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Soils in a young landscape on the coast of southern Finland

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Soils in an agricultural landscape on the southern coast of Finland (60° 13'N 25° 02'E) were characterized and classified according to Soil Taxonomy, the FAO-Unesco system (FAO), and the World Reference Base for Soil Resources system (WRB). The impact of human activity (<500 years) on the soil forming processes was discussed. The cultivated land studied (200 ha, elevation of <1 to 10 m) consists primarily of lacustrine sediments. It is surrounded by forested bedrock high areas dominated by Spodosols/Podzols, and by reedy wetlands, partially occupied by Sulfaquents/Thionic Gleysols. Cultivated pedons had mollic or ochric epipedons and cambic horizons. High base saturation of epipedons is likely man-made by liming. These soils have naturally high water tables and the development of the cambic horizons has been significantly promoted by artificial drainage (ditches >150 years ago, tile lines at the depth of 1 m in the 1950s). They now meet the criteria for Mollisols and Inceptisols (Soil Taxonomy), Phaeozems and Gleysols (WRB), and Cambisols (FAO and WRB) but before drainage were likely Entisols (Soil Taxonomy) or Gleysols (FAO and WRB) with ochric, umbric, or histic epipedons and without a diagnostic B horizon.

Key words: soil formation, artificial drainage, structure, redoximorphic features, catena, Soil Taxonomy, FAO-Unesco System, World Reference Base for Soil Resources

Introduction

The landscape around the Gulf of Finland was formed during the last 12000 years. The archaean granitic bedrock, which is part of the Fennoscandia Shield and is composed of silicic granitic plutonic rocks and magmatites, was eroded by the latest glacier and stratigraphically covered by till or material deposited during several evolutionary stages of the Baltic Sea. The development of the basin is related to the melting

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of the ice and the gradual uplift of the earth's crust which was depressed 800–900 m by the glacier. As a result of isostatic land uplift after glaciation and changes in the water level of the sea, land became exposed to soil forming processes. During the Baltic Ice Lake stage (12000–10200 BP) and the Yoldia Sea stage (10200–9500 BP), the Helsinki region was under rather deep water. Signs of the highest shoreline of the Ancylus Lake stage (9500–8500 BP) are located 50 m above the present sea level (Taipale and Saarnisto 1991). The fine-textured deposits formed at this stage and later on the bottom of the basin are symmictic and contain markedly more organic material than the older ones. During the Littorina Sea stage (7500–4500 BP) saline water re-entered the basin and gave rise to sediments with high sulphate concentration and biological activity. In the Helsinki region the highest shoreline of this period is about 30 m above the present sea level. The present brackish water conditions have prevailed for about 2500 years (Taipale and Saarnisto 1991). Presently, land in the Helsinki area is rising in relation to sea level about 3 mm per year (Eronen et al. 1995, Seppä and Tikkanen 1998).

In the national soil classification, organogenig soils have more than 20% organic matter (OM) and mineral soils less than 20% OM. Mineral soils are divided into classes according to particle size distribution. Pedogenic features have not been systematically studied in agricultural soils and they are not used in natonal soil classification. Finnish contribution to the soil map of Denmark, Finland, Norway and Sweden (Rasmussen et al. 1979) and to the Soil Geographical Databse of Europe (European Soil Bureau 1998), both using the FAO-Unesco classification, is mostly based on the interpretation of topographic maps. Podzolization process mainly in forested soils has been intensively studied in Finland (e.g. Aaltonen 1941, Mount et al. 1995, Righi et al. 1997, Giesler et al. 2000) but only recently have morphological descriptions of agricultural soils (Yli-Halla and Mokma 1999, Yli-Halla et al. 2000) been published.

The emphasis of this study was in relationships between the pedons and geomorphology in a very young agricultural landscape. The soil forming processes and their impact on soil properties are discussed as related to the drainage history and cultivation practices. Problems in the classification of these young soils are also presented. The coastal area of the Gulf of Finland is of importance for agricultural production even though the intensive land-use around coast line cities is claiming land for construction of buildings and roads. The information obtained from the studied area can be extrapolated to corresponding landscapes on the shore of the Gulf of Finland.

