SEQS Symposium

INQUA-SEQS '98

THE EEMIAN
Local sequences, global perspectives

Excursion Guide

September 6-11, 1998, Kerkrade (The Netherlands)
The Eemian
Local sequences, global perspectives

Excursion guide
September 9, 1998
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Demonstration of a selection of cores

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based on contributions by and discussions with
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1.1 Introduction

For centuries the surface water in the coastal plain of The Netherlands had been used for human consumption. When in the middle of the last century it became clear that the poor water quality one of the main problems was affecting public health, measures were taken to secure the distribution of high-quality drinking water. Apart from transporting water from areas with a good water quality, in many areas aquifers in unconsolidated deposits were tapped. In the coastal areas however, the geological situation may change considerably over relatively short distances. Therefore, geological studies were necessary to gain insight into the three dimensional occurrence of lithological units: a stratigraphical framework became necessary.

In this process Dr. P. Harting was a central character. Trained as a medical doctor he was also knowledgeable in other areas of science of which geology was not the least. Using marine shells to establish the age of the sediment in which they were found, he tried to correlate the results from boreholes in the western part of the Netherlands into schemes published in Belgium and England. In 1874 (in Dutch) and 1875 (in French, a former language of the scientific community) he explained the stratigraphy of an area near the town of Amersfoort, in the valley of the river Eem. Here he encountered sediments with a mollusc-assemblage, which did not fit into known subdivisions. He proposed a new time-unit for the period in which these sediments were deposited and called it 'système éémien' in French (fig. 1.1), our 'Eemian'.

continue. Ce qui est surtout caractéristique dans les deux cas, c'est la présence du Cerithium lima et de la Venus rotundata, qui ne font plus partie de notre faune. La formation dont il s'agit, située dans un sol d'alluvion, au-dessus du diluvium, ne peut être rapportée à l'un des systèmes pliocènes de Dumont. On est donc en droit de la désigner sous un nom particulier, celui de système éémien.

Figure 1.1 First (international) use of the term 'Eemien' by Harting (1875).

The main differentiating criteria was that part of the mollusc-species in these deposits clearly differed from both Lower Pleistocene and Holocene species. Part of the assemblage consisted of shells presently known from western France, south of the Straits of Dover, the Lusitian Province and from the Mediterranean Province. Early in the twentieth century similar mollusc-assemblages were found in Denmark and Germany as well and the name Eemian was used accordingly.

In the Netherlands not many publications have been devoted to the lithology and paleontological contents of Eemian sediments. Before World War II several studies were published in connection with hydrogeological studies as well as with malacological and diatom research. In this period an Eemian pollen zonation was introduced by Jessen and Milthers (1928), based on the situation in Denmark and Northwest Germany. This made correlation across NW-Europe possible and was applicable in the Netherlands as well (e.g. Louman, 1934). In 1956 the Geological Survey of the Netherlands undertook a project to study the type locality.
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Figure 1.2  Stratigraphical scheme of the Late Pleistocene in the Netherlands.

At Amersfoort three boreholes were cored and a few deep excavations, made for infrastructural works, were sampled as well. The resulting studies on foraminifers (van Voorhuijzen, 1958) and pollen (Zagwijn, 1961) were published. This last monograph became the standard publication for the palynological subdivision of Eemian deposits in the Netherlands. Data on molluscs and diatoms remained unpublished in the archives of the Survey. During the seventies cored samples were studied from a number of boreholes made in Amsterdam. The results of the pollen study (Zagwijn, 1996, esp. the boreholes Valkenweg) demonstrated the presence of a more complete sequence than that at Amersfoort, especially deposits at the transition from the older cold period, the Saalian, to the Eemian. Based on more data from the Netherlands Zagwijn (1983) presented a sealevel-curve for the Eemian. Later data on diatoms and molluscs were presented in combination with the palynological zonation by de Wolf & Cleveringa (1994), showing the changes in environmental parameters during this period.

At the INQUA-congres in Berlin (1995) the INQUA-SEQS-committee showed interest in devoting special attention to the Eemian during the present intra-congres period. The Geological Survey of the
Netherlands agreed to embark upon an integrated study of the Eemian deposits in the type area of Amersfoort and Amsterdam. However, this was delayed until 1997, when a start was made with both a study of the archive data and the raw sample material from the boreholes at Amersfoort. Furthermore in Amsterdam a nearly 79 m deep borehole was cored at a locality not far from the boreholes Amsterdam-Valkenweg (Zagwij, 1996). The cores of this borehole were cut in half longitudinally. One side was reserved for your inspection during this symposium, the other half was used for specialist studies. During the present symposium the results of the studies pertaining to the Amsterdam boring will be presented in the lecture of van Leeuwen et al., while the results of the renewed investigation of the Amersfoort data will be presented in the lecture of Cleveringa et al. The setting of the Amsterdam basin will be discussed in the lecture of de Cans et al. Finally, several specialists will display their results in the poster session. Now, at the beginning of August, many of the specialist studies have been reported. However, due to the short time-period between the sampling of the deposits and our symposium a number of specialists will not have their results ready until the symposium takes place and some even later. During the project questions arose which may be answered by turning to other specialists; look for our wishes below! When new interpretations come up, the present reconstruction might change!

1.2 Borehole Amsterdam-Terminal (25E0913)

In order to find a suitable location for an extensive study of Eemian deposits it was decided to set a borehole not far from borehole Valkenweg, from which results were published by Zagwij (1996). This area shows the thickest and most complete Eemian sequence studied until present. As time was pressing, the other option, drilling at a location where the sequence is even 20 m thicker, was discarded as the presence of erosional breaks could not be ruled out beforehand. At Amsterdam however the area with thick Eemian deposits is very limited. In earlier boreholes especially the older Eemian sediments were not very completely developed. For reconnaissance a cone-penetration-test was executed. It showed a sequence, which closely resembled that of the Valkenweg-hole. In July 1997 the Terminal borehole was cored by a crew of NITG-TNO down to a depth of 78.70 m below the surface. The location is situated 52° 22’ 45” N and 4° 54’ 51” E (in the national grid system x=122780, y=487920). In the borehole a multi-spectral gamma-measurement was performed. The closed cores were X-rayed for the greater part. Colour photographs (comp. fig. 1.3) were made of the whole sequence, directly after opening the cores. A description of lithology and sedimentology was made and lacquerpeels were taken.

Samples were taken for each discipline, starting with paleomagnetism, to be studied by Dr. C.G. Langereis, Department of Geophysics, Faculty of Earth Sciences, Universiteit Utrecht. The analysis of clay minerals was performed at the Laboratory of Soil Science and Geology, Wageningen Agricultural University. At present the analysis of the stable isotope composition of foraminifers is underway in Cambridge with Dr. N. Shackleton. U/Th-analyses of marine shells were executed by Dr. C.J. Beets and R.W. Kruk, Faculty of Earth Sciences, Vrije Universiteit Amsterdam. The results of this last investigation could not be included in this guide, but will be presented at the symposium in the lecture of Kruk et al..

Samples for the study of plant-macromerains were sent to Dr. M. Field. As the samples were small and, at first appearance, did not contain much plant material, this core is not expected to yield much new information. The other studies, presented here, were done at the Netherlands Institute of Applied Geoscience TNO.

The inclinations of the characteristic remanent magnetisation (ChRM), determined as part of the paleomagnetic study (fig. 1.12), show clearly that no reversal is present: the Blake event must be
Amsterdam-Terminal 25E 0913
surface 1.45m + NAP

Lithogenetical units
8 Diatomite; Harting layer
7 Sandy diatomite
6 Diatomite
5 Sand
4 Lacustrine clay

Pollenzones
E4a Corylus zone (Eemian)
E3 Quercus zone (Eemian)
E2 Pinus zone (Eemian)
E1 Betula zone (Eemian)
LS Artemisia zone (Saalian)

Figure 3: Photographs of the cores, showing the base of the Eemian sequence
younger than the part of the Eemian studied in our core. The intensities are in general rather constant and therefore no big changes in grain size and concentration of detrital material occur. However, between 35 and 38 m and between 61 and 64 m higher intensities correlate with more sandy, resp. diatomaceous intervals. The high intensities in units 2 and 3 show the coarser nature of the varved sediment.

