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ANALYSES OF SOIL PROFILES IN DWARF-SHRUB VEGETATION IN SOUTH GREENLAND

BY

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WITH 6 FIGURES AND 17 TABLES IN THE TEXT

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Abstract

In 1965 analyses were made of vegetation and soil profiles in South Greenland, at about 62° lat. N, in 13 localities with different types of dwarf-shrub vegetation, situated at 3 stations at different distances from the outer coast.

Results are given of analyses of each layer in each of the 13 soil profiles, comprising the depth of the layer, its colour, content of organic matter, particle size, pH, conductivity, contents of exchangeable K, Na, Ca, Mg, and Mn, content of P (extracted by means of 0.2 N H_2SO_4), and contents of Fe, Cu, Zn, and Pb (extracted by means of EDTA).

A summary is given of the average values of measurements of edaphic conditions in each layer of the profiles at each station. The vertical variation of these values has been found to depend on the soil material, as well as on the distance of the station from the outer coast. Profiles on gneissic material show, at an increasing depth, a decrease in the contents of organic matter, of conductivity, and of the contents of K, Na, Ca, Mg, Mn, Fe, Cu, and Zn—an increase in pH and in the content of P, but mostly an almost unchanged content of Pb. A profile on diabasic material for all edaphic factors shows approximately the same value in the layers. The profiles at the off-shore station, with a relatively low amount of precipitation, are those most faintly differentiated, while the profiles at the near-shore station, with a higher amount of precipitation, show a pronounced podsolization. Furthermore, a certain connection has been found between type of profile and vegetation. Some species of dwarf-shrubs are mainly connected with diabasic, or with off-shore profiles, while other species have the highest frequencies on podsolized, gneissic profiles near the outer coast.

CONTENTS

I. INTRODUCTION

Problems regarding development and classification of soil types in arctic areas have frequently been studied in Eurasia as well as in North America. On the basis of investigations of soil profiles a great number of arctic soil types have been set up and arranged in different lines of development, dependent on the occurrence of permafrost, draining conditions, coarseness of the material, and the depth down to the solid subsoil, *cf.* DREW and TEDROW (1962), GORSHENIN (1963), TEDROW and CANTLON (1958), TEDROW, DREW, HILL, and DOUGLAS (1958), TEDROW and HARRIES (1960).

The investigations of the soil profiles, however, have most frequently been limited to studies of immediately visible conditions such as, *e.g.*, the thickness of the soil layers, their structure, colour, estimated content of organic matter, and to analyse of physical conditions, such as the distribution of the mineral particles of different magnitudes, and pH and C/N ratio, *cf.* RETZER (1965), TEDROW and DOUGLAS (1964), TEDROW and HILL (1955), UGOLINI and TEDROW (1963). Recently, however, studies have also been made of the chemical conditions in arctic soil profiles, comprising analyses of conductivity, cation exchange capacity, and contents of some of the most important nutrients, *cf.* BROWN and TEDROW (1964), DOUGLAS and TEDROW (1960), DREW and TEDROW (1957), KARAVAYEVA (1958), KREIDA (1958), MIKHAYLOV (1960, 1961).

As far as Greenland is concerned, only a few published investigations of soil profiles are available. From North East Greenland (UGOLINI 1965, 1966 a, 1966 b) descriptions are available of Arctic brown soils, Podsol-like soils, Lithosols, Regosols, Tundra soils, Protoranker and Tundra Ranker. Information is, however, only given of the thickness of the layers, their colour, structure, and, in some cases, also of particle size, pH, and conductivity; of the vegetation, however, little information has been given. From the middle part of the west coast of Greenland DE LESSE (1952) gives rough descriptions of the layers of soil profiles in different types of vegetation. FREDSKILD (1961) offered analyses of pH, specific conductivity, water-retaining capacity, loss on ignition, and particle size in soil profiles from some of the plant communities analysed. From the continental parts of central West Greenland a few particulars are available concerning particle size, pH, conductivity, as well as content of organic matter as a few nutrients in some highly saline soil samples (BÖCHER 1949, 1959, 1963), but no analyses have been given of layers in soil profiles. MIRSKY (1964) gives brief information of observations of Arctic brown soils and faintly developed Podsol in an area in Southwestern Greenland.

In 1965 the author made both physical and chemical analyses of the individual layers in soil profiles from types of vegetation analysed in the more oceanic areas in low-arctic South Greenland. The investigations have been concentrated on the profiles which occur in varying types of dwarf-shrub vegetation under different climatic conditions. The purpose of these investigations has been to procure exact information of the edaphic conditions which are important to the plants, in the layers in different types of soil profiles, and to illustrate possible relations between climate and soil material, and the soil profiles and types of vegetation developed.

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II. CLIMATIC CONDITIONS IN THE AREA

The investigations were made in an area between 61°38′ and 62°05′ N, and between 48°34′ and 49°00′ W. From this area, however, no meteorological measurements are available. The nearest meteorological stations are Ivigtut (61°12′ N, 48°10′ W, 30 m a.s.l.) and Frederikshåb (62°00′ N, 49°43′ W). Ivigtut is situated about 20 km within the outer coast, and is protected from the direct influence of the ocean by rather high coastal mountains, while Frederikshåb is situated very far out in the skerries. From other parts of South Greenland it is known (*cf.* Petersen 1938: 47) that there may be great differences in climatic conditions at stations with a different situation in relation to the outer coast. The area investigated is situated at some distances from the ocean, and, as regards many climatic conditions, it can, therefore, be assumed to have the strongest resemblance to Ivigtut. In table 1 some climatic values recorded by Petersen (1938) have been grouped. The climate is rather oceanic, with an annual amount of precipitation of 1133 mm,

Table 1. *Climatic conditions at Ivigtut, 61°12′ N and 48°10′ W.*

Period	Precipitation mm 1876–1925	Temperature, °C Mean 1880–1925	Max. mean 52 years	Min. mean 55 years	Annual No. of days with Precip. ≥ 0.1 mm	Snowfall	Frost
January	84	−7.4	1.0	−11.6	12	11	30.2
February	66	−7.1	4.0	−14.2	10	9	27.1
March	85	−4.5	2.9	−12.1	12	10	28.7
April	64	−0.5	4.7	−5.5	10	8	25.1
May	89	4.5	8.3	1.9	10	5	13.2
June	81	8.0	11.0	4.4	10	1	1.5
July	78	9.9	12.8	7.6	9	0.02	0
August	96	8.6	10.8	5.8	10	0.02	0.1
September	147	5.0	8.3	3.2	13	2	6.0
October	144	1.1	4.4	−2.0	12	6	21.0
November	118	−2.9	1.1	−7.3	12	9	26.4
December	81	−5.9	0.6	−12.1	11	10	29.0
Year	1133	0.8			139	70	208

distributed on 139 days per year, the 70 days of which have snowfall. The summers are rather cool, with a mean temperature of 9.9° C in July. The winters are relatively mild, with a mean temperature of −7.4° C in January. The area lies in the zone which by BLACK (1954) has been described as having only sporadic permafrost, and in none of the soil profiles examined, which all stem from well-drained localities, any signs were found of permafrost.