Material and methods

The study area was in the research farm of the University of Helsinki at Viikki along the coast about 7 km from the center of Helsinki (Fig. 1). The area consists of cultivated land (200 ha) and of forested bedrock high areas, surrounding the fields on the west, north, east, and partly south. Also, within the cultivated land there are small islands of bedrock highs which usually serve as locations for buildings and support forest vegetation. The bedrock highs are covered with glacial till but the tops are usually exposed bedrock. On the south, the landscape consists of some forested glacial till areas, wetland forests, and a large area of reeds which serves as a haven for many birds. In the fields small grains and grasses are grown and dairy cows are pastured. The cultivated area is a former bay of the Baltic Sea and consists of lacustrine materials. Agriculture at Viikki began in late Middle Ages, and in 1550 a royal manour was established there. The fields are artificially drained. Drainage was first (>150 years ago) accomplished with open ditches and in the 1950s with subsurface drainage pipes. The fields are surrounded by ditches which empty into a major ditch, at the lowest elevation in the cultivated area, delivering the drainage waters to the sea.

Eight pedons were selected to represent the landscape: six pedons on cultivated fields at the elevation of <1 m to 10 m above sea level and two pedons outside the cultivated area, one in the bedrock high area and one in a wetland between the fields and the sea (Fig. 2). The pedons were described (Table 1) and sampled in June and July of 1997 according to the methods of Soil Survey Staff (1993). Pedon 5 was not sampled. The rate of land uplift (3 mm per year) was used to estimate the maximum age of each pedon (Table 1). Particle size distribution was determined by a pipette method (Elonen 1970) after digestion with hydrogen peroxide. In this study, clay (<0.002 mm), silt (0.002–0.06 mm), sand (0.06–2 mm) and coarser materials (>2 mm) were separated. Organic C was determined using a Leco dry combustion apparatus (Laboratory Equipment Corporation, St. Joseph, MI). Soil pH was measured in water. In the acid sulfate soils (pedons 7 and 8) pH in water was determined in fresh samples and after six weeks of aerobic incubation. These samples were also analysed for SO_4-S, extracted with 0.01 M $CaCl_2$, and some samples were analysed for total S after digestion with 1.4 M HNO_3. Base saturation, on the basis of the sum of exchangeable cations, was determined by ammonium acetate extraction (pH 7.0). In one pedon (pedon 1), Fe and Al were extracted with 0.5 M ammonium oxalate (pH 3.0) to check for the presence of spodic horizon. Phosphorus was extracted with 1% citric acid to identify anthropogenic accumulation of P in the soil (Soil Survey Staff 1975, FAO 1988). In some fields, soil P status was characterized by the soil testing data (an acid ammonium acetate method, pH 4.65, Vuorinen and Mäkitie 1955) available at the research farm. In a bedrock high area, the variation in depth to bedrock or thickness of glacial till was determined at two meter intervals in a transect located along a street being constructed for residential development. The pedons were classified according to Soil Taxonomy (Soil Survey Staff 1998), the FAO-Unesco system (FAO 1988) and the World Reference Base for Soil Resources system (FAO 1998) assuming that the pedons have a cryic temperature regime (Yli-Halla and Mokma 1998).

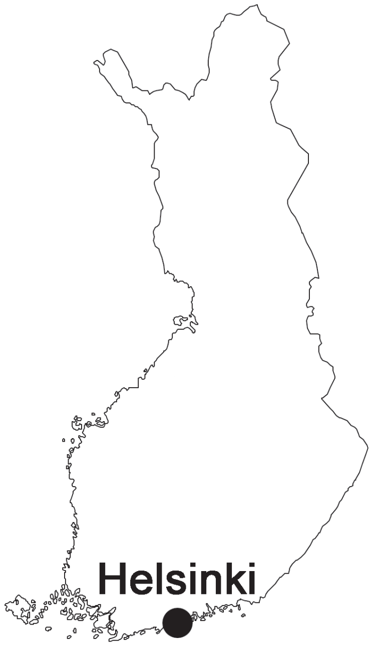

Fig. 1. The study area is in Helsinki on the southern coast of Finland.

Results and discussion

Texture of the pedons

Pedon 1 formed in glacial till in a bedrock high area (Fig. 1). The till had more than 70% sand (Table 2). The low content of silt and clay particularly in the E and Bs horizons can be attributed to the washing away of the fine materials by littoral forces. The area around pedon 1 is composed of exposed bedrock and relatively shallow soils. Of the 69 observations made along the transect, 20 percent had depth to bedrock between 0 and 50 cm, 28 percent between 50 and 100 cm, 33 percent between 100 and 150 cm,

Fig. 2. Location of the investigated soil profiles. The contour interval is 5 m. © Maanmittauslaitos / National Land Survey of Finland, permission 429/MYY/00.

and 19 percent greater than 150 cm. The bare rock resulted from erosion of the till by the Littorina phase of the Baltic Sea (Hyyppä 1950).