Grain size was measured by laser diffraction (Malvern Mastersizer-X) after removing carbonates and organic matter. The clay-sized fraction is taken as the percentage of all particles, smaller than 8 μm (Konert & Vandenberghhe, 1997). The sand fractions are given as calculated by the laboratory. It has been found that medium and coarser sand fractions are somewhat finer (about ½ phi) when analysed by the sieve-method. In the descriptions the Wentworth size fractions are used (63 v.f. 125 f. 250 m. 500 c. 1000 v.c. 2000 mu). The grain size-diagram is presented in figure 1.4.

Heavy minerals; in the interval between 38.00 and 75.15 m only low percentages of sand-sized sediment are present. Most probably the sand fraction in some of these deposits has a different source than the clay-fraction. Comparison between figures 1.4 and 1.10 shows that the minerals indicative of a Rhine provenance, especially aliterite, are high when more than 30% of the sediment is coarser than 150 μm. This supplements the Late Pleistocene regional mineral-signal for this part of the North Sea basin, which is composed of epidote, hornblende and garnet. The Rhine material is partly (esp. below 64 m) derived from the ice-pushed ridges surrounding the basin and partly (above 32 m) consists of material deposited by the river at that time and washed into the basin from outside.

Geochemical analysis was performed on ground whole rock samples by X-ray Fluorescence (XRF; ARL8410) for major and trace elements and for C and S using an element analyzer (Strohlein CS mat 5500). In general the group of elements found in particles of the clay-sized fraction is large and correlates positively with Al₂O₃ (fig. 1.11); K₂O, Cr, Nb, Nb, V, MgO, Pb, Ni en Y. The silt- and sand-sized fractions do not show a similar good correlation with SiO₂. Only Zr correlates (weakly) with silica. CaO is positively correlated with LOI (loss-on-ignition) and Sr and, although weaker, with S. LOI has a fair correlation with MnO. The curves of a number of important elements are given for Saalian and Eemian sediments in fig. 1.11.

Clay-minerals were measured by X-ray Diffraction (XRD; Philips PW1820/PW 1710) at the Laboratory of Soil Science and Geology of Wageningen Agricultural University. Seven samples were analysed (fig. 1.11). Four samples, at 35.00, 41.20, 50.00 and 73.00 m, consist mainly of smectite and illite (resp. ca. 45 and 35%) with traces of kaolinite and chlorite and possibly vermiculite. Three samples, at 55.00, 61.20 and 66.80 m, consist mainly of illite, smectite and vermiculite (resp. 40, 20 and 20%) again with minor amounts of kaolinite and chlorite.

In the near future we would like to supplement our study with the following specialist studies; micromorphology, organic geochemistry, stable isotope measurements of the fresh water diatomite, amino-acid-ratio determinations of molluscs, TL- and OSL-measurements and the study of fish remains.

1.3 Description of sedimentary units

At first, units were defined on the basis of lithological and sedimentological criteria. After the completion of the specialist studies this scheme was further refined. In order to do justice to all the data, some of the original units have been split up, while others have been combined. The redefinition resulted in a scheme of twenty-one units (fig. 1.4), of which, from bottom to top, five were formed in
the Saalian, ten in the Eemian, four in the Weichselian and two during the Holocene. Depositional breaks are present at the transition to the next chronostratigraphical unit. The boundaries between the units formed during the Eemian are (very) gradual.

As the Saalian deposits are genetically more intimately linked to the overlying Eemian deposits and their sedimentary development, in the description more attention is paid to these than to the Weichselian and Holocene deposits in the upper part of the borehole. In the following description the results of the various disciplines are presented, however, without making explicit reference to the figures based on specialist studies on pollen (fig. 1.5), diatoms (fig. 1.6), dinoflagellates (fig. 1.7), foraminifers (fig. 1.8), molluscs (fig. 1.9), heavy minerals (fig. 1.10) and geochemistry (fig. 1.11). In chapter 1.4 these results are integrated into a genetical reconstruction of the sedimentary environments.

All depths are given in meters below surface, which is 1.45 m above NAP (levelling datum of the Netherlands, indicating MSL at the coast of the North Sea).

1.3.1 Saalian

1 Glacial till (76.45-78.70)
Lithology and sedimentology Brownish grey very silty sand with fine gravel; not a typical boulder clay.
Heavy minerals Higher values for garnet and aliterite, indicating a source in pre-glacial deposits, similar to those glacially deformed in the surrounding hills.
Gravel Glacial composition, a.o. with crystalline rock, limestone and flint.
Geochemistry Very low C$_{org}$ and S. CaO and Al$_2$O$_3$ normal for calcite-bearing clay.
Grain size High silt-content (60%).

2 Varved clay (75.15-76.45)
Lithology and sedimentology Brown firm silty and sandy clay, graded layers, thickness decreasing from a few cm to mm, at the base of some layers solemarks are visible. About 60 varves are counted.
Geochemistry C$_{org}$ and S contents remain low. CaO decreases towards the top of the unit.
Grain size High content silt-sized particles, relatively high content of poorly sorted sand.

3 Varved clay, rich in organic material (73.55-75.15)
Lithology and sedimentology Greyish dark-brown very silty firm clay, very humic, graded layers. About 90 varves have been counted.
Geochemistry The extremely high CaO-contents (max. 33%) are equivalent to 40-60% calcite. High C$_{org}$ and S contents indicate high primary production and reduced conditions at the lake bottom, with S derived from microbiological degradation of organic matter. The organic matter may be derived from annual plants surrounding the lake, or from algae etc. in the lake itself. This issue will be subject to further studies, using organic geochemistry.
Grain size High content of silt-sized particles, lower sand-content.

4 Lacustrine clay (63.60-73.55)
Lithology and sedimentology Greyish green clay, with thin layers of silt and very fine sand, in the lowermost meter developed as varves. In the lacquerpeels of this unit small round 'holes' are found and interpreted as gasfilled cavities. Several syngenetic faults are preserved in the cores, especially below 71 m.
Pollen From 63.60 to 65.60 m occurrence of Artemisia, Helianthemum, Gramineae, Cyperaceae and Juniperus (pollenzone LS). Obviously a treeless tundra is present with some patches of Juniper.
Diatoms The very top of the clay (from 64.07 m) contains diatoms. An assemblage is present with species as *Navicula jaenefeltii*, *Fragilaria pinnata* and *Amphora pediculus*, suggesting a freshwater pond with a depth of about 0.5 m in a treeless landscape.

Heavy minerals As in unit 1, indicative of a provenance of the sand fraction from the surrounding hills. In the uppermost sample changing to a hornblende-epidote association.

Geochemistry A sudden drop in $C_{eq}$ and $S$ indicate either a drop in primary productivity or increased circulation leading to bottom water oxygenation. CaO-levels drop considerably and remain more or less constant up to 35 m. More or less constant $Al_2O_3$ levels reflect the more or less constant clay contents.

Clay mineralogy Illite and vermiculite contents increase from 73 to 66.80 meter, while smectite contents decrease. Since vermiculite is a product of weathering of illite in soils, the increasing vermiculite contents indicate an increase in the importance of local sediment sources and possibly the onset of soil formation related to an amelioration of the climate.

Grain size Very high amount of clay-sized particles (56 to 70%). Sand-content is high in some samples, more specific; a high proportion of medium sand. In the sediment the sand is concentrated in distinct layers.

