats. The stenophyllism and probably also the glabrescence seem to be nonadaptive characters, which may be linked to physiological characteristics of serpentinophytes with a high selective value.

The tendency of serpentine to further an increased evolution is probably due to very effective isolation mechanisms operating in these habitats. Serpentine is very unfavourable to plant life in general, and plants thriving well on this substratum are, in many cases, particular ecotypes physiologically adapted to serpentine. Such a physiological differentiation is known to precede the development of morphological and genetical discontinuities (Clausen 1951). Moreover, a spatial isolation may exist in connection with serpentine in so far as these rocks usually crop out very distinctively in isolated chains or clusters. The serpentine flora will, therefore, form islands in the surrounding vegetation. The fact that in serpentine a single species may often occur over a wide area with hardly any competitors may also contribute to an increased variation.

Many serpentinophytes are true endemics, having arisen in a single station only. However, more often one and the same serpentinophyte seems to have evolved in different places independently. The serpentinophytes of N Sweden with one exception occur in several different geographically isolated areas, which is indicative of their polytopic origin.

Serpentine soil.

In chapter IV (pp. 112–121) the chemical properties of serpentine soil are dealt with, and the particular factors responsible for the pronounced effect on vegetation are discussed.

An important contribution to the knowledge of the pedological properties of serpentine soil has been made by Robinson, Edgington, and Byers (1935) who studied serpentine soils from different parts of the United States. They found that, in a humid and rather cold climate, the changes in the composition of the soils are only relatively small as compared with the parent rock. In a humid and warm climate (Cuba and Puerto Rico), serpentine weathers into a lateritic soil from which nearly all the magnesium of the parent rock is leached out, while sesquioxides of iron and chromium are accumulated.

No complete chemical analyses of the serpentine soils of N Sweden are available. However, the climatic conditions for weathering indicate the improbability of any considerable difference between soil and parent rock. Accordingly, the rock analyses given by T. Du Rietz (1935) cited on pp. 10–42, give an approximate idea of the chemical composition of the soils. The average composition of a serpentine soil in N Sweden is as follows: SiO_2 and MgO each approx. 40 %; Fe_2O_3 and FeO each approx. 5 %; Cr_2O_3 approx. 0.4 %; NiO approx. 0.2 %; CaO, MnO, and $Na_2O \cdot K_2O$, only in traces. Chromium occurs partly as a highly insoluble chromite and partly as more soluble silicates. Nickel occurs partly as silicate and partly as sulphides. For evidence as to whether or not chromium and nickel in serpentine are soluble enough to affect the plants, Robinson *et al.* tested the solubility and exchangeability by leaching with acetate, and found "appreciable quantities of available chromium in all the soils and the presence of available nickel in all but one of the soils tested".

As regards serpentine soil analyses, my own studies cover pH, soluble potassium and phosphates, and in some cases the total calcium content. As emerges from Table I, p. 44, the pH varies between 6.1 and 7.2. Most of the serpentine soils of North America have a pH between 6 and 7. In the serpentine soils of N Sweden, soluble potassium and phosphates are very low. However, the values are not lower than in many other more fertile soils. According to Robinson *et al.*, the serpentine soils of North America show similarly low values. Yet even these values are not lower than in many fertile soils. The serpentine soils of N Sweden are generally very low in calcium, mostly less than 1 % CaO. However, in some cases a calcium content exceeding 10 % was established. This may be due to the occurrence of calcium-bearing pyroxene, often rather locally as pockets. Nevertheless, calcium in the form of silicate seems to have but a rather limited effect on vegetation. Within the serpentine areas of Graipesvare and Murfjället, the serpentine shows a comparatively high calcium content in the form of carbonate (about 25 % calcite). The flora of these areas shows an increasing number of species and the vegetation is dominated by such calcicolous plants as *Dryas octopetala* and *Carex rupestris*.

As mentioned on pp. 100, 114, the serpentine in one particular area (No. 4: the Kall peridotite) contains mica which is responsible for the considerable content of alkali metals (cf. p. 12). Besides, the chromium content of this rock is low. Moreover, some peridotites of Ammarfjällen (No. 38) contain largely chlorite and have a very low nickel content. In both instances, the vegetation is by no means typical of serpentine. However, as many factors (altitude, etc.) differ in these cases, no far-reaching conclusions can be drawn as to the influence of the different rock compositions on the vegetation.

The mechanical composition of two samples of serpentine soil from N Sweden was determined. The soils proved to be very rich in silt and fine sand. The high percentage of these fractions in the serpentine soil is the main reason why serpentine soils of N Sweden are as a rule highly congeliturbate. According to Robinson *et al.*, who analyzed the mechanical composition of a large number of serpentine soils in the United States, these generally show a clear maximum in the silt fraction. They stated that the infertility of serpentine soils was not due to the mechanical composition.

Elements in serpentine affecting plant life.

