Lithostratigraphy and palaeoenvironment of the pleistocene deposits at Maastricht-Belvédère, southern Limburg, the Netherlands

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LITHOSTRATIGRAPHY AND PALAEOENVIRONMENT OF THE PLEISTOCENE DEPOSITS AT MAASTRICHT-BELVÉDÈRE, SOUTHERN LIMBURG, THE NETHERLANDS

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ABSTRACT

Firstly, a general description is given of the lithostratigraphical units of the Belvédère pit, located NW of Maastricht on the left bank of the river Maas, in the southern part of The Netherlands. The pit is situated on the edge of the Caberg terrace.

From top to bottom are exposed:

Unit 7: a silt loam above with Holocene soil formation (a Luvisol), representing a typical loess deposit of the Weichselian Pleniglacial.

Unit 6: a less well sorted silt loam (contains more sand and clay than Unit 7), which can be divided into 4 subunits (6.4-6.1). These are at the top a calcareous upper unit with the cryoturbated Nagelbeek Horizon (6.4), and at the bottom (6.1.) a dark humic layer, probably a truncated steppe soil. In between, fine laminated silt loams (6.3) and local pebble zones (6.2) occur.

Unit 5: 'Loams'. This unit consists of two subunits: a lower Unit 5.1.: a mixture of sand and silt loam, with remnants of soil formation in situ, and an upper Unit 5.2: a silt loam, only slightly mixed with sand, with a clear developed argillic horizon on top of it, comparable with that of the Eemian Rocourt palaeosol.

Unit 4 consists of grayish-white to light greenish sands, with intercalated pebble horizons, and is of fluvial origin. In this unit remnants of a palaeosol, e.g. a truncated Luvisol, are present.

Unit 3: heterogeneous, laminated terrace gravels deposited by a braided river system. Below the last mentioned Unit 3, Palaeocene Chalk occurs (Unit 1), with only locally in between Oligocene clayey sands (Unit 2).

Secondly, Unit 4 is discussed in more detail, using sedimentary characteristics and grain-size composition to reconstruct the palaeoenvironments during sedimentation of the subunits 4a to 4c. In the third part of this paper special attention is given to the reconstruction of the sedimentary environment of the 'Loams' of Unit 5, and the silt loams of Unit 6. Unit 5.2 shows in the pit, macroscopically, often a large resemblance with primary aeolian loess deposits, which could, however, not be confirmed by analytical data.

Finally, the cryoturbated zones and other frost phenomena of the Units 3, 5.1., 6 and 7 are described in more detail, and their palaeoclimatic significance discussed.

INTRODUCTION

The Belvédère pit is situated in the loess region of the southern Netherlands (province of Limburg), ca 1 km NW of the city of Maastricht, on the edge of the Caberg terrace on the left bank of the river Maas (Figure 1).

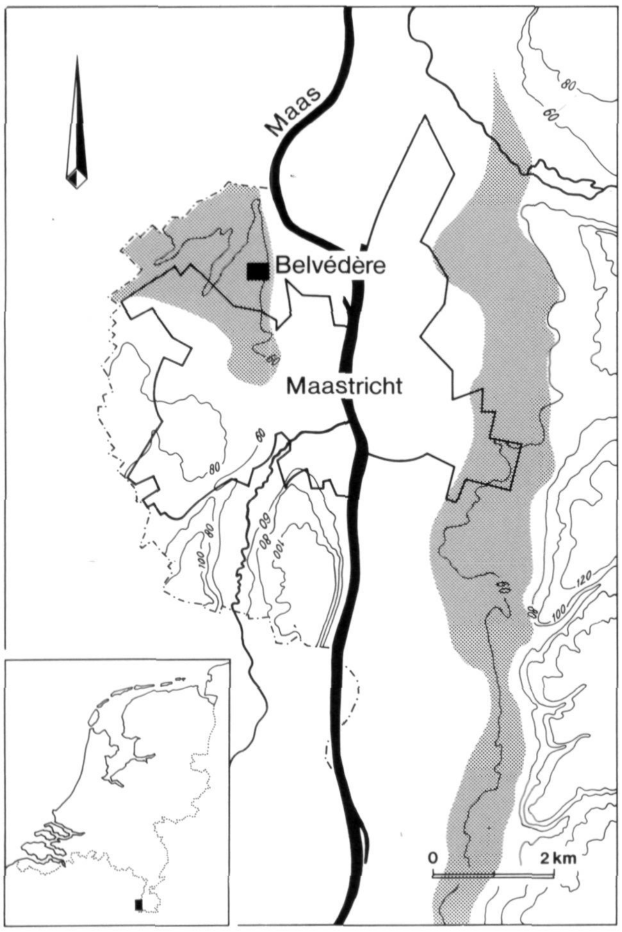

Fig. 1. Location of the Maastricht-Belvédère pit and in gray, distribution of the Caberg Middle Terrace sediments (after: Brueren 1945).

A characteristic loess deposit is exposed at the top of the pit immediately below which are present redeposited, mostly laminated, loess-derived materials.

In between the above mentioned deposits and the deeper occurring terrace sands and gravels the so-called 'Loams' are exposed. In the field those resemble the Saalian loess increments exposed at other pits in Southern Limburg and Belgium. A Rocourt palaeosol-like formation in the upper part of the 'Loams' contributes to this resemblance. As already stated characteristic loess deposits occur on top of the sequence. They have been used as reference for the discussion of the underlying 'Loams'; consequently the upper deposits (Unit 7) will be discussed first.

In the 19th and 20th century many mammal fossils were found in the pit sections, while on the surface of the pit important Neolithic finds and artifacts from the Iron Age and later periods were collected. The new archaeological project of the Institute of Prehistory of Leiden University required lithological and structural data from the pit, which could form a framework for investigations by archaeologists and their co-workers from other disciplines, such as palaeontology, soil science, etc.. For this reason, the various layers and palaeosol formations in the Belvédère pit were studied macroscopically, described and sampled for grain-size analysis, in order to establish a lithostratigraphical sequence of events and to reconstruct the palaeoenvironments of the lithological units and palaeosols during their formation.