Most cultivated land in this landscape is composed of lacustrine materials. Fields that border on bedrock highs usually have greater slope gradients than the central parts of the fields which are nearly flat. Pedons 2 and 3 represent cultivated soils near the major bedrock high areas and they had the highest elevations among the cultivated pedons (5 and 10 m, respectively). These pedons had sandy upper horizons which are probably beach deposits originating from the glacial till of the neighboring bedrock high areas. In pedon 2, the Ap and Bw horizons contained a substantial amount of material coarser than 2 mm which also reflects the glacial till origin. Both pedons 2 and 3 had lacustrine materials beneath the beach deposits. In pedon 2 glacial till was encountered at 108 cm (4Cg2), whereas till was

Table 1. Selected morphological properties and estimated age of pedons. For the classification according to the FAO-Unesco and WRB systems, see Table 3.

Horizon	Depth cm	Texture	Matrix	Redoximorphic features	Structure
Helsinki 1, Typic Haplocryod (emerged from water >7000 B.P.)					
Oa	0–10	sapric	7.5YR 2.5/1		1m pl
E	10–14	ls	7.5YR 5/2		1m sbk
Bs	14–52	s	7.5YR 4/4		1m sbk
BC	52–82	ls	10YR 5/6		1c sbk
C	82–143	ls	2.5Y 5/2	c2p 7.5YR 4/4, c2p 10YR 5/6	0 m
Helsinki 2, Aquic Haplocryoll (3625 B.P.)					
Ap	0–36	sl	10YR 3/1 1)		1c pl/1c sbk
Bw	36–43	ls	10YR 5/3		1c sbk
2Bg	43–59	c	2.5Y 4/2	m2p 10YR 4/4,c1p 7.5YR 4/6	2c sbk
3Cg1	59–108	sil	10YR 6/1	c3p 7.5YR 4/6	1c pl
4Cg2	108–150	sl	2.5Y 5/1	c3p 7.5YR 5–4/6, c3f 2.5Y 5/3	1vc sbk
1) dry color 10YR 5/2					
Helsinki 3, Aquic Haplocryoll (1800 B.P.)					
Ap	0–35	sl	10YR 2/2 2)		1c pl
E	35–43	ls	10YR 6/3	c2p 5YR 4/6, c2p 7.5YR 4/6	1c pl
Eg	43–51	ls	2.5Y 6/1	c2p 5YR 4/6, c2p 7.5YR 4/6	1c pl
Bg	51–59	sl	2.5Y 4/2	c2p 10YR 4/4, c2p 5YR 4/6	1m pl
Cg1	59–99	sl	10YR 6/1	c2p 7.5YR 4/4	1c pl/1f sbk
2Cg2	99–124	cl	2.5Y 5/1	c2p 7.5YR 4/6	1m pr/2m abk
3Cg3	124–170	c	10YR 4/1	f3p 7.5YR 4/4, c2p 10YR 4/4	1m pl/2m abk
2) dry color 10YR 5/1					
Helsinki 4, Typic Cryaquept (975 B.P.)					
Ap	0–30	sicl	10YR 3/2 3)		2f gr
Bg1	30–37	c	10YR 4/2	c2p 7.5YR 4/4, f1f 10YR 6/1	2vf sbk
Bg2	37–50	c	10YR 5/1	c2p 7.5YR 4/6	2f abk
2Cg1	50–61	sl	10YR 6/1	m3d 10YR 5/6	1m sbk
3Cg2	61–123	c	10YR 5/1	c3p 7.5YR 4/4	0 m
3) dry color 10YR 6/2					
Helsinki 5, Typic Cryaquoll (625 B.P.)					
Ap	0–36	l	10YR 3/2 4)		1c sbk
Bg	36–51	fsl	2.5Y 6/2	c2p 7.5YR 5/6, c2p 10YR 5/6	1c sbk
2BC	51–71	sic	5Y 5/1	c2p 7.5YR 4/4	2c pr
2Cg1	71–110	sic	5Y 5/1	c3p 10YR 4/4	0 m
2Cg2	110–138	sic	2.5Y 5/1	f2f 2.5Y 5/4	0 m
3Cg3	138–163	fsl	2.5Y 5/1		0 m
4) dry color 10YR 5/2					
Helsinki 6, Aquic Haplocryoll (100 B.P.)					
Ap	0–28	c	10YR 3/2 5)		1f sbk and 2m gr
Bg1	28–60	sic	10YR 4/2	m2p 7.5YR 4/6, f2d 10YR 5/8	2vf sbk
Bg2	60–70	sic	10YR 4/2	c2d 10YR 5/8, c2p 2.5Y 6/4	1m sbk
BC	70–100	c	10YR 5/2	m3p 7.5YR 4/6, m3p 2.5YR 3/3	3vc pr/2m abk
C	100–117	c	10Y 5/1		0 m
5) dry color 10YR 5/2					

