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Fossil and recent soil formation in Late Pleistocene sand deposits in the eastern part of the Netherlands

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Summary

Along the Slinge Brook near Winterswijk, a profile was investigated morphologically which is assumed to consist of two aeolian deposits: Old Coversand I at the bottom and Old Coversand II at the top, between which a fluvioglacial deposit occurs, the Beuningen Complex. The profile, which now is well-drained, was poorly drained from the beginning of the Holocene up to some centuries ago.

The following soil forming processes were recognized micromorphologically: decarbonation, biological activity, clay illuviation, decomposition of illuviated clay and one or two cycles of gleying. It was concluded that: (1) during the deposition of the Beuningen Complex a hydromorphic cycle may have occurred in this profile; (2) between the beginning of the Bölling interstadial and the rise of the watertable at the beginning of the Holocene, biological activity and clay illuviation occurred and possibly some decarbonation; (3) between the beginning of the Holocene and recent times a hydromorphic cycle (possibly the second) took place; (4) finally in recent times biological activity and decarbonation occur.

Introduction

In Late Pleistocene sandy deposits in the Netherlands colour patterns have been observed in the field which obviously do not result from recent soil formation (van de Westeringh, 1971). Micromorphological studies in recent years revealed the nature of soil forming processes which have been active in such soils (van Oosten et al., 1974, Vink & Sevink, 1971). It was found very difficult, however, in well-drained soils to disentangle the results of fossile and recent soil formation. Although a relative chronology of the successive soil forming processes could be established, an absolute dating of these processes could only partly be presented up till now.

The present paper deals with a profile which had a high groundwater level for the better part of Holocene. Consequently fossil soil formation was conserved and holocene soil formation was limited. The data presented in this paper result from macromorphological and micromorphological investigations. For the presentation of the micromorphology the terminology of Brewer (1964) was used.

Observations

Soil site characteristics
The investigated profile is located in the 'Achterhoek' area, in the Eastern part of the Netherlands; topographical map of the Netherlands, scale 1: 25.000, sheet 41E, coordinates N 440.015-E 245.075. The profile is situated in a fresh escarpment of the Slinge Brook. It is developed in sandy Pleistocene deposits, which locally are 4-5 metres thick. The altitude is about 32 metres above mean sea level. At present the profile is well-drained, due to its position at the side of the deepened brook. Formerly the brook was very shallow and the area was poorly drained.

Macromorphology
The profile was subdivided into three zones:
1. deeper than 125 cm below the soil surface;
2. 70-125 cm;
3. 0-70 cm.

Zone 1 (+ 125 cm). Very fine sand, rich in calcium carbonate; 10 YR 6/6, dry; mainly undisturbed sedimentary stratification; locally some lime nodules; some gray spots (10 YR 8/0), larger than 2 cm in diameter, containing root remnants; few, very large, very faint iron-segregations along biogenic voids. Gradual transition to

Zone 2 (70-125 cm). Lower part (110-125 cm). Very fine sand containing some gravel, which is randomly distributed. 7.5 YR 5/6 (dry); nearly undisturbed sedimentary stratification parallel to the present soil surface. Locally containing calcium carbonate. Upper part (70-110 cm) Medium sand with gravel, 10 YR 8/2 (dry). Nearly undisturbed sedimentary stratification. Mainly cross-bedding. No calcium carbonate. Few clay balls; Zone 2 in some places contains few or no ferric mottles, in other places many, coarse prominent ferric mottles. Very diffuse transition to

Zone 3 (0-70 cm). Fine sand; 10 YR 8/4 (dry); mainly disturbed sedimentary stratification; few biopores and rootremnants; deeper than 30 cm: abundant, coarse, irregular, ferric and common, medium, irregular manganese mottles; between 50 and 60 cm, this zone almost entirely consists of very coarse, hard ferric manganese nodules; no calcium carbonate.

Micromorphology
The groundmass in the entire profile consist almost exclusively of skeleton grains. In zone 1, all of them are finer than 250 μm; in the lower part of zone 2, most of the skeleton grains are smaller than 250 μm but some grains up to 2000 μm and

larger occur. In the upper part of zone 2, a large amount of skeleton grains coarser than 250 μm (reaching up to more than 2000 μm) occur. In zone 3, all skeleton grains again are finer than 250 μm. They are, however, distinctly coarser than those in zone 1.