As mentioned above, the climate, particularly the amount of precipitation, can be highly dependent on the distance of the station from the ocean, and as this factor must be assumed to be of importance to the distribution of the different types of vegetation as well as the formation of the soil profiles, the investigations were made at 3 stations, situated at different distances from the ocean, and hence presumably having also different climates. One of the stations (Neria) is situated at about the same distance from the outer coast as Ivigtut, while the two other stations are situated closer to the outer coast (Tasiussakasik), and far away from it (Nigerdlikasik), respectively.

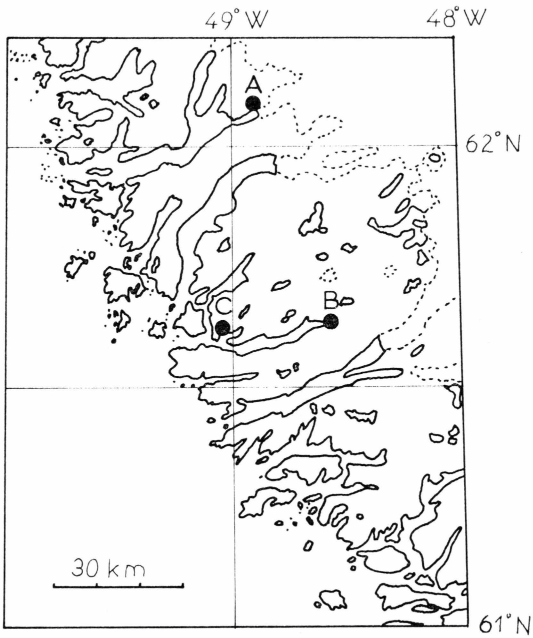

Fig. 1. Situation of the stations A. Nigerdlikasik, B. Neria, and C. Tasiussakasik (cf. figs. 2, 3).

III. SITUATION AND GEOLOGICAL CONDITIONS OF THE STATIONS

The geographical situation of the stations appears from fig. 1.

Station A. Nigerdlikasik. 62°05′N, 48°51′W. (13.–18. August 1965). The station is situated at the head of a long inlet, about 40 km from the coast line, and abuts on a glacier debouching into the inlet (*cf.* fig. 2, p. 11). The prequaternary formations are composed of precambrian gneiss formations. The quaternary formations mainly consist of rather new and fresh moraine material of predominantly gneissic origin, or sporadically of primarily deposited weathering materials.

Station B. Neria. 61°38′N, 48°34′W. (14.–19., 24.–28. July 1965). The station is situated at the head of an inlet, about 20 km from the coast line, at the outfall of a large river into a broad valley. The prequaternary formations are composed of precambrian, light, homogeneous gneiss formations, with a relatively high content of orthoclase. In the area there are broad dykes of diabase, with a high content of apatite, rich in phosphorus. The quaternary formations consist of old moraine material, alluvial formations, or – sporadically – of primarily deposited weathering materials.

Station C. Tasiussakasik. 61°38′N, 49°00′W (28. July–4. August 1965). The station is situated on the north side of the mouth of an inlet, close to the coast line, which is shown on the right-hand side of fig. 3. The prequaternary formations are gneiss, with dykes of diabase. The quaternary formations consist of old moraine material, alluvial formations, or primarily deposited weathering materials.

Further information about geological conditions at the station can be found in BERTHELSEN & NOE-NYGAARD (1965).

Fig. 2. Station A. Nigerdlikasik, at the head of a long inlet, into which a glacier debouches (*cf.* fig. 1, p. 9). Analyses from the vegetation in the foreground, left, dominated by *Betula glandulosa*, *Vaccinium uliginosum microphyllum*, *Salix glauca callicarpaea*, *Rhododendron lapponicum*, or *Juniperus communis nana*, *cf.* figs. 4 (p. 17) and 5 (p. 18). Photo by the author, 15.8. 1965.

Fig. 3. Station C. Tasiussakasik, at the head of an inlet (*cf.* fig. 1, p. 9). Analyses from the area in the front half of the picture, dominated by *Betula glandulosa*, *Empetrum nigrum hermaphroditum*, and lichens, *cf.* fig. 6 (p. 23). Photo by the author, 29.7.1965.

Fig. 2.

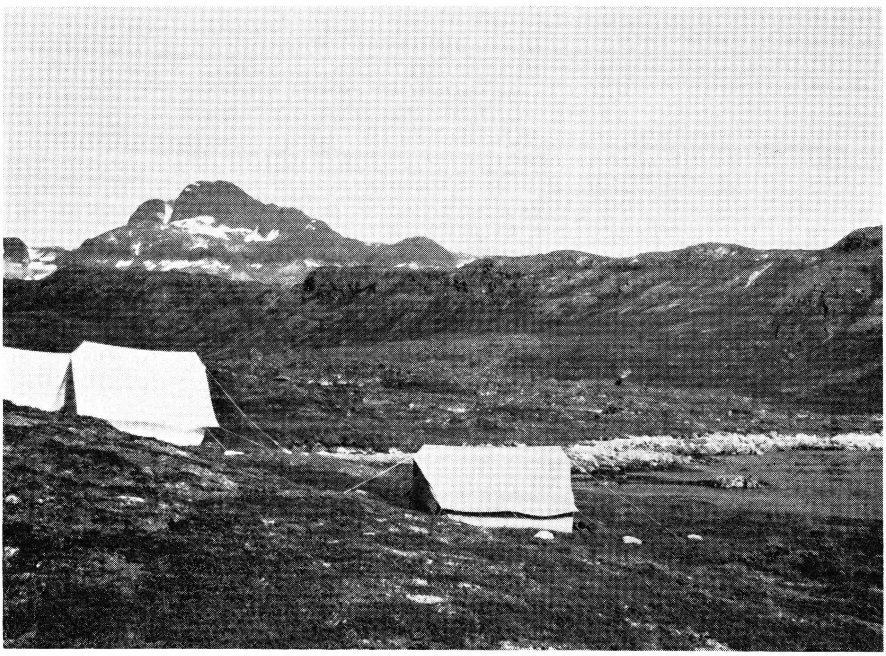

Fig. 3.

IV. FREQUENCY OF DWARF-SHRUBS AND RELATIVE CLIMATIC CONDITIONS AT THE STATIONS

At all three stations observations were made of all species of vascular plants with regard to quantitative occurrence, expressed by a scale from 5–1, covering the designations: very common, common, sparse, rare, and very rare. In table 2 these values have been indicated for dwarf-shrubs and bushes, found at the 3 stations. For some of the species, viz. *Juniperus communis nana*, *Salix uva-ursi*, *Sorbus groenlandica*, and *Rhododendron lapponicum*, it is shown in the table that these can be classed with a climatic type of distribution which in Greenland is more or less closely connected with areas with a relatively continental climate. For other species, viz. *Empetrum nigrum hermaphroditum*, *Ledum groenlandicum*, *Salix arctophila*, *S. herbacea*, and *Harrimanella hypnoides*, it is indicated that they can be classed with a climatic type of distribution which is mainly connected with areas with a relatively oceanic climate.