THE GEOLOGICAL SEQUENCE

THE DEPOSITS ON TOP OF THE TERRACE GRAVELS

The uppermost Unit (7) is a massive, yellowish-brown silt loam with a carbonate content of ca. 15% and a thickness up to 6 m (fig. 2). The upper part is transformed by Holocene soil formation. According to the

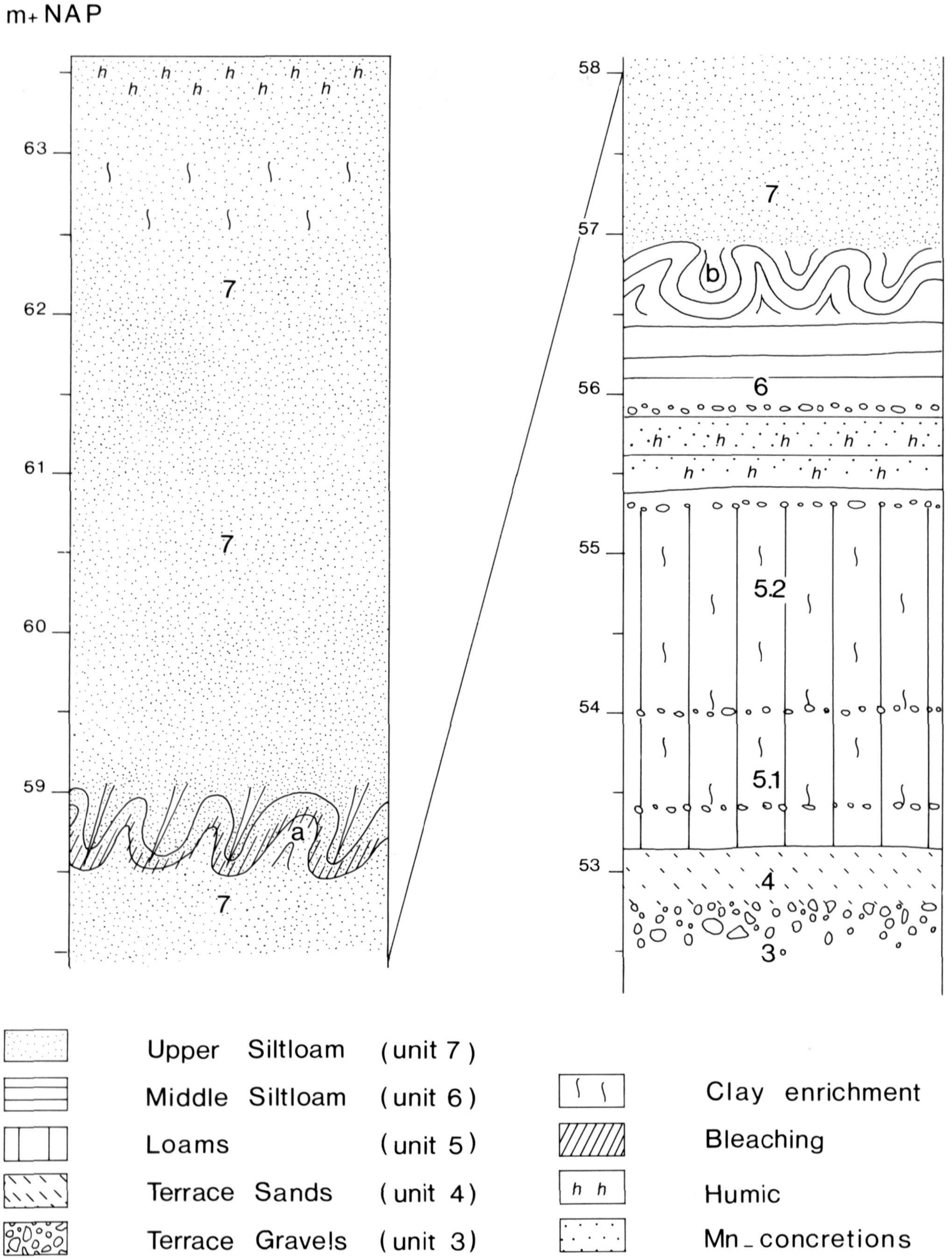

Fig. 2. General lithological sequence of the deposits on top of the terrace gravels in the Belvédère pit.

granulometric characteristics these sediments represent a typical loess (Mücher, 1973): low sand content, a modal value between 30 and 40 μm, a relatively good sorting and a high positive skewness (figs. 3-4-5, table 1). This unit corresponds with the Upper Silt Loam of Vreeken & Mücher (1981) and was deposited at the end of the *Weichselian Pleniglacial period* (Vreeken, 1984). At ca. 2 m above the base of the unit locally a bleached soil horizon occurs which has been involuted afterwards. This zone of involution ('a' in fig. 2) occurs over large distances with a thickness of ca. 30 cm. This period of non-deposition ended with the development of a polygonal network of narrow fissures. They are 5 mm wide at the top and 50 cm deep, while the diameter of the polygons is also ca. 50 cm.

The upper part of Unit 6 consists of calcareous, gray-yellow silt (6.4). This has also been disturbed by involutions 'b' with an amplitude of ca. 30 cm and limited at the top by an erosional surface. The underlying silt loams (6.3) contain no or only small amounts of carbonate. Unit 6.2 occurs only locally, and will be discussed below (section 4.2). The presence of a dark *humic layer in the basal part (6.1) suggests the presence* of a well-developed steppe soil. The sediments below the humic zone are slightly bleached. The boundary between 6.1. and 6.3. is sharp and is often accompanied by a pebble horizon. This points to an erosive phase. The steppe soil is generally heavily involuted ('c' see below). No pollen has been found in the humic zone. Units 6.1. and 6.3. show a fine lamination. In comparison with the overlying loess (7), Unit 6 is significantly more sandy and clayey and consequently less sorted. The skewness is less positive,

