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Formation of Arctic soils in Chamberlindalen, Bellsund, Spitsbergen

Jerzy MELKE and Jacek CHODOROWSKI

Zakład Gleboznawstwa, Instytut Nauk o Ziemi, Uniwersytet Marii Curie-Skłodowskiej, Akademicka 19, 20-033 Lublin, Poland
<melkej@biotop.umcs.lublin.pl>
<jchodor@biotop.umcs.lublin.pl>

Abstract: Soils in the Chamberlindalen area (Bellsund, Spitsbergen) have been formed under polar climatic conditions, influenced by many years of permafrost, and chemical and physical weathering. The type of bedrock and local water conditions are considered to be significant soil-forming factors. The following soil units were distinguished according to the FAO-UNESCO Revised Legend (1997): Gelic Leptosols, Gelic Regosols, Gelic Gleysols, and Gelic Cambisols. The basic properties of the soils studied are (i) shallow soil profile with poorly differentiated genetic horizons, (ii) the particle size distribution of sands and loams, (iii) a considerable content of the silt fraction, (iv) different pH, and a considerable organic carbon content.

Key words: Arctic, Spitsbergen, soils.

Introduction

Since 1986, the soils of the Bellsund area (77°25’– 77°35’ N, 13°45’ – 15°00’ E; see Fig. 1) in Spitsbergen have been studied during several geographical expeditions organised by Maria Curie-Skłodowska University in Lublin, Poland. The pedological studies were mainly concentrated in the central and western part of Bellsund (Klimowicz and Uziak 1988; Melke and Uziak 1989; Melke *et al*. 1990; Klimowicz *et al*. 1996; Klimowicz and Uziak 1996a). In the eastern part, the studies were also carried out at Reinsletta (Klimowicz and Uziak 1996b; Uziak *et al*. 1999) and in the area of Observatoriefjellet, ~565 m above sea level (Klimowicz *et al.* 1997).

The aim of this study is to characterise the Arctic soils in the Chamberlindalen in the south Bellsund area. These areas are characterised by varied natural environment, *e.g.* geologic structure (Birkenmajer 2004; Dallman *et al.* 1990). The study summarises the fundamental soil research in the N-W Wedel Jarlsberg Land area.

Fig. 1. Sketch map of Svalbard showing location of the study aera.

Study area

The Chamberlindalen is located in Wedel Jarlsberg Land, in the southeastern part of Bellsund. It is a broad valley between mountain ranges stretching N-S, with summit height from 495 to 765 m a.s.l. in the west, and from 565 to 725 m in the east (Fig. 2). The valley developed in the zone of a complex synclinal structure built up of the Proterozoic rock sequence dominated by diamicite, dolomite, quartzite, phyllite, greenstone, meta-gabbro, and serpentinite (Dallmann *et al*. 1990). Quaternary is represented by glacial (blocks, boulders, gravel and sand, as well as till), fluvioglacial (mainly gravel and sand), alluvial, coastal marine (mainly clays with participation of sand and gravel), and slope deposits (rock debris and covering loamy deposits) (Pękala and Repelewska-Pękalowa 1988).