Table 2. *Frequency of shrubs at the three stations, expressed by a scale from 5 = very common, to 1 = very rare. The species arranged according to relationship to climatic type of distribution in Greenland.*

Clim. type	Station	Nigerdlikasik	Neria	Tasiussakasik
	Betula glandulosa	5	5	5
	Salix glauca callicarpaea	5	5	5
	Vaccinium uliginosum microph.	5	5	5
cont.	*Juniperus communis nana*	5	4	4
cont.	*Salix uva-ursi*	4	4	3
cont.	*Sorbus groenlandica*	4	4	1
cont.	*Rhododendrom lapponicum*	4	3	3
ocean.	*Empetrum nigrum hermaphr.*	4	5	5
ocean.	*Ledum groenlandicum*	4	4	5
ocean.	*Salix arctophila*	3	4	5
ocean.	*Salix herbacea*	3	4	5
ocean.	*Harrimanella hypnoides*	2	3	4

Betula glandulosa, *Salix glauca callicarpaea*, and *Vaccinium uliginosum microphyllum* were found to be very common at all three stations, while as regards the other species, the following pronounced differences between the stations (Table 2) were found:

Station Nigerdlikasik is, *e.g.*, characterized by having the highest frequencies of the species of a continental type of distribution, but relatively low frequencies of the oceanic species. At this station were, furthermore, found *Arabis arenicola*, *Juncus filiformis*, and *Botrychium lanceolatum*, a fact which also indicates that the station has rather a continental climate, as compared with the two other stations.

Station Tasiussakasik is characterized by having the lowest frequencies of the continental species, and the highest frequencies of the oceanic species. At the station we, furthermore, found *Viola labradorica*, as well as sporadic growths of *Nardus stricta*, which clearly indicates that the station has a relatively oceanic climate.

Station Neria has, on an average, a medium frequency of the continental as well as the oceanic species, and it can therefore be assumed that the amount of precipitation is between the values of those existing for the two other stations.

V. METHODS EMPLOYED AT ANALYSES OF SOIL PROFILES

In each of the localities investigated a hole was drilled, and from each of the visibly well-defined layers a soil sample was taken, which was immediately dried at about 50° C. After screening off particles > 2.0 mm, the analyses mentioned below were made of each of the dried soil samples, according to the following methods:

Colour: Determined on the dried soil.

Particle size: The content of inorganic particles of the magnitudes 2.0–0.2 mm determined by mechanical, dry screening. Expressed in percentages by weight of particles < 2.0 mm.

Organic matter: Oxidation with $K_2Cr_20_7$ and H_2SO_4, and then titration with Fe $(NH_4)_2$ $(SO_4)_2 . 6$ H_2O (Walkley-Black's method, *cf.* Jackson 1958). Expressed in percentages by weight of dry soil.

pH: 10 g soil + 50 ml H_2O.

Specific conductivity: 10 g soil + 50 ml H_2O. Expressed in μ mho at 20° C.

K, Na, Ca, Mg, Mn: Exchangeable contents, extracted by means of 1 N NH_4OAc. K and Na measured by a Coleman Flame Photometer 21. Ca, Mg, and Mn measured by a Perkin-Elmer Atomic Absorption Spectrophotometer 303. Expressed in meq/100 g dry soil. + indicates content < 0.002 meq.

P: Extracted by means of 0.2 N H_2SO_4. Measured according to the ammonium molybdate method (Jackson 1958) by a Coleman Spectrophotometer Universal 14. Expressed in ppm dry soil.

Fe, Cu, Zn, Pb: Extracted by means of 0.02 M EDTA (Titriplex III). Measured by a Perkin-Elmer Atomic Absorption Spectrophotometer 303. Expressed in ppm dry soil.

VI. ANALYSES OF VEGETATION AND SOIL PROFILES

Analyses of vegetation have been made by estimating the degree of covering of each species on 1 m², according to the scale of Hult–Sernander, from 1–5:

$$\left(1 = <\frac{1}{16},\quad 2 = \frac{1}{8} - \frac{1}{16},\quad 3 = \frac{1}{4} - \frac{1}{8},\quad 4 = \frac{1}{2} - \frac{1}{4},\quad 5 = >\frac{1}{2}\right).$$

The nomenclature used for vascular plants and for lichens is in accordance with Böcher, Holmen and Jakobsen (1966) and Hale and Culberson (1966), respectively.

A. Station Nigerdlikasik

At the station analyses of vegetation and soil profiles were made at four different places, all on mainly gneissic material, at heights between 2 and 10 m a.s.l.

1. Analyses of vegetation in An. A1–A4 (Table 3, p. 16):

An. A 1: *Rhododendron lapponicum – Betula glandulosa – Salix glauca callicarpaea* – community, rich in herbs and lichens (*cf.* fig. 4, p. 17). Common type of vegetation.

An. A 2: *Betula glandulosa – Juniperus communis nana* – community, rich in herbs and lichens (*cf.* fig. 5, p. 18). Common type of vegetation.

An. A 3: *Betula glandulosa – Vaccinium uliginosum microphyllum* – community, poor in herbs and lichens. Common type of vegetation.

An. A 4: *Vaccinium uliginosum microphyllum – Empetrum nigrum hermaphroditum* – community, poor in herbs and lichens. Sparse type of vegetation.

Table 3. *Degree of covering of the species on 1 m² according to Analyses A 1–A 4 at Station Nigerdlikasik, all developed on mainly gneissic material. Expressed by a scale from 1 to 5* (HULT-SERNANDER). *Analyses of pertaining soil profiles in tables 4, 5 and 6.*

Analysis No.	A 1	A 2	A 3	A 4
Altitude, m a.s.l.	10	10	10	2
Exposure and slope	0°	S 10°	0°	0°
Rhododendron lapponicum	3			
Betula glandulosa	3	4	4	
Salix glauca callicarpaea	3	1		
Juncus trifidus	2	1		
Carex bigelowii	2	1	1	1
Hierochloë monticola	1	1		
Juniperus communis nana		3		
Luzula spicata		1		
Poa glauca		1		
Chamaenerion angustifolium		1		
Campanula gieseckiana		1		
Vaccinium uliginosum microph			4	4
Empetrum nigrum hermaphrod.				4
Ledum groenlandicum				1
Festuca vivipara			1	
Cladonia alpestris	2	2		
Cladonia rangiferina	2	2	1	
Stereocaulon alpinum	2			
Alectoria ochroleuca	1			
Cladonia coccifera	1			
Cetraria nivalis	1			
Stereocaulon paschale		1		
Cladonia mitis			1	
Cetraria delisei				1

2. Analyses of soil profiles in An. A1–A4:

The four profiles investigated all show approximately the same stratification, consisting at the top of a dark layer of topsoil (Table 4, p. 17), and below it upper subsoil (Table 5, p. 18) and lower subsoil (Table 6, p. 19), which can be distinguished on the basis of the differences in colour.