5 Sand (63.50-63.60)

Lithology and sedimentology Greyish green fine sand (240μm), few fine gravel particles.

Diatoms As in unit 4

Heavy minerals Garnet and epidote.

1.3.2 Eemian

6 Diatomite (61.95-63.50)

Lithology and sedimentology Greyish green diatomite (fig. 1.3), horizontally laminated.

Pollen Five local pollenzones are discriminated, in brackets the ‘national’ pollenzone is given;

- 62.05-62.13 (E3) *Quercus* forest, extension of *Corylus* and *Pinus*
- 62.13-62.35 (E3) Optimum of *Quercus* forest
- 62.45-62.65 (E3) *Quercus* and *Ulmus* important, *Betula*-shoots, first occurrence of *Hedera*
- 62.73-63.25 (E2) *Pinus* forest, increase of *Ulmus*
- 63.33-63.50 (E1) *Betula* forest with patches of *Pinus*

These zones show the transition from tundra vegetation to deciduous forest.

Dinoflagellates Very few specimens, all from the Brigantedinium-group. As no other marine organisms are found in this unit these are interpreted as syngenetical ‘contamination’, through birds etc.

Diatoms High percentage of *Aulacoseira italica* are found, indicating the presence of plants and trees around a fresh-water lake with a low nutrient level (oligo- to mesotrophic).

Heavy minerals Hornblende and epidote.

Geochemistry Decreasing $Al_2O_3$ marks the lower clay content. Further decreasing $S$ and $C_{eq}$ suggest increased circulation or decreased primary production. CaO contents remain constant.

Grain size High silt-content. However, the results of the analyses have probably been greatly influenced by the presence of diatom-frustules.

7 Sandy diatomite (61.80-61.95)

Lithology and sedimentology Greyish brown sandy diatomite (fig. 1.3), slightly humic.

Pollen *Quercus* forest with *Corylus* (E3), *Pediastrum* shows a strong increase.

Diatoms Fragilaria-species, suggesting fresh-water circumstances with a higher nutrient level.
Geochemistry High SiO₂, very low S and C₄₄
Grain size High silt-content, with about 40% sand, even up to 10% coarse sand. However, the results of the analysis will have probably been influenced very much by the presence of diatom-frustules.

8 Diatomite (61.00-61.80); Harting Layer
Lithology and sedimentology Dark brown slightly clayey gyttja (fig. 1.3), few fine pieces of wood.
Pollen Two local pollen zones;
61.00-61.39 (E4a) Corylus-Quercus forest, first occurrence of Hystrichosphaeridae from 61.45 m
61.55-61.80 (E3) Quercus forest with Corylus, Pediastrum values up to 61.60 m
Diatoms In addition to the several fresh-water Fragilaria-species of unit 7 the first marine diatoms occur between 61.63 and 61.80 m. From 61.55 m the gyttja contains Hyalodiscus scoticus and Grammatophora oceanica, indicating a marine environment with a very low tidal amplitude, clear water and a seaweed vegetation. Interesting is the presence of resting spores of the oceanic species Chaetoceros; after being washed into the lagoon the reaction to unfavourable living conditions led to their formation.
Dinoflagellates Around 61.73 m few specimens are present. From 61.27 the high percentages of the Brigantedinium-group are a clear indication of a marine environment with a high nutrient level.
Foraminifers From 61.73 m relatively few forams, but with a high diversity, coming from a wide range of environments: from open-marine to brackish water. Interpreted as an allochthonous fauna.
Molluscs Between 61.57 and 61.65 two samples, in which Cerastoderma edule, Peringia ulvae and Mytilus edulis are the most important species, with Bittium reticulatum, Venerupis aurea senescens and Corbula gibba. The first group is indicative of a littoral, the second of a shallow sublittoral environment. Even in this lowest mollusc-zone, representatives of the ‘warm’ Eemian fauna are already present: Acanthocardia paucicostata, B. reticulatum, Modiolus adriaticus, V. aurea senescens, Gasarana fragilis and Turboella radiata balkei. Many shells are fragmented.
Geochemistry Very low contents of C₄₄ are at odds with the humic character of this layer as based on macroscopical observations. They indicate very low primary production.
Grain size High silt-content. However; the results of the analysis will have probably been influenced very much by the presence of diatom-frustules.

9 Laminated clay (53.95-60.70)
Lithology and sedimentology Black to dark-green firm clay, rhythmically laminated (mainly differences in colour, but possibly diatom-layers as well), few shells. Between 53.95 and 55.95 m bivalved molluscs. Big siderite (iron-carbonate) concretion at 56.60 m.
Pollen Three local pollen zones, with Hystrichosphaeridae all the way from 60.70 to 54.25;
53.95-56.55 (E4b) Taxus-Quercus forest, first occurrence of Ilex
56.75-58.15 (E4a) Corylus optimum, Taxus shows a continuous curve
58.15-60.70 (E4a) Corylus-Quercus forest, first occurrence of Taxus
Diatoms Many resting-spores of the oceanic species Stephanopyxis turris and the autochthonous species Cocconeis disculoides indicate an environment comparable to that of unit 8. In the upper part (53.95-56.95) the decrease in Stephanopyxis indicates a decrease of ocean water. The presence of Cocconeis disculoides suggests a shallow marginal zone with higher water-temperatures in the summer, whereas the presence of Thalassiosira nordenskioldii is indicative of cold water in winter and spring.
Dinoflagellates All marine Eemian deposits (units 9 up to 13) contain the lagoonal species Diplopleta symmetrica, Lingulodinium machaerophorum and Tuberculodinium van campoae. These last two, together with Spinarites mirabilis indicate subtropical water temperatures. At the base (below 57.76 m) the abundance of Lingulodinium machaerophorum with small processes indicates a low salinity. The interval between 54.80 and 57.76 is very rich in cysts.
Foraminifers Low-diversity faunas. Buccella frigida, Elphidium excavatum s.l. and Elphidium
albiumbilicatum s.l. are the most abundant species, but their proportions fluctuate strongly. The lower part (56.80-60.55) is characterized by the consistent occurrence of Elphidium albiumbilicatum s.l. This species flourishes in the brackish surface-waters of the present-day Baltic Sea and deposition in a similar system, i.e. a large “lagoon” with a strong salinity stratification is inferred. The variability of the fauna probably reflects variation in the depth of the pycnocline. In the upper part (54.31-55.80) percentages of Elphidium excavatum s.l. increase, interpreted as recording a (further) deepening of the basin. The presence of B. frigida may be taken as an indication of seasonally low temperatures at the bottom.

Molluscs Turboella radiata balkei is the most frequently occurring mollusc. It lives on a substrate of plants, most likely Zostera. The remains of this seaweed are found in the upper part of the unit. The water is clearly deeper than in unit 8, but not more than a few meters. As shown by the presence of Ostrea edulis, it is calm and clear. From 55.00 m upward Corbula gibba occurs most frequent, indicating an increase in the depth of the basin.

Heavy minerals Hornblende and epidote.

Geochemistry Increased Corg and S indicate high primary production, starting somewhat above the Harting Layer. Corg and S have a linear correlation here and in the units following above, which indicates that the formation of sulfides is C-limited. For this an ample supply of sea-water derived SO4²⁻ and continuing reduced bottom water conditions are necessary. Fluctuations in Corg suggest fluctuations in primary production. CaO-contents increase slightly.

Clay mineralogy Vermiculite levels remain high, indicating a local sediment source. Soil material was probably transported into the more or less closed lagoon by local stream erosion.

Grain size The silt- and clay-sized fractions are about equal. A very low amount of very fine sand is present.

Varia With the naked eye no bioturbation is visible.

10 Crumbly clay (48.35-53.95)

Lithology and sedimentology Green homogeneous very firm clay with a crumbly texture, few marine shells.