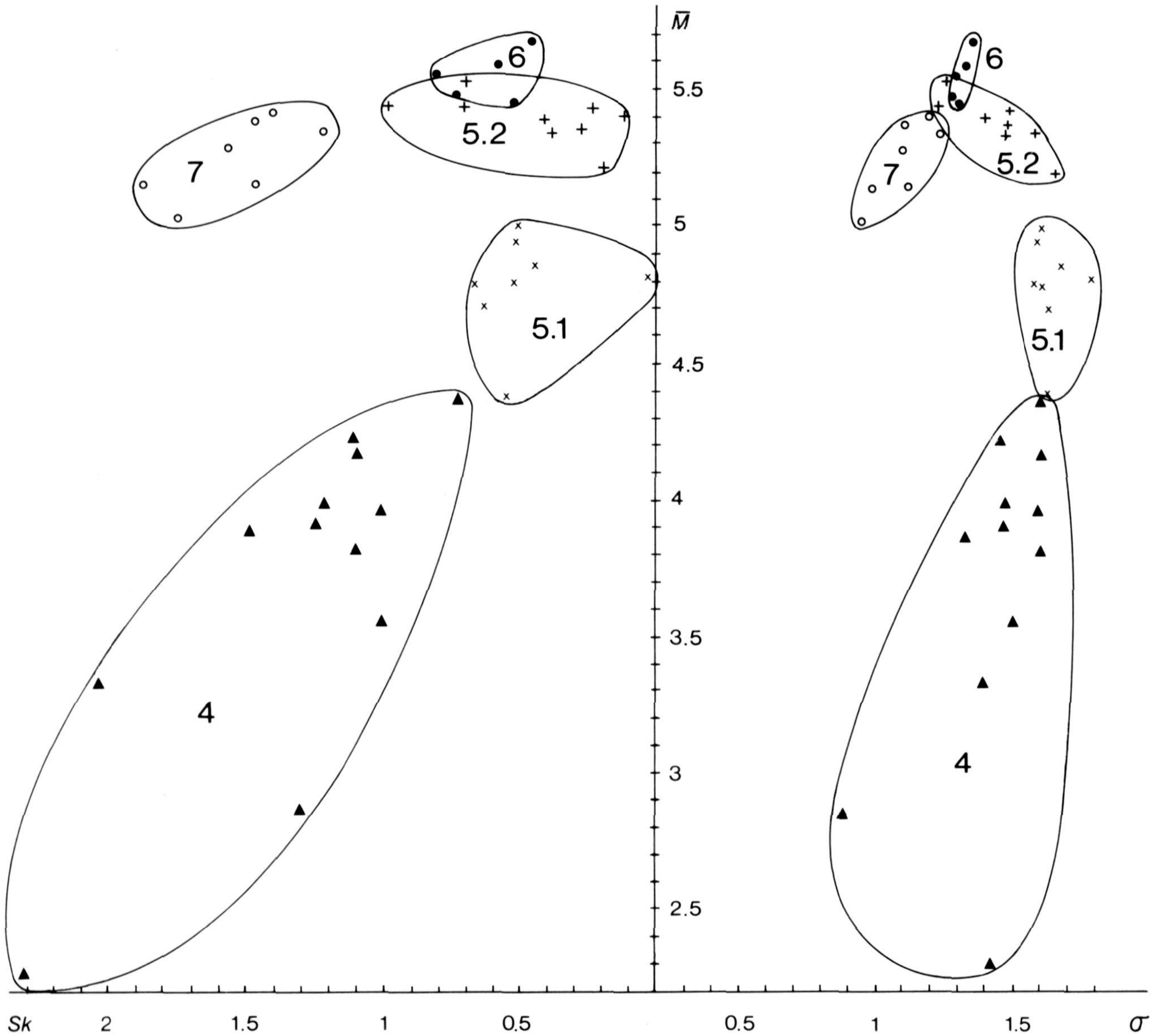

Fig. 3. Grain-size distributions of Units 4, 5.1, 5.2, 6 and 7 as characterized by their mean ($\bar{M}$), standard deviation (σ), and moment of skewness (Sk.).

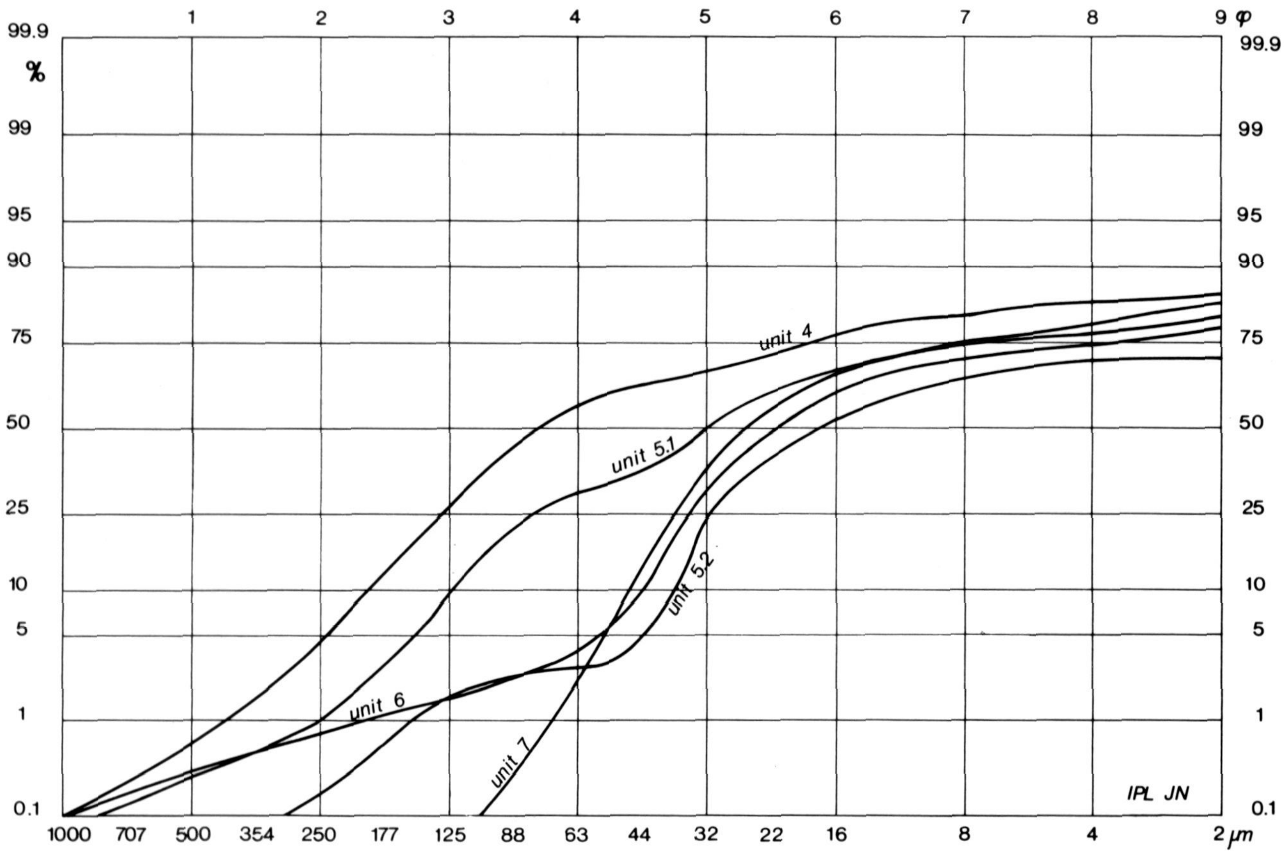

Fig. 4. Cumulative grain-size distribution of Units 4 to 7.

but the model value is the same (fig. 3, table 1). These characteristics could point to partial reworking of older loessic sediments. Lithostratigraphically Unit 6 may be correlated with the 'Middle' and 'Lower Silt Loam' in this region (Vreeken & Mücher, 1981) and the involuted top layer (6.4) with the Nagelbeek Horizon (Haesaerts et al., 1981), although the Eltville tuff layer (Meys et al., 1983) is absent here.