Fig. 4. Station A. Nigerdlikasik, Analysis A1. Vegetation dominated by *Rhododendron lapponicum* (foreground, left), *Betula glandulosa* (foreground, right), *Salix glauca callicarpaea* (background), *Juncus trifidus*, *Carex bigelowii*, and *lichens* (Table 3). Profile analyses in tables 4, 5 and 6. Photo by the author, 15.8. 1965.

Table 4. *Analyses of topsoil according to Analyses A 1–A 4 (Nigerdlikasik), cf. table 3, all developed on mainly gneissic material.*

Analysis No.	A 1	A 2	A 3	A 4
Depth, cm	0–4	0–3	0–5	0–6
Colour, dry soil	greyish brown	greyish brown	yellowish brown	yellowish brown
Org. matter, %	10	13	37	14
pH	4.2	4.4	4.2	4.4
Conduct., μ mho	79	100	286	143
K, meq/100 g	0.23	0.29	0.70	0.23
Na, –	0.09	0.10	0.33	0.19
Ca, –	0.38	1.26	5.00	5.00
Mg, –	0.44	1.05	2.30	1.65
Mn, –	+	0.024	0.006	0.006
P, ppm	33	28	95	95
Fe, -	750	525	1325	850
Cu, -	1.0	1.0	4.0	2.5
Zn, -	0.5	5.0	6.0	3.0
Pb, -	5.0	5.0	4.0	3.5

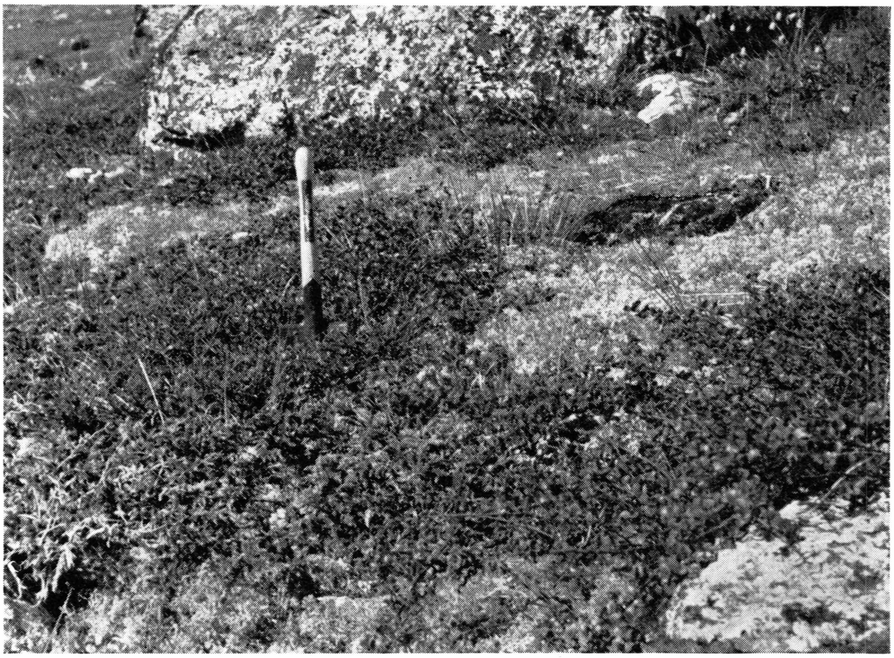

Fig. 5. Station A. Nigerdlikasik, Analysis A 2. Vegetation dominated by *Betula glandulosa* (right), *Juniperus communis nana* (left), and lichens (Table 3). Profile analyses in tables 4, 5 and 6. Photo by the author, 15.8. 1965.

Table 5. *Analyses of upper subsoil according to Analyses A 1–A 4 (Nigerdlikasik), cf. table 3, all developed on mainly gneissic material.*

Analysis No.	A 1	A 2	A 3	A 4
Depth, cm	4–30	3–35	5–10	6–15
Colour, dry soil	greyish orange	brownish orange	orange grey	orange grey
Org. matter, %	5	5	2	4
2.0–0.2 mm, %	51	57	52	44
pH	5.0	4.9	5.0	4.9
Conduct., μ mho	17	18	16	43
K, meq/100 g	0.07	0.07	0.04	0.10
Na, –	0.07	0.07	0.06	0.11
Ca, –	0.12	0.11	0.60	1.71
Mg, –	0.07	0.12	0.16	0.50
Mn, –	+	+	+	+
P, ppm	64	89	190	20
Fe, -	425	300	250	550
Cu, -	0.5	0.5	0.5	2.5
Zn, -	0.5	0.5	+	1.0
Pb, -	4.8	5.8	2.5	2.0

Table 6. *Analyses of lower subsoil according to Analyses A 1–A 2 (Nigerdlikasik), cf. table 3, both developed on mainly gneissic material.*

Analysis No.	A 1	A 2
Depth, cm	30–35	35–40
Colour, dry soil	orange grey	yellowish white
Org. matter, %	2	2
2.0–0.2 mm, %	59	60
pH	5.2	5.2
Conduct., μ mho	9	7
K, meq/100 g	0.04	0.04
Na, –	0.07	0.07
Ca, –	0.23	0.10
Mg, –	0.04	0.03
Mn, –	+	+
P, ppm	260	310
Fe, -	200	100
Cu, -	0.5	0.5
Zn, -	0.5	0.5
Pb, -	4.0	5.5

B. Station Neria

At the station analyses of vegetation and soil profiles were made at five different places, at heights between 10 and 50 m a.s.l. Of these, An. B1–B4 are on mainly gneissic material, and An. B5 on diabasic material.

1. Analyses of vegetation in An. B1–B5 (Table 7, p. 20):

An. B 1: *Betula glandulosa – Empetrum nigrum hermaphroditum* – community, poor in herbs and lichens. On gneissic morainic material. Common type of vegetation.

An. B 2: *Betula glandulosa – Empetrum nigrum hermaphroditum – Ledum groenlandicum* – community, poor in herbs and lichens. On gneissic morainic material. Common type of vegetation.

An. B 3: *Empetrum nigrum hermaphroditum – Loiseleuria procumbens* – community, poor in herbs and lichens. On gneissic morainic material. Sparse type of vegetation.

An. B 4: *Ledum groenlandicum – Betula pubescens – Sorbus groenlandica* – community, rich in herbs, without lichens. On gneissic material. Sparse type of vegetation.

