MITTEILUNGEN

der

DEUTSCHEN BODENKUNDLICHEN GESELLSCHAFT

Band 47

XIII. Congress
of the International Society of Soil Science

Hamburg 13.-20.8.1986

ISSS - AISS - IBG

Guidebook Tour B

Soils and Landscapes around the Rhine Valley
Germany and the Netherlands

ISSN - 0343-107X

Mitteilgn. Dtsch. Bodenkundl. Gesellsch. 47, 1 - 420, 1986

13th Congress

International Society of Soil Science

Hamburg, Germany

August 1986

Guidebook Tour B

Landscapes, Soils and Use on both Sides of the River Rhine

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RHEINGAU

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Geology

The term "Rheingau" is applied to the predominantly wine growing region between Wiesbaden and Rüdesheim. These Taunus foothills are formed by several step faults from 250 m to 80 m above sealevel. The Rheingau is approximately 3-4 km wide and stretches for 25 km parallel to the south rim of the Taunus mountains. Its western boundary is formed by the deeply incised rhine valley, whereas its eastern boundary extends to the Frankfurt-Wiesbaden plains. Geologically the Rheingau is part of the tertiary basin, named "Mainzer Becken".

During the Devonian age large areas of middle europe were covered by some several 1000 m of sediments (sand, clay etc.), which were folded up during the following Variscian orogeny (Carboniferous). Ordovician and silurian layers were included, now being fenster like exposed at the south rim of the Taunus (Rauenthal phyllites). It was during the Carboniferous age that the formation of the intramontane Saar-Nahe-trough began, which now still borders the Taunus and the Hunsrück to the south. During the Permian this trough was filled with red colored sediments, that underwent subsidence in the Rheingau region and eventually were covered completely by tertiary sediments.

During the Mesozoic the sea receeded from Rheingau and the Taunus, bringing

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about peneplanation and leaving no sediments in the area in question. Tectonic activity began again in the Tertiary with the formation of the upper rhine graben, leading to Oligocene and Miocene ingressions from the south. The Tertiary seas deposited sands, clays and calcareous sediments, reaching northwards as far as the Taunus mountains. Thus several times the Rheingau region became a coastal area with the Oligocene coast line leaving rubbles and sands. Further offshore the "Septarien clay" was being deposited at the same time. The Oligocene is also characterized by the marine "Schleichsande" (sands) and the "Cyrenenmergel" (marl), whereas the last, Miocene ingression caused solid calcareous layers ("Corbicula-Schichten").

Today's morphological features date back to the Eocene with the uplift of the Taunus mountains and the subsidence of the upper rhine rift valley. Since that time the southern rim of the Taunus has been lifted up to approximately 250 m a.s.l., including step faults in the transition of the Taunus and the Mainz basin. They are covered completely by thick tertiary and quaternary sediments. The tertiary divisions, represented by gravel, sand, loam and clay and mainly marl, is the parent material of only about 15% of the soil, because these sediments are again covered by fluvial terraces almost everywhere. The latter is mostly coated by loess. The system of pleistocene terrace flights is morphologically distinct, with the terrace gravels only rarely appearing at the surface because of the loess cover. The loess is the parent material of the prevalent and most fertile soils of the Rheingau. For details consult the following publications:

LEPPLA (1904a), LEPPLA (1904b), LEPPLA (1930), MICHELS (1931), ZAKOSEK & STÖHR (1963), ZAKOSEK (1964), MICHELS (1965), ZAKOSEK (1965).

Climate

Concerning the climatic situation the Rheingau region is part of the Rhine-Main area, which is among the warmest and driest climatic parts of middle europe. Though the adjacent regions, i.e. the Taunus and the Hunsrück, the valley of the Nahe and the rhine-hessian hills are partly included, a comparison of the climatic factors (1891-1930) relevant for the grape, as temperature and rainfall with those of adjoining landscapes indicates the favorable position of the Rheingau (ZAKOSEK 1980).

table 1: Climate Rheingau

place	temperature year (^{o} C)	temperature May-Oct. (^{o} C)	precipitation year (mm)	precipitation May-Oct. (mm)
Geisenheim Rheingau	9.5	15.0	517	296
Wollmersried Taunus	8.0	--	648	372
Kirchberg Hunsrück	7.7	14.2	642	354
Schloßböckelheim Nahe	9.5	14.5	540	310
Alzey	8.9	14.4	537	316

The climatic situation is characterized by mostly mild winters, comparingly warm summer and evenly distributed precipitation throughout the year. The sunshine hours amount to approximately 1600 hours. Favorable microclimatic particularities stress the general climatic suitability for the viticulture. The rhine has a compensating thermal effect and above all the vineyards on adret slopes gain substantial extra radiation.

Site investigations for Hessian viticulture

In 1862 the phylloxera appeared for the first time in Europe. Originating in Portugal it radiply spread over europe. In Germany it took nearly a century until the grafting of wines offered a suitable method against phyllo-xera. Initial setbacks with cultivations lead to investigate in detail the interrelationship between soils and combinations of grafted wines during the 1950s. Special emphasis was laid upon the question which combination of grafted wines would yield the best crops as well as the highest qualities on a certain soil, but at first a deficiency of systematic soil analyses was noticed.

Therefore already in 1947 a systematic large scale mapping of Hessia's wine growing areas was initiated. The field work was brought to an end until 1958. The mapped terrain of 10.000 ha did not only cover 3.000 ha wineyards, but also enclosed the total agricultural terrain of the wine growing regions.

table 2: Climate Geisenheim

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
temperature (° C) (averages 1950-1980) 1950-1980	1.1	2.2	5.6	9.6	13.9	17.1	18.5	17.8	14.6	9.7	5.2	2.3	9.8
precipitation (mm)	39	34	34	35	49	59	54	59	39	38	49	46	535
sunshine (h)	40.2	70.2	126.7	174.4	214.5	212.6	217.7	201.5	160.2	98.2	44.7	35.7	1600

(from: DEUTSCHER WETTERDIENST 1984 a, p. 77-78)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
temperature (° C) 1984	2.7	1.9	4.2	8.3	11.5	15.2	17.7	18.3	13.6	11.2	5.7	3.4	
precipitation (mm) 1984	61	61	18	31	123	36	55	47	88	43	33	10	

(from: DEUTSCHER WETTERDIENST 1984 b)

In order to regard even minor spatial differences of the soil 40 to 50 2 m-drillings per ha were carried out, enabling to discern more than 500 soil units. They are represented on maps of different scales (1: 2000 and 1: 2500). A special microclimatic mapping (1:5.000) completed the pedological field and laboratory investigations. Furthermore adaption experiments on typical soils and on climatically significant sites were carried out, including the most important phylloxera resistent stock cultivars of american origin. The result of these research efforts have been introduced to the practical viticulture by means of lectures, publications and maps (cf. KREUTZ et al.(1967), ZAKOSEK (1971), ZAKOSEK et al. 1972, ZAKOSEK et al. 1979), SCHOLZ (1983), ZAKOSEK et al. (1983), ZAKOSEK et al. (1984)).

Waldäcker

The tour starts at the castle of Johannisberg, giving an overview of the landscape. Then we visit the adaption experiments, situated on a pseudogley and we deal with holocene soil erosion problems. The field part of the excursions ends in a vineyard, where a Pararendzina-Rigosol is shown.

The adaption experiment at the microclimatic very unfavourable site Waldäcker is situated outside of the authorized wine growing area. The Pseudogley-Rigosol with a long wet phase and pronounced dry phase (SCHRADER 1974) has developed on solifluidal material containing weathered loess and Devonian slate and quartzite detritus. The growth the wine roots is severly limited by the compact subsurface.

profile Waldäcker 1

location: Winkel/Rheingau, TK 25 sheet 5913 Presberg, 750 m northwest of castle Johannisberg

site position: 245 m a.s.l., inclination 2^{0} SE

land use: vineyard, deep tillage

soil type: Pseudogley-Rigosol

genetic material: solifluidal material (weathered loess, quartzite and slate)

horizon design.	depth (cm)	description
R 1	0- 25	gravelly silt loam (SiL), containing organic matter, grayish yellow brown (10 YR 4/2), subangular blocky structure, few roots, diffus lower boundary (smooth)
R 2	25- 45	gravelly loamy sand (LS), dull yellowish brown (10 YR 5/3.5), subangular blocky structure, diffus lower boundary (smooth)
R 3	45- 60	gravelly sandy loam (LS), dull yellow orange (10 YR 6/3.5), subangular blocky structure, Fe-concretions, diffus lower boundary (smooth)
Sd	60-150+	very gravelly clay loam (CL), primary color: dull orange (7.5 YR 6/4 - 5 YR 5/4), secondary color: orange - dull yellow orange (7.5 YR 6/6 - 10 YR 6/4), angular blocky structure, Fe- and Mn- concretions

profile Waldäcker 2

location; site position: cf. profile Waldäcker 1

land use: grassland

soil type: Pseudogley

genetic material: solifluidal material (weathered loess, quartzite and clayey slate) covering Devonian slates

horizon design.	depth (cm)	description
Ah	0- 5/10	gravelly silty sand (LS), containing little organic matter, brownishgray (10 YR 6/1), cloddy structure, rooted, clear lower boundary (smooth)
Sw	5/10-40	gravelly loamy sand to sandy loam (SL), dull yellow orange (10 YR 6/4), subangular blocky structure, Fe-concretions, clear lower boundary (broken)

Sd	40- 85	gravelly sandy clay loam (CL), reddish-brown (5 YR 4/6 - 4/8), massive structure, clear lower boundary (smooth)
IISd	85-160+	silt loam (SiL), primary color: reddish brown (5 YR 4/6), secondary color: bluish gray (7.5 YR N 5), tertiary color: orange (7.5 YR 6/6), angular blocky structure

table 3: Physical and chemical properties of profile Waldäcker 1

horizon	depth cm	clay	silt f	silt m	silt c	sand f	sand m+c	sto. %
R	0- 25	5.6	9.0	24.5	15.5	21.7	23.7	25.9
R	25- 45	12.4	8.4	21.3	13.9	19.9	24.1	19.6
R	45- 60	16.1	8.5	20.5	10.0	18.4	26.5	22.3
Sd	60-100	27.1	8.0	18.0	13.0	16.3	17.6	27.1
Sd	100-150	21.6	5.0	6.5	3.0	21.0	42.9	43.8

horizon	depth cm	total PW Vol.%	water content at pF (Vol.%) -1.8	-2.5	-4.2	>4.2	bulk dens. g/cm^3
R	0- 20	48.3	18.7	5.6	14.5	9.5	1.36
R	25- 45	46.4	18.8	5.0	14.3	8.3	1.42
R	45- 60	41.5	17.0	2.2	15.6	6.7	1.55
Sd	100-130	36.2	8.8	3.4	6.4	17.6	1.69

horizon	depth cm	pH KCl	exchang. (Ca,Mg, Na,K) meq/kg	cations (H, Al) meq/kg	CEC meq/kg	V %	lactate sol. K_2O	P_2O_5 mg/100g	org.C %	N_t ‰	C/N
R	0- 25	6.14	50.0	33.8	83.8	59.7	12.8	8.9	1.19	0.9	13.22
R	25- 45	6.51	48.0	15.6	63.6	75.5	5.5	0.6	-	-	-
R	45- 60	6.49	52.0	15.6	67.6	76.9	5.3	0.4	-	-	-
Sd	60-100	6.10	112.0	21.5	133.5	83.9	6.0	0.3	-	-	-
Sd	100-150	6.31	72.0	12.0	84.0	85.7	3.5	0.7	-	-	-

table 4: Physical and chemical properties of profile Waldäcker 2

			texture of humus-/carb.-free fine soil (%)					
horizon	depth	clay	silt			sand		sto.
			f	m	c	f	m+c	(%)
Ah	ca. 0-5/10	6.2	9.2	25.3	9.7	34.4	15.2	17.7
Sw	5/10-40	14.6	10.0	20.5	1.0	33.2	20.7	25.6
Sd	40-85	31.6	6.5	17.5	9.5	18.7	16.2	23.5
IISd	85-160+	23.6	7.5	25.5	28.5	9.8	5.1	0.2

horizon	depth cm	total PV Vol.%	water content at pF (Vol.%) -1.8	-2.5	-4.2	>4.2	bulk dens. g/cm^3
Ah	0- 5/10	49.6	12.0	5.3	23.4	8.9	1.32
Sw	20- 35	41.1	14.4	3.0	8.4	15.3	1.56
Sd	60- 80	40.4	2.0	3.0	11.0	24.4	1.58
IISd	140-150	37.4	3.0	2.4	6.0	26.0	1.66

horizon	depth cm	pH KCl	exchang. (Ca,Mg, Na,K) meq/kg	cations (H, Al) meq/kg	CEC meq/kg	V %	lactate sol. K_2O mg/100g	P_2O_5	org. C %	N_t %.	C/N
Ah	0- 5/10	5.93	56.0	40.0	96.0	58.33	2.60	3.70	1.62	1.1	14.7
Sw	5/10-40	5.91	50.0	23.4	73.4	68.12	5.00	1.00	-	-	-
Sd	40-85	6.31	146.0	16.6	162.6	89.79	6.20	0.40	-	-	-
IISd	85-160+	6.30	140.0	14.0	154.0	90.90	6.60	3.50	-	-	-

FUCHSBERG

Microclimatic measurements are carried out during the growing season at the site "Fuchsberg". Additional tensiometer recordings between the soil surface and a depth of 200 cm are used as base informations to investigate the water balance of the site (ZEPP 1986). The loess-derived Pararendzina-Rigosol offers good conditions for the grapes.

site description

location: Geisenheim/Rheingau, TK 25 sheet 6013 Bingen,
49^o 49' N, 7^o 58' E, H 55 39350 R 3424950

site position: lower slope of the mid-pleistocene rhine-terrace,
102 m a.s.l., inclination 2^o S

land use: vineyard, deep tillage

soil type: Pararendzina-Rigosol

genetic material: loess

horizon design.	depth (cm)	description
RAp	0-45	weak gravelly silt loam (SiL), containing organic matter, brown - dark brown (10 YR 3.5/4), highley calcareous, roots: plentiful, worm passages, cloddy-subangular blocky structure, fragments of slates and angular sandstones, gradual lower boundary

R 1	45- 80	weak gravelly siltloam (SiL), low content of organic matter, brown (7.5 YR 4/6), highley calcareous, roots: few - plentiful, many worm passages, subangular blocky structure, angular and rounded slates and sandstones, diffus lower boundary
R 2	80-107	weak gravelly loam (L), brown (7.5 YR 4/5), highely calcareous, rooted, worm passages, subangular structure, plates of slate and sandstone gravels
Cc 1	107-120	weak gravelly silt loam (SiL), brown (7.5 YR 4/5), secondary carbonate enrichment (pseudomycel), roots: few, worm passages, subangular structure, plates of slate and sandstone gravels
Cc 2	120-150+	silt (Si), bright yellowish brown (10 YR 6.5/6), highely calcareous, upper part showing pseudomycel, very few roots, very few worm passages

table 5: Physical and chemical properties of profile Fuchsberg

depth cm	pH H_2O	pH $CaCl_2$	C_{org} %	N_t ‰	C/N	Fe_o ‰	Fe_d ‰	Al_o ‰	Al_d ‰	Mn_o ‰	Mn_d ‰
10	8.2	7.4	1.01	1.26	8	0.975	9.115	0.719	0.787	0.470	0.542
30	8.2	7.5	0.84	1.05	8	0.980	9.312	0.719	0.695	0.501	0.565
55	8.2	7.5	0.75	0.95	7.9	0.916	9.175	0.656	0.737	0.482	0.535
70	8.3	7.6	0.51	0.71	7.2	0.823	8.407	0.844	0.620	0.420	0.457
90	8.4	7.7	0.51	0.71	7.2	0.753	7.897	0.781	0.502	0.395	0.427
110	8.5	7.7	0.40	0.55	7.3	0.670	6.470	0.656	0.592	0.240	0.270
135	8.6	7.8	0.28	0.36	7.8	0.630	6.110	0.625	0.540	0.188	0.210

depth	CEC		exchang. cations						V	$CaCO_3$
cm	meq/kg		meq/kg						%	%
	P	a	Ca	Mg	Na	K	H	Al		
10	162		137.0	14.0	0.4	10.6			100	9.6
30	165		141.4	14.9	0.4	8.3			100	9.4
55	176		151.7	16.7	0.5	7.1			100	9.6
70	156		135.3	17.0	0.5	3.2			100	12.0
90	176		155.7	16.7	0.7	2.9			100	12.5
110	144		126.9	14.3	0.7	2.1			100	21.8
135	125		105.7	17.0	0.8	1.5			100	25.5

			texture of humus-/carb.-free fine soil (%)						
hor.	depth	sto.	sand			silt			clay
	cm	%	c	m	f	c	m	f	
RAp	10	24.4	5.1	10.6	10.3	21.1	15.9	6.3	30.7
	30	20.0	5.1	10.2	10.5	22.6	16.0	6.4	29.2
R 1	55	20.5	6.0	10.3	10.4	21.8	15.8	6.7	29.0
	70	17.2	5.2	10.0	8.8	22.0	17.8	7.2	29.0
R 2	90	21.8	5.0	9.2	9.1	25.0	17.0	7.1	27.6
Cc 1	110		0.6	3.3	6.6	31.5	24.2	9.4	24.4
Cc 2	135	0	1.7	5.9	7.4	27.8	18.3	11.2	27.7

depth	bulk	total	water content at pF (Vol. %)				kf
cm	dens. g/cm^3	PV Vol.%	-1.8	-2.5	-4.2	>4.2	cm/d
10	1.64	40.1	30.2	28.2	12.5	27.6	21.6
30	1.60	41.8	30.1	27.7	14.9	26.9	164.2
55	1.70	37.5	32.2	29.8	13.7	23.8	164.2
70	1.48	47.2	31.4	26.5	10.9	36.3	613.4
90	1.52	45.5	33.3	27.9	12.4	33.1	101.7
110	1.41	49.1	36.8	30.5	13.4	35.7	203.4
135	1.46	47.1	39.4	31.7	12.9	34.2	66.5

Soil erosion on vineyards in the Upper Rheingau (Eltville Sonnenberg)

In the Rheingau area investigations in the problem of soil erosion are carried out for more than 30 years. On the whole the reasons for the slope eroding processes are known and also the way they take place, but in regard to the velocity of erosion uncertainties do still exist.

By example of the Eltville Sonnenberg it is to be demonstrated how the extent of soil erosion can be estimated with the help of precise analysis of soil profiles of a slope catena.

The parent material is Würm-loess that contains a silt fraction of 70 to 80% and a carbonate content of 25 to 30% (table 6 and fig. 3 and 4). The thickness of the loess deposits varies according to exposition and inclination of the slope. On the lower middle terrace of the River Rhine (T3 from Kandler, 1967) 13 m have been bored near Steinheim. At the middle slope of the Eltville Sonnenberg 7 m have been proved. At the base of the hill and on the terrace-place in front of it occasionally, the rest of an Ah-horizon (fAh) of a Preboreal to Boreal chernozem can be identified at a depth of 60 to 135 cm (Zakosek, 1962). On top of this chernozem a luvisol developed in which the fAh was altered into a Bt (table 1, sample 16 and 17). Herein, proof of a considerable long period of pedo-genesis is seen that either directly or by way of a chernozem in climatically favourable position (continental, little sum of precipitation) lead to the development of a luvisol.
At the base of the Sonnenberg and on the T3-terrace in front of it colluvium occurs that reaches a thickness of more than 1 m. Here it is a question of accumulation profiles (fig. 5). When regarding the luvisol as a climax state of a sequence of soil development in the cool-temperate climate of Central Europe with precipitation in every month, mapping of the soil types can give you sound clues on the extent of soil erosion.

Due to farming for centuries the soils have been transformed considerably. In this respect, besides surface run-off also deep-ploughing and filling with foreign material must be mentioned. All of the vineyard soils have lost their natural profile structure by deep-ploughing so that on top of the Cv-horizon a 50 to 80 cm thick R-horizon occurs that differentiated to a

Rl and R2 in the run of its development (fig. 6).

The parent soil type of today's deep ploughed soil at slopes is commonly a calcaric rigosol that developed out of a luvisol by soil erosion. Remnants of the luvisol, esp. the Bt, are still found at the terrace-plaine below the Sonnenberg. Hints for soil reorganization are to be found in the profiles in the different depths of the horizons. At the upper slope the profile is less deep than at the middle slope. Hence, it might be concluded that we are dealing with erosion profiles at the upper slope and with transition profiles at the middle slope.

Slope catena II - it was recorded at the east slope of the Sonnenberg - also gives evidence of the loss of material due to soil erosion at the slope and of the accumulation at the base of it (fig. 7). Although the Bt-horizon of a luvisol is still preserved it must be regarded as a rest because of its limited depth. The absence of the Al-horizon indicates the luvisol not to be in order any more.

It is obvious that soil erosion processes at this eastfacing slope took place less severe than at the southfacing Sonnenberg. The reasons are not to be found in the inclination of the slope but in the different land use. At the east side there have never been vineyards, but arable land or grassland with orchards which is less prone to erosion (Tisowsky, 1961).

Due to the profile structure it becomes clear that erosion just effected the Al- and part of the Bt, here. Although we do not know the original depth of the luvisol for sure it can be assumed that the Ah-, Al- and Bt-horizons together will not have exceeded 80 to 100 cm. So, if 10 to 20 cm of the Bt are still conserved, then the soil loss merely amounts to 0-80 cm since the onset of farming by man.

Naturally, these results cannot be transferred to the situation at other slopes. But with the knowledge that mainly heavy summer rainstorms result in soil erosion (Kuron et al. 1956, Richter, 1979), data concerning the fairly reliable calculation of the speed of soil erosion can be obtained with the help of irrigation experiments at slopes with different exposition, inclination and land use.

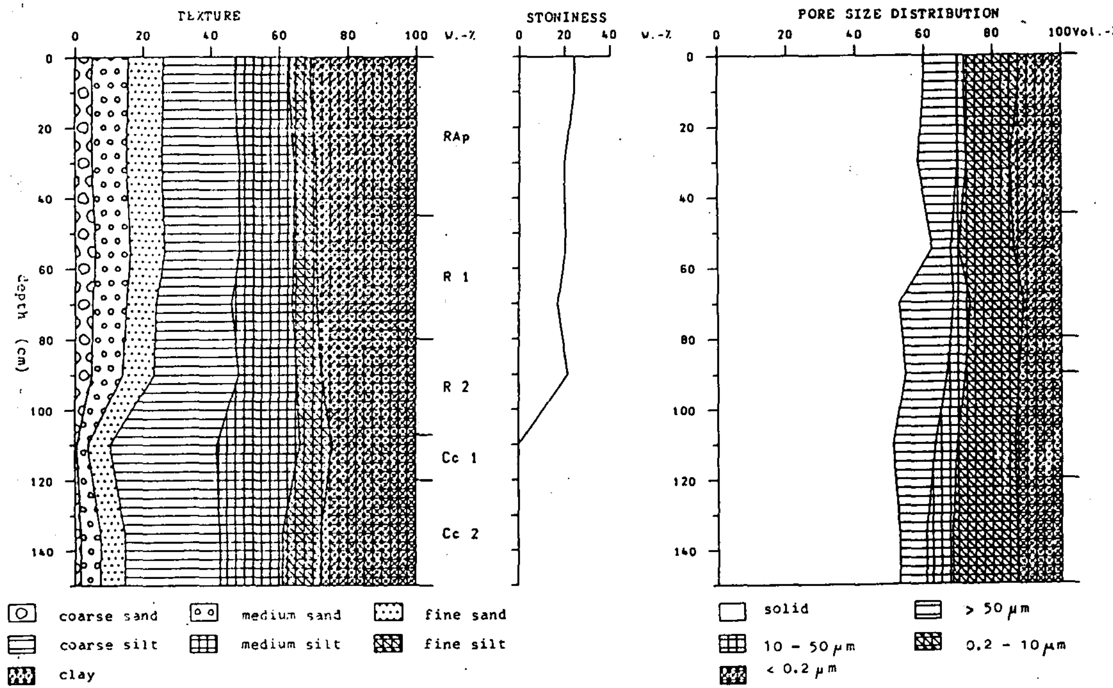

Fig. 1: Fuchsberg soil physical properties

Fig. 2: CAPILLARY POTENTIAL
GEISENHEIM · PROFILE FUCHSBERG

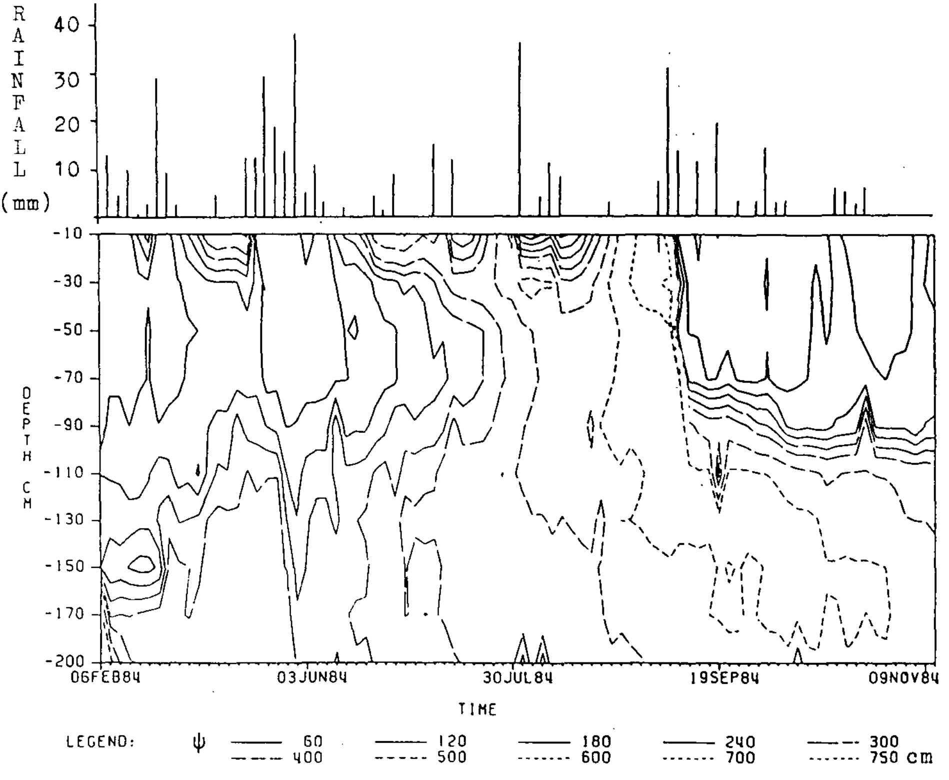

Fig. 3:

Profil Sonnenberg
Parabraunerde-Rigosol

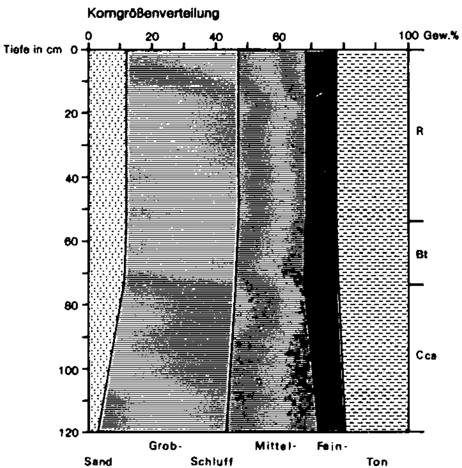

Fig. 4:

Profil Steinheimer Hof II
Kalkbraunerde

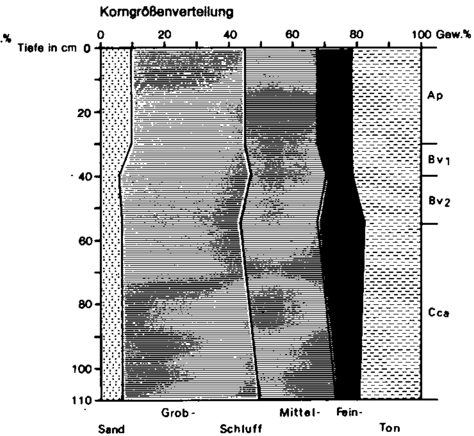

Fig. 5:

Profil Steinheimer Hof I
Kalkbraunerde aus Kolluvium

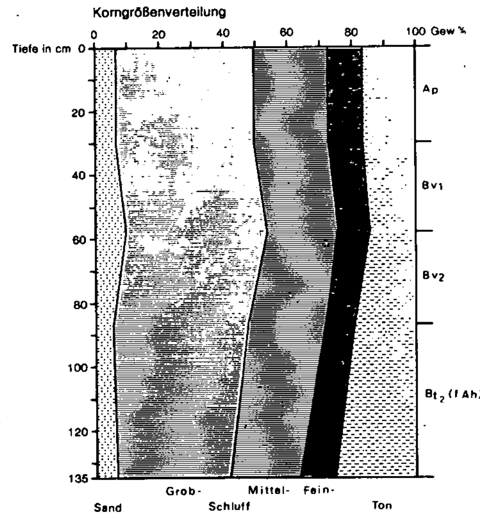

Fig. 6: Slope catena I

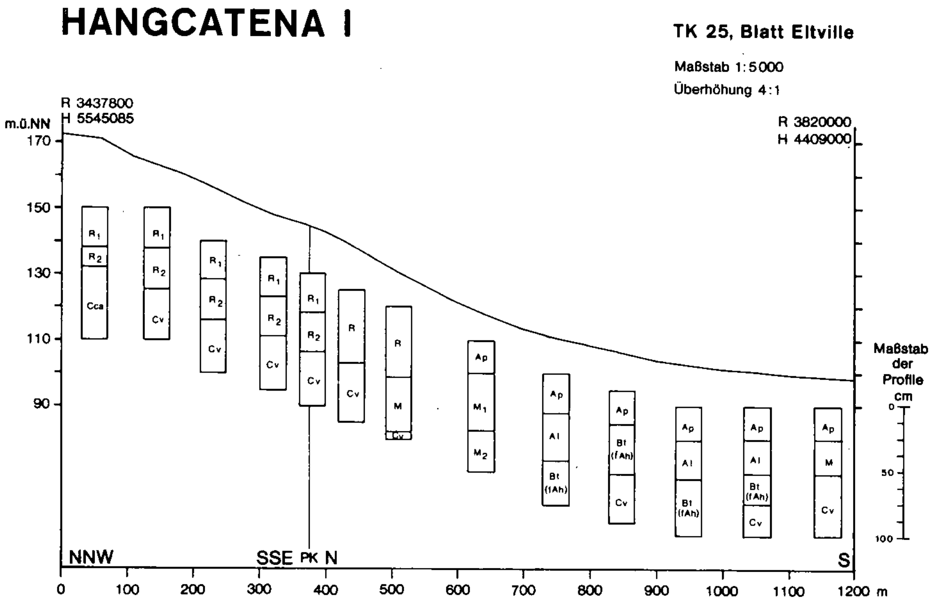

Fig. 7: Slope catena II

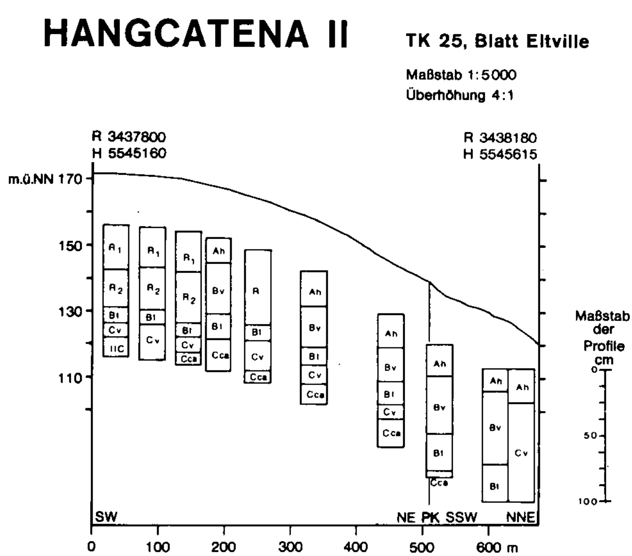

table 6: Selected physical and chemical properties of the profiles Sonnenberg, Steinheimer Hof II and Steinheimer Hof I

horizon depth (cm)	sample no.	total PV (%)	PV (%) >50um	PV (%) <50um	pH $CaCl_2$	C_{org} %	$CaCO_3$ %
Sonnenberg							
R_1 - 54	6	41.0	3.9	37.1	7.6	0.98	7.57
R_2 - 54	7	44.8	9.2	35.6	7.6	0.63	6.85
Bt - 74	8	47.1	10.7	36.4	7.6	0.31	2.33
Cca -120+	9	55.6	10.9	44.7	7.8	-	27.16
Steinheimer Hof II							
Ap - 30	10	41.6	3.1	38.5	7.5	1.19	7.51
Bv_1 - 40	11	39.8	3.6	36.2	7.4	0.45	6.43
Bv_2 - 55	12	47.6	7.5	40.1	7.7	0.45	5.25
Cca -110+	13	58.0	2.0	56.0	7.8	-	27.03
Steinheimer Hof I							
Ap - 30	14	46.3	9.7	36.6	7.6	1.18	2.60
Bv - 58	15	52.4	12.0	40.4	7.7	0.37	2.37
Bt_1 - 87	16	49.9	11.9	38.0	7.7	0.36	1.38
Bt_2 -135 (fAh)	17	49.0	6.2	42.8	7.5	0.45	0.41

hor.	depth cm	sample no.	sto. %	texture of humus-/car.-free fine soil (%) sand c	m	f	silt c	fm	f	clay
Sonnenberg										
R_1	- 54	6		3.4	3.4	5.9	35.4	20.1	10.2	21.6
R_2	- 54	7		3.0	3.6	5.2	34.5	21.9	9.2	22.6
Bt	- 74	8		2.2	2.5	6.1	35.3	21.8	10.2	21.9
Cca	-120+	9		0.4	0.6	2.0	40.3	28.7	8.5	19.5
Steinheimer Hof II										
Ap	- 30	10		1.1	1.5	6.8	35.3	22.6	10.8	21.9
Bv_1	- 40	11		0.3	1.2	4.2	41.3	23.2	8.4	21.4
Bv_2	- 55	12		0.7	1.2	4.4	37.5	24.0	14.3	17.9
Cca	-110+	13		0.6	0.4	4.6	43.7	23.8	7.3	19.6
Steinheimer Hof I										
Ap	- 30	14		0.5	1.8	4.3	43.3	22.6	10.7	16.8
Bv	- 58	15		0.8	2.6	6.4	43.7	22.4	9.8	14.3
Bt_1	- 87	16		0.3	1.5	3.3	42.2	24.1	9.3	19.3
Bt_2 (fAh)	-135	17		0.3	1.4	4.6	35.6	21.8	10.7	25.6

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Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 26 - 29, 1986

Excursion Wissberg

by

E. Krauter[+] and K. Steingötter[++]

The Wissberg, famous for landslides, is situated north of Gau-Bickelheim, a small village in Rheinhessen in the south-west of the FRG (Fig. 1).

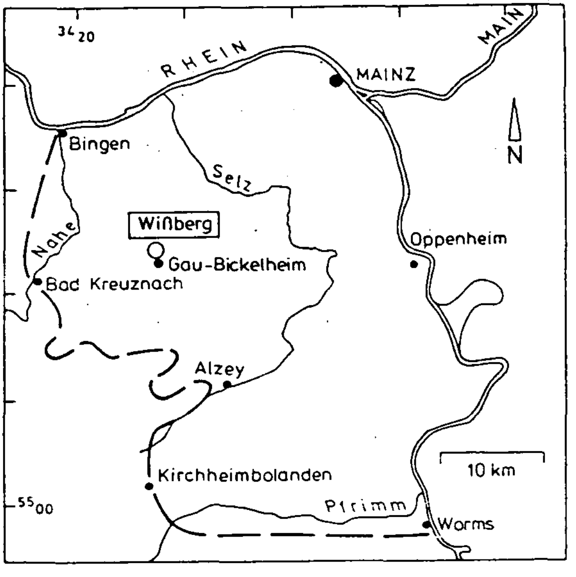

Fig. 1: Geographical Position

The hill shows the typically geological and morphological structures of the Mainz Tertiary Basin in the north-western widening of the Oberrheintalgraben. The flat-undulated landscape is built up of a number of plateaus, flat hillsides (2-20^{0}) and wide valleys. The hills are maximally 150 m high, up to 270 m over N.N..

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The basin consists of oligocene clays, silts and sands. The top is built up of resistent miocene limestones and marls. The top shows steeper hillsides. The plateaus are covered by pliocene and pleistocene sands, gravels and loess (Figs. 2 and 3).

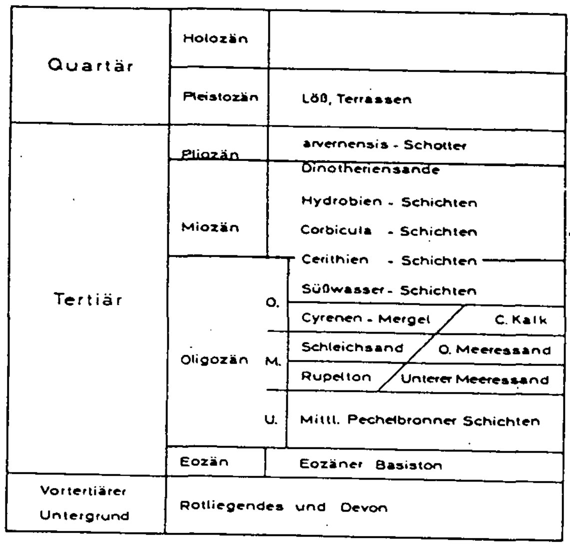

Fig. 2: Stratigraphy (after SONNE, 1984)

The reasons of the landslides are the geological and morphological structures of the Wissberg. The miocene limestones and marls and the younger sediments are permeable for rain-water. The water flows quickly through them and reaches the clays and silts. On the hillside this kimit is marked by springs (Fig. 3).

The water softens the clays and silts and they get to weak that the land-slides are initiated. This interrelation is shown in Fig. 4. You can see the landslides on the outcrop of the upper surface of the oligocene sediments. The sliding planes reach from 2 or 3 m of depth up to over 20 m.
The landslide areas can be recognized by the undulated and humpy ground sur-faces. The hillsides in Rheinhessen are so unstable, that very small anthro-pogen interferences can initiate or accelerate the slope movements, for example agricultural road building. The kinematic of the landslides is due to the rainfalls and the snowmelting.

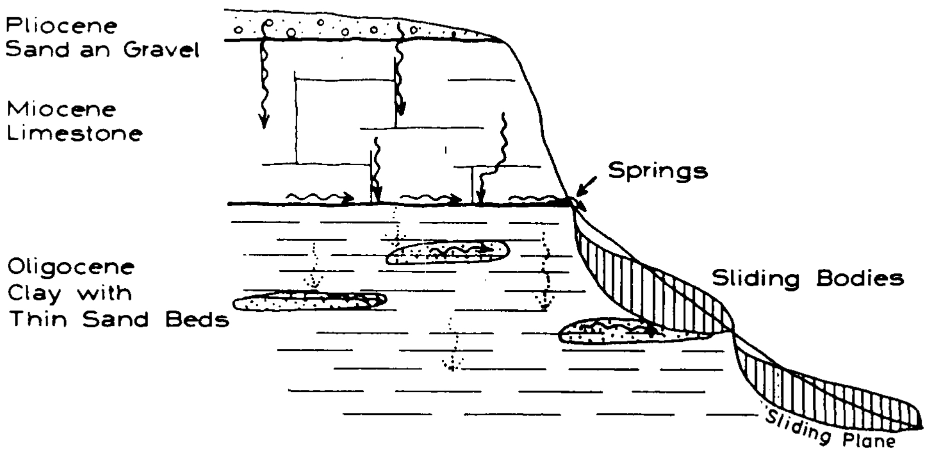

Fig. 3: Schematic geology and water circulation

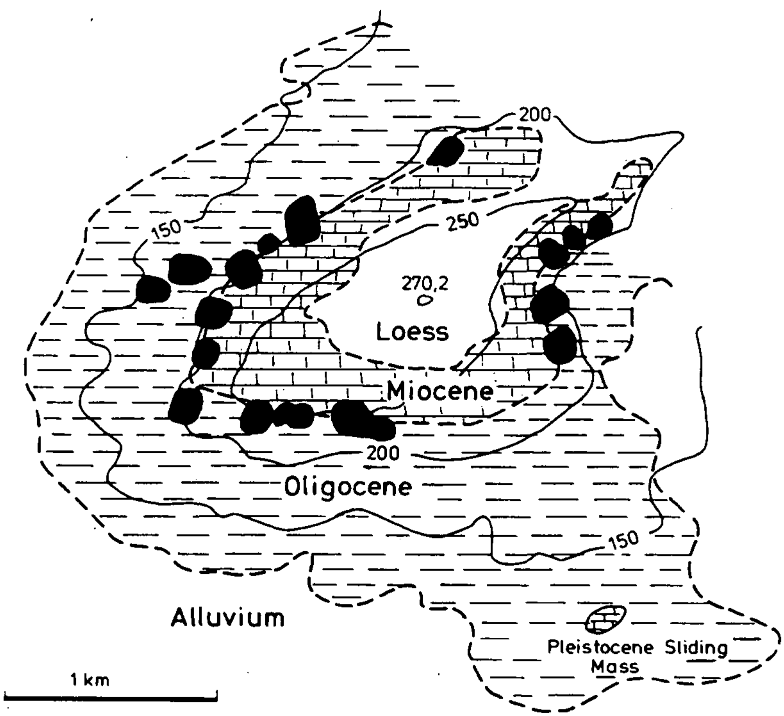

Fig. 4: Landslides of the Wissberg (after WAGNER, 1935)

The example Wissberg documents the characteristical problems in Rheinhessen. There is potential danger of landslides in 8% of this area mutatis mutandis 110 square kilometers. A slope stability map of this region exists since 1983.

The stabilization of the landslides is very expensive and therefore is not done often. The best and cheapest stabilization methods are artificial drainage measures, which have to reach deeper than the sliding planes.

Mitteilg. Dtsch. Bodenkundl. Gesellsch., 47, 30 - 52, 1986

LANDSCAPE AND SOILS IN RHEINHESSEN

by

U. Leßmann+, T. Schöbel+ and S. Stephan+

1. RHEINHESSEN - a young, hilly country between the old mountains

Between Basel and Mainz, the river Rhine uses the Upper Rhine Rift Valley down to the Basin of Mainz and to the barrier of the Rhenish Massive, where it turns westwards to the beginning of the middle Rhine canyon at Bingen. The excursion area (Fig. 1) west and southwest of Mainz is a hilly part of the tectonic basin of Mainz. It belongs to the Federal State of Rheinland-Pfalz, but traditionally it is named "Rheinhessen" as a former part of the Province of Hessen limited now to the right side of the river.

As Rheinhessen is well protected by mountain regions in the west, it is relatively dry and warm, allowing the grapes to grow even at level fields. The main climatic data are:

Mean temperature 9^{0}C, with annual deviation of 18^{0} C
Precipitation   500 - 550 mm/a
Mai to July (vegetation period): 15 - 16^{0} C, 140 - 160 mm
Temperatures $< 0^{0}$ C at 80 days
Temperatures not $> 0^{0}$ C at 20 days.
The soil moisture regime was certainly ustic, but is now nearly udic (since Atlanticum).

Climate would now woods enable to grow, but some less precipitation should be dangereous to trees. Predominance of steppe vegetation during the early Holocene is supposed by most authors writing about former conditions at Rheinhessen.

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Fig. 1: Excursionsroute to landscape and soils in Rheinhessen
Route: Mainz - Wissberg near Gau-Bickelheim (GB) - brickyardpit of Wallertheim (triangle near W) - farm at Undenheim (U) - profile pits of Friesenheim (triangle near Fr) - Mainz.
Further places: Geisenheim (G), Rüdesheim (R), Bingen (B), Bad Kreuznach (BK), Ensheim (E), Nierstein (N).

The landscape formed since the Miocene, when the tertiary sea left the basin of Mainz. Weathering, erosion, redistribution and removal of the sediments created a landscape with valleys, basins and plateaus. A loess cover of mainly younger pleistocene loess (Wuerm glaciation) is lost at wide areas allowing tertiary sediments to crop out.

Predominant parent material for soil formation are the Wuerm loess and materials of oligocene age (most important: smectitic clay to marl, e.g. of the Rupelian, "Rupelton").

The region is under agriculture since neolithic times and wood had no chance for extension since than. Viticulture began at Roman times, in places perhaps earlier: There have been indigenous vitis species, too. At the moment, there are only agriculture and viticulture, without cattle-breeding.

2. Soils

Rheinhessen is covered by soils formed since the latest Pleistocene and early Holocene. On loess, covering the main part of the region, soils have formed which are rather deep, dark, and without any clay migration. They are the RHEINTAL-TSCHERNOSEMS of our nomenclature, belonging to the CALCARIC PHAEOZEMS of the FAO Map. With the definitions of the US Soil Taxonomy, they are VERMUDOLLS or sometimes HAPLUDOLLS. They are distinguished from the continental TSCHERNOSEMS due to the mild climate allowing a more continuous organic matter decomposition and mineralization.

On the outcropping smectite-rich marls of tertiary age, a different species of the RHEINTAL-TSCHERNOSEM has been formed. With a black soil color and a high swelling capacity, it is intergrading to the VERTISOLS. With respect to the priority, it should be named SMONICA, belonging to that soil type well known in eastern Europe, but very rare in our country. It belongs to CALCARIC PHAEOZEM (FAO) and TYPIC VERMUDOLL resp. HAPLUDOLL (Soil Taxonomy). The SMONICA is in most cases covered by a black colluvium (SMONICA material) or a brown one (mainly from RHEINTAL-TSCHERNOSEM).

Due to soil erosion, there are weakly developed soils on the loess as well as on the other marls: PARARENDZINAS in the German system, belonging to the RENDZINAS (FAO) resp. HAPLUDOLLS of ORTHENTS (Soil Taxonomy). Further associated soils are transitions to GLEY with ground water and PSEUDOGLEY with influence of perched water (FAO: CALCARIC GLEYSOLS resp. STAGNO-CALCARIC GLEYSOLS, Soil Taxonomy: GLEY and PSEUDOGLEY as MOLLIC INCEPTISOLS, with indication of the characteristic moisture regime.

Steppe soils of Rheinhessen probably have been formed under semiarid (ustic) conditions in the early Holocene and are now relictic. Pollen analysis of such mineral soils has been executed to get more information.

3. POLLEN ANALYSIS OF MINERAL SOILS

Pollen is seperated of the mineral soil by a liquid solution of CdJ_2/KJ with density 2,3 (URBAN 1978) and then subjected to acetolysis (ERDTMAN 1954).

As there is a stratification of 14C-profiles of TSCHERNOSEMS, recent bioturbation does not homogenize the whole humous horizon but only special layers. Therefore we also expected a stratified pollen-profile in this type of soil.

Pollen in soils developed on aeolian sediments may have different sources:

- simultanous sedimentation of pollen and sediment;
  we distinguish between pollen from the recent local vegetation, pollen from the recent vegetation of the site of erosion and fossile pollen of erosion (secundary pollen).
- infiltration of pollen by percolating water
- vertical distribution of pollen by the activity of soil-animals.

Besides the different sources there are other factors complicating the interpretation of pollen-diagrams:

- the different pollen-productivity of plants
- the different kinds of transport (wind, insects, ...)
- the different resistance against corrosion

This keeping in mind, we interpreted the obtained pollen spectra carfully possible.

4. VISITED SOIL PROFILES

4.1. WALLERTHEIM

In the brickyard pit of Wallertheim sediments and fossil soils from the early Wuerm to the Holocene have been excavated. Brook deposits with humous semiterrestric soils form the basis. The Blake event (80.000 years bp Th/U) is recorded in these deposits and the overlying humous colluviums are of the same age. Above it follows loess which is subdivided by a WIESENTSCHERNOSEM (43,000 years TL) and TUNDRAGLEYS (20,000 years TL). A relictic DUNKELBRAUNER RHEINTAL-TSCHERNOSEM forms the top.

Topogr. Map 1:25,000 sheet 6114 Wörrstadt, r 343165 h 552215, 135 m NN, long extended middle slope (HMG), S exp., DUNKELBRAUNER RHEINTAL-TSCHERNOSEM (TBn, FAO: BROWN CALCARIC PHAEOZEM, Soil Taxonomy: BROWN TYPIC VERMUDOLL, from wuerm-loess), formerly used as brickyard pit.

ApAh 0-30 cm	10 YR 3/2, very dark grayish brown, weakly humous (h2), rich in carbonates (c4), silty loam (Lu), fine crumbly to fine subpolyhedral structure (kru/sub2) in loose packing (Vfl-2), numerous worm-casts (spongy structure), numerous roots (W5), active soil-biology.
Ah 30-50 cm	10 YR 3/3, dark brown, weakly humous (h2), very rich in carbonates (c4), silty loam (Lu), The structure is similar to the ApAh, but rather coarser and at the basis slightly coherent. The number of roots diminishes, but the number of the mainly vertical worm-burrows do not. The transition to the next horizon is gradually and flowing.
ACc 50-80 cm	10 YR 3/3 dark brown, weakly humous (h1), very rich in carbonates (c4), very silty clay (Tu4), coherent (koh), few roots (W1) but numerous worm-burrows filled with dark Ah-material, "Pseudomycelien" formed of secondary lime, the transition to the lC-horizon is flowing.
lC 80-150 cm	10 YR 6/4 light yellowish brown, hardly humous, very rich in carbonates (c4), silty loam (Lu), few roots (W0-1), many worm-burrows, soft concretions of lime.

The top of the profile presents a mollic epipedon of 50 cm over a 30 cm transition zone with worm holes and dark patches decreasing with depth. The surface has a rather slight tendency to silt up. Grain-size distribution demonstrates a certain lithologic dicontinuity between ACc and lC the latter containing more sand (Tab. 1). There is no indication of recent weathering, and only a slight decalcification (Tab. 1, 3, 4).

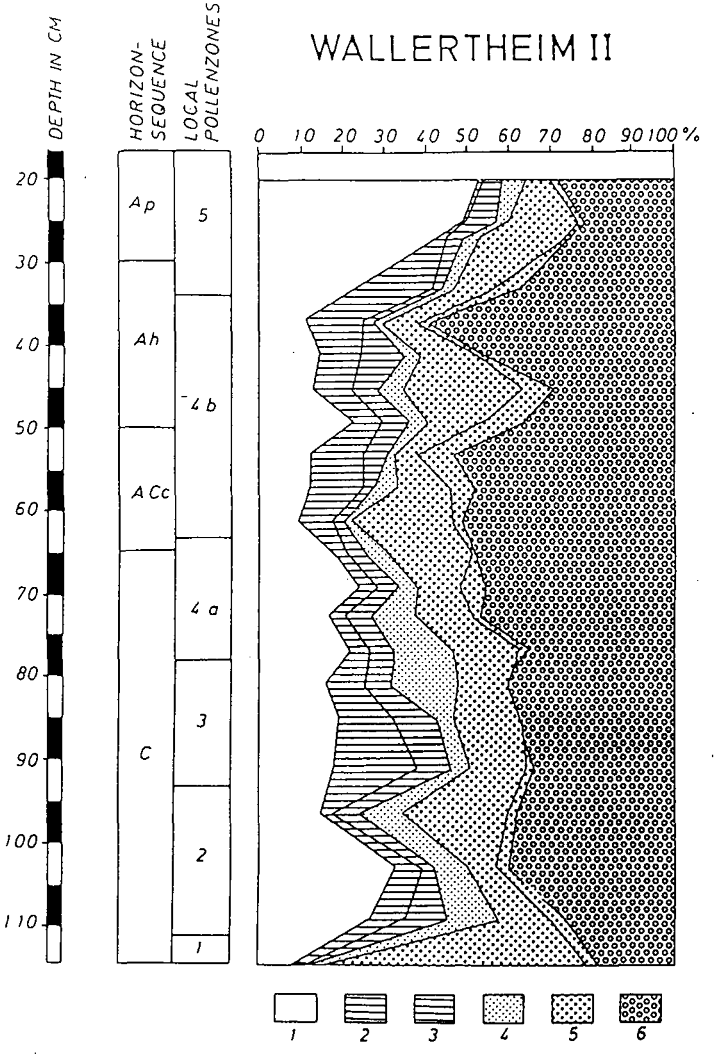

Fig. 2: Pollen diagram WALLERTHEIM II

1 Pinus sylvestris and Pinus haploxylon-type, 2 Betula and Salix,
3 thermophilous trees, 4 Σ Poaceae,
5 culture and steppe elements, and pastureland elements,
6 indifferent non-arboreal pollen (NAP), 7 indeterminatae

Organic matter content diminishes slightly in the A horizons, but is low in the C material. C/N ration is near to 7 pointing to a good humus form (Tab. 4). CEC decreases with the humus content and is in the range of illite, but some higher in the 1C possibly due to smectite. The Ca/Mg ratio in the CEC is 5-6 in the Ah horizons, but 1,6 in the 1C. Na increases with depth, too, whereas K is high at the surface due to fertilization (Tab. 3).

Water penetration is high to very high, and 300 mm water may be stored at pF 1,8 to 4,2: more than half of the yearly precipitation (Tab. 2).

With 92 mg P_2O_5/kg CAL soluble P in the upper 30 cm, P content is insufficient, but K has a medium level with 242 mg K_2O/kg (Tab. 4). The upper 30 cm contain 7,5 t/ha N as stored in the organic matter, what is more than normal.

POLLEN ANALYSIS

(WALLERTHEIM II, close to pedological pit)

The whole profile (Fig. 2) is characterized by an open plant association. The NAP (non-arboreal pollen) content is between 41 and 80 %. The pollen zone corresponds in its pollen content to the recent open culture vegetation. The high amount of NAP originates from the environment and the pollen of Pinus has to be explained as transported by the wind probably from the dunes around Mainz. The rest of the diagram is characterized by the dominance of NAP whereby the Poaceae, the culture- or steppe-elements and the pastureland-elements appear more abundant than in the PZ 5. There is no difference between the fossil A-horizon and the C-loess in their pollen association. For some general explanations see paragraph 3.

4.2 FRIESENHEIM III

Topogr. Map 1:25,000 sheet 6155 Undenheim, r 344785 h 552330, 155 m NN, middle slope, nearly level (HME NO.1-2), S. exp., BRAUNER RHEINTAL-TSCHERNOSEM (TBn, FAO: BROWN CALCARIC PHAEOZEM, Soil Taxonomy: BROWN TYPIC VERMUDOLL, from loess colluvium and loess, used by agriculture and viticulture.

Micromorphology doesn't show any sign of clay movement or redistribution of clay.

