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Zbigniew KLIMOWICZ, Jerzy MELKE and Stanisław UZIAK

Department of Soil Science
Institute of Earth Sciences
Maria Curie-Skłodowska University
Akademicka 19
20-033 Lublin, POLAND

Mountain soils derived from massive rocks in the northwestern Wedel Jarlsberg Land, Spitsbergen

ABSTRACT: Mountain soils derived from massive rocks were studied in the northwestern Wedel Jarlsberg Land. Main soil properties were examined for collected samples. Soils were classified as lithosols with common loamy and silty composition, and small amount of colloidal fraction. Soils were mostly alkaline due to high content of $CaCO_3$. Much more organic substance occurred at westerly- than easterly-exposed hills and located close to a sea. Examined soils contained much soluble forms of Ca, Mg and occasionally Na, little of P and K. Density of plant cover corresponded to contents of organic substance.

Key words: Arctic, Spitsbergen, mountain soils.

Introduction

Mountain areas which are common in Spitsbergen, occur at relatively low altitudes. Because of their relief and short distance from a sea, they were considered by King and Akermann (1993) for typical mountains, with clear ridges and long slopes, and adjoining plains — being relatively narrow stripes along a sea coast. Sometimes, alpine character of certain mountain areas in Svalbard is underlined (Hisdal 1985).

Due to their altitude, soils of cold areas were examined by a few authors only, *e.g.* by Tedrov *et al.* (1958) and Retzer (1974). Szerszeń (1974) compared processes in mountain soils of a temperate climatic zone (the Sudeties) with the ones in soils of the Hornsund area.

There are only occasional papers on mountain soils in Spitsbergen. There have been however numerous papers concerning soils in plains of the northwest-

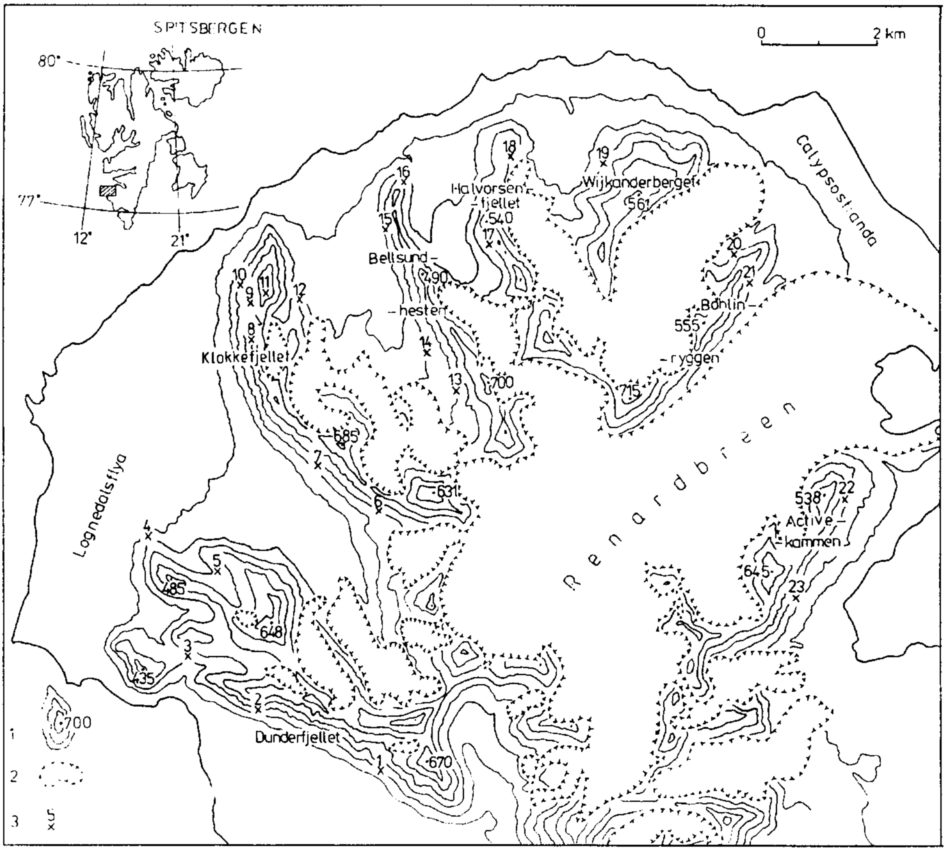

Fig. 1. Location of study area.
1 — mountain ridges with altitude points, 2 — glaciers, 3 — soil pits.

ern Wedel Jarlsberg Land (Melke, Chodorowski and Uziak 1990, Uziak 1992, Klimowicz, Melke and Uziak 1993). This paper on soils derived from massive rocks, is a necessary supplement to a description of soils in the studied region.