Table 7. *Degree of covering of the species on 1 m² according to Analyses B 1–B 5, at Station Neria, developed on mainly gneissic material (B 1–B 4), or on diabasic material (B 5). Expressed by a scale from 1 to 5* (HULT-SERNANDER). *Analyses of pertaining soil profiles in tables 8 and 9.*

Analysis No.	B 1	B 2	B 3	B 4	B 5
Altitude, m a.s.l.	20	20	10	50	25
Exposure and slope	W 10°	W 10°	0°	S 20°	S 20°
Betula glandulosa	3	3			
Empetrum nigrum hermaphrod.	5	3	4		
Ledum groenlandicum		4		3	
Carex bigelowii	1	1		1	1
Loiseleuria procumbens			3		
Betula pubescens		1		4	3
Salix glauca callicarpaea		1		1	2
Deschampsia flexuosa			2		
Lycopodium selago			1		
Sorbus groenlandica				3	
Phegopteris connectilis				2	
Coptis trifolia				1	
Listera cordata				1	
Poa glauca				1	
Vaccinium uliginosum microph.				1	1
Rhododendron lapponicum					3
Juniperus communis nana					3
Carex scirpoidea					1
Campanula gieseckiana					1
Juncus trifidus					1
Polygonum viviparum					1
Saxifraga aizoon					1
Bartsia alpina					1
Cetraria islandica	1				
Cladonia alpestris		1			
Cetraria delisei			1		
Stereocaulon paschale			1		

An. B 5: *Rhododendron lapponicum – Betula pubescens – Juniperus communis nana* – community, rich in herbs, without lichens. On diabasic dyke. Sparse type of vegetation, occurring only on diabasic dykes.

2. Analyses of soil profiles in An. B1–B5:

Of the five analyses: B1–B5, An. B1–B4 are on mainly gneissic material, and in all of them two different layers can be distinguished, on the basic of the colour: one layer of topsoil (Table 8, p. 21) and one layer of upper subsoil (Table 9, p. 21). Analysis B5 is on weathering materials

Table 8: *Analyses of topsoil according to Analyses B 1–B 5 (Neria), cf. table 7, developed on mainly gneissic material (B 1–B 4), or on diabasic material (B 5).*

Analysis No.	B 1	B 2	B 3	B 4	B 5
Depth, cm	0–10	0–15	0–10	0–10	0–10
Colour, dry soil	dark brown	dark brown	light brown	dark brown	light brown
Org. matter, %	49	60	23	41	10
pH	4.1	4.7	3.8	4.2	5.8
Conduct., μ mho	257	214	157	300	43
K, meq/100 g	1.06	0.63	0.37	0.70	0.11
Na, –	0.32	0.30	0.10	0.17	0.11
Ca, –	9.60	24.30	0.91	5.60	3.54
Mg, –	5.30	3.80	1.00	2.70	1.00
Mn, –	0.009	0.015	0.005	0.017	0.005
P, ppm	70	58	38	113	840
Fe, -	2950	2775	1100	9000	500
Cu, -	5.0	6.5	1.0	3.0	2.5
Zn, -	20.0	7.0	4.0	6.0	1.5
Pb, -	5.0	6.5	1.5	5.0	0.5

Table 9: *Analyses of upper subsoil according to Analyses B 1–B 5 (Neria), cf. table 7, developed on mainly gneissic material (B 1–B 4), or on diabasic material (B 5).*

Analysis No.	B 1	B 2	B 3	B 4	B 5
Depth, cm	10–20	15–20	10–15	10–15	10–25
Colour, dry soil	yellowish brown	yellowish brown	yellowish brown	yellowish brown	light brown
Org. matter, %	3	8	5	15	7
2.0–0.2 mm, %	57	87	10	68	66
pH	4.6	5.6	4.9	4.6	5.9
Conduct., μ mho	21	30	11	114	40
K, meq/100 g	0.04	0.07	0.05	0.18	0.11
Na, –	0.06	0.09	0.05	0.11	0.10
Ca, –	0.80	2.55	0.05	2.32	4.50
Mg, –	0.43	0.36	0.03	0.95	1.12
Mn, –	+	0.005	+	0.002	0.005
P, ppm	13	103	165	63	820
Fe, -	500	200	175	1775	400
Cu, -	0.5	3.0	0.5	1.5	6.0
Zn, -	1.0	1.5	0.5	1.5	2.5
Pb, -	3.5	7.5	2.0	1.5	0.5

on a diabasic dyke. Also in this case two layers have been analysed: One layer of topsoil (Table 8), and one layer of upper subsoil (Table 9).

C. Station Tasiussakasik

At the station analyses were made of vegetation and soil profiles at 4 different places, all on alluvial formations of mainly gneissic material, at heights between 2 and 10 m a.s.l.

Table 10. *Degree of covering of the species on 1 m² according to Analyses C1–C4, at Station Tasiussakasik, all developed on alluvial, mainly gneissic material. Expressed by a scale from 1 to 5* (HULT-SERNANDER). *Analyses of pertaining soil profiles in tables 11, 12, 13 and 14.*

Analysis No.	C 1	C 2	C 3	C 4
Altitude, m a.s.l.	10	2	10	10
Exposure and slope	0°	0°	0°	0°
Betula glandulosa	4	4	3	4
Empetrum nigrum hermaphrod.		5	3	4
Vaccinium uliginosum microph.			1	1
Salix glauca callicarpaea			2	
Carex bigelowii		1		
Trisetum triflorum molle		1		
Luzula spicata		1		
Cladonia rangiferina	3		3	1
Cladonia mitis	3		1	1
Cladonia gracilis chordalis	1			
Cetraria nivalis		1	1	
Stereocaulon paschale			1	1
Alectoria ochroleuca			1	

1. Analyses of vegetation in An. C1–C4 (Table 10):

An. C 1: *Betula glandulosa – Cladonia rangiferina – Cl. mitis* – community, without herbs. Common type of vegetation.

An. C 2: *Betula glandulosa – Empetrum nigrum hermaphroditum* – community, poor in herbs and lichens. Common type of vegetation (*cf.* fig. 6).

An. C 3: *Betula glandulosa – Empetrum nigrum hermaphroditum – Cladonia rangiferina* – community, without herbs, but rich in lichens. Very common type of vegetation.

Fig. 6. Station C. Tasiussakasik, Analysis C 2. Vertical incision through podsolized profile, developed on alluvial, mainly gneissic material, with high contents of coarse particles (analyses in tables 11, 12, 13 and 14). Vegetation dominated by *Empetrum nigrum hermaphroditum* and *Betula glandulosa* (Table 10). Photo by the author, 3.8. 1965.

An. C 4: *Betula glandulosa – Empetrum nigrum hermaphroditum* – community, without herbs, but rich in lichens. Very common type of vegetation.

2. Analyses of soil profiles in An. C1–C4:

In each of the four profiles investigated four clearly defined layers can be distinguished on the basis of the colour: at the top a humus layer (Table 11, p. 24) and below it a bleached layer (Table 12, p. 24), a depositing layer (Table 13, p. 24), and a lower subsoil layer (Table 14, p. 24).