MAp1 0-17 cm	10 YR 3/2, very dark grayish brown, medium humous (h3), medium carbonate content (c 3.3), silt very rich in clay (Ut4). The structure is fine crumbly to subpolyhedric (kru/sub2) and very loose (Vf1), with numerous roots (W4) and an intensive soil biology.- Microscopy shows mainly biogenic fabric forms.
Ap2 17-30 cm	10 YR 3/3, dark brown, medium humous (h3), medium carbonate content (c 3.3), silty loam (Lu) with coarser subpolyhedric structure (sub/pol 3-4), in places weakly prismatic (pri4) and loose to medium consolidated (Vf2-3). There are numerous roots (W4) and a well developed soil fauna.- Microscopy presents mainly biogenic fabric, though with some cracks.
Ah 30-40 cm	10 YR 3/3, dark brown, weakly humous (h2), rich in carbonates (c4), silty-clayic loam (Ltu). The structure is similar to the Ap2, but prisms disappeared, and the surface of the aggregates is rougher. There are less roots (W3), the worm casts are as numerous as above.- Microscopy: The soil matrix is lighter and shows light and dark patches representing animal casts with material of the other horizons inside. Separation was stronger as above, but not attaining the biogeneous activity.
AhCc 40-55 cm	10 YR 4/3, brown to dark brown, weakly humous (h2), rich in carbonates (c4), silty-clayic loam (Ltu), structure coarse subpolyhedric (sub3-4), in the lower part intergrading to coherent (koh), medium strong (Vf3). Numerous earthworm casts with Ah material, some small, light gray accumulations of carbonate, some roots (W2), intergrading to the Cc horizon.- Microscopy: The matrix shows some physical separation and numerous channels formed by roots and soil animals (conduction channels), but only few patches of Ah material. It is mainly loess with carbonates inclusively fine-siltic carbonate throughout the soil plasma, and a certain accumulation. The intensive faunal activity didn't influence the chemistry, it is probably subfossil, if not synsedimentary.

1Cc1 55-80 cm	10 YR 4/3, brown, very weakly humous (h1), very rich in carbonates (c5), silty loam (Lu), coherent (koh), carbonate accumulated on fine roots (pseudomycelium), few roots, some earthworm casts with dark Ah material.- Microscopy: Loess with carbonate accumulation and well developed biogeneous fabric, probably synsedimentary.
1Cc2 80-105 cm	10 YR 6/4, light yellowish brown, silty loam (Lu), medium firm (Vf3), coherent (koh), very rich in carbonates (c5), humus only in earthworm casts.- Microscopy: The sample seems to be looser, again with intensive biogeneous fabric formed before the carbonate has been accumulated.

The soil profile consists of a dark epipedon over a light brown loess, with a thick transition zone showing patches of both the loess and the epipedon. The surface tends to silt up.

Micromorphology doesn't reveal clay movement, but the grain-size distribution (Tab. 1) points to weathering, as the clay content comes up to 38 % in the Ah horizon and diminishes with depth. The Fe_d maximum is in the same Ah horizon (Tab. 4). The top represents a colluvium with only 21 % clay in the MAh and influencing the Ap2 horizon. Weathering may occur in the more humide climate of Atlanticum, whereas severe soil erosion and accumulation is produced by man because the region is settled since stone ages. Unfortunately the material is not homogeneous enough to permit a reliable balance of weathering.

The dark soil part down to 40 cm is a true mollic epipedon, and still in the AhCc, humus contents and biological activity are high, but the color is lighter. Biogenic pores dominate throughout (Tab. 5), and cracks are of the same importance only in the AhCc horizon.

The carbonates, mainly $CaCO_3$, are near 30 % in the C horizons and decrease in the surface to 4 % (Tab. 3). Microscopy shows very many fine-distributed carbonate grains and important carbonate accumulation in the C horizons and in the patches of C material more above. There are, however, carbonate grains with "primary" aspect in every horizon, and any supposed complete decalcification cannot be confirmed (Tab. 5).

Water conduction is very good (Tab. 3), porosity is always near 50 %, water storage is rather high. The important part between pF 1,8 and 4,2 is between 18 and 27 %, not counting th upper 17 cm. 204 mm of precipitated water may be stored in the upper meter. As the wide pores are at 10 %, root penetration and air contents are well, too. Physical conditions are those of Tschernozems.

Humus decreases only slightly with depths and is rich in nitrogen (Tab. 4). CEC is relatively high, reflecting a certain participation of smectites (Ah 7 %, AhCc 9 %, lCcl 17 %, lCc2 28 % of the clay content). K is increased in the subsoil by fertilization, Na increases with depths due to leaching. The exchangeable Ca/Mg is about 9, but decreases in the lCc down to 3.2 (Tab. 3).

The Ap contains 240 mg P_2O_5/kg CAL soluble, and 330 mg K_2/O kg CAL soluble, what is regarded as to be high resp. very high (Tab. 4). In the upper 30 cm there are 8,3 t/ha N, mainly stored in organic matter as a save reserve.

POLLEN ANALYSIS:

Two profiles were analysed at this site (Friesenheim II and III) but only in the samples of Friesenheim II the pollen content was high enough for an interpretation (Fig. 3). The Ah-horizon differs from the others by its high amount of NAP (non-arboreal pollen), mainly of the group of cultural- and steppe-elements. Pinus dominates in the C- and Ah-horizons, whereby in the subsoil the Pinus haploxylon-type prevails. This type diminishes from the base of the profile to the top of the Ah-horizon. Pinus haploxylon-type did not grow in this area in late- and post-glacial so that either the pollen must be explained as a secundary pollen from tertiary deposits or Pinus haploxylon-type was part of the vegetation during loess sedimentation in an early loess building period (middle Wuerm ?).

4.3 FRIESENHEIM IV

Topogr. Map 1:25,000 sheeet 6115 Undenheim, r 344798 h 552390, 155 m NN, weakly inclined middle slope (HMG N2), S exp., RHEINTAL-TSCHERNOSEM as SMONICA with Kolluvium (TBn, FAO: CALCARIC PHAEOZEM, US Soil Taxonomy: TYPIC VERMUDOLL, from clay-rich marl (Rupelton) covered by smonica colluvium with

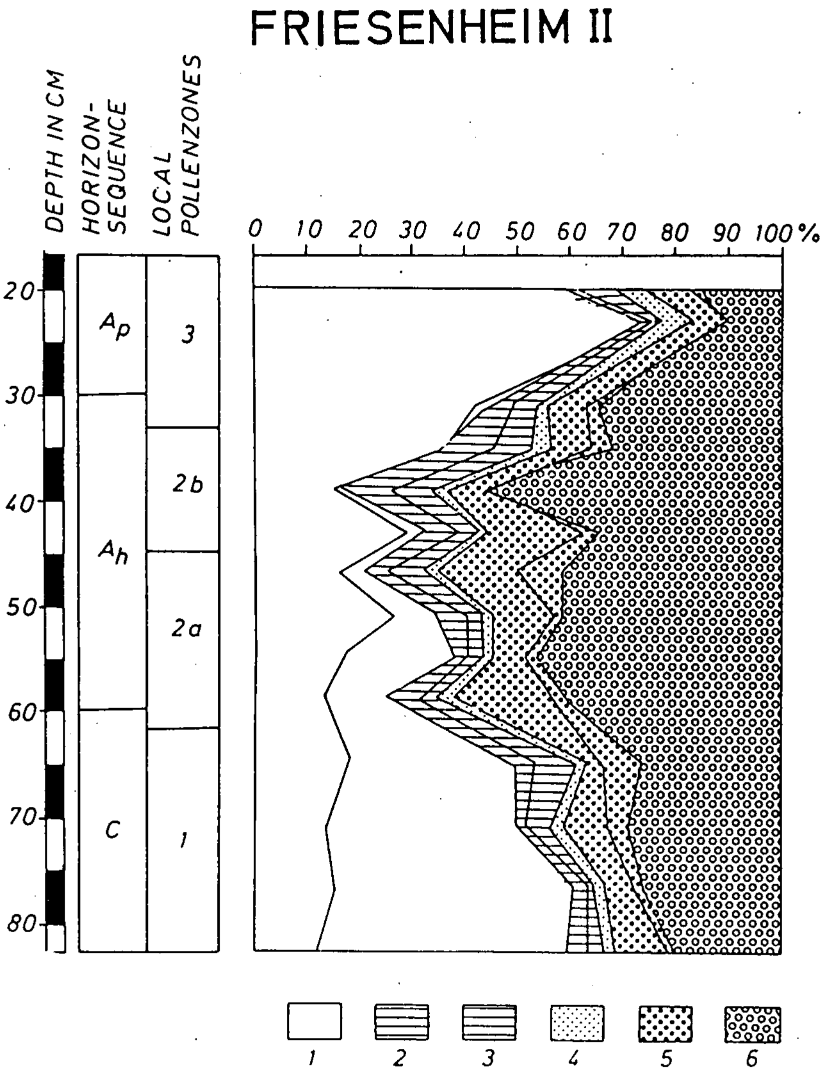

Fig. 3: Pollen diagram FRIESENHEIM II
legend units: 1 Pinus sylvestris and Pinus haploxylon-type

some loess participation), used by agriculture and viticulture. The upper 30-50 cm have been dug up for about 30 years after clearing of a vineyard, the soil being now under agriculture.

MApl
0-15 cm

10 YR 3/2, very dark grayish brown, medium humous (h3), medium carbonate content (c3.3), silty loam (Lu), consisting in fine crumbs, in places fine polyhedrons (krul/pol2), loose (Vf1), and subdivided by broad and deep cracks (ris4.3). Numerous roots (W4), few additions from outside (ca 1 % Org, Zgl).- Microscopy: The material is subdivided into small bodies which are, respectively to their form,something between crumbs and subpolyhedrons, and are produced by selfmulching or faunal activity, now being situated very loosely. Calcareous fine silt only exists in places, but coarser carbonate grains are better represented. The small but striking Fe-Mn-concretions formed in situ.

MAp2
15-27 cm

10 YR 3/3, dark brown, medium humous (h3), medium carbonate content (c3.3), clay-rich silt (Ut4), subdivided into medium polyhedrons to coarse prisms (pol3/pri4). Between the deep-going cracks there is a network of medium to fine secondary ones (ris2-3). The aggregates are medium firm (Vf3-4), there are numerous roots (W3), few earthworm channels, and some additional material (1 % Org, Zgl).- Microscopy is like that of the MApl horizon.

Ahl
27-40 cm

10 YR 3/3, dark brown, weakly humous (h2), rich in carbonates (c3.4), loamic clay (Tl) forming coarse prisms (pri4-5) and very firm (Vf5). The surfaces of aggregates are often smooth, partly with slickensides. Roots (W3), but few signs of greater soil animals.- Microscopy: Biogeneous fabric is dominant. Oriented fine clay is well represented, sometimes even in channels. There are in-situ accumulations of carbonates and Fe-Mn-hydroxides. Some patches contain material from the lower soil part.

Ah2
40-60 cm

10 YR 3/3, dark brown, weakly humous (h2), medium carbonate content (c3.3-4), loamy clay (Tl), coarse polyhedrons to prisms (pol/pri5) subdivided by secondary cracks. Some black,

soft Mn-Fe-patches and concretions (emfl/kegr2) demonstrate water stagnation. Aggregate surfaces sometimes with slickensides. Few roots (W1-2). Lower limitation irregular.- Microscopy is similar to the Ah1, but the material is more compact, shows more carbonate, and there are some patches of material from other horizons.

Cc1 60-82 cm	10 YR 5/4, yellowish brown, very weakly humous (h0-1), very rich in carbonates (c5), loamy clay (Tl), coherent (koh) with some cracks from above, few roots (W1), small yellowish orange (Yr 6-8/3) patches in the soil matrix.
Cc2 82-95 cm	10 YR 6/4, light yellowish brown, nearly free of organic matter (h0-1), rich in carbonate (c4), clay (T), coherent, yellowish patches like Cc1, but also black ones (Fe-Mn accumulations). Roots nearly absent (W0-1) except in greater channels and cracks. The wide cracks from above don't reach this depth. This subhorizon causes some water-stagnation.- Microscopy: The striking fine carbonate dominates the picture of the matrix, clay is hardly visible. The carbonates show a certain redistribution. Water stagnation caused Fe-Mn patches as well as regions turned in pale. There are some inclusions of clay-rich material, and a small worm cast with Ah material.

The Cc2 horizon is dominated by clay (73 %) with 35 % smectite. Both Ah horizons and the Cc1 have about 50 % clay with an increasing smectite content (10 % in the Ah2), and the MAp horizons have less than 25 % clay with less than 5 % smectite. The upper part is a colluvium with high loess input, Ah to Cc1 are influenced by pleistocene solifluction ("Decksediment"), but prevailing formed from Rupelton what is the material of the Cc2. There is no influence of ploughing deeper than 27 cm (Tab. 1).

Micromorphology (Tab. 5) is dominated by biology, but there are wide, deep cracks, some slickensides and a slight selfmulching showing a certain tendency to Vertisol. The humus content decreases only slightly with depths and forms mainly dark grains of few microns of size (Tab. 4, 5). C/N ratio is small, but may be influenced by some fixed ammonium in the deeper soil part.

Water penetration is generally high, but in the Cc2 some perched water may

FRIESENHEIM I

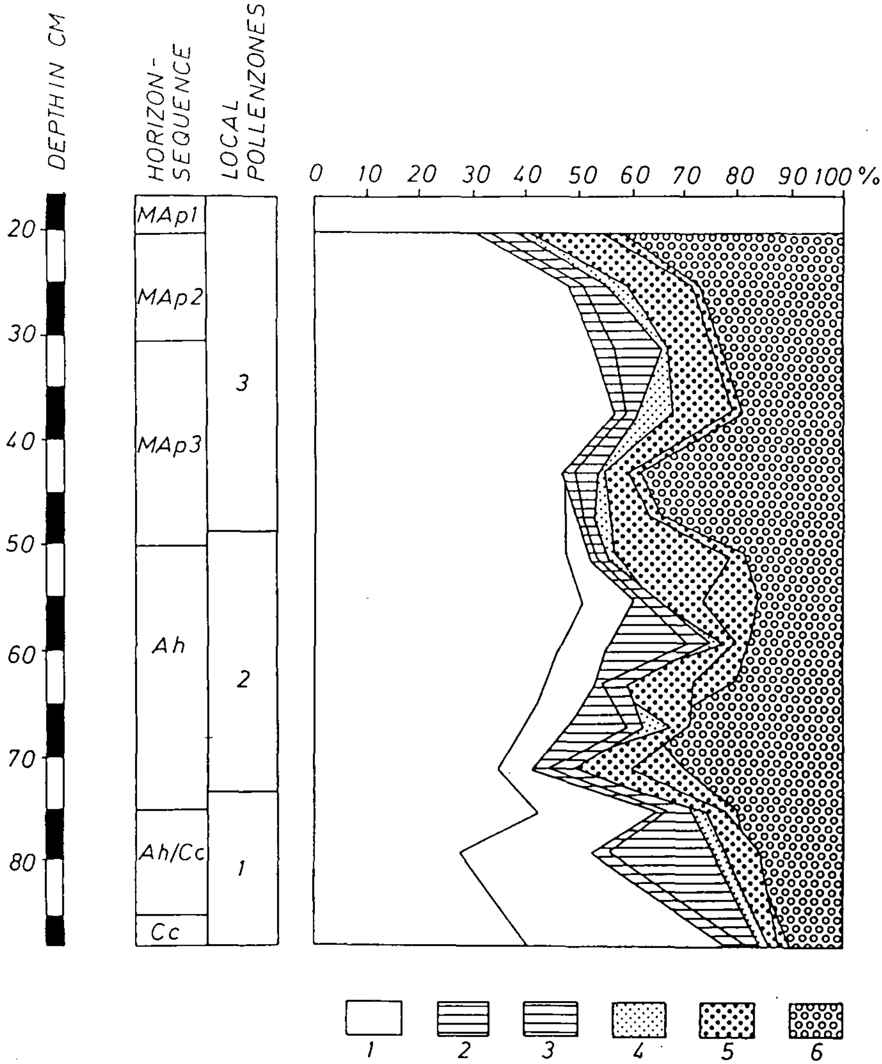

Fig. 4: Pollen diagram FRIESENHEIM I
legend units like Fig. 3

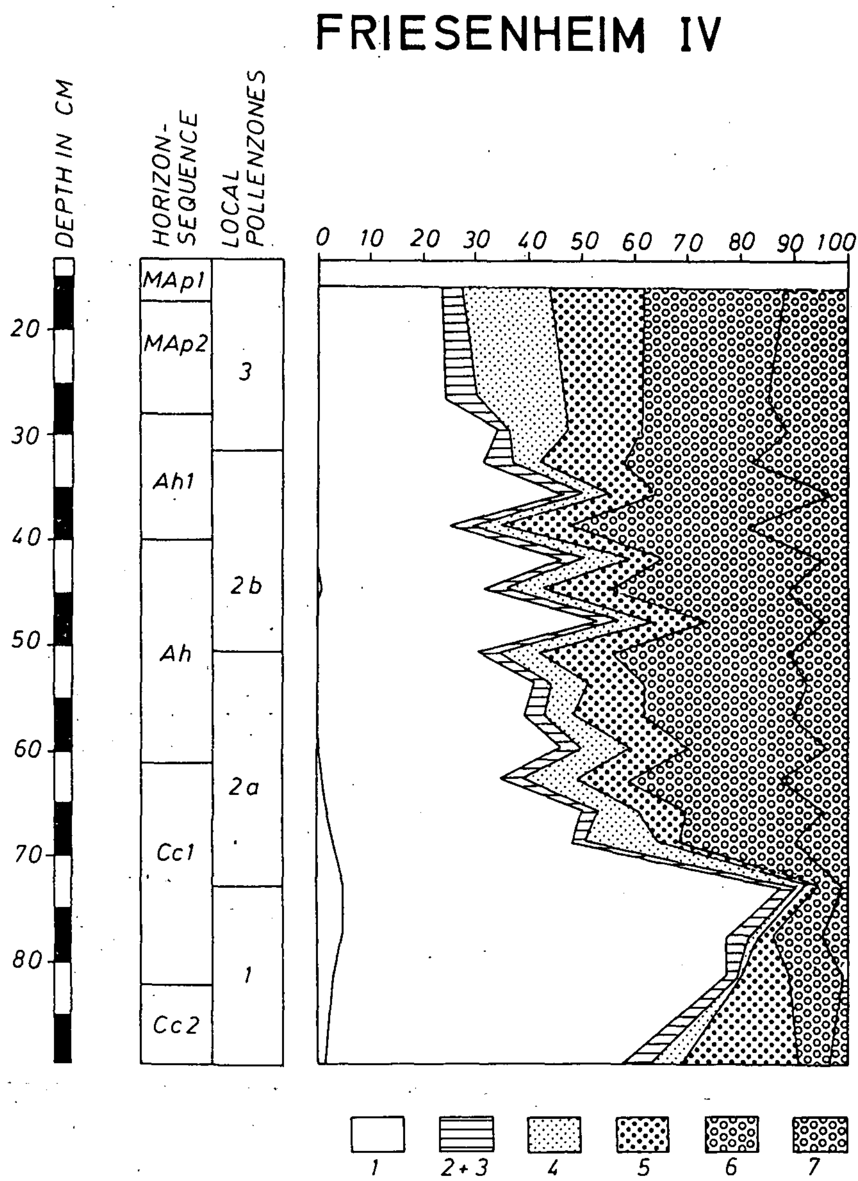

Fig. 5: Pollen diagram FRIESENHEIM IV

be found. The physical conditions of the Ap2 were bad at the moment of sampling. The volume of water held with 4.2 pF is high, and available water storage is only 113 mm in the upper meter. Air supply may be low in the moist soil (Tab. 2).

In spite of the changing smectite contents, CEC is uniformly high (about 300 meq/kg) due to the interaction of humus, with the exception of the Cc2 adsorbing 372 meq/kg. The Ca/Mg ratio of the exchangeable cations increases from 3.2 at the surface to 1.8 in the Ah2 horizon. It is 0.9 in the Cc1 and 0.5 in the Cc2, reflecting the chemical environment of the tertiary sea. Correspondingly, Na is 1 meq/kg at the surface, increasing to 8 meq/kg in the Cc. K, however, decreases with depth, reflecting some fertilising (Tab. 3).

Another effect of fertilization is the high CAL soluble P_2O_5 (780 mg/kg) and K_2O (960 mg/kg) in the Ap what is out of economic range (Tab. 4).

Fe contents (Tab. 4) point to stratification more than to weathering effects. A certain local iron concentration is visible by microscopy.

The whole profile contains carbonates. Accumulation is remarkable in the Ah horizons, but is not distinguible in the Cc horizons due to the striking masses of powder-like carbonate (Tab. 5).

POLLEN ANALYSIS:

At this site samples of two parallel profiles were taken (Friesenheim I and IV; Fig. 4 and 5).

The diagram IV shows signs of pollen destruction (high amount of indeterminatae and unbalanced curves in the pollen zone 2b). Both diagrams are in the Ah-horizon characterized by a plant association richer in NAP than the underlying C. The differentiation between Ah and the overlying colluvium is in Friesenheim IV expressed by ascending curves of cultural elements and grasses (mainly cereals) and in Friesenheim I by the increase of Pinus.

5. SUMMARY

Soil investigation in Rheinhessen is mainly focused to problems of soil history as the dominant soils of the region are dark relict soils which have been formed during early Holocene under a probably ustic moisture regime (steppe). Predominance of steppe and cultural plants is prooved by pollen analysis.

These prevailing relict soils are RHEINTAL-TSCHERNOSEMS (German system), CALCARIC PHAEOZEMS (FAO), or VERMUSTOLLS (US TAXONOMY) resp. They have mainly formed from wuerm loess, but there are soils of tertiary marls, too, with a certain tendency to VERTISOLS and easily affected by hydromorphy, which may be named SMONICA in the German system.

Under agriculture, soil redistribution is strong and numerous soil profiles are partly eroded or covered by colluvium.

Physical conditions are good in the soils formed from loess, whereas on the tertiary sediments, some problems may occur. Carbonate contents are high, K is at a medium level, and P may be insufficient under natural conditions.

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Tab. 1: Grain Size Distribution

hor.	depth	sand			silt			clay
	cm	c	m	f	c	m	f	
WALLERTHEIM								
Ap	0- 30	0.5	1.7	6.2	35.2	19.8	9.6	27.0
Ah	30- 50	0.3	1.3	5.8	32.0	23.0	8.2	29.4
AhCc	50- 80	0.2	1.9	5.5	28.9	23.7	8.4	31.4
lC	80-150	0.4	5.4	10.6	34.0	25.4	7.0	17.2
FRIESENHEIM III								
Ap1	0- 17	0.7	1.9	3.2	29.4	31.3	12.2	21.3
Ap2	17- 30	0.6	2.2	3.1	29.2	24.4	14.0	26.5
Ah	30- 40	0.7	1.1	2.1	29.0	21.0	7.6	38.5
AhCc	40- 55	0.7	0.6	2.6	29.6	24.0	10.4	32.1
lCc1	55- 80	0.2	0.6	3.4	33.2	25.4	8.1	29.1
lCc2	80-105	0.0	0.2	2.0	38.8	29.0	7.2	22.8
FRIESENHEIM IV								
MAp1	0- 15	0.6	1.7	3.1	23.4	28.4	18.0	24.8
MAp2	15- 27	0.5	1.9	3.5	24.6	32.2	16.6	20.7
Ah1	27- 40	0.2	0.6	2.0	18.8	14.3	8.1	56.0
Ah2	40- 60	0.3	0.7	2.0	18.6	15.4	8.4	54.6
Cc1	60- 82	0.1	0.3	1.8	20.5	15.8	9.6	51.9
Cc2	82- 95	0.0	0.1	0.6	1.5	10.0	14.8	73.0

Tab. 2: Soil Physics

hor.	bulk dens. g/cm^3	total PV %	water content (Vol. %) at pF -1.8	-2.5	-4.2	>4.2	kf cm/d
WALLERTHEIM							
Ap	1.64	48.3	11.9	7.5	16.8	12.1	48
Ah	1.20	61.5	20.7	10.3	21.2	9.3	388
AhCc	1.33	55.5	16.5	10.9	20.3	7.8	82
lC	1.38	55.5	11.9	12.4	22.4	8.8	224

hor.	bulk dens. g/cm³	total PV %	water content (Vol. %) at pF - 1.8	-2.5	-4.2	>4.2	kf cm d
FRIESENHEIM III							
Ap1	1.40	50.3	13.7	4.2	6.0	26.4	334
Ap2	1.46	48.4	8.0	4.0	14.2	22.2	268
Ah	1.36	50.7	12.6	4.3	15.3	18.5	313
AhCc	1.40	50.3	11.5	4.8	13.7	20.3	136
lCc1	1.48	48.0	9.5	6.6	18.1	13.8	22
lCc2	1.47	50.7	12.5	8.0	18.8	11.4	96
FRIESENHEIM IV							
MAp1	1.23	56.7	20.2	1.7	13.3	21.5	1170
MAp2	1.55	43.4	2.3	1.5	12.2	27.4	5
Ah1	1.47	46.8	7.0	3.0	1.2	35.6	233
Ah2	1.47	46.5	7.0	3.1	12.1	24.3	233
Cc1	1.59	42.1	5.1	2.4	7.3	27.3	175
Cc2	1.58	42.5	0.4	1.6	8.1	32.4	3

Tab. 3: Soil Chemistry 1

hor.	CEC meq/kg P	exchang. cations meq/kg Ca	Mg	K	Na	pH H_2O	$CaCl_2$	carbonate %
WALLERTHEIM								
Ap	163.3	127.7	25.9	9.4	0.3	8.60	7.82	11.3
Ah	169.4	142.2	23.0	3.6	0.6	8.80	7.96	21.3
AhCc	139.1	107.1	28.5	1.5	2.0	8.55	7.92	23.6
lC	121.3	72.0	44.3	1.5	3.5	8.60	7.90	22.1
FRIESENHEIM III								
Ap1	254.5	212.8	25.3	14.2	2.2	8.30	7.64	4.1
Ap2	256.4	208.0	26.1	20.5	1.8	8.40	7.65	4.4
Ah	268.8	237.3	26.0	4.0	1.5	8.61	7.85	13.5
AhCc	237.5	210.6	23.6	2.0	1.3	8.71	7.92	21.0
lCc1	193.2	165.6	25.3	1.5	0.8	8.76	7.95	28.4
lCc2	149.0	111.9	35.2	1.1	0.8	8.72	7.98	29.9

hor.	CEC meq/kg P	exchang. cations meq/kg Ca	Mg	K	Na	pH H_2O	$CaCl_2$	car-bo-nate %
FRIESENHEIM IV								
MAp1	299.8	196.0	61.2	41.6	1.0	8.42	7.71	5.2
MAp2	296.0	185.9	69.0	38.9	2.2	8.54	7.75	5.2
Ah1	312.3	200.9	83.2	24.9	3.3	8.72	7.91	10.0
Ah2	315.6	190.2	106.3	15.4	3.7	8.71	7.92	8.6
Cc1	287.4	128.2	143.7	11.6	3.9	8.71	8.05	25.6
Cc2	372.1	114.1	246.6	3.5	7.9	8.59	8.12	23.2

Rem.: V = 100%, exchang.H and Al = 0, CEC p = CEC a at all samples

Tab. 4: Soil Chemistry 2

hor.	$C_{org.}$ %	N_t mg/g	C/N	Fe_d mg/g	Fe_o mg/g	Mn_o mg/g	K_{CAL} mg/kg	P_{CAL} mg/kg
WALLERTHEIM								
Ap	1.14	1.70	6.7	8.91	0.63	443	200	41
Ah	0.61	0.85	7.1	8.99	0.49	370	25	12
AhCc	0.33	-	-	8.90	0.46	220	0	7
lC	0.18	-	-	9.64	0.47	289	10	0
FRIESENHEIM III								
Ap1	1.48	1.97	7.5	10.41	0.89	577	235	114
Ap2	1.49	1.91	7.8	10.16	0.99	506	300	95
Ah	0.92	1.19	7.7	11.03	1.15	390	30	0
AhCc	0.69	0.91	7.6	10.41	0.68	338	10	0
lCc1	0.51	0.69	7.4	9.78	0.63	233	10	0
lCc2	0.28	0.33	8.5	8.30	0.54	204	0	0
FRIESENHEIM IV								
MAp1	1.47	1.90	7.7	11.17	1.53	577	835	379
MAp2	1.38	1.74	7.9	11.38	1.43	545	740	299
Ah1	0.72	1.03	7.0	11.52	1.15	452	388	33
Ah2	0.79	0.98	8.1	11.59	1.07	425	125	0
Cc1	0.49	0.65	7.5	13.15	0.82	306	30	0
Cc2	0.25	0.42	6.0	20.72	1.13	342	48	0

Tab. 5: Some micromorphological values of the FRIESENHEIM profiles

depth cm	fabric l/d	meso-struct.	biog. pores	cracks	carbo-nate grains >10 um	organic remnants	colloids earthy
FRIESENHEIM III							
1- 4	l,ll	K,B,(S)	4	2	3	3	3
14-20	l,d	S,K,L	4,3	2-3	2-3	2	3
31-40	d,l	S,K,L,B,P	3-4	3	2,4	2	3,2
47-51	d(l)	S,L,(B,K,P)	3-4	3-4	4	2	1(2)
64-68	d(l)	L,S,(B)	3-4	3	4	1-2	1-2
82-86	l(d)	B,L,(S)	4	2	4	1-2	1-2
FRIESENHEIM IV							
1- 4	ll	B,fS-fK	undiscernible		2	3	2,3
18-22	ll(d)	S,K,(B)	undiscernible		2-3	2-3	2,3
30-34	l	K,S,(P)	4	2-3	3	2-3	2,3
48-52	l,d	L,S,B,(P)	3	2	3	2	2,3
83-87	d	C,L,(P)	3	0	4	0	1-2

VALUES: 0 absent, 1 very few or very weak to 4 very many or very intensive, after comma: in other parts, in brackets: in some places; ll very loose, l loose, ld medium, d compact, dd very compact; K crumbly, B spongy, L with channels, P patchic, S subpolyhedric, C coherent mesostructure, f fine

depth cm	colloids loamy	with humus grains	with fine lime	special features: lime ac-cumulat.	oriented clay: patches	oriented clay: flat	chan+	Fe,Mn accumul.
FRIESENHEIM III								
1- 4	3,4	3	1	2	2	2	0	0
14-20	3	3,2	1	1-2	1	1	1	0
31-40	3(1)	1,3(4)	1,3	2	0	0	1	0
47-51	1	1(3)	4(2)	2-3	0	0	0	0
64-68	1	2	4	3	0	0	0	0
82-86	1-2	2	4	3	1	0	0	1

depth cm	colloids loamy	with humus grains	with fine lime	special features lime accumulat.	oriented clay patches	flat	chan+	Fe,Mn accumul.
FRIESENHEIM IV								
1- 4	3(4)	3,4	0,2	2 all	2	0	0	2-3 all
18-22	3(4)	3,4	0(2)	2	2	1	0	2 all
30-34	4(2)	3(2)	1(4)	3	3	1	1-2	2-3
48-52	4,2	3,2	2,4	3	3	2	1	2-3
83-87	1(4)	1(3)	4(1)	undist.	0(3)	0	0++	3

COMMENTS: + cutans in conduction channels, ++ in places 4 all,
all allochthoneous, or at least redistributed

Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 53 - 56, 1986

Datas of the agriculture in the administration district Mainz-Bingen and Rhein-Hunsrück

by

F. Hoffmann and K. Knoll

District Mainz-Bingen:

1. Natural conditions

average precipitation	529 - 555 mm
average temperature	9,3 - 10,0^{0} C
hight above zero	100 - 250 m

2. Size of farms

	1971	1983
0- 5 ha	4.058	3.221
5-10 ha	1.026	685
10-20 ha	918	645
20-30 ha	292	258
30-50 ha	-	140
more than 50 ha	-	49

3. Soil use 1983

total size of soil under cultivation		34.098 ha
pastures		979 ha = 2,9%
vineyards		10.898 ha = 32,0%
fruit-culture		2.700 ha = 7,9%
plowed land		19.351 ha = 56,8%
grain	15.041 ha = 77,7%	
sugar beets	2.892 ha = 14,9%	
winter colza	280 ha = 1,5%	
potatoes	296 ha = 1,5%	
fodder plants	864 ha = 4,4%	

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4. Live stock 1983

horned cattle	2.876 pieces in 187 farms
dairy cows	780 pieces in 121 farms
fattened pigs	10.293 pieces in 921 farms
breeding sows	1.573 pieces in 135 farms
hens	25.724 peices in 650 farms

Facts of a sample farm

Owner: Landwirtschaftsmeister Dieter Schilling, Wörrstädterstr. 5, 6509 Undenheim

Situation:

hight above zero	150 - 180 m
average precipitation	540 mm
average precipitation April-September	305 mm
average temperature	9,3° C
soils	loess (rendzina, chernozem), clayey marl

Size of farm:

plowed land	17,5 ha
vineyards	3,5 ha
total	21,0 ha

Live stock:

breeding sows	22 pieces
fattened pigs	350 pieces

Soil use:

1. Plowed land:	sugar beets	54, ha = 30,9%
	winter wheat	6,7 ha = 38,3%
	durum wheat	2,0 ha = 11,4%
	winter barley	3,4 ha = 19,4%

2. Vineyards: species Huxelrebe, Bacchus, Optima, Ortega, Kerner, Scheurebe (each 0,58 ha)

delivery of grapes on Winzergenossenschaft Nierstein (mutual association)

Labour force:

farmer himself	1,0
wife	0,2
father	0,8

District Rhein-Hunsrück

1. Natural conditions

Precipitation: 600 - 700 mm per year

Temperature: Ø 7,5 - 8,5° C

Soil Types: Argillite, Pseudogley - brown soil

2. Size of farms

	Total number of farms	10-20 ha	20-30 ha	30-50 ha	more than 50 ha
1949	9.261	486	-	-	-
1960	7.513	995	-	-	-
1971	5.039	1.215	261	60	7
1983	3.006	631	246	215	103

3. Types of soil use 1983

Total size of soil under cultivation: 38.018 ha

individual distribution:

pastures: 12.302 ha

soil under the plow: 25.348 ha

individual distribution:

winter wheat	6.588 ha
rye	289 ha
winter barley	3.819 ha
summer barley	6.684 ha
oats	3.717 ha

total area of grain production 21.097 ha = 83%

Leguminous plants	13 ha
winter colza	1.516 ha
maize for silo storage	695 ha
clover fields	955 ha
fodder beets	630 ha
other	442

4. Keeping of cattle 1983

Dairy cows: 13.992 pieces in 1.371 farms

Dairy cows - pieces:

945 farms up to 10 cows

364 " between 11 - 29 cows

60 " " 30 - 90 cows

In 1984 great change as a result of limitations imposed by the Government and the commun market.

Trends in cow keeping

Year	1950	1960	1970	1983
Number of animals	21.500	21.600	18.500	14.000

Number of pigs in 1982

fattened pigs: 37.000 pieces in 1.800 farms
breeding sows: 2.800 " in 280 farms

A sample farm: facts and figures

Owner: Landwirtschaftsmeister Edwin Rheingans, 6542 Rheinböllen, Uhlenbergerhof

Situation:

Hight above zero:	430 m	Soil type:	sandy loam, Pseudogley brown soil
average Precipitation	660 mm Ø		
average temperature	8,1^{0} C	Soil category:	30 - 45
plots	35	Distance farm-field:	Ø 3,0 km
size of plots on an average	2,3 ha		

Size of farm	owned	under lease	total	Soil use	
Plowed land	11 ha	17 ha	28 ha	Grain	26 ha
Pastures	20 ha	44 ha	64 ha	Grass	2 ha
total area used	31 ha	61 ha	92 ha	Pasture	64 ha

Live stock

Dairy cows	85 pieces
Pregnant cows	25 "
Females	53 "
Breeding bulls	2 "

Amount of milk

1984: 4.933 kg milk, 3,99% fat = 197 kg
Protein: 3,53% = 174 kg
Valve of concentrated feed per cow and year: 825,-- DM
Price fetched for milk DM 0,70/kg

Fertilizer used: 550 DM per hectare
Purchasing worth of technical equipment: 340.000,-- DM
" " " " " per hectare: 3.695,-- DM
Leasing fees per hectare Ø: 150,-- DM

Labour force

farmer himself 1,0 wife 0,6 father 0,0 apprentice 0,5

Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 57 - 63, 1986

Middle Rhine area geology

by

H.G. Mittmeyer[+]

The rockground of the Middle Rhine area consists mainly of Lower Devonian marine strata. Predevonian rocks are not yet evidenced nearby the Rhine canyon.

Upper Emsian	Kondel	dark slate
	Hohenrhein, Laubach	sandstone, sandy slate
	Emsquarzit	white quartzite
Lower Emsian	Singhofen, Vallendar	slate/quartzite
	Hunsrückschiefer	black slate
Siegenian	Siegener Schichten (northern area) or	sandy slate, quartzite
	Taunusquarzit (southern area)	white quartzite
Gedinnian	Bunte Schiefer	red or green slate

Table 1: Lower Devonian stratigraphy in the Middle Rhine area (Lower Devonian = 400 - 380 mill. years ago)

Occurrences of the areas oldest sediments, the Bunte Schiefer (Upper Gedinnian), are restricted to the central parts of the Soonwald anticline in the south (fig. 1 and 2). Probably the sequences of colored slates without marine fauna are of not marine origin.

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The overlying white quartzites represent the Siegenian stage in the southern area (Soonwald and Katzenelnbogen anticlines). Facies and great thickness of the quartzites are very good to oversee in the big quarry nearby Trechtingshausen in the Rhine valley.

In the Wisper syncline and the central area (Bornhofen - Mosel trough) the Siegenian is developed mainly in black slate facies. Northwestwards of the central trough area the Siegenian outcrops in the typic sandy Siegen facies.

In the Siegenian the begin of a facies differentiation into sandy swells and argillaceous troughs indicates early tectonic movements.

Hunsrückschiefer (Lower Emsian), a monotonous slate sequence, fills up the Wisper trough (impressive outcrops in the Rhine valley around Kaub) and the central area (Bornhofen, Neuwied). The thickness of the slates exceeds 3000 meters in the trough centers. Thin sandy Hunsrückschiefer equivalents are overlying the Siegenian in the swells sporadically. In the uppermost Hunsrückschiefer the volcanic activity begins with keratophyr tuffs (Porphyroidtuffite).

During the younger Lower Emsian thick monotonous sequences of slates and quartzites have been sedimentated in the troughs. The thickness of the whole Lower Emsian is about 8000 meters in the trough centers.

In the upper Emsian the central area has been separated into the Lahn trough and the Mosel trough by lifting of the Salzig swell. Since the Emsquarzit time the facies of the two trough areas are different (in the Lahn trough reduced conodont slates, in the Mosel trough thick sequences of typic rhenish sandstones and slates). In the southernmost situated Stromberg syncline the Upper Emsian is incomplete and reduced.

Middle Devonian sediments are restricted on the reef limestone complex of Stromberg and some smaller occurrences of slates and diabase tuffs in the southern Stromberg area and in the phyllites (fig. 1). Furthermore Upper Devonian slates have been evidenced in the same area.

In the Upper Devonian and the Lower Carboniferous the Middle Rhine area has been folded and faulted strongly by continuing plate movements. Intensive compression changed the swells and troughs into anticlines and synclines. Generally the southern flanks of the troughs (synclines) are missing by subduction completely, correspondingly the northern flanks of the swells (anticlines) (fig. 2).

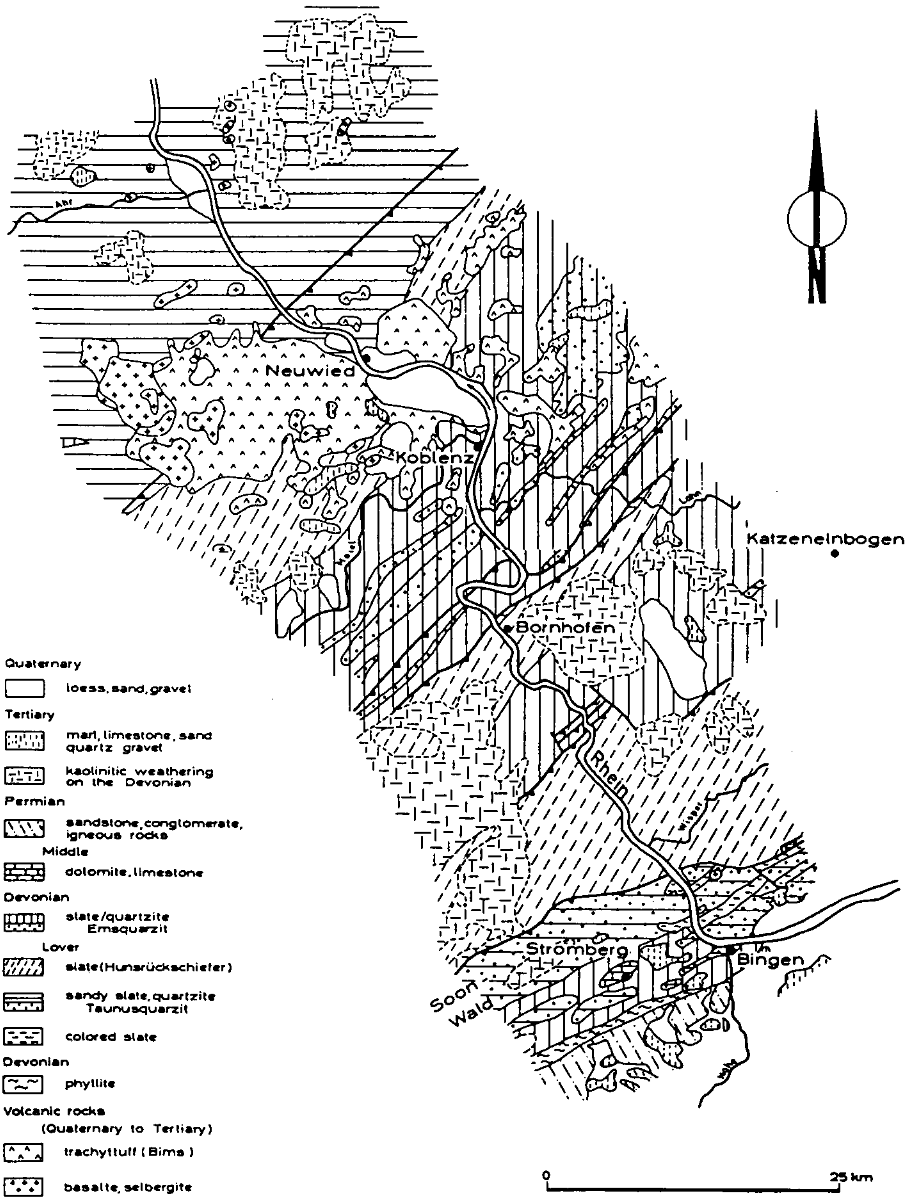

Fig. 1: Geology of the Middle Rhine area

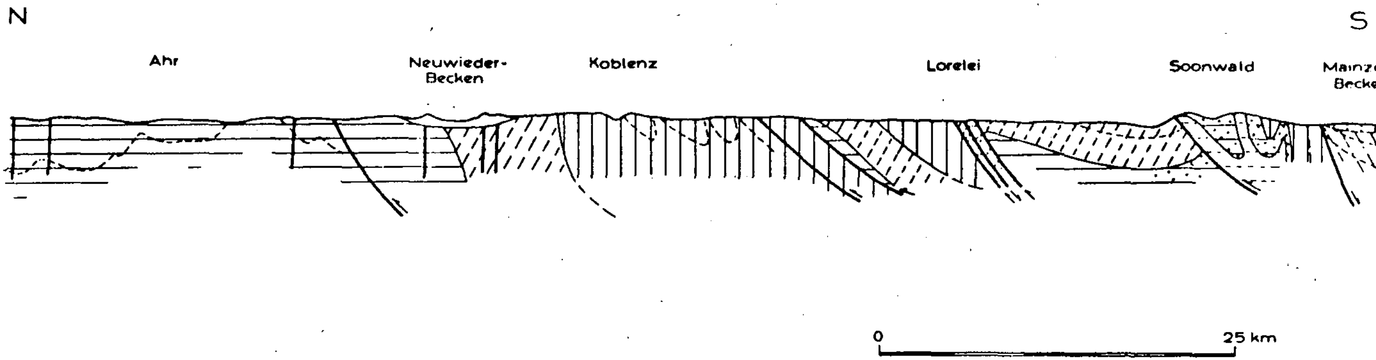

Fig. 2: Cross section through the Middle Rhine area

		Mainzer Becken	Neuwieder Becken	Volcanism
Quarternary	Pleistocene	Niederterrasse Mittelterrasse Hauptterrasse		Trachyttuff (Bims) Basalt Selbergit Basalt
	Pliocene	Sande u. Schotter Bohnerzton		
Tertiary	Miocene	Dinotheriensande Hydrobien Sch. Corbicula Sch. Cerithien Sch.	Knubbsand	Basalt u. Trachyttuff
	Oligocene	Süßwasser Sch. Cyrenenmergel Schleichsand Rupelton Pechelbronner Sch.	Blauton Maifeld Sch.	
	Eocene	Eozäner Basiston	Braunkohlenton Vallendar Schotter	Basalt

Table 2: Tertiary and Quaternary stratigraphy in the Middle Rhine area

Some diabase dikes are mostly of Middle to Upper Devonian age. During Upper Carboniferous the area has been lifted up to a mountinous country after folding.
In the Permian the erosion transformed the area to a peneplain, whereas sedimentation displaced into the Saar Nahe trough. The Saar Nahe trough has been filled up by Permian sandstones, conglomgerates and volcanic materials. Lateron, in the Mesozoic era, only erosion and deep weathering took place in the area.

In the Tertiary tectonic movements initiated a basaltic eruption activity especially around the sinking Neuwieder Becken and the Westerwald basalt area. The Neuwieder Becken was a lake, filled up by fresh water sediments, with a short time marine Lower Oligocene intermezzo comming from the Mainzer Becken. The Mainzer Becken has a Eocene to Pliocene sequence of marls, limestones and sands, in the Oligocene and Miocene partly of marine origin.

In the mountain area the intensive weathering of the Mesozoic continued with a short time interruption by the Oligocene transgression. White and red colored kaolinite soil relicts are preservated on the mountain peneplain, especially on the Hunsrückschiefer of the Hunsrück.

During Tertiary the river Rhine in the todays importance was not yet existent. The main drainage of the area was the old Tertiary Mosel, flowing into the Tethis of the Oberrhein sea. With the breach through the Soonwald in the old Pleistocene the river Rhine has been originated.

Since Quarternary a bloc tectonic brought more or less lifting of the units, marked impressively in the varying altitude of the Pleistocene terraces in the river canyon. In the Pleistocene sand, gravel and loess have been accumulated on the terraces. Around the Neuwieder Becken and the Westerwald area a intensive basalt, selbergite and trachyte (Bimstuff) magmatism took place. The old mountain peneplain has been destroyed partly by intensive erosion.

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Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 64 - 75 , 1986

Soils with thick laminated argillic horizons on Oligocene gravelly deposits at Rümmelsheim

von

H. Wiechmann, C. Backhaus and P. Braun+

Near the village of Rümmelsheim in the transition area of the Rhenish Slate Mountains and the Hessisches Plateau and Hill Country we found soils with a marked clay illuviation different from other soils with clay translocation in this region.
Especially striking is the more than 10 meters thick zone with laminated clay illuviation and the reddish colour of the illuviated material. Investigations should answer the question, wether there is a relationship to relict soils with more or less strong desilification and kaolinization in the neighbouring Rhenish Slate Mountains or in the tertiary Plateau and Hill Country.

Geology

In several pits sands and gravels of the "Lower Marine Sands" are excavated. These sediments belong stratigraphically to the lower middle Oligocene. Sediments from the Oligocene sea show drastic facial differences. While sedimentation of clays (Rupelton) and sandy marls (Schleichsand) took place in the inner sea basin, at the south rim of the Rhenish Slate Mountains sands and gravels formed beach deposits. These sediments contain mainly quartz and quarzite from the surrounding rocks (Falke, 1960). In the visited pits tilted sands and gravels are overlying by more flat layered similar sediments and marls in small basins or channels. All these deposits belong to the "Lower Marine Sands" from the lower middle Oligocene. The recent position war reached by tectonical uplift of the Rhenish Slate Montains at the late tertiary and the early Pleistocene. On the surface we find a gravelly solifluction and a loess cover, at which the latter is mainly removed by erosion.

Climate

Rümmelsheim is situated at the border of a small dry area (lower Nahe region)

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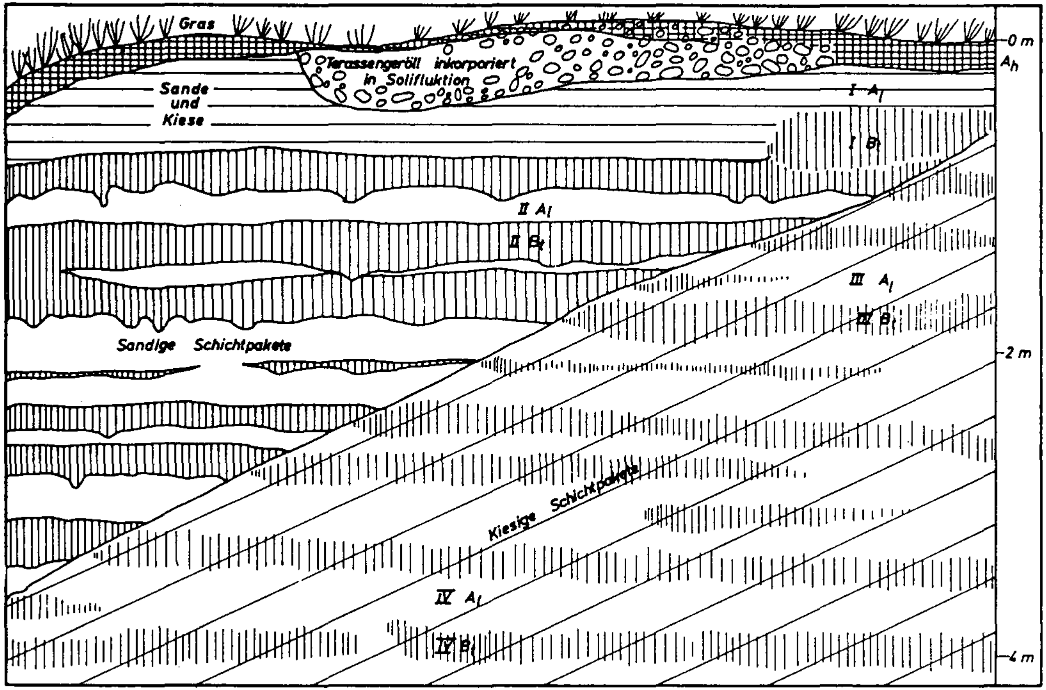
Rümmelsheim 1



Scheme of the Rümmelsheim soil profile

Cross layered marine sandy and gravelly sediments with pedogenetic clay illuviation with a some more continental climate with mild winters and warm summer (>9^{0} C average annual temperature, ~550 mm annual precipitation). Despite high summer rainfall this is a relative warm and dry part of Germany.

Soils

Three examples of several investigated soils which show the introductory mentioned characteristics very clearly were selected for this paper.

Rümmelsheim 1 (Rü 1)

Location: Rümmelsheim, gravel pit at the road to Waldalgesheim
topographic map 1:25 000: 6013 Bingen
r: 34.1740, h: 55.3455
S-slope, 8-12^{0} inclination

Elevation: 370 m

Land use: vine yard

Soil type: basenreiche, stark durchschlämmte Bänderparabraunerde (FRG), arenic (typic) Hapludalf (Soil Taxonomy), brunic (orthic) Luvisol (FAO/UNESCO).

ApR 0- 20 cm	Remnant of a deep cultivated horizon. Shortened and distrubed by gravel pit operation (not investigated).
Al 20- 70 cm	7.5 YR 5/4 (gray brown), weakly coherent, loose, well rooted.
Bt 70-120 cm	5 YR 4/8 (reddish brown), coherent, moderate rooted, clearly visible clay illuviation.
BvBt 120-200 cm	5 YR 5/8 (reddish brown), weakly coherent, clay illuviation clearly visible but much less than Bt. Beginning of lamination.

Lamination zone

200-225 cm (gravelly)

Al	10 YR 7/3 (gray yellowish orange), weakly coherent
Bbt	5 YR 4/6 (reddish brown), coherent

200-225 cm (sandy)

Al	10 YR 7/4 (gray yellowish orange), weakly coherent
Bbt	2.5 YR 4/6 (reddish brown), coherent

400-435 cm

Al	10 YR 7/3 (gray yellowish orange), weakly coherent
Bbt	5 YR 4/8 (reddish brown), coherent

depth cm	horiz.	skeleton >2 mm (%)	grain size distribution (%) 2-0.6	-0.2	-0.06	-0.02	-0.006	-0.002	< 2 µ
20- 70	Al	83	23.6	11.9	18.7	9.6	13.3	10.2	12.9
70-120	Bt	80	22.5	10.8	23.0	3.4	1.4	5.2	33.9
120-200	BvBt	73	26.6	18.2	23.1	2.0	2.8	4.3	23.3
200-213	Al	71	9.9	18.2	64.2	1.3	1.1	3.9	1.6
213-225	Bbt	65	12.1	24.0	44.3	1.2	2.5	4.2	11.8
200-213	Al	2	2.1	31.9	53.9	6.3	0.9	3.5	1.6
213-225	Bbt	6	2.8	17.6	55.5	4.8	1.5	3.3	14.6
400-420	Al	64	21.1	22.4	43.7	3.6	1.6	4.4	3.3
420-435	Bbt	69	8.2	21.0	48.0	1.6	2.2	3.8	15.4

depth cm	pH $CaCl_2$	Fe_d ‰	Mn_d ‰	Al_d ‰	EC meq/100g clay	SiO_2 % (clay fract.)
- 70	6.63	17.25	0.23	1.12	38.5	33.9
-120	4.70	23.88	0.06	2.14	43.0	32.9
-200	5.80	15.80	0.07	1.29	57.0	34.0
-213	6.58	0.58	0.02	0.15	47.3	40.4
-225	6.54	8.31	0.05	0.58	43.0	30.5
-213	6.48	0.74	0.02	0.10	30.4	40.6
-225	6.47	7.00	0.05	0.74	50.0	34.1
-420	6.43	1.56	0.02	0.17	48.5	41.0
-435	6.70	5.76	0.05	0.70	69.0	35.8

Rümmelsheim 2 (Rü 2)

Location: Rümmelsheim, gravel pit (south west rim)
topogr. map 1:25 000: 6013 Bingen
r: 34.1630, h: 55.3370
NNW-slope, 6-15^{o} inclination

Elevation: 350 m

Land use: devastated vine yard

Soil type: basenarme, stark durchschlämmte (Bänder-) Parabraunerde (FRG), arenic (typic) Hapludalf (Soil Tax.), brunic (orthic) Luvisol (FAO-UNESCO).

ApR 0- 35 cm	10 YR 3/4 (dark brown), loose, well rooted. Remnant of a deep cultivated horizon shortened by cultivation and erosion.
Al 35-105 cm	7,5 YR 4/6 (brown), loose-coherent, well rooted, separate spots with reddish brown clay illuviation. Irregular transition to
Bt_1 105-155 cm	5 YR 5/8 (reddish brown), coherent, clearly visible but irregular clay illuviation. Smooth transition to
Bt_2 155-260 cm	5 YR 5/8 (reddish brown), like Bt_1, but less marked. Smooth transition to
Bt_3 260-360 cm	5 YR 5/7 (reddish brown), like Bt_2 but less marked. Smooth transition to
BvBt 360-460 cm	7,5 YR 6/7 (strong orange brown), loose-coherent, transition to laminated clay illuviation.
Lamination zone	
~550 cm	
Al	10 YR 7/2 (light yellow brownish gray)
Bbt	5 YR 5/8 (reddish brown)
1100 cm	
Al	10 YR 7/2 (light yellow brownish gray)
Bbt	5 YR 5/8 (reddish brown)

Rümmelsheim 3 (Rü 3)

The profile is situated 75 m south-east Rü 2. General datas like Rü 2.