Pollen Two local pollenzones;
    48.35-49.35 (E5) Carpinus increase, Alnus important, decrease of Taxus and Quercus
    50.65-53.95 (E4b) Taxus-Quercus forest

From 53.95 m onward all Eemian spectra contain Chenopodiaceae. No plant remains of Zostera are found in this unit.

Diatoms This unit contains a poor diatom-assemblage, which is also poor in preservation. Paralia sulcata, with a robust silica-skeleton, is the most frequent diatom in this unit. In the lowest sample of this zone the occurrence of Cymatosira belgica could be established. The absence of this species in the rest of this unit, together with the poor quantity and quality of the retrieved diatoms, is interpreted to be the result of dissolution. It is clear that from the base of this zone onward the tidal range is increased.

Dinoflagellates See unit 9, gradual increase in marine influence.

Foraminifers High values for Elphidium excavatum group, further decreasing Ammonia parkinsoniana. This last species lives in the shallower part of the lagoon. Therefore the assemblage as a whole is interpreted as an indication of a further deepening of the lagoon.

Molluscs In an otherwise poor fauna, apart from Corbula gibba, Hyala vitrea is an important species in this and the following units. At present this species thrives at a depth of more than 10 m. According to the mollusc-content, the conclusion must be made that this unit represents the deepest part of the Eemian lagoon; the interval from 51.23 to 52.27 contains the purest assemblage. Here two species indicative of the warm Eemian waters, Abra nitida and Hinia pygmea, are missing.

Heavy minerals Epidote and hornblende.

Geochemistry Decrease of Corg and S contents in this unit suggests a decreasing primary production.
CaO-contents decrease again.

Grain size The silt- and clay-sized fractions are about equal at the base. The silt fraction increases higher up (together with the very fine sand fraction) at the expense of the clay fraction.

11 Homogeneous clay (45.45-48.35)

Lithology and sedimentology Green firm clay with many marine shells
Pollen (E5) Carpinus increases, Alnus important, Taxus and Quercus decrease
Diatoms The samples in this unit are rich in diatoms. The presence of Cymatosira belgica, Paralia sulcata and several Rhaphoneis-species shows open marine tidal conditions, similar to depositional environments along this part of the Dutch coast during the Holocene.
Dinoflagellates See unit 9
Foraminifers Highest values (>90%) for the Elphidium excavatum-group. Interpreted as the deepest lagoon-facies, found in the Eemian sequence.
Ostracods First (sparse) occurrence of marine ostracods. At 46.03 valves of Loxoconcha rhomboidea (Fischer) are present. This species, found in all other ostracod-containing samples as well, lives on plants.
Molluscs In this poor fauna C. gibba and H. virea remain the more important species. In the samples many Zostera-leaves are found. The depth of the lagoon is decreasing a little.
Heavy minerals Hornblende and epidote.
Geochemistry The trend upward of increasing C\textsubscript{44} and S levels suggests increased primary production.
Grain size The silt-sized fraction shows percentages about 20% higher than the clay-sized fraction. Values for sand, mainly in the fraction very fine sand, remain below 14%.
Varia Fish remains and ophiuroid skeletal elements.

12 Laminated clay (38.00-45.45)

Lithology and sedimentology Green firm clay with many marine shells, lamination seems to be caused more by the colour than by the texture.
Pollen Two local pollen zones:
38.00-42.70 (E5) Carpinus optimum
43.45-45.45 (E5) Carpinus increases, Alnus important, Taxus and Quercus decrease
Diatoms As in unit 11; Assemblage resembles the Holocene open marine conditions with tides.
Dinoflagellates See unit 9.
Foraminifers Elphidium excavatum-group remains high. However, from 41 m upward an increase of Buccella frigida and species of unit 13 indicates a drastic environmental change. Interpreted as deep lagoon, from 41 m transition to tidal lagoon. In the top of this assemblage (even up to 37 m) Elphidium translucens, a Lusitanian species, reaches very high percentages.
Ostracods A poor fauna with L. rhomboidea (Fischer) and Pcalmoconcha guttata (Norman). This last species is indicative of low oxygen conditions.
Molluscs Corbula gibba remains the most important species. Species living on Zostera (Turboella radiata balkei, Musculus sp., Haminea navicula and, from 40 m onwards, Bittium reticulatum) are present as well. Ostrea edulis shows the presence of clear and calm water. The assemblage shows that the lagoon is less than 10 m deep. Probably in or at the bottom occasional oxygen-deficiency occurred.
Heavy minerals Hornblende and epidote. In one sample, at 39.55 m, an assemblage with 53% garnet is found. Obviously (well rounded) sand was dumped in the basin, either by the wind or rafted in plantmaterial.
Geochemistry C\textsubscript{44} and S contents reach a maximum at 43 meter and remain constant higher in the unit. Apparently a peak in primary production has been reached. The high Al\textsubscript{2}O\textsubscript{3} contents correlate with the high clay content.
Grain size Highest percentages (47-56%) of clay-sized material of the Eemian sequence, lowest percentage sand-sized material.

Variation In the laminated sediment macroscopically no bioturbation is visible.

13 Clay, with an increasing sand-content upward (32.65-38.00)

Lithology and sedimentology Green clay, with thin sand layers increasing in thickness towards the top, few marine shells and shell-remains.

Pollen (E5) Carpinus optimum

Diatoms As in unit 11; Assemblage resembles the Holocene open marine conditions with tides.

Dinoflagellates Increase of Operculodinium centrocarpum seems to indicate more open marine conditions.

Foraminifers Diverse assemblages characterized by a high proportion of shallow lagoonal species, such as Ammonia parkinsoniana, Nonion depressulum, N. germanicum and the occurrence of open marine species, e.g. Trifarina angulosa. Similar to modern Wadden Sea assemblages and interpreted as tidal lagoon facies, from below MLW.

Ostracods Two subzones; below 35.10 m species indicative of a marine environment, in which plants serve as a substratum. At the top complemented by species indicating a habitat with more sand and with brackish-water tolerant species, indicating a nearby fresh-water source. The presence of Aurila convexus (Baird) and Tenedocythere sp. above 35.10 m are the lusitani, possibly even mediterranean elements of this fauna.

Molluscs An increase of littoral species as Peringia ulvae shows the shallowing of the lagoon. Many species living on Zostera, especially Bittium reticulatum, are present. In the upper 2.75 m. no molluscs are found.

Heavy minerals Hornblende and epidote.

Geochemistry The upward increasing sand contents are reflected in a considerable drop in Al₂O₃ percentages. Also C₄₄ and S contents drop, reflecting decreased primary production. The bottom waters remain reduced however. CaO contents show a considerable drop as well.

Grain size Sand-sized fraction increases from 16 to 65%, clay-sized fraction decreases from 36 to 12%.

Variation Upper interval (32.65-35.50 m) is rich in spines of Echinocardium cordatum.

14 Shells (32.00-32.65)

Lithology and sedimentology Grey very sandy conglomerate of marine shells, with peat-lumps, admixture of clay and coarse sand.

Pollen Chenopodiaceae-optimum in the Carpinus zone (E5).

Diatoms As in unit 11; open marine conditions with tides. At 32.57 m the occurrence of Nitzschia navicularis and Diploneis interrupta indicates the regional presence of higher mudflats and saltmarshes.

Dinoflagellates Very poor in dinoflagellates.

Foraminifers Poor assemblage of shallow lagoonal species, among which Ammonia predominates. Probably a relic fauna, recording deposition of tidal sediments.

Molluscs These faunas are clearly different from those of the underlying units. Many littoral species, as Peringia ulvae, Cerastoderma edule, Mytilus edulis, Littorina saxatilis and L. littorea, are present. Conservation is poorer than before. The classical warm Eemian-fauna is well represented with Bittium reticulatum, Modiolus adriaticus, Gastrana fragilis, Hinia reticulata, Venerupia aurea senescent, Turboella radiata balki, Lucinella divaricata etc. Influence of fresh water influxes is found in the presence of some land- and fresh water-molluscs.