Table 11. *Analyses of the humus layer according to Analyses C 1–C 4 (Tasiussakasik), cf. table 10, all developed on alluvial, mainly gneissic material.*

Analysis No.	C 1	C 2	C 3	C 4
Depth, cm	0–5	0–5	0–8	0–10
Colour, dry soil	dark brown	dark brown	dark brown	dark brown
Org. matter, %	71	41	68	64
pH	3.7	4.2	3.8	3.6
Conduct., μ mho	372	129	300	300
K, meq/100 g	1.75	0.54	0.97	1.10
Na, –	0.80	0.42	0.88	0.77
Ca, –	4.58	2.67	8.85	3.45
Mg, –	5.40	2.60	7.80	4.80
Mn, –	0.018	0.009	0.014	0.004
P, ppm	123	63	85	85
Fe, -	1500	1525	1450	1875
Cu, -	4.0	3.0	4.0	2.5
Zn, -	10.0	7.5	29.0	19.0
Pb, -	10.0	4.5	5.5	5.0

Table 12. *Analyses of the bleached layer according to Analyses C 1–C 4 (Tasiussakasik), cf. table 10, all developed on alluvial, mainly gneissic material.*

Analysis No.	C 1	C 2	C 3	C 4
Depth, cm	5–15	5–20	8–20	10–25
Colour, dry soil	brownish grey	orange grey	yellowish grey	brownish grey
Org. matter, %	3	2	2	2
2.0–0.2 mm, %	70	86	74	85
pH	4.5	4.7	4.4	4.5
Conduct., μ mho	24	24	24	15
K, meq/100 g	0.05	0.08	0.06	0.04
Na, –	0.06	0.11	0.07	0.07
Ca, –	0.18	0.24	0.70	0.17
Mg, –	0.11	0.34	0.60	0.14
Mn, –	+	+	+	+
P, ppm	79	79	33	120
Fe, -	425	563	475	413
Cu, -	0.5	0.5	0.5	0.7
Zn, -	0.5	1.0	0.5	1.0
Pb, -	1.5	3.3	3.0	0.5

Table 13. *Analyses of the depositing layer according to Analyses C1–C4 (Tasiussakasik), cf. table 10, all developed on alluvial, mainly gneissic material.*

Analysis No.	C 1	C 2	C 3	C 4
Depth, cm	15–17	20–30	20–25	25–30
Colour, dry soil	reddish brown	reddish brown	reddish brown	reddish brown
Org. matter, %	2	1	3	2
2.0–0.2 mm, %	84	65	68	98
pH	5.0	5.3	5.0	5.1
Conduct., μ mho	13	9	17	10
K, meq/100 g	0.04	0.06	0.04	0.03
Na, –	0.06	0.15	0.08	0.06
Ca, –	0.12	0.10	0.14	0.17
Mg, –	0.07	0.07	0.12	0.08
Mn, –	+	+	+	+
P, ppm	340	250	125	245
Fe, -	550	275	425	600
Cu, -	0.5	0.5	0.5	0.5
Zn, -	0.5	0.5	0.5	1.0
Pb, -	3.5	4.5	2.0	2.5

Table 14. *Analyses of lower subsoil according to Analyses C1–C3 (Tasiussakasik), cf. table 10, all developed on alluvial, mainly gneissic material.*

Analysis No.	C 1	C 2	C 3
Depth, cm	17–25	30–50	25–30
Colour, dry soil	light brown	light brown	light brown
Org. matter, %	1	1	1
2.0–0.2 mm, %	73	56	67
pH	5.3	5.5	5.3
Conduct., μ mho	7	8	9
K, meq/100 g	0.03	0.04	0.04
Na, –	0.07	0.08	0.07
Ca, –	0.07	0.12	0.08
Mg, –	0.03	0.07	0.03
Mn, –	+	+	+
P, ppm	380	275	310
Fe, -	250	75	150
Cu, -	0.5	0.5	0.5
Zn, -	1.0	0.5	0.5
Pb, -	3.0	3.0	2.0

VII. VARIATION OF EDAPHIC CONDITIONS IN THE PROFILES

Comparisons of the average value of the edaphic factors in corresponding layers from the profiles show that the edaphic conditions in the profile vary to a higher or lower degree in the different layers, amongst other things dependent on the question whether the profiles have been developed on mainly gneissic material or on diabasic material (Tables 15, 16 and 17).

a. Profiles on mainly gneissic material

(from Nigerdlikasik, Neria, and Tasiussakasik)

Organic matter (Table 15): At increasing depth, all profiles show a decrease in the content of organic matter. At Nigerdlikasik the difference is particularly great between topsoil and upper subsoil (18.5 and 4.0 per cent, respectively). At Neria, the corresponding two layers contain

Table 15: *Average values of contents of organic matter, pH, and conductivity in each layer of the profiles at the three stations, and on different soil material.*

Station and soil material	Layer	No. of analyses	Org. matter %	pH	Con- duct. μ mho
Nigerdlikasik	Topsoil	4	18.5	4.3	152
Mainly gneiss	Upper subsoil	4	4.0	5.0	24
	Lower subsoil	2	2.0	5.2	8
Neria	Topsoil	4	43.3	4.2	232
Mainly gneiss	Upper subsoil	4	7.8	4.9	44
Neria	Topsoil	1	10.0	5.8	43
Diabase	Upper subsoil	1	7.0	5.9	40
Tasiussakasik	Humus layer	4	61.0	3.8	275
Mainly gneiss, alluvium	Bleach. layer	4	2.3	4.5	22
	Deposit. layer	4	2.0	5.1	12
	Lower subsoil	3	1.0	5.4	8

43.3 and 7.8 per cent organic matter, respectively. The most pronounced difference between profile layers has, however, been found at Tasiussakasik, where all the four profiles must be described as being highly podsolized. The topmost layer (humus layer) has an average content of organic matter of 61.0 per cent, while the contents of the bleached layer, the depositing layer, and the lower subsoil layer are 2.3, 2.0 and 1.0 per cent, respectively, i.e. approximately the same contents as in the lower subsoil at Nigerdlikasik.

pH (Table 15): At increasing depth, all profiles show a marked increase in pH. At Nigerdlikasik, the average values in the three layers from the top downwards are 4.3, 5.0 and 5.2, respectively, i. e. a particularly great increase (0.7) from topsoil to upper subsoil. At Neria, the average values in topsoil and upper subsoil are 4.2 and 4.9, respectively, i.e. an increase of 0.7, too. At Tasiussakasik, the increase from the top layer to the bottom layer is 1.6, the average values measured being 3.8 in the humus layer, 4.5 in the bleached layer, 5.1 in the depositing layer, and 5.4 in the lower subsoil layer.

Conductivity (Table 15): At increasing depth, all profiles show a considerable decrease in conductivity. At Nigerdlikasik and Neria the decrease is particularly great from topsoil (152–232 μ mho) to upper subsoil (24–44 μ mho), and at Tasiussakasik there is also a great decrease from the humus layer (275 μ mho) to the 3 lower layers (22, 12 and 8 μ mho, respectively).