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Horizon	Depth cm	Texture	Matrix	Redoximorphic features	Structure
Helsinki 7, Sulfic Cryaquept (325 B.P.)					
Ap	0–31	sic	10YR 3/3 [6)]		1f sbk
Bg1	31–50	c	10YR 5/2	m2d 7.5YR 4/6	3f sbk
Bg2	50–68	c	5Y 5/1	c2p 10YR 5/6	3m pr/3m sbk
Bj	68–84	c	5Y 5/1	m3p 5YR 3/3, c2p 7.5YR 4/4 c2p 2.5Y 6/4	3m pr/3m sbk
Cg	84–117	c	5Y 5/1	m3p 5YR 3/3, c2p 7.5YR 4/4	3m pr/3m sbk
C	117–170	c	10Y 3/1		0 m
[6)] dry color 10YR 6/2					
Helsinki 8, Histic Sulfaquent (0 B.P., mineral soil surface approximately at sea level)					
Oi	0–25	fibric	10YR 3/2		2f gr
Bg1	25–42	l	5Y 3/1		1vc pl
Bg2	42–75	sic	10YR 4/1		1m abk
Cg1	75–90	c	10YR 4/1	c2p N 3/1	1vf abk
Cg2	90–150	c	10YR 5/1		0 m

Abbreviations:

Texture: c=clay, sic=silty clay, cl=clay loam, sicl=silty clay loam, l=loam, sil=silt loam, sl=sandy loam, fsl=fine sandy loam, s=sand, ls=loamy sand

Redoximorphic features: f=few (<2% of surface), c=common (2–20%), m=many (>20%), 1=fine (<5 mm), 2=medium (5–15 mm), 3=coarse (>15 mm), f=faint, d=distinct, p=prominent

Structure: 0=structureless, 1=weak, 2=medium, 3=strong, vf=very fine, f=fine, m=medium, c=coarse, gr=granular, sbk=subangular blocky, abk=angular blocky, pl=platy, pr=prismatic, m=massive. The slash between two structural attributes stands for larger aggregates parting to smaller ones.

not found in pedon 3 within 170 cm of the soil surface. Pedons 4–8, which are further away from the major bedrock highs, did not have a sandy topsoil and they were composed of lacustrine materials with no glacial till within the investigated depth. Pedon 4 had an 11-cm stratum of sandy shore deposit. This is likely the result of its close proximity to a minor bedrock high area.

The different surfaces in this landscape have highly variable textural properties. Nearly all pedons had lithological discontinuities, i.e. horizons were composed of materials of different origins. There appears to be two clayey lacustrine materials; one has 40 to 70% clay and the other more than 70% clay. The lacustrine materials in pedons 2, 3, 4 and 7 and the upper parts of pedons 6 and 8 were the coarser material and those in the lower parts of pedons 4 and 7 were the finer material. This reflects the different depths of water during deposition. Currents in shallower waters have more energy and a greater capacity to move coarser particles. The clay in the investigated pedons was not varved, indicating that the studied horizons had been deposited after the retreat of the continental ice sheet. No slickensides or pressure faces (signs of pedoturbation) were found.

Soil forming processes

Pedon 1 at an elevation of 30 m emerged from water during late Ancylus or early Littorina period about 7000 BP. It is well drained; no water table was encountered during sampling. Owing to coarse texture and the litter from the vegeta-

Table 2. Selected physical and chemical properties of pedons in Helsinki. Soil pH values marked with an asterisk (*) represent fresh pH, and, in the parentheses, a pH after eight weeks of aerobic incubation. Other pH values were measured in samples dried as usual. P was extracted with 1% citric acid. Clay stands for particles <0.002 mm, silt for 0.002–0.06 mm and sand for 0.06–2 mm.

Horizon	Particle size distribution					Base	Org.	P
	>2mm	sand	silt	clay	pH	saturation.	C	
	%					%	%	mg kg^{-1}
Helsinki 1								
Oa	n.d.	n.d.	n.d.	n.d.	3.8	11	43.1	73
E	12	87	11	3	3.5	9	1.1	7
Bs	29	92	5	3	4.6	15	0.9	21
BC	6	74	23	3	4.7	12	0.3	23
C	15	73	24	3	5.1	11	0.1	64
Helsinki 2								
Ap	4	68	16	16	6.0	75	4.9	470
Bw	6	84	6	10	5.5	55	0.6	
2Bg	0	13	20	67	5.3	67	0.7	
3Cg1	0	15	80	5	5.8	68	0.1	
4Cg2	2	58	39	3	5.8	67	0.1	
Helsinki 3								
Ap	1	72	17	11	6.4	81	2.7	310
E	0	76	21	3	6.4	57	0.3	
Eg	0	76	21	3	6.4	55	0.2	
Bg	0	62	24	14	6.7	85	1.9	
Cg1	0	57	28	15	6.8	80	1.5	
2Cg2	0	22	44	34	6.8	86	0.2	
3Cg3	0	9	25	66	6.8	91	0.4	
Helsinki 4								
Ap	3	14	48	38	6.2	82	3.9	346
Bg1	0	7	37	56	4.9	42	2.4	
Bg2	1	18	33	49	4.8	41	1.5	
2Cg1	0	68	23	9	5.2	78	0.2	
3Cg2	1	4	39	57	6.2	86	0.3	
Helsinki 6								
Ap	0	18	41	41	6.2	83	3.7	619
Bg1	0	16	40	44	5.0	65	0.7	
Bg2	0	4	53	43	5.2	75	0.4	
BC	0	3	13	84	4.4	76	0.6	
C	0	2	12	86	5.8	90	0.4	
Helsinki 7								
Ap	0	8	45	47	6.2*	70	4.8	214
Bg1	0	3	39	58	4.4*	23	2.4	
Bg2	0	3	32	65	4.0(3.9)*	18	1.8	
Bj	0	4	29	67	3.8(3.9)*	16	1.9	
Cg	0	5	28	67	3.55(3.4)*	18	3.0	
C	0	3	32	65	6.5(2.9)*	63	3.2	
Helsinki 8								
Oi					4.7*	61	16.7	151
Bg1	0	32	45	23	7.1(3.0)*	52	1.6	205
Bg2	0	6	39	55	7.2(4.3)*	92	0.5	305
C1	0	1	12	87	7.3(6.1)*	96	0.7	374
C2	0	3	18	79	7.2(6.7)*	100	0.5	376

Table 3. Classification of the investigated pedons according to Soil Taxonomy (Soil Survey Staff 1998), FAO-Unesco system (FAO 1988) and Word Reference Base for Soil Resources (WRB) system (FAO 1998).

Pedon	Soil Taxonomy	FAO–Unesco	WRB
1	Typic Haplocryod	Haplic Podzol	Haplic Podzol
2	Aquic Haplocryoll	Eutric Cambisol	Gleyic Phaeozem/Mollic Gleysol
3	Aquic Haplocryoll	Eutric Cambisol	Gleyic Phaeozem/Mollic Gleysol
4	Typic Cryaquept	Dystric Cambisol	Dystric Cambisol
5	Typic Cryaquoll	Eutric Cambisol	Gleyic Phaeozem/Mollic Gleysol
6	Aquic Haplocryoll	Gleyic Cambisol	Gleyic Phaeozem
7	Sulfic Cryaquept	Thionic Gleysol	Hyperdystric Gleysol
8	Histic Sulfaquent	Thionic Gleysol	Protothionic Gleysol

tion dominated by Scotch pine, translocation of C, Al, and Fe was evident by the presence of a grayish colored (7.5YR 5/2) continuous albic E horizon with no redoximorphic features and a reddish colored (7.5YR 4/4) spodic Bs horizon (Table 1). Spodic materials were identified from the color, pH, and organic C content. In the Bs horizon the index of accumulation of Fe and Al ($0.5 \bullet Fe_{ox} + Al_{ox}$) was 0.43% but it is likely that in the upper part of the Bs horizon the index would be higher. The index for the E horizon was only 0.067%, indicating marked depletion of Fe and Al. Our interpretation is that pedon 1 is a weakly developed Spodosol/Podzol (Table 3).

Soil forming processes began altering the materials in pedon 2 about 3600 years ago (Table 1), in pedon 3 about 1800 years ago, and in pedons 4–8 less than 1000 years ago. The major processes were the addition of organic matter from the vegetation growing on the site and the reduction of Fe because of the anaerobic environment. The intensity of other soil forming processes is likely dependent upon the effectiveness of the drainage system and they have probably been more active since artificial drainage was gradually intensified less than 150 years ago.

The six pedons in the cultivated area had naturally high water tables and are somewhat poorly or poorly drained, as evidenced by the redoximorphic features (redox depletions and concentrations) above 50 cm (Table 1). When these pedons were described and sampled, the water tables were at depths of 63–162 cm. The high water tables are attributable to the cool and humid climate, low elevation, and proximity to the sea. Water also enters the cultivated soils as lateral flow from the surrounding bedrock high areas, and the clayey subsoil of these pedons inhibits vertical water movement.

All cultivated soils had cambic B horizons, owing to the development of structure and pronounced redoximorphic features. These features formed quickly after the soils were artificially drained. The Bg1 horizon in pedon 7 (emerged from water 325 BP and drained about 70 years ago) had a strong grade of blocky structure, stabilized by thick coatings of iron (hydr)oxides (Table 1). The BC horizon of pedon 6 (100 BP and drained for 70 to 90 years) had redox concentrations and strong prismatic structure parting to moderate angular blocky aggregates. In comparison, the C horizons of pedons 6 and 7 were structureless (massive) with no redox concentrations. The C horizons were greater than 1 meter below the soil surface, the approximate depth of the drainage tile. The Bg and Cg1 horizons of pedon 8 had a weak grade of structure, a chroma of 1 and no redox concentrations and the Cg2 horizon was massive. The area in which pedon 8 is located has not been artificially drained and has not been used even for pasture and therefore represents the soil in its native state. From these findings it can be concluded that subangular blocky structure and continuous, thick coatings of iron (hydr)oxides formed in the horizons above the drainage tile in less than 70 years.

An earlier study (Yli-Halla and Mokma 1999) on soil pH before and after aerobic incubation indicate that pedons 7 and 8 had sulfidic materials. This was confirmed in the present study by the analyses of total and sulphate sulphur (Table 4). In pedon 8, which is commonly water-logged, sulfidic materials occurred at 25–42 cm immediately below the histic epipedon but the lower horizons were nonsulfidic. Sulphate is available in the brackish sea water and energy for the microbial reduction is provided by the organic matter from the grassy and reedy vegetation. These results suggest that sulfidic materials are currently accumulating on the coast of the Gulf of Finland. Sulfidic materials were also present in pedon 7 (below 117 cm) where they likely originated from the Littorina period during which most sulfidic sediments were deposited in Finland. The upper horizons in pedon 7 were oxidized and had thick coatings of iron (hydr)oxides. Some light colored mottles (2.5Y 6/4) in the Bj horizon suggest the presence of jarosite, a mineral typical of acid sulfate soils but the pH and sulphate content of these horizons was, however, marginal to meet the criteria for a sulfuric horizon.

Table 4. Contents of total and sulfate sulfur in selected horizons of two acid sulfate soils of the Viikki landscape. Sulfate sulfur was determined after eight weeks of aerobic incubation.

Pedon and horizon	Total S, mg kg^{-1}	SO_4-S, mg kg^{-1}
Helsinki 7		
Bg2	1400	94
Bj	2200	113
Cg	4400	497
C	17500	4820
Helsinki 8		
Bg1	10700	7590
Bg2	8900	1220
C1	2500	690
C2	1100	244

Mollic plow layers and gleyic properties

One of the criteria of a mollic epipedon in Soil Taxonomy and the FAO-Unesco system is the P content of the soil which must not exceed given limits. The levels of P extractable with citric acid in Ap horizons vary from 214 to 619 mg kg^{-1} (P_2O_5 491 from 1420 mg kg^{-1}) (Table 2). All levels were less than the new criterion (654 mg P kg^{-1}, i.e. 1500 ppm P_2O_5, Soil Survey Staff 1999) but greater than the criterion of the FAO-Unesco system and the criterion of Soil Taxonomy applied until 1998 (109 mg P kg^{-1}, i.e. 250 ppm P_2O_5, Soil Survey Staff 1975, FAO 1988). The P originates from manure and fertilizers and from the parent material. In five topsoil samples of the fields of the Viikki area, included in the study of Hartikainen (1979), there was on average 260 mg P kg^{-1} in apatitic form, indicating the young age of the soil. Apatitic P is dissolved with acidic solutions, e.g. sulphuric acid (Chang and Jackson 1957) and acid (pH 3.0) oxalate (Uusitalo and Tuhkanen 2000). Particularly on the basis of the results of citric acid extractable P in the subsoil of the non-cultivated pedon 8, we can assume that citric acid also dissolves native P and may not be suitable for identifying anthropogenic P inputs in soils rich in apatitic P. Furthermore, when the fields of the research farm had been tested in 1999, the P concentrations extracted from the Ap horizons with an acid ammonium acetate solution ranged from 10.1 to 17.0 mg dm^{-3} of soil in samples collected around pedons 2, 4, 6, and 7 (the field around pedon 3 was not tested). According to the seven-step classification used in soil testing in Finland, none of the values was ‘high’ or ‘excessive’, showing that the soils are not overly enriched with anthropogenic P inputs.

The moist colors (Table 1) of the Ap horizons of the cultivated soils were all dark enough to meet the moist color requirement of the mollic epipedon (FAO 1988 and 1998, Soil Survey Staff 1999). However, the dry colors of pedons 4 and 7 were too light (value of 6 rather than 5). The thickness of the Ap horizon was great enough and the base saturation was high enough to meet the Mollisol requirement of Soil Taxonomy in pedons 2, 3 and 6. The ochric epipedons and low base saturation excluded pedons 4 and 7 from being Mollisols. Pedon 5 was considered to have a mollic epipedon on the basis of color, even though it was not chemically analysed. The occurrence of soils formally meeting the criteria of Mollisols has not been systematically surveyed in Finland but mollic epipedons seem to occur mostly in cultivated soils which have sandy plow layers (Yli-Halla et al. 2000). A similar observation has been made in Denmark (Greve et al. 2000).

In the FAO-Unesco system, most cultivated soils of this landscape are Cambisols (Table 3). Even though they are rather poorly drained, they don't usually meet the requirements of gleyic properties and thus, only few can be classified as Gleysols. The ones showing the mollic colors are excluded from Phaeozems by the high P content. In the WRB system, the gleyic color pattern was defined (FAO 1998). This pattern was identified within 50 cm of soil surface in pedons 2, 3, 5, 7 and 8 which thus, were classified as Gleysols. The gleyic colors may, however, reflect the wetness of earlier times. Over time, artificial drainage and isostatic land uplift promote aeration and make the matrix colors redder, rendering the gleyic properties less pronounced. For many of these soils, Phaeozem is presented as an alternative name (Table 3) in the WRB system where the P content is not a criterion of this soil unit. In the WRB system, sulfidic materials which are deeper than 1 m are not taken into account while in the FAO-Unesco system they are recognized within 125 cm of soil surface. Thus, pedon 7 doesn't get the thionic attribute in the WRB system.

Pedogenesis and man

Man has profoundly influenced the present agricultural soils at least by drainage, tillage, liming, fertilization and manuring. Drainage has promoted oxidizing conditions of the soil profile and contributed to increased redox concentrations and to the formation of structure, the two characteristics from which the cambic horizon was identified. Therefore, it can be assumed that the cambic horizon in these low-lying soils is at least partialy a result of human activity.

When classifying according to Soil Taxonomy (Soil Survey Staff 1998), Mollisols dominate the cultivated land of this landscape, Inceptisols being second in frequency (Table 3). In their origin, Mollisols of the present landscape deviate strongly from the original concept of Mollisols (soils formed under native grassland). It is probable that the organic C in the subsoils originated mostly from the high biological activity during the deposition of the lacustrine material, not from recent biological activity in the soil profile. Furthermore, there is an abrupt decrease of organic C content in these soils between the Ap and the horizon below. This feature is caused by additions of organic matter as crop residues and animal manures and mixing of the plow layer annually. Possibly some, maybe most, of the cultivated soils of this landscape have, in the native state, had a histic epipedon similar to that of pedon 8. When reclaimed for agriculture, drainage accelerated the rate of decomposition of the organic matter and tillage mixed the organic materials into the plow layer. The high base saturation of the Ap horizon was at least partially caused by liming, not by calcareous parent materials, and without liming the epipedon might be umbric.

It is impossible to find a native soil equivalent to the cultivated ones in this landscape because all lacustrine sediments at the same elevations have been reclaimed for agriculture. In addition, the native areas are glacial till in the bedrock high areas and very low-lying soils between the cultivated land and the sea. Therefore it is impossible to check the occurrence of a cambic horizon, a mollic epipedon, or gleyic properties in the native state at the same elevation as the present culvivated soils of this landscape. It can, however, be assumed that in the native state the base saturation of the epipedons would be lower. Without artificial drainage, the cambic horizons would also be less developed or absent and gleyic properties would be more pronounced, resulting in the soils being classified as Entisols (Soil Taxonomy) or Gleysols (FAO and WRB).

Conclusions

In this landscape, a catena of Spodosols, Mollisols, Inceptisols, and Entisols of Soil Taxonomy was identified. According to the FAO-Unesco system, the catena consists of Podzols, Cambisols, and Gleysols while according to the WRB system Phaeozems are also included. It needs to be pointed out that the mollic epipedons had the highest color value and chroma allowed, while in the ochric epipedons the color was borderline to the mollic epipedon. This is problematic since the mollic epipedon is one of the strongest characteristics influencing classification. It was also difficult to differentiate between the cultivated Cambisols and Gleysols of the WRB system. Thus, soils which differ from one another only marginally get different names at the highest level of classification. This lability, which is a potential source of inconsistent soil classification, can be attributed to the young age and weak development of the pedogenic features and to the varied impact of man on soil properties, not only in plow layers but also in subsoils down to the drainage depth. Conclusions about the native state of the soil, and about the further development upon termination of human impact, are quite uncertain. Therefore it is difficult to follow the principle that “short-term management effects should not influence soil grouping” (FAO 1998, p. 11). More discussion is needed about the classification of these young soils, particularly on how the different effects of human influence should or shouldn’t be taken into account.

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SELOSTUS

Nuoria maita Viikin pelloilla

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Helsingin yliopiston Viikin opetus- ja tutkimustilan pelloilla, niiden vieressä olevalla moreenialueella ja meren äärellä olevassa ruovikossa tutkittiin kahdeksan maaprofiilia n. 1,5 metrin syvyyteen ja niissä esiintyvät maannostumisen merkit kuvailtiin. Maannokset nimettiin amerikkalaisen Soil Taxonomy -järjestelmän, FAOn-Unescon järjestelmän ja vuonna 1998 julkaistun World Reference Base for Soil Resources (WRB) -järjestelmän mukaan. Maannosten suhdetta niiden sijaintiin maastossa luonnehdittiin. Moreenialue, joka on paljastunut merestä noin 7000 vuotta sitten, oli heikosti podsoloitunutta maata. Viljelyalueen korkeimmat kohdat ovat paljastuneet merestä 2000–3000 vuotta sitten. Näiden maiden pintakerros on karkeaa hietaa, joka on kulkeutunut veden vaikutuksesta läheisiltä moreeni- ja avokallioalueilta, ja hiedan alla on savea. Viljelyalueen keskiosissa, jotka ovat nousseet merenpinnan yläpuolelle alle 1000 vuotta sitten, koko tutkittu maprofiili on savea. Kaikissa viljelymaissa oli tumma mollic-horisontti tai hieman vaaleampi ochric-horisontti. Syvemmällä niissä oli cambic-horisontti, jonka tuntomerkkejä olivat rautahydroksidilaikut ja maahan kehittynyt rakenne. Lähimpänä merta esiintyi happamia sulfaattimaita, joiden veden kyllästämissä horisonteissa oli sulfidia. On todennäköistä, että ojitus on merkittävästi edistänyt rakenteen kehittymistä Viikin alueen viljelymaissa, jotka ovat luontaisesti märkiä. Viljelymaat kuuluivat Soil Taxonomy -järjestelmän Mollisol- ja Inceptisol-luokkiin, FAOn-Unescon järjestelmän Cambisol- ja Gleysol-luokkaan ja WRB-järjestelmän Phaeozem-, Cambisol- ja Gleysol-luokkiin.