The underlying 'Loams' (Unit 5) form a heterogeneous deposit. Pebble horizons may occur in the lower part. Individual boulders may reach a diameter of a few dm. The mean grain size increases towards the base where thin sand lenses occur. The lamination is subhorizontal to gently undulating, while gullies occur only locally. In the lower part patches of contrasting hue and grain-size are traced by sharp boundaries. They represent reworked soil material. Unit 5 shows a characteristic bimodal grain-size distribution with peaks at 80-115 μm and 30-38 μm (figs. 4-5, table 1). At the base both fractions occur in comparable amounts but towards the top the fine fraction is largely dominating. A general trend is found from a true mixture of sand and silt loam at the base (5.1) to a better sorted silt loam with slight sand mixture towards the top (5.2). The lower part is characterized especially by a large variation of the granulometric parameters. The described sedimentary structures and the heterogeneous grain-size characteristics of the lower part (5.1) exclude both a fluvial as well as an aeolian origin, but they rather point to processes of mass movement and overland flow (sheet and rill wash). The discontinuous pebble horizons represent lag deposits. Towards the top (5.2) the silt component increases while the amount of heterogeneous coarser sediment decreases. The grain-size composition of Unit 5.2 resembles the one of Unit 6, and by comparison with the loess, Unit 7, points clearly to a (derived) loess as a principal component. The sedimentary environment is further discussed below.

TABLE 1. Modal value, sand and clay content of the main lithological and pedological units on top of the terrace gravels.

unit	modal value	content (%) sand	content (%) clay	number of samples
Upper Silt Loam (7) Holoc. B_{2t}	32 à 45 μm	1-6.5	14-16 21	7
Middle Silt Loam (6)	30 à 35 μm	3-4	16-23	5
Loams (5.2.) (upper part) B1 Rocourt B_2	30 à 35 μm* ±85 μm**	3-12	24 28-32	8
Loams (5.1) (lower part)	±35 μm and 85 à 115 μm	15-46	19-38	10
Terrace sands (4) heavy backswamp clay	>160, ±110, ±85 μm* ±35, ±20 μm**	44-90 10	2-21 35	14

* main modal value, ** secundary modal value.

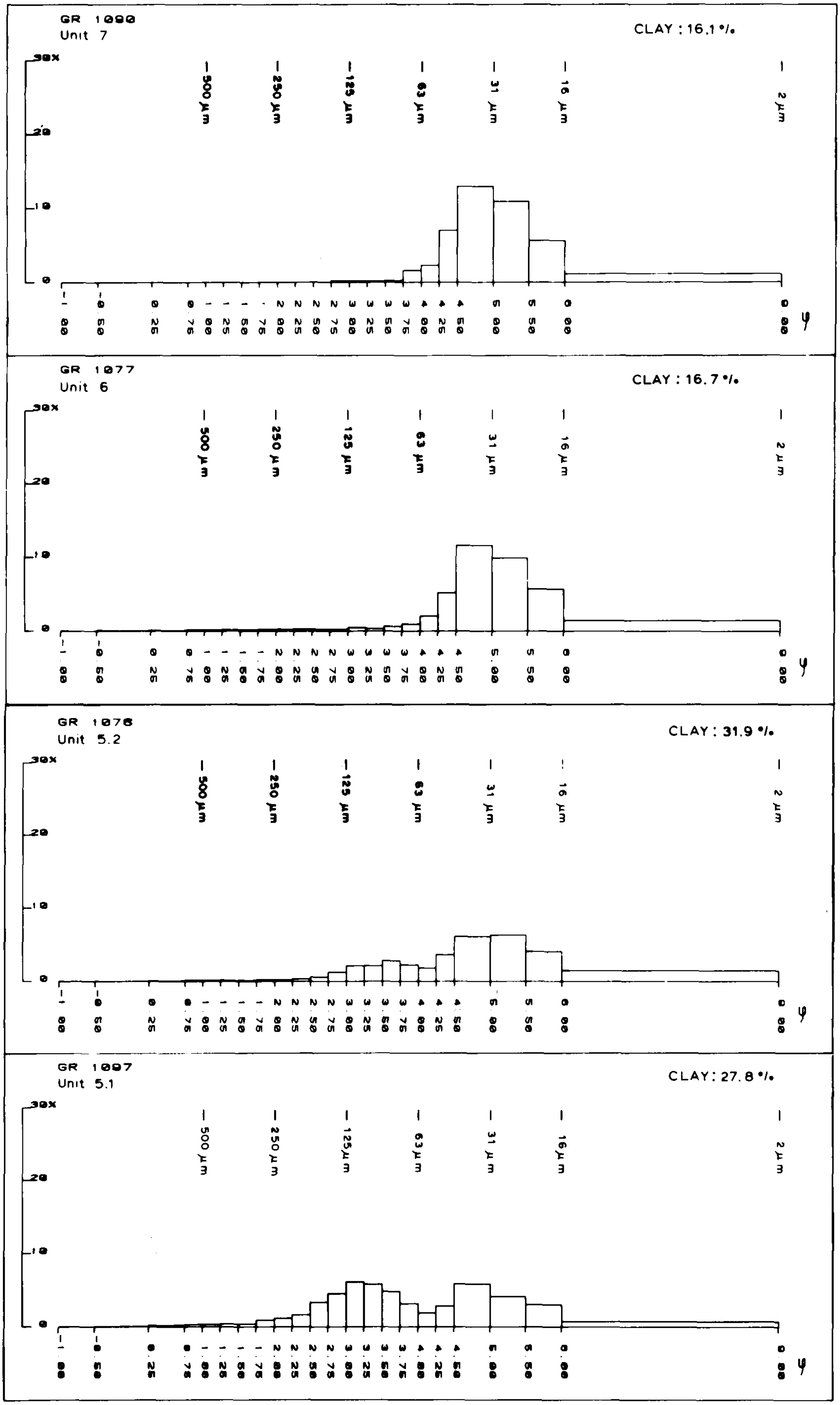

Fig. 5. Comparison of typical histograms of the grain-size distribution in Units 5.1, 5.2, 6 and 7.