Research area and methods

Research was carried out during geographical expeditions to Spitsbergen, organized by the M. Curie-Skłodowska University of Lublin. It focused on soils in mountain complexes from Dunderdalen in the southwest (Dunderfjellet), then (clock-wise) around the relatively wide Renard Glacier (Klokkefjellet, Bellsund-hesten, Halvorsenfjellet, Wijkanderberget, Bohlinryggen), and near the vast Chamberlin valley (Activekammen). Most of these mountain complexes or ranges run meridionally, at general altitude of 500–700 m and always below 1000 m a.s.l.

(Fig. 1). The ranges are cut by more or less wide valleys which, at their higher parts, are filled with small glaciers and morainic material (Szczęsny *et al.* 1989).

Types of parent rocks are important for soil properties. The complexes Dunderfjellet and Bellsundhesten are mantled with diamictite of mostly quartzite clasts. Diamictites are a non-sorted residuum of sea-glacial origin. The complexes Klokkefjellet and Activekammen are also covered by diamictites but with dolomite and quartzite clasts. In the Wijkanderberget area there are diamictites with dolomite clasts, while in the Bohlinryggen — diamictites and phyllites (Dallmann *et al.* 1990). All the mentioned formations belong, according to this author, to the Kapp Lyell sequence (Upper Proterozoic) but their stratigraphic composition has not been determined yet.

The examined soil profiles were located mostly on slopes of the mentioned mountain ridges. Slope inclination was usually equal to 30–50%, and altitude 100–500 m a.s.l. Predominance of western and eastern exposition was another criterion for such choice. Bird colonies were avoided. Samples for laboratory tests were also collected. In a close neighbourhood of pits, density of a plant cover was estimated, and species composition of most common plants in the area was recorded.

Main soil properties as grain size composition, pH, contents of $CaCO_3$ and organic C were determined by standard methods (Tables 1–2). Contents of Ca, Mg, K, Na, and P, available for plants and soluble in 0.03M acetic acid were evaluated. The first four elements were determined by absorbtion atomic spectrometry (AAS) and with a use of the Perkin-Elmer 3300 instrument. P was determined by colorimetric method. Soil colour in dry samples was defined with a use of charts of Oyama and Takehara (1967). Mean values with deviation limits for selected soil properties are presented in graphs (Fig. 2).

Results and discussion

Grain size distribution of the studied mountain soils is quite uniform. Sandy, silty and finer fractions are predominant. Moreover, these soils are usually the skeleton ones (Table 1). There is a small amount of particles finer than 0.002 mm in these soils (only a few %). This fact is easy to explain as disintegration of mineral material by physical weathering, which increases the amount of silt fraction, is common at this latitude and especially in mountain areas.

Significantly higher amount of colloidal fraction was evident at coastal terraces (Melke, Chodorowski and Uziak 1990, Klimowicz, Melke and Uziak 1993). But even in this area, distinctly high amount of silt particles was noted.

Mountain soils of the studied area, considering soil particles below 1 mm, mostly belong to two grain sizes *i.e.* light, rarely medium silty loams (56% of all examined soils) and silts (36%). If their typology is concerned, they are initial

Table 1

Grain size composition and colour of soils.