15 Sand with shells (28.10-32.00)

Lithology and sedimentology Greenish brown fine and medium sands (180 to 400 µm) with marine
shells, peat-lumps at the base of the unit. Sedimentary structures as high- and low-angle cross-lamination, herringbone structures and wave ripples were found in the lacquerpeels.

Pollens: Probably Picea-zone (E6)

Molluscs: As in unit 14.

Heavy minerals: Apart from a high hornblende content an increase of the Rhine-minerals alterite and augite.

Grain size: This unit contains the coarsest sediments (sand with a median of 190 increasing upward to 425 μm) of the Eemian sequence; 95 to 99% of the sediment belongs to the sand-sized fraction, of which about 20-25% belongs to the coarse and very coarse sand fractions. At the top of the unit the Ca-content drops to 1.4%, the lowest of all Eemian sediments.

1.3.3 Weichselian

16 Sand (20.45-28.10)
Lithology and sedimentology: Greyish and greenish brown fine and medium sand (170 to 340 μm), locally rich in mica, thin clay-layers at the top, few reworked shell-remains at the base. High- and low-angle cross-lamination.
Pollens: In the clay (24.60 -24.95) Hippophaë and Juniperus, well known as pioneers in an open landscape, most probably under cold climatic conditions (pollenzone EW).
Heavy minerals: Alterite and augite decrease, but remain present in addition to hornblende.
Geochemistry: SiO₂ high, low S, C₄v, Al₂O₃ and related elements.
Grain size: Most of the deposits contain less than 5% silt- and clay-sized particles. A clay-layer with high silt-content at 24.75 m. Sandmedians range from 150 to 300 μm below the clay to 100 to 180 μm above it.

17 Fluvio-periglacial sand (17.70-20.45)
Lithology and sedimentology: Greenish brown loam, very fine and fine sand (80 to 230 μm), rich in mica, few reworked marine shells.
Pollens: Pollenzone PW
Heavy minerals: Epidote, garnet and alterite.
Geochemistry: SiO₂ and Na₂O high.
Grain size: The silt-content is about 70%, the sand-content 20%.

18 Gytta (17.45-17.70)
Lithology and sedimentology: Brown gyttja with few micas.
Pollens: Pollenzone PW
Geochemistry: SiO₂, As and Na₂O high, C low.
Grain size: Similar to that of unit 17.

19 Fluvio-periglacial and eolian sand (13.85-17.45)
Lithology and sedimentology: Brownish to yellowish grey fine sand (175 μm) with few silt-layers, at the top with traces of roots.
Heavy minerals: Hornblende and epidote with an increasing amount of garnet. The 31% of garnet, present at 15 m, is a clear indication of eolian influence.
Grain size: For 95 to 99% sand, especially belonging to the fine sand fraction.
1.3.4 Holocene

20 Clay with shells (13.45-13.85)
Lithology and sedimentology X-ray image shows shells, partly bivalved (Cerastoderma?), in a clayey matrix.

21 Landfill (0-13.45)
Lithology Sand with pieces of brick and large woodremains. Until 100 years ago the IJ was more than 10 meter deep and has been filled in order to construct harbourworks.

1.4 Environmental interpretation

The interpretation, presented here, only deals with the units found in the borehole Amsterdam-Terminal. The incorporation into the three-dimensional frame of the glacial basin of Amsterdam will be presented in the lecture of de Gans et al.

The availability of data from many disciplines was essential in the reconstruction of the changes in the palae-environment. From the descriptions above it can be learnt that the conclusions of the various disciplines do not always point in the same direction. Discussions on variability within environments and on reworking and transport have been intensive to reach a balanced reconstruction. As the Amsterdam Basin had a rather high depth gradient, reworking of material over short distances can easily lead to a wrong interpretation. A provisional reconstruction of the water depth in the basin throughout the Eemian puts constraints on the results of other disciplines.

Saalian

In the Saalian the Scandinavian land-ice had an extension which reached 10 km south of the location of borehole Amsterdam-Terminal. At Amsterdam the ice-masses excavated a basin of about 80 m. deep by pushing the pre-glacial deposits into ridges, now surrounding the basin. Unit 1 represents the sediment, formed at the base of the glacier; a sandy till. After the melting of the ice-sheet a non-stratified lake remained in which varved clays (unit 2) were formed. A clear grading of each varve-layer is macroscopically visible. The geochemical composition of units 1 and 2 shows similar patterns, indicating the same sediment-source. A second sequence of varved clays (unit 3) shows a different content. Very high Corg and CaO values indicate extremely high biological activity. The organisms, responsible for this, have not been identified yet. The high S-contents indicate reduced conditions; a stratified lake with stagnating bottom waters. The presence of a thermocline suggests that melting land ice is no longer present in the basin.

During the last stage of the Saalian a further infilling of the lake takes place. The laminated clay (unit 4), the thickest sediment of the Saalian basinfill, is probably of local origin, as indicated by the high vermiculite levels in the upper part of this unit. In the lower part Rhine influence may be present. At first appearance in the CPT-diagram the sediment does not look like a clay, but more like a loam.

Grain-size characteristics and geochemical analyses show that two-thirds of the deposit consists of clay-sized particles with clay-mineral composition. Possibly the presence of gas-filled voids, of iron-carbonates or the low water-content have changed the aspect of the clay considerably. Moreover the grain-size analyses show relatively high quantities of poorly sorted fine, medium and coarse sand (similarly present in units 2 and 3), which most probably originates from ice-rafting of sandy material from the lakeshore into the deeper parts of the basin.

Only in the very uppermost part of this unit are pollen and diatoms present, which are not reworked. In the upper 2.00 m an Artemisia-dominated pollen assemblage (pollenzone LS) is found, the first indication of vegetation in the still cold treeless environment. A rich diatom-flora in the upper half meter of this unit shows the presence of shallow pools, in which Navicula jaerntefeltii thrived. Lastly
the area receives an influx of poorly sorted sand (unit 5), possibly transported by slope-processes. Most probably at this level a major break in the sedimentation is present. It is not clear whether or not the lake in the basin had fully dried out. However, the Eemian deposits could only be deposited after a rise in the local ground- and surface-watertable.

**Eemian**

The Eemian starts with the formation of biogeneous deposits; the influx of mainly clay-sized clastic sediment was so small that finely layered very calcareous diatomite (unit 6) could be formed. The formation lasted from pollenzone E1 through E2 and far into zone E3. During this period the initial *Betula* forest develops through a phase with *Pinus* and *Ulmus* into the optimum *Quercus* forest, in which *Hedera*, one of the Eemian indicator species, is already present. In this period the Amsterdam basin was not directly linked to a major river or the sea. The main influence of the outside world was felt by the rise of the regional watertable, causing a rise of the lake-level. As shown by the presence of *Aulacoseira italic* the water had a rather low nutrient level. The overlying thin layer of light-coloured diatomite contains sand (unit 7). In this sediment the presence of many diatoms of *Fragilaria* and of the algae *Pediastrum* points to a higher nutrient level in the fresh-water lake. Unit 8 consists of a dark-coloured sediment with many diatoms. This deposit has been studied in detail by Harting (1852), who paid special attention to the diatom flora. Therefore, the term Harting Layer is used for this unit. From the base of the unit upward traces of marine organisms are present; dinoflagellates, foraminifers, molluscs and diatoms. The impression is that salt water invades the basin and intrudes under a fresh-water body, which can persist for some time. Many of the marine organisms are allochthonous. The pollen in this unit don't show evidence of marine influence yet. The marine ingress must be placed in the very last part of the E3-pollenzone.