The upper 1 to 2 m of Unit 5 shows a friable and platy structure. A sedimentary lamination is absent. The clay content amounts to ca. 30%. This zone probably represents the B_{2t} horizon of a truncated 'Parabraunerde' (Mückenhausen, 1962) or a Luvisol (F.A.O., 1974) or of a 'Radebrikgrond' in the Dutch Soil Classification System (de Bakker & Schelling, 1966). Sometimes it is overlain by a thin zone with lower clay content (24%). It is recognized as the B_1 horizon of the same soil, resembling the Eemian interglacial soil type. Comparison of the described sequence with lithostratigraphic series in the same region allows the correlation of the Parabraunerde formed at the top of Unit 5 with the Rocourt soil (Gullentops, 1954; Haesaerts et al., 1981). Both soils show a remarkable macroscopic similarity. In the Belvédère pit the top of the Rocourt-soil has distinctly been eroded and locally a pebble horizon has been preserved at this level. The transition between Units 4 and 5 may be difficult to recognize especially when no gravel horizon is present at the boundary. Unit 4 consists of gray-white to light greenish sand which contains tiny clayey and silty lenses (4a). The clear lamination finds still more expression in the occurrence of many pebble horizons. The latter represent the base gravel deposits of wide flat channels. The intersections between them occur at acute angles. A fluvial origin of this unit is further demonstrated by the grain-size characteristics. The cumulative granulometric curves clearly show the presence of a rolling population (fig.4). Almost clay and silt free, medium sand alternate with fine ill-sorted clayey sands. The former sediments represent the channel filling while the latter deposits require a calmer environment outside the channel. The great variability of the sediments is reflected in the wide range of grain size and kurtosis (especially those of clay content, mean skewness and kurtosis (fig. 3, table 1)). The fluvial character of Unit 4 is discussed in more detail below.

THE TERRACE GRAVELS

The gravel Unit 3 is heterogeneous (Figure 6). Beds and lenses of different size and content alternate frequently, but trough and narrow tabular cross-bedding are dominant. The stratification varies from horizontal to dipping at different angles or it is absent. Imbrication is often observed in the stratified beds. The troughs have a large width-depth ratio. The sorting varies considerably. Cobbles of several dm are not rare but generally the pebble diameter is a few cm. Lenses of fine to coarse, gravelly sand frequently occur. Occasionally silt and clay have been deposited in depressions at the base of which a gravel horizon occurs. Fining upward trends are often found in thin, individual gravel beds. The unstratified or flat-bedded tabular strata extend over large areas, whereas tabular strata with dipping bedding are of limited extent. They are both the results of the development of longitudinal or diagonal bars. They are formed at high discharges with shallow water depth. The troughs have been formed by scouring, while the silts and clays have been deposited in abandoned channels. According to the sedimentary sequence observed, the river was of a multi-channel type while individual channels, did not persist for a long time. The heterogeneity of clasts and the quick alternation of lithology and structures are caused by abrupt changes of energy. All these characteristics indicate deposition by a braided-river system. Slightly inclined beds with fining upwards sequences representing point-bar deposits occur on a few occasions.

The fluvial series (Units 3 and 4) belong to the Caberg terrace (Caberg-Gronsveld terrace according to Brueren (1945) and Van Straaten (1946), Caberg-Lutterade terrace according to Zonneveld (1949) and Caberg-Pietersem terrace according to Paulissen (1973). They form part of the Veghel Formation (Doppert et al. 1975). The gravels have been deposited on the Palaeocene chalk subsoil (Unit 1) belonging to the Houthem Formation (Kuyl, 1971). Locally Oligocene clayey sands (Unit 2) are found on top of the chalk. The base of the terrace is at 46 à 47 m NAP (Klein, 1914; Brueren, 1945; Bosch, 1975).

THE TERRACE SANDS (UNIT 4)

As already discussed in the previous section, Unit 4 has a fluvial genesis. In figure 7 a detailed picture is shown of the laterally changing lithology and thickness. Unit 4, situated on top of the coarse gravels of Unit 3, may be subdivided into three facies 4a, b and c. A ridge 2 to 2.5 meters high (see fig. 7) consisting of grayish-yellow to greyish-olive sands and intercalated gravel layers (Unit 4a) can be seen in the middle of fig. 7. At the eastern side of this ridge Unit 4 is represented by laminated yellow-brown to brown sands and clayey sands, 1 to 2.5 metres thick, with locally layers of gravel especially in the lower part of the unit and with increasing amounts of silts in upward direction.

At the western part of the ridge a lateral variation in grain-size can be seen, the sediments becoming finer with increasing distance from the ridge. In that area the terrace sands are composed of fine and coarse sands (max. 1 metre thick) with intercalated loamy lenses and layers of gravel (Unit 4a), on top of which about 20 tot 50 cm of grayish-olive silty clay are present (Unit 4b).

At the upper part of Unit 4, locally calcareous tufa (ca. 25% $CaCO_3$) (Unit 4c), up to 40 cm thick occurs. When Unit 4c is present, the deposits below the tufa are also rich in carbonate. The tops of the Units 4b and 4c are in general characterized by involutions, with a maximum penetration of 20 cm.

Micromorphological investigations (Mücher, 1985, this volume) revealed that at the top of Unit 4 a palaeosol characterized by clay illuviation, is present. At higher levels this soil is heavily truncated, and on the ridge itself, completely eroded. In lower positions, i.e. on the western side of the ridge, this palaeosol also contains gley-phenomena.

In the calcareous part of Unit 4 a rich micro- and macrofauna has been found (see: van Kolfschoten, 1985, Meijer, 1985, both this volume), locally associated with remains of human activities (Roebroeks, 1985, this volume).

In view of:

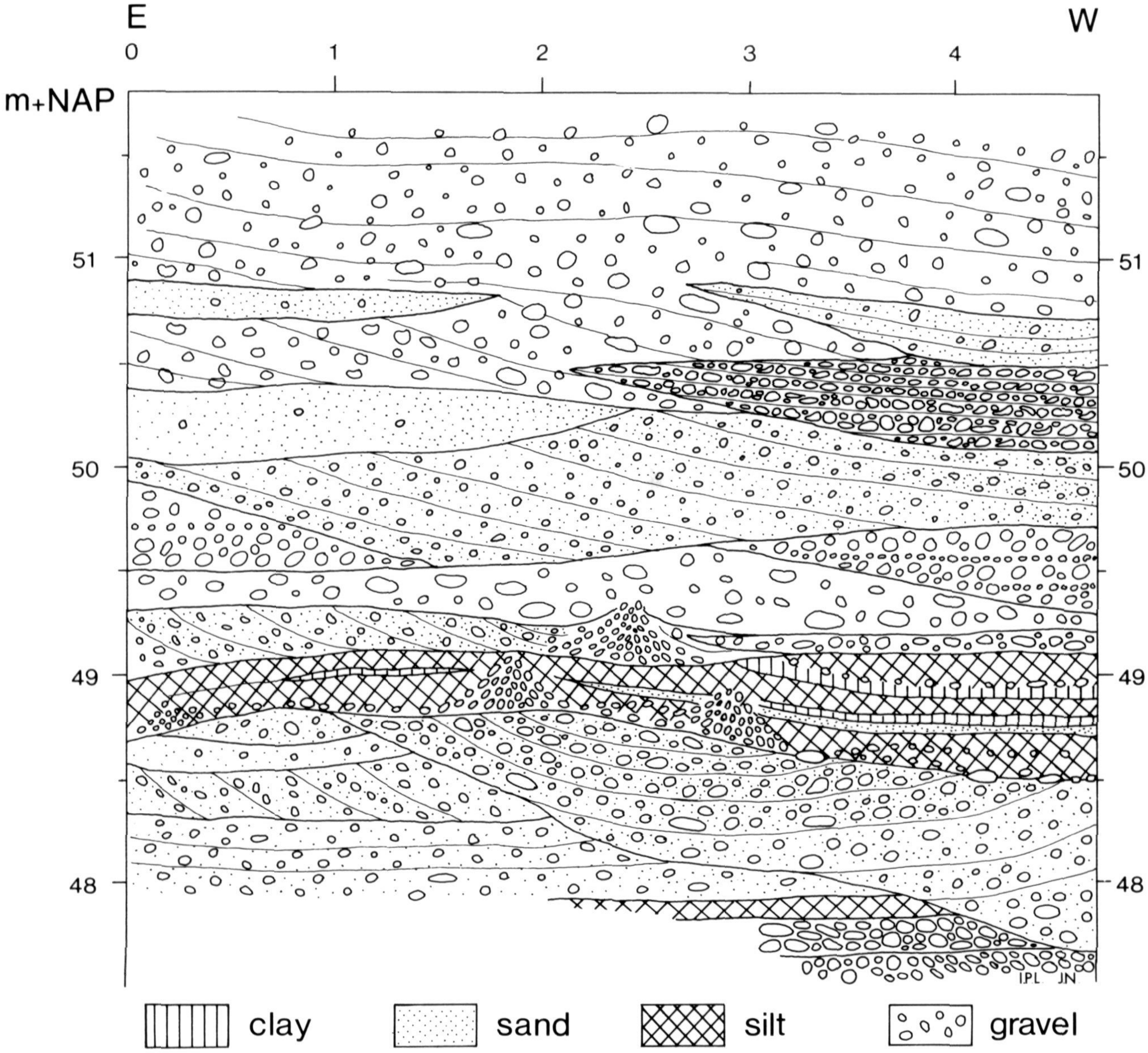

Fig. 6. Representative vertical section of the terrace gravel. Unit 3.

- the occurrence of sand, clay and silty laminae in parallel position, with intercalated laminae of gravel,
- the fining upwards of the deposits,
- the fact that the texture becomes finer to the west of the ridges,

Unit 4 is interpreted as a complex of fluvial deposits consisting of a 'levee-like' structure (the ridge), with backswamp-like deposits in the western parts of the section (Units 4a and 4b), and a channel-infilling in the eastern part (Unit 4a) (fig. 7b). This interpretation is in accordance with Ruegg (1982).

Since the channel has eroded the eastern part of the 'levee', the channel-infilling must have occurred after the formation of the 'levee'. As can be seen in fig. 7, in the western part of the section another 'levee', heavily deformed by karstification, is present.

The carbonate tufa (Unit 4c), locally occurring in depressions on top of Units 4a and 4b, are interpreted as accumulations of carbonates, determined by the hydrological palaeoregime, which caused a supply of carbonates-rich groundwater. According to Meijer (1985) carbonate accumulation may partly have been stimulated by certain plants (e.g. *Chara* sp.).

LOAM DEPOSITION ON THE CABERG TERRACE

UNIT 5 ('LOAMS')

Above a general description of Units 5 and 6 was given. It is worthwhile to consider more closely their mode of deposition and the resulting sedimentary characteristics especially in relation to the underlying fluvial sands (4) and the overlying loess (7). Brownification, clay enrichment and homogenisation as a result of soil formation, often disturb the original sedimentary structures and change the textural properties