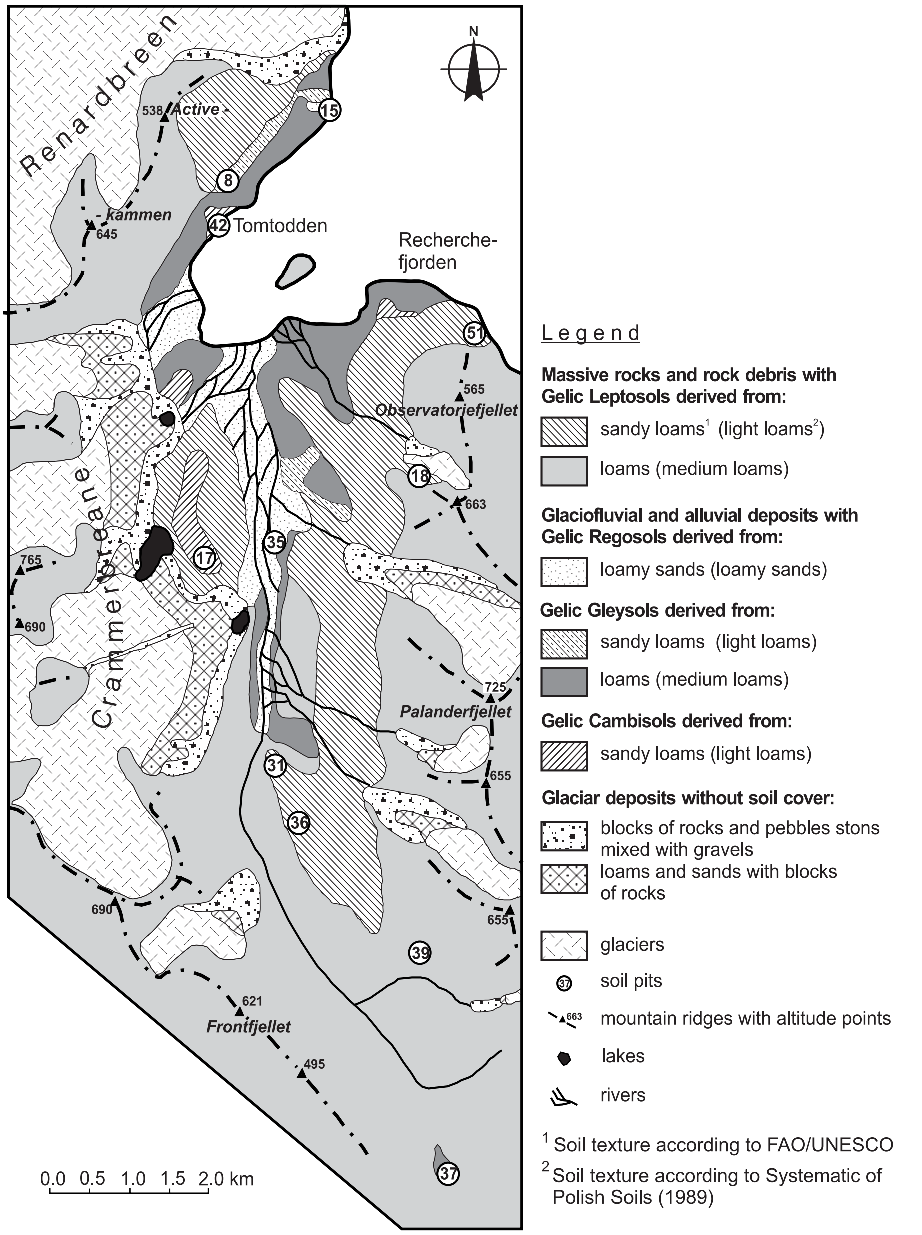

Fig. 2. Map of soils in Chamberlindalen, Spitsbergen.

The relief of the Chamberlindalen was formed as a results of denudation processes (denudation levels, ridges), activity of flowing water (alluvial plains, outwash fans and alluvial fans), glacial activity (frontal, lateral and ground moraines), as well as slope processes (talus fans) and solifluction (Pękala and Repelewska-Pękalowa 1988).

Table 1

Texture and some chemical properties of selected soils in the Chamberlaindalen, Spitsbergen.