K and Na (Table 16): At increasing depth, a great decrease has been found in all profiles of the content of as well K as also Na. At Nigerdlikasik and Neria the decrease is particularly great from topsoil to upper subsoil, whereas at Nigerdlikasik there are about the same low contents in the upper and in the lower subsoil. At Tasiussakasik, there is also a great decrease from the humus layer to the underlying 3 layers, which, with regard to K as well as to Na, contain approximately the same quantities.

Ca and Mg (Table 16): At increasing depth, all profiles show a steadily decreasing content of Ca as well as Mg. There is a great decrease from topsoil to upper subsoil (Nigerdlikasik and Neria), but also from upper to lower subsoil there is a great decrease (Nigerdlikasik). Likewise, in the profiles at Tasiussakasik, the highest content by far has been found in the humus layer, but a decrease has also been established from the bleached layer to the depositing layer, and from the latter to the lower subsoil.

Table 16. *Average values of contents of K, Na, Ca, Mg and Mn, respectively, in each layer of the profiles at the three stations, and on different soil material.*

Station and soil material	Layer	No. of analyses	meq/100 g soil K	Na	Ca	Mg	Mn
Nigerdlikasik	Topsoil	4	0.36	0.18	2.91	1.36	0.009
Mainly gneiss	Upper subsoil	4	0.07	0.08	0.64	0.21	+
	Lower subsoil	2	0.04	0.07	0.17	0.04	+
Neria	Topsoil	4	0.69	0.22	10.10	3.20	0.012
Mainly gneiss	Upper subsoil	4	0.09	0.08	1.43	0.44	0.002
Neria	Topsoil	1	0.11	0.11	3.54	1.00	0.005
Diabase	Upper subsoil	1	0.11	0.10	4.50	1.12	0.005
Tasiussakasik	Humus layer	4	1.09	0.72	4.89	5.15	0.011
Mainly gneiss,	Bleach. layer	4	0.06	0.08	0.32	0.30	+
alluvium	Deposit. layer	4	0.04	0.09	0.13	0.09	+
	Lower subsoil	3	0.04	0.07	0.09	0.04	+

Mn (Table 16): The contents of Mn are low (0.009–0.012 meq), in the topsoil (Nigerdlikasik and Neria), as well as in the humus layer (Tasiussakasik); in all the underlying layers the content is, however, still lower (<0.002 meq).

P (Table 17): At increasing depth, a pronounced increase has been found in all profiles. From topsoil to upper subsoil the increase is only small (Nigerdlikasik and Neria), whereas it is very steep from upper to lower subsoil (Nigerdlikasik). At Tasiussakasik, there is a small decrease from the humus layer (92 ppm) to the bleached layer (78 ppm), but a very great increase from the bleached layer to the depositing layer (240 ppm), and again a distinct increase from this layer to the lower subsoil (321 ppm).

Fe (Table 17): The contents of Fe have been found to decrease markedly at increasing depth in all profiles, with the exception of the podsolized profiles at Tasiussakasik. Here the humus layer has the highest content (1588 ppm), while, by the method of extraction employed, the same quantities of Fe have been measured in the bleached layer and in the depositing layer (469 and 463 ppm, respectively). At the transition to the lower subsoil, there is again a marked decrease of the content of Fe (158 ppm), corresponding to the content in the lower subsoil at Nigerdlikasik (150 ppm).

Cu and Zn (Table 17): In all profiles there is, at increasing depth, a marked decrease in the contents of Cu as well as Zn. The greatest diffe-

Table 17. *Average values of contents of P, Fe, Cu, Zn and Pb, respectively, in each layer of the profiles at the three stations, and on different soil material.*

Station and soil material	Layer	No. of analyses	ppm soil				
			P	Fe	Cu	Zn	Pb
Nigerdlikasik	Topsoil	4	63	863	2.1	3.6	4.4
Mainly gneiss	Upper subsoil	4	91	381	1.0	0.5	3.8
	Lower subsoil	2	285	150	0.5	0.5	4.8
Neria	Topsoil	4	70	3956	3.9	9.3	4.5
Mainly gneiss	Upper subsoil	4	86	663	1.4	1.1	3.6
Neria	Topsoil	1	840	500	2.5	1.5	0.5
Diabase	Upper subsoil	1	820	400	6.0	2.5	0.5
Tasiussakasik	Humus layer	4	92	1588	3.4	16.4	6.3
Mainly gneiss,	Bleach. layer	4	78	469	0.6	0.8	2.1
alluvium	Deposit. layer	4	240	463	0.5	0.6	3.1
	Lower subsoil	3	321	158	0.5	0.7	2.7

rence is from topsoil to upper subsoil, while the contents in the upper and in the lower subsoil are of the same size (Nigerdlikasik and Neria). At Tasiussakasik, the contents in the topmost layer, the humus layer, are also much higher than in the three underlying layers, which have approximately the same contents, with regard to Cu as well as to Zn.

Pb (Table 17): Both at Nigerdlikasik and at Neria the contents are about the same in topsoil as well as upper and lower subsoil. At Tasiussakasik, the humus layer has the highest content, while the content is markedly less in the three underlying layers, particularly in the bleached layer.

b. Profile on diabasic material (from Neria):

The profile differs markedly from the profiles on mainly gneissic material at all three stations by the fact that, for all factors examined the same, or approximately the same, values have been found in the topsoil and in the upper subsoil (Tables 15, 16 and 17).

VIII. RELATIONS BETWEEN CLIMATE, PROFILES AND VEGETATION

On the basis of difference in the frequency of species of dwarf-shrubs at the three stations (Section IV, p. 12), it is assumed that there is some difference in the climatic conditions, particularly in the amount of precipitation, at the stations. This variation, which manifests itself in a different development of types of vegetation, due to the different frequency of e.g. species of shrubs, is also assumed to be greatly contributory to the formation of different soil profiles at the stations.

As demonstrated in Section VII (p. 26), a change in the values of the edaphic factors has been found in the profiles at all three stations as the depth increases. The variation of these values in the profiles differs, however, for the three stations, and between these there is a marked difference in the development of the soil profiles (Tables 15, 16 and 17).

At Nigerdlikasik the average values in the individual layers of the profiles thus show the following differences in relation to the other stations: pH is higher, content of organic matter lower, in topsoil as well as in upper subsoil, and podsolization does not seem to take place. These conditions can be assumed to be due partly to the relatively small amounts of precipitation, partly to the fact that all the profiles at Nigerdlikasik have been developed on material with the lowest content of coarse particles.

At Neria profiles were investigated partly on mainly gneissic material, partly on diabasic material, and these profiles have been found to differ greatly. The profiles on gneissic material resemble the profiles on gneissic material at Nigerdlikasik. They have, however, a lower value of pH, and a higher content of organic matter, but, as was the case at Nigerdlikasik, no signs of podsolization were found, neither in profiles with high, nor in profiles with low contents of coarse particles. It is to be assumed that it is the relatively smaller amounts of precipitation at the stations Nigerdlikasik and Neria which cause the profiles at these stations not to be podsolized, as are the profiles at Station Tasiussakasik, with its higher amount of precipitation. The profile on diabasic material at Neria differs from all the profiles on gneissic material by not showing any pronounced stratification, and by having a considerably higher value of pH, a lower content of humus, and a particularly high content of P.