The causal connection between the peculiar vegetation and the chemical composition of serpentine rocks has been much discussed. Apparently, the serpentine soils are unfavourable to most plants. This may be due to the direct toxic effect, to an unfavourable balance between different ions, or to a deficiency in necessary elements. NOVÁK (1928) considered an excess of magnesium and a high value of the ratio MgO/CaO to be responsible for the serpentine effect. His theory is based mainly on observations in Moravia and statements from the literature. From available geological data, he demonstrated that the ratio MgO/CaO > 1 whenever typical serpentine vegetation occurs. This was an application of data obtained some ten years earlier by O. LOEW, who studied the effect of a different Mg/Ca ratio for certain cultivated plants, and demonstrated that an excess of magnesium over calcium has generally an injurious effect on plant growth. However, the difficulties of applying LOEW's results to natural soils were emphasized by ROBINSON *et al.* As a rule, only the total concentrations of Ca and Mg are known, while only the quantities occurring as exchangeable cations are available to plants. NOVÁK's theory was criticized by LÄMMERMAYER (1928 b) who found the floras of magnesite and serpentine to be different, though the Mg/Ca ratio was nearly the same.

GORDON and LIPMAN (1926) made experiments with water cultures obtained by the water extraction on serpentine soils. They stated that the infertility of serpentine soils might be caused by a dificiency of nitrogen, potassium, and phosphates. To this the objection may be raised that the solution obtained by extracting serpentine soils in water does not correspond to the amount of elements available to the plants.

ROBINSON *et al.* (op. cit.) found comparatively large quantities of chromium and nickel in serpentine soils, and stated the general and dominant cause of infertility in these soils to be the rather high concentrations of those elements. This they deduced from investigations of the toxicity of chromium compounds carried out by KOENIG (1910) who studied the reaction of different plants cultivated in water, sand, and humus soil cultures, to which different chromium compounds were added. With regard to nickel toxicity, ROBINSON *et al.* cited the results of SCHARRER and SCHROPP (1933) who found that nickel salts in low concentrations slightly stimulated plant growth, but became toxic at higher concentrations.

KOTILAINEN (1944) also assumed the serpentine effect to be due to a high concentration of chromium in the serpentine rock. PICHI-SERMOLLI (op. cit.) refuted the idea that chromium should be the main cause of the serpentine effect. He admitted that chromium toxicity may be of a certain significance. However, he emphasized that factors other than the chemical composition, e.g., micro-climate, mechanical composition, etc., might be responsible for the unique character of the serpentine vegetation.

The chemical composition of the ash from serpentinicolous plants was studied by WHERRY (1936), among others, who in some cases found a very high content of magnesium. MINGUZZI and VERGNANO (1948) published analyses from the ash of a typical serpentinophyte, *Alyssum bertolonii* DESV., known from Italy and the W Balkans. They found a varying but always considerable content of nickel in the different organs of the plant (up to 10 % NiO). Within the different organs, the sum Ni + Mg and the Ca/Ni ratio were constant, and the authors assumed nickel to play a certain part in the metabolism of this plant. KRUCKEBERG, in his aforementioned study, briefly sets down his chemical approach to the serpentine problem. Serpentine soils were reconstituted with varying amounts of calcium, a nitrate-phosphate-potassium mixture, and molybdenum. In this way, only calcium was found to be able to bring about a "normal" growth of a non-serpentine strain on serpentine soil.

My own observations from N Sweden concerning these questions may be summarized as follows. The deficiency of plant nutrients in serpentine soil is, no doubt, an important factor which may to some degree be responsible for the poorness of the serpentine vegetation. However, in the cold and humid climate of the mountain districts, where the weathering is slow and the leaching of ions considerable, many soils — even the quite fertile ones — show low values similar to those of serpentine soils. Accordingly the serpentine may be assumed to possess elements unfavourable to most plants. The high magnesium content in serpentine rock was often suspected to be responsible for the so-called serpentine effect. The toxicity of magnesium may be considered from two points of view: 1) whether or not the absolute high Mg concentrations are toxic; 2) whether or not the balance between Mg and other cations, above all Ca, is unfavourable. LÄMMERMAYER (1928 a and b) pointed out that in the Austrian Alps the flora of other rocks with a high magnesium content, e.g., magnesite and dolomite, did not show a serpentine character.

Magnesite is very sparse in the mountain districts of Scandinavia and only a few data exist concerning its vegetation. Still, they prove the Swedish magnesite vegetation to be different from that of serpentine. The most conclusive proof that magnesium is not the main cause of the "serpentine effect" is presented by ROBINSON *et al.* who pointed out that the serpentine rocks of Cuba weather into a laterite soil from which nearly all magnesium is lost by leaching (cf. p. 112). The vegetation of these soils has, nevertheless, a marked serpentine character (cf. CARABIA 1945).

The fact that the serpentine character of the vegetation decreases whenever calcium is present may be interpreted as the result of a decrease in the Mg/Ca ratio. Further, KRUCKEBERG's experiments showed that the serpentine toxicity was counteracted by adding calcium. However, these observations are ambiguous because toxicity caused, e.g., by chromium, is also counteracted by calcium, as shown by KOENIG (op. cit.).