The skeleton grains in zone 1 and the lower part of zone 2, generally occur in a banded distribution pattern, the bands running parallel to the soil surface. In the upper part of zone 2, the skeleton grains generally occur in bands too, but the bands run under an angle of about 30° with the soil surface. The skeleton grains in zone 3 mainly occur in a random and clustered distribution pattern.

Among the skeleton grains in zone 1, many calcitic grains occur. A number of them are corroded, the corrosion decreasing in intensity with increasing depth. In the upper part, many of the calcitic skeleton grains are surrounded by a ferric cutan; the amount of these ferric cutans decrease with depth. The presence of this cutan does not depend on whether the grain is corroded or not. In the lower part of zone 2, identical ferric cutans occur along normal voids which originate from completely dissolved calcitic skeleton grains. In the upper part of zone 2 and in zone 3 calcitic skeleton grains were not observed; neither were ferric cutans observed which originally surrounded calcitic skeleton grains.

Nearly all non-calcitic skeleton grains in zone 1 and the lower part of zone 2 are enveloped by a very thin strongly birefringent cutan (primary cutan: de Coninck & Laruelle, 1964). In the upper part of zone 2, these primary cutans were seldomly found. In zone 3, the occurrence of primary cutans is like that in zone 1.

In the upper part of zone 2, fine textured sedimentary relicts up to 2000 μm and more were observed. They contain round sharply bounded ferric concentrations with sizes from 10-30 μm. These sedimentary relicts were not observed in zones 1 and 3.

In all three zones, the sedimentary stratification has been partly disturbed, the degree of disturbance decreasing with increasing depth. The number of biogenic voids decreases in the same direction.

Illuviation phenomena of fine clay were observed in zone 3 and the lower part of zone 2. They occur mostly as free grain and sometimes as channel cutans. The free grain cutans mainly occur in bands parallel to the soil surface. Five types of clay illuviation cutans were found: ferri-argillans, argillans, ferri-argillans rich in ferric compounds, 'grainy' ferri-argillans and 'grainy' argillans (for the latter two types see Brinkman et al., 1973).

In the lower part of zone 2, both ferri-argillans and normal void ferrans were observed. If they were found together the ferri-argillan covered the ferran. Apart from corrosion of calcium carbonate in zone 1, some secondary lime was noticed as free grain calcitans, locally grown together so that they fill a number of neighbouring simple packing voids.

In all three zones bleached parts alternate with parts enriched with ferric and/or manganese compounds. The ferric compounds occur as free grain ferrans in all three zones, in zone 3 locally being grown together to fill clusters of primary packing voids. The largest concentration of ferric compounds was found in zone 3. Manganese compounds were only observed in zone 3.

Interpretation

On basis of the macromorphological and micromorphological observations, the following can be stated about the geogenesis of this profile. The homogeneous size class distribution of the skeleton grains, the fact that the largest grains are smaller than 250 μm and the absence of sedimentary relicts, such as occur in the upper part of zone 2, point to an aeolian origin for the material of zones 1 and 3.

The heterogeneous size class distribution of the skeleton grains, the presence of gravel, coarse sedimentary relicts and cross-bedding in the upper part of zone 2, indicate that this sediment is water-laid. The grain size distribution in the lower part of zone 2 suggests admixture of material as occurs in the upper part of zone 2 to material as occurs in zone 1. The occurrence of normal void ferrans which originally coated relatively fine grained calcitic skeleton grains (which have been dissolved completely) in the lower part of zone 2 supports the above conclusion.

From the fact that the majority of the skeleton grains in the upper part of zone 2 is not enveloped by a primary cutan, it is concluded that this material already underwent a very intensive soil formation elsewhere. Such a soil formation only occurs after decalcification. Therefore the sediment of the upper part of zone 2 did not contain calcium carbonate when deposited on this spot. The observations do not allow for a conclusion about the lime content of the sediment of zone 3 at the moment of sedimentation.