Soil type: basenreiche, stark durchschlämmte Parabraunerde (FRG), typic Hapludalf (Soil Tax.), brunic Luvisol) FAO/UNESCO)

AlBt(R) 0- 30 cm	Deep cultivated surface horizon with high loess content. Shortened and disturbed by pit management (not investigated).
Bt_1 30- 60 cm	10 YR 3-4/4 (dark brown-brown), coherent, well rooted, single visible clay cutans. Smooth transition to
Bt_2 60- 75 cm	7,5 YR 4/6 (brown), weakly rooted, polyhedrous, many clay cutans. Smooth transition to

depth cm	horiz.	skeleton >2 mm (%)	grain size distribution (%) 2-0.6	-0.2	-0.06	-0.02	-0.006	-0.002	< 2 µ
0- 35	ApR	56	18.0	10.0	14.1	23.2	15.0	7.7	12.0
35-105	Al	78	31.9	12.6	18.7	13.4	5.1	4.9	13.4
105-155	Bt_1	79	3.8	14.0	36.7	8.2	4.1	3.7	29.5
155-260	Bt_2	63	5.0	18.5	32.7	7.6	3.6	3.6	29.1
260-360	Bt_3	72	9.4	41.4	20.0	5.1	2.6	2.5	19.0
360-460	BvBt	75	21.6	20.8	23.5	7.5	3.9	3.8	18.9
~550	Al	50	30.3	38.0	18.8	6.3	1.5	2.7	2.4
	Bbt	48	26.8	34.0	14.5	4.0	1.6	2.1	17.0
~1100	Al	57	30.5	39.1	21.0	5.2	2.1	1.2	0.9
	Bbt	56	31.8	34.0	14.4	5.1	2.1	2.3	10.3

depth cm	pH $CaCl_2$	$CaCO_3$ %	C_t %	Fe_d ‰	Mn_d ‰	Al_d ‰	EC meq/100 g clay
- 35	7.13	0.2	0.76	7.48	0.26	0.79	45.7
-105	5.46		0.17	8.45	0.08	0.79	35.8
-155	3.76		0.15	14.30	0.07	1.46	39.3
-260	3.59			13.30	0.07	1.39	40.8
-360	3.75			9.50	0.04	0.89	33.2
-460	4.40			6.30	0.04	0.49	36.4
~550	5.63			1.11	0.03	0.44	
	3.62			7.08	0.04	1.18	27.6
~1100	6.65			0.45	0.02	0.33	
	4.11			4.45	0.04	0.79	34.0

Bt_3 75-110 cm — 5 YR 4/8 (reddish brown), strong developed polyhedrons and prisms, moderately dense, many thick clay cutans. Abrupt change to

II(BV)Cv 110-175 cm — 10 YR 4/6 (brown), coherent-weakly polyhedral). In the deeper layer several $CaCO_3$-concretions. Marl-deposit in a small çhannel or basin.

depth	horiz.	skeleton	grain size distribution						
cm		>2 mm (%)	2-0.6	-0.2	-0.06	-0.02	-0.006	-0.002	<2 µ
30- 60	Bt_1	40	9.2	6.5	9.6	32.6	18.0	5.7	18.4
60- 75	Bt_2	64	16.8	2.9	4.7	23.1	16.7	8.2	27.6
75-100	Bt_3	51	15.6	2.4	2.8	12.8	7.3	6.0	53.1
100-175	IIBvCv	10	11.8	9.2	6.7	26.1	16.2	7.1	22.9

depth	pH	$CaCO_3$	C_t	Fe_d	Mn_d	Al_d	EC
cm	$CaCl_2$	%	%				meq/100 g clay
- 60	7.15	0.3	0.31	7.22	0.48	0.61	51.0
- 75	6.85	-		8.90	0.20	0.70	36.2
-100	6.69	-		16.70	0.17	1.96	46.1
-175	7.94	59.3		3.58	0.14	0.17	50.7

Results and discussion

From the maximum depth of exposure of 16 m you could see that never unweathered material was reached. Laminated clay illuviation was more or less clearly visible to this depth. In some parts the reddish clay illuviation is superimposed by yellow-brown iron oxides accumulated by lateral water flow. All sediments are clearly stratificated with strong changes in stone, gravel and sand contents, while each layer may be relatively uniform. The inclination of the sediment layers is due to sedimentation and tectonic uplift.

The during pleistocene blown up loess cover was partly mixed in the surface layers and is now extensive eroded. Remainders of the loess cover could be detected in the surface horizons of the profile by enhanced clay and silt contents. The profile-morphology of the soils is marked by clay illuviation, which formed compact argillic horizons and many meters thick zones with laminated illuviation. In the illuvial horizons the structure is more coherent because of wrapping the gravels and sand grains and/or because of clay accumulation at the points of contact (wedges). Only in illuvial horizons with very high clay contents (Rü 3) we can recognize a jointing structure (polyhedrous, prisms).

The illuvial horizons are only partly related to stratification, rather the laminated accumulation is pedogenetic and it often crosses layers and different sediments (sands or gravel). It is excluded that the lamination is caused by alternate reddish brown and light brownish sediments or silicate-rich and silicate-poor layers due to changes in sedimentation. The thickness of clay bands is in accordance with observations in other laminated argillic horizons (summarized literature see Goetz, 1970).

Intensive work with micromorphology showed very strong developed clay cutans with distinct orientated double refraction.

Less clear is the question answered about the origin of clay minerals. Because of inhomogeneity and the possible shortening of the profiles a balance can't be calculated and the decision about pedogenous or lithogenous origin is impossible. While the clay content in the upper illuviated argillic horizons may be enhanced by the incorporated loess, this is improbable for the deeper horizons. A rough estimation leads to the conclusion that clay minerals are formed by weathering. Although more than 90 % of the parent material is quartz, there are enough weatherable silicates.

Compared with the tertiary relict soils as noticed in the beginning the degree of weathering is much less in the Rümmelsheim profiles. The chemical and mineralogical investigations show a dominating part of muscovite with high potassium contents in the clay fraction of lower horizons. Even the upper illuvial horizons contain still micas besides of feldspars.

From x-ray analysis, which are confirmed by the exchange capacity related to clay content, we find in all horizons mainly illites with high contents of residual potassium. The share of expanded illites and alternate bedding minerals is only slightly enhanced in the upper layers. In addition the kaolinite content is very low and there are no distinct variations with depth or between Al- and Bt-horizons.

From the slight variation of the Fe_d/clay-quotient it can be concluded, that there is a joint migration of clay and iron oxides and no relative or absolute accumulation of pedogenous iron oxides.

The age and the duration of clay illuviation can't scarcely be determined exactly. Soils with clay illuviation in laminated zones are found widespread in the northern german glaciated regions on Würmian as well as on Saalian glacial deposits (Goetz, 1970; Mückenhausen, 1976). The tertiary marine sands are decalcificated very early because of low lime contents (Rothausen and Sonne, 1985).

Quotients of Fe_d/clay contents in the Rümmelsheim profiles

horiz. Rü 1	Fe_d/clay	horiz. Rü 2	Fe_d/clay	horiz. Rü 3	Fe_d/clay
Al	1.45	ApR	0.62	Bt_1	0.39
Bt	0.70	Al	0.63	Bt_2	0.32
BvBt	0.68	Bt_1	0.48	Bt_3	0.31
		Bt_2	0.46	IIBvCv	0.16
Al	0.46	Bt_3	0.50		
Bbt	0.48	BvBt	0.23		
Al	0.36				
Bbt	0.70	Al	0.46		
Al	0.47	Al	0.50		
Bbt	0.37	Bbt	0.43		

Therefore the dispersion and migration of clay minerals could occur very early too. If there a marl with high lime content is found not very deep below the recent surface (Rü 3), this may be due to erosion. But in connection with the relict profiles (remainders of Al-horizons) it points out a not so highly intensive, younger weathering and decalcification. The high base saturation in the profiles and small lime contents in some upper horizons resulted from decalcification of the loess cover or from liming by the vine-dressers. If there was a remobilisation of illuvated immobilized clay minerals is uncertain. The laminated clay illuviation in Würmian deposits and Holocene dune sands was frequently observed but these laminations are not comparable with the Rümmelsheim profiles in respect to thickness and development. Besides the upper layers in these profiles were included in solifluction during the last ice age. From these facts, thickness of lamination zones, marked weathering of silicates and formation of 3-layer clay minerals but no kaolinitization and the solifluidal shifting, a relict character and and a Pleistocene genesis can be concluded.

Laminated argillic horizons are formed in sandy and gravelly deposits but we are lacking information about critical grain size distribution. If there are more than 20-30 % clay + silt a compact illuvial horizon may be formed (Gardner a. Whiteside, 1952). Nevertheless in many profiles we find in the upper part more or less compact illuvial horizons which are splitting up in the deeper laminated zone. This is true in Rümmelsheim too.

A definite explanation for the development of all forms of laminated argillic horizons is lacking until now. A review on the proposed formation is given by Goetz (1970). Mainly 3 mechanisms are discussed:

1. Lowering of transporting strenght of water flow in the unsaturated soil (porous discontinuities).
2. Rhythmical precipitation or flocculation of migrating clays (Folks a. Rieken, 1956).
2. Stoppage of a water leakage front by included air bubbles (Meyer a. Moshrefi, 1969).

The explanation by the first mechanisms is frequently possible in stratificated sediments especially when the bedding is parallel with the surface and clay illuviation bands are formed at grain size and/or porous inhomogeneities. The rhythmical flocculation or precipitation requires laminated changes of the soil chemistry which can't scarcely be expected and evaluated. The inclusion of horizontal air bubbles by frontal water leakage is probably impossible in these coarse porous materials with only unsaturated water flow.

An additional striking feature was the reddish colour of the illuvial horizons and the x-ray identified hematite. Because of this, the formation of hematitic iron oxides similar to relict soils in the region was taken into consideration. But the origin of the red colour may be lithogenous and/or pedogenous. It can't be excluded that the red hematitic iron oxides are remnants from eroded tertiary soils or more likely from the removal of solid red conglomerates (Rotliegendes - Lower Permian) outcropping in the surroundings. The lithogenous hematites are very stable even at changing climatic conditions, and result in a very intensive colouring. So the very deepgoing reddish colour may be explained by sediment characteristics. On the other hand there is no change in colour hue from the lower to the upper horizons. Therefore newbuild iron-oxides must have the same colour like the pedogenous or all iron-oxides are formed with the soil. But red iron oxides are not only formed in tertiary soils, they are also known in german Holocene and Pleistocene soils from glacial deposits.

Soil classifying

Following the systematic of the FRG soils with characteristic features of clay illuviation and horizons with orientated clay cutans are classified as

Parabraunerden (Para-brown earth, Lessivê, Al-Bt). A variation from the normal soil type is the Bänderparabraunerde (B<u>b</u>t = <u>b</u>anded or laminated argillic horizon) in which most of the migrated clay is accumulated in the laminated zone.

According to Soil Taxonomy all conditions for the diagnostic argillic horizon are fulfilled. The soils can be classified as Alfisols and in the suborder as Hapludalfs. Best fits the term typic Hapludalf the characteristics of Rü 3, the profiles Rü 1 and Rü 2 may be also classified as arenic Hapludalf. The term ultic Hapludalf for Rü 2 is not used because the colours are probably more lithogenous.

Agricultural use

Because of the very high skeleton content and high inclination agricultural use is rendered. If the loess cover is some decimeters thick or if the loess mixed to the solifluction mass reaches a considerable amount soils are used in this climate for viticulture. The numeral soil value is mostly lower 45. The outcrop of the Lower Marine Sands is restricted, so the importance as agricultural sites is low.

Summary

At the introducted soils near Rümmelsheim a relation to tertiary soils in the region with strong weathering and desilification was supposed, because of very strong developed argillic horizons and the reddish hue of the illuviated material.

From the investigationsthis couldn't be proved, because the weathering led only to the formation of illite and chlorite clay minerals.

The reddish hue may be due to pedogenous hematite iron oxides but lithogenous origin from the tertiary eroded soils ore more probably from removed red Lower Permian sediments (Oberrotliegendes) must be taken into account too.

The deep reaching laminated zone of clay illuviation is certainly pedogenous and typical for gravelly-sandy parent materials. Formation of argillic horizons probably occured in the interglacial periods.

The base saturation in this Hapludalfs is secondary increased by the loess cover and/or by fertilization. Amount of skeleton and depth of potential root penetration determine the agricultural value of these soils. At south exposited slopes they are used for viticulture in this climate.

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Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 76 - 99, 1986

Soil Development from Tertiary to Holocene and Hydrothermal Decomposition of Rocks in the Eastern Hunsrück Area

P. Felix-Henningsen & E. D. Spies+

1. Introduction
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1. Introduction

Since Permian till today the Rhenish Massiv predominantly was a continent. During this time the Paleozoic rocks of this region were subject to weathering and truncation. Especially the tropical climate of the Mesozoic and Lower Tertiary led to the formation of a peneplain with an extremely deep kaolinitic weathering mantle.

In consequence of tectonical uplift and climatic changes during the Upper Tertiary and predominantly the Quarternary this weathering mantle was degraded to a different extent. In V-shaped valleys of Pleistocene age as well as in the central regions of Eifel, Taunus and Sauerland, with a strong tec-

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tonical uplift, the kaolinitic weathering zone was completely removed, so that in these regions the unweathered paleozoic rocks were exposed to the recent land surface. In areas with lesser tectonical movements, as in the flat upland area of the eastern Hunsrück, more or less captured residuals of the old weathering mantle occur, which strongly influenced development and properties of the recent soils.

Beside these pedogenetic aspects of the excursion, some features of decomposition and kaolinization of Paleozoic rocks by ascending postvolcanic waters will be shown and discussed.

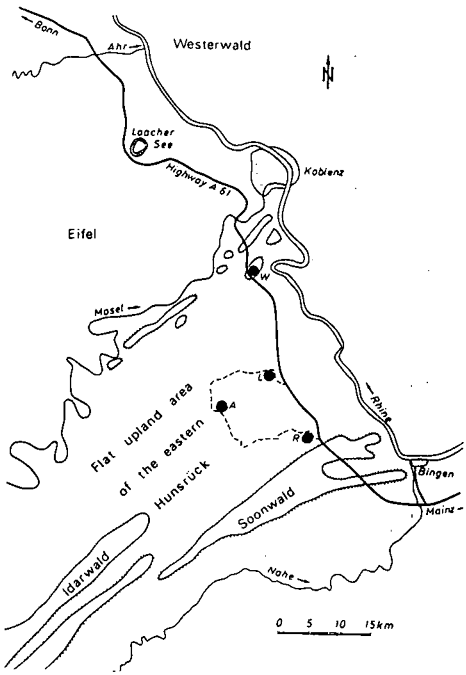

Fig. 1: Generalized map of the eastern Hunsrück area with the excursion stops (L = Lingerhahn, A = Alterkülz, R = Rheinböllen, W = Waldesch).

2. <u>General view of the geological development of the eastern Hunsrück area</u>

a) The basement rocks of Lower Devonian age, folded by Variszian orogeny, consist of non-calcareous silica rocks. Dark gray silt/clay slates are predominating besides greywakes, sandy and partly quartzitic slates and quartzites. Since Late Paléozoic these rocks were subject to continental weathering and removal. From Upper Mesozoic to Lower Tertiary, a time of relatively less tectonic movements, a peneplain with a thick weathering mantle was formed by deep and intensive chemical weathering under tropical or subtropical climate. The kaolinization of the Devonian rocks exceeded a depth of more than 50 m. In the eastern Hunsrück area relicts of this kaolinized weathering mantle are widely spread and have been early recognized by the mapping geologists as an own geological formation.

b) In the Upper Middle Oligocene a marine transgression of short duration reworked the soil zone in the upper part of the weathering mantle. The few relicts of Lower Tertiary clays, sands and gravels represent the dislocated weathering products.

c) At the end of Lower Tertiary the uplift of the Rhenish Massif began and went on during Upper Tertiary and Quarternary till today. In the eastern Hunsrück area warping and faulting connected with this uplift were relatively weak. The central part suffered a weak uparching together with flexure-like bending and less fault tectonics. The perpendicular throws of the faults are mostly far below 50 m.

d) In the Upper Tertiary the river system of Rhine and Mosel already began to develop. In sprite of increasing removal as a consequence of uplifting, the kaolinitic weathering mantle may have covered the whole eastern Hunsrück area at the end of Tertiary, because the tropical to subtropical climatic conditions lasted on to the Pliocene and caused a permanent reformation of the partly denudated weathering zone.

e) With the beginning of Pleistocene, about 1 mio. years ago, climate and morphogenesis began to change in a distinct way. The latter was considerabely intensified by the strengthened and sometimes jerking uplift of the Rhenish Massif. The eastern Hunsrück area, like the whole Rhenish Massif, was a periglacial region during ice age. The permafrost soil of the treeless tundra were subject to mechanical weathering by frost splitting. During the yearly melting periods the congelifractates were transported downhill by solifluction. That way, the big streams as Rhine and Mosel incised deeper and deeper into the basement, the tributaries forced their way onward to the watersheds of the flat upland areas. Their V-shaped valleys undercut the old weathering mantle and dissected the formerly connecting peneplain in many smaller relict plains. In the deeper incised valleys the fresh Devonian rock was exposed. On the relict plain the pre-Pleistocene soils were vastly removed by intensive erosion and denudation, and only more or less thick parts of the saprolite zone remained .

f) During the cold periods - at least during Würm glacial period - the whole area was covered by loess, which in the interglacial periods changed to loessial loam by soil formation. In the following cold period it was subject to redeposition by fluvial or solifluction processes. Therefore talus deposits mostly contain a loessial component.

g) In the late Würm glacial period, at the end of the Alleröd interstadial, the "Laacher See"-volcanoe had an extremely gasrich eruption, which was accompanied by an extrusion of pumice, up to the northern part of the eastern Hunsrück. Due to subsequent eolian drifting of the pumice during the cold Younger Tundra Period the loessial pumice dust arose, which was spread as a thin cover over the whole eastern Hunsrück area. After sedimentation of this dust layer, it was partly redistributed by solifluction. Most of the recent soils of this area contain this layer in their uppermost 20 - 40 cm.

h) With beginning Holocene the influence of the cold ice age periods ended and the now existing landscape scenery only changed little more. Bottom clays, alluvial cones and gravel layers in the valleys are the main deposits of the latest geological past. The thin loessial pumice dust layer was removed in wide areas with the beginning of agricultural using. Nowadays it occurs mainly in soils of old forest habitats.

3. Excursions Stops

3.1 Lingerhahn: Soil development in the area of the Mesozoic-Tertiary peneplain remnants

During Mesozoic and Tertiary the Lower Devonian slates weathered some 10 m deep under the influence of a subtropical to tropical climate. The slates changed to a soft kaolinitic saprolite, which preserved the undisturbed rock structure. From this saprolite a several metres thick, clay-rich and kaolinitic soil developed, with gray, red or mottled colours, according to the ground water level. Such autochthonous Tertiary fossil soils above a saprolite and covered by Tertiary and Pleistocene sediments were exposed at some locations in the Rhenish Massif (JARITZ 1966, FELIX-HENNINGSEN & WIECHMANN 1985). According to their argillaceous texture and the colour these paleosoils are designated as Red or Gray Plastosols (MÜCKENHAUSEN 1958). Morphology and properties are similar to fersiallitic or siallitic hydromorphic soils of the recent tropics (MÜCKENHAUSEN 1978). From Upper Tertiary to Lower Pleistocene this soil zone was removed by areal degradation. Below the Pleistocene superficial layers the kaolinitic saprolite follows directly.

In extended areas of the eastern Hunsrück the basal layer of Pleistocene surface strata, from which the recent soil has developed, consists of saprolite material redistributed by solifluction processes. The relict structure of the saprolite was disturbed with consequence of formation of a gray argillaceous layer, which is designated as "Gray Loam". It is contaminated with talus deposits and eolian sediments in different amounts (v. ZEZSCHWITZ 1970).

Thus, in wide areas of the Rhenish Massif morphology and properties of the recent soils are strongly influenced by relicts of the old weathering mantle. This has been discussed in several papers by MÜCKENHAUSEN. STÖHR (1967) described the "Gray Loam" of the eastern Hunsrück area.

3.1.1 The Mesozoic-Tertiary saprolite

The mineralogical and geochemical properties of the saprolite zone have been investigated on the core of a 50 m deep drilling near Lingerhahn village, which did not reach the completely unweathered slate.

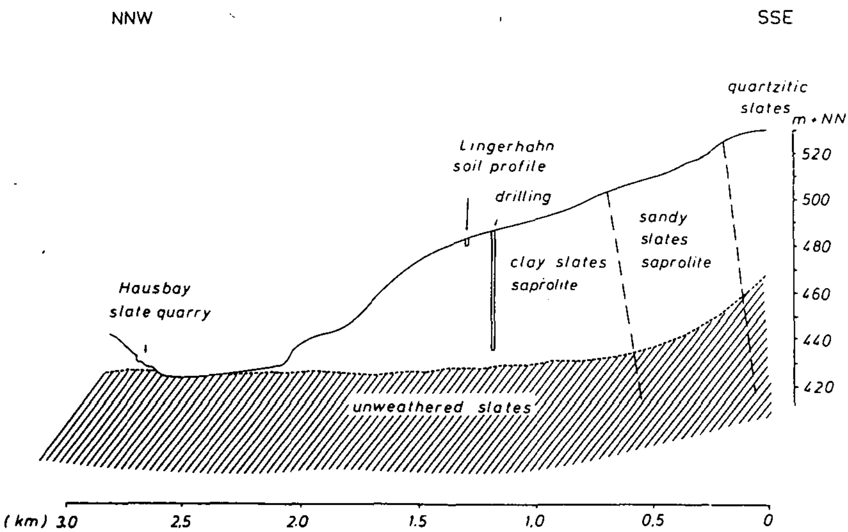

Fig. 2: Cross section of the area east of Lingerhahn village.

a) Stratigraphy and morphology:

0 - 1.30 m:

Pleistocene surface layers: Solifluction layers from destructurated, softened saprolite material (gray loam), loess loam and loessial pumice dust (soil formation s. 3.1.2).

1.3 - 22 m:

Saprolite from clay slates, predominantly yellowish white (7,5 Y 8/1). whith some irregular reddish gray, yellowish and redbrown zones of relatively weak oxide enrichment.

22 - 30 m:

Saprolite from clay slates, narrowly interbedded with sandy silt slates, dark gray to black gray (N 4-3/0) by coaly-bituminous organic matter.

30 - 43 m:

Saprolite from clay and silt slates, strongly pervaded by quartz veins, red (10 - 2,5 R 4/3) to yellowish brown (7,5 YR 5/8) by accumulation of Fe oxides with a narrow changing intensity, from more or less infiltrated slates up to an alteration of quartz veins to solid ferricrusts. The boundaries of this subzone are predominantly following the nearly vertical standing cleavage plains (not demonstrated in fig. 3). From the vertical section of this zone by the drilling results a great apparent thickness. Its real thickness is about 2 m.

43 - 50 m:

Black gray, coaly-bituminous saprolite like 22 - 30 m.

Generally this saprolite can be divided in two parts:
0 - 22 m: Bleached white saprolite,
22 - 50 m: Gray black, coaly-bituminous saprolite with deep penetration of bleached and partly iron oxide enriched zones, boardering the quartz veins.

In the upper metres of the bleached saprolite the relictic slate structure is preserved weakly while it is of increasing distinctness to the depth. The compactness of both, the bleached and the coaly-bituminous saprolite is low. The slates are soft, friable or easy to break by hand. Only zones with strong oxide enrichment are harder. The formation of ferricrusts and oxide infiltration of the boardering saprolite is bound to quartz veins, which primary penetrate the slates. These quartz veins, which are compact and close in the unweathered stage, underwent partly dissolution. Therefore they show fine fissures, solution channels and caverns, which in a secondary process were filled up and cemented by iron oxides.

b) Geochemistry and mineralogy (fig. 3):

The mobilization of elements, especially of Fe and Mg, and the new formation of kaolinite is a result of the complete decomposition of primary chlorite minerals, which participate in total samples of unweathered slates with an amount of 30 %, beside muscovite (40 %) and quartz (30 %) (MOSEBACH 1954). The kaolinization of chlorite went over the formation of smectite of chlorite mixed-layer minerals as intermediate stages occurring in the lowest parts of the saprolite. While the clay fraction from the bleached saprolite

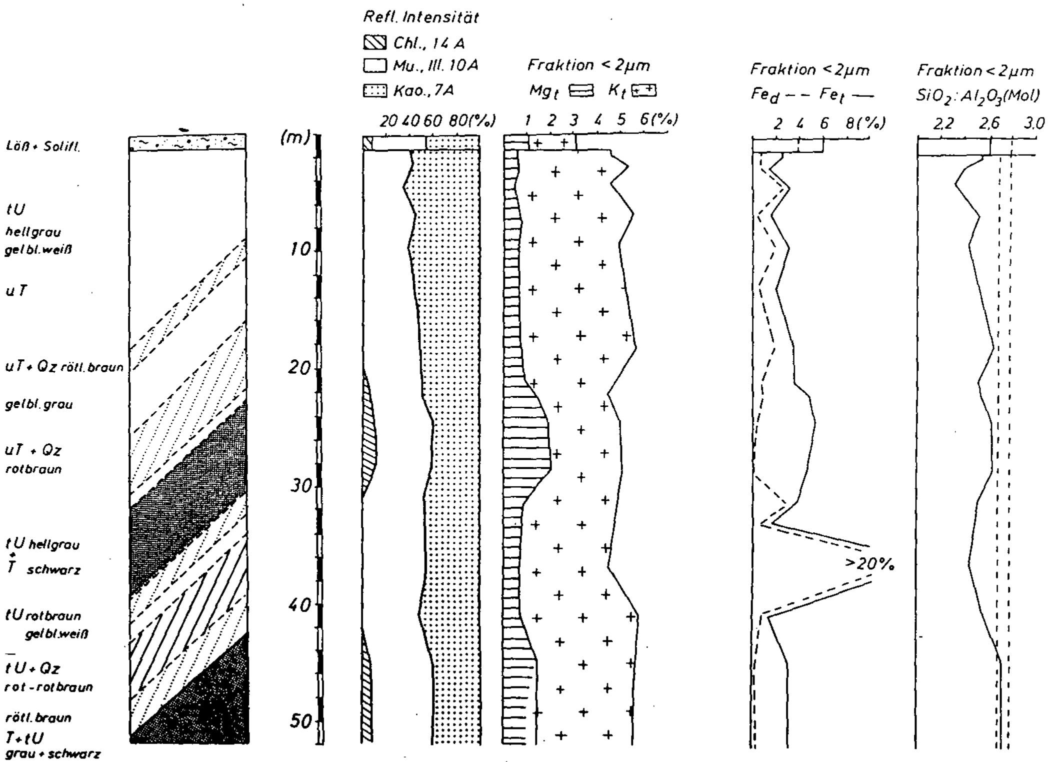

Fig. 3: Lingerhahn drilling - profile morphology, mineralogy and geochemistry of the clay fraction.

of Lingerhahn drilling shows a complete kaolinization of the chlorite, the coaly-bituminous saprolite contains kaolinite as well as chlorite and chlorite-vermiculite mixed-layer minerals, which is indicative for the transition zone from the saprolite to the unweathered rock. Weathering and new formation of minerals were accompanied by solution of quartz and desilification. In all depths of the saprolite only the muscovite remained nearly stable. Within the uppermost Tertiary soil zone the muscovite was affected and diminished by kaolinization due to the higher weathering intensity.

3.1.2 Soil development in the superficial layers

Near the Lingerhahn drilling location the recent soil, developed from the Pleistocene superficial layers, is exposed in an excavated pit.

a) Profile description:

Locality:	300 m behind the eastern exit of Lingerhahn village at a forest edge, 80 m distance to the drilling location, TK 5911 Kisselbach, r 55 52050 h 33 98380
Relief:	Weakly sloped plain , N exposition
Altitude a. sea lev.:	482 m
Annual precipit.:	700 (200) mm
Mean annual temp.:	7^{o} ($13,5^{o}$) C
Land use:	Mixed forest
Parent materials:	Solifluction layers from bleached Mesozoic-Tertiary saprolite, loess loam and loessial pumice dust.
Soil type:	(Relict Para Brown Earth) Brown Earth-Pseudogley FAO: Transition (relict Luvisol) Cambisol-Stagnic Gleysol USDA: Aeric Ochraquult
Of 4 - 0 cm:	Fermented mor from mulch of grasses and spruce needles.

Ah	0 - 4 cm:	Black (10 YR 2/2) fine duff mull with a sharp lower boundary.
SwBv	4 - 37 cm:	Dull yellowish brown (10 YR 5/4), silty loam, slightly stony and rooted, weak polyhedral structure, roundish black and dark brown concretions till 1 cm Ø. Skeleton: Angular fragments of vein quartz, quartzite and ferricrusts. Geogenesis: Solifluction layer from loessial pumice dust.
BvSw	37 - 52 cm:	Bright yellowish brown (10 YR 6/4-6) silty loam, stony, polyhedral structure, slightly rooted, black and dark brown concretions -0,5 cm Ø, irregular lower boundary. Skeleton: Like SwBv Geogenesis: Lower part of the solifluction layer from loessial pumice dust.
II (rBt)Sd1	52 - 90 cm:	Yellowish brown (10 YR 5/6) and yellowish gray (5 Y 7/2) mottled silty loam, stony, polyhedral-prismatic structure, single fine roots. In the lowest 20 cm strong skeleton accumulation forming irregular pocket-like intrusions into the underlying horizon. Skeleton: Fragments of vein-quartz, ferricrusts and bleached slate saprolite. Geogenesis: Solifluction layer from loess with intermixed softened saprolite material.
III (rBt)Sd2	90 -110 cm:	Light gray matrix (7,5 Y 7/1-2), yellowish orange to brown (10 YR 6/3-6) mottled clayey loam, stony and gravelly, prismatic structure with grayish brown cutans on ped surfaces.

Skeleton: Fragments of vein-quartz, ferricrusts and bleached saprolite, some rounded quartz gravels.
Geogenesis: Solifluction layer from softened saprolite (= Gray Loam) without visible intermixing of loess.

IV (rBt)Sd3 + 110 cm: Softened saprolite material from silt slates (texture = silty loam), yellowish gray (2,5 Y 6/1-5 Y 5/1) with diffuse orange mottles, ped surfaces and root channels with clay cutans.
Geogenesis: Periglacial disturbance of saprolite material by outcrop bending at the basis of the superficial solifluction layers.

b) Micromorphology:

Matrix:

Only the matrix of the SwBv horizon (4-37 cm) shows a subdivision in roundish aggregates with an intertextic micro fabric. This marked aggregation is a typical feature of the "Loosening Brown Earth" from pumice bearing loess. In deeper horizons the clayey - loamy textured matrix is of higher density with pores and fissures.

In the III (rBt)Sd2 horizon (90-110 cm) the homogenous clayey ground mass contains small fragments of bleached silt slate in an irregular and dense bedding, which reflects its saprolitic source below.

Cutans:

While the SwBv horizon is free of oriented clay cutans within the pores, the underlying BvSw horizon contains thin pore- standing undisturbed clay cutans. The II (rBt)Sd1 horizon (52-90 cm) has only single and thin, undisturbed cutans within the recent pores. But fragments of thick cutans, which are spread in the matrix, testify about the redeposition of an interglacial Bt horizon by solifluction processes during the Upper Pleistocene.

Mottles and concretions:

Down to a depth of 90 cm the horizons contain well rounded, sharply boardered allochthonous concretions, which often show inclusions of oriented clay cutans. Also micro fragments of oxide impregnated slates and ferricrusts are occurring.

In consequence of logging surface water, the fine dispersed Fe oxides of the clayey matrix were partly redistributed, so that oxide accumulations, especially in the surrounding area of pores occur beside diffuse boardered, light gray bleached zones.

c) Distribution of heavy minerals:

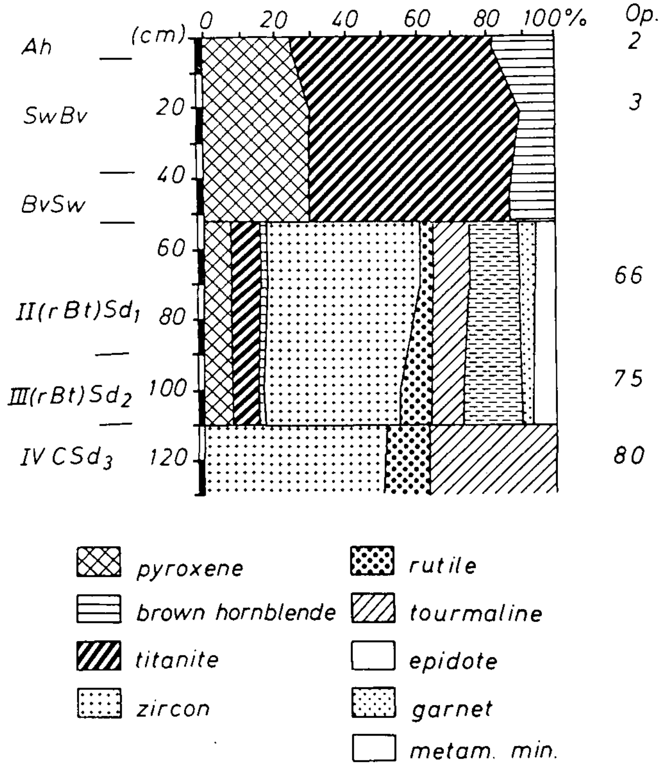

Fig. 4: Lingerhahn soil profile - distribution of heavy minerals of the 30-400 µm fraction.

The distribution of heavy minerals reflects the stratigraphy of solifluction layers of different ages and the source of the materials:

- Sw-horions with an absolute dominance of the volcanic minerals assemblage, which is typical for the loessial pumice dust of the Late Pleistocene age (Younger Tundra Period).
- Sd horizons with an instable and metamorphic mineral assemblage, which is characteristic for the loess deposits of this region, beside the stable spectrum of the saprolite material.
- Saprolite with the stable spectrum of Lower Devonian sedementary rocks with a high amount of opaque minerals.

d) Clay minerals:

Table 1: Lingerhahn soil profile - mineral composition and semiquantitative (reflex intensity) distribution of the Mg-saturated clay fraction.

horizon	prim. chl. (14)	sec. chl. (14)	ver. (14)	ml (12)	mu/ ill (10)	kaol. (7,2)	qtz. (4,26)	fsp. (3,2)
Bv Sw	4	11	-	-	35	50	+	++
BvSw	+	10	-	-	38	52	+	++
II(r Bt)Sd1	-	10	-	-	42	48	+	++
III(r Bt)Sd2	8	-	2	chl/v	48	42	+	+
IV Sd3	9	-	5	chl/v	59	27	+	+
kaol. sapr.	-	-	-	-	55	45	+	+

The saprolite of this profile has not yet been completely kaolinized, whereas in the drilling, about 80 m apart, primary chlorite (beside kaolinite) occurs for the first time in 20 m depth (s. kaol.sapr. in table 1). This shows, that the degree of kaolinization of the saprolite may strongly change on short distance according to the properties of the rocks (quartz veins, clay content).

Table 2: Lingerhahn soil profile - analytical data.

hor.	depth	sto.	Texture of humus-/carb.-free fine soil (%) sand			silt			clay
	cm	%	c	m	f	c	m	f	
Ah	0- 4	0	0,7	4,8	7,0	20,3	27,8	17,6	21,8
SwBv	4- 37	13	5,4	6,2	5,6	22,1	20,9	13,1	26,7
BvSw	37- 52	13	5,7	4,1	4,2	22,3	21,4	14,1	28,2
II(rBt)Sd_1	52- 90	17	4,6	4,0	5,3	19,8	22,7	17,9	25,7
III(rBt)Sd_2	90-110	25	6,3	5,9	6,3	12,0	19,6	17,3	32,6
IV	>110	-	1,9	2,8	5,4	14,4	25,8	21,8	27,9

depth cm	bulk dens g/cm^3	total PV Vol. %	water content at pF (Vol. %) -1.8	-2.5	-4.2	>4.2	kf cm/d
0- 4							
4- 37	1,35	48,1	7,2	5,4	20,6	14,9	62,1
37- 52	1,57	41,9	4,5	3,4	17,7	16,3	2,4
52- 90	1,73	36,4	0,4	2,5	17,9	15,6	1,2
90-110	1,78	36,2	1,2	2,8	16,3	15,9	1,3
>110	1,76	40,1	0,0	2,6	22,6	14,9	0,5

depth cm	pH H_2O	$CaCl_2$	C_{org} %	N_t ‰	C/N	Fe_o ‰	Fe_d ‰	Al_o ‰	Al_d ‰	Mn_o ‰	Mn_d ‰
0- 4	3,55	2,93	9,3	7,6	12	4,6	9,9	3,2	3,6	0,05	0,10
4- 37	4,10	3,85	1,0	1,0	10	3,1	10,6	2,1	2,4	0,80	0,80
37- 52	4,09	3,79	0,4	,	-	2,4	14,6	1,5	2,1	0,54	0,58
52- 90	4,67	3,98	0,1	-	-	1,0	21,5	0,7	1,5	0,23	0,26
90-110	5,03	3,96	0,1	-	-	0,6	13,7	0,6	1,2	0,06	0,08
>110	4,87	3,92	0,2	-	-	0,4	5,4	0,4	0,6	0,01	0,03

depth cm	CEC meq/100 g P	a	exchang. cations meq/100 g Ca	Mg	Na	K	H	Al	V %
0- 4	55,5	15,5	1,44	0,60	0,16	0,28	3,00	10,00	4,5
4- 37	11,4	4,4	0,27	0,08	0,03	0,08	0,34	3,55	4,0
37- 52	16,3	5,0	0,08	0,10	0,05	0,10	0,50	4,20	2,0
52- 90	9,7	3,8	0,52	0,78	0,03	0,09	0,40	2,00	14,6
90-110	12,1	5,7	0,83	1,68	0,06	0,12	0,48	2,49	22,2
>110	8,9	4,2	0,53	1,26	0,04	0,08	0,28	1,96	21,5

e) Pedophysics and chemistry

The analytical data are represented in table 2.

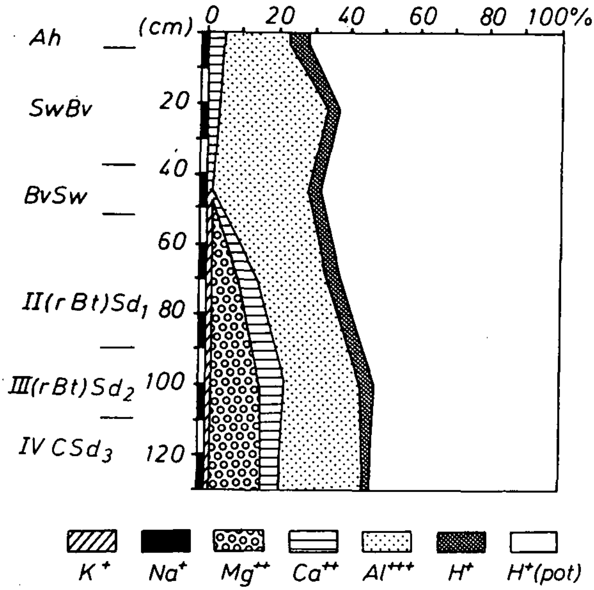

Fig. 5: Lingerhahn soil profile - distribution of exchangable cations.

3.2. Alterkülz soil profile: Soil development on Lower Devonian slates in erosion areas.

In tectonically weak stressed areas like the eastern Hunsrück, outcrops of unweathered slates are only restricted to the deeply incised Pleistocene erosion valleys. The erosion of the Mesozoic-Tertiary weathering mantle originally started at the Tertiary trough valleys, which traversed the old peneplain. They were transformed to V-shaped valleys, in which the saprolite was eroded down to the base of weathering. Other valleys are oriented along tectonic faults, because the destabilized rocks were more erodible and boundaries of tilted fault blocks influenced the water course.

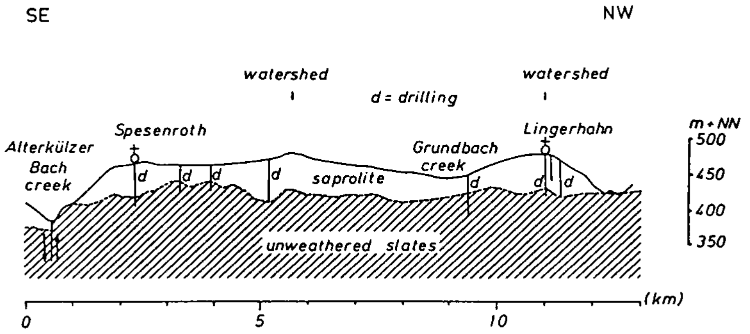

Fig. 6: Cross section of the eastern Hunsrück area between Lingerhahn and Alterkülz, showing relief and depth of weathering.

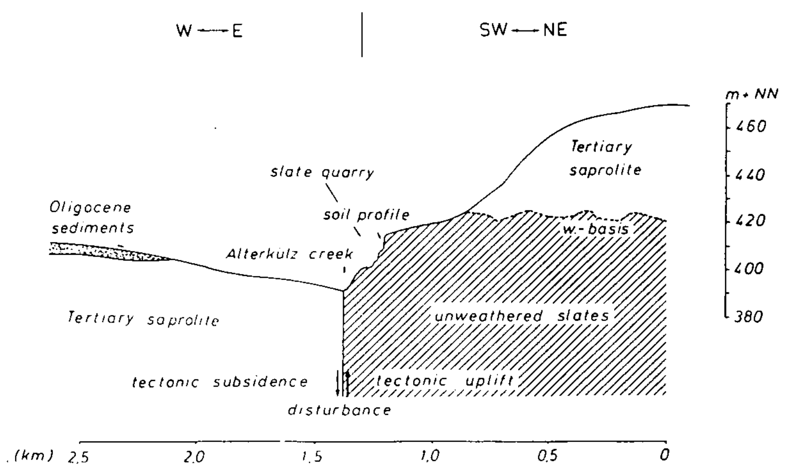

Fig. 7: Cross section through the Külzbach valley at Alterkülz.

In a slate quarry, which was established in a slope of an uplifted block at the northwestern edge of Alterkülz village, the unweathered Lower Devonian slates ("Hunsrück slates") are exposed. According to their good cleavability they were used as roof slates.

From the top of the quarry a weakly inclined erosion surface continues upslope, following the transition from the saprolite to unweathered hard rocks (fig. 7).

a) Profile description:

Locality:		Slate quarry, northwestern edge of Alterkülz village, TK 5910 Kastellaun, r 55 45530, h 26 04450.
Relief:		Gentle inclined slope, SW exposition.
Altitude a. sea lev.:		450 m
Annual precipit.:		680 (190) mm
Mean annual temp.:		7^{o} ($13,5^{o}$) C
Land use:		Edge of a field.
Parent rock:		Lower Devonian clay slates and loessial pumice dust.
Soil type:		Brown Earth (medium acid) FAO: Dystric Cambisol USDA: Typic Dystrochrept
Ah	0 - 15 cm:	Brownish black (10 YR 3/3 - 2,5 Y 3/2) sandy loam, stony, much slate grit, strongly rootened, marked crumb sturcture; near the lower bondary horizontal orientation of coarser slate fragments by outcrop bending.
CvBv1	15 - 25 cm:	Dull yellowish brown (10 YR 4/3) silty sandy loam, humous, very stony, much slate grit, strongly rootened, crumb to fine polyhedral structure.
CvBv2	25 - 50 cm:	Dull yellowish brown (10 YR 5/4) silty sandy loam, very stony, much slate grit; longish slate fragments are bedded in cleavage direction of the underlying massive rock, on the skeleton surfaces fine soil accumulation with a fine polyhedral structure.

/

BvCv	50 - 90 cm:	Dull yellowish brown (10 YR 5/3) silty sandy loam, very stony, fine slate grit; skeleton orientation like in the superficial horizon.
Cn	+ 90 cm:	Unweathered Hunsrück slate, dark gray (N 4/0), silty clay slate, thin oxide accumulations on joint and cleavage plains.

At the basis of the BvCv horizon, on top of the massive slate, a water outlet could be noticed during the field investigation of this profile after a period of precipitation.

b) Distribution of heavy minerals:

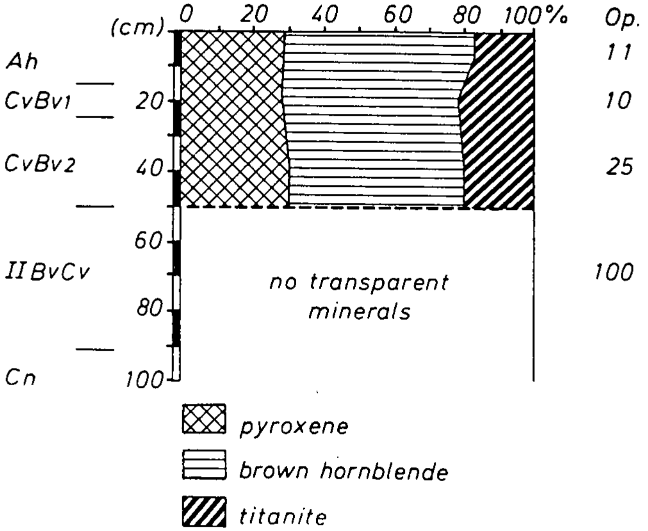

Fig. 8: Alterkülz soil profile - distribution of heavy minerals in the fraction 30 - 400 µm

In the upper 50 cm of the profile the volcanic heavy mineral assemblage, typical for the loessial pumice dust, is dominating. Characteristic heavy minerals of Wuermian loess, which perhaps was already eroded at the time of loessial pumice dust deposition in the Younger Tundra Period, are missed. The small amount of stable heavy minerals the slate contains, cannot be identified. It occurs in form of opaque, cemented particles, according to the less degree of rock weathering.

c) Clay minerals:

Tab. 3: Alterkülz soil profile - mineral composition and semiquantitative (reflex intensity) distribution of the Mg-saturated clay fraction.

horizon	chl (14)	ver (14)	ml (12)	mu/ill (10)	kaol (7)	qtz (4,26)	fsp (3,2)
Ah	11	5	chl/v	71	13	+	++
CvBv1	13	8	chl/v	63	18	+	+++
CvBv2	14	4	chl/v	65	17	++	++
BvCv	13	5	chl/v	72	10	++	++
Ch	19	-	-	81	-	+	++

d) Pedophysics and chemistry

The analytical data are represented in table 4

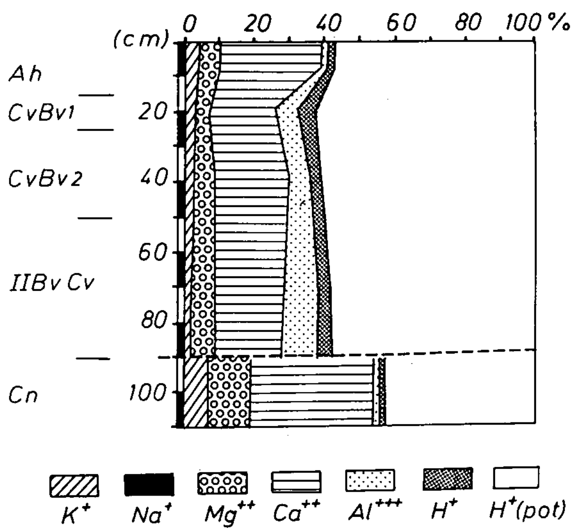

Fig. 9: Alterkülz soil profile - distribution of exchangeable cations.

Table 4: Alterkülz soil profile - analytical data.

hor.	depth	sto.	texture of humus-/carb.-free fine soil (%)						
			sand			silt			clay
	cm	%	c	m	f	c	m	f	
Ah	0-15	43	14,5	8,7	6,1	13,9	19,4	14,1	23,2
$CvBv_1$	15-25	64	11,2	9,5	6,1	16,0	18,6	15,3	23,3
$CvBv_2$	25-50	74	16,5	9,3	4,8	15,1	18,0	15,4	20,9
BvCv	50-90	86	10,7	13,8	9,4	20,2	17,6	11,5	16,8
Cn	>90	100							

depth	pH		C_{org}	N_t	C/N	Fe_o	Fe_d	Al_o	Al_d	Mn_o	Mn_d
cm	H_2O	$CaCl_2$	%	‰		‰	‰	‰	‰	‰	‰
0-15	5,15	4,57	3,8	3,9	10	3,0	12,2	1,9	1,9	1,14	1,24
15-25	4,95	4,22	2,5	2,5	10	3,1	12,4	2,0	2,1	1,30	1,30
25-50	5,40	4,55	0,7	-	-	2,4	11,3	1,4	1,8	1,15	1,25
50-90	5,20	4,38	0,4	-	-	2,3	11,8	1,2	1,5	1,80	1,80
>90	6,57	6,17	0,3	-	-	0,7	4,2	0,4	0,5	0,54	0,64

depth	CEC		exchang. cations						V
cm	meq/100 g		meq/100 g						%
	P	a	Ca	Mg	Na	K	H	Al	
0-15	18,6	7,8	5,34	1,07	0,02	0,70	0,38	0,28	38,3
15-25	14,7	5,5	2,74	0,60	0,00	0,47	0,66	0,98	25,9
25-50	10,5	4,1	2,24	0,62	0,00	0,32	0,30	0,60	30,3
50-90	8,9	3,7	1,72	0,60	0,00	0,17	0,32	0,86	27,9
>90	5,1	2,9	1,75	0,62	0,00	0,36	0,08	0,08	53,5

3.3 Rheinböllen: Agricultural utilization of soils in the flat upland area of the eastern Hunsrück.

In contrast to the soil under forest at Lingerhahn, the Rheinböllen soil profile represents a typical soil under agricultural use.

Locality: Farm RHEINGANS, in the west of Rheinböllen village,TK 5912 Kaub, r 34 04900, h 55 42000

Relief: Weakly sloped plain, E exposition

Altitude a. sea lev.: 405 m

Annual precipt.: 680 mm
Mean annual temp.: 8° C
Land use: Field
Parent materials: Solifluction layers from Mesozoic-Tertiary saprolite, loess loam and loessial pumice dust.
Soil type: Brown Earth - Pseudogley
FAO: Transition Cambisol - Stagnic Gleysol
USDA: Aquic Dystric Eutrochrept

Ap	0 - 30 cm:	Grayish yellow brown (10 YR 4/2) loamy silt, stony, humous, sharp lower boundary.
BvSw	30 - 40 cm:	Dull yellow orange (10 YR 6/4) with orange brown and black mottling, sandy loamy silt, stony, polyhedral structure, Fe/Mn concretions up to 1,5 cm Ø, irregular lower boundary. Skeleton: Fragments of vein quartz, yellowish to purplish brown clay slate saprolite and reddish brown ferricrusts. Geogenesis: Solifluction layer from loessial pumice dust.
IISd1	40 - 75 cm:	Light grayish brown (10 YR 6/3) with bright brown mottling (7,5 YR 5/6), clayey loam, stony, coarse polyhedral to prismatic structure, black Mn oxide accumulations on ped surfaces, irregular lower boundary. Skeleton: Yellowish to reddish brown fragments of clay slate saprolite, mostly softened and friable.
IIISd2	75 -100 cm:	Grayish yellow (2,5 Y 7/2) and bright brown (7,5 YR 5/6) mottling, clayey loam, stony, coarse polyhedral to platy structure, black Mn oxide accumulations on ped surfaces, higher density than in the Sd1 horizon. Skeleton: Like Sd1 horizon. Geogenesis: Solifluction layer from saprolite.

3.4 Waldesch: Alteration and decomposition of rocks by ascending hydrothermal solutions.

Since the beginning of this century the question has been discussed, whether kaolinization of rocks is a weathering process or a consequence of ascending, post volcanic or hydrothermal solutions. Though for the most of the kaolinized rocks of the European hill countries a genesis by weathering is proved, locally, however, signs exist for an ascendent genesis or at least a participation of ascending solutions in the kaolinization. In the Rhenish Massif this often occurs in tectonically strong stressed areas with Tertiary and Quarternary volcanism.

The locality Waldesch (TK 5711 Boppard, r 33 94250 h 55 68200) is situated only some km south of the volcanic fields of the eastern Eifel and single Tertiary basaltic dykes are known in the surrounding. Partly thermal hydrogene carbonate waters, which occur today in a surrounding of 6-8 km (Rhens village at the Rhine and Winningen village at the Mosel) are looked upon as a sign of continuing post volcanic activity of Quarternary volcanism. The Horstkopf quarry is situated some km south of Waldesch village upon the ridge of a small relict mountain chain. This ridge from quartzite juts out of the old peneplain about 50-100 m, as the height of the correlated Tertiary sediments proves. Therefore this relict mountain was exposed to the intensive pre-Pleistocene weathering and a huge part of the thick saprolite zone is preserved. At the up to 15 m high walls of the quarry, steep-standing, 0,5-2 m thick banks of quartzite, interbedded with 0,1-2 m thick layers of saprolite from sandy silt slates, are outcropping. Quartzite and slates are bleached and their chlorite content is completely kaolinized. Along joints oxides in form of hematite and goethite are infiltrated into the bleached rock, forming hard crusts. Predominantly within the joints of the slates, white monomineralic infillings of dickite, up to 1 cm thickness, occur. Jointplains within the quartzite are often covered with fresh quartz crystals, unaffected by weathering, partly overlain by fibrous brown iron ore from well crystallized goethite. Here the pre-Pleistocene saprolite seems to have been superimposed by ascending post-volcanic solutions. The processes of lateral secretion led to the mineral newformation of dickite, quartz, hematite and goethite. The mineral phases precipitated from hot waters, which were mineralized by rock-water interaction processes, probably by rapid cooling. These mineral phases do not occur within the Mesozoic-Tertiary saprolite of the Hunsrück flat upland area, which is situated far away from a possible post volcanic influence.