In contrast with the Harting Layer, which contains very little clastic sediment, in the overlying laminated clay (unit 9) high quantities of silt and clay are found. It is dated in pollenzone E4a with the *Corylus*-optimum and the first part of E4b, the *Taxus*-zone. *Ilex*, a second Eemian indicator element, is first encountered at 56.35 m. Initially the sedimentary environment resembles the previous one. Higher up indications are present of an increase in depth and salinity of the lagoon and molluscs suggest that a vegetation, most probably *Zostera*, was growing on the bottom. Reconstruction of the water depth indicates that the basin remained 20 m deep. The undisturbed lamination of the sediment shows that virtually no bottom dwellers were living here. The high quantities of S and the presence of structureless organic material indicate low oxygen conditions, especially in the lower part. In the upper part of the unit the conditions at the bottom improve so much, that bivalved *Corbula* can survive. Temperature indications, derived from diatoms and forams, suggest warm summers and relatively cold winters in this period.

The very firm homogeneous crumbly clay (unit 10) is the next lithogenetical unit. It is formed for the main part during pollenzone E4b and in the transition to E5, the *Carpinus*-zone. The signals derived from the organisms in this zone show two aspects. Firstly an increase of the marine influence, especially the introduction of tidal action, is indicated by the dinoflagellates and by the occurrence of the diatom *Cymatosira belgica*. Secondly the depth of the basin remained more than 10 m. as can be concluded from the foraminifers and the presence of *Hyala vitrea*. This corroborates the reconstructed water depth for this period. Not well understood is the crumbly texture of the sediment: possibly diagenetic processes caused this. Dissolution of the fine diatom-frustules is a clue that could help in solving this question. The change in clay-mineralogy supports the conclusion that the more local restricted environment changes into a system more influenced by the open sea.

The overlying homogeneous clay (unit 11) is formed during pollenzone E5 as well. The basin is at its deepest according to the foraminifers, but getting a little shallower (less than 10 m) according to the molluscs. At the bottom low oxygen-conditions are present again. Unit 12, a laminated clay, contains the Eemian sediment with the highest content of clay-sized particles. During pollenzone E5, containing the *Carpinus*-optimum, these very quiet sedimentary conditions suggest a dense stand of
Zostera-vegetation. The basin will have been not less than 10 m deep with occasional oxygen-deficiency at the bottom.

Unit 13, a clay in which an increasing sand-content is found, is formed during pollenzone E5, during the Carpinus-optimum, as well. In general a change is found towards more open marine circumstances; a tidal lagoon, initially with plants but later with more energetic sedimentation conditions and in the upper part even with influxes of fresh water, resulting in a more brackish environment.

At this point it is important to note that the sedimentary record in borehole Amsterdam-Terminal shows no obvious breaks in the interval between 35.00 and 63.50 m. From the following unit onward this continuity can no longer be substantiated.

The shell-conglomerate (unit 14) is probably the last deposit formed during the E5-pollenzone. The sedimentary setting poses the difficulty of separating allochthonous and autochthonous elements. Littoral and brackish elements most probably reflect the actual environment, in which indications are found for the regional presence of intertidal mudflats and supratidal saltmarshes. Diatoms as Nitschia navicularis and Diploneis interrupta and pollen of Chenopodiaceae are good indicators for this environment. Notably the classical warm (Lusitanian) Eemian mollusc-fauna is also well represented in this unit.

The shell-containing sands of unit 15 form the upper part of the Eemian sequence. As the grain-size data show this unit is formed in very energetic conditions. It is a shallow marine basin, which is provisionally dated in the E6-pollenzone. The low CaO-values toward the top of the unit are interpreted to be secondary; here decalcification has reduced the calcium-content.

**Weichselian and Holocene**

The Weichselian periglacial deposits are mostly water-laid deposits; to the top the eolian influence increases. Pollenanalysis shows Early Weichselian from 24.60 to 24.95 m and Pleniglacial from 17.45 to 19.70 m. Indications of marine deposition are absent.

The core in which the base of the Holocene is present has not been opened yet. From an X-ray image the presence of bivalved molluscs is clear. Probably erosion of the IJ has removed part of the Weichselian sequence.
1.5 References


Wolf, H. de, & P. Cleveringa (1994), Eemian diatom floras in the Amsterdam glacial basin In; D. Marina & M. Montresor Proc.. 13th International Diatom Symposium, Biopress Ltd., Bristol, p. 489-505.


Figure 1.4 Lithological and sedimentological column of borehole Amsterdam-Terminal and grain size-diagram.
Figure 1.5 Pollen-diagram and zonation of borehole Amsterdam-Terminal.
Figure 1.7
Dunflagadian diagram of borehole Amsterdam-Ferriera.
Figure 1.8  Foraminifera-diagram of borehole Amsterdam-Terminal.
Figure 1.9 Mollusc-diagram of borehole Amsterdam-Terminal.

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Figure 1.11  Selected results of the geochemical study of borehole Amsterdam-Terminal.
Figure 1.12  Inclination and intensity of the characteristic remanent magnetisation, of borehole Amsterdam-Terminal.

EEMIAN project

inclinations & intensities

depth in m

inclination

intensity in A/m
2 The Rocourt Soil: a pedo-stratigraphic marker for the Last Interglacial

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F. Gullentops (1954) defined the Rocourt Soil at the Gritten sand pit, located NW of Liège along the Meuse-Geer interfluve on the eastern edge of the Hesbaye plateau. According to the author, it consisted of a thick red brown illuvial (Bt) horizon overlain by a whitish eluvial (E) horizon. The soil developed during the Last Interglacial under slightly warmer conditions than the present-day climate. A humiferous horizon present between the Rocourt Soil and the upper loess cover was ascribed to a more continental episode heralding the Last Glaciation. The humiferous horizon further contained volcanic ash characterized by the presence of enstatite and later defined as the Rocourt Tephra (Juvigné 1978). Up to today this tephra functions as a tephrostratigraphic marker for the Rocourt Soil in Belgium.

During the sixties and seventies the Rocourt Soil was commonly used as a pedostratigraphic marker for the Last Interglacial in Belgium (Paep and Vanhoorne, 1967) and surrounding countries (Somme et al., 1980). In 1994 a new project was started to reconstruct the pedo-sedimentary and climatic signal, using the soil characteristics of these soils (Haesaerts et al. 1998). New loess sections in Belgium, such as Kesselt, Remicourt and Fexhe Le-Haut-Clocher, were examined. They provided new and valuable data, which prove to be critical in the understanding of the Last Interglacial and Early Glacial in Belgium and abroad.

2.1 The Rocourt Soil and Early Glacial deposits in Kesselt

A recent extension of the Nelissen brickyard in Kesselt allowed a revision of the stratotype at this key-site (Juvigné et al., 1996), since an interglacial soil was observed in between the so-called Brabantian and Hesbayen Loesses (figure 1). Preserved in a shallow depression, filled with colluvial and eolian sediments, this soil occurs as a thick reddish brown horizon (LBA = Limon brun argileux) with a light grey silty layer on top (LGC = Limon gris clair). It is overlain by a humiferous horizon (LH = Limon humifère). Since this humiferous horizon contains high amounts of reworked ash of the early Weichselian Rocourt Tephra it allows the correlation of the interglacial soil (LBA + LGC) with the classical Rocourt Soil.

Considering the position of the Rocourt Soil in the 1995-section in Kesselt, the so-called Nassbödenloess, formerly ascribed to the Hesbayen (Lower Weichselian) by F. Gullentops (1954), clearly belongs to the Upper Saalian (Juvigné et al. 1996). This reinterpretation is also strengthened by the TL-stratigraphy presented by Balescu (1988). The 1995-section in Kesselt further allowed a reevaluation of the chronostratigraphy of the Kesselt Soil, considered by Gullentops (1954) as a major Weichselian interstadial, since this soil undoubtedly corresponds with the decalcified zone of the Rocourt Soil (figure 2).
2.2 Pedo-stratigraphic characteristics

The decalcified zone of the Rocourt Soil

This decalcified zone can be ascribed to a B3tg-horizon of the interglacial profile. It is marked by textural banding (10YR5/6) in brownish yellow loamy sediment (10YR6/6), crossing the former stratification. The platy pedality of this horizon gradually thickens. The horizon is underlain by a sharp calcification boundary.

