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Decription of a Danish clayey moraine in which the illuvial horizon is degradated with the result that albic tongues of sandy loam penetrate into a Bt-horizon of sandy clay-loam.

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The pedological development on well-drained clayey deposits in the humid parts of Western Europe has been described by Ameryckx 1960. From the regosol, a cambisol characterized by a structural or coloured B-horizon, will develop. Due to leaching and yearly drying and rewetting of the soils, clay migration will often occur in this region, and a Bt-horizon will be formed, and - if high base saturation is present - the cambisol will develop into a luvisol, otherwise into an acrisol. The next step in soil formation is the development of albic interfingering and tonguing into the Bt-horizon due to destruction and/or migration of clay minerals from ped surfaces. If tonguing is present in the Bt-horizon, the soil is classified as podzoluvisol (FAO 1974). In the eluviated horizon of these soils, there will often develop a micro podzol because of sandy texture and low pH-value.

Geographically, podzoluvisols cover areas in USSR where they are found in the transitional zone between the podzol belt and the chernozem belt. In Belgium, this soil type is also covering great areas in the loess belt. For Denmark, the earlier stages in the pedological development on clayey soils have been described by Fobian 1966, Faizy 1973, Møberg 1975, and Madsen 1979, but so far no description of the podzoluvisol has been made.

LOCATION AND DESCRIPTION OF THE PROFILE

The profile (fig. 1) was situated at Munkeskov 20 km SW of Køge, Zeeland. It had developed under a beech forest in a calcarious clayey moraine from the Würm glaciation. The soil profile was situated at the top of a toposequence in which it was the only profile showing degradation in the Bt-horizon. The external drainage was relatively good with highest occurring groundwater level about 1 m, the internal drainage was poor due to textural variations.

The area has a mesic temperature regime with a mean temperature of 17°C in the warmest month and 0°C in the coldest month. The area has a udic soil moisture regime with a soil moisture deficit in May and June of about 100 mm. The field investigation was carried out in May 1979, the profile described according to FAO's guideline for soil profile description, and undisturbed samples were taken for constructing soil-water characteristic curves. Moreover, samples were taken for determining texture, organic matter, pH and soluble iron and aluminium.

O (3-0): morr layer.

A1 (0-9): very dark grey sandy loam (10YR 3/1) moist, weak subangular blocky, friable, no gravel and stones, very frequent roots of all sizes, strongly acid (pH 3.2), clear smooth boundary.

A (9-24): dark yellowish brown sandy loam (10YR 4/4) moist, weak subangular blocky, friable, very little gravel and few stones some strongly weathered, common roots of all sizes, strongly acid (pH 3.5), clear smooth boundary.

A2g (24-36): yellowish brown sandy loam (10YR 5/4) moist, few distinct yellowish red mottles and few small soft knobby nodules (5YR 5/8) moist, moderate granular, friable, few aggregates with brittle structure, little gravel and few stones some strongly weathered, strongly acid (pH 4.0), gradual smooth boundary.

A3g/Blg (36-44): yellowish brown and pale brown sandy loam (10YR 5/4 & 10YR 6/3) moist, common distinct yellowish red mottles and few small soft knobby nodules, moderate angular to subangular blocky and moderate granular, firm to friable, few silt cutans, very little gravel and stones some weathered, few medium roots, strongly acid, gradual smooth boundary.

B2tg (44-70): dark yellowish brown sandy clay loam (10YR 4/4) moist with brown parts (7.5YR 5/4) moist, continuous bleached silt cutans on the ped surfaces (1 mm thick), 15 to 25% of the upper part was albic tongues (10YR 6/3) moist, strong angular to subangular blocky, friable to firm, very little gravel and stones some weathered, few roots, acid (pH 4.8 inner ped., pH 4.3 tongues), gradual, wavy boundary.

B3tg (70-101): brown sandy clay loam (10YR 5/3) moist, common distinct brown mottles, few albic narrow tongues in the upper part, moderate subangular blocky, friable to firm, very little gravel and few stones, some weathered, very few roots, acid (pH 4.9).

Cg (101): olive grey sandy clay loam (5Y 5/2) wet, many distinct yellowish brown mottles (10YR 5/4) wet, weak angular blocky, plastic non sticky, lime concretions, very little gravel and few stones, very few roots, neutral (pH 6.6).

ANALYSIS

Organic matter was determined on an IR-leco apparatus (Tabatabei & Bremner 1970), and pH in 0.01M $CaCl_2$. The grain size distribution was determined by sieving, and by the Andreasen pipette method. Soil water content at different pF-values up to pF 3 was determined in a pressure membrane apparatus and pF 4.2 was calculated by a formula (Hansen 1976). The iron- and aluminium contents were determined by the dithionite-citrate method.