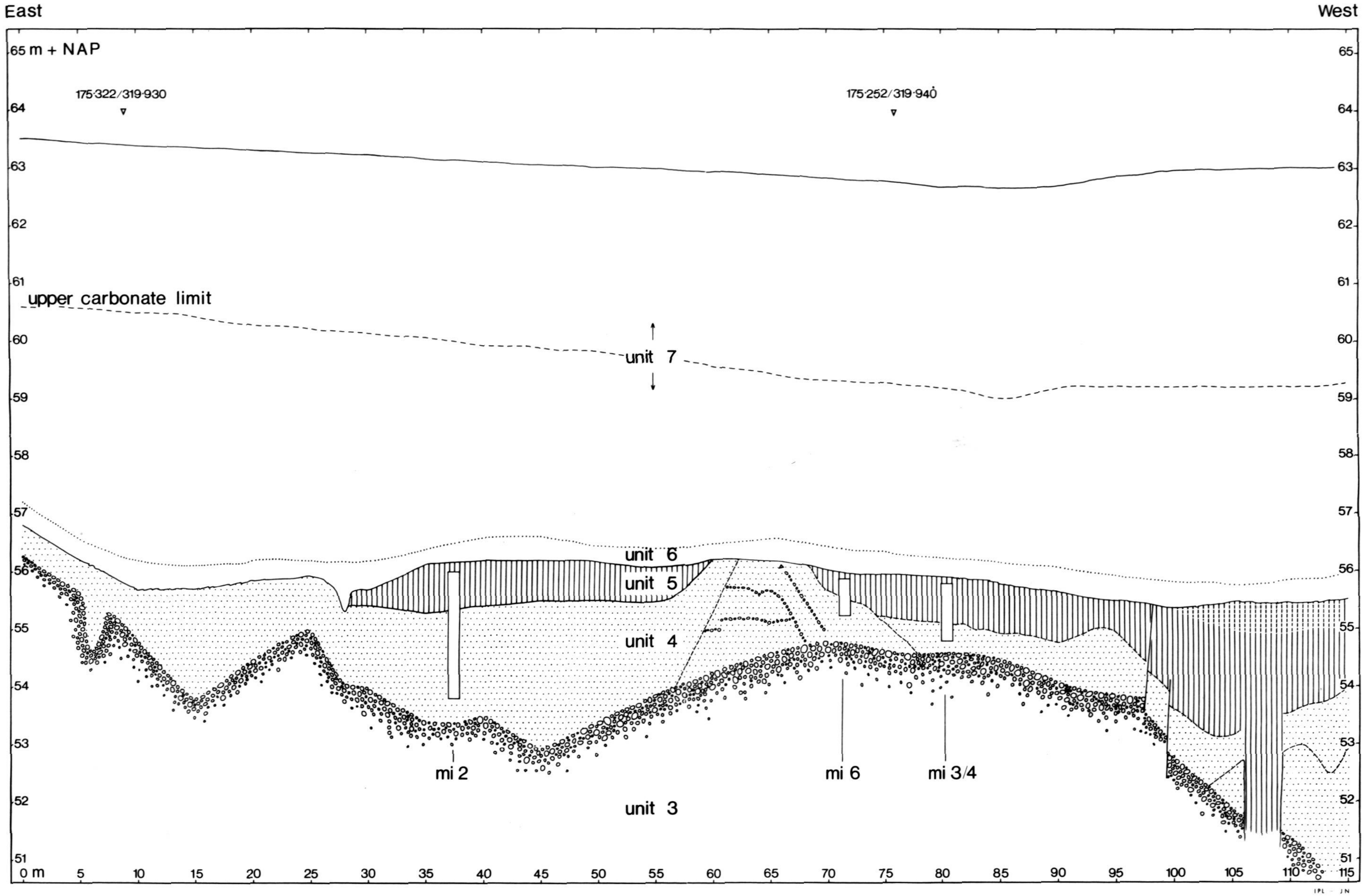

Fig. 7. Idealized E-W cross-section through the Belvédère-pit, with Units 4 to 7 (modified after Felder & Bosch, in: Ruegg, 1982). The vertical bars refer to the stratigraphical location of the micromorphologically investigated profiles (mi 2, mi 3/4, mi 6). The numbers in top of the section refer to the coordinates of the topographical map, sheet no. 61 F (1:25.000).

of both Units 4 and 5. In contrast to the fluvial sands (Unit 4), the 'Loams', especially the lower parts, show a distinct bipartition in their grain-size distribution. By comparison with the loess Unit 7, it may be concluded that the fine fraction (mode 35 μm) represents a loess-derived population. On the other hand, the sedimentary structures of Unit 5 point to waterlaid and slope deposition (section 2.1) by which the coarse fraction (85-115 μm) within the 'Loams' has been incorporated. A clear difference may be observed between the base and the top of the 'Loams'. The 'mean' grain-size and the sand content show a rather gradual increase towards the base but the change of the other granulometric parameters is abrupt indicating a clear bipartition of the unit (table 1). The upper part (5.2.) contains considerably more (derived) loess (section 2.1) and less reworked sediment than the lower part (5.1.). Moreover, the lower part is characterized by erosion unconformities and lag deposits. The boundary between the two subunits is not obvious in the field, but sometimes it is marked by an erosion surface characterized by the occurrence of pebbles and cobbles. According to Mücher (1985) a truncated palaeosol is present at the top of Unit 5.1.

In order to find the sedimentary environment of the 'Loams' the grain-size characteristics of Units 5.1. and 5.2. are analyzed in detail and compared with typical fluvial and aeolian sediments. The particular hydrodynamical conditions of Unit 4 are expressed by the relatively high content of very fine sand (fig. 6). On the other hand typical loess consists mostly of grain sizes in the medium silt fraction (e.g. Unit 7). Hence, for Units 4 and 5 the fraction 32-44 μm is compared with the amount of very fine sands by the Q-ratio (table 2). A clear distinction is revealed between Units 4, 5.1 and 5.2. It may be concluded that fluvially transported fine sand is absent in Unit 5 while it is confirmed that the amount of (derived) loess is higher in the upper part of the 'Loams' than in the lower part. On the other hand Unit 5 may be considered as a backswamp deposit sequential to the deposition of Unit 4 by the river Maas carrying large amounts of reworked loess. The clay and fine silt fraction of backswamp deposits is generally high in comparison to loess or locally reworked loess. Unfortunately, the clay content of Units 4 and 5 is influenced by soil formation (clay illuviation). Therefore the clay content is not used, but the U-ratio between the fraction 16-44 μm and the fine silt fraction (2-16 μm) of Unit 5 is compared with those of the sandy backswamp deposits of Unit 4 and also with Holocene silty flood plain deposits (data from Paulissen, 1973) in table 2. It is obvious that both Units 5.1 and 5.2 do not show the enrichment of sediment finer than 16 μm characteristic of backswamp deposits and thus the assumption of a flood basin environment for Units 5.1 and 5.2 is not valid.

TABLE 2. Ratios of significant grain-size fractions for Unit 4, 5.1, 5.2 and Holocene backswamp deposits.

unit	Q-value*	U-value**
Loams (upper part) 5.2)	2.44-25.3	1.87-3.47
Loams (lower part) (5.1)	0.96-2.74	1.89-4.75
Terrace sands (4)	0.17-0.61	1.10-1.84 (backswamp deposits)
Holocene backswamp deposits (Paulissen, 1973)		0.67-1.90

* Q = 32-44 μm/62 - 88 μm; ** U = 16 - 44μm/2 -16 μm.

From the foregoing considerations about sediment structure and grain-size properties Unit 5.1 may be conceived as a mixture of sediments which were locally reworked by processes of mass flow and overland flow (e.g. sheetwash, rill wash). Conditions for such an environment may be met in a zone near the foot of hillslopes, represented at Belvédère by the valley or terrace scarps. Apart from sediments transported from these slopes, material may also have been provided by some small rivulets coming from the higher terraces and building small alluvial fans with occasionally larger gullies. The slope and fan deposits may have been reworked afterwards by renewed surficial runoff and splash. The alternation of these different processes of deposition is reflected in the equally varying grain-size parameters. In Unit 5.2 mass flow deposits and large gullies are absent. This unit may be interpreted as deposited by low-energy slope wash of terrace deposits mixed with loess which was slightly displaced (e.g. by splash or discontinuous runoff) after the original deposition by wind and possibly also with loess which was directly deposited by wind.

THE LOWER PART OF UNIT 6

Unit 6 can be distinguished from Unit 5 by its laminated structure and lower sand content (table 1). Typical loess in situ (Unit 7) differs significantly by its better sorting, lower clay content and higher skewness (fig. 3, table 1). Unit 6 is thus composed of loess material enriched with clay derived from a former soil formation. The sedimentary structures point to sedimentation by processes of local surficial runoff.

The lower part of the unit (6.1) is characterized by its light gray colour. Its deposition is followed by soil formation. The soil consists of a homogeneous black humic horizon. It may be interpreted as a steppe soil of which the top is usually eroded. The black zone may laterally be replaced by a brown oxidation zone (left side of fig. 8). In the lower areas the black colour is most prominent. This soil sequence suggests a catenary relationship. Locally the complete soil and the underlying sediments are eroded and redeposited as a dark grayish layer (Unit 6.2) with the same laminated appearance and grain-size composition as Units 6.1 and 6.3. It forms a blanket over the erosion level or occurs locally in wide, shallow gullies (fig. 8). Small pebbles at the base emphasize the erosion boundary with the underlying soil.