The illuviated horizons of the Rocourt Soil (LBA)

Based upon the soil characteristics this unit can be subdivided in a Bt- horizon and an overlying Bth-horizon.

The yellowish brown (10YR5/6) Bt-horizon has a coarse platy (up to 10 mm) pedality, coated by organo-mineral substances (humiferous clay coatings). Reddish brown clay coatings (7,5YR5/4) are present on the pores as well as within dessication cracks which start at the upper boundary of this horizon. These coatings (grey under oblique incident light) occur in situ in the voids and may partially be fragmented or coated by skeleton grains within these voids. The boundary between the Bt- and Bth-horizon is marked by a sudden decrease in thickness of the platy peds.

The remarkable yellowish brown (10YR5/6) B2th-horizon has an uncoated coarse platy (up to 6 mm) pedality. The horizon is further characterized by pupal chambers (up to 15 mm Ø). Grey (oblique incident light) clay coatings are either in situ along the large pores or fragmented in the matrix. Dark organo-mineral substances (humiferous clay) always occur in situ. Skeleton grains are associated with freeze-thaw features or fill small dessication cracks, which start from the overlying E-horizon (LGC).

The light grey horizon of the Rocourt Soil (LGC)

The so-called E-horizon of the Rocourt Soil is very pale brown loam (10YR7/3); it shows a platy pedality. Skeleton grains and rounded (soil-) fragments (10YR5/3) form a discrete banding. Fragmented clay coatings of various origin occur in the matrix.

The humiferous loam above the Rocourt Soil (LH)

LH corresponds with the humiferous horizons, which contain the Rocourt Tephra.

The lower part of LH is brown (10YR5/3) and has a clear platy pedality generally covered by skeleton grains. The horizon is characterized by abundant biogalleries, which are filled by humiferous and light grey loam.

The upper part of LH is a homogeneous dark greyish brown loam (10YR4/2); its pedality is very faint platy. The top, locally marked by prominent oxido-reduction features, is overlain by a yellowish brown and finely stratified sediment (LO = Limon Ocre), which contains abundant capped soil fragments.
2.3 Pedo-sedimentary evolution

Combining the macro-, meso- and micromorphological observations it was possible to unravel 11 pedo-sedimentary phases (table 1). The odd figures of this evolution (phase 1, 3,...) are related to erosion, cryogenic and sedimentation processes, while the even figures indicate periods with surface stability and pedogenesis.

The Rocourt Soil in Kesselt developed on Saalian loess (phase 1) and embraces the phases 2 up to 7 pro parte (Figure 3). These phases are ascribed to three major soil forming processes.

Soil I (phase 2) and Soil II (phase 4) are characterized by two periods of clay illuviations and resemble Luvisols. Clay illuviation belonging to Soil I occurs in situ or partially fragmented in the voids of the Bt-horizon. These clay coatings are completely fragmented in the overlying Bth-horizon. Clay illuviation of Soil II on the other hand occurs in situ in the Bth-horizon and the large dessication cracks.

Soil III (phase 6) is attested by common pupal chambers and translocation of organo-mineral substances, which induce the main characteristics of the Bth-horizon. Soil III resembles a Greyzem.

The discrete banding of the E-horizon (LGC) indicates a partial reworking of the upper part of Soil III by solifluxion, while the accumulation of skeleton grains is the result of percolating melt water.

The humiferous horizon (LH) which contains the Rocourt Tephra, is represented by two soil forming processes respectively related to a Chernozem (phase 8) and a sub-arctic soil (phase 10); they were separated by a period of frostcreep and eolian sedimentation. The ochre loam (LO) overlying the humiferous horizon was deposited by gelification (phase 11).

2.4 Chronostratigraphic background

The Last Interglacial and Early Glacial sequence in Kesselt confirms the reproducibility of the pedo-stratigraphical record of the Rocourt Soil in the Hesbaye (Haesaerts et al. 1998). Indeed, the macro-, meso- and micromorphological data gathered here allowed a match of the Rocourt Soil with three major soil forming processes (phase 2, phase 4 and phase 6) which were also recorded in Rocourt, Fexhe Le-Haut-Clocher and Remicourt, as well as in Harmignies in the Haine Basin (Haesaerts et al. 1998). The presence of the Rocourt Tephra in the humiferous horizon confirms this correlation (Juigné et al. 1996).

Considering the stratigraphic positioning of the Rocourt Soil at Remicourt and Harmignies (Haesaerts et al. 1998), these three soil forming processes could be ascribed respectively to the Eemian and to the first half of Saint Germain I (O-substages 5e and 5c, cf. G. Woi'dard, 1978). On the other hand, the overlying humiferous horizon containing the Rocourt Tephra could be linked with the second half of Saint Germain I.
2.5 References


Table 1  Pedo-sedimentary evolution of the Rocourt Soil and Early Glacial Deposits in Kesselt

<table>
<thead>
<tr>
<th>Unit / pedostratigraphy</th>
<th>Phase</th>
<th>Definition</th>
<th><em>O</em>-stages</th>
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<tr>
<td>Haasbüdenloess</td>
<td>1</td>
<td>Eolian deposition: Saalian Loess</td>
<td>6</td>
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<td>LBA (Rocourt Soil)</td>
<td>2</td>
<td><strong>Pedogenesis Soil I:</strong> Decalcification of the calcareous loess and pedogenesis of the Interglacial soil starts. The pedogenesis of this Interglacial soil is marked by the first generation of clay illuviation (= fragmented grey clay coatings in Bth-horizon and in situ grey clay coatings in the Bt-horizon).</td>
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<td>3</td>
<td><strong>Soil erosion / dessication cracks:</strong> Phase 3 is a period with deep seasonal freezing. Apart from the presence of ice lenses, dessication cracks penetrate Soil I. Clay coatings are further broken and churned within the remaining soil profile; this periglacial churning of former pedostructures is stronger near the surface (= Bt-horizon).</td>
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<td>4</td>
<td><strong>Pedogenesis Soil II:</strong> Soil II is marked by the second generation of clay illuviation (= in situ grey oblique incident light) clay coatings of the Bth-horizon). This clay also penetrates the dessication cracks. The common presence of fragmented clay coatings within the matrix belonging to phase 2 is in sharp contrast to the &quot;fresh&quot; clay coatings belonging to phase 4 along biogalleries.</td>
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<td>5</td>
<td><strong>Deep seasonal freezing:</strong> A new set of platy peds is well localised in the Bth-horizon. This pedality formed during a period of deep seasonal freezing.</td>
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<td>6</td>
<td><strong>Pedogenesis Soil III:</strong> During phase 6 starts a third generation of clay illuviation, characterized by organo-mineral substances. Organo-mineral substances (= humiferous clay coatings) are translocated and are found upon the platy peds in the Bt-horizon and along the voids in the Bth-horizon. The soil formation resembles a Greyzem.</td>
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<td>LGC (top of Rocourt Soil)</td>
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<td><strong>Solifluction / sedimentation:</strong> Several arguments assert that the so-called E-horizon in the upper part of the Rocourt Soil is no longer completely in situ. A subsequent process disrupted in cold climatic conditions the A1, E- and part of the Bth-horizon of Soil III.</td>
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<td>LH (humiferous horizon)</td>
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<td><strong>Pedogenesis Soil IV:</strong> The lower half of LH consists of a horizon characterized by a high biological activity. This lower half of LH is ascribed to a stable surface during humid continental conditions with a steppe or forest-steppe vegetation. The soil formation resembles a Chernozem-like soil.</td>
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<td>9</td>
<td><strong>Creep / sedimentation:</strong> The horizons of the Chernozem-like soil are characterized by a blady pedality, which are plastically deformed and rounded. The fabric therefore resembles a frost creep fabric (Van Vliet-Lanoe, 1985), which suggests a slight movement of Soil IV along the slope during cold climatic conditions. Sedimentation followed.</td>
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<td>10</td>
<td><strong>Pedogenesis Soil V:</strong> Locally the top of the LH is marked by a superficial gley. The pedofeatures are indicative for an arctic to sub-arctic humiferous soil. The oxidoreduction features suggest humid (seasonal) conditions.</td>
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<td>LO (ochre loam)</td>
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<td><strong>Strong erosion / gelification:</strong> The non calcareous layer, which covers LH, is micro-morphologically characterized by fine capping of rounded soil fragments. This fabric corresponds to gelification. Such a pedo-sediment results from numerous freeze-thaw cycles and rapid displacement of the sediment due to the steep slope or high watersaturation.</td>
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Figure 2.1  Revision of the Kesselt stratotype (after: Juvigné et al. 1996).
Figure 2.2  Positioning of the 1995 section in Kesselt and its relation with the former sections.
Figure 2.3  Pedostratigraphic reconstruction of the Rocourt Soil in the type locality (Rocourt) and Kesselt.