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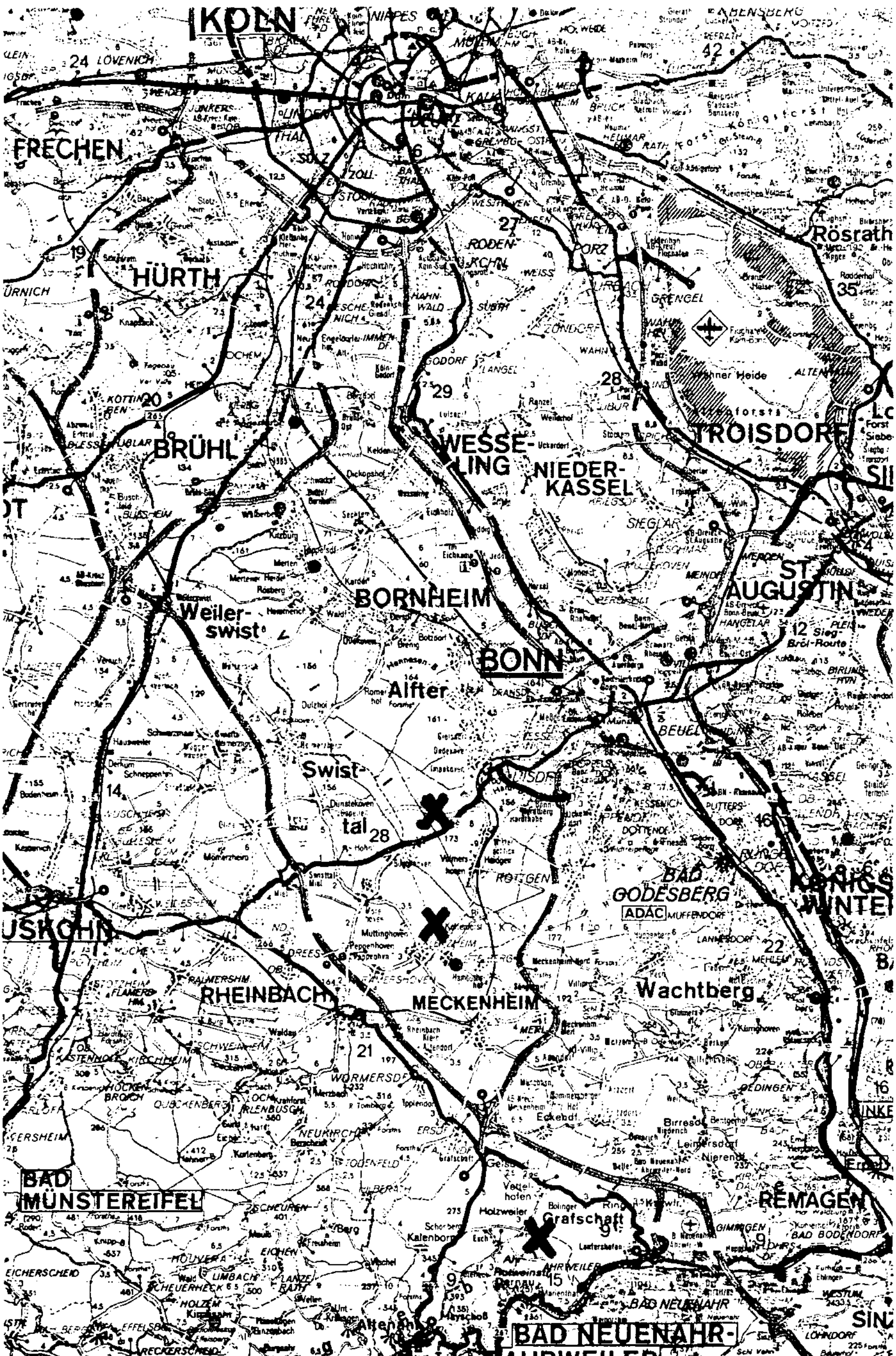
Excursion area (Compacted soils with impeded drainage and amelioration)



Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 100 - 112, 1986

The amelioration of compacted soils

H. Schulte-Karring[+] and D. Schröder[++]

Area of excursion

The area of excursion is located at the northern fringe of the Eifel mountains (fig. 1). Mainly, it comprises the area of the Ahreifel. Here, the Rhenish Slate Mountains descend to the Lower Rhine Bay. The dominating parent rocks are Lower Devonian shists and greywackes. These rocks are weathered primarily during the Tertiary into the so-called grey plastosols (Graulehm) (a detailed description can be found by Mückenhausen 1971 and in this excursion guide by Felix-Henningsen 1985).

The uplift of the area in the Upper Tertiary and Pleistocene as well as periglacial processes caused the severe erosion of the grey plastosol cover so that autochthonous grey plastosols are present only residually today. Grey plastosols that were rearranged by solifluction are still to be found on plateaus, along lower slopes and in depressions. During glacial times they were covered with loess up to elevations of app. 400 m and were also partly mixed by solifluction and cryoturbation with loess and Devonian material of recent weathering. The loess rsp. loess loam is eroded on a large scale by agricultural activity so that presently the following substrata occur within the area of excursion:

a) autochthonous grey plastosol
b) rearranged grey plastosol
c) soil creep masses of grey plastosol, loess loam and clay shist origin
d) loess veil on top of soil creep masses
e) soil creep masses out of loess loam

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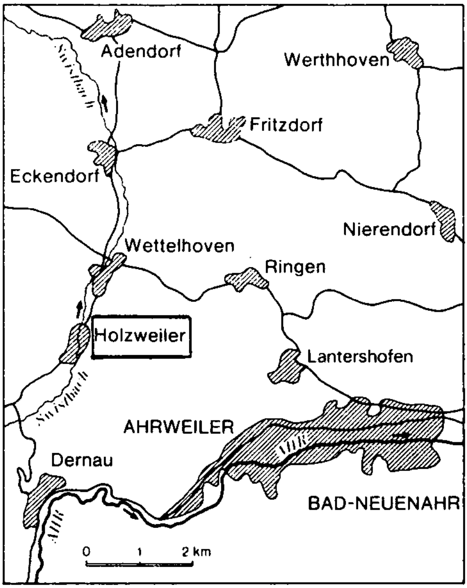

Fig. 1 Sites of the experimental fields

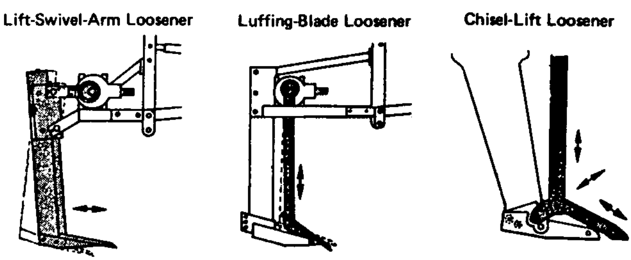

Fig. : 2 The different techniques of power transmission

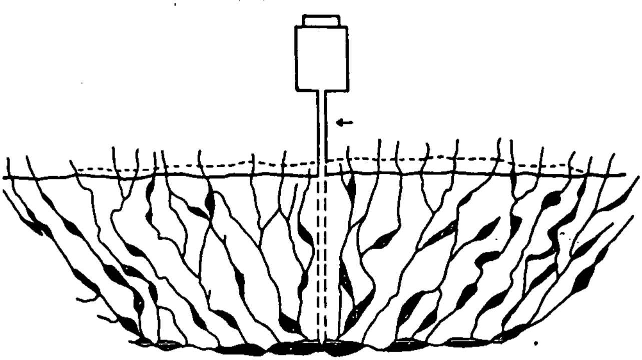

Fig. 3 Pneumatic loosening system

f) autochthonous loess
g) greywackes and clay shist
h) solifluction debris of greywacke and clay shist origin

This distribution of substrata results in the following soil distribution:

At the more erosion-prone sites rankers and cambisols occur on Devonian bedrock. At the few steep locations these soil types are common on solifluction debris. On plateau- and in hollow positions as well as on lower slopes primary pseudogleys are developed on the rests of soil creep masses of grey plastosol origin that widely bear a thin loess veil. On the plains bordering the Lower Rhine Bay luvisols and luvisol-pseudogleys occur on loess and soil creep masses out of loess loam.

Except for the recent soils developed on Devonian rocks and the luvisols the soils mentioned above are more or less compacted and thence need to be ameliorated.

As an example of a compacted soil due to impeded drainage an often found type to simigley of this area out of soil creep mass of grey plastosol origin with a 40 m thick loess cover is shown. In 1961 the soil has been drained systemathically in the amelioration project "Upper Swist Creek Valley (oberes Swistbachtal) and the plots have been subsoiled in 1963. The soil profile and its characteristics are described as follows.

Description of the excursion profile Holzweiler

Location:	Holzweiler near Ahrweiler
Topographical map:	1:100 000 5483 Bad Neuenahr-Ahrweiler, coordinates R 2574100 H 5603500
Elevation:	280 m, topography: weakly inclined east facing
Area:	Northeast fringe of the Eifel mountains (Ahrgebirge)
Landuse:	arable land
Rock formation:	soil creep mass of grey plastosol origin with loess veil
Soil type:	Pseudogley (Eutric Gleysol, Haplaquept)

Horizon	depth (cm)	characteristics
Ah	0-25	brown 10 YR 4/4 humic, weakly skeletal, silty loam, crumbly to subpolyedric, densely rooted, some worm holes, linear, sharp trasition
Sw	25-45	dull yellow-orange 10 YR 6/4, weakly skeletal, silty clayey loam, subpolyedric, marbled, many small, soft Fe-Mn concretions, well rooted, few earthworm holes, distinct transition
II Sd_1	45-60	orange 7,5 YR 6/8, dull yellow 2,5 Y 6/3, spotted, weakly skeletal clayey loam, polyedric to prismatic, numerous soft concretions, weakly rooted, continuous transition to
II Sd_2	60-80	like Sd_1

In all horizons is illite the predominant clay mineral. In small quantities kaolinite is present. Chlorite and goethite are occuring only in minor contents.

Historic development of the amelioration of compacted soil due to impeded drainage

Up to the half of this century compacted, impermeable soils were drained systematically. But as the volume of the coarse pores was very small the success of drainage of the commonly compacted soils was unsatisfactorily.

Increasing mechanization opened the possibility of deep loosening of the soils that was designed to do away with the cause of damage, that was soil compaction, and also to improve the water uptake capacity. At first this was done by tractor-pulled rigid devices. In his dissertation, Schulte-Karring (1957) investigated in the effect of loosening. Although being positive it remained insufficient because of unsuitable technical equipment (depth of loosening, intensity of loosening). For this reason the LLVA Ahrweiler specialized in the technique of loosening implements in cooperation with the manufacturing companies. Simultaneously, the testing and production of powerful deep fertilizer machinery took place.

The result of the development of machinery are wheel- and caterpillar-drawn one or-more armed loosening devices that are powered by the engine of the cart and are movable loosening devices and throw-blow fertilizers (fig. 2).

The amelioration of soils with impeded drainage is of great importance for they are a commonplace. In West-Germany they comprise 1,5 mill. ha = 10% of the agriculturally used area (Eggelsmann 1980). On a worldwide scale soils that need to be loosened, i.e. compacted, saline or crusted soils are also largely present.

The new technique of loosening was primarly applied on a large scale at the land clearing projects (96) in Rhineland-Palatinate and was also successfully employed in countries of West- and Southeast Europe (simigleysols, planosols, solonetz-smonicas), in North Africa (carbonate compactions), in South Africa (incrusted soils), and in Argentina (planosols).

For the loosening of narrowly spaced plantations with lasting crops and for the use on soils that must be kept from driving on a new pneumatically loosening and deep fertilizing machine is at hand.

The performance of the machinery mentioned above is shown in fig. 3.

Conventional loosening by a sword and a loosening share, pneumatic loosening or loosening by explosives is a kind of loosening that works by lifting the soil. However, satisfactory success with this type of loosening can be merely accomplished, if the soil is sufficiently hard at the loosening basis (share, probe tip, explosives), i.e. dry. But in areas with humid climate the desiccation of compacted soils is not sufficient each year in deeper horizons. This difficulty recently lead to the development of a new loosening method called breaking-loosening. Hopefully, a newly developed machine can be demonstrated at the time of inspection, whose soil loosening is largely independent from the water content of the soil. This device is thought to mix stabilizers that have been spread beforehand as well and to apply e.g. gypsum for the amelioration of saline soils by a fan.

Impact of deep loosening on soil-physical characteristics

The first loosening experiment plots have been established at Ahrweiler 25 years ago and are since continually being surveyed jointly by the Soil Science Departments of the Universities of Bonn and Trier (Schröder and

Table 1 Properties of the analized soils

Location	Horizon DBG	Horizon FAO	Deepth	clay T <2µm	silt U 2-63µm	sand S 62-2000µm	pH $CaCl_2$
1 Krupp-Mönchesch-Pseudogley	Ap	Ap	0-22	18,9	64,3	16,8	5,8
(Dystric Gleysol, Haplaquept)	Sw	Eg	22-40	23,5	65,8	10,7	4,2
from grey plastosol covered	$IISd_1$	Bg_1	40-70	30,8	56,3	12,9	3,8
with thin loess veil:	$IISd_2$	Bg_2	70-80	28,6	62,4	9,0	3,7
loosening 1963							
2 Giffels-Gelsdorf Pseudogley	Ap	Ap	0-25	15,9	64,1	20,0	5,8
(Dystric Gleysol, Haplaquept)	SwSd	Eg	25-45	25,7	57,7	16,6	4,0
from grey plastosol covered	IISd	Bg_1	45-60	42,6	42,3	15,1	3,6
with very thin loess veil:	$IISd_2$	Bg_2	60-80	33,5	56,1	18,4	3,5
loosening 1963							
3 Höfer-Holzweiler 2 Pseudogley	Ap	Ap	0-28	26,6	59,1	14,3	6,5
(Eutric Gleysol, Haplaquept)	Sw	Bg_1	28-50	36,7	52,3	11,0	6,3
from loess composing soil	Sd_1	Bg_2	50-70	41,8	47,1	11,1	5,1
creep mass out of grey plasto-	Sd_2	Bg_3	70-90	42,7	48,8	8,5	5,1
sol: lossening 1971							
4 Höfer-Holzweiler 1 Pseudogley	Ap	Ap	0-25	16,5	64,2	19,3	6,5
(Eutric Gleysol, Haplaquept)	Sw	Eg	25-45	25,9	60,1	14,0	6,1
from grey plastosol with 50 cm	$IISd_1$	Bg_1	45-60	40,0	47,5	12,5	5,4
thick loess composing soil	$IISd_2$	Bg_2	60-80	41,4	48,1	10,5	5,1
creep mass: loosening 1963							
5 Krupp-Gelsdorf Parabraunerde-	Ap	Ap	0-30	23,3	54,3	22,4	6,2
Pseudogley (Gleyic Luvisol,	ALSw	Eg	30-50	26,6	66,4	7,0	6,0
Hapludalf) from loess loam:	BtSd	Bg_1	50-70	33,1	58,4	8,5	5,3
loosening 1964	Sd	Bg_2	70-90	33,9	56,8	9,3	5,3

Table 2 Pores 50>µm (%), bulk density (g/cm^3), waterpermeability ($kf \cdot cm/s\ 10^{-4}$)

	pores 50>µm (%)				bulk density (g/cm^3)				waterpermeability ($kf \cdot cm/s\ 10^{-4}$)			
	deepth (cm)											
loosening	10-15	35-40	55-60	75-80	10-15	35-40	55-60	75-80	10-15	35-40	55-60	75-80
					Mönchesch							
no loosen.	9.1	7.1	4.6	4.9	1.31	1.59	1.66	1.72	170.0	4.8	8.6	2.5
loosening		11.4	7.5	4.8		1.62	1.58	1.75		15.0	50.0	0.4
					Giffels, Gelsdorf							
no loosen.	8.1	5.4	4.1	5.9	1.53	1.63	1.65	1.73	4.7	17.0	0.5	0.1
loosening		6.2	6.9	5.0		1.63	1.59	1.81		0.6	24.0	0.1
					Höfer, Holzweiler 2							
no loosen.	14.8	9.3	7.5	5.3	1.48	1.55	1.59	1.74	220.0	8.3	2.3	0.5
loosening		12.7	11.6	5.9		1.52	1.49	1.68		54.0	47.0	0.1
					Höfer, Holzweiler 1							
no loosen.	5.8	9.9	8.5	5.1	1.60	1.59	1.65	1.67	30.0	6.0	6.8	0.1
loosening		13.4	13.6	6.5		1.49	1.45	1.68		19.0	120.0	5.1
					Krupp, Gelsdorf							
no loosen.	8.5	10.4	9.7	6.2	1.59	1.55	1.57	1.60	33.0	35.0	3.7	0.2
loosening		9.3	10.8	7.4		1.49	1.34	1.56		3.1	130.0	1.8

GD 5% location/loosening/deepth = 3.9 location/loosening/deepth = 0.1 location/loosening/deepth = 78.3

Schulte-Karring 1984). The locations investigated and the results of the soil-physical investigations are presented in table 1 and 2. The results obtained after 24 years prove the loosening that had been conducted with rigid devices and only to a depth of 60 cm at that time to be still well preserved. Just in the upper subsoil (30-40 cm) recompaction occured. On the average the increases in yield at the deep-loosened plots amount to 11%, whereas at the deep-fertilized plots an increase of 28% was reached.

At a test site that was designed in 1979 the working capacity of a movable loosening device (stabbing-lifting loosener - 70 cm) and a pneumatic loosening device (60-100 cm) were investigated (Martinović, Mückenhausen, Schröder 1983 a and b). The details of the location are given in table 3, the coarse pore volume in table 4. On all soils the volume of the coarses pores increased substantially. When comparing both methods the mechanical loosening was considerably superior to the pneumatical loosening. Similarly, numerous other soil-physical parameters have been improved too. The yields were considerably increased as well thanks to loosening (table 5).

Beside the loosening experiments carried out in the Ahrweiler area mentioned in this paper, many more experiments were conducted in West-Germany (Rojahn 1973, Zwicker 1973, Blume and Parasher 1974, Borchert 1975, Franz 1975, Schröder and Scharpenseel 1975, Kuntze and Bartels 1980).

In correspondance to the Ahrweiler tests they all show that deep loosening of compacted soils is only successful, if it is done solidly, i.e. if the loosening is carried out with a powerful device, deep enough, and on dry soil. Additionally, the installation of a widely spaced pipe drainage system is commonly necessary in this climatic area, to divert spring water that cannot be retained by the newly created structure.

Also, a long lasting preservation of the loosening effects can only ce expected, if the soils are treated carefully, esp. during the first years. A suitable rotation of crops belongs to it as well. Soils with a labile structure need the application of stabilizers in form of fertilizers (Ca, N, P, K). The deeply applied nitrogen is esp. effective with the corresponding rotation of crops.

Table 3 Properties of the analized soils

Location	Horizon DBG	Horizon FAO	Deepth	clay T < 2µm	silt U 2-63 µm	sand S 62-2000µm	pH $CaCl_2$
Löhndorf-Ahrweiler Pseudogley	Ap	Ap	0- 30	22.7	47.9	29.4	6.7
(Eutric Gleysol, Haplaquept)	Sw	Bg_1	30- 50	29.9	42.4	27.7	6.1
soil creep mass of grey plasto-	Sd_1	Bg_2	50- 70	25.7	46.0	28.3	5.0
sol origin with loess veil	Sd_2	Bg_3	70-100	28.9	53.5	17.6	5.8
Löhndorf-Ahrweiler Deposol	Ap	-	0- 30	23.3	64.5	12.2	6.6
(Deposed material)from piled	Y_1	-	30- 50	21.8	53.4	24.8	6.1
weathered shist: loosening 1979	Y_2	-	50- 70	25.2	55.0	19.8	6.6
	Y_3	-	70-100	22.5	59.3	18.2	6.0
Volxheim/Bad Kreuznach Vertisol	Ap	Ap	0- 30	47.6	35.2	17.2	7.4
Pelosol (Chromic Vertisol,	Ah	Ah	30- 50	51.4	31.6	17.0	7.5
Chromudert) from tertiary marl:	AhC	AhC	50- 90	62.8	33.1	4.1	7.6
loosening 1979	Ckc	Ckc	90-100	59.2	40.2	0.6	7.7

Table 4 Pores 50 u (Vol. %)

Treatment	year	deepth	soil type Gleysol	Deposol	Vertisol	$\bar{x}$-treatment
No loosening	1980	0- 30	12.4	7.9	11.6	10.5
	1981	0- 30	15.2	15.9	9.2	13.4
Pneum. loosening	1980	0- 30	12.3	9.5	15.6	12.4
	1981	0- 30	14.3	15.5	10.6	13.4
Mech. loosening	1980	0- 30	12.9	13.6	14.1	13.5
	1981	0- 30	16.5	18.7	12.7	15.9
$\bar{x}$ soil type			13.9	13.4	12.3	13.2
		GD 5% soil type/treatment/year = 6.38				
No loosening	1980	30- 50	7.4	5.4	7.0	6.6
	1981	30- 50	4.9	3.7	7.2	5.2
Pneum. loosening	1980	30- 50	12.3	8.4	15.0	11.9
	1981	30- 50	9.2	10.7	6.7	8.8
Mech. loosening	1980	30- 50	13.6	13.0	18.3	14.9
	1981	30- 50	11.4	14.2	21.9	15.8
$\bar{x}$ soil type			9.8	9.2	12.6	10.5
		GD 5% soil type/treatment/year = 5.27				
No loosening	1980	50- 70	4.9	3.8	8.3	5.6
	1981	50- 70	2.3	1.5	4.1	2.6
Pneum. loosening	1980	50- 70	8.2	4.4	9.0	7.2
	1981	50- 70	5.6	3.5	5.2	4.7
Mech. loosening	1980	50- 70	13.1	7.7	14.8	11.8
	1981	50- 70	13.2	13.9	20.4	15.8
$\bar{x}$ soil type			7.8	5.8	10.3	7.9
		GD 5% soil type/treatment/year = 2.66				
No loosening	1980	70-100	5.2	5.2	1.7	4.0
	1981	70-100	1.8	0.4	4.8	2.3
Pneum. loosening	1980	70-100	10.8	4.1	8.2	7.7
	1981	70-100	4.8	4.1	4.4	4.4
Mech. loosening	1980	70-100	8.7	8.1	10.1	8.9
	1981	70-100	1.2	3.5	4.5	3.0
$\bar{x}$ soil type			5.4	4.2	5.6	5.0
		GD 5% soil type/treatment/year = 3.72				

Table 5 Crop Yields (dt/ha)

Gleysol

Year and Crops	1980	1981	$\bar{x}$
Treatment	w. wheat	w. barley	Treatment
No loosening	38.42	50.72	44.57
Pneum. loosening	40.20	52.23	46.22
Mech. loosening	46.34	58.07	52.20
$\bar{x}$ Crop/Year	41.65	53.67	47.66
LSD 5% Treatment = 6.78			

Deposol

Year and Crops	1980	1981	$\bar{x}$
Treatment	oat	oat	Treatment
No loosening	25.35	27.03	26.19
Pneum. loosening	26.46	27.51	26.98
Mech. loosening	28.96	40.41	34.68
$\bar{x}$ Year	26.92	31.65	29.28
LSD 5% Treatment = 5.43			

Vertisol

Year and Crops	1980	1981	$\bar{x}$
Treatment	w. wheat	s. barley	Treatment
No loosening	59.33	36.60	47.96
Pneum. loosening	66.89	38.35	52.62
Mech. loosening	73.02	50.62	61.82
$\bar{x}$ Crop/Year	66.41	41.85	54.13
LSD 5% Treatment = 3.81			

Presentation of the machinery

After the introduction into the topic and the discussion on the location with the help of soil profiles the presentation of the different loosening devices will take place.

The following machines will be shown:

1st Lifting-loosening (mechanical loosening-rigid and movable devices, pneumatic loosening)
2nd Turning loosening
3rd Breaking-loosening

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Pseudogleyic soils in the Kottenforst area

by

Wiechmann, H. and Brunner, C[+]

Hydromorphic soils are found widespread in North Rhine Westfalia (NRW). These characteristic soils cause several problems in agricultural and forestry use. Especially marked soils are found in the area of the Kottenforst-Ville. The compacted early pleistocene terrace of the river Rhine is overlapped by loess with variable thickness. The developed soils range from pseudogleyic para-brown earth to extremly wet pseudogleys (sometimes stagnogleys). At a soil catena under deciduous forest and at an arable soil the effect of loess thickness on hydromorphic properties shall be demonstrated. Additional long-term moisture measurements led to an ecological interpretation of the sites.
The profiles are situated in an area which is intensively investigated by the Soil Survey (Geologisches Landesamt NRW; Butzke, 1978), by the Forestry Planning Survey (Landesanstalt f. Ökologie, Landschaftsentwicklung und Forstplanung NRW; Dohmen a. Dorff, 1984) and by the Institute of Soil Science Bonn.

Geology (Butzke, 1978)

The excursion area is situated in the part of the Lower Rhine Bay, which is a mainly tertiary depression area intersecting the northern Rhenish Slate Mountains. This depression was filled with erosion masses from the neighbouring mountains. In the Pleistocene followed the sedimentation of Rhine fluvial deposits. By block faulting due to younger tectonics, by fluvial erosion and by sedimentation the recent landscape was formed. The geomorphological complex of the Kottenforst-Ville is a horst bordered by step faults separating the Erft-basin in the west from the Rhine-valley in the east.

Devonic rocks in the deeper underground are overlapped by thick series of gravelly to clayey tertiary sediments. They are covered with gravels and sands

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of the early pleistocene main Rhine terrace. These main terrace sediments are 5-8 m thick in this area, containing often high silt and clay contents and in addition are often cemented by iron and manganese oxides. In connection with reddish brown colours (5 YR) an intensive fossil weathering is concluded. The main terrace is widespread covered with loess (max. 3 m), which often is totally eroded. Loess sedimentation took place mainly in the Würm, but remnants of older loesses are proved. At the base of the mostly decalcified Loess in many cases you can observe a silty-clayey loam with small gravel content at the transition to the terrace material.

Climate (Dohmen a. Dorff, 1984)

Maritime climatic conditions are dominant in the Lower Rhine Bay. The position in lee of the Eifel mountains causes something lower precipitation. Westwinds amounts to 65%. The temperature regime is marked by 9^{0} C average annual temperature, by mild winters (2.4^{0} C) and moderate warm summers (July ø 17^{0} C). The precipitation amounts to 650 mm, more than one half is falling in the forestry vegetation period from May to September. Nevertheless considerable damages caused by dryness could be observed at spruce and japanese larch in irregular occuring dry years.

Vegetation (Wolf, 1984)

Due to the widespread found pseudogleyed soils the most common potential natural vegetation is the Stieleichen-Hainbuchen-Wald (Stellario-Carpinetum) with Sternmiere (Stellaria holostea) and Maiglöckchen (Convallaria majalis). The lime-tree rich Stieleichen-Hainbuchen-Wald (Quercus robur-Carpinus betulus forest) is found as a particularity only in the Lower Rhine Bay. There are mostly mesotrophic forests. The form with Pfeifengras (Molinia coerulea) characterizes the lowest base status, the form with Goldnessel (Galeobdolon luteum) the highest. Sites with natural beech forests are restricted to loamy soils without temporarily wetness. Prevailing are forms of the Hainsimsen-Buchenwald (Luzulo-Fagetum).

The recent forms of silviculture are substitution communities of the potential natural vegetation. These standard coppice forests are still very common in small parcelled private forests.

Soils

Soils of the Kottenforst are mainly developed from loess. If there is more

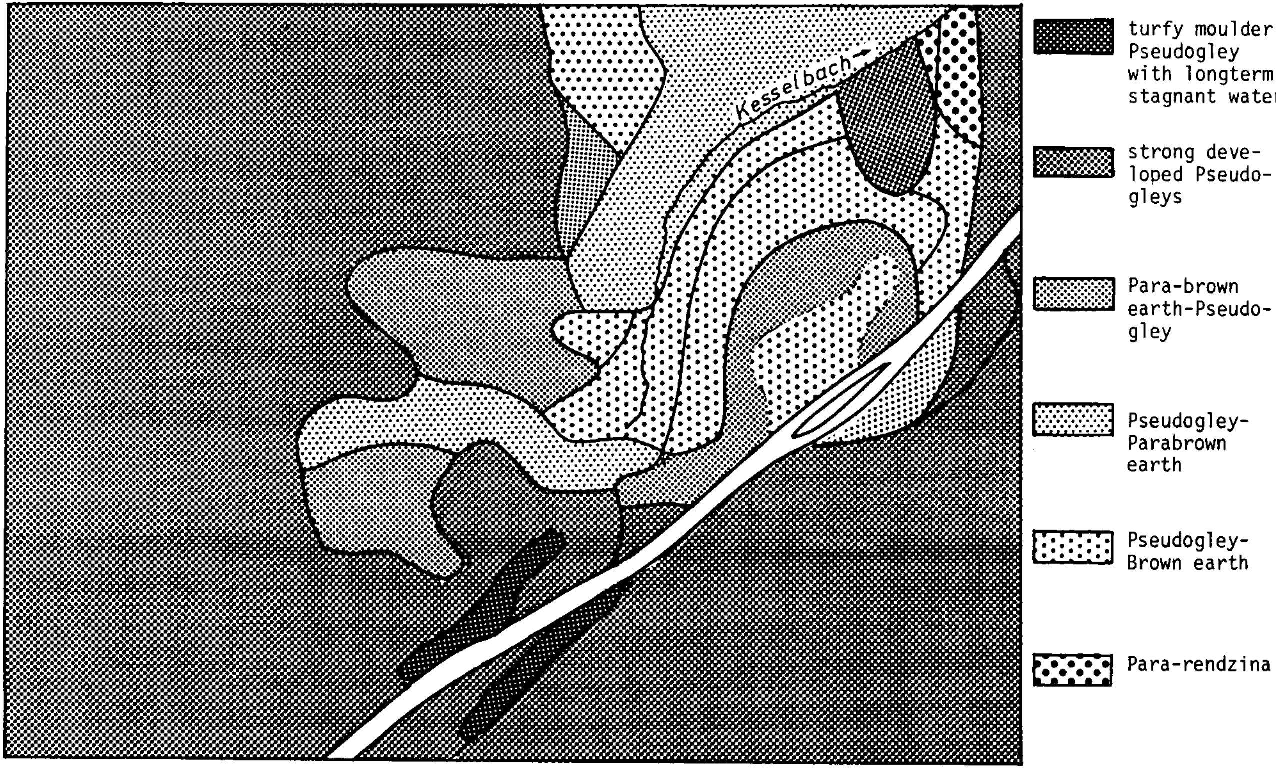


Fig. 1: Soil sketch map of the Kottenforst excursion area
(from: Bodenkarte zur Forstlichen Standortserkundung, Dorff, 1985)

than about 80 cm loess the properties of the para-brown earth are clearly marked. Because the loess-loam is enriched with clay and compacted by clay illuviation and/or fossil weathering and because this is true for the upper parts of the terrace too, soils with temporarily stagnating wetness are predominant (80-90% of the area).

The visited soil sites are situated near Bonn at the road B 56 between Impekoven and Buschhoven (catena under deciduous forest) and near Lüftelberg.

Profile 1

Location: topogr. map 1:25 000
5307 Rheinbach
r: 25.7060 h: 56.1355

Exposition: terrace plain

Inclination: plain

Vegetation, land use: field

Parent rock: Würmian loess overlaying gravelly main terrace

Soil type: (FRG) pseudovergleyte Parabraunerde
(FAO/UNESCO) Orthic Luvisol
(Soil Taxonomy) Typic Hapludalf

Ap 0- 30 cm	10 YR 3/3 (dark brown), coherent-subpolyhedral, moderately compacted-dense, well rooted.
AlBt 30- 45 cm	7,5 YR 4/4 (brown), coherent-platy, compacted, moderately rooted, reduced parts = plough sole.
Bt_1 45- 60 cm	7,5 YR 4/5 (brown), coh.-pol., moderately dense - dense, Mn-concretions, weak reduced and oxidized spots.
Bt_2 60- 75 cm	7,5 YR 4/6 (brown), like Bt_1.
IISdBvt 75-100 cm	7,5 YR 4/6 (brown), coh., dense, weak pseudogleying decreasing with depth.

hor.	depth	sto.	texture of humus-/carb.-free fine soil (%)						
			sand			silt			clay
	cm	%	c	m	f	c	m	f	
Ap	- 30		3.9	6.6	9.5	44.7	20.0	5.9	9.4
AlBt	- 45		2.5	4.3	7.1	43.1	20.5	5.4	17.1
Bt_1	- 60		1.4	2.3	4.5	41.2	22.2	6.3	22.1
Bt_2	- 75		4.1	3.0	4.3	36.8	18.2	5.4	28.2
IISdBvt	-100		11.6	5.6	5.4	29.8	13.3	4.0	30.3

depth cm	bulk dens. g/cm^3	total PV Vol.%	water content at pF (Vol.%) -1.8	-2.5	-4.2	>4.2	kf cm/d
-30	1.53	43.7	10.2	6.6	18.7	8.3	$4.7\cdot10^1$
-45	1.60	44.9	8.6	7.7	18.9	9.7	$4.8\cdot10^0$
-75	1.65	41.6	6.1	5.4	16.8	13.2	$4.1\cdot10^1$

depth	pH		C_{org}	N_t	C/N	Fe_o	Fe_d	Al_d	Mn_d
cm	H_2O	$CaCl_2$	%	‰		‰	‰	‰	‰
- 30	7.7	6.89	1.02	1.09	9.4	2.26	6.34	0.68	0.64
- 45	7.9	7.01	0.45	0.71	6.3	2.32	7.00	0.72	0.57
- 60	8.0	7.22	0.31			2.11	8.21	0.87	0.53
- 75	7.9	7.25	0.24			1.80	10.63	1.11	0.56
-100	7.7	7.18	0.21			1.47	12.05	1.20	0.57

depth	CEC		exchang. cation						V
cm	meq/kg		meq/kg						%
	P	a	Ca	Mg	Na	K	H	Al	
- 30	105	98	87	4	1	6			93
- 45	108	102	92	4	1	5			94
- 60	121	117	108	6	1	2			96
- 75	154	149	137	9	1	2			97
-100	178	175	158	3	1	3			99

Profile 2

Location: topogr. map 1:25 000, 5308 Bad Godesberg
r: 25.7083 h: 56.1793

Exposition: hollow.

Inclination: 2% NE

Vegetation: forest (poplar tree standard coppice)

Parent rock: Würmian loess

Soil type: (FRG) pseudovergleyte Parabraunerde
(FAO/UNESCO) Gleyic Orthic Luvisol
(Soil Taxonomy) Typic Hapludalf/Aquic Hapludalf

Ah 0- 15 cm	7,5 YR 2/2 (black brown), crumby-subpol., loose, well rooted.
AlBt 15- 25 cm	7,5 YR 4/3 (brown), subpol.-coh., loose, well rooted.
Bt_1 25- 40 cm	7,5 YR 5/4 (gray brown), subpol.-coh., loose - moderately dense, decreasing rooting, weak rusty spots and Mn-concretions.
Bt_2 40- 70 cm	7,5 YR 5/4 (gray brown), pol., moder. dense, weakly rooted, many Mn-concretions, larger rusty spots (7,5 YR 4/6).
$SwBt_1$ 70- 90 cm	7,5 YR 4/4 (brown), pol., moder. dense - dense, scarcely rooted, marked pseudogleying.
$SwBt_2$ 90-130 cm	7,5 YR 4/4 (brown), mostly like $SwBt_1$.
BvCv 130-150 cm	7,5 YR 4/4 (brown), coh., loose-moder. dense, weak rusty spots, calcareous (2,7% $CaCO_3$).

hor.	depth	sto.	texture of humus-/carb.-free fine soil (%) sand			silt			clay
	cm	%	c	m	f	c	m	f	
Ah	- 15		0.5	2.9	6.5	43.2	19.6	5.3	22.0
AlBt	- 25		1.4	3.7	5.3	39.5	21.2	6.3	22.6
Bt_1	- 40		1.4	3.4	4.9	35.6	22.2	6.1	26.4
Bt_2	- 70		1.7	3.9	5.2	40.8	17.1	5.3	26.0
$SwBt_1$	- 90		0.9	3.3	5.5	39.7	18.9	4.4	27.3
$SwBt_2$	-130		0.9	3.3	5.9	37.2	18.6	5.1	29.0
BvCv	-150		0.1	0.8	3.0	33.0	29.3	7.6	26.2

depth cm	bulk dens. g/cm^3	total PV Vol. %	water content at pF (Vol. %) -1.8	-2.5	-4.2	> 4.2	kf cm/d
10	1.11	57.0	18.2	11.9	20.4	6.5	$3.0 \cdot 10^3$
35	1.48	47.3	8.5	13.5	16.9	8.4	$7.9 \cdot 10^2$
65	1.65	38.0	4.0	3.9	15.0	15.1	$9.5 \cdot 10^0$
95	1.70	35.7	2.5	2.9	12.8	17.5	$3.3 \cdot 10^1$
140	1.55	38.1	4.1	2.9	16.1	15.0	$2.9 \cdot 10^0$

depth cm	pH H_2O	pH $CaCl_2$	C_{org} %	N_t ‰	C/N	Fe_o ‰	Fe_d ‰	Al_d ‰	Mn_d ‰
- 15	4.6	4.05	3.57	2.49	14.4	3.66	7.82	1.72	1.13
- 25	4.5	3.88	0.65	0.67	9.8	3.40	7.79	0.97	0.60
- 40	4.6	3.95	0.33	0.51		3.66	9.26	1.16	0.94
- 70	4.8	4.06	0.18			2.79	9.04	1.17	0.91
- 90	5.0	4.31	0.18			2.54	9.07	1.04	0.60
-130	5.5	4.74	0.15			2.60	9.57	1.01	0.52
-150	7.7	7.13				1.18	8.97	0.88	0.42

depth cm	CEC meq/kg p	CEC meq/kg a	exchang. cations meq/kg Ca	Mg	Na	K	H	Al	V %
- 15	118	63	24	8	<1	3	8	20	23
- 25	156	57	14	7	<1	1	5	30	19
- 40	133	60	19	9	<1	2	3	27	23
- 70	142	67	27	14	<1	2	6	18	31
- 90	133	77	39	24	<1	2	2	10	49
-130	126	90	56	26	<1	2	0	6	68
-150	113			28	1	2	0	0	100

Profile 3

Location: topogr. map 1:25 000
5308 Bad Godesberg
r: 25.7075 h: 56.1788

Exposition: upland area

Inclination: 0 - 2% N

Vegetation: forest (Oak tree standard coppice)

Parent rock: Loess overlaying main terrace

Soil type: (FRG) Parabraunerde-Pseudogley
(FAO/UNESCO) Gleyic Luvisol
(Soil Taxonomy) Aquic Hapludalf, Aeric Ochraqualf

Ah 0- 12 cm	7,5 YR 3/3 (dark brown), subpol., loose, well rooted, irregular transition to
SwAl 12- 30 cm	7,5 YR 5/3 (gray brown), subpol., loose, moderately rooted, many Mn-concretions and rusty spots (7,5 YR 4/6).
AlSw 30- 45 cm	7,5 YR 5/4 (gray brown), pol., loose-moder. dense, strong pseudogleying with Mn-concretions, clearly marked off.
$BtSd_1$ 45- 60 cm	5 YR 5/4 (gray reddish brown), pol., dense, strong pseudogleying.
$BtSd_2$	like $BtSd_1$, stronger pseudogleying.
IISd 95-120 cm	very dense and clayey gravels (main terrace).

hor.	depth	sto.	texture of humus-/carb.-free fine soil (%)						
			sand		silt				clay
	cm	%	c	m	f	c	m	f	
Ah	- 12		1.2	2.8	5.5	51.9	21.7	5.3	12.4
SwAl	- 30		1.8	4.1	4.0	49.8	22.0	4.9	13.4
AlSw	- 45		1.3	2.6	3.8	46.5	23.0	5.5	17.3
$BtSd_1$	- 60		0.6	1.4	2.8	40.9	20.8	4.9	28.6
$BtSd_2$	- 95		0.9	2.4	4.2	40.1	17.5	4.6	30.3
IISd	-120		4.6	9.4	12.2	34.1	12.9	3.8	23.0

depth cm	bulk dens. g/cm^3	total PV Vol. %	water content at pF (Vol. %) -1.8	-2.5	-4.2	> 4.2	kf cm/d
10	1.23	50.9	15.9	6.4	19.7	8.9	$2.9 \cdot 10^3$
40	1.56	42.3	4.4	2.3	14.2	21.4	$9.3 \cdot 10^2$
65	1.60	41.0	2.3	0.7	13.3	24.7	$8.2 \cdot 10^1$

depth cm	pH H_2O	pH $CaCl_2$	C_{org} %	N_t %	C/N	Fe_o %	Fe_d %	Al_d %	Mn_d %
- 12	4.6	3.97	3.15	2.22	14.2	3.17	6.64	1.28	0.73
- 30	4.4	3.81	0.29	0.42	6.9	2.15	7.02	1.12	0.86
- 45	4.7	3.91	0.18	0.33	5.5	2.71	8.25	1.12	0.68
- 60	4.9	4.05	0.17			2.40	13.27	1.61	0.50
- 95	5.3	4.47	0.16			2.66	13.75	1.56	0.48
-120	5.6	4.78	0.13			2.44	16.44	1.41	0.90

depth cm	CEC meq/kg P	a	exchang. cations meq/kg Ca	Mg	Na	K	H	Al	V %
- 12	141	53	22	5	1	2	6	17	21
- 30	95	44	8	5	1	1	2	27	15
- 45	121	77	22	26	1	2	4	22	42
- 60	186	124	59	37	1	4	5	18	54
- 95	218	125	81	27	1	4	2	10	52
-120	158	91	77	4	1	3	-	6	54

Profile 4

Location: topogr. map 1:25 000
5308 Bad Godesberg
r: 25.7073 h: 56.1787

Exposition: upland area

Inclination: 0 - 2% E

Vegetation: forest (Oak-tree standard coppice)

Parent rock: Würmian loess everlaying clayey gravels (main terrace)

Soil type: (FRG) stark entwickelter Pseudogley
(FAO/UNESCO) Gleyic Luvisol
(Soil Taxonomy) Typic Ochraqualf, Aeric Ochraqualf

Ah 0- 15 cm	7,5 YR 2/1 (black), subpol., loose, well rooted, irregular transition to
AhSw 15- 20 cm	7,5 YR 4/2 (brownish gray), coh., loose, well rooted, weakly bleached.
AlSw 20- 50 cm	7,5 YR 6/3 (gray orange), coh., loose, very few roots, many partly firm Fe- and Mn-nodules, rusty spots.
BtSw 50- 80 cm	7,5 YR 5/6 (light brown), pol-coh., moderately dense, few concretions, many rusty spots.
IISd 80-100 cm	very dense loamy-clayey gravels (main terrace).

			texture of humus-/carb.-free fine soil (%)						
hor.	depth	sto.	sand			silt			clay
	cm	%	c	m	f	c	m	f	
Ah	- 15		1.6	2.6	4.0	48.2	22.4	5.6	15.6
AhSw	- 20		1.4	2.6	4.8	49.6	22.0	5.1	14.5
AlSw	- 50		2.3	2.5	4.1	47.3	21.9	5.4	16.5
BtSw	- 80		1.4	1.7	2.9	41.7	21.2	5.0	26.1
IISd	-100		27.8	5.9	3.3	18.9	11.0	3.5	29.6

depth	bulk dens. g/cm^3	total PV Vol. %	water content at pF (Vol. %) -1.8	-2.5	-4.2	>4.2	kf cm/d
10	1.22	54.3	12.4	9.3	24.2	8.4	$3.6 \cdot 10^2$
25	1.55	43.8	8.9	4.6	18.4	11.9	$2.7 \cdot 10^2$
40	1.59	43.0	8.6	2.2	16.7	15.7	$2.2 \cdot 10^2$
70	1.59	41.9	7.6	2.4	16.1	15.8	$1.8 \cdot 10^2$

depth cm	pH H_2O	$CaCl_2$	C_{org} %	N_t ‰	C/N	Fe_o ‰	Fe_d ‰	Al_d ‰	Mn_d ‰
- 15	4.2	3.55	4.80	2.95	16.4	4.69	7.10	1.74	0.14
- 20	4.1	3.60	2.02	1.12	18.1	1.96	4.21	1.23	0.04
- 50	4.6	3.88	0.28			2.37	9.15	1.14	0.17
- 80	5.2	4.35	0.20			2.34	10.47	1.17	0.77
-100	5.3	4.65	0.20			2.75	19.40	1.92	2.89

depth cm	CEC meq/kg P	a	exchang. cations meq/kg Ca	Mg	Na	K	H	Al	V %
- 15	200	74	11	4	1	2	2	45	9
- 20	120	60	6	3	1	1	2	37	9
- 50	94	48	7	8	1	1	1	30	18
- 80	150	106	55	33	1	2	1	13	61
-100	169	132	78	41	2	3	1	7	73

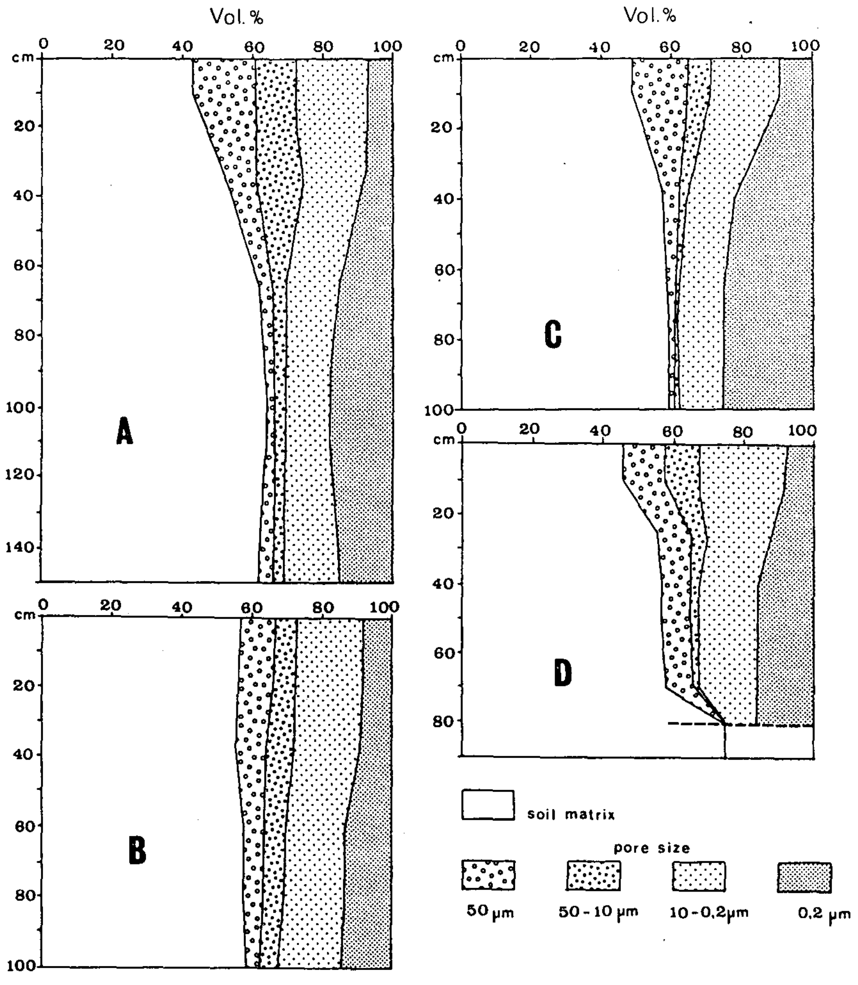


Fig. 2: Pore volume and pore size distribution in the Kottenforst profiles

A: pseudovergl. Parabraunerde (Typic Hapludalf), forest

B: pseudovergl. Parabraunerde (Typic Hapludalf), field

C: Parabraunerde-Pseudogley (Aquic Hapludalf), forest

D: Pseudogley (Typic Ochraqualf), forest

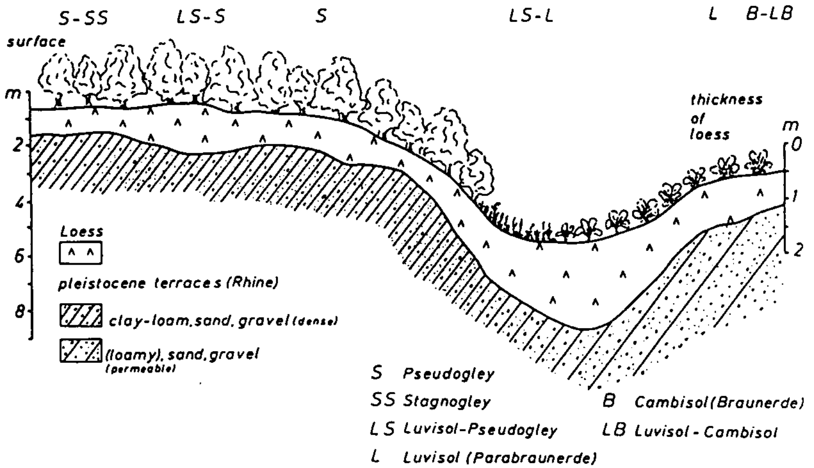


Fig. 3: Scheme of soil pattern (Lithosequence) in the Kottenforst area

Soil moisture measurements

The characteristic of these sites is a pronounced temporarily wetness with reducing conditions during the vegetation period and dry phases during summer time. The risk for damaging forest trees increases with decreasing loess thickness. Because of lacking knowledge about quantitative datas of the moisture regime and it's temporal progress soil moisture measurements at the four sites were carried out. The measurements started in 1983 after a very long dry period just before the first winter rainfall. The soils were dried up very deep and reached nearly the permanent wilting point. In the strong pseudogleyic soils the still present moisture content was somewhat higher. 1984 was a very wet and cool year (Fig.3). The precipitation amounts 901 mm, with extremely high rainfall in May and September. The precipitation was summarized in decades and graphed with the soil moisture progress (Fig.5 and 6

High precipitations result in the field-para-brown earth to short term perched water, which reaches the surface due to compaction beneath the plough layer. The water input to the forest soil is modified by interception changing with the leaves cover. In the forest para-brown earth the pronounced wetness was

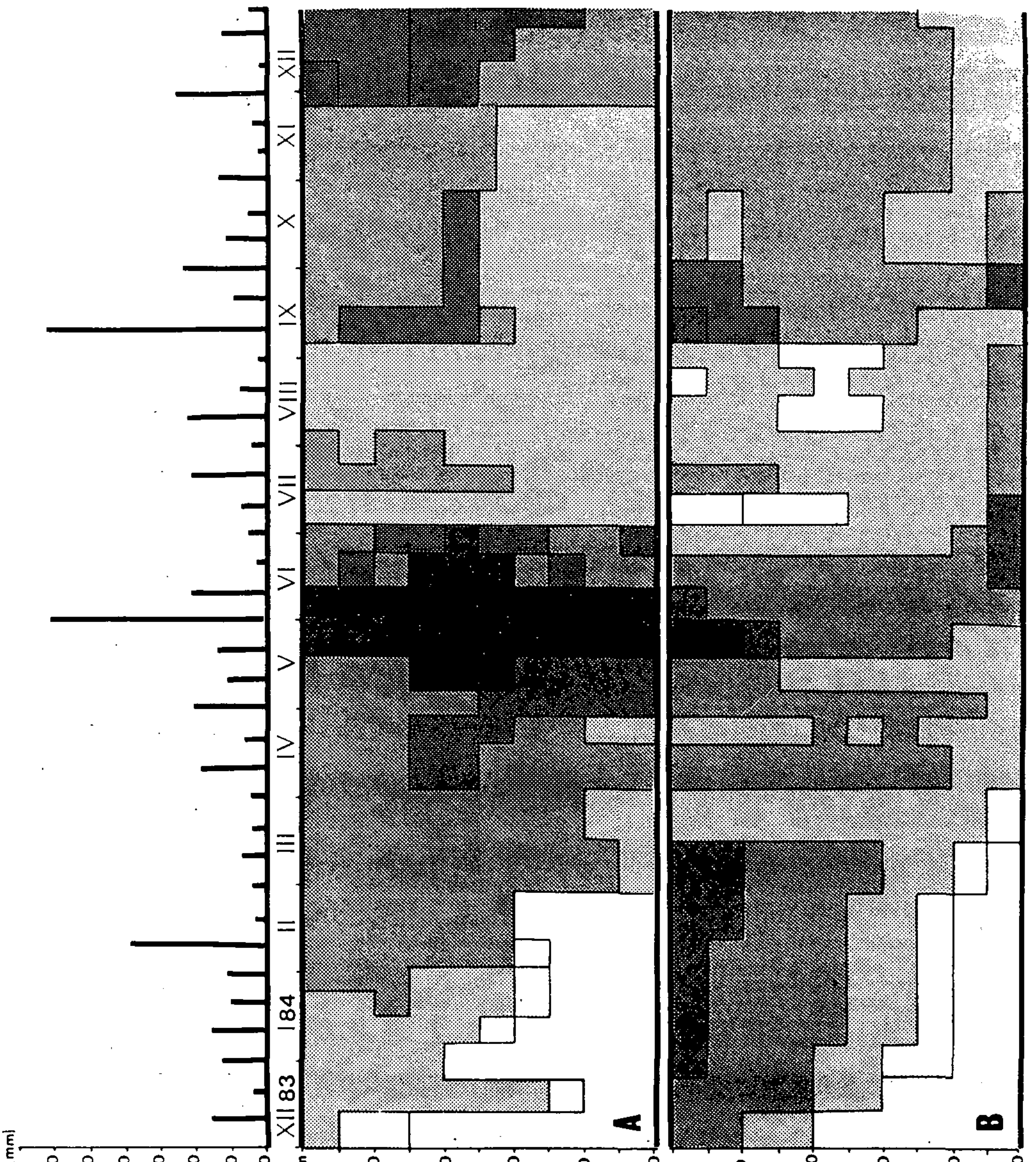


Fig. 5: Soil moisture tension in two Kottenforst soils (1984)
A: typic Hapludalf (forest)
B: typic Hapludalf (field)

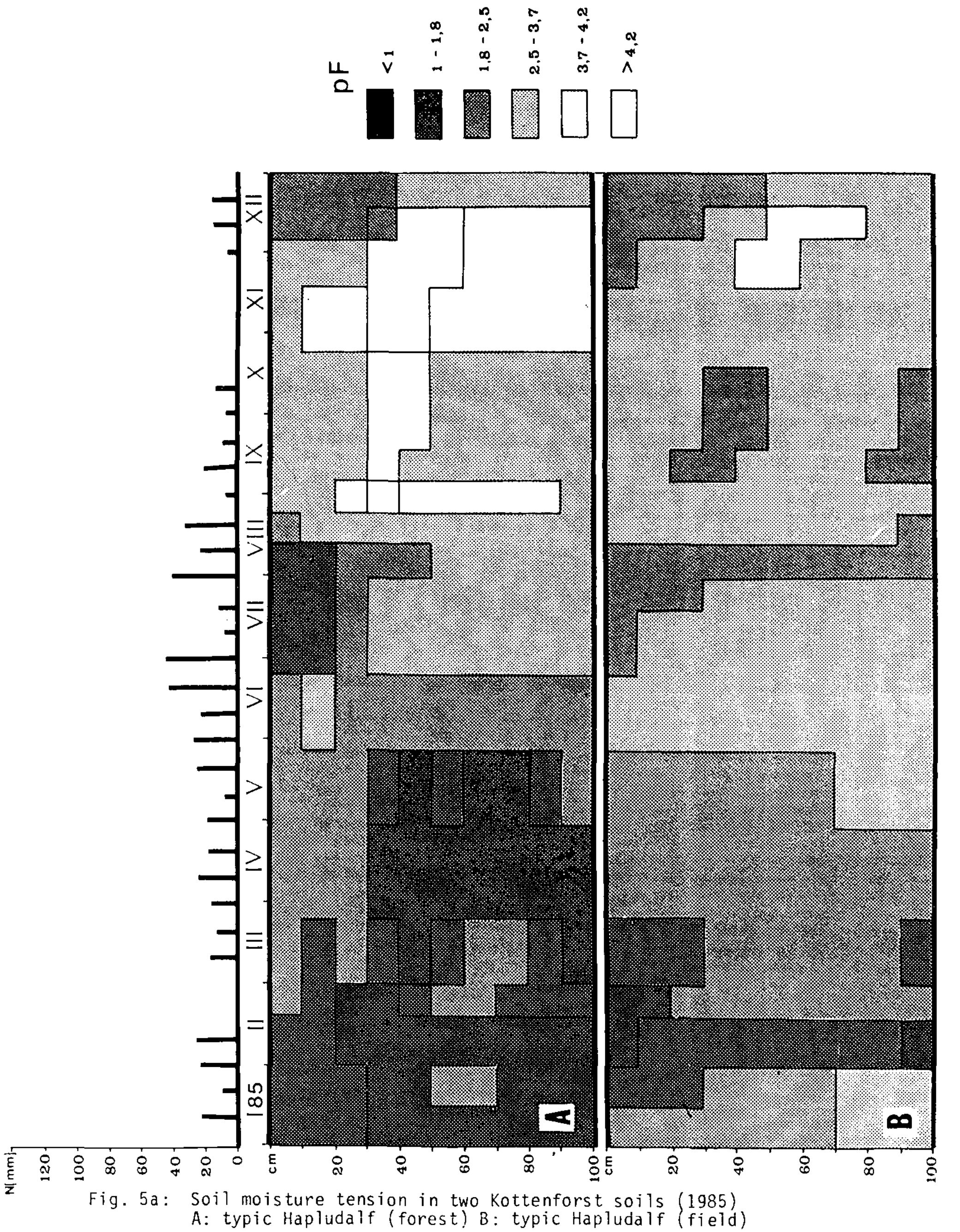


Fig. 5a: Soil moisture tension in two Kottenforst soils (1985)
A: typic Hapludalf (forest) B: typic Hapludalf (field)

Fig. 6: Soil moisture tension in two Kottenforst profiles (1984)

C: Aquic Hapludalf (forest)

D: Typic Ochraqualf (forest)

Fig. 6a: Soil moisture tension in two Kottenforst profiles (1985)
C: Aquic Hapludalf (forest) D: Typic Ochraqualf (forest)

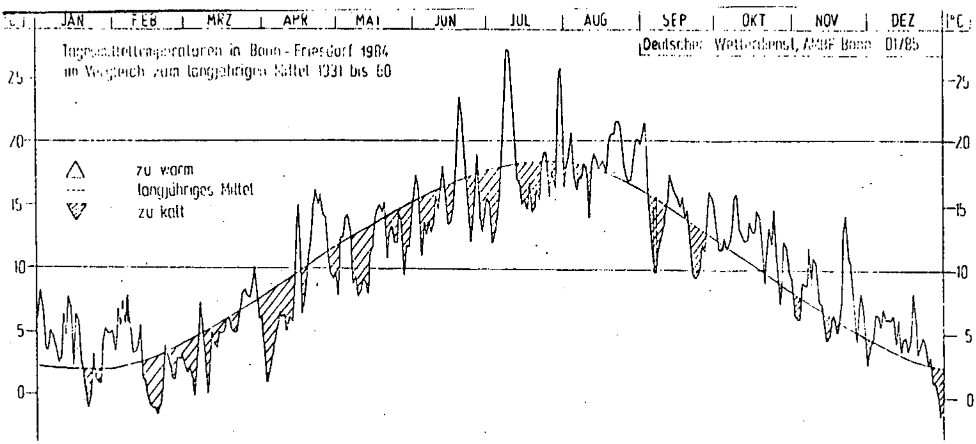


Fig. 4: Average temperatures in 1984 (daily temperatures compared with the longterm average)

caused by lateral water flow from higher located pseudogley areas. In 1984 twice surface water supply was observed. Long term wetness during the vegetation period is not very common. In the arable soils the tillage in autumn and spring can be restricted. The soil is compacted from the surface by heavy machines, so the wetness will be intensified.