At Tasiussakasik a pronounced podsolization has been found in all the four profiles, with a humus layer at the top with a very low value of pH and a high content of organic matter, and at depths between 15 and 30 cm a hard, reddish brown depositing layer with a thickness of 2–10 cm. These profiles have all been developed on gneissic material with a high content of coarse particles, which must be assumed to have furthered the podsolization. This, however, must first of all be due to the fact that at this station, as compared with the other stations, the amount of precipitation is larger.

A comparison between the types of profiles and types of vegetation at the stations shows that on different soil profiles different types of vegetation with different species as dominants have been developed. *Betula glandulosa*, however, occurs with a high degree of covering on profiles at all three stations. Likewise, *Salix glauca callicarpaea* and *Vaccinium uliginosum microphyllum* have been found at all stations, but both of these species have the lowest degree of covering on the podsolized profiles at Tassiusakasik. A similar type of distribution is even more pronounced as regards *Juniperus communis nana* and *Rhododendron lapponicum*, which have only been found on the non-podsolized profiles at Nigerdlikasik and Neria, and at the latter station only at the profile on diabasic material. The analysis of the vegetation from this profile furthermore shows other characteristic features in relation to the profiles on gneissic material at Neria, partly because the number of species is larger, partly because the species are different from the species on the gneissic profiles, with regard to shrubs as well as to herbs (Table 7, p. 20).

Empetrum nigrum hermaphroditum was found, with a great degree of covering, on the podsolized profiles at Tasiussakasik, but this species is rarer in the analyses of the non-podsolized profiles at Nigerdlikasik, nor does it occur at the profile on diabasic material at Neria.

The vegetation on the podsolized profiles is extremely poor in species of vascular plants, while lichens quantitatively play an important part. On the non-podsolized profiles the variation in the composition of the vegetation is greater. Likewise, the number of species of vascular plants is larger at most of these profiles, while the degree of covering of lichens varies a great deal. It can thus be concluded that the vegetation show a direct relation to the development of soil profiles, which on the other hand are dependent on the bed-rock and, undoubtedly, on the amount of precipitation.

IX. LITERATURE

BERTHELSEN, A., and NOE-NYGAARD, A., 1965. The Precambrium of Greenland. – *In:* RANKAMA, K.: The Precambrium. II. – J. Wiley & Sons.

BLACK, R. F., 1954. Permafrost – a review. – Bull. Geol. Soc. Amer. 65: 839–856.

BROWN, J., and TEDROW, J. C. F., 1964. Soil of the Northern Brooks Range, Alaska: 4. Well-drained soils of the glaciated valleys. – Soil Science 97: 187–195.

BÖCHER, T. W., 1949. Climate, soil, and lakes in continental West Greenland in relation to plant life. – Medd. om Grønl. 147,2.

— 1959. Floristic and ecological studies in Middle West Greenland. – Medd. om Grønl. 156,5.

— 1963. Phytogeography of Middle West Greenland. – Medd. om Grønl. 148,3.

BÖCHER, T. W., HOLMEN, K., and JAKOBSEN, K., 1966. Grønlands Flora. 2nd ed. – København.

DOUGLAS, L. A., and TEDROW, J. C. F., 1960. Tundra Soils of Arctic Alaska. – 7th Intern. Congress of Soil Science, Comm. V, vol. IV: 291–304.

DREW, J. V., and TEDROW, J. C. F., 1957. Pedology of an Arctic Brown Profile near Point Barrow, Alaska. – Soil Science Society of America, Proceedings 21: 336–339.

— 1962. Arctic soil classification and patterned ground. – Arctic 15: 109–116.

FREDSKILD, B., 1961. Floristic and ecological studies near Jakobshavn, West Greenland. – Medd. om Grønl. 163, 4.

GORSHENIN, K. P., 1963. Basic principles in the classification of Siberian soil.– Soviet Soil Science 1: 15–19.

HALE, M. E., and CULBERSON, W. L., 1966. A third checklist of the lichens of the continental United States and Canada. – Bryologist 69,2: 141–182.

JACKSON, M. L., 1958. Soil chemical analysis. – New Jersey.

KARAVAYEVA, N. A., 1958. High mountainous soils of Eastern Sayan. – Soviet Soil Science 4: 61–66.

KREIDA, N. A., 1958. Soils of the Eastern European Tundras. – Soviet Soil Science 1: 62–67.

DE LESSE, H., 1952. Flore et Végétation de l'Eqe, Groenland. – Actualités Scientifiques et Industrielle 1180. – Paris.

MIKHAYLOV, I. S., 1960. Some Features of Sod Arctic Soils on Bolshevik Island. – Soviet Soil Science 6: 649–652.

— 1961. Soil Investigations in Northern Alaska. – Soviet Soil Science 2: 209–214.

MIRSKY, A., 1964. Polar Geology. – Science 143: 1196–1197.

PETERSEN, H., 1938. Das Klima der Küsten von Grönland. – Handb. d. Klimatologie II, K. – Berlin.

RETZER, J. L., 1965. Present soil forming factors and processes in arctic and alpine regions. – Soil Science 99: 38–44.

TEDROW, J. C. F., and CANTLON, J. E., 1958. Concepts of soil formation and classification in arctic regions. – Arctic 11: 166–179.

TEDROW, J. C. F., and DOUGLAS, L. A., 1964. Soil investigations on Banks Island. – Soil Science 98: 53–65.

TEDROW, J. C. F., DREW, J. W., HILL, D. E., and DOUGLAS, L. A., 1958. Major genetic soils of the Arctic Slope of Alaska. – The Journal of Soil Science 9: 33–45.

TEDROW, J. C. F., and HARRIES, H., 1960. Tundra soils in relation to vegetation, permafrost, and glaciation. – Oikos 11: 237–249.

TEDROW, J. C. F., and HILL, D. E., 1955. Arctic Brown Soil. – Soil Science 80: 265–275.

UGOLINI, F. C., 1965. The Recognition of Arctic Brown Soils in Northeast Greenland. – Arctic 18: 49–51.

— 1966 a. Soils of the Mesters Vig District, Northeast Greenland. 1. The Arctic Brown and Related Soils. – Medd. om Grønl. 176, 1.

— 1966 b. Soils of the Mesters Vig District, Northeast Greenland. 2. Exclusive of Arctic Brown and Podzol-like Soils. – Medd. om Grønl. 176, 2.

UGOLINI, F. C., and TEDROW, J. C. F., 1963. Soils of the Northern Brooks Range, Alaska: 3. Rendzina of the Arctic. – Soil Science 96: 121–127.

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