RESULTS AND DISCUSSION

Table 1 shows that the soil was strongly leached in the upper part of the profile though the lime was already present at 1-m depth. The variation in clay content showed clearly the eluvial horizon with 10 to 15% of clay, the illuvial horizon with about 30% of clay, and C-horizon intermediate with 25% of clay. The profile was developed on a textural homogeneous moraine, and there are only small differences in the grain-size classes if clay content is put equal to that of the unaltered C-horizon. The bleached tongues in the B2tg-horizon had nearly the same grain-size distribution as the one found in the A-horizons indicating a clay migration from the ped surfaces in the illuvial horizon. Where the eluviated clay from the ped surfaces redeposits is not evident, but probably it either migrated vertically down into B3t, into the calcarious C-horizon, or, horizontally into the peds during the rewetting of the soil in autumn.

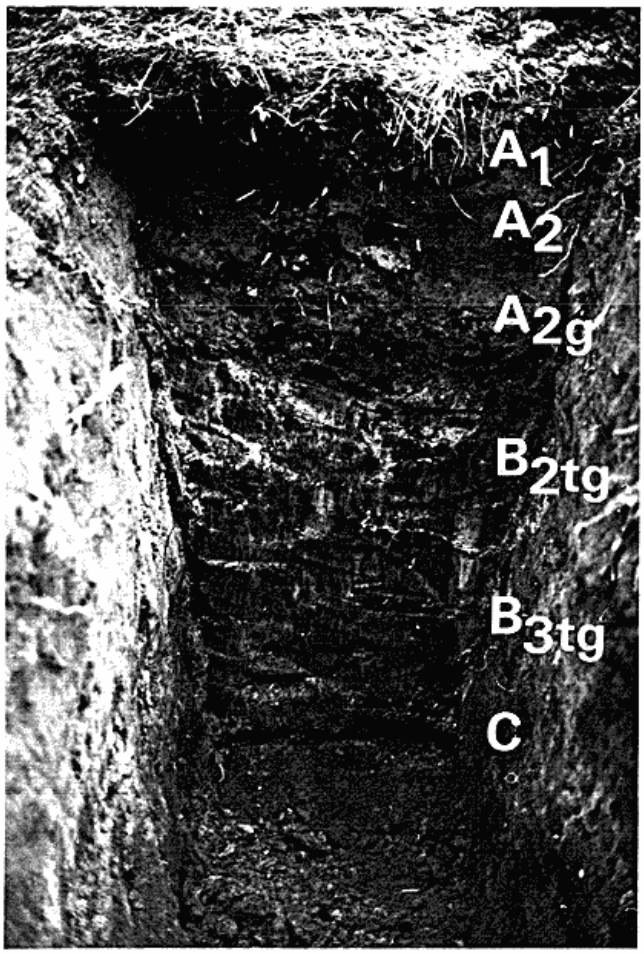

Fig. 1. Picture showing the investigated profile with horizon symbols.
Fig. 1. Billede af den undersøgte profil med horisontbetegnelser.

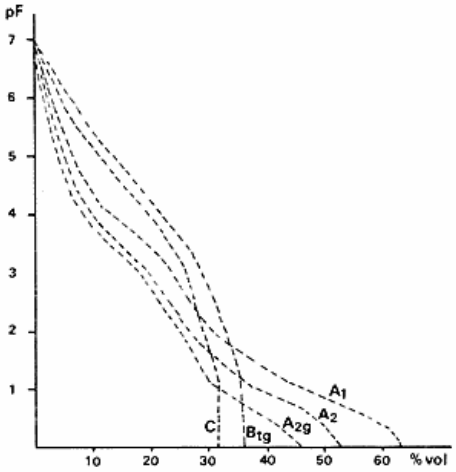

Fig. 2. Soil water characteristic curves for the different horizons.
Fig. 2. Retentionskurver for de forskellige horisonter.

The bulk density increased with depth due to higher bioturbation and humus content in the upper horizons and due to the weight of the overlying soil. The soil-water characteristic curves (fig. 2) showed a greater amount of coarse pores in the upper horizons than in the lower ones in contrast to the fine pores due to the higher specific surface area in the B- and C-horizons.

The values of soluble iron and aluminium are mean values and cover great variations caused by mottling. The distribution of iron and aluminium is an interplay between chemical weathering of the top soil, movements by pedological processes such as podzolization, clay migration, and oxidation/reduction. The iron content was highest in the clayey part of the B3t-horizon, probably due to migration from the top soil, and lowest in the albic tongues. The aluminium content decreased generally with increasing depth, but with a local maximum value in B2tg. The high amount of iron and aluminium in A2g might be due to a beginning podzolization in the eluvial horizons which the brittle structure in A2g also indicates.

The influence of texture on the internal drainage of the degradated B-horizon is demonstrated in table 2, where the horizontal distribution of dithionite-citrate soluble iron and aluminium from an albic tongue to the center of the ped is shown.

The distribution of iron is due to oxidation/reduction processes. During autumn and winter, the water surplus percolates rapidly down through the A-horizons and the albic ton-

	clay	silt µ		sand µ			gravel	OM	pH	Fe	Al	b.d.
	<2 µ	2-20	20-50	50-125	125-500	500-2000	0.2-2cm	%	$CaCl_2$	0/00	0/00	g/cm³
A1	14	15	9	20	35	7	1	7.7	3.2	4.5	1.4	0.94
A2	12	14	11	22	31	8	5	3.1	3.5	4.5	1.4	1.23
A2g	11	11	14	18	35	11	12	-	4.0	4.8	1.6	1.44
B2tg*	15	13	9	22	34	7	1	-	4.2	1.2	0.4	1.70
B2tg**	31	15	7	17	25	5	1	-	4.8	5.0	1.7	
B3tg	28	16	6	18	26	5	1	-	4.9	6.8	0.8	
Cg	25	19	7	17	26	6	2	-	6.6	4.9	0.4	1.81

* ped surfaces. ** ped interior.

Table 1. Texture, organic matter, pH ($CaCl_2$), iron- and aluminium content, and bulk density in the different horizons.

Tabel 1. Tekstur, organisk indhold, pH ($CaCl_2$), jern- og aluminiumindhold og volumenvægt i de forskellige horisonter.

gues, while the clayey part of the B-horizon restricts the percolation. In this period there will be a water-saturated zone upon the clayey part of B2t, and the iron oxides in the tongues and the lower part of A2 will be reduced. During periods with only little or no water surplus, the water-saturated zone will disappear and the zone be aerated. In A2g and A3g/Blg this will result in mottling and nodules, in B2tg a migration of iron from the tongues to the interior of peds will be the result. The tongues will be poor in iron, the outer part of the ped, however, will be significantly enriched with iron, whereas the inner part of the peds is not, or only little, influenced by the process. The difference in aluminium content from the tongue to the interior of the ped is probably due to differences in specific surface area.

According to FAO 1974, the profile will be classified as gleyic podzoluvisol and, according to Soil Taxonomy 1975, as aquic glossudalf.

SUMMARY

The profile was developed on a calcarious clayey moraine from the Würm glaciation 20 km SW of Køge, at Munkeskov. There was clear evidence of clay migration in the profile and development of eluvial and illuvial horizons. The illuvial horizon had tonguing and interfingering of bleached sandy loam along the ped surfaces, and the textural differences between the clayey and sandy part of B2t give rise to a temporary watertable upon B2t in the profile. The true groundwater had its upper limit at about 1-m depth. The soil was classified as a gleyic podzoluvisol according to FAO and as an aquic glossudalf according to Soil Taxonomy.

	Fe 0/00	Al 0/00
Bleached tongue	2.2	0.7
Dark reddish-brown ring around the bleached tongue	19.5	1.2
Yellowish brown inner part of the ped	7.0	1.1

Table 2. Content of iron and aluminium in zones from an albic tongue to the ped interior.

Tabel 2. Jern- og aluminiumindholdet i zoner fra en "albic tongue" til aggregatets indre.

RESUMÉ

Denne artikel beskriver jordbundsudviklingen på en kalkholdig leret moræne, der er beliggende i Munkeskov ca. 20 km sydvest for Køge. Profilen havde en veludviklet eluvial horisont samt en illuvial horisont, der var under delvis nedbrydning, hvilket viste sig ved, at aggregatoverfladerne var belagte med siltcoatings. Profilen havde et tydeligt gleypræg i de nederste dele af A2 samt i B2tg, hvilket sandsynligvis skyldes de teksturelle forskelle i profilen, der betinger udviklingen af et sekundært grundvandsspejl ovenpå den ikke degraderede del af B2tg-horisonten. Profilen klassificeres efter FAO som gleyic podzoluvisol og efter Soil Taxonomy som aquic glossudalf.

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