In the para-brown earth-pseudogley a clear division of the soil moisture characteristics can be seen. Above the $BtSd_1$ perched water was found over a long time in this year, only the first 10 cm were something dryer. Remarkable is the strong change in water tension from the Sw to the Sd. How the lateral water flow the perched water increases is not clear, but it may be presumed.

The pseudogley was wet to a large part of the year. On the contrary to the preceding soil the wetness is distributed in the whole soil. Impeded drainage is due only to the transition to IISd ("Kottenforst-Loam"). The uppermost 20 cm, at the same time the most important root zone, are distinctly dryer, probably because of transpiration.

Discussion

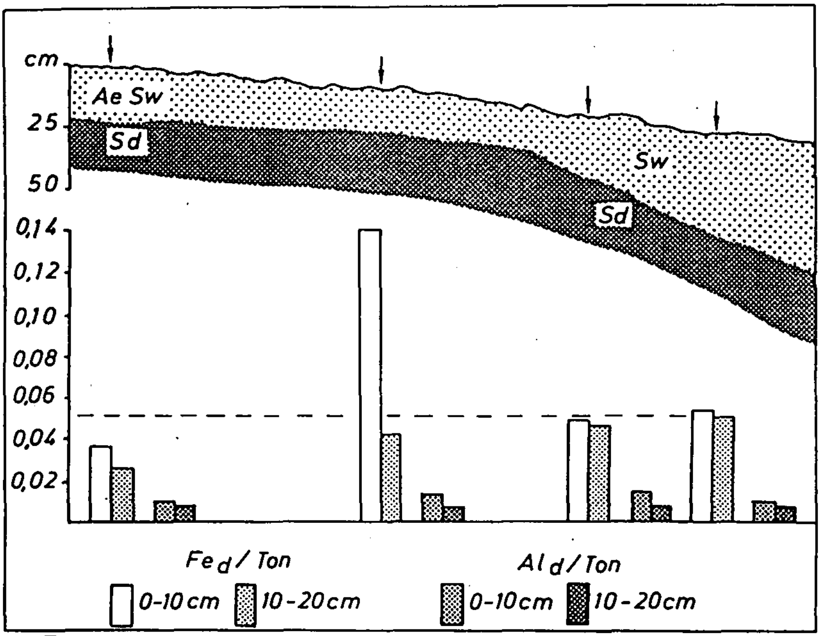
Because of similar grain size quotients the loess cover is relatively homogenous. Higher sand/coarse silt values in the transition to the main terrace are due to cryoturbate mixing of loess with the fossil weathered material (so called "Kottenforst-Loam"). The grain size distribution is determined by the clay translocation. Probably the pseudogleyic para-brown earths in the field and under forest are shortened by erosion about 20-40 cm, as it can be concluded from the thickness of Al-horizons in other profiles in the region.

Some differences are obviously between pore size distribution and the soil moisture measured in the field. Although the soils are very loose in the Sw-horizons, probably the total pore space and therefore the pores >50 μ too may be overestimated. The instability of soil structure is expressed by the compaction of the arable soil. Because of intensive tillage (root out of sugar beets and following sowing of whinter wheat until december) the unfavourable physical soil conditions grow up more and more. It must be taken into consideration, that at the field site the main terrace is more sandy and permeable, the dense "Kottenforst-Loam" is absent (Fig.3).

The thickness of the root zone is determined by the density of the horizons (physical) and/or by oxygen deficiency (water table) during the vegetation period (physiological). Spruce react extremely sensitive to unfavourable rooting conditions, resulting in very shallow root stocks and increasing wind throw. Shallow root stocks cause rapid water stress in dry periods, therefore damages from dryness happen frequently at spruce and beech on the pseudogley areas. Melioration of these soils is scarcely possible. Loosening of compacted layers until 80 cm depth is possible, but it is not for the deeper Sd-horizons of the main terrace. Ecological judgement of the temporarily wetness is rendered by lateral water flow. Despite of only some decimeters difference in altitude you can observe a considerable water flow above the dense horizons. Many deep eroded brooks are only running in wet periods and are fed only from perched water.

The distribution of elements is dependent of the percolation and of the lateral water flow. Additional Fe- and Mn-oxides are mobilized or immobilized according to redox-gradients. So in **extreme** pseudogleys the beginning of bleaching in the uppermost humous horizons and a lateral transport of Fe and Mn can be observed. In the most pseudogleyic horizons the translocation is restricted to accumulation in spots and/or mm- to cm-large concretions.

Like many other forest soils, these soils are very acid with low base saturation and high exchangeable Al-content in the upper 40-60 cm. Under that the base saturation increases very quickly. The exchange capacity is more than 50 mval/100 g clay, so the buffering capacity is high.



$Fe_{o/d}$					
	0-10	0,67	0,91	0,64	0,48
	10-20	0,57	0,70	0,49	0,35
Fe_d/Fe_{py}					
	0-10	0,44	0,54	0,32	0,30
	10-20	0,35	0,37	0,24	0,22

Fig. 7: Translocation of iron oxides by redox-processes in the top layers of Ochraqualfs (⟶ Hapludalfs)

Fe_d, Al_d: Na-dithionite/Na-citrate soluble Fe and Al

Fe_o: NH_4-oxalate extractable Fe

Fe_{py}: Na-pyrophosphate extractable Fe

Ton = clay

X-ray analysis showed in all soils an identical clay mineral composition. In the deeper horizons illites and expanded illites are dominant beside chlorits. In the uppermost layers the reverse can be seen. Alternate-bedding minerals and chlorites are increased while the illite-content has decreased. A relatively marked kaolinite content is characteristic for loesses in this region. There is no clear sign for the occurence of old loess in this profile.

The mineralization of organic matter is well. Despite of high C/N-ratios the forest humus type is typical mull ("L-Mull") or Of-mull ("F-Mull") (Kartieranleitung, 1982) because of the influence of the N-rich herb-vegetation. Normally the wetness in the Ah-horizon is not high enough to prevent mineralization or to form humus layers like in stagnogleys. On the contrary the moist conditions in periods with higher temperature favour the decomposition of organic matter. The higher C/N-ratio of the organic matter in the more wet subsoils may be due to restricted mineralization and humification under wetter conditions.

Summary

Four typical soils derived from loess overlaying main terrace sediments of the Rhine in the Kottenforst/Ville area are demonstrated. By clay illuviation, by fossil weathering of the old terrace materials and by cryergic mixing dense horizons are formed. Therefore perched water is a common feature in these pseudogleyic soils.

The temporal progress and the extent of soil moisture is shown by continuous measurements. Decreasing thickness of loess is mostly connected with increasing temporarily wetness. Despite of low fall lateral water flow of perched water plays an important role. The root zone is restricted by oxygen deficiency caused by wetness during the vegetation period. Shallow root depth leads to damages by wind throw and by water stress in dry summers.

The soils are very acid in the upper horizons, but show a good decomposition of the organic litter. Especially with herb vegetation mull-like humus types are formed. Deeper than 60 cm the base saturation rises to >50%. Fe- and Mn-oxides are distributed by clay illuviation and by redox-processes. Bleaching and lateral translocation of these elements with perched water discharge are found in strong developed pseudogleys.
Fields are situated in areas with less temporarily wetness because of better

soil permeability. Nevertheless these soils are temporarily wet because of increasing compaction by tillage in the late autumn after sugar beets harvesting. In a swinging up-process soil wetness in the upper horizons and destruction of soil-structure are enhanced.

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Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 135 - 140, 1986

Rhenish Lignite District

by

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Geologisches Landesamt Nordrhein-Westfalen, Krefeld

Depositional and geological situation

The Rhenish Lignite District is situated in an area between Cologne, Düsseldorf and Aachen. The lignite reserves are an estimated 55 billion tons, of which 35 bil. tons can be recovered according to the current ecological and technical feasibility. Therefore the Rhenish District can be considered as the largest continous lignite deposit in Europe.

The lignite was deposited during the Tertiary (Miocene) when in the southern part of the Lower Rhine Basin enormous amounts of peat were deposited on a gradually subsiding basement under subtropical conditions. This peat was then gradually altered into lignite. The coal seam reaches its maximum thickness of about 100 m near Bergheim in the center of the basin. During the Tertiary the North Sea transgressed several times from the northwest into this area of tectonical subsidence and subsequently covered the peat deposit with marine sands. On the other hand, the extended coastal swamps of the southwestern area of the basin were covered by fluviatile sands, silts and clays. Therefore in these marginal areas the main seam was split into several smaller seams.

Surface mining and Environment

Due to the geological setting, and also for technological, ecological and safety reasons, the lignite can only be recovered by open pit mining. The areas with coal near to the surface and with a favorable waste to coal ratio have been almost entirely exploited already. For the 5 bil. tons of coal recovered up to 1985, almost 21 000 ha of land have been used up.

For a long time running and also for the future about 120 mil. tons of lignite are being annually mined in the Rhenish District. With the increasingly less favorable ratio of waste to coal this operation requires measures of soil removements at a scale of several hundred million cubic metres per year. Therefore in the coming decades a further thousands of hectares will be claimed which are now being used for farming as well as for forestry purposes.

To keep the open pits dry right down to their lowest level, the groundwater level has been delowered by an already decade-long pumping of about 1 bil. cubic metres per year. As regards extension and depth, the lowering of the groundwater table in the Rhenish Lignite District can be considered as the largest in the world.

Similar far reaching consequences for the environment can be also expected from the dumping of the power plant residues. They consist of sulphate-bearing ashes plus the extra gypsum sludge produced by future desulphurization units. There is no question that the only briefly outlined measures due to the lignite mining operations will have enormous consequences for the natural realm such as soils, water and vegetation, climate, fauna and land use. The open pit Hambach I for instance which was started in 1978 requires earth shifting operations of gigantic dimensions: 2,4 bil. tons of lignite covered by 15 bil. tons of overburden will be mined within the next 50 years. In connection with the eastward adjoining field Hambach II, about 4,5 bil. tons of lignite will be available for exploitation which equals the energy potential of 1,6 bil. tons of hard coal units.

The earth movements necessary for the lignite mining will drastically alter the present-day character of the landscape. Whereas at "Sophienhöhe", situated northwest of the open pit Hambach I, waste material is dumped up to a height of 275 m above zero, meaning a 170 m above the local surface, the coal in the southeast of the mining field will have to be mined up to a depth of about 400 metres.

When the groundwater delowering in this mining field has come to an end, a remaining lake will develop with a water content of about 2 bil. cubic metres. This will exceed the combined storage capacity of all water dams in the Federal Republic of Germany.

Subsequently an explanation of the various measures to maintain or restore a new functioning environment will be given.

Reclamation

The overburden layers of the open pits can be subdivided according to their petrographical composition and stratigraphical features as follows:

Loess	
Gravels and sands of the Main and Middle Terrace of the Rhine and the Meuse	Pleistocene
Sandy gravel (Kieseloolith-schichten)	Pliocene
Sand with clay layers	uppermost Miocene

For the planning of the subsequent it is neccessary to investigate the overburden layers at a very early stage from the geological and soil-scientifical aspect in order to explore their properties. Of special importance is the loess which as a major parent rock can be found in all areas of the mining district. It covers the gravels and sands of the Pleistocene terraces with a varying thickness. Maps that show these varying loess thickness at a scale of 1:10 000 were compiled from which were deduced the amounts of soil material appropriate for reclamation pruposes. Many hundred millions of cubic metres of loess are available in the northern, medium and western sector of the lignite mining district. Because of it's good properties as an easily arable soil material, this loess can be considered as an important gift of nature which is suitable for various reclamation purposes.

The quality of the available loesses depends mostly on its thickness and on its soil-typological development. At a thickness of 0,5 to 1,2 metres the existing soils are predominantly pseudogley soils of secondary origin. A periodical change of intense water-logging interrupted by times of more or less extreme desiccation is a typical feature of these stagnant water soils. Therefore they are commonly used for forestry. Their widespread appearance depends on the fact that percolating water is held back by the deeper lying gravelly-sandy Main-Terrace which in its upper parts was compacted by a fossil soil formation process of a brown-loamy development.

Under the temperature-humid climate of the Kölner Bucht (medium annual temperature 9^{0} C, average annual precipitation 650 mm), parabraunerde soils with a high base content and a deep development originated from loess covers more than 2 m thick. The top level of the unweathered calcareous loess can mostly be found at a depth of 1,8 - 2,5 m. In locally more slanted areas the solum appears to be less thick, as the readily erodable loess loam was removed in large sheets down to the B_t- or to the B_v-horizon.

For all the open pit areas maps of soil types at a scale of 1:10 000 were elaborated from which one can read the soil kind, the soil kind layering, the water conditions and the dominating soil type. Information about quality and quantity of the loess material suitable for reclamation can be obtained from these maps.

For the agricultural reclamation mostly the thick loess layers, developed as parabraunerde soils, are being used. This happens in a way that the loess loam of various horizons is mixed with calcareous loess at a ratio of about 1:1 to 1:3; this material is used for covering the raw material dumps. This loess mixture is a sandy-silty loam with a clay content of marginally less than 10%, with a neutral to weak basic reaction and a content of free $CaCO_3$ of about 7%. The content of organic matter in these new soils is initially about 0,6% and is enriched in the top soil by an annual 0,04%, until a humus content of 2% with C/N ratios of about 12 to 15:1 is reached. This equals the typical values of the natural parabraunerde soils in this area.

The thickness of the loess cover for the open pits of the northern, middle and western lignite district has been fixed to reach 2 m in a settled condition. Under appreciation of the relatively low rate of precipitation, of the generally low lying groundwater table, of the water capacity of the loess and of the depth of rootability, this loess thickness guarantees optimum yields.

As regards forestry reclamation one uses generally the originally thin loess covers which are developed as pseudogley soils. A mixing of this loess loam with the deeper lying sandy-pebbly layers of the Main or Middle terrace already takes place at the state of recovery. For the reclamation of plane areas the loess loam share in the cultivable soil material should be 25 to 70%. On slopes the amount of loess should be limited to 20 to 25% because of the increased risk of erosion.

The thickness of soil material appropriate for afforestation normally comes up to 4 m. Experience showed that in such a way forest soils were reclaimed which possess a natural potential for forestry purposes and which under normal management maintain and guarantee a good continuous growth rate.

Waste material dumps

A share of a hundred million tons annually of the entire coal output of the Rhenish lignite district is being used for the generation of electricity. This leads to a residue of about 8 mio. tons of power plant ashes which consist on one hand of the mineral substance incorporated in the coal itself and of small sand, silt, and clay layers which occur along with the coal. Since decades these waste materials have been dumped in abondoned sections of the near by open pits.

Extensive investigations of the Geological Survey on the effect of power plant ashes on the chemistry of groundwater revealed that the ashes contain a considerable amount of soluble sulphates. This can be concluded from the fact that with the burning of the lignite about 60% of its sulphur content are emitted as SO_2 into the atmosphere, whereas the remaining 40% stay with the ashes mostly as $CaSO_4$. The total sulphur content of the ashes is about 7%.

As the dumped normal overburden and the ashes have about the same water permeability ($K_f = 5 \times 10^{-5}$ m/s), the groundwater will penetrate and migrate through the ash deposits after the pumping of a certain mining field has come to an end. This leads to an initial dissolution of those sulphates that are fixed to potassium, natrium and magnesium. This results in concentrations of sulphate in the groundwater of up to 40 000 mg SO_4/l. For a very long period then the sulphate fixed to calcium goes into solution with a level of about 1 000 mg/l. This water which is highly enriched in sulphates will therefore pollute the groundwater also outside the mining district and subsequently also the receiving rivers to an unbearable extent. To avoid any detriment of the groundwater quality, extensive protection measures (sealing of the ash dumps with clay or with plastic foil) would be required which in return would be very costly.

After extensive investigations a new method of dumping power plant ashes without detriment to the environment was developed in the GLA. It works the following way: In the process of dumping water is added and mixed with the ashes until they have the consistency of a pulp or freely flowable slurry. The compaction achieved this way plus the spontaneously starting chemical reaction result in a far reaching alteration of the physical properties of the ashes that were treated in such a way.

The application of the new procedure in the mining practice showed a reduction of the water permeability to $K_f = <1 \times 10^{-8}$ m/s, i.e. a reduction by the factor 1 000 to 10 000 compared to normal ash dumps. The ash dumps built up according to the new method therefore turn out to be so impermeable that water percolation will practically not accur at all. The current problem of dumping sulphate bearing lignite power plant ashes can be regarded as being scientifically and technically solved.

The just demonstrated procedure is especially highlightened by the fact that the installation of chimney gas desulphurizors is compulsary since 1983 to reduce the admospheric SO_2-level and its subsequent effects on the environment ("acid rain"). In the near future this will lead to enormous amounts of $CaSO_4$ and/or $CaSO_3$ residues as well as to heavily polluted waste waters. Although a certain amount of the gypsum might be used up by the building industries, one can surely assume that a substantial proportion of this residue will have to be dumped. This actually means that the lingering problem of the SO_2-pollution will be shifted from the atmosphere to the soils and finally into the groundwater.

However, a method was also developed to dump these residues without detriment to the environment. Accordingly, those slurry or liquid waste materials produced by wet desulphurization have to be mixed with the lignite power plant ashes. The resulting final product is relatively impermeable; there is practically no dilution of pollutants as was proven by long-term experiments.

These new two procedures show a practicable way for dumping the sulphate-bearing power plant ashes as well as the residues of the wet desulphurization without detriment to the environment.

Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 47, 141 - 152, 1986

Pedological investigations in the lower rhine area near Bocholt (Westf.)

by

G. Einars and G. Schollmayer+

1. INTRODUCTION

More and more intensive methods of agriculture production, coupled with increased use of fertilizers, have lead in the last two decades -especially in farming areas with very permeable soils- to constantly rising concentrations of substances in groundwater close to the surface. A particular role is played in this context by the greatly risen proportion of nitrogen, which -as a function of numerous parameters, e.g. agricultural use, frequency and amount of nitrogen fertilization, type of soil, and quantities of seepage water- can result in increased amounts of nitrates/nitrogen being washed out of root-penetrable soil and hence in greater nitrate concentrations in groundwater. In many agricultural areas where groundwater is used for drinking water supplies, a large number of utility companies are thus likely to encounter considerable operational difficulties on account of the legally stipulated reduction from 1985 onwards of the limit value for nitrate in drinking water from 90 mg/l to 50 mg/l.
In the catchment areas of the Mussum and Liedern waterworks in the Bocholt region (Fig. 1), which have already been examined in earlier projects (OBERMANN, 1981), further studies are to be carried out on natural nitrate decomposition in the unsaturated soil zone and the waterbearing stratum in an area of Schüttenstein Forest intended to be used for obtaining drinking water.

On the basis of the results of the pedological mapping (Fig. 2) and the hydrochemical sampling to determine substance concentrations at the groundwater surface and with due regard to the use of land for forestry or agricultural purposes, six representative sites with different degrees of denitrification in the unsaturated soil zone were selected for the soil-chemical and physical investigations. Schü 1, 3 will be presented for the excursion stops.

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The following objectives have been established:

- Mapping of hydrogeological, pedological and agricultural situation in the catchment area of the drinking water procurement envisaged at Schüttenstein.
- Measurement of substances at the groundwater surface as a function of agricultural uses and pedological conditions in the catchment area.
- Measurement of substances concentrations in the waterbearing stratum.
- Description of nitrate mobility -with die regard to laboratory, lysimeter and model-test results- determined by field measurements in the unsaturated zone and at the groundwater surface.
- Interpretation of the possibility of NO_3/SO_4 decomposition processes in the soil, seepage water and groundwater.

Position of area under investigation

The area concerned lies to the west of the town of Bocholt in Borken District in the north-eastern part of the Lower Rhine Basin near the German-Netherlands border.

In terms of natural regions, the area under investigation is part of the western edge of the Bocholt Sand Plain. It lies in the Issel Plain, which, on the right of the Rhine and north of Wesel, embraces large portions of the Lower Rhine (Issel) Terrace.

The surface relief is determined by late-Pleistocene drifting cover sands over silty to gravelly Lower Terrace sands not far below, the sands frequently being fluvially reassorted.

Climate

The climate is, owing to the Lower Rhine Basin being open in the direction of the North Sea, of a maritime nature with moderate summers and fairly mild winters only a few days snow or frost on a long-term average. Annual precipitation usually lies between 650 and 850 mm; the long-term mean (1951-80) for Bocholt weather centre is 742 mm. The mean air temperature is 9.6^{o} C. Mean annual evaporation in the Bocholt region is 475 mm.

Land use

By far most of the area under consideration is used for agriculture (approx. 65% of the total) or forestry (approx. 12%, Schüttenstein Forest). Because of turf fertilization up to the mid-19th century, humous up to 4-12 dm thick formed on the higher drifting cover sand bars; mainly cereals were cultivated on them. The Aa and Issel lowlands were originally used only to a limited extend for grassland farming owing to regular flooding and substantial soil moisture caused by the high groundwater level.

2. Geological overview

The Tertiary sea transgressed especially during the Oligocene and Miocene into the Dutch/Lower Rhine Tertiary basin, which had been sinking to differing extents in individual regions ever since the start of the Tertiary. In the area under investigation, the Tertiary sea left behind an approx. 250 m thick, mainly silty to clayey sequence of sediments. In the course of the Quarternary, the present-day terraced terrain of the Lower Rhine region evolved above the sediments. Remains of the younger Main Rhine Terrace have been preserved to the east of Bocholt over the Tertiary eminence in the form of the Dingden Heights.

During the Elster ice age, the entire terrain of the younger Lower Rhine deposits (Lower Terrace, lower Middle Terrace) was -assisted by eustatic changes of the sea level and tectonic upheavals- washed away by the Rhine right down to the Tertiary base. The groove cast consists of gravelly medium-grained sands of the Krefeld groove layers, which were covered during the Saale and Weichsel ice age by the sandy gravels of the lower Middle Terrace and the Lower Terrace.

The area under investigation received its present surface configuration through the cover sands drifts of the Lower Terrace in the last glacial stage of the Weichsel ice age and, in the lowlands, through the Holocene flood sedimentation of the Issel and Aa rivers.

In the Middle Ages, land clearance, turf-cutting and excessive grazing in many parts caused heath formation and the more recent dune formation, e.g. in Schüttenstein Forest.

3. Excursion stops

3.1 profile: Schüttenstein Forest 1:

location: north-east part of Schüttenstein Forest; topogr. map 1:50 000
sheet 4104 Bocholt (Herzebocholt-East)
R: 25 34925 H: 57 44970

groundlevel: ~19.0 m >NN

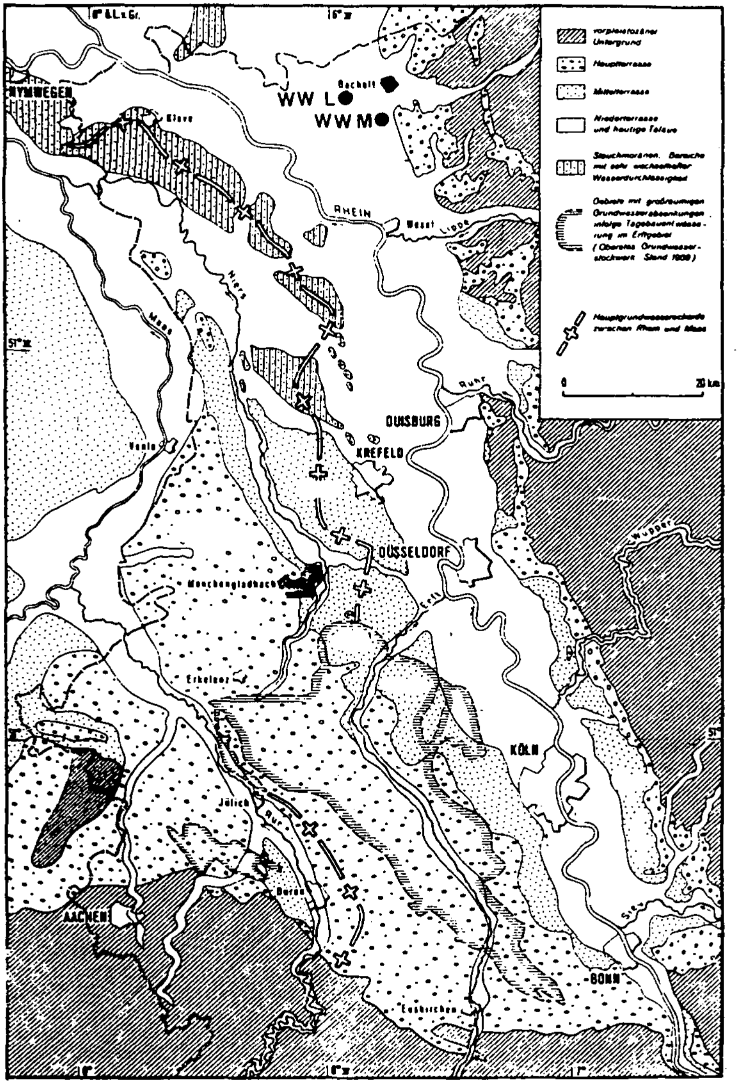

Fig.1: Locations of the investigation area
WWL = waterworks Liedern
WWM = waterworks Mussum

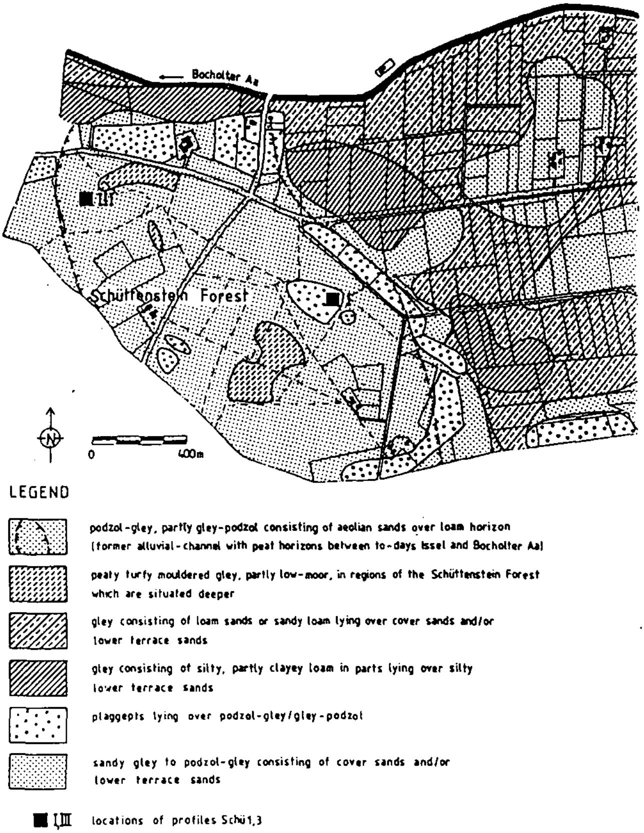

Fig. 2: Soil Sketch map of the investigation area with the excursion stops

morphology: anthropogenic arable area over planed dune area with horizontal ground level
vegetation: pine forest with gras, partly blackberrys
climate: average annual temperatures 8.3^{o} C; mean annual precipitation 757 mm
initial material: plaggen epipedon over valley- and dune sands (16 dm) over meadow loam (3 dm) over fine-medium sands of the low terrace
groundwater level: 25 dm under soil surface (aug. 84)
soil-type: Plaggenesch over Gleypodsol (E/gP); FAO: plaggensoil over gleyic podzol; US Soil Taxonomy: plaggept over artificial drained haplaquod
land value (soil characteristic): low (grade) to medium (25-35)

Ah	0- 17 cm	recent, anthropogenic altered soil;
E1	17- 35 cm	10 YR 3/2 blackbrown, humous partly loamy fine to medium sand, with etiolared quartz grains, well regular rooted and a light coherence structure; microscopy: single-grain structure sand with organic matter (interconnecting coproliths), ~63 um coproliths with detritus, some fungal sclerothies and charcoal;
E2	35- 60 cm	10 YR 2/1 black, humous fine to medium sand, homogenous rooted with a coherence structure; microscopy: predominantly single grains with more humic envelope and charcoal; slight undulating transition to IIf(Ae)Bh;
IIf(Ae)Bh	60- 70 cm	10 YR 3/1 blackbrown, humous, fine to medium sand, etiolated quartz grains, well rooted; microscopy: main part less humus in the ground mass, some parts with peaty and disintedrated, brownished plant residues, roots and fungi; slight undulating and irregular transition to IIfBh;
IIfBh	70- 80 cm	7.5 YR 3/4 irregular dark brown, humous, fine to medium sand, well rooted with a coherence structure and more compacted humic accumulations; microscopy: very light, incomplete envelope

		structure with thin relatively bright humic envelopes, partly single grain structure with few coproliths, intergranular space most empty, some roots; very undulating transition to IIfBhvl;
IIfBhvl	80- 95 cm	7.5 YR 4/6 irregular diffuse, faded brown, humous, loamy fine to medium sand, more humus infiltration along root-tubes; downwards yellowish gray to yellow grayish, little coherence structure by predominant humus accumulation; diffuse transition to IIfBhv2;
IIfBhv2	95-120 cm	10 YR 7/1 clearer yellowish gray, diffuse distribution, humous loamy fine to medium sand, less coherence structure with irregular formed single clay-aggregates, no more roots; undulating transition to Grl;
Grl	120-150 cm	2.5 YR 7/2 uniform, light yellowish gray, loamy sand, more coherence structure with stronger clay aggregates, no humus-infiltration;
Gr2	150-180 cm	2.5 YR 6/2 light brownish gray, more coherence, no humus accumulation.

<u>Profile Schüttenstein Forest 1</u>

			texture of humus-/carb.-free fine soil (%)						
hor.	depth	sto.	sand			silt			clay
	cm	%	c	m	f	c	m	f	
Al	0- 8	-	0.8	58.3	31.4	3.3	1.6	0.1	4.5
A2	8- 17	-	0.8	60.4	30.3	3.2	1.3	0.7	3.3
El(Ap)	17- 35	-	1.0	60.4	26.8	3.6	1.6	1.9	4.7
E2(Ap)	35- 60	-	0.7	59.5	27.4	2.5	3.6	1.4	4.2
(AeBh)	60- 70	-	0.8	60.2	31.0	1.9	1.4	1.1	3.6
Bh	70- 80	-	1.1	62.6	28.8	1.8	1.4	0.9	3.4
Bhvl	80- 95	-	1.2	66.3	27.2	1.1	1.0	0.9	2.3
Bhv2	95-120	-	0.8	66.1	27.9	1.5	0.8	0.8	2.1
Grl	120-150	-	0.4	67.1	26.4	2.8	1.1	0.6	1.6

depth cm	CEC meq/kg P	a	exchang. cations meq/kg Ca	Mg	Na	K	H	Al	V %
0- 8	130,0	41,1	4,8	1,7	0,4	1,2	8,0	25,0	6,2
- 17	74,1	30,4	1,4	0,4	0,2	0,4	6,0	22,0	3,2
- 35	127,4	43,0	1,1	0,7	0,6	0,6	5,0	35,0	2,3
- 60	118,8	44,2	0,9	0,5	0,4	0,4	6,0	36,0	1,8
- 70	65,7	24,7	0,5	0,3	0,6	0,3	4,0	19,0	2,5
- 80	68,5	18,9	0,8	0,3	0,5	0,3	2,0	15,0	2,7
- 95	41,0	13,4	0,4	0,3	0,4	0,3	2,0	10,0	3,4
- 120	32,3	11,4	0,5	0,3	0,3	0,3	2,0	8,0	4,3
- 150	25,9	9,4	0,2	0,2	0,1	0,1	1,0	6,0	2,3

depth cm	pH H_2O	$CaCl_2$	C_{org} %	N_t ‰	C/N	Fe_o ‰	Fe_d ‰	Al_o ‰	Al_d ‰	Mn_o ‰	Mn_d ‰
- 8	4,09	3,30	3,74	2,07	18,1	0,47	1,23	0,95	1,20	13	20
- 17	4,29	3,37	1,86	0,93	20,0	0,27	0,90	1,44	1,85	8	10
- 35	4,14	3,57	3,84	1,47	26,1	0,75	1,19	1,66	1,93	5	5
- 60	4,27	3,76	3,78	1,26	30,0	0,80	1,25	1,92	2,32	10	15
- 70	4,42	4,23	1,09	0,50	21,8	0,08	0,26	2,65	3,08	35	35
- 80	4,46	4,27	0,91	0,43	21,2	0,05	0,39	2,56	2,96	18	20
- 95	4,51	4,37	0,46	-	-	0,03	0,50	2,19	2,39	10	10
-120	4,56	4,40	0,30	-	-	0,03	0,53	1,35	1,39	5	5
-150	4,57	4,41	0,18	-	-	0,04	0,37	0,98	1,00	0	0

depth cm	bulk dens. g/cm	total PV Vol.%	water content at pF (Vol.%) -1,8	-2,5	-4,2	4,2	Kf cm/d
- 26	1,13	59,18	34,2	18,0	6,7	52,4	807
- 48	1,23	53,08	34,5	18,1	7,3	45,8	387
- 65	1,24	54,25	26,2	15,4	4,0	50,2	410
- 75	1,34	52,25	25,0	12,9	4,8	47,4	1117
- 88	1,52	45,65	22,8	7,5	3,6	42,0	2050
-108	1,57	43,78	19,5	8,0	2,8	40,9	461
-135	1,58	44,22	20,3	7,1	2,3	41,9	1540

3.2 profile: Schüttenstein Forest 3

location: north-west part of the schüttenstein forest; topogr. map 1:50 000
sheet 4104 Bocholt (Herzebocholt)
R: 25 33915 H: 57 45390

groundlevel: 18.5 m NN

morphology: down slope of dune, SW-exp., nearly horizontal soil surface

vegetation: pine forest with subordered oaks, birches; soil cover formed by accumulated needle matter and partly moss

humus-form: typic moulder

climate: see profile 1

initial material: gleyic podzol from aeolian cover sands over meadow loam and fine to medium sands of the low terrace

groundwater level: 25 dm under soil surface (aug. 84)

soil type: Gley-Podsol (gP); FAO: Gleyic Podzol (Transition Podzol-Gleysol); US Soil Taxonomy: artificial drained Haplaquod

L	0.5 cm	undecomposed pine-litter with birch-leafs and moss-remains; irregular transition to Of;
Of	2 - 4 cm	loose to netted structure with irregular transition to Oh;
Oh	0.5- 2 cm	loose texture (bedding) with undulating transition to Ahe;
Ahe	0 - 6 cm	2.5 YR 2/0 blackgray, medium humous, fine to medium loose sand, well rooted with etiolated quartz grains;
AeBh	6 - 15 cm	10 YR 3/2 gray-black brown, tends to a violett hue, humous, fine to medium sand with numerous roots and vertical humus mottling;
Bh1	15 - 21 cm	2.5 YR 4/2 yellow brownish gray, partly mottled by eluvation, humous, fine to medium loose sand, partly rooted;
Bh2	21 - 30 cm	5 YR 4/3 gray reddish brown with low roots, downwards humus lamination; diffus transition to BhGo;
BhGo	30 - 45 cm	10 YR 7/3 gray yellowish orange, slight humous fine to medium sand with a coherence structure and diffus humus mottling;

GoGr	45- 65 cm	10 YR 7/2 light yellowish brownish gray, fine to medium loose sand with partly vertical root-tubes and humus infiltration;
Grl	65- 95 cm	2.5 Y 7/2 light yellowish gray, fine to medium loose sand with sharp sub-boundary line to the humus-banding;
H.-bd.	95-100 cm	2.5 Y 4/2 yellow brownish gray, clearly laminated bedding (cm-banding);
Gr2	100-135 cm	10 Y 7/1 light yellowish gray, humous, medium loose sand;
Gr3	135-150 cm	7.5 GY 6/1 greenish gray loamy, unclearly bedded fine to medium sand (fluvital redeposition?), brownish humous streaks, big bunchy plant remains, downwards more solidifaction.

Profile Schüttenstein Forest 3

			texture of humus-/carb.-free fine soil (%)						
hor.	depth	sto.	sand			silt			clay
	cm	%	c	m	f	c	m	f	
Ahe	0- 6	-	2.4	63.3	23.2	3.4	2.0	1.4	4.3
AeBh	6- 15	-	2.6	67.9	19.2	3.8	1.4	1.0	4.1
Bhl	15- 21	-	2.8	65.8	21.9	2.8	1.0	0.7	5.0
Bh2	21- 30	-	2.9	66.3	20.9	3.3	0.9	0.6	5.1
BhGo	30- 45	-	1.9	69.2	22.5	0.7	0.6	0.7	4.4
GoGrl	45- 55	-	1.2	64.8	27.7	1.2	0.9	0.9	3.3
GoGr2	55- 65	-	1.0	73.5	20.9	1.1	0.7	0.3	2.5
Grl	65- 95	-	0.6	65.2	29.7	1.2	0.7	0.3	2.3
H.bd.	95-100	-	0.8	60.5	31.8	2.2	1.0	0.3	3.4
Gr2	100-135	-	1.0	65.7	28.9	0.2	0.1	0.4	3.7

depth cm	CEC meq/kg P	CEC meq/kg a	exchang. cations meq/kg Ca	Mg	Na	K	H	Al	V %
- 6	149.9	34.9	3.5	0.9	0.5	0.7	1.3	28.0	3.7
- 15	129.7	41.9	1.0	0.3	0.3	0.4	0.9	39.0	1.5
- 21	98.1	35.3	0.3	0.3	0.2	0.1	0.4	34.0	0.9
- 30	85.8	39.0	0.3	0.2	0.1	0.1	0.3	28.0	0.8
- 45	44.0	13.5	0.1	0.1	0	0.1	0.2	13.0	0.6
- 55	30.6	10.6	0.1	0.2	0	0.1	0.2	10.0	1.3
- 65	24.6	8.7	0.1	0.2	0.1	0.1	0.2	8.0	2.0
- 95	18.9	8.7	0.1	0.3	0.1	0.1	0.1	8.0	3.1
-100	34.4	12.8	0.3	0.3	0.1	0.1	0	12.0	2.3
-135	21.5	13.1	0.3	0.3	0.2	0.2	0.1	12.0	4.6

depth cm	pH H_2O	pH CaCl	C_{org} %	N_t ‰	C/N	Fe_o ‰	Fe_d ‰	Al_o ‰	Al_d ‰	Mn_o ‰	Mn_d ‰
- 6	3.70	2.84	5.05	1.47	3.43	0.40	0.79	0.65	0.83	0	10
- 15	3.65	3.00	2.90	0.93	3.12	0.05	0.16	1.05	1.31	0	5
- 21	3.90	3.54	1.95	0.59	3.31	0.02	0.12	1.95	1.89	0	5
- 30	4.04	3.79	1.47	0.53	2.77	0.02	0.29	2.19	2.11	-	5
- 45	4.26	4.14	0.57	-	-	0.02	0.55	1.42	1.44	-	5
- 55	4.27	4.23	0.31	-	-	0.02	0.48	1.02	1.09	-	0
- 65	4.34	4.27	0.19	-	-	0.02	0.31	0.63	0.70	-	0
- 95	4.43	4.27	0.13	-	-	0.02	0.21	0.42	0.56	-	0
-100	4.30	4.17	0.61	-	-	0.02	0.46	0.92	1.30	-	6
-135	4.26	4.18	0.11	-	-	0.02	0.18	0.50	0.69	-	6

depth cm	bulk dens g/cm	total PV Vol.%	water content at pF (Vol.%) -1.8	-2.5	-4.2	>4.2	Kf cm/d
- 3	1.15	57.2	32.8	17.6	7.1	50.1	388
- 11	1.25	52.8	33.9	16.8	8.1	44.7	668
- 21	1.35	49.6	33.1	20.7	5.6	44.0	223
- 38	1.60	46.4	15.0	6.7	1.8	44.6	2082
- 65	1.65	41.8	17.7	5.4	2.0	39.8	1235
-118	1.70	38.8	24.2	17.3	2.3	36.5	43

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ENVIRONMENTAL CONDITIONS IN THE NETHERLANDS

Introduction

The Netherlands is one of the small countries in northwestern Europe. It is situated between the North Sea in the north and Belgium in the south (between latitudes 51° N and 54° N), and between the North Sea in the west and the Federal Republic of Germany in the east (between longitudes 3° E and 6° E). The total area of The Netherlands (1983) is 34 000 km^2 (exclusive of water). About 15% is built-up area (residential districts, industrial areas, roads, airports, parks); 9% is under forest, of which about half is coniferous forest; about 71% is agricultural land (of which 61% is grassland, 33% is arable land and 5,5% is horticultural land); the remaining area (5%) consists of heathlands, coastal and inland dunes, coastal marshes, reed marshes, these formerly were called waste land, but today they are very valuable for outdoor recreation and nature conservancy.

By enclosing new polders the area has been increased by about 5000 ha per year in the last decades, but urban expansion has claimed yearly 8000 to 10 000 ha in the same period.

Some information on environmental conditions is given in terms of the classical factors of soil formation in the following five sections entitled: Parent material, Climate, Time, Topography, and Biotic factors.

Parent material

Nearly all mineral soils in The Netherlands are developed from clastic sediments, with textures ranging from fine sands to clays. They may be aeolian (loess, cover sand, coastal and inland dune sands), fluviatile (sediments of the Rhine and the Meuse), marine (tidal sediments of the North Sea and its inlets), or glacial (glacial till and fluvioglacial). The only soils developed from solid rock in The Netherlands, are the rendzina soils developed from Cretaceous chalk outcropping on slopes in the south of the country. The parent material of the organic soils ranges from eutrophic wood peat to oligotrophic Sphagnum moss peat.

Figure 1 shows a generalized distribution of the various kinds of parent materials in The Netherlands, differentiated according to geological age, texture and origin.

Fine sands of coastal and inland dunes

The first mapping unit comprises coastal and inland dunes. The latter, being derived from the Pleistocene cover sand, is always non-calcareous. The coastal dune sand in the north is also non-calcareous, the sands of the south are calcareous. It are fine sands with practically no clay and no silt, and 70-80% of the sand separate is between 100 and 350 µm.

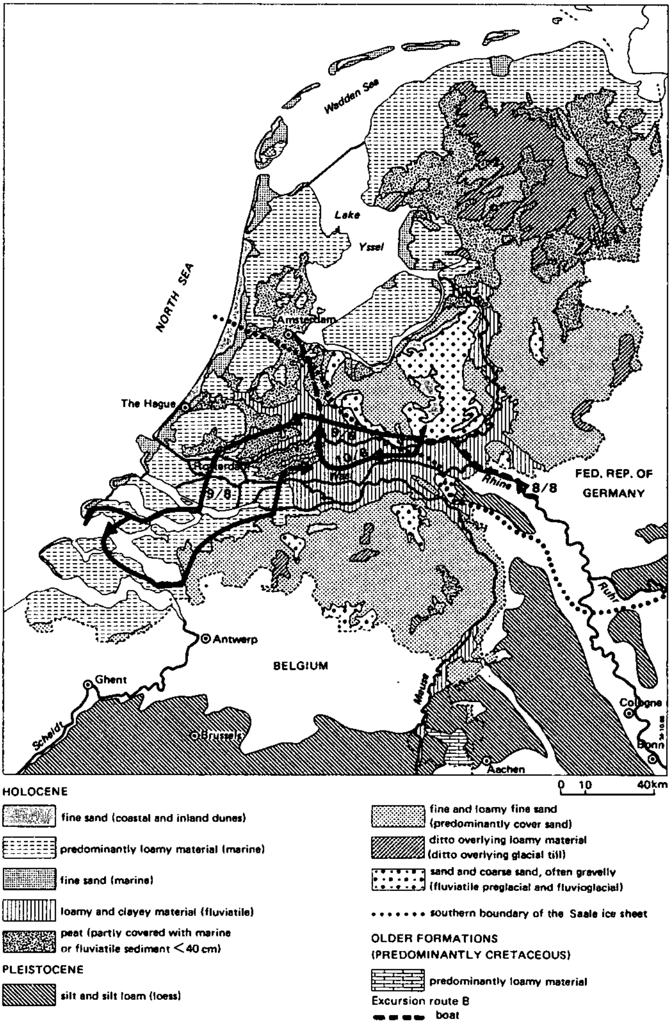

Fig. 1 Parent material and surface geology in The Netherlands. In Belgium and the Federal Republic of Germany only the loess is indicated (from De Bakker, 1979).

Loamy materials of marine origin
These materials range between 10 and 40% clay, and have practically no grains over 150 um. They may be calcareous and non-calcareous (synsedimentary or decalcified). Soils developed from these materials will be shown during excursion B (August 9, 1986) and during excursion H (August 23 and 24, 1986).

Sands of marine origin
These sands have practically clay and no silt. Alongside the North-Sea coast they are fine, with the main bulk of the sand separate between 75 and 200 µm. The sand in the western part of the Lake-IJsselpoldders is much finer, it may have over 80% smaller than 150 µm; in the east these polders are part of the embanked foreset beds of the delta of the river IJssel, the sand here is much coarser (40-50% between 150 and 200 µm). These sands mostly are calcareous.

Loamy and clayey materials of fluviatile origin
The soils on the natural levees have 20 to 30% clay, the sand separate is much coarser than in marine parent material. In the backswamps soils with more than 50% clay occur. The soils on the levees of the Rhine are calcareous or shallowly non-calcareous, those of the Meuse are mostly non-calcareous. The fine-textured soils of the backswamps are always non-calcareous. During excursion B (August 10, 1986) both types will be demonstrated.

Organic materials
The o.m. content of these materials vary between 30% in the clayey wood peats to neraly 100% in the Sphagnum peats. Large areas of peats are disappeared, mostly by excavation for fuel, partly by erosion (e.g. in the Lake-IJsselpolders). In the north remnants of peat are topdressed with sand, such a soil will be shown on excursion H (August 23, 1986), an exposed bog floor and a wood peat also on excursion H (August 24, 1986).

Loamy materials derived from loess
The soil parent meterials in Belgium and Germany are not shown on figure 1, except for the loess, which has been put in to show that the Dutch loess region is part of the West European loess belt. Dutch loess has 10-20% clay and also 10-20% sand. No loess soils will be shown in The Netherlands.

Sandy materials derived from cover sands
Cover sand (the seventh mapping unit on Figure 1) is a widespread aeolian deposit mainly of late Weichsel age. In places it is several metres thick, elsewhere it veneers older sandy sediments, for example preglacial coarse river sediments and glacial outwash, hence its name: cover sand.

It is non-calcareous, at least in its upper part, its clay content is negligible, its silt content varies between 5 and 30%, between 50 and 70% is between 75 and 200 µm. During excursion B (August 10, 1986) soils developed from cover sand will be demonstrated.

Thin cover sands overlying glacial till
In the north of the country, cover sand overlies glacial till (the eighth mapping unit). The clay content of the till is rather low, mostly between 15 and 25%, it is a compact and cohesive material, excellently suited for dike-building. It outcrops on the sea bed near the enclosure dam in the north, it was dredged and used to build this dam in 1932. No soils will be shown of this unit.
Sandy and gravelly material of the ice-pushed ridges
Ice-pushed ridges and fluvioglacial plains form the ninth mapping unit. The ridges to the north of the dotted line on Figure 1 are preglacial deposits shaped into low hills by the Saale ice sheet at the end of the middle Pleistocene. The fluvioglacial plains date from the same period.

It are gravelly coarse sands, during the excursion the landscape will be shown in an area blanketed with cover sand.
Weathering residue
In the south 'real soils' developed from chalk are found. Partly the weathering product is thin and overlying chalk, partly thicker with a brown soil. Locally this product is thin and overlying chalk (rendzina), partly it is thick and has a brown soil. Locally it is rich in chert and comparable with the clay-with-flints in Britain and the argile à silex in France. No such soils will be shown in the excursions.

Climate

The climate of The Netherlands is a Cfb-climate according to Köppen's classification. The winters are mild, even the temperature in the coldest month is above 0°C; in summer there are four months with a mean temperature over 10°C, and the precipitation is evenly distributed over the year (Table 1).

Due to differences in evaporation there is a precipitation deficit during the growing season. For this reason the water supply of crops depends for a major part on the availability of soil moisture. Shallow soils or shallowly rootable sandy soils suffer from drought in dry summers, except when the lower boundary of the rooting depth is within the capillary fringe. Deep soils have a higher water-holding capacity, thus enabling crops to bridge dry periods more easily than crops on shallow soils.

There is a clear precipitation surplus in autumn and winter, dutch soils certainly undergo leaching, e.g. decalcification (see Van der Sluijs, 1970). There are podzols in The Netherlands, but these are only developed in sands of late-Pleistocene age; loamy materials of similar age carry Alfisols. Desalinization studies in Dutch polders flooded with sea water have indicated that on average 160 mm of precipitation is added to the groundwater yearly.

Table 1. Climatic data of The Netherlands; montly averages from 1951-80 at De Bilt (near Utrecht)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Sunshine(hours)	48.9	68.5	111.3	160.8	202.5	209.0	184.0	182.4	140.5	102.5	52.6	43.8	1506.8
Temperature (°C)	2.0	2.3	4.8	8.0	12.1	15.2	16.6	16.4	14.0	10.3	5.8	3.2	9.2
Maximum temperature below 0°C(days)	9	3	0	0	0	0	0	0	0	0	2	3	17
Minimum temperature below 0°C(days)	15	15	12	5	1	0	0	0	0	1	7	6	62
Maximum temperature 20°C or above(days)	0	0	0	2	7	13	18	18	10	2	0	0	70
Maximum temperature 25°C or above(days)	0	0	0	0	2	4	4	5	1	0	0	0	16
Maximum temperature 30°C or above(days)	0	0	0	0	0	0	1	1	0	0	0	0	2
Precipitation (mm)	66.6	51.7	51.3	52.3	54.1	69.5	76.8	88.2	64.9	68.9	74.7	78.6	797.6
Days with at least 1.0 mm precipitation	13	10	11	10	10	10	11	13	10	11	13	13	135
Evaporation (Eo) in mm.acc. to Penman	2	13	42	70	105	119	111	90	57	27	7	1	644

In Soil Taxonomy there are five main classes of soil temperature regions, clearly ours has be called: mesic. Soil Taxonomy also defines soil moisture regimes; the Dutch climate is such that nearly all soils satisfy the definition of the udic moisture regime. Only the soils of the coastal marshes (such as soils B-NL3 and B-NL4) have a peraquic moisture regime. Because practically all our hydromorphic soils are artificially drained there are hardly any soils left with an aquic soil moisture regime.

Time

In roughly half of the area of The Netherlands the parent materials are of Holocene age (British equivalent: Flandrian); in the other half they are of Pleistocene age, and in less than 1% older formations outcrop (Fig. 1).

The parent materials of Holocene age are mineral and are of marine or fluviatile origin (mostly loamy and clayey), or are organic; the Pleistocene sediments are all mineral and are predominantly sandy (cover sands) with only a small part loamy (loess and glacial till).

The boundary between the Holocene and Pleistocene sediments has been put at 8000 B.C., but more than three-quarters of the surficial Holocene sediments are less than a thousand years old. The upper part of the 100 000 ha of the drained lake-bottoms (e.g. soil H-NL6) was deposited in the mid-Holocene age, and sedimentation ceased between 3000 and 2000 B.C., depending on the site. However, these sediments were covered with peat shortly after sedimentation had stopped, and have only recently been revealed by peat cutting and subsequent drainage. Thus soil formation has only been under way in the last few hundred years since the reclamation of these shallow lakes. Only some of the marine sediments have been exposed for more than a thousand years, and surfaces of Roman age occur only locally, while older surfaces (late-Neolithic) are even rarer.