The following soil forming processes can be deduced from the morphological observations. The presence of corroded calcitic skeleton grains in zone 1 (the intensity of corrosion decreasing with increasing depth), the presence of the normal void ferric cutans in the upper part of zone 1 and in the lower part of zone 2, point to a process of *decarbonation*. At least part of the dissolved calcium carbonate precipitated in the same profile at some greater depth as can be concluded from the presence of pedogenic lime. From the disturbance of the sedimentary stratification and the presence of biogenic voids, it was concluded that *biological activity* has been present in this soil. Its intensity decreased with increasing depth. From the presence of clay illuviation cutans the process of *illuviation of fine clay* was concluded to have been active.

Hydromorphic conditions have been present in this soil in at least one, but possibly two periods. If the ferrans which coat calcitic skeleton grains, are formed 'in situ', they result from a first hydromorphic cycle. The fact that the amount of ferrans decreased with depth support the hypothesis of their 'in situ' formation. The alternative would be a sedimentation of an eolian sand which contained calcitic skeleton grains coated by a ferran. Independent of whether the ferrans are formed 'in situ' or elsewhere, it is obvious that the clay illuviation is a younger process, since the normal void ferrans in the lower part of zone 2 (resulting from dissolution of calcitic skeleton grains) are covered by ferri-argillans.

A period of hydromorphy, possibly the second, occurred after the clay illuviation as is proved by the argillans and ferri-argillans enriched in ferric compounds, both occurring in zone 3. The argillans occur in parts where the groundmass is bleached, due to iron-segregation under reductive conditions. The iron-enriched ferri-argillans occur amidst clusters of free grain ferrans and mangans, observed in the field as coarse ferric and manganese mottles and hard nodules. The presence of 'grainy' ferri-argillans and 'grainy' argillans, point to *decomposition of clay* under periodically wet conditions (Brinkman et al., 1973).

Discussion

Comparison of the above observations with those of van der Hammen (1971), Wijmstra & Schreve-Brinkman (1971), and Wijmstra et al., (1971) lead us to the conclusion that our section represents a display of the Lutterzand member (zone 1: Older Coversand I; zone 2: Beuningen Complex; zone 3: Older Coversand II) which is formed in the Upper Pleniglacial of the Tubantien (Weichselian). The sediment would have been deposited (Wijmstra & Schreve-Brinkman, 1971) under cold and dry conditions, without or with little vegetation. The Older Coversand I and II would have a niveo-aeolian origin, the Beuningen Complex would have been transported by a more niveo-fluviatile system.

In the following, a tentative chronology of the soil forming processes will be presented against the background of the assumption that the investigated profile represents the Lutterzand member. Zone I (the Older Coversand I) would have been deposited as a calcareous niveo-aeolian sediment. During the deposition of this sediment little or no soil formation took place. At the beginning of the sedimentation period of the Beuningen Complex some superficial erosion might have taken place. Thus the occurrence of fine sand with few gravel (which originally included a number of calcitic skeleton grains at the basis of the Beuningen Complex, the lower part of zone 2) might be explained. The possibly first period in which hydromorphy occurred in this profile (formation of free grain ferrans on calcitic skeleton grains) occurred in this epoch, if at all.

The clay illuviation phenomena in zone 3 and the lower part of zone 2, have not been formed earlier than the biogenic voids along which they occur. The formation of biogenic voids, however, cannot be placed earlier than the Bölling interstadial. The formation of biogenic voids and of clay illuviation cutans may have proceeded in the Alleröd interstadial, but not much longer.

In fact at the change from the Pleistocene to the Holocene, the profile became too wet to allow biological activity, clay illuviation and decarbonation. Then possibly the second, hydromorphic cycle in the development of this profile started. It resulted from the general rise of the watertable as the climate became more humid. Seepage which occurred in the low area in the landscape where the profile is situated, gave rise to the large iron and manganese concentration as observed in zone 3. Moreover, the shallow groundwaterlevel drowned the lower part of the profile. During recent times, the groundwaterlevel was lowered artificially by man.

The dating of the decarbonation can not be made unambiguously. Zone 1 and the lower part of zone 2, originally contained calcium carbonate, and partly still do. The clay illuviation in the lower part of zone 2, stops at the level where the normal void ferrans begin, suggesting that the clay moving downwards was flocculated by the calcium carbonate, which only dissolved later. Decarbonation might have taken place after clay illuviation before the end of the Pleistocene or in recent times or both. If zone 3 (Old Coversand II) originally contained calcium carbonate, it must have been removed before the clay mobilization took place.

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