The lower part of Unit 6.3 as well as the underlying bed show an intense bioturbation. The biopores are always filled with sediment from the brown-coloured Unit. 6.3. The soil formation, manifested by the dark

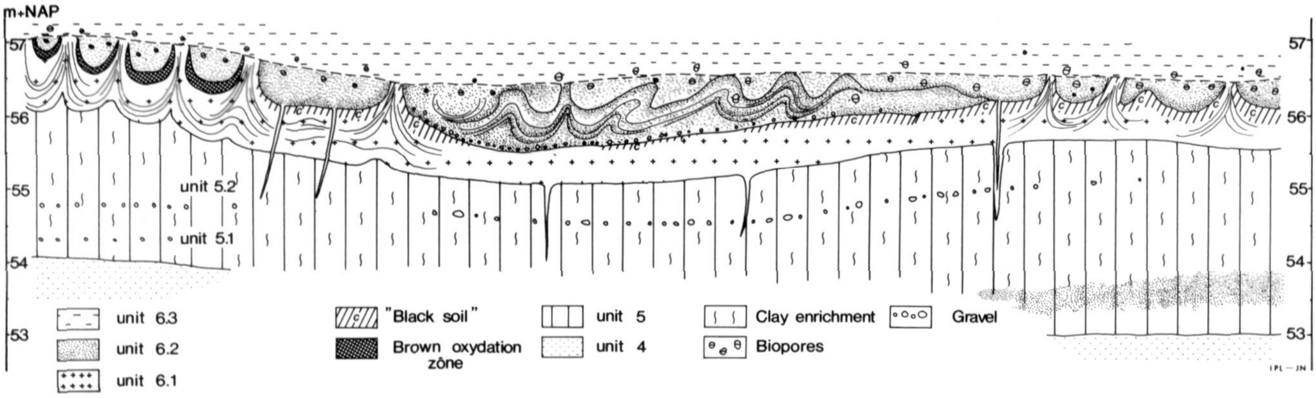

Fig. 8. Detailed vertical section of the lower part of Unit 6 with periglacial deformations and soil development.

humic zone at the top of 6.1, has thus continued until the initial deposition of Unit 6.3.

PERIGLACIAL PHENOMENA AND DEPOSITS: LITHOSTRATIGRAPHIC POSITION AND PALAEOCLIMATIC SIGNIFICANCE

In the present Belvédère pit several levels of involutions are present (see section 2). They are all characterized by a constant depth and the regular development of the deformations over large areas in homogeneous material. Consequently they may be interpreted as cryoturbations (Vandenberghe, 1983).

INVOLUTIONS AND CRACKS AT THE BASE OF UNIT 7 AND THE TOP OF UNIT 6 (FIG. 2)

The upper two cryoturbation levels at the base of Unit 7 (a) and the top of Unit 6 (b) are probably separated by only a short period according to the stratigraphical data (Vreeken, 1984). Hence they may belong to the same cold phase. The relative small amplitude of the cryoturbations indicates at least deep seasonal frost. However, in a nearby outcrop at Nagelbeek ice-wedge casts, pointing to permafrost conditions, have been found by Meys et al. (1983) at the base of the Upper Silt Loam (Unit 7) and just above the Nagelbeek horizon (Unit 6.4) (see also Vandenberghe 1985, this volume). This level of ice-wedge casts corresponds most likely with the uppermost cryoturbation level at Belvédère (a). The cold phase, manifested by the cryoturbation level a, the cryoturbated Nagelbeek horizon (b) and the ice-wedge casts, corresponds with the period with permafrost condition in the Weichselian Upper Pleniglacial dated at 18-22.000 yrs. B.P. (Vandenberghe, 1983). Soil formation during this period is mainly limited to shallow bleaching. After the final cryoturbation a polygonal network of fissures has developed either by desiccation or seasonal frost.

INVOLUTIONS AND CRACKS IN THE LOWER PART OF UNIT 6

The cryoturbations (c) at the top of Unit 6.2 show larger amplitudes than the upper ones. Values between 70 and 120 cm are observed, but, since the top of the involutions is eroded, higher values may have existed. This type of involution also points to the presence of a former permafrost (Vandenberghe & Van den Broek, 1982), although no ice-wedge casts are observed at this level. Up until now only one Weichselian period with permafrost conditions before 25.000 yrs. B.P. has been found in this region, namely in the Lower Pleniglacial (ca. 60-72.000 yrs. B.P.; Vandenberghe, 1985). Consequently, the cryoturbation level c is, for the time being, dated at that period.

At the base of Unit 6 frost fissures occur (width: a few cm, except at the top ca. 10 cm). They indicate circumstances of deep seasonal frost. Very narrow cracks have been formed during the initial deposition of Unit 6.2. They also point to cold conditions with no or only minor snow cover. Still more severe conditions, however, were reached after the deposition of Unit 6.2. Rather regular involutions were developed to a same depth.

SLOPE DEPOSITS IN UNIT 5.1. (FIGS. 2 AND 8)

Sedimentary structures and textural characteristics suggest the presence of muddy flows. They require a temporary, impermeable subsoil and the lack of forest vegetation. The sediments may best be interpreted as solifluction deposits formed under humid conditions with seasonal frozen ground and poor vegetation.

INVOLUTIONS WITHIN THE GRAVEL UNIT 3

Small isolated disturbances occur within the gravel body at different levels. Generally they appear as upward directed features containing vertically directed pebbles. The very permeable nature of thė gravel unit suggests an origin due to frost action. A seasonally frozen ground may have been sufficient for their development. On the other hand, in a nearby exposure (Klinkers quarry) a series of large involutions is found at the top of the terrace gravels. They are regularly developed and testify to, at least local, permafrost conditions (Vandenberghe & Van den Broek, 1982).

CONCLUSIONS

In general terms, the Pleistocene deposits at the Maastricht-Belvédère pit show a progressive transition from a fluvial environment at the base (Units 3 and 4) to a pure aeolian genesis at the top (Unit 7).

In the field Unit 5 showed a striking resemblance with typical loess deposits; grainsize analysis and study of the sedimentary structures, however, showed that this unit has been redeposited and only partly derived from an original loess deposit.

Unit 6 is a loess-derived deposit, reworked by overland flow.

The sedimentary structures of the gravel Unit 3 indicate a cold environment during the formation of this unit, which according to the terrace stratigraphy may be situated in the Saalian period. Towards the end of the river activity lower energetic conditions prevailed (Unit 4); the fluvial series is concluded by the development of a soil of interglacial type.

The sedimentary structures of Unit 5 suggest a return to colder conditions, interrupted by a period of warmer conditions between the deposition of Units 5.1 and 5.2, as exemplified by the occurrence of palaeosol remnants. In the top of the Unit 5 (Saalian deposits) the Rocourt-soil is developed, generally ascribed to Eemian soil formation.

The Weichselian deposits show evidence of two periods with permafrost conditions.

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