In the fluvial district nearly all superficial deposits predate the construction of the artificial levees (between 1000 and 1300 A.D.). Few predate Roman times; but in those that do there is evidence of progressive soil formation, not only decalcification but also translocation of clay.

The upper part of the sediments in the Pleistocene district of the country consists of cover sands, an aeolian sediment from late-Weichsel ice age (British equivalent: Devensian). The oldest cover sands date from 10 000 B.C., in many places the superficial sands are somewhat younger, locally from the boundary between Pleistocene and Holocene (8000 B.C.).

The sediments forming the coarse-textured hills in central Netherlands, are mostly Rhine sediments from the pre-Saale interglacial period, the Holsteinien (British equivalent: Wolstonian). The glacial till in the north of the country also dates from the Saale ice age. Due to erosion and solifluction in the tundra climate of the Weichselien the actual surface of these sediments is much younger than the age of the sediments themselves: it is also about 10 000 to 12 000 years old.

The loess in the south of The Netherlands is mostly as old as the older cover sands, namely dating from about 10 000 B.C.

Topography

Broadly speaking, The Netherlands slopes from the southeast to the north-west (Fig. 2), the highest point (321 m above sea level) being near the meeting point of the boundaries of The Netherlands, Belgium and the Federal Republic of Germany; the lowest point is just north of Rotterdam, and is 6.6 m below sea level on the bottom of a reclaimed lake. The coastal dunes generally are between 10 and 30 m above sea level, the highest point being 56 m.

There are two irregularities in this general pattern: the hills in the centre of the country (highest point 103 m, north of Arnhem), and the 'holes' in the west of the country, scattered areas below the minus 2.5 m contour. The hills were formed by the Scandinavian ice sheet that pushed coarse sediments into low hills in the Saale ice age; the holes are reclaimed lakes, initiated by peat cutting, the larger areas

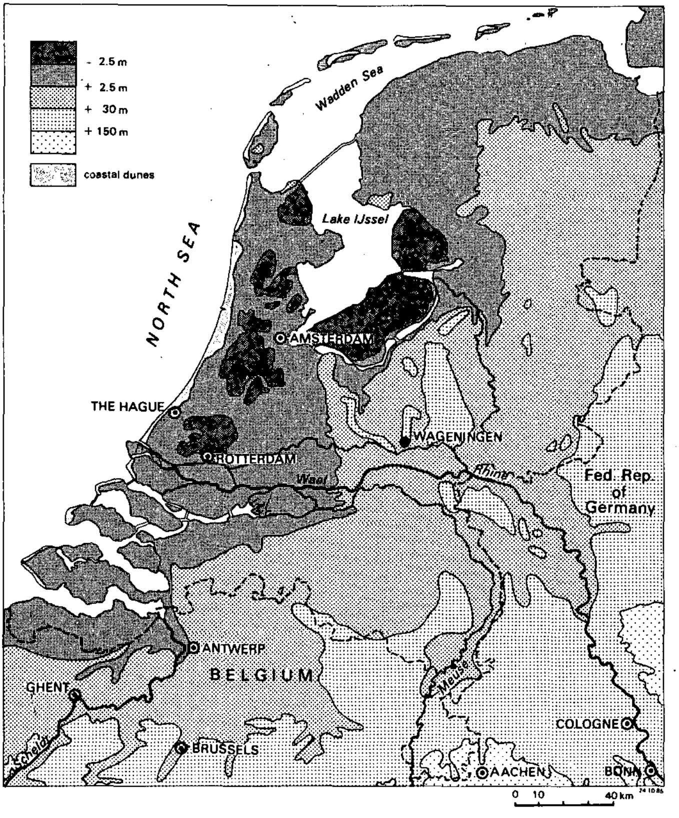

Fig. 2 Contour map (below or above sea level) of The Netherlands and the adjacent parts of Belgium and the Federal Republic of Germany (from De Bakker, 1979).

below sea level are the Zuyderzee Polders (both shown on excursion H).

The general relief is mainly explained by the geological situation of The Netherlands: it forms a part of a large depression that is gradually sinking and being infilled with Quaternary sediments.

Far more important for pedology (and for agriculture) are the small differences in elevation above the gently sloping ground-water table. The soil-forming factor 'relief' or 'topography' could better be replaced by 'depth to ground water' in The Netherlands.

Most subsoils of Dutch soils are moderately to rapidly permeable, and the water in the saturated zone can be characterized as Grundwasser (free ground water) and not as Staunässe (excess surface wetness). This is an important distinction made in the German and British systems of soil classification.

The ground-water table fluctuates in the course of the year; even in artificially drained soils this fluctuation may be between 90 and 130 cm the depth of the fluctuating ground water varies between just below ground level and a depth of several metres. This phenomenon is classified in seven 'water-table classes'. The definitions of these classes are based on the depths of the mean highest (MHW) and mean lowest water (MLW) tables (Van Heesen, 1970). On modern Dutch soil maps all mapping units are annotated according to soil and ground-water class. Only about 10% of the Dutch soils have the MLW deeper than 2 m.

Biotic factors

Animals

In the Department of Soil Science and Geology of the Wageningen Agricultural University some research has been done on burrowing animals, such as earthworms and moles, which have obviously been active in the well-drained calcareous fluviatile soil B-NL9. The process whereby these animals cause the gradual disappearance of soil lamination has been labelled 'homogenization'.

Vegetation.

In the Netherlands there is hardly any 'natural' vegetation, only some semi-natural and near-natural vegetations. The latter are only found in those areas called 'waste lands' in the introductory section to this contribution; these occupy 5% of the country.

The climatic climax vegetation on the mineral soils and the eutrophic organic soils must have been a forest, with alder, ash, beech, birch, elm, hornbeam, oak and willow in different combinations and with different undergrowth, depending on the site (rich or poor, calcareous or acid, waterlogged or well drained, or subject to flooding with fresh, brackish or saline water); on the oligotrophic raised bogs the natural vegetation was a treeless wilderness with peat mosses predominating.

However, many soils never had a forest vegetation before being used for agriculture; some never had a vegetation at all. All the coastal polders (De Bakker and Kooistra, 1982) that were enclosed and drained were reclaimed partly from saltings supporting a vegetation of salt-tolerant grasses and herbs (soils B-NL3 and 4) and partly from bare tidal mud flats. The Zuyder Zee Polders were reclaimed from the sea bottom (soils H-NL3 and 4), and only a few years supported a reed vegetation that had been sown deliberately to accelerate the ripening of the mud (Pons and Zonneveld, 1965). The hypothetical climax vegetation on these fertile, calcareous, well-drained polder soils would probably be an ash/elm forest.

Other soils, such as the base-rich well-drained soils of the natural levees in the fluviatile district (soil B-NL9) carried some kind of ash/elm forest before reclamation, but there are no records or relics of such forests, for they have disappeared more than a thousand years ago.

The Pleistocene district must have known the whole vegetational sequence after the tundra vegetation, followed by hazel, oak and alder and later the beech and hornbeam and the arrival of cultivated plants and their accompanying weeds, indicating the start of man's agricultural activities.

Every treatise on vegetation as a soil-forming factor in the Pleistocene district in northwestern Europe has to take into account that vegetation has changed considerably since soil-formation time zero (roughly 10 000 to 12 000 years ago).

An important change in vegetation in the Pleistocene district is the gradual transformation of the forests on the poor sands into heathlands. This started about 5000 years ago and it is assumed that Neolithic people induced this change by felling the trees for timber and for fuel and then burning and grazing the vegetation on soils that had a low potential for forest regeneration.

Man.

In the densely populated Netherlands (14.3 million inhabitants, i.e. about 420 inhabitants per km^2) human influence is an important soil-forming factor. When using the old saying 'God created the earth, but the Dutch made their own country', most people point to the polders, particularly to the Zuyder Zee Polders. However, there are other soils modified and reshaped by man, e.g. the plaggen soil (soil B-NL7).

Not only soil morphology but also soil fertility has been changed by man. As the result of the heavy application of fertilizers (see section 'Soil Fertility and Soil Testing in The Netherlands') the chemical fertility of Dutch soils is generally high, even of soils that were orginally poor or acid. The fertility of the same kind of soil may differ depending on the kind of land use and the skill of the farmer or horticulturist.

To give an idea bout the intensive Dutch agriculture some statistical data are given below. There are 5516 thousand cattle in The Netherland, of which 2549 thousand are dairy cows (= 1.89 cows per ha of grassland and fodder crops): the dairy cows produced 12 415 million kg of milk in 1983. Three quarters of the consumption of nitogen fertilizers is used on grassland, which occupies 61% of the agricultural land. The increasing application of fertilizers and other agricultural improvements has considerably increased crop yields. In 1984 the average yield of winter wheat was 7900 kg/ha, of potatoes 42 700 kg/ha and of sugar beet 54 000 kg/ha. The growers of vegetables and flowers are organized in auction societies. All their produce has to be marketed in central auction buildings. In 1984 2192 million kf of vegetables were auctioned, worth Dfl 3038 million; and in the same year the turnover all flower auctions was Dfl 3031 million.

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SOIL FERTILITY AND SOIL TESTING IN THE NETHERLANDS

The Institute for Soil Fertility (Haren, Gr.)

Established in 1890 as a State Agricultural Experiment Station in Groningen, the Institute for Soil Fertility (IB) conducts research on soils and plant nutrition for field crops and grassland an for horticulture. The research is aimed at the study of the relation between the soil and the growth of agricultural crops, trees, and other types of vegetation; further, the consequences of the effects of human activities on the soil as a natural resource are studied. The concept "soil" is broadly defined to include artificial substrates. The research is approached from different angles:

Soil biology
Relation between farming systems and biological soil fertility and soil quality; the consequences of the use of biocides and other "xenobiotic" compounds for the soil ecosystem, and the biological decomposition of such compounds; biological waste disposal; the potential of the soil's microbial population to control soil-borne plant pathogens.

Soil physics
Significance of soil physical factors, as temperature, texture, structure, transport potential of water, gases, heat, nutrients and contaminants, for yield and quality of agricultural crops.

Soil chemistry
Various factors and processes that determine the uptake of plant nutrients, heavy metals, and organic pollutants by crops, and their effects of the biological activity, structure, and long-term quality of the soil.

Fertilization
The importance and efficiency of organic and inorganic fertilizers and waste products in relation to yield and quality of agricultural and horticultural crops; their short-term and long-term effects on soil properties and productivity.

Plant nutrition
The relation between soil properties and plant growth; development and functioning of plant roots; this research is conducted in collaboration with that on soil biology, soil physics, soil chemistry and fertilizer research.
In recent years, the Institute has further developed its ties with agricultural research institutes in developing countries. It has committed more than 5% of its own budget to joint research activities with institutes in Nigeria and Indonesia, and on consultancy and training.
With its scientific and technical staff of 170, the Institute is able to conduct a diverse research program. It is well-equipped for soil, plant and water analysis, and for field and greenhouse trials. Its facilities include two experimental farms (17 and 38 ha), a workshop, computer centre and library.

Laboratory for Soil and Crop Testing (BLGG)

This laboratory is the largest organization of its kind in the country and perhaps in the world, originally came into being as a scion of the old Agricultural Experiment Station in Groningen, now the Institute for Soil Fertillity. In 1927 it was taken over by the combined farmers 'and market gardeners' organizations; representatives of these organizations now constitute the Management Board. The laboratory later moved to Oosterbeek near Arnhem.
The laboratory, which has a staff of more than 200, annually processes a total of more than 300,000 samples (soil, crop, manure, sewage sludge, water, feeds, fertilizers) in which some 250 different determinations (including nematode counts) are made, mainly as a basis for recommendations to growers. The samples are taken by about 60 fieldmen, who operate in their own regions. To process the tremendous amount of data, computers are used, which also issue fertilizer recommendations based on the results of soil analysis.
Although the laboratory is an independant organization, it maintains close contacts with a number of research institutes, specialists groups and coordinating committees. The fertilizer recommendations, although issued to the grower by the laboratory, are the responsibility of the State Advisory Service which, in turn, is guided by committees whose membership includes the Institute for Soil Fertility. This institute keeps itself informed of developments in soil analysis at home and abroad and evaluates new methods.

Participants in excursions B and H will receive, on the spot, soil fertility data and fertilizer recommendations pertaining to the soil types and/or regions that will be visited.

CLAY MINERALOGY OF HOLOCENE SEDIMENTS IN THE NETHERLANDS

The holocene fluviatile and marine soils cover about 9 and 33%, respectively, of the country. The fluviatile deposits have been transported by the Rhine and , to a smaller extent, by the Meuse. The river sediment has been formerly characterized as an illitic clay. However, besides illite the clay fraction has also appreciable amounts of vermiculite and/or smectite. Following AIPEA-nomenclature the river clays are now identified as an illite-vermiculite-smectite complex and the marine clays as an illite-smectite complex. The occurrence of vermiculite differentiates the fluviatile clays from the marine clays (Table 1). This mineral accounts for the high K-fixation by the fluviatile clays and also for the higher cation exchange capacity. The smectite minerals in both clays are in fact interstratified illite-smectites as shown by studies of the fine clay fraction (0,04 µm). The percentage of expandable layers is usually less for the river clays, and the K-content somewhat higher.

Table 1 Major differences between the clay fractions of the most recent fluviatile and marine sediments.

sediment	colour (aerated soil)	K-fix	CEC mmol(+)g^{-1}	K_2O	vermiculite	smectite interlayering (% exp. layers)
				——— % ———		
fluviatile	10 YR	high	0,50	3,5	10-15	30
marine	2,5 Y	low	0,45	3,2	< 5	50

The differentiation between fluviatile and marine soils is important for agriculture in relation to soil fertility. The K-fixation is now being used by the Dutch Soil Survey as a differentiating criterion in addition to colour, texture and sedimentation pattern.

The Delta Plan

The disaster as a result of the severe gale coinciding with a spring tide on January 31st, 1953, led to a speeding up of the decision process to increase the safety of the southwestern Netherlands. The so-called Delta Plan was developed and taken into execution. The following are the most important parts of the project (see the numbers on Fig. 1):

. 1. the construction of a movable storm surge barrage in the Holland IJssel (1958), to protect a large part of the polderland of Holland from flooding

. the construction of five "primary dams" to seal off the estuaries at their seaward ends:

2. Brielse Maas (1950)
3. Haringvliet (1971)
4. Brouwershavense Gat (1972)
5. Eastern Scheldt (1986)
6. Veerse Gat (1961)

The dates show that, in order to gain experience, the dams were built in increasing order of size, beginning with the smallest. The dam in the Veerse Gat, which was the first primary dam to be built after the disaster, sealed off an estuary with a tidal volume of 175 million cubic metres. The corresponding figure for the final dam, that in the Eastern Scheldt, is 2,200 million cubic metres.

. the construction of five "secondary dams", situated farther to the east:

7. Zandkreek (1960)
8. Grevelingen (1965)
9. Volkerak (1970)
10. Philips Dam (1987)
11. Oester Dam (1986)

The importance of the first three of these dams is partly of a temporary nature, i.e. in order to prevent strong tidal currents around the islands during the construction of the primary dams. In addition, they fit into the network of road connections.

The Philips Dam and the Oester Dam were added to the Delta Plan at a later stage, after it was decided to leave the Eastern Scheldt partly "open" (see below). One of their functions is to separate salt water from fresh water, now that the water in the Eastern Scheldt is to remain salt. The Scheldt-Rhine Canal will also remain non-tidal, thanks to the Oester Dam.

. strengthening of the dikes along:

12. New Waterway (= Nieuwe Waterweg in Fig. 1)
13. Western Scheldt (= Westerschelde in Fig. 1),

which are not being dammed because of the shipping interests of Rotterdam and Antwerp, respectively.

. the construction of two major bridges:

14. Haringvliet Bridge (1964)
15. Zeeland Bridge over the Eastern Scheldt (1965)

which complete the network of new road connections already referred to. It should be remarked that these bridges do not form part of the original Delta Plan, but are the result of the initiative of the municipalities and provinces concerned. The sums invested are being recovered through the charging of tolls. As far the Haringvliet Bridge is concerned, the full amount had been recovered by 1973 and so the toll has been abolished.

As appears from the dates, the plan has been completed apart from the construction of the 9 kilometre long dam in the Eastern Scheldt and the two additional secondary dams; work on these is progressing steadily.

Out of concern for the environment (e.g. "nursery" function for North Sea fish and large bird populations on sandbanks at low tide) and for the interests of the coastal fisheries and shellfish cultures (oysters, mussels etc.), several interest groups have for many years been campaigning for the Eastern Scheldt to be kept open. They claimed that the necessary security could also be obtained by raising the height of all the dikes along the coasts of the islands in the entire Eastern Scheldt basin. There were strong protests against these proposals from those anxious to secure optimum safety and favourable conditions for agriculture. After years of discussion the following compromise solution was finally decided upon in 1976. In the three remaining gaps of the Eastern Scheldt dam (parts of the dam have already been completed) there will be 62 openings each 45 metres wide, between gigantic piers, and into which metal gates can be lowered. Under normal conditions, when the gates are raised, some 75% of the tidal flow in the Eastern Scheldt will be retained, while the water will obviously remain salt. In times of danger the gates are lowered, so that the dam is completely sealed. A highway will be constructed along the top of the dam, 12 metres above the water level. This solution also necessitated the building of two additional secondary dams further east, the Philips Dam and the Oester dam.

In addition to the safety aspects as main objective of the Delta Plan, there are a number of important secondary consequences deriving from the Delta Plan, such as the creation of areas of fresh water and of new traffic routes. Consequently great changes took place in this region. The network of new roads resulted in a greater mobility of the population and the increase of recreation. Reduction of the tides and change in salinity of the water resulted in a decline of the fishing industry. The change in water quality in certain areas has a positive effect on the agriculture as the seepage of salt water and, in dry summers, the lack of water is reduced. For shipping the disappearance of the tides and the stabilisation of navigation channels is advantageous.

After:

Meijer, H. 1984. The South-West Netherlands. 3rd revised ed. Information and documentation centre for the geography of the Netherlands (IDG), Utrecht/The Hague, The Netherlands, 48 p.

IDG is a national body supplying people and instititutions outside the Netherlands with information and documentation about the country. Its publications - in several language versions - are obtainable free of charge from the Netherlands Embassies and from IDG (Dept. of Geography, IDG; P.O.Box 80115, NL3508 TC Utrecht).

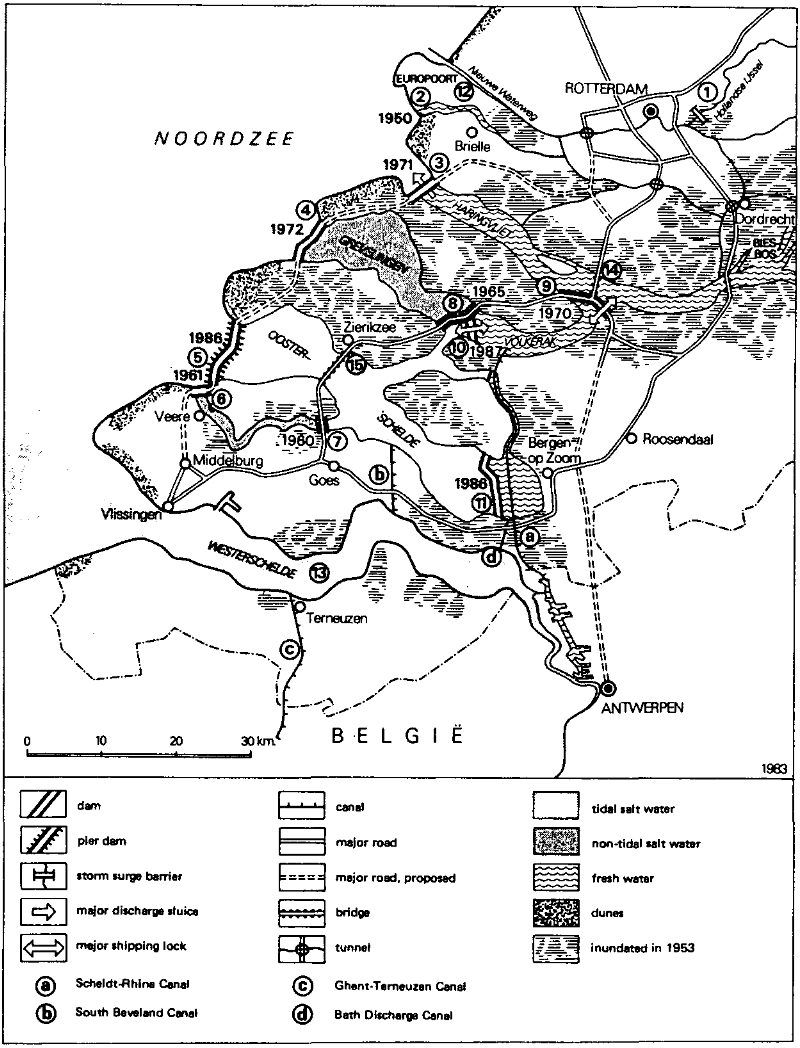


Fig. 1 Delta Plan

SOUTHWESTERN COASTAL AREA

General itinerary

- 7.45 h. Departure Wageningen. Via the holocene riverplain of the Rhine to Rotterdam-Zuid, via the Hellegatsplein, Grevelingendam to the former shoal 'Neeltje Jans'.
- 10.00 h. Arrival at 'Neeltje Jans', short coffee break, film Delta Works, guided tour storm surge barrier, Oosterschelde.
- 12.00 h. Departure, via the Zeeland-bridge (fotostop) to Zuid Beveland.
- 13.00 h. Yerseke Moer, soils B-NL1 and B-NL2.
- 14.00 h. Salt-marsh at the Rattekaai, soils B-NL3 and B-NL4.
- 15.00 h. Coastal polder soils in the Tweede Bathpolder, soils B-NL5 and B-NL6.
- 16.00 h. Departure for Wageningen, via Bergen op Zoom, Zevenbergen en Gorinchem.
- ±18.00 h. Arrival Wageningen.
- 19.00 h. Dinner on the ship
- 20.00 h. Visit to International Soil Reference and Information Centre (ISRIC).

Excursion area

Geology

The coastal area of the southwest of the Netherlands is characterized by several large estuaries and sea-arms, surrounded by a number of islands. They have formed since Atlantic times (8000 B.P.) by repeated inroads of the sea in an area of peat over pleistocene sand, protected by a system of coastal barriers. Sea level rose continuously throughout the Holocene and drowned the lower parts of the peat, covering it with mainly fine textured deposits. Locally the peat was eroded and gullies were cut into Pleistocene deposits. Hereafter several phases of marine transgressions occurred, alternated with quiet periods (regressions). During transgressions incursions of the sea caused erosion as well as deposition. In the following regressions marine sedimentation ceased and new peat formation started on top of the marine deposits. In the Netherlands two main transgressive periods are distinguished during the Holocene: one beginning in the Mid-Atlantic (about 7000 B.P.), the so-called Calais period and a second beginning in the middle of the Subboreal (about 3500 B.P.), the Dunkirk (Dunkerque) period. Each of these transgression periods has minor regressions in between. Consequently a number of Calais and Dunkirk phases can be distinguished in the deposits laid down in these periods, each separated from the former and the next by renewed peat formation (Figure 1).

Sedimentation and landscape

During every transgressive phase, when the sea invaded the land also deposition occurred, regulated by the tides. As the level of sedimentation increased the deposits became finer textured. This process of particle sorting from sea to land also operates from the source of sediment supply (gullies and creeks) to their backlands. Sediments present at or above mean

EPOCH	AGE	TIME SCALE B.P.	MARINE TRANSGRESSIVE INTERVALS	DATES B.P.
HOLOCENE	SUB-ATLANTIC	0	DUNKERQUE III B	0
				700
		1000	DUNKERQUE III A	800
				1100
			DUNKERQUE II	1400
				1750
	SUB-BOREAL	2000		
			DUNKERQUE I	2200
				2500
		3000	DUNKERQUE 0	3000
				3500
		4000	CALAIS IV	4000
			CALAIS III	4700
	ATLANTIC	5000		5300
		6000	CALAIS II	
			CALAIS I	6300
		7000		
	BOREAL	8000		8000
	PRE-BOREAL	9000		
		10 000		

(mainly after Rijks Geologische Dienst)

Fig. 1 The chronology of the Holocene

low tide level are shoals, intertidal flats and salt-marshes. The shoals and flats constitute the lowest parts of these deposits. They are bare, slightly undulating areas, dissected by a few gullies. The relief is mainly determined by ripple patterns. The salt-marshes form the highest part of the intertidal zones. They have fine textured topsoils and are covered with a dense vegetation. Three landscape elements can be distinguished: creeks, natural levees and basins. In Figure 2 the major shore types on sheltered coasts in the southwestern part of the Netherlands are given.

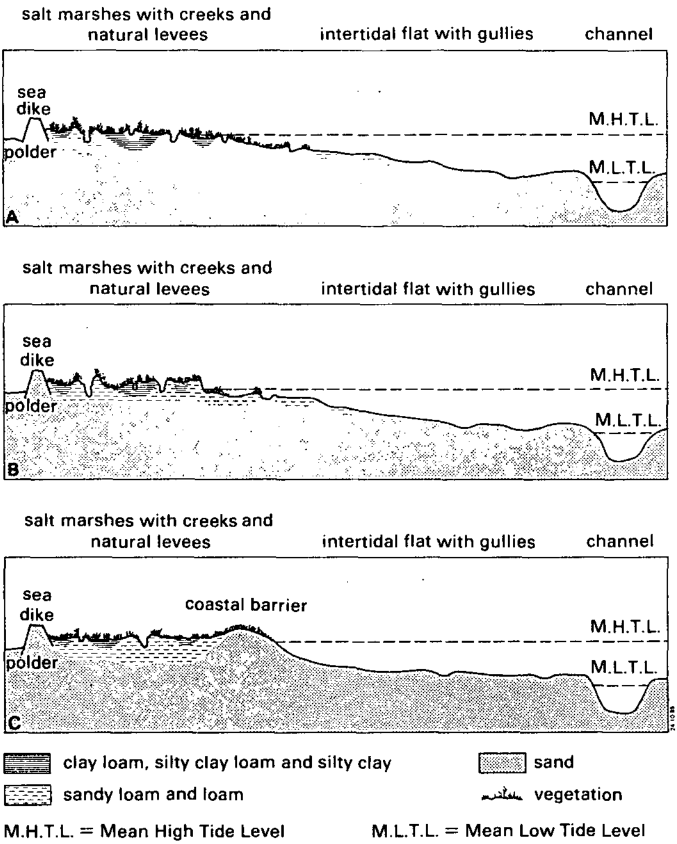


Fig. 2 Major shore types on sheltered coasts in the Netherlands

During regressions these landscapes were partly covered with peat. Subsequent transgressions caused erosion and deposition on top of older deposits, generally starting with shoals and flats. The Calais and Dunkirk deposits mentioned before are built up of alternating intertidal deposits and peat layers. The vertical height of the intertidal deposits varies. The thickness of a complete sequence from shoal to and inclusive salt-marsh is related to the vertical difference in floodtide and ebb-tide levels in combination with tidal current speeds. In the southwestern part of the Netherlands tidal amplitudes from a few decimeters to more than 4 m are recorded. When the amplitude of the tides is more than 2 m and current speeds are high, well developed natural levees are found. With the increase in height of the levee the differentiation in granular composition of the levee and adjoining basin becomes more pronounced. High natural levees are composed of sand or loamy sand; the adjoining basins have a silty clay loam texture. Low levees are fine textured and differ hardly in composition from the adjoining basin (Kooistra, 1978, 1983).

Settlement

From the Stone- and Bronze Age artifacts (before 2000 B.P.) found in Zeeland it is clear that hunting was the major occupation. During these times up till the end of the Roman time (about 1800 B.P.) people lived on the highest parts in the coastal landscape, e.g. on the high levees boundering the main creeks in the marshes and on the coastal barriers. After the Roman time several transgressive phases occurred. During this time men started to build low dams in small creeks to enclose their villages and pieces of land. Locally, mounds of earth were made as refuge during inundations. The first low dams known are made about 1200 B.P. in the landscape of the Dunkirk II deposits, the result of post-Roman transgressions. During subsequent invasions much land was eroded. Nowadays the surface remnants of the Dunkirk II deposits form the nuclei of the present-day islands and are known as "old land". The next phase of invasions of the sea occurred between 900 and 1200 A.D. During this period land was still protected by low dams. Men used the land for husbandry. At low tide flocks of sheep and herds of cattle grazed on the salt-marshes. Only upon spring tides, refuge had to be taken on higher ground, often behind the dams. In the late Middle Ages storm tides were very frequent and many low dams collapsed. Land reclamation started around 1200 A.D. The sediments reclaimed are embanked from tidal foreland or new islands, silted up to about mean high tide level. These offensively reclaimed areas are known as coastal polders or "new land" (De Bakker and Kooistra, 1982). Reclamation occurs up till now. In the late Middle Ages and afterwards storm tides were very frequent and often many low dams or polder embankments collapsed. Particularly notorious are the Elisabeth Floods of 1404-1421 and the incursions of 1531, as a result of which the island of Noord Beveland, the Land of Reimerswaal and Saaftinge were drowned and deep gullies formed. Fig. 3 shows a map of the area lost since 1531 in the eastern part of the Oosterschelde. Afterwards a new cycle of reclamations started, beginning from the new siltings around the remaining islands.

The last high stormtide occurred on 31 January, 1953. During that stormtide sealevel rose three metres above the predicted level at high water. Many dikes breached, villages and farmsteads were invaded with flood water. Over 160 000 ha land was flooded; 1800 people drowned. This disaster was soo great that a big project was started, not only to close the dike breaches but to protect the whole of the southwestern part of the Netherlands against the sea. This project is known as the Delta Plan, executed by the Delta Division of the State Public Works Department with as main task to close off the major sea arms and to enlarge and heighten the sea dikes.

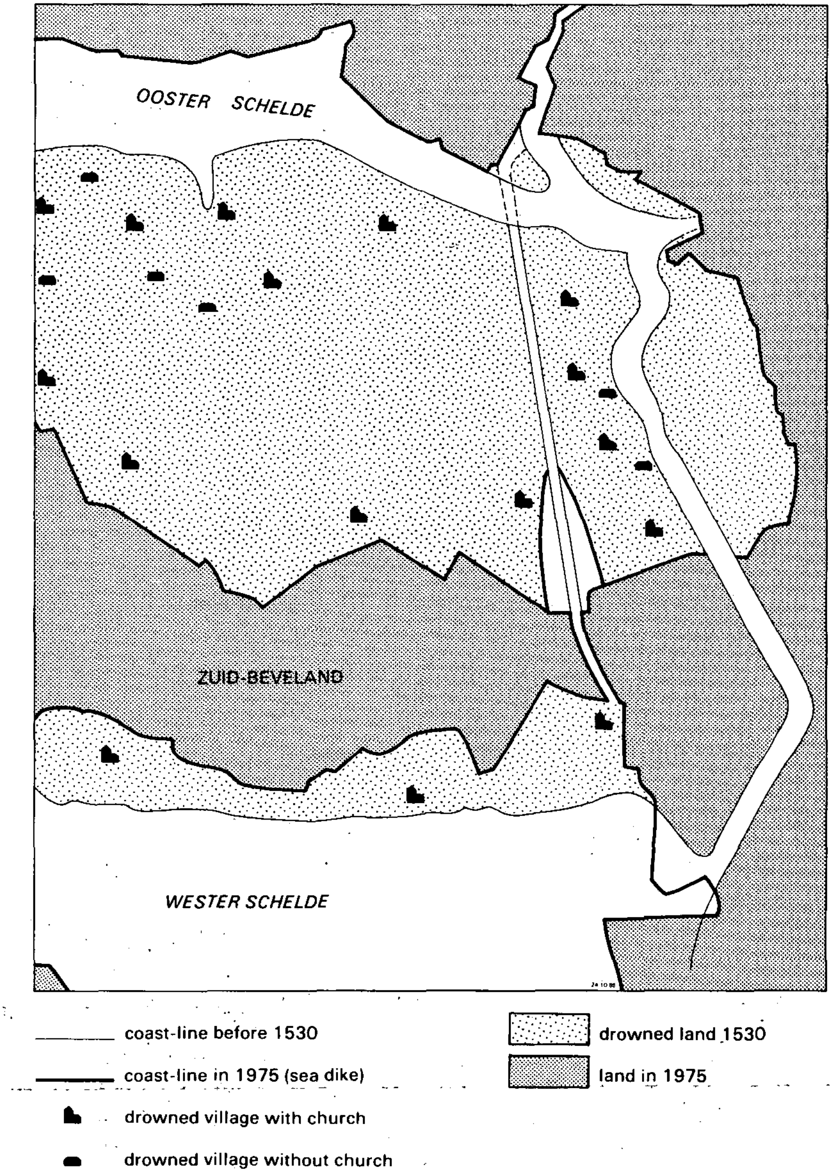


Fig. 3 Drowned land after the storm surges of 1530 and 1531

Table 1 Ripening classes (De Bakker & Schelling, 1966)

Code	Class name	Consistence
1	wholly unripened	very weak, material runs through the fingers
2	nearly unripened	weak, material can be squeezed through the fingers
3	half ripened	rather weak, material can still be squeezed through the fingers
4	nearly ripened	rather firm, material can be squeezed through the fingers with difficulty
5	ripened	firm

Table 2 Comparison between bulk densities and water contents at two clay contents for samples from the intertidal zone and adjoining polder soils (Kooistra, 1978)

	Clay content %	Bulk density $g\ cm^{-3}$	Water content % of oven-dry soil
Intertidal zone	9	1.21-1.37	45.0- 33.4
Polder	9	1.50	19.0
Intertidal zone	39	0.47-0.60	186.5-134.6
Polder	39	1.38	31.8

After deposition aeration of the sediment can take place. In principle the longer the sediment is exposed to the air, the deeper the air can penetrate. But besides the height of the terrain, also the granular composition of the sediment and the drainage conditions play a role. In sandier deposits the aeration proceeds deeper than in the fine-textured deposits of the adjoining basins, especially along creek courses where drainage conditions are favourable. Aeration of the sediment starts from the surface and penetrates along the channels and cracks present. In the lower salt basins hardly one centimeter of the sediment is aerated, increasing to several decimeters in higher basins. Along creeks aeration depths of 40 to 80 cm are not uncommon.
Except loss of water and aeration many processes are acting in the sediments situated above Mean Low Tide level. They can be traced with the aid of field data, physical and chemical analyses, knowledge of the flora and fauna, and of micromorphological observations. The processes we are dealing with are soil-forming processes, due to climatic conditions (temperature, precipitation, wind) and organisms (flora and fauna). The changes occurring can be translated into biological, physical and chemical processes. In Figure 5 the occurrence and importance of ten processes over the intertidal zone are given.

Biological processes

Fauna. The environmental conditions in an intertidal zone may set limits to the permanent macrofauna. Few forms of life are adapted to the extreme conditions. But the populations of these forms of life are often very large. The most important species

Salt marsh and intertidal flat at the Rattekaai (Oosterschelde)

In the Oosterschelde, one of the main sea-arms in the southwestern part of the Netherlands, large areas occur where sediments are found deposited above Mean Low Tide level during the rise and fall of the tides. In Fig. 2 vertical cross-sections of the major aspects of intertidal zones are given: (1) the increase in height in relation to tidal levels; (2) the changes in granular composition as altitude increases and (3) the occurrence of a phanerogamous vegetation. The salt-marshes to be visited are situated at the southern edge of the Oosterschelde. The intertidal zone concerned belongs to the shore type with a gradual transition from intertidal flat to salt-marsh, represented in Fig. 2A.

Any accretion starts with sedimentation of marine sands at a level below Mean Low Tide level. Gradually as accretion continues finer-textured sediments, first sandy loams, loams and later silt loams to silty clay loams, are deposited. The sediments are laid down from seawater and consequently contain a high amount of water. Generally, under the same circumstances, the sediment with the highest clay content has the highest water content and the weakest consistence.

In the intertidal zone, however, the fine-grained sediments are deposited in the higher basins situated at and above Mean High Tide level. These sediments are exposed to the air for a longer time between the floods and therefore dry out to some extent. Consequently, the most unripened sediments are found in the transitional zone between intertidal flat and salt marsh and in the low salt marsh, situated below Mean High Tide level (Fig. 4). The presence of creeks also influences the water content of the sediment. Near creeks the soil consistence remains firm while the clay content of the sediment can vary considerably. The ripening classes in the field are given in Table 1.

An example of the actual water content of these soils compared with adjoining reclaimed polder soils with the same granular composition is given in Table 2.

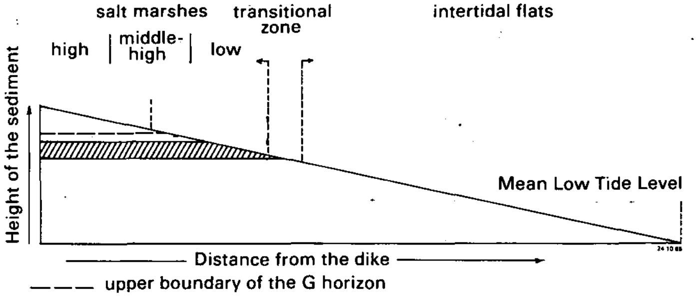


Fig. 4 Schematic cross-section of the intertidal zone showing the position of the zone with the highest water contents (hatched) (Kooistra, 1978)

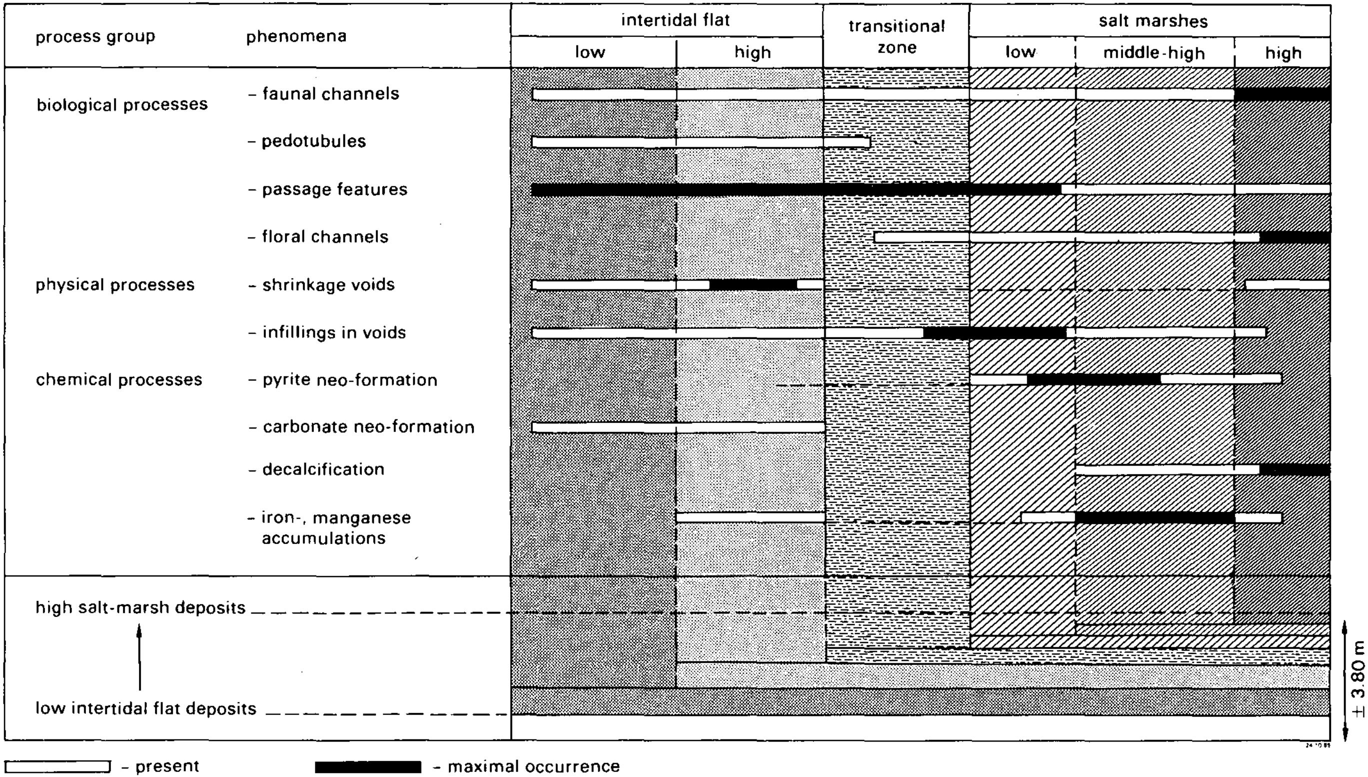


Fig. 5 Characteristic processes and phenomena in the intertidal zone

belong to the Mollusca, Vermes and Crustacea.
The phenomena produced by the fauna are related to the way of living and feeding of these animals. They can be devided into 3 groups: channels, pedotubules and passage features. All three groups can be associated with excrements produced by the animals and by molluscs and snails. Faunal channels in the intertidal zone usually are simple straight ones, with only a few bifurcations (Fig. 6). This is due to the instability of the unripened sediment. The channels produced by animals, mainly species of the Vermes and Crustacea, are in use for longer periods. These channels occur over the whole intertidal zone and are most numerous in the high salt marshes as a result of the higher consistency of the sediment.
Pedotubules are infilled channellike features. Two types were distinguished. The fist type consists of channels infilled with excrements. The second type are the so called striotubules (Fig. 6), mainly produced by species of the Mollusca. Pedotubules only occur in the bare parts of the intertidal zone.
Passage features are also channellike phenomena, but they miss a distinct external boundary. They are a result of a single passage of an animal through wet unconsolidated soil material. They are produced by animals which move with flood tide to the surface of the sediment and retreat into the sediment at ebb tide. They are the most numerous phenomena of faunal activities and occur in the whole intertidal zone, but become less numerous in the firmer sediments. Passage features are produced by Vermes, Gastropods, Crustacea and perhaps some small juvenile Pelecypods.
Flora. The parts of the vegetation present below the surface form systems of branching channels of different diameters with circular cross-sections and smooth walls. These channels are only found in the salt marshes. The effect of biological processes mainly results in disturbance of the tidal lamination and the presence of voids. These changes in the sediment are important for aeration, drainage and transport of material.

Physical processes

Due to water losses of the sediments cracks are formed. These cracks may occur individually or form polygons in sandy as well as in finer-textured sediments. In the intertidal flat polygon patterns with diameters between 40 - 120 cm are often found. In the walls of natural levees individual cracks can be found and in the high salt basins a polygon pattern of polygons less than 30 cm in diameter may develop.
The second group of phenomena due to physical processes are the infillings of soil material in existing voids. The voids can be of biological as well as of physical origin. These phenomena are dominantly found in the part of the intertidal zone were the most unripened sediments occur e.g. the transitional zone and low salt marsh.

Chemical processes

In the sediment distinct accumulations of newly formed pyrite occur. The pyrite present is composed of small micro-aggregates: framboidal pyrite. They generally occur in the form of

spheres. Pyrite is formed in fine-textured sediments containing organic matter under reductive conditions. The largest accumulations are found in the basins of the low and middle-high salt marshes.
In the intertidal flat near and adjoining voids and along the walls of voids accumulations consisting of fine carbonate particles can be found. Local evaporation caused the carbonate to precipitate from an oversaturated solution.
At a shallow depth from the surface, zones with low carbonate contents occur in the middle-high and high salt marshes. The smallest quantities of carbonates in these zones are found just above the Cr horizon. The carbonate deficiencies are the largest in fine-grained sediments. Therefore these deficiencies are most marked in the salt basins. Here the lowest pH values are found and the base saturation is below 100%. In thin sections the decalcification was shown by the disappearance of fine carbonate particles. Probably the decalcification mainly results from cyclic oxidation of iron and depends too on the possibilities for internal drainage within the sediment (Fig. 7).
Iron and manganese accumulations occur where aeration is possible, mainly along cracks, channels and crabholes. Iron accumulations are found in the intertidal flat, in natural levees and in the middle-high and high salt basins.
Manganese accumulations were observed in combination with iron accumulations along cracks and channels in sandy deposits.
Due to the difference in occurrence and intensity of the different processes over the intertidal zone the deposits get a specific combination of phenomena at different sedimentation levels in the intertidal zone. This is represented in the lower part of Figure 5.

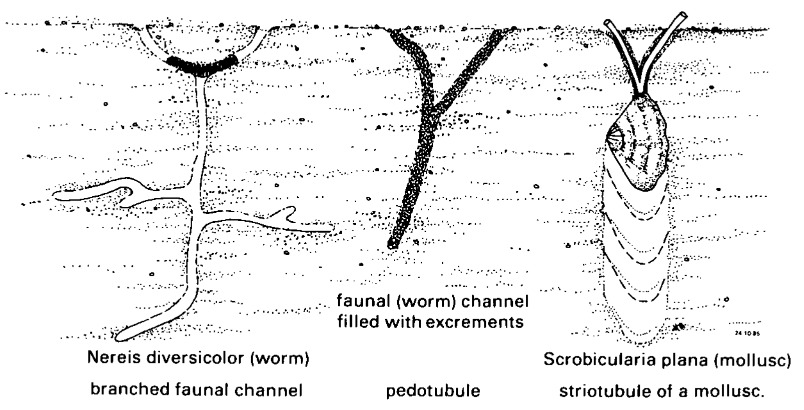


Fig. 6 Faunal channels and pedotubules

It is the least level part of the polder area, characterized by relatively high "creekridges" (about 0.5 m above to 0.5 m below mean sea level) and low "basins" (1 to 1.5 m below mean sea level). Soil conditions of ridges and basins differ greatly in many respects.

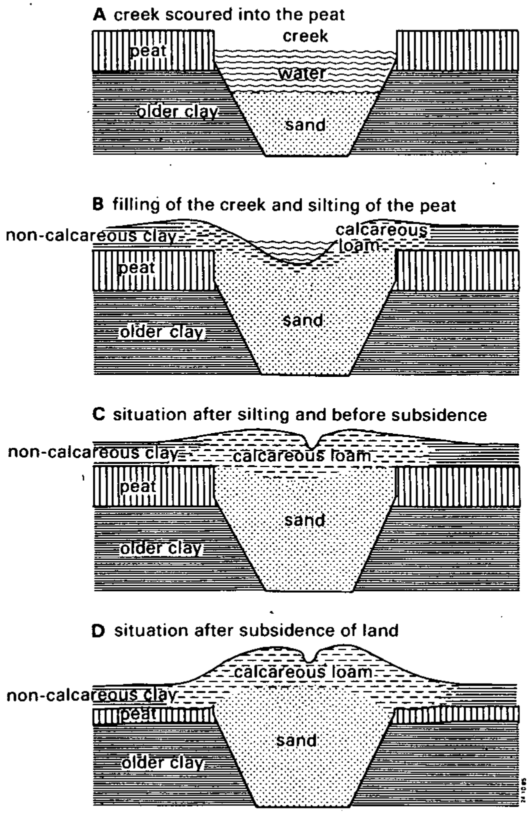


Fig. 8 Development of a "creekridge"

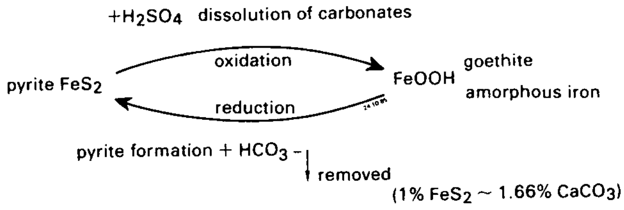


Fig. 7 Schematic representation of the reduction-oxidation cycles involving iron, resulting in carbonate dissolution (Kooistra, 1978, 1982)

Coastal polder soils in the "Tweede Bathpolder"

As already mentioned coastal polders are "offensively" embanked accretions. They are reclaimed from tidal marshes, silted up to about or above mean hihg-tide level, mostly as accretions against old land or earlier embanked coastal polders. The reclaimed marsh is most elevated and finest textured (silty clay loams) near the old land or seadike of the previously embanked polder and becomes lower and coarser textured (sandy loams) towards the sea. Each successive embankment has a higher level than the previous embankment. With depth the soils grade to loamy very fine sand of the former intertidal flat deposits. In coastal polders the influence of man on the arrangement of the land is large. The main creeks remained open as drainage channels. Smaller creeks are filled in and the land is levelled. Most ditches have rectangular patterns and the fields are generally larger and more regular than in the old land. Polder roads are straight or are situated on top of dikes. Farmsteads are situated along polder roads or at the foot of the dikes. Villages developed as dike-villages or along roads or at crossroads.

Land use is predominantly arable with potatoes and sugar beet as main cash crops. A wide variety of crops is grown on a lesser scale: onions, seed potatoes, malting barley, winter wheat, colza, flax, etc. Locally fruit growing is important, mainly apples (De Bakker, 1979; De Bakker and Kooistra, 1982). The land generally is tile-drained with pumping levels 1-2 m below the land surface. Due to these improved drainage conditions the soils are ripened. The bulk densities of sandy materials increased by 20-25% and fine-textured material increased in bulk density by 2-3 times its former weight (see Table 2). After reclamation in fine-textured soils a prismatic structure developed. In arable land of the coastal polders no distinct evidences of other new soil forming processes started after reclamation are observed.

Old land

As already stated the "oldland" consits of sediments dating before 1000 to 800 B.P. The areas where these sediments occur at or near the surface form the nuclei of the (former) islands.

The "creekridges" are not the natural levees of creeks, but form the whole body of a former creek, including the levees by "inversion" of the relief being a high lying ridge composed of (sandy) loam and sand bedded in clay-over-peat of the adjoining basin (Fig. 8). This clay-over-peat was subject to a marked subsiding as a result of shrinkage of the peat and clay, especially after increasingly improved artificial drainage. First small sluices were built, only opened at low tide, later by wind mills and to-day diesel and electrical pumps are used. The infilled creeks and their levees, consisting of (sandy) loams and sands did not subside and therefore form now the higher ridges ("creekridges").

The basins consist of non-calcareous clay loam to silty clay overlying peat, mostly beginning at a depth between 0.5 m to 1.50 m below the surface. Often the topsoil in somewhat coarser textured (loam) and sometimes slightly calcareous because of a 'rejuvenation' during inundations of a next transgression phase. Underneath the peat an older marine clay can be found (Calais-formation). In the profile pit of soil B-NL1 these deposits are found at about 1.5 m below the surface (about 2.5 m below mean sea level).

A special complication in soil conditions of the basins is caused by the activity of man. They excavated peat from the subsoil. Already in the Roman era, but especially between the 11th and the 14th century A.D. peat cutting was a common practice in this part of the country. The peat was used for fuel, but its main application was the manufacturing of salt out of the peat. The peat, saturated with salt water from the marine inundations, could be extracted with (salt) water, evaporated by boiling using (dried) peat as fuel. Salt-making out of peat was a main commodity here during the Middle Ages, and there was a lively trade of this product with neighbouring countries. After excavating the peat, the pits were hardly filled-in, resulting in a very irregular terrain in the basins, as will be shown during the excursion. In Fig. 9 a cross-section through such a landscape is given.

Early land reclamation often followed the pattern of the tidal creeks, which is reflected in the ditch patterns of the "old land". As a consequence the road and field pattern is very irregular, except in areas where recent reallocations reshaped the landscape.

The low-lying basins generally are brackish and mostly used for pasture. Through such pastures the creekidges are seen to meander. Human activity was concentrated in early times upon and along these ridges that were better drained. Roads were also built on such ridges and the soil used as arable land and/or for fruit growing.

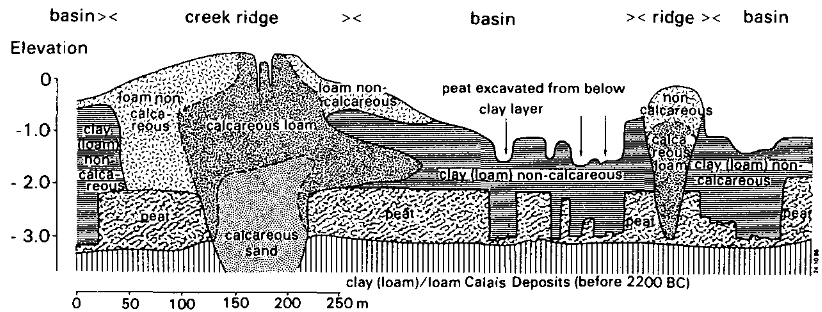


Fig. 9 Cross-section of "old land" (mainly Dunkirk II - Deposits, 250 - 600 A.D.)

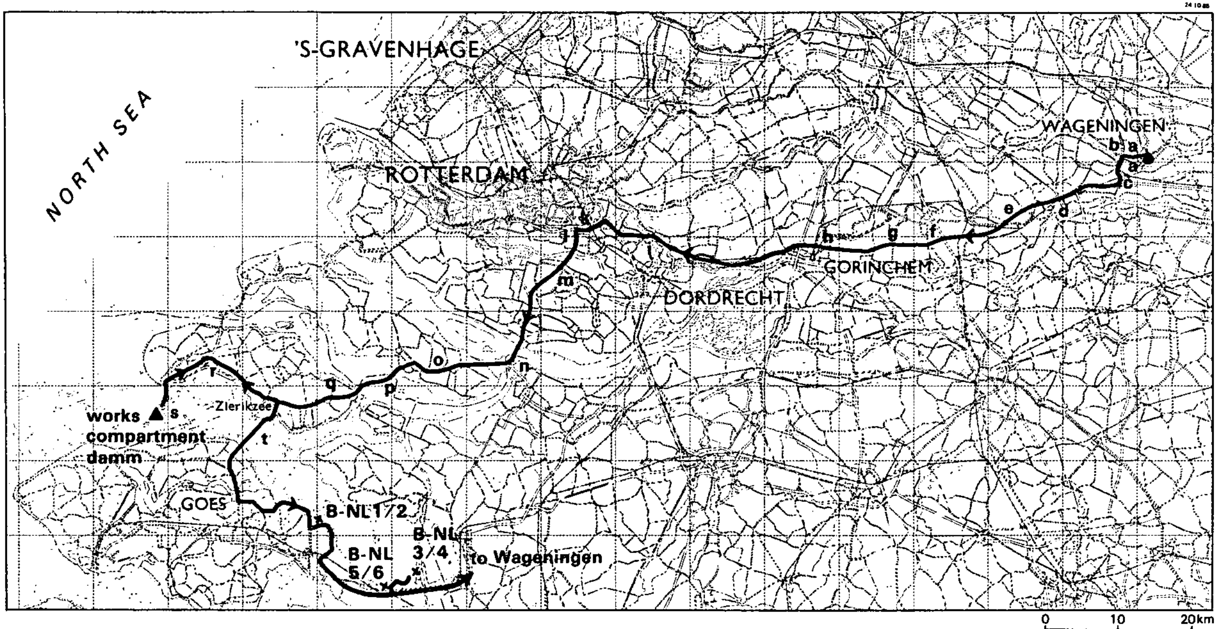


Fig. 10

EXCURSION ROUTE August 9 th 1986

Route description

From Wageningen (Fig. 10) the route leads westward through an embanked young sediment of the river Rhine (about 8 m + mean sea level). The road is built on the natural levee with calcareous, brown soils (Calcaric Fluvisol; Eutrochrept); many orchards (a). On the right side (northward) the grasslands of the non-calcareous, fine textured basin (Eutric Fluvisol; Fluvaquent) are to be seen. After 3 km there is a sharp boundary in the landscape (b): the foot of an ice-pushed ridge (a 50 m high "mountain"), formed during the Riss- or Saale glaciation. It consists of gravelly coarse sand (Leptic Podzol; Haplorthod) with mixed oak woodland and coniferous trees. Here in May 1940 the main battle between the Netherlands and the German army took place. On top of the ridge a war memorial and a war cemetery.