Profile No.	Location	Altitude m a.s.l.	Exposure	Horizon	depth (cm)	Colour (dry)	Skeleton >1 mm	Fraction content (%) 1–0.1 mm	0.1–0.2 mm	<0.02 mm	<0.002 mm
1	Dunderfjellet	110	SW	AC	0-5	7.5 YR 5/4	70	29	37	34	2
2	Dunderfjellet	100	SW	A/B	0-2	7.5 YR 4/1	20	20	43	37	2
				C	6-10	10 YR 6/2	60	37	32	31	3
3	Beisknatten	230	SSW	AC	0-2	7.5 YR 7/3	50	18	26	56	5
				C	8-15	7.5 YR 7/4	40	23	27	50	7
4	Hamaren	110	NNE	AC	0-3	10 YR 4/2	60	19	44	37	2
5	Hamarho	200	NNW	AC	1-6	2.5 Y 5/3	40	27	41	32	3
6	Storgubben	270	SW	AC	0-4	10 YR 5/2	40	23	47	30	2
7	Ringaren	210	SW	AC	0-4	10 YR 5/2	70	32	36	32	2
8	Klokkefjellet	360	ENE	AC	2-5	10 YR 6/2	50	38	43	19	2
9	Klokkefjellet	370	W	AC	2-5	7.5 YR 6/3	40	41	36	23	1
10	Klokkefjellet	280	(W)	AC	0-3	2.5 Y 7/4	30	30	37	33	5
				C	5-10	2.5 Y 7/4	30	27	36	37	6
				C	20-30	2.5 Y 7/6	30	30	35	35	5
11	Klokkefjellet	490		AC	2-6	10 YR 4/3	70	41	34	25	3
12	Klokkefjellet	280	(E)	AC	0-2	10 YR 6/3	40	35	29	36	5
				C	5-15	10 YR 5/4	30	32	34	34	5
13	Bellsundhesten	300	W	AC	0-5	10 YR 5/2	30	1	50	49	1
14	Bellsundhesten	240	W	AC	0-2	10 YR 6/2	20	25	41	34	5
				C	3-12	10 YR 6/2	20	24	42	34	4
15	Bellsundhesten	120	WSW	AC	0-5	7.5 YR.5/2	0	4	38	58	2
				C	9-14	7.5 YR.5/2	60	18	41	41	2
16	Bellsundhesten	160	WSW	AC	0-5	2.5 Y 5/2	40	19	32	49	2
17	Tjørndalsegga	350	WSW	AC	0-5	7.5 YR 4/3	30	12	44	44	1
				C	22-33	7.5 YR 5/3	50	38	43	19	1
18	Halvorsenfjellet	380	(W)	AC	0-7	7.5 YR 5/4	50	27	37	36	3
19	Wijkanderberget	308	W	AC	2-8	10 YR 5/4	40	41	39	20	3
20	Bohlinryggen	250	NNW	AC	0-3	2.5 Y 5/2	nd	44	24	32	2
				C1	5-10	5 Y 5/2	nd	49	24	27	3
				C2	15-25	5 Y 5/3	nd	43	32	25	3
21	Bohlinryggen	265	ESE	AC	0-2	10 YR 6/3	nd	49	24	27	3
				C	5-12	10 YR 6/3	nd	53	24	23	4
22	Activekammen	215	SE	AC	0-5	2.5 Y 6/2	80	45	27	28	4
23	Activekammen	160	SE	AC	0-5	5 Y 5/2	0	3	46	51	9

rock soils *i.e.* lithosols (according to FAO — Gelic Lithosols). Some of them, can be considered for initial rendzinas (*e.g.* profiles 8, 15, 18, 20–22).

Calcium carbonate was noted in all examined soils (maximum to about 50%) and they usually indicated the alkaline reaction. Significantly higher content of $CaCO_3$ and a little higher pH are characteristic for soils to the east and southeast of Kapp Lyell, *i.e.* in the area less exposed to marine influence if compared to soils of the western stripe (Table 2, Fig. 2).

Clear regularities were also evident in distribution of such important soil component as organic matter. Higher amount of organic C is characteristic for

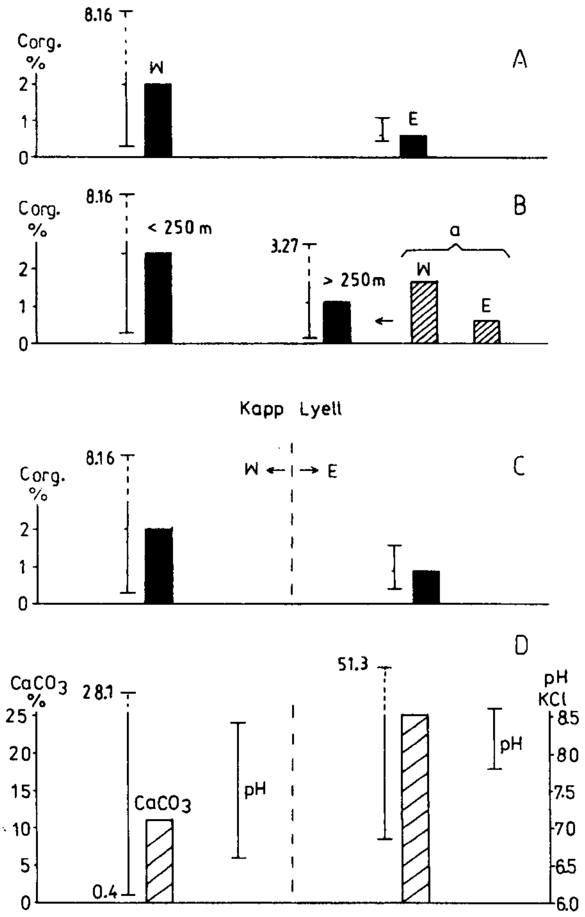

Fig. 2. Effect of exposure and location on mean and extreme contents of organic C, $CaCO_3$ and pH. A — content of organic C; B — content of organic C dependent on altitude, a — effect of exposure on content of organic C in soils located above 250 m a.s.l; C — content of organic C in soils to the west and east of Kapp Lyell; D — content of $CaCO_3$ and pH in soils to the west and east of Kapp Lyell.

soils on hills with predominant western exposure (average of 2%), in comparison to the opposite exposure (0.5%). This fact was observed earlier by Klimowicz and Uziak (1994). To make it clear, such exposure was determined for soils at varying altitudes and soils located at different distance from a sea.

The other factor which delimits contents of organic matter is the altitude. Less organic C was noted, of course, at higher parts of mountains (about 1%). A similar relation is also in horizontal distribution. Soils close to a sea, with more favourable climatic conditions for plants (rainfall, temperature) and the same — for soils, indicate much higher content of organic matter than soils at larger distance from a sea (Fig. 2).

Table 2

Some chemical properties of studied soils.

Profile No.	Horizon depth cm		$CaCO_3$ (%)	pH KCl	C org. (%)	Content of soluble forms in 0.03M CH_3COOH (mg/100g of soil)				
						Ca	Mg	K	Na	P
1	AC	0-5	5.0	7.7	1.89	149.4	43.4	0.99	1.83	2.10
2	A/B	0-2	0.4	6.6	8.16	137.3	36.2	2.83	6.07	2.25
	C	6-10	19.0	8.0	0.65	315.9	30.0	1.03	1.34	2.15
3	AC	0-2	9.5	8.0	1.15	240.6	47.2	0.98	1.52	2.10
	C	8-15	7.2	8.1	0.86	267.6	33.9	0.66	1.07	2.25
4	AC	0-3	6.8	7.2	8.04	505.1	38.3	3.75	32.90	5.20
5	AC	1-6	12.2	8.3	0.64	387.2	10.7	0.65	1.20	2.10
6	AC	0-4	11.6	7.8	1.83	292.9	35.6	1.56	23.60	2.10
7	AC	0-4	14.7	7.8	2.02	364.7	15.4	1.61	8.30	2.95
8	AC	2-5	28.1	8.3	0.43	386.2	11.4	0.95	2.95	2.00
9	AC	2-5	4.5	7.5	1.32	132.4	40.8	0.94	1.55	1.35
10	AC	0-3	8.4	8.0	0.81	180.8	57.6	0.90	7.05	2.00
	C	5-10	9.4	8.1	0.54	249.8	45.5	0.51	3.99	2.00
	C	20-30	7.9	8.0	0.57	188.7	53.6	0.53	1.20	2.10
11	AC	2-6	4.4	7.1	2.28	331.8	21.2	1.17	13.41	2.00
12	AC	0-2	14.5	8.1	0.49	380.0	12.6	0.91	0.90	2.25
	C	5-15	7.0	8.1	0.60	360.1	20.9	0.49	0.87	2.15
13	AC	0-5	9.9	7.8	2.56	188.7	49.9	1.62	2.04	2.45
14	AC	0-2	15.4	8.4	0.28	382.0	12.1	0.68	1.11	2.25
	C	3-12	16.6	8.4	0.27	373.7	10.5	0.39	0.54	2.30
15	AC	0-5	17.6	7.4	5.70	207.0	51.4	2.68	4.31	3.10
	C	9-14	20.1	7.6	3.91	249.7	41.4	1.56	7.60	2.30
16	AC	0-5	15.5	7.9	1.56	226.7	56.1	1.43	3.09	2.15
17	AC	0-5	2.1	7.4	3.27	145.2	31.5	0.96	4.68	1.75
	C	22-33	7.4	7.9	0.96	188.6	50.3	0.46	3.68	1.60
18	AC	0-7	51.3	8.0	1.15	316.8	34.2	0.58	3.38	2.00
19	AC	2-8	8.4	8.2	0.41	262.7	37.3	1.08	1.66	1.75
20	AC	0-3	15.6	7.8	1.54	189.5	55.2	1.38	1.38	1.95
	C1	5-10	35.6	7.9	1.09	186.5	55.1	1.10	4.20	1.95
	C2	15-25	21.5	8.1	0.52	188.1	57.5	0.91	0.92	1.75
21	AC	0-2	27.7	8.0	0.93	349.4	24.9	1.49	0.73	2.10
	C	5-12	22.3	8.1	0.61	355.8	20.8	1.04	0.83	2.10
22	AC	0-5	28.7	8.6	0.17	382.1	24.3	0.81	1.81	1.75
23	AC	0-5	15.7	7.9	1.09	181.9	58.6	1.42	29.90	2.00

No regularity was observed in terms of distribution of elements which are soluble in 0.03M CH_3COOH (Table 2). High contents of Ca, Mg and sometimes of Na are worth mentioning, the same as small amounts of P and K. Similar observations were collected by the authors for soils close to lakes on seaside terraces (Klimowicz and Uziak, *in press*).

High contents of easily available Ca and Mg should be related to geological composition, because many parent rocks of the studied soils contain much dolomite (Dallmann *et al.* 1990). In the case of Na, most of it occurs in Na-Ca rocks. More information about contents of this element in soils of the Bellsund area were presented by Klimowicz and Uziak (1996). Small amounts of available K are due to its small content in bedrock. Small amounts of P are caused by small biological activity, due to hard climatic conditions.

There is interesting relation between contents of organic C, pH, and components soluble in acetic acid. Higher content of organic C is usually related to lower pH and abundant forms which are soluble in 0.03M CH_3COOH, especially of Na but also of Mg, P and K. Quite opposite is with Ca — there is more Ca in soils with small content of organic compounds.

Plant cover in these soils corresponds to contents of organic matter. For this reason, westerly-exposed hills which are closer to a sea are mostly green, whereas easterly ones are grey (Klimowicz and Uziak 1994). We should keep in mind positive influence on soil-plant conditions of the northern part of the warm Gulf Stream. The latter reaches Spitsbergen from the west.

Species composition of plants on mountain soils is not very rich, especially in eastern part of the studied area. Our observations indicate that there are mostly the plants as *Saxifraga oppositifolia, Cerastium arcticum, Saxifraga caespitosa,* lichens, including rock lichens, mosses, willows — *Salix polaris* and its mouintain species — *Salix reticulata,* and rarely *Silene acaulis* or *Dryas octopetala.* Species of plants on hills near a sea are slightly different, with numerous mosses, willows and *Saxifraga oppositifolia. Saxifraga caespitosa, Cerastium arcticum* and *Silene acaulis* are also common, but there is less grass.

Conclusions

1. Mountain soils in the northwestern Wedel Jarlsberg Land are lithosols (FAO — Gelic Lithosols) from a typological point of view, resembling sometimes the initial rendzinas derived from massive rocks and composed of loams and silts. They have quite uniform grain size composition, with considerable skeleton and silt fraction, and insignificant content of colloidal fraction.

2. Mentioned soils contain much $CaCO_3$ and their reaction is usually alkaline. Amount and distribution of organic matter are limited by exposure, altitude and distance from a sea. All these factors indicate influence on climatic conditions, which affect habitat with rare plants in the area.

3. In the examined soils high contents of forms (soluble in 0.03M CH_3COOH), Ca, Mg and sometimes Na as well as small amount of P and K were noted. There are no spatial regularities in distribution of the mentioned elements.

4. Density of plant cover and, to some degree — number of plants of particular species correspond to content of organic matter.

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Streszczenie

Badaniami objęto gleby górskie północno-zachodniej części Ziemi Wedel-Jarlsberga (fig. 1). W zebranym materiale oznaczono skład granulometryczny, zawartość $CaCO_3$, pH, C organiczny, a także rozpuszczalne w 0,03M CH_3COOH formy Ca, Mg, K, Na i P (tab. 1–2). Wartości średnie wybranych właściwości gleb przedstawiono w formie graficznej (fig. 2). Badane gleby należą do litosoli (FAO — Gelic Lithosols). Wykazują one najczęściej skład glin i utworów pyłowych o małym udziale frakcji poniżej 0,002 mm. Są one z reguły alkaliczne i zasobne w $CaCO_3$. Zawartość substancji organicznej zależy bezpośrednio od pokrycia roślinnego, limitowanego warunkami klimatycznymi, na które z kolei ma wpływ ekspozycja oraz położenie w układzie pionowym (wysokość n.p.m.) i poziomym (odległość od morza). Badane gleby zasobne są w łatwo rozpuszczalne w kwasie octowym Ca i Mg i niekiedy Na oraz ubogie w P i K. Rozmieszczenie wspomnianych pierwiastków nie wykazuje prawidłowości. Gęstość pokrycia roślinnego koreluje z zawartością substancji organicznej.