Apart from magnesium, serpentine also contains a considerable amount of iron (c. 10 %). A variable and sometimes considerable part of it occurs in the ferrous form. ROBINSON *et al.* (op. cit.) found a gain in weight when they treated some serpentine soils with hydrogen peroxide. They concluded that this was due to an oxidation of the ferrous iron. NOVÁK (1928) and KRETSCHMER (1931) assumed that the high iron content might contribute to the "serpentine effect". A particular iron vegetation is described from pyrite mines in N Italy by BRAUN-BLANQUET (1951). The same author refers also to VIELLARD who contended that so-called red soils of New Caledonia have a flora characterized by particular plants. However, these cases may include small amounts of other elements, e.g., zinc or chromium, causing the effect. In Finland, KOTILAINEN (1944) found a special type of mire vegetation connected with vivianite deposits. In Sweden, however, I have not found that the flora of rocks rich in, e.g. magnetite resembles that of serpentine, except when connected with olivine (Mt Taberg) or minerals holding other heavy metals (Cu, Pb, Zn, and Mn, as in some ores of the Bergslagen district, cf. p. 107).

In the ferric form, at least, iron does not seem responsible for the serpentine effect. However, high concentrations of ferrous iron are known to be toxic to plant growth. The mechanical composition of serpentine soils doubtless makes them tend towards an easy reduction, as demonstrated by ROBINSON *et al.* The occurrence of ferrous iron in serpentine soil may, therefore, sometimes be connected with infertility (cf. ROBINSON *et al.* op. cit. p. 13).

Finally, some minor elements remain to be discussed that occur in relatively large quantities in serpentine, viz., chromium and nickel. Chromium occurs in serpentine partly as a highly insoluble chromite, and partly as a more soluble silicate; together they usually total 0.5 % (cf. p. 113). ROBINSON *et al.* (op. cit.) assumed a chromium and nickel toxicity to be the main cause of the infertility of serpentine. I have found some evidence in support of this theory, particularly in regard to nickel. The only peridotite of N Sweden which is low in chromium, viz., the Kall peridotite (p. 12), does not harbour serpentine vegetation. However, this rock is also unique in that it contains mica, which may certainly contribute to the decreased serpentine character. Actually, the solubility of the chromium content is a more important question than the total chromium content. In serpentine the chromium occurs partly as highly insoluble chromite and partly as more soluble silicates, as demonstrated by ROBINSON *et al.* (cf. present paper p. 113) and SUNDIUS (cf. present paper p. 26). However, the content of the more soluble form seems to increase with increasing serpentinization (cf. p. 120).

The nickel content of the serpentine rocks of N Sweden is usually between 0.1 and 0.4 % NiO. Nickel occurs partly as a silicate and partly as sulphide, in the latter form particularly at increased serpentinization. Thus, also in the case of nickel the solubility seems to increase with increasing serpentinization. Therefore, the observation that the serpentine character of the vegetation increases with increasing serpentinization may support the theory of ROBINSON *et al.*

Certain plants which appear in abundance in connection with copper and zinc have been described earlier in this paper (cf. pp. 103, 127). In Fennoscandia, the plants known to be connected with copper, viz., *Viscaria alpina* and *Melandrium rubrum*, are also characteristic of serpentine. In addition, *Viscaria* is reported as a nickel ore indicator (cf. p. 105).

Outside Fennoscandia, members of the *Caryophyllaceae* show a similar inclination, partly towards serpentine and partly towards copper ores. As regards the effect on plant life, a link seems to exist between the ores of zinc and copper, and the serpentine. Presumably, this link comprises the three metals Ni, Cu, and Zn, occupying the order numbers 28, 29, and 30, respectively, in the Periodic System, all belonging in the group of true minor elements. From a physiological point of view, Cu, Zn, and Ni, seem to have a rather similar effect on plants. Thus, in small concentrations they act as stimulants and appear essential to plant growth, but are injurious in higher concentrations. The physiological effect of these elements has only been studied in regard to Cu and Zn, while hardly anything is known in this respect concerning Ni. As we know of plants associated with copper and zinc ores, it should be natural to assume nickel to have a similar effect on serpentine. This assumption is, moreover, borne out by an investigation by MINGUZZI and VERGNANO (cf. the present paper, p. 117).

In conclusion, it may be stated that my observations support the assumption of ROBINSON *et al.* (op. cit.) that the rather high contents of chromium and nickel are general and dominant causes of infertility. Special indications have been noted in regard to nickel. It should be emphasized that the effect of these elements on the serpentine soil depends on many other properties of this rock, e.g., the low nutrient content, absence of calcium, high magnesium content, presence of iron in reduced form, pH value, mechanical composition, etc.

The "infertility", no doubt, explains several important characteristics of the serpentine flora, for it leaves the members of that flora largely without serious competition. Still, the problem of the effect of the serpentine on plant life is too complex for a general explanation. Thus, the abundance and vigour of many serpentinicolous plants might justify the contention that serpentinicolous plants are, nevertheless, stimulated by the minor elements in question. However, conclusive proof of this is beyond the scope of a comparative ecological study, since it rather belongs to physiology and biochemistry.

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Figures in italics indicate passages where data are given concerning the distribution etc. of a plant or this is dealt with at some length.

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