Profile No.	Horizon	Depth (cm)	Skeleton >1 (mm)	Particle size fractions (wt.%) (mm) 1.0–0.1	0.1–0.05	0.05–0.02	0.02–0.005	0.005–0.002	< 0.002	pH 1 M KCl	C org. (%)	Org.matt. (%)	$CaCO_3$ (%)
Gelic Leptosols													
18	O	0–2								3.66		34.08	
	A	3–6	18.8	51.5	13.5	15	12	3	5	3.71	2.86		
	AC	8–15	27.1	52.8	13.2	10	17	5	2	4.12	1.02		
	C	23–29	61.3	71.3	3.7	6	10	5	4	5.25	0.43		
31	Ah	2–0								3.85	7.71		
	A	5–10	68.0	48.2	7.8	13	13	10	8	3.41	1.80		
	C	19–25	90.1	59.2	6.8	11	11	5	7	4.30	0.67		
36	A	0–1	68.7	51.7	3.3	12	11	12	10	4.05	1.33		
	C	10–16	62.4	53.8	7.2	13	11	9	6	4.22	0.10		
39	A	0–1	33.0	35.7	5.3	17	18	9	15	6.84	0.98		
	AC	14–24	50.9	37.6	3.4	13	18	11	17	6.81	0.67		
51	ACk	1–15	79.9	45.3	12.7	16	17	6	3	7.29	3.54		34.15
Gelic Regosols													
15	Ak	0–1	41.3	78.7	1.3	4	7	7	2	7.85	0.99		15.82
	Ck	3–28	62.9	82.8	2.2	4	5	2	4	8.12	0.46		22.46
35	A	0–2	82.7	58.9	13.1	14	8	4	2	7.06	1.86		
	Ck	16–24	93.5	65.4	8.6	9	10	5	2	7.27	0.61		7.03
Gelic Gleysols													
8	O	0–3								6.38		55.76	
	A	4–5	46.9	45.0	7.0	17	15	8	8	6.51	2.38		
	Ckg	12–23	53.1	55.0	5.0	12	11	6	11	7.28	0.67		1.24
37	A	0–1	58.1	27.6	5.4	17	21	15	14	5.76	1.94		
	Cg	14–24	50.0	28.7	9.3	19	20	10	13	6.03	0.72		
Gelic Cambisols													
17	A	1–4	16.3	41.7	16.3	18	16	4	4	5.25	3.20		
	Bw	7–15	22.0	49.3	12.7	16	13	6	3	6.49	1.61		
	2C	20–28	82.6	78.4	3.6	7	4	4	3	6.98	0.51		
42	A	1–4	41.9	43.8	12.2	14	15	7	8	3.53	2.61		
	AB	9–14	59.5	46.3	11.7	11	15	9	7	3.49	1.74		
	C	27–34	67.4	54.8	9.2	13	11	6	6	4.50	0.61		

Table 2

Content of pedogenic iron and haevy metals in selected soils of Chamberlaindalen, Spitsbergen.

Profile No.	Horizon	Depth	Fe_t	Fe_d	$Fe_{t\text{-}d}$	Fe_d/Fe_t	Fe_o	$Fe_{d\text{-}o}$	Fe_o/Fe_d	Mn_t	Zn_t	Cu_t	Pb_t
		(cm)	($g \cdot kg^{-1}$)			(%)	($g \cdot kg^{-1}$)			($mg \cdot kg^{-1}$)			
Gelic Leptosols													
18	O	0–2	41.67	22.67	19.00	54.40	5.00	17.67	0.22	429.93	67.92	26.38	17.26
	A	3–6	64.84	33.67	31.17	51.93	6.68	26.99	0.20	715.59	111.01	34.69	19.17
	AC	8–15	63.49	42.65	20.84	67.18	7.79	34.86	0.18	602.55	149.11	49.86	20.37
	C	23–29	59.49	45.61	13.88	76.67	5.51	40.10	0.12	354.13	113.33	54.95	21.04
31	Ah	2–0	24.27	16.58	7.69	68.30	4.02	12.56	0.24	55.20	43.45	8.66	18.09
	A	5–10	33.48	20.76	12.72	62.00	3.49	17.26	0.17	83.66	57.23	13.81	22.31
	C	19–25	38.18	24.74	13.44	64.79	4.57	20.17	0.19	60.38	68.59	15.40	24.46
36	A	0–1	34.60	13.84	20.76	40.00	3.05	10.79	0.22	135.67	62.42	16.41	30.63
	C	10–16	32.06	12.06	20.00	37.62	3.16	8.90	0.26	122.67	74.04	15.09	23.95
39	A	0–1	41.27	31.31	9.96	75.87	2.54	28.77	0.08	322.88	68.33	24.13	27.01
	AC	14–24	51.80	38.66	13.15	74.62	2.51	36.14	0.07	429.37	72.22	26.56	26.11
51	ACk	1–15	18.97	10.20	8.77	53.76	5.75	4.44	0.56	338.61	37.34	23.84	19.39
Gelic Regosols													
15	Ak	0–1	21.85	7.28	14.57	33.31	3.99	3.29	0.55	269.18	51.19	10.48	16.92
	Ck	3–28	19.59	5.53	14.07	28.20	7.23	–	1.31	268.95	38.73	11.80	18.47
35	A	0–2	40.63	12.56	28.07	30.91	4.00	8.56	0.32	525.18	76.72	27.49	13.60
	Ck	16–24	45.99	14.76	31.23	32.09	5.78	8.98	0.39	519.22	80.65	40.02	17.00
Gelic Gleysols													
8	O	0–3	14.62	8.56	6.07	58.51	2.36	6.20	0.28	301.39	50.44	33.28	33.47
	A	4–5	36.14	13.57	22.57	37.55	2.40	11.17	0.18	301.64	81.61	28.87	29.39
	Ckg	12–23	37.22	12.58	24.63	33.81	3.29	9.29	0.26	242.48	81.29	29.8	24.65
37	A	0–1	28.74	13.89	14.86	48.31	2.41	11.48	0.17	191.31	57.36	27.66	31.75
	Cg	14–24	29.71	14.13	15.59	47.54	2.33	11.79	0.17	190.73	59.59	26.05	29.28
Gelic Cambisols													
17	A	1–4	36.74	29.44	7.30	80.14	6.10	23.34	0.21	875.25	50.39	17.49	25.76
	Bw	7–15	44.97	38.18	6.79	84.91	7.08	31.10	0.19	1044.04	75.29	27.99	49.62
	2C	20–28	41.38	22.34	19.04	53.98	3.93	18.41	0.18	903.76	63.63	50.53	34.70
42	A	1–4	31.19	25.78	5.41	82.66	6.24	19.54	0.24	239.52	78.22	14.34	22.55
	AB	9–14	31.19	26.11	5.07	83.74	6.25	19.87	0.24	247.87	40.53	13.68	21.27
	C	27–34	39.05	31.92	7.13	81.74	1.54	30.39	0.05	633.05	61.32	31.50	32.38