At the foot of the ridge we turn southward and cross the river Rhine. Between the dikes lie the forelands with brick factories. South of the village of Kesteren (Castra in Roman times) on a levee of the Rhine we turn westward on the motorway to Rotterdam (c). This newly built road "cuts" straight through the landscape, unlike the old roads that follow the natural levees. As it avoids the villages and towns, it mostly leads through the fluviatile basins with grassland, at the beginning of the road about 4.5 m above mean sea level. After 9 kms we pass a bridge over the Amsterdam-Rhine canal with a large complex of ship-locks on the left (d). On the westside of the canal the road follows about 5 kms the natural levees of the small rivulet Linge, the meanders of which we cross several times (e). Gradually the level of the land drops and near a round-about it reaches about 1.5 m above mean sea level (f). The extended basins here have a peaty subsoil. The region has recently been reallotted. The once almost swampy basin without roads and without farmhouses is drained, new roads are constructed and new farms were built (g).

Further westward the claycover of the basins becomes more and more shallow and west of the town of Gorinchem the riverbasins (altitude 1.5 m below mean sea level) consist almost entirely of clayey wood-peat (Eutric Histosol; Eutric Medihemist). Here we reach "Holland" (h), being only a province of the Netherlands, indeed the Low Countries (in French Pays-Bas).

We pass north of the town of Dordrecht, one of the oldest towns and most important imporiums of medieval Holland. After crossing the bridge over the riverbranch Noord (i), we reach the marine district, but at first we only see shipyards, industrial areas and residencial districts. These are satelite towns and later on the southern outskirts of Rotterdam (k), the second largest city of the country (600 000 inhabitants) and the largest harbour of the world (over 10^9 tons).

At a big round-about with fly-overs we turn southward and reach the marine polder area (l) with calcareous soils of various textures (Calcaric Fluvisol, Fluvaquent), mostly used as arable land (sugar beet, potatoes, winter wheat) and horticulture (open air and glasshouses). We pass through a subway below a branch of the river Meuse, into another polder area (m).

About 25 kms south of Rotterdam we arrive at the border of the Hollandsch Diep, a now dammed sea-inlet. We drive over the bridge (1964) and pass a small round-about constructed on a sand flat midstreams (n) and leave the sand flat by a 4 km dam (1970). At the end of the dam we arrive at the island Overflakkee (o), with dominant coarse textured, calcareous marine soils, mainly used as arable land (the island is famous for its potatoes). After about 15 kms we cross another sea inlet, the Grevelingen, by an almost 6 km long dam (p), built in 1968 and arrive at the next island, called Schouwen-Duiveland (q). Just as the foregoing island it was very seriously damaged during the inundations of 1953. The whole area we are crossing, has since been reconstructed and newly allocated. Many new farmsteads were built.

After a 10 kms drive to the west we pass north of the old town of Zierikzee, in the Middle Ages famous for its salt-factories and in the 17th century a centre of trade on the Carribeans and South-America. About 10 kms west of Zierikzee we have on our left the enormous former gap in the dike, caused by the storm surge of 1953 (r). It was nearly 3 km wide and reached a depth of over 30 m. The water inside the dike is the remainder of the big scour-hole of the dike-breach.

We arrive at the information centre of the Delta-works on the island Neeltje Jans (2) where we will visit the storm-surge barrier in the Oosterschelde.

After the visit to the Delta-works we return to the town of Zierikzee and branch off southward via the Zeeland-bridge (t) towards the former islands North- and South-Beveland to visit the profiles B-NL1-6. The Zeeland-bridge (1965) is nearly 5 km long and 16 m above mean sea level. There are 52 spans on piers, each comprising 3 hollow concrete cylinders up to 50 m long. The first span on the northside is movable, as it crosses the navigation channel with locks. More information of the route is given together with the profile descriptions at each stop.

Stop 1, soils B-NL1 and B-NL2

General information

Profile B-NL1 is situated in a basin of the "old land". The sediment is formed during the Dunkirk II transgression phase (1750-1350 B.P.) as a non-calcareous (silty) clay (loam) over peat (see Fig. 9).

The peat began to develop as a eutrophic reed-sedge (Phragmites-Carex) peat and gradually turned oligotrophic (Sphagnum-moss and Calluna/Erica). The top of it was hardly affected by erosion at places were the fine textured sediments were deposited. Profile B-NL2 is demonstrated as a core-sample, taken on a nearby "creekridge". It is from the same transgression phase and developed as a natural levee along a creek, that was scoured into and partly through the peat (see Fig. 8). It originally consisted of a calcareous (silt) loam. Since its formation it has been decalcified to a considerable depth. In the centre of the ridges no peat is left; the sides of the ridge may have some peat in the deeper subsoil. The core of the bigger creekridges mostly consists of calcareous very fine sand.

As a result of the embankment and the subsequent drainage a substantial subsidence of the low basins occurred. It resulted in a marked increase of the relief. During the Middle Ages the peat below the clay was irregularly excavated for fuel and salt making. Still to-day the salt content of the peat is very high. The topsoil has on most places a low salt content as a result of desalination by percolating rainwater. In the lowest places of the basin a salt-tolerant vegetation is locally present.
The very detailed soil map, original scale 1 : 1000 (Fig. 11) shows the presence of a creekridge in the centre. Only the core of this ridge is free of peat and it has a sandy subsoil. The basins show a broad variation in the depth of the peat. In the cross-section of Fig. 8 these variations are also illustrated.

Site Description soil B-NL1

Location	: Yerseke Moer ("basin") Top. Sheet: 49 West Bergen-op-Zoom Grid.rep. : 51° 30' NB 390.270 Northings 4° 02' WL 60.540 Eastings Municip. : Reimerswaal, near village of Yerseke
Elevation	: 1.2 m below mean sea level
Landform	: Small, basin-shaped depression, nearly level; along the borders of the silted-up creeks slightly sloping
Drainage	: Class: Inperfectly drained No tile-drainage in the field
Depth of groundwater	: Mean highest level 15 cm below surface Mean lowest level 70 cm below surface
Landuse	: Permanent grassland; shortly natural reserve and gradually turning into rough grazing land; the lowest spots salt affected and with a salt-tolerant vegetation
Human influence	: Embanked (before 900 B.P.); on many places disturbed soils by peat digging for fuel and salt
Parent material & geology	: Non-calcareous, fine-textured, illitic marine sediment of young-holocene age (1750-1350 B.P. Dunkirk II transgression phase), overlying oligotrophic over mesotrophic peat; at a depth of about 1.60 m overlying older holocene marine sediments (Calais transgression periods)
Soil classification	: FAO : Eutric Fluvisol, fine textured level, saline

Analyses

Profile B-NL1 Yerseke Moer ("basin")

Hor.	Depth cm	Granulometric analysis in % of oven-dry soil in µm						$CaCO_3$ %	pH-KCl	Org. matter %	Exchangeable bases in me/100 g			
		2000 -150	150- 105	105 -50	50- 16	16 -2	<2				Ca	Mg	K	Na
Ahg	5-10	0.8	0.8	14	45	14	25	0	5.0	16.7	n.d.	n.d.	n.d.	n.d.
Cg1	13-23	0.5	0.4	14	45	14	26	0.1	5.7	2.1	4.8	5.8	0.7	3.0
Cg2	23-50	0.6	0.3	7	35	16	42	0	5.9	2.1	7.7	10.1	1.4	5.1
2H	50-65	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	6.0	87	n.d.	n.d.	n.d.	n.d.

Hor.	Depth cm	Fe-dith. %	Bulk dens. g/cm^3	Pore vol. %	Water content in % at pF						
					1.0	1.5	2.0	2.3	2.7	3.4	4.2
Ahg	5-10	0.64	816	66	65	61	58	55	47	35	23
Cg1	13-23	0.57	1474	45	43	41	38	36	34	33	22
Cg2	23-50	2.71	848	69	66	62	59	57	53	34	26

Site Interpretation

The peaty part of the soil shows from bottom to top a gradual change from eutrophic to oligotrophic peat, starting from a brackish peat with many rootstocks of Phragmites (reed) to a dominancy of Carex (sedge) peat. After a period of stagnation and 'earthifying' (layer 110-120 cm) peat formation started again, which gradually became oligotrophic. The final phase (Spagnum-moss) again is characterized by earthification.
A transgression of the sea abruptly ended the peat formation about 1750 B.P. In the present-day basin a very fine textured sediment was deposited in a probably densely vegetated environment, resulting in a non-calcareous (silty) clay. This material is still not fully ripened as appears from its low bulk density and its high pore volume. The sodium content of the layer is high, as is the Mg-content.
With increasing level of sedimentation the clay-content diminishes, as is the salt content, a result of desalination by percolating rainwater. The Mg-content is still high. Ripening of these layers is completed.

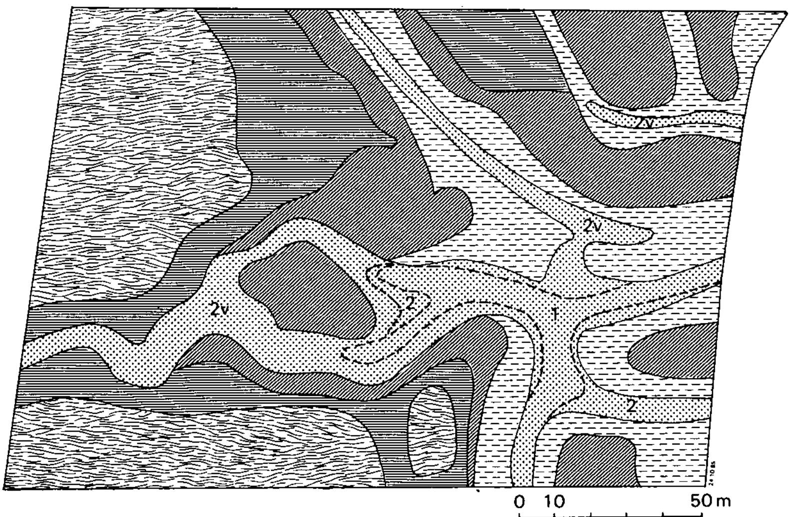
Site description soil B-NL2

Location	: As B-NL1, but Northings 390.280 Eastings 60.540
Elevation	: 0.2 m above mean sea level
Landform	: small elongated ridge
Drainage	: Class: Well drained No tile-drainage in the field
Depth of groundwater	: Mean highest level 45 cm below surface Mean lowest level 130 cm below surface

Landuse : Permanent grassland; shortly natural reserve and gradually turning into rough grazing land; long ago used as arable land

Parent material & geology : Decalcified medium-textured illitic marine sediment of young-holocene age, sometimes overlying calcareous, very fine sea sand, elsewhere also overlying peat. Natural levee of silted-up creek

Soil classification : FAO: Eutric Fluvisol, slightly calcareous, medium textured; ridge
U.S.: Fine-silty, mixed, mesic Typic Fluvaquent
Germ.: (leicht verbraunte) Kleimarsch (kalkhaltige Seemarsch)



CREEK RIDGE

1 Calcaric Fluvisol; (sandy) loam over very fine sand

2 Eutric Fluvisol; (sandy) loam; > 80 cm non-calcareous silty clay

2v The same; peat beginning between 80 and 120 cm

3v Eutric Fluvisol; loam over silty clay with jarosite; peat beginning between 80 and 120 cm

BASIN

4V Eutric Fluvisol; silt loam over silty clay loam; peat beginning between 40 and 80 cm; salt affected

5V Eutric Fluvisol; silty clay loam; peat beginning between 40 and 80 cm; salt affected

6 Eutric Histosol; 10-40 cm non-calcareous silty clay over 10-30 cm earthified oligotrophic peat overlying reed-sedge peat; salt affected

Fig. 12 Detailed soil map of a field in the Yerseke Moer

U.S. : Fine-clayey, illitic, mesic, Typic Fluvaquent
Germ.: Nasse Knickmarsch

Profile Description :

Horizon (FAO)	Depth (cm)	
Ahg	0-13	very dark greyish brown (2.5YR3/2m) silt loam (uL^u), non-calcareous; few fine distinct mottles; moderate medium subangular blocky; sticky; abundant roots; abrupt smooth boundary (sample)
Cg1	13-23	grey (5Y5/1m) silt loam (uL), non-calcareous; many coarse prominent rust mottles; moderate coarse prismatic sticky; common roots; gradual smooth boundary (sample)
Cg2	23-50	dark grey (5Y4.5/1m) silty clay (utL), non-calcareous; many coarse prominent rust mottles, few yellowish jarosite stains (catclay); moderate and weak coarse prismatic; very sticky; few roots; abrupt irregular boundary (sample)
2Har1	50-65	black (5YR2/1m) peat, weakly earthified, strongly decomposed; gradual smooth boundary (sample)
2Her1	65-110	brown (10YR4/3m) reed-sedge peat, not aerated; abrupt irregular boundary
2Har2	110-120	black (5YR2/1m) reed-sedge peat, weakly decomposed; abrupt smooth boundary
2Her2	120-150	brown (10YR4/3m) reed-sedge peat; not aerated; abrupt smooth boundary
3Cr	155+	dark greenish grey (10GY4/1w) clay (lT); many vertical reed roots; stratified; unripened; very weak (Calais formation)

Analytical Data : See next page

Profile description:

Horizon (FAO)	Depth (cm)	
Ah	0-10	Very dark greyish brown (2.5Y3/2m) silt loam, humose, non-calcareous; moderate fine subangular blocky; gradual smooth boundary (sample)
Ap	10-18	dark greyish brown (2.5Y4/2m) silt loam, non-calcareous; moderate subangular blocky; abrupt smooth boundary (sample)
Bw	18-37	brown (10YR4/3m) loam, non-calcareous; compound moderate medium to fine prismatic and fine subangular blocky; gradual smooth boundary (sample)
Cg1	37-48	greyish brown (2.5Y5/2m) silt loam, slightly calcareous; medium distinct rust mottles; moderate medium prismatic; gradual smooth boundary (sample)
Cg2	48-82	grey (2.5Y5/1m) silt loam, slightly calcareous; many distinct rust mottles; weak medium prismatic; gradual smooth boundary (sample)
Cg3	82-120	dark grey (N4m) silty clay loam, slightly calcareous; medium weak prismatic; few distinct rust mottles (sample)

Analytical Data :

Profile B-NL2 Yerseke Moer ("creekridge")

Hor.	Depth cm	Granulometric analysis in % of oven-dry soil in µm						$CaCo_3$ %	pH-KCl	Org. matter %	Exchangeable bases in me/100 g			
		2000 -150	150 -105	105 -50	50 -16	16 -2	<2				Ca	Mg	K	Na
Ah	4- 9	1	1	27	43	8	20	0	3.9	9.8	4.8	2.1	0.3	0.2
Ap	13- 18	1	1	27	43	8	20	0	3.7	6.0	4.2	1.8	0.3	0.2
Bw	20- 37	0.5	1	32	41	7	18	0	3.8	3.0	3.9	1.9	0.2	0.2
Cg1	37- 48	0.5	0.5	27	45	6	22	0.1	4.1	0.4	5.5	3.8	0.3	0.2
Cg2	48- 82	1	1	25	45	6	22	0.1	5.1	0.1	6.4	4.2	0.3	0.4
Cg3	82-110	1	0.5	16	45	10	28	0.4	6.7	0.3	10.1	5.6	0.5	0.9

Hor.	Depth cm	Bulk dens. g/cm^3	Pore vol. %	Water content in % at pF						
				1.0	1.5	2.0	2.3	2.7	3.4	4.2
Ah	4- 9	946	61	61	62	57	53	47	36	25
Ap	13- 18	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Bw	20- 37	1186	54	55	51	46	42	37	26	19
Cg1	37- 48	1485	45	48	47	46	45	42	36	24
Cg2	48- 82	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cg3	82-110	1277	53	55	52	50	48	45	33	24

Site interpretation

As a contrast to the fine textured "basin"-soil overlying peat the core sample of a nearby "creekrdige"-soil shows the next most striking contrasts:

- no peat layers in the subsoil
- a coarser textured profile
- a slight carbonate content in the subsoil
- a browner colour, resulting in the formation of a weakly developed Bw-horizon
- no reduction within 1.20 m
- much deeper groundwater levels in summer and in winter
- no salt in the subsoil
- a completely ripened profile, although the pore volume is still rather high
- the pH of the upper layers is low, but there are no signs of cat-clay forming

Stop 2, soils B-NL3 and B-NL4

General information

Profile B-NL3 and 4 are situated in a middle-high salt-marsh developed as tidal foreland against an earlier embanked coastal polder (Tweede Bathpolder) in the Oosterschelde estuary. In salt-marshes three geomorphic elements can be distinguished: creeks, natural levees and basins. In the Oosterschelde natural levees are well developed. Pairs of sites need to be studied, one on a natural levee and one in the adjoining basin, because these locations represent two altitudinal extremes in the field with largest differences in granular compositions and therefore illustrate the different kinds of soil and vegetation. Soil B-NL3 (a pit) developed in a natural levee, exposed in the wall and soil B-NL4 (a core) from the adjoining salt-basin. The elevation of the site at the natural levee is 2.08 m + N.A.P. (Dutch Ordnance Level = approximately mean sea level) and of the adjoining basin 1.94 m + N.A.P. The vegetation of the natural levee consists of Halimione portulacoides with a minor admixture of Festuca rubra. This zone stands clearly out from the vegetation of the adjoining basin which consists of Spartina townsendii (± 60%), Aster tripolium (± 20%), Puccinellia maritima (± 10%), Salicornia europaea and Limonium vulgare. Between these two vegetation types locally a small zone only covered with the Aster tripolium can be found. The soils developed in these recent marine deposits are Entisols and classified as Hydraquents (Soil Survey Staff, 1975) or as Fluvisols (FAO-UNESCO, 1975).

Profile descriptions

Soil B-NL3

U.S. Soil Taxonomy (1975): Hydraquent

Dutch classification (De Bakker & Schelling, 1966): Gorsvaaggrond

AC	0-14 cm	Very dark grayish brown (2.5Y3/2); sandy loam; moderately very fine angular blocky; ripening 4; common fine pores; strongly calcareous; many very fine, fine and few medium roots; presence of grubs and snails; abrupt smooth boundary to:

Cg1	14-38 cm	Very dark grayish brown (2.5Y3/2) 60%, dark gray (5Y4/1) 25% in mottles, dark reddish brown (5YR3/6) 15% in mottles and along pores; sandy loam; weak coarse prismatic and weak very fine angular blocky; ripening 3 to 4; continuous thin to moderately thick ferruginous coatings along vertical ped faces, pores and holes; many fine and medium tubular pores; calcareous to 20 cm depth, slightly calcareous 20-38 cm depth; many fine and medium roots; clear smooth boundary to:
Cg2	38-50 cm	Gray (7.5Y4/1) 60%, dark grayish brown (2.5Y4/2) 20% in mottles, dark red (2.5YR3/6) 20% in mottles; sandy loam; moderately coarse prismatic; ripening 3; moderately thick to thick continuous ferruginous coatings on vertical ped faces, pores and holes; many fine vertical pores; slightly calcareous 38-45 cm, calcareous deeper than 45 cm; few small spherical black/red mottles probably of manganese/iron; common fine mainly vertical roots; crabholes; wavy clear boundary to:
Cr1	50-70 cm	Black (N2), dark gray (5Y4/1) in zones along channels; sandy loam; ripening 3; many fine and some medium vertical pores; strongly calcareous; many very fine, fine and medium roots, about 60% dead ones; thin dark gray (5Y4/1) layer with many Hydrobia ulvae snails; clear smooth boundary to:
Cr2	>70 cm	Black (N2), dark gray (5Y4/1) 15% along pores; sandy loam; faint lamination; ripening 2 to 3; many very fine and some fine and medium vertical pores; strongly calcareous; few fine and very fine vertical roots; effects of faunal activity.

Soil B-NL4
U.S. Soil Taxonomy (1975): Sulfaquent
Dutch classification (De Bakker & Schelling, 1966): Slikvaaggrond

Cr1	0-26 cm	Gray (7.5Y4/1) 55%, dark brown (10YR3/3) 40% along ped faces and pores; and dark reddish brown (5YR3/6) 5% along ped faces and pores; silty clay loam; weak very fine angular blocky; ripening 2; deeper than 6 cm continuous moder-

		ately thick ferruginous coatings on ped faces and pores; common fine random pores; first 3 cm strongly calcareous, decreasing to non calcareous at 9 cm depth, from 9-20 cm non calcareous, deeper than 20 cm slightly calcareous; abundant very fine, fine and medium roots; first 6 cm many specimen of Hydrobia ulvae; abrupt, smooth boundary to:
Cr2	26-37 cm	Black (N2) and olive black (10Y3/1) along some vertical pores; clay loam; ripening 2; common fine, mainly vertical pores; calcareous; many fine and medium roots, partly black coloured; abrupt smooth boundary to:
Cr3	37-49 cm	Very dark gray (N3); loam; weak lamination; ripening 2; few to common fine vertical pores; calcareous; common fine and medium vertical roots, partly dead ones; abrupt smooth boundary to:
Cr4	>49 cm	Dark gray (N4) and olive gray (2.5GY5/1) in sandy laminae; sandy loam; strong lamination; ripening 2 to 3; few fine vertical pores; strongly calcareous; few to common fine and medium roots; sand at 82 cm depth.

Analytical data : see next page

Profile B-NL3 Hydraquent

Depth	Moisture	Granulometric analysis in % of oven-dry soil in µm							$CaCO_3$	pH		$E.C._{2.5}$	%	%	ppm P_2O_5-	% Fe_2O_3
in cm	%	210-150	150-105	105-74	74-50	50-16	16-2	<2	%	H_2O	KCl	x 10^3	C	N	Olsen	dithionite
5-15	2.3	0.1	10.0	24.6	15.1	24.2	8.9	17.1	5.19	7.8	7.5	11.5	1.88	0.19	118	1.33
25-35	2.7	0.3	7.9	19.8	15.8	26.9	9.1	20.1	3.76	7.7	7.4	12.2	2.06	0.22	92	2.24
45-55	1.0	0.1	6.8	19.0	14.6	27.5	12.3	19.6	6.45	7.7	7.3	10.0	2.27	0.21	31	1.16
65-75	1.4	0.4	25.7	28.9	14.4	14.4	3.1	12.9	6.65	8.2	7.6	6.5	1.21	0.11	18	0.81

Depth in cm	me/100 g						E.S.P.	% Base saturation	$E.C._e$ x 10^3	1 : 5 waterextract, me/100 g										
	Exchangeable bases					C.E.C.				$E.C._5$ x 10^3	cations					Anions				
	Ca	Mg	K	Na	Sum						Ca	Mg	K	Na	Sum	Sum	HCO_3	Cl	SO_1	NO_3
5-15	9.08	6.07	1.26	2.42	18.8	20.3	12	93	62.6	7.60	2.30	4.54	0.72	33.4	41.0	42.2	0.57	37.5	4.04	0.01
25-35	9.12	6.35	1.43	3.32	20.2	23.5	14	86	42.6	8.40	2.06	5.06	0.79	36.8	44.7	46.5	0.56	41.8	4.06	0.01
45-55	9.97	5.73	1.50	2.34	19.5	21.1	11	92	41.2	7.00	2.27	4.47	0.78	29.6	37.1	38.5	0.46	32.1	5.80	0.02
65-75	11.4	6.46	1.82	1.55	21.2	22.3	7	95	40.2	3.00	4.21	6.23	1.05	33.5	45.0	45.8	0.52	35.4	9.83	0.01

Profile B-NL4 Sulfaquent

Depth in cm	Moisture %	Granulometric analysis in % of oven-dry soil in µm 210-150	150-105	105-74	74-50	50-16	16-2	<2	$CaCO_3$ %	pH H_2O	pH KCl	$E.C._{2.5}$ x 10^3	% C	% N	ppm P_2O_5- Olsen	% Fe_2O_3 dithionite
5-15	5.5	0.2	0.5	2.3	5.9	31.1	19.0	40.8	1.24	7.0	6.8	19.6	5.63	0.60	191	3.18
25-35	3.8	0.1	0.5	4.2	6.6	39.8	11.0	37.7	2.54	7.0	6.8	15.9	4.32	0.38	30	0.97
45-55	2.6	0.1	4.8	15.2	14.0	29.8	10.3	25.7	3.38	7.4	7.1	10.7	2.40	0.22	21	0.51
65-75	1.7	0.1	3.2	18.9	21.4	34.0	7.5	14.8	8.09	7.9	7.6	7.5	1.39	0.11	19	0.22
85-95	1.3	0.2	7.8	25.5	24.4	29.7	4.4	7.8	9.29	8.0	7.6	6.0	1.24	0.09	13	0.22

Depth in cm	me/100 g Exchangeable bases Ca	Mg	K	Na	Sum	C.E.C.	E.S.P.	% Base saturation	$E.C._e$ x 10^3	1 : 5 waterextract, me/100 g $E.C._5$ x 10^3	cations Ca	Mg	K	Na	Sum	anions Sum	HCO_3	Cl	SO_1	NO_3
5-15	9.12	14.6	3.12	10.8	37.6	53.6	20	70	x	17.3	3.70	13.9	1.89	82.6	102	106	0.30	94.8	10.6	0.04
25-35	10.8	10.3	2.80	4.28	28.2	32.3	13	87	57.4	13.8	5.46	11.4	1.56	57.5	76.0	80.0	0.82	65.1	14.0	0.03
45-55	9.11	6.72	2.00	1.55	19.4	21.2	7	92	47.0	8.11	2.82	5.89	1.31	33.5	43.6	45.1	0.41	36.2	8.54	0.03
65-75	8.26	4.02	1.28	0.65	14.2	14.8	4	96	35.6	5.12	1.53	3.00	0.78	21.0	26.4	30.8	0.41	22.0	8.46	0.02
85-95	7.97	3.25	0.93	0.58	12.7	11.9	5	>100	35.0	4.64	2.53	3.16	0.80	17.6	24.0	24.4	0.37	18.3	5.69	0.02

Data on the accumulation of pyrite and ferric iron measured directly in fresh soil samples of a related large natural levee and a comparable salt-basin of the same area:

Depth in cm	pH-H_2O	E_H(V)	Fe (tot) %	SO_4 (tot) %	SO_4 (dil. in H_2O)	% <2 µm	% C	% $CaCO_3$
Natural levee								
10- 20	7.9	-	1.50	0.23	0.064	7.8	0.77	3.8
74-103	7.8	+0.2	1.40	0.09	0.084	8.2	0.46	5.5
104-123	8.0	+0.2	1.18	0.35	0.087	8.7	0.46	5.1
135-140	8.0	+0.1	1.35	0.98	0.098	8.9	0.54	7.1
Cr-horizon from - 104 cm								
Salt basin								
10- 20	7.2	+0.2	4.30	0.77	0.314	36.3	3.31	2.5
55- 70	7.8	-0.2	2.84	3.65	0.177	21.8	1.77	8.7
90-105	7.9	-	1.66	1.64	0.106	11.7	0.85	7.7
Cr-horizon from - 24 cm								

Micromorphological data of the pedogenetic phenomena

Zone, location and depth in cm of the thin sections		Biological processes					Physical processes		Chemical processes		
		faunal channels	floral channels	pedotubules agrotubule	striotubule	passage features	cracks	infillings in voids	Pyrite neoformations	decalcification	iron-manganese accumulations
middle-high salt-marsh											
natural levee	0-15	+	++	+							
profile B-NL3	17-32	+	++	+					(+)	+-++	+
	39-54	+-++	+-++			+	+	+	(+)		++
	75-90	+	++		(+)	++		++	+		
salt-basin	0-15	+	+++			++		+	(+)	++	(+)
profile B-NL4	17-32		+++			++		+	+-++	++-+++	
	38-53		++-+++			+-++		+	++	+	
	68-83		++			+-++		+	+		

\+ = few
++ = common
+++ = abundant

Stop 3, soils B-NL5 and B-NL6

General information

Profile B-NL5 and 6 are situated in the Tweede Bathpolder, a coastal polder embanked in 1857. The two basic types of polder soils are those developed on natural levees and in former basins. In between integrades occur. Profile B-NL5 (a pit) is a soil developed in a former salt-basin and profile B-NL6 (a core) is a soil developed in a natural levee near profile B-NL5. The elevation of the site of profile B-NL5 is about 1.60 m + N.A.P. (Dutch Ordnance Level = approximately mean sea level). The elevation of the site B-NL6 is about 1.25 m + N.A.P. The following explanation for this difference in height has to be given. The site of profile B-NL5 is situated near the earlier embanked coastal polder where the tidal foreland is silted up highest and the top of the natural levee is used to fill in a part of the adjoining creek. The surrounding relief in this polder is flat, due to levelling. The land use is arable with a rotation of potatoes, sugar beet and cereals, mainly winter wheat. The fields are tile-drained. The soils developed in these young marine deposits are Entisols and classified as Fluvents or Fluvaquents (Soil Survey Staf, 1975) or as Fluvisols (FAO-UNESCO, 1975). These soils have ACg profiles.

Profile descriptions

Soil B-NL5, Tweede Bathpolder
U.S. Soil Taxonomy (1975): Typic Fluvaquent
Dutch classification (De Bakker & Schelling, 1966): Poldervaaggrond

Ap1	0-5 cm	Dark grayish brown (2.5Y4/2) moist; silty clay; medium fine crumb; non sticky, plastic; common fine pores; calcareous; evidence of faunal activity; clear smooth boundary to:
Ap2	5-35 cm	Dark grayish brown (2.5Y4/2) moist; silty clay; medium angular blocky, fine aggregates and structureless material; non sticky, plastic; common fine inped random pores; calcareous; evidence of faunal activity; abrupt smooth boundary to:
Cg1	35-50 cm	Grayish brown (2.5Y5/2) on ped faces, brown (7.5YR4/3) in the peds and dark reddish brown (5YR3/3) along pores and in some mottles, moist; silty clay; moderately medium to coarse prismatic and fine to medium angular blocky; non sticky, plastic; continuous moderately thick to thick cutans resembling argillans, on ped faces and along some pores; common fine inped pores; calcareous; few to common fine roots, mainly between ped faces; gradual smooth boundary to:

Cg2	50-70 cm	Grayish brown (2.5Y5/2) on ped faces, brown (7.5YR4/3) in the peds and dark reddish brown (5YR3/3) along pores, moist; clay loam; moderately to strong coarse prismatic and moderately fine and medium angular blocky; few slickensides; non sticky, plastic; some manganese mottles; continuous moderately thick and thick cutans resembling argillans, mainly on ped faces and along pores; common fine and very fine inped pores; calcareous; few fine roots; gradual smooth boundary to:
Cg3	70-82 cm	Grayish brown (2.5Y5/2), brown (7.5YR4/3) and dark reddish brown (5YR3/3) 50% in mottles, moist; loam; distinct lamination; thin platy with vertical cracks; slightly sticky, slightly plastic; common continuous cutans, resembling argillans, along pores and some vertical cracks; calcareous; few fine roots, mainly in vertical cracks; sharp smooth boundary to:
Cg4	82-108 cm	Light gray (5Y6/1) and dark reddish brown (5YR3/3) in mottles, moist; sandy loam; strong lamination; non sticky, non plastic; ferruginous coatings along pores and afterwards infilled pores; some discontinuous cutans, resembling argillans in vertical pores; common fine and medium vertical pores; calcareous; shell fragments and doublets; gradual smooth boundary to:
Cg5	108-155 cm	Brown (10YR5/3) 80%, light gray (5Y6/1) 10% and dark brown (7.5YR4/4) 10% in mottles and along pores, moist; sand; weak lamination; few infilled pores with ferruginous coatings; abrupt smooth boundary to:
Cr	>155 cm	Dark gray (N4) moist; sand.

Soil B-NL6, Tweede Bathpolder
U.S. Soil Taxonomy (1975): Typic Fluvaquent
Dutch classification (De Bakker & Schelling, 1966): Poldervaaggrond

Ap	0-35 cm	Dark grayish brown (2.5Y4/2) moist; sandy loam; moderate medium crumb; slightly sticky; slightly plastic; many fine and medium tubular pores; strongly calcareous; abundant fine roots; abrupt smooth boundary to:

Cg1	35-52 cm	Grayish brown (2.5Y5.2) moist, dark reddish brown (5YR3/3) 20%, moist, along pores; sandy loam; moderately fine to medium angular blocky, very weak coarse prismatic; distinct lamination; non sticky, slightly plastic; moderately thick cutans, resembling argillans, on ped faces and along pores; common fine and very fine inped tubular pores, some with ferruginous coatings; strongly calcareous; many fine roots; few to common infilled channels and chambers; shell fragments; gradual smooth boundary to:
Cg2	52-70 cm	Grayish brown (2.5Y5/2) moist in clay-rich laminae; light gray (5Y6/1) moist in sandy laminae; sandy loam; distinct lamination; non sticky, non plastic; continuous moderately thick ferruginous (7.5YR4/3) coatings, mainly along common fine to medium pores; strongly calcareous; few fine roots; few infilled burrows; shell doublets; abrupt smooth boundary to:
Cg3	70-100 cm	Grayish brown (2.5Y5/2) moist, in clay-rich laminae, light gray (5Y6/1) moist, in sandy laminae; sandy loam; strong lamination; slightly sticky, slightly plastic; many ferruginous (7.5YR4/6) coatings along pores, and infilled pores; few to common fine, medium and coarse vertical pores; strongly calcareous; shell doublets; clear smooth boundary to:
Cg4	100-125 cm	Yellowish brown (2.5Y5/3) light gray (5Y6/1) 10%, brown (7.5YR4/6) and dark brown (7.5YR4/4) in many mottles, moist; sand; weak lamination; non sticky, non plastic; few ferruginous coatings along pores, afterwards infilled pores and cracks; few fine and medium vertical pores; strongly calcareous; shell fragments; abrupt smooth boundary to:
Cr	>145 cm	Dark greenish gray (5G3/1) moist, sand.

Analytical data : see next page

Profile B-NL5

Depth	Moisture	Granulometric analysis in % of oven-dry soil in µm									$CaCO_3$	pH		$E.C._{2.5}$
in cm	%	2000-300	300-210	210-150	150-105	105-75	75-50	50-16	16-2	<2	%	H_2O	KCl	x 10^3
5- 35	2.9	0.2	0.1	0.1	1.9	5.8	7.3	18.3	19.3	47.0	7.73	7.9	6.9	0.28
35- 65	3.4	0.0	0.0	0.4	0.4	1.1	1.2	15.7	23.4	57.8	10.5	8.0	7.0	0.35
65- 82	2.6	0.0	0.1	1.8	12.8	17.8	17.5	17.3	7.6	25.1	11.7	8.1	7.3	0.23
82-105	1.4	0.0	0.0	0.2	3.0	9.0	9.0	16.6	16.6	44.6	9.86	8.0	7.1	0.34
105-120	0.5	0.0	0.2	3.2	29.2	33.0	17.0	6.6	0.5	10.2	7.22	8.3	7.8	0.15

Depth in cm	me/100 g						% Base saturation	%	%	% Fe_2O_3
	Exchangeable bases					C.E.C.		C	N	dithionite
	Ca	Mg	K	Na	Sum					
5- 35	27.8	2.12	0.95	0.18	31.1	25.3	>100	1.36	0.17	1.92
35- 65	25.1	2.74	0.83	0.09	28.8	29.1	99	1.12	0.16	2.21
65- 82	12.3	1.84	0.47	0.17	14.8	12.7	>100	0.59	0.07	1.21
82-105	19.8	2.85	0.63	0.09	23.4	22.1	>100	0.93	0.13	1.98
105-120	5.78	0.51	0.23	<0.01	6.57	4.37	>100	0.25	0.03	0.68

The bulk densities of the polder soils vary between 1.16 and 1.55 g cm^{-3}. The sandy soils have the highest bulk densities (1.45-1.55 g cm^{-3}) and the clayey soils the lowest (1.16-1.35 g cm^{-3}).

Profile B-NL6

Depth in cm	Moisture %	Granulometric analysis in % of oven-dry soil in µm: 2000-300	300-210	210-150	150-105	105-75	75-50	50-16	16-2	<2	$CaCO_3$ %	pH H_2O	pH KCl	E.C.$_{2.5}$ x 10^3
0- 30	1.2	0.1	0.1	0.9	23.2	30.2	15.4	8.5	3.1	18.5	6.75	8.0	7.3	0.20
30- 45	1.3	0.1	0.1	0.2	14.7	29.7	18.9	12.7	4.4	19.2	9.03	8.0	7.4	0.28
45- 70	0.6	0.1	0.1	0.6	24.5	32.0	21.3	9.1	1.2	11.1	6.97	8.3	7.7	0.19
70-100	0.8	0.0	0.0	0.3	24.5	35.0	18.1	8.4	0.0	12.7	9.41	8.3	7.7	0.16
100-125	0.5	0.0	0.0	0.3	30.3	39.1	14.3	6.6	0.0	9.4	6.73	8.3	7.8	0.14

Depth in cm	me/100 g: Exchangeable bases: Ca	Mg	K	Na	Sum	C.E.C.	% Base saturation	% C	% N	% Fe_2O_3 dithionite
0- 30	11.9	0.25	0.23	<0.01	12.4	10.8	>100	0.76	0.09	0.87
30- 45	11.4	0.28	0.28	<0.01	12.0	10.5	>100	0.45	0.05	0.87
45- 70	6.79	0.15	0.18	<0.01	7.12	5.03	>100	0.23	0.02	0.50
70-100	5.80	0.25	0.13	<0.01	6.18	4.38	>100	0.19	0.02	0.43
100-125	5.28	0.21	0.15	<0.01	5.64	3.72	>100	0.18	0.02	0.47

The bulk densities of the polder soils vary between 1.16 and 1.55 g cm^{-3}. The sandy soils have the highest bulk densities (1.45-1.55 g cm^{-3}) and the clayey soils the lowest (1.16-1.35 g cm^{-3}).

Micromorphological data of the pedogenetic phenomena

Region, polder, year of embankment profile number and depth in cm of the thin sections		Features of the soil development <u>before</u> embankment							
		Biological processes					Physical processes	Chemical processes	
		faunal channels	floral channels	pedotubules aggrotubule	striotubule	passage features	infillings in voids	Pyrite neoformations	iron-manganese accumulations
Zuid Beveland									
Tweede Bathpolder	12- 27	-	-	-	-	-	-	-	+
1857	35- 50	+	+	-	-	-	-	-	+
profile B-NL5	61- 76	+	+	(+)	(+)	(+)	+	-	+
	76- 91	+	(+)	(+)	+	+	(+)	-	+
	95-110	+	-	+	+	+	(+)	-	+
profile B-NL6	10- 25	-	-			-	-	+	+
	35- 50	-	(+)			(+)	(+)	+	+
	60- 75	(+)	+			(+)	+	+	(+)
	78- 93	+	+			+	+	-	(+)
	95-110	+	-		+	+	(+)	-	+

+ = occurs
- = absent
(+) = rare, but present

Micromorphological data (continued)

		Features of the soil development after embankment				
		Biological processes		Physical processes		Chemical processes
		floral channels	aggrotubules	peds	clay-rich compound coatings	pyrite oxidation
Zuid Beveland						
Tweede Bathpolder	12- 27	+	+	-	-	-
1857	35- 50	+	+	-	(+)	-
B-NL5	61- 76	+	(+)	-	(+)	-
	76- 91	(+)	-	-	-	-
	95-110	-	-	-	-	-
B-NL6	10- 25	+	-	-	+	+
	35- 50	+	+	+	+	+
	60- 75	+	+	+	+	(+)
	78- 93	-	-	-	(+)	-
	95-110	-	-	-	(+)	-

+ = occurs
- = absent
(+) = rare, but present

Site interpretation

After reclamation the most obvious changes in the soil are the ripening and related increase in bulk density, and the prismatic structures developed in clay-rich soil material. The micromorphological observations reveal that all the groups of faunal activities distinguished in the intertidal zone deposits can still be observed in the polder soils: channels, pedotubules and passage features.

Parts of channel systems formed by the former vegetation were also found. Of the shrinkage cracks distinguished in the prereclamation phase, only the coarse polygon pattern of the intertidal flats was recognized. Voids infilled with soil material from the surface were still observed, as infilling that occurred since reclamation had other characteristics. In the thin sections of the polder soils pyrite was still present. These occurred in locations comparable with the pre-reclamation phase. Carbonate neoformations were also observed. Distinct zones with carbonate deficiencies did not occur. Ferrans and neoferrans were common, occurring in identical locations to those in unembanked areas.

The large number of inherited phenomena enabled the patterns present in thin sections to be classified according to the same system developed for the intertidal zone deposits. The patterns in the oldest deposits of the intertidal zone were best preserved. The patterns in the former middle-high saltmarsh deposits, especially the basins, were only partly recognizable.

The reconstruction for the two coastal polder soils is as follows:

Tweede Bathpolder, 1857

B-NL5	12- 27 cm	- Ap horizon
	35- 50 cm	- low, middle-high salt marsh
	61- 76 cm	- low salt marsh
	76- 91 cm	- transition
	95-110 cm	- intertidal flat deposits
B-NL6	10- 25 cm	- Ap horizon
	35- 50 cm	- middle-high salt basin
	60- 75 cm	- low, middle-high salt basin
	78- 93 cm	- transition
	95-110 cm	- intertidal flat deposits

The coastal polder soils generally are calcareous. Most of the coastal polders are reclaimed as soon as the tidal foreland has silted up till mean high tide level. The decalcification starts at this level and often did hardly take place.

From the above given information it is evident that in intertidal zone deposits many specific processes occur, producing phenomena that remain visible long after the land has been reclaimed and the processes themselves have ceased. In holocene polder soils in use for agricultural purposes the effects of actual soil forming processes are limited.

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SOME INFORMATION ABOUT ISRIC

History

ISRIC (International Soil Reference and Information Centre) was born out of an initiative of the International Society of Soil Science. It was founded in 1966 by the Government of the Netherlands, upon assignment by the General Conference of Unesco.
Up to 1984 the name was International Soil Museum.

Aims and Programme

- To serve as a documentation centre on land resources, with emphasis on the developing countries (see 1-4).
- To improve methods of soil analysis, with emphasis on soil characterization and classification (see 5).
- To transfer the collected information by lecturing and publishing and by advising on the establishment of natural soil reference collections (see 6-9).
- To stimulate and contribute to new developments in soil genesis and classification, soil mapping and land evaluation (see 10, 11).

1. Soil monolith collection
   To assemble and analyse representative samples of the major soils of the world and display a reference collection of soil profiles and related information.
   Each of the soils is represented by a soil monolith: an artificially hardened soil profile. This collection, now comprising nearly 700 monoliths from over 50 countries, is a helpful instrument for instruction and demonstration. It enables scientific research to be carried out on a large number of soils.

2. Laboratory
   To analyse samples, mostly of the collected soils;
   To test and improve methods and procedures of soil analysis;
   To support/instruct guest researchers.
   The laboratory is equipped to carry out most of the physical, chemical and mineralogical analyses necessary for soil characterization. Research is, in part, aimed at improvement of methods with emphasis on the suitability of a method to be used in laboratories with relatively simple equipment.

3. Micromorphology
   To prepare, study and describe thin sections of soils belonging to the collection, or for other purposes.
   Most thin sections prepared belong to the soil monolith collection. Others are made for special purposes, e.g. the ISSS Subcommission on Soil Micromorphology has requested ISRIC to set up a reference collection of thin sections, to support the new ISSS-sponsored "Handbook for Soil Thin Section-Description.

4. Documentation.
To build up a collection of soil and related maps and reports. A systematic collection of soil maps and reports, with emphasis on the developing world, is built up. This is available for consultation and needed for updating the 1 : 1 million FAO-Unesco Soil Map of the World and the compilation of a new, computerized world soil map at 1 : 1 million. ISRIC aims at a collection of small-scale maps at a scale of 1:200,000 or smaller of each country, and a reference system of soil surveys carried out at any scale.

5. Laboratory exchange programme (Labex)
To compare and possibly standardize methods and procedures of laboratory analysis, accompanied by the exchange of sample material.
Soil material, representing a range in chemical and physical properties, serves as reference samples. Subsamples are sent to participating soil laboratories. The results of the analyses from 85 laboratories are collected, together with a description of the methods used, and compiled into a report.

6. Visitors services
To give information on soils of the world, soil impregnation and display techniques, etc.
Visitors in groups are mainly from higher educational institutions, international training courses and participants of meetings. Individual visitors are mostly professional soil scientists from all over the world.

7. Guest research
To host soil scientists who will study the collection for comparison and correlation.
This relatively new programme aims at the preparation of scientific papers en presentations.
Guest researchers are usually experts from non-European countries, who study for a half to one year ISRIC's soils in relation to soils of their own country/region. They also may develop and test new analytical procedures.

8. National soil reference collections (Nasrec)
To help in establishing Nasrec's for research, land use planning, extension, etc.
For nearly a century, soil profile bodies have been collected in the field and put on display. The development of easier methods of impregnation with suitable chemicals has prompted a number of institutions to set up modern Nasrec's.
ISRIC advises and assists in, and gives a training course on the collection of soil profiles, their impregnation, and in displaying and using them.

9. Publications
To issue publications on the collected soils, analytical methods and techniques, and make available teaching materials.
The publication programme includes:
Soil Monolith Papers: deal with one soil monolith as an example of a soil unit of the FAO-Unesco Soil Map of the World legend. Each SMP has a colour photograph and 8 slides.
Monographs: give results of studies in soil genesis and classification, soil analysis and land evaluation of a major group of soils. These are usually written by guest researchers.
Technical Papers: contain methods, procedures and standards and field extracts of major soil classification systems.
Annual Reports.
Working Papers and Preprints.
Consultancy/Mission Reports.
Slides.

10. Soil classification
To study and correlate soil classification systems that have an international reach;
To assist in the elaboration of new classification systems.
ISRIC assembles documentation on all national and international soil classification systems. Principles and the criteria used are compared and evaluated. Active support is given to the establishment of an International Reference Base for soil classification (IRB), to the elaboration of an improved and more detailed legend of the FAO-Unesco Soil Map of the World.

11. Reference laterite collection (Corlat)
To build up a reference collection of whole laterite profiles (CORLAT);
To develop a descriptive terminology and classification of laterites.
Recently, the need for a Corlat was expressed. ISRIC was chosen to provide reference material for objective and standardized descriptions of laterites and for their classification. It will be an important tool to facilitate communication in laterite research, both at international and interdisciplinary levels.
To date, two profiles of 15-20 m depth have been collected.

MAN-MADE SOILS IN THE PLEISTOCENE SANDY LANDSCAPE

General Itinerary

8.00 Departure from Wageningen

8.30 Excursion De Ginkel (soil profiles B-NL-7 and B-NL-8)

11.30 Lunch at "De Wereld", Wageningen

Introduction

Plaggen soils are man-made soils, which have been gradually raised by the addition of material by agricultural practice.

Plaggen soils are restricted to part of the (peri)glacially influenced landscapes of the Netherlands, Belgium and Western Germany and mainly occur in areas with fluvio(peri)glacial sands and cover sands. Though similar landscape conditions exist in Denmark, Eastern Germany and Poland, plaggen soils are not known to occur there. It is assumed that the agricultural practice which led to these soils was restricted to the German tribe of the Saxons and partly to the Franks, and that the Frisians, the Scandinavians and the Slavs did not use this practice (De Bakker, 1979).

One third of the Netherlands consists of glacially influenced landscapes with plaggen soils in many locations.

The aim of this excursion is to gain insight into the origin and properties of the plaggen soils, by description and demonstration of the human use of the sandy landscape and of the consequences of this type of landuse for the character of the landscape and the soil conditions. The hamlet De Ginkel, near Ede (Fig.1), is a representive example.

Description of the excursion area

Geology

The area to be visited was mainly formed by Saalian glacial erosion and deposition and modified under Weichselian periglacial conditions. During the Saalian the Scandinavian ice-sheet reached the Netherlands. At its margin the ice-sheet was split up into a number of distinct lobes. These tongues of ice exerted great pressure on the valley sides, contorting and pushing up earlier loamy, sandy and gravelly Rhine and Meuse deposits into a series of ice-pushed ridges. These ridges mark the limit reached by the ice-sheet and outline the position of the main ice-lobes.

The ridges are a prominent element in the landscape of the southern Veluwe. Near Ede their elevation is about 50 meters above sea level, elsewhere on the Veluwe they are up to 110 meter high. On its flanks and between the ridges gently sloping mainly gravelly and sandy glacial outwash (sandr) was laid down.

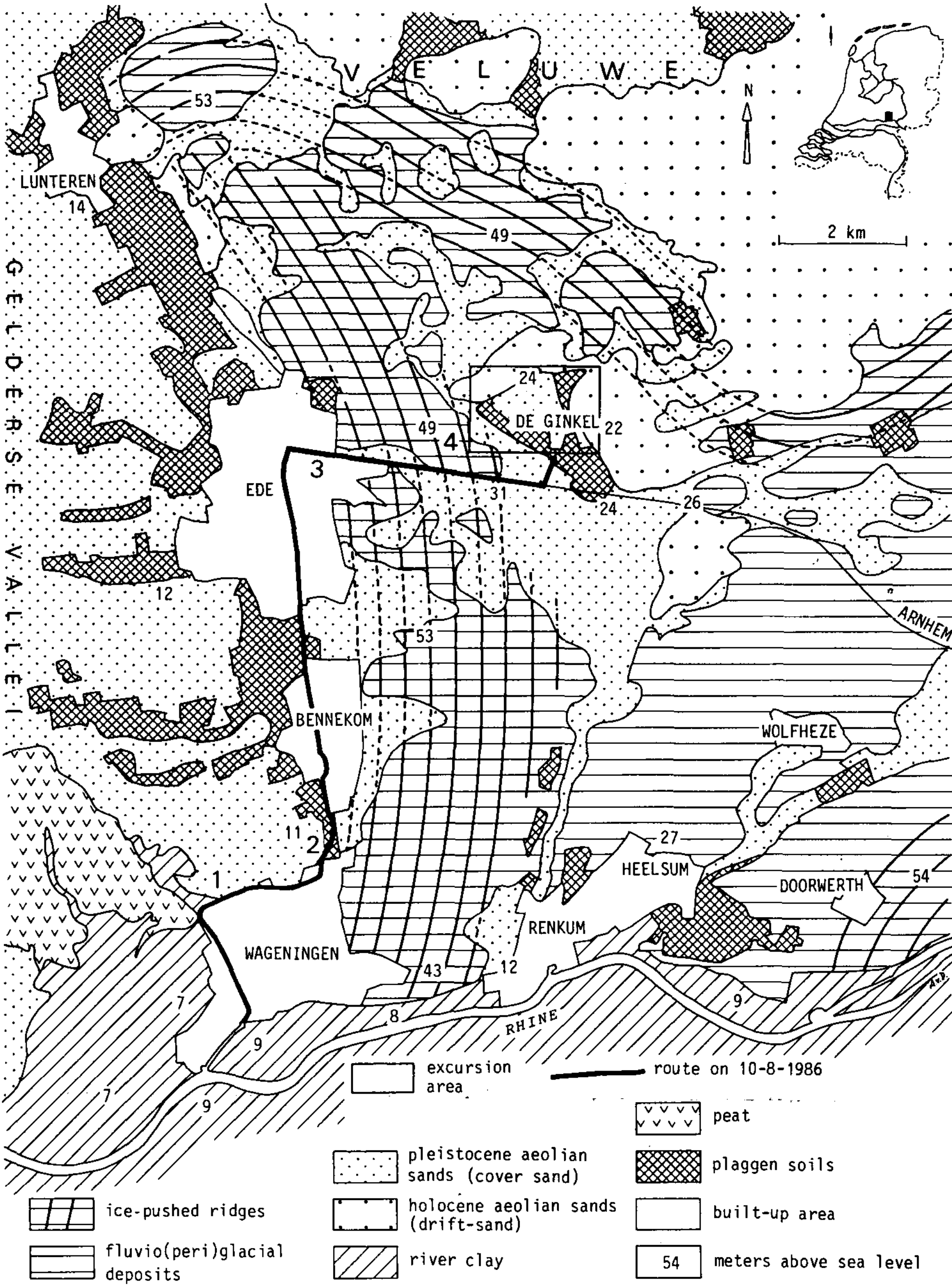
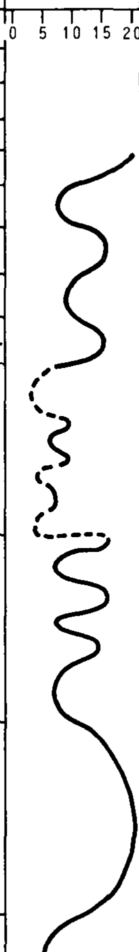


Fig. 1. Physiographic map.

During the Weichselian the ice-front did not reach the Netherlands, but periglacial conditions prevailed. The subsoil was permanently frozen. In the brief summers a shallow surface layer thawed out and gelifluction occurred on the slopes. Downwards percolation of the melt water being prevented, the water collected into small streams and rivulets, which carved out valleys. The poorly-sorted sediments thus formed are called fluvioperiglacial deposits.

Table 1. Chronostratigraphy of the central and eastern part of the Netherlands.

Years B.P.	Epoch				Inferred mean July temp. (°C)	Lithostratigraphy and genesis
	HOLOCENE			Subatlantic	0 5 10 15 20	local formation of drift-sands
	HOLOCENE			Subboreal		peat growth
	HOLOCENE			Atlantic		fluvial deposits along the rivers
	HOLOCENE			Boreal		
10.000	HOLOCENE			Preboreal		
	PLEISTOCENE	Weichselian	Late Glacial	Late Dryas Stad.		Younger Cover Sand II
	PLEISTOCENE	Weichselian	Late Glacial	Allerød Interst.		local peat growth soil formation
	PLEISTOCENE	Weichselian	Late Glacial	Early Dryas Stad.		Younger Cover sand I
12.000	PLEISTOCENE	Weichselian	Late Glacial	Bølling Interstad.		weak soil formation
60.000	PLEISTOCENE	Weichselian		Pleniglacial		Old Cover Sand I + II cryoturbation gelifluction meltwater deposits,mainly sand alternating with loam and/or peat layers (fluvioperiglacial deposits)
90.000	PLEISTOCENE	Weichselian		Early Glacial		sandy deposits, mainly aeolian
125.000	PLEISTOCENE			Eemian		peat growth marine and terrestric deposits in valleys
	PLEISTOCENE			Saalian		formation of ice-pushed ridges glacial outwash deposits (fluvioglacial deposits)



The upper soil layers were thouroughly mixed by repeated freezing and thawing (cryoturbation) and by gelifluction. Relicts of the Eemian soil formation were largely obscured.

In the course of the Weichselian the area became an arctic desert with strong westerly winds. The finer soil particles, not hold in place by the scanty vegetation, were blown far afield and were deposited over large areas. Such aeolian sandy deposits are called cover sand. The older cover sands are laminated and slightly loamy. They were laid down as a gently undulating sheet over much of the country. The younger cover sands are notably coarser and have a very low heavy-mineral content.