Graphic symbols:
1  illuviated horizon
2  textural banding
3  bleached patches with ferruginous rims:
    bleached sediment
5  platy pedality
6  lower limit of the platy pedality (not given)
7  whitish silt
8  dark brown humiferous
9  light brown humiferous
10  biogalleries and krotovina

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The Eemian
Excursion guide 1998
Local sequences, global perspectives
3 Preliminary report of an exceptional palaeosol catena of the last interglacial in the loess area of Belgian Limburg near Veldwezelt

Gullentops¹, F., A.J. Groenendijk¹, E.P.M. Meijs¹, H.J. Mücher², P.M. Vermeersch¹ and J.P. de Warrimont¹.


After the discovery of some Middle Palaeolithic artefacts, detailed stratigraphical research was started in 1996 on the sequences of the brickyard pit, which exploits the south-east facing side of the valley of the Hezerwater (tributary of the river Maas). The pit is situated about one km south-east of Veldwezelt (Belgium), latitude 50° 51' 15" N and longitude 5° 38' 45" E, Belgian map 34/1-2, scale 1:25000.

In the western part of the pit remnants of Maasterrace sediments have been preserved, including four metres of gravel and one meter of overlying sand and silt loam. The Hezerwater valley was cut into these Maasterrace deposits. The valley scarp is buried by a first loess (OL; see figure 3.1). The Maas deposits and the loess have been affected by an important soil catena, consisting of a luvisol (Rocourt palaeosol) and humic layers, which contain the characteristic volcanic Enstatite tephra (Rocourt tephra).¹ The whole sequence corresponds with the Rocourt soil pedocomplex of the last interglacial. To the east the OL loess is merging into fluviol Hezerwater deposits, containing laminated sand with thin silt loam laminae. These deposits show a fining upwards sequence and are found in the upper part of a massive sandy silt loam (see figure 3.2). Locally the Rocourt palaeosol is changing over a distance of twenty metres from an upland facies into a lowland palaeosol, syngenetically formed in slope deposits, filling an abandoned channel of the Hezerwater (see figure 3.2). The buried soil profile on the channel bank is especially interesting because of its alternating phases of sedimentation and soil formation. Three stages of soil formation could be distinguished. The upper- and lowermost palaeosol horizons (VBLB and VLB) contain Middle Palaeolithic artefacts and charcoal.

On the basis of the sedimentology, its (cryo)pedological analysis and palaeontological contents a preliminary climate curve is presented of the whole Veldwezelt-Hezerwater sequence (see figure 3.3). According to our interpretation the climate became drier at the end of the Saalian period and the sedimentation of air-blown loess was high: in the beginning with intercalations of sand, later sedimentation of loess was took place, with five periods of tundra soil formation (see figure 3.2). Because of the high sediment load the Hezerwater could not incise her channel bed at that moment. Instead the river deposited huge amounts of sand and silt loam on her gravel bed. In these deposits cryogenic phenomena are observed. At the beginning of the Eemian stage a little incision took place and the river moved to the east, leaving a gravel lag at the bottom of its abandoned channel. More upland continuous soil formation took place during the Eemian, while near the channel bank slope material filled the abandoned

¹ The mineralogical composition of the first loess (OL) is identical to that of the loess underlying the Rocourt palaeosol in the Nelissen brickyard pit in Kesselt (Meijs, in preparation).
channel. Here periods of more intensive soil formation alternated with periods of sedimentation of slope deposits. In general the soil formation could keep pace with the sedimentation.

The Weichselian Pleniglacial starts with intense erosion in cold and very snow-rich conditions, in which a flat valley bottom was eroded by the Hezerwater with different gravel layers. Near the west-bank of the Hezerwater some exceptional gelifluction and colluvial deposits have been preserved and SL(GBL; see figure 3.1 and 3.3).

With the onset of new Weichselian loess deposition (beginning at unit TSL; see figure 3) the valley was filled by asymmetrical progression with up to thirty metres of laterally juxtaposed sediments (progression from west to east; see figure 1). The lower part is deposited in a generally boreal and humid climate with numerous fluctuations from colder to wetter, but with almost continuous abundant biological activity of worms, molluscs and rodents. This Haspengouw loess is typical for the Middle Pleniglacial, but has never been seen in such detail. At its end permafrost conditions reveal the onset of the harsh Upper Pleniglacial (LL).

Then the dry polar climate brings about the typical Nagelbeek/Kesselt Horizon of wide stratigraphical value. It begins with an extreme deflation phase (PL), cutting through the earlier deposits.

Stratigraphically it is well situated just after the wide spread volcanic Eltville tephra and before the humic tundra palaeosol of Nagelbeek/Kesselt.

The following characteristic powdery Brabant loess can for the first time be divided in at least three cycles by the intensity of blow-in of coversands in this area near the border of the Belgian coversand area.

In the Holocene period the soil formation near the channel of the Hezerwater could not keep pace with sedimentation processes because of the high sedimentation of slope material due to the deforestation in Neolithic, Roman and Mediaeval times, resulting in four metres of colluvium.
Figure 3.1  Idealized W-E transect of the Hezerwater valley cover, showing various fluvial and loess derived deposits, alternating with soil formation and erosion. For abbreviations see figure 3.3.
Figure 3.2 NW-SE transect of the western part of the Hezerwater valley cover, showing various fluvial and loess derived deposits, alternating with soil formation and erosion. The original valley slope surface was about seven meters higher, and has been lowered by the brickyard factory. The items of the legend concern Eemian and Saalian deposits and palaeosol horizons. A Weichselian gully cutting the sediments in the middle part of this transect is not presented.
Figure 3.3  Idealized loess sequence of the Veldwezel-Hezerwater brickyard pit, showing its sedimentological, pedological and cryogenic characteristics and their climatic interpretation.

Veldwezel-Hezerwater

LEGEND:

- C  CARBONATE
- NC  NON-CARBONATE
- D  DECALIFIED
- H  RODENT DIGGING HOLES
- M  MOLLUSCES
- RT  ROCOURT TEPHRA
- ET  ELTVILLE TEPHRA
- CLIMATE-CURVE
- LOESS
- STRONGLY STRATIFIED LOESS
- COLLUVIATED LOESS
- GELIFLUCTED LOESS
- RECENT COLLUVIATED LOESS
- CREEP-LOESS
- LV-2-3
- SLEACHED HORIZON
- HUMIC HORIZON
- WEAK LV-SOL
- TUNDRA SOIL

GROENENDIJK, MEUS, & WARMONT, JULI 1998