The climate of the western Spitsbergen coast is characterised by an average temperature of about 5°C (Hisdal 1985) in July. The coldest period is February–March, with an average monthly temperature between –8°C and –16°C. The annual atmospheric precipitation is low (below 400 mm) with maximum in Autumn.

Material and methods

During the field studies, 46 soil pits were investigated and sampled for laboratory analyses. Selected soil profiles are presented in Tables 1 and 2. In the soil material, the following properties were determined: (i) colour of moist and dry soil using the Munsell's table, (ii) particle size distribution using the Casagrande's areometric method modified by Prószyński (Lityński *et al.* 1976), with sand separated on sieves, (iii) a suspension of soil in 1M KCl was used to determine pH, (iv) organic carbon content using the Tiurin method, (v) organic matter content by combustion at a 550°C, and (vi) calcium carbonate content using the Scheibler method (Lityński *et al.* 1976). Free iron compounds (Fe_d) were extracted with dithionite-citrate-bicarbonate (DCB) solution (Mehra and Jackson 1960). The extraction of poorly crystallized iron compounds (Fe_o) was performed using the ammonium oxalate solution (Schwertmann 1964). Total content of Fe_t, Mn_t, Zn_t, Cu_t, and Pb_t was determined using the extraction with aqua regia (ISO 11 466 1995). The metals as well as Fe_d and Fe_o were determined using AAS Perkin-Elmer 3300.

Results

The soil classification according to FAO-UNESCO Revised Legend (1997) was used in the present study. The following soil units were distinguished in Chamberlindalen: Gelic Leptosols, Gelic Regosols, Gelic Gleysols, and Gelic Cambisols. Schematic distribution of these soil units in the Chamberlindalen area is presented in Fig. 2.

The Gelic Leptosols occur locally in the area of *in situ* weathered massive rocks forming ridges and slopes of the valley. These are mostly very shallow soils at initial stage of development that were formed mainly from light and medium loams. Depending on the slope inclination, solifluction terraces (steps) covered with compact plant cover or solifluction strips have been formed on the surface of the Gelic Leptosols. In relatively flat areas, non-sorted polygons can be observed on the surface of the soils. Some Gelic Leptosols are gleyed or contain calcium carbonate. The general morphology of the Gelic Leptosols is as follows: A-AC or O-A-C. Profiles 31 (Fig. 3) and 36 (Fig. 4) are examples of the Gelic Leptosols morphology.

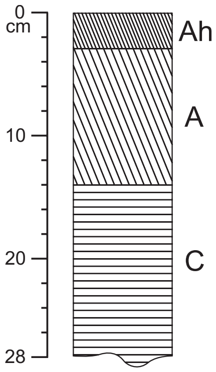

Fig. 3. Gelic Leptosol, profile 31.

Profile 31. — Gelic Leptosol. Slope of a valley with an inclination of 10–15°, western exposition. Vegetation consists of moss, grasses, and lichens.

0–3 cm, horizon Ah with dark grey colour (5Y 3/1) when moist and olive grey (5Y 4/2) when dry;

3–14 cm, horizon A, sandy loam[1] (light loam low sandy[2])

with an olive colour when moist (5Y 4/3) and dry (5Y 5/3);

14–28 cm, horizon C, sandy loam (light loam high sandy) with dark grey colour (5Y 4/1) when moist and olive grey (5Y 5/2) when dry.

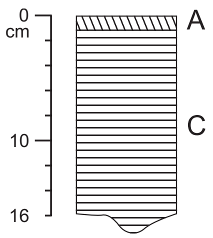

Fig. 4. Gelic Leptosol, profile 36.

Profile 36. — Gelic Leptosol. Slope of the valley with inclination of 5–10°, western exposure. Solifluciton strips on the surface. Vegetation in 40–50% [*Draba alpina* (*L.*), *Luzulla wahanbergii* (Rupr.), mosses].

0–1 cm, horizon A, skeleton sandy loam (light loam low sandy) with dark olive grey colour (5Y 3/2) when moist and pale olive colour (5Y 6/3) when dry, humid, gradual transition;

1–16 cm, horizon C, skeleton sandy loam (light loam low sandy) with olive grey colour (5Y 4/2) when moist and light olive grey colour (5Y 6/2) when dry.

The Gelic Regosols occur at the bottom of the valley in the area of sandurs, alluvial fans, and pingos. Similarly to the Gelic Leptosols, these are soils at the initial stage of development. Gelic Regosols also occur in the coastal area, and less commonly at margins of glaciers. Gelic Regosols have been formed mainly from skeleton loamy sands. The morphology of the Gelic Regosols is as follows: A-Ck, Ak-Ck. Profile 35 (Fig. 5) is an example of the Gelic Regosol morphology.

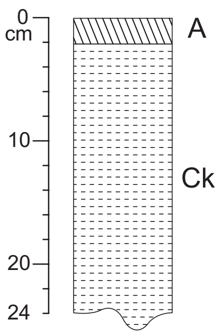

Fig. 5. Gelic Regosol, profile 35.

Profile 35. — Gelic Regosol. Bottom of the valley. Almost flat. Vegetation in 80–95% [*Cetraria* (Walenb.), *Salix polaris* (Walenb.), *Saxifraga oppositifolia* (L.)].

0–2 cm, horizon A, skeleton loamy coarse sand (silty light loamy sand) with olive colour (5Y 3/2) when moist and olive grey colour (5Y 4/2) when dry, gradual transition;

2–24 cm, horizon Ck, skeleton loamy coarse sand (heavy loamy sand) with olive colour (5Y 3/2) when moist and olive grey colour (5Y 5/2) when dry, reacts with 10% HCl.

[1] Soil texture according to FAO/UNESCO.

[2] Soil texture according to Systematics of Polish Soils 1989.

The Gelic Gleysols tend to occur at places where the groundwater comes near the surface. This favours generation of permanent or periodical anaerobic conditions in the soil that promote gleying processes. The bottom of Chamberlindalen and lower parts of its slopes are favourable places of the soil formation. The Gelic Gleysoils can also be found at the foot of local hills. They have been formed mainly from skeleton light, medium or heavy loams. On the surface of the soils, various forms of micro-relief and effects of cryogenic processes can be observed. They are thufurs and non-sorted nets often filled with organic substance. Calcium carbonate is common in these soils. The general morphology of the Gelic Gleysol profile is as follows: A-Cg, O-A-Ckg. Profile 8 (Fig. 6.) is an example of the Gelic Gleysol morphology.

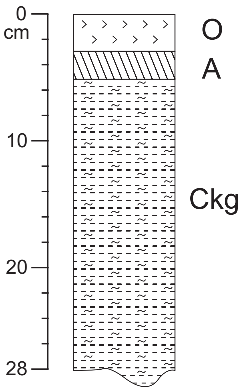

Fig. 6. Gelic Gleysol, profile 8.

Profile 8. — Gelic Gleysol. Slope with an inclination of 10–15°, south-east exposure. On the surface, there are thufurs up to 0.3 m high and showing oval shapes (the longer axis – 0.4 m, the shorter axis – 0.3 m). Vegetation consists of *Salix polaris* (Walenb.), *Saxifraga oppositifolia* (L.), *Deschampsia alpina* (L.), grasses and mosses.

0–3 cm, horizon O, dark brown weakly decomposed;

3–5 cm, horizon A, skeleton sandy loam (light loam low sandy), dark grey in colour (5Y 4/1) when moist and grey (5Y 6/1) when dry;

5–28 cm, horizon Ckg, skeleton sandy loam (light loam low sandy), saturated with water, dark grey in colour (5Y 4/1) when moist or grey (5Y 6/1) when dry.

The Gelic Cambisols were found in the area of the mutoned rock humps close to the Crammerbreaen glaciers of the coast (old cliffs and coast packers) (Fig. 2). In places, there are inactive crack nets often covered with plant vegetation on the surface of the Gelic Cambisols. A characteristic feature of their morphology is

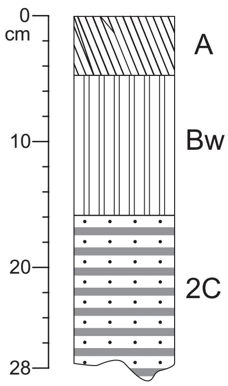

Fig. 7. Gelic Cambisol, profile 17.

Profile 17. — Gelic Cambisol. A mutoned hump in the area of Crammerbreane glaciers. Compact vegetation on the surface [*Salix polaris* (Walenb.), *Saxifraga oppositifolia* (L.), *Saxifraga cespitosa* (L.), lichens and moss].

0–5 cm, horizon A, sandy loam (silty light loam high sandy) dark olive brown in colour (2.5Y 3/3) when moist and light olive brown (2.5Y 5/4) when dry, gradual transition;

5–16 cm, horizon Bw, sandy loam (silty light loam high sandy) dark olive brown in colour (2.5Y 4/4) when moist and light olive brown (2.5Y 5/6) when dry;

16–28 cm, horizon 2C, skeleton loamy coarse sand (light loamy sand) olive brown in colour (2.5Y 4/4) when moist and light yellow brown (2.5Y 6/3) when dry.

brown colour of the horizon Bw. According to Hill and Tedrow (1961), the brown colouration of the Arctic soils results from the oxidation of iron-rich mineral phases under good drainage conditions. Ugolini and Sletten (1988) noticed the *in situ* weathering origin of the Bw horizons in Arctic brown soils. The morphology of the Gelic Cambisols is as follows: O-A-AB-2C, A-Bw-C. Profile 17 (Fig. 7) is an example of the Gelic Cambisol morphology.

Discussion

Small thickness and poor colour differentiation within a soil profile are typical morphological properties of the soils studied. No clear colour differentiation was found, especially in the Gelic Gleysols. Mixing of soil materials under the cryogenic processes takes place in these soils. It influences soil colour and makes the borders between individual genetic horizons less clear (Plichta 1993). The Gelic Cambisols and some of the Gelic Leptosols exhibit cleaver colour contrast within individual genetic horizons.

The cryogenic processes are manifested by various microforms of the soil surface. Drew and Tedrow (1962), Tedrow (1977), and Plichta (1977) described relations between systematic units of Arctic soils and the forms of cryogenic microrelief.

The soils studied showed a particle size distribution of sands and loams (Tables 1 and 2). These are loamy sands, light loams, medium and heavy loams with a considerable content of soil skeleton particles. Sands (Table 2) are characterised by an especially high content of soil skeleton particles (75.2% on average). Another characteristic feature of the soils studied is the higher content of the silt fraction (0.1–0.02 mm) in the upper horizons (Table 2). The soils of the Chamberlindalen also show a considerable content of fine particles (< 0.02 mm), and a rather low content of colloidal particles (< 0.002 mm). Similar feature was observed in soils occurring in other parts of the Bellsund area (Klimowicz and Uziak 1988, 1994; Melke *et al*. 1990).

It seems that the high content of the fine fractions in the upper soil horizons is a characteristic feature of Arctic soils. Hill and Tedrow (1961) demonstrated that an increase in the content of the fractions < 0.05 mm in the surface horizons of brown Arctic soils cannot be explained exclusively by wind activity or by weathering. These authors pointed to the importance of mechanical disintegration in the process of enriching the Arctic soils in fine fractions. On the other hand, Ugolini (1986) and Ugolini and Sletten (1988) suggested that accumulation of fine soil particles (< 0.05 mm) in the surface horizons could be related to eolic processes. Uziak (1992) mentioned that an increase in the silt fraction of Arctic soils could be a result of frost weathering.

Organic matter occurs first of all in the surface organic horizons O (Table 1). Its amount varies. The content of organic carbon in the soils studied is relatively high, especially in the Ah horizons of the Gelic Leptosols (6.67–8.47%), and it generally decreases with depth. Also the horizons A and Ak with particle size distribution of sands (on average 2.1%) are characterised by a relatively high content of organic carbon (Table 2). Among others, Szerszeń (1974) and Plichta (1993) drew attention to the considerable content of organic carbon in the soils of Spitsbergen. According to Plichta (1993), the plant communities in the region of Kaffiryra (78°35’–78°41’ N, 11°50’–12°20’ E) are characterised by low productivity. It seems that despite the low productivity of tundra, there are favourable conditions for the accumulation of organic matter due to the low rates of mineralization. Low temperature and high humidity level in the Arctic are the factors that determine the intensity of mineralization.

The pH of the soils studied varies considerably. The lowest pH value was determined in loams ($pH_{KCl} = 3.05$), and the highest in sands ($pH_{KCl} = 8.12$) (Table 3). The pH usually increases in the soil profile with depth.

The pH of the soils studied correlates with the type of bedrock. The occurrence of calcium carbonate or calcium-magnesium carbonate in soil increases pH. The analysis of our results leads to the conclusion that mineral soils of Chamberlindalen show similar differentiation in their pH as do the soils of the lower section of the Dunderdalen (Klimowicz and Banaś 1997); whereas, the mineral soils of the central and western parts of the Bellsund area show only neutral or alkaline pH (Klimowicz and Uziak 1988; Melke *et al*. 1990; Klimowicz *et al*. 1996).

Table 3

Medium and extreme numerical values of granulometric composition together with some chemical properties of the soils in Chamberlaindalen, Spitsbergen.

Texture	Horizon	Skeletonφ > 1 mm	Particle size fractions (wt. %) 1–0.1 (mm)	0.1–0.02	< 0.02	< 0.002	pH 1 M KCl	C org. (%)	$CaCO_3$[§] (%)
Sands	A, Ak	46.1* 13.4–89.5**	57.5 49.4–78.7	25.8 5.3–34.8	16.6 13.0–20.0	3.2 2.0–5.0	6.33 3.71–7.85	2.10 0.81–3.55	12.04 5.86–15.82
	C, Ck, Ckg, 2C, 2Ck	75.2 61.3–93.5	72.6 65.4–82.8	13.4 6.2–20.0	14.0 11.0–19.0	2.6 1.0–4.0	7.02 5.25–8.12	0.48 0.32–0.61	11.02 2.38–22.46
Loams	A, Ak, AC, ACk, ACg, AB, ABk	39.6 7.6–79.9	37.0 8.8–53.3	24.8 15.3–38.2	38.1 22.0–59.0	8.7 2.0–19.0	5.68 3.05–7.89	1.80 0.11–4.52	6.40 0.37–34.15
	Bw, BC, C, Ck, Cg, Ckg	43.2 14.5–88.7	40.5 19.6–62.7	21.5 13.3–28.7	38.0 22.0–61.0	11.3 3.0–22.0	6.53 3.71–7.95	0.71 0.10–1.61	3.46 0.39–11.71

* medium value ** border values

§ relates to soil levels containing calcium carbonate

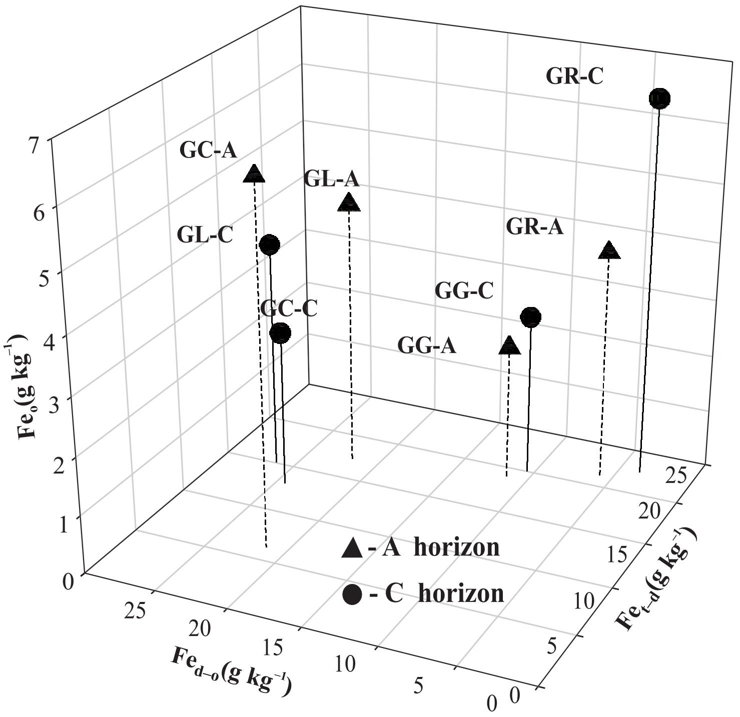

Fig. 8. Silicate-bound iron ($Fe_{t\text{-}d}$), well-crystalized iron oxides ($Fe_{d\text{-}o}$), and poorly crystalized iron compound (Fe_o) in horizons A and C Gelic Leptosols (GL), Gelic Regosols (GR), Gelic Gleysols (GG), and Gelic Cambisols (GC).

Calcium carbonate was found in all soil units of the Chamberlindalen. The highest content of $CaCO_3$ (34.15%) was noted in the Gelic Leptosols (Table 1). Considerable amounts of $CaCO_3$ also occur in the Gelic Regosols (up to 22.46%) and in the Gelic Leptosols (up to 19.13%). In the Gelic Cambisols, the content of calcium carbonate does not exceed 5.55%. The genetic horizons are characterised by an increased content of $CaCO_3$, showing a sand particle size distribution (Table 2). The soil profiles showing no $CaCO_3$ have been also found. The Chamberlindalen soils differ from other Belsund soils in which $CaCO_3$ was always found (Klimowicz and Uziak 1988; Melke *et al.* 1990; Klimowicz *et al.* 1996).

Blume and Schwertmann (1969), McKeauge *et al.* (1971), and Schwertmann (1985) highlighted the role of iron in the soil forming processes. The total iron content is influenced by bedrock. The contents of the individual forms of this element (Fe_t, Fe_d, Fe_o) characterise pedogenesis (Blume and Schwertmann 1969; Melke 1997).

The Fe_t as well as Fe_d content in the distinguished soil units varies substantially (Table 2). The free iron in the profile shows no correlation with the soil morphology (Plichta 1993). The Fe_d/Fe_t and Fe_o/Fe_d ratios indicate advanced chemical weathering processes in the Gelic Cambisols and in some of the Gelic Leptosols. The low ratio of Fe_o/Fe_d suggests an increased content of well-crystallized iron-oxides and the decreased content of poorly crystallized iron-compounds (Birkeland *et al*. 1989; Blumel *et al*. 1993). In respect of iron forms, the analysed soils can be classified as (i) the Gelic Cambisols and the Gelic Leptosols characterised by an increased content of iron-oxides, and (ii) the Gelic Gleysols and the Gelic Regosols characterised by an increased content of silicate-bound iron (Fig. 8).

Also total contents of heavy metals (Table. 2) show a considerable differentiation in the profiles of the same soil units (Gelic Leptosols) as well as among various soil units (Gelic Leptosols and Gelic Regosols). The heavy metals average values given by Plichta and Kuczyńska (1991), Plichta *et al*. (1991), and Skiba *et al* (2002) are comparable with the results obtained in Chamberlindalen, except for the manganese content reaching 1000 mg/kg.

Conclusions

1. Soils in Chamberlindalen have been formed under polar climatic conditions including long-term permafrost, physical and chemical weathering processes, and decelerated rates of organic matter mineralization. The bedrock type and water conditions are also significant factors in the soil-forming processes.

2. The following soil units are have been distinguished: the Gelic Leptosols, the Gelic Regosols, the Gelic Gleysols, and the Gelic Cambisols. These soil units are characterized by shallow soil profile and weakly differentiated genetic horizons.

3. Soil particle size distribution is mainly sandy or loamy, with a noticeable contribution of the silt fraction in the upper genetic horizons. Soil pH varies considerably from strongly acidic to alkaline, which clearly differentiates the soils studied from the soils of the central and western part of the Bellsund area. The content of organic carbon is usually quite high, which can be considered a prominent feature of the Arctic soils.

4. Pedogenic forms of iron indicate the advanced chemical weathering processes, especially in the Gelic Cambisols. The contents of heavy metals, such as Mn_t, Cu_t, Zn_t, and Pb_t, in the Chamberlindalen soils vary and are similar to those found in other Spitsbergen areas.

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