These younger cover sands generally occur at the surface in the Guelders Valley (Gelderse Vallei) and also locally in sheltered places on the Veluwe.

During the Holocene, in the excursion area geological processes were restricted to the formation of local drift-sands (inland-dunes), as a result of clearing the woods and destructing the vegetation by man.

The sequence of geological events is given in Table 1. The excursion area, De Ginkel, is enclosed by two ice-pushed ridges, as is shown in Fig. 1. The fluvioperiglacial deposits are covered by younger cover sands. Westwards fluvioperiglacial deposits occur at the surface. North and east of De Ginkel there are areas of drift-sands. The general dip of the area is to the southeast. A cross section of De Ginkel is shown in Fig. 3.

Hydrological situation in De Ginkel

Due to the relatively low position between two ice-pushed ridges and to the occurrence of a slowly permeable, loamy fluvioperiglacial deposit on 2-5 meters below the surface, a shallow water table is present at De Ginkel. This slowly permeable layer is not continuous, considering the variable water regimes and local fens (Fig.2), but occurs throughout in the central part of the mapped area.

The surface water flows of in southeasterly direction, and infiltrates in the soil where the slowly permeable layer is lacking. Drainage is improved by ditches.

The loamy strata at shallow depth separate the perched water table from the deeper ground water.

Human influence on the landscape

Plaggen soils have developed in the Pleistocene sandy area of the Netherlands as the result of a typical system of agricultural practice, using "pot"-stables. This system was used for centuries until the introduction of industrial fertilizers.

The pot-stable system dates from the Middle Ages. The sandy soils had to be manured for greater productivity. Because these soils are too poor to recover by just a fallow period a management system has been developed in which as much manure was gathered as possible. Therefore the livestock - both cattle and sheep - were stabled at night to restrict manure losses. Because sheep produce more dung than cattle, few cattle was kept to supply only the household needs. A great amount of litter and earth was used in the stables to absorb the liquid components of the manure in such a way that a tolerable bedding for the animals could be obtained.

The dung-impregnated bedding of the stables was used to manure the arable land. The mineral part in this manure stayed behind after decomposition of the organic matter. As a consequence the arable fields were gradually raised, changing podzol soils into plaggen soils.

The plaggen soils lie in a typical pattern in the landscape: in this area on the fringes of the ice-pushed ridges, as is shown in Fig. 1. The settlers had specific needs which were based on self-sufficiency and preferred sites with the following qualifications:
- good drainage conditions for arable land
- sufficient moisture supply for pasture
- availability of drinking water
- adequate fertility level

Therefore settlements are found at the transition from (topographically and hydrologically) higher to lower parts. Thus the slopes of the gently undulating area could be used for arable land, the wet soils were used for grazing of the livestock and for making hay and the dry sites were used for collection of litter and fuel.

The litter used was heather sods, grass sods, forest litter, peat and sand. Most of it came from range land on which the livestock also grazed. The continuous removal of organic matter from the range lands caused a decline in fertility and the original forest vegetation impoverished to heath. Therefore heath sods were increasingly used. The sods were cut with special implements. They were 25-30 cm square and about 3 cm thick. Though the sods were cut as thin as possible, some sand was inevitable taken along, often derived from the E-horizon of the podzol soils. High heather was burned before being used as sods. It is possible that much of the charcoal in the plaggen epipedon emanates from this process.

Normally the heath sods were cut once every 5-8 years. In those places where they were cut deeply, intervals were 12-15 years. Also use was made of grass sods. These had less favourable moisture-absorbing properties than heath sods, but sometimes they contained more nutritional compononents, supplied by ground water and flood water. In wooded areas forest litter was important for use in the stables. If "Sphagnum" peat was available, sods of young peat were used on a wide scale, due to the favourable moisture absorption capacity. Although not an absorbing organic material, sand was also used in the stable, sometimes in large quantities.

For a farmer it was necessary to have a large area of range land at his disposal. It has been calculated that a farm with 4 hectares of arable land had to have about 3 ha of heath land at its disposal each year. With an average recovery time of 10 years, 30 ha of heath land were thus necessary to keep the farm going (Pape,1970).

Through the increasing population ever more range land was cultivated and an increasing amount of sods had to come from a decreasing area. This led to a degradation of the heather vegetation and the sandy soil started to drift. This wind erosion started already in the Middles Ages and soon there were some government regulations for prevention, i.e. it was forbidden to let sheep graze on soils which were freshly desodded. In the 17th century afforestation was started already. However, the regulations did not help much. Around 1850 about 10 % of the range land in the centre of The Netherlands had turned into drift-sand. It took till the 20th century until all sand-movements were controlled.

At the beginning of this century industrial fertilizers were introduced in the Netherlands, which led to the gradual disappearance of the pot-stable system. Therefore the sheep were not longer necessary for producing manure. The heather fields in this area, however, were not cultivated, because they were used for military purposes. Nowadays, periodically sod-cutting is necessary to maintain the heather vegetation.

Continuously practising the pot-stable system (about 8 centuries) introduced typical elements in the landscape. The arable land is elevated with respect to its surroundings by 40-100 cm. It was separated from the range lands by a thick barrier of oak coppice, with deep ditches on either side to protect the crops against the game and the roaming livestock.

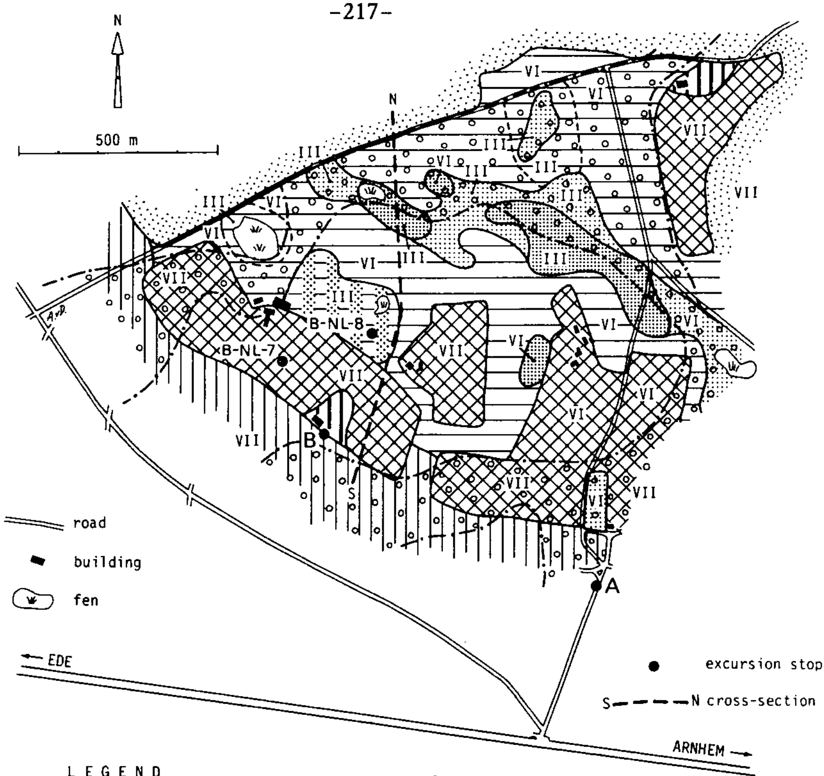
Soil conditions at De Ginkel

Fig. 2 shows the soil types occuring in this area. Besides human influence the main soil forming factors are topography, hydrology and parent material. This led to a coherent pattern in the soil conditions as may be clear from a cross section of De Ginkel (Fig.3).

On the flank of the ice-pushed ridge Leptic Podzols are developed in the relatively rich, somewhat loamy parent material. These soils generally have a thin A horizon of about 10 cm. According to the requirement "distinct dark pellets of coarse silt size" (Soil Taxonomy p.32) these soils may have a spodic B horizon. The B horizon extends to about 60 cm below the surface and has a rather bright brown colour. The transition of the B to the C horizon is gradual. Occasionally weak clay illuviation has been found. Generally the upper part of the B horizon is dark yellowish brown, because of illuviation of amorphous organic matter. This proces is obviously caused by the removal of the original forest vegetation and subsequently by the continuously sod-cutting, which led to impoverishment. However, podzolisation processes are weak in these profiles, weathering of the primary minerals and biological homogenisation are the dominant processes. Because of the relatively high topographic situation, there are no ground water influences.

On the transition to the valley Gleyic Podzols occur. Because of the poor parent material (cover sand) eluviation of organic matter and sesquioxides from the A horizon and illuviation into the B horizon has taken place. As a consequence of the periodically wet circumstances, iron has been leached. Commonly the B horizon has a dark brown colour and a very gradual transition to the C horizon. The boundary between the B and C horizon may vary between 60 and 120 cm.

In the valley the water accumulates and drainage is very poor. This led to the development of Humic Gleysols. These soils are characterized by hydromorphic properties within 50 cm of the surface. Many of these soils have iron mottles which can be very prominent, if iron-rich water flowed in from adjacent areas. A notable part of the Humic Gleysols have no mottling within 50 cm or deeper. Mainly the subsoil colour is light brownish grey. These soils have to be considered as intergrades to the Gleyic Podzols.



LEGEND

	parent material:
Humic Gleysol	cover sand
Humic Gleysol, no mottling within 50 cm of the surface	
Gleyic Podzol	cover sand
Leptic Podzol	cover sand
Leptic Podzol, plaggen phase *)	
Dystric Regosol	drift-sand
Plaggen soils **)	cover sand
Association	
Gleyic Podzol/ Humic Gleysol	cover sand
Addition	
fluvioperiglacial material within 120 cm of the surface	

All soil units have textural class 1 (= coarse textured) and slope class a (= level to gently undulating).

*) Plaggen phase: A man-made surface layer of more than 30 cm but less than 50 cm thick

**) Plaggen soils: Soils that have a plaggen epipedon, 50 cm or more thick, as described by U.S.D.A. Soil Taxonomy. These soils are not included in the FAO-classification

Estimated ground water class (conform the 1:50000 Soil Map of the Netherlands)

class:	average highest level between:	average lowest level between:
III	0 - 40 cm	80 - 120 cm
VI	40 - 80 cm	> 120 cm
VII	> 80 cm	> 120 cm

------ boundary between the classes

Fig. 2. Soil map of De Ginkel.

North and east of De Ginkel Dystric Regosols are found. Mainly in these soils almost no soil forming processes have taken place, because the parent material (drift-sand) is of recent origin. However, it can be noticed that podzolisation occurs. In most cases it is too weak to qualify for podzols, but in the oldest drift-sands Humic Podzols are found.

Excursion

Route description: Wageningen - De Ginkel

The route to follow is indicated in Fig. 1. Wageningen, a small town with roughly 30.000 inhabitants, accomodates the Dutch Agricultural University, where about 6000 people are studying. It is also the centre of agricultural research by a range of several governmental institutes.

Travelling north, after departure from the port, at the left the pastures of the "Gelderse Vallei" can be seen (point 1). This valley was formed by an ice-lobe. Cover sand occurs at the surface, in the southern part overlain by deposits of Holocene origin. The main activities in this region are dairy farming and intensive animal husbandry.

The road follows the transition from the ice-pushed ridge to the "Gelderse Vallei" (point 2). Like Wageningen en Bennekom and other villages in the area, Ede is situated at the foot of the ice-pushed ridge. It is a fastly expanding village with small industries and trade companies.

At point 3 the route turns east and crosses the ice-pushed ridge. On the dry soils of the ridge mainly forest is growing. More to the east, on the outwash plain, open heath land is found, which is now used for military purposes, recreation or nature conservation.

Burial mounds, dating from the Neolithic Age, are lying at the left hand (point 4).

After arrival at De Ginkel the bus is left at point A (see Fig. 2) and a walk of about 800 meters is following, along the transition of the heath land to the arable land. A game hedge, originally consisting of two parallel dams, a few meters in width, covered by oak coppice, marks the transition.

At point B, where a sheep-fold is situated, an introduction will be given and relevent maps and monoliths will be displayed.

Next two soil profiles will be demonstrated:

B-NL-7 : Plaggen soil

B-NL-8 : Gleyic Podzol

At about 11.00 a.m. departure to Wageningen for lunch.

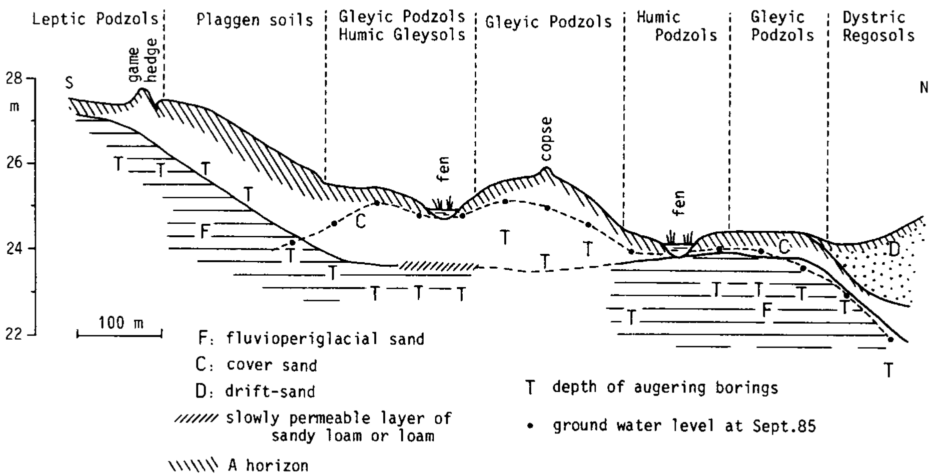


Fig. 3. Cross section.

As a result of long-continued manuring (described in detail in the previous paragraph) plaggen soils have developed in this area. These soils are characterized by a man-made surface layer of 50 cm or more thickness, usually containing artefacts, such as charcoal and pieces of brick. The colour of this A horizon depends on the type of sods used. At De Ginkel both "black" and "brown" plaggen soils occur, there are also profiles with both brown and black layers. Plaggen soils with an A horizon of more than 80 cm thick are found in the southwest and northeast of De Ginkel.

Because of the scale of the FAO soil map of the world it has not been possible to separate soils which are characterized by such man-made surface layers. Therefore these soils can not be classified with the FAO-key to the soil units. According to Soil Taxonomy most of the plaggen soils are classified as Plaggepts.

In the south of De Ginkel plaggen soils are situated on Leptic Podzols, adjacent to Gleyic Podzols. The plaggen soils on Leptic Podzols are assumed to be the oldest reclamations (Pape, 1970). This idea conforms with the nature of Leptic Podzols which normally have a higher fertility and better drainage conditions than Gleyic Podzols. The latter may also have severe nutrient restrictions. In the east and middle of De Ginkel there are also plaggen soils on Gleyic Podzols. These are assumed to be more recent.

The buried Leptic Podzols often differ from similar podzols in the vicinity, which have no plaggen epipedon. The organic matter content of these profiles is somewhat higher and their colour is more prominent.

Excursion points

B-NL-7: PLAGGEN SOIL

Classification: No suitable category, according to FAO
Plaggept, according to U.S.D.A. Soil Taxonomy
Location: Topographical map 1:25 000, sheet 32H: N 451.000/ E 177.780
Parent material: Cover sand on fluvioperiglacial material
Land-form: Elevated field in weakly undulating landscape, located on outwash plain, about +27 meter O.D. level
Drainage: Well-drained, ground water level below 1.20 meter. Profile moist throughout at the time of description
Land use: pasture

Profile description:

Ap1	0 - 30 cm	Very dark brown (10 YR 2/2) loamy sand; structureless massive; friable; many fine pores and few medium channels; frequent very fine roots; charcoal, pieces of brick; abrupt smooth boundary.
Ap2	30 - 55 cm	Very dark grayish brown (10 YR 3/2)loamy fine sand; structureless massive; friable; common fine pores and few medium channels; common very fine roots; charcoal, pieces of brick; occasional gravels; clear smooth boundary.
Ap3	55 - 72 cm	Black (10 YR 2/1) loamy fine sand; structureless massive; very friable; common fine and very fine pores, few medium channels; very few very fine roots; occasional gravels; clear smooth boundary.
(A+E)pb	72 - 85 cm	Very dark brown (10 YR 2/2) sand; structureless massive; friable; common fine pores and few medium channels; few very fine roots; few fine mottles of organic material; occasional gravels; clear smooth boundary.
Bhsb1	85 - 95 cm	Brown (10 YR 4/3) sand; structureless massive; friable; common very fine pores; very few very fine roots; common medium iron mottles; clear smooth boundary.
Bhsb2	95 -110/130 cm	Dark brown (10 YR 3/3) fine sand; structureless massive; friable; many very fine pores; very few very fine roots; few medium iron mottles; abrupt irregular boundary.
Cgb	> 110/130 cm	Brownish yellow (10 YR 6/6) sand; structureless massive; loose; common very fine pores; very few very fine roots; common coarse iron mottles.

Analytical data:

hor.	depth (cm)	C (%)	N (%)	C/N	pH-KCl	$\frac{1}{2}Ca^{2+}$	$\frac{1}{2}Mg^{2+}$	Na^+ (mmol/kg)	K^+	$\frac{1}{3}Al^{3+}$	H^+	ΣCat	CEC 1)
Ap1	0-30	2.05	0.13	15.8	3.5	2	3	<1	1	6	12	24	26
Ap2	30-55	2.59	0.11	23.5	3.7	1	2	3	2	9	14	31	63
Ap3	55-72	2.54	0.10	25.4	3.7	<1	0	<1	<1	9	14	23	44
Bhsb1	85-95	0.73	0.04	18.3	3.7	<1	0	<1	<1	6	12	18	23
Bhsb2	95-120	0.90	0.05	18.0	4.2	<1	0	<1	1	7	10	18	26
Cgb	>120	0.20	0.02	10.0	4.7	<1	0	<1	<1	2	8	10	11

hor.	depth (cm)	P_2O_5 2) (mg/kg)	free iron 3)	amorph. iron (%) 4)	particle size distribution (%) <2	2-16	16-50	50-105	105-210	>210
Ap1	0-30	674	0.36	0.19	3.7	2.3	6.4	13.2	43.2	31.2
Ap2	30-55	375	0.39	0.25	3.5	2.4	10.4	14.7	43.1	25.9
Ap3	55-72	337	0.39	0.29	3.4	3.2	10.9	15.9	40.0	26.6
Bhsb1	85-95	339	0.43	0.30	3.4	2.4	6.1	13.7	44.8	29.6
Bhsb2	95-120	332	0.32	0.20	4.0	2.7	7.7	13.0	41.6	31.0
Cgb	>120	99	0.17	0.06	1.9	1.0	3.1	12.1	51.8	30.1

hor.	depth (cm)	bulk density (kg/m^3)	moisture volume fraction (%) pF 2.0	pF 4.2	available moisture (mm/10 cm)
Ap(1+2+3)	0-72	1400	25	6	19
Bhsb(1+2)	72-120	1510	14	3	11
Cgb	>120	1550	11	2	9

1) Li-EDTA-method, pH is buffered at 7.0 (Begheijn, 1980)
2) citric acid extractable
3) dithionite EDTA
4) NH_4 oxalate and oxalic acid extractable, pH 4.5

<u>Land suitability</u>

These soils are suitable for arable farming. They are deep, well drained and because of the deep humose A horizon they have an improved water holding capacity. In spite of the latter these soils are still liable to drought. However, for modern agriculture the size of the fields and total acreage are too restricted.

For use as pasture the possibilities are limited. Although these soils have a good trafficability and there is no danger of poaching, the grass production is too low in dry years and shows even stagnation in growth in normal summers.

At De Ginkel these soils are partly used as pasture. In spring the trafficability is good and the grass production starts early. Therefore they form a favourable combination with the wet pastures for a farmer.

B-NL-8: GLEYIC PODZOL

Classification: Gleyic Podzol, according to FAO
Haplaquod, according to Soil Taxonomy
Location: Topographical map 1:25 000, sheet 32H: N 451.300/ E 177.960
Parent material: Cover sand
Land-form: Weakly undulating landscape, in depression between two ice-pushed ridges, about +25 meter O.D. level.
Drainage: Imperfectly drained, the ground water fluctuates between 25 and 100 cm. Profile moist till 55 cm, deeper wet at the time of description.
Land use: pasture.

Profile description

Ap	0 - 25 cm	Very dark brown (10 YR 2/2) loamy fine sand; structureless massive; friable; common fine pores and few medium channels; frequent fine roots; clear smooth boundary.
AB	25 - 30/35 cm	Black (10 YR 2/1), very dark brown (10 YR 2/2) and brown (7.5 YR 4/4) loamy fine sand; structureless massive; friable; common fine pores and few medium channels; frequent fine pores; clear wavy boundary.
Bh	30/35 - 45/80 cm	Dark brown (7.5 YR 4/4) fine sand; structureless massive; very friable; few fine pores and few medium channels, dark coated; locally mole-holes, partly filled up with material from overlying horizons; few very fine roots; clear smooth boundary, locally irregular.
BC	> 45/80 cm	Yellowish brown (10 YR 5/6) fine sand; structureless single grain, disturbed stratification. In upper part vertical streaks filled in with organic matter; non sticky, non plastic.

Analytical data:

hor.	depth (cm)	C (%)	N (%)	C/N	pH-KCl	$\frac{1}{2}Ca^{2+}$	$\frac{1}{2}Mg^{2+}$	Na^+ (mmol/kg)	K^+	$\frac{1}{3}Al^{3+}$	H^+	ΣCat	CEC 1)
Ap	0-25	3.22	0.18	17.9	5.0	8	0	<1	<1	1	1	10	75
AB	25-30/35	4.30	0.18	23.9	4.7	<1	0	<1	<1	3	4	7	106
Bh	30/35-45/80	0.50	0.03	16.7	4.6	3	0	1	<1	3	.5	12	14
BC	>45/80	0.30	0.01	30.0	4.6	2	0	<1	<1	3	4	9	11

hor.	depth (cm)	2) P_2O_5 (mg/kg)	3) free iron	4) amorph. iron (%)	Particle size distribution (%) <2	2-16	16-50	50-105	105-210	>210
Ap	0-25	448	0.27	0.21	3.2	3.1	8.8	15.3	43.7	25.9
AB	25-30/35	218	0.16	0.10	3.8	4.7	9.7	14.1	41.0	26.7
Bh	30/35-45/80	94	0.07	0.01	1.9	0.7	3.9	13.5	50.6	29.4
BC	>45/80	105	0.06	0.01	1.6	0.4	2.5	20.5	54.2	20.8

hor.	depth (cm)	bulk density (kg/m^3)	moisture volume fraction (%) pF 2.0	pF 4.2	available moisture (mm/10 cm)
Ap + AB	0-30/35	1450	33	8	25
Bh	30/35-45/80	1580	18	3	15
BC	>45/80	n.d.	16	2	14

1) Li-EDTA-method, pH is buffered at 7 (Begheijn, 1980)
2) citric acid extractable
3) dithionite EDTA
4) NH_4 oxalate and oxalic acid extractable, pH 4.5

Land suitability

These soils have limited possibilities for arable farming. The trafficability is low, causing limitations in management, i.e. with sowing and harvesting.

The possibilities for grass production are large. There is no reduction in growth, although there may be damages caused by poaching.

The nutrient status of the Gleyic Podzols is from origin very poor. Due to the recent management system, which produces a lot of liquid organic manure, a notable amount of manure is used for fertilizing. This may be the reason for the rather high amount of phosphate and for the intensive biological activity in the upper horizon.

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THE FLUVIATILE DISTRICT

General itinerary

12.00 - 13.00 h	Lunch in Wageningen
13.00 - 13.30 h	Drive to stop one
13.30 - 14.15 h	Soil B-Nl 9
14.15 - 14.30 h	Drive to stop two
14.30 - 15.15 h	Soil B-N110
15.15 - 16.00 h	Drive to Utrecht
16.00 - 19.00 h	Boat trip Utrecht - Amsterdam, dinner on board

Excursion area

General information

Holocene sediments, associated with the Rhine and the Meuse (Fig. 1 in 'Environmental conditions in the Netherlands'), occupy about 270 000 ha, or nearly 8% of the total area of the country.

At the border with Germany, a few km southeast of Arnhem, the Rhine is about 15 m above sea level. It bifurcates twice shortly after entering the Netherlands; the major branch is the Waal, which is the shipping lane between Rotterdam and the Ruhr industrial area in Germany. The two smaller branches are called the IJssel (which flows north to Lake IJssel) and the Lower Rhine, which flows west past Arnhem and Wageningen. The Meuse leaves Belgium just north of Luik (Liège) at about 50 m above sea level. Both river plains converge at about 6 m above sea level; the Meuse and the Waal-branch of the Rhine actually meet at about 4 m above sea level (Fig. 1). In 1904 a shipping canal was constructed at this point. The fluvial sediments pass beneath the marine sediments at 0.5 m above sea level.

The transition from floodplain to the adjacent higher grounds formed from Pleistocene deposits is generally gradual, because these older sediments dip very gradually under the fine-textured sediments of the backswamps. In a few places the river plain is bordered abruptly by 20-30 m high bluffs, caused by river erosion of the southern slopes of the ice-pushed hills.

The Pleistocene outcrops shown in the middle of Fig. 1 are partly buried fossil river dunes bordering buried channels of the braided river systems of the Pleistocene Rhine and Meuse. They have a westward slope of about 30 cm/km and near Nijmegen disappear beneath the Holocene fluviatile sediments which have a lower seaward gradient of 10-15 cm/km.

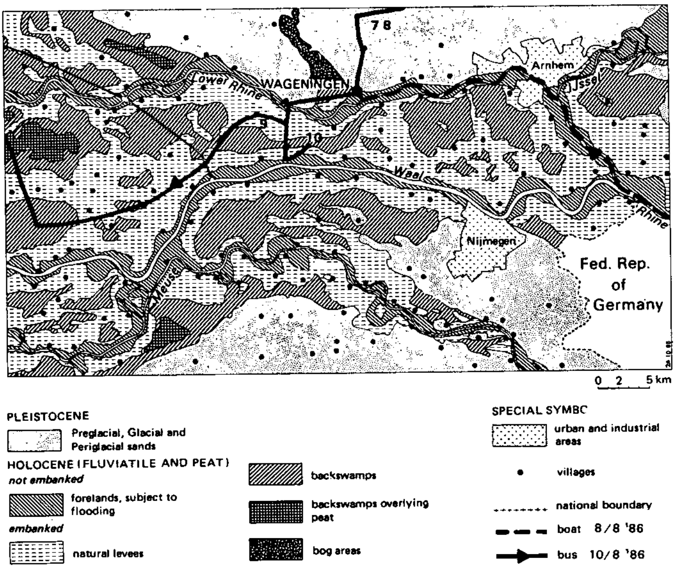

Fig. 1. The main Holocene geomorphological elements in the fluviatile district; 7, 8, 9 and 10 are the sites of soils B-NL 7, 8, 9 and 10 (from DE BAKKER, 1979)

Geomorphology and soils

The floodplain has three major elements: forelands, meander belts and backswamps (Fig. 1).

The forelands lie outside the artificial levees or river walls, and are subject to flooding. On the forelands land use is limited to pasture and meadow. The hay is protected from the rare, and mostly low, summer floods by low banks, called summer dikes. During periods of high discharges by the rivers the forelands are flooded. Flooding across the forelands enables high flood levels to be contained in the rivers. The main river banks are much higher than the summer dikes, and must be able to stem higher floods, which occur mainly in winter; hence the name winter dikes. The area lying landwards of this dike is only flooded when the dike is breached. This happened frequently in the past, as is witnessed by the many scour holes which remain. During the last winter of the Second World War the riverine area was no-man's-land after the Battle of Arnhem. On 3 December 1944 the southern dike of the Lower Rhine west of Arnhem was blown up by the Germans and practically the whole area between the Waal, the Amsterdam-Rhine canal and the Lower Rhine was inundated. The previous time that this area was flooded was in 1855, when the southern dike of the Lower Rhine was breached in four places at a time of high floods.

Brick making is the only industry on the forelands; the chimneys of the brick kilns are a typical feature of the skyline. The buildings are situated on elevated sites and surrounded by partly excavated areas.

Actual and fossil river courses in the Netherlands are accompanied by ridges that are 1 m higher than the backswamps. These ridges, ranging from several hundred metres to 2 km wide, are the former meander belts. All the villages (Fig. 1) and old roads are situated above the floodplain on these levees. Most villages pre-date embankment (roughly before 1200-1400 A.D.). The centre of many villages is slightly elevated and has deep, dark soils where medieval or even Roman artefacts may be found.

The soils on the meander belt, formerly called river-ridge soils, are characterized by a medium-textured, well-structured upper part of the solum, overlying a coarse-textured subsoil at varying depth, resulting in a well-drained soil (B-NL9). The relative elevation of these soils enables them to be used mainly for arable land and orchards. The soils of the meander belts of the Rhine are mostly calcareous at a shallow depth. Locally there are remnants of older meander belts up to 3000 to 5000 years old, which have survived a rejuvenation of the meander belt. Soils at such sites show progressive soil formation; not only decalcification but also evidence of clay translocation. By comparison, the analogous soils from Meuse deposits are non-calcareous throughout. This difference in lime content between Rhine and Meuse sediments is up till now not yet satisfactorily explained.

The medium-textured brown soils of the meander belts grade gradually in the fine-textured grey soils of the backswamps, the third element in the Rhine - Meuse floodplain. Edelman spoke of 'basins' referring to their low-lying situation between the surrounding ridges.

Until the end of the Second World War the landscape of the backswamps was characterized by widespread grasslands, lacking farm buildings and with only some gravel and unsurfaced roads leading to meadows used for extensive grazing. Trees were limited to scattered willow-coppices, some surrounding duck decoys. The soils in these areas are fine-textured, non-calcareous and sometimes have peat at shallow depth. Until fairly recently these soils were badly drained, therefore ground-water levels were high and drainage conditions poor.

In the last twenty years many of these areas have been reclaimed, new metalled roads, lined with poplars, now cross the backswamps. Originally most villages were connected only by roads on top of the winding dikes. Now there is a four-lane highway running east-west in this area. Modern farmsteads have been built in the former uninhabited backswamps. With the reallocation schemes drainage conditions have been improved by digging new main drains, by tile-draining and installing modern pumping stations to lower water levels, and by better maintenance of the field ditches.

Two soils have been selected to illustrate the soil conditions in the fluviatile district. Soil B-NL9 is from a meander belt and B-NL10 from a backswamp.

Soils in meander belts often have a coarse sandy subsoil, B-NL9 is an example of a deep soil (coarse sand at 130 cm depth). Locally shallow soils occur, with sand within 50 cm depth. In dry summers shallow soils are clearly recognizable by differences in the colour of sugar-beet leaves.

The high clay content of soil B-NL10 illustrates the calm conditions during sedimentation in this former backwater area. The presence of the buried Ah-horizons (see section 'Vegetation horizons') one dating from the Bronze Age, the other from Roman times, demonstrates that this site has been free from erosion by river meanders for over 3000 years.

Route description

Wageningen (about 30 000 inhabitants of which nearly 10 000 students, Agricultural University, agricultural research institutes, small industries, important river port) is situated at the foot of a sandy hill (ice-pushed preglacial river sediments) in the embanked Holocene river plain of the Lower Rhine (Fig. 1). Founded before 1263 A.D. when the already existing village got 'city-status' accompanied with the right to enclose the town with ramparts and a moat (relics still present). On the hill are Plaggepts (plaggensoils) and Haplorthods.

The first 5 km of the route crosses the former glacial valley scoured by the Saale-glacier, filled in with late-glacial and post-glacial sediments, ending with the Holocene Rhine deposits.

The next part goes uphill: the other side of the glacial valley with the same origin as the Wageningen Hill. On this hill are the same sandy soils as on the Wageningen Hill.

After turning south and crossing the Lower Rhine we enter the fluviatile district. Between the foot of the hill and the river are the forelands, at the other side of the river the forelands are situated between the winter dike and the river; on both sides of the river the low summer dikes are recognizable.

Both demonstrated soils (B-NL9 and 10) are not far from the bridge. The difference in landscapes will be demonstrated on the route to soil B-NL9 and from this soil to B-NL10 and from there to Utrecht. This is a city of about 300 000 inhabitants, founded by the Romans (lat. Trajectum): Bishop's See since 695 A.D.; university since 1634; administration, industrial and trade centre (yearly Trade Fair since 1917); main railway and highway junction (head-office of the Netherlands Railways).

In Utrecht the participants board the boat at the quay of the Amsterdam-Rhine canal (excavated to connect Amsterdam with the Rhine, the shipping lane between Rotterdam and Germany). The canal has a fixed water level (40 cm below sea level), the same as in the canals in the city of Amsterdam. During the sail to Amsterdam we see polders on both sides of the canal with water levels in the ditches still lower than in the canal; the polders have Histosols (peat) and Fluvisols (tidal sediments), mainly used for dairy farming.

Arriving in Amsterdam Port (the IJ) and mooring behind the Central Station, at one km from the Dam and the Royal Palace. Dinner, bed and breakfast on board and next day by bus to Hamburg.

Stop 1, soil B-NL9

Site description

Classification	:	FAO-UNESCO (1974): Calcic Cambisol USDA (1975): Fluventic/Typic Eutrochrept, fine-silty, mixed, mesic Netherlands: mapping unit Rd90A on the Soil Map of the Netherlands, scale 1:50 000
Location	:	Experimental farm 'De Schuilenburg', 10 km west of Wageningen
Top. map	:	1:25 000, sheet 39 E (Rhenen), 16524394
Elevation	:	7 m
Land form	:	Level natural levee in the alluvial plain of the river Rhine, protected from flooding by artificial levees or dikes
Land use	:	Orchard. The profile is located in a wind break with deciduous trees (Fraxinus, Fagus, Acer, Corylus, Crataegus, Prunus)
Parent material	:	Holocene deposits of the river Rhine
Drainage	:	Controlled polder water in ditches, spaced 100-140 m apart. The fields are not tile-drained. The ground-water level fluctuates between 130 and 200 cm depth

Profile description

Ah	0- 28 cm	Dark greyish brown (10YR4/2.5) moist en light brownish grey (10YR6/2) dry, silt loam; weak coarse prismatic breaking to strong very fine angular and subangular blocky; slightly sticky, slightly plastic, friable moist, slightly hard dry; many continuous medium, fine and very fine pores; common worm casts on the soil surface; many filled form burrows; few coarse roots, common very fine, fine and medium roots; calcareous; clear, smooth boundary
Bw1	28- 45 cm	Brown (10YR4.5/3) moist and brown (10YR5/3) dry, with common vertically oriented worm burrows filled with dark greyish brown material from Ah, silt loam; weak coarse prismatic breaking to moderate very fine subangular blocky; slightly sticky, slightly plastic, friable moist, slightly hard dry; few large open burrows; common continuous fine and medium pores; few coarse roots, common fine and medium roots; strongly calcareous; clear wavy boundary

Bw2	45- 77 cm	Brown (10YR4.5/3) moist and yellowish brown (10YR4.5/4) when rubbed, silt loam; weak coarse prismatic breaking to strong very fine angular and subangular blocky; slightly sticky, slightly plastic, friable moist, few large open burrows; common continuous fine and medium pores pores; common vertically oriented filled worm burrows, very few coarse roots, common fine and few medium roots; strongly calcareous; clear smooth boundary
BCg	77-110 cm	Brown (10YR5/3.5) moist, few, fine, distinct, sharp brownish yellow mottles, silt loam; weak very fine subangular blocky; slightly sticky, slightly plastic, friable; few large open burrows; few continuous fine and medium pores; few fine and medium roots; strongly calcareous; clear smooth boundary
C1g	110-127 cm	Greyish brown (2.5YR5.5/2) moist and layers with various colours; stratified silt, sandy loam and loam; structureless; nonsticky, non-plastic, loose moist, strongly calcareous.

Analytical data

Hor.	Depth (cm)	C (%)	N (%)	C/N	$CaCO_3$ (%)	pH (KCl)	Texture (%) <2	2-50	>50 µm
Ah	0- 28	2.29	0.30	7.6	2.7	7.0	24.6	48.6	26.8
Bw1	28- 45	0.75	0.12	6.3	4.3	7.4	30.4	50.9	18.7
Bw2	45- 77	0.68	0.08	8.5	14.2	7.5	27.8	51.1	21.1
BCg	77-110	0.54	0.05	10.8	17.9	7.6	23.2	48.6	28.2
C1g	>110	0.43	0.03	14.0	16.9	7.8	13.4	29.4	57.2

Hor.	Depth (cm)	P_2O_5 (mg/kg)	Fe_2O_3 (%) dith	ox	Extr. cations (mmol/kg) ½Ca^{++}	½Mg^{++}	Na^+	K^+	CEC
Ah	0- 28	1021	1.61	0.34	155	12	4	4	189
Bw1	28- 45	282	1.87	0.30	117	10	3	1	207
Bw2	45- 77	159	1.86	0.36	137	7	2	<1	180
BCg	77-110	135	1.41	0.33	98	5	3	2	103
C1g	>110	137	1.05	0.25	42	<1	1	3	53

Site interpretation

Some aspects of this soil are:

- calcareous throughout;
- high biological activity: many worm channels and a good structure, consequently a good permeability and rootability;
- loamy texture grading into coarse sand in the deeper subsoil;
- both features from a young soil (fluvic properties; stratification in the subsoil), and features of progressive soil formation (the subsurface horizon satisfies the definition of the Cambic horizon), the soil is an intergrade between Fluvisols and Cambisols.

This kind of soils practically has no limitations, it is excellently suited for arable and horticultural crops and for grassland. Because of its slightly elevated situation above the general level of the floodplain, these sites were selected for the settlements. In Fig. 1 it appears that the villages are either on the natural levees (the meander belts) or on the bordering higher Pleistocene sands.

All these aspects of soil B-NL9 are in striking contrast with the next soil (B-NL10).

Stop 2, soil B-NL10

Site description

Classification	: FAO-UNESCO (1974): Eutric Fluvisol USDA (1975): Typic Fluvaquent, fine-clayey, illitic (nonacid), mesic Netherlands: mapping unit Rn44C on the Soil Map of the Netherlands, scale 1:50 000
Location	: Dodewaardse Veld, 5 km south of Wageningen
Top. map	: 1:25 000, sheet 39 H (Bergharen), 17134367
Elevation	: 6 m
Land form	: Level backswamp in the alluvial plain of the river Rhine, protected from flooding by artificial levees or dikes.
Land use	: Grassland, alternating pasture and meadow, both hay and silage grass
Parent material	: Holocene deposits of the river Rhine
Drainage	: Controlled polder water in ditches spaced 80-100 m apart. The fields have a ridge-and-furrow system, spaced 10-15 m. The ground-water level fluctuates between 30 and 100 cm depth

Profile description

Ah1	0- 7 cm	Very dark greyish brown (10YR3/2) moist, clay; weak very fine subangular blocky; sticky, plastic, friable moist; common fine and very fine pores; many very fine and fine roots; clear, smooth boundary

Ah2	7- 20 cm	Very dark greyish brown (10YR3/2.5) moist, clay; moderate coarse prismatic breaking to moderate fine angular blocky; sticky, plastic, friable moist; common fine and very fine pores, common fine and very fine roots; clear, smooth boundary
ACg	20- 40 cm	Greyish brown (10YR4.5/2) moist, common, fine, distinct, sharp strong brown mottles around root channels; clay; weak coarse prismatic breaking to strong fine to medium angular blocky; sticky, plastic, friable moist; few pores, few roots, abrupt, smooth boundary
2Ahg	40- 53 cm	Dark grey (10YR4/1) moist, few fine faint brown mottles; clay; weak coarse prismatic breaking to strong medium angular blocky; few small slickensides; sticky, plastic, friable moist; few pores; abrupt/clear, smooth boundary
2Cg	53- 72 cm	Grey (10YR5/1) moist, common, fine, distinct reddish yellow mottles; clay; strong coarse prismatic; few small slickensides; sticky, plastic, friable moist; few pores; abrupt, smooth boundary
3Ahg	72- 80 cm	Dark grey (10YR4/1) moist, many fine, prominent, strong brown and reddish yellow mottles; clay; weak medium prismatic breaking to moderate very fine angular blocky; sticky, plastic, friable moist; few pores, clear smooth boundary
3Cg	80-100 cm	Grey (10YR5/1) moist, many fine prominent strong brown mottles; clay, 'half-ripened'; weak medium prismatic breaking to moderate fine angular blocky; sticky, plastic, friable moist, abrupt smooth boundary
4Ahg	100-110 cm	Very dark grey (10YR3/1) moist; clay, 'half-ripened'; moderate coarse prismatic; sticky, plastic, friable moist; clear boundary
4Cr	110- cm	Greyish brown (10YR5/2) moist; clay, 'half-ripened'; moderate coarse prismatic, sticky, plastic, friable moist.

Analytical data

Hor.	Depth (cm)	C (%)	N (%)	C/N	$CaCO_3$ (%)	pH (KCl)	Texture (%) <2	2-50	>50 μm
Ah1	0- 7	5.26	0.59	8.9	0.2	6.0	47.7	45.0	7.3
Ah2	7- 20	3.24	0.37	8.8	0.1	5.4	55.3	38.9	5.8
ACg	20- 40	1.19	0.16	7.4	0.1	5.5	59.4	36.8	3.8
2Ahg	40- 53	1.61	0.17	9.5	0.1	5.8	67.9	30.5	1.6
2Cg	53- 72	0.81	0.10	8.1	0.1	5.7	55.8	42.6	1.6
3Ahg	72- 80	1.28	0.12	10.7	0.1	6.0	58.4	38.1	3.5
3Cg	80-100	0.81	0.09	9.0	0.1	5.9	51.4	47.2	1.4
4Ahg	100-110	4.09	0.24	17.0	0.1	6.1	72.4	27.2	0.4
4Cg	>110	1.72	0.18	9.6	0.1	6.0	62.0	37.0	1.0

Hor.	Depth (cm)	P_2O_5 (mg/kg)	Fe_2O_3 (%) dith	ox	Extr. cations (mmol/kg) $\frac{1}{2}Ca^{++}$	$\frac{1}{2}Mg^{++}$	Na^+	K^+	CEC
Ah1	0- 7	806	2.66	1.25	189	32	<1	7	303
Ah2	7- 20	214	3.00	1.41	176	27	2	4	296
ACg	20- 40	55	3.35	0.75	207	32	<1	5	303
2Ahg	40- 53	60	2.11	0.40	202	26	3	13	344
2Cg	53- 72	103	2.56	0.97	203	17	1	6	258
3Ahg	72- 80	441	4.15	2.28	170	8	<1	11	336
3Cg	80-100	428	3.70	2.02	237	23	2	12	259
4Ahg	100-110	215	1.62	0.82	252	20	2	12	372
4Cg	>110	235	1.74	0.76	283	25	<1	18	444

Site interpretation

Some aspects of this soil are:

- non-calcareous throughout, but non-acid;
- low biological activity, angular blocky and prismatic structure, low permeability (see section 'Soil physical measurement techniques in clay soils');
- clay texture, even to greater depth, with the conclusion: although these sediments are from the Holocene river, the river itself (its course) never was on this site;
- buried A-horizons and no Cambic features, clearly a Fluvisol for the buried Ah-horizons, see section 'Vegetation horizons').

This kind of soil is too fine-textured for the economically most important crops in this country (potatoes, both seed and consumption, and sugar-beet). There are problems in preparing the seed bed and also during harvesting with machines: low trafficability during wet spells, and in dry periods the seed bed will be too coarse and these root crops then are not easily harvestable.

Because of their slightly lower situation in the flood plain of the foregoing soil, these sites were not preferred for settlement (cf. Fig. 1).

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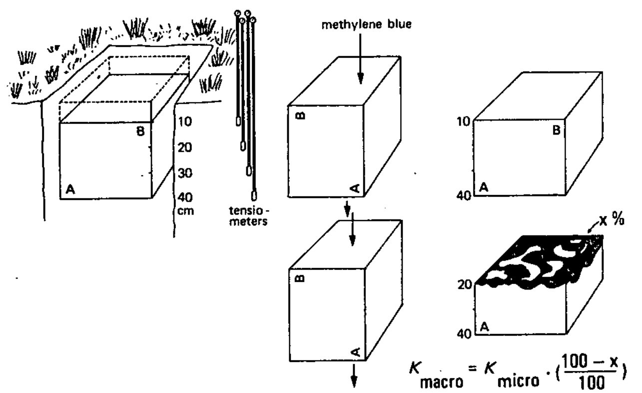
SOIL PHYSICAL MEASUREMENT TECHNIQUES IN CLAY SOILS

Determination of soil physical parameters in clay soils offers many problems because of the unstable porous medium that swells and shrinks with changing moisture content. The following methods are developed in The Netherlands.

Measurement of K_{sat}

For the measurement of K_{sat} in clayey soils the cube method is used. A cube of soil (25 cm x 25 cm x 25 cm) is carved out in situ and encased in gypsum on four vertical walls. First, the K_{sat} (vert) is measured by determining the flux leaving the cube while a shallow head is maintained on top. Next, the cube is turned 90°. The open surfaces are closed with gypsum and the new upper and lower surfaces are exposed. Again, a K_{sat} is measured which now represents the K_{sat} (hor) of the soil in situ, indicating the influence of horizontal cracks.



Measurement of K_{unsat}

The cube method also can be extended to provide K_{unsat} data near saturation. This procedure represents a version of the crust test. Two tensiometers are placed about 2 and 4 cm below the surface of infiltration, which is covered by a series of crusts, composed of mixtures of sand and quick-setting cement. Dry sand and cement are thoroughly mixed, water is applied and a paste is formed which is applied as a 0.5 to 1 cm thick crust on top of the cube. The crust, which has perfect contact with the underlying soil because of the application method, hardens within 15 minutes. Light crusts (5 to 10% of cement by volume) induce pressure heads (h) near saturation and relatively high fluxes. Heavier crusts (20% cement and more) induce lower h values and fluxes. These fluxes, when steady, are equal to K_{unsat} at the measured subcrust h-value. Fluxes are measured as outflow rates from the cube.

Measurement of short-circuiting

Irrigation of dry, cracked clay soils presents problems because much of the applied water may rapidly disappear into the subsoil. As a result, the bulk of the soil between the cracks is hardly wetted or leached (relevant in saline soils), and surface-applied fertilizers and pesticides may rapidly move beyond rooting depth. Downward movement of "free" water along the walls of continuous macropores in unsaturated soil has been called short-circuiting. Short-circuiting can be measured by using larger undisturbed cores of surface soil with a height that is equal to rooting depth. The cores are placed in the path of a spraying gun in the field which is commonly used for sprinkling irrigation. The volume of water that leaves the column is measured as a function of time, thus allowing an estimate of short-circuiting which can be expressed as a percentage of the applied quantity of water. The process of infiltration during sprinkling irrigation can be demonstrated by showing stains in the soil formed by water containing methylene-blue. The total vertical area of peds which is being stained is only 1-2% of the total vertical surface area of the prisms. Thus, lateral infiltration is very low.

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VEGETATION HORIZONS

Vegetation horizons are regularly present in Holocene marine and fluvial deposits. These horizons are in general dark brown to black bands which consist of a clayey matrix with a certain concentration of organic matter. In the fluvial area of the Netherlands vegetation horizons are often called "laklagen" (lacquer layers), whereas in the coastal area of north-west Germany they are called "Dwog" or "Dwoghorizont".

Generally speaking, vegetation horizons can be considered to represent buried shallow O/Al-soil horizons which developed on top of the underlying marine and fluvial deposits during essentially non-depositional phases. Vegetation horizons have, in both the marine and the fluvial districts, a higher content of organic matter and nitrogen, a higher C/N ratio, and a higher clay content than the underlying and overlying deposits, and normally have a very dense structure.

The occurrence of vegetation horizons in the coastal plain will not be shown during this excursion. In an area in the Northern Netherlands coastal plain (Schildmeer area) vegetation horizons have been studied in detail (Schoute, 1984). This coastal plain developed during the Holocene mainly as a result of tidal deposition under conditions of a sea level rise.

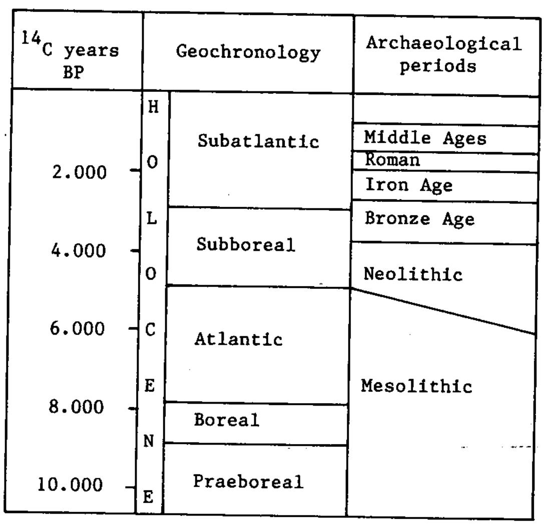

Figure 1 Geological and archaeological subdivision of the Holocene

Transgressive and regressive intervals alternated during which marine influences increased and respectively decreased. Vegetation horizons are regularly associated with accompanying non-depositional unconformities of younger Holocene regressive intervals.

In the fluvial area of the Netherlands distinct vegetation horizons are more or less limited in their occurrence to transitional zones in-between the backswamp or flood basin areas and the natural levees of actual and palaeo (a.o. buried) riversystems. Here, the oldest occurrence dates back to the Late Atlantic (c. 5500 14C years BP; cf. figure 1).
The presence of vegetation horizons is primarily dependent on prevailing environmental conditions.
Vegetation horizons occurring in the younger Holocene coastal deposits in the Northern Netherlands and Germany are largely formed in a semi-terrestrial environment. Whether this is also valid for vegetation horizons occurring in the fluvial areas is subject for current investigations.
In the fluvial area of the Netherlands vegetation horizons are being studied in detail in the neighbourhood of Dodewaard (not far away from the fine-textured Fluvisol demonstrated during the excursion). A general outline of the geological setting of the Dodewaard study area with indication of the occurrence of vegetation horizons shows schematically the following order of units (cf. also figure 2):

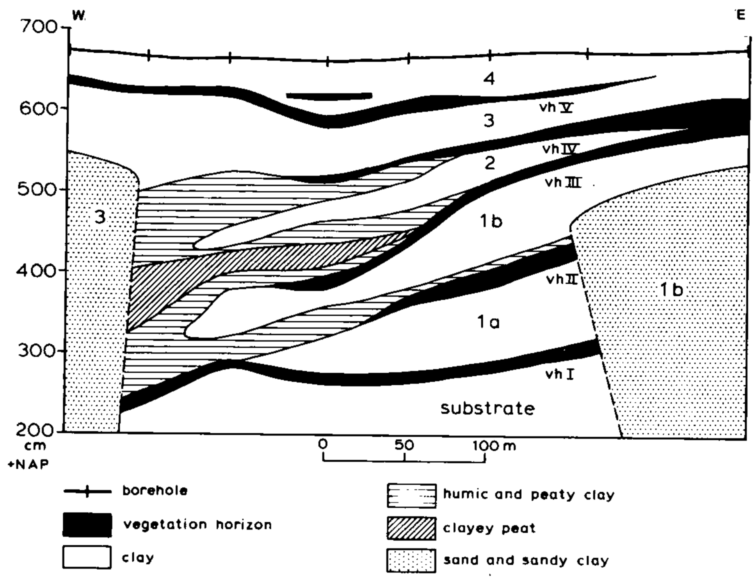

Figure 2 Schematic W-E cross section near Dodewaard

- Substrate : Late Pleistocene/Early Holocene river deposits capped with a vegetation horizon (vhI);
- Unit 1 (a and b) : Older fluvial deposits of the River Rhine starting in the Late Atlantic and showing a rejuvenation phase (1b) separated by a vegetation horizon (vhII) or a humic clay layer. About 4000 BP this stream is losing its function. On these deposits a vegetation horizon (vhIII) respectively a clayey peat layer in lower places, is developed. On the topographically highest places of these deposits traces of human occupation of the Neolithic and Bronze Age have been found;
- Unit 2 : Intermediate, local clay deposition by a breakthrough channel (crevasse) during a phase of limited fluvial activity, in and upon which a series of vegetation horizons (vhIV), with laterally deposition of humic clay in lower places, is developed;
- Unit 3 : Younger fluvial deposition by a minor branch of the River Rhine, presumably sedimented from c. 2800-2250 BP, upon which locally a vegetation horizon (vhV) is formed. Elsewhere in the fluvial area traces of human occupation dating from the Roman period have frequently been found at this latter level;
- Unit 4 : Youngest clay bed.

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Methods

Stone content: Weight-percentage of the whole soil

Texture: Destruction of $CaCO_3$ (HCl) and organic matter (H_2O_2). Dispersion of the fine earth (<2mm) with $Na_4P_2O_7$ and ultra sonics.
Sieving (sand fractions) and pipetting (silt and clay fractions (DIN 19683).

coarse sand (2-0.6 mm), medium sand (0.6-0.2 mm), fine sand (0.2-0.06 mm), coarse silt (0.06-0.02 mm), medium silt (0.02-0.006 mm), fine silt (0.006-0.002 mm), clay (<0.002 mm).

bulk density: unit weight (g/cm^3) of the undisturbed soil

Pore volume and pore size distribution: Dehydratation of undisturbed water-saturated soil samples with air pressure at pF 1.8, 2.5 and 4.2 (DIN 19683)

Water permeability (kf): Estimation with undisturbed water saturated soil columns in the laboratory and calculation with the Darcy equation in cm/day (DIN 19683)

The following chemical methods were carried out with the air-dry fine earth fraction (<2 mm)

pH: Suspending 10 g soil with 25 ml H_2O or 0.01 m $CaCl_2$ and electrometrically measuring

C_{org}: Oxidation of organic matter with $K_2Cr_2O_7$ in sulfuric acid and colorimetric measuring of the reduced Cr-ions (Lichterfelder method)

N_t: Disintegretion according to Kjeldal. Water vapor destillation of NH_3 (Parnas-Wagner)

$CaCO_3$: Measurement of CO_2-Volume after reaction with HCl according to Scheibler. Calculation as $CaCO_3$-equivalence

Pedogenic sesquioxides (Fe_d, Al_d, Mn_d): Extraction of sesquioxides with $Na_2S_2O_4$ and Na-citrate under alkaline conditions (pH 7.3, 80° C). Element measuring by atomic absorption

Reactive (amorphons) iron oxides (Fe_o): NH_4-oxalat/oxalic acid extractable iron (Tamm). Element measuring by atomic absorption

Cation exchange capacity (CEC): Actual (CEC_a with unbuffered 0.1 n NH_4Cl) and potential cation exchange capacity (CEC_p with 1 n NH_4 acetate, pH 7). H and Al was only determined at soils with pH <4.5 in the 0.1 n NH_4Cl-extract. V (%) is the percentage

Ca-lactate soluble P and K (P_{CAL}, K_{CAL}): Extraction with 0.05 m Ca-lactate, 0.05 m Ca-acetate, 0.3 m acetic acid, pH 4.1 according to Schüller (LUFA-method)

For detailed informations see

DIN 19680-86 (1970-81): Bodenuntersuchungsverfahren im Landeskulturbau. Beuth-Vertrieb GmbH, Berlin u. Köln
19683 Teil 1-3 Bestimmung der Korngrößenzusammensetzung
19683 Teil 5 Bestimmung